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DESCRIPTORS *Air Conditioning Equipment; *Auto Mechanics; Behavioral Objectives; Course Descriptions; Curriculum Guides; Engines; *Equipment Maintenance; *Industrial Arts; Inspection; Learning Activities; Lesson Plans; Motor Vehicles; Postsecondary Education; Programed Instructional Materials; *Repair; Secondary Education; Skilled Occupations; Study Guides; *Vocational Education

IDENTIFIERS Military Curriculum Project

ABSTRACT

This plan of instruction, lesson plans, student study guides, and programed texts for a secondary-postsecondary level course in engine mechanics is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. It is the fourth of a four-part course (see Note for other sections) covering general vehicle mechanics, including inspection, maintenance, and repair. The plan of instruction suggests number of hours of class time devoted to each lesson in two blocks of instruction (Blocks VI and VIII), a total of 139.5 hours of instruction: (1) Brakes and Suspension (8 lessons, 94 hours), including hydraulic brakes, conventional and power steering systems, and service and adjustment of beam-type, front axle and independent suspension systems and (2) Compression Ignition Engines and Automotive Air Conditioning, (4 lessons, 45.5 hours), including compression ignition engine familiarization, operation, and servicing and principles of, construction, operation, inspection, troubleshooting, evacuating, and charging air conditioning systems. It also details criterion objectives and support materials needed. Lesson plans outline teaching steps. Student materials in Block VI include two study guides containing objectives, text, and review questions and seven programed texts and in Block VII a study guide. Military manuals, commercial texts, and audiovisuals are suggested, but not provided. (YLB)

Military Curricula for Vocational & Technical Education

General Purpose Vehicle Mechanic

Blocks VI & VII, 8-12

THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

MILITARY CURRICULA FOR VOCATIONAL & TECHNICAL EDUCATION

GENERAL PURPOSE VEHICLE MECHANIC, BLOCKS VI AND VII

Classroom Course

8-12

Developed by:

United States Air Force

Development and Review Dates

November 6, 1975

Occupational Area:

Engine Mechanics

Target Audiences:

Grades 11-adult

Print Pages

632

Cost:

$12.75

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans	Programmed Text	Student Workbook (No. of pages)	Handouts	Text Materials	Audio Visuals	Instructional Design: Performance Objectives	Tests	Review Exercises	Additional Materials Required	Type of Instruction: Group Instruction	Individualized
Block VI – *Brakes and Suspension*	•	•	97		•	*	•			*	•	•
Block VII – *Compression Ignition Engines and Automotive Air Conditioning*	•				•	*	•			*	•	

* Materials are recommended but not provided.

Expires July 1, 1978

Course Description

This section is the last of a four-part course covering general vehicle mechanics. The entire course covers training in inspecting, servicing, testing, adjusting, troubleshooting, and repairing automotive general purpose vehicles; gasoline engine tune-up and repair; manual and automatic transmission replacement and adjustment; lubrication system servicing and repair; cooling systems servicing; power train repair; front end steering system adjustment and repair; brake system adjustment and repair; warning and lighting system repair; hydraulic control repair; air conditioning systems servicing; corrosion control and preparation of vehicles for climatic conditions and shipment. The two blocks of instruction presented in this section cover brakes, suspension, and compression ignition engines and automotive air conditioning.

Block VI — *Brakes and Suspension* contains eight lessons covering 94 hours of instruction. The lesson topics and hours follow:

- Hydraulic Brakes and Vacuum Brake Boosters (8 hours)
- Hydraulic Brake System Servicing (16 hours)
- Air and Air-Over Hydraulic Brake Systems (15 hours)
- Conventional and Power Steering Systems (16 hours)
- Frame Alignment and Wheel Balancing (8 hours)
- Steering Factors, Springs, and Shock Absorbers (8 hours)
- Service Adjustment of Beam-Type, Front Axle Suspension Systems (8 hours)
- Service and Adjustment of Independent Suspension Systems (15 hours)

Block VII — *Compression Ignition Engines and Automotive Air Conditioning* contains four lessons covering 45.5 hours of instruction. One additional lesson was deleted because it discusses military technical orders.

- Compression Ignition Engine Familiarization, Operation and Servicing (19 hours)
- Principles of Refrigeration and Air Conditioning (6 hours)
- Construction and Operation of Air Conditioning Components (5 hours)
- Inspection, Troubleshooting, Evacuating, and Charging Air Conditioning Systems (15.5 hours)

This course contains both teacher and student materials. Printed instructor materials include lesson plans, outlining teaching steps and a plan of instruction detailing units of instruction, criterion objectives, duration of lessons, and support materials needed.

The student materials in Block VI consist of two study guides containing objectives, text and review questions and seven programmed texts on hydraulic brake systems, conventional steering gears, frame alignment, wheel balancing, steering factors, springs and shock absorbers, and scuff testers and portaliners. In Block VII student materials consist of a study guide on compression ignition engines and automotive air conditioning. The study guide contains objectives, text readings, and review questions.

Several military manuals and commercially produced texts are referenced, but not provided. Audiovisuals suggested for use with the entire course include 53 transparencies, 10 films and 205 slides. This section used in conjunction with the previous three sections provide a comprehensive coverage of vehicle inspection, maintenance and repair. Some documents can be used individually as sub-units, remedial or individualized study, and the entire course can be used in a group instructional setting or adapted for individual use.

GENERAL PURPOSE VEHICLE MECHANIC, BLOCKS VI AND VII

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PLAN OF INSTRUCTION	COURSE TITLE General Purpose Vehicle Repairman - Part I	
BLOCK TITLE Brakes and Suspension		
UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Hydraulic Brakes and Vacuum Brake Boosters a. Without reference, identify basic facts and terms related to the principles of operation, function, and relationship of hydraulic brake systems and vacuum brake booster components with 70% accuracy.	8 (6/2) Day 46	**Column 1 Reference** 1a — **STS Reference** 18a **Instructional Materials** 3ABR47330-SG-601, Hydraulic Brakes and Vacuum Brake Boosters 3ABR47330-PT-601, Hydraulic Brake System 3ABR47330-SG-601A, Hyd Principles and Principles of Operation of Drum and Disc Type Brakes 3ABR47330-SG-601B, Principles of Operation of Vacuum Booster Brake Systems, Troubleshooting, and Servicing Boosters **Audio Visual Aids** Charts - Brake Systems Film: TF 1-6332, Hydraulic Brakes, Principles of Operation Transparencies, Brake Systems **Training Equipment** Trainers: 61-2830, Brake Shoe Assembly (60-2531, Master Cylinder Assembly (10) 60-2525, Hydrovac Assembly, Third Series (10) Bench Items: Master Cylinder (2) Wheel Cylinder (2) Disc Brake Components (2) **Training Methods** Discussion/Demonstration (6 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (6 hrs)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		<u>Instructional Guidance</u> Discuss safety, principles of hydraulics, and operating principles of brakes and brake boosters. Use study guide, PT, and necessary reviews to accomplish training objectives. Stress energy and material conservation.
2. Hydraulic Brake System Servicing	16 (12/4) Day 47,48	<u>Column 1 Reference</u> — <u>STS Reference</u> 2a — 3, 4d, 9, 18b 2b — 3, 4d, 18c
a. Given technical orders, vehicles, bench items, tools, and equipment, practice automotive personnel and equipment shop safety, repair or service brake systems and components IAW the technical order.	(4)	<u>Instructional Materials</u> 3ABR47330-SG-602, Hydraulic Brake System Servicing ~~TO 36A2-3-6-2~~ TO 36A2-3-14-2-1 TO 36A2- 4-17-2 3ABR47330-SG-602A, Servicing of Hydraulic Brake Systems [illegible] <u>Audio Visual Aids</u> Transparencies, Brake Systems,
b. Provided with technical orders, vehicles, tools, and equipment, using automotive personnel and equipment shop safety, use visual, auditory, and operational means to check brake systems IAW technical publications.	(8)	<u>Training Equipment</u> Mechanic's Common Handtools (1) Special Tools (1) Brake Bleeding Equipment (4) Vehicles (2) Brake Drum Lathe (10) Brake Honing Equipment (5) <u>Training Methods</u> Discussion/Demonstration (4 hrs) Performance (8 hrs) Outside Assignment (4 hrs) <u>Instructional Environment/Design</u> Classroom (4 hrs) Laboratory (8 hrs)

PLAN OF INSTRUCTION NO.	DATE	BLOCK NO.	PAGE NO.
3ABR47330	2 January 1975	VI	38

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss safety, principles of hydraulics, and operating principles of brakes and brake boosters. Assign each student a project from the workbook and supervise closely, pointing out and correcting errors on the spot. Rotate students so each student completes all projects.
3. Air and Air-Over Hydraulic Brake Systems	15 (11/4) Day 49,50	Column 1 Reference / STS Reference 3a — 18a 3b — 3, 9, 18b 3c — 3, 18c
a. Without references, identify basic facts and terms related to the principles of operation, function, and relationship of air brake system components with 70% accuracy.	(6)	**Instructional Materials** 3ABR47330-SG-603, Air and Air-Over Hydraulic Brake Systems 3ABR47330-WB-603, Air and Air-Over Hydraulic Brake Systems TO 36A2-2-1-122, IHC Truck
b. Provided with technical orders, vehicles, bench items, tools, and equipment, and applying automotive personnel and equipment shop safety, repair or service air brake systems and components IAW technical publications.	(3)	**Audio Visual Aids** Transparencies, Air and Air-Over Hydraulic Brakes Charts - Air Brakes and Air-Over Hydraulic Brake Systems
c. Supplied with technical orders, vehicles, tools, and equipment, and observing automotive personnel and equipment shop safety, use visual, auditory, and operational means to check the air brake system IAW the technical order.	(2)	**Training Equipment** Trainers: 63-2996, Brake Assembly (10) 60-2526, Air Governor Assembly (10) Mechanic's Common Handtools (1) Special Tools (1) Vehicles (2) Bench Items: Air Brake System Components (1) Air-Over Hydraulic System Components (1) **Training Methods** Discussion/Demonstration (9 hrs) Performance (2 hrs) Outside Assignment (4 hrs) **Instructional Environment/Design** Classroom (9 hrs) Laboratory (2 hrs)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss safety in regard to high pressure fluid and air, and principles of operation. Demonstrate operation of air brakes using trainer. Assign each student a project from the workbook and supervise him closely, pointing out and correcting errors on the spot. Rotate students so each completes all of the projects.
Measurement Test and Test Critique	1	
4. Conventional and Power Steering Systems	16 (12/4) Day 51,52	Column 1 Reference — STS Reference 4a — 19a 4b — 3, 9, 19b 4c — 19c
a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of steering system components with 70% accuracy.	(6)	**Instructional Materials** 3ABR47330-SG-604, Power Steering System Units 3ABR47330-WB-604, Power Steering System Units 3ABR47330-PT-604, Conventional Steering Gears 3ABR47330-SG-604A, Principles of Operation and Servicing of Power Steering Components 3ABR47330-SG-604B, Troubleshooting and Maintenance of Power Steering Components
b. Provided with vehicles, tools, and equipment, bench items, technical orders, and applying automotive personnel and equipment shop safety, repair or service steering systems and components IAW the technical publications.	(3)	**Audio Visual Aids** Charts - Steering Systems
c. Supplied with tools and equipment, vehicles, technical orders, and observing automotive personnel and equipment shop safety, use visual, auditory, and operational means to check steering systems IAW technical publications.	(3)	**Training Equipment** Trainers: 59-2451, Steering Gear Assembly (10) 61-2423, Steering Gear Assembly (10) 59-2433, Steering Gear, Worm and Nut (1) 63-2995, Power Steering Assembly (10) 60-2530, Steering Gear Assembly (10) Mechanic's Common Handtools (1) Special Tools (1) Vehicles (1) Bench Item: Steering Gear Assembly (1)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Training Methods Discussion/Demonstration (6 hrs) Performance (6 hrs) Outside Assignment (4 hrs) **Instructional Environment/Design** Classroom (6 hrs) Laboratory (6 hrs) **Instructional Guidance** Discuss constructional features and principles of operation of the different type steering gears and power steering systems. Assign students to a project from the workbook and supervise closely while they remove, disassemble, inspect, repair as required, reassemble, adjust, and check steering gear assemblies. Use PT for outside assignment.
5. Frame Alignment and Wheel Balancing a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of frame alignment components and wheel balancing with 70% accuracy. b. Provided with technical orders, tools, and test equipment, vehicles, and practicing automotive personnel and equipment shop safety, use visual, auditory, operational means, and test equipment to check frame alignment and wheel balance IAW technical publications.	8 (6/2) Day 53	**Column 1 Reference** — **STS Reference** 5a — 20a 5b — 3, 9, 20c **Instructional Materials** 3ABR47330-SG-605, Frame Alignment and Wheel Balancing 3ABR47330-PT-605, Frame Alignment 3ABR47330-PT-605A, Wheel Balancing **Audio Visual Aids** Transparencies, Frame Alignment and Wheel Balancing Film: TV 77-662, Wheel Balancing **Training Equipment** Mechanic's Common Handtools (1) Special Tools (1) Vehicles (2) Wheel Balancer (2) **Training Methods** Discussion/Demonstration (3 hrs)

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Performance (3 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (3 hrs) Labor: v (3 hrs) Instructional Guidance Discuss the purpose and procedures for frame alignment and wheel balancing. Demonstrate use of wheel balancers and point out all safety factors. Assign students projects from the workbook and supervise closely to ensure the use of proper procedures and safety practices. Rotate the students so each student performs all projects. Point out and correct errors on the spot. Use PT for outside assignment.
6. Steering Factors, Springs, and Shock Absorbers a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of steering factors, springs, and shock absorbers with 70% accuracy. b. Given technical orders, tools, and equipment, vehicles, and observing automotive personnel and equipment shop safety, repair or adjust steering factors, springs, and shock absorbers IAW the technical publications. c. Supplied with tools and equipment, vehicles, technical orders, and applying automotive personnel and equipment shop safety, use visual, operational means, and test equipment to check steering factors, springs, and shock absorbers IAW technical publications.	8 (6/2) Day 54	Column 1 Reference — STS Reference 6a — 20a 6b — 3, 9, 20b 6c — 3, 20c Instructional Materials 3ABR47330-SG-606, Steering Factors, Springs and Shock Absorbers 3ABR47330-PT-606, Steering Factors 3ABR47330-PT-606A, Springs and Shock Absorbers Training Equipment Trainers: 60-2538, Wheel Alignment, Rigid Axle (10) 61-2432, Steering Geometry (10) 61-2878, Ball Joint Suspension (10) VE-1102, Caster, Camber, Toe (10) Portable Wheel Alignment Equipment (2) Training Methods Discussion/Demonstration (4 hrs) Performance (2 hrs) Outside Assignment (2 hrs)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Instructional Environment/Design Classroom (4 hrs) Laboratory (2 hrs) **Instructional Guidance** Discuss purpose, constructional features, and operating principles of shock absorbers and springs and steering factors in relation to wheel alignment. Assign students in pairs and supervise closely while they perform a prealignment inspection and service shock absorbers. Point out and correct errors on the spot. Use PT for outside assignment.
7. Service and Adjustment of Beam-Type, Front Axle Suspension System a. Without references, identify basic facts and terms related to principles of operation, function, and relationship of beam-type front axle suspension system components with 70% accuracy. b. Provided with vehicles, tools, and equipment, technical publications, and observing automotive personnel and equipment shop safety, adjust and service beam-type front axle suspension systems IAW the technical order. c. Supplied with technical orders, vehicles, tools, and equipment, and practicing automotive personnel and equipment shop safety, use visual, operational means and test equipment to check beam-type front axle suspension systems IAW technical publications.	8 (6/2) Day 55	**Column 1 Reference** — **STS Reference** 7a — 20a 7b — 3, 4d, 9, 20b 7c — 3, 4d, 9, 20c **Instructional Materials** 3ABR47330-SG-607, Service and Adjustment of Beam Type Front Axle Suspension System 3ABR47330-PT-607A, Scuff Tester and Portaliner TO 36A2-3-6-22-1, 1965 Ford Truck Shop Manual TO 36A2-3-6-2 **Audio Visual Aids** Film: TVL 47-4, Portaliner ~~Charts - Beam-Type Suspension Systems~~ **Training Equipment** Trainers: 61-2432, Steering Geometry (10) 60-2538, Wheel Alignment (10) Mechanic's Common Handtools (1) Special Tools (1) Vehicles (2) Floor Jacks (2) Jack Stands (2) Portable Wheel Alignment Equipment (2) Scuff Tester (2)

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
		Training Methods Discussion/Demonstration (2 hrs) Performance (4 hrs) Outside Assignment (2 hrs) **Instructional Environment/Design** Classroom (2 hrs) Laboratory (4 hrs) **Instructional Guidance** Discuss constructional features, relationship of components and service procedures. Discuss safety and demonstrate use of necessary equipment. Assign students in pairs and supervise them closely while they follow the task list and perform all the steps necessary to accomplish the service and adjustment of beam-type suspension systems. Point out and correct errors on the spot. Use PT for outside assignment.
8. Service and Adjustment of Independent Suspension System	15 (11/4) Day 56,57	**Column 1 Reference** — **STS Reference** 8a — 20a 8b — 3, 4d, 9, 20b 8c — 3, 4d, 20c
a. Without references, identify basic facts and terms related to principles of operation, function, and relationship of independent suspension system components with 70% accuracy.	(4)	**Instructional Materials** 3ABR47330-SG-608, Service and Adjustment of Independent Suspension System TO 36A2-3-14-2-1 TO 36A2-4-17-2
b. Supplied with vehicles, technical orders, tools, and equipment, and observing automotive personnel and equipment shop safety, adjust and service independent suspension systems IAW technical publications.	(4)	**Audio Visual Aids** Transparencies, Independent Suspension System Charts - Independent Suspension System
c. Provided with vehicles, tools, and equipment, technical publications, and applying automotive personnel and equipment shop safety, use visual, operational means and test equipment to check independent suspension systems IAW the technical order.	(3)	**Training Equipment** Trainers: 61-2878, Ball Joint Suspension (10) 61-2432, Steering Geometry (10) VR-1003, Caster, Camber Adjustment Simulator (5) VR-1102, Caster, Camber Toe Adjustment Simulator (5) Mechanic's Common Handtools (1)

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		Special Tools (1) Vehicles (2) Floor Jack (2) Jack Stand (2) Portable Alignment Equipment (2) Scuff Tester (2) **Training Methods** Discussion/Demonstration (4 hrs) Performance (7 hrs) Outside Assignment (4 hrs) **Instructional Environment/Design** Classroom (4 hrs) Laboratory (7 hrs) **Instructional Guidance** Discuss constructional features, relationship of components, repair, reassembly, and safety associated with the maintenance involved, and demonstrate use of equipment. Assign students in pairs and supervise them closely while they follow the task list and perform all steps necessary to accomplish the service and adjustment of suspension systems.
9. Measurement Test and Test Critique	1	

PLAN OF INSTRUCTION NO. 3ABR47330	DATE 2 January 1975	BLOCK NO. VI	PAGE NO. 45

PLAN OF INSTRUCTION	COURSE TITLE General Purpose Vehicle Repairman - Part I

BLOCK TITLE
Compression Ignition Engines and Automotive Air Conditioning

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
1. Technical Orders a. Without references, identify basic facts and terms concerning the scope and application of the Air Force technical order system. Eighty percent of the facts must be identified correctly. b. Provided a list of research problems and a student technical order index file, locate specific information, with instructor assistance on the hardest parts, to 100% accuracy.	3 Day 58	Column 1 Reference / STS Reference 1a / 4b 1b / 4d Instructional Materials 3ABR47330-SG-701, Technical Orders 3ABR47330-PT-103, Technical Orders TO 0-1-01, Numerical Index and Reg Table TO 0-1-02, General Technical Order TO 0-1-32, Standard and Special Tools TO 0-1-33-3, Armament and Automotive Test Equipment TO 0-1-34, Shop Machinery and Associated Equipment TO 0-1-36, Vehicles, Construction, Material Handling, and Components TO 0-1-38, Non-Aeronautical Engines Training Methods Self-Instruction (1 hr) Performance (2 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (2 hrs) Instructional Guidance Accomplish instruction by explaining purpose, numbering system, filing procedure, and proper use of technical order system. Assign each student specific information to be located in the technical order from available file. Monitor student progress. Stress energy and material conservation.
2. Compression Ignition Engine Familiarization, Operation, and Servicing	19 (15/4) Day 58,59 60	Column 1 Reference / STS Reference 2a / 21a 2b / 21a 2c / 3, 4d, 5, 21b

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
a. Without references, identify basic facts and terms pertaining to principles of operation, function, and relationship of compression ignition engine systems and components with 70% accuracy.	(3)	**Instructional Materials** 3ABR47330-SG-702, Compression Ignition Engine Familiarization, Operation, and Servicing 3ABR47330-WB-702, Compression Ignition Engine Familiarization, Operation, and Servicing 3ABR47330-SG-702A, Compression Ignition Engine Familiarization, Operation, and Servicing (Fuel System and Tune-Up) 3ABR47330-WB-702A, Multifuel Engine Familiarization and Servicing 3ABR47330-SG-702B, Multifuel Engine Familiarization TO 38G1-16-121, Maintenance Manual, In-Line 71 Engine Components
b. Without references, identify basic facts and terms related to the operating principles and function of compression ignition engine fuel system components with 70% accuracy.	(8)	**Audio Visual Aids** Charts - Diesel Engines Films: FLC 1-28M8, ABC of Diesel TF9-3469, Multifuel Engines
c. Supplied with tools and equipment, technical orders, engine trainers, and observing automotive personnel and equipment shop safety, inspect, troubleshoot, and service compression ignition engine systems IAW technical publications.	(4)	**Training Equipment** Trainers: 67-2941, Injector Diesel Fuel Kit (2) 68-4038, Engine Multifuel (5) 62-7945, Engine 671 Diesel (5) Mechanic's Common Handtools (1) Special Tools (1) Bench Items: Fuel Injector (1) Fuel Transfer Pump (10) Hydraulic Governor (10) Fuel Injector Pump (10) **Training Methods** Discussion/Demonstration (11 hrs) Performance (4 hrs) Outside Assignment (4 hrs) **Instructional Environment/Design** Classroom (11 hrs) Laboratory (4 hrs)

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	DURATION (HOURS)	SUPPORT MATERIALS AND GUIDANCE
		Instructional Guidance Discuss compression ignition engine operating principles, function, and relationship of components of the two and four cycle diesel engines. Discuss safety and methods of troubleshooting and servicing. Assign students to engines and supervise them closely while they operate, service, inspect, test, troubleshoot fuel system and injector linkage of compression ignition engine. Point out and correct errors on the spot.
3. Principles of Refrigeration and Air Conditioning a. Without references, identify basic facts and terms pertaining to the principles of operation, function, and relationship of air conditioning systems and components with 70% accuracy.	6 Day 61	**Column 1 Reference** 3a — **STS Reference** 22a **Instructional Materials** 3ABR47330-SG-703, Principles of Refrigeration and Air Conditioning Commercial Manual GA-279A **Audio Visual Aids** Charts - Refrigeration Systems Film: TF 5536A, Refrigeration Principles **Training Methods** Discussion/Demonstration (6 hrs) **Instructional Environment/Design** Classroom (6 hrs) **Instructional Guidance** Accomplish instruction by explaining operating principles, function, and relationship of components. Have each student accomplish assignment in study guide on refrigeration and air conditioning.
4. Construction and Operation of Air Conditioning Components a. Provided with tools and equipment, commercial manual, bench items, and practicing automotive personnel and equipment shop safety, repair or service air conditioning system components IAW technical publications.	5 Day 62	**Column 1 Reference** 4a — **STS Reference** 9, 22b **Instructional Materials** 3ABR47330-SG-704, Construction and Operation of Air Conditioning Components Commercial Manual GA-279A

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
		<u>Audio Visual Aids</u> Charts - Refrigeration System and Components <u>Training Equipment</u> Kit, Air Conditioning Service (5) Vacuum Pump (5) Adapter 90° Angle (5) Tester, Radiator & Cap (5) Mechanic's Common Handtools (1) Special Tools (1) Air Conditioned Equipped Vehicle (10) Bench Items: Air Conditioning System Components (3) Trainers: 72-4288, Auto Air Conditioner (3) 72-4289, Auto Air Conditioner (3) 72-4290, Auto Air Conditioner (3) 74-4362, Vehicle Sedan 4 Door (10) <u>Training Methods</u> Discussion/Demonstration (2 hrs) Performance (3 hrs) <u>Instructional Environment/Design</u> Classroom (2 hrs) Laboratory (3 hrs) <u>Instructional Guidance</u> Discuss safety and the method of repair or servicing air conditioning system components, including the use of special tools and test equipment. The instructor will monitor the performance of each student.
5. Course Critique	1 Day 62	

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PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
6. Inspection, Troubleshooting, Evacuating, and Charging Air Conditioning Systems a. Supplied with an assigned air conditioning trainer, tools, and equipment commercial manual, and observing automotive personnel and equipment shop safety, use visual, auditory, operational means, and test equipment to check, adjust, and isolate malfunctions in the air conditioning systems IAW technical publications.	15.5 Day 63,64 65 (15.5)	Column 1 Reference: 6a — STS Reference: 3, 9, 22c **Instructional Materials** 3ABR47330-SG-706, Inspection, Troubleshooting, Evacuating, and Charging Air Conditioning Systems Commercial Manual GA-279A **Audio Visual Aids** Film: TF 5536B, Refrigeration, Evacuating, and Charging Charts - Air Conditioning Servicing Procedures **Training Equipment** Kit, Air Conditioning Service (5) Vacuum Pump (5) Adapter 90° Angle (5) Mechanic's Common Handtools (1) Special Tools (1) Trainer: 72-4288, Auto Air Conditioner (3) 72-4289, Auto Air Conditioner (3) 72-4290, Auto Air Conditioner (3) 74-4362, Vehicle, Sedan 4 Door (10) **Training Methods** Discussion/Demonstration (9.5 hrs) Performance (6 hrs) **Instructional Environment/Design** Classroom (9.5 hrs) Laboratory (6 hrs) **Instructional Guidance** Explain and demonstrate visual, auditory, operational means and use of test equipment to check air conditioning systems. Monitor student progress. Point out and correct errors on the spot.

PLAN OF INSTRUCTION (Continued)

UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1	DURATION (HOURS) 2	SUPPORT MATERIALS AND GUIDANCE 3
Related Training (identified in course chart).	12	
7. Measurement Test and Test Critique	1.5 Day 65	
8. Graduation	1 Day 65	

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 21 Feb 75	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47330	General Purpose Vehicle [redacted] Mechanic Part I

BLOCK NUMBER	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE
Hydraulic Brakes and Vacuum Brake Boosters

LESSON DURATION

CLASSROOM /Laboratory	/Complementary	TOTAL
D&D 6 hrs/ None	2 hrs	8 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
37	2 JAN. 1975	1

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 61-2830 2. Trainer: 60-2531 3. Trainer: 60-2525 4. Wheel Cylinder 5. Master Cylinder 6. Disc Brake Components	None	None	1. 3ABR47330-SG-601 2. 3ABR47330-SG-601A 3. 3ABR47330-SG-601B 4. 3ABR47330-PT-601 5. Film: TFI-6332 6. Chart: CAFB59-3140 7. Chart: CAFB59-3141 8. Trans: CAFB74-360 thru 371

CRITERION OBJECTIVES AND TEACHING STEPS (OVER)

a. Without reference, identify basic facts and terms related to the principles of operation, function, and relationship of hydraulic brake systems and vacuum brake booster components with 70% accuracy.

Teaching Steps are Listed in Part II.

ATC FORM AUG 73 770

SAFR. IL 73-25000

GRAPHIC AIDS AND UNCLASSIFIED MAT.

9. T70-2003
10. T70-2011
11. Trans: CT74-369
12. Trans: T71-3587
13. Trans; T71-3593
14. Chart: 73-214
15. Chart: 73-215
16. Chart: 73-216
17. Chart: 73-217
18. CC73-93
19. CC74-175
20. CC74-176
21. CC74-177

INTRODUCTION 10 Min

1. Attention and Motivation: Gain students' attention by asking about any personal experience that they may have encountered regarding the use of brakes on a vehicle in which they were a passenger or driver. Stress the importance of knowledge gained in this subject area from the standpoint of safety.

2. Review: Review Summary questions from Student Study Guide 3ABR47330-SG-601 and check 3ABR47330-PT-601 to insure that each student has completed all frames in text. Grade outside assignment.

3. Overview & Tie-in: Relate vehicle motion to slowing, stopping and holding a vehicle from moving. Briefly explain the sequence in which the material will be presented and the student's responsibility during the presentation. Remind students of energy and materials conservation. (Heat, cooling, light, study materials, etc.)

BODY 5 Hrs 30 Min

PRESENTATION:

1. Ref: Para a, Part 1.	3ABR47330-SG-601A 3ABR47330-SG-601B 3ABR47330-PT-601 Hydraulic Brake System (S.G.s to be re-used) conservation of materials
a. System Components & Operation	
(1) Master Cylinder	
(a) Purpose	Film: TFI-6332 Trans: T71-3593 (Avg. stopping distance) Notes
1 Converts mechanical energy to hydraulic pressure	Show Trans: CT 74-360
2 Multiplies residual line pressure into high hydraulic pressure	Bench Item: Master Cyl.
(b) Location:	Trainer 60-2531 Master Cyl.
1 Most passenger cars & light duty trucks have cylinder mounted on engine firewall	Trans: CT74-360
2 Larger trucks -- under floorboard, mounted to frame	
(c) Adjustment: Some vehicles have brake pedal free travel-linkage	
(d) Types	

1 Single

2 Double - used with dual brake system

(e) Housing and reservoir

1 Compensating port allows fluid to return to reservoir when brakes are released. It is the smallest of two ports.

Trans: CT 74-361 Notes T71-3587 Master Cyl. Assembly

2 Breather port allows fluid to enter cylinder from reservoir and maintains fluid in cylinder

3 Filler cap with vent provides means of filling reservoir and maintains atmospheric pressure on fluid

Bench Item: Master Cyl.

(f) Push rod: Link between brake pedal and piston

(g) Boot

1 Located on front of cylinder around push rod

2 Prevents dirt from entering cylinder

3 Vented to prevent air build up

(h) Secondary cup: Serves as a seal to keep fluid in cylinder and prevents fluid from leaking into boot. Usually part of piston

Trans: CT 74-362 Notes

(i) Piston

1 Holes in piston head allow fluid to fill cylinder as brakes

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are released. Piston returns faster than fluid in lines, allow fluid from the breather port to fill cylinder through holes in piston head

2 Converts mechanical pressure received to hydraulic pressure applied through primary cup

(j) Washer (shield): Prevents fluid from going in reverse during brake application by covering holes in piston head

(k) Primary cup

1 Expands as mechanical Pressure is received to maintain hydraulic pressure throughout system

2 Actual component responsible for converting mechanical pressure to hydraulic pressure

Bench Item: Master Cyl.

(l) Spring (return and retaining)

1 Hold primary cup against piston

2 Holds check valve in place against seat

3 Aids in returning piston to stop when brakes are released

(m) Check valve (one way)

Trans: CT 74-363 Notes

1 Allows fluid to pass from cylinder through valve into lines when brakes are applied

2 Fluid returning from wheel cylinders after brakes are released unseats check valve, allowing fluid to return to reservoir

3 Returns to seat and maintains slight pressure on wheel cylinders when returning brake fluid pressure drops to 8 - 16 psi

Trans: CT 74-363
Notes

(n) Double Master Cylinder

Trans: CT 74-364

1 Two pistons - Tandem

2 One piston to front brakes

3 One piston to rear brakes

Charts: 73-214 Master cylinder
73-215 Front & Rear line failure
73-216
Bench Item: Master Cyl.

(2) Wheel cylinders

Trainer: 60-2531
Master Cylinder

(a) Purpose - converts hydraulic pressure to a mechanical force

Trans: CT 74-365
Notes

(b) Location - Usually on upper portion of brake backing plate

Bench Item:
Wheel Cyl.

1 Housing

Trans: CT 74-366
Notes

a Mounted on brake backing plate

b Contains bleeding valve screw to allow for removal of air from system

2 Rubber cups - Convert hydraulic pressure to mechanical force

3 Pistons

a Receive mechanical pressure from rubber cups b Transfer this pressure to push rods which expand brake shoes

4 Retaining spring - keeps rubber cups separated and against the pistons

5 Dust covers - prevent foreign matter from entering cylinder

6 Push rods

a Move shoes against drum — Bench Item: Wheel Cyl.

b Connect shoes with pistons

(c) Types wheel cylinders — Trans: CT 74-367 Notes; T70-2003-Wheel Cyl.; T70-2011 Pressure bleeder

1 Straight

2 Stepped

(3) Brake Fluid

(a) Types

1 Standard duty — Trans: CT 74-365 Notes

2 Heavy duty - used where high operating temperatures exist

(b) Qualities

1 High boiling point - prevents vapor lock

2 Low freezing point - remains fluid at low temperatures

(4) Tubing, hoses and fittings — Trans: CT 74-367 Notes

(a) Composition

1 Lines are made of steel for strength against high pressure

2 Must be double lap flared to produce strong leakproof joints

3 Hoses are high pressure and flexible to withstand all conditions of stress and twist

4 Reinforced rubber with a steel core

5 Fittings are usually steel or brass alloy to withstand pressure

(b) Preservation

1 Copper coated to resist rust

2 Tin plated to resist corrosion

(5) Brake Assembly

Trans: CT 74-368
Notes
Trainer: 61-2830
Brake shoe assembly

(a) Brake shoes and lining

1 Purpose - to produce friction between the linings and drum to slow, stop, or hold a vehicle

2 Construction

a Shoes are pressed steel for economy and equal shoe and drum heat dissipation

Trainer: 61-2830

b Molded lining - most common, has low frictional qualities, but wears longer and dissipates heat quickly c Woven linings - has high frictional qualities, but retains heat and wears quickly.

3. Shoe types

a Primary - initial shoe to self-energize (usually front)

b Secondary (65% of load)

(b) Springs — Trans: CT 74-369 Notes

1 Purpose

a Retracting - returns shoes to original position when brakes are released

b Retaining - prevents shoes from scraping on lug portions of drum

(c) Adjustments

1 Major - .ichored shoes,

2 Minor - (Free Floating)

3 Final - (Self-adjusting)

(d) Brake shoe adjusters - manual and self-adjusting — Trainer: 61-2830

1 Purpose - maintain proper shoe to drum clearance — Brake shoe assembly

2 Location

a Star adjustment on top or bottom of brake backing plate b Cam adjustment on upper portion of backing plate on both sides

(e) Operation

1 Manual adjusters - cam or star wheel adjustment to spread brake shoes against drum

2 Self-adjusting - star wheel adjustment occurs automatically, when brakes are alternately applied and released with vehicle in reverse motion

(6) Drums

(a) Purpose - provide surface against which shoes are applied, resulting in stoppage or slowing down of wheel

Trans: CT 74-369 Brake Assembly

(b) Composition - pressed steel housing with cast iron liner

(7) Stop light switches

Trans: CT 74-370 Notes

(a) Purpose - means of warning vehicles approaching from rear of intentions to slow down or stop

(b) Location - on master cylinder or under dash on brake pedal linkage

(c) Types and operation

1 Mechanical - contacts closed by linkage connected to brake pedal

1 Pressure sensitive -

brake fluid pressure causes disc to close contacts

(8) Parking brakes — Trans: CT 74-370 Parking brake (External contracting)

(a) Purpose - hold vehicle stationary when not in use

(b) Location - on rear wheels or drive shaft

(c) Inspections - periodic check for kinks in cable or binding linkage

(d) Operations - mechanical

1 External contracting - drive shaft

2 Internal expanding - rear wheels

(9) Disc Brakes — Chart CT 74-175

(a) Hub and disc assembly

1 Purpose - provides frictional surface against which the shoe is applied to stop or slow down the spi ning wheel — 3ABR47330-SG-601A (SG to be re-used)

(b) Shield - protects disc from cross splash

(c) Caliper - (Fixed or floating)

1 Purpose - provides means of applying shoe and lining assemblies to the disc — Chart: CC 73-93 Disc Brake Assembly - floating caliper

2 Operation — Chart: CC 74-177 Floating Caliper Assembly - sectional view

a Caliper - malleable iron castings mounted to the support plate — Show Disc Brake Components b Shoe and lining assemblies - positioned on the caliper so they straddle the disc

c Casting - Bored to receive a piston(s)

d Hydraulic pressure is applied to piston(s) applying shoe and lining assembly to disc surface

Chart: CC 74-176 Function of piston seal

e Hydraulic pressure released - shoes relax

(b) Combination Valve

1 Metering valve - "Holds off" Disc brake application until drum brakes make contact

Chart: CC 73-217 Combination Valve

2 Failure warning switch - activates dash lamp in event of either front or rear brake system failure

3 Proportioner - Delays rear wheel skid during high deceleration stops

(10) Vacuum operated brake boosters

Trans: CT 74-371 - Hydrovac
Trainer: 60-2525 - Hydrovac Assembly

3ABR47330-SG-601 Hydraulic Brakes & Vacuum Brake Booster

(a) Purpose - reduce drivers effort

(b) Location - as a separate unit, it will be located between the master cylinder and the wheel cylinders. With the Bendix power brake and the Midland Ross type booster, the master cylinder is integral with the booster usually found on left side of vehicle under hood or floor board

(c) Factors needed for operation — Chart 59-3141) 59-3140) Hydrovac Operation; Trans: CT 74-371 Notes

1 Hydraulic pressure

2 Atmospheric pressure

3 Engine Vacuum

4 Vacuum check valve (intake manifold)

(d) Control valve assembly — Chart 59-3141) 59-3140) Hydrovac Operation

1 Atmospheric valve - closed/brakes released. Open/brakes applied

2 Vacuum valve - open/brakes released. Closed/brakes applied

3 Diaphragm

4 Relay valve - hydraulic piston

5 Atmospheric control line

(e) Vacuum power cylinder

1 Diaphragm or piston and seal - moved by differential pressure — Trainer: 60-2525 Hydrovac

2 Actuating rod - moved by the piston, reduces effort the driver needs to put forth

3 Return spring - returns piston to be released, position when brakes are released

(f) Slave cylinder

1 Piston and cup - applies hydraulic pressure to the wheel cylinder

2 Return spring - return piston to released position

3 Check valve - high hydraulic pressure is returned to master cylinder as low hydraulic pressure

Ref: Para A, Part 1.

EVALUATION:

1. What is meant by horsepower of brakes?
2. What besides brakes are used to slow a moving vehicle?
3. What is a fulcrum?
4. What is usually the rotating member of a brake system?
5. What determines the holding qualities of a brake system?
6. What determines output force of a wheel cylinder piston?
7. What direction are wheel cylinder cups installed?
8. What are the qualities of hydraulic brake fluid?

CONCLUSION 20 Min

SUMMARY AND REMOTIAVTION:

1. Summarize the principles, function and relationship of the following:
   a. Master & wheel cylinders
   b. Brake fluid, tubing, hoses & fittings
   c. Shoes & lining
   d. Brake drums
   e. Major & minor adjustments
   f. Disc brake components
   g. Vacuum operated brake booster system
2. Explain the advantages to be gained through a thorough utilization of the material learned in today's lesson. Remind students of energy and materials conservation.

ASSIGNMENT AND CLOSURE: CTT POI Part 1, Para A 2 Hrs

1. Using the SQ3R method of study, read SG 3ABR47330-602 & 602A Hydraulic Brake System Servicing & complete summary questions.

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2. We now have an understanding regarding the theory of operation for a hydraulic brake system and its components. In our next lesson, we will combine servicing procedures with this theory to repair and service hydraulic brakes on a vehicle.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 2/7/75 [handwritten initials]	
COURSE NUMBER	**COURSE TITLE**
[redacted] 3ABR47330	General Purpose Vehicle [redacted] Mechanic, Part I
BLOCK NUMBER	**BLOCK TITLE**
VI	Brakes and Suspension

LESSON TITLE
Hydraulic Brake System Servicing

LESSON DURATION

CLASSROOM/Laboratory	[redacted]/Complementary	TOTAL
D&D 4 hrs/Perf 8 hrs	4 hrs	16 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
38	2 JAN. 1975	2

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Vehicles 2. Brake Bleeding Equip. 3. Brake Honing Equip. 4. Brake Drum Lathe 5. Mechanic's Common Hand Tools 6. Special Tools	None	None	1. 3ABR47330-SG-602 2. 3ABR47330-SG-602A 3. T036A2-3-6-2 4. T036A2-3-14-2-1 5. T036A2-4-17-2 6. Trans: T71-3588 7. Trans:CAFB T71-3589 8. Trans:CAFB T70-2011

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given technical order, vehicles, bench items, tools, and equipment, practice automotive personnel and equipment shop safety, repair or service brake systems and components IAW the technical order.

b. Provided with technical orders, vehicles, tools, and equipment, using automotive personnel and equipment shop safety, use visual, auditory, and operational means to check brake systems IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM 770 AUG 72 — SAFB, IL 73-21400

INTRODUCTION 20 Min

1. Attention and Motivation: Ask students why they feel that hydraulic brake system theory of operation is important. Point out how this knowledge will be of great value to the individual during the process of serving brake.

2. Review: Review summary questions from student study guide, 3ABR47330-602, 602A Hydraulic Brake System Servicing. Re-teach as needed.

3. Overview & TIE-IN: Relate major component operation to component servicing. Describe the sequence in which today's lesson will be presented. Insure that each student is aware of his responsibility toward accomplishment of each objective. Remind students of energy and materials conservation. (Heat, cooling, light, study material, etc.).

BODY 11 Hrs 30 Min

PRESENTATION:

1. Ref: Para A, Part 1.

3ABR47330-SG-602A
Hyd. Brake System Servicing
3ABR47330-SG-602
(SG to be re-used)
Trans: T71-3588
Front Wheel Bearings

   a. Wheel bearings

      (1) Purpose: Take up load, thrust and reduce friction

      (2) Types

         (a) Ball bearings

         (b) Tapered roller bearings

      (3) Service and inspection

         (a) Wash in cleaning solvent - dry with lint-free rag

         (b) Use compressed air to air dry the bearing. DO NOT Spin

         (c) Check for pits, binding or discoloration

      (4) Adjustment

         (a) Torque to applicable specifications (preferred method)

         (b) Tighten until snug, then back off nut approx. one castellation (field method)

(5) Lubrication

Transparency T71-3589
Front Wheel
Bearing Lubrication

(a) Use high temperature grease

(b) Machine packing of bearing (preferred)

(c) Hand packing (Alternate or field)

b. Brake drums

(1) Inspection

(a) Out of round - (Dial indicator)

(b) Thickness - (micrometer)

(c) Cracks and Groves (visual)

(2) Service

(a) "Turn" or recondition on drum lathe

(b) Mark amount removed on unmachined portion of drum

c. Shoes and Lining

(1) Primary shoe - closest to front of vehicle

(2) Linings - may have different frictional quality

(a) Shortest lining usually on primary shoe

(b) May be bonded or riveted to shoe

d. Springs

(1) Retracting

(a) Color and number of coils - (Length)

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(2) Retaining

(a) Equal strength and interchangable

e. Cylinders - (Master and wheel)

(1) Wet hone to remove minor pits and scratches

(2) Replace all moving parts

f. Brake Pedal

(1) Free travel adjustment

g. Parking brake

(1) Clean, lubricate and adjust after service brakes are adjusted

h. Bleeding procedures - (Removal of air from system)

(1) Manual or two man method

(2) Pressure bleeding tank

Transparency T70-2011
Pressure brake bleeder

(a) One man operation

i. Disc Brakes

(1) Disc

(a) Inspect for cracks, grooves and run-out

(b) Disc is measured with gauge bar and ball - critical

(c) Refinish with disc brake lathe

(2) Caliper bore

(a) Inspect for scores, pitting, nicks and corrosion

(b) Polish with fine crocus cloth and wash with denatured alcohol

(c) Defects cannot be cleaned - replace caliper housing

(3) Piston

(a) Inspect for scores, nicks, corrosion and worn or damaged chrome plating

(b) Minimal damage can cause leak between piston and seal

(c) Damaged piston must be replaced

APPLICATION: Para A, Part 1
Interspersed throughout the lesson

EVALUATION:

1. What is the purpose of the wheel bearings?

2. What is the advantage of bonded lining over riveted lining?

3. How can the primary retracting spring be identified?

4. How much air pressure is applied to the pressure bleeding tank?

5. What should be done to a wheel cylinder that has minor scratches?

END OF DAY SUMMARY

SUMMARY:

1. Summarize principles of operation, function, and relationship of the following: Wheel Bearings, Brake Drums, Shoes and Lining, Springs, Cylinders, Parking Brake, Bleeding Procedures, Disc Brake Components and Troubleshooting Procedures

ASSIGNMENT: CTT POI Para 2A 2 Hrs

3ABR47330-SG-602

1. Read complete statements SG 3ABR 47330-602 Servicing of Hydraulic Brake Systems, using the SQ3R method of study. Remind students of energy and materials conservation.

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INTRODUCTION TO NEW DAY'S WORK

1. Arouse student interest by discussing possible results of system malfunctions.

2. Review and grade outside assignment. Re-teach as needed.

3. Briefly review how brake systems are serviced.

PRESENTATION:

1. Ref: Para A, Part I
   Ref: Para B, Part I

   a. Troubleshooting brake system

      (1) Leaks or insufficient fluid

         (a) Spongy pedal

         (b) Excessive brake travel

         (c) Brakes do not apply

      (2) Distorted or improperly adjusted brake shoe

         (a) One brake drags

         (b) All brakes drag

         (c) Hard pedal

         (d) Vehicle pulls to one side

         (e) One wheel locks when applied

         (f) Excessive pedal travel

         (g) Noisy or grabbing brakes

      (3) Drum out of round

         (a) One brake drags

         (b) Vehicle pulls to one side

         (c) Brakes chatter

      (4) Glazed for worn lining

         (a) Hard pedal

(b) Vehicle pulls to one side

(c) One wheel locks

(d) Brakes chatter

(e) Noisy or grabbing brakes

(f) Brakes do not apply

(5) Oil grease in lining

(a) Vehicle pulls to one side

(b) One wheel locks

(c) Brakes uneven

(d) Noisy or grabbing brakes

(e) Brakes do not apply

(6) Faulty wheel cylinder

(a) One brake drags

(b) Vehicle pulls to one side

(c) One wheel locks

(7) Dirty brake fluid

(a) One brake drags

(b) All brakes drag

(c) Brakes uneven

(d) Brakes do not apply

(8) Faulty master cylinder

(a) All brakes drag

(b) Excessive pedal travel

(c) Pedal gradually goes goes to floor

(d) Brakes do not apply

(9) Air in hydraulic system

(a) One brake drags

(b) Spongy pedal

(c) Excessive pedal travel

(d) Brakes do not apply

(10) Self-adjusters not operating

(a) Vehicle pulls to one side

(b) Excessive pedal travel

(c) Shoe click release

(11) Sticking booster control valve

(a) All brakes drag

(b) Noisy or grabbing brakes

b. Discuss procedures for removing, inspecting, repairing or replacing new or reconditioned vehicle hydraulic booster units (Hydrovac).

Do not write in Study Guides or TOs

(1) Removal - use applicable publications

TO 36A2-3-6-2 1965 Ford Econoline Shop Manual

(a) Place drip pan under unit

TO 36A2-3-14-2-1 1968 Ford Fairlane Service Manual

(b) Disconnect all lines

TO 36A2-4-17-2 1967 Chev Sedan Service Manual

1 Hydraulic

2 Vacuum

3 Atmospheric

(c) Remove mounting bolts

(d) Remove unit from vehicle

(2) Inspections

(a) Visual inspection of external components

(b) Disassembly (by Manual)

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(c) Check condition of slave cylinder

1 Scores

2 Pits, etc.

(d) Check condition of valve seats

(3) Repair - usually consists of installing a repair kit while assembling unit

(4) Installation - reverse procedure of removal

(5) Bleeding system

(a) Air must be bled from system upon replacement of unit

1 Manual

2 Pressure

a Follow applicable publication for sequence

b Start at control valve, slave cylinder, then R.R.L.R. - R.F. L.F. wheel cylinders

c. Participate in a discussion of the brake reconditioning equipment

APPLICATION:

1. Ref: Para A, Part 1
Ref: Para B, Part 1

TOs 36A2-3-6-2
36A2-3-14-2-1
36A2-4-17-2
Vehicles
Remove all jewelry
Use hand & special tools
Operate brake drum lathe, honing equipment

EVALUATION:

1. What safety practices must be followed?

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2. What affects the compensating port of the master cylinder?

3. After machining, where are the drums marked?

4. Why are drums marked?

5. What are the advantages of pressure brake bleeding?

6. How are wheel bearings adjusted?

7. What precaution must be observed while adjusting parking brake?

8. What should be done if oil or brake fluid gets on lining?

CONCLUSION 10 Min

SUMMARY & REMOTIVATION:

1. Summarize use of tools & equipment; repair or service procedures for hydraulic brake systems and components; visual, auditory, operational means and test equipment procedures to check the hydraulic brake system.

2. Remind students of benefits to be derived by becoming a competent brake system mechanic. Remind students of energy and materials conservation.

ASSIGNMENT & CLOSURE: CTT POI Para 2A, 2B 2 Hrs Use 3ABR47330-SG-603

1. Using the SQ3R method of study, read SG 3ABR47330-603 Air and Air/Over Hydraulic Brake Systems. Complete summary questions.

2. We have now completed Hydraulic Brake Systems and our next lesson on Air and Air.Over Hydraulic Brakes will be more easily understood.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 21 Feb 75 Econ	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	General Purpose Vehicle MECHANIC [redacted], Part I

BLOCK NUMBER	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE

Air and Air-Over Hydraulic Brake Systems

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXXXX/Complementary	TOTAL
D&D 9 hrs/Perf 2 hrs	4 hrs	15 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
39	2 Jan. 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 63-2996 2. Trainer: 60-2526 3. Vehicles 4. Mechanic's Common Hand Tools 5. Special Tools 6. Air Brake Sys Comp 7. Air-Over Hydraulic System Components	None	None	1. 3ABR47330-SG-603 2. 3ABR47330-WB-603 3. Chart:CAFB59-3139 4. Chart:CAFB59-3139 5. Chart:CAFB59-3142 6. Trans:CAFB CT74-372 thru376 (OVER)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without references, identify basic facts and terms related to the principles of operation, function, and relationship of air brake system components with 70% accuracy.

b. Provided with technical orders, vehicles, bench items, tools, and equipment, and applying automotive personnel and equipment shop safety, repair or service air brake systems and components IAW technical publications.

c. Supplied with technical orders, vehicles, tools, and equipment, and observing automotive personnel and equipment shop safety, use visual, auditory, and operational means to check the air brake system IAW the technical order.

Teaching Steps are Listed in Part II.

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GRAPHIC AIDS AND UNCL. MATERIAL

7. Trans:CAFB T70-2005
8. T036A2-2-1-122
9. Chart CC74-174

INTRODUCTION

20 Min

1. Attention and Motivation: Discuss the need for greater braking effort in the operation of larger vehicles. Relate importance of proper air brake system operation and maintenance to the Air Force in relation to vehicle cost, cargo and personnel.

2. Review: Review summary questions from 3ABR47330-SG-603 Air and Air/Over Hydraulic Brake Systems. Re-Teach as Needed.

3. Overview: Describe the lesson sequence to the students and carefully explain the tasks each student will be required to perform during the application step. Remind students of energy and materials conservation. (Heat, cooling, light study materials, etc.)

BODY

10 Hrs 20 Min

PRESENTATION:

1. Ref: Para A. Part 1 — 3ABR47330-SG & WB 603 (SG to be re-used)

   a. System components and operation

      (1) Compressor

         (a) Purpose: Source of Air Pressure for system use — Transparency: CT 74-372 Notes T70-2005 Compressor

         (b) Location: Usually at the front of engine on driver's side — Trainer: 63-2996 Brake Assembly

         (c) Operation:

            1 Belt driven off engine crankshaft pulley

            2 Cooled and lubricated by engine systems

            3 Inlet ports: Located in cylinder wall and allow air to enter cylinder (B.D.C.)

            4 DISCHARGE (Exhaust) valves: Means of allowing compressed air to escape from cylinders to air reservoirs

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5 Unloader mechanism: Receives air from governor which opens unloader valves, temporarily preventing compressed air build-up

6 Alcohol injector: Prevents system components from freezing

(2) Reservoirs (two - wet and dry)

(a) Purpose - store air under pressure for future use in the system

Transparency: CT 74-373 Notes

(b) Location - on underside of vehicle frame

(c) Wet tank - first tank to receive air from compressor - majority of moisture is condensed here allowing dry air for the system

(d) Dry tank - second tank through which air passes to the system - remainder of moisture condensed here allowing dry air for the system

(e) Safety valve - in case of governor failure, releases excess pressure (popped type)

(f) Drain cocks - one on each reservoir

1 Purpose - drain moisture and release air from the system

(g) Automatic bleeder

1 Purpose - automatically "bleeds" moisture from reservoirs each time brakes are applied

(3) Governor

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(a) Purpose - control maximum compressor output

Demonstrate: Trainer 60-2526 Air Governor Assy

(b) Location - mounted on compressor or engine firewall

Transparency: CT 74-373 Notes

(c) Operation air pressure acts on a mechanical device forcing a valve to open or (when the air is removed) allows the mechanical device to close the valve

(d) Types

1. Bourdon tube - air pressure forces tube to straighten out pulling a valve open

2. Diaphragm - air pressure acts on diaphragm to operate spring loaded valve

3. Piston - air pressure acts on piston to operate spring loaded valve

(4) Unloader mechanism - compressor

(a) Purpose - unloads compressor by destroying its capability to compress air

(b) Location - usually on compressor head

(c) Operation

1. Air pressure from governor actuates unloading mechanism, causing an unloader valve, located above the piston in the cylinder head, to open, thus destroying the cylinder's capability to build pressure

2 This cycle is repeated each time brake application causes air in reservoirs to drop below specified pressure — Transparency CT74-372 Notes

(5) Safety and warning devices

(a) Located in cab of vehicle

(b) Low pressure indicator - buzzer, bell, light, pendulum or a combination of any — Demonstrate: Air brake component: air gauge & stop light switch

(c) Air gauge -registers amount of air pressure available in system

(d) Stop light switch - warning that brakes are being applied (Located near brake valve) — Transparency CT74-373 Notes

(6) Air supply valve

(a) Located inside cab on fire wall

(b) Ready source of air pressure to use for outside source

(7) Brake valve - treadle valve — Transparency CT74-374 Air brake valve

(a) Mounted on frame

(b) Heart of air brake system, meters the air throughout system

(c) Also known as foot valve — Demonstrate: Air brake sys. components Brake & hand valve, quick release & double check valve

(8) Hand control valve

(a) Located in cab on steering column

(b) Allows operation of trailer brakes independently of tractor brakes

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(9) Minor valves in system — Transparency CT74-374 Quick release valve

(a) Quick release valve - allows air to escape quickly when brakes are released

(b) Double check valve - allows air to flow from two sources (foot valve - hand control valve)

(c) One way check valve - allows air to flow in one direction only

(10) Tractor protection valve — Transparency: CT74-374 Notes

(a) Valve located in air system, switch located on dashboard

(b) Valve protects tractor system by cutting off pressure in lines to trailer (trailer break away)

Demonstrate: Air brake system components - tractor protection & relay valves

(c) Switch is usually manually controlled for emergency use, usually left in normal position

(11) Limiting - quick release valve — Transparency CT74-374 Notes

(a) Usually found on front axle

(b) Valve controls front tractor brakes for wet or dry conditions, cuts pressure 50% for wet conditions

(c) Controlled by switch on dash

(12) Relay valve — Transparency: CT74-375 Notes

(a) Applies rear tractor brakes at same time front brakes are applied

(13) Filter

(a) Purpose - clean air before entry into emergency relay valve

(b) Location - on trailer

(14) Emergency relay valve

Demonstrate: Air brake system Components - Emer. relay valve & brake chambers

(a) Used on trailers only

(b) Will automatically set trailer brakes when source of air pressure to trailer is lost

(15) Brake chambers

Transparency CT74-375 Brake chamber

(a) Mounted on axle near each wheel (one at each wheel)

(b) Changes air pressure to mechanical force

(16) Slack adjusters

CC74-174 Slack adjuster

(a) Located between brake chambers and backing plate

Demonstrate: Air brake system Components - slack adjusters, hose lines, couplings and fittings

(b) Mechanical advantages is provided here

Trainer: 63-2996 Brake Assembly

(c) Provide quick and easy adjustment for normal wear

(d) In the released or applied position angle between push rod and slack adjuster must be greater than 90 degrees

(17) Hoses, lines, couplings, and fittings

(a) Tubing - copper (rigid)

Transparency: CT74-375 Notes

(b) Hoses - special high pressure reinforced neophrene, spring wire wrapped at friction points

(c) Couplings - provide a quick means to connect or disconnect hoses

1 Two rubber gaskets form an air tight seal

(d) Fittings - usually brass

APPLICATION EVALUATION Para a Part 1. Interspersed throughout Lesson

1. How does the piston type compressor operate?
2. How is the compressor cooled and lubricated?
3. Through which valves does the compressed air leave the compressor?
4. What is the purpose of the wet and dry reservoirs?
5. How does the bourdon tube type governor operate?
6. When should the reservoirs be bled?
7. Why is a quick release valve necessary in the system?
8. What is meant by the term "Lapped position"?
9. Why does the hand control valve operate only the trailer brakes?
10. Explain the slack adjuster angle.

END OF DAY SUMMARY

SUMMARY

1. Summarize principles, operation, function, and relationship of the following: compressor, reservoirs, governor, brake valve, hand control valve, safety & warning devices, plus other minor valves in system.

ASSIGNMENT CTT P.O.I. PARA 3a 2 Hrs 3ABR47330-SG-604

1. Read complete statements SG-3ABR47330-604 Air & Air/Over Hydraulic Brake System, using the SQ3R method of study. (7)

Remind students of energy and materials conservation.

INTRODUCTION TO NEW DAY'S WORK

1. **Arouse student interest through discussion on possible results of system malfunctions. Note: Energy and materials conservation.**

2. Review and grade outside assignment. Re-teach as needed.

3. Briefly review how each air brake component functions within the system.

PRESENTATION:

1. Ref: Para a, Part 1.

   Ref: Para b, Part 1.

   Ref: Para c, Part 1.

   A. The air over hydraulic brake system combines certain hydraulic components with certain air brake components — Transparency CT74-376 Air/Over Hydraulic Brake Booster System

      (1) Hydraulic components

         (a) Master cylinder and linkage — Chart 59-3142 Air/Over Hydraulic Brake Booster System

         (b) Lines, fittings and flexible hoses

         (c) Wheel cylinders at each wheel

      (2) Air brake components

         (a) Compressor

         (b) Governor

         (c) Reservoirs - wet or dry

         (d) Safety valve

         (e) Pressure gauge

         (f) Low pressure warning buzzer

         (g) Air supply valve

         (h) Extended lines of air for trailer

         (i) Hand control valve (trailer brakes

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b. The combining of these air and hydraulic components to form an air over hydraulic brake system is accomplished by adding a brake booster unit (air-pac booster)

Chart 59-3139 Air/Hyd. Booster (released)

(1) Brake booster unit components

(a) Air cylinder and power piston: Compressed air moves power piston, resulting in greatly increased hydraulic pressure to wheel cylinders

Chart 59-3139-1 air/hyd. Booster (applied)

(b) Control valve: Means of applying air pressure to power piston

(c) Hydraulic slave cylinder: Receives power piston force and converts to hydraulic pressure

Trainer: 63-2996 Brake Assembly

Show Air Over Hydraulic System Components

(d) Bleeder valves

1 Means of removing air from hydraulic portion of booster

2 One located at control valve assembly - other at slave cylinder

c. Maintenance of system

(1) All air must be exhausted from system prior to bleeding or removing system components

(2) Components of the hydraulic portion of the system are maintained as previously discussed

(3) Components of the air portion of the system are maintained as previously discussed

(4) Booster unit maintenance consists of:

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(a) Removal and replacement

(b) Installation of rebuild kits

APPLICATION:

1. Ref: Para b, Part 1

Ref: Para c, Part 1.
(Also interspersed throughout body of lesson)

Hand & Special Tools
Vehicles - T.O. 36A2-2-1-122

1. Remove all jewelry.
2. Watch for oil slick on lab floor.
3. Use hand & special tools, vehicles.

EVALUATION:

1. How effective is a booster unit?

2. What procedure is used to bleed brakes on air over hydraulic system?

3. What maintenance is required on an air over hydraulic brake system?

4. What is the difference in the air over hydraulic system and the hydrovac?

5. What unit applies the brakes in the air over hydraulic system?

6. What safety feature allows the brakes to be applied?

7. What is the purpose of the booster unit?

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Summarize repair or service procedures for air brake compressor, governor, reservoirs, system valves, brake chambers and slack adjusters. Also air/over hydraulic power cylinder, master cylinder and wheel cylinder.

2. Strengthen student desire to become proficient on all types of brake systems by pointing out safety involved and personal gain through promotion and pay. Remind students of energy and materials conservation.

ASSIGNMENT AND CLOSURE: CTT P.O.I. Para 3b, 3c 2 Hrs

1. Using the SQ3R method of study. Review 3ABR47330-SG-604 & 604A, PT-3ABR47330-604 Conventional & Power Steering. Answer Summary questions.

2. We have now completed basic information on all present day brake systems used within the General Purpose Career Field of the Air Force. Our next lesson will enable us to understand and service steering gear assemblies, another important means of control for a vehicle in motion.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 21 Feb 75	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	General Purpose Vehicle [redacted], Part I (MECHANIC)

BLOCK NUMBER	BLOCK TITLE
II	Brakes and Suspension

LESSON TITLE

Conventional and Power Steering Systems

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXX/Complementary	TOTAL
D&D 6 hrs/Perf 6 hrs	4 hrs	16 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
40	2 Jan. 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 59-2451 2. Trainer: 61-2423 3. Trainer: 59-2433 4. Trainer: 63-2995 5. Trainer: 60-2530 6. Mechanic's Common Hand Tools 7. Special Tools	None	None	1. 3ABR47330-SG-604 2. 3ABR47330-SG-604A 3. 3ABR47330-SG-604B 4. 3ABR47330-WB-604 5. 3ABR47330-PT-604 6. Chart:CAFB59-3236 7. Chart:CAFB59-3145 8. Chart:CAFB63-425(1

(OVER) **CRITERION OBJECTIVES AND TEACHING STEPS** (OVER) of 2

a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of steering system components with 70% accuracy.

b. Provided with vehicles, tools, and equipment, bench items, technical orders, and applying automotive personnel and equipment shop safety, repair or service steering systems and components IAW the technical publications.

c. Supplied with tools and equipment, vehicles, technical orders, and observing automotive personnel and equipment shop safety, use visual, auditory, and operational means to check steering systems IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770 SAFB, IL 73-

EQUIPMENT LOCATED IN LABORATORY

8. Steering Gear Assy.
9. Vehicle

GRAPHIC AIDS AND UNCLASSIFIED MAT.

9. Chart:CAFB63-425 (2 of 2)

INTRODUCTION

20 Min

1. Attention and Motivation: Gain students' attention by pointing out the possible consequences of improper vehicle steering or handling. Stress the importance of quick and sure steering response during normal operation or in case of emergency.

2. Review: Review 3ABR47330-SG-604. Give an appraisal. Review summary questions. Re-teach as needed.

3. Overview & TIE-IN: Explain sequence in which the lesson will be presented placing emphasis on objectives. Show how placing a vehicle in motion & being able to stop the vehicle is of no consequence unless you can control the vehicle direction while it is in motion. Point out to each student, what will be expected of him during the presentation and application steps of lesson. Remind students of energy and materials conservation. (Heat, cooling, light, study materials, Etc.)

BODY

11 Hrs 2_ Min

PRESENTATION:

1. Ref: Para a, Part 1.	3ABR47330-SG-604 3ABR47330-SG-604A 3ABR47330-SG-604B (SG's to be re-used) 3ABR47330-P.T.-604 3ABR47330-W.B.-604 (Do not write in P.T. or W.B.)
a. Steering Gear Types	
(1) Worm and sector	
(2) Worm and roller	
(3) Cam and lever	
(4) Worm and nut-(recirculating ball)	
b. Construction and operation	
(1) Worm and sector	Chart: 59-3236 worm & sector
(a) Worm gear integral with column shaft on lower end	
(b) Mounted between tapered roller bearings at top and bottom in gear case	Trainer: 60-2530 worm & sector
(c) Worm has "Hour Glass" shape to provide:	
1 Better tooth contact	

2 Variable ratio

(d) Sector gear is integral with cross shaft on inner end

(e) Tapered to aid adjustment and mesh with worm gear

(f) Outer end of cross shaft is splined to receive the "Pitman" arm

(g) Lube seal in cross shaft housing

(2) Worm and roller

(a) Column shaft and worm gear same as worm and sector — Trainer: 61-2423

(b) Roller gear mounted in ball bearings on cross shaft

1 Replaces sector gear and reduces friction

(c) Gear operation same as worm and sector

(3) Cam and lever — Trainer: 59-2451

(a) Cam replaces worm as integral part of column shaft on lower end — Steering gear assembly

(b) "Lever" is actually two studs mounted on inner portion of cross shaft that mesh with cam to actuate pitman arm during rotation

(4) Worm and nut or recirculating ball — Trainer: 59-2433 Worm & Nut

(a) Worm is integral part of column shaft on lower end

(b) Nut is mounted on worm by means of ball bearings and travels up and down worm during steering wheel rotation — Chart: 59-3145

(c) Nut has teeth on one side that are tapered and mesh with a sector gear mounted on the cross shaft

(d) Nut has two guides which assist in recirculating the bearings through nut to reduce friction during turns

c. Inspection

(1) Fluid level

(2) Housing

(a) Cracks, leaking gaskets or seals

(b) Correct mounting

(3) Column shaft alignment

(a) Dash or cowl mounting

(b) Gear box mounting

(c) Prevents binding on one-piece shaft

(d) Done prior to "In-Box" adjustments

d. Adjustments - (Manual steering)

(1) Disconnect drag link or relay rod prior to "In-Box" adjustments

(2) Worm gear end play - (Bearing pre-load) - (Clay weight method)

(a) Loosen lash adjusting screw all the way out-then back in one turn

(b) Position steering wheel one turn off either extreme

(c) Place two clay weights (½ lb) on steering wheel rim at 10:00 or 2:00 o'clock position. (Wheel should hold)

61.

(d) Add one additional weight (Total 3/4 lb)(Wheel should drop toward six o'clock position).

(3) Cross shaft backlash - (Lash)

(a) Center steering gear by determining total number of turns from one extreme to the other - then place steering wheel at mid-position or "Hi-point"

(b) Tighten lash adjusting screw until "Free Play" at Pitman arm has been removed

(4) Upon completion of both adjustments, a slight drag through mid-position or hi-position should be felt - a spring scale tester may be used

(5) Most modern vehicle manufacturers recommend the use of a torque wrench to accomplish the adjustments to their specifications

APPLICATION: Para A, Part 1
Interspersed throughout the lesson

EVALUATION:

1. Name the four types of conventional steering gears.

2. Which steering gear is used on heavy duty vehicles?

3. What is meant by the term "variable ratio"?

4. What should be done before installing a new steering gear cross shaft?

5. Why does the recirculating ball steering gear nut have external teeth on one side?

6. Define the term "Hi-point".

END OF DAY SUMMARY

SUMMARY:

1. Summarize principles of operation, function and relationship of the following: Types of Steering Gears, Construction features, Inspection and Adjustment Procedures.

ASSIGNMENT: CTT POI Para 5A 2 Hrs 3ABR47330-SG-604

1. Read SG 3ABR47330-604 & 604A, PT-604 Conventional and Power Steering, using the SQ3R method of study. Write out answers to SG questions.

INTRODUCTION TO NEW DAY'S WORK

1. Arouse student interest by discussing possible system malfunctions and their results.

2. Review and grade outside assignment. Re-teach as needed.

3. Briefly review how steering systems are inspected and adjusted.

PRESENTATION:

1. Ref: 5A
   Ref: 5B
   Ref: 5C

   a. Types of hydraulic power steering

      (1) Linkage - all components in steering linkage except pump & reservoir — Trainer: 63-2995 Power steering assembly

      (2) Semi-integral pump and reservoir on L.F. side of engine - Power cylinder in linkage - control valve on gear box

      (3) Integral - Pump and reservoir on L.F. side of engine - control valve and power cylinder in steering gear case

   b. Major power steering components

      (1) Reservoir - holds hydraulic fluid for system use — Chart: 63-425 (1 of 2) 63-425 (2 of 2)

(2) Pump - (Roller - vane type)

(a) Belt driven off engine crankshaft - positive displacement

(b) Pressure relief valve located in pump body, controls system pressure

(3) Control valve

(a) Directs fluid flow from pump to the power cylinder

(b) Valve location determines the type of power steering system

(c) Adjustable to prevent vehicle "creep"

(4) Power cylinder

(a) Receives fluid pressure from pump through control valve

(b) Increases pressure to steering linkage, lessening driver effort

c. illing and bleeding system

(1) Operate engine and rotate steering wheel from side to side, prior to checking fluid level

(2) System is self - bleeding

APPLICATION: Also interspersed throughout lesson

Ref: Para b, Part 1.
Ref: Para c, Part 1.

Mechanic's Hand & Special Tools: Vehicles
Bench Item: Steering Gear As...

1. Remove jewelry in lab ar...

2. Watch for oil spots on ... floor

04

EVALUATION:

1. What should be done before making an end play or bearing preload adjustment on the vehicle?

2. What controls the maximum pressure of a power steering system?

3. What is meant by the term steering gear alignment?

4. What is the major source of trouble within the power steering system?

5. What is bearing preload?

6. Where is the control valve located on the simi-integral power steering system?

7. What is the purpose of the hour-glass worm?

8. What are the major components of a power steering system?

9. What should be used to check the lash or backlash adjustment?

10. What is indicated when wheels creep to one side with front wheels jacked up and engine is running on a power steering system?

11. What is the last item installed when installing a steering gear?

12. How is air removed from hydraulic power steering system?

13. What position should a steering gear be in to make a cross shaft adjustment? Why should it be in this position?

14. Would you have a steering kick back on a vehicle equipped with power steering? Why?

15. How do you check and correct steering alignment?

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16. What safety items are observed while working on manual and power steering systems?

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Summarize repair or service procedures for worm and sector, worm and roller, cam and lever, worm and nut conventional steering gears and components; linkage, semi-integral, integral type power steering systems and components; methods used to perform visual, auditory, operational means and test equipment to check steering systems.

2. Explain how each objective attained will be of value to the individual and the Air Force. Remind students of energy and materials conservation.

ASSIGNMENT AND CLOSURE: CTT POI Para 5A, 5B, 5C 2 Hrs 3ABR47330-SG-605

1. Using the SQ3R method of study, read SG-3ABR47330-605 & PT 605. PT-3ABR47330-605A Frame Alignment & Wheel Balance. Answer Summary questions.

2. This completes our discussion of the steering gear systems. Our next lesson on Frame Alignment and Wheel Balance will show a general relationship to vehicle steering.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 21 Feb 75	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	Mechanic General Purpose Vehicle [redacted], Part I

BLOCK NUMBER	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE

Frame Alignment and Wheel Balancing

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXX/Complementary	TOTAL
D&D 3 hrs/Perf 3 hrs	2 hrs	8 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
41	2 JAN. 1975	65

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Wheel Balancer 2. Vehicles 3. Mechanic's Common Hand Tools 4. Special tools	None	None	1. 3ABR47330-SG-605 2. 3ABR47330-PT-605 3. 3ABR47330-PT-605A 4. Film:TVZ7-662 5. Trans:T71-3591A

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of frame alignment components and wheel balancing with 70% accuracy.

b. Provided with technical orders, tools, and test equipment, vehicles, and practicing automotive personnel and equipment shop safety, use visual, auditory, operational means and test equipment to check frame alignment and wheel balance IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM 770 AUG 72

SAFB, IL 71-25690

INTRODUCTION

20 Min

1. Attention and Motivation: Describe the action of a vehicle that "dog-tracks" or vibrates excessively at certain speeds. Explain that understanding of today's objectives will enable them to eliminate such unwanted conditions from vehicles.

2. Review: Review and grade summary questions from 3ABR47330-SG-605. Give an appraisal on SG-605A. ALSO check each student's 3ABR47330-PT-605 to insure completion of all frames in text.

3. Overview and TIE-IN: Describe the sequence in which the lesson will be presented and the responsibility each student will have during the presentation and application steps. Explain that proper frame alignment and wheel balance add to the ease of vehicle handling, as does the proper operation of steering gear assemblies. Remind students of energy and materials conservation. (Heat, light, cooling, and study materials).

BODY

5 Hrs 20 Min

PRESENTAION:

1. Ref: Para a, Part 1

   a. Frame alignment and tracking

      (1) Frame components — 3ABR47330-SG-605

         (a) Side rails or members, — 3ABR47330-PT-605

         (b) Cross members — 3ABR47330-PT-605-A

      (2) Definitions pertinent to frame alignment — (Study materials to be re-used)

         (a) Wheel base - distance from front wheel spindle to rear wheel axle with wheels in straight ahead position and "toe" equally divided

         (b) Tracking - equal wheel base on both sides of vehicle and all wheels in their original relationship to each other

      (3) Suspension problems

         (a) Knee back

         (b) Rear axle shifted

(4) Frame Damage

(a) Diamond

(b) Swayed

(5) Use of Tracking Gauge

(a) Assemble gauge and set to the vehicle wheel base specifications. (Driver's side)

(b) With no change in gauge setting, compare to passenger side of vehicle

(c) Indications:

1 Equal wheel base, but, incorrect tracking- (Frame damage)

2 Unequal wheel base and incorrect tracking- (Suspension problems)

(6) Determining extent of frame damage

(a) Visual inspection

(b) "Projection method" to pinpoint damaged area of frame

1 Plumb Bob-(Minimum of eight points)

2 Chalk Line-(Center Line and two diagonals)

3 Steel tape measure- (Usually 3/8" overall tolerance)

b. Wheel Balance

(1) Purpose

(a) Eliminate excessive vibration which normally results in tire and front end component wear

(2) Preliminary inspection of wheel and tire assembly

(a) Remove all old weights

(b) Remove dried and caked mud from wheel

(c) Remove rocks, nails, and glass from tire tread

(d) Check wheel bearing adjustment

(e) Check wheel run-out (one eighth inch is maximum tolerance)

(f) Check tire pressure

(g) Check for dragging brakes

(3) Unbalanced wheel conditions — Film: TV77-662

(a) Static (still) — Wheel Balance

1 Caused by heavy spot on center of tire tread

2 Results initially in low speed up and down wheel pounding action — Transparency T71-3591 (A)

(b) Dynamic (running)

1 Caused by heavy spot off center of tire tread — Wheel & Tire Balancing

2 Results in high speed side to side wheel wobble

c. Demonstration regarding the preparation and use of tracking and wheel balance equipment

APPLICATION:

1. Ref: Para b Part 1
(Also interspersed within lesson body

Hand & Special Tools;
Vehicle; Wheel Balancer
Remove jewelry in lab
Watch for oil spots on lab foor

EVALUATION:

1. Define the terms "wheel base" and "tracking".

2. List the frame misalignment conditions.

3. Identify conditions of incorrect tracking not caused by frame damage.

4. Explain the use of a "plumb bob".

5. Why must we have a minimum of eight drop points?

6. What is the difference between static and dynamic wheel balance?

7. Which item in the preliminary inspection would most conclusively prevent satisfactory wheel balance?

8. Where are the wheel weights placed for correction of static unbalance?

   Dynamic?

9. What is the purpose of the number two (2) scale on the alemite portable balancer?

10. How are rear wheels balanced?

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Summarize principles of operation, function, and relationship of frame alignment components and wheel balance factors (side rails, cross members, wheel base, tracking, knee back condition, diamond condition, swayed condition, rear axle shifted condition, static unbalance and dynamic unbalance); methods allowing visual, auditory operational means and test equipment to check frame alignment and wheel balance.

2. Point out major benefits that may be derived from a thorough understanding of frame alignment and wheel balance principles. Remind students of energy and materials conservation. (Heat, light, cooling, and study materials).

ASSIGNMENT AND CLOSURE: CTT P.O.I. Para 6A, 6B, 2 Hrs 3ABR47330-SG-606

1. Using the SQ3R method of study, read SG-3ABR47330-606 and PT 3ABR47330-606 and 606A. Answer summary questions and complete text.

2. Now that we have completed our studies of frame alignment and wheel balance, we should be able to understand the next lesson on steering factors; springs and shock absorbers as related to the vehicle frame.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 21 Feb 75 [signature]	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	General Purpose Vehicle Mechanic [redacted], Part I

[redacted]	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE

Steering Factors, Springs, and Shock Absorbers

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXX/Complementary	TOTAL
D&D 4 hrs/Perf 2 hrs	2 hrs	8 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
42	2 Jan. 1975	6

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 60-2538 2. Trainer: 61-2432 3. Trainer: 61-2878 4. Trainer: VE-1102 5. Portable Wheel Alignment Equip.	None	None	1. 3ABR47330-SG-606 2. 3ABR47330-PT-606 3. 3ABR47330-PT-606A

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of steering factors, springs, and shock absorbers with 70% accuracy.

b. Given technical orders, tools, and equipment, vehicles, and observing automotive personnel and equipment shop safety, repair or adjust steering factors, springs, and shock absorbers IAW the technical publications.

c. Supplied with tools and equipment, vehicles, technical orders, and applying automotive personnel and equipment shop safety, use visual, operational means, and test equipment to check steering factors, springs, and shock absorbers IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM 770 AUG 72 — SAFB IL 71-25690

INTRODUCTION

20 Min

1. Attention and Motivation: Ask students why a vehicle is difficult to steer when driving in "reverse". Also why a vehicle steering wheel returns to the straight ahead position after turning a corner. Explain to the students that the principles which they are about to learn are applicable to all vehicles and therefore quite valuable.

2. Review: Review and grade summary questions from 3ABR47330-SG-606. Check each student 3ABR47330-PT-606 and 3ABR47330-PT-606-A to insure correct completion of each frame in the texts. Reteach as needed.

3. Overview and TIE IN: Describe the sequence in which today's lesson will be presented and the responsibility each student will have during the presentation and application steps. Explain how each previous lesson in the block added to ease of vehicle handling, safety, comfort, and reduced the overall cost of vehicle component replacement. Remind students of energy and materials conservation. (Heat, cooling, light, and study materials).

BODY

5 Hrs 20 Min

PRESENTATION:

1. Ref. Para a, Part 1

   a. Shock absorbers

      (1) Types

         (a) Single acting — 3ABR47330-SG-606

         (b) Double acting or — 3ABR47330-PT-606

         Direct acting (most common on vehicles today) — 3ABR47330-PT-606-A

         (Study materials to be re-used)

      (2) Purpose

         (a) Regulate spring rebound

         (b) May also dampen compression of springs

      (3) Construction

         (a) Outer shell and base assembly

         (b) Sleeve assembly

         (c) Pressure tube

         (d) Piston assembly

(4) Operating principles

(a) Hydraulically operated

(b) Piston forces hydraulic fluid through restricted opening during spring flexing

b. Springs

(1) Types

(a) Laminated leaf or semi-elliptical

(b) Coil springs

(2) Purpose

(a) Permit vehicle suspension flexibility

(b) Reduce road shock

(c) Support vehicle weight

(3) Laminated leaf type construction

(a) Series of spring steel leaves

(b) Held together by spring clips and center bolt

(4) Coil spring construction

(a) Spring steel shaped in form of coil

(b) Designed to mount between lower control arm and frame (at side rail and front cross member or above upper control arms)

c. Wheel Alignment

(1) Definition: Series of inter-related angles of various front end components

(2) Purpose: Allow wheels to roll freely without scuffing and provide ease of vehicle handling

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(3) Alignment Angles (Steering Factors)

(a) Camber

1 Definition - inward (neg) or outward (pos) tilt of the wheel at the top

Trainer 60-2538 Wheel Alignment Rigid Axle

2 Purpose - off-set load deflection (I-beam) or center tire tread at point of load (independent suspension)

61-2878 Ball Joint Suspension

3 Measured in degrees from a true vertical zero

4 Definite tire wearing angle

a Excessive pos - outer edge

b Excessive neg - inner edge

5 Causes wear on king pin bushings or ball joints - also inside wheel bearing wear

6 Can, but does not usually, cause vehicle pull (toward more pos side)

7 Weight distribution inside vehicle has a direct effect on camber settings

(b) Caster

Trainer: 60-2538 Rigid Axle
61-2878 Ball Joint Suspension

1 Definition: Backward (Pos.) or forward (Neg.) tilt of the king pin or steering axis at the top.

2 Purpose

a Steering stability

b Return wheels to straight ahead position after turns

c Off-set "road crown"

3 Measured in degrees from a true vertical zero

Does not directly cause tire wear

4 Effects of incorrect caster

a Hard steering - difficult to turn - (pos)

b Road shock-(pos)

c Shimmy - (pos)

d Pull to one side - (pos, equal or neg depending on road crown and setting)

e Wander - (neg)

f Parts wear due to all of the above,

5 NOTE: A vehicle will always "Pull" toward the least positive or most negative caster setting

(c) Steering axis inclination (S.A.I.) - (king pin inclination or K.P.I.)

1 Definition: Inward (Pos.) Tilt of the king pin or steering axis at the top

Trainer 60-2538 Rigid axle
61-2878 Ball Joint Suspension

2 Purpose

a Steering stability

b Return wheels to straight ahead position after turns

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6 Pre-determined angle set at factory - not adjustable

7 Readings affected by work done on tie rod linkage, incorrect toe or bent arms

8 Readings should be taken after other factors are set to specifications

(e) Toe (in or out)

1 Definition - comparative difference in distance between front and rear portions of front wheels, when measured at spindle height

Trainer VE-1102 Caster, Camber, Toe

2 Purpose - off-set the compression (rear mounted) or extension (front mounted) of the tie rod assembly, due to the forward motion of the vehicle (wheel spread)

3 Measured in fractions of an inch

4 Worst tire wearing angle

5 Adjusted by lengthening or shortening the tie rod assy.

APPLICATION:

1. Ref: Para b, Part 1
Ref: Para c, Part 1
(Also interspersed within lesson body)

Portable Alignment Equipment

Remove jewelry in lab area.
Watch for oil spots on lab floor.

Vehicles
Portable alignment equipment

EVALUATION:

1. Name and define each steering factor.

2. Explain the purpose(s) of each factor.

3. Describe the purpose(s) of shock absorbers.

4. Explain the operating principles of a direct acting shock absorbers.

5. Explain the purpose of vehicle springs.

6. Which steering factors are not adjustable?

7. Which factor causes most tire wear?

8. Which factor does not directly cause tire wear?

9. Explain the terms "scrub radius" and "road crown"?

10. What determines the side to which a vehicle leads, when setting caster?

11. How does excessive S.A.I. affect wheel bearings?

12. What controls the degree of turn in steering geometry?

13. How does incorrect toe-in affect tires?

14. List the "included angles" and explain how this term is derived.

15. Which factor is primarily responsible for king pin or ball joint wear?

16. When is a vehicle aligned at curb weight?

17. How are shock absorbers checked for condition?

18. How is the steering linkage checked for looseness?

19. Which factor would cause tire sqeal while rounding a curve at low speed?

20. Which adjustment is made on a steering gear when it is on "high point or mid-position"?

CONCLUSION

20 Min

SUMMARY AND REMOTIVATION:

1. Summarize principles of operation, function, and relationship of steering factors (cambers, caster, steering axis inclination, turning radius & toe)

springs (leaf and coil type) and shock absorbers (single and double acting); repair and adjustment procedures for steering factors, springs and shock absorbers; methods allowing visual, auditory, operational means and test equipment to check steering factors, springs, and shock absorbers.

2. Point out the versatility which the knowledge of steering factors will now permit each student when performing wheel alignment. Remind students of energy and materials conservation. (Heat, cooling, light, study materials.)

ASSIGNMENT AND CLOSURE: C.T.T. P.O.I. Para 7a,b,c, 2 Hrs 3ABR47330-SG-608

1. Using the SQ3R method of study, read SG-3ABR47330-607 and PT-3ABR47330-607A. Answer summary questions and complete text.

2. We have now completed today's lesson. In our next lesson, we will learn how these factors are put to best use on Beam-Type front axle suspension systems.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 2/7/75 [illegible]	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	General Purpose Vehicle MECHANIC [redacted] Part I

BLOCK NUMBER	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE

Service and Adjustment of Beam-Type, Front Axle Suspension System

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXXX/Complementary	TOTAL
D&D 2 hrs/Perf 4 hrs	2 hrs	8 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
43	2 JAN. 1975	87

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Vehicles 2. Trainer: 61-2432 3. Trainer: 60-2538 4. Portable Wheel Alignment Equip 5. Scuff Tester 6. Mechanic's Common Hand tools (OVER)	None	None	1. 3ABR47330-SG-607 2. 3ABR47330-PT-607A 3. T036A2-3-6-2 4. Film: TVL 47-4 5. T036A2-3-6-22-1

CRITERION OBJECTIVES AND TEACHING STEPS

a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of beam-type front axle suspension system components with 70% accuracy.

b. Provided with vehicles, tools, and equipment, technical publications, and observing automotive personnel and equipment shop safety, adjust and service beam-type front axle suspension systems IAW the technical order.

c. Supplied with technical orders, vehicles, tools, and equipment, and practicing automotive personnel and equipment shop safety, use visual, operational means and test equipment to check beam-type front axle suspension systems IAW technical publications.

Teaching Steps are Listed in Part II.

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EQUIPMENT LOCATED IN LABORATORY

7. Special Tools
8. Floor jacks
9. Jack stands

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INTRODUCTION

20 Min

1. Attention and Motivation: Explain to students that straight axle suspension was used on passenger cars at one time. Create a brief discussion by asking why they are no longer used on passenger cars. Point out the current lack of knowledgeable people, capable of correcting, adjusting and servicing Beam-Type suspension and how the student may gain through understanding of this system.

2. Review: Review Summary questions from 3ABR47330-SG-607. Check frame completion in each student's PT-607Aand 607A. Reteach students as needed.

3. Overview and TIE-IN: Discuss the sequence in which the lesson is to be presented and what each student's responsibility will be during the presentation and application steps. Explain how knowledge of steering factors, plus an understanding of Beam-Type suspension systems combine to allow good wheel alignment. Remind students of energy and materials conservation. (heat, cooling, light, study materials).

BODY

5 Hrs 20 Min

PRESENTATION:

1. Ref: Para a, Part 1

a. Constructional features and components

(1) Axle — Trainer 60-2538 Wheel Alignment

(a) I Beam (dead) — 3ABR47330-SG-607

(b) Tublar — 3ABR47330-PT-607-A

(2) Springs (leaf type) — (Study materials to be re-used)

(a) Center bolt

(b) U-bolts

(c) Shackles and Hangars

(d) Rebound Clips

(3) Steering knuckle and integral spindle

(4) King pin

(a) Bushings

(b) Bearing (thrust)

(c) Steel shims

(d) Lock pin

(5) Steering knuckle arms

(6) Steering arm

(7) Tie rod

(8) Tie rod ends (2 ea)

(9) Drag link

(a) Adjustable

(b) Non-adjustable

Film # TVL - 47-4 Portaliner

(10) Shock absorbers

b. Preliminary inspection - front end alignment

(1) Curb weight

(2) Tires

(a) Pressure

(b) Size

(c) Tread Depth

(3) Wheels

(a) Lug nuts

(b) Bearings

(c) Run out - (Lateral and Radial)

(4) King pins and bushings

(5) Front and rear suspension - loose, damaged, or missing components

(6) Steering linkage

(7) Center steering gear

c. Adjustments, corrections, and repair

(1) Camber

(a) Not adjustable

(b) Correct by bending axle ends in desired directio

1 Up-Negative

2 Down-Positive

(c) K.P.I. also changes in comparison

(2) Caster

(a) Adjust by adding or subtracting tapered shims between axle and springs

(b) Position thick part of shims toward the direction you want king pin to tilt

1 Thick part forward - Negative

2 Thick part back - Positive

(3) King pin inclination (K.P.I.)

(a) Not adjustable

(b) Corrected during camber change

(c) Replace parts

1 Camber corrected, K.P.I. usually is correct

2 Camber correct and K.P.I. is wrong, replace steering knuckle with integral spindle

3 Recheck camber

(4) Steering geometry

(a) Not adjustable

Trainer 61-2432 Steering geometry

(b) Not corrected

(c) Replace parts - steering knuckle arms

(5) Toe (in or out)

(a) To adjust, lengthen or shorten tie rod

Trainer: 60-2538 Wheel Alignment

(b) Dead axle, tie rod always located behind axle

(c) Live axle - tie rod may sometimes be located in front of axle

(6) Position steering gear, with wheels straight ahead

(a) Adjustable drag link

(b) Non-adjustable drag link

T.O.s 36A2-3-6-2
36A2-3-6-22-1

APPLICATION:

Ref: Para b, Part 1
Ref: Para c, Part 1.
(Also interspersed within lesson body)

Portable wheel alignment equipment; scuff tester; Hand & Special Tools; Vehicles; Floor Jack; Jack stands

EVALUATION:

1. What are the adjustable factors?

Remove jewelry in lab

2. To increase positive camber, what would you be required to do?

Watch for oil on lab floor

Safety: Application step

3. How is caster adjusted?

4. If camber is correct and K.P.I. is wrong, what should be done?

5. Why are steel shims included in a king pin kit?

6. What should be done with bent steering knuckle arms?

7. What safety practices should be observed during I-Beam axle corrections?

CONCLUSION 20 Min

SUMMARY AND REMOTIVATION:

1. Summarize principles of operation, function and relationship of Beam-Type front axle suspension system components (axle, king pins, steering knuckle, knuckle arms, tie-rods, etc.); adjustment and service procedures; methods for visual, auditory, operational means and test equipment to check Beam-Type front axle suspension system.

2. Explain advantages of being knowledgeable in this specialized area of the General Purpose career field. Remind students of energy and materials conservation.

ASSIGNMENT AND CLOSURE: CTT POI Para 8A,B,C, 2 Hrs

1. Using the SQ3R method of study, read SG-3ABR47330-608. Answer summary questions and complete the text.

2. We have now concluded wheel alignment procedures and servicing for vehicles using Beam-Type front axle suspension systems. In our next lesson, we will accomplish the same procedures on independent suspension systems.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 2/ 7/15 75 [signature]	

COURSE NUMBER	COURSE TITLE
[redacted] 3ABR47232	General Purpose Vehicle [redacted] MECHANIC, Part I

BLOCK NUMBER	BLOCK TITLE
VI	Brakes and Suspension

LESSON TITLE

Service and Adjustment of Independent Suspension System

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXXX/Complementary	TOTAL
D&D 4 hrs/Perf 7 hrs	4 hrs	15 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
44	2 JAN. 1975	98

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Vehicles 2. Trainer: 61-2878 3. Trainer: 61-2432 4. Trainer: VE-1003 5. Trainer: VE-1102 6. Mechanic's Common Hand Tools 7. Special Tools	None	None	1. 3ABR47330-SG-608 2. TO36A2-3-14-2-1 3. TO36A2-4-17-2 4. Chart:CAFB63-359 5. Chart:CAFB62-829 6. Chart:CAFB62-827 7. Chart:CAFB62-828 8. Chart:CAFB66-34

(OVER) CRITERION OBJECTIVES AND TEACHING STEPS (OVER)

a. Without references, identify basic facts and terms relative to the principles of operation, function, and relationship of independent suspension system components with 70% accuracy.

b. Supplied with vehicles, technical orders, tools, and equipment, and observing automotive personnel and equipment shop safety, adjust and service independent suspension systems IAW technical publications.

c. Provided with vehicles, tools, and equipment, technical publications, and applying automotive personnel and equipment shop safety, use visual, operational means and test equipment to check independent suspension systems IAW the technical order.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770.

EQUIPMENT LOCATED IN LABORATORY

8. Floor Jacks
9. Jack stands
10. Scuff Tester
11. Portable Alignment Equipment

GRAPHIC AIDS AND UNCLASSIFIED MAT.

9. Trans: 71-3590

INTRODUCTION 20 Min

1. Attention and Motivation: Gain student attention by giving examples of various unwanted handling characteristics of vehicles, effects of worn suspension parts and illustrations of tire wear. Point out to students, that a thorough understanding of how an independent suspension functions can make their job as vehicle repairmen easier.

2. Review: Review and grade the summary questions from 3ABR47330-SG-608. Re-teach as needed.

3. Overview: Explain the sequence in which today's lesson is to be presented and each student's responsibility during the presentation and application portions of the lesson. Stress how today's lesson objectives tie-in with the objectives previously covered in the Beam-Type suspension system. Remind students of energy and materials conservation. (Heat, cooling, light, study materials)

BODY 10 Hrs 30 Min

PRESENTATION:

1. Ref Para a, part 1 — 3ABR47330-SG-608 (Study materials to be re-used)

a. Constructional features and components

(1) Coil spring suspension system components — Trainer 61-2878 Ball joint Suspension

(a) Control arms-(parallel arms or "A" frames)

1 Inner cross shaft

2 Bushings

(b) Ball joints

1 Usually riveted to outer end of upper and lower control arms

2 Provide steering axis

(c) Spindle support arms with integral spindle

(d) Coil springs

1 Located between lower control arm and frame (large sedans)

2 Located between upper control arm and frame bracket in fender well (Smaller, lighter, sedans)

CHART: 62-829 Falcon front suspension

3 Spring location determines placement of floor jack when checking ball joints for wear.

(e) Stabilizer bar

1 Single bar, mounted across frame horns of vehicle down to link at each lower control arm.

2 Designed to prevent vehicle "roll-over" during high speed turns

(f) Strut rods

1 One on each side of vehicle, attached between outer end of lower control arm and frame horn.

2 Minor caster adjustment

3 Primary use is to re-enforce or stabilize the lower control arms

Chart 62-828 falcon stabilizing strut

(g) Shock absorbers

Trans: T71-3540 Shock absorbers

(h) Tie rod linkage

1 Tie rods, sleeves and ends

2 Relay rod

3 Idler arm and bushings

(i) Compression rubber bumpers

(2) Torsion bar suspension components

(a) Same components as ball joint suspension system

(b) Torsion bar replaces coil spring on each side of vehicle

(c) Mounted parallel to each frame side rail, between the center frame cross member, forward to the lower control arms (near inner shafts)

(d) Cold rolled spring steel, designed to take stress in <u>one direction only</u>!

<u>1</u> Marked "L" or "R" at rear orbar

<u>2</u> May be color coded

<u>3</u> <u>Not</u> interchangeable

(e) Riding height adjustment

<u>1</u> Usually located under each side lower control arm.

<u>2</u> Comparison between lower control arm inner shaft and ball joint height

<u>3</u> Very important! Must be accomplished <u>prior</u> to checking steering factors.

(3) Twin I beam suspension system components

(a) I beam axles (2 ea) — Chart 66-34 Twin I-beam Suspension System Principles

<u>1</u> Pivoted from side member of frame

<u>2</u> Radius arms and insulators

(b) Springs (coil) mounted above axles to frame

(c) Tie rod linkage

<u>1</u> Relay rod

<u>2</u> Tie rod

<u>3</u> Ends

(d) All other components same as I beam conventional axle (3)

(e) Only adjustment is "TOE"

(f) Correct caster by twisting axle end

(g) Correct camber and KPI by bending axle end

b. Preliminary inspection - front end

(1) Curb weight

(2) Tires

(a) Pressure

(b) Size

(c) Tread depth

(3) Wheels

(a) Lug nuts

(b) Bearings

(c) Run-out

(4) Ball Joints - (check)

(a) Coil spring on lower control arm - place floor jack under lower control arm

(b) Coil spring on upper control arm - place floor jack in center of frame front cross member

(5) Front and rear suspension - loose, broken, damaged or missing components

(6) Steering linkage

(7) Center steering gear

c. Adjustments and corrections

(1) Caster — Trainer VE-1003 Caster, Camber Adjustment simulator

(a) Shims - add to or subtract from one bolt only

(b) Cams

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1 Hold one and turn the other for small caster change	Chart 62-827 Falcon caster adjustment
2 Turn cams in opposite direction for large caster change	
(c) Strut rods - lengthen or shorten rod (restricted adjustment due to effect on vehicle wheel base)	Chart 62-628 Falcon stabilizing Strut
(d) Correct caster on twin I-beam axles by twisting axle	
(2) Camber	
(a) Shims - add or subtract shims at both bolts equally	Trainer VE-1003 Caster, Camber Adjustment Simulator
(b) Cams - move both in the same direction	
(c) Correct camber on twin I-beam axles by bending axle end in desired direction	Trainer VE-1102 Caster, Camber Toe, Adjustment Simulator
1 Up - Negative	
2 Down - Positive	
(3) Steering axis inclination, king pin inclination	
(a) Not adjusted	
(b) Not corrected	
(c) Replace parts - if camber correct and SAI wrong, replace spindle	
(4) Steering geometry (toe out on turns or turning radius)	Trainer 62-2432 Steering Geometry
(a) Not adjusted	
(b) Not corrected	

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(c) Replace steering knuckle or spindle arms

(5) Toe (in or out)

(a) Lengthen or shorten both tie rods the same amount

(b) Lengthen or shorten the tie rod - twin I-Beam suspension

(6) Positioning steering gear

(a) Toe O.K.

1 Lengthen one tie rod shorten the other the same amount

Chart 63-359 Steering wheel off center

2 Same as I-Beam conventional suspension system

(b) Toe not O.K. - Lengthen or shorten one tie rod ONLY

END OF DAY SUMMARY

SUMMARY

1. Summarize principles, function & relationship of the following:

a. Control arms, springs, stabilizer bar & strut rods, shock absorbers, tie-rod linkage, torsion bars, twin I-beam axles. Remind students of energy and materials conservation.

1. Restate objectives of the lesson (covered in this day).

2. Emphasize the area of major importance.

3. Use oral questions to determine areas to be retaught.

ASSIGNMENT CTT POI Para A,B,C, Part 1 2 Hrs

3ABR47330-SG-608

1. Review study materials on front suspension service & adjustment procedures using SQ3R method of study

1. Identify study materials.

2. Give reasons for student to study assignment.

3. Mention method of study.

INTRODUCTION TO NEW DAY'S WORK

1. Arouse student interest by pointing out to students they are now ready for the final subject matter that will enable them to successfully perform wheel alignment on all types of vehicles. (6)

2. Remind student of the objectives stated in previous day's lesson. Review key points. Give an appraisal on SG 608.

State objectives for today's lesson and make sure each student is aware of his responsibility during the lesson. Remind students of energy and materials conservation. (Heat, light, cooling, study materials).

APPLICATION:

Ref: para b, part 1
Ref: Para c, part 1
(Also interspersed within lesson body)

Scuff tester: Portable Alignment
Equip: TO's 36A2-3-14-2-1
36A2-4-17-2
Hand & Special Tools
Vehicles: Floor Jack & Jack Stands
Remove all jewelry before entering lab. Watch for oil on floors!

EVALUATION:

1. What are the three(3) types of independent suspension systems?

2. Where is the coil spring mounted on ball joint suspension systems?

3. How is caster change accomplished on the twin I-beam suspension system?

4. What safety precautions must be observed while working on vehicles with torsion bars?

5. What effect would adjusting caster with strut rods have on the vehicle?

6. If camber is correct and SAI wrong what would have to be done?

7. Name three methods of adjusting caster.

8. What suspension has adjustable riding height?

9. What is the purpose of an idler arm?

10. What sequence is followed when adjusting steering factors on coil spring type independent suspension:

CONCLUSION 10 Min

SUMMARY AND REMOTIVATION:

1. Summarize service and adjustment procedures for independent suspension systems; visual auditory, operational means & test equipment procedures to check adjustment of independent suspension systems.

Remind students of the good start they have accomplished toward becoming proficient in a highly specialized field. Remind students of energy and materials conservation.

ASSIGNMENT AND CLOSURE: CTT POI Para 9a,b,c 2 Hrs

1. Using the SQ3R method of study, read SG-3ABR47330-701. Answer summary questions.

2. We have now completed all lessons on brakes and suspension systems. In your next area of instruction, your first lesson will be on Principles of Compression-ignition engines.

PREPARE THE MAN

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STUDY GUIDE 3ABR47~~330~~ 232-SG-600

WORKSHEET 3ABR47330-[illegible]-603 AND 604

Technical Training

8-12

General Purpose Vehicle ~~Repairman~~ Mechanic

BLOCK VI
BRAKES AND SUSPENSION

3 June 1970

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes SSG 3ABR47330-601 THROUGH 608 and SWS 3ABR47330-601A-II THROUGH 608A-II, 22 May 1968
OPR: TSDT
DISTRIBUTION: X
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August 1969

HYDRAULIC BRAKES AND VACUUM BRAKE BOOSTERS

OBJECTIVES

After completing this unit of instruction, you will understand the operating principles of the hydraulic brake system and components, and the principle on which the vacuum booster system operates.

INTRODUCTION

The safety of a modern automotive vehicle and its cargo or towed load depends more often on the proper operation of the brakes than on any other unit except that of the steering gear. Not only must the brakes stop the vehicle, but they must bring it to a stop within certain and very definite limits of space. The brakes must be able to do this within one-eighth or one-sixth of the time it takes the engine to develop the speed. Besides being efficient, the brakes must be reliable against mechanical failure, weather of all types, dirt, grit, and grease. They must operate easily and with a wide margin of safety. Brakes must be long-lasting and tough. They must be made so that braking force, when applied, will be uniform.

INFORMATION

BRAKING SYSTEM

In early motor vehicles brake systems were rather simple. Not much attention was given to their improvement. More attention was given to the increase of power for moving the vehicle than for stopping it. Early automotive vehicles used a simple brake band attached to the transmission. Later, drums were attached to the rear wheels and external bands were supplied for holding the vehicle in a parked position. As higher speeds became possible, two-wheel brakes were unable to control the vehicle and four-wheel brake systems were developed. Programmed Text 3ABR47330-PT-601 will teach you some basic information about hydraulic brake systems. The information will include identification of components, location of components, hydraulic principles, and some repair procedures to be followed. The remainder of this study guide contains information relative to the construction and operation of vacuum brake boosters.

Brake Boosters (Vacuum, Hydrovac)

Heavy motor vehicles and their towed loads generally require more powerful braking effort than can be exerted by the unaided efforts of the driver. Systems have been developed for use on heavy vehicles whereby the operator simply controls a valve or switch which releases stored energy as needed to produce braking action of the desired intensity.

Vacuum System

In order to understand the principle on which the vacuum booster system operates, it is necessary to know what a vacuum is and how it can be used.

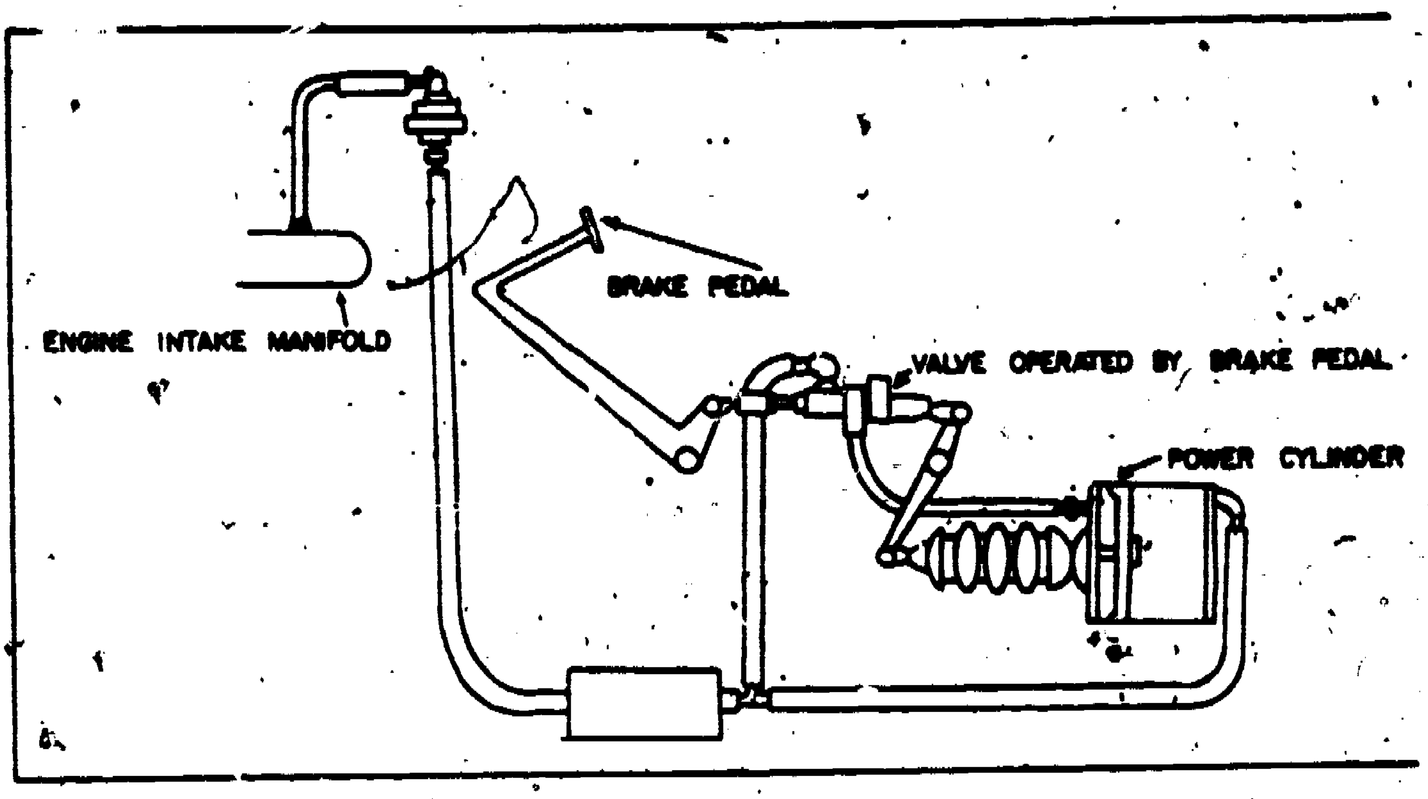

Figure 1. Vacuum System.

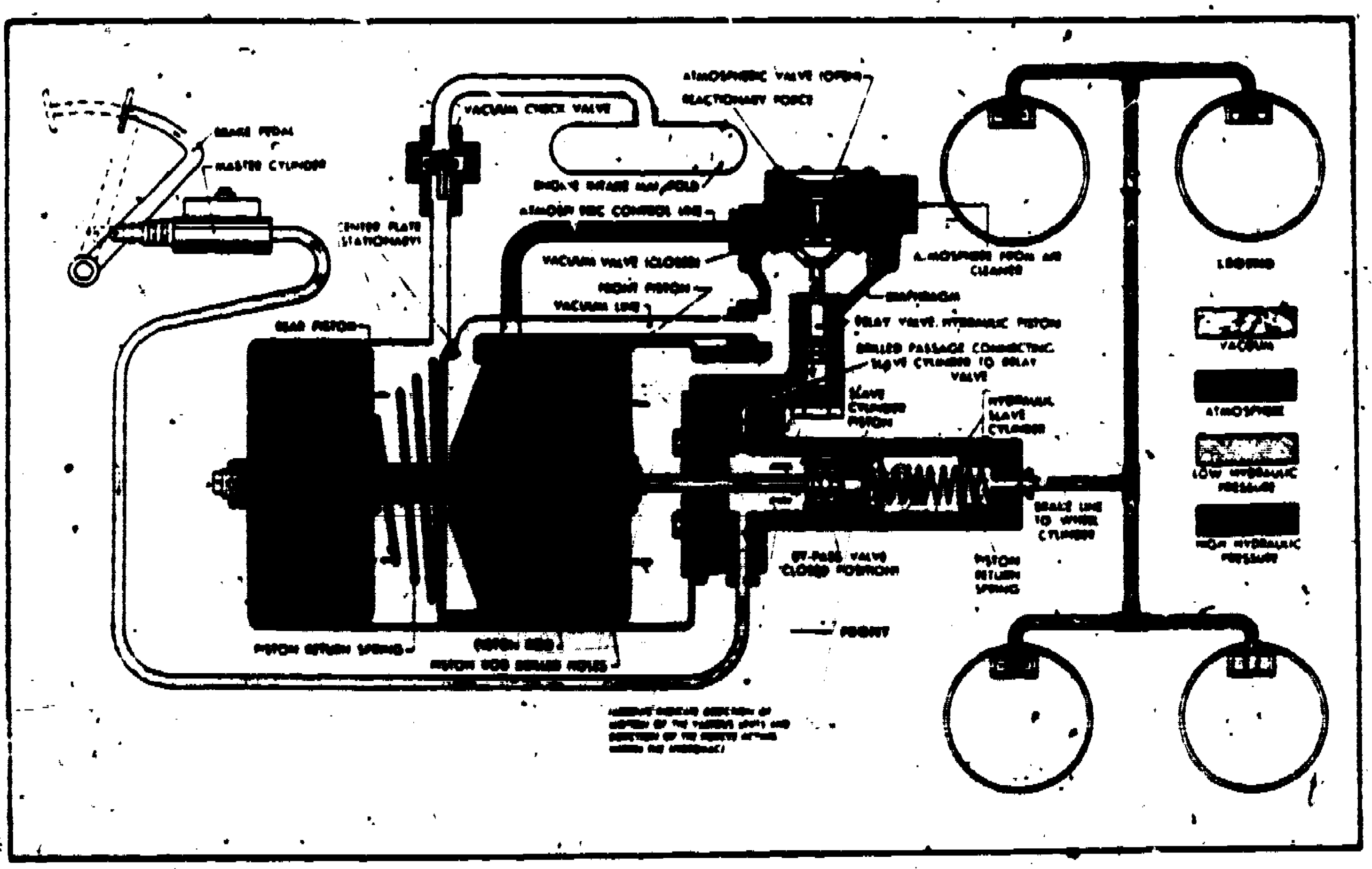

Figure 2. Hydrovac Operation--Applied Position.

For practical purposes a vacuum may be defined as a space from which air or gas has been partly exhausted. Air, like all matter, has weight. Since air extends upward from sea level for several hundred miles, the weight of the air exerts a pressure termed "atmospheric pressure" at sea level of about 15 psi (14.7 to be exact). This pressure is equally distributed in all directions upon all objects of the earth's surface.

Atmospheric pressure may be used to operate brakes by creation of a vacuum. Since a vacuum is created by removing air, the pressure within a vacuum is less than that of the atmosphere. A perfect vacuum from which all matter has been removed has no pressure whatsoever. A perfect vacuum is not obtainable, although it can be closely approached. Hence, the full force of 14.7 psi atmospheric pressure cannot be utilized. If air in a container has been pumped out or evacuated until only 5 psi remains, the 10 psi differential existing between "vacuum pressure" and "atmospheric pressure" may be used to perform work. The pumping action of the engine pistons causes a partial vacuum to be created in the intake manifold of an internal combustion engine. When the engine is coasting in high gear, with the carburetor throttle fully closed, very little air is admitted into the intake manifold so that the pumping actions of the pistons reduces the pressure so that only about 5 psi exists in the manifold.

The driver's foot is taken off the accelerator pedal when he applies the brakes so that about 10 psi difference (often called differential) between the vacuum pressure (5 psi) and atmospheric pressure (15 psi) are available to operate the brakes. Any chamber connected to the intake manifold will have air exhausted from it when the engine is running. The power cylinder, which contains a piston, depends on this fact for its operation. A valve operated by the brake pedal is inserted between the cylinder and manifold, as shown in figure 1, to control the operation of the power cylinder. When the valve is opened, air is exhausted from the chamber ahead of the piston. Atmospheric pressure acts on the other side of the piston to exert a force on the rod attached to the piston. The amount of force depends upon the area of the piston on which the pressure acts and upon the degree of vacuum on the evacuated side of the piston. When the valve is closed, the chamber ahead of the piston is shut off from the intake manifold and connected to atmosphere. Air enters this chamber through the valve and raises the pressure on the front side of the piston to that of the atmosphere. The pressure is then the same on both sides of the piston so that no pull is exerted on the pull rod and it remains in the released position.

Hydrovac

Heavyload carrying motor vehicles use a combination of a hydraulic system and a vacuum to operate the braking power. Such a system is shown in figure 2. Note that the power brake cylinder is the important unit; in fact it is about the whole system. It consists of a vacuum cylinder and piston, a control valve, and a slave cylinder. As the name implies, the control valve directs vacuum pressures to various parts of the vacuum cylinder from the engine intake manifold and admits and meters atmospheric air to other parts of the vacuum cylinder.

The difference between vacuum and atmospheric pressure (usually called pressure differential) actuates the slave cylinder piston which creates hydraulic pressure in the hydraulic slave cylinder. This pressure is transmitted to the wheel cylinders in amounts proportional to the pressure created in the hydraulic slave cylinder, which in turn is determined by the amount of pressure differential existing in the vacuum cylinder. The whole cycle of events is controlled by the relay valve hydraulic piston, and the vacuum and atmospheric valves located in the control valve assembly.

When the brake pedal is depressed these events take place. Hydraulic pressure in the master cylinder is built up high enough to cause a shifting of the relay hydraulic piston. This closes the vacuum valve in the diaphragm plate and opens the atmospheric valve and admits atmospheric pressure, which is directed to the left side of the front and rear pistons of the vacuum cylinder. You will note that these two sections of the cylinder are interconnected by a passage in the piston rod. At the same time, remember that when the driver takes his foot off the accelerator to place it on the brake, he closes the butterfly valve, thus increasing the vacuum in the manifold. This vacuum pressure (suction) is admitted to the right side of the rear and front pistons. This vacuum, coupled with the atmospheric pressure admitted through the atmospheric valve, creates a pressure differential which results in the piston being forced toward the right. This force is transmitted by the push rod to the slave cylinder piston. The slave cylinder piston develops hydraulic pressure which is transmitted to the brake cylinders, thus applying the brakes.

When pressure on the brake pedal is released, the valve spring causes the atmospheric and vacuum valves to shift into the released position. This connects the atmospheric control line to vacuum pressure, which reduces pressure in the left side of both rear and front cylinder pistons, equalizing the pressure differential. Springs in the cylinder and in the hydraulic slave cylinder cause the whole assembly (piston, push rod, and slave cylinder piston) to shift to the left, thus releasing hydraulic pressure in the brake lines.

There are several advantages to this system. The first one is that it compensates for speed, for at high engine (piston) speeds with the butterfly closed (during deceleration) the manifold vacuum is highest; therefore, a greater piston differential is caused, resulting in higher brake pressure application at higher speeds. As the vehicle slows down and the engine piston action becomes slower, vacuum pressure (suction) is not as great as at high speeds, and pressure differential is not as great. As the vehicle approaches a stop, pressure differential tapers off and braking effort tapers off accordingly.

A second advantage is gained through central location of the power brake cylinder; high pressures are not carried through long distances as is the case in a typical hydraulic system. The line between the master brake cylinder and the slave cylinder need not be very heavy, for pressure in this line is never very great and should a leak appear in it, it would not be critical. The power brake cylinder may be centrally located so that none of the brake lines to the wheel cylinders need be long.

HYDRAULIC BRAKE SYSTEM SERVICING

OBJECTIVES

After completing this unit of instruction, you will be able to remove, inspect, clean, service, install, and adjust vehicle hydraulic brake components, bleed the hydraulic brake system, using special tools and equipment including publications and safety procedures.

INTRODUCTION

In the case of brakes, various difficulties may arise that require inspection and correction to keep them in good operating condition. Although the difficulties vary somewhat according to type of system (hydraulic, vacuum, mechanical, or air) only the hydraulic brake system is considered in this guide.

INFORMATION

CONSTRUCTION, OPERATION AND SERVICING

Brake systems require periodic inspection, adjustment, and occasional parts replacement. Remember! This is your responsibility. The reading material presented in the following paragraphs will assist in providing you with the required information.

Factors Which Affect Braking

The amount of retardation (or slowing down) obtained by the braking system of a vehicle is affected by several factors; the amount of pressure exerted on the braking surfaces (lining and drum), the weight carried on the wheel, the overall radius of the wheel (from center to outer thread of tire), the radius of the brake drum, coefficient of friction between brake drum and lining, and the coefficient of friction between the tire and the road are some of the more common factors.

When brakes are applied, the wheel either rolls or skids, depending on relative values of coefficients of friction or gripping qualities existing between braking surfaces, and between tire and road. Rapidly jamming the braking surfaces together tends to increase the friction to such a degree that the wheel will lock and skid along the road. When this happens, braking action is caused by friction between tire and road, which heats and wears the tire.

Maximum retardation is reached when friction between the brake surfaces is such that the wheel is about to lock. At this point, friction between the brake surfaces is almost the same as that between tire and road.

Construction and Types of Brake Drums

Brake drums are made of pressed steel, cast iron, or a combination of the two metals. Cast iron drums dissipate the heat generated by friction more rapidly than steel drums, and have a higher coefficient of friction with any particular brake lining. However, cast iron drums are not of sufficient strength. Centrifuse brake drums which are brake drums of steel with a cast iron liner for the braking surface, figure 3, are most commonly used. A solid cast iron drum of the same total thickness as the centrifuse drum would be too weak, while one of sufficient strength would be too heavy for the average passenger car. To give greater strength and better heat dissipation, cooling ribs are often added to the outside of the drums.

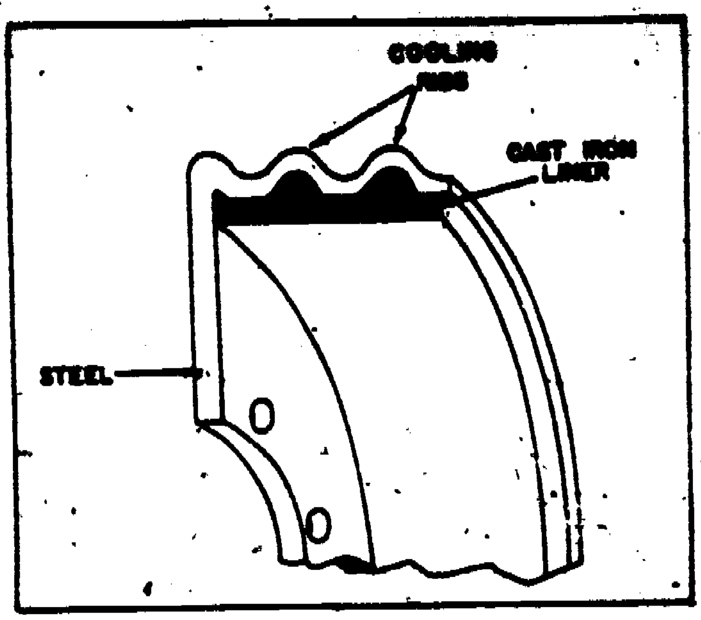

Figure 3. Cross Section of a Centrifuse Brake Drum.

Removal, Inspection and Reconditioning of Brake Drums

When removing the hub and brake drum from a vehicle, care should be taken not to drop the wheel bearings. Bearings should be cleaned in solvent, inspected, and repacked with fresh grease before they are reinstalled.

Brake drums should be cleaned with solvent and inspected for cracks, scores, and warpage. Cracked drums should be replaced. Generally, scored and warped drums can be reconditioned by resurfacing them on a brake drum lathe. However, if they are warped or scored to a great extent, they should be replaced.

When a brake drum is machined, the thickness of the metal removed from the inside of the brake drum should be plainly marked on the unmachined part of the drum, so that the brake shoe may be shimmed accordingly.

Removal, Inspection, Replacement and Adjustment of Brake Shoes and Brake Lining

Most of the wear in a brake takes place on the brake lining. Over a long period of operation, the lining will become worn to the extent it needs replacing, or occasionally, defective grease seals may cause the lining to lose its efficiency. In either case, the lining must be removed and replaced. Before replacing the new lining, the shoes should be cleaned thoroughly and all burrs and rough spots removed.

Brake linings are of two general types, molded and woven, figures 4 and 5. The molded lining is the most commonly used on service brakes. Linings are fastened to brake shoes by two methods, by bonding or riveting. Riveting has its disadvantages due to the fact that as the lining wears the rivet heads are exposed and come in contact with the brake drum, causing it to score. Bonding is the best process due to the fact that the lining is bonded to the shoes and will wear much longer without damage to the brake drums.

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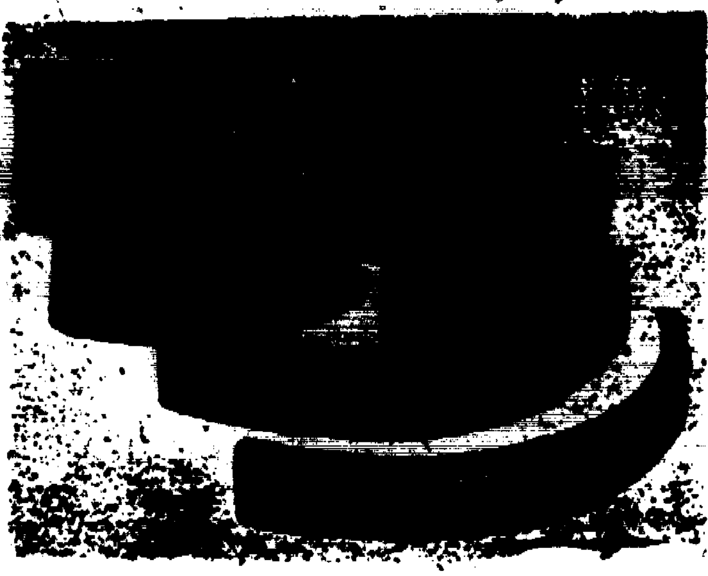

Figure 4. Molded Brake Lining.

Figure 5. Woven Brake Lining.

When shoes are removed for inspection, the brake cylinders on each wheel should be removed and inspected for condition and repaired or replaced. The lines should be inspected for leaks and kinks and be replaced as required.

After the brake system has been inspected and the required repairs or replacements made, the wheels should be installed and the necessary adjustment made on the linkage and shoes. The bleeding of the hydraulic system is necessary to eliminate any air that might have entered the system.

Self-Energizing Action

The brake operating linkage alone does not provide sufficient mechanical advantage for positive braking. A self-energizing action, supplementing the physical application of the braking system, has to be used to increase pressure on the brake shoes. While there are variations of this action, it is always obtained by the shoes themselves, which tend to revolve with the revolving drum.

When the brake shoes are anchored, as shown in figure 6, and the drum revolves in the direction shown, the shoes will try to revolve with the drum when they are forced against the drum. As a result, the shoe will exert considerable self-energizing force against the anchor pin. Since the pin is fixed to the brake shield, this force tends to wedge the shoe tightly in between the pin and the drum as indicated. As the initial braking force is increased on the cam, the wedging action increases and the shoe is forced still more tightly against the drum to increase the self-energizing action. Brakes making use of this principle to increase force on the braking surfaces are known as self-energizing brakes.

The amount of self-energizing action available depends mainly on location of the anchor pin. As the pin is moved toward the center of the drum, wedging action increases until a point is reached where the shoe automatically locks. The pin must be located outside of this locking point so that the operator can control the braking.

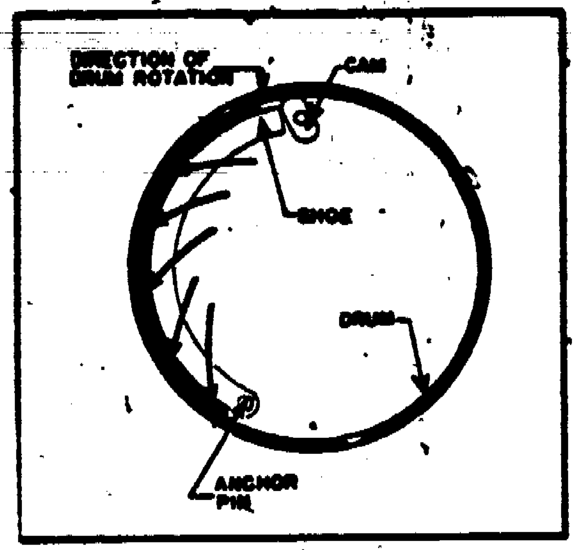

Figure 6.
Self-Energizing Action.

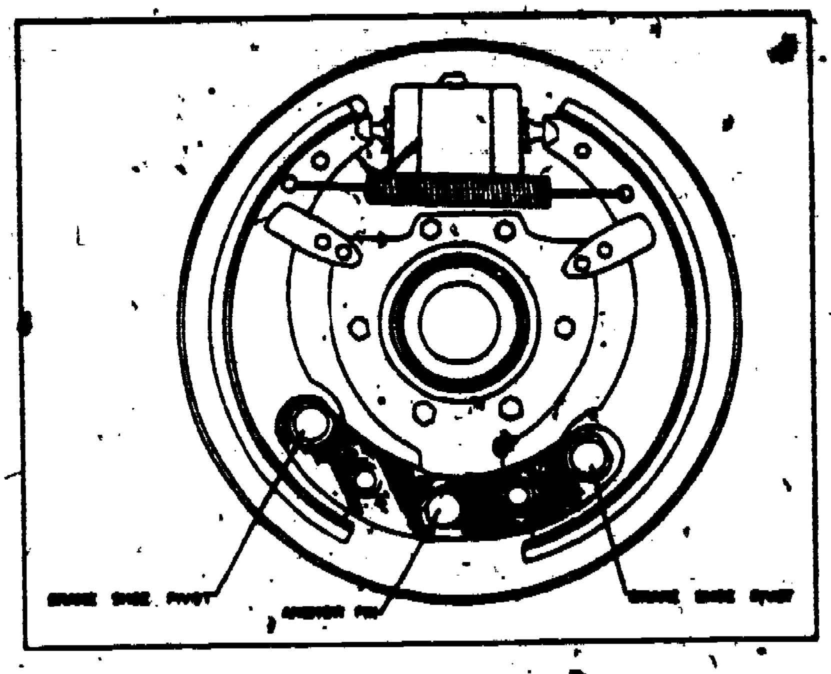

Figure 7. Brakes with Articulating Links.

When two shoes are anchored on the bottom of the brake shield, as shown in figure 6, self-energizing action is effective on only one shoe. The other shoe tends to revolve away from its pivot, which reduces its braking action. When the wheel is revolving in the opposite direction, the self-energizing action is produced on the opposite shoe. Two shoes are usually mounted so that self-energizing action is effective on both. This is accomplished by pivoting the shoes to each other and leaving the pivot free of the brake shield. This brake is known as an articulating link brake, as shown in figure 7. The only physical effort required is for operating the first or primary shoe. Both shoes tend to revolve with the drum and are wedged against the drum by the one anchor pin.

Hydraulic Action

The service brake pedal operates a piston in the master cylinder to force fluid through the lines to the wheel cylinders which in turn operate the brakes. Each unit of the system must serve its intended purpose to keep the brakes operating properly.

Fluid Lines and Hoses

High-pressure flexible hoses are used between the front wheel cylinders and frame connectors, also between rear axle tee and frame connectors. Special metal tubing is used between the master cylinder and frame connectors, also between rear axle tee and rear axle wheel cylinders. Any sign of fluid leak along the line indicates a loose connection or damaged line and should be tightened or replaced. Kinked or restricted lines restrict the flow of fluid between master and wheel cylinders, and should be replaced.

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Brake Cylinders

When a master cylinder or wheel cylinder becomes excessively worn, leaky, or develops sticking pistons, it must be removed, repaired or replaced with a serviceable cylinder.

Removal, Inspection, Repair and Replacement of Brake System Units

When inspecting the brake shoes and cylinders of a hydraulic brake system, it is necessary to remove the wheels. The vehicle should be jacked up and trestles placed under the axles of the vehicle as a support. The wheels should be removed and placed in a position so they will not roll or tilt. (It is recommended they be placed flat on the floor.)

The brake shoes should be removed, cleaned, and inspected. Brake cylinders should be cleaned of all dirt on the outside before disassembling. After disassembling, the cylinders should be repaired in accordance with the applicable publication. If the cylinder walls of the brake cylinders are found to be scored or rusted, they should be reconditioned or discarded. It is necessary to always use new rubber parts when reconditioning cylinders.

> Note: Brake cylinder repair kits usually contain all the parts required to recondition a brake cylinder. These parts should be used even if it does not appear the replacements are needed. Experience has proven that the added safety and braking efficiency offsets the cost of parts.

Before replacing cylinders and shoes, all brake lines and connections should be inspected, repaired or replaced (as required). After completing the inspection and making the required repairs, it is necessary to install the units to the backing plate and prepare the wheels for replacement.

Before replacing the wheels, the bearings and races should be cleaned and inspected for serviceability. If found serviceable, they should be lubricated and installed in accordance with procedures outlined in the publication applicable to vehicle in use. In addition, tightening of the wheels is also governed by the procedures established in the applicable publication.

Brake Adjustment

Brake systems are provided with an adjustment to compensate for normal lining wear. This is called a minor brake adjustment. It consists of adjusting the brake shoe at one end.

On some types of brakes an additional adjustment is also provided to adjust the other end of the brake shoe. When both ends are adjusted, it is called a major brake adjustment. Major brake adjustments are required when the brakes are being relined, parts are being replaced, or any time the position of the anchors has been changed.

Major brake adjustments position the brake shoe so the linings contact the drum the full length of the lining when the brakes are applied. If the shoes are improperly adjusted, the braking action will be poor and distortion or damage may result to the brake parts. This is shown in figure 8.

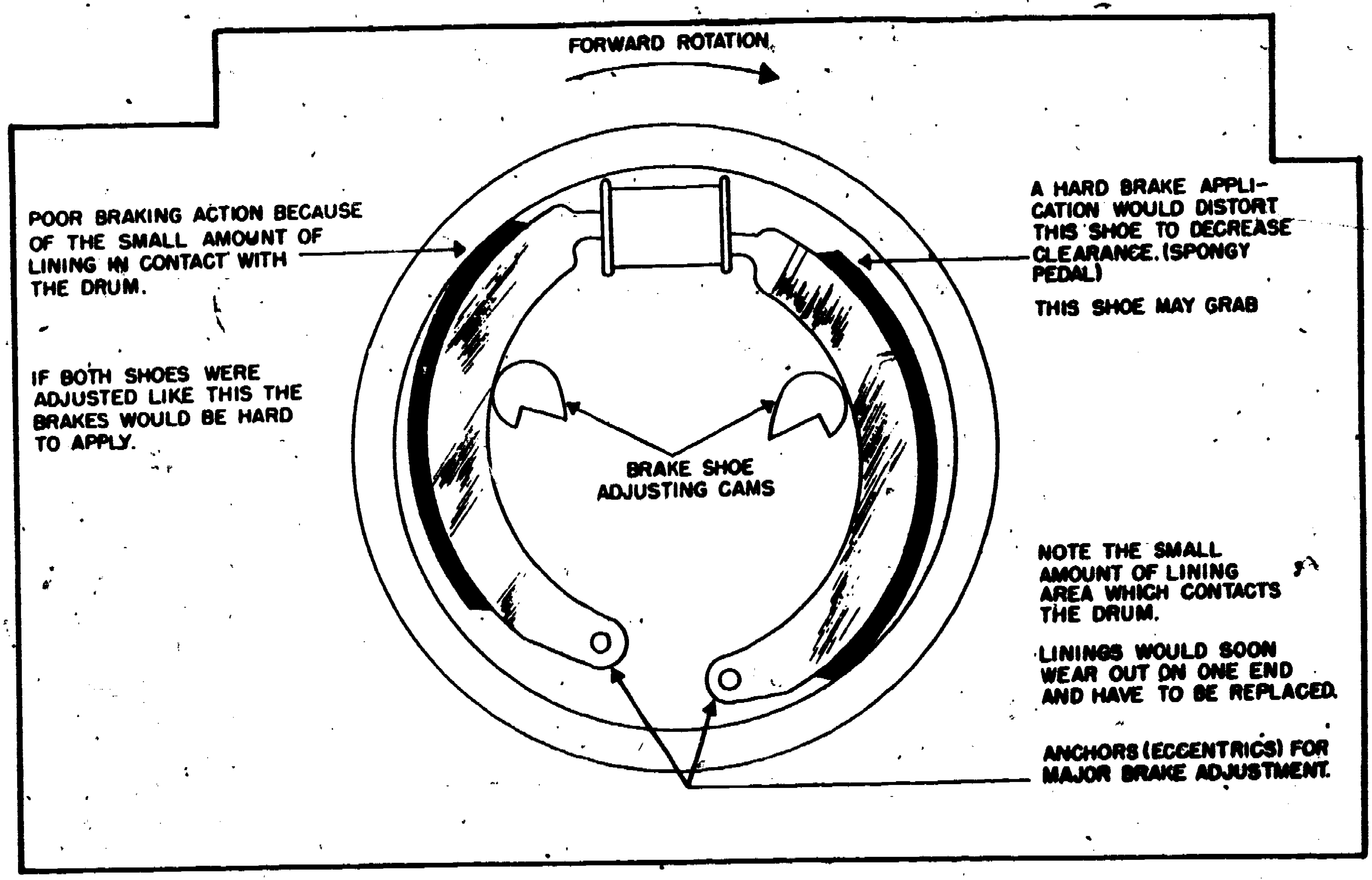

Figure 8. Showing Improper Brake Shoe Adjustment.

Whenever any unit of the hydraulic system is disconnected or replaced, the fluid must be replenished and the system bled free of air.

Wheel Bearing Lubrication

Vehicle manufacturers usually recommend the lubrication of wheel bearings annually or at 25,000-mile intervals. Lubricating wheel bearings is mechanically known as "packing" wheel bearings; the job consists of removing, cleaning, inspecting, lubricating, replacing and adjusting the bearings.

Bearings should be washed with volatile mineral spirits or dry cleaning solvent and dried thoroughly with a clean cloth.

Caution: As a safety precaution, bearings must not be spun with compressed air to prevent injury to personnel.

Bearing cups and bearings should be inspected for condition, and damaged parts replaced as required.

Wheel bearings are usually packed by hand or by the use of a mechanical packer, introducing lubricant into all spaces between the rollers and race. Care must be exercised to insure that dirt, grit, lint, or other contaminants are not introduced into the bearings. If the bearings are not installed immediately after packing, they should be wrapped in clean oilproof paper as a protection from contamination.

After the bearings have been properly lubricated the hub should be packed with a sufficient amount of lubricant to uniformly fill it to the inside diameters of the inner and outer bearing races. The spindles and hub caps should be coated with a thin layer of lubricant (not over one-sixteenth of an inch) to prevent rusting. Remember! Hub caps must not be filled to serve as grease cups under any circumstances.

Lubricant in the bearings is sufficient to provide enough lubrication until the next service period. Excessive amounts of lighter lubricant than specified by the manufacturer usually results in leakage past the grease seals and damage to the brake linings.

Troubleshooting Hydraulic Brake Systems

The type of difficulty experienced in brake systems is often an indication of the cause of the trouble. Following is a detailed diagnosis of the more common hydraulic brake troubles.

PEDAL GOES TO FLOOR BOARD. When the brake pedal goes all the way to the floor board, several conditions could be the cause. The brake shoes may be improperly adjusted, or the brake linings may be out of adjustment. In addition, there may be air in the brake lines or, the fluid level may be low in the master cylinder or the master cylinder may be worn or defective.

ONE BRAKE DRAGS. When the brake shoes of one wheel drag, the indication is that the lining is not moving away from the drum when the brakes are released. This could be due to improper brake shoe adjustment, clogged brake line, sticking wheel cylinder pistons, weak or broken retracting springs, or a loose wheel bearing.

ALL BRAKES DRAG. When all the brakes drag, the brake pedal does not have enough free travel because of improper adjustment. The master cylinder vent may be clogged, or brake fluid of mineral oil content could have been added to the brake system so that the rubber pistons have swollen and stuck. Mineral oil must never be used in vehicle hydraulic brake systems. Any oil in the system other than the specified brake fluid is apt to cause serious trouble.

CAR PULLS TO ONE SIDE. If the car pulls to one side when the brakes are applied, it indicates that more braking pressure is being applied on one side than is being applied on the other. This happens if some of the brake linings have become oil soaked, if the brake shoes are unevenly or improperly adjusted, if tires are not properly or uniformly inflated or if one of the brake lines is clogged or restricted. In addition, a brake backing plate may be loose on the axle housing or the steering knuckle. If two different types of brake lining are being used, trouble also results.

SPONGY PEDAL. When the pedal action is soft or spongy, it indicates that there is air in the brake system. Improperly adjusted brake shoes could also cause this condition.

BRAKES HARD TO APPLY. When excessive pressure on the brake pedal is required to slow down or stop a vehicle, the trouble is due to oil soaked brake linings, improper brake shoe adjustment or the use of the wrong lining. When the brake linings get wet, it is difficult to stop a vehicle; however, brake action returns to normal as the linings dry.

BRAKES GRAB. Brakes grab if the brake linings are greasy, if the brake drums are scored, if the brake shoes are improperly adjusted, if brake backing plates are loose or if the wrong type of lining has been installed.

NOISY BRAKES. When brakes squeak as they are applied, the indication would be that the brake shoes are warped, the linings or shoes are loose, or the linings are so worn that the shoes or rivets are making contact with the brake drum. Occasionally, brakes which are in good operating condition, such as on a new vehicle, squeal. This is due to the type or construction of the brake and is not of a serious nature.

Troubleshooting Hydrovac Brake Systems

The outside of the hydrovac unit should be cleaned thoroughly at least every six months. All hose clamps should be tightened and all pipe fittings and hydraulic connections checked for security. One ounce of Bendix Vacuum Cylinder oil should be added to the power cylinder at the lubrication plug at 12,000-mile intervals, or each six-month period and especially before anticipated cold weather operation. The air cleaner should be removed, disassembled and cleaned at least twice a year. If the vehicle is operating under adverse conditions, it is necessary to clean the air cleaner more frequently. Regular maintenance should be performed to keep this unit in proper operating condition so that it continues to provide trouble-free service. If trouble should develop in the system, it is recommended that the following points be checked before actually checking the hydrovac unit.

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MAIN CYLINDER PRIMARY CUP TO COMPENSATING PORT CLEARANCE. It is necessary that the linkage is properly adjusted to permit opening of compensating port with brake pedal in normal full released position. Failure to properly uncover the compensating port may cause sufficient pressure to be maintained in the brake system to hold the hydrovac valve in a partially applied position and thus cause dragging brakes.

RESTRICTED VACUUM LINES. Vacuum is checked at the hydrovac by disconnecting the vacuum line at the hydrovac vacuum connection fitting and holding a thumb over the line with the engine operating. If no vacuum exists, or if airflow is slow, a check of the vacuum line to manifold should be made for kinks in tubing, collapsed lines or hoses and to determine if the check valve opens properly.

RESTRICTED AIR LINE AND AIR CLEANER. It is necessary to disconnect the air cleaner line at the hydrovac and blow into the line. If the line is restricted it is necessary to check for collapsed hose or tubing.

BRAKES. The brake shoe should be adjusted for proper clearances. These clearances should be in accordance with the recommendations given in the hydraulic brake adjustment manual. Excessive shoe clearance causes excessive pedal travel. Insufficient clearance may cause dragging brakes.

Note: Troubleshooting the remaining parts of the system employing hydrovac, is the same as outlined in troubleshooting the hydraulic brake system.

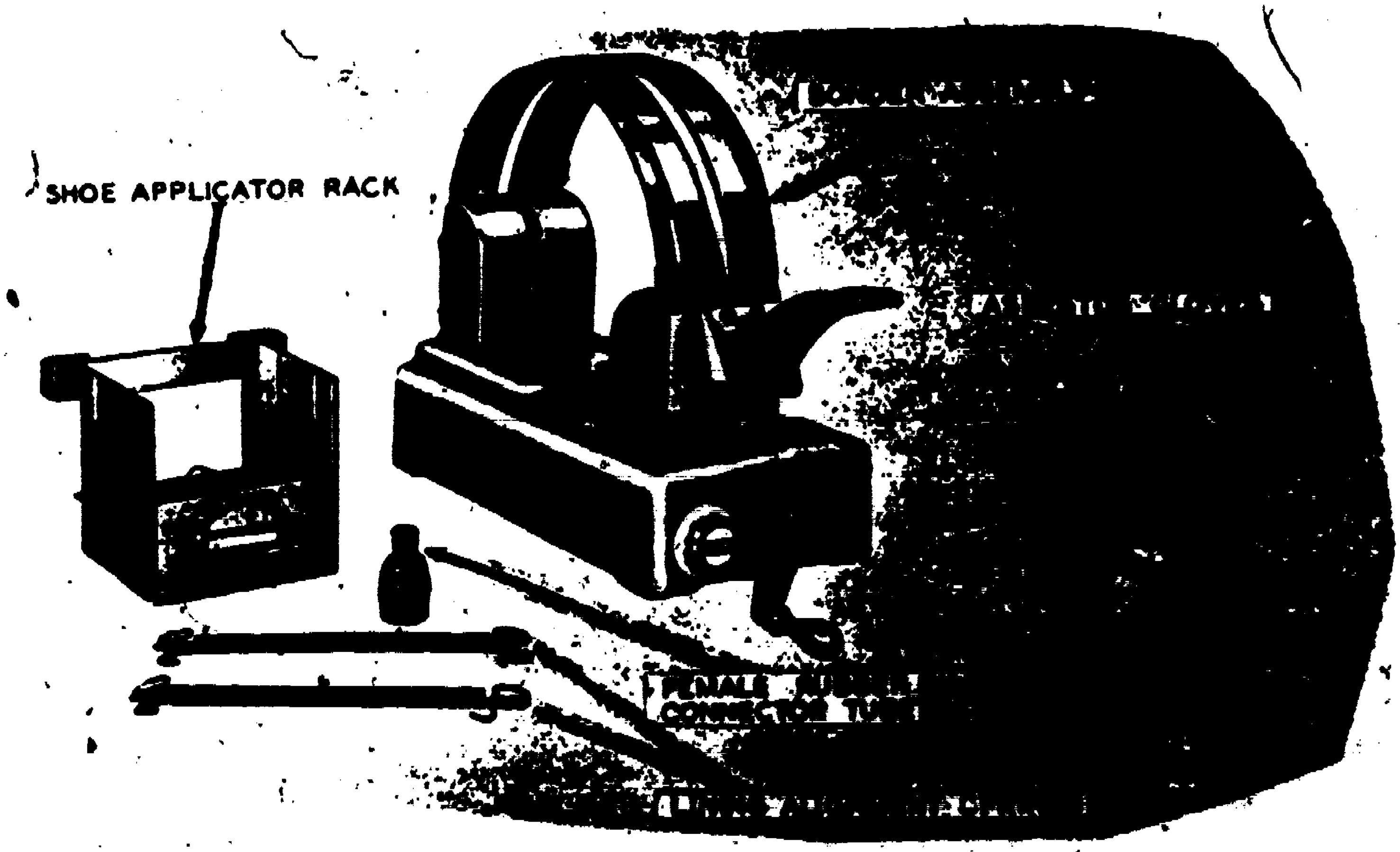

Figure 9. Bonder and Debonder Machine with Associated Equipment.

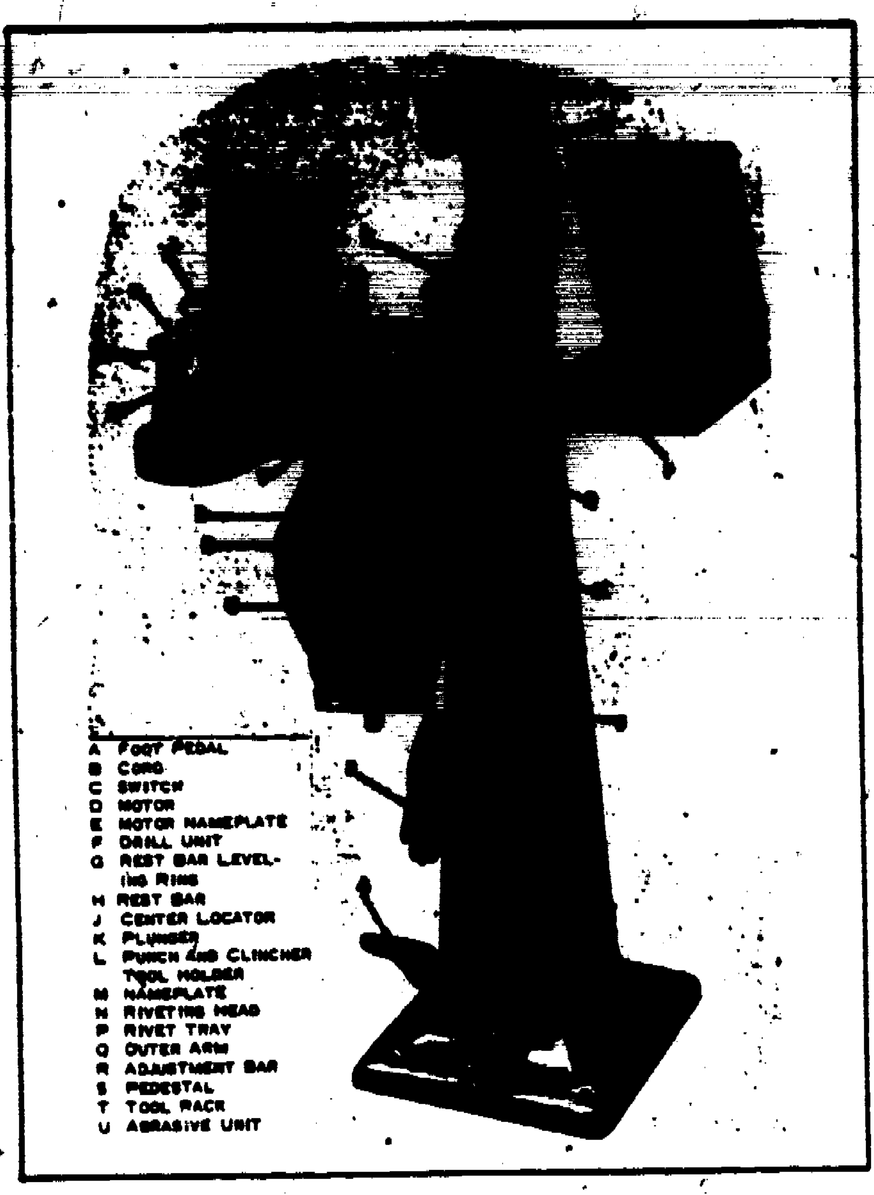

Figure 10. Brake Riveting (Reliner) Machine Complete with Abrasive Unit.

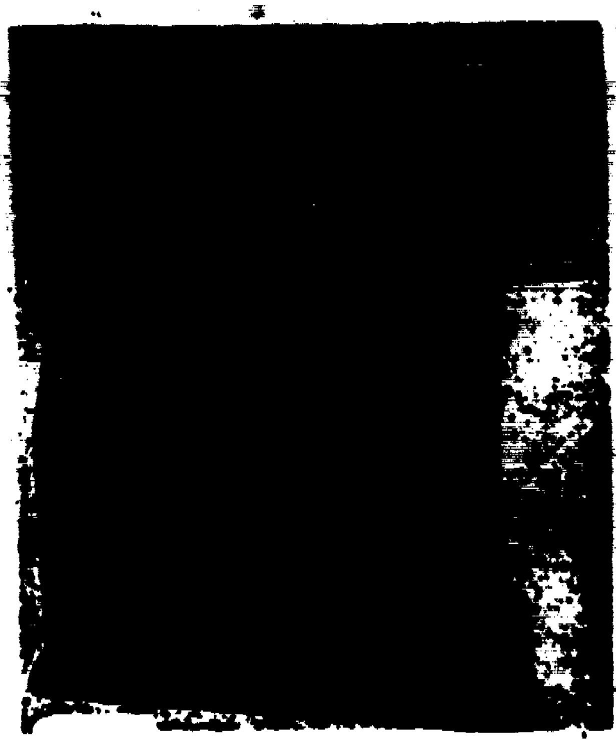

Figure 11. Lathe, Brake Drum.

Brake Reconditioning Equipment

Various types of brake reconditioning equipment may be used by AF maintenance shops to repair brake systems units. The following paragraphs are designed to familiarize you with some of the representative types.

BONDER AND DEBONDER MACHINE. The purpose of a bonder and debonder machine is to reline brake shoes through the use of heat and a bonder tape. The advantage of a bonder and debonder machine over riveting is the brake lining can be worn down closer to the brake shoe than a lining put on by rivets. Figure 9 shows a typical bonder and debonder machine complete with accessories.

BRAKE RIVETING MACHINE. The purpose of a riveting machine is similar to a bonder and debonder machine. Brake linings put on by rivets require less equipment. Figure 10 shows a brake riveting (reliner) machine.

ABRASIVE MACHINE. The purpose of an abrasive machine is to grind the brake shoe and lining to the contour of the brake drum, figure 10. An abrasive machine is included with the riveting machine.

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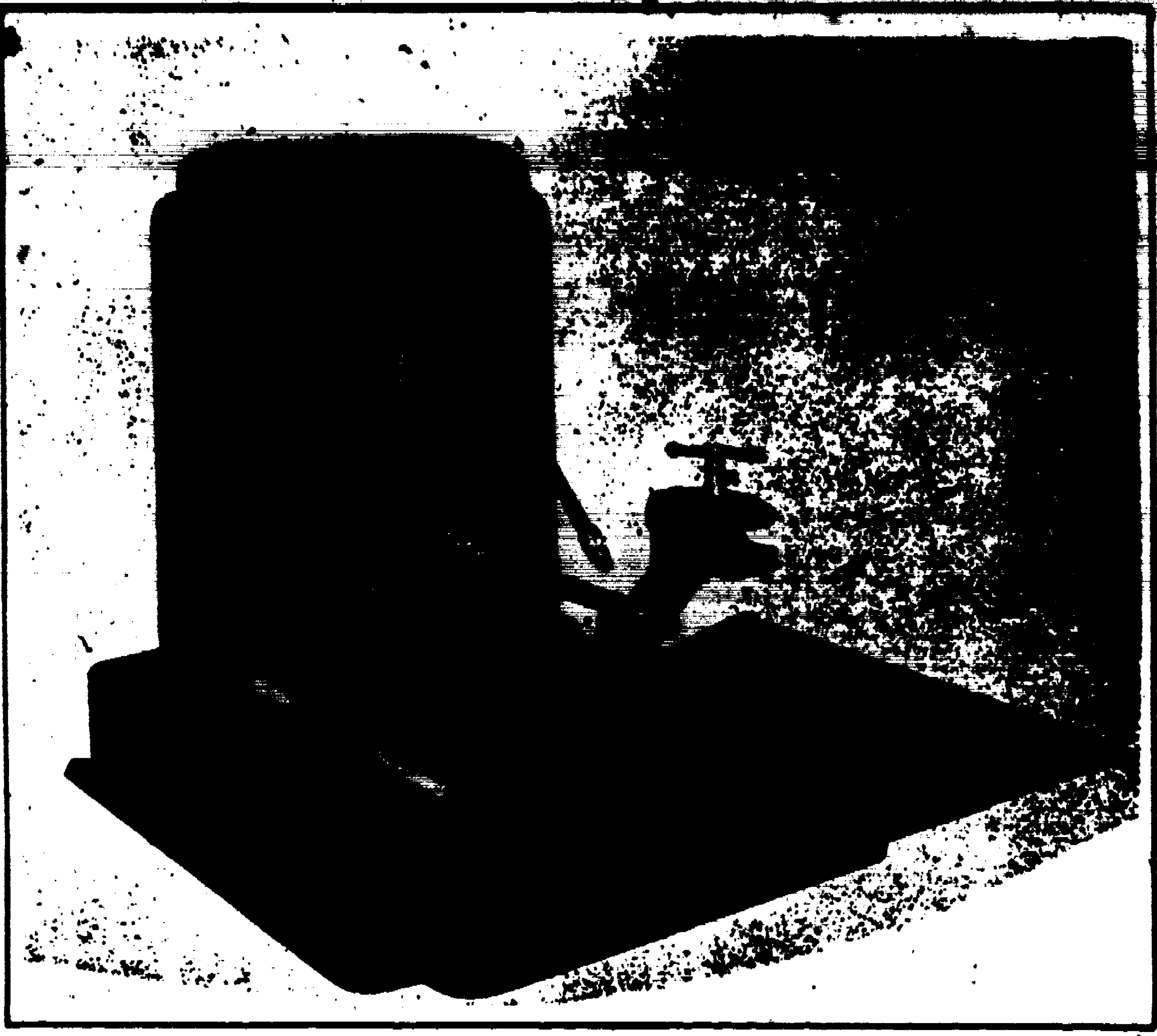

Figure 12. Wet Honing Machine.

BRAKE DRUM LATHE. The brake drum lathe is used to refinish brake drums that have become pitted, grooved, or out-of-round. Figure 11 shows a brake drum lathe complete with accessories.

WET HONING MACHINE. This machine is used to hone brake cylinders and master cylinder to remove pits, scratches, and foreign materials that may hinder the efficient operation of these units. Figure 12 shows a typical honing machine. This machine may also be used to hone many other automotive units. The use of these machines will be demonstrated by your instructor; therefore, further information can be obtained on the procedures for operation during this time.

Adjustment of Handbrake

Most vehicles are equipped with a handbrake or parking brake to hold the vehicle when stopped. It should be noted that the term "handbrake" referred to in this training publication is often called the "parking brake."

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Both of these units are the same brake. Most trucks use an external contracting type handbrake.

The brake drum is mounted on the rear of the transmission or transfer case and when applied, holds the propeller shaft and keeps the wheels from turning. The brake is applied through linkage from the cab of the vehicle. Adjustment on this type of brake consists of bringing the band closer to the drum as the lining wears down. Care must be taken, during adjustment, to be sure that the lining does not drag at any spot on the drum. The procedure for adjusting this type of brake will be covered during the practical work assignment of this training project outline where the actual equipment is available.

QUESTIONS

1. What are the factors which affect braking action?

2. When or at what point do vehicle brakes reach their maximum retardation (or slowing down) action?

3. What inspection should be performed on brake drums? Why?

4. How should you be able to determine if a brake drum has been turned?

5. How should wheel bearings be cleaned?

6. How are wheel bearings lubricated?

7. How much grease should be placed in the wheel hub when packing wheel bearings?

8. What usually happens if too much grease is used to lubricate wheel bearings?

9. What conditions could cause the brake pedal, when applied, to go all the way to the floor board?

10. If the vehicle pulls to one side when the brakes are applied, it indicates that more braking pressure is being applied one side than the other. Why would two different types of brake linings cause the vehicle to pull to one side?

11. If brakes were adjusted with no brake pedal free travel, what would be the result?

12. When the brake pedal action is soft and spongy, it indicates that there is air in the brake system or the brake shoes are improperly adjusted. how can you best determine whether there is air in the brake system or the brake shoes are improperly adjusted?

13. Brake linings may be put on brake shoes by two different methods. What are the two methods, and what advantages does one have over the other?

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14. Why is it necessary to refinish brake drums?

15. From what source can information be obtained when troubleshooting brake systems?

16. What safety precautions should be observed when troubleshooting brake systems?

17. What causes brake drums to get out-of-round?

18. What is self-energizing action?

19. What should be used to clean hydraulic cylinder parts?

20. How do major and minor brake adjustment differ?

21. Why must wheel bearings be properly adjusted before adjusting brakes?

22. How does a parking brake mounted on the transmission or transfer case hold the vehicle wheels from turning?

REFERENCES

1. TO 36A-1-76, Principles of Automotive Vehicles.

2. IHC Motor Truck Service Manual.

AIR AND AIR-OVER HYDRAULIC BRAKE SYSTEMS

OBJECTIVES

After completing this unit of instruction, you will be able to explain the location, construction and operating principles of the air brake system units and to remove, inspect, repair or replace, install and adjust these units and disassemble, inspect, repair and reassemble air-over-hydraulic cylinders using special tools, applicable publications and safety procedures.

INTRODUCTION

The fundamental characteristic of the air brake system is that the brakes, although controlled by the driver, are applied by compressed air. Compressed air provides sufficient braking force to control even the heaviest vehicle.

INFORMATION

AIR BRAKE EQUIPMENT

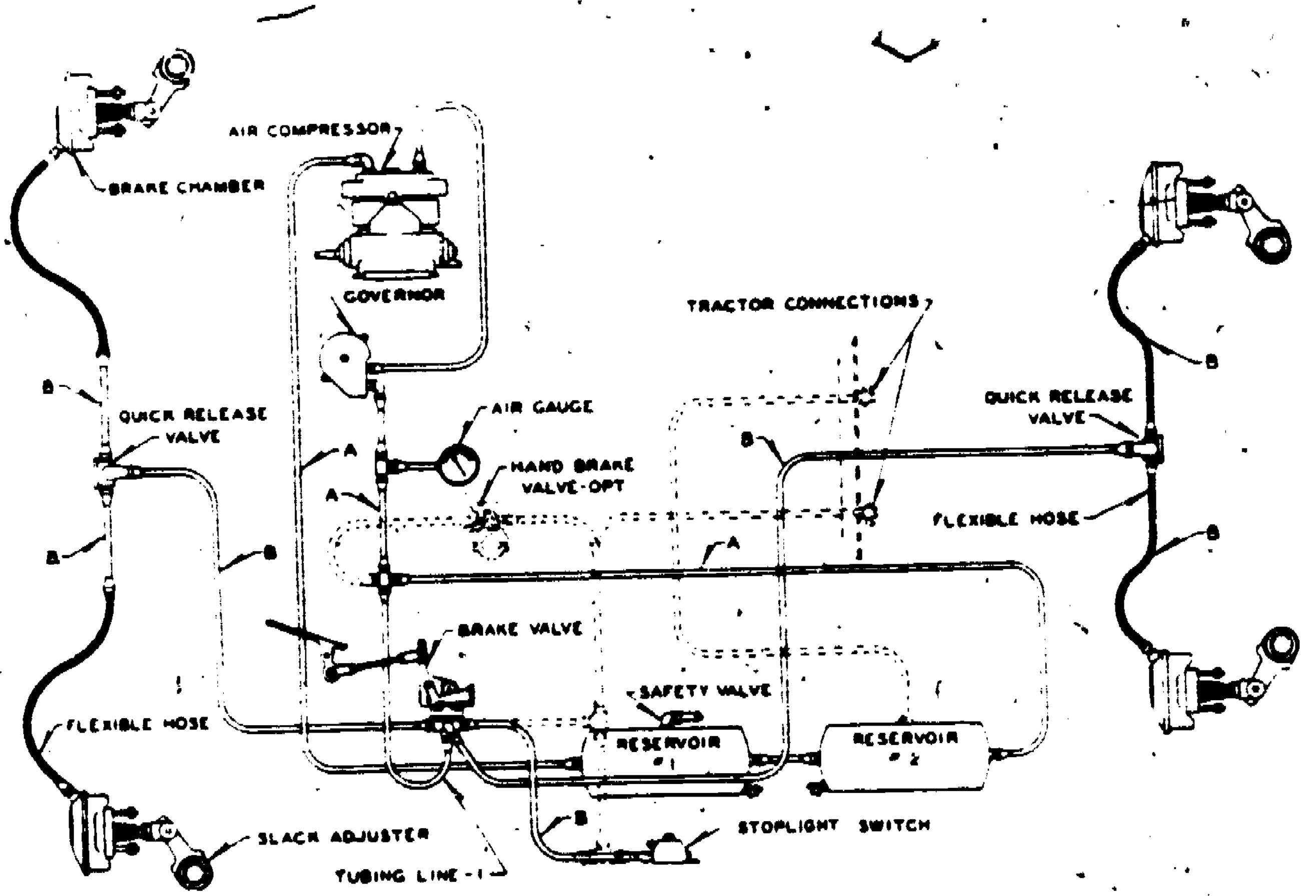

Figure 13. Simple Air Brake System.

Air brake equipment on trucks and truck-tractors provides a means of controlling the brakes through the medium of compressed air. Air brake equipment consists of a group of devices, figure 13. Some maintain a supply of compressed air, some direct and control the flow of the compressed air and others transfer the energy of compressed air into the mechanical force

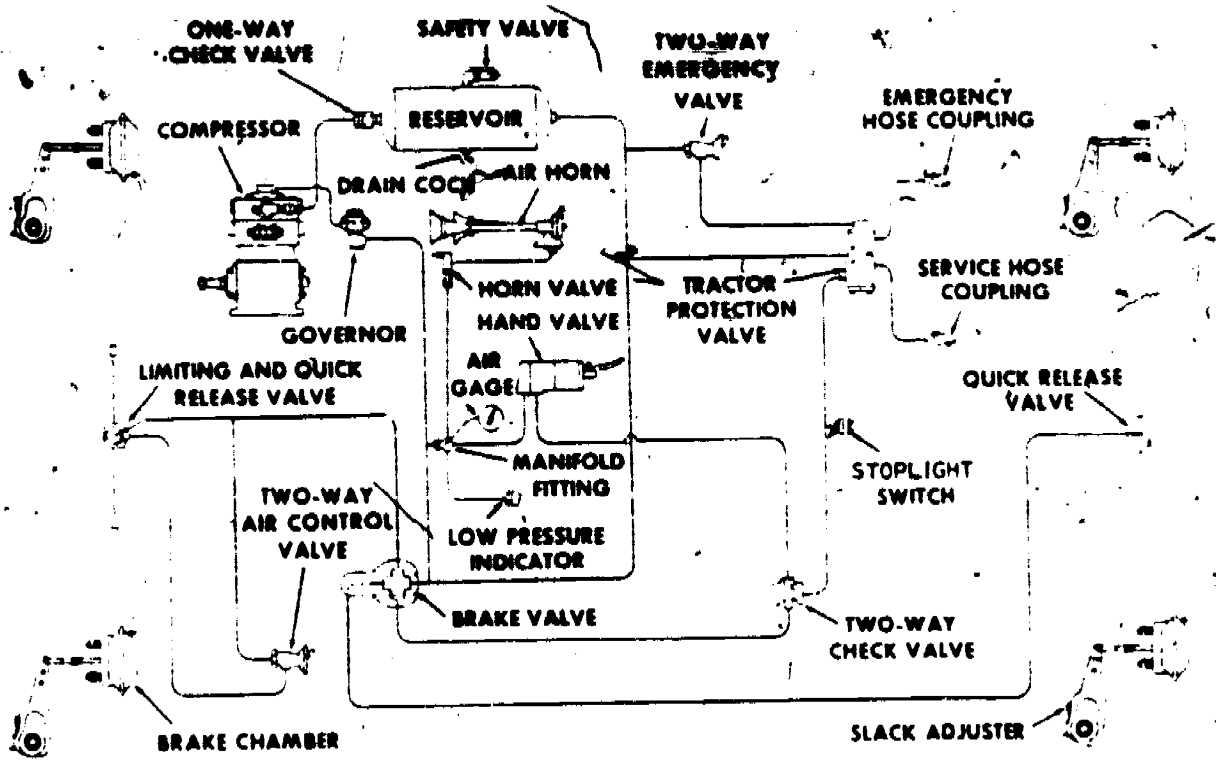

Figure 14. Typical Air Brake Circuit Diagram.

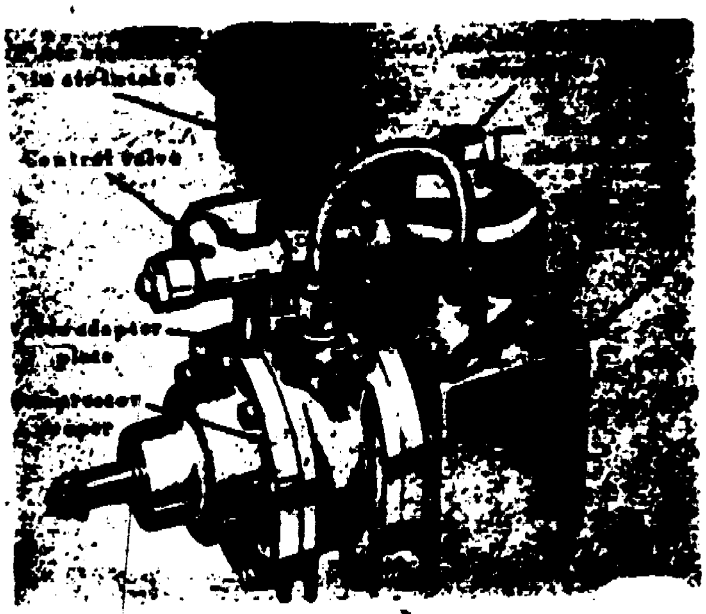

Figure 15. Rotary Air Compressor.

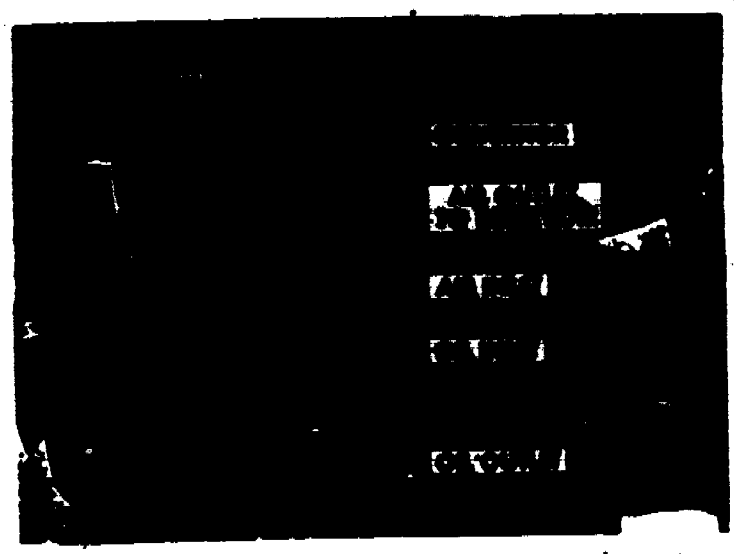

Figure 16. Piston Type Compressor.

and motion necessary to apply the brakes. Different types and sizes of devices are in use on different types of vehicles to meet operating requirements, figure 14, but they are all fundamentally the same. Following are the devices comprising a typical truck or truck-tractor air brake system, with a brief description of the function of each device.

Compressor

The compressor supplies the compressed air to operate the brakes. Two types of compressors may be found in vehicles, namely, the rotary, figure 15, or piston type compressor, figure 16.

The rotary type uses a rotor with four blades in the rotor, figure 17. The rotary type air compressors employ three principal functional components to accomplish air compression and reservoir pressure regulation:

The compressor proper which compresses the incoming air.

The air dome and oil sump, which separates oil from the compressed air pumped by the compressor and stores the reserve supply of oil.

The control valve (governor) which regulates the pumping action of the compressor to maintain the correct pressure range in the air reservoir tank.

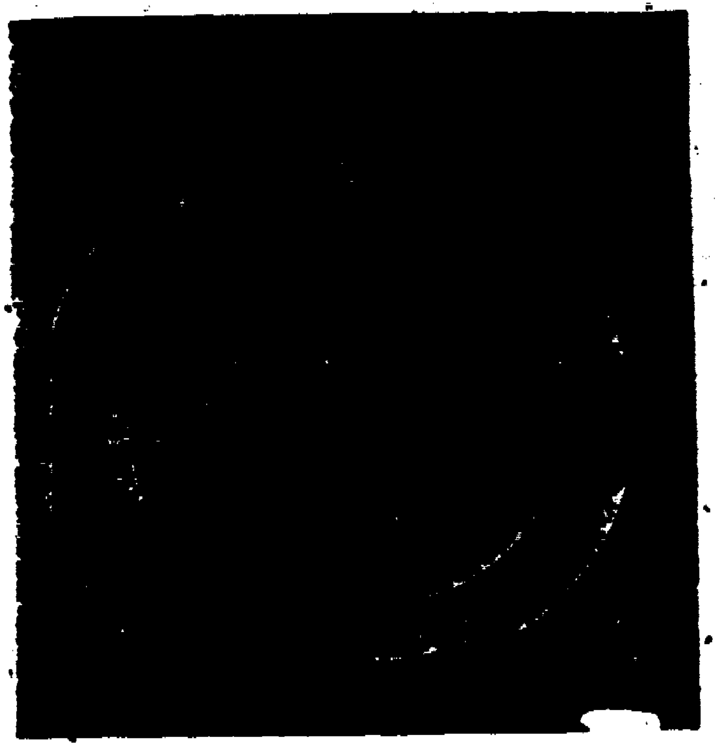

Figure 17. Cross Section of Rotor and Stator.

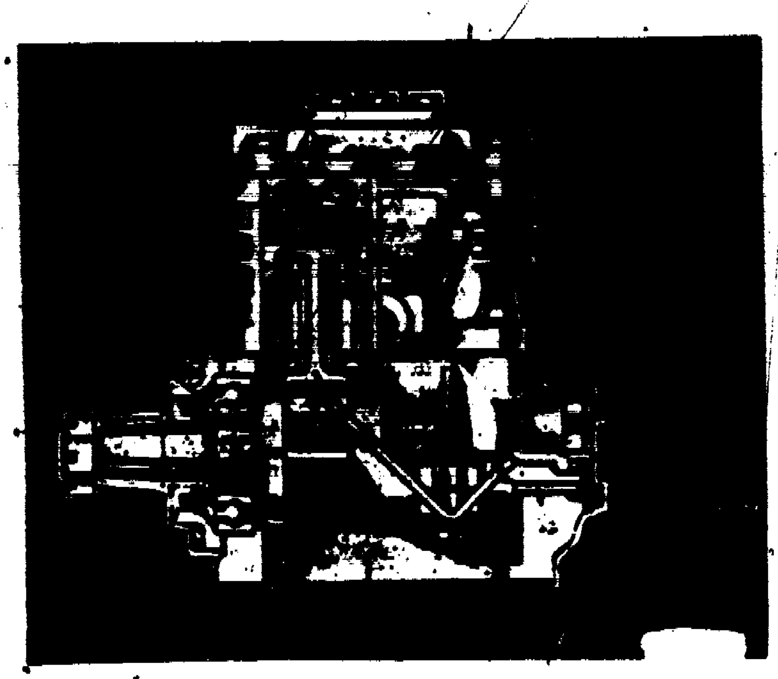

Figure 18. View of Compressor Oiling System.

Engine lubricated compressors include a fourth functional component, the oil supply valve, which units the compressor oil sump to the engine pressure oiling system. It automatically supplies oil from the vehicle engine crankcase reserves as required to maintain the correct oil level in the compressor oil sump.

Compression Chamber

The compressor rotor revolves with a shaft supported on bearings in each end plate. This rotor is positioned eccentric in relation to the stator, which surrounds it, with the small clearance at the top. Four equally spaced rotor blades contact the stator wall at an acute angle; separating the space between rotor and stator into four compression chambers, figure 17. These four chambers each have their capacity progressively increased and reduced to pass through three stages; intake, compression, and discharge, during each revolution.

Piston Type Compressor

Another compressor commonly used is the piston type; this compressor may be a two-cylinder or more. The one shown in figure 16 is a two-cylinder water cooled and is lubricated from the engine systems. The air intake makes use of the carburetor air cleaner. The lubrication system is a force feed from the truck engine lubrication system, figure 18. The piston type compressor is driven by a belt or belts from the engine crankshaft or auxiliary shaft. The compressor runs continuously while the engine is running, but the actual compression of air is controlled by the governor, which, acting in conjunction with the unloading mechanism in the compressor cylinder head, starts or stops the compression of air by loading or unloading the compressor when the pressure in the air brake system reaches the desired minimum (80 to 85 psi) or maximum (100 to 105 psi).

COMPRESSING AIR (LOADED). During the downstroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve allowing air drawn through the intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir. As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

UNLOADED, NOT COMPRESSING AIR. When the air pressure in the reservoir reaches the maximum setting of the governor (100-105 psi), compressed air from the reservoirs passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. This air pressure lifts the unloading pistons which in turn lift the inlet valves off their seats.

PASSAGE OF AIR DURING NONCOMPRESSION. With the inlet valves held off their seats, the air during each upstroke of the piston is forced through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir is reduced to the minimum setting of the governor (80-85 psi), the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the pistons down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

Governors

There are several types of governors used on vehicle air brake systems. Regardless of type or make, the purpose for the governor is to maintain a maximum and minimum air pressure in the air brake system. The location of the governor is different for different types and makes. Some are located on the fire wall and some are on the compressor, and other at different locations. One of the old standby governors is known as the Bourdon tube (Bourdon gage) governor, figure 19, also shown on figure 13. This type of governor operates on the Bourdon gage principle of a curved metal tube that tends to straighten under internal pressure. It is adjustable for different air pressures, but it is not adjustable to change the difference between the minimum and maximum pressure.

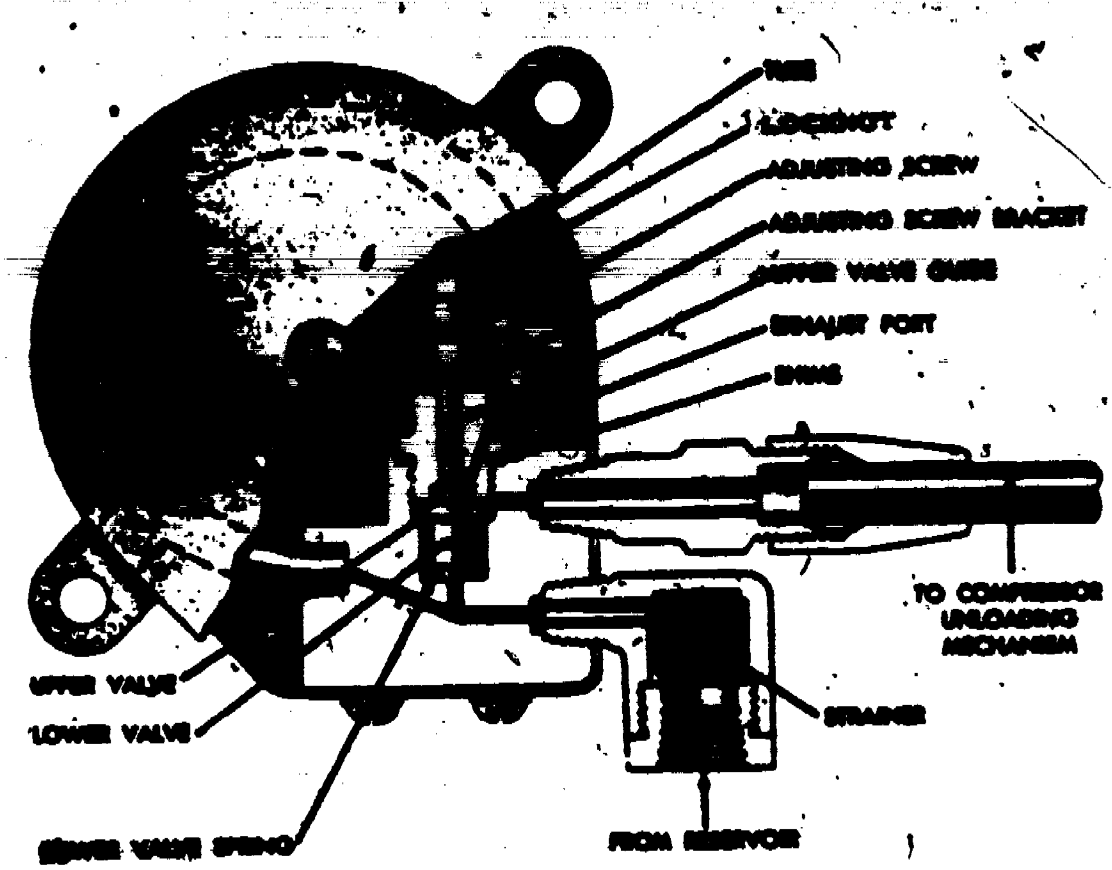

Figure 19. Air Brake System Governor - Cross Sectional View.

The type D governor, shown in figure 20, is usually mounted on the fire wall and is a diaphragm type. This governor consists essentially of a diaphragm upon which air pressure acts, a spring to control the movement of the diaphragm assembly, and a valve mechanism controlled by the position of the diaphragm assembly which admits air to, or exhaust air from, the unloading mechanism in compressor cylinder heads. This governor is adjustable for maintaining the correct air pressure in the system by increasing or decreasing the spring tension on the pressure setting spring. This adjustment will be practiced on the vehicle in the training area during practical work.

Figure 20. Type "D" Governor.

Another type of governor used on some vehicles is mounted on the compressor shown in figure 16. This governor is for the same purpose as the others shown here, except that the mounting place is different. The adjustment instructions on these governors will be instructed in the classroom by the instructor; and additional instructions and specifications can be found in the applicable publication on the vehicle you will be assigned to for practical maintenance.

Air Cleaner

Some compressors use the carburétor air cleaner for intake of clean air as shown in figure 16. Some compressors have an air cleaner fastened to the air intake of the compressor and cleans the air for the compressor, figure 21. This air cleaner (air strainer) must be disassembled periodically and cleaned, dried, and lubricated.

Figure 21.
Exploded View of Air Strainer.

There are some air cleaners for this purpose known as the wet type. These air cleaners are similar to the type used for carburetors, but smaller in size. The service required for this type is to remove and wash clean, then fill with oil up to the mark shown in the reservoir of the air cleaner.

Caution: Do not overfill.

Reservoirs (Air Tanks), Safety Valve and Drain Cocks

RESERVOIRS. The reservoir is sometimes known as the air tank, figure 22. There are usually two of these reservoirs used on each truck and are known as the wet reservoir and the dry reservoir. The air used for the operation of the brakes is taken off the dry one. The purpose of the reservoirs is to provide a place to store compressed air so that there will be an ample supply available for immediate use in brake operation. The reservoirs also provide storage for sufficient compressed air to permit several brake applications after the engine has stopped. Another function of a reservoir is to provide a place where the air, heated during compression, may cool and cause the oil and water vapors to condense. Reservoirs are tested against a 200-pound pressure and treated on the inside with a rust preventive.

Figure 22.
Reservoir, Safety Valve and Drain Cock.

SAFETY VALVE. The purpose of the safety valve is to protect the air brake system against excessive air pressure. Should the air pressure in the air brake system rise above the setting of the safety valve at 150 pounds, the ball valve opens and permits pressure above 150 pounds to be exhausted, figure 23. The safety valve is located on one of the reservoirs, figure 22. The safety valve consists of a spring-loaded ball check valve which should be adjusted to "BLOW OFF" at 150 pounds air pressure, figure 23.

DRAIN COCKS. The drain cocks have a brass body fitted with a tapered brass key. The drain cock is open when the handle is parallel to the body, and closed when the handle is at right angles to the body. Drain cocks are

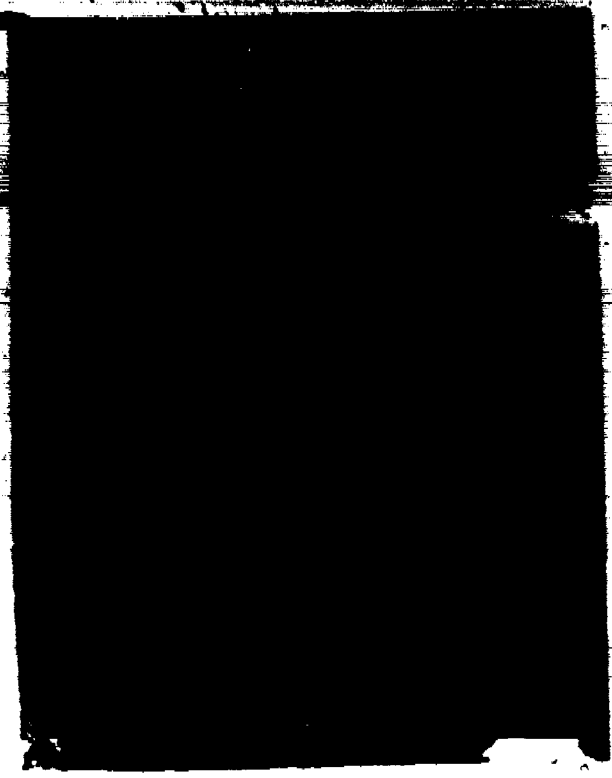

Figure 23. Sectional View of Safety Valve.

Figure 24. Sectional View of Low Pressure Indicator.

installed in the bottom of each reservoir, figure 22, in the air brake system to provide a convenient means of draining the condensation which normally collects in the reservoir. Always open a drain cock by hand. Never strike the handle with a hammer or any other instrument, as the cock will be damaged and leakage will develop.

Low Pressure Indicator

The low pressure indicator, figure 24, is a safety device designed to give an automatic warning whenever the air pressure in the air brake system is below approximately 60 pounds. Operating as an air-controlled switch of an electrical circuit, the low pressure indicator automatically sounds a buzzer when the air pressure drops too low. On some vehicles a light is used to indicate low pressure in place of the buzzer.

Air Supply Valve

In some cases the air supply valve is included to provide an easy means of obtaining compressed air from the air brake system for such purposes as tire inflation, or for whatever need you may have for compressed air.

Quick Release Valve

The purpose of the quick valve, figure 25, is to reduce the time required to release the brakes by hastening the exhaust of air pressure from the brake chambers. It is most commonly used with front wheel brake chambers.

The valve consists of a body containing a spring-loaded diaphragm so arranged as to permit air pressure to flow through the valve in one direction. However, when the supply pressure is reduced, the air which has passed through the valve is permitted to escape through the exhaust port, figure 25.

Figure 25. Sectional View of Quick Release Valve.

Figure 26. Sectional View of Double Check Valve.

Double Check Valve

Double check valves, figure 26, are used in an air brake system where it is necessary to automatically direct the flow of air pressure into a common line from either of two other lines.

There are two types of double check valves, the shuttle type and the disc type. The shuttle type double check valve consists of a die cast body and two end caps. Inside the valve are two rubber seal gaskets and a brass metal shuttle.

The disc type double check valve consists of a cast body and one end cap. Inside the valve is a rubber disc and a disc guide. One end of the end cap serves as the disc seat, and the other end is tapped for air line connection.

Fundamentally, the only difference in the design of the two valves is that the shuttle type has a movable metal shuttle which contacts rubber seats to seal off the line not being used, whereas the disc type has a movable rubber disc which contacts metal seats.

Tractor Protection and Two-Way Valves

The purpose of the tractor protection valve, figure 27, is to provide extra brake protection for towing vehicles. It provides for complete braking control of the truck or tractor by permitting closure of service and emergency lines leading to the trailer hose lines in the event of a trailer breakaway or other malfunction in the trailer or tractor air brake system.

The manually controlled type valve, figure 28, installed on vehicles consists of a two-way control valve and a tractor protection valve. The handle of the two-way control valve may be put in either one or two positions called "NORMAL" and "EMERGENCY."

For all normal operating conditions the two-way control valve handle is placed in the "NORMAL" position which permits reservoir pressure to enter the tractor protection valve and act on the diaphragm and plunger assembly. During initial charging, the emergency valve and service disc valve in the tractor protection valve remain closed until 30-40 psi air pressure is reached in the tractor reservoir and up to that pressure no air is supplied to the trailer through the trailer emergency line.

When approximately 30-40 psi tractor reservoir pressure is reached, the emergency valve and service disc valve in the tractor protection valve open and remain open allowing air pressure to be delivered through the emergency line charging the trailer reservoir. All normal braking and emergency functions for both truck-tractor and trailer are retained as long as the tractor reservoir pressure is above 30-40 psi.

Figure 27. Sectional View of Tractor Protection Valve.

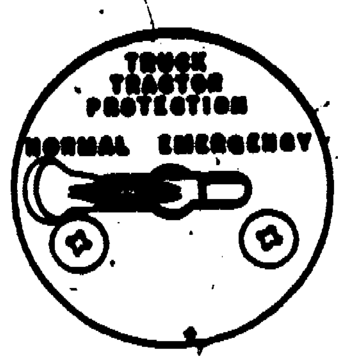

Figure 28. Two-Way Control Valve.

Combination Limiting Quick Release and Two-Way Valves

The limiting quick release valve and two-way valve are used as a combination in air brake system of trucks, buses and tractors. This combination permits full brake valve delivery pressure to the front wheel brakes when on dry roads, or at the option of the driver, limits the pressure to the front wheel brakes 50 percent of the brake valve delivery pressure when on slippery roads.

The two-way valve is mounted on the dash within easy reach of the driver. The limiting quick release valve is mounted at or on the front axle, whichever is convenient. An air line from the brake valve delivery port is connected to the inlet port of the two-way valve and also to the brake valve port of the limiting quick release valve. Another air line is taken from the side delivery port of the two-way valve and connected to the port opposite the mounting pad of the limiting quick release valve. The two other side ports of the limiting quick release valve are connected to the front brake chambers.

The limiting quick release valve, besides providing for 50 percent reduction of front wheel braking pressure, also serves as a quick release valve upon release of brakes.

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Hand Control Valve

Figure 29.
Hand Control Valve Assembly.

The hand control valve, figure 29, is used for controlling the brake on a trailer independently of the brakes on the towing truck. The valve is usually mounted on the steering column or on the dash. The driver may put the handle in any one of several positions between brakes released and brakes fully applied position so the brakes on the trailer are kept applied until the brake valve handle is returned to release position. The distance the brake handle is moved in a clockwise direction toward applied position determines the severity of the brake application. Thus the brake application on the trailer may be graduated during both application or release of the brakes and the position of the brake valve handle always determines the air pressure being delivered through the service line to the trailer brake equipment.

The handle of the brake valve is fitted with a friction lock so it will remain in whatever position it is placed by the driver. The brake valve should never be used to hold the brakes applied when the vehicle is parked or when the driver is off duty.

Brake Valve (Treadle Type)

The foot operated brake valve, which is the main air control device of the air brake system, may be one of two different types. One of these is the treadle type brake valve, figure 30, which is operated by a foot treadle. The other is the lever type brake valve, figure 31, which is fitted with a lever that connects to a conventional brake pedal.

Movement of the treadle or pedal controls the movement of an inlet and exhaust valve which controls the air pressure delivered to, or exhausted from, the brake chambers. Full depression of the treadle or pedal results in full brake application; partial return of the treadle or pedal results in correspondingly less braking force. At any time the brakes may be partially released by the driver permitting a partial return of the treadle or pedal to release position. The amount of force being applied to the brakes is always proportional to pedal pressure applied by the driver.

Brake Chambers, Roto Chambers, Brake Cylinders

There are several types or kinds of brake chambers used on air brake systems, but the purpose is the same. Brake chambers, roto chambers, or brake cylinders all transform the energy of compressed air into the mechanical force and motion necessary to apply the brakes. One of these units is used to operate the brakes on each wheel.

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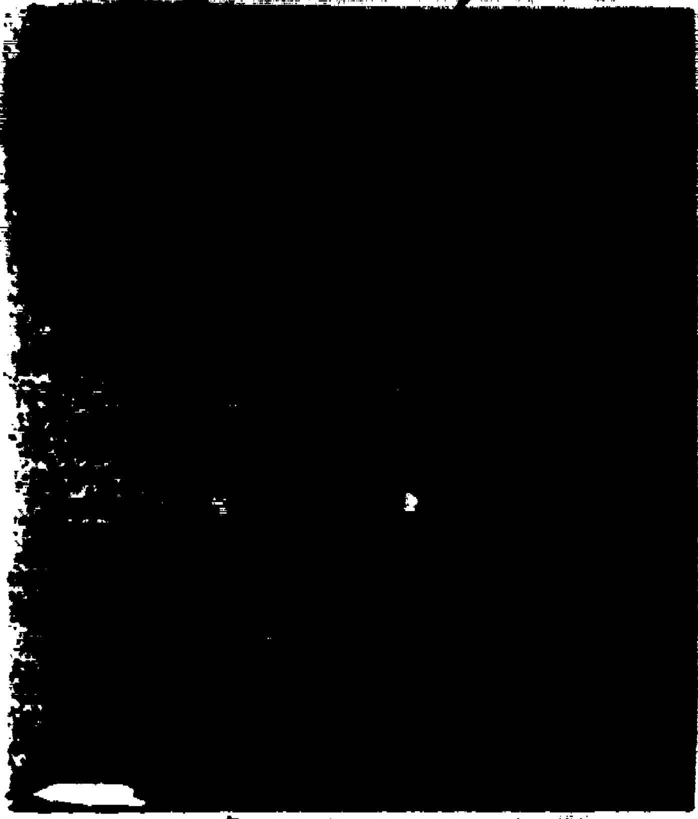
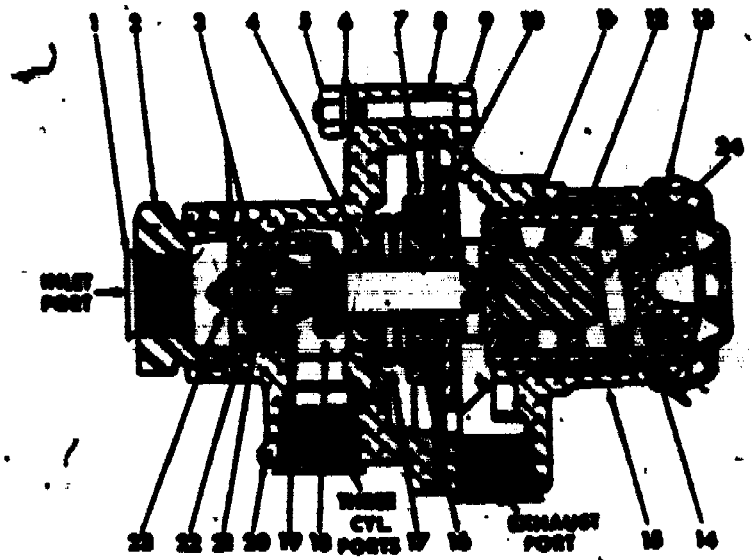


1. BODY
2. PLATE, MOUNTING
3. LOCKWASHER
4. CAPSCREW
5. BOOT
6. PLUNGER
7. RING, SNAP
8. GUIDE SPRING
9. CLEANER, AIR
10. CAP
10A. SCREEN
11. WASHER, SHIM
12. SPRING
13. RING, SNAP
14. SEAL, VEE-BLOCK
15. WASHER, SHIM
16. SPRING
17. O-RING
18. PISTON
19. VALVE, EXHAUST
20. O-RING
21. LOCKWASHER
22. CAPSCREW
23. SPRING, VALVE
24. CAP, END
25. VALVE, INLET
26. NUT
27. GASKET
28. SCREW

Figure 30. Brake Valve, Treadle Type (Cross Sectional View).



1. FITTING
2. CAP, END
3. GASKETS
4. O-RING
5. NUT
6. LOCKWASHER
7. WASHER, CUP
8. DIAPHRAGM
9. BOLT
10. WASHER, DIAPHRAGM
11. PISTON
12. SPRING
13. BOOT
14. GUIDE, SPRING
15. COVER
16. NUT
17. SPRING
18. VALVE, EXHAUST
19. SPRING
20. BODY
21. VALVE, INLET
22. CAGE
23. NUT

Figure 31. Brake Valve Lever Type (Cross Sectional View).

BRAKE CHAMBERS (DIAPHRAGM TYPE). The brake chamber consists of two dished metal plates, namely the nonpressure plate and the pressure plate separated by a diaphragm, figure 32.

In front of the diaphragm are the nonpressure plate, push rod and push rod spring. Behind the diaphragm is the air-tight cavity into which is connected a tubing line from the brake valve. Due to the extreme sensitivity of the diaphragm this arrangement permits the push rod to respond to the slightest variation of air pressure from the brake valve, thus permitting the driver to apply or release brakes as rapidly or gradually as the various road and operating conditions warrant.

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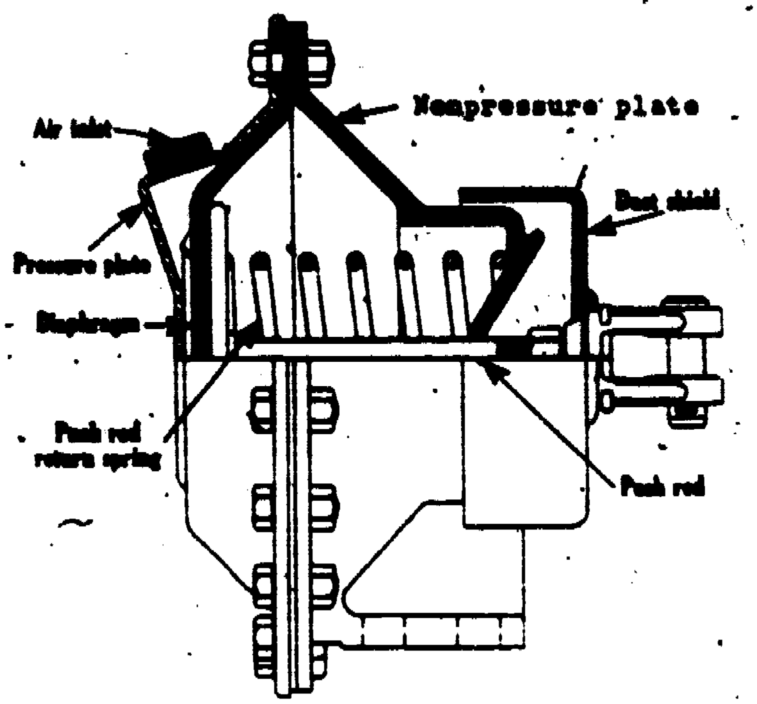
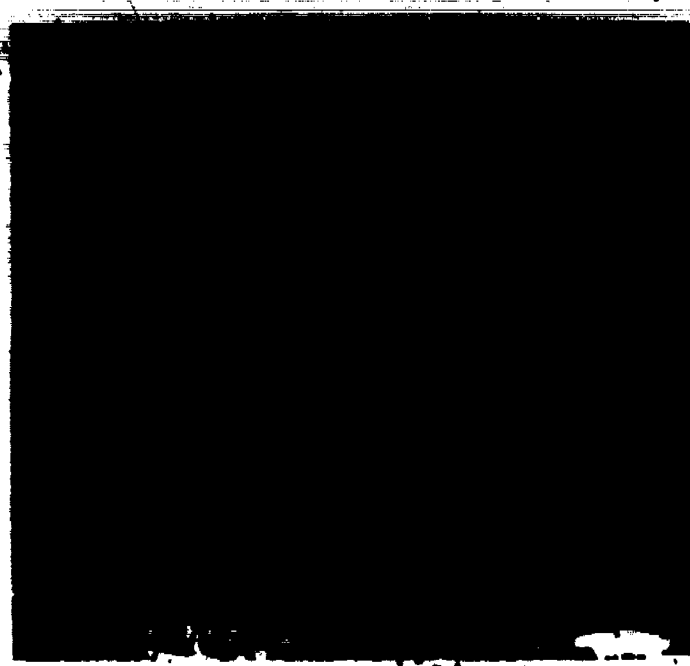


Figure 32. Typical Brake Chamber (Diaphragm Type).



1. RETAINER, SPRING
2. COVER
3. DIAPHRAGM
4. NUT
5. BOLT
6. BAND, CLAMP
7. BODY
8. SPRING
9. LOCKWASHER
10. LOCKNUT
D. NUT
E. YOKE
F. PIN COTTER
G. PIN CLEVIS

Figure 33. Brake Chamber (Cross-Sectional View).

Figure 34. Typical Brake Chamber (Roto Chamber).

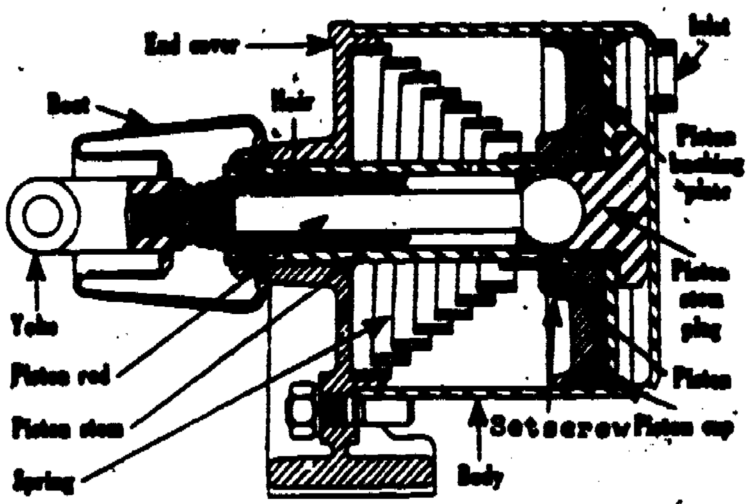


Figure 35. Typical Brake Chamber (Piston Type).

In order to meet requirements for different braking forces, brake chambers are made in several different sizes. All sizes are made for several different type mountings, such as stud mountings, bracket mounting and flange mounting. Figure 33 shows a typical brake chamber (diaphragm type) using a brand clamp around the brake chamber instead of bolts.

BRAKE CHAMBER (ROTO CHAMBER). Roto chambers, figure 34, convert the energy of compressed air into the mechanical force and motion necessary to operate the brakes. The major detail parts of a roto chamber are a cylindrical body, tubular diaphragm, inner and outer diaphragm clamps, push rod, spring, cover, mounting studs and yoke.

One end of the diaphragm is connected to the inside wall of the body by a clamp called the outer clamp. The push rod is attached to a push plate and the push rod - push plate assembly is attached to the diaphragm guide. The cover is attached to the outer body and a yoke is screwed onto the end of the push rod completing the roto chamber assembly.

BRAKE CHAMBER (PISTON TYPE). The air cylinder (piston type), figure 35, requires very little attention, but to insure proper operation the cylinder should be kept lubricated. At intervals of approximately four months or 15,000 miles the air connection at the rear of the cylinder should be removed and one quarter pint of lubricant (similar to graphite type grease with 10% neat's-foot oil) inserted.

Figure 36.
Sectional View of Slack Adjuster.

Figure 37. Illustrates
Locking Sleeve on Adjusting Nut.

Slack Adjusters

Slack adjusters provide a quick and easy method of adjusting the brake to compensate for brake lining wear. One slack adjuster is used for the brakes on each wheel. Slack adjusters consist of a worm and gear inclosed in a body which serves as an adjustable lever, figure 36. They provide a quick and easy means of adjusting the brakes to compensate for brake lining wear, figure 37. During brake operation, the entire slack adjuster rotates bodily with the brake camshaft. During brake adjustment, the worm moves the gear so as to change the position of the lever arm in relation to the brake camshaft.

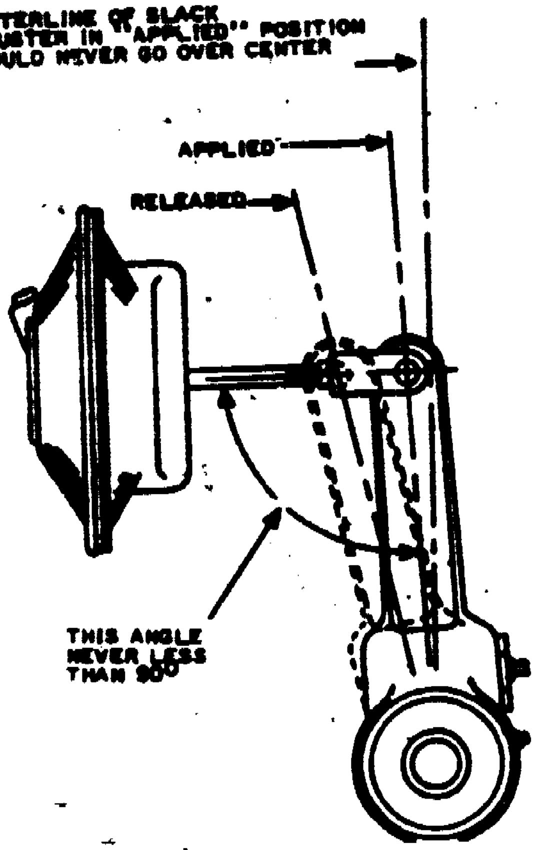


Figure 38.
Slack Adjuster Angle.

1. Cover, assembly
2. Spring, return
3. Disc, contact
4. Gasket
5. Collar
6. Diaphragm
7. Body

Figure 39. Stoplight Switch (Cross-Sectional View).

When slack adjuster movement does not give the desired brake action, adjustment of the push rod length by altering the location of the yoke may be necessary. With brakes released the angle formed by the push rod and slack adjuster must be greater than 90°, figure 38, and all slack adjusters should be set at the same angle. With the brakes fully applied, after being adjusted, this angle should still be greater than 90°. In other words, the slack adjuster should not go "over center" when the brakes are applied, figure 38. The position on the push rod should be adjusted, if necessary, until these conditions prevail.

1. BODY, VALVE.
2. SPRING.
3. SEAL, ASSEMBLY.
4. WASHER, CAP TO BODY.
5. CAP, VALVE.

Figure 40. One-Way Check Valve (Cross-Sectional View).

Stoplight Switch

The stoplight switch consists of a die cast body containing a diaphragm and contact disc. Electric contacts and a diaphragm return spring are contained in an insulated cover, figure 39.

One-Way Check Valve

The one-way check valve, figure 40, is used to permit passage of air pressure through the valve in one direction only as indicated by an arrow on side of valve.

Air Gage

The purpose of the dash mounted air pressure gage is to register the amount of air pressure in the air brake system. While air pressure gages of this type are commercially accurate, they must never be confused with, or substituted for, test air gages which are intended primarily for accurately checking air pressure in the air brake system.

Only test gages known to be accurate are to be used for checking brake valve delivery pressure, governor pressure settings and other tests. Test gages differ from ordinary dash gages in respect to material and workmanship just as an expensive watch differs from a cheaper one. Due to these differences they are more accurate over entire range and maintain their accuracy over longer periods.

Tubing and Tubing Fittings

Tubing and tubing fittings connect the different air brake devices in the air brake system.

If any evidence is found that a tubing line is restricted, remove and blow air through it in both directions to be sure the passage through the tubing is not obstructed in any way. Inspect tubing for partial restrictions such as may be caused by dents or kinks. Damaged tubing must be replaced.

With the air brake system fully charged, the governor cut out and brakes applied, coat all tubing lines and fittings with soapsuds to check for leakage. No leakage is permissible. Leakage at a tubing fitting is sometimes corrected by tightening the tubing fitting nut. If this fails to correct the leakage, replace the tubing fitting, the tubing, or both.

Hose, Hose Assemblies and Hose Connectors

Hose and hose fittings provide a means of making flexible air connections between points on a vehicle which normally change their position in relation to each other, also for making flexible connections between two vehicles. All hose assemblies include detachable type hose connectors with spring guards. Hose assemblies used to connect the air brake system to another vehicle are fitted with hose couplings. The two hose lines or hose couplings at the rear of the tractor-truck are marked by tags identifying them as "service" or "emergency."

Hose Couplings and Dummy Couplings

Hose couplings provide an easy and convenient method of connecting and disconnecting air lines between vehicles by hand. The design of the hose couplings is such that when two of them are coupled together pressure is put on two rubber gaskets, making an air-tight seal.

Dummy couplings are made in two general designs, some being fitted with brackets to permit them to be rigidly mounted on the vehicle, while others are fitted with a chain attaching them to the vehicle. The bracket type is used when the dummy coupling is to serve as a fastening for holding hose lines when not in use, whereas the chain type is used for blocking off hose couplings rigidly mounted on the vehicle as used on the tractor-truck. The purpose of the dummy coupling is to prevent the entrance of dirt or other foreign matter into the air brake lines when the lines are not being used.

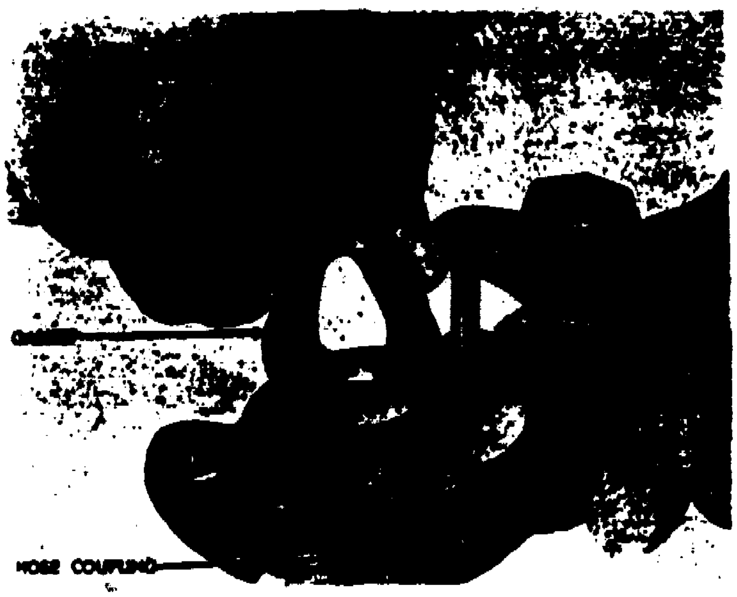


Figure 41. Installing a New Gasket.

Figure 42. Pushing Gasket into Place.

Testing Couplings

With the hose couplings connected and brakes applied, coat the hose couplings all over with soapsuds to check for leakage. There must be no leakage.

Leakage is usually caused by worn, damaged, or improperly installed gaskets. To correct leakage, install new gaskets, figure 41.

Remove the old gasket by prying it out with a screwdriver. Before attempting to install a new gasket, be sure the groove in the coupling in which the gasket fits is thoroughly cleaned, otherwise it will be impossible to install a new gasket properly.

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To install a new gasket, partially collapse it with the fingers, figure 41, and enter one side of the gasket flange in the groove in the coupling. Then use a blunt nosed screwdriver or similar instrument to push the gasket into place, figure 42. When properly installed, the exposed face of the gasket should be flat, not twisted or bulged at any point.

Operation of the Air Brake Equipment

The reservoirs are charged with air by a compressor. The reservoir air has access to the inlet valve chamber of the brake valve and the inlet valve is then closed by the tension of its spring and air pressure.

When it is desired to apply the brakes, foot pressure is applied to the brake pedal, which action is carried through the brake rod pulling up on the lever of the brake valve. This compresses the spring, deflects the diaphragm downward, and through the medium of the rocker arm closes the exhaust valve and opens the inlet valve. Air is thereby admitted from the reservoir to the brake valve, thence out the two side outlets to the front and rear brake chambers. The power thus exerted against the brake chamber diaphragms or pistons forces the push rods out, rotating the camshafts to apply the brakes.

In flowing to the rear brake chambers the air pressure passes through the quick release valve entering at the top, deflecting the diaphragm and its seat to seal the exhaust opening while the air pressure passes around the diaphragm to the two side connections, each leading to a brake chamber.

When the pressure built up in the brake chambers and acting against the brake valve diaphragm is enough to compress the regulating spring, the diaphragm moves upward, allowing the inlet valve to close by action of its spring.

The exhaust valve remains closed by action of the inlet valve spring and tilting of the rocker arm. Further increase of brake chamber pressure is thus prevented. If, however, there should be leakage from the brake chambers or piping, while the brake valve lever remains in this position, the resulting drop in pressure under the brake valve diaphragm will cause the regulating spring to again unseat the inlet valve and restore the lost pressure.

When the foot is removed from the brake pedal, the brake valve lever is moved back toward normal position again, which relieves the tension on the regulating spring so that the diaphragm will be moved upward to its normal position by brake chamber pressure underneath it. This permits the exhaust valve to be unseated by its spring which opens the brake chamber line to atmosphere and allows air to exhaust from the brake chamber.

If the brake valve lever is moved all the way back to normal position and left there (foot entirely removed from brake pedal), the brakes will entirely release, but if moved only part way back (foot pressure eased), the brakes will only partially release, the exhaust valve will remain open until the brake chamber pressure has reduced to such an amount as will no longer hold the diaphragm up, whereupon the regulating spring will move the diaphragm with rocker arm downward again and close the exhaust valve.

The brake chamber line to the rear wheels is released only up to the quick release valve or relay valve. This allows the diaphragm to unseat, uncovering the exhaust port through which the rear brake chambers are then exhausted.

Air-Over-Hydraulic Brake Booster System

The air-over-hydraulic brake booster system is nothing more than hydraulic brakes with an air booster cylinder to step up the hydraulic pressure in the wheel cylinder of the vehicle.

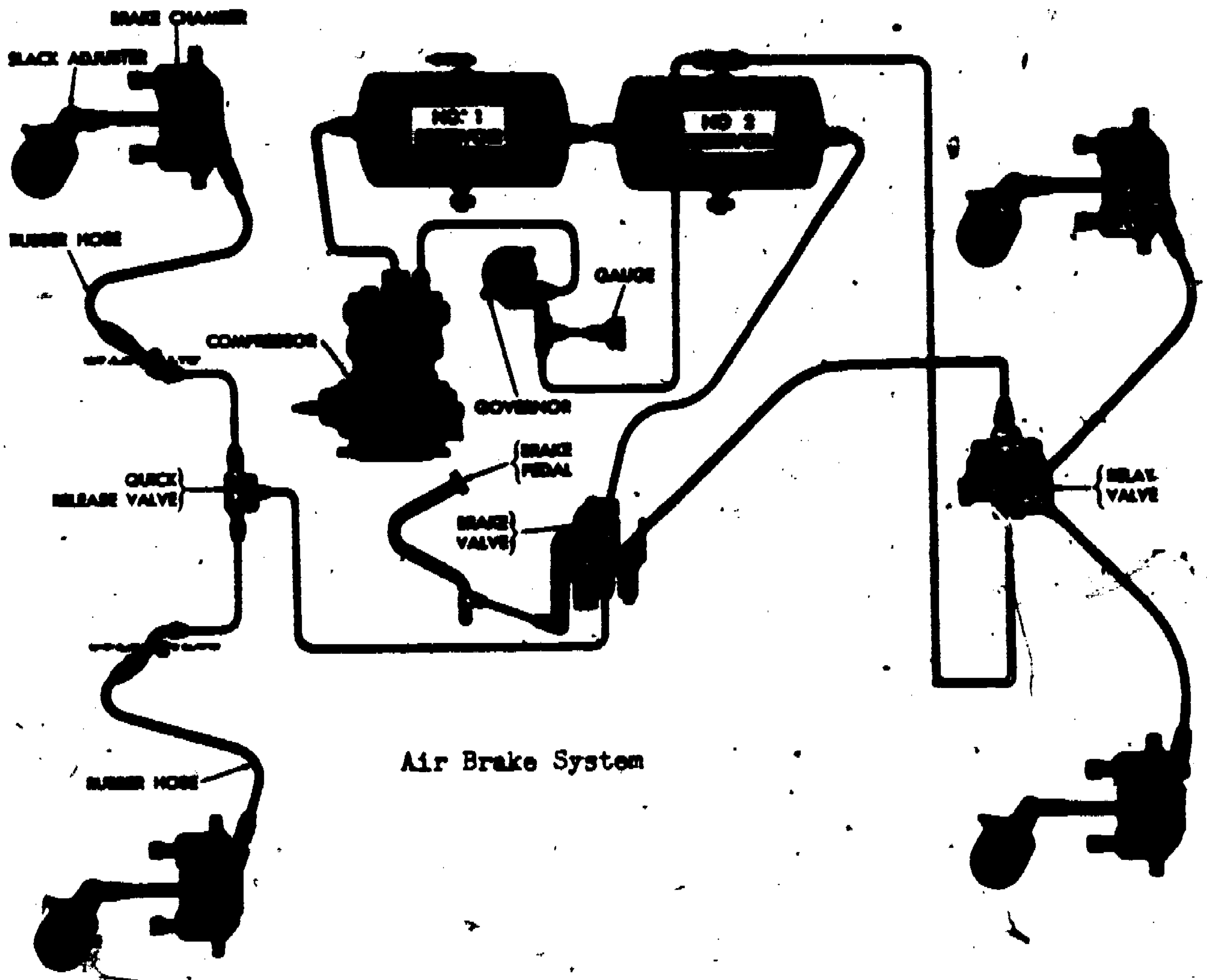

Figure 43. Air Hydraulic Booster Cylinder.

Booster Cylinder

This system requires the addition of a booster cylinder, figure 43, to the regular hydraulic brake system. The brakes are applied by a regular master cylinder which exerts pressure on the control valve of the booster. The booster, in turn, builds up the applied pressure and sends it out to the wheel cylinders to apply the brakes as shown in figure 44.

The booster cylinder is operated by compressed air and this requires different accessories, such as used on the regular air brake system, including:

1. Compressor.

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2. Reservoirs.

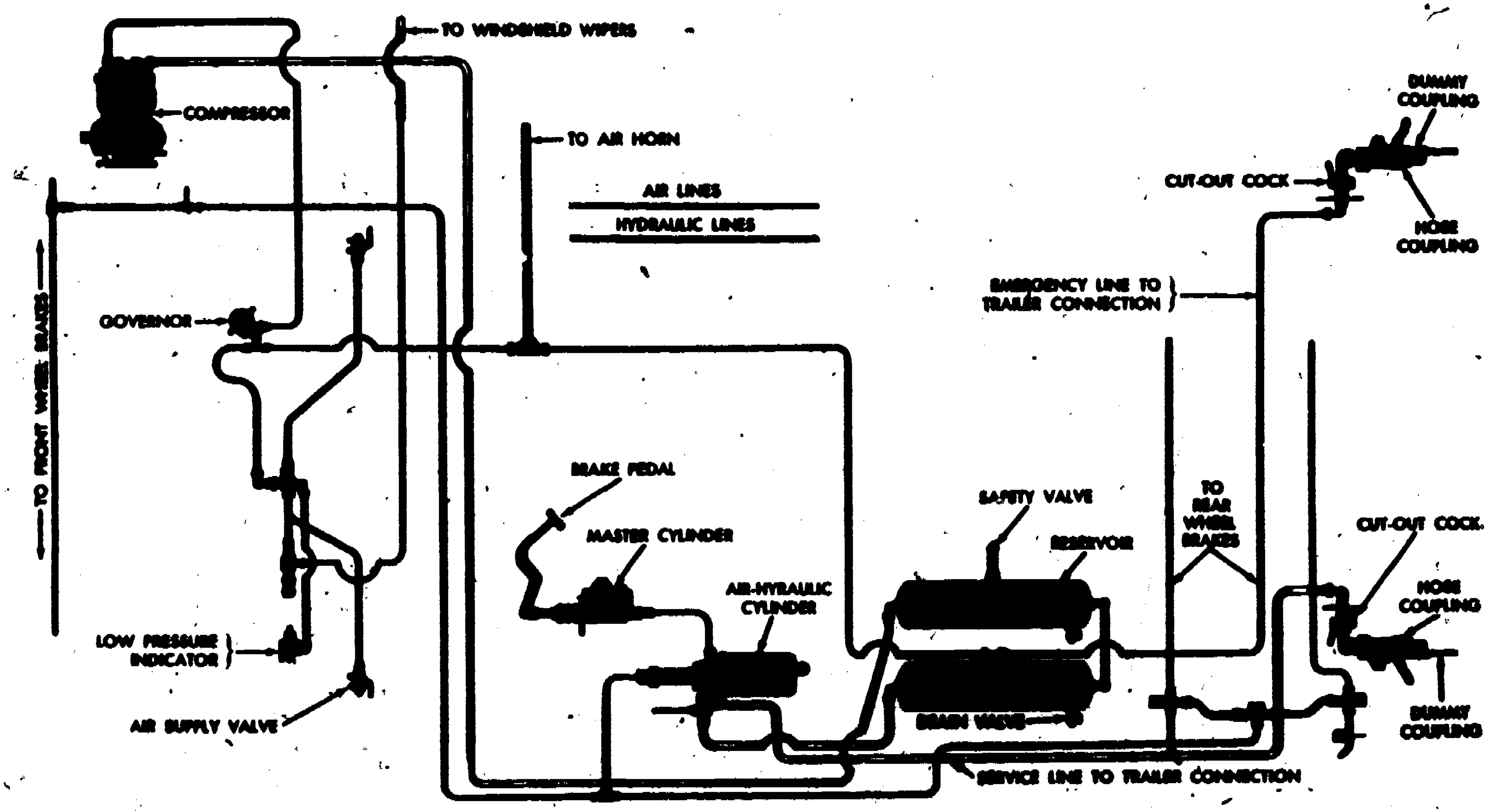


Figure 44. Air-Over-Hydraulic Braking System.

3. Governor.

4. **Safety valve.**

5. Air pressure gage.

6. Low pressure indicator.

As long as there is air pressure in the reservoirs, and the system is in operating condition the hydraulic brakes can be applied with very little pressure exerted on the brake pedal.

The air hydraulic booster has a bypass port in the hydraulic cylinder of the booster which makes it possible to apply the brakes even though the booster does not operate. This is merely a safety device in case the booster should fail, but in this event, the brakes apply only with master cylinder pressure and are not nearly as efficient.

This type of booster can be adopted for use with trailer brakes by extending the lines and adding a few more units.

Advantage of Boosters

Booster brakes have the advantage of giving more braking effort with less pedal pressure. Modern passenger cars have started using boosters (power brakes) because of the greater stopping power required as the speed and weight of automobiles increases. The vacuum brake is generally used on automobiles as it requires no additional accessories other than the booster itself.

The air hydraulic booster is in common use on trucks because of the greater amount of pressure differential that can be developed with compressed air. It is also easily adapted for pulling trailers as it has service and emergency line outlets making it possible to use any trailer equipped with air brakes, figure 44.

Removal of Boosters

The air hydraulic booster requires only the removal of the hydraulic lines, air lines and mounting bolts to be taken off the vehicle. Removal of the booster requires the brakes to be bled after the units have been reinstalled.

Bleeding Brakes

It is necessary to bleed the brake system whenever air gets in the lines. Air in the system is indicated by a "spongy" brake pedal which will become hard as the air is removed.

The booster brake system is bled in the same manner as regular hydraulic brakes with the exceptions that the booster has to be bled first and all compressed air has to be released from the reservoirs on the air hydraulic system to prevent personal injury resulting from the extreme hydraulic pressure created by the booster. 15

QUESTIONS

1. How is the compressor driven?

2. What is the function of the brake chambers?

3. Why is it necessary to adjust newly installed air governor?

4. Why is it necessary to adjust the slack adjusters of an air brake system?

5. Why are the soft metals like brass or copper used in lines and fittings?

6. How are the various valves of the system checked for operation?

7. How are the trailer brakes applied?

8. What is the job of the air supply valve?

9. What causes air to enter the cylinder of the compressor?

10. The air compressor is cooled by the engine coolant. Why is it necessary to periodically inspect or service engine cooling system?

11. How do you determine the working force of a booster?

12. What makes it possible to apply the brakes of a booster system if the booster is inoperative?

13. Why is it not a common practice to use air-hydraulic boosters on passenger cars?

14. When is it necessary to bleed brakes on an air-hydraulic brake system?

15. What is meant by the term PSI?

16. What is the advantage of the air-hydraulic booster over the hydrovac?

17. Would there be any moisture in the reservoirs on an air-hydraulic brake system when in operation?

18. What brake system on the automotive vehicle is usually a mechanical system?

19. What two methods are used to bleed hydraulic booster brakes?

20. What malfunctions may be found in an air brake system if it fails to pump up air pressure?

21. What may be the trouble in an air brake system if the front brakes do not release fast enough?

22. There are two methods for applying the air brakes on the trailer; what are they?

23. What is a full power-brake system?

24. What do we mean by pressure differential in the booster cylinder?

25. What would happen if the bypass port in the booster cylinder would not close?

26. What safety precautions should be observed when troubleshooting air-over-hydraulic brakes?

REFERENCES

1. TO 36A-1-76, Principles of Automotive Vehicles.

2. Applicable Vehicle Technical Publication.

15

AIR AND AIR-OVER HYDRAULIC BRAKE SYSTEMS

OBJECTIVES

When you have completed the exercises in this WS you will be able to:

- Locate, identify, service and adjust air brake system components.

PROCEDURE

This worksheet contains schematic drawings and diagrams of the air brake system and components. As the instructor discusses each component, you will be required to complete statements, answer questions, and take notes in the spaces provided.

1. What is the purpose of the compressor?

____

____

2. How is the compressor driven?

____

3. What happens to the air when it leaves the compressor?

____

4. What is the purpose of the brake chamber?

____

5. What does the linkage include?

____

6. What is the purpose of the slack adjuster?

____

7. What is the purpose of the air governor?

____

8. What is the purpose of the unloader valves in the compressor head?

____

9. Why are there two reservoirs?

____

____

10. What is the purpose of the brake valve?

____

11. How is the brake valve actuated?

____

____

12. What is the purpose of the intake valve on the brake valve?

____

13. What is the purpose of the exhaust valve on the brake valve?

____

14. What is the purpose of the quick release valve?

____

15. Why is it necessary to have a relay valve?

____

____

16. Does the relay valve incorporate a quick release valve? (YES/NO)

17. Where is the compressor located? ____________ ____________

18. Where is the air governor located on this particular vehicle?

   a. Firewall.
   b. Instrument panel.
   c. Engine.
   d. Compressor.

19. Where are the reservoirs located on this particular vehicle?

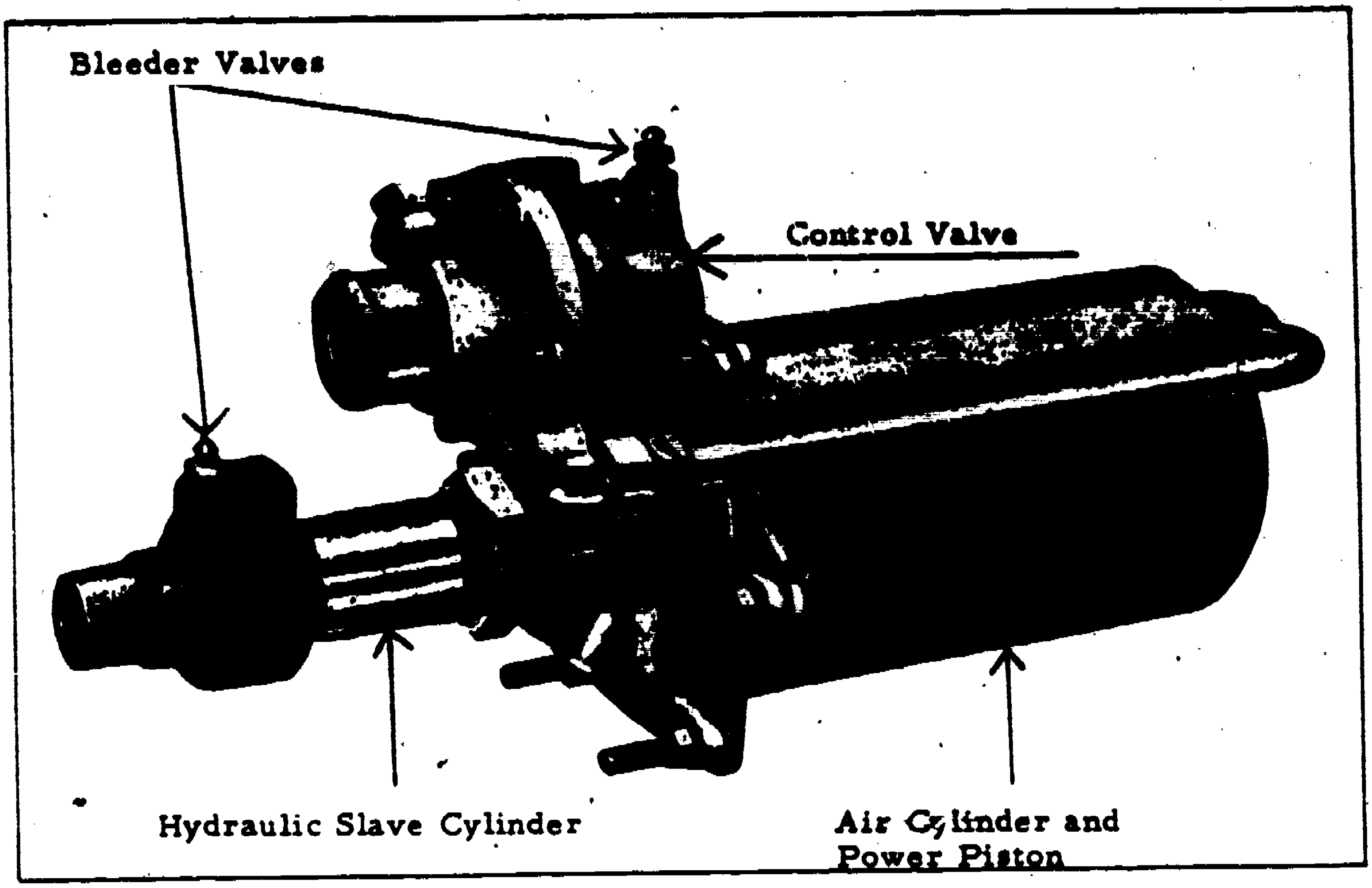
   a. Engine compartment.
   b. Firewall.
   c. Under side of vehicle.
   d. Passenger compartment.

20. Where is the quick release valve located? ____________________

21. Where is the relay valve located? ____________________

____

22. How many brake chambers on this particular vehicle? (2) (4) (6) (8)



The above illustration is a schematic drawing of a typical air brake system. During this lesson your instructor will discuss each component.

As the instructor discusses each component, you will be required to complete statements, answer questions, and take notes. Each page of this note book contains a miniature diagram of the air brake system with a specific component magnified. Under each component are provided spaces for notes, questions, and other information.

At the end of this lesson you should be able to identify all of the components in the diagram and know its purpose.

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AIR BRAKE SYSTEM GROUP

1. Constant Supply.

   Purpose: ____________________

   ____

2. Service Supply.

   Purpose: ____________________

   ____

3. Exhaust.

   Purpose: ____________________

   ____

4. Mechanical.

   Purpose: ____________________

   ____

5. Hoses and Lines.

   Purpose: ____________________

   ____

6. Fittings and Couplings.

   Purpose: ____________________

   ____

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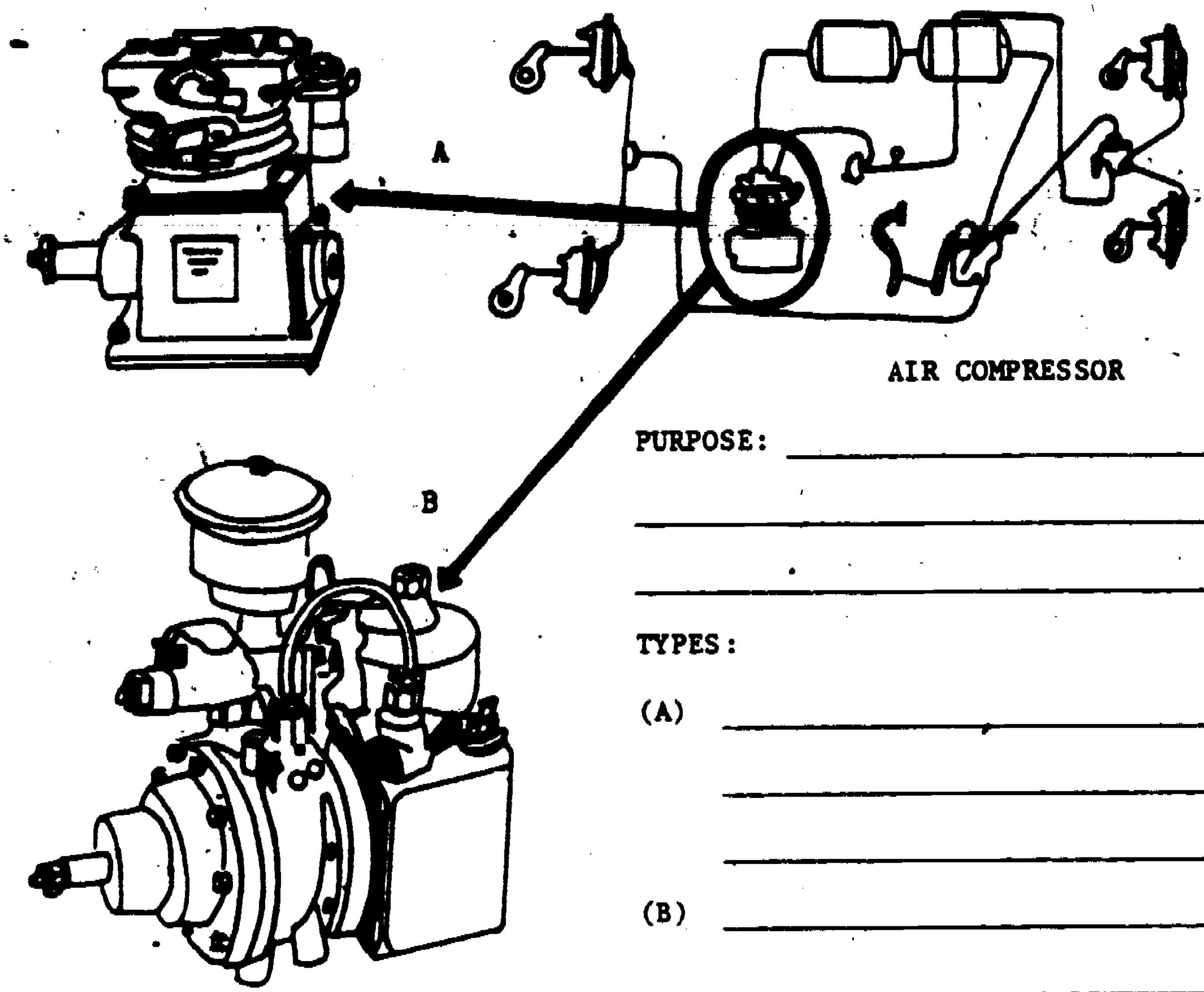

AIR COMPRESSOR

PURPOSE: ____________________

____

____

TYPES:

(A) ____________________

____

____

(B) ____________________

____

____

NOTES: ____________________

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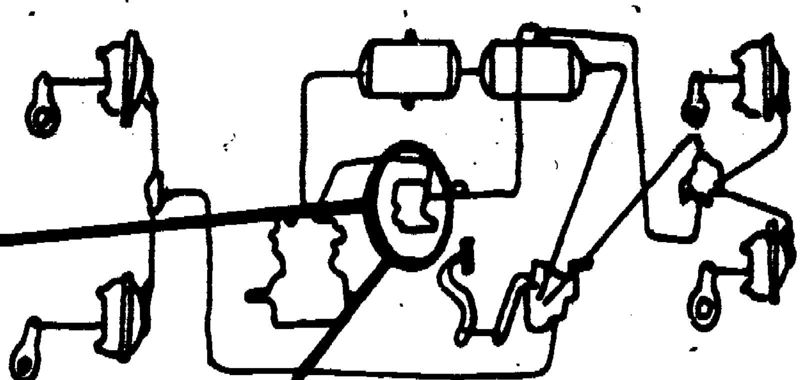

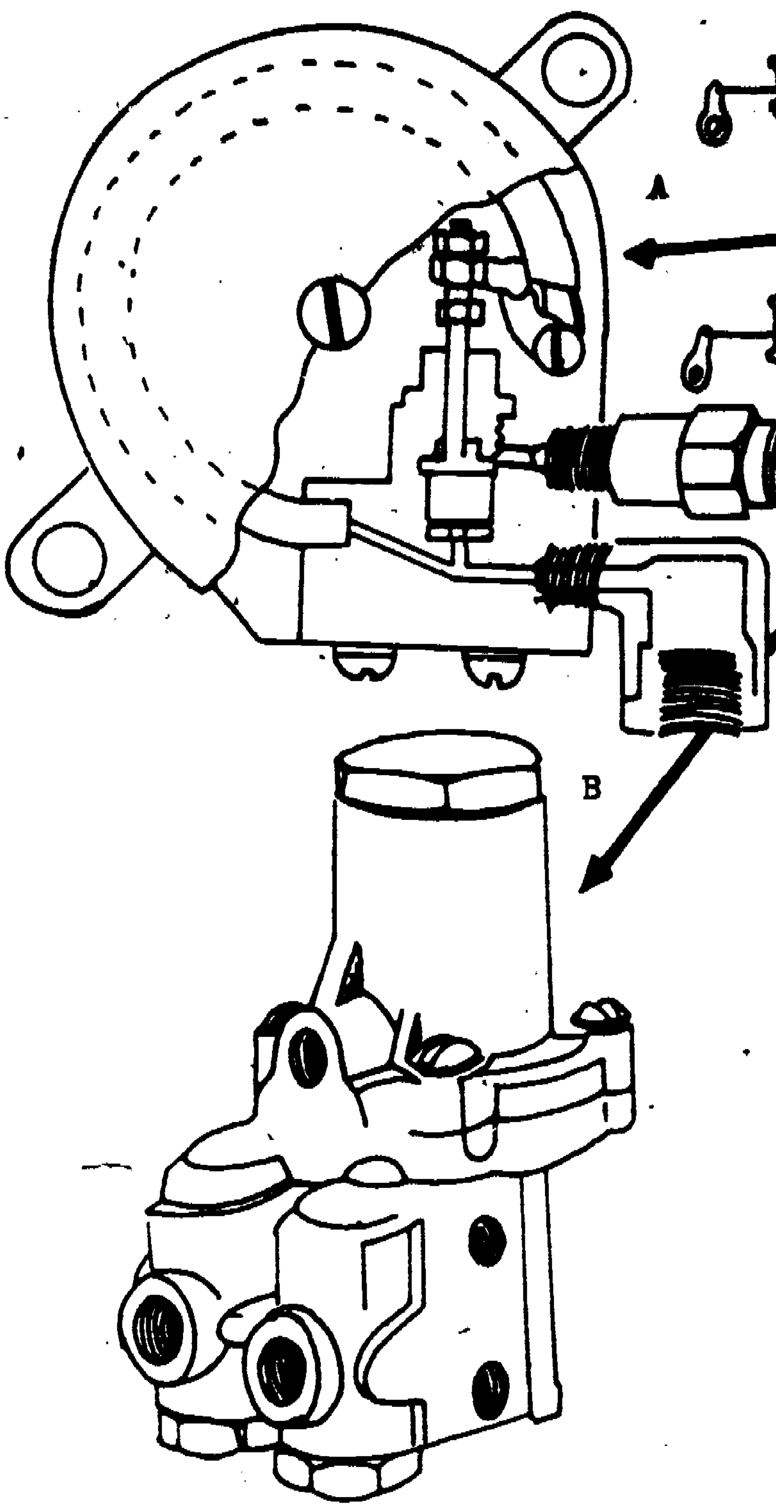

GOVERNORS

PURPOSE: ____________________

____

____

TYPES:

(A) ____________________

____

____

(B) ____________________

____

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ADJUSTMENTS: ____________________

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NOTES: ____________________

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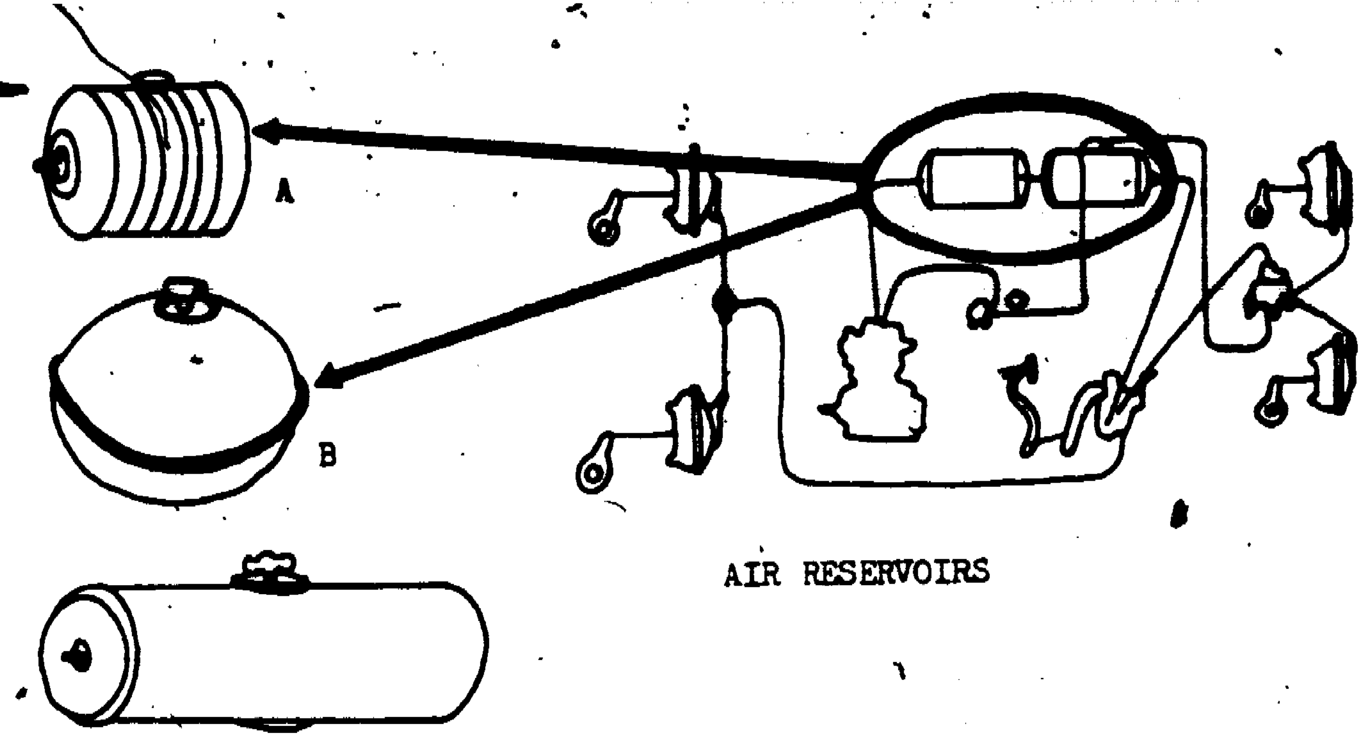

AIR RESERVOIRS

PURPOSE: ______________________________

____

____

TYPES: ______________________________

____

____

SERVICE PROCEDURES: ______________________________

____

____

DRAIN COCK: ______________________________

____

____

NOTES: ______________________________

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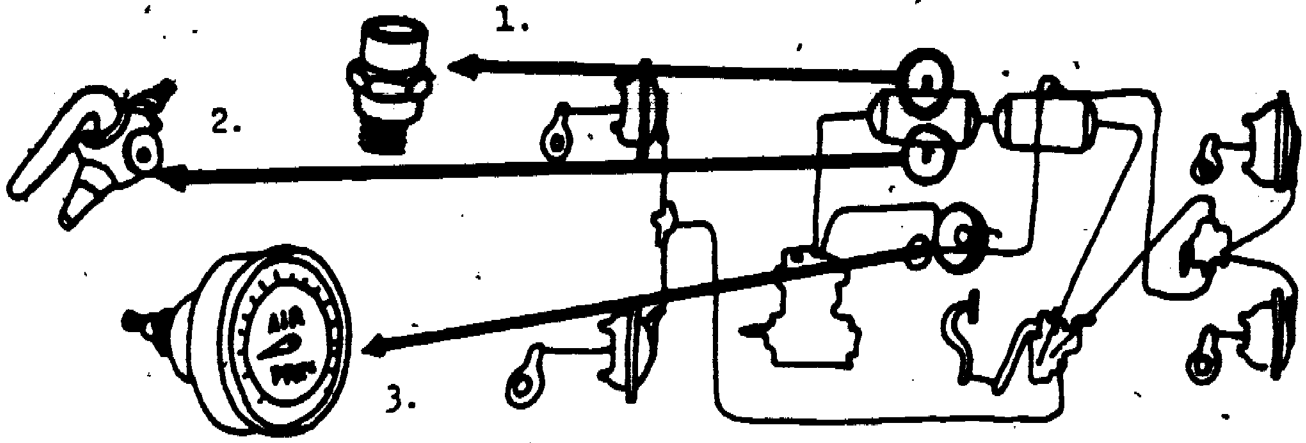

SAFETY VALVE:

PURPOSE: ______________________________

____

NOTES: ______________________________

____

AIR SUPPLY VALVE:

PURPOSE: ______________________________

____

NOTES: ______________________________

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AIR PRESSURE GAUGE:

PURPOSE: ______________________________

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NOTES: ______________________________

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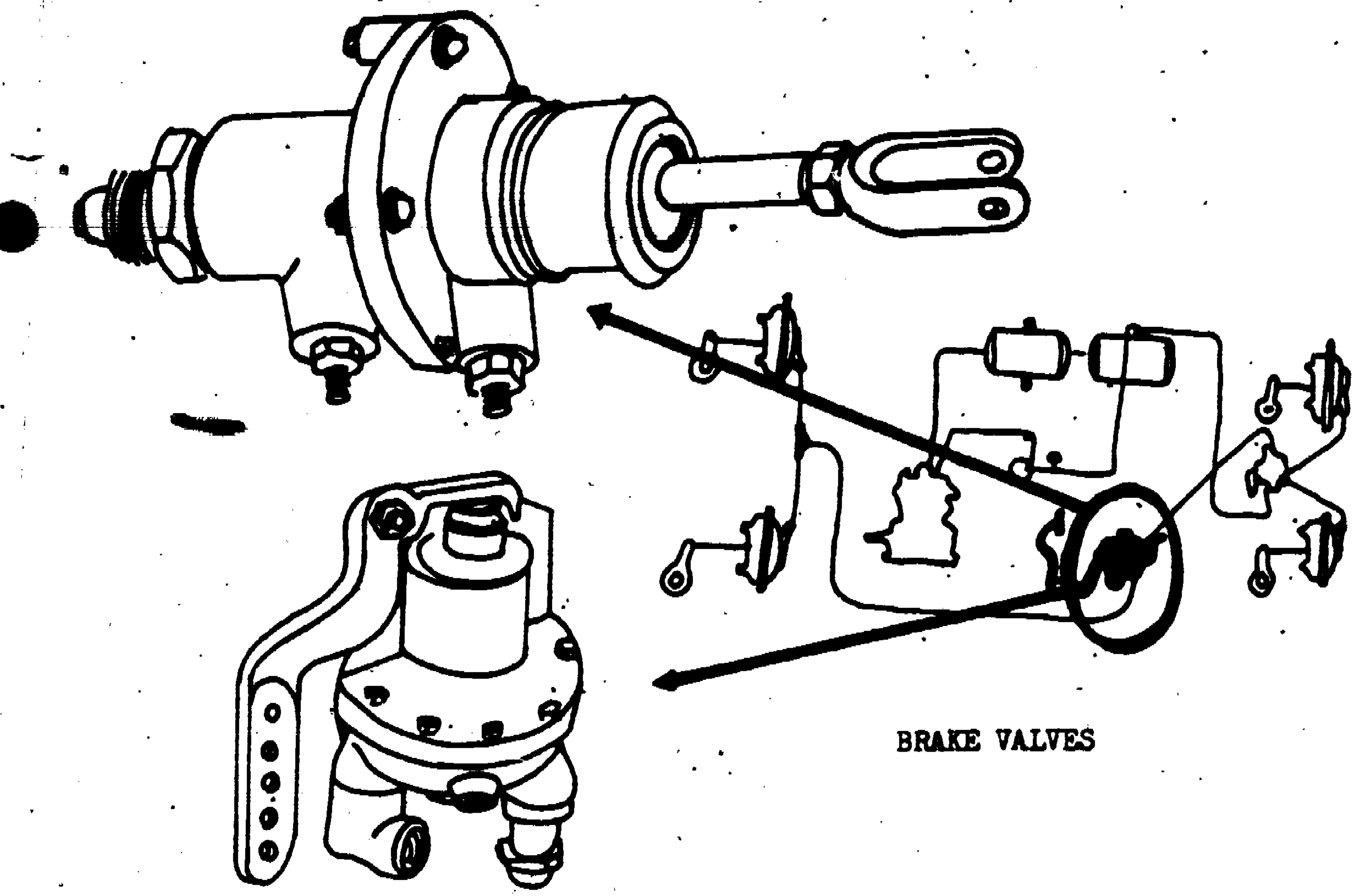

BRAKE VALVES

PURPOSE: ____

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NOTES: ____

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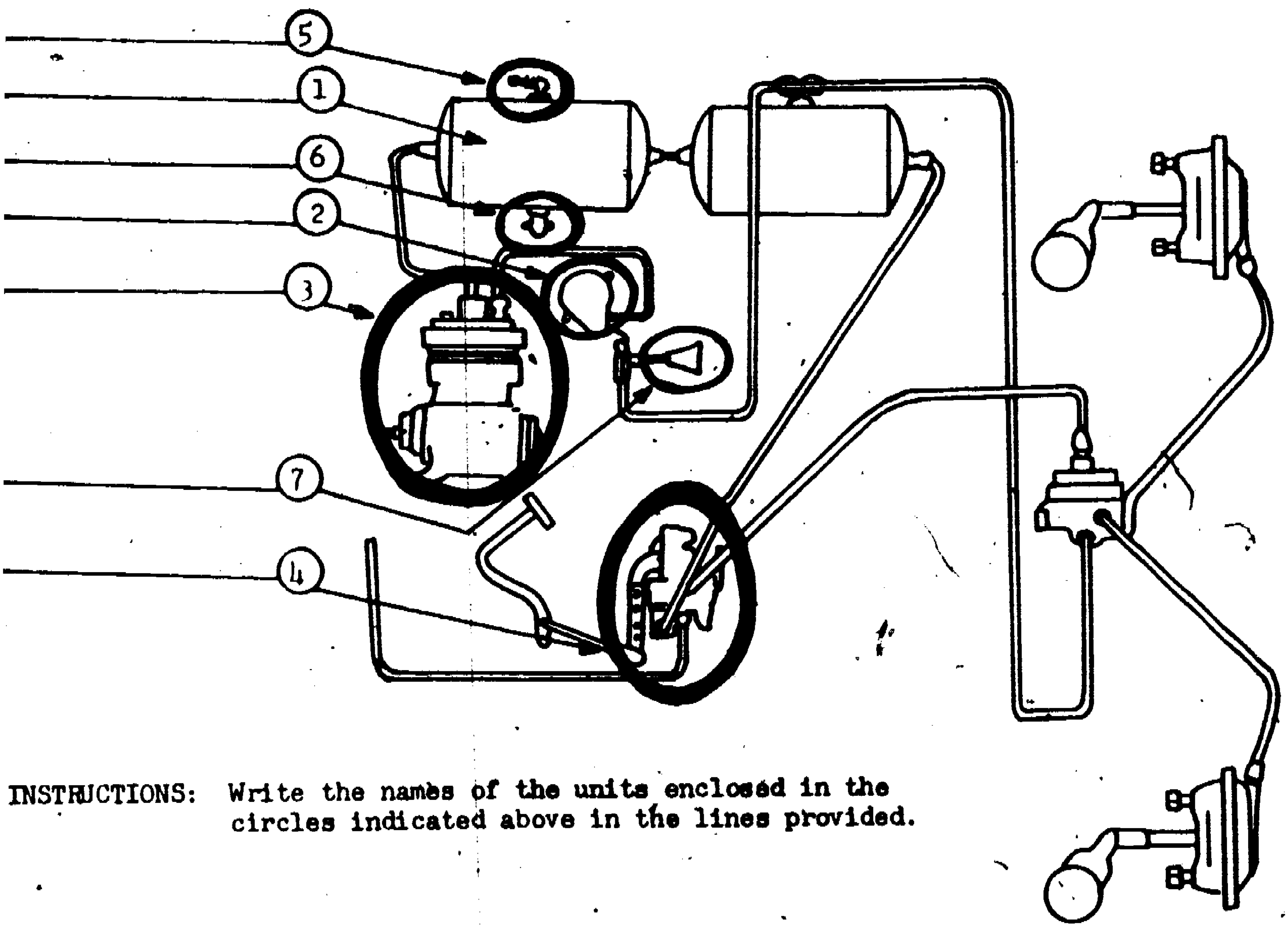

INSTRUCTIONS: Write the names of the units enclosed in the circles indicated above in the lines provided.

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Circle the correct alternative to the statements below.

8. The purpose of the brake valve is to

   a. release air to the reservoir.
   b. regulate the air going to the compressor.
   c. regulate the air into the service line for braking.
   d. release air from the service line.

9. The purpose of the governor is to

   a. regulate the air in the brake service line.
   b. limit the amount of air used in any one brake application.
   c. maintain a predetermined amount of air pressure in the air reservoirs.
   d. regulate the amount of air entering the compressor.

Complete the statements below.

10. The purpose of the air compressor is to ______________________________

____

11. What is the purpose of the air reservoir safety valve? ____________

____

12. The purpose of the air gauge is to ______________________________

____

13. The purpose of the air reservoir is to ______________________________

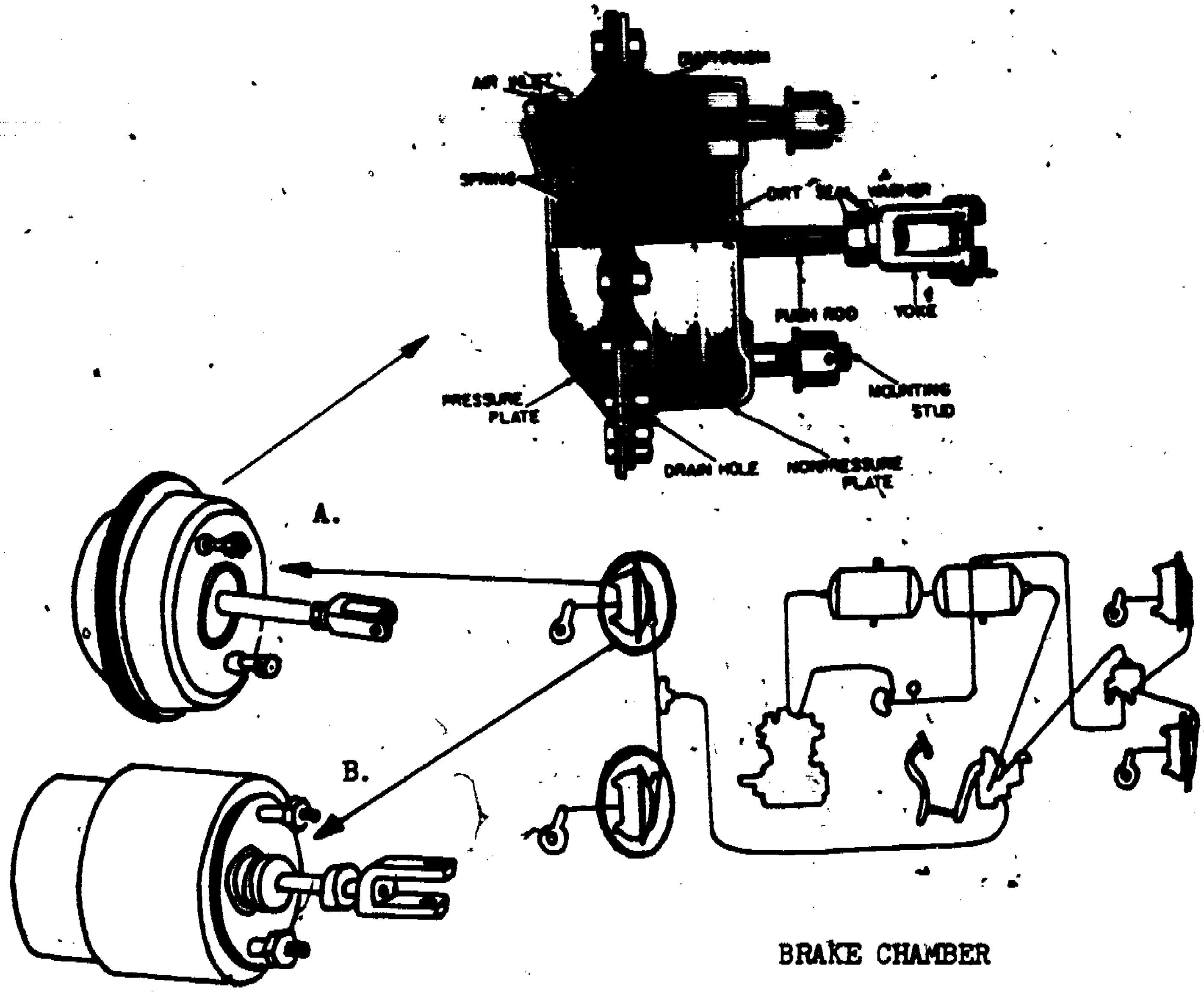
____

14. How is water drained from the air brake system? ______________

____

15. What is the purpose of the unloading valve? ______________

____



BRAKE CHAMBER

PURPOSE: ____

____

____

ADJUSTMENTS: ____

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NOTES: ____

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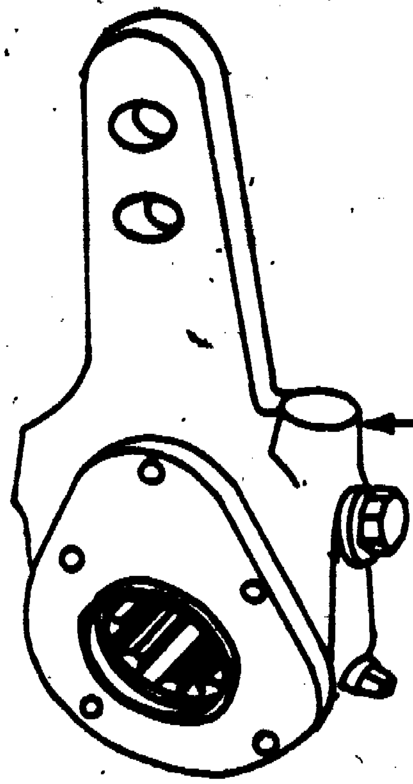
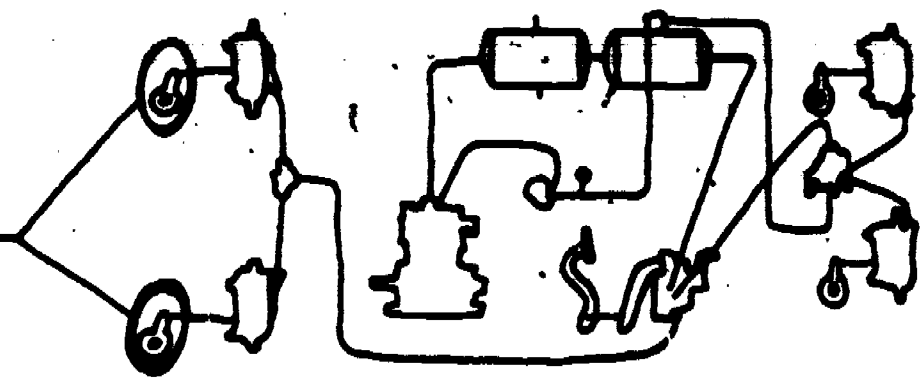
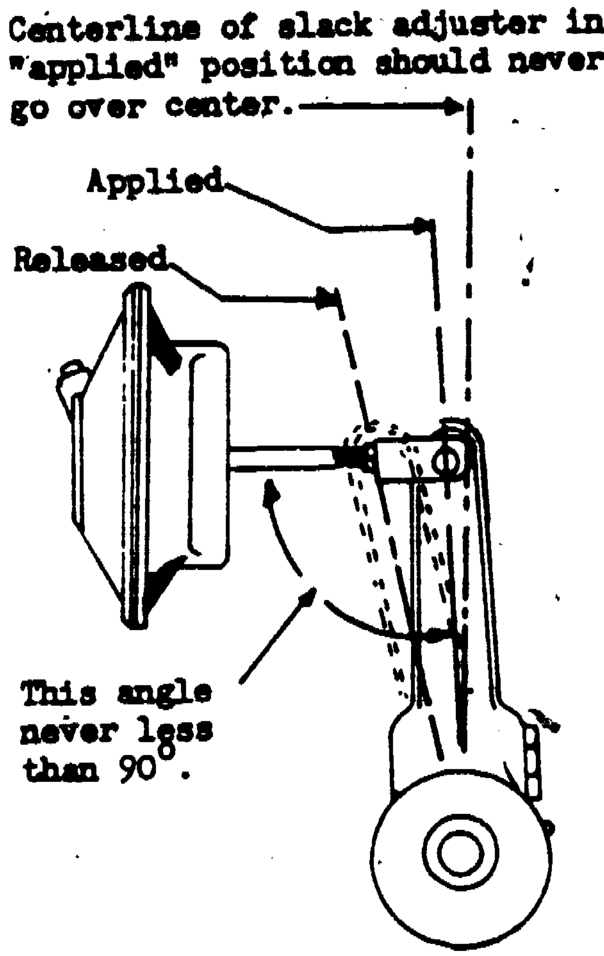




SLACK ADJUSTERS

PURPOSE: ______________________________

____



ADJUSTMENTS: ______________________________

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NOTES: ______________________________

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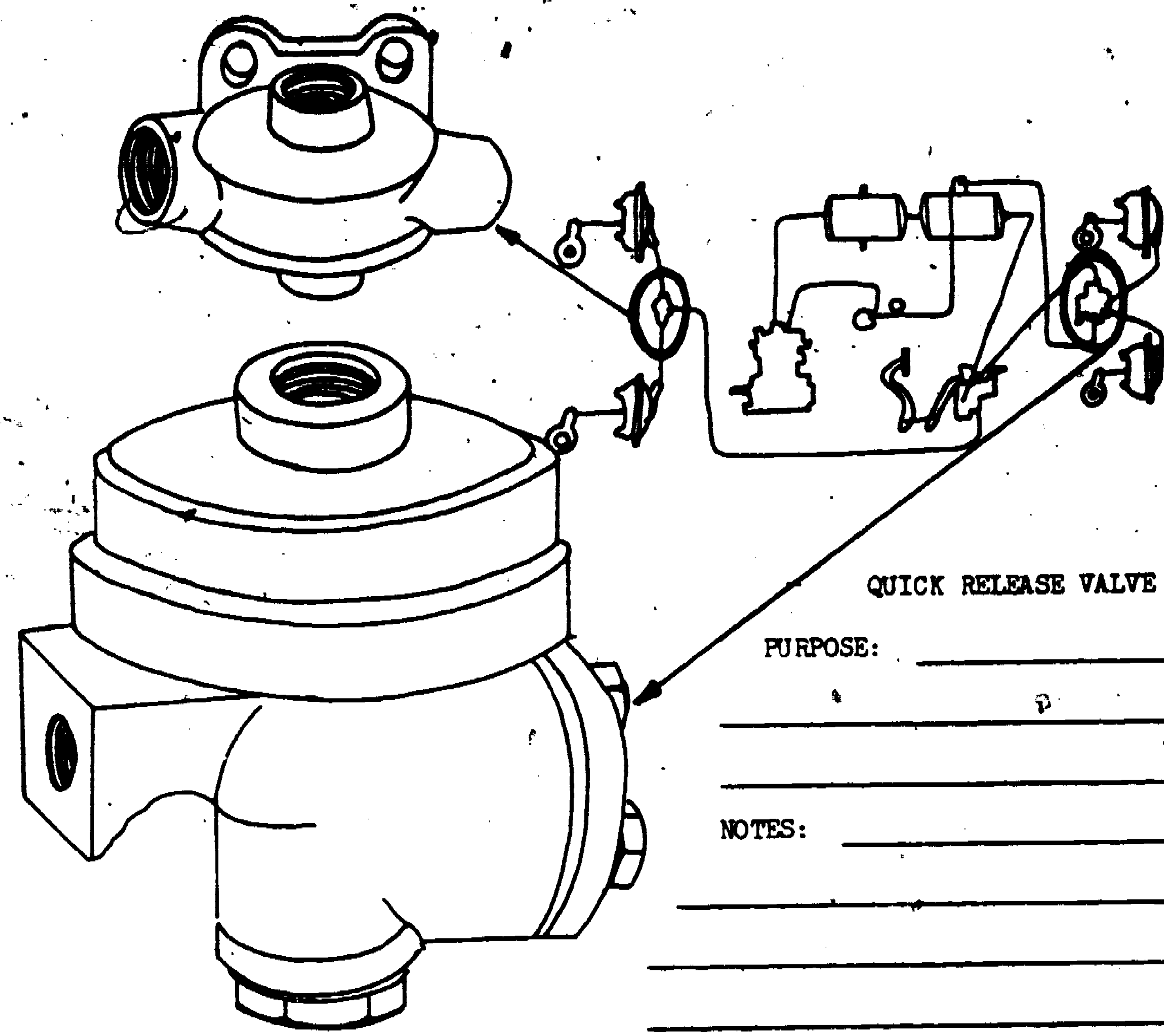


QUICK RELEASE VALVE

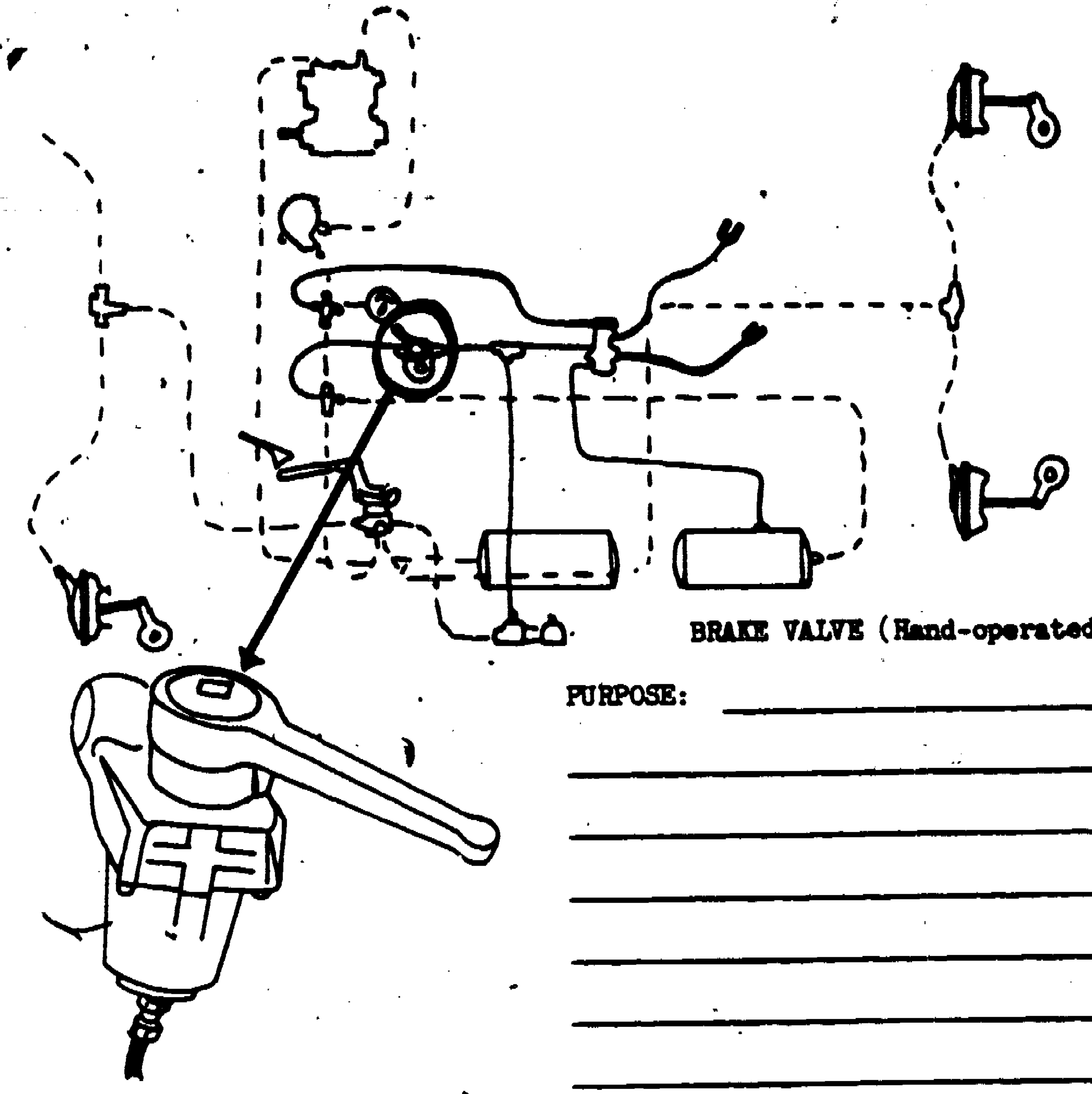
PURPOSE: ____________________

NOTES: ____________________

RELAY VALVE

PURPOSE: ____________________

NOTES: ____________________



BRAKE VALVE (Hand-operated)

PURPOSE: ______________________________

NOTES: ______________________________

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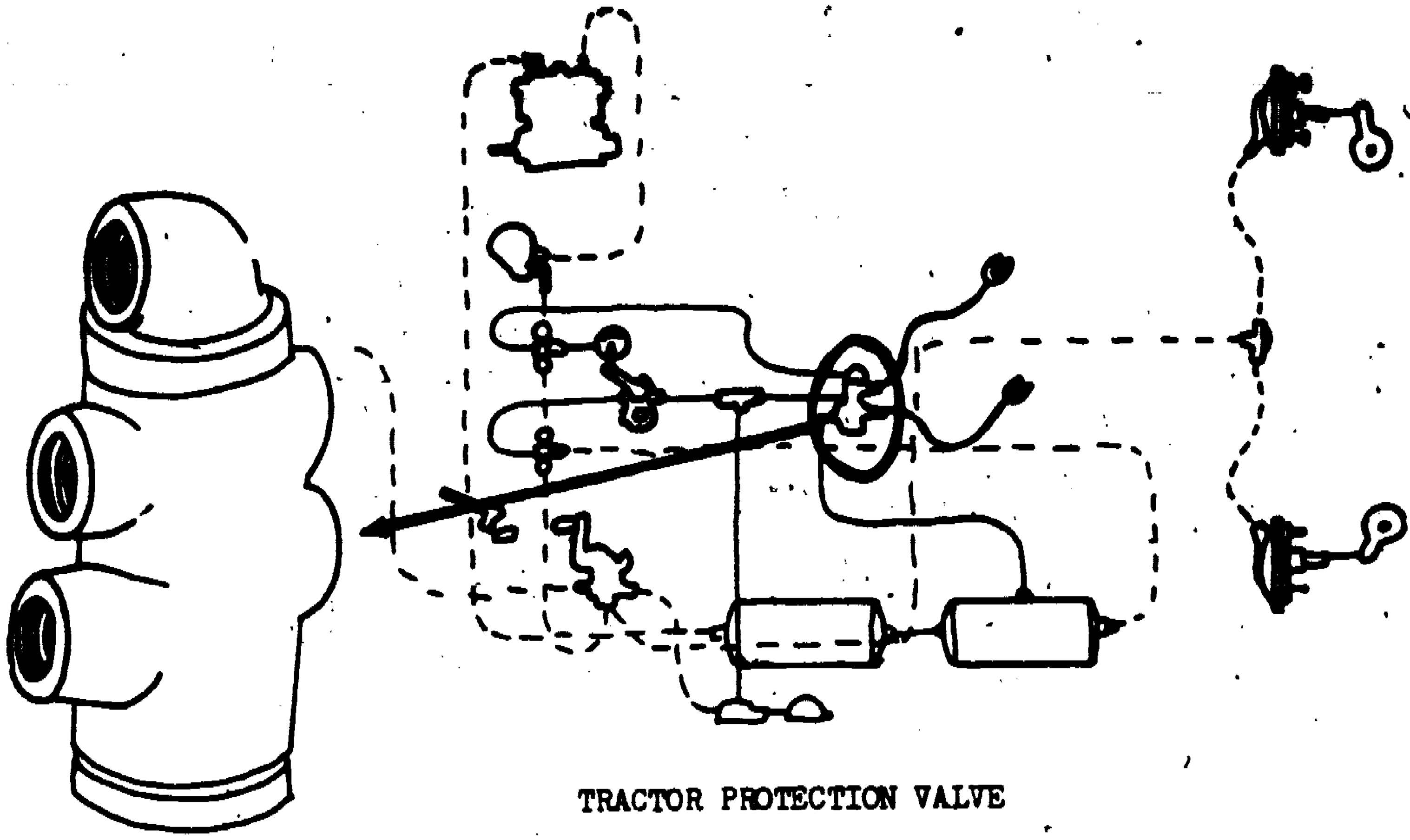

TRACTOR PROTECTION VALVE

PURPOSE: ____

____

____

____

NOTES: ____

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____

____

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1...

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20. The purpose of the quick release valve is to

  a. release the front wheels quickly.
  b. release the air to the front brake chambers more quickly.
  c. release excessive air pressure when the brakes are applied.
  d. release the front brakes while the vehicle is turning.

21. What is the purpose of the brake chamber? ______________________

____

22. The relay valve is actuated by

  a. hydraulic pressure from the brake valve.
  b. air pressure from the air tanks.
  c. air pressure from the brake valve.
  d. air pressure from the compressor.

23. What is the purpose of the slack adjusters? ______________________

____

____

24. What is the purpose of the limiting/quick release valve? __________

____

____

25. What is the purpose of the hand-operated brake valve? __________

____

____

26. What is the purpose of the tractor protector valve? __________

____

____

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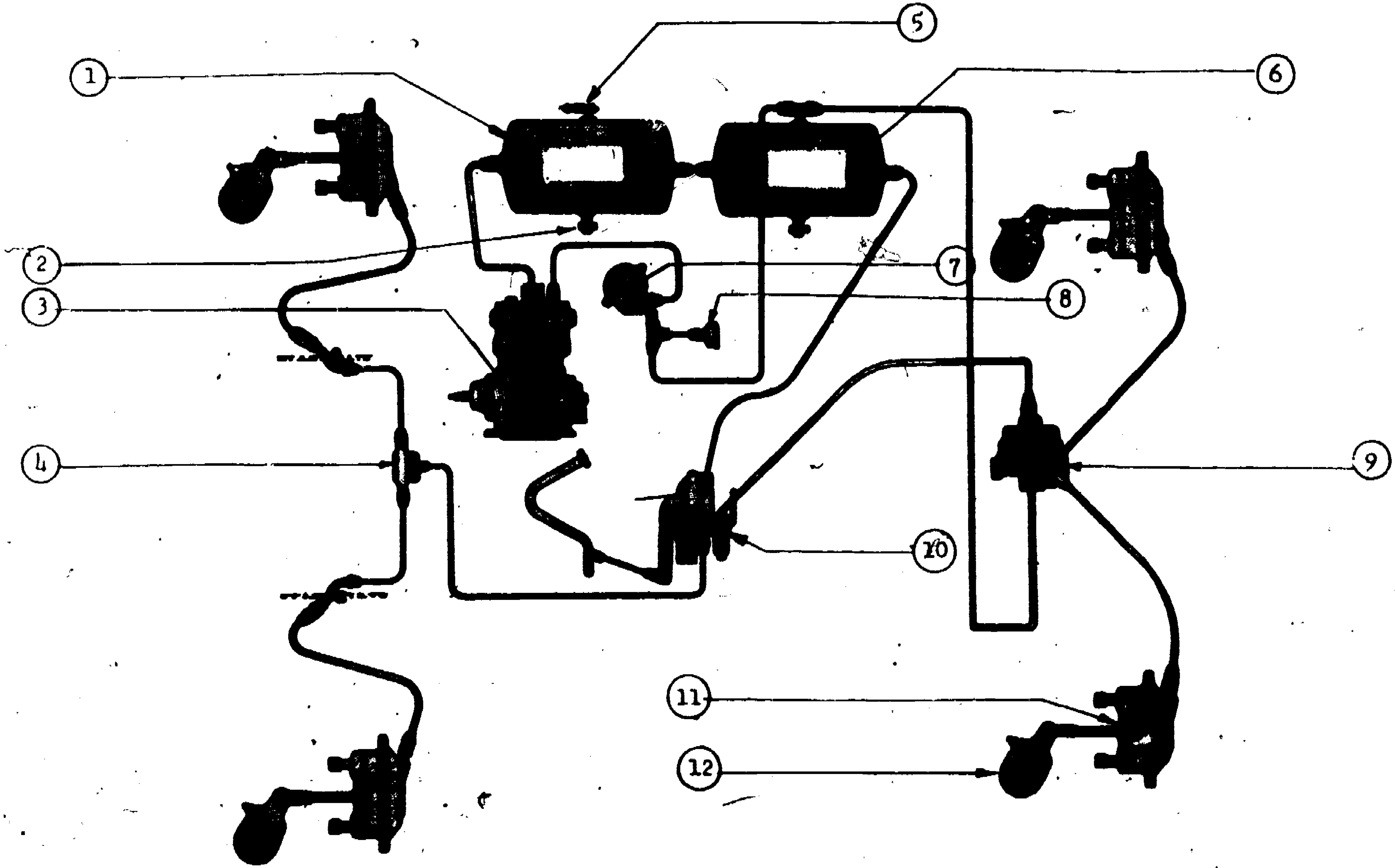

INSTRUCTIONS: Labeled items are to be identified.

POWER STEERING SYSTEM UNITS

OBJECTIVES

After completing this unit of instruction, you will be able to explain the construction and operating principles of power steering systems and to remove, inspect, repair, replace and adjust the power steering system.

INTRODUCTION

Heavy wheeled vehicles are hard to steer because large loads on the tires increase their turning resistance. The average passenger car today also can make good use of power steering because the large tires used cause a heavy turning resistance; this resistance is very noticeable when parking or driving away from the curb. This difficulty cannot be overcome satisfactorily by using a steering gear with a very high reduction ratio because it would require numerous revolutions of the steering wheel to turn the vehicle wheels. Some form of power steering to aid the driver is therefore desirable. Air steering is very satisfactory on some heavy vehicles using air brakes because they have air supply available, but for the average passenger car and some trucks the hydraulic power steering is favored. Some manufacturers have been using electrical mechanisms for this purpose, but this is not a general practice on motor vehicles.

INFORMATION

HYDRAULIC STEERING SYSTEM

The term power steering has become well known in the automotive field since the introduction of hydraulic steering systems on various passenger cars. While there are variations in the different systems used on the different passenger cars, the description of the steering systems used on some cars will serve, in a general way, to explain how these systems function.

Types of Power Steering Systems

There are three general types of power steering systems, they are known as:

INTEGRAL TYPE. This type the power operating assembly is part of the steering gear.

SEMI-INTEGRAL. This type the control valve mounts on the steering gear proper, with the power cylinder on the linkage.

LINKAGE TYPE. This type the power operating assembly is part of the steering linkage.

The integral type power steering unit is located at the lower end of the steering column on the steering gear, and is connected by two oil lines to the hydraulic pump mounted on the generator as shown in figure 45. On some vehicles the hydraulic pump may be a unit by itself and driven by a "V" belt.

The pump is of the conventional rotor type with a relief valve to prevent excessive oil pressures. The power steering unit consists of a valve body with four valves and two cylinders with pistons, one on each side of a piston arm, attached to the steering shaft. In operation, the valves direct oil to the piston that will assist in making a turn as explained in the following paragraphs.

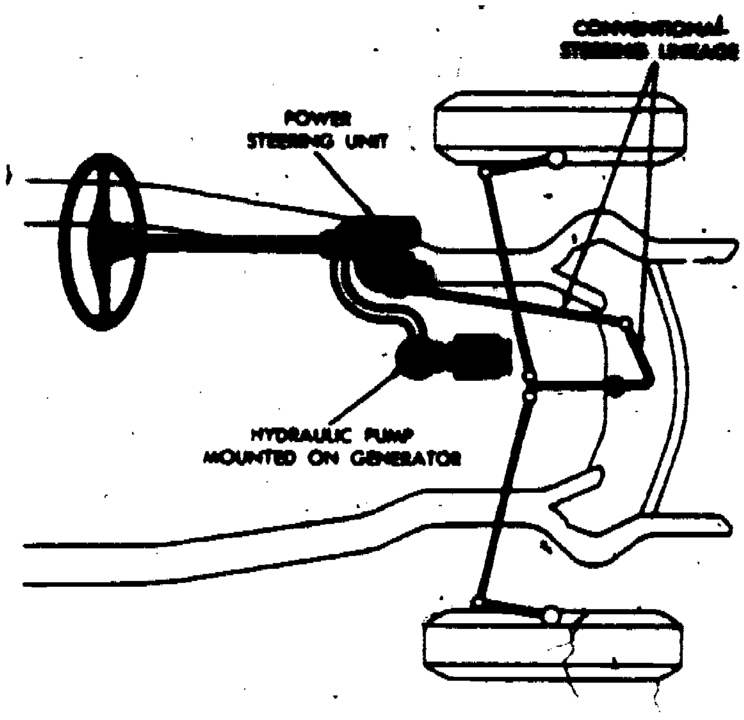

Figure 45.
Location of Power-Steering Unit.

The semi-integral power steering system operates by a hydraulic pump located on the engine in a position to permit driving through a "V" belt from the fan or engine crankshaft pulley. The control valve is mounted with the steering gear proper. This valve controls the fluid flow to the power cylinder. The power cylinder serves to convert the fluid, delivered to it under pressure, into mechanical movement taking the steering effort away from the driver.

The linkage type power steering system operates on the same principle as the integral or the semi-integral, the main difference being the location of the hydraulic pump, control valve and power cylinder. The following text is an explanation of the operation and hydraulic fluid flow through the power steering system. While there may be minor differences in construction between the larger and the smaller valves, the principle of operation is the same.

A valve-operating block in the valve body is mounted on the lower end of the steering column. The lower section of the two-piece steering column is mounted in a spherical bearing to permit the lower section of the steering column to pivot slightly in this bearing. This movement permits the steering column spur gear (at the extreme lower end of the column) to move several thousandths of an inch with respect to the spur gear on the worm shaft. When the steering wheel is turned one way or the other, the resulting torque on the spur gears causes the steering column spur gear to climb up and down (a fraction of an inch) on the worm shaft spur gear.

Maintenance

FILLING THE HYDRAULIC SYSTEM.

Note: The following maintenance instructions apply to the IHC truck power steering system. It is recommended that the applicable publication be consulted for the vehicle being serviced. Not all power steering systems use SAE 10 motor oil in the hydraulic steering systems.

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1. Fill reservoir with SAE 10 motor oil to the indicated level and replace the cap.

2. Start engine and idle turning wheels to the full left and right three times. Shut off engine and refill reservoir to indicated level.

3. Continue operation in step 2 until system maintains its proper indicated oil level.

4. Run engine at faster speed and continue turning wheels slowly from full left to full right and back again for approximately five minutes to check for leaks. This will bleed the system of air. Again refill the reservoir to the indicated level or to 1-1/2" below top of filler neck on reservoir without dipstick attached to filler cap.

Note: The preceding instructions are important.

BELT TENSION: Check and maintain belt tension periodically. Pump belt tension is obtained by loosening the adjusting screw and moving the pump upward and outward. The proper belt tension is obtained when the belt can be depressed approximately 3/8" half-way between the two pulleys. Tighten pump mounting bolt securely.

QUESTIONS

1. What is the difference between the integral and the semi-integral power steering system?

2. Where is the power cylinder located on the linkage type power steering system?

3. Where is the valve body located on the linkage type power steering system?

4. Where is the valve body located on the integral type power steering system?

5. Where is the valve body located on the semi-integral type power steering system?

6. On the power steering system the hydraulic oil is pumped to the valve body; how is the pressure controlled?

7. What are two causes for steering resistance on vehicles without power steering?

8. Would a power steering system help reduce kickback on the steering wheel?

REFERENCES

1. TO 36A-1-76, Principles of Automotive Vehicles.

2. IHC Motor Truck Service Manual.

POWER STEERING SYSTEM UNITS

OBJECTIVES

When you have completed the task lists in this WS you will be able to service and maintain power steering pumps and cylinders.

EQUIPMENT

Pump, Power Steering
Cylinder, Power Steering
Mechanics Handtools

PROCEDURE

Complete all tasks outlined in this worksheet, following all steps carefully, and notifying your instructor of any assistance needed.

FRAME 1

The purpose of a power steering system is to provide easier and safer steering.

There are three types of power steering assemblies. They get their names from the manner in which they are integrated with the manual steering system.

The integral power steering system has the control valve and cylindr built into the steering gear.

The semi-integral power steering system has the control valve in the gear and the cylinder connected in linkage.

The linkage system has both the control valve and the cylinder connected in linkage.

In all of the above systems, the pump is driven from the engine or from the rear of the generator by a belt.

Read the statements below. Determine which statement is correct. Follow the directions found after the statement you choose.

1. The three types of power steering systems are integral, semi-integral, and linkage. . . Go to Frame 2.

2. The three types of power steering systems are control valve, cylinder, and pump. . . . . Go to Frame 4.

FRAME 2

The statement you selected read: "The three types of power steering systems are integral, semi-integral, and linkage."

You are correct.

Go on to Frame 3.

FRAME 3.

Your entry should look like this:

2. Types

   a. integral.

   b. semi-integral.

   c. linkage.

Make any corrections necessary in your notebook, then skip to Frame 8.

FRAME 4

You selected the statement listing the control valve, cylinder, and pump as types of power steering systems.

This is not correct. These items are components found in any power steering system.

The type of system is determined, not by the components, but by the manner in which these components are mounted in the system.

"Integral" means, literally, belonging to the while. A power steering system having the control valve and pump as a part of the whole steering gear is an integral power steering system.

A system with the control valve as a part of the steering gear but with the cylinder mounted separately and connected by linkage is a semi-integral system.

A linkage system has both the control valve and cylinder mounted separately and connected by linkage.

Answer the question below and proceed to the frame indicated after the answer you choose.

What are the three types of power steering systems?

a. Integrated, separate connection, and linkage. . . . . Go to Frame 5.

b. Integral, semi-integral, and linkage. . Go to Frame 6.

FRAME 5

You are still incorrect. The three <u>types</u> of power steering systems are: integral, semi-integral, and linkage.

Return to Frame 4.

FRAME 6

You have selected the correct answer.

Go to Frame 7.

FRAME 7

Your entries should look like this:

2. Types.
   a. integral.
   b. semi-integral.
   c. linkage.

Make the necessary corrections in your notebook, then go on to Frame 8.

FRAME 8

Answer the question below and proceed to the frame indicated after the answer you choose.

What are the components common to all three types of power steering systems?

a. Integral, semi-integral, and linkage. . . . Go to Frame 9.

b. Control valve, cylinder, and pump. . . . Go to Frame 10.

(15)

FRAME 9

You have selected the statement listing the types of power steering systems. You were asked to identify the basic components, or parts, common to each of these systems.

Go to Frame 10.

FRAME 10

The basic components common to all power steering systems are a control valve, a cylinder, and a pump.

Notify your instructor that you are ready for Part II of this project.

PART II: PUMP DISASSEMBLY TASK LIST

DIRECTIONS: All steps must be accomplished in the order listed. If one man is working alone he will, of course, accomplish each step. If two men work together, one man should accomplish the disassembly while the other man reads the steps aloud. The man accomplishing the disassembly should then read the steps while his partner accomplishes the reassembly.

Begin with Step 1 below:

STEP 1. Remove the reservoir filler cap assembly (Item a in Figure 1).

STEP 2. Loosen reservoir cover mounting bolt (Item b in Figure 1) and remove reservoir cover assembly (Item c in Figure 1).

STEP 3. Remove the reservoir cover gasket.

STEP 4. Remove filter element (Item d in Figure 2).

STEP 5. Drain oil from the reservoir.

STEP 6. Remove return stud from the body assembly (Item e in Figure 2).

STEP 7. Remove reservoir to body mounting screws and lock washers (Item f in Figure 2).

STEP 8. Remove the reinforcement plate (Item g in Figure 2) and reservoir.

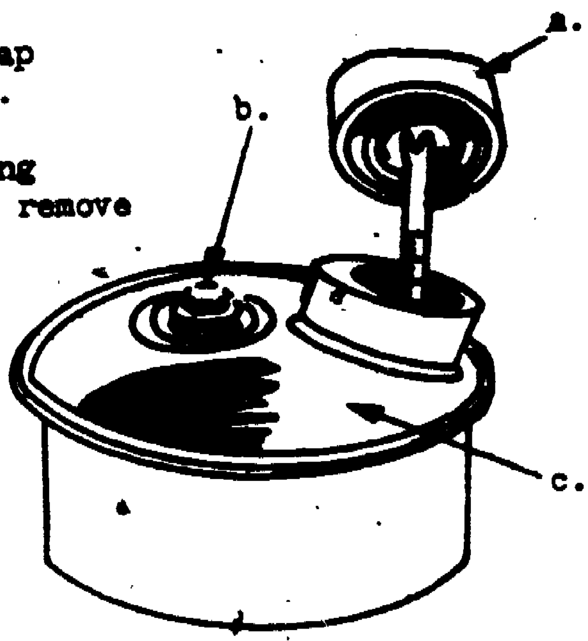

Figure 1

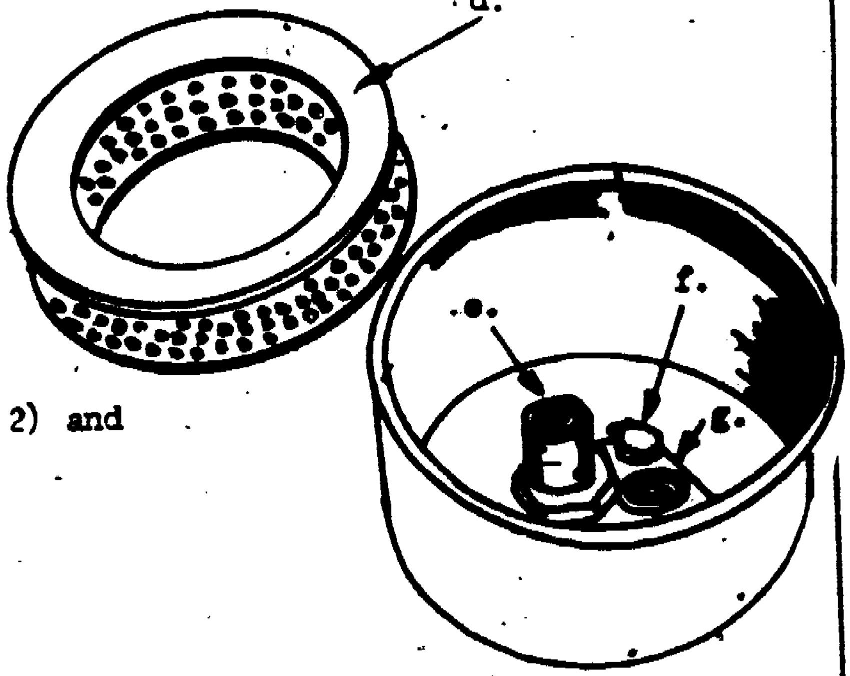

Figure 2

Continued on next page.

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STEP 9. Remove and discard the four "O" ring seals between the reservoir and pump body (Item h in Figure 3).

STEP 10. Remove intake "O" ring seal retainer (Item i in Figure 3).

STEP 11. Remove the five cover to body mounting screws (Item j in Figure 4) and separate the cover from the body.

STEP 12. Remove body to cover gasket.

STEP 13. Remove and discard "O" ring seal from body (Item k in Figure 5).

STEP 14. Scribe a line across the inner and outer rotors for reassembly purposes.

STEP 15. Remove the outer rotor (Item l in Figure 5).

STEP 16. Remove the inner rotor (Item m in Figure 5).

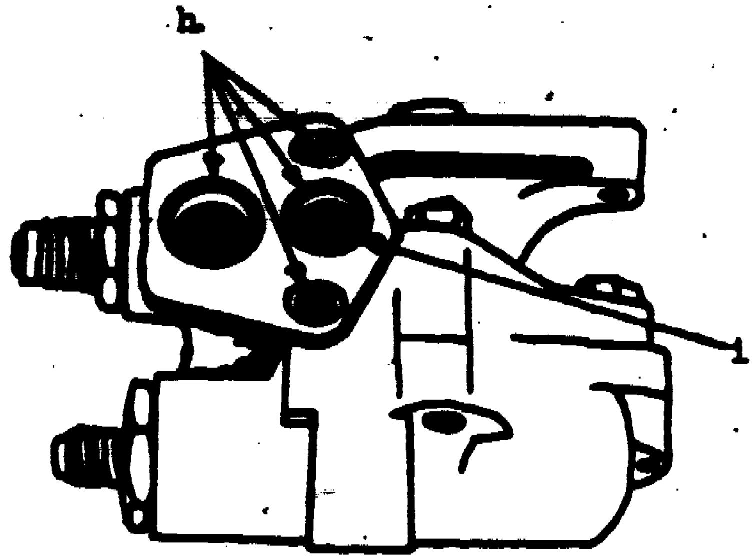

Figure 3

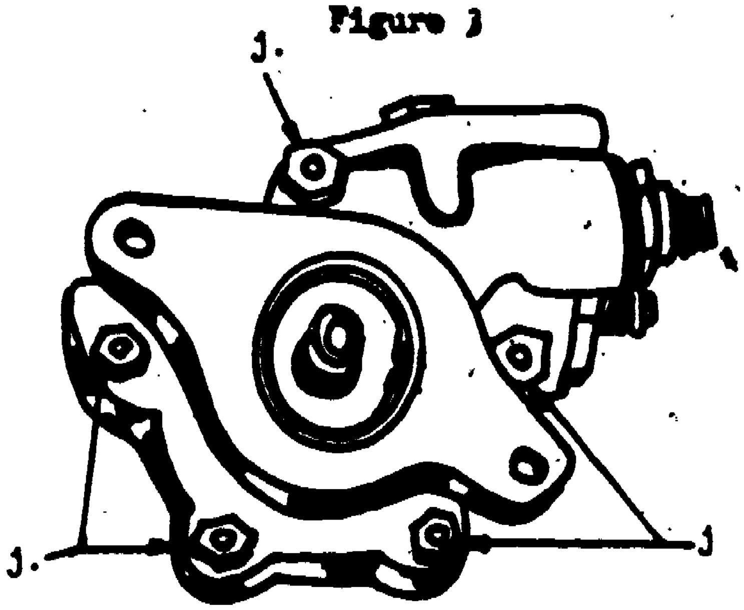

Figure 4

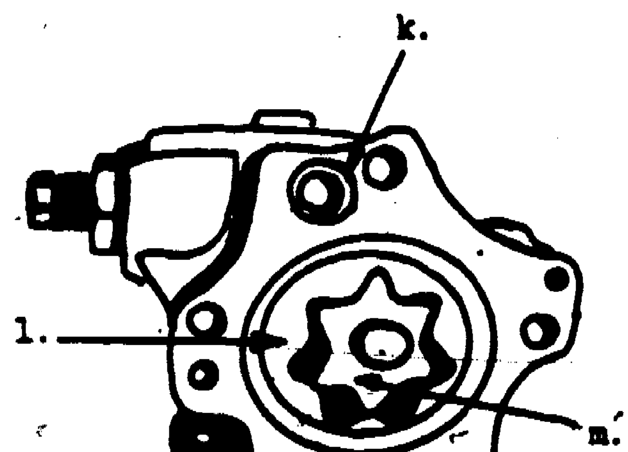

Figure 5

Continued on next page.

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STEP 17. Remove the inner rotor drive pin (Item n in Figure 6) from shaft.

STEP 18. Remove the bearing retaining ring (Item o in Figure 7) using internal snap ring pliers.

STEP 19. Remove shaft (Item p in Figure 7) and bearing from body.

STEP 20. Press bearing from shaft.

STEP 21. Remove shaft seal from body.

STEP 22. Remove spring retainer cap fitting (Item q in Figure 7). Discard the "O" ring seal.

STEP 23. Lift out the flow control valve spring.

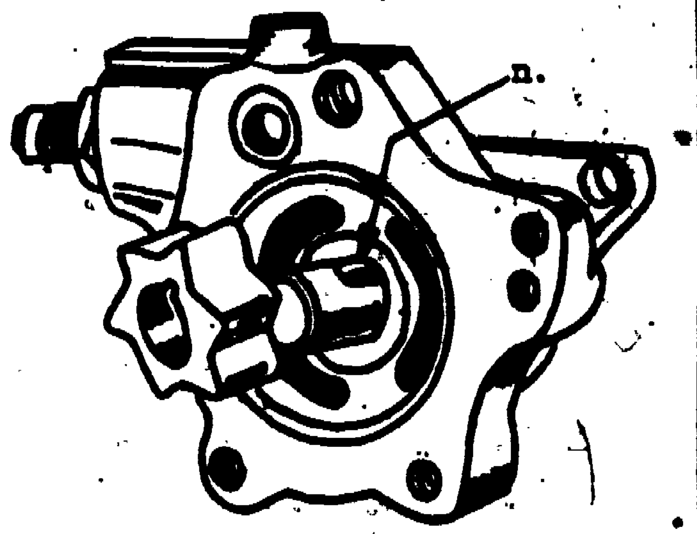

Figure 6

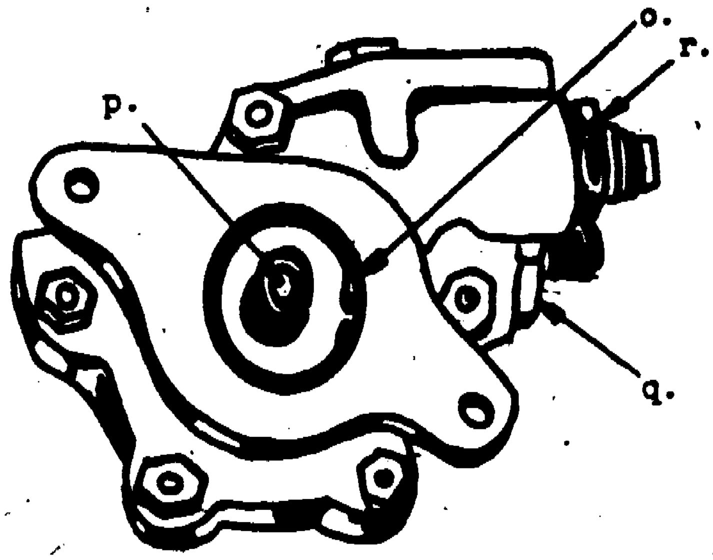

Figure 7

STEP 24. Tap cover on wooden block to remove the combination flow control and relief valve.

STEP 25. To remove the pressure relief valve and spring from the flow control valve body, place the valve in a vise (use soft jaws) place punch against the relief valve and relieve spring pressure. Remove the retaining ring using internal snap ring pliers. Remove relief valve and spring.

STEP 26. Remove the return hose adapter (Item r in Figure 7) from the body.

YOU HAVE COMPLETED DISASSEMBLY OF THE PUMP.

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PART III: PUMP ASSEMBLY TASK LIST

DIRECTIONS: All steps must be accomplished in the order listed. If one man is working alone he will, of course, accomplish each step. If two men work together, the one who disassembled the pump should read each step aloud and his partner should accomplish the assembly procedures.

STEP 1. Place spring and relief valve in the relief valve body.

STEP 2. Install the flow control valve into the pump cover.

STEP 3. Install flow control valve spring.

STEP 4. Install new "O" ring seal on flow control valve cap fitting and install in pump cover.

STEP 5. Replace seal in pump body.

STEP 6. Press bearing onto pump shaft until the bearing seats against the shoulder on the shaft and install the shaft and bearing into pump body.

STEP 7. Install bearing retaining ring using internal snap ring pliers.

STEP 8. Install inner rotor drive pin in groove in shaft.

STEP 9. Install inner rotor making sure that the scribe line is facing upward.

STEP 10. Install outer rotor, making sure scribe line is facing upward.

STEP 11. After the rotors have been nested in the pump body, tooth clearance should be checked with a feeler gauge as shown in Figure 1 (next page). If the clearance exceeds 0.008 inch, the rotors should be replaced with a new set. The rotor end clearance should be checked as shown in Figure 2 (next page). The rotors should be replaced if this clearance exceeds 0.0025 inch.

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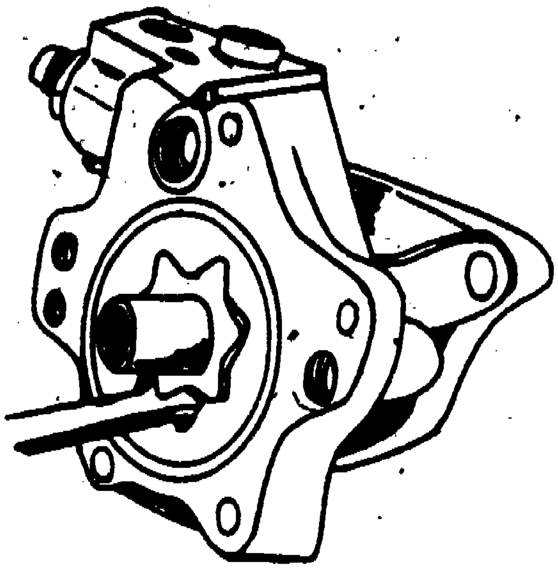

Figure 1

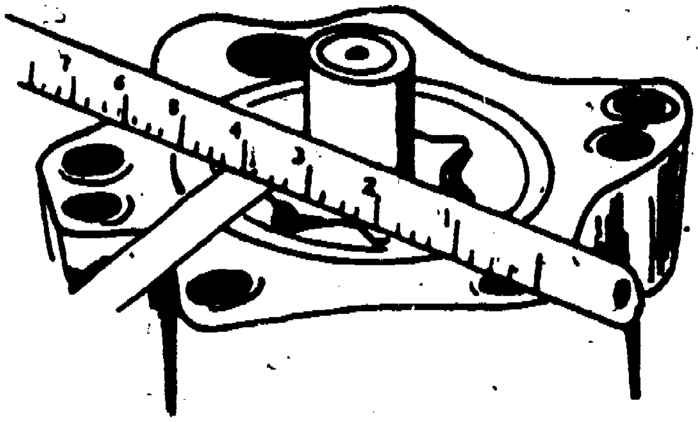

Figure 2

STEP 12. Install new "O" ring seal in body and new body to cover gasket.

STEP 13. Position cover on body and attach cover with screws and lock washers. Torque assembly screws to 20-25 foot-pounds. Rotate pump shaft and check for freedom of rotation.

STEP 14. Install "O" ring retainer into pump body.

STEP 15. Position four new "O" ring seals on pump body to mount reservoir.

STEP 16. Position reservoir over "O" ring seals and pump body.

STEP 17. Place reservoir reinforcing plate in position.

STEP 18. Secure reservoir and reinforcing plate to body with two screws and lock washers.

STEP 19. Install pump return stud into body.

STEP 20. Install new filter element.

STEP 21. Install new reservoir cover gasket; install cover and tighten bolt securely.

YOU HAVE COMPLETED ASSEMBLY OF THE PUMP.

DIRECTIONS: All steps must be accomplished in the order listed. If one man is performing this operation he must, of course, accomplish all steps. If two men are working together, one should disassemble the cylinder while the other reads the steps aloud.

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Begin with Step 1 below.

STEP 1. Drain fluid by running piston rod from end to end.

STEP 2. Use a spanner wrench to loosen the cover about 1/8 of a turn (as shown in Figure 1 below). This will bend out the staked portion of the outer cylinder. The cylinder should then be tapped lightly with a mallet in the staked area in order to straighten out the threads.

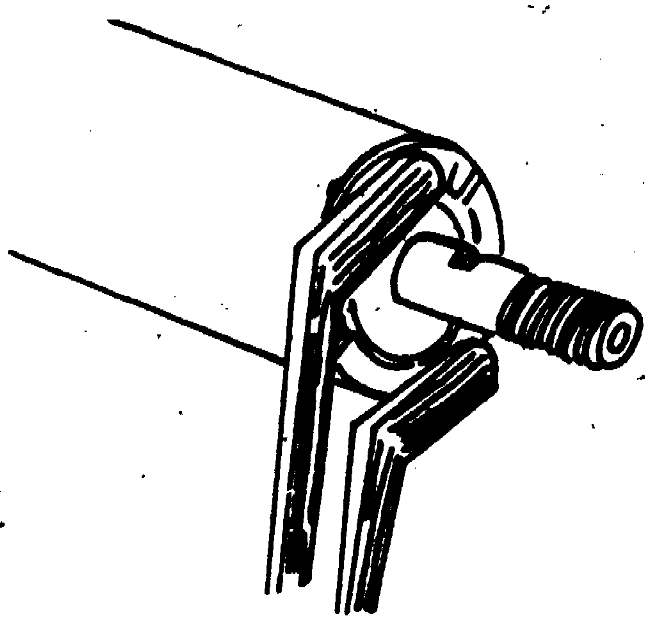

Figure 1.

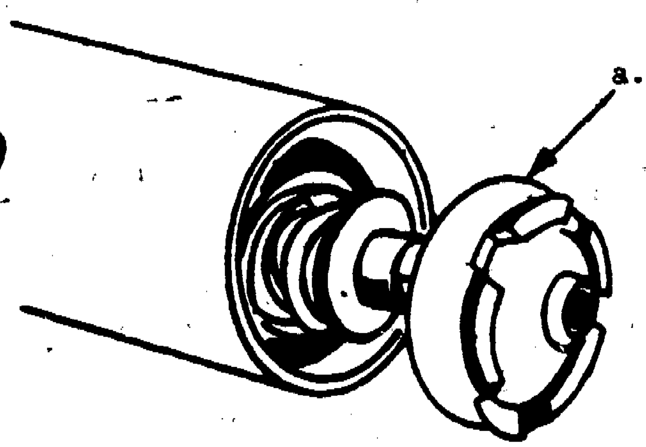

Figure 2.

STEP 3. Unscrew and remove cover (Item a in Figure 2).

STEP 4. Remove seal from piston rod.

STEP 5. Remove spring retainer and spring.

Continued on the next page.

STEP 6. Loosen packing from around bearing (Item b in Figure 3) and remove.

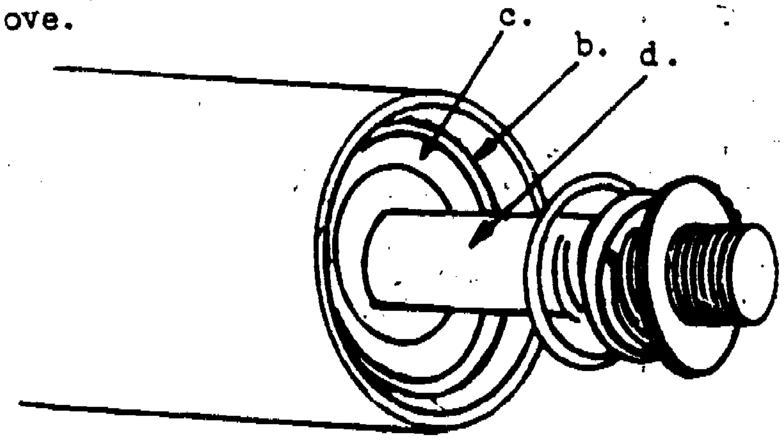

Figure 3.

STEP 7. Remove bearing (Item c in Figure 3) from cylinder barrel and piston rod (Item d in Figure 3).

STEP 8. Take hold of the threaded portion of the piston rod and pull out rod, piston, and piston ring assembly.

STEP 9. Remove piston rings (Item e in Figure 4) from the piston (Item f in Figure 4).

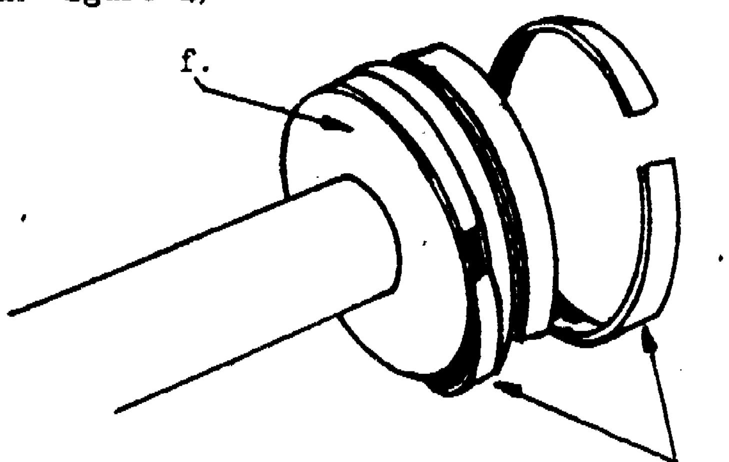

Figure 4

THIS COMPLETES DISASSEMBLY OF THE CYLINDER

NOTIFY YOUR INSTRUCTOR

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PART V: CYLINDER ASSEMBLY TASK LIST

DIRECTIONS: All steps must be accomplished in the order listed below. If two men are working together, the man who disassembled the cylinder should read the steps aloud and his partner should accomplish the assembly.

Begin with Step 1 below.

STEP 1. Install piston rings to piston and rod assembly.

STEP 2. With the aid of a piston assembly installer sleeve, insert the piston rod assembly in barrel.

STEP 3. Slide bearing onto piston rod and into barrel.

STEP 4. Position new packing into barrel and around bearing.

STEP 5. Install spring with the large diameter next to the bearing, making sure it rests in its seat.

STEP 6. Insert spring retainer into the spring.

STEP 7. With the rod seal thimble positioned on the threaded end of the rod and over the wrench flats, install a new piston rod seal, making sure the side with the lettering "THIS SIDE OUT" is started on the rod.

STEP 8. Install cover and tighten securely with the spanner wrench. The face of the cover should now be flush with the end of the outer cylinder barrel.

STEP 9. Stake outer cylinder barrel into a wrench slot with a blunt nosed tool. Select a point on the cylinder not previously staked, if possible.

YOU HAVE NOW COMPLETED ASSEMBLY OF THE CYLINDER

FRAME ALIGNMENT AND WHEEL BALANCING

OBJECTIVES

After completing this unit of instruction, you will be able to check vehicle frame alignment and perform wheel balancing using special shop equipment.

INTRODUCTION

The importance of wheel alignment, wheel balance and body-frame straightening in the automotive field cannot be minimized. Its proper understanding by service men is essential if motorists are to conserve costly tires and prolong the life of their automobiles. No other phase of automotive operation when neglected can be so costly or so dangerous to the owner of a car or truck.

INFORMATION

Every wheel alignment mechanic should know how to accurately check alignment of the frame and should have a thorough knowledge of how frame misalignment directly affects wheel and steering alignment. The procedures for checking vehicle frame alignment and performing wheel balancing are contained in Programmed Text 3ABR47330-PT-605. Study this information and illustrations carefully and be able to answer the questions therein.

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STEERING FACTORS, SPRINGS AND SHOCK ABSORBERS

OBJECTIVES

After completing this unit of instruction, you will better understand vehicle steering factors and the purpose of springs and shock absorbers.

INTRODUCTION

The front-end assembly of the modern motor vehicle is one of the most remarkable engineering accomplishments on the entire vehicle. It is a system of interrelated angles of axles or other suspension, wheels and other chassis parts to permit ease of steering, greater safety and to prevent abnormal and wasteful wear of tires and suspension parts. In wheeled vehicles the suspension must provide for absorption of road shocks, allow the driver to steer the vehicle, and be efficient over a wide range of speed and load conditions. The keeping of the suspension system in top condition at all times is of utmost importance for the safe and efficient operation of the automotive vehicle.

INFORMATION

Information relative to steering factors, springs and shock absorbers is contained in Programmed Text 3ABR47330-PT-606. Study this information and illustrations carefully and be able to answer the questions therein.

SERVICE AND ADJUSTMENT OF BEAM-TYPE FRONT AXLE SUSPENSION SYSTEM

OBJECTIVES

After completing this unit of instruction, you will be able to remove, inspect, repair or replace, install, and adjust conventional front axle steering system units.

INTRODUCTION

Automotive vehicles use various types of front suspension systems. Although these suspensions will differ in design, they must provide for up and down movement of the wheels, plus allowing wheels to swing at various angles to the vehicle frame for steering. In order to permit the front wheels to swing to one side or the other, each wheel is supported on a spindle which is a part of a steering knuckle. The steering knuckle is then supported, through a kingpin, by the front axle beam or by a steering knuckle support.

INFORMATION

FRONT AXLE

The axle on the conventional type steering system is of the I-beam type. This axle must not be bent or sprung in any way during vehicle operation. A bent axle will cause difficult steering and excessive tire wear. Conventional front axles are sometimes known as "dead" or I-beam axles, figures 46 and 47. "Dead" axles are so named because they have no driving power. Front axles that have driving power are known as "live" axles. However, both types of axles are equipped with a steering system which must be maintained, figure 46.

Steering System Components

STEERING KNUCKLE. A typical steering knuckle is illustrated in figure 47. It is attached to the axle by a kingpin and bushings. In the ball joint suspension used by some of the modern passenger cars the kingpins are omitted. Excessive wear at the kingpins requires the installation of new kingpins, bushings, or bearings. In live front axles the wear may be adjusted by removing shims next to the taper roller bearing. The bearing must be lubricated as required.

The front wheel is attached to the spindle of the steering knuckle. Excessive wear in the front wheel bearings will also cause improper steering. The front wheel bearing must be adjusted as recommended by the manufacturer of the vehicle.

STEERING KNUCKLE ARM. A steering knuckle arm is bolted and keyed to each steering knuckle or to the brake backing plate which, in turn, is attached to the steering knuckle. A two-bolt attaching arrangement is often used to reduce localization of stress. Very little trouble is encountered with the steering knuckle arms. Bent steering knuckle arms should be replaced, since it is almost impossible to align them in their original position.

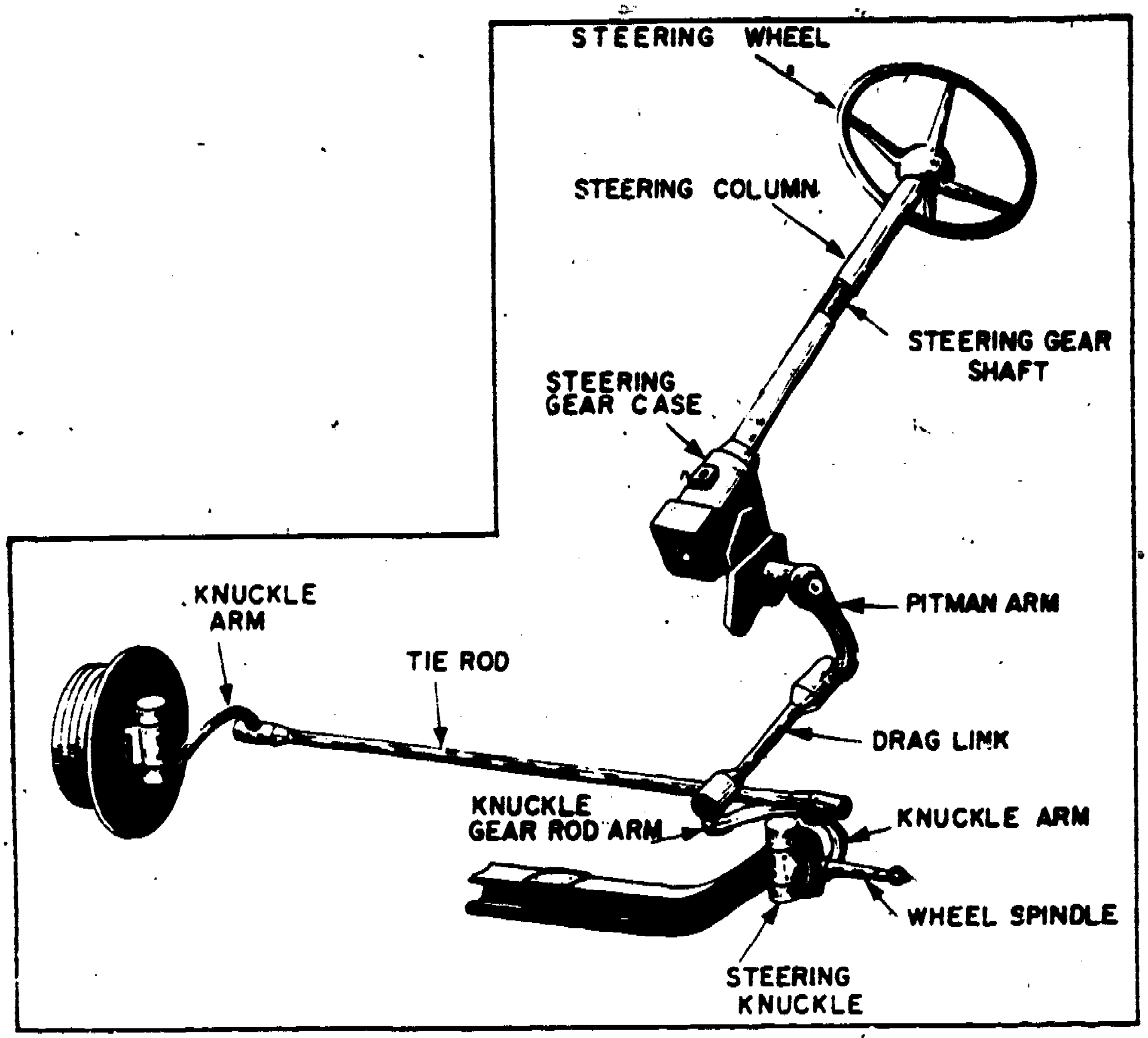

Figure 46. A Conventional Type Steering System.

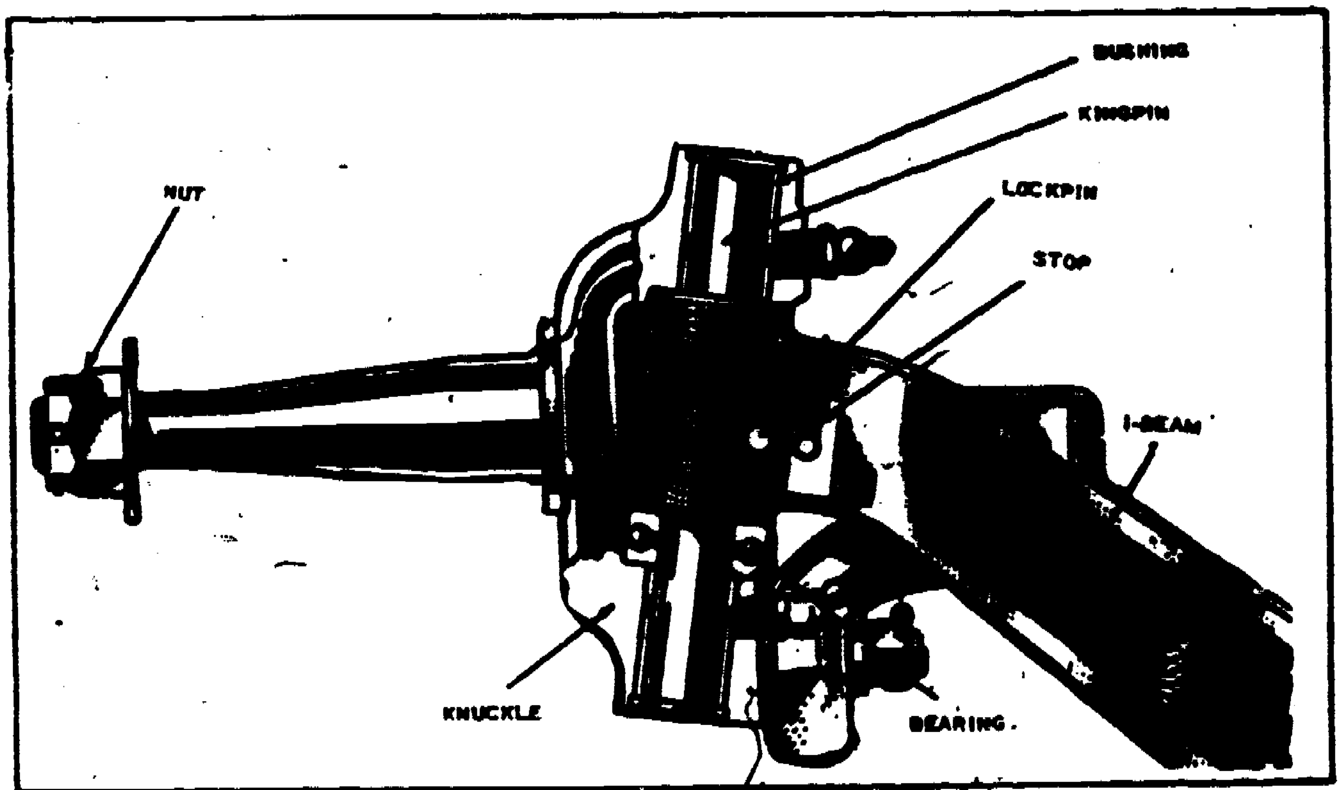

Figure 47. A Typical Steering Knuckle.

TIE ROD. The steering knuckle arms are interconnected by a tie rod. The ends of a tie rod for most passenger cars and light trucks are fitted with tie rod ends of the type shown in figure 48. Heavier vehicles usually are equipped with tie rod ends similar to those shown in figure 49. The tie rod ends are threaded to the tie rod so that the tie rod can be lengthened or shortened to adjust the front wheel toe-in. Some steering systems, especially the independent type suspension, are equipped with two tie rods. The tie rod ends should be lubricated as recommended by the lubrication chart pertinent to vehicle in use.

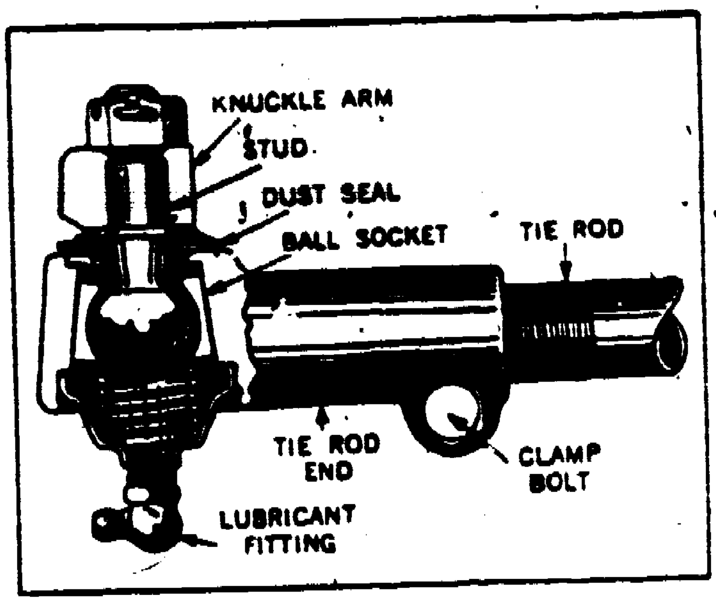

Figure 48.
A Light Duty Tie Rod End.

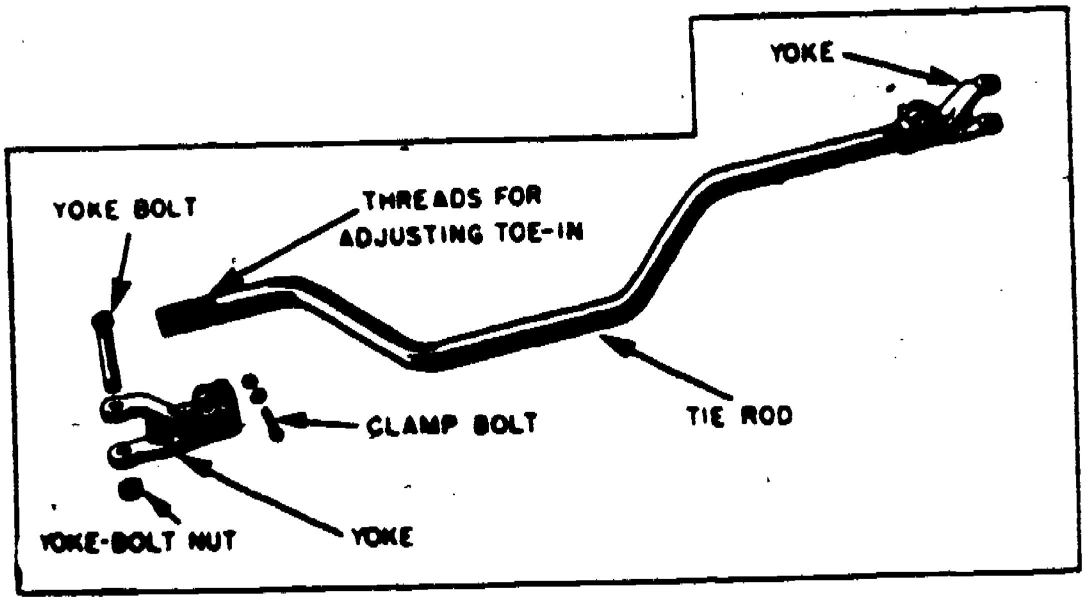

Figure 49. A Heavy Duty Tie Rod and Ends.

DRAG LINK. The drag link is similar to a tie rod and connects the pitman arm with the steering knuckle arm. The ends of a drag link are similar in construction to tie rod ends. Parallel arm suspension, in most cases, does not make use of a drag link. The ball and socket joints in a drag link may be adjusted to compensate for wear, figure 50. Some drag link ends are like the tie-rod end in figure 48 and cannot be adjusted. The drag link ends should be lubricated in accordance with the lubrication chart.

STEERING GEAR ARM. The steering gear arm, commonly referred to as the pitman arm, connects the steering gear cross shaft with the steering drag link. It is fastened to the splined end of the cross shaft by a nut. No particular maintenance is required of this unit. However, the nut should always be tight.

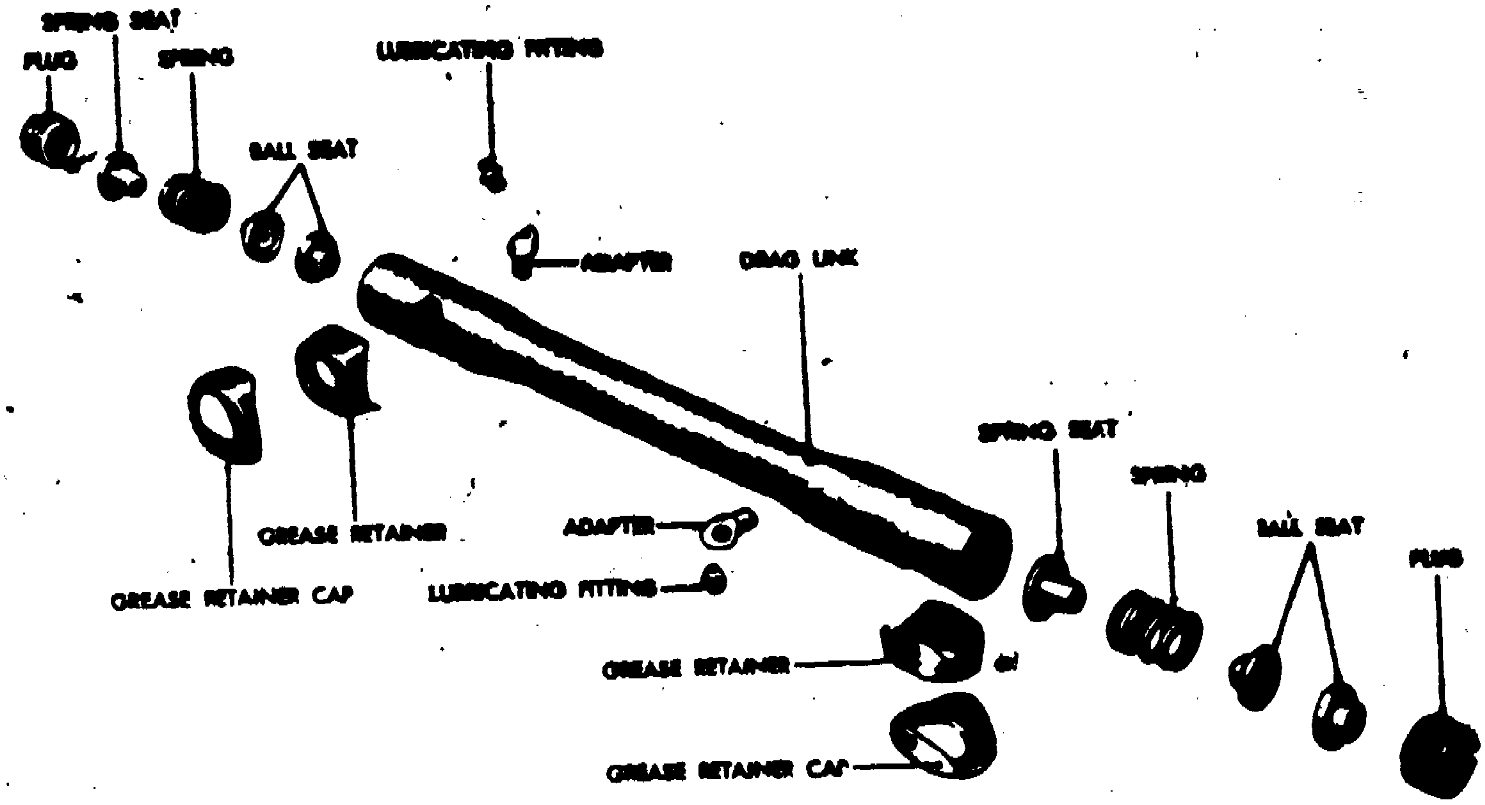

Figure 50. Drag Link - Disassembled View.

STEERING ALIGNMENT. Steering alignment, as referred to in the automotive field today, may be defined as a system of interrelated angles of the axles, wheels, and other chassis parts, to permit ease of steering, greater safety and to prevent abnormal and excessive wear of tires and front end parts.

The main purpose of steering alignment is to make the four wheels roll without scuffing, dragging, or slipping under all road operating conditions. This gives greater safety in driving, easier steering, longer tire wear and less strain on the parts that make up the front end of the vehicle.

Correct steering alignment is obtained through interrelated angles. Thus, any service of this type includes a complete inspection of the chassis, wheels and steering linkage. Misalignment of one may distort others. Modern methods and equipment make it possible to check each steering angle, irrespective of others, quickly and accurately.

All settings, when once established by the manufacturers, should be rigidly complied with. Any changes due to wear, accidents, strain, etc, must be corrected to the original specifications. Nearly all of the steering angles are engineered within a degree or two, or even fractions of a degree. That is why they are so easily disturbed by loose bearings, weak or broken springs.

For this reason, periodic steering alignment inspections followed by whatever corrective steps necessary, result in a tremendous saving of tires and money.

If camber is wrong on a conventional steering system and nothing can be found worn or loose, the axle could be sprung and would have to be corrected by bending.

Caster is adjusted by the use of shims between the springs and the axle, but it could also be that the "U" bolts are loose and not holding the axle in alignment with the springs, or the springs could be weak.

Glossary of Terms

Following is a glossary of terms that are used throughout this course of instruction.

Camber. The inward or outward tilt of the wheel at the top.

Camber Roll. An inherent characteristic of certain independent front suspension vehicles to momentarily change the front wheel camber angle under certain driving conditions.

Camber Wear. Wear on one side of the tire tread caused by the tire tread running at an angle to the road surface.

Caster. The backward or forward tilt of the steering knuckle pivot pins.

Center of Gravity. An imaginary point about which the vehicle's weight is balanced.

Cornering Force. The side slippage force generated between the tire and pavement when rounding a turn.

Cornering Wear. An abrasive type of tire wear caused by cornering force.

Curb Weight. The net weight of a vehicle including a full supply of fuel, oil and water.

Distortion. A twisting or twisted condition.

Frequency. The number of oscillations, vibrations, cycles, or changes in direction in a unit of time.

Front Suspension. A series of linkages by which the front wheels are attached to the frame used to support the front end of the vehicle and keep the front wheels in proper alignment (Independent Front Suspension).

Kingpin Inclination. The amount in degrees the upper end of the kingpin or knuckle pin is tilted inward toward the center of the vehicle.

Knuckle. A movable joint, of which the front wheel spindle is a part, which can be turned to left or right to steer the car on its desired course.

Knuckle Pin. A steel pin that attaches the steering knuckle to the vertical support or axle, around which the knuckle can pivot.

Knuckle Support. That part which connects the outer ends of the upper and lower suspension support arms and to which the steering knuckle is attached.

Leverage. The mechanical advantage gained by the use of a lever.

Pitman Arm (Steering Gear Arm). The arm or lever which transmits the rotating force of the steering gear cross shaft to the lateral movement of the steering connecting rod or drag link.

Pull (Lead). The tendency of a vehicle to pull or lead to the right or left of the highway.

Radius. The distance from the center of rotation to the arc or circumference of the circle made by the rotation.

Road Shock (Wheel Flight of Steering Kick). A shock movement or kick transmitted to the steering wheel through the steering linkage caused by irregularities in the road surface or a faulty steering system.

Scrub Radius. The distance between the intersection of an imaginary centerline of the steering knuckle pin and the centerline of a tire on the road.

Shim. A spacer to adjust and maintain the distance between two parts.

Shimmy (Wobble). A rapid series of oscillations of the steering knuckle, wheel and tire assembly about the steering knuckle pin.

Stabilizer. A torsional bar and linkage to eliminate sway and decrease the side rolling tendency of the car from the body.

Support Arms. The horizontal arms of the front suspension by which the front wheels are attached to the frame used to support the front end of the vehicle.

Toe-In-Toe-Out. The difference in distance between the front tires at the extreme front and the extreme rear at spindle height when the wheels are in the straight-ahead position.

Toe-Out on Turns. The difference in turning radius of the two front wheels when making a turn to left or right.

Torque. A force that tends to produce a rotating or turning motion.

Tramp. The action of a wheel to jump or hop up and down.

Unsprung Weight. The weight of that part of a vehicle that is not supported by the springs.

QUESTIONS

1. What is an I-beam type of front axle?

2. What would be the results of a sprung front axle?

3. What procedure should be used for correcting a bent steering knuckle?

4. Figure 47 shows a lockpin. What does this pin lock?

5. Why are some front axles known as "dead" axles and some "live" axles?

6. The pitman arm is connected between two other parts. What are they?

7. What is the purpose of the tie rod?

8. What is the purpose for a rod having left threads on one end and right threads on the other?

9. What is the difference between heavy duty tie rod ends and light duty?

10. What is the purpose for steering alignment?

11. The tie rod ends are connected to what two parts?

12. How do you change camber on the conventional front axle?

13. If caster is wrong on the conventional axle, how would you change it?

14. What steering factor would badly worn kingpins and bushings change?

15. What steering factors would loose wheel bearings change?

16. If toe-out on turns is wrong, what part of the steering system should be changed?

17. What is unsprung weight?

18. What is curb weight?

19. What is positive camber?

20. What is negative caster?

SERVICE AND ADJUSTMENT OF INDEPENDENT SUSPENSION SYSTEMS

OBJECTIVES

After completing this unit of instruction, you will be able to inspect, repair or replace, install and adjust independent suspension steering system units.

INTRODUCTION

Most modern automobiles now use some type of independent front suspension. This means that each front wheel is independently supported. There are several different designs of front suspensions in present use. Each vehicle manufacturer uses his own type so always refer to the manufacturer's manual for specific information about these.

INFORMATION

OPERATION AND ADJUSTMENT

Due to greater flexibility, new type suspension systems are easily knocked or jarred out of proper alignment. In addition, they are subject to far greater strains in driving than were earlier models. Think of the extra wear and stresses resulting from impacts at high speeds, sudden application of brakes, skidding and swerving. It is little wonder that even under average driving conditions steering alignment angles become disturbed resulting in costly tire wear and hard steering.

Checking Vehicle

Checking a vehicle equipped with any of the various types of independent suspension units does not differ materially from that of the conventional axle designs except where reference is made to the act[illegible] check of the axle itself. All tests should be made with the vehicle in a level position.

It is important that the vehicle is at curb weight, with no passenger load, but with spare tire and with normal supply of water, fuel, and oil. The parallel arm type of independent wheel suspension consists of a set of arms supported through a coil spring and dampened by shock absorbers.

The corrections of camber and caster are performed through the adjustment of the component arms and levers. There are several vehicles that use this type, all the same in principle, but differing in construction and adjustment procedures.

Wheel Mounting

If one of two wheels mounted at opposite ends of a rigid axle receives a jar or jolt, the whole suspension system, including the axle is affected. This means that a large unsprung weight is set in motion which results in poor riding qualities. When a wheel hits an obstruction, the force of the impact is directly proportional to the unsprung weight which it carries. The force of the impact places a strain on the wheel, axle, springs, steering mechanism, etc, and has a destructive effect on the road. Hence, it is highly desirable to reduce the unsprung weight as much as possible.

With independent suspension the wheels of a motor vehicle are individually supported so that each wheel functions independently of the others. The following are the most important features of independent suspension: When one wheel passes over an obstruction, the shock is not transmitted to the opposite wheel, thereby aiding steering and reducing chassis distortion; the unsprung weight is reduced to a minimum and is confined to the weight of the wheel itself and does not include the axle, springs, and steering linkage, thereby improving riding qualities.

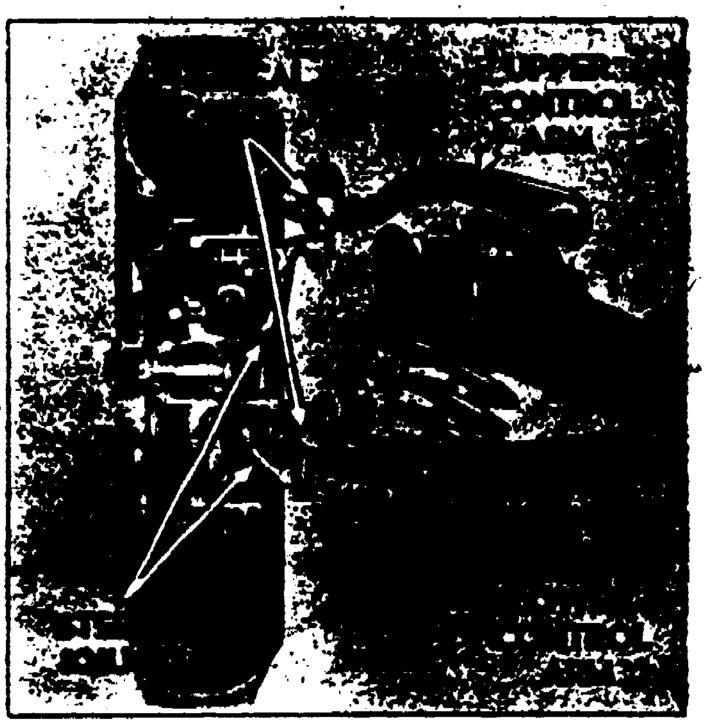

Figure 51. Ball Joint Suspension Upper and Lower Control Arms.

Figure 52. Ball Joint Suspension Shock Absorber and Coil Spring.

Parallel Arm Suspension System

The parallel arm suspension is the most commonly used of the several independent wheel suspension types manufactured, figures 51 and 52. The upper and lower control arms are pivoted to the frame in an approximately parallel position. The steering knuckle support is mounted between the ends of these triangular shaped control arms. The inner ends of the upper control arm are attached to the frame by a control arm shaft and bushings, figure 51. The inner ends of the lower control arm are pivoted on a shaft having bearings (bushings) at each end of the shaft and supported by brackets bolted to the bottom of the frame cross member. Shock absorbers used are usually direct acting, mounted inside of the coil spring, figure 52, or on the control arm outside of the coil spring. Regardless of mountings the shock absorbers must be inspected for proper operation because they have a lot to do with good steering and riding qualities.

The control arms allow the steering knuckle and wheel to move vertically. The lower control arm is longer than the upper one to maintain the distance between the tires where they must meet the roadway and to prevent side slip from unduly scuffing and wearing the tires. Ball pivots are provided at both ends of the steering knuckle and shims are usually used on the upper control arm so the inclination of the steering knuckle pivot can be adjusted, figures 53 and 54.

Coil springs are mounted between sheet metal cups riveted to the lower control arms and cups provided in the frame front cross member, figure 52.

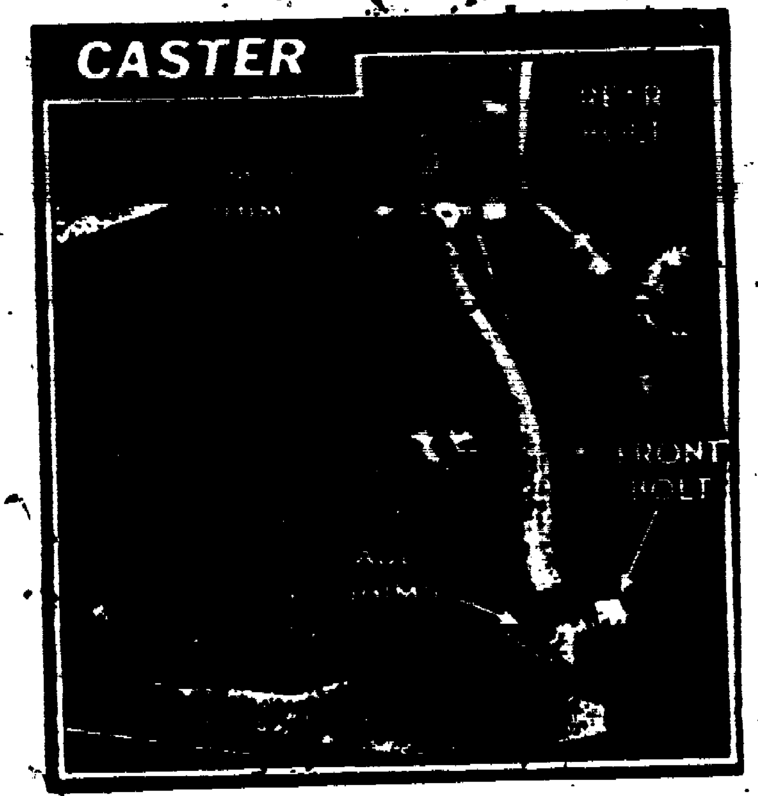

Figure 53. Caster Adjustment.

Rubber bumpers are mounted on the outer end of the front cross member or on the control arms to prevent metal to metal contact as the coil spring compresses and rebounds, figure 52.

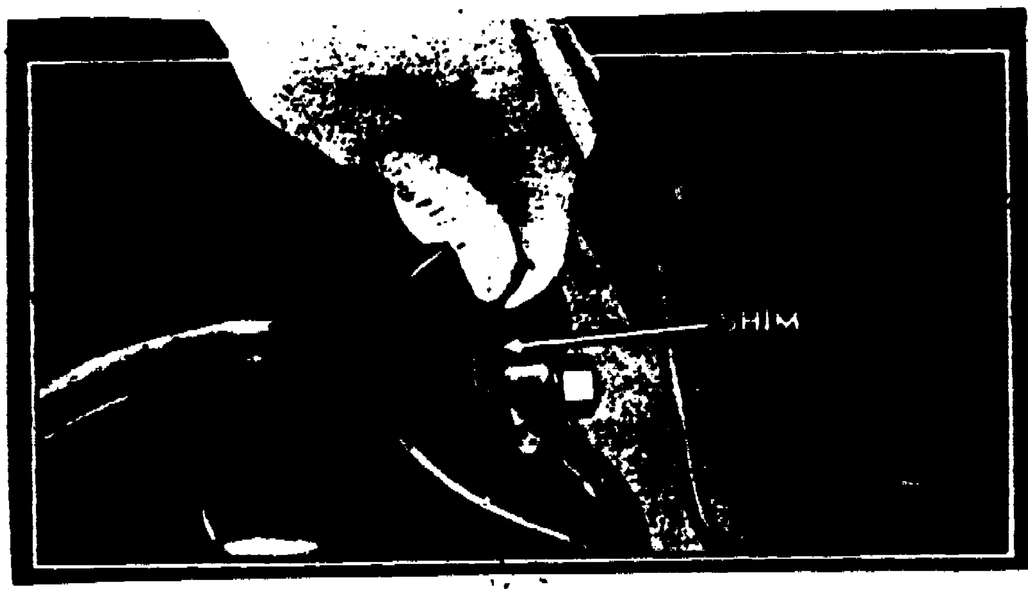

Figure 54. Adding or Removing Shims.

Adjustment Procedures for Caster, Camber and Toe-In

Due to the difference in design of motor vehicles the manufacturer may use a different system for adjusting, mounting and maintaining steering system. Regardless of design the alignment principles are the same. For example, some motor vehicles use eccentric (off center) bushings to adjust camber and caster, and on some adjustments are made on the lower control arm and on others the upper. The vehicle referred to in this study guide uses shims for this adjustment, located on the upper control arm, figure 54.

Caster can be adjusted by removing shims at one side of the cross shaft and replacing shims at the other, figures 53 and 54. This tilts the top of the steering knuckle support forward or backward, changing the caster angle. When making this caster adjustment it will be necessary to loosen the bolts holding the shims and upper control arm against the frame. After this adjustment has been made special care must be taken to see that these bolts are tightened to correct specifications.

Camber may be adjusted by using the same procedure as explained for adjusting "caster." However care must be taken that the same amount and size of shims are taken from both shim packs or the caster will be changed. Again you must make sure that the bolts are tightened to specifications and both camber and caster is measured as a final check.

The adjustment of toe-in is made by turning the tie rods. These tie rods have left-hand threads on one end and right-hand threads on the other. This causes the tie rod to lengthen when turned one direction and shorten when turned the other. To adjust toe-in you must position the steering wheel in the center position and then turn both tie rods until the front wheels are straight ahead. Then without disturbing the steering wheel, it will be necessary to turn both tie rods an equal amount until the toe-in is correct and equal at each wheel.

Removal and Replacement

Since each front wheel moves independently of the other in this system, you will find that the procedure for the removal and replacement of the parts are different from those used for removing and replacing the parts used on a rigid type axle.

Special tools are required to remove and replace the upper and lower control arms, bushings (bearings) and springs. If there is any problem about this procedure ask your instructor what steps to take.

All seals should be renewed at time of reassembly since mud and dirt getting into the moving pivots soon cause them to wear rapidly causing faulty steering.

Different manufacturers may use slightly different designs of independent suspension but a little time spent studying the proper publication will guide you through the removal and replacement of these units.

QUESTIONS

1. There are two definite reasons for pivot pin inclination. What are these two reasons?

2. All wheel alignment tests should be made with the vehicle in a desired position. What is this position? Why should the vehicle be placed in this position?

3. When adjusting wheel alignment factors the vehicle should be a desired weight. What is this desired weight? Why is this necessary?

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4. How is the adjustment of camber and caster performed on the parallel arm type of independent wheel suspension?

5. Shims are usually used between the upper control arm and the frame. What is the purpose for these shims?

6. Figure 52 shows two compression rubber bumpers. What is the purpose for these rubber bumpers?

7. Toe-in is adjusted by the tie rods. What position should the steering wheel be in when adjusting toe-in?

8. What type of springs does the independent suspension system use?

9. What do we mean by the term "independent suspension" steering system?

10. What type shock absorbers are used in this study guide, figure 52?

11. Bolts holding these control arms should be tightened to correct specifications. Where are these specifications found?

12. What could cause hard steering?

13. What could cause a vehicle to wander?

14. What could cause the vehicle to pull to one side during normal driving?

15. What may cause front wheel shimmy at low speeds?

16. Caster can be adjusted by removing or replacing shims on the upper control arm. What does this do?

17. How would you check a shock absorber to determine if it is in satisfactory condition?

18. How would you increase or decrease caster on this independent suspension system?

19. Does front wheel bearings have anything to do with wheel alignment? Why?

20. How many tie rods are there to adjust when making a toe-in adjustment?

21. If camber measured correctly and pivot pin measured wrong, what correction should be made?

REFERENCES

1. Bear Wheel Alignment, Axle and Frame Straightening Service Manual.

2. TO 36A-1-76, Principles of Automotive Vehicles.

PREPARE THE MAN

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Technical Training

8-12

Power Steering and Power Brakes
Power Steering/Brakes Maintenance
General P.H. Dis rakes I/O
General Purpose Vehicle Repairman

POWER STEERING AND POWER BRAKES, GENERAL PURPOSE VEHICLE

11 September 1973

AIR TRAINING COMMAND

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HYDRAULIC PRINCIPLES AND PRINCIPLES OF OPERATION OF DRUM AND DISC TYPE BRAKES

OBJECTIVES

After completing this unit of instruction, you will be able to explain the principles of hydraulics and principles of operation of drum and disc type brakes.

INTRODUCTION

The safety of a modern automotive vehicle and its cargo or towed load depends more often on the proper operation of the brakes than on any other unit except that of the steering gear. Not only must the brakes be able to stop the vehicle, they must bring it to a stop within certain and very definite limits of space. The brakes must be able to do this within one-eighth or one-sixth of the time it takes the engine to develop the speed. Besides being efficient, the brakes must be reliable against mechanical failure, weather of all types, dirt, grit, and grease. They must operate easily and within a wide margin of safety. Brakes must be long-lasting and tough. They must be made so that braking force, when applied, will be uniform.

INFORMATION

HYDRAULIC PRINCIPLES

Before we discuss power steering and power brakes, it is necessary to understand and review the principles of hydraulics.

Liquids Cannot Be Compressed

This rule simply says that applying pressure to liquids will not reduce the volume of the liquid.

Motion Can Be Transmitted By Liquids

Figure 1 shows two pistons in a cylinder, with a liquid separating them. If piston A is moved to the right, piston B will be moved to the right the same distance. This is due to the rule stated in the preceding paragraph. Two cylinders of the same diameter are connected by a tube, as shown in figure 2, and one piston is in each cylinder. If the space between the two pistons is completely filled with liquid, then a movement of piston A to the right will cause corresponding movement of piston B to the right, with the liquid flowing through the tube.

Pressure in a closed system, in pounds per square inch (PSI), is the appling force divided by the area of the applying piston. In figure 3, a 100-pound force on a piston of one square inch will

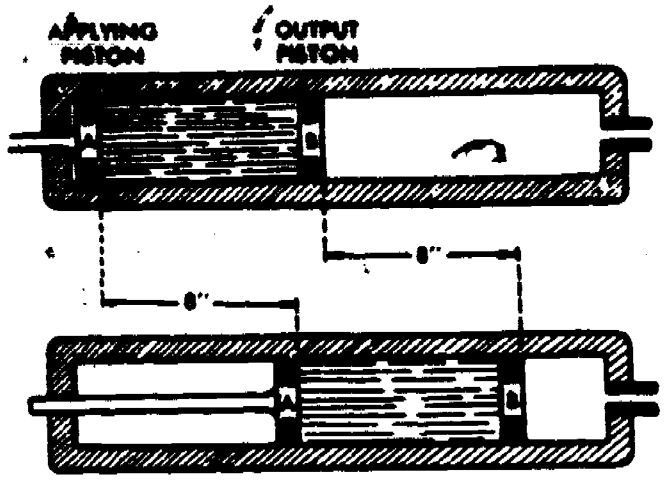

Figure 1. Liquids Cannot be Compressed.

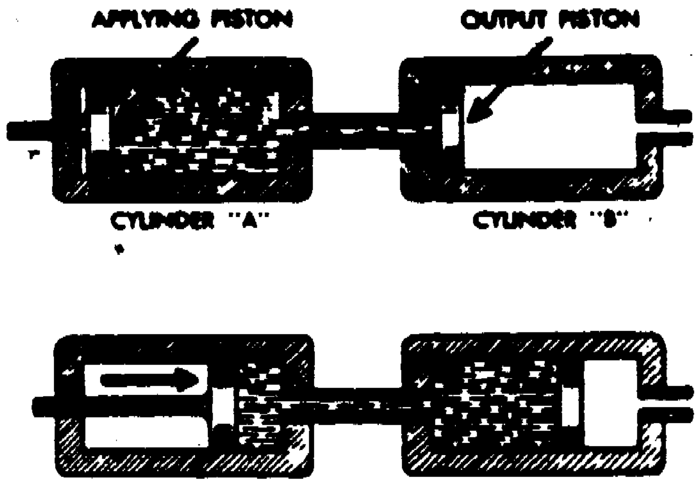

Figure 2. Liquids Cannot be Compressed.

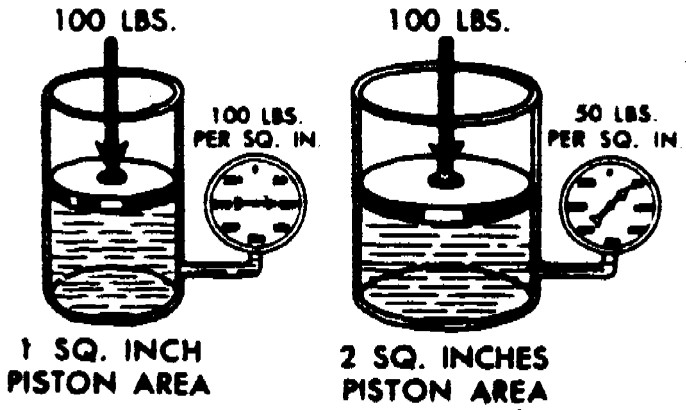

Figure 3. Pressure-Force-Area.

produce a pressure in the liquid of 100 psi. If the same force (100 pounds) is applied to a piston of two square inches in area, the resulting hydraulic pressure will be 50 psi. The formula for this relationship is

$$P = \frac{F}{A} \text{ or pressure in pounds per square inch} = \frac{\text{Force in pounds}}{\text{Area in square inches}}$$

A liquid under pressure transmits pressure equally in all directions. A pressure gauge placed anywhere in a closed hydraulic system will read the same at any point, as shown in figure 4.

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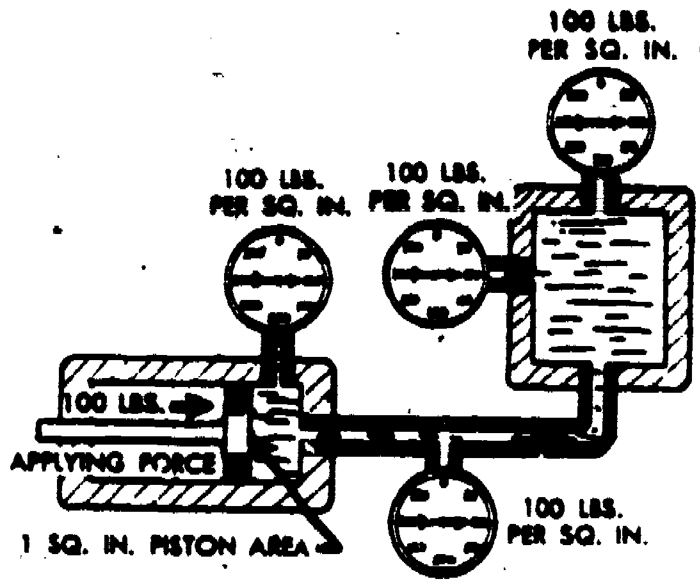

Figure 4. Equal Pressure Through System.

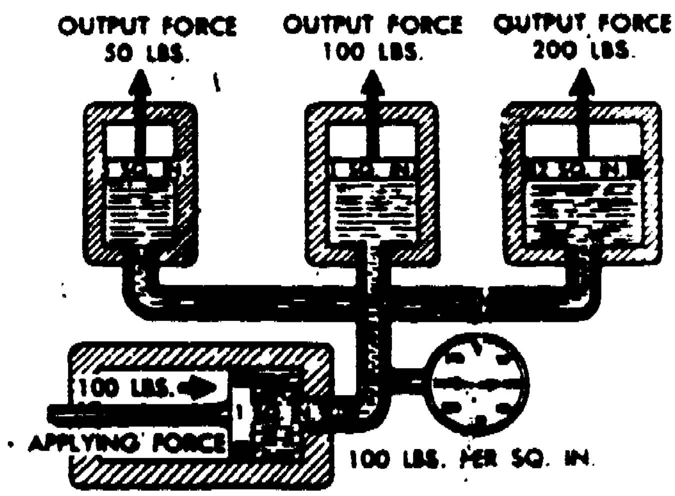

Figure 5. Force Output.

Force developed on an output piston is the pressure in the system times the area of the output piston. Figure 5 shows a 100-pound force on 1 square inch piston developing 100 psi in a closed system. On piston A 1/2 square inch, a force of 50 pounds, will be developed. On piston B of 1 square inch area, 100 pounds force will be developed. On piston C of 2 square inches, 200 pounds force will be developed.

The above rules for hydraulic circuits govern the properties of oil under pressure. In order for power steering and power brakes to operate, several basic items are required. These items will be covered in principles of operation of drum and disc type brakes.

PRINCIPLES OF OPERATION OF DRUM AND DISC TYPE BRAKES

Now that we have reviewed and understand the principles of hydraulics, let's look at the operations of the drum and disc type brake systems.

When the brakes are fully released, the master cylinder piston is held against the retaining ring; and the primary cups are held just

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clear of the compensating ports by the master cylinder springs. The pressure chambers are filled with fluid at atmospheric pressure due to the open compensating ports and the flexible reservoir diaphragm.

When the brake pedal is depressed to apply the brakes, the push rod forces the master cylinder piston and primary cups forward. As this movement starts, the lips of the primary cups cover the compensating ports to prevent escape of fluid into the reservoirs. Continued movement of the piston builds pressure in the pressure chambers and fluid is then forced through the lines leading to the wheel cylinders. Fluid forced into the wheel cylinders between the cups and pistons cause the pistons and connecting links to move outward and force the brake shoes into contact with the drum.

On disc type brakes of the single piston mechanism, hydraulic pressure acts on two surfaces.

The first, and most obvious, is the piston. The second is in the opposite direction against the bottom of the bore of the caliper housing. Since the area of the piston and bottom of the caliper bore are equal, equal forces are developed.

Hydraulic force in the caliper bore is exerted against the piston which is transmitted to the inner brake shoe and lining assembly and the inner surface of the disc. This tends to pull the caliper assembly inboard, sliding on the four rubber bushings. The outer lining, which rests on the caliper housing, then applies a force on the outer surface of the disc and together the two linings brake the car. Since an equal hydraulic force is applied both to the caliper housing and the piston, the force created against the outer surface of the disc is the same as to the inner. Since there are equal forces on the linings, no flexing or distortion of the disc occurs regardless of the severity or length of application and lining wear will tend to be equal.

Now that we understand the operation of the drum and disc type brake system, let's take a look at the different components that make up the brake systems.

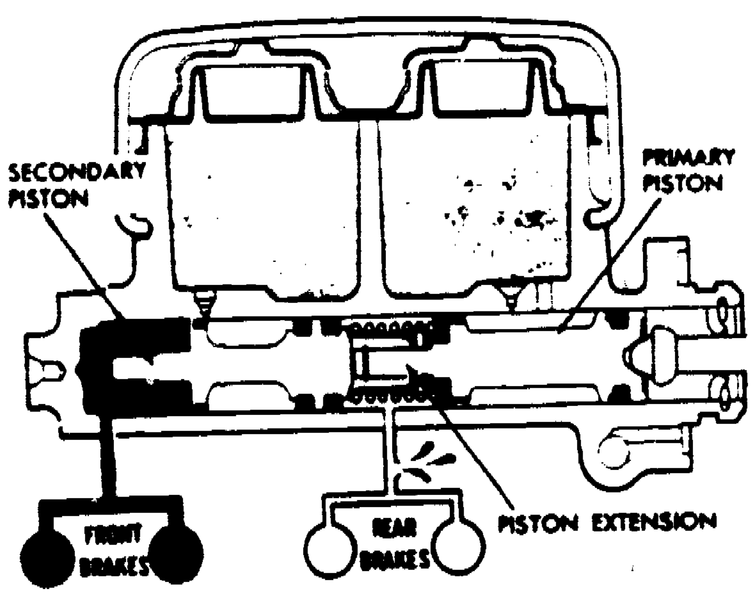

Figure 6. Rear Line Failure.

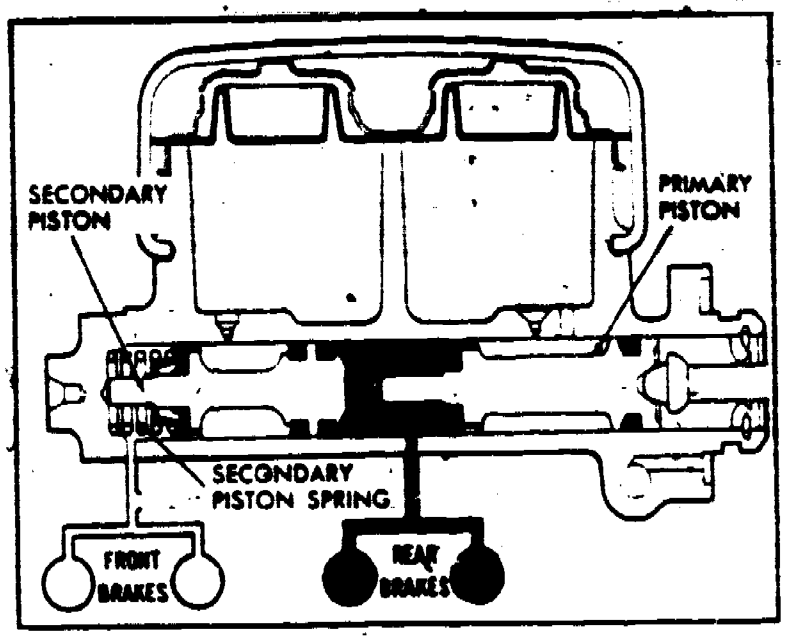

Figure 7. Front Line Failure.

Master Cylinder

The master cylinder is pedal operated and applies the brakes at all four wheels with equalized pressure. The master cylinder, connecting lines, and wheel cylinders, are filled with special hydraulic fluid which is forced through the system by the movement of the master cylinder piston. The master cylinders used today have split reservoirs. This means that the front and rear brakes are separated from each other by the design of the master cylinder. Refer to figures 6 and 7.

The master cylinder contains two fluid reservoirs and two cylindrical pressure chambers in which force, applied to the brake pedal, is transmitted to the fluid which actuates the brake shoes or brake disc. Breather ports and compensating ports permit passage of fluid between each pressure chamber and its fluid reservoir during certain operating conditions. A vent cover and flexible rubber diaphragm, at the top of the master cylinder reservoir, seals the hydraulic system from possible entrance of contamination, while at the same time permitting expansion or contraction of fluid within the reservoirs without direct venting.

In the pressure chambers, coil springs hold rubber primary cups against the end of the piston. These cups, and rubber secondary seals on the opposite end of the piston, prevent escape of fluid past the pistons. The piston is retained in the cylinder by a stop plate. A rubber boot is installed over this end of the cylinder to prevent foreign matter getting into the system. Refer to figure 8.

Stroking or pushing the brake pedal causes the primary pistons in the main cylinder to move forward. At the same time a combination of hydraulic pressure and force of the primary piston spring moves the secondary piston forward. When the pistons have moved forward so that their primary cups cover the compensating holes, hydraulic pressure is built up and transmitted to the wheels.

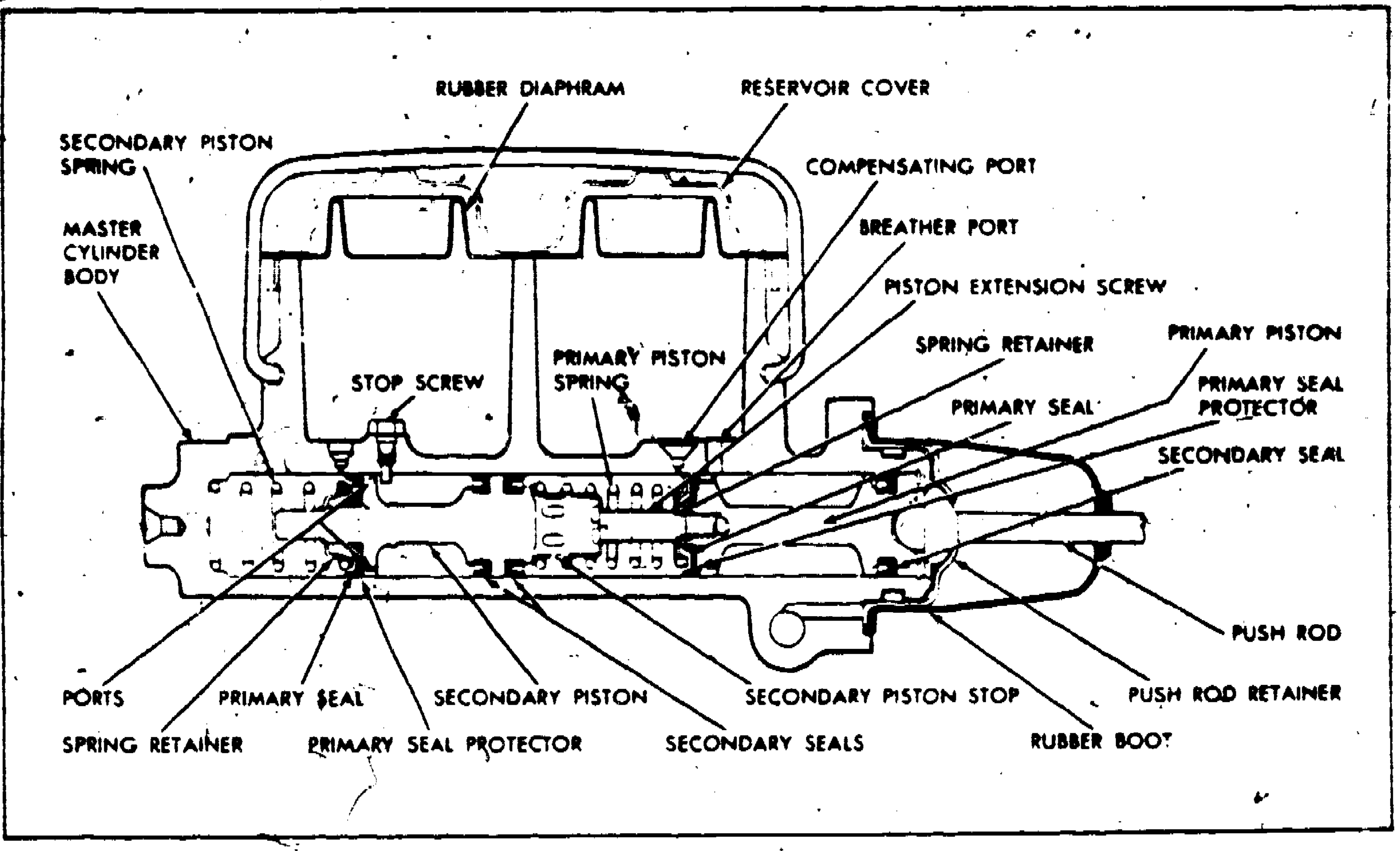

Figure 8. Master Cylinder.

When the brake pedal is released the master cylinder pistons move rearward and hydraulic pressure on the system is released.

Wheel Cylinder

Each wheel cylinder, as shown in figure 9, contains two pistons and two rubber cups which are held in contact with the piston by a central coil spring (sometimes with cup expanders to provide a fluid-tight seal). The wheel cylinder cups are of a special heat resisting rubber. Cups of this material must have an expander to hold the lips of the cup out against the wheel cylinder bore. These cup expanders are crimped on each end of the wheel cylinder spring. The inlet port for brake fluid is located between the pistons so that when fluid pressure is applied, both pistons move outward toward the ends of wheel cylinder. The piston imparts movement to the brake shoes by means of connecting links which seat in the piston and bear against the shoes. Rubber boots enclose both ends of the cylinder to prevent foreign matter from getting into the system. A valve for bleeding the brake lines and wheel cylinder is located above the inlet port.

Disc-Rotor Assembly

The purpose of the disc is to provide the frictional surfaces required to stop the vehicle. The cast iron disc is of the ventilated rotor-type incorporating fins and is attached to and rotates with the wheel hub. A splash shield bolted to the spindle is used

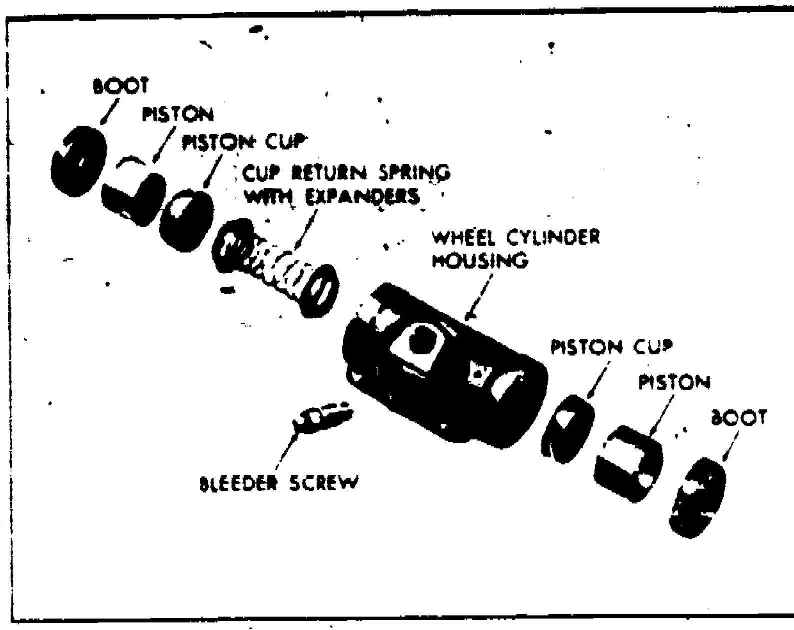

Figure 9. Typical Wheel Cylinder.

primarily to prevent road contaminants from contacting the inboard rotor and lining surfaces. The wheel provides protection for the outboard surface of the rotor.

Caliper-Fixed and Floating

The caliper provides a means of applying the shoe and lining assemblies to the disc. It is connected to the system by a hydraulic line. It is mounted to the support plate by two housing retainer bolts, two sleeves and four rubber bushings. An inner caliper rubber bushing is installed between each sleeve and groove in the housing, and an outer caliper rubber bushing is installed between each bolt and groove in the housing. Shoe and lining assemblies are positioned on the caliper so they straddle the disc.

The fixed caliper disc brake is called "fixed" caliper type because the complete caliper assembly is rigidly bolted to the steering wheel spindle. The caliper assembly consists of two caliper halves bolted together. Each half has a pair of pistons. Internal passages in the caliper housing and an external transfer tube between the two caliper halves hydraulically connect the cylinders. Each caliper assembly has one bleeder screw and fluid inlet fitting. Refer to figure 10.

Shoes and lining assemblies are located between parallel machined abutments within the caliper. Tabs on the outer ends of the shoe assemblies radially support the shoes. The shoes slide axially in the caliper abutments by means of the tabs, which ride on machined ledges (bridges) when hydraulic pressure is applied to the pistons. The shoes thus squeeze against the rotor to stop the wheel. Clips attached to the top of the caliper retain the shoe and lining assemblies. The lining is either riveted or bonded to a metal plate (shoe). It is replaced as a unit.

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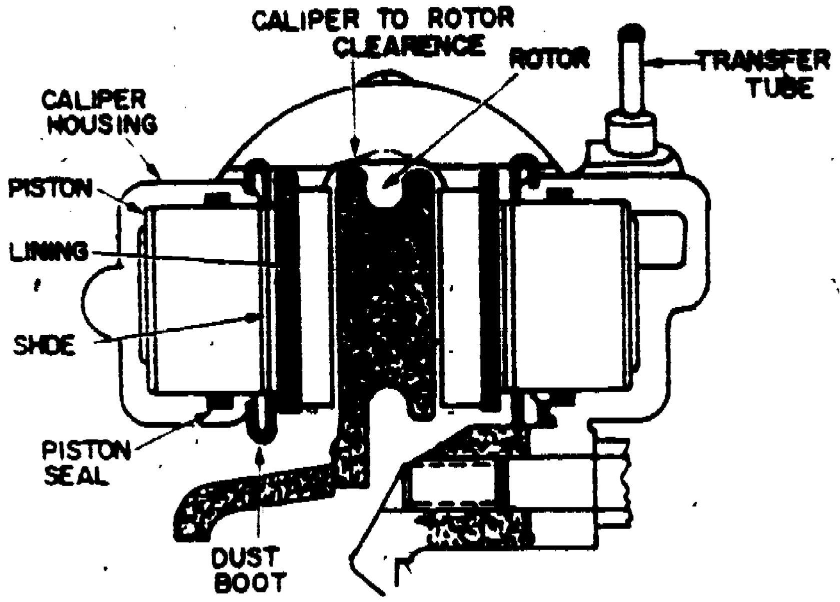

Figure 10. Fixed Caliper.

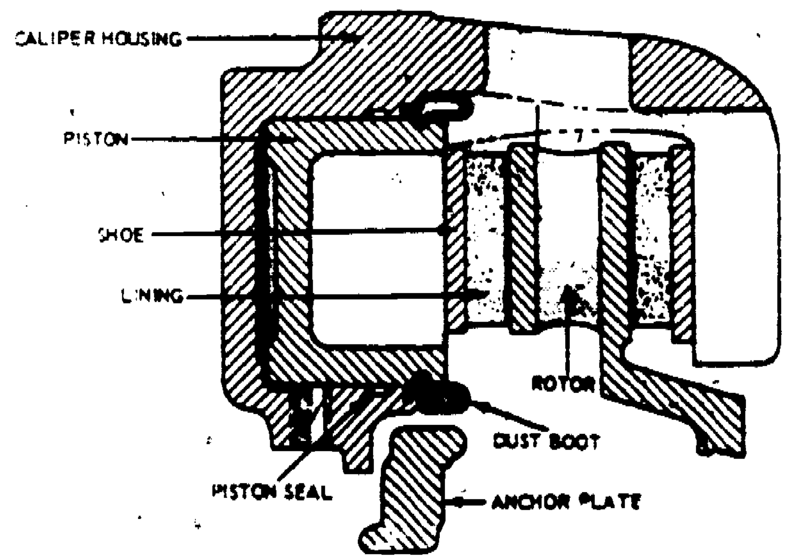

Figure 11. Floating Caliper.

The "floating" caliper disc brake, figure 11, functions much differently than the fixed type. The floating caliper consists of a one-piece housing, not a two-piece assembly. It is not bolted to the wheel spindle but is free to move inboard and outboard (float) parallel to the spindle axle, as the brakes are applied and released. Only one piston is used instead of four.

The one-piece caliper housing slides in and out a fraction of an inch on two caliper locating pins that screw into ears on the claiper housing, and pass through insulators fitted into holes in the anchor plate. The anchor plate bolts to the wheel spindle. Stabilizers control the caliper's position in relation to the rotor. The stabilizers are fastened to the caliper by the caliper locating pins and to the anchor plate by two cap screws.

The single piston fits into a bore in the inner portion of the caliper. The inner brake shoe and lining assembly fits against the piston and has ears on the outer ends that rest on the anchor plate bosses. Two hold-down clips, bolted to the anchor plate, hold the shoe in position. The outer shoe and lining, which is longer, attaches to the outer legs of the caliper.

The floating caliper brake works like a "C" clamp. When the brakes are applies, hydraulic pressure forces the piston outward, moving the inboard shoe and lining into contact with the rotor. No appreciable braking effect occurs, however, until more hydraulic fluid enters behind the piston. It does not exert greater pressure force on the piston, but because the caliper can "float," the additional hydraulic pressure develops a reaction force that moves the caliper inward, forcing the outboard shoe and lining against the rotor. Additional hydraulic pressure forces both linings to grip the rotor in a "sandwiching" action to stop the wheel.

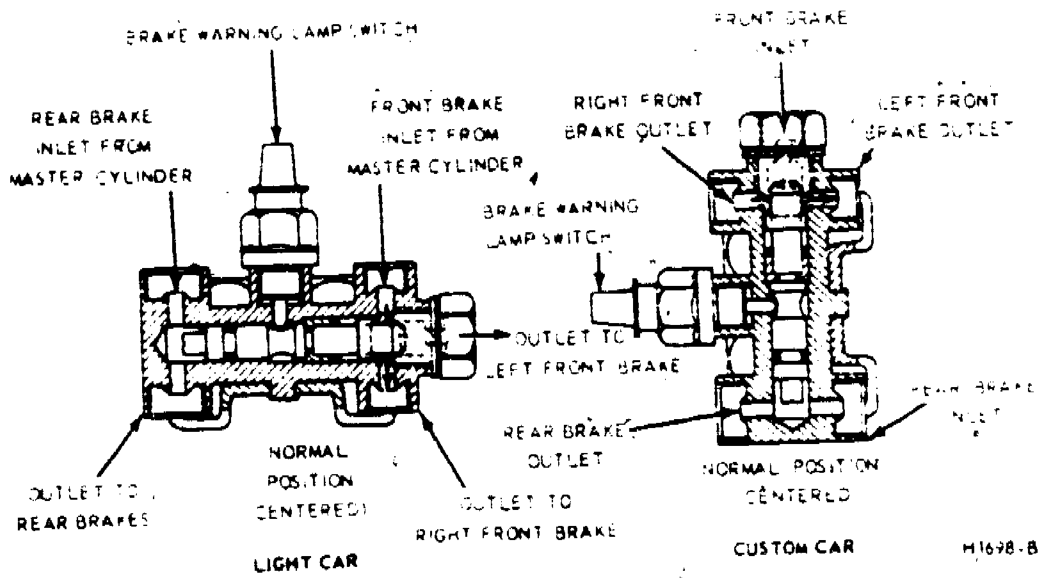

Figure 12. Pressure Differential Valve and Brake Warning Light Switch.

BRAKE SYSTEM SAFETY DEVICES

Today's hydraulic brake systems have several safety devices built into the system that warn the operator of brake failure and assist in a balanced braking action. The following paragraphs will briefly explain the function of these safety devices.

Pressure Differential Valve

The pressure differential valve also called a failure warning switch, is activated if either front or rear brake system fails and when activated, completes a circuit to the dash warning lamp. If the rear hydraulic system fails, the pressure of the good front system forces the switch position to the right. The switch pin is forced up into the switch by the piston ramp, figure 12, and makes the electrical circuit lighting the dash lamp and is held in this position by the piston.

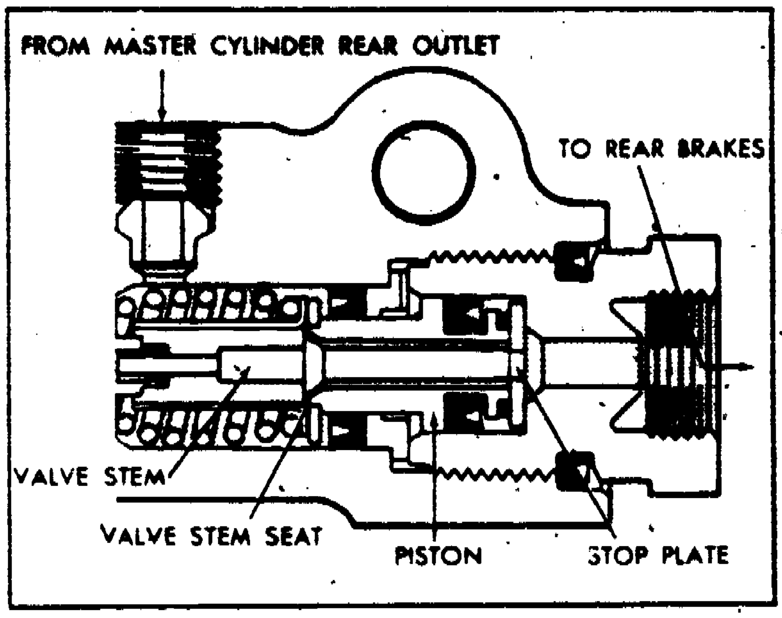

Figure 13. Normal Brake Stop.

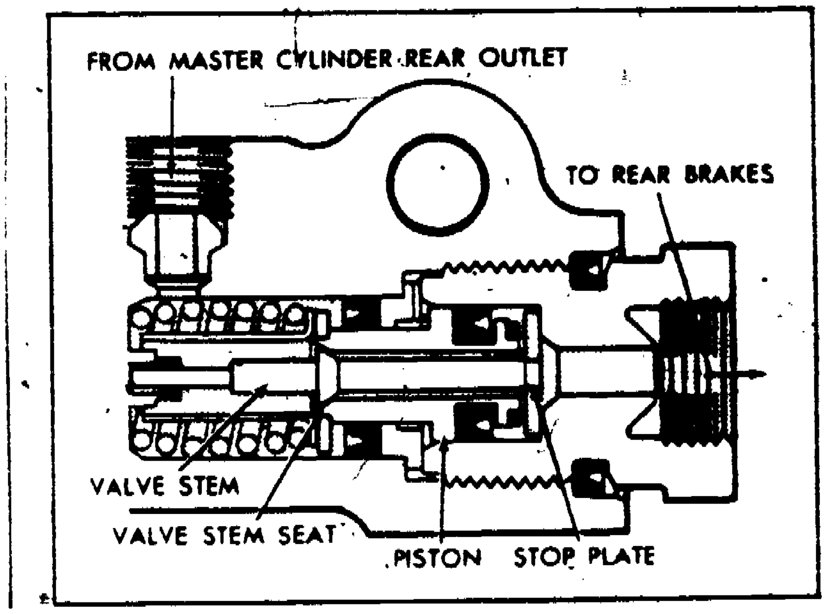

Figure 14. Proportioning Action.

Proportioning Valve - (Disc Brake Only)

The proportioning valve improves front to rear brake balance at high deceleration. During high deceleration stops, a percentage of the rear weight to the rear wheel contributes to early rear wheel skid. The proportion valve reduces the rear brake pressure and delays the rear wheel skid.

The proportion valve does not operate during normal brake stops (below 10 ft deceleration). Fluid normally flows into the proportioner, through the space between the piston center hole and valve stem, through the stop plate and out to the rear brakes. The spring loads the piston so that it rests against the stop plate for normal brake pressures. Pressure developed within the valve pushes against the large end of the piston and when sufficient to overcome the springload, moves the piston to the left. The piston "contacts" the spherical stem seat and starts proportioning by restricting pressure through the valve. See figures 13 and 14.

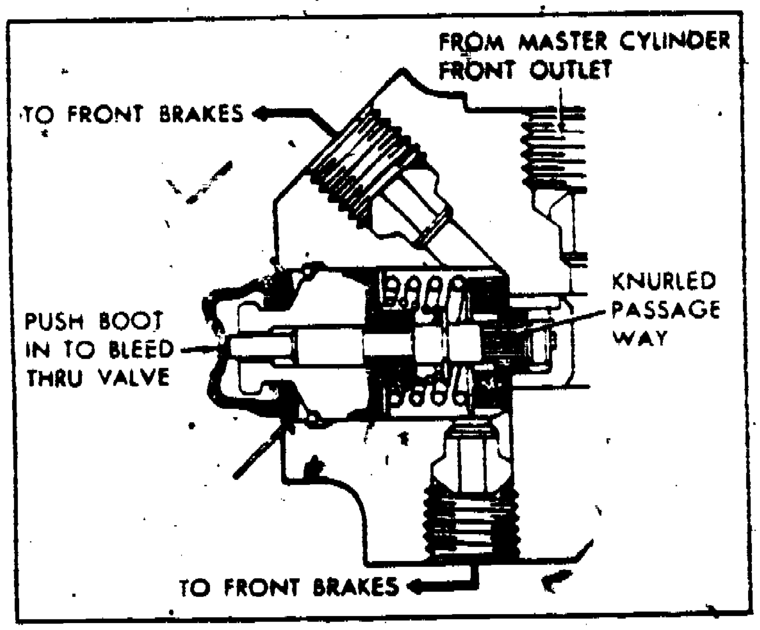

Figure 15. Brakes Not Applied.

Metering Valve - (Disc Brakes Only)

The metering valve holds off front disc braking until the shoes of the rear drum brake contacts the drum.

When brakes are not applied, the metering valve allows free flow of brake fluid through the valve. This allows the fluid to expand and contract with temperature changes.

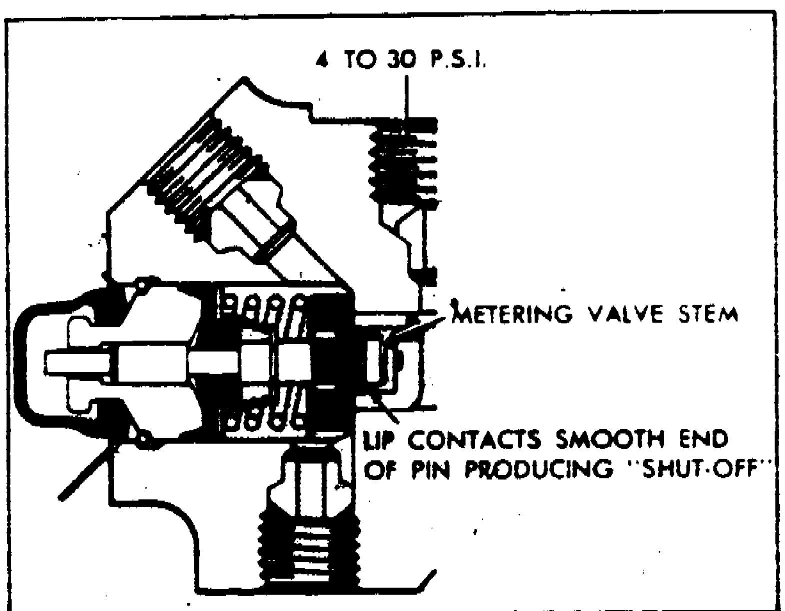

Figure 16. Shut-Off Point.

When the Shut-Off-Point (initial brake application) occurs, the metering valve stem moves to the left, and at 4 to 30 psi the smooth end of the stem is in a sealing position with the metering valve seal

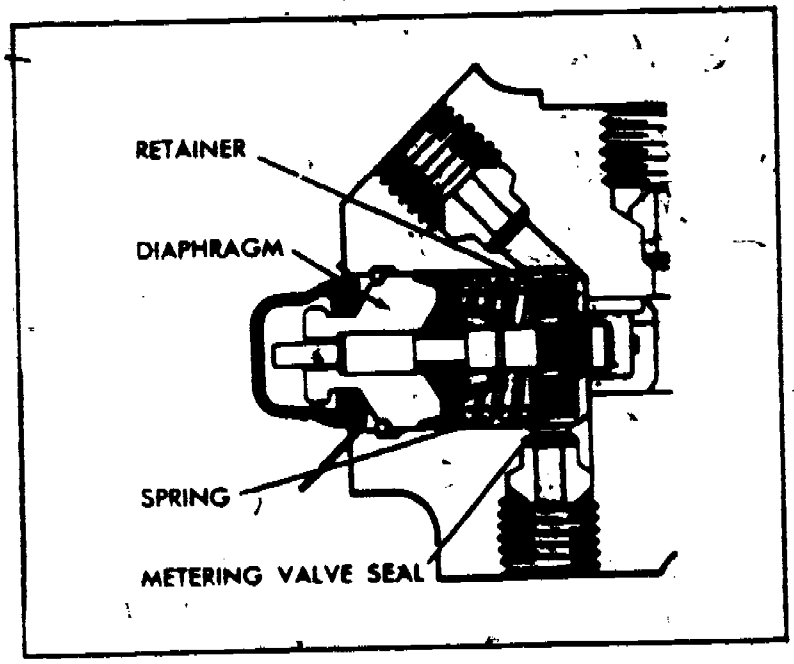

Figure 17. Hold-Off Blend Pressure.

lip and this is the shutoff point. The metering valve stem continues to the left on initial brake application and stops on the knurl at the metal retainer. The metering valve spring holds the retainer against the seal until a predetermined psi is produced at the inlet of the valve. This pressure overcomes the spring and allows pressure through the valve to the front brakes. The continued increase of pressure into the valve meters through the metering valve seal, through to the front brakes, and produces an increasing force on the diaphragm. The diaphragm pulls the pin and the pin in turn pulls the retainer, thus reducing the spring load on the metering valve seal. Eventually, the pressure reaches a typical range of 440 to 750 psi and the spring is completely pulled away by the diaphragm pin and retainer, leaving the metering valve seal free to pass unrestricted pressure through the valve.

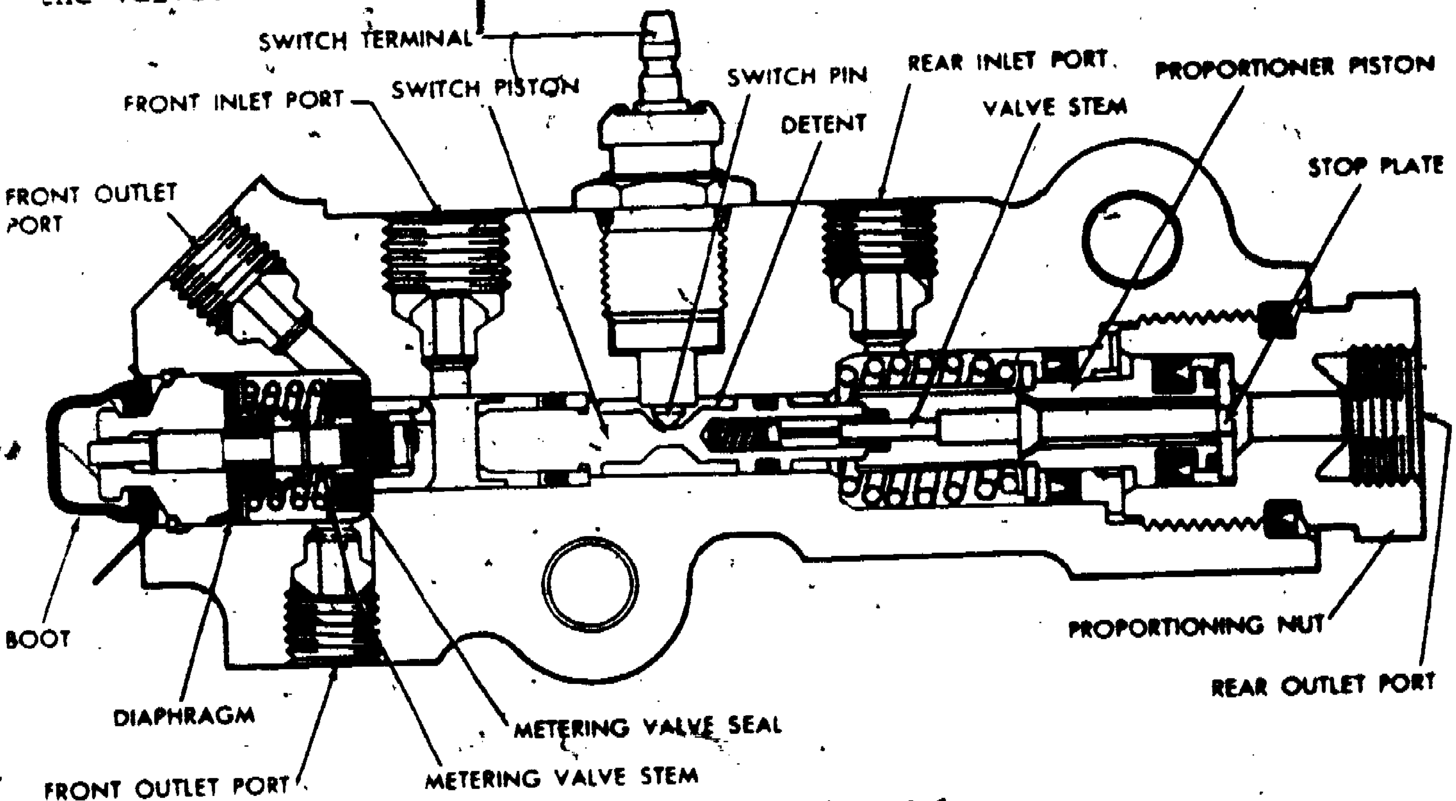

Figure 18. Combination Valve.

Combination Valve

This valve, figure 18, is a combination valve consisting of a proportioning valve, metering valve, and pressure differential valve.

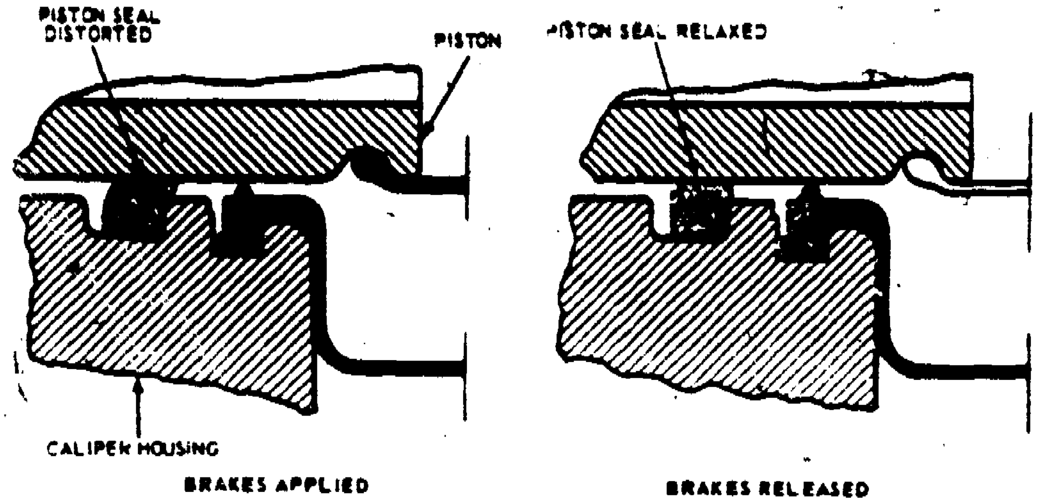

Figure 19. Function of Piston Seal.

Caliper Piston Seal

Figure 19 shows a caliper piston seal which performs the self-adjusting action on disc brakes, instead of a mechanical set-up as used in drum brakes. During brake application, the caliper piston seal distorts as hydraulic pressure, pushes the piston out for the distance required to press the brake shoes against the rotor. Removing the foot from the brake produces pressure and the seal returns to a relaxed position. As the seal relaxes, or rolls back, it moves the piston inward in the caliper housing bore. As the piston moves inward, the stabilizers position the caliper housing and outer brake shoe lining assembly on the rotor, to automatically maintain the correct clearance. This retracting action, however, is always limited by rotor runout and amount of seal rollback, or relaxation, that in turn causes the piston to travel back.

QUESTIONS

1. Explain the basic principles of hydraulics.

2. How is motion or force transmitted by liquids?

3. Explain the difference between the "fixed caliper" and "floating caliper" assembly.

4. What is the purpose of the pressure differential valve?

5. How does the proportioning valve prevent rear wheel skid?

6. Explain the function of the metering valve.

SERVICING OF HYDRAULIC BRAKE SYSTEMS

OBJECTIVES

Upon completion of this unit of instruction, you will be able to: (1) inspect, locate, and identify malfunctioning components in the hydraulic brake system, (2) make necessary adjustments to components in the hydraulic brake system, and (3) bleed the hydraulic brake system.

INTRODUCTION

In brake operation various difficulties may arise that require inspection and correction to keep them in good operating condition. Although the difficulties vary somewhat according to type of system (drum or disc brakes), servicing procedures are similar.

INFORMATION

Brake systems require periodic inspection, adjustments and occasional parts replacement. This is your responsibility. The reading material presented in the following paragraphs pertain to inspection and servicing of the brake system.

PRELIMINARY INSPECTION

Before you adjust or repair any part of the hydraulic brake system you must first inspect the system for leaks or malfunctions. This is called a preliminary inspection and consists of the following checks:

1. Check the fluid level of the reservoirs in the master cylinder. If the fluid level is below specifications, more fluid should be added.

2. If, during checking of the master cylinder you found it lower than normal, it is a good indication of a leak in the system. Check for leaks at the master cylinder, lines and hoses, safety devices, and wheel cylinders or calipers. When checking for leaks on a power hydraulic brake syste, you must also check the booster for leaks.

3. Check the fluid for contamination. There should not be any traces of rust or sludge. If there is cause to believe incorrect fluid may have been added to the system, a check for mineral oil contents must be made.

CONDITIONS THAT AFFECT BRAKING

In addition to previous mentioned inspections the following conditions may affect brake performance and should be corrected before work is done on the brake mechanism.

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1. Tires having unequal contact and grip on the road could cause unequal braking. Tires should be equally inflated and tread pattern of right and left tires should be approximately equal.

2. When the car has unequal loading, the most heavily loaded wheel requires more braking power than others.

3. A very loose front wheel bearing could, on a drum brake vehicle, permit the drum to tilt and have spotty contact with brake shoe linings.

4. Faulty shock absorbers that permit bouncing of the car on quick shops may give the erroneous impression that brakes are too severe.

READING ASSIGNMENT

In the manual provided by your instructor, locate and read portions dealing with inspection, adjustment, and bleeding procedures of the hydraulic brake system components.

PRINCIPLES OF OPERATION OF VACUUM BOOSTER BRAKE SYSTEMS, TROUBLESHOOTING AND SERVICING BOOSTERS

OBJECTIVES

After completing this unit of instruction, you will be able to explain the location, construction, and operating principles o the vacuum booster, and to troubleshoot and service the booster using applicable publications and safety procedures.

INTRODUCTION

The vacuum booster is used with the brake system to reduce the braking effort required by the driver. The unit is used in conjunction with a conventional brake system master cylinder. The vacuum booster utilizes engine manifold vacuum and atmospheric pressure, to provide power assisted application of vehicle brakes.

INFORMATION

In order to understand the principle of how the vacuum booster system operates, it is necessary to know what a vacuum is and how it can be used.

For practical purposes, a vacuum may be defined as a space from which air or gas has been partly exhausted. Air, like all matter, has weight. Since air extends upward from sea level for several hundred miles, the weight of the air exerts a pressure termed "atmospheric pressure" at sea level of 14.7 psi. This pressure is equally distributed in all directions upon all objects of the earth's surface.

Atmospheric pressure may be used to operate brakes by creation of a vacuum. Since a vacuum is created by removing air, the pressure within a vacuum is less than that of the atmosphere. A perfect vacuum from which all matter has been removed has no pressure whatsoever. A perfect vacuum is not obtainable, although it can be closely approached. Hence, the full force of 14.7 psi atmospheric pressure cannot be utilized. If air in a container has been pumped out or evacuated until only 5 psi remains, the 10 psi differential existing between "vacuum pressure" and "atmospheric pressure" may be used to perform work. The pumping action of the engine piston causes a partial vacuum to be created in the intake manifold of an internal combustion engine. When the engine is coasting in high gear, with the carburetor throttle fully closed, very little air is admitted into the intake manifold so that the pumping actions of the piston reduces the pressure so that only about 5 psi exists in the manifold.

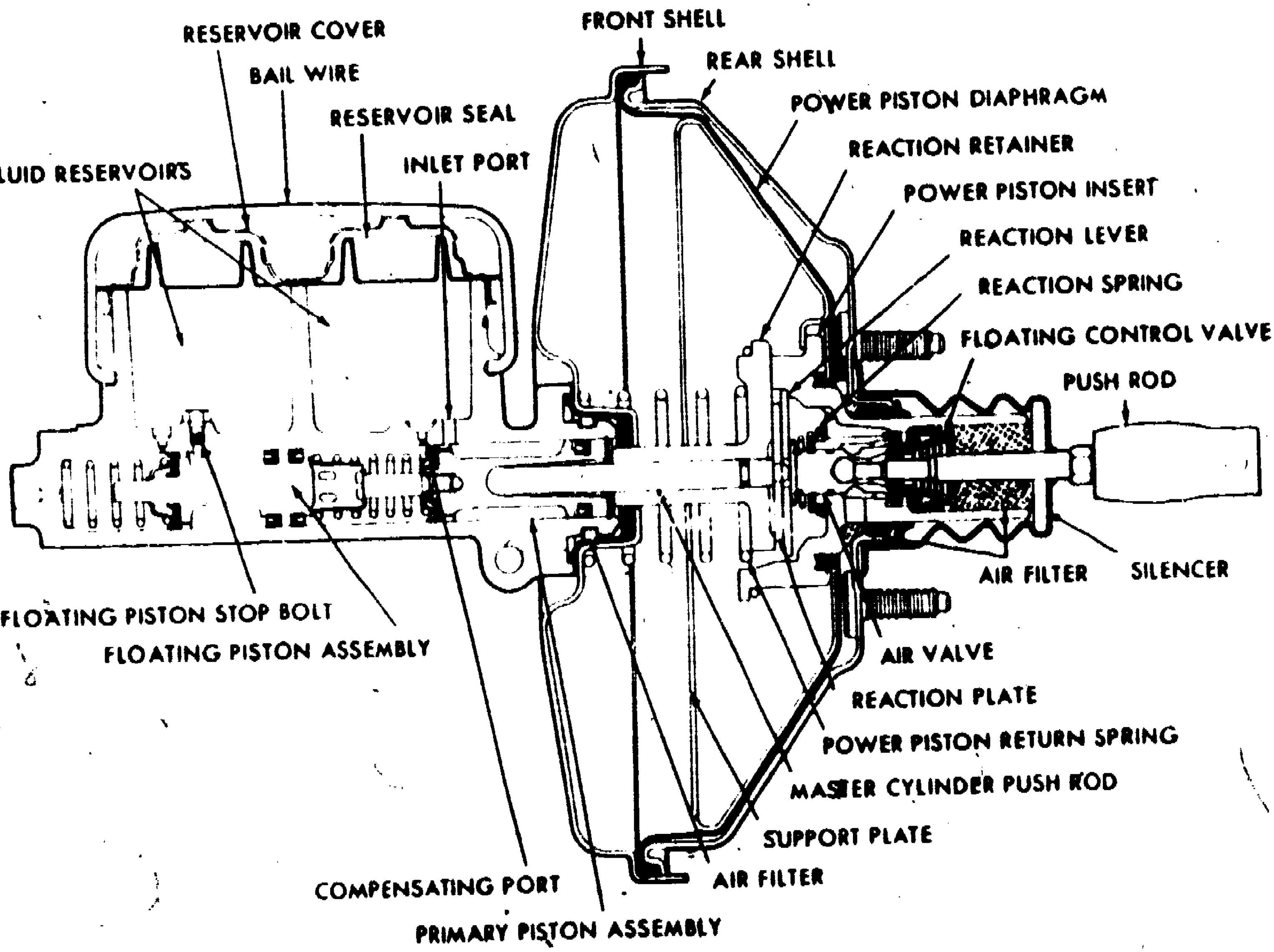

Figure 20. Typical Power Unit - Released.

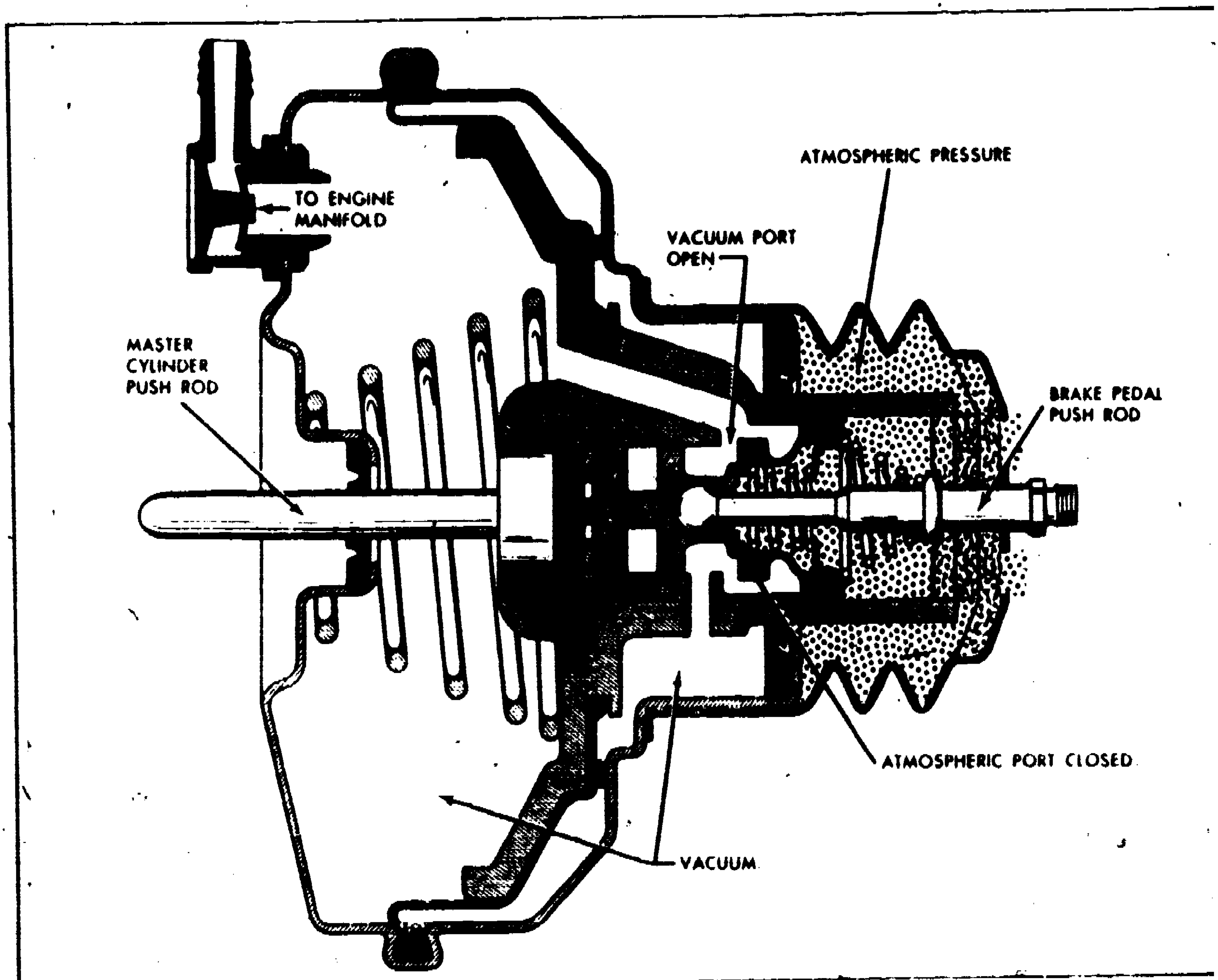

Figure 21. Typical Circuit - Released.

PRINCIPLES OF OPERATION OF VACUUM BOOSTER BRAKE SYSTEMS, TROUBLESHOOTING AND SERVICING BOOSTERS

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Atmospheric pressure may be used to operate brakes by creation of a vacuum. Since a vacuum is created by removing air, the pressure within a vacuum is less than that of the atmosphere. A perfect vacuum from which all matter has been removed has no pressure whatsoever. A perfect vacuum is not obtainable, although it can be closely approached. Hence, the full force of 14.7 psi atmospheric pressure, cannot be utilized. If air in a container has been pumped out or evacuated until only 5 psi remains, the 10 psi differential existing between "vacuum pressure" and "atmospheric pressure" may be used to perform work. The pumping action of the engine piston causes a partial vacuum to be created in the intake manifold of an internal combustion engine. When the engine is coasting in high gear, with the carburetor throttle fully closed, very little air is admitted into the intake manifold so that the pumping actions of the piston reduces the pressure so that only about 5 psi exists in the manifold.

plate is held against the reaction retainer. The air valve spring holds the reaction levers against the hydraulic reaction plate and also holds the air valve against its stop in the tube of the power piston. The floating control valve assembly is held against the air valve seat by the floating control valve spring. With the power brake at released position the primary seals on both the rear piston and the floating piston are back past the two compensating ports in the bore.

As the pedal is depressed, figures 22 and 23, the valve operating rod (push rod) carries the air valve away from the floating control valve. The floating control valve will follow until it is in contact with the raised seat in the power piston insert. When this occurs, vacuum is shut off to the rear of the power piston and air under atmospheric pressure rushes through the air filter and travels past the seat of the air valve and through a passage into the housing at the rear of the power piston. Since there is still a vacuum on the front side of the power piston, the atmospheric air pressure at the rear of the piston will force the power piston to travel forward.

As the power piston travels forward, the hydraulic push rod carries the master cylinder piston further into the bore of the master cylinder. The pressure on the master cylinder piston spring forces the floating piston to move forward. As the primary seal on both the rear master cylinder piston and the floating piston pass the compensating ports in the bore, hydraulic pressure will build up in the lines to the front brakes and the lines to the rear brakes. As the pressure builds up on the end of the master cylinder piston, the hydraulic reaction plate is moved off its seat on the power piston and presses against the reaction levers. The levers, in turn, swing about their pivots and bear against the end of the air valve operating rod assembly. In this manner approximately 30% of the load on the hydraulic master cylinder piston is transferred back through the reaction system to the brake pedal. This gives the operator a feel, which is proportional to the degree of brake application.

When the desired pedal pressure is reached, figures 24 and 25, the power piston moves forward until the floating control valve, which is still seated on the power piston, again seats on the air valve. The power piston will now remain stationary until either pressure is applied or released at the brake pedal. As the pressure of the pedal is released, the air valve spring forces the air valve back to its stop on the power piston. As it returns, the air valve pushes the floating control valve off its seat on the power piston insert. The air valve seating on the floating control valve has shut off the outside air source. When it lifts the floating control valve from its seat on the power piston insert, it opens the space at the rear of the power piston to the vacuum source.

Since both sides of the power piston are now under vacuum, the power piston return spring will return the piston to its released position against the rear housing. As the power piston is returned, the hydraulic master cylinder piston and floating piston move back and the fluid from the wheel cylinder flows back into the master cylinder. If the brake pedal is released quickly, the master cylinder

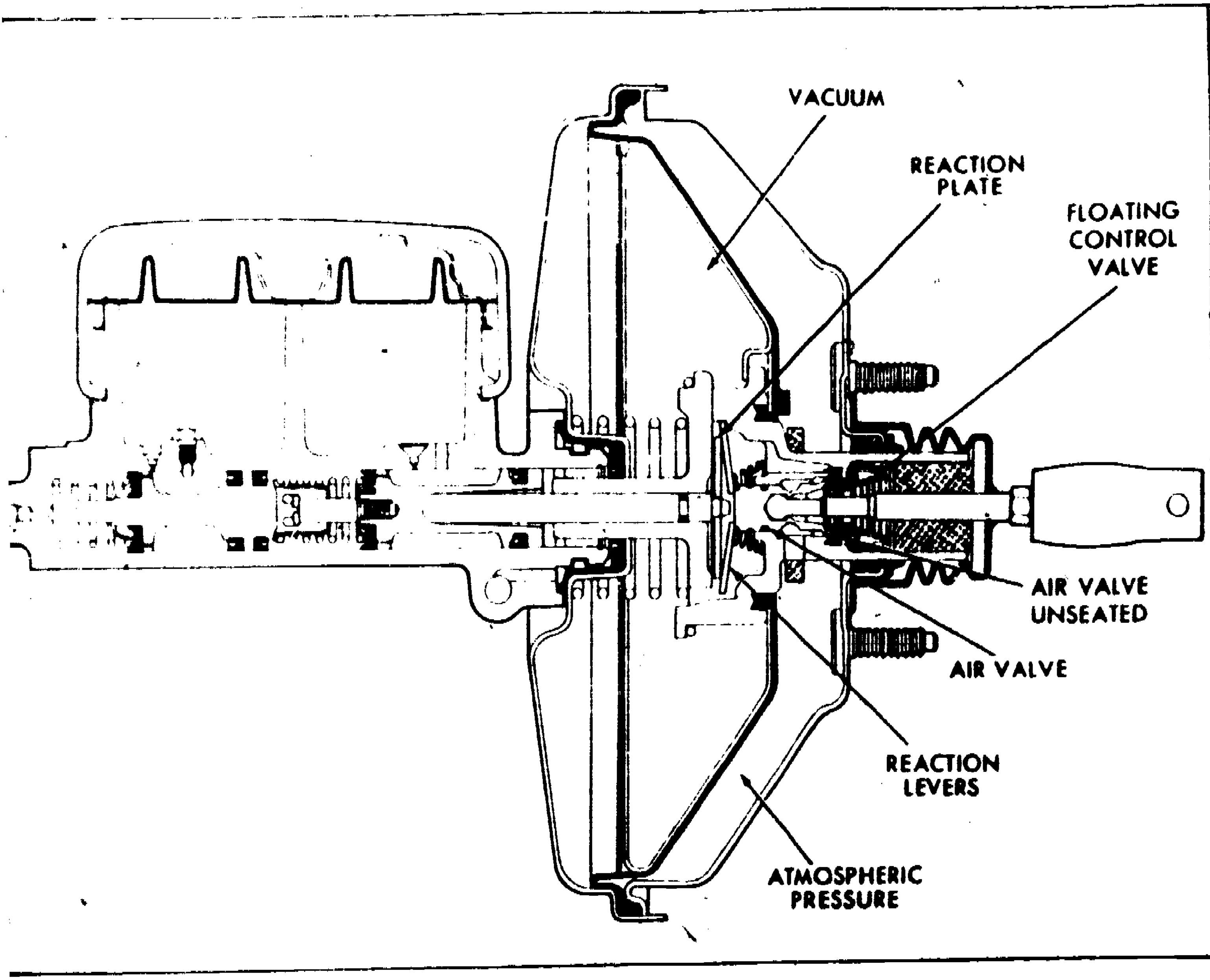

Figure 22. Typical Power Unit - Applying.

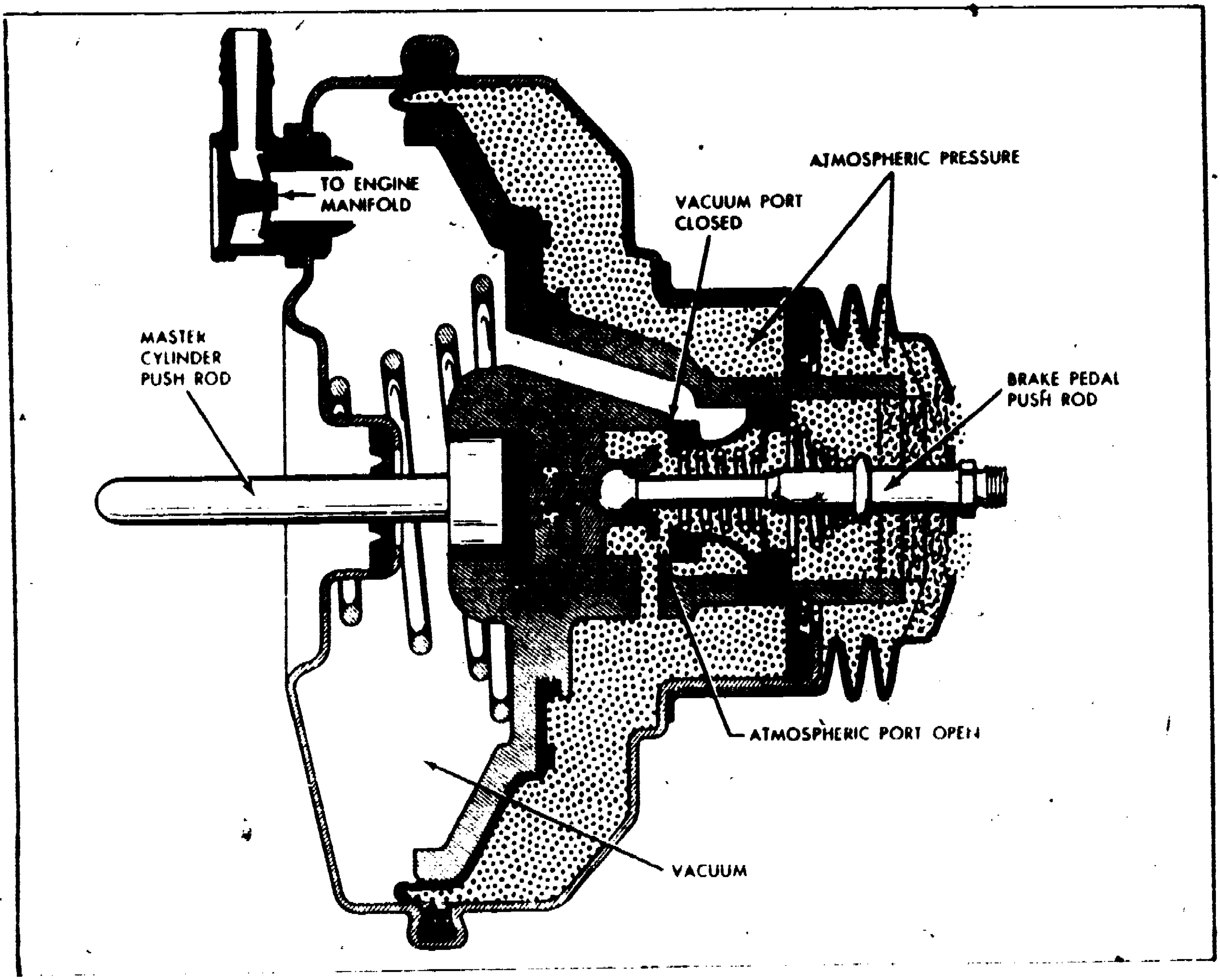

Figure 23. Typical Circuit - Applying.

2.

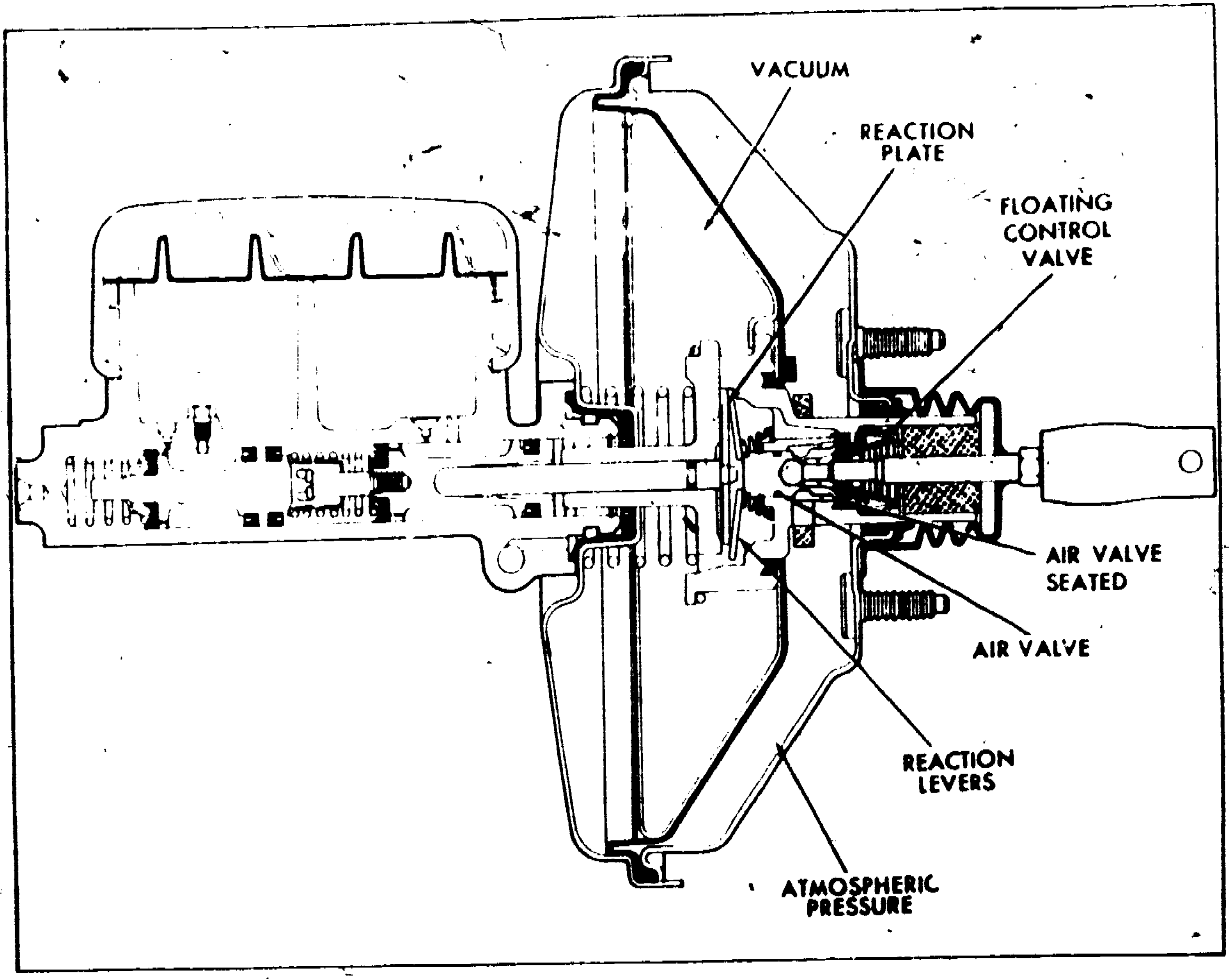

Figure 24. Typical Power Unit - Holding.

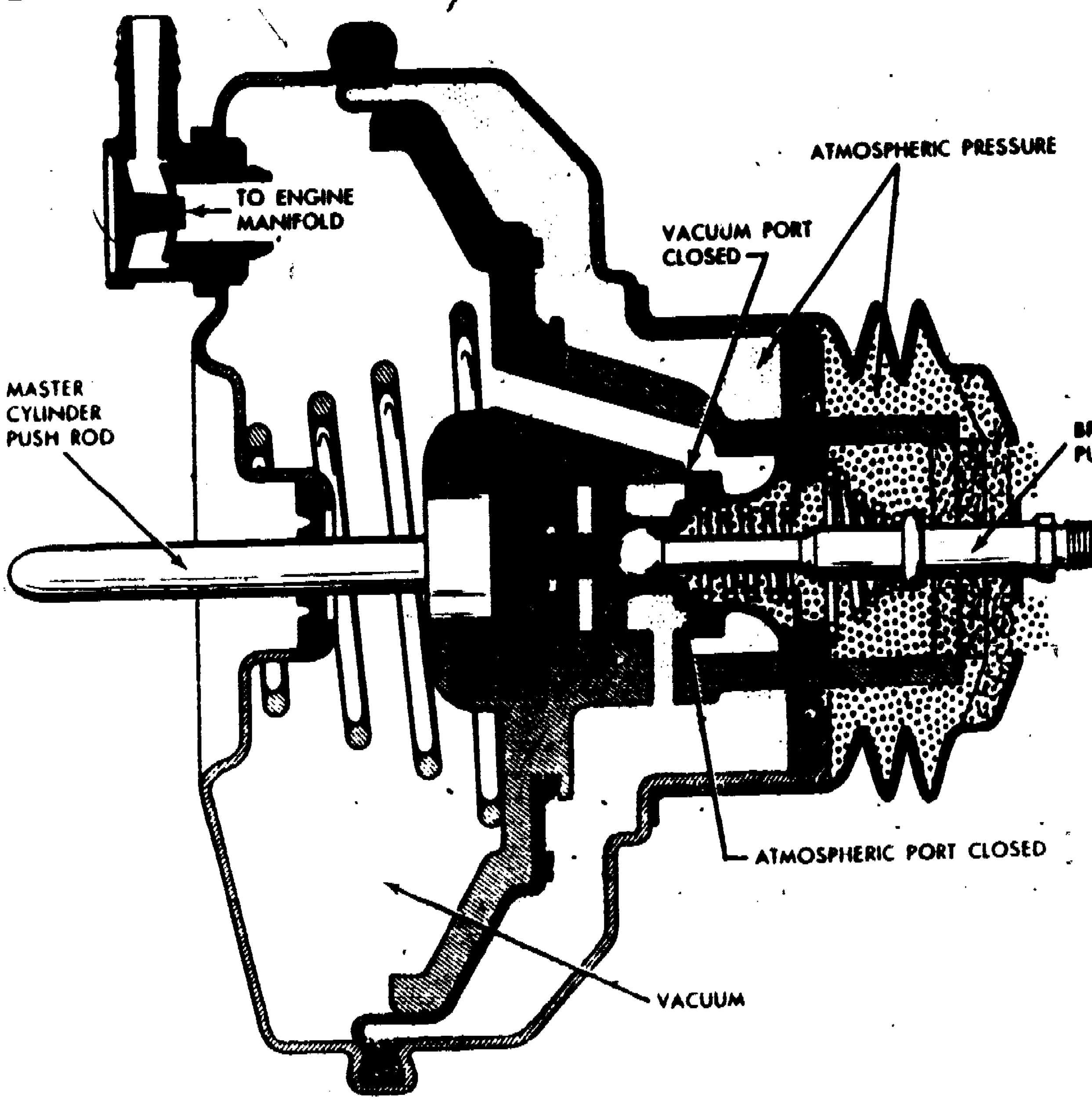

Figure 25. Typical Circuit - Holding.

piston and floating piston immediately return to the released position. If the fluid in the lines cannot return as quickly as the pistons, this is compensated for by the flow of fluid from the space between the primary cups and the secondary seals through the compensating holes in the pistons. The excess fluid in the system can flow back to the fluid reservoirs through the small compensating posts in the master cylinder bore.

In case of vacuum failure, the brake unit operates in the following manner:

As the pedal is pushed down, the end of the air valve contacts the reaction levers and pushes, in turn, against the hydraulic reaction plate. Since the hydraulic reaction plate is fastened to the master cylinder push rod, it forces the push rod against the master cylinder piston, which builds up the hydraulic line pressure. With this condition you have, in effect, a standard brake unit.

TROUBLESHOOTING POWER BRAKES

1. With transmission in park, stop the engine, and exhaust all vacuum in the system by depressing the pedal several times.

2. Depress the brake pedal and hold it in the applied position for one minute with approximately 20 lbs pedal force. If the pedal gradually falls away or the brake warning light comes on, it is an indication that the hydraulic system is leaking or that there is a malfunction in the master cylinder.

3. If the brake pedal feels spongy, it is an indication of air in the hydraulic system. Bleed the air from the system and recheck the pedal feel.

4. Depress the brake pedal and start the engine. If the vacuum system is operating the brake pedal will tend to fall away when the engine starts and less pedal pressure will be needed to hold it in the applied position. If no action is felt when the engine starts, the vacuum system is inoperative.

BRAKE SYSTEM MALFUNCTIONS

No Boost - Hard Pedal (Probable Cause)

1. Bent, broken, obstructed tube, collapsed hose.
2. Stuck check valve.
3. Air inlet blocked.
4. Air valve stuck.
5. Faulty diaphragm.
6. Faulty piston seal.
7. Leaks internally.

Note: For repair procedures, refer to applicable maintenance manual.

Slow Brake Pedal Return (Probable Cause)

1. Excessive seal friction in power unit.

2. Faulty valve action.

3. Broken return spring.

Note: For repair procedures, refer to applicable maintenance manual.

Brake Grabbing (Probable Cause)

1. Broken valve spring.

2. Sticking vacuum valve.

3. Reaction diaphragm.

Note: For repair procedures refer to applicable maintenance manual.

Brake Pedal Chatter (Bellows Type) (Probable Cause)

1. Power brake trigger is out of adjustment or bent.

2. Master cylinder push rod is improperly adjusted.

3. Power brake trigger rubber collar is missing or damaged.

4. Binding inside of power unit.

Note: If trouble is determined as being caused by the power booster, refer to the applicable service or overhaul manual for service procedure.

The preceding diagnoses are malfunctions that apply to most power brake systems. For further diagnoses of power brake systems, refer to the applicable service manual.

SERVICING BOOSTER

Removal and replacement of the vacuum booster should be accomplished by closely following the applicable service manual. Some manufacturers recommend replacement of the vacuum booster with a new one if the booster is damaged or inoperative. Some brake boosters are serviced only as an assembly.

READING ASSIGNMENT

In the manual provided by your instructor, locate and read portions dealing with the operation, troubleshooting and servicing of the vacuum booster.

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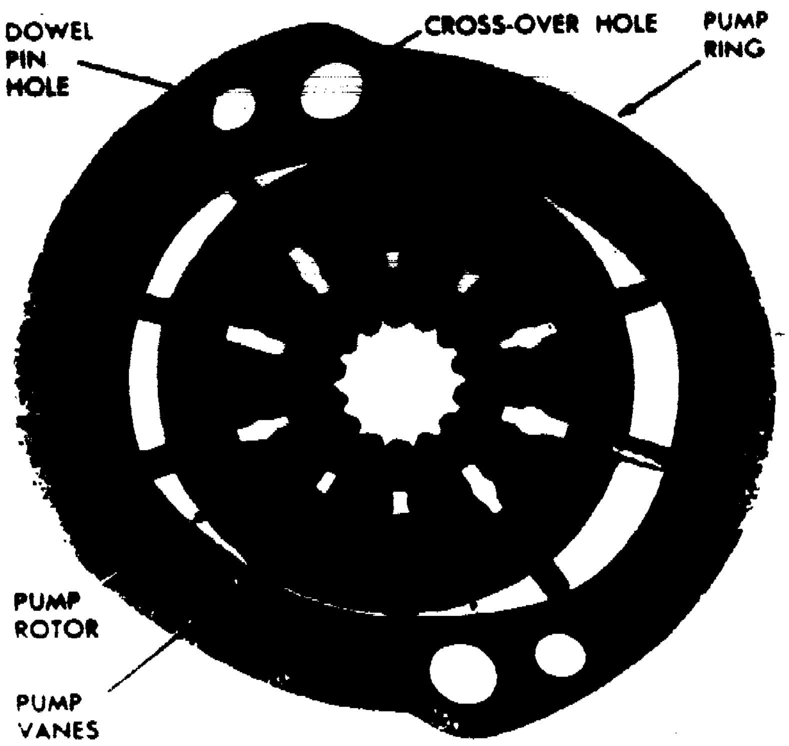


Figure 26. Vane Type Pump.

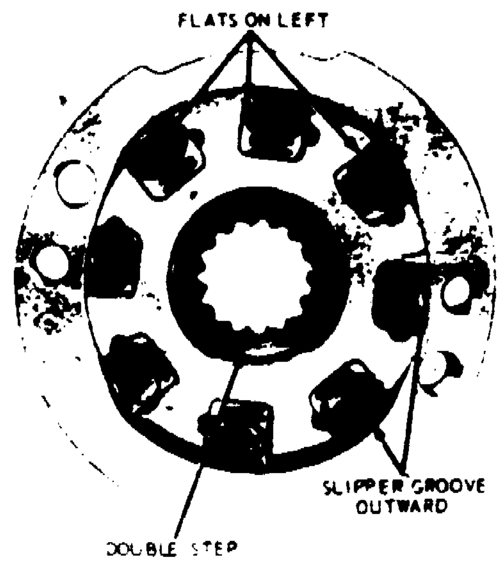
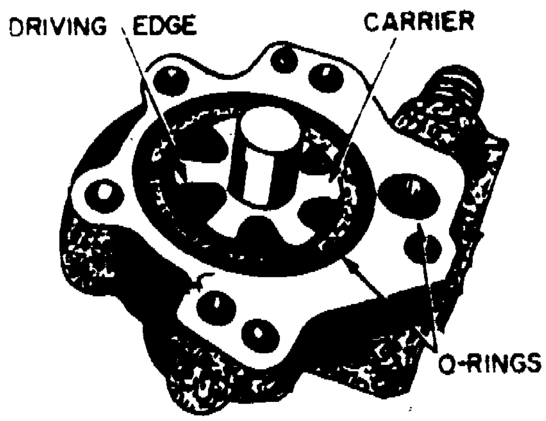


Figure 27. Slipper Type Pump.



ROLLER TYPE PUMP

Figure 28. Roller Type Pump.

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PRINCIPLES OF OPERATION AND SERVICING OF POWER STEERING SYSTEMS

OBJECTIVES

Upon completion of this unit of instruction you will be able to explain the principles of operation of the power steering assembly and also be able to service the system.

INTRODUCTION

Power steering at one time was an extra cost option on most vehicles. Today, many vehicles have power steering as a standard item of equipment. You, as a member of the Air Force vehicle maintenance team, must be able to diagnose troubles related to the power steering system and service this item when the need arises.

INFORMATION

The power steering unit furnishes power to reduce the amount of turning effort required at the steering wheel.

Because of the complexities and variations of the power steering systems that are available on the different makes of vehicles, we will cover only one extensively, "The Integral Power Steering System." We will discuss the integral system because it is most widely used system on automobiles today.

There are two distinct types of power steering in current automotive use. The first is the "tie-rod power assist" type and the second is the "steering gear power assist" which is the integral system.

The integral system is so called because the hydraulic assist unit incorporates as an integral unit with the steering gear. The following paragraphs cover the different components that make up the power steering system.

PUMP

There are three major types of hydraulic pumps used in conjunction with current automotive power steering. They are: (1) vane, (2) slipper, and (3) roller. Figures 26, 27 and 28 illustrate these three types of pumps.

Power steering pumps are either mounted on the engine and belt-driven from the crankshaft, fan drive pulley, or driven directly by the engine.

All power steering pumps have a fluid reservoir integrally mounted on top of the pump. A pressure relief and bypass valve is incorporated within the pump to prevent excessive pressure within the system.

The mode of operation of the power steering pump is based upon the demand of the power steering gear.

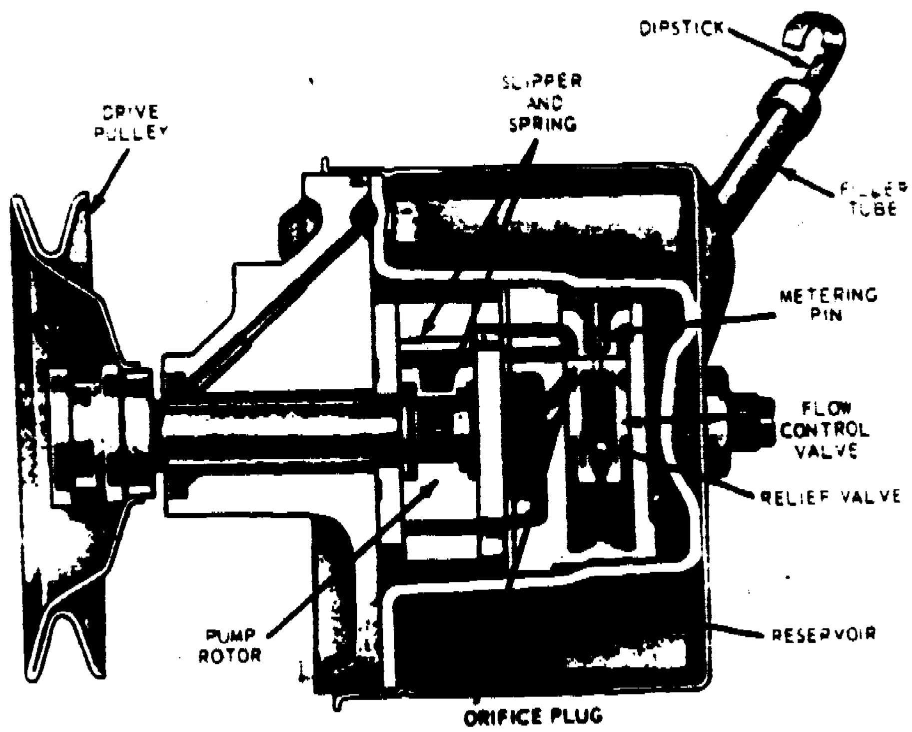

Figure 29. Power Steering Pump.

The various major modes of operation are: slow cornering, moderate to high speed straight ahead driving, and cornering against the wheel stop. The pump is designed to recognize these conditions as required by the steering gear valve and compensates for them internally. Figure 29 illustrates a power steering pump. All power steering pumps are positive displacement pumps, which means that they will move a definite volume of fluid depending on the speed at which they are operated.

STEERING GEAR - INTEGRAL SYSTEM

The integral power steering gear has an open center, three-way control valve, which directs oil to either side of the rack piston. The rack piston converts hydraulic power into mechanical output. The steering gear incorporates the recirculating ball system in which steel balls act as a rolling thread between the steering wormshaft and rack piston. The rack piston nut is geared to the sector of the pitman shaft. The control valve is contained in or on the gear housing. Figure 30 illustrates a power steering gear. Figure 31 illustrates a disassembled power steering gear assembly.

The fluid flow is continuous from the reservoir to the pump, to the control valve, and back to the reservoir.

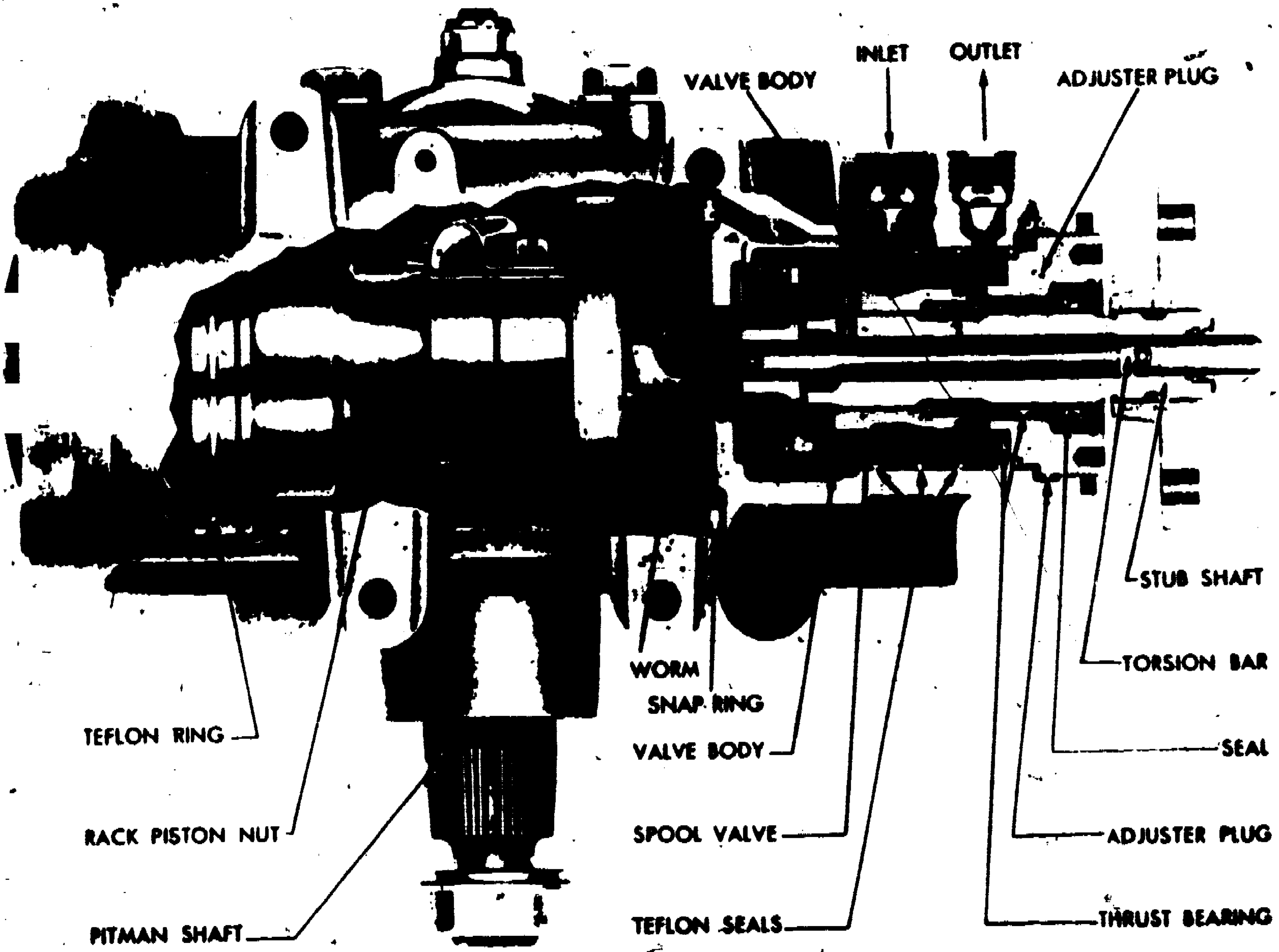

Figure 30. Power Steering Gear.

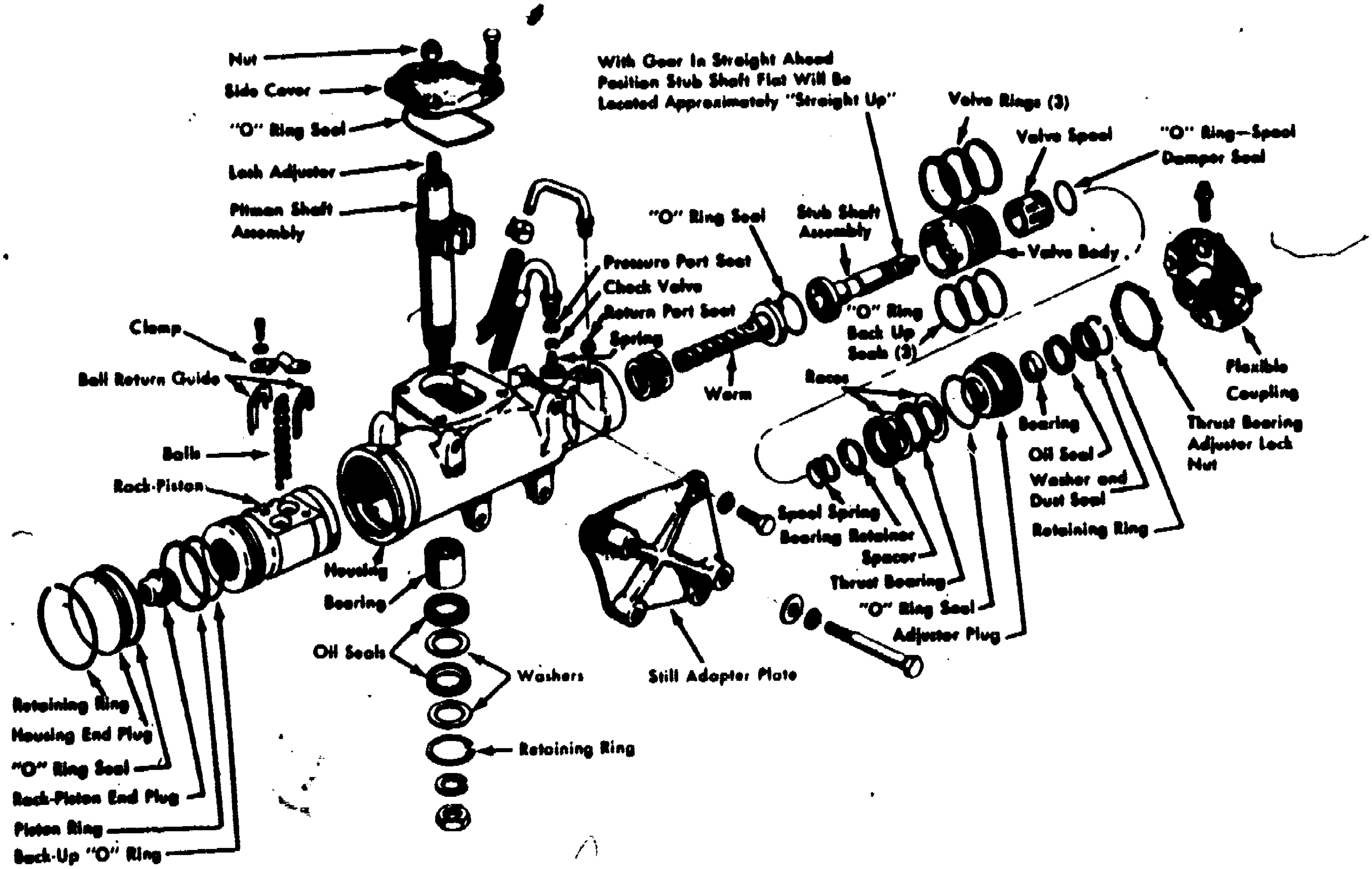

Figure 31. Power Steering Gear Assembly (Disassembled).

This type of power steering also opposes "road shock" or "kick-back" caused by rough roads. Some vehicles, especially those equipped with air conditioning, require a power steering system fluid cooler. The cooler compensates for the higher temperatures inherent in some vehicles, and protects the hoses and seals from excessive temperatures under extreme operating conditions.

The integral steering gears have internal oil passages within the gear except the pressure and return hoses between the valve and pump.

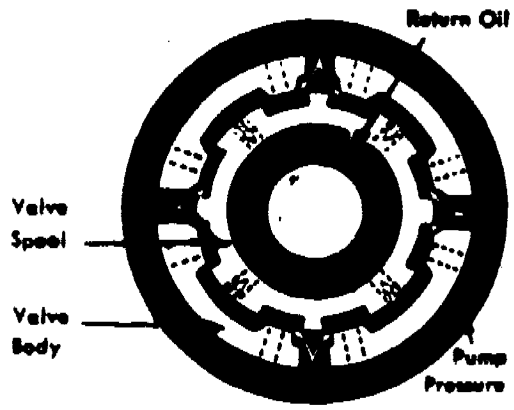

Figure 32. Valve Oil Flow - Straight Ahead Position.

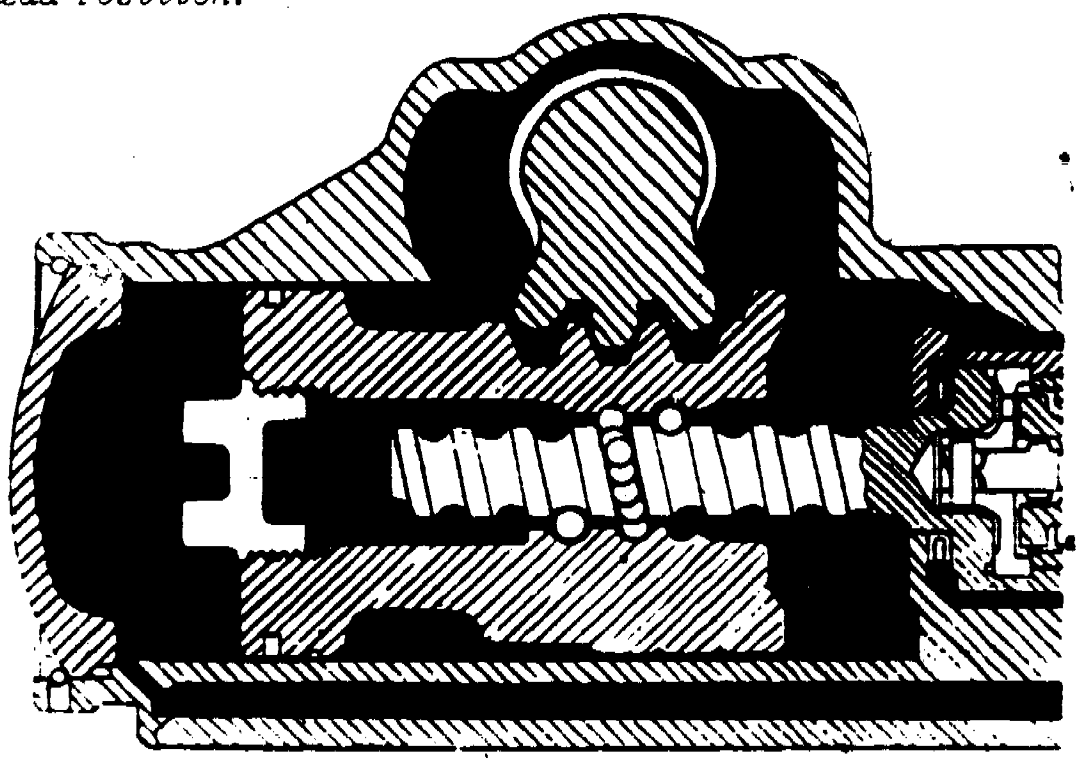

Figure 33. Steering Gear Straight Ahead Position.

POWER STEERING GEAR OPERATION

With the steering wheel in straight ahead position, oil flows from the pump through the open center valve and back to the pump reservoir without traveling through the power cylinder. See figure 32. The valve is in the open-center position at all times except when steering, reducing pump losses to a minimum. The power gear assembly is always full of oil which acts as a cushion to absorb road shocks so that they are not transmitted to the driver. In addition, this oil lubricates all the internal components of the gear, as shown in figure 33.

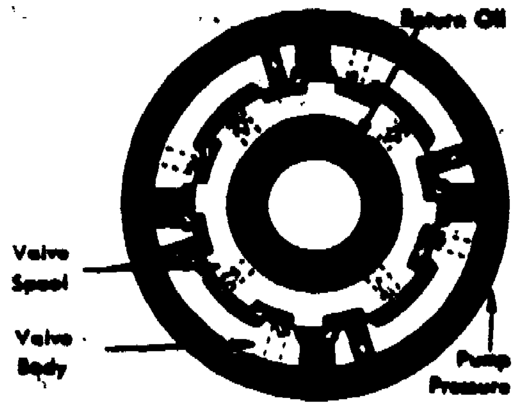

Figure 34. Valve Oil Flow - Right Turn Position.

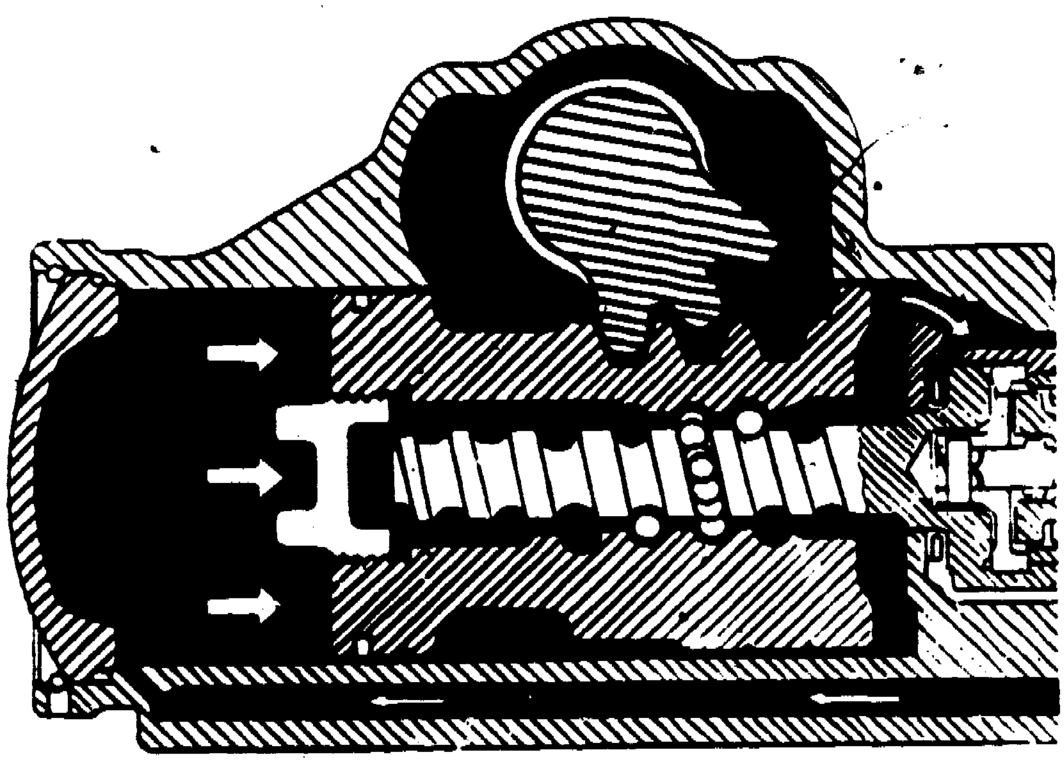

Figure 35. Steering Gear Oil Flow - Right Turn Position.

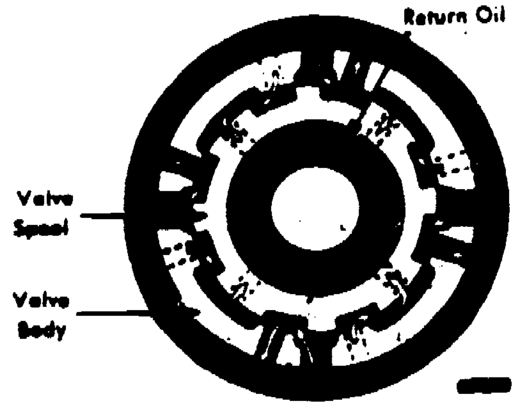

Figure 36. Valve Oil Flow - Left Turn Position.

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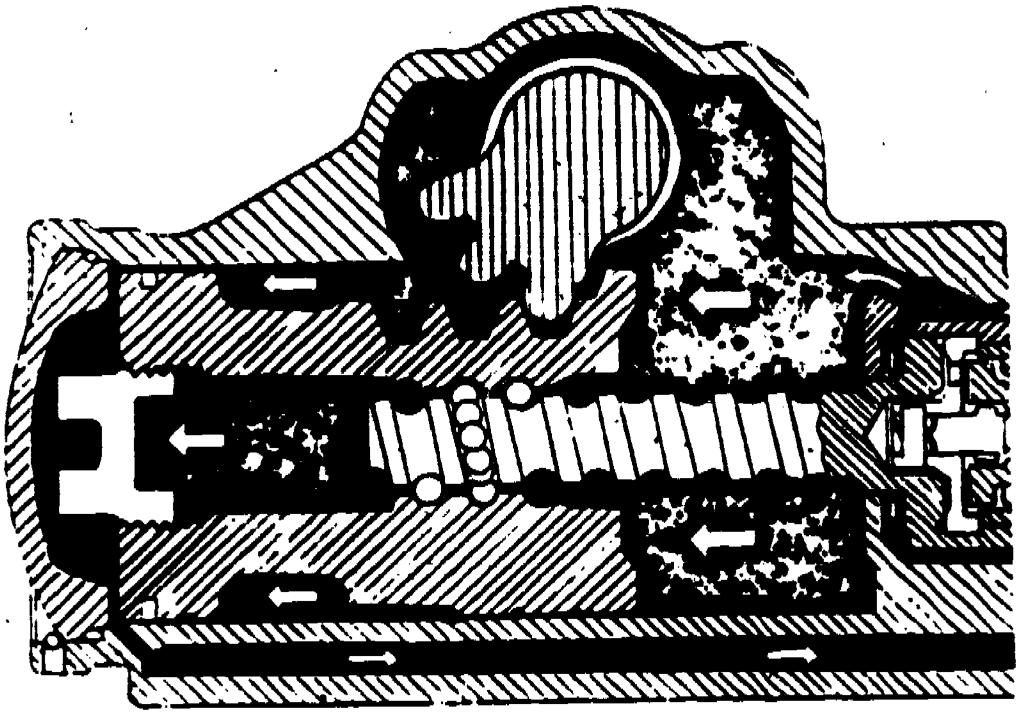

Figure 37. Steering Gear Oil Flow - Left Turn Position.

When the steering wheel is turned to the right or left, due to the turning resistance between the front wheels and the road, the steering control valve is actuated. The respective power cylinder piston face will be pressurized while the opposite end will be open to return fluid to the reservoir. Refer to figures 34, 35, 36 and 37 for the various positions.

During slow cornering maneuvers, figure 38, the oil pressure required will usually not exceed 400 psi. The speed of the pump is not high enough to require internal bypassing of oil, therefore, the pump bypass port remains closed. The high pressure discharge oil is slightly lower in pressure than the internal high pressure oil. The drop in pressure occurs as oil flows through the flow control orifice. This lower pressure is communicated to the bottom end of the pump control valve, via orifice and passage, resulting in a pressure unbalance on the valve itself. The flow control valve moves away from the discharge fitting, but due to the force of the flow control spring the valve remains closed to the bypass hole. The oil pressure does not build up high enough to cause the pressure relief valve to actuate because the oil pumped through the steering gear is allowed to recirculate through the entire system.

When operating at moderate to high speed, figure 39, it is desirable to limit the temperature rise of the oil. This is done by flow controlling. The control valve in the steering gear is an open center rotary valve. When this valve is in the straight ahead position, oil flows from the pump through the open center valve and back to the pump reservoir without traveling through the power cylinder. When this flow exceeds the predetermined system requirement, oil is bypassed within the pump. This is accomplished by the pressure drop which

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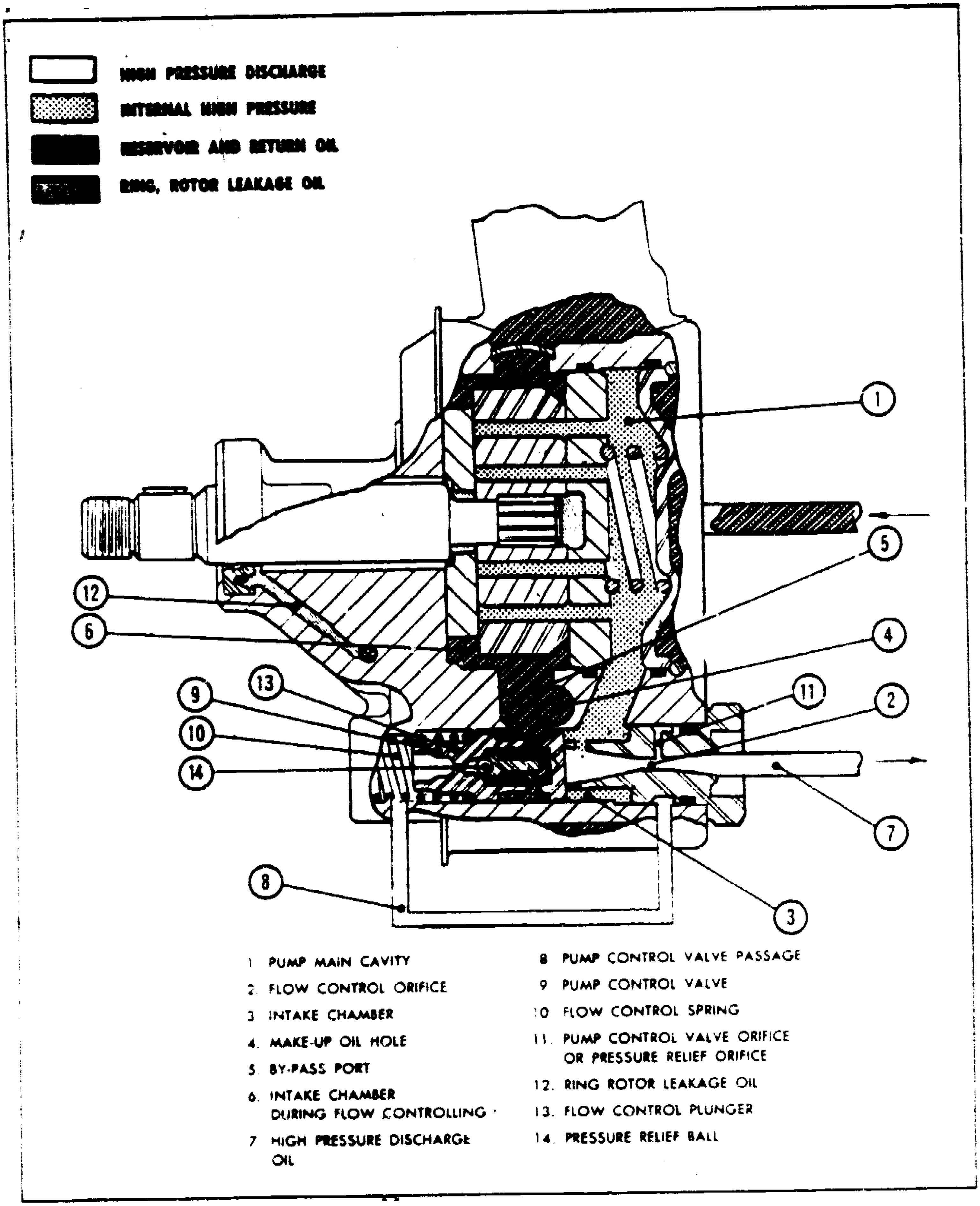

Figure 38. Pump Flow During Slow Cornering.

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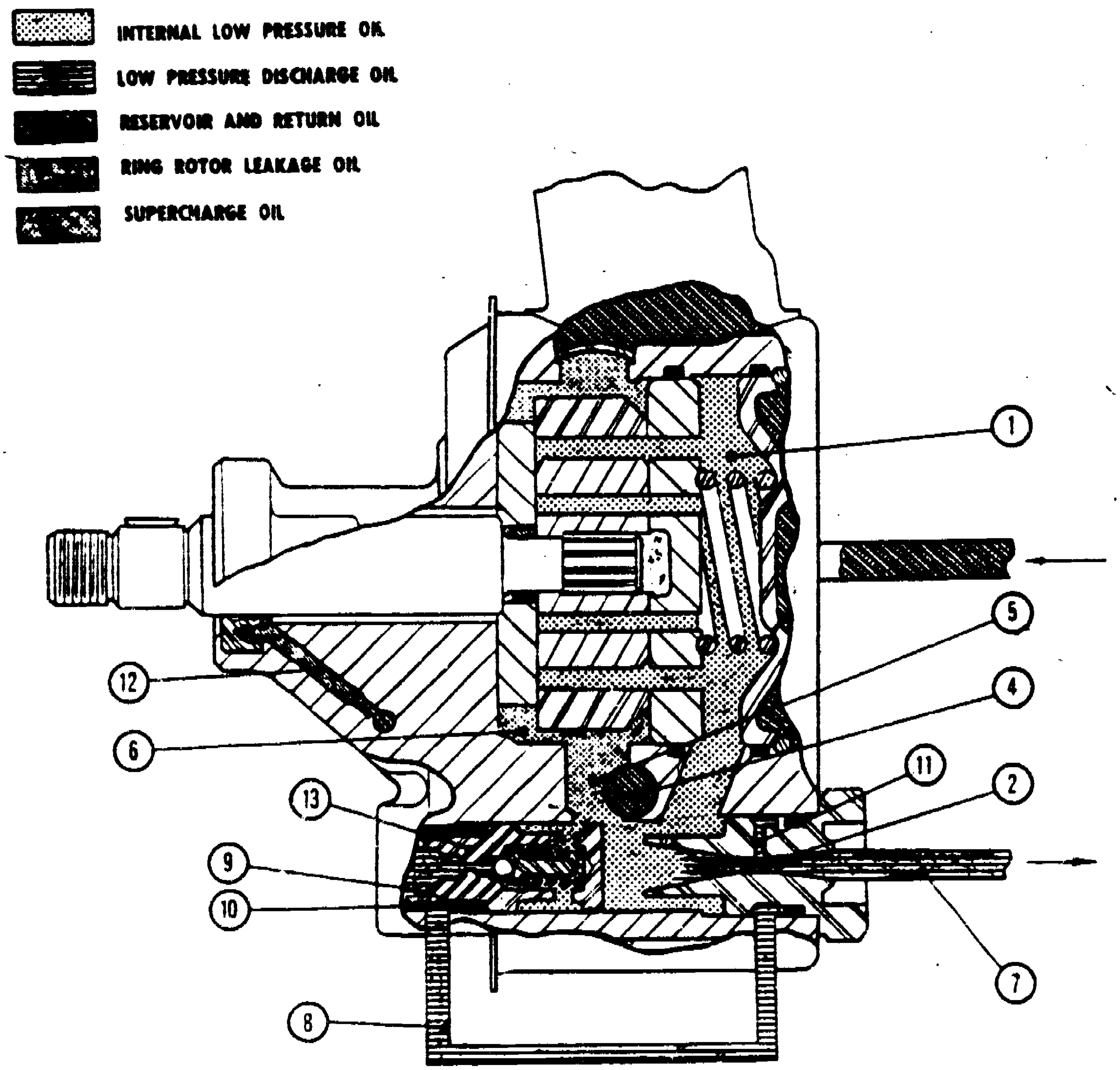

1. PUMP MAIN CAVITY
2. FLOW CONTROL ORIFICE
3. INTAKE CHAMBER
4. MAKE-UP OIL HOLE
5. BY-PASS PORT
6. INTAKE CHAMBER DURING FLOW CONTROLLING
7. HIGH PRESSURE DISCHARGE OIL
8. PUMP CONTROL VALVE PASSAGE
9. PUMP CONTROL VALVE
10. FLOW CONTROL SPRING
11. PUMP CONTROL VALVE ORIFICE OR PRESSURE RELIEF ORIFICE
12. RING ROTOR LEAKAGE OIL
13. FLOW CONTROL PLUNGER
14. PRESSURE RELIEF BALL

Figure 39. Pump During Flow Controlling (Moderate to High Speed Operation).

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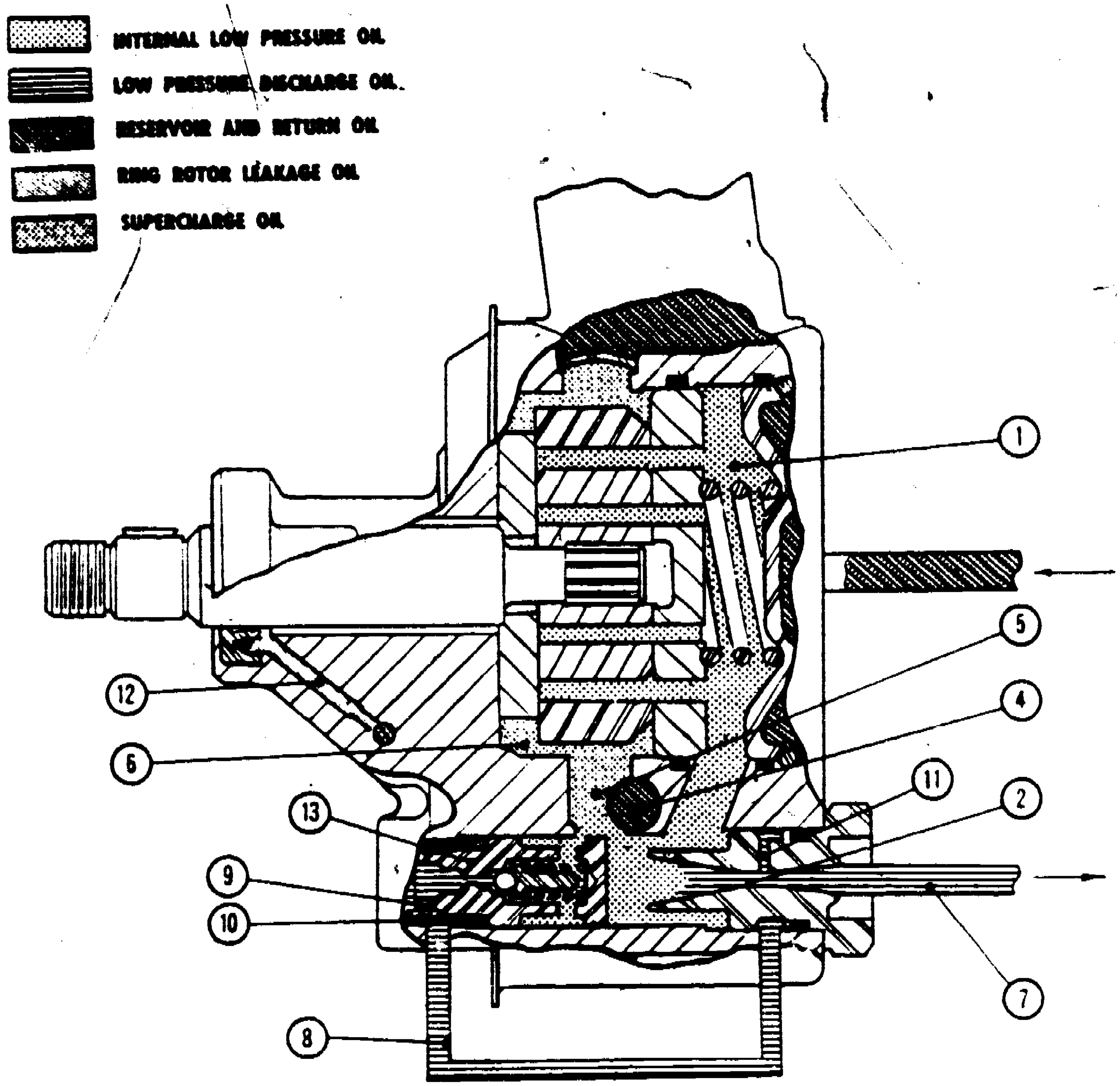

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12. RING ROTOR LEAKAGE OIL
13. FLOW CONTROL PLUNGER
14. PRESSURE RELIEF BALL

Figure 40. Pump During Flow Controlling (Moderate to High Speed Operation).

occurs across the flow control orifice. The pressure is reduced at the bottom of the flow control valve, via orifice and passage. The pressure unbalance on the valve is sufficient to overcome the force of the spring, allowing the valve to open the bypass hole and diverting oil into the intake chamber. Supercharging of the intake chamber occurs under these conditions. Oil at high velocity discharging past the valve into the intake chamber picks up make-up oil at the hole from the reservoir on the jet pump principle. By reduction of velocity, velocity energy is converted into super charged pressure in the cavity. During this straight ahead driving condition, the discharge pressure should not exceed 100 psi.

When the steering gear control valve is actuated in either direction to the point of cut-off, the flow of oil from the pump is blocked. This condition occurs when the front wheels meet the wheel stop, figure 40, or when the wheel movement is otherwise blocked by a curb or deep sand or mud. The pump is equipped with a pressure relief valve. The relief valve is contained inside the flow control plunger. When the pressure exceeds a predetermined pressure (greater than maximum system requirements), the pressure relief ball unseats, allowing a small amount of oil to flow into the bypass hole. This flow of oil passing through the pressure relief orifice causes a pressure drop and resulting lower pressure on the bottom end of the control valve.

The pressure unbalance then causes the valve to compress the spring allowing the major portion of the oil to bypass into the intake chamber in the same manner as is accomplished by flow controlling. Relief pressures are usually between 750 and 1450 psi depending on the vehicle requirements. Refer to applicable service manual for recommended specifications.

If the engine is not running or the power system should fail, the steering gear will operate manually, with increased steering effort, giving the driver full control of the car.

SERVICING POWER STEERING SYSTEM

Conditions such as shimmy, hard or loose steering, and road shocks may be caused by damaged or faulty front suspension and steering components, steering shaft and coupling alignment, front end alignment, shock absorbers, wheel bearings, wheel balance, tires or tire pressure. These items should all be checked for proper operation before performing repairs on the power steering system. Before doing any major service work, check and correct the fluid level and condition, belt adjustment, pump pressure, and steering gear adjustment. Always refer to the applicable service manual for removing and replacing procedures of the steering gear assembly.

Disassembly and assembly of the unit and the subassemblies must be made on a clean work bench. Cleanliness is of utmost importance in repairing this or any other hydraulically operated unit. The bench, tools, and parts must be kept clean at all times. Thoroughly clean the exterior of the unit with a suitable solvent and when necessary drain as much of the oil as possible.

Lubrication of the hydraulic mechanism is not required. However, check the hydraulic fluid level in the reservoir periodically and replenish to the indicated level mark. Use the manufacturer's recommended fluid or its equivalent. For repairs of the steering gear on the vehicle, refer to applicable service manual.

READING ASSIGNMENT

In the manual provided by your instructor, locate and read portions covering the operation and servicing of the power steering system.

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TROUBLESHOOTING AND MAINTENANCE OF POWER STEERING COMPONENTS

OBJECTIVES

Upon completion of this unit of instruction, you will be able to troubleshoot and explain the repair procedures of the power steering system of general purpose vehicles.

INTRODUCTION

The vast majority of power steering gears and pumps are remarkably dependable and trouble-free. As a matter of fact, the only things that must be checked periodically are pump drive belt adjustment and power steering fluid level. But seldom is anything absolutely fool-proof so power steering troubles do happen now and then to tax your diagnostic know-how and service skills.

The information in this study guide will improve your know-how and tip you off to the more common service pitfalls.

INFORMATION

Many factors affect power operation of the steering system, of which the most common are:

1. Fluid level and condition.

2. Drive belt tension.

3. Loose component mountings.

4. Loose pump pulley.

These factors must be checked and corrected before making any further diagnoisis of the steering system. The need for proper diagnosis cannot be over-emphasized.

After the source of the problem has been found, determine the cause. For example, if the oil level in the reservoir is found to be low, refill and check the entire hydraulic system for oil leaks.

When adjusting a power steering pump belt, never pry against the pump reservoir or pull against the filler neck. To increase belt tension move the pump outward by prying against the pump housing casting extension directly behind the pump drive pulley. Pump drive belt tension cannot be checked accurately using the thumb pressure or belt deflection methods. Correct belt adjustment is assured only with the use of a belt tension gauge. Tension settings differ in that if the belt is old or new. A belt that has been run longer than 15 minutes is considered an old belt.

During the breaking-in period of the vehicle, it is probable that some of the factory adjustments will change. These changes in adjustment do not necessarily affect the satisfactory operation of the steering gear assembly and ordinarily do not require readjustment unless there is excessive lash or other malfunctioning. The only adjustment that should be performed in the vehicle is the total over center position load (mesh load) to eliminate excessive lash between the sector shaft and rack teeth. Always refer to the applicable service manual for adjustment procedures.

Another check for locating malfunctions is the power steering flow and pressure test which will show whether the pump, steering gear or power assist control valve is causing the trouble. Refer to the applicable service manual for pump flow and pressure test procedures.

MALFUNCTION DIAGNOSIS GUIDE

In the following paragraphs are some malfunctions and probable causes that are usually common to all or nearly all power steering systems. For all inspections or servicing of the systems or components always refer to the applicable technical publication.

Hard or Erratic Steering

1. Low or uneven tire pressure.

2. Incorrect steering gear adjustment.

3. Improper front wheel alignment.

4. Insufficient or incorrect lubrication.

5. Suspension parts, steering, or linkage components damaged or misaligned.

6. Tight wheel bearings.

7. Sagging springs.

Excessive Play or Looseness in the Steering

1. Steering wheel loose on shaft.

2. Steering gear adjustment loose or parts badly worn.

3. Steering linkage or attaching parts loose or worn.

4. Steering arms loose.

5. Loose or worn wheel bearings.

6. Steering gear housing attaching bolts loose.

7. Pittman arm loose on shaft.

Wheel Shimmy or Tramp

1. Wheels, tires, or brake drums out of balance - wheel run-out.

2. Loose or worn steering parts or connections.

3. Incorrect tire pressure.

4. Inoperative, loose, or worn shock absorbers or mounting parts.

5. Loose or worn wheel bearings.

6. Incorrect steering gear adjustments.

7. Cupped, eccentric, or bulged tires.

8. Incorrect front wheel alignment.

Pump Leaks

1. Pump shaft seal worn or damaged.

2. Reservoir too full.

3. Inlet or outlet connections damaged.

4. Reservoir or pump body "O" rings or gaskets damaged.

5. Porosity in pump casting.

Noisy Pump Operation

1. Low fluid level.

2. Drive shaft or pulley loose or bent.

3. Air in system. Check vent in reservoir cover-bleed system.

4. Pump bushings or internal parts worn or scored.

5. Dirt in pump or gear.

6. Slipping drive belt.

7. Loose mounting parts; hoses touching other parts of the vehicle.

Hard Steering or Insufficient Power Steering Assistance

1. Weak oil flow in system. Inspect pump relief valve and flow control valve; inspect oil hoses for restrictions.

2. Drive pulley loose.

3. Drive belt worn, slipping, or oil on belt.

4. Lack of pump speed due to low engine idle.

Hard Steering While Driving

1. Lower coupling flange rubbing against adjuster.

2. Incorrect column alignment.

Hard Steering When Parking

1. Loose pump belt.

2. Low oil level in reservoir.

3. Improper lubrication in linkage or front suspension.

4. Low or uneven tire pressure.

5. Insufficient oil pressure - check operating pressure.

Low Oil Pressure

1. Restrictions in hoses; kinks or foreign objects in hoses.

2. Pressure loss in cylinder due to worn piston ring or scored housing bore.

3. Leakage at valve rings, valve body to worm seal, or rack-piston end plug.

4. Loose fit of spool in valve body or leaky valve body.

Steering Wheel Surges or Jerks When Turning With Engine Running, Especially When Parking

1. Loose pump belt.

2. Low system pressure.

Poor Return of Steering Gear to Center

1. Lower coupling flange rubbing against adjuster.

2. Steering wheel binding.

3. Incorrect tire pressure.

4. Incorrect front end alignment.

5. Tight steering linkage.

6. Tie-rod ball studs not centered.

7. Steering gear misalignment.

8. Tight suspension ball joints.

9. Steering adjustment tight. Disconnect pitman arm and readjust.

10. Thrust bearing adjustment too tight.

11. Rack-piston nut and worm preload too tight.

12. Sticky valve spool - remove and clean valve or replace valve.

Momentary Increase in Effort When Turning Wheel Fast to Right or Left

1. Oil low in pump.

2. Pump belt slipping.

3. High internal leakage - replace rack-piston ring and "O" ring, rack-piston end plug, valve body to worm seal, and/or replace valve assembly.

External Oil Leaks

1. Loose hose connections.

2. Damaged hose.

3. Defective side cover "O" ring seal.

4. Defective pitman shaft seals.

5. Defective housing end plug seal.

6. Defective adjuster plug seal.

7. Defective torsion bar seal.

Gear Noise (Rattle or Chuckle)

1. Loose over-center adjustment.

2. Flexible coupling misaligned and rubbing.

3. Gear loose at frame mounting.

Excessive Wheel Kickback or Loose Steering

1. Lash in steering linkage or suspension components.

2. Air in system.

3. Steering gear loose on frame.

4. Excessive lash between pitman shaft sector and rack-piston.

5. Loose thrust bearing adjustment.

6. Shaft flex coupling loose.

7. Ball nut and worm preload incorrect.

Valve Squawk When Turning or Recovering from a Turn

1. Cut or worn damper ring on valve spool.

2. Loose or worn valve.

No Effort Required to Turn

1. Broken torsion bar - requires valve replacement.

2. Damaged torsion bar.

READING ASSIGNMENT

In the manual provided by your instructor, locate and read portions pertaining to preliminary checks and troubleshooting of the power steering system.

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PREPARE THE MAN

232

PROGRAMMED TEXT 3ABR47~~330~~-PT-601
3ABR47231-1-PT-601
3ABR47231A-PT-601
3ABR47231B-PT-601
3ABR47231C-PT-601

Technical Training

8-12

General Purpose Vehicle Repairman
Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Crash/Fire Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)

HYDRAULIC BRAKE SYSTEM

23 November 1971

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-PT-601, 22 April 1970.
OPR: TDWS
DISTRIBUTION: X
TDWS - 800; TTOC - 6

Designed For ATC Course Use
Do Not Use on the Job.

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OBJECTIVES

After completing this programmed text you will be able to accomplish the following objectives with 85% accuracy.

1. State two hydraulic principles used in hydraulic brake system operation.

2. State how the pressure in a hydraulic brake system is indicated.

3. Given the area of a brake cylinder piston and the applied force, compute the system pressure.

4. State the rule of thumb used to design a typical brake system in relation to engine size.

5. List the two fluids used to compose hydraulic brake fluid.

6. List the major components of the hydraulic brake system.

7. Given an illustration of the following components label the part of each one:

    a. Master cylinder.

    b. Wheel cylinder.

    c. Drums and shoes.

8. State the purpose of bleeding a brake system.

VALIDATION

This programmed text was validated in 1964 by 30 students enrolled in the 3ABR47330 course at Chanute AFB. At least 90% of the students used in the validation exercise achieved the objectives as stated. The text has trained approximately 5000 students and is considered to be still valid.

INSTRUCTIONS

The Programmed Text which you are about to use will teach you some basic information about hydraulic brake systems. The information will include: identification of components, location of components, hydraulic principles, and some repair procedures to be followed. You will receive additional training in the shop, but the information you receive from this package will make your work in the shop easier. The program is presented in a series of small steps called "frames." You will be required to make a response to most of these frames, and the responses will help strengthen your knowledge of the material. Record your responses in Response Booklet 3ABR47330-PT-601. Check your answer with the one given at the top of the next frame. If they are the same proceed to the next frame. If your answer is different, reread the frame to find your error before moving ahead to the next frame. At the completion of this program you will be given a test which covers the material. Read the background information immediately below then proceed to Frame 1 on the top of the next page. Answer all questions in the response booklet.

BACKGROUND

One problem that has "bugged" the designer of every vehicle is "How to stop it?" Early animal-drawn vehicles could be stopped successfully by application of a block of wood, sometimes covered with iron, to the rim of one of the wheels. The principal use of such a brake was to hold the vehicle while it was stopped, rather than to stop it while in motion. The animals which pulled the vehicle were also trained to voice and rein signals and to use their weight and strength to stop the vehicle. As mechanical propulsion began to replace animals, the need for more efficient stopping or braking mechanisms soon became evident. From about 1905 until 1928 vehicles manufactured in the U.S. were equipped with brakes on the rear wheels only. At this time several states passed legislation which required all vehicles manufactured after that date to be equipped with brakes on all wheels. Most vehicle manufacturers still favored mechanically-operated brakes actuated by rods or cables. As the vehicles became faster, heavier, and more numerous, the need for better braking systems became more critical. The manufacturers who pioneered the use of hydraulic brake systems received the approval of the buying public, and competition finally forced all manufacturers to adopt them. The last major manufacturer to adopt hydraulics put them on in 1939. Since that date, only the parking brake is mechanical.

We said that early brakes were merely a wooden block which was applied to the outer rim of the wheel. In a modern automobile the wheels may be turning as fast as 1,500 revolutions per minute. This speed would make any sort of primitive brakes not only impractical, but impossible. Braking action in the modern vehicle is the result of friction between a rotating drum and a set of movable shoes. The drum is secured to the wheel and the shoes are mounted to the vehicle at the axles. The shoes are actuated by pistons in a hydraulic cylinder.

QUESTION 1.

Which of the statements below are correct? (Mark your answer in the Response Booklet.)

a. Braking action is caused by the contraction of the brake shoes.

b. Friction between the shoes and the drums causes braking action.

c. Pistons in a hydraulic cylinder actuate the brake shoes.

d. Brake shoes actuate pistons in the hydraulic cylinder to stop the vehicle.

Frame 2.

Statements "b" and "c" are both correct.

One of the hydraulic principles used in designing hydraulic brake systems is that fluids cannot be compressed under ordinary pressures. With this principle in mind, the problems are reduced to finding a way to transmit the fluid where needed, sealing it against leaks, and determining how much pressure must be applied to perform the task of stopping the vehicle.

QUESTION 2.

? ?

? In the parenthesized statement below, select the word or words which make it a true statement. Write the word in the provided space in your Response Booklet. ?

? "Fluids (can) (cannot) be compressed under ordinary pressures." ?

? If you picked "cannot" you are correct. Proceed. If you picked anything else, you don't belong here. ?

? ?

QUESTION 3.

? ?

? Fill in the blank provided for Question 3 in your Response Booklet. ?

? Since fluid cannot be ________________ under ordinary pressures, the next move is to determine how much pressure is needed to perform the task of stopping the vehicle. The essential factors here are the weight of the vehicle and the speed at which it is to be operated. Pressure generated in a hydraulic brake system may run up to 1,400 pounds per square inch (PSI). ?

? ?

Answer to Question 3:

You should have answered "compressed."

QUESTION 4.

? ?

? How high in pounds per square inch, is the pressure of a hydraulic ? brake system? __________ PSI. (Answer in the Response Booklet.)

? ?

Check your answer at the top of Frame 4.
If you are incorrect, return to Question 3 at the bottom of Frame 2 and read it again.

We have learned that one of the principles of hydraulics applied to the design of brake systems is that fluids cannot be compressed under ordinary pressure. Another principle used is that force may be transmitted through fluids in a closed system.

QUESTION 5.

? ?

? How is force transmitted in a hydraulic brake system? ?

? Write your answer in the space provided in your Response Booklet. ?

? ?

Frame 4.

Answer to Question 4 is <u>1,400</u> PSI

Answer to Question 5: Through fluids, since they cannot be compressed. (You may not have included the last portion of the answer, but it is in direct correlation.)

QUESTION 6.

? ?

? What is the physical use of fluids in a hydraulic brake system? ?

? (Write your answer in the blank space provided in your Response ? Booklet)

? ?

The answer to Question 6 is: Fluids are used to transmit force in a hydraulic brake system (or words to that effect).

If force is transmitted through fluids, pressure must be applied to create this force. Since there must be a means of describing and measuring this force the term "pounds per square inch" or PSI was selected as being the most descriptive. This is a common means of measuring gases and fluids.

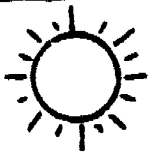
QUESTION 7.

? ?

? How is the pressure in a hydraulic brake system indicated? ?

? (Write the answer in the space provided in your Response Booklet.) ?

? ?



The answer to Question 7 is: **Pressure in a hydraulic brake system is indicated in pounds per square inch, or its abbreviation "PSI." (PSI is sufficient.)**

QUESTIONS 8, 9, and 10.

? ?

? As a review of what has been covered so far, complete the sentences ? below by writing the answers in the space provided in the Response ? Booklet.

Question 8. **Fluids cannot be ______________ under ordinary pressures.** ?

? Question 9. **Force may be ______________ through fluids in a closed system.** ?

? Question 10. **Pressure in a hydraulic brake system is measured in ____________ ______ ____________ ____________** ?

? ?

Frame 6.

The answers to the questions asked in Frame 5 are:

8. compressed.
9. transmitted.
10. pounds per square inch.

We have learned that pressure must be applied to the system to create the force which is transmitted to the wheels to stop the vehicle. We have learned that this pressure is measured in pounds per square inch. The amount of pressure is determined by dividing the applied force (in pounds) by the area of the piston (in square inches) to which this force is applied. Thus, a piston with an area of 3 square inches to which a force of 15 pounds is applied will create a pressure of 5 pounds per square inch, or 5 PSI.

QUESTIONS 11, 12, and 13.

? ?

Complete the statements below. Write your answers in the Response Booklet.

Question 11. With a piston of 4 sq. in. area and a force of 20 pounds, what would be the pressure created?

______________________________.

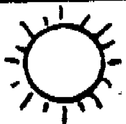
Question 12. With a piston having 5 sq. in. and a force of 30 pounds, what pressure would be created?

______________________________.

Question 13. A force of 24 pounds exerted on a piston having 3 sq. in. would give what pressure in the system?

______________________________.

? ?



The answers to the questions asked on Frame 6 are:

Question 11. 20 divided by 4 = 5 pounds per sq. in. or 5 PSI.
Question 12. 30 divided by 5 = 6 PSI.
Question 13. 24 divided by 3 = 8 PSI.

As can be readily seen, the formula remains constant and changing the values for the piston area and the force applied will enable the designer of the brake system to create any pressure needed to stop the vehicle. A rule of thumb used by brake system engineers is to design the braking system to control eight times the horsepower of the engine to be used in the vehicle.

QUESTIONS 14, 15, and 16.

??? ?

Complete the statements below, by writing your answers in the spaces provided in your Response Booklet.

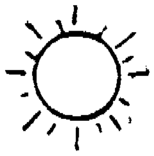
Question 14. If the engine of a vehicle develops 200 horsepower, how much horsepower control will be designed into the brak system? ____________________.

Question 15. If the engine develops 250 horsepower, how much control will be designed into the vehicle's brake system? ____________________.

Question 16. With a 300 horsepower engine, how much control is required? ____________________.

? ?

Frame 8.



The answers to the questions asked on Frame 7 are:

Question 14. 1,600 horsepower.
Question 15. 2,000 horsepower.
Question 16. 2,400 horsepower.

QUESTIONS 17, 18, 19, and 20.

? ?

? Complete the statements below by writing your answers in the spaces provided in your Response Booklet. ?

Question 17. How is pressure determined, and how is it expressed?

Question 18. A force of 25 pounds applied to a piston of 5 sq. in. area would give how much pressure in the system?

________________________________.

Question 19. How many times the horsepower of the vehicle's engine can be controlled by the brake system of the vehicle? ____________________.

Question 20. If an engine of a vehicle developed 225 horsepower, how much would the brakes be capable of controlling?

________________________________.

? ?

The answers to the questions asked on Frame 8 are:

Question 17.	Divide the applied force (in pounds) by the area of the piston (in sq. in.). Pressure is expressed in pounds per square inch or PSI.
Question 18.	5 pounds per square inch, or 5 PSI.
Question 19.	8 times the horsepower of the vehicle's engine.
Question 20.	225 x 8, or 1,800 horsepower of energy.

Although the lack of compressibility of most fluids is similar, other properties of various fluids make their use impractical in brake systems. Brake fluid must not boil, freeze, or evaporate. It must not rust the steel lines and cylinders. It must not soften the rubber or neoprene seals or flexible lines. The most reliable and inexpensive fluid which meets all of these requirements is a mixture of castor oil and alcohol. The proportions used are not critical, but when the fluid is manufactured a 50-50 mixture is used. As part of the alcohol evaporates the fluid thickens somewhat, but this is not important. Addition of the regular mixture is always made, rather than trying to restore the original balance by the addition of alcohol only.

QUESTION 21.

? ?

? Hydraulic brake fluid is composed of ?

? a. half alcohol and half castor oil. ?

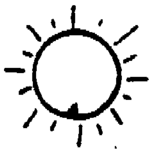
? b. 1/3 castor oil and 2/3 alcohol. ?

? c. any rust-proof liquid. ?

? d. 2/3 castor oil and 1/3 alcohol. ?

??? ?

Frame 10.



The answer to Question 21 is: "a" (Brake fluid is composed of 50% castor oil and 50% alcohol.

Even though other fluids possess most of the qualities of hydraulic brake fluid it is very important to remember that only the approved hydraulic brake fluid be used in a hydraulic brake system. Other fluids may work for a while but all hydraulic brake system components may have to be replaced due to deterioration of rubber parts or rust damage to the metal parts.

QUESTION 22.

? ?

Why is it so important to use only the approved Hydraulic Brake Fluid in a hydraulic brake system?

? ?

The answer to Question 22 is: Other fluids may damage rubber or metal parts of the hydraulic brake system (or words to that effect).

Any system is composed of a number of units or "components." While each of the components of the hydraulic brake system has a number of parts, we only consider the entire unit. The major components of the hydraulic brake system include: the master cylinder, a wheel cylinder for each wheel on the vehicle, brake drums, and shoes, along with both solid and flexible brake lines to connect all the components into a closed system.

QUESTION 23.

? ?

? Which of the following statements lists the major components of the ? hydraulic brake system?

a. Master cylinder, wheel cylinders, brake drums, brake shoes, hydraulic fluid.

b. Brake drums, brake shoes, backing plate, return springs, wheel cylinders.

c. Master cylinder, wheel cylinders, drums and shoes, solid and flexible lines.

d. Master cylinder, wheel cylinders, drums and shoes, and parking brakes.

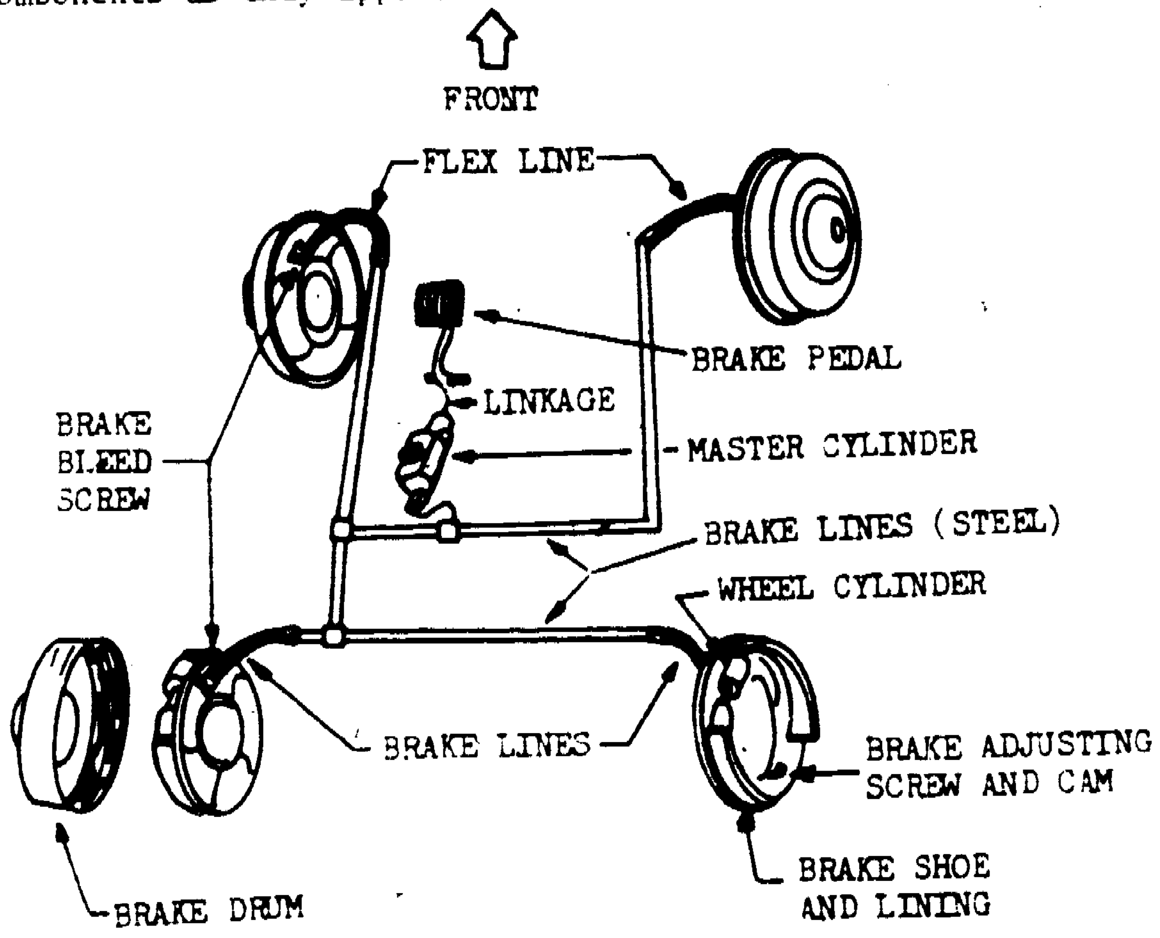
? ???

Frame 12.

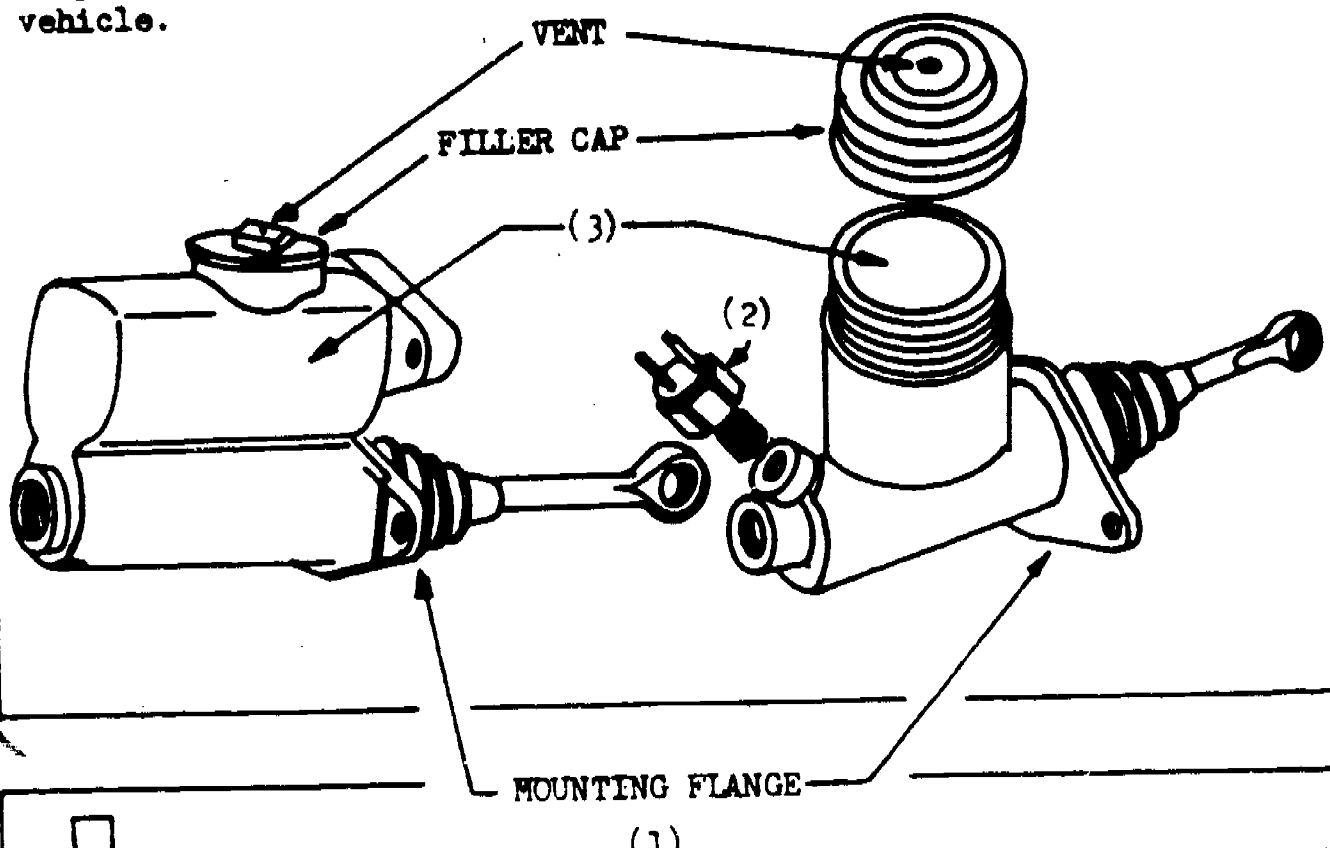
The answer to question 23 is: (c)

These components are essential to form a system. Any additional units are either refinements or part of those listed.

A typical vehicle hydraulic system is illustrated below. A similar illustration is in your Response Booklet shown as item 24. Label all the components as they appear in the illustration below.



Of the components listed, the first is the master cylinder, shown in the figure below. The master cylinder provides power to operate the brakes by converting mechanical force into hydraulic pressures. In addition, to provide the power to operate the brakes, the master cylinder contains the fluid reservoir for the hydraulic brake system (3). This unit is usually mounted on the firewall for easy access (1), and may also contain the stoplight switch (2), as in the example shown in the illustration. This is not a fixed rule, however. The stoplight switch may be located in any convenient place on the vehicle.



A similar illustration is shown in your Response Booklet on page 2. Locate the fluid reservoir, firewall mounting flange, and the stoplight switch. Write the names in the corresponding numbered spaces in the Response Booklet.

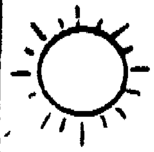
QUESTION 25.

? ?

? What unit of the vehicle hydraulic system is illustrated above? (Write your answer on the bottom of page 2 in the Response Booklet.) ?

? ?

Frame 14.



The answer to question 25 is: Master Cylinder.

The master cylinder is the heart of the hydraulic brake system. If some other part of the system fails there may be some braking action remaining, but if the master cylinder fails the entire brake system fails. A defective master cylinder may be replaced with a serviceable unit, or it may be repaired. Repair consists of removal from the vehicle, disassembly, reconditioning of the cylinder by honing, replacement of all internal parts, assembly, installation and testing.

QUESTION 26

? ?

? Which of the following statements are correct? ?

? a. A defective master cylinder must be discarded. ?

? b. Master cylinders may be replaced or repaired locally. ?

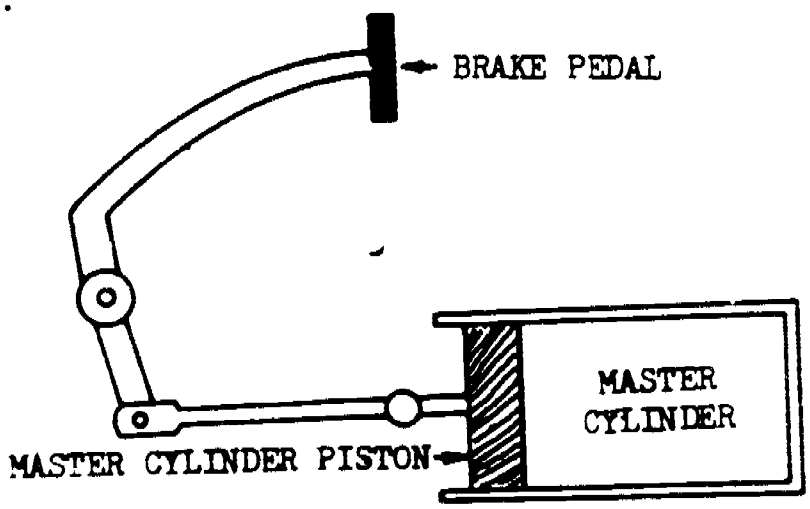
? c. Repair includes replacement of all internal parts. ?

? d. The stoplight switch can be mounted in any convenient place. ?

? ? ? ? ? . ?

The answer to question is: b., c., and d.

The accompanying figure illustrates how the master cylinder transforms mechanical energy into hydraulic pressure. Force applied to the brake pedal actuates the piston in the master cylinder, which attempts to compress the brake fluid in the cylinder. Since we know that fluids cannot be compressed under ordinary pressures, the resistance of the fluid to the mechanical action of the piston creates pressure in the fluid. Within reasonable limits, the more force that is applied to the brake pedal, the more the pressure that is created in the cylinder.



QUESTIONS 27 and 28.

27. Which of the following statements is true?
    a. The foot pedal acts through linkage to compress the fluid in the master cylinder.
    b. The greater the force applied to the foot pedal, the greater the pressure in the master cylinder.

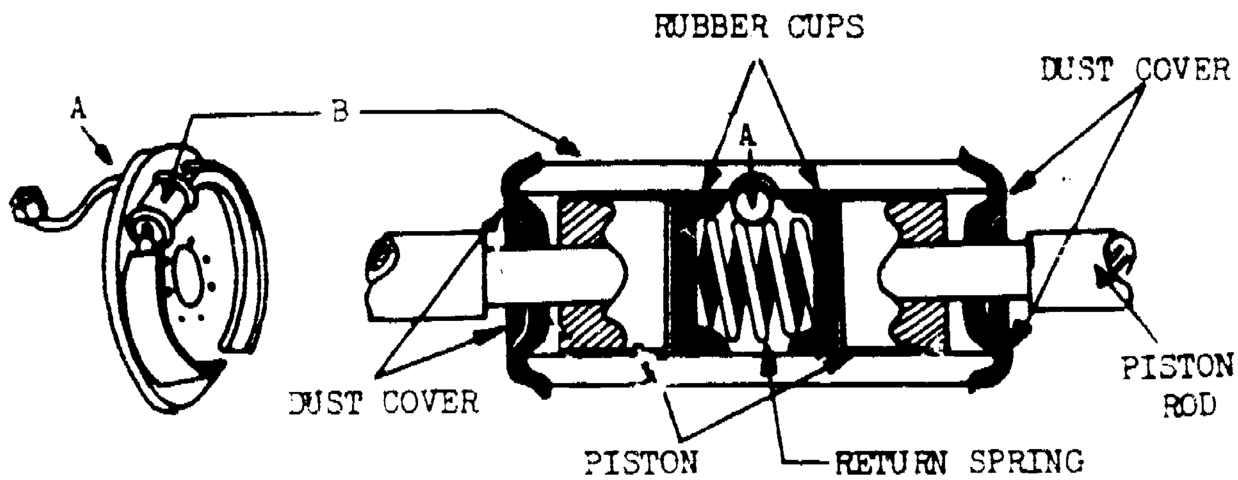
28. What is the purpose of the master cylinder?

Frame 16.

The answers to questions on Frame 15 are:

27. b.
28. convert mechanical energy into hydraulic pressure.

Next on our list of major components are the wheel cylinders (B). They contain some of the same parts as the master cylinder, but they transform hydraulic pressure into mechanical energy. In the figure below, note that fluid enters the cylinder at fitting A, and forces the pistons outward.



Label each part of the illustration shown as item 28 in your Response Booklet. Then, answer Questions 29 and 30 below.

QUESTIONS 29 and 30.

? ?

29. Study the figure above closely. Is this a single-acting cylinder or a double-acting cylinder? Why?

30. What is the purpose of the wheel cylinders.

? ?

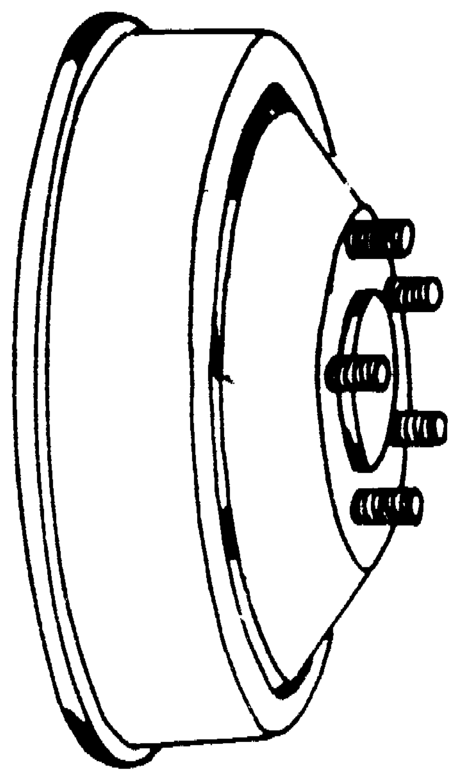
The answers to questions on Frame 16 are:

29. a. double-acting cylinder.
    b. there are two pistons.

    NOTE: If you answered this question correctly, you are to be congratulated! There was no mention of single- or double-acting cylinders, but you did some creative thinking and followed through.

30. Convert hydraulic pressure into mechanical energy.

Brake drums are constructed of cast iron, pressed steel, or both. In the latter case the pressed steel shell is used for strength with a cast iron liner to help dissipate the heat generated by braking action. Some of the heavy passenger cars have aluminum fins fitted to the outside of the drums to aid in cooling, since aluminum dissipates heat faster than steel or cast iron. Front brake drums are a part of the wheel hub and contain the wheel bearings. Rear brake drums have no support function and merely slip over the hub of the rear axle.



QUESTION 31

? ?

? In the figure above, is depicted a brake drum. From the information given, this is a (front) (rear) drum. (Write your answer in the space ? provided.) ?

? ?

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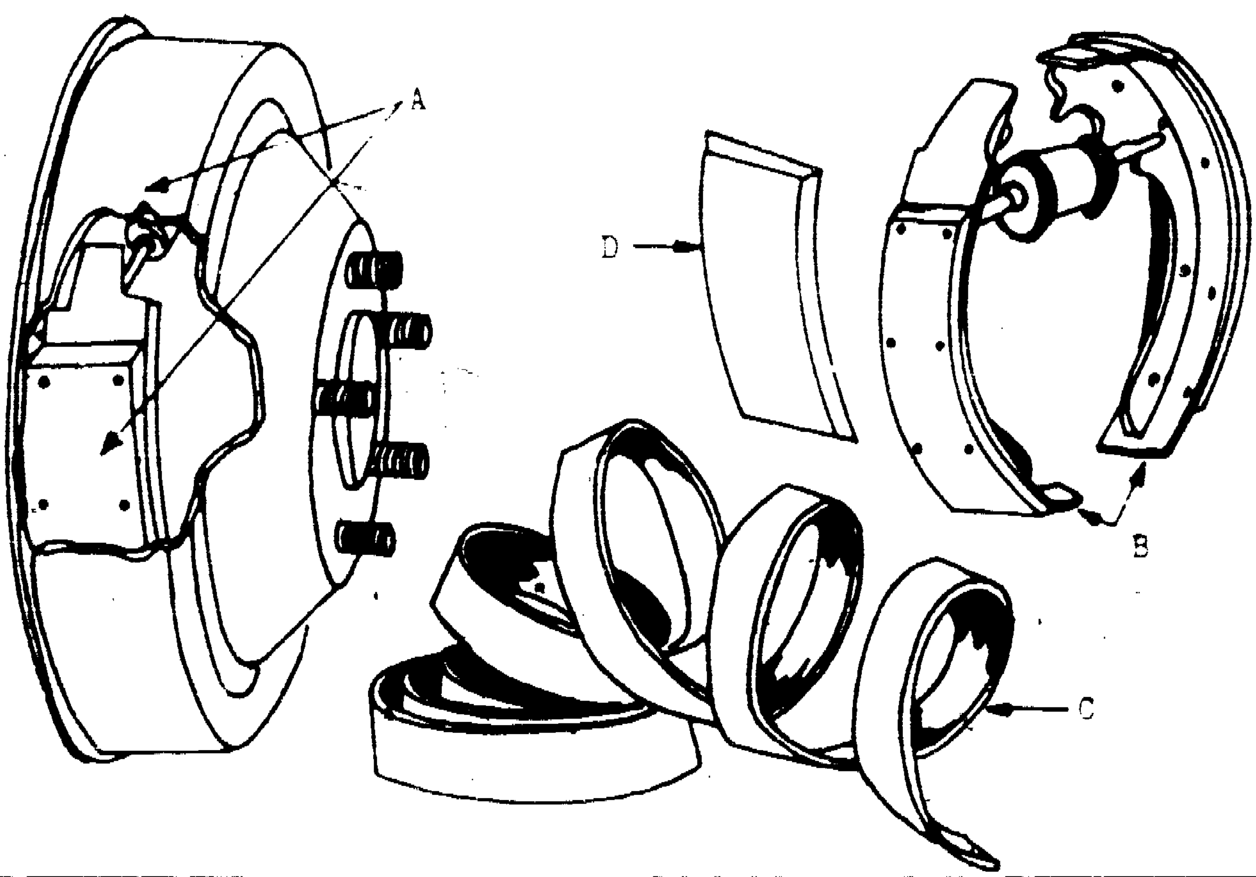
Frame 18.

The answer to Question 31 is: (rear).

This is a rear brake drum since it does not contain the wheel hub.

Brake shoes press the lining against the brake drum. creating the necessary friction with the drums to stop the vehicle (A). They come in pairs; one pair for each wheel (B). The shoes are constructed from flat steel stock that is shaped and welded. Each steel shoe is covered, on the outer curve, with a fiber lining. Early brake lining was woven (C) but now all vehicles are equipped with molded lining (D). This change came about because the molded lining proved to wear much longer, especially under the increased demands of heavier, more powerful vehicles. Note that the molded lining has holes to receive the rivets used to secure the lining to the brake shoe. Item 31 in your Response Booklet shows this same illustration. Label the parts as in this illustration in the booklet. Then, answer the questions found below the illustration on your Response Booklet.



The answer to 32 is: to press the lining against the rotating brake drum to create the friction necessary to stop the vehicle (in other words, to transmit the mechanical energy from the wheel cylinder to the brake drum.

The answer to 33 is: Brake lining, brake drum.

The answer to 34 is: Woven, molded.

The change from woven brake linings to molded lining increased the interval between adjustments or replacements. Both types of lining were secured to the shoes with rivets. The useful thickness of the lining was limited to that portion which extended beyond the rivets. Particles of dirt lodged in the recesses of the rivet holes and wore grooves in the drums. This required that the drums be turned on a brake drum lathe to restore smoothness to the drums.

QUESTIONS 35 nd 36.

35. Select the alternative which correctly completes the statement below.

Woven or molded brake lining can be used until

a. it is worn down to the brake shoes.

b. the rivets are touching the drums.

36. Grooved brake drums

a. must be discarded.

b. should be turned on a lathe.

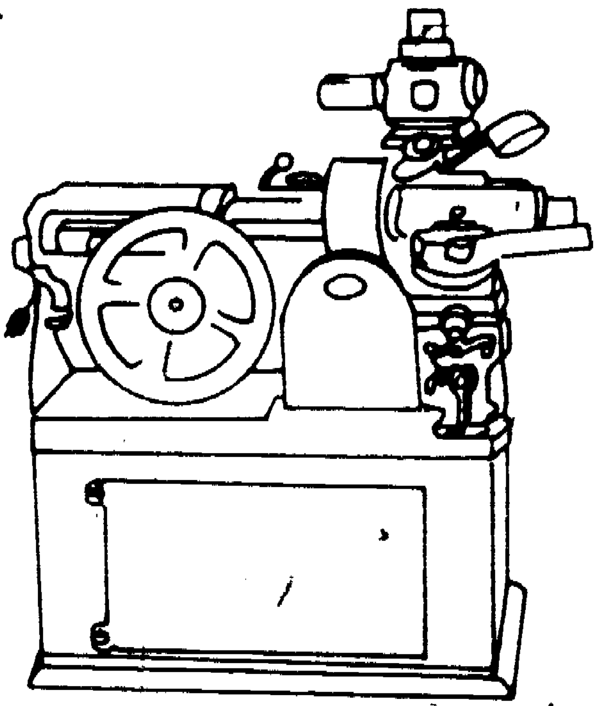
Frame 20.

The answers to the previous questions are:

35. (b)
36. (b)

Turn to page 4 of your Response Booklet. Read the instructions under item 36. Then, answer questions 37 through 41.

In the last frame we discussed turning grooved brake drums on a brake drum lathe. The special lathe used for this purpose is shown in the drawing below.



QUESTION 42.

? ?

? The brake drum lathe is used to ?

a. restore the drum to its original thickness.

b. remove grooves from the drum.

? ?

The answer to Question 37 is: B Master cylinder.
The answer to Question 38 is: C Wheel cylinder.
The answer to Question 39 is: D Brake shoe.
The answer to Question 40 is: A Brake drums.
The answer to Question 41 is: E Brake lining.

The answer to Question 42 is: (b) The brake drum lathe is used to remove grooves from the drum.

The next significant change in brake lining was not in the lining itself, but in the method of attachment to the brake shoes. Since the woven and the first type of molded linings were both attached with rivets, the usefulness of the lining was limited to that portion which extended beyond the rivets. The bonding process is accomplished with a high-strnegth adhesive bonder tape and the application of heat. Bonded brake linings have a distinct advantage over riveted lining in that the full thickness of the bonded lining is available for use. Also, because there are no holes for the dirt to lodge in, less abrasive action takes place on the drums and they do not become grooved. This eliminates the necessity for turning them on the brake drum lathe, except in the cases where heat-warping has caused the drum to become out of round.

QUESTION 43.

? ?

? What is the main advantage of bonded brake lining over riveted lining? ?

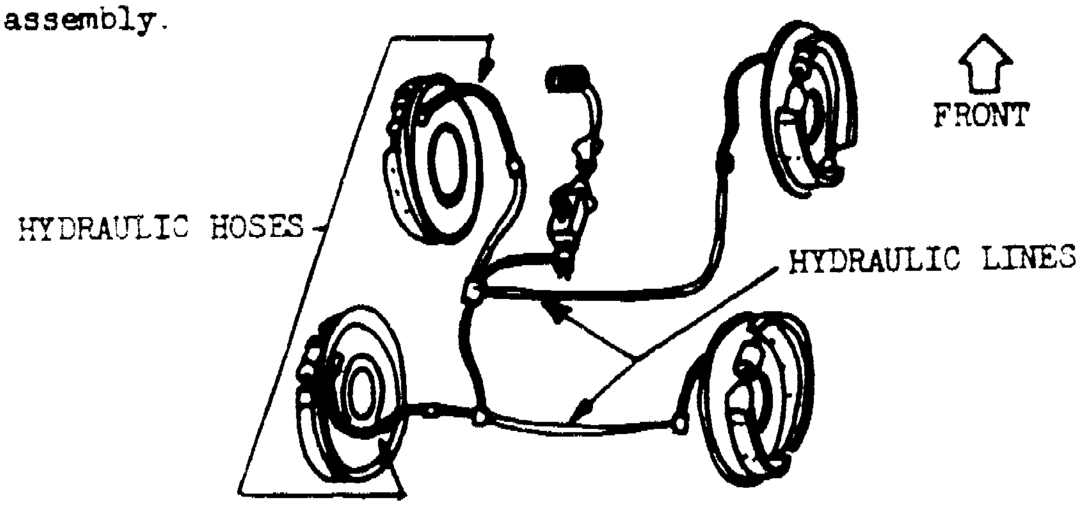
? ?

? ?

Frame 22.

Answer to Question 43: The full thickness of the lining can be used before replacement is necessary.

We have already covered most of the main components of the hydraulic brake system. The master cylinder, wheel cylinders, brake drums, and brake shoes have been covered. These units must be connected together in order to form a system, and the connectors are called hydraulic brake lines, both solid and flexible. The solid lines are made of steel tubing to withstand the high pressure that is sometimes developed. The flexible lines are made of neoprene, reinforced with steel mesh. The figure below is a composite drawing of a typical hydraulic brake system. The drums are omitted in order to show greater detail. Note that a flexible line is used from the frame bracket to the rear wheels as well as to the front wheels. This is necessary because of the up-and-down movement of the rear axle assembly.



QUESTION 44.

? ?

Pressure in the hydraulic system is

a. greatest at the master cylinder.
b. greatest at the wheel cylinder.
c. greatest in the lines since they are the smallest in diameter.
d. equal throughout the system.

? ?

The answer to question 44 is: (d) Pressure in the hydraulic system is equal throughout the system.

Our hydraulic brake system has now been assembled and connected with solid and flexible lines. We now add hydraulic brake fluid (50% castor oil - 50% alcohol), remove any residual air from the system, check for leaks, and we are in business. The process of removing air from the brake system is called "bleeding" and must be accomplished when any of the components of the system are changed, when a leak develops, or when the fluid level in the master cylinder gets low enough for air to enter the system. Remember, fluid cannot be compressed but air <u>can</u> be; and a bubble of air any place in the system will cushion the pressure applied to the brake pedal. For this reason, all air must be eliminated from the brake system to insure positive braking action.

QUESTIONS 45, 46, and 47.

? ?

45. What is the composition of hydraulic brake fluid?

46. What does bleeding of the brakes accomplish?

47. Why must brake systems be bled?

? ?

Frame 24.

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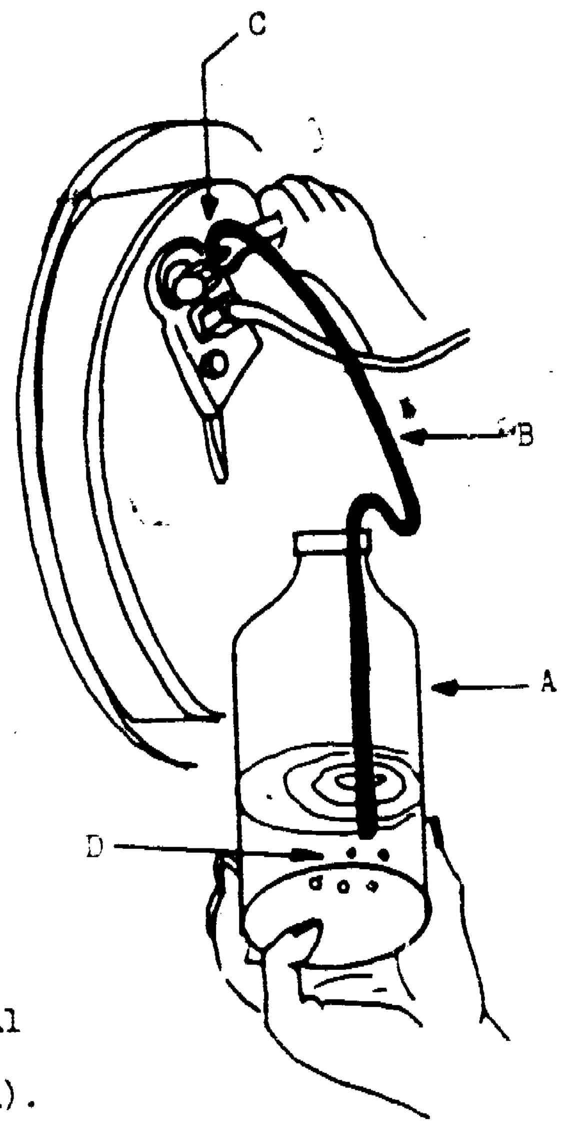
The answers to questions asked on Frame 23 are:

45. 50% castor oil - 50% alcohol.
46. Bleeding removes all air from the system.
47. Brakes must be bled to insure positive braking action.

The picture to the right shows a typical brake bleeding arrangement. A clean glass jar (A), a short length of rubber or neoprene hose (B), and a fitting to screw into the bleeder valve (C), are the only materials required. To bleed the brakes: (1) attach the hose to the bleeder valve; (2) check the master cylinder reservoir to make sure that it is full of fluid; (3) insert the loose end of the bleeder hose into the glass jar so that the end is submerged in the fluid (D); (4) have another person apply pressure to the brake pedal; (5) using a box-end or open-end wrench, loosen the bleed valve and allow fluid to flow into the jar; (6) close the bleed valve and tell your helper to release the brake pedal (this prevents air from being drawn in while the valve is open). Repeat this procedure until all bubbles stop coming from the hose.



When all of the air has been bled from one brake, repeat the procedure for all other brakes on that vehicle. Since each wheel cylinder is at the end of a brake line the only way to insure complete removal of all of the air is to bleed each brake. Make sure that the bleeder valve is closed before the brake pedal is released each time, and make sure that the master cylinder reservoir is kept full.

QUESTIONS 48 and 49.

? ?

48. Why must the bleeder valve be closed before the brake pedal is released?

49. Why must each wheel be bled?

? ?

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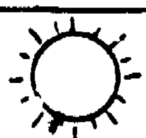
Frame 26.



The answers to the questions on Frame 25 are:

48. To prevent air from entering through the open bleeder valve.

49. Because each wheel cylinder is at the end of a brake line.

With the addition of hydraulic brake fluid and the removal of air from the system by bleeding each of the wheel cylinders, we now have a complete brake system ready to function. We have already determined that force may be transmitted through fluid in a closed system. It follows, then, that movement of the piston in the master cylinder, caused by pushing the brake pedal will create movement of the pistons in the wheel cylinders. Remember, fluid cannot be compressed under ordinary pressures so there is no lost motion in a fluid-filled system.

QUESTION 50.

? ?

Indicate which of the following statements are correct.

a. Movement of the pistons in the wheel cylinders is caused by compression of the brake fluid.

b. Movement of the piston in the master cylinder causes the pistons in the wheel cylinders to move.

c. Force may be transmitted through fluid in a closed system.

d. Depressing the brake pedal forces fluid into the reservoir.

? ?

The answers to Question 50 are: b. and c.

Pressure, in pounds per square inch, is equal throughout a closed system. If movement of the piston in the master cylinder creates movement of the pistons in the wheel cylinders, the amount of fluid displaced in the master cylinder must be divided among the number of wheel cylinders on the vehicle. Thus, if all the cylinders are of the same diameter and the vehicle has four wheels, each wheel cylinder will receive ¼ of the fluid displaced from the master cylinder. If each wheel cylinder has two pistons, that is, if they are double-acting cylinders, the individual wheel cylinder pistons will only move 1/8 of the distance traveled by the piston in the master cylinder.

QUESTIONS 51, 52, 53, and 54.

? ?

In all of the following problems we are assuming that the diameter of all cylinders is the same.

51. 4-wheel single-acting master cylinder moves 2 inches. Wheel cylinders move ____________.

52. 4-wheel, double-acting master cylinder moves 2 inches. Wheel cylinders move ____________.

53. 6-wheel, double-acting master cylinder moves 3 inches. Wheel cylinders move ____________.

54. 4-wheel, double-acting master cylinder moves 3 inches. Wheel cylinders move ____________.

? ?

Frame 28.

The answers to the questions asked on Frame 27 are:

51. 2 inches divided by 4 (for 4 wheels) = 1/2 inch.

52. 2 inches divided by 4 (for 4 wheels) = 1/2 inch, which divided by 2 (double-acting) = 1/4 inch.

53. 3 inches divided by 6 (for 6 wheels) = 1/2 inch, which divided by 2 (double-acting) = 1/4 inch.

54. 3 inches divided by 4 (for 4 wheels) = 3/4 inch. which divided by 2 (double-acting) = 3/8 inch.

The exercise just completed in the previous frame was not intended as an arithmetic drill. It was designed to show how a small increase in the clearance between the brake shoe and the brake drum would multiply by 4, 8, or even 12 times the necessary travel of the piston in the master cylinder. Normal wear on the brake lining makes adjustment of the clearance between the shoe and drum necessary. There is no set time or mileage involved since some vehicles are driven for long distances in open country with little demand placed on the brakes, while others, such as taxicabs, are driven almost exclusively in traffic with much brake usage per mile traveled. Brake shoes should be adjusted when the brake pedal can be pushed to within three inches of the floor.

QUESTION 55.

? ?

? Which of the statements below are correct? ?

? a. Brake shoes should be adjusted every 10,000 miles. ?

? b. Brake shoes are adjusted as normal wear decreases the thickness of the lining. ?

c. Brakes are adjusted when the brake pedal can be pushed to within 3 inches of the floor. ?

? d. All vehicles wear out their brakes at about the same rate. ?

? ?

The answers to Question 55 are: b. and c.

In all hydraulic brake systems, the shoes are held against the drums by pressure in the system. The shoes are returned from the drums to their normal position by return springs. If the pressure is not allowed to bleed off, the springs cannot return the shoes to their normal poisition. To insure the release of hydraulic pressure, the brake pedal is adjusted for "free travel." If there is no free travel in the pedal, the piston inside the master cylinder has not returned and there is fluid trapped in the system, causing pressure.

QUESTION 56.

Which of the statements below is correct?

a. The return springs are strong enough to overcome the trapped fluid.

b. The brake lining will soon wear off enough to provide a clearance.

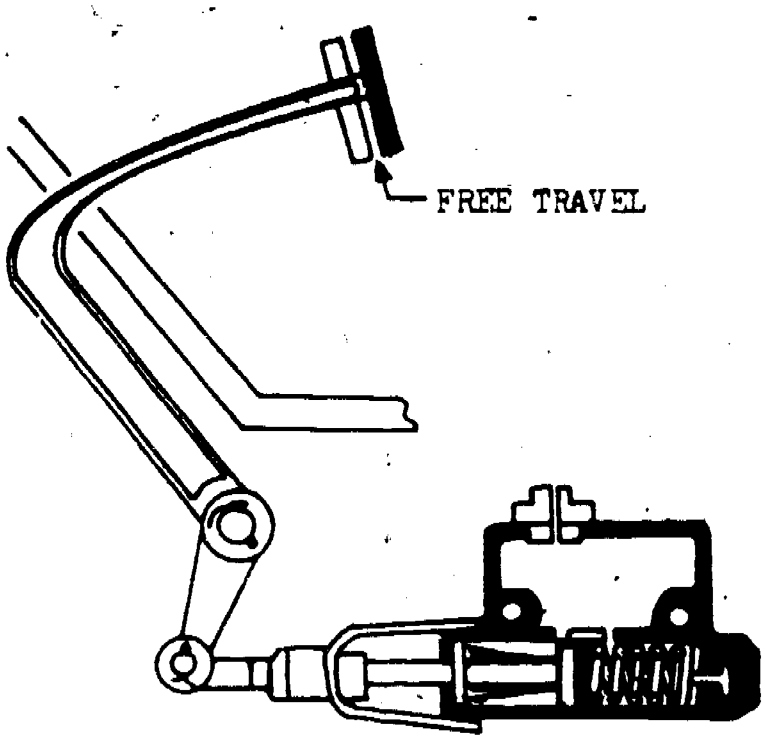
c. The brake pedal must have free travel to release the hydraulic pressure.

d. Kicking the pedal several times will release the pressure.

Frame 30.

The answer to Question 56 is: (c) The brake pedal must have free travel to release the hydraulic pressure.

To insure complete return of the piston in the master cylinder, the brake pedal must be adjusted for free travel. As shown in the picture at the right, the adjustment is made in the master cylinder push rod linkage. To test for free travel, use light finger pressure on the brake pedal. There should be at least 1/2 inch travel of the brake pedal before resistance is felt.



QUESTION 57.

? ?

? Which of the statements below is correct? ?

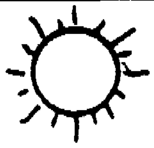
? a. Free travel is adjusted on the pedal. ?

b. Free travel should be at least 1/2 inch.

? c. Free travel should be at least 2". ?

? d. Adjustment is on the push rod linkage of the master cylinder. ?

? ?



The answers to Question 57 are: b. and d.

The last part of the brake system that we will study with this program is the parking brake. Most vehicles utilize the brake shoes and drums on the rear wheels for parking brakes as well as service brakes. Since there would be no practical way of applying pressure to the hydraulic system, the parking brakes are actuated mechanically.

QUESTION 58.

? ?

? Which of the statements below is correct? ?

? a. Parking brakes can be either hydraulic or mechanical. ?

? b. Parking brakes may utilize some units of the service brake system. ?

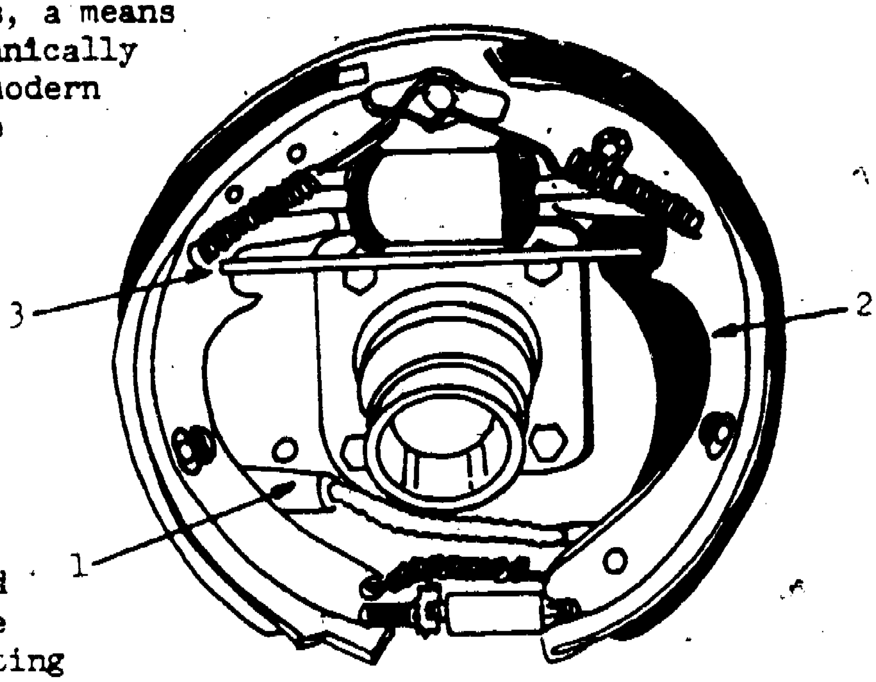
? ?

? ?

Frame 32.

The correct answer to Question 58 is: b.

While some parking brake installations share the rear brake shoes and drums with the service brakes, a means of actuating them mechanically must be devised. All modern vehicles use a flexible cable which extends through the brake backing plate and connects to a lever inside the brake assembly. In the picture at the right, the parking brake cable (1) is connected to the actuating lever (2) which moves the actuating rod (3) when the hand brake is applied. The actuating lever pushes the secondary shoe against the drum, and the rod pushes the primary shoe against the drum.



QUESTION 59.

? ?

? Which of the statements below are true? ?

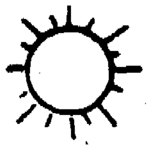
a. Parking brakes are cable actuated.

b. The springs help actuate the brakes.

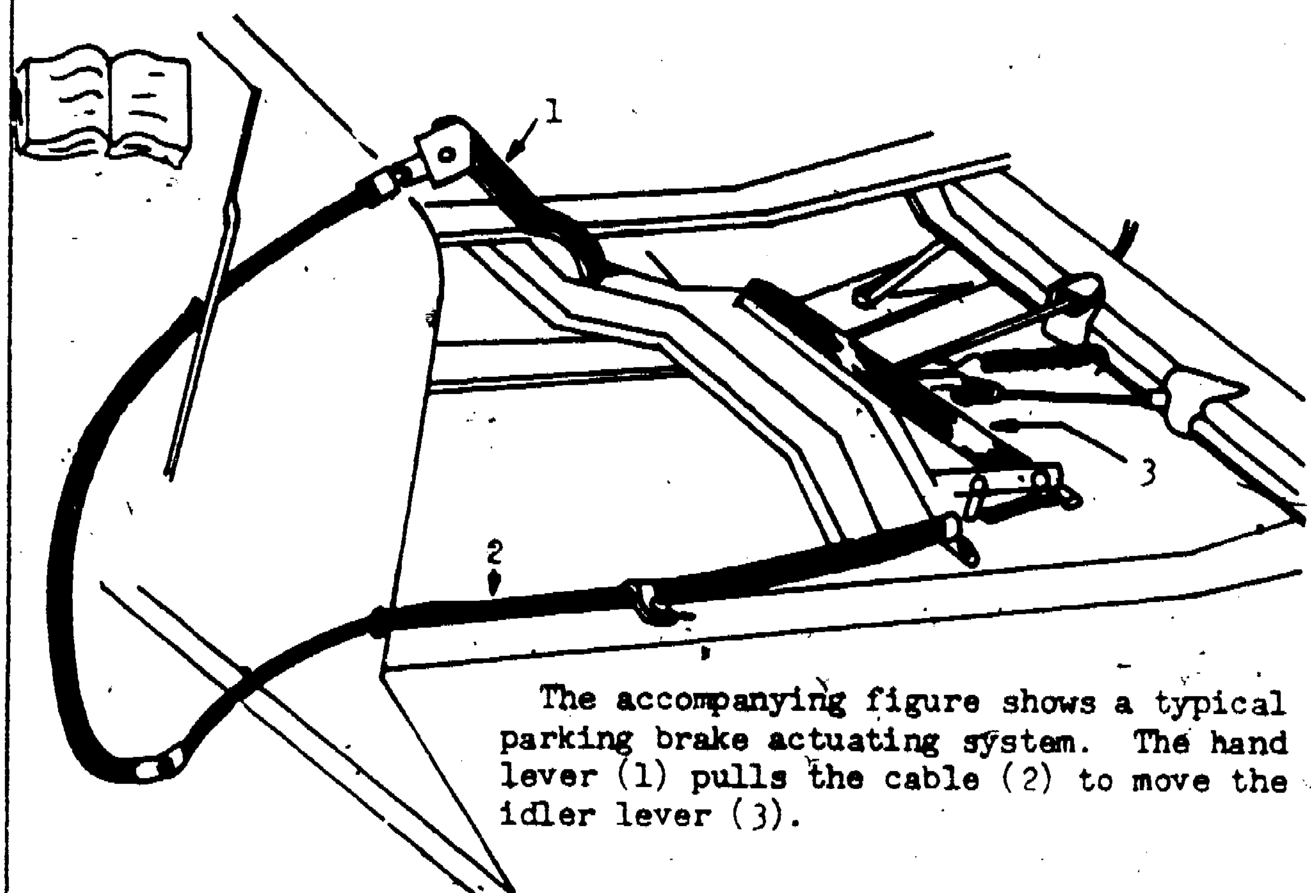
c. Parking brakes are on all wheels.

d. The actuating lever pushes on the secondary shoe.

? ?



The answer to Question 59 is: a. and d.



The accompanying figure shows a typical parking brake actuating system. The hand lever (1) pulls the cable (2) to move the idler lever (3).

QUESTION 60.

? ?

? Could a foot-operated lever be substituted for the hand-operated lever (1) in the illustration above? ?

a. Yes.

b. No.

? ?

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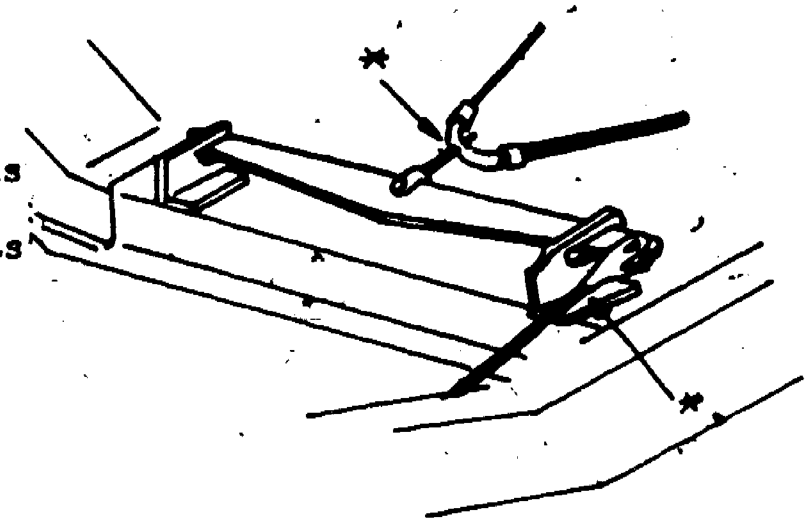
Frame 34.

The answer to Question 60 is: Yes. (A different arrangement would be necessary.)

The figure at the right is a closer view of the idler lever showing the adjustments that can be made (*). The cable going forward to the hand lever (or foot lever) can also be adjusted.



QUESTION 61.

? ?

? Which of the statements below are correct? ?

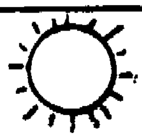
? a. Slack in the cables to the rear wheels cannot be removed. ?

? b. The rear wheel cables can be shortened or lengthened. ?

? c. The hand brake cable must be replaced. ?

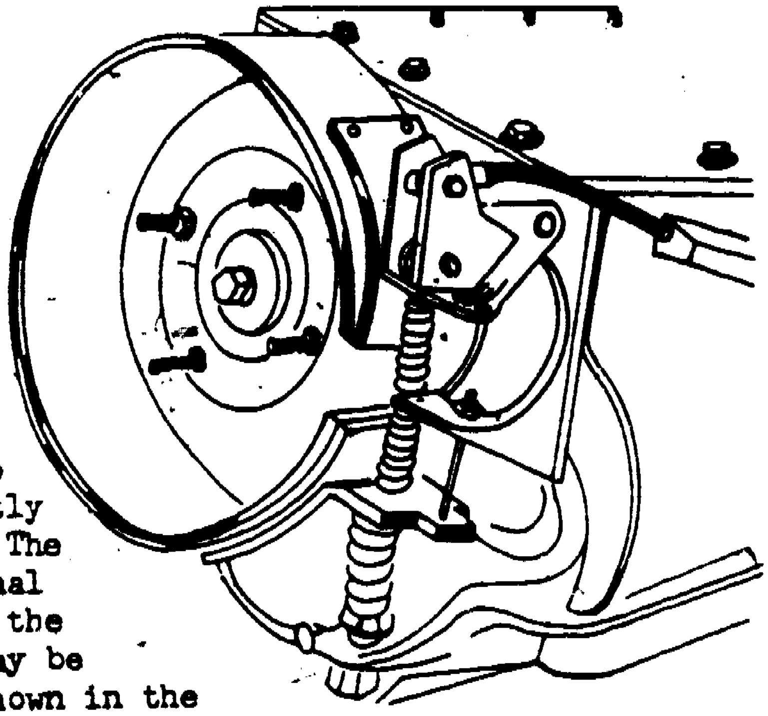
? d. An adjustment can be made in the hand brake cable. ?

? ?



The answers to Question 61 are: b. and d.

While some vehicles utilize the rear brake shoes and drums of the service brake system for parking, there are some vehicles which use a completely separate unit. It is operated mechanically by a cable, and the drum is secured to the propeller shaft directly behind the transmission. The shoes may be either internal expanding, as they are in the service brakes, or they may be external-contracting as shown in the figure to the right.



QUESTION 62.

? ?

? Which of the statements below are correct? ?

? a. This figure shows an internal expanding brake. ?

? b. This figure shows an external contracting brake. ?

? c. All parking brakes are mechanical. ?

? d. Some parking brakes are hydraulic. ?

? ?

Frame 36.

The answers to Question 62 are: b. and c.

QUESTION 63.

? ?

The following questions are a review of the parking brake.

a. Are parking brakes ever hydraulically operated? ________

b. Can parking brakes be equipped with a foot pedal? ________

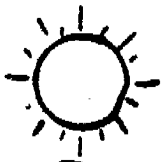
c. Are parking brakes always on the rear wheels? ________

d. If not, where else may they be located? ________

e. Are the parking brakes adjustable? ________

f. Are "parking brakes" and "hand brakes" the same? ________

? ?



The answers to Question 63 are:

a. No.

b. Yes.

c. No.

d. On the propeller (drive) shaft.

e. Yes.

f. Yes.

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PREPARE THE MAN

PROGRAMMED TEXT 3ABR47~~330~~232-PT-604
3ABR47231-1-PT-602A
3ABR47231A-PT-602A
3ABR47231B-PT-602A
3ABR47231C-PT-602A

Technical Training

General Purpose Vehicle ~~Repairman~~ Mechanic
Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Crash/Fire Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)

8-12

CONVENTIONAL STEERING GEARS

23 November 1971

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-PT-604, 20 April 1970.
OPR: TDWS
DISTRIBUTION: X
TDWS - 800; TTOC - 6

OBJECTIVES

After completing this programmed text you will be able to accomplish the following objectives with 85% accuracy.

1. Given a list of descriptive statements and a list of components, match the descriptive statement to the proper component.

2. Given an illustration of a steering gear assembly and a list of components, match each component to the correct numerical designation of the part.

3. List the types of manual steering gear assemblies.

VALIDATION

This programmed text was validated in 1964 by 30 students enrolled in the 3ABR47330 course and has proved to be successful since that time. Approximately 2,500 students have been trained with this text.

INSTRUCTIONS

To correctly use this program you need a response sheet, ATC Form 26, a pen or pencil, and a Student Notebook.

Read the information in each frame and answer the question or questions following the frame. Make all of your responses on the response sheet. Be sure the number on your response sheet corresponds to the number of the question you are answering.

When you have responded to a question, check your response against the correct response. The correct response is usually found at the top of the page following the question. If you made an incorrect response, reread the frame to see why the correct response is preferable to the one you made. Then, change your response to agree with the one printed in the program.

The Notebook is yours to keep. Be sure to fill it out completely as directed in the program.

When you have completed the program, place the response sheet in the front of the booklet and return both of them to the instructor.

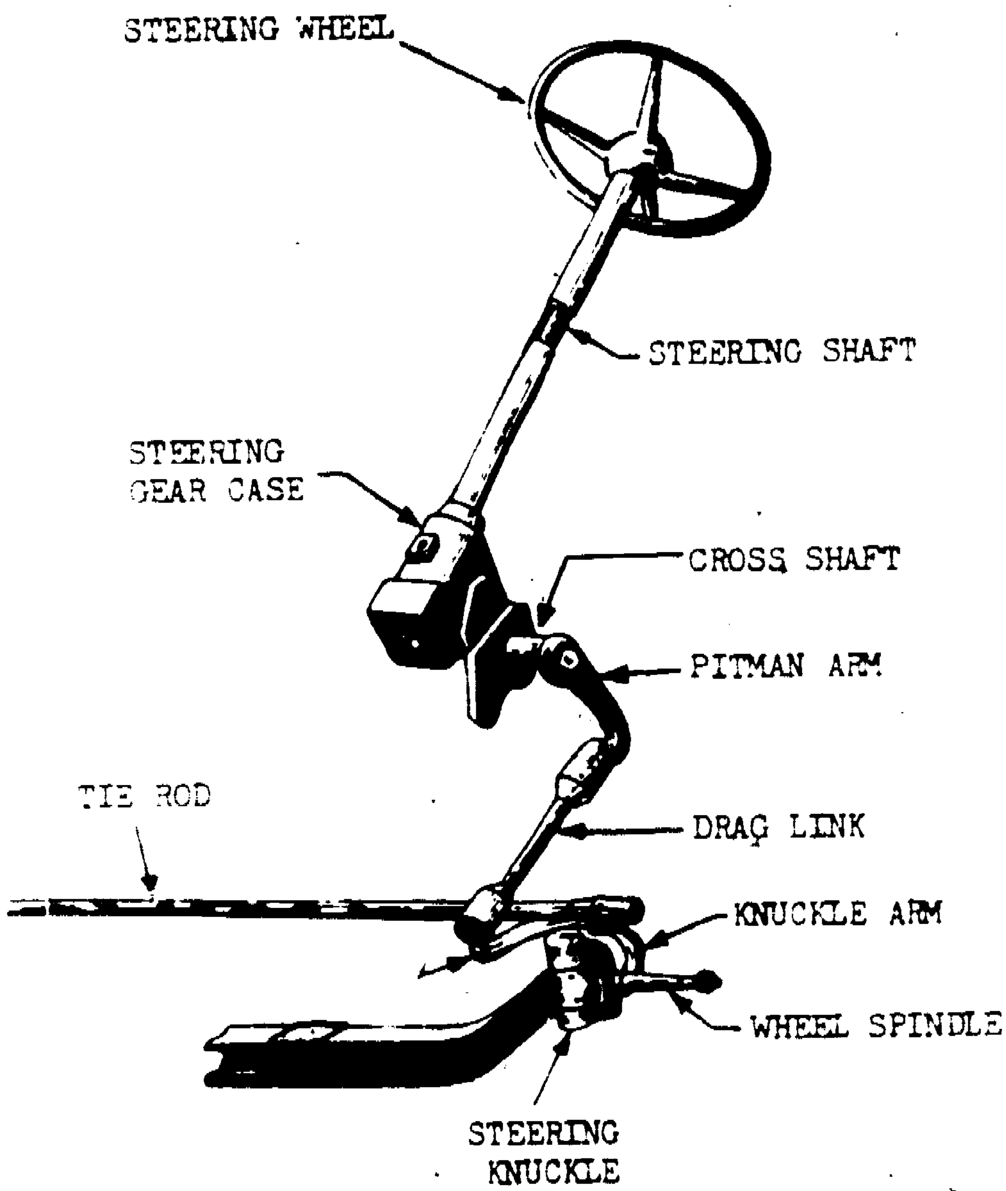
I N T R O D U C T I O N

This programmed text has been prepared to teach you the various types of steering gears used in Air Force vehicles. While the purpose of all types of steering gears is the same (multiplying the strength of the driver and extending his hands to the front wheels of the vehicle) there are several methods used by the different automotive engineers. After you complete this text, you should know the names of the components, and their relationship to each other in helping the driver to control his vehicle.

NO RESPONSE REQUIRED

Frame 2.

There are four types of manual steering gears. The purpose of all of these gears is the same: to aid the vehicle operator in controlling the movement of the front wheels of the vehicle. Each of the four types of steering gears have certain components in common. The illustration below shows these components.



Study the drawing presented in Frame 2. Then, match the descriptive statements in Column A below to the list of components in Column B. Record your answers in the proper spaces on your response sheet.

Column A

1. The component that transfers torque applied to the steering wheel to the steering gear.
2. The component that connects the steering gear to the pitman arm.
3. The component that attaches the entire steering mechanism to the drag link.
4. The component attached to the tie rod by the steering arm.
5. The component that is attached to the drag link by the steering arm and coordinates movement of both front wheels.

Column B

a. Cross shaft

b. Drag link

c. Pitman arm

d. Steering shaft

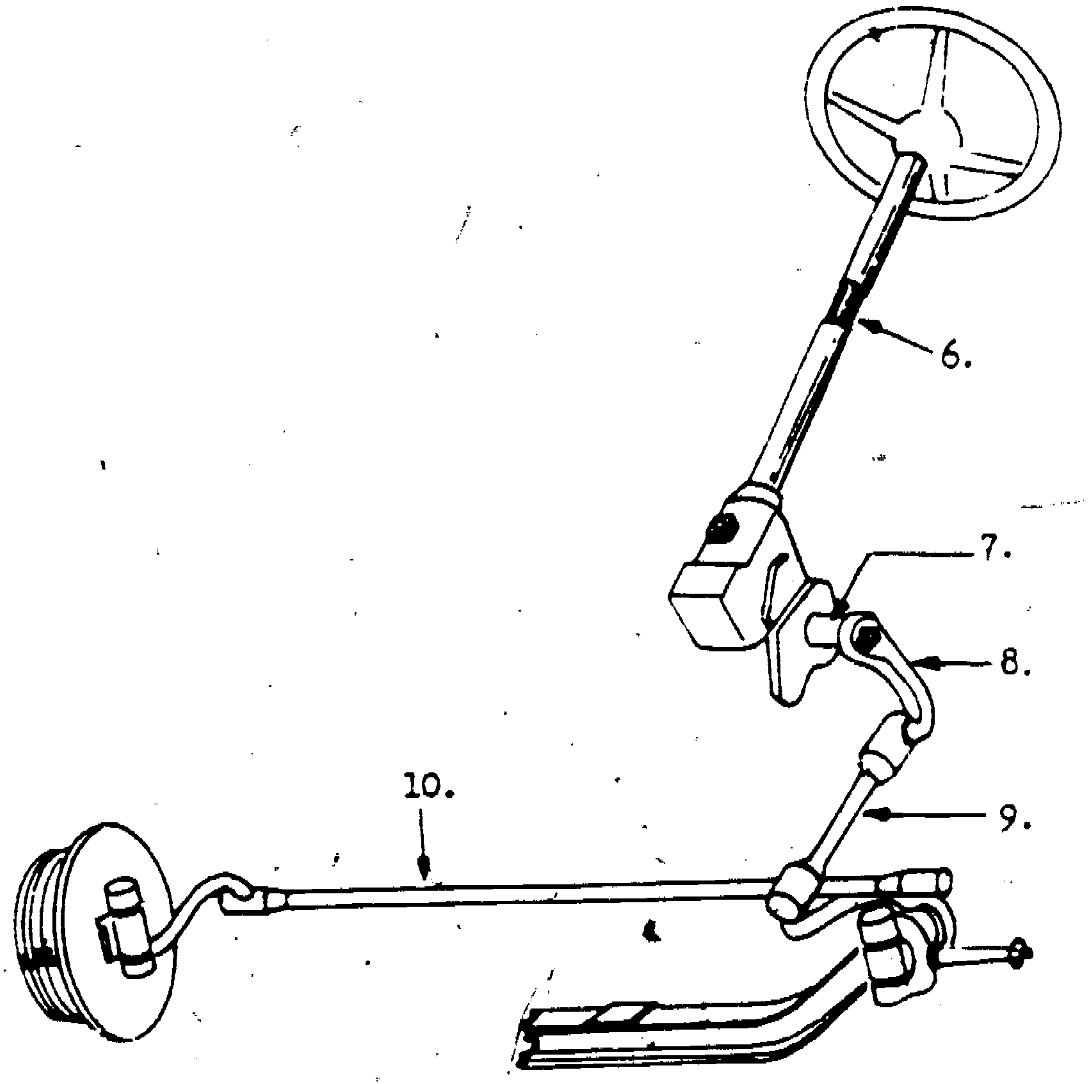
e. Tie rod

Frame 4.

Answers to previous questions:

1. d.
2. a.
3. c.
4. b.
5. e.

Use the drawing below to assist you, and answer the questions on the next frame. The numbers on the illustration below refer to the question numbers.



Match the descriptive statements in Column A to the list of components in Column B. Record your answers in the proper spaces on your response sheet.

Column A

6. The component that transfers torque from the steering wheel to the steering gear.
7. The component that attaches the steering gear to the pitman arm.
8. The component that connects the entire steering mechanism to the drag link.
9. The component attached to the tie rod by the steering arm.
10. The component that coordinates movement of both front wheels.

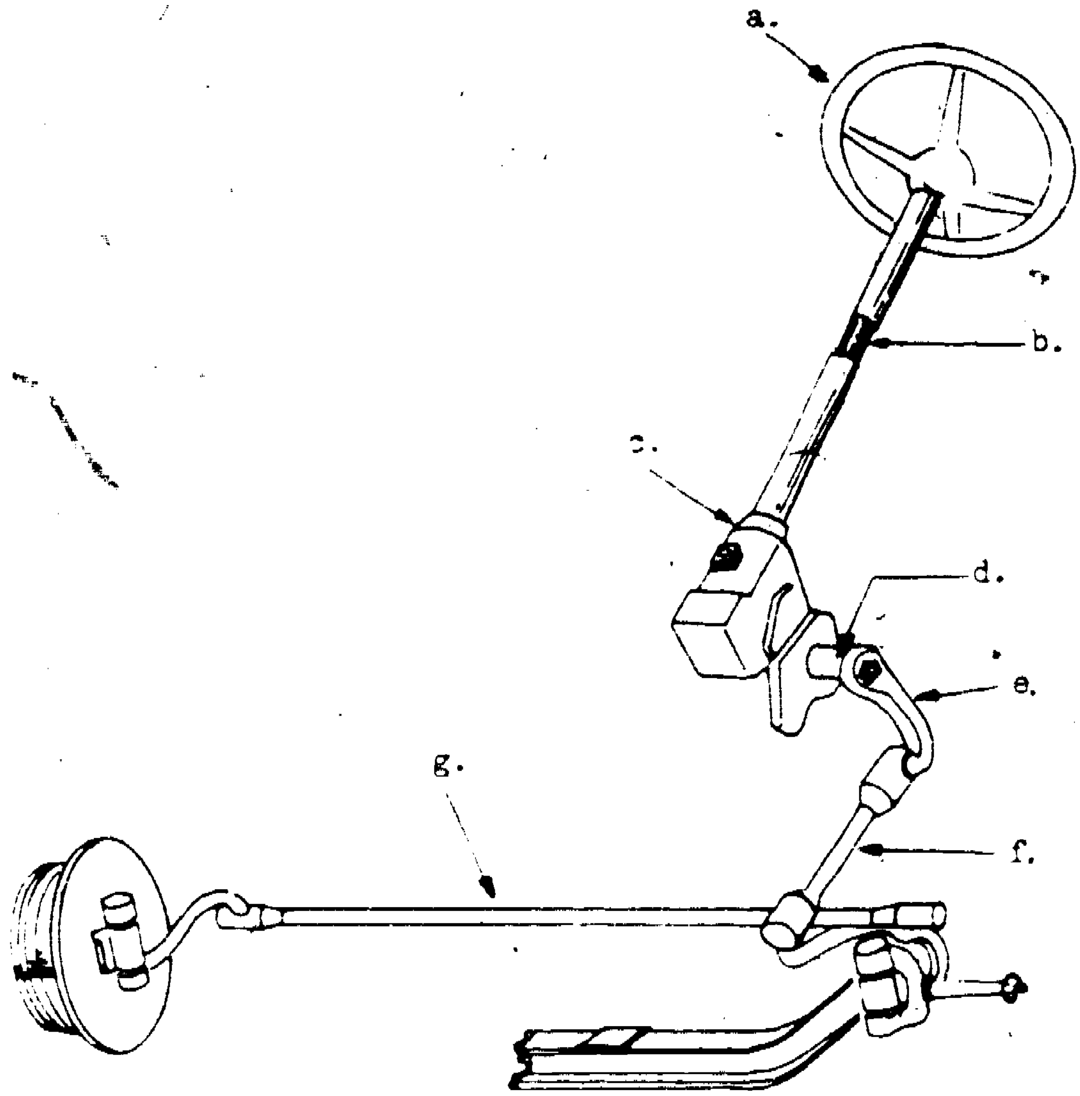
Column B

a. Tie rod.
b. Steering shaft.
c. Pitman arm.
d. Drag link.
e. Cross shaft.

Go to Page 3 of your note book and fill in the blanks below Figure 3 with the names of the components.

Frame 8.

Your note book entry should look like this:



a. Steering wheel.

b. Steering shaft.

c. Steering gear.

d. Cross shaft.

e. Pitman arm.

f. Drag link.

g. Tie rod.

Make any corrections necessary in your note book, then proceed to the next frame.

Go to Page 4 of your note book and complete items 2.a. through 2.g. (Note: Items 2.a. and 2.g. are already completed.)

Frame 10.

Your note book entries should look like these:

2.b. The component that transfers steering wheel torque to the steering gear is the steering shaft.

2.c. The component that connects the steering gear to the pitman arm is the cross shaft.

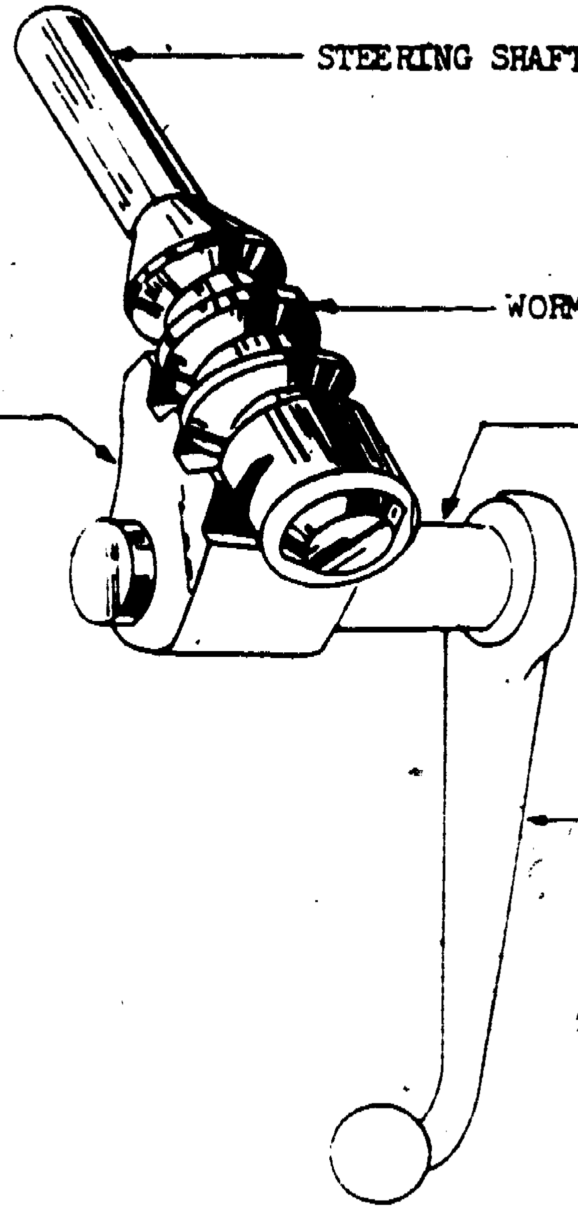
2.d. The component that attaches the steering gear mechanism to the drag link is the pitman arm.

2.e. The component attached to the tie rod by the steering arm is the drag link.

2.f. The component attached to the drag link by the steering arm that coordinates movement of both front wheels is the tie rod.

Make any corrections necessary in your note book, then go to the next frame.

The illustration below shows one of the types of steering gears. This type is known as the "worm and sector" steering gear. Locate the worm gear and the sector gear in the illustration.

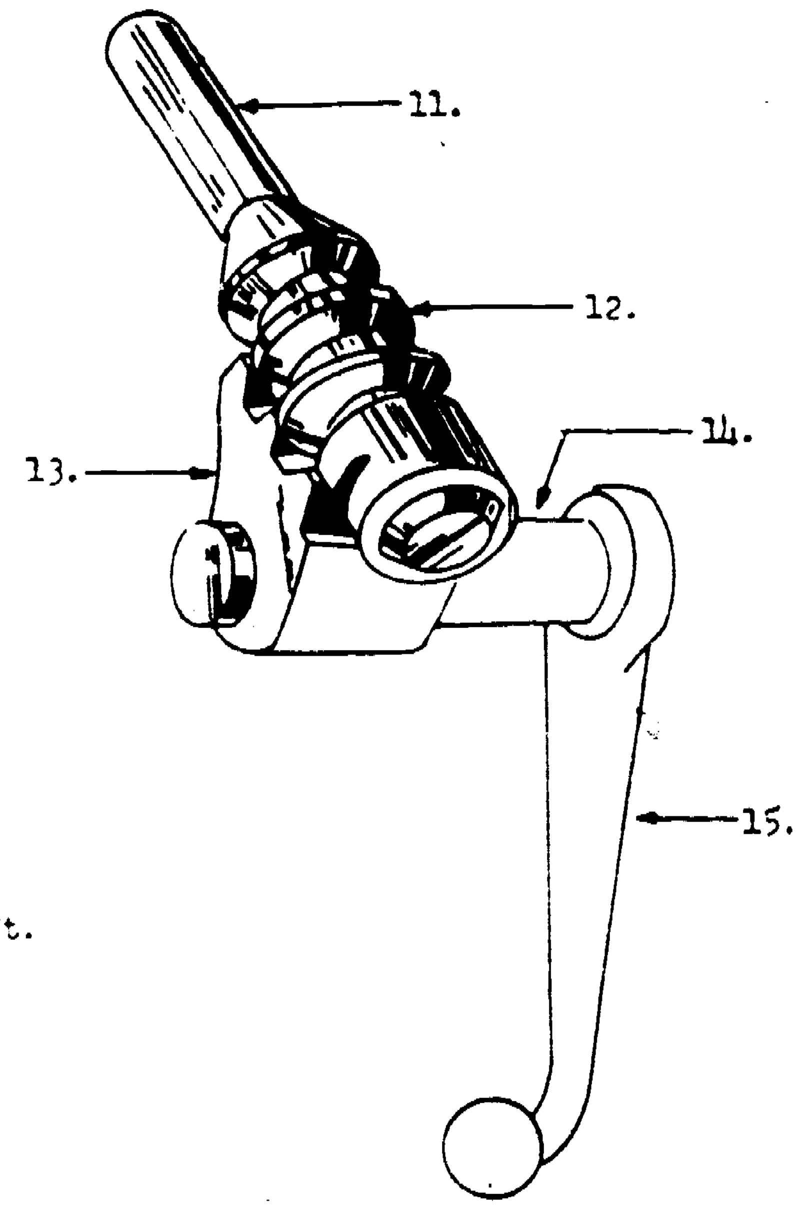


As the steering wheel is turned, the worm gear at the end of the steering shaft turns. Since this is a spiral-type gear, the sector gear works "up" or "down" the worm gear as the worm gear turns. As the sector gear moves, it causes the pitman arm, through the cross shaft, to force the drag link to the left or right, turning the front wheels.

Go on to the next frame.

Frame 12.

The numbers 11 through 15 identify components of the worm and sector steering gear assembly. From the list at the lower left, select the component identified by each number and record your answer in the proper spaces on your response sheet.



a. Cross shaft.

b. Pitman arm.

c. Sector gear.

d. Steering shaft.

e. Worm gear.

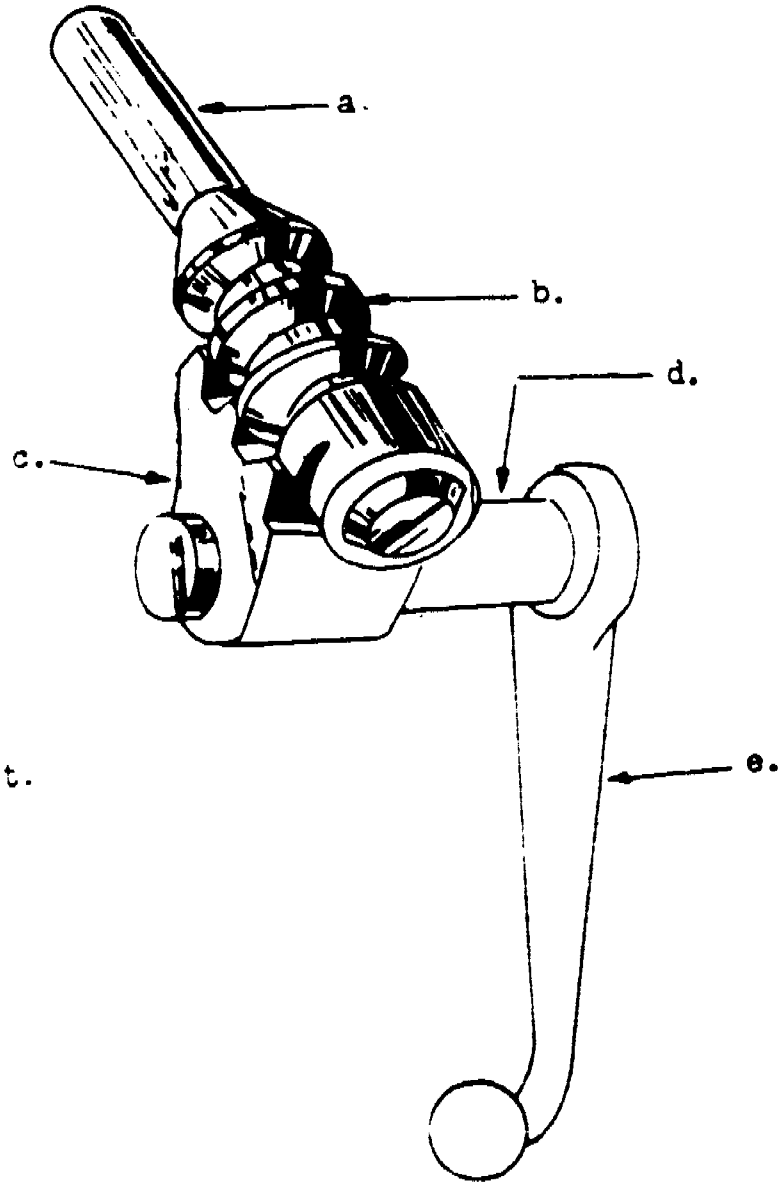
Turn to Page 4 of your note book and complete item 3.a., then go to Figure 4, Page 5, and identify the components of the worm and sector steering gear indicated by each arrow. Write the name of the components indicated in the appropriate space below the figure. After you have done this, go on to the next page of this program.

Frame 14.

Answers to Frame 12:

11. d.
12. e.
13. c.
14. a.
15. b.

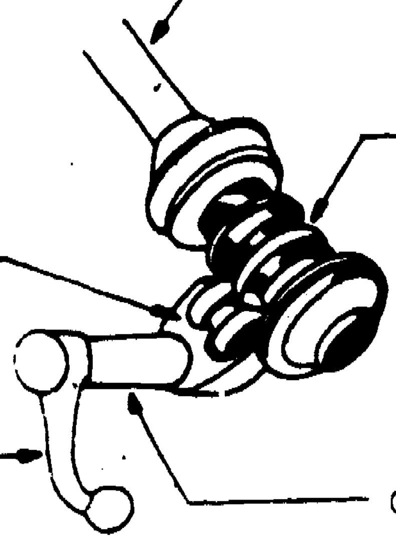
Figure 4 in your note book should have the components labeled as shown below:



a. Steering shaft.
b. Worm gear.
c. Sector gear.
d. Cross shaft.
e. Pitman arm.

Make any changes necessary in your note book, then go on to the next frame.

The illustration below shows another type of steering gear. This type is known as the "worm and roller." Locate the worm gear and the roller in the illustration below.



As the steering wheel is turned, the worm gear turns and causes the roller to move up or down the worm gear much in the same manner as the sector gear moves up and down the worm gear in the worm and sector type. As the roller moves along the worm gear, the pitman arm is forced, through the cross shaft, to move, causing the drag link to turn the vehicle wheels to the left or right.

Go on to the next frame.

Frame 16.

The numbers 16 through 20 in the illustration below indicate components of the worm and roller steering gear assembly. From the list at the lower left, select the component identified by each number and record your choice in the proper space on your response sheet.

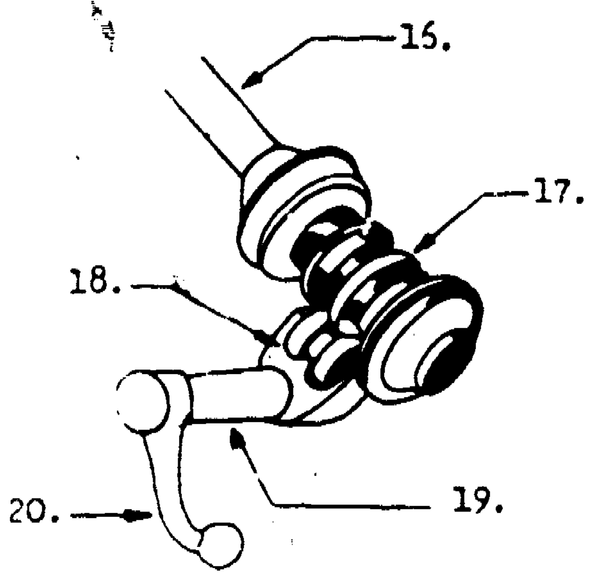
a. Cross shaft.

b. Pitman arm.

c. Roller.

d. Steering shaft.

e. Worm gear.



Turn to Figure 5, Page 6, of your note book and identify the components of the worm and roller steering gear as indicated by the arrows. Write the name of the part in the space below the drawing. Complete note book item 3.b. on Page 4. After you have done all of this, go on to the next frame in this program.

Frame 18.

Answers to Frame 16:

16. d.
17. e.
18. c.
19. a.
20. b.

Figure 5 in your note book should have the components labeled as shown below.

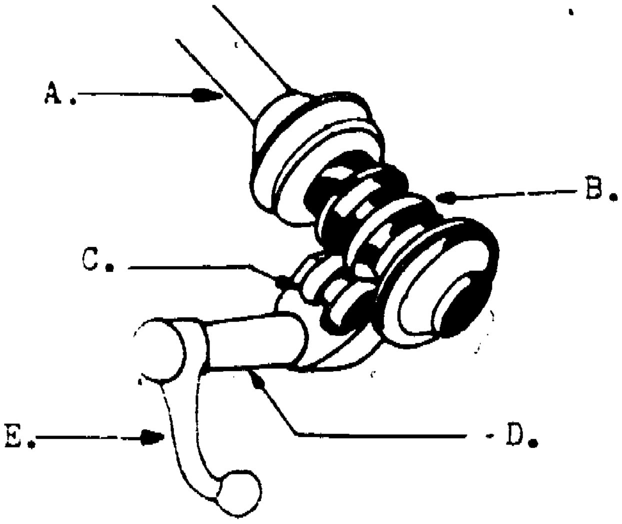
A. Steering shaft.

B. Worm gear.

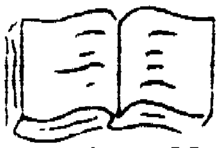
C. Roller.

D. Cross shaft.

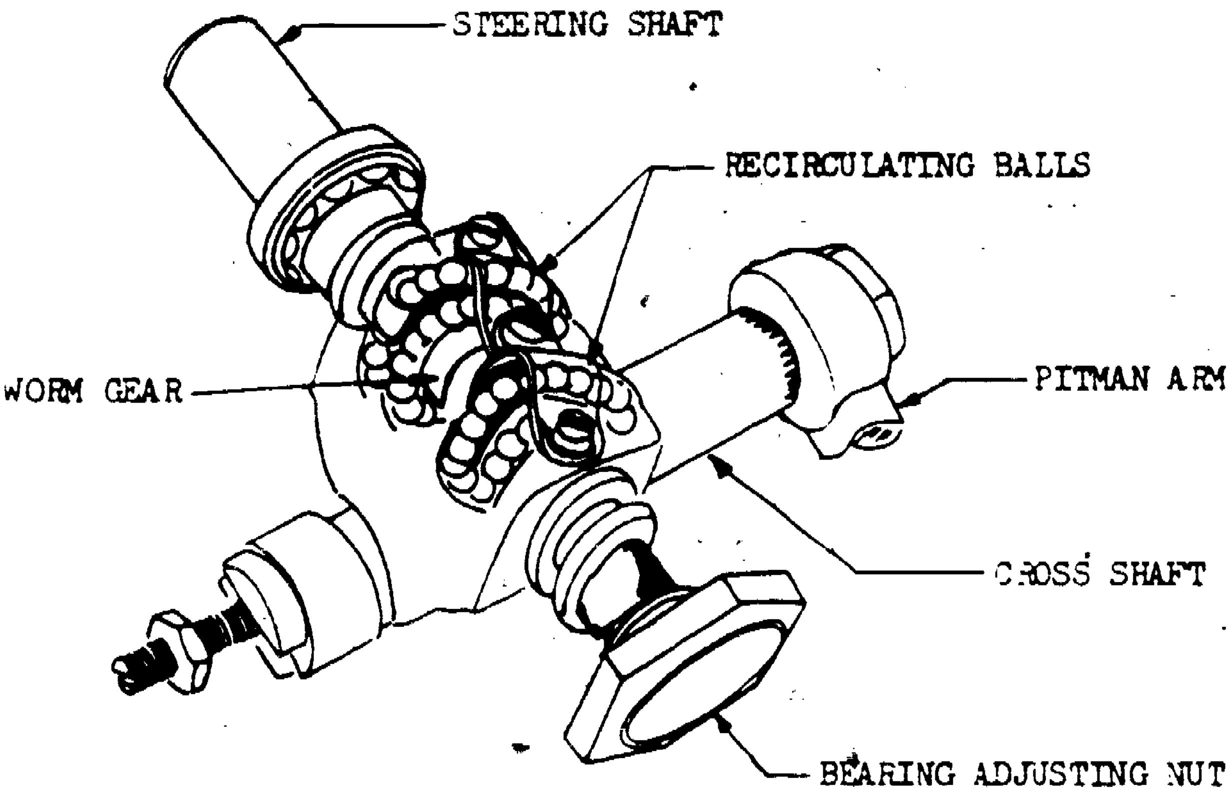
E. Pitman arm.



Make the changes as necessary in your note book, then refer to the next frame.



The illustration below shows yet another type of steering gear. This type is known as the "recirculating ball." Study the illustration below.



As the steering shaft turns, the balls are forced around the worm gear, turning the cross shaft. The cross shaft causes the pitman arm to move the drag link, turning the wheels. This type of steering gear has an adjusting nut to pre-load the worm gear bearings.

Proceed to the next frame.

Frame 20.

The numbers 21 through 25 in the illustration below identify components of the recirculating ball steering gear assembly. From the list to the left, select the component identified by each number and record your choices in the proper spaces on the response sheet.

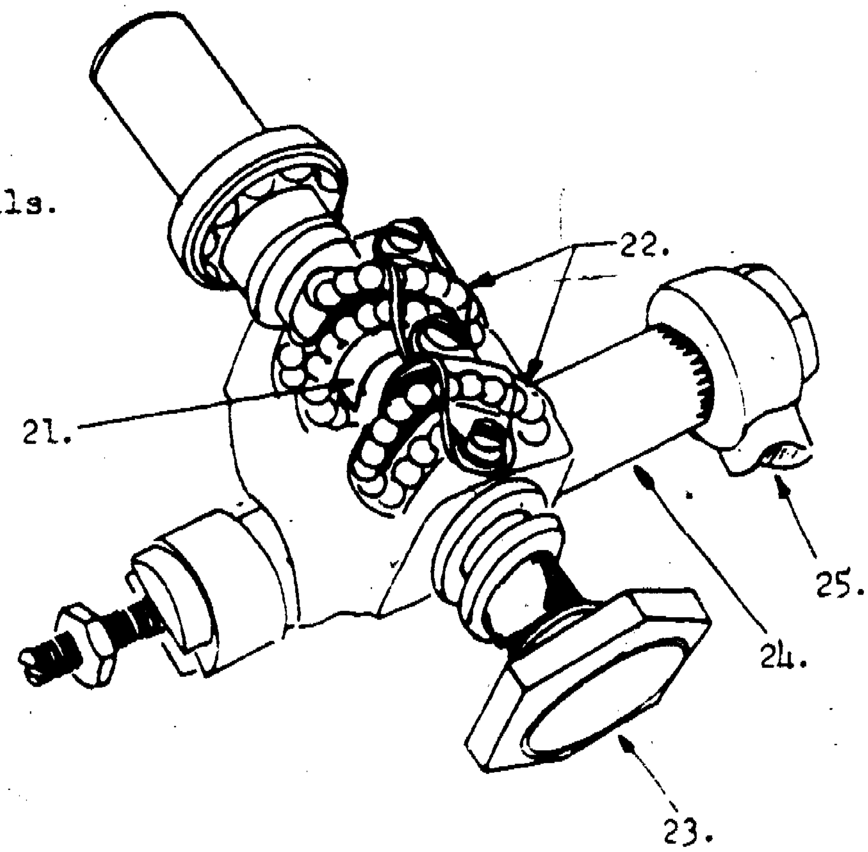
a. Bearing adjusting nut.

b. Cross shaft.

c. Pitman arm.

d. Recirculating balls.

e. Worm gear.



Turn to Figure 6 on Page 7 of your note book and identify the components of the recirculating ball steering gear indicated by arrows by writing in the name of the part below the drawing. Complete item 3.c. on Page 4 of your note book and then go on to the next frame of this program.

Frame 22.

Answers for Frame 20.

21. e.
22. d.
23. a.
24. b.
25. c.

Figure 6 in your note book should have the components labeled as shown below.

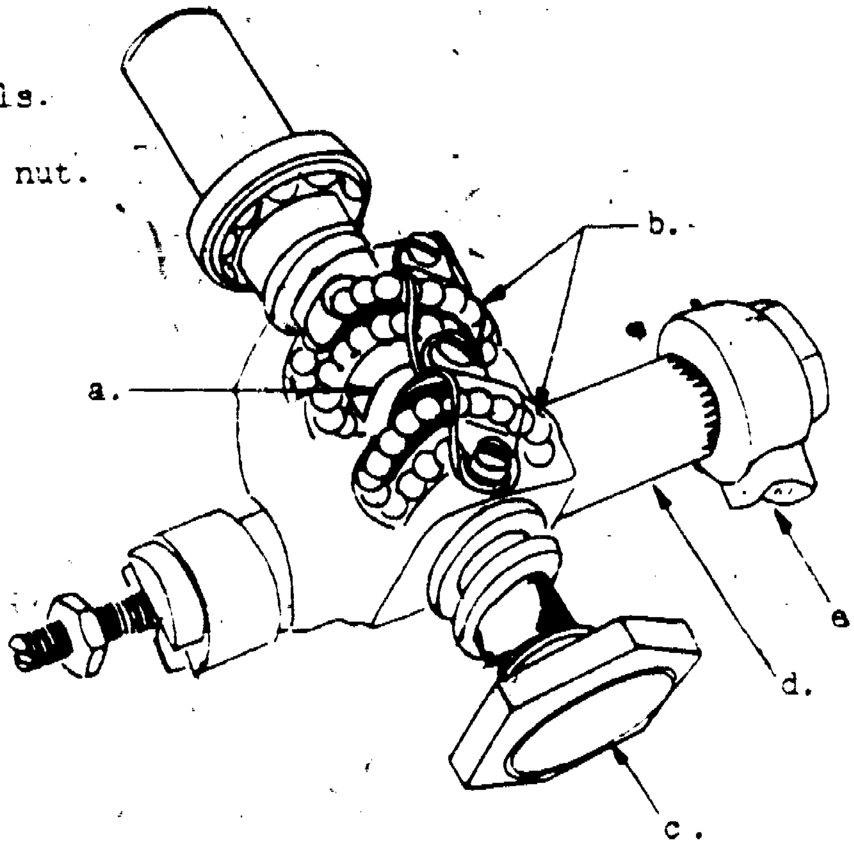
a. Worm gear.

b. Recirculating balls.

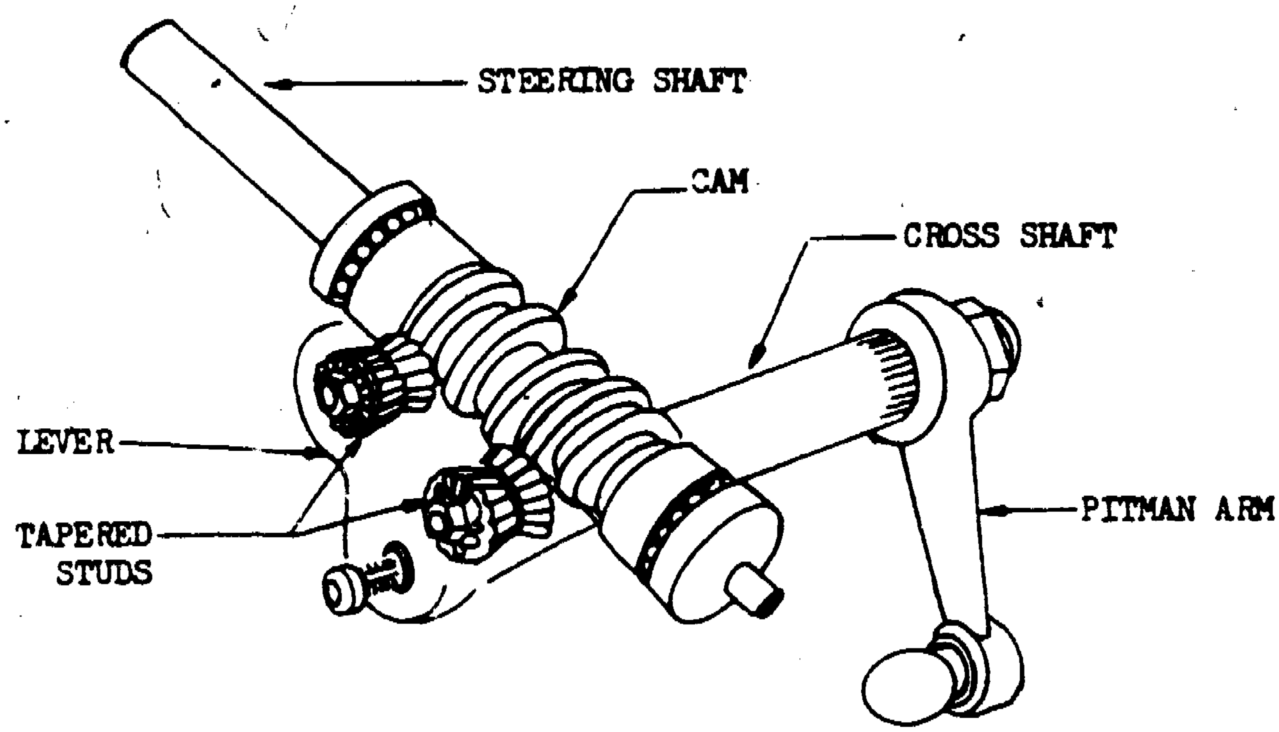
c. Bearing adjusting nut.

d. Cross shaft.

e. Pitman arm.



The illustration below shows the fourth type of manual steering gear. This type is known as the "cam and lever" steering gear. Locate the cam and the lever in the illustration below.



As the steering wheel and the steering column shaft turn, the cam rotates causing the tapered studs to move up and down the cam. Movement of the studs forces the lever to move. The cross shaft, linked to the lever and to the pitman arm, causes the pitman arm to move the drag link to the left or to the right, turning the vehicle's front wheels.

Go on to the next frame.

Frame 24.

Numbers 26 through 30 in the illustration below indicate components of the cam and lever steering gear assembly. From the list at the left, select the component identified by each number and record your choices in the proper spaces on the response sheet.

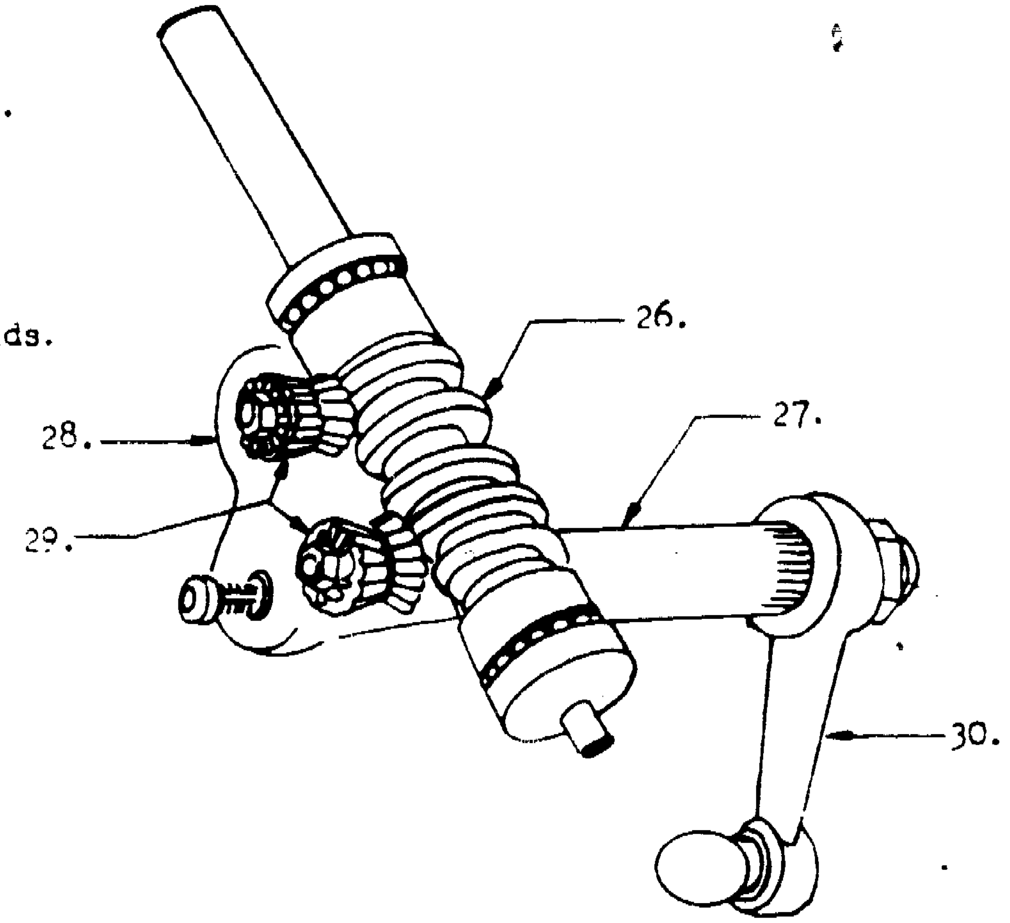
a. Cam.

b. Cross shaft.

c. Lever.

d. Pitman arm.

e. Tapered studs.



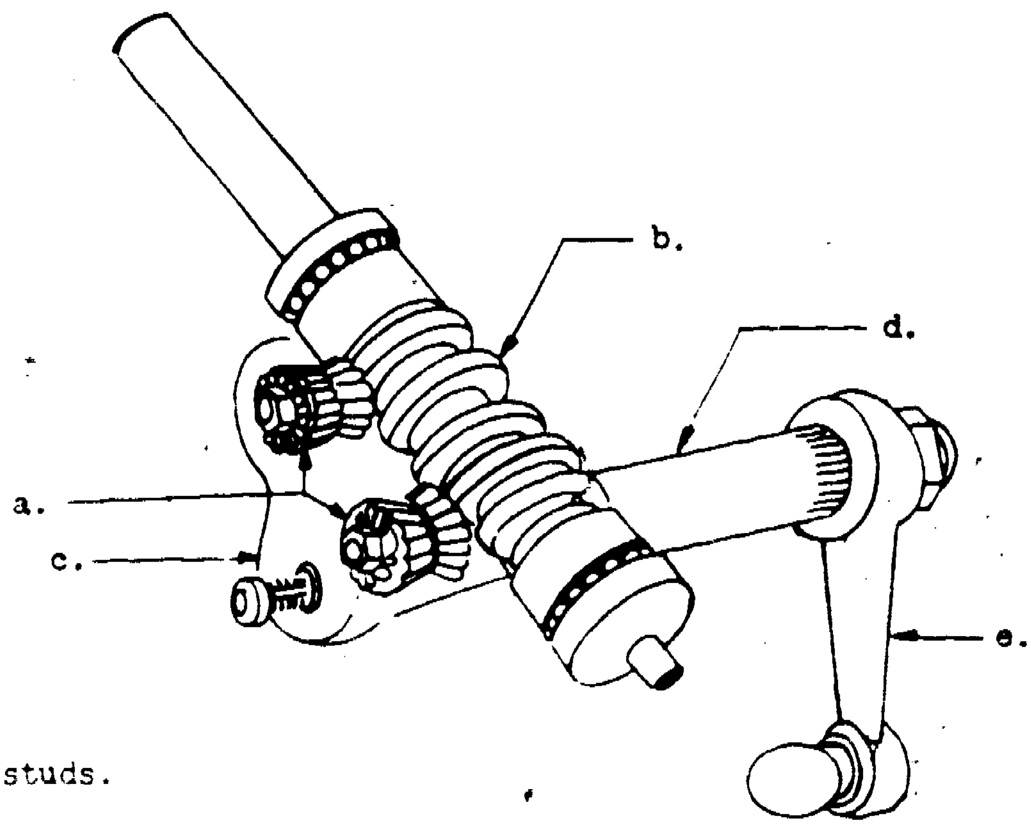
Turn to Figure 7 on Page 8 of your note book and identify the components of the cam and lever steering gear indicated by the arrows. Then, complete item 3.d. on Page 4. After you have done this, go on to the next page in this program.

Frame 26.

Answers to Frame 24:

26. a.
27. b.
28. c.
29. e.
30. d.

Figure 7 in your note book should have the components labeled as shown below:



a. Tapered studs.

b. Cam.

c. Lever.

d. Cross shaft.

e. Pitman arm.

Make any changes necessary in your note book, then go on to the next frame.

Select the correct answer to the questions below and record your choice in the proper space on the response sheet.

QUESTION 31.

Which of the following is <u>not</u> a type of manual steering gear?

a. Cam and lever.
b. Semi-integral.
c. Recirculating ball.
d. Worm and roller.
e. Worm and sector.

QUESTION 32.

Which of the components listed below transfers steering wheel torque to the steering gear?

a. The cross shaft.
b. The drag link.
c. The pitman arm.
d. The power steering unit.
e. The steering shaft.

QUESTION 33.

Which of the components listed below attaches the steering gear to the pitman arm?

a. The cross shaft.
b. The drag link.
c. The manual steering gear.
d. The power steering unit.
e. The steering shaft.

Frame 28.

Answers to previous questions: 31. b., 32. e., 33. a.

QUESTION 34.

Which of the components listed below connects the entire steering gear assembly to the drag link?

a. The cross shaft.
b. The pitman arm.
c. The steering gear.
d. The steering shaft.
e. The suspension mechanism.

QUESTION 35.

Which of the components listed below is connected to the tie rod by the steering arm?

a. The cross shaft.
b. The drag link.
c. The pitman arm.
d. The steering gear.
e. The steering shaft.

QUESTION 36.

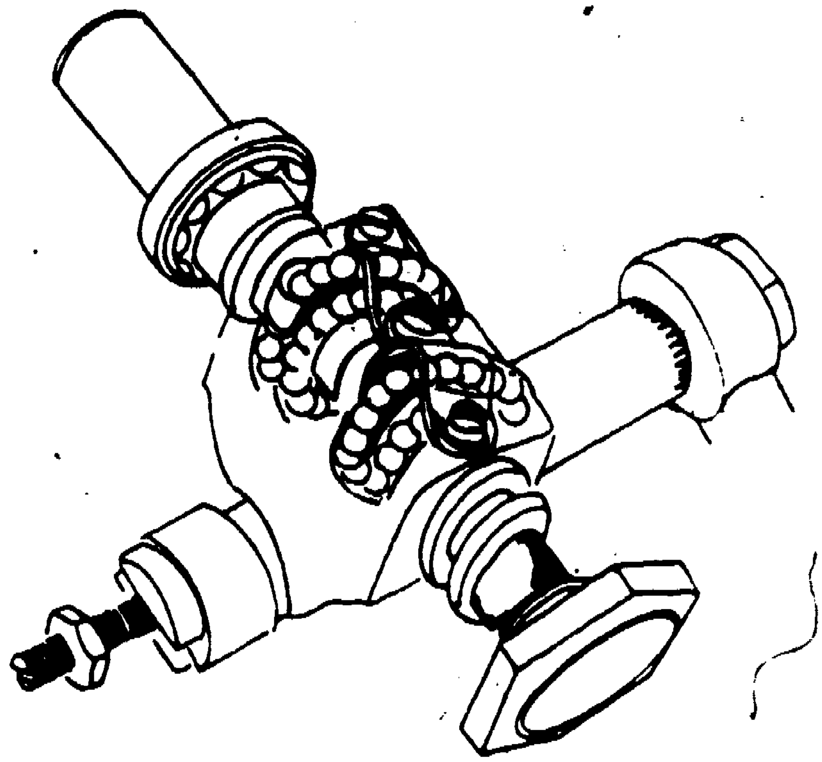
Which of the following listed components coordinates movement of both front wheels?

a. The cross shaft.
b. The drag link.
c. The pitman arm.
d. The steering shaft.
e. The tie rod.

QUESTION 37.

? ?

Study the illustration below then answer the question found below the illustration. Record your choice in the proper space on the response sheet.



Which type of steering gear is shown in the above illustration?

a. Cam and lever.

b. Recirculating ball.

c. Worm and roller.

d. Worm and sector.

? ?

Frame 30.

Answers to Frame 28:

34. b.
35. b.
36. e.

Answers to Frame 29:

37. b.

QUESTION 38.

? ?

Study the illustration below then answer the question found just below the illustration. Record your choice in the proper space on the response sheet.

Which type of steering gear is illustrated above?

a. Cam and lever.

b. Recirculating ball.

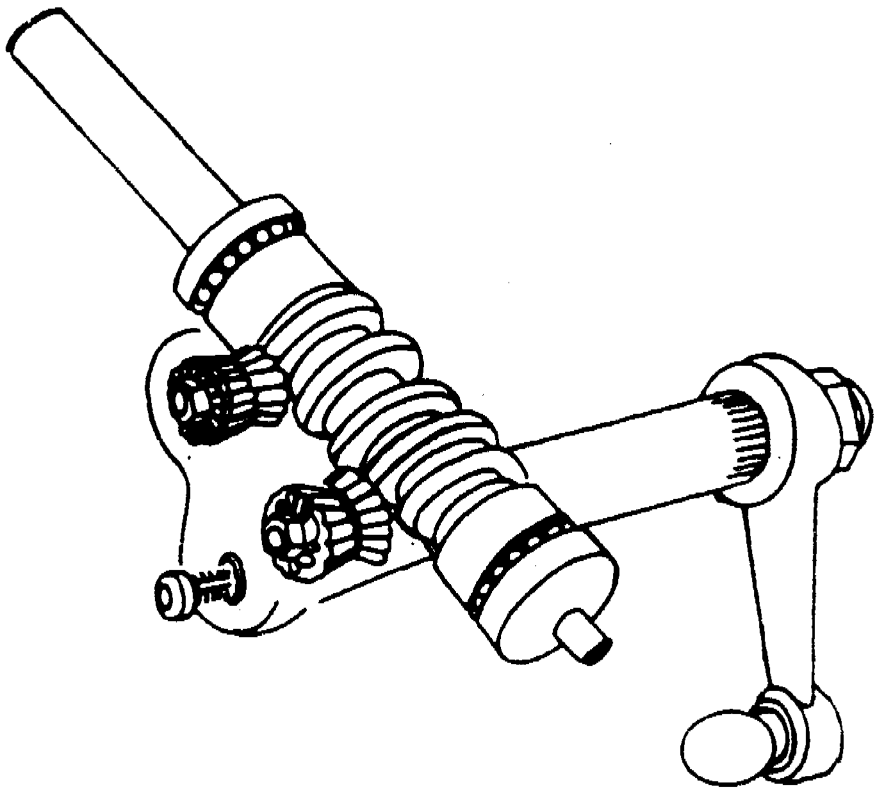
c. Worm and roller.

d. Worm and sector.

? ?

QUESTION 39.

Study the illustration below then answer the question just below the illustration. Record your choice in the proper space on your response sheet.



Which type of steering gear is illustrated above?

a. Cam and lever.

b. Recirculating ball.

c. Worm and roller.

d. Worm and sector.

Frame 32.

Answers to previous frames:

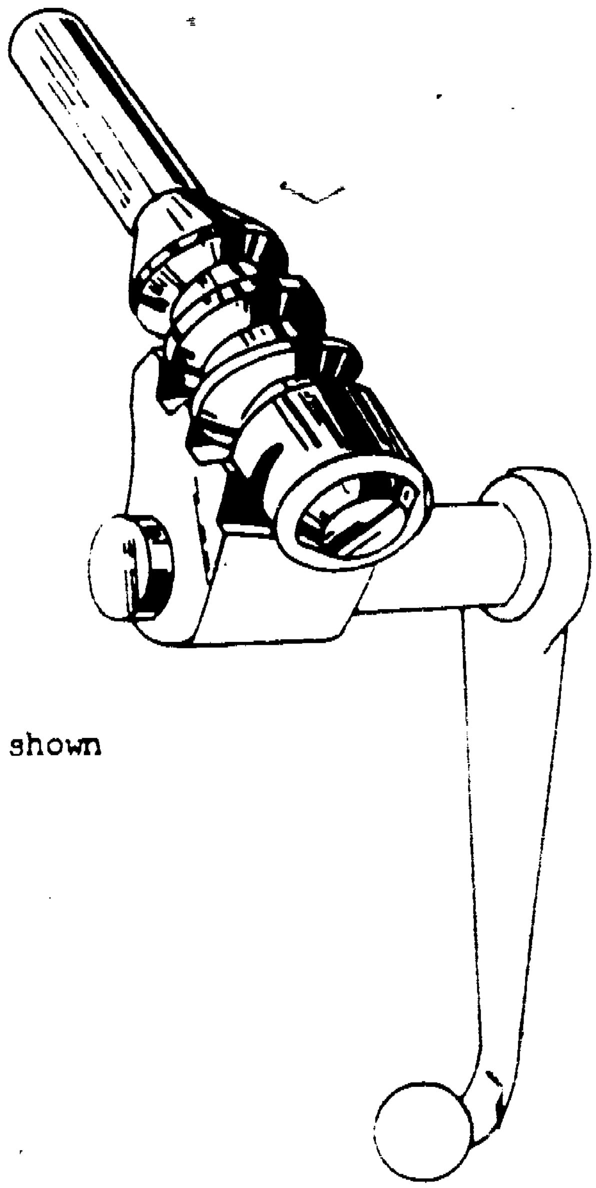
38. c.

39. a.

QUESTION 40.

? ?

? Study the illustration below, then answer the question found just ?
below the illustration. Record your choice in the proper space on
? the response sheet. ?



? Which type of steering gear is shown
? in the above illustration? ?

? a. Cam and lever. ?

? b. Recirculating ball. ?

? c. Worm and roller. ?

? d. Worm and sector. ?

? ?

QUESTIONS 41 through 45.

Identify the numbered components in the illustration below by placing the appropriate letter in the corresponding numbered space on your answer sheet. Use the list at the left to supply answers.

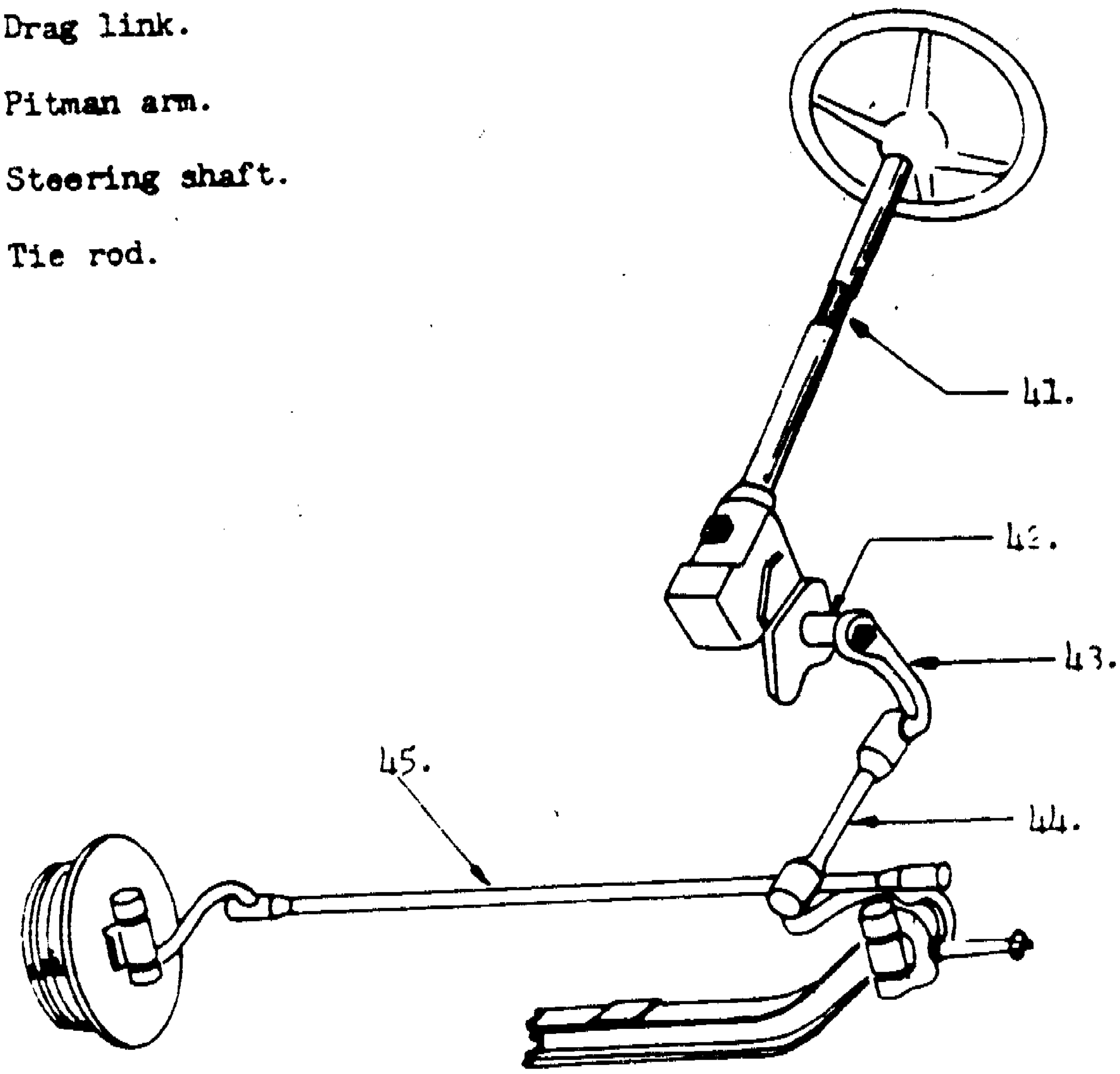
a. Cross shaft.

b. Drag link.

c. Pitman arm.

d. Steering shaft.

e. Tie rod.



FRAME ALIGNMENT

OBJECTIVES

Upon completion of this text you will be able to accomplish the following objectives with 85% accuracy.

1. Given four drawings that illustrate different alignment problems and a list of the four types of alignment problems, match each drawing with the proper type of alignment problem.

2. Given a list of the four major steps in the "Projection Method" of frame alignment, label then in their proper sequence.

3. Given a drawing showing a complete automobile frame and a list of frame components, label each component.

4. Given two drawings showing a knee-back condition and a shifted rear axle condition, label each drawing with the correct condition.

Validation

This Programmed Text was validated by students enrolled in the General Purpose Vehicle Repairman Course in 1964. It has continued to be successful since that time.

8-12

OPR: TSDT
DISTRIBUTION: X
TSDT - 600; TSOC - 2

INTRODUCTION

As you probably know, a bent, twisted, or swayed frame will greatly effect the alignment of the front wheels and steering. Frame defects cannot be corrected with the portable aligner or the Visualiner. Suspected frame defects can be identified with a few simple tools such as a plumb bob, a level, a measuring tape, and a piece of chalk. The use of the tools to determine frame defects is called the "Projection Method." Once the presence of a defect is determined, the vehicle can be sent to a frame aligning machine.

QUESTION 1.

What method of determining frame alignment are you about to study?

(Write your answer in the space provided on the answer sheet at the end of this package.

You will find the correct answer at the top of the next page.

You should have the words "Projection Method" written on the line provided for item one (1) on your answer sheet.

Since this program will teach you to check vehicle frame alignment, it will be necessary for you to know the correct name of the parts. To see if you already know, we have provided a sketch (figure 1) below, and a list of the correct names of the parts of the frame. Make your entries on the identical sketch provided as item 2 of your answer sheet.

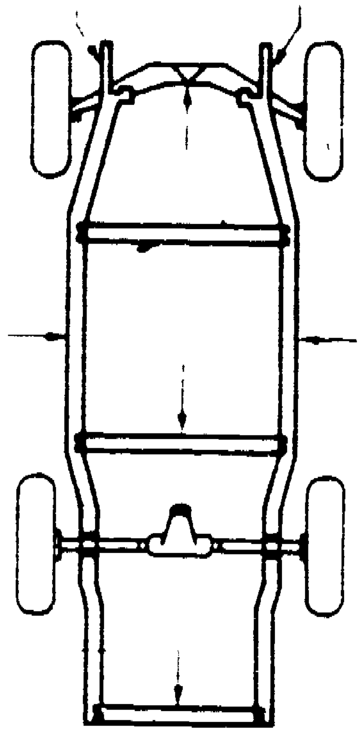


Figure 1.

A. Left side rail.

B. Middle cross member.

C. Left frame horn.

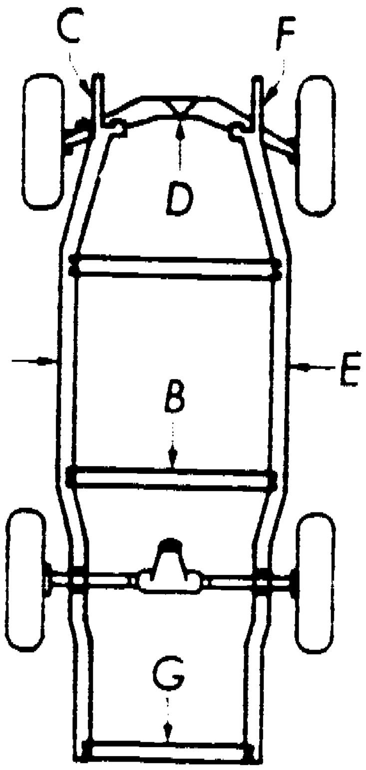
D. Front cross member.

E. Right side rail.

F. Right frame horn.

G. Rear cross member.

Be sure that you have made your own entries on the worksheet provided, then check your answers against the sketch provided at the top of the next page. If you made any errors, look the sketch over again to firm up the corrections in your mind before going further.



Item 2.

Item 2 on your worksheet should look like the sketch at the left. If it does not, you have made an error. Make the necessary corrections on your answer sheet before proceeding further.

Basically, the frame of the vehicle positions the four wheels in a true running plane, exactly parallel to the line of travel when the vehicle is moving straight forward. The frame also positions the wheels so that each front wheel is the same distance from the center line of the vehicle and each rear wheel is the same distance from the center line of the vehicle. Thus, it may be said that the vehicle frame keeps the four wheels in their proper relation to each other. Study the drawing below.

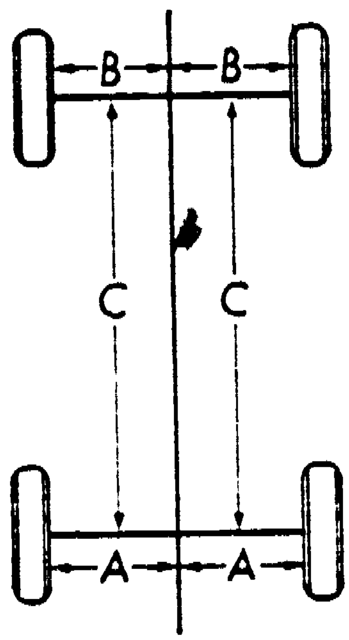


Figure 2.

QUESTION 3.

What keeps measurements "A-A," "B-B," and "C-C" of the figure above in their proper relation?

a. The vehicle frame.

b. The front and rear axles.

32

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Frame 5.

Choice "a." The vehicle frame keeps the wheels in their proper alignment relationship.

The drawing below is an illustration of a vehicle chassis with the frame out of alignment. Study the drawing and then answer the question below.

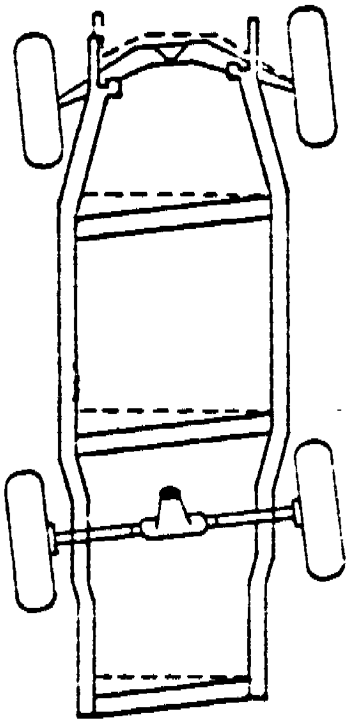


Figure 3.

QUESTION 4

What can happen when the vehicle frame is out of alignment?

a. The tires will wear excessively.

b. The vehicle will be difficult to steer.

c. Both choices a and b above are correct.

d. Neither choice a nor b are correct.

Choice "c" is correct. Both conditions will exist, the severity being determined by how seriously the frame is out of alignment.

PROBLEM: The vehicle pulls to one side, even on a flat road. All suspension, steering, and brake factors have been checked. A frame alignment check is the next order of business.

When the projection method of frame alignment is used, the vehicle should be setting on a hard, flat, level surface with the front wheels in the straight ahead position.

The first step in making the frame alignment check is to make a preliminary measurement with a "Tracking Gauge." A <u>tracking gauge</u> consists of a long, straight bar with graduations marked near one end and equipped with a fixed and movable pointer.

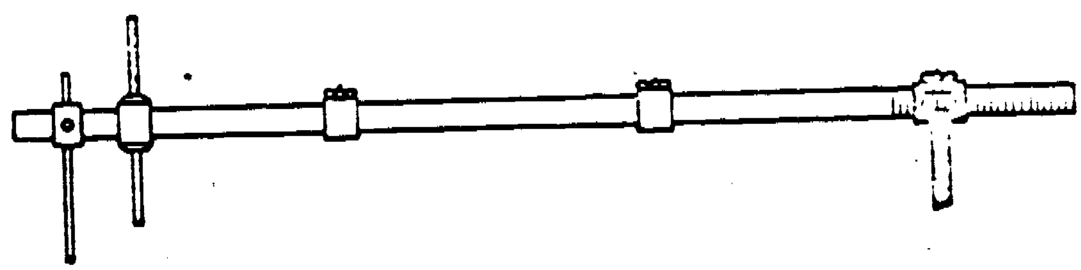


Figure 4.

QUESTION 5.

What is the first step in preparing a vehicle for a frame alignment check? (Write your answer on your answer sheet).

Frame 7.

Your answer should be: "Make a preliminary check with a tracking gauge," or words to that effect.

The primary purpose of a tracking gauge is to measure the wheel base of the vehicle, as shown in the illustration to the right.

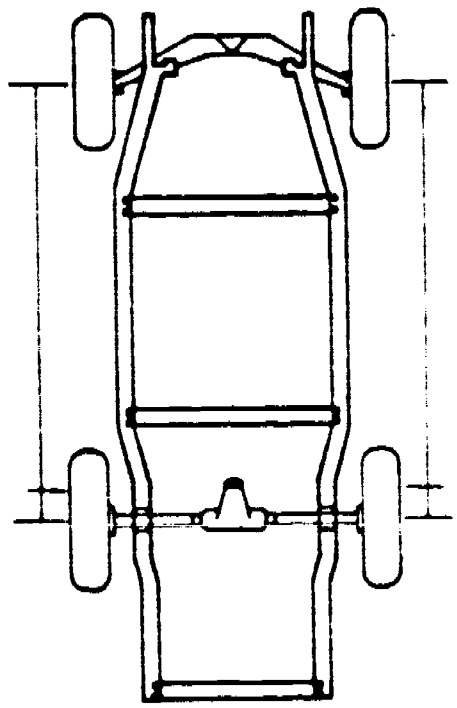


Figure 5.

QUESTIONS 6 and 7.

6. What is the purpose of a tracking gauge?

7. TRUE or FALSE. The wheel base of a vehicle is the distance from the center of the front wheel hub to the center of the rear wheel hub.

32

6. Measure the wheel base of the vehicle.
7. TRUE.

You may have asked yourself, "Why is this so important when checking for proper frame alignment?" Well, the tracking gauge is used to determine the need for continuing with the frame alignment check. Figure 5 (on the previous frame) illustrated a frame which was in proper alignment. The wheel base measurement was identical on both sides of the vehicle. Study the drawings below and then answer Question 8.

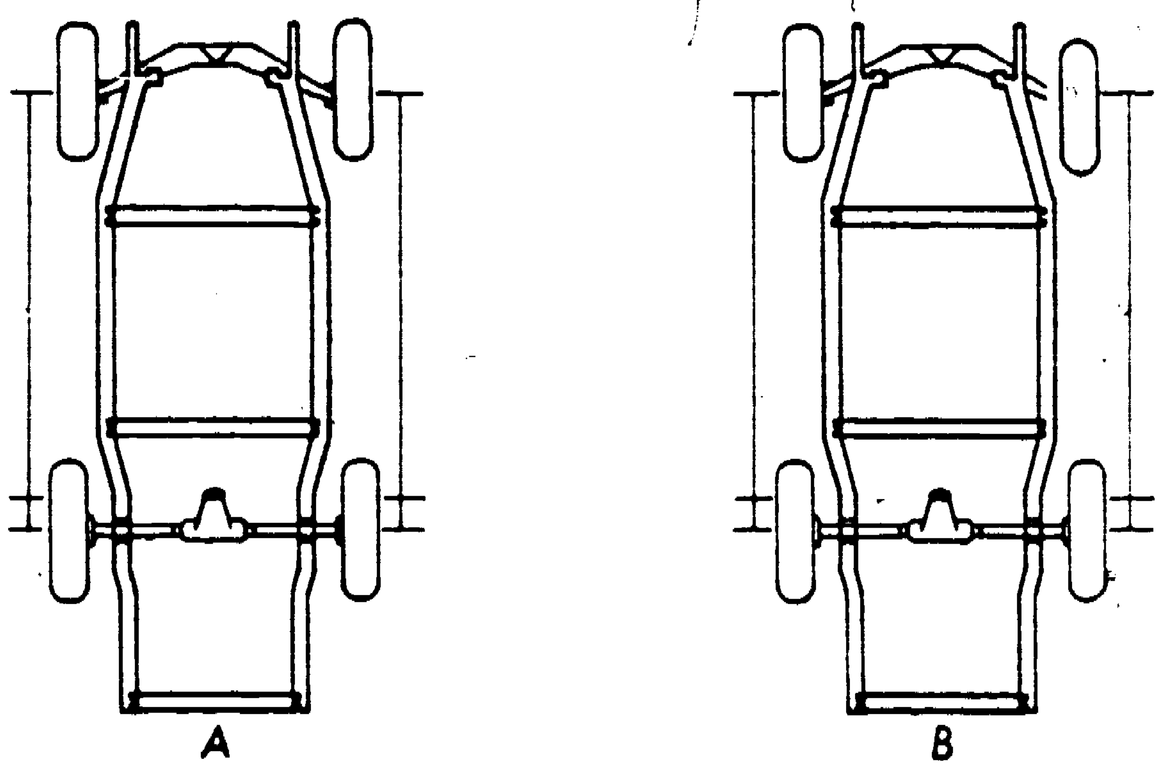


Figure 6.

QUESTION 8.

Which of the drawings in figure 6 above indicates the need for continuing the procedure for checking frame alignment?

a. a.

b. b.

Frame 9.

Drawing b indicates that the measurement for the left side of the vehicle might be normal, but the right side measurement is shorter.

You may have noticed that the pointers in figure 6 were not lined up with the centers of the wheel hubs, but rather that the pointers are aligned with the outer edges of the wheel rim. Look at the illustration below then answer Question 9.

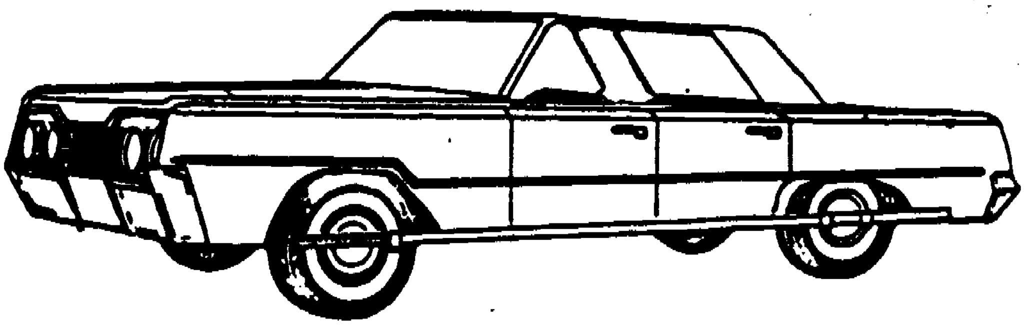


Figure 7.

QUESTION 9.

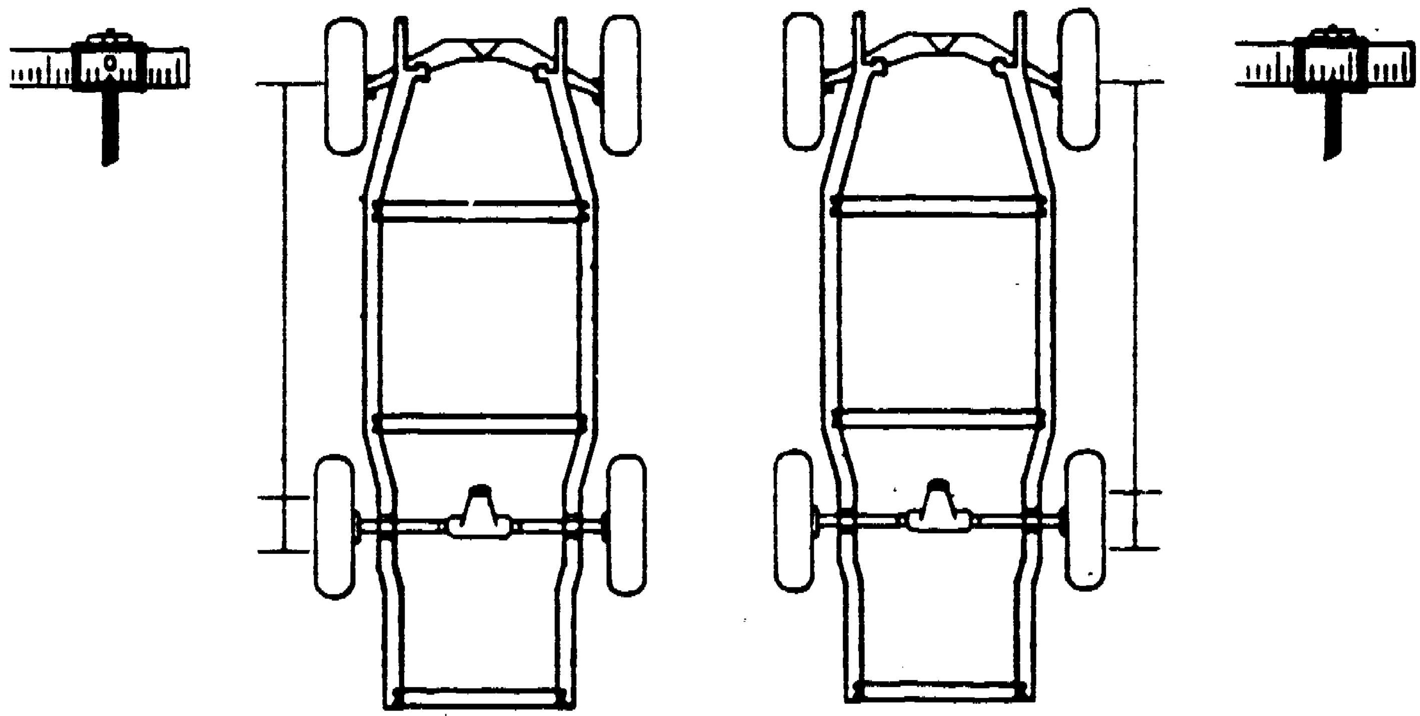
The pointers are adjusted to touch the outer portions of the rim at

a. axle height.

b. just below the wheel hub.

Drawing b indicates that the measurement for the left side of the vehicle might be normal but that the right side is shorter.

The drawing in figure 6b indicates a frame alignment defect known as "knee-back" which we will discuss later. More important at this moment is: How was it determined that the right side wheel base was shorter than the left side wheel base? Read the instructions accompanying the drawings below then answer Question 10.



a. b. c. d.

Figure 8.

1. Set one pointer to "0". (Graduated end of tracking gauge.)
2. Align both rear pointers to the outer edges of rear wheel rim and front pointer to the center of the front wheel hub, and lock the pointers in place. (Either side wheel base may be measured first.)
3. Align the pointers to the identical points of the front end rear wheel on the other side of the vehicle. (Reposition the pointer on the graduated end if necessary.)
4. If the pointer on the graduated end of the tracking gauge had to be moved more than 3/8-inch either way, then further checking is necessary.

QUESTION 10.

According to the scale (Item d above) the wheel base on the right side is (longer) (shorter) than the wheel base on the left side.

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Frame 11.

10. Shorter.

The tracking gauge is used to determine if an alignment problem exists. There are four types of alignment problems. Each problem shows up a little different when using the tracking gauge. Each of the drawings below illustrates a type of alignment problem. Remember - the tracking gauge is set on one side of the vehicle and the other side is compared against it, so the gauge you see on the right side of the drawing is an identical setting as the left side. Notice how the different types of alignment problems appear on the gauge.

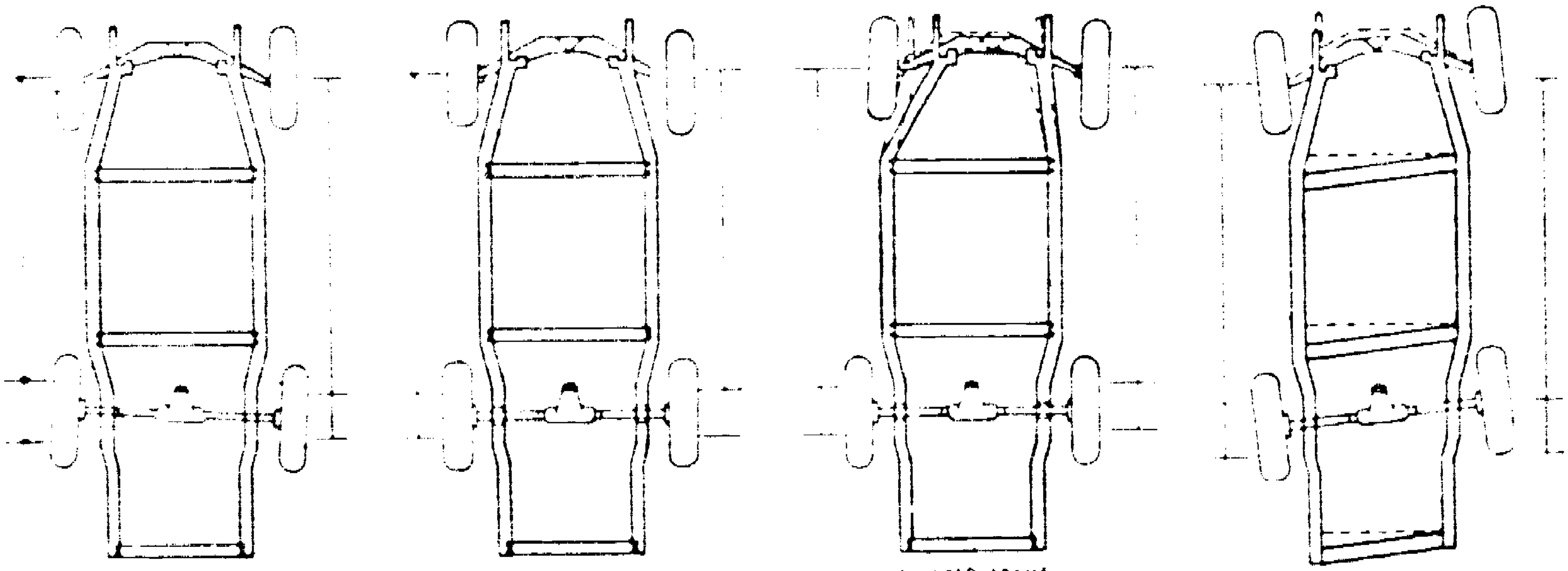


Figure 9.

QUESTION 11.

Does the tracking gauge indicate the exact location and type of alignment problem?

a. Yes.

b. No.

11. (b) No. You were right if you made this choice. The tracking gauge is used to perform a preliminary check to determine if further checking is necessary.

It was mentioned earlier in the lesson that you were going to study the "Projection Method" of determining frame misalignment. The "Projection Method" is simply the projecting of several check points of the frame to the shop floor, where more accurate measurements may be made. The tools needed are chalk, plumb bob, measuring tape, level, body stands, and chalk line.

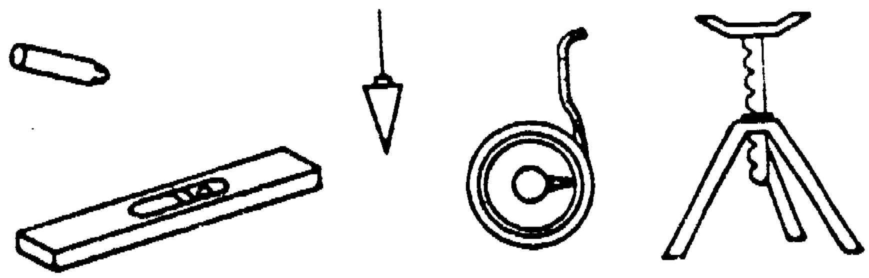


Figure 10.

QUESTION 12.

Having determined that it is necessary to continue checking the frame for misalignment and having gathered the tools, the next step is to

a. level the vehicle and crawl under it.

b. jack up the vehicle and place body stands under it.

c. project selected points of the frame to the shop floor.

Frame 13.

12. b. Jack up the vehicle and place body stands under it.

Since you will be working under the vehicle, you must put body stands under the vehicle frame in strategic locations to prevent the vehicle's falling on you. There is also another reason why body stands must be placed under the vehicle. Study the illustrations below and then answer Question 13.

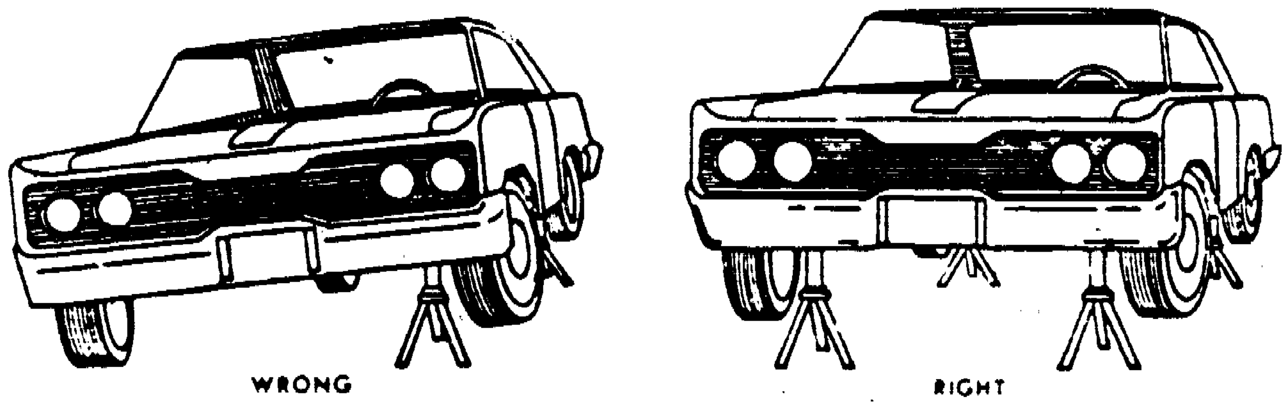


Figure 11.

QUESTION 13.

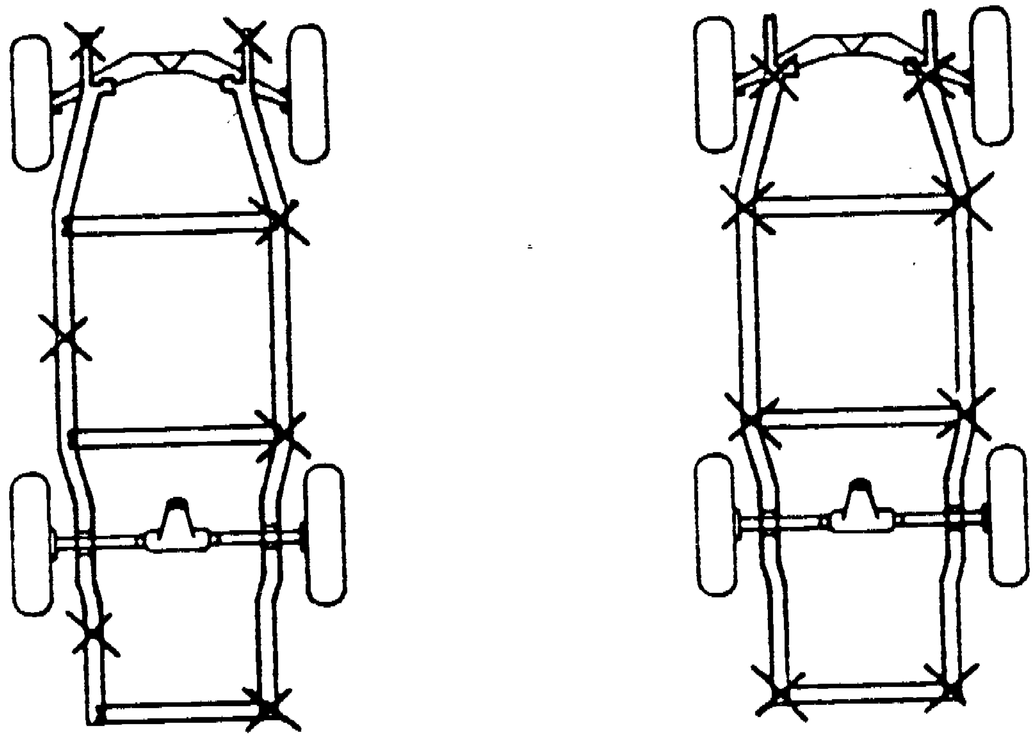
The next step in preparing the vehicle for frame alignment checking is to

a. crawl under the vehicle and hang the plumb bobs from the vehicle frame to the shop floor.

b. make sure the body stands are level and locked.

13. b. The next step of the "Projection Method" for checking frame alignment is to make sure that the body stands are level and locked.

After the vehicle has been jacked and leveled, you are ready for the third step. This step requires you to suspend a plumb bob from a minimum of eight (8) different points on the vehicle frame to the shop floor. The two illustrations below depict a top view of the frame with the suspension points identified by "X's." Study the drawings and answer Question 14 below.



a. b.

Figure 12.

QUESTION 14.

Which drawing above, in your opinion, shows correct suspension points?

a. Drawing a.

b. Drawing b.

Frame 15.

Drawing b. The point being made here was that there must be at least eight suspension points and they must be identically placed on each side rail. The drawing here should help you to visualize where these points might be. It is important to remember that identical points on the side rails must be projected to the shop floor. Otherwise, an erroneous measurement may result.

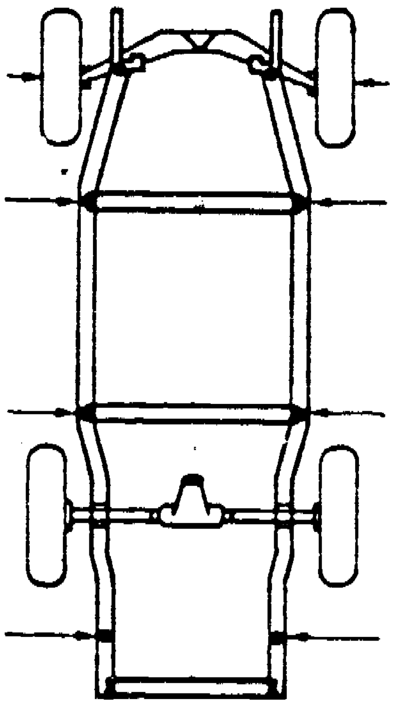


Figure 13.

QUESTION 15.

The steps necessary to perform a frame alignment check by the "Projection Method" are:

a. Place the vehicle on body stands. Level the vehicle, suspend plumb bobs from eight random points from the vehicle frame.

b. Level the vehicle, jack the vehicle and place body stands under it and suspend plumb bobs from random points from the frame.

c. Jack up the vehicle, place body stands under the vehicle. Level the vehicle and lock the body stands, suspend a plumb bob from four identical points on each side of the vehicle frame.

15. c.

Obviously, you cannot suspend the plumb bob from 8 points at once, so you must mark each point with chalk on the shop floor, then move on to the next point. Study the illustration below. The "X's" mark the appropriate suspension points.

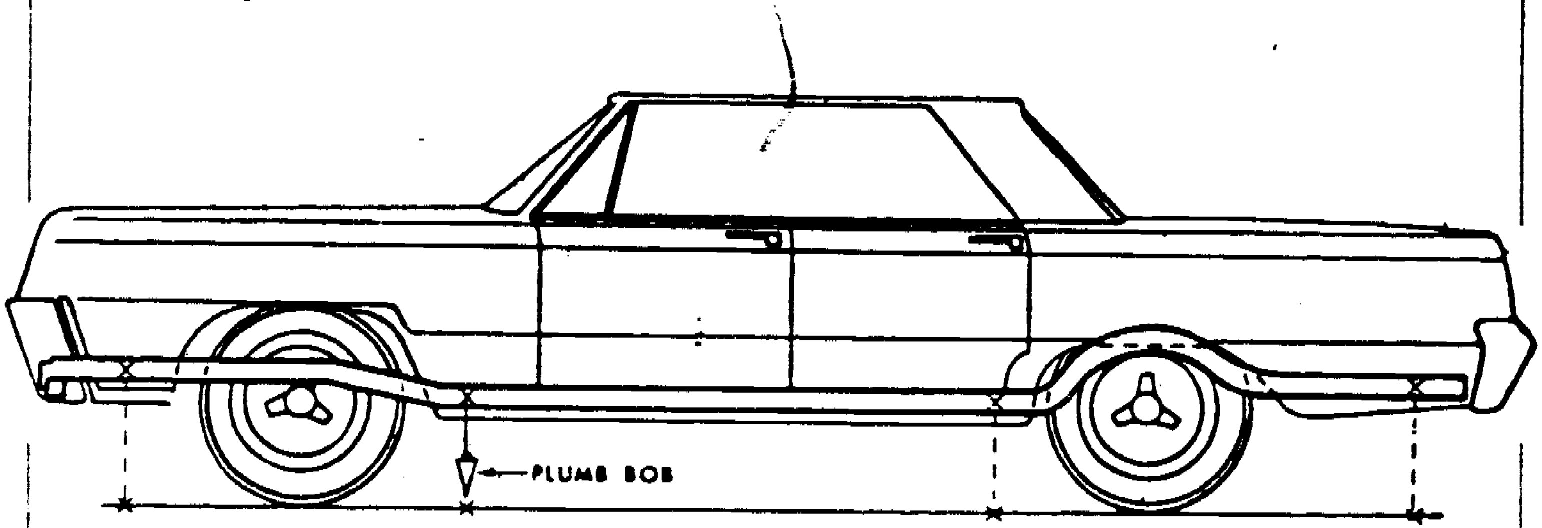


Figure 14.

QUESTION 16.

Before moving from one suspension point to the next, you must

a. memorize the point on the shop floor where the plumb bob is now touching.

b. place a chalk mark on the shop floor directly under the point of the plumb bob.

Frame 17.

b. Of Course! You must mark each point on the shop floor with chalk.

After suspending the plumb bob from a point on the vehicle frame, you make a chalk mark on the shop floor under the plumb bob point. Repeat this procedure at each check point on the frame rail. Cross over to the rail on the other side of the vehicle and repeat the entire procedure. Make sure that the check points selected are identical for both rails. Use the junction of a cross member and the side rail or some other easily identifiable check point.

QUESTION 17.

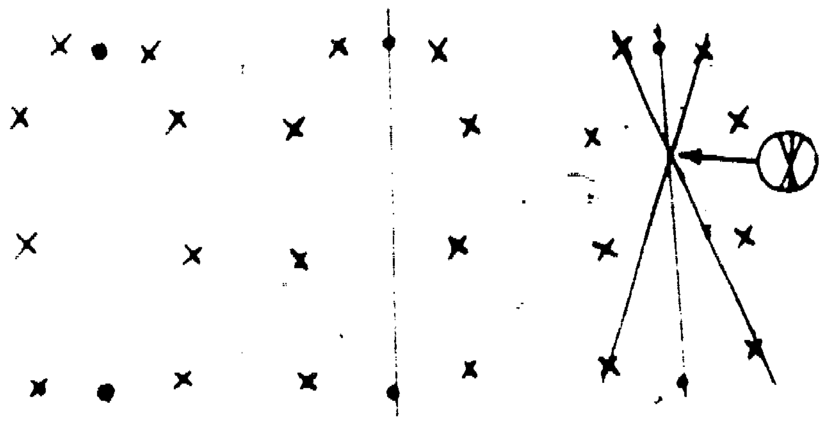
After marking all eight points on the shop floor, what, in your opinion, is the next step?

a. Measure the distance between the chalk marks.

b. Raise the vehicle, remove the body stands, lower the vehicle, and drive it away from the chalk-marked area.

b. Of course! Get the vehicle out of your way so that you have plenty of room in which to work.

The next step is to determine the mid-points between the two front chalk marks and the two rear chalk marks, see part a of the illustration below. When these two points have been determined, then draw a chalk line connecting the two mid-points, see part b of the illustration. Next, draw two diagonal lines connecting the CORNER chalk marks, part c of the illustration below. This procedure gives a very general outline of the frame and the general area of the frame defect.



Diagonal lines should intersect on the center line for a frame in GOOD alignment.

a. b. c.

Figure 15.

QUESTION 18.

The procedure described above

a. determines whether the frame is "swayed" or "diamond" shaped.

b. gives a general outline of the frame and a general idea of the area of the frame defect.

Frame 19.

18. b. **Good! The procedure described in the previous frame gave** a GENERAL outline of the frame and the GENERAL AREA of the defect.

The next steps will determine if the frame is "swayed" or "diamond-shaped." After studying the drawings below, answer Question 19.

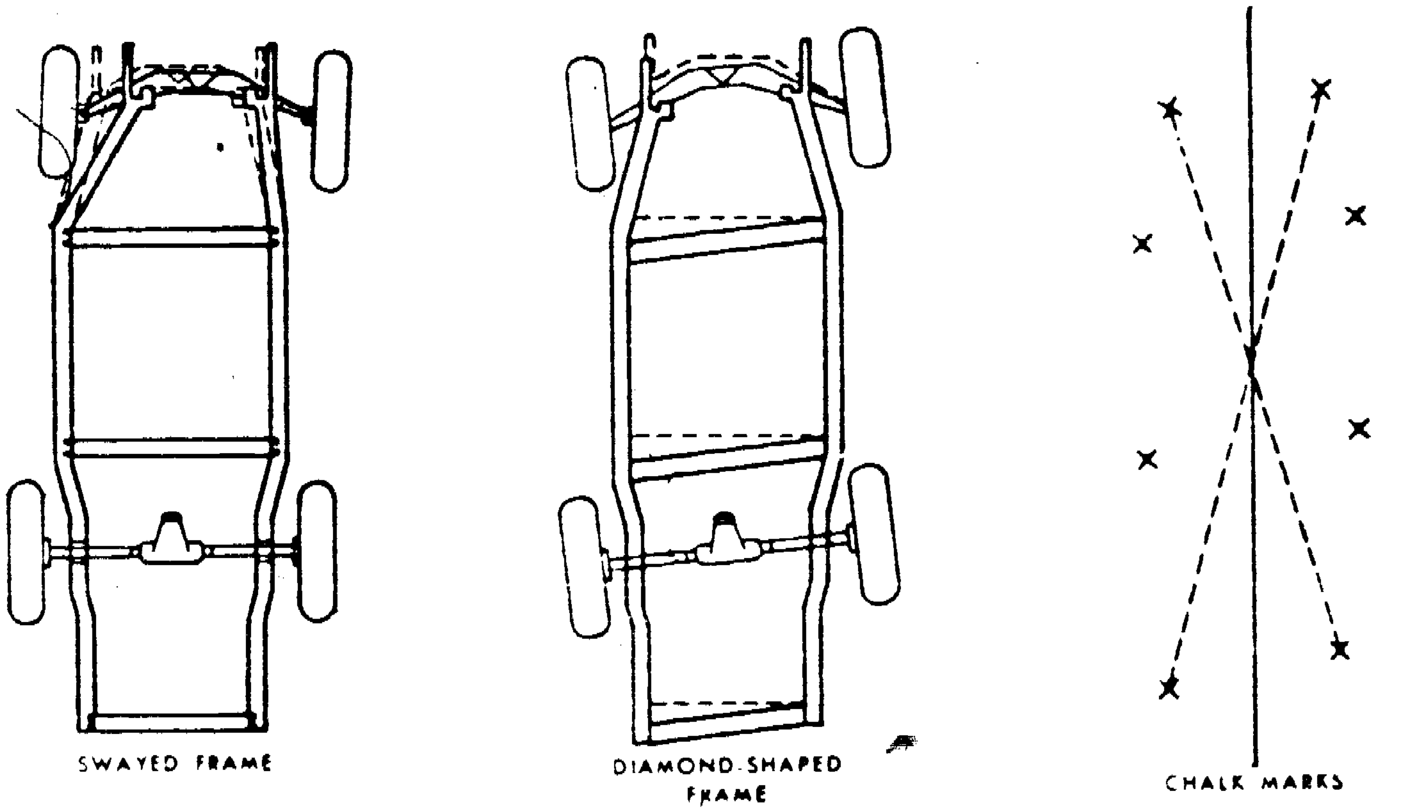


Figure 16.

QUESTION 19.

The chalk marks were projected from a vehicle with a

a. "swayed" frame.

b. "diamond-shaped" frame.

19. b. The drawings in figure 16 have been exaggerated to make it obvious to you that a pattern of the frame has been "Projected to the shop floor."

Actually, it is nearly impossible to determine if the frame is in fact out of alignment UNTIL some measurements have been taken. The measurement will be accomplished using a steel tape measure at least 30 feet in length. Study the drawing below, then answer Question 20 found below the drawing.

```
 4 x   x 5
3 x     x 6
2 x     x 7
1 x     x 8
```

Figure 17.

QUESTION 20.

Between which points should you measure to determine frame alignment?

a. Between 1 and 4, then between 5 and 8.

b. Between 1 and 5, then between 4 and 8.

Frame 21.

20. b. All measurements must be taken on the diagonal.

When a vehicle has a "diamond-shaped" frame, one side is shifted or pushed back, as indicated in the drawing below.

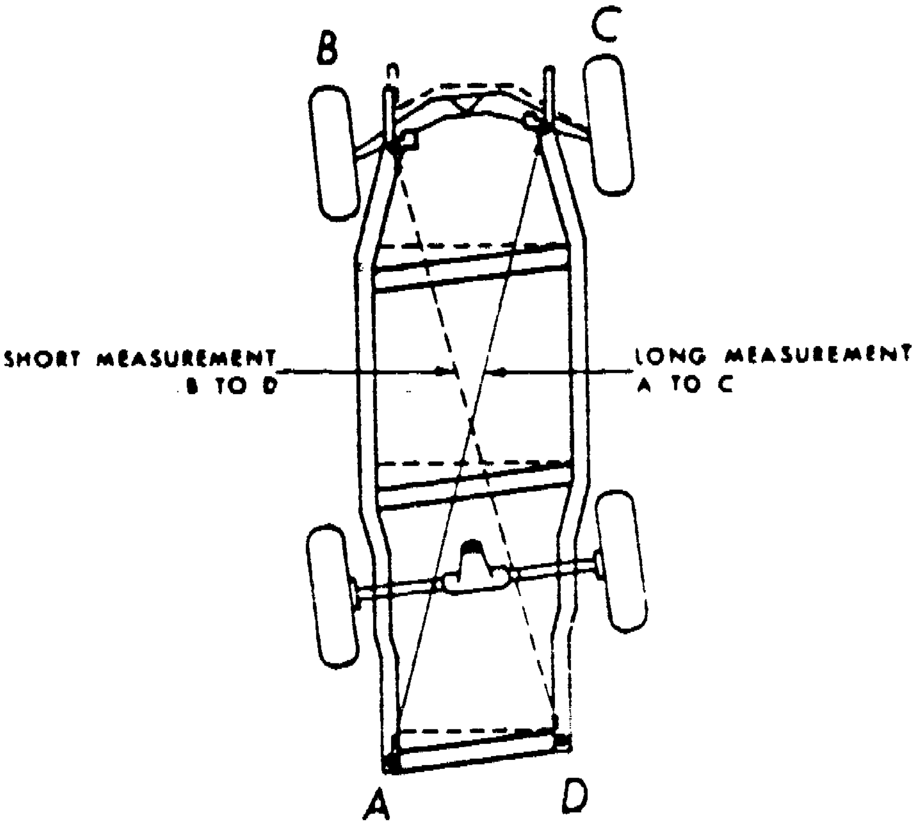
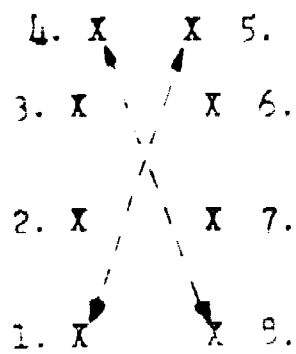


Figure 18.

As you can see, the diagonal measurement B-D is longer than the other diagonal measurement, A-C.

QUESTION 21.

In the illustration to the right, the measurement between chalk marks 1 and 5 is 13 feet 6 inches. The measurement between chalk marks 4 and 8 is 13 feet and 7 inches. Can you tell from these measurements whether the frame is swayed or diamond-shaped?



a. Yes.

b. No.

21. b. NO is right. When a frame is out of alignment, from either a "swayed" or "diamond-shaped" condition, the corner to corner measurements are usually UNEQUAL. To determine which of the conditions is causing the problem, at least one more set of measurements need to be taken. Thus, a minimum of four measurements are necessary to pinpoint a "swayed" or "diamond-shaped" condition.

An automobile frame is not constructed as precisely as, for instance, a lathe. Also, lack of quality control during manufacture, minor twists incurred through everyday use, human error, and other factors all combine to make it extremely IMPROBABLE that diagonal measurements will be exactly alike on even a properly aligned frame. Therefore, a tolerance between measurements is allowed. The greatest tolerance being allowed is on the longest diagonal measurement. In this case it is 3/8 of an inch.

In the previous frame it was established that the longest measurement was 13 feet 6 inches and 13 feet 7 incnes. The difference in these measurements is one inch. This difference is considerably more than 3/8 inch so it can be said that a frame alignment problem exists.

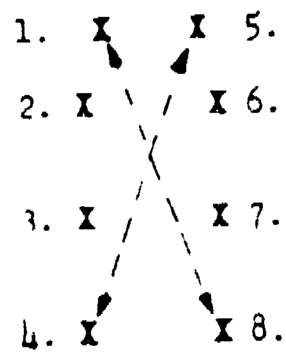
QUESTION 22.

Between what two points should the next set of measurements be made?

a. Between 1 and 3, then between 6 and 8.

b. Between 3 and 5, then between 4 and 6.

c. Between 1 and 6, then between 3 and 8.



Frame 23.

22. b. Did you get it correct?

The first measurements were from points 1 to 5, and from 4 to 8.

The distances between these points were 13'6" and 13'7".

The next measurements were from points 3 to 5, and from 4 to 6.

The distances between these points were 5'4" and 5'4 1/2".

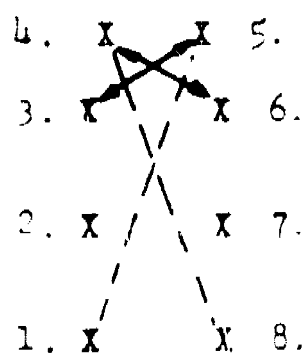


Figure 19.

QUESTION 23.

Can you tell after making the second set of measurements if the frame is "racked" or diamond-shaped?"

a. Yes.

b. No.

23. b. NO! The figures indicate that the defect is in the forward part of the frame, however.

Pairs of short diagonal measurements may not differ by more than 1/8 inch. The tolerance on the long measurements is 3/8 inch.

The first (long) measurements were: from 1 to 5 was 13'6".
from 4 to 8 was 13'7".

The second (intermediate) measurements were: from 3 to 5 was 5'4".
from 4 to 6 was 5'4 1/2".

The third (short) measurement from 2 to 6 is 5'8",
and from 3 to 7 is 5'8 1/2".

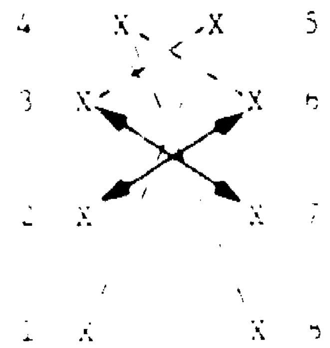


Figure 20.

QUESTION 24.

What is the alignment problem of the frame in the above case?

a. It cannot yet be determined.

b. It is "swayed."

c. It is "diamond-shaped."

Frame 25.

24. d. It cannot yet be determined.

The illustrations below show all of the measurements. Study each and every one of them carefully, study the RULE, then answer Question 25 below.

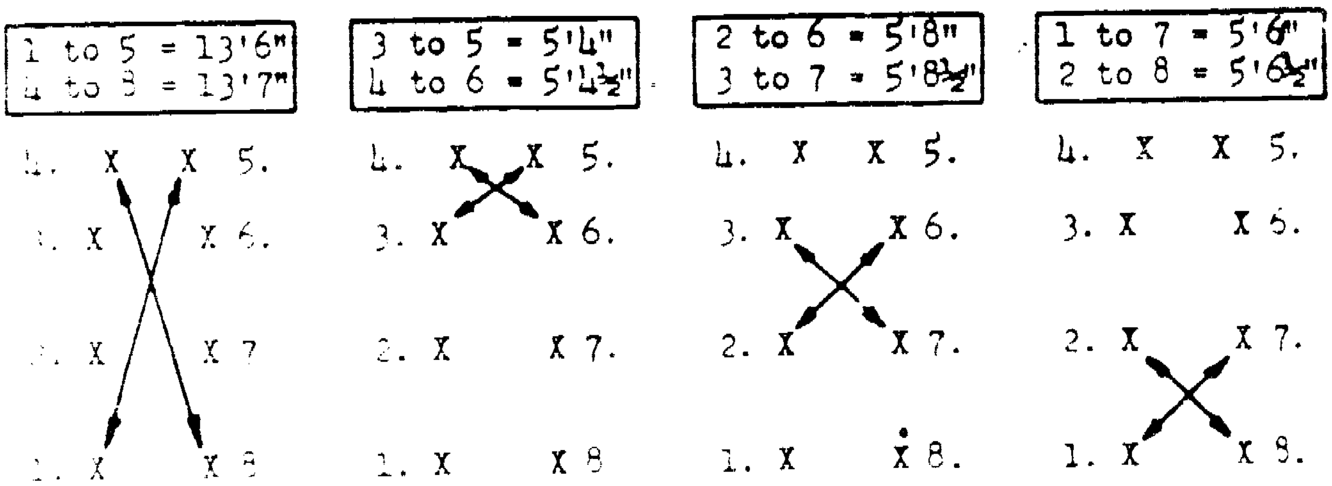


Figure 21.

RULE: After making the long diagonal measurements, if all of the short measurements are unequal the frame can be identified as being "diamond-shaped." If only one short measurement is unequal (that is, if the other two pairs of short measurements are within tolerance) the frame is "swayed." The "swayed" portion of the frame is located in the area of unequal measurements.

QUESTION 25.

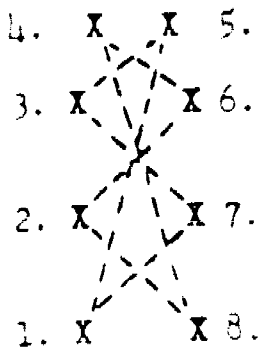
What is the alignment problem of the frame with the measurements shown above?

a. It is "diamond-shaped."

b. It is "swayed."

25. a. The measurement figures given indicate that the frame is "diamond-shaped."

In the figure below, the measurements indicate that the frame is "swayed." Study the measurements given, then answer Question 26.



1 to 5 = 13'6" 4 to 8 = 13'7"	**First measurements (unequal)**
3 to 5 = 5'4" 4 to 6 = 5'4½"	**Second measurements (unequal)**
2 to 6 = 5'8" 3 to 7 = 5'8"	**Third measurements (equal)**
1 to 7 = 5'6" 2 to 8 = 5'6"	**Fourth measurements (equal)**

Figure 22.

QUESTION 26.

What is the rule for determining if the frame is swayed?

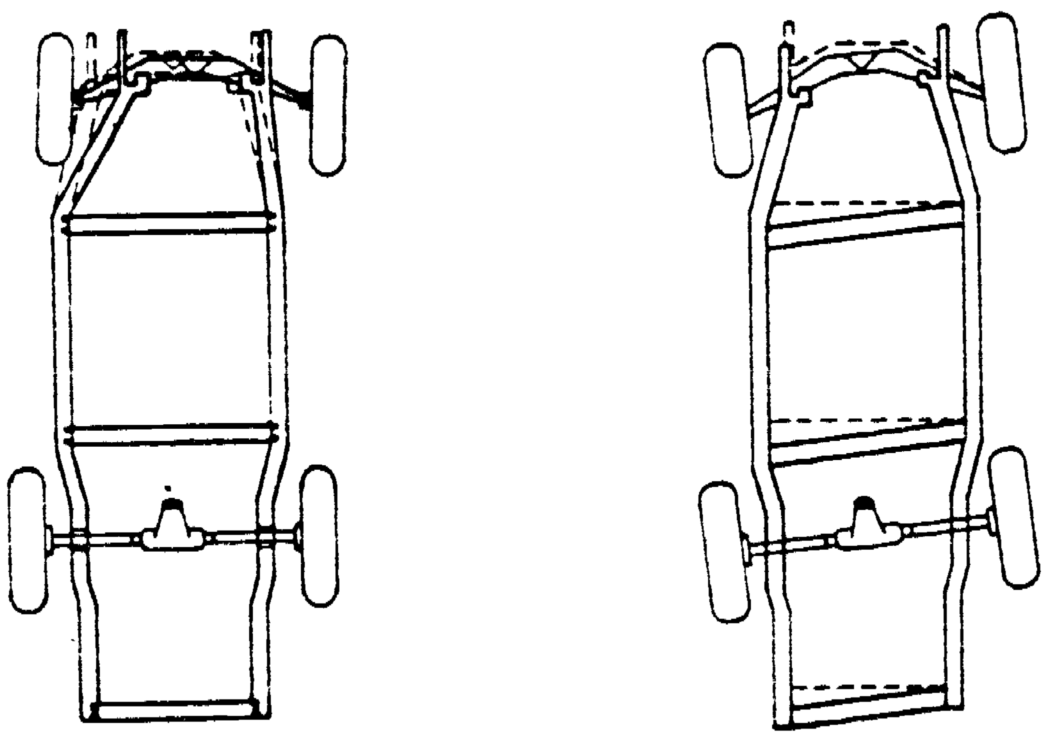
a. When each set of diagonal measurements is unequal, the frame is "diamond-shaped."

b. When one set of short diagonal measurements is unequal and the other two sets of short diagonal measurements are equal, the frame is "swayed."

Frame 27.

26. b. Very good! The rule is: "When one set of short diagonal measurements is unequal and the other two sets of short diagonal measurements are equal, the frame is swayed."

Study the drawings below, then answer Question 27 below.



a.　　　　b.

Figure 23.

QUESTION 27.

Which frame shown in figure 23 above is diamond-shaped and which is swayed?

a. Drawing a is diamond-shaped and drawing b is swayed.

b. Drawing a is swayed and drawing b is diamond-shaped.

27. b. Drawing a was swayed and drawing b was diamond-shaped.

REVIEW TEST

Answer each of these questions as directed by the instructions. The answer sheet has space provided for these answers. Do not write on this Program.

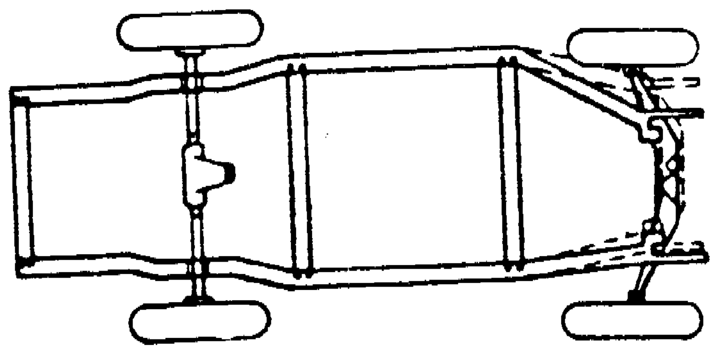
Question 1. The "Projection Method" of frame alignment is accomplished in four major steps. In the spaces provided on your worksheet, enter the letter identifying the description of the four steps.

____	Step 1	a.	Suspend the plumb bob from at least 8 points and chalk mark each point on the floor.
____	Step 2	b.	Measure diagonally between the chalk marks.
____	Step 3	c.	Jack up the vehicle, level it, and place on the body stands.
____	Step 4	d.	Raise the vehicle, remove the body stands, lower the vehicle, and move the vehicle away.

Question 2. A frame is out of alignment when the longest diagonal measurements are unequal by more than

a. 3/8"
b. 1/2"
c. 5/8"
d. 3/4"

Question 3. This question is based on the illustration below:



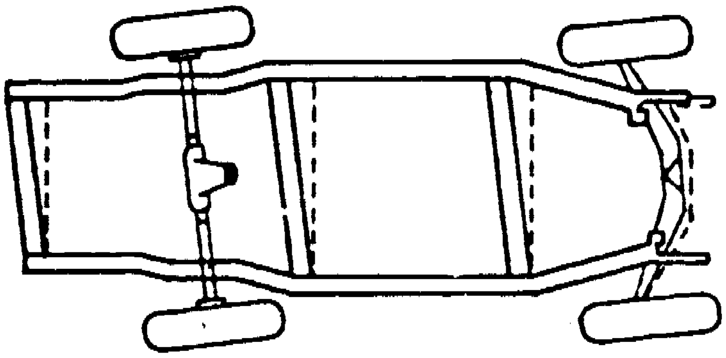
Is this frame, (a) swayed, OR (b) diamond-shaped?

CONTINUED ON NEXT PAGE

Frame 29.

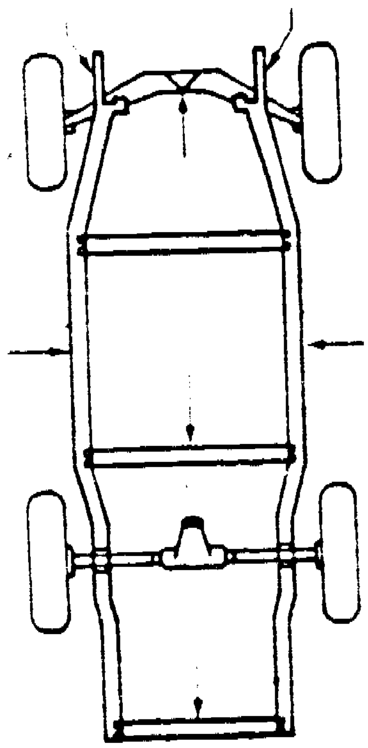
REVIEW TEST (CONTINUED)

Question 4. This question is based on the following illustration:



Is this frame, (a) swayed, OR (b) diamond-shaped?

Question 5. In the space provided on the answer sheet, enter the letter identifying each part shown in the illustration.



A. Left side rail.

B. Middle cross member.

C. Left frame horn.

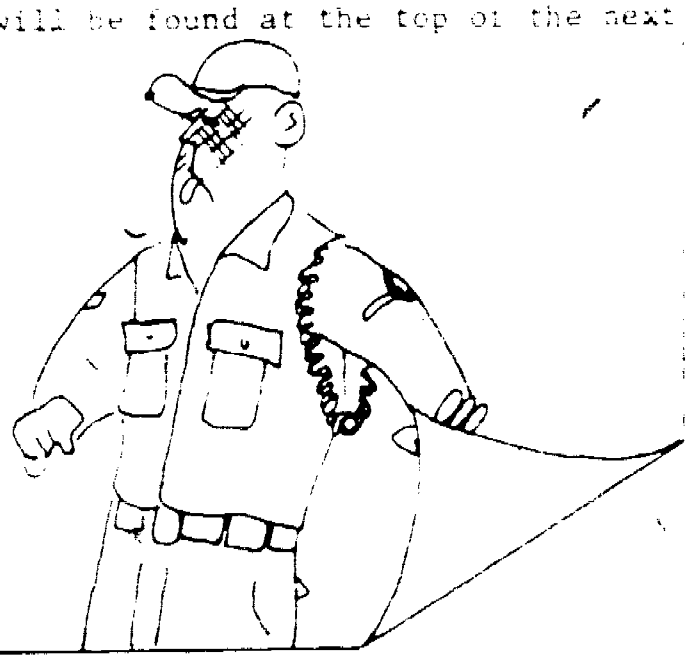
D. Front cross member.

E. Right frame horn.

F. Rear cross member.

G. Right side rail.

The answers to this REVIEW TEST will be found at the top of the next page.



HEY! QUIT THE PEEKIN' !

Answers to the questions asked on the REVIEW TEST.

Question 1. c Step 1

a Step 2

d Step 3

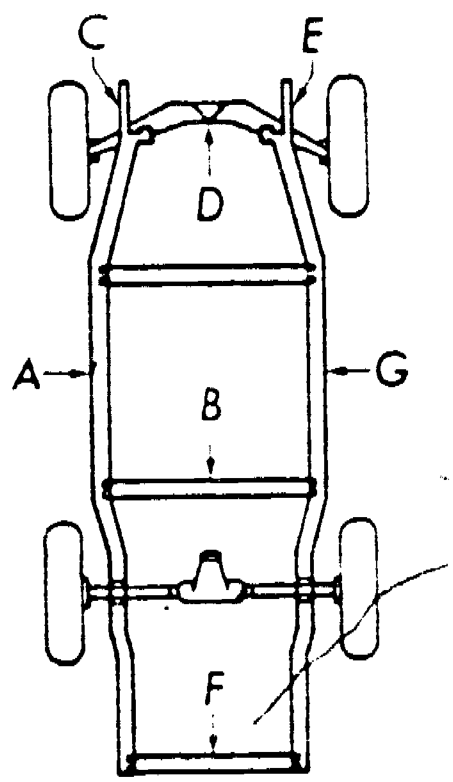
b Step 4

Question 2. a (3/8")

Question 3. a (swayed)

Question 4. b (diamond-shaped)

Question 5. See drawing below:



NOTE: If you missed any of the questions on the REVIEW TEST, make sure that you understand the correct answer before you proceed to the next page.

Frame 31.

Now that you have completed the portion of the Program which deals with damaged frames, we can think about other alignment problems. Of course, we know that caster, camber, and toe-in are adjustable by use of alignment equipment. There are two other alignment problems which can cause steering wander, excessive tire wear, or poor tracking (sometimes all three!). These conditions are called "knee-back" and "shifted axle." Knee-back is a condition where one front wheel is pushed slightly toward the rear of the car. It can be caused by striking the curbing while parking or turning into a driveway, or it might be caused by striking a hole or other obstruction in the road. It is not readily detected by a routine alignment check. If a car steers poorly or wears the front tires excessively <u>after</u> routine alignment has been accomplished, a check for knee-back might well be in order. Shifted rear axle may be defined as any condition in which the rear axle is not perpendicular to the frame of the vehicle.

The drawing below depicts a typical diagonal parking operation.

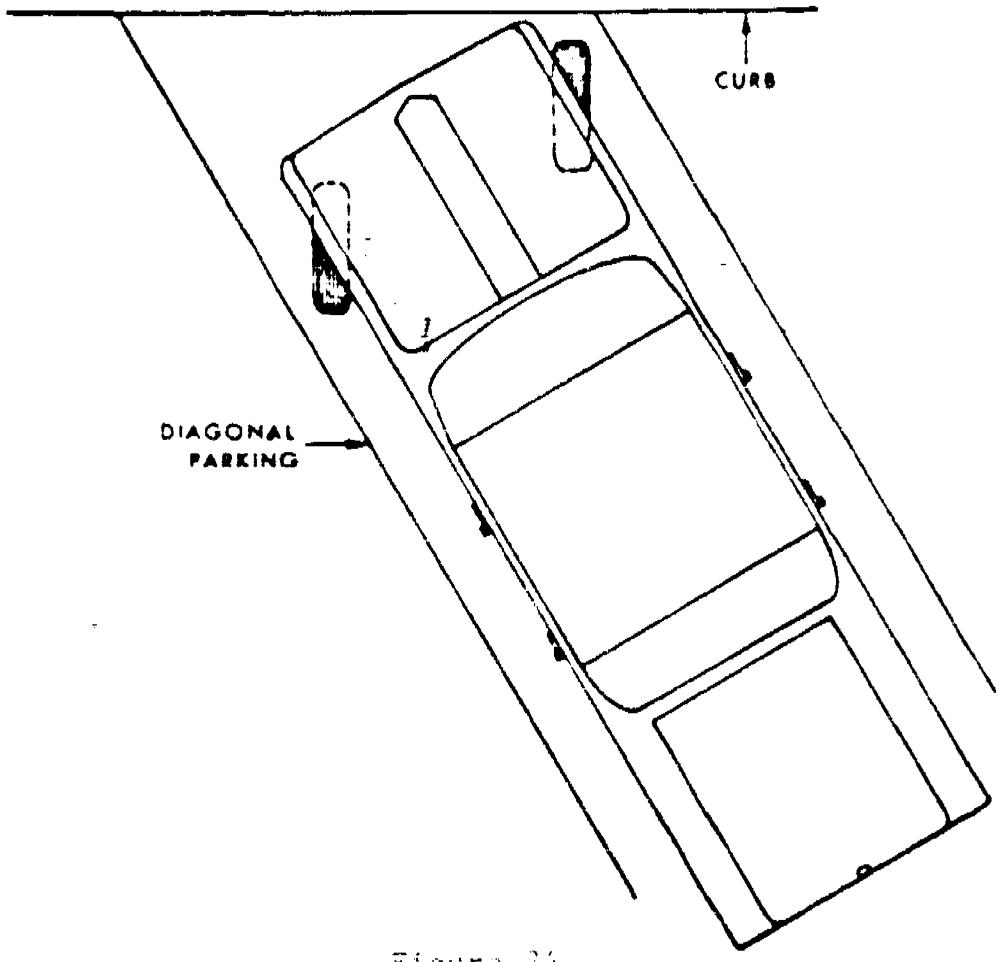


Figure 24.

QUESTION 28.

What could be the possible result of a maneuver such as that shown in the illustration above?

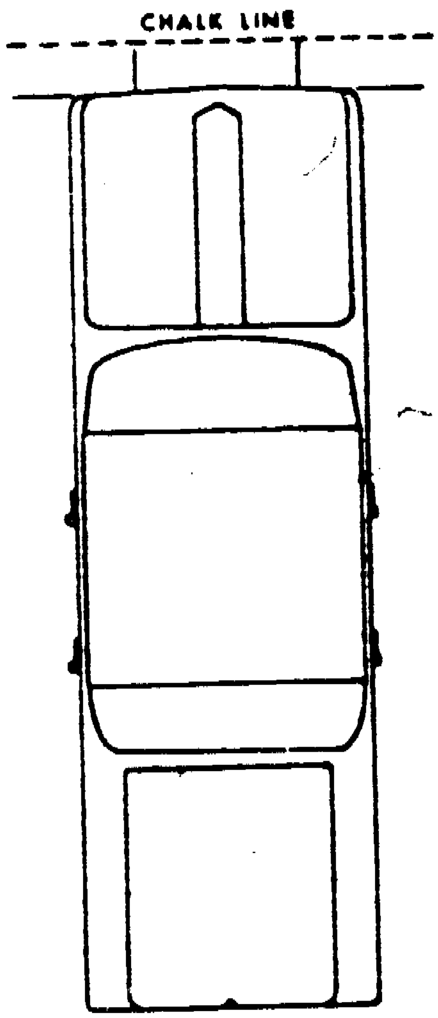
a. A knee-back condition could result if the curb is struck too hard.

b. A shifted rear axle could occur.

28. a. Knee-back could result from this. If you parked against the curb and wound up with a shifted rear axle, I'm afraid that you would need the services of a tow truck!

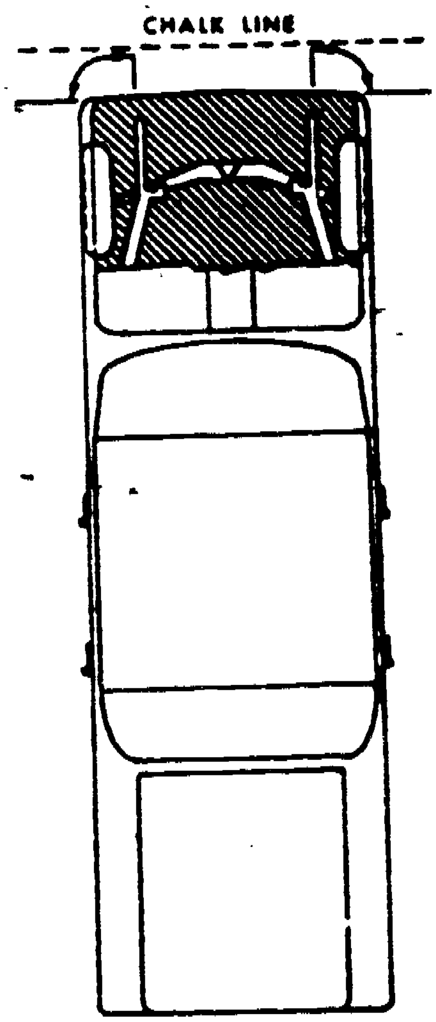
We will study the procedure for determining the presence of a knee-back condition first, then go to the procedure for determining a rear axle shifted condition. Before checking for knee-back, make sure that the frame is straight, because either a swayed or diamond-shaped frame could masquerade as a knee-back condition.

The first step is to place the vehicle on a level surface. Next, you must establish a line which is parallel to the front of the vehicle. The two drawings below show different methods of establishing this line.



Drawing # 1.

Suspend a plumb bob from the bumper at two points. Measure 12" forward and draw a chalk line between the two marks.



Drawing # 2.

Suspend a plumb bob from the front of the front cross member at the junction of the side rail. Measure 12" forward and draw the chalk line parallel to the front of the vehicle.

Figure 25.

343.

Frame 33.

QUESTION 29.

Will drawing #1 or drawing #2 of figure 25 (previous frame) be the more accurate method?

The next step is to measure from the chalk line to the center (hub) of each front wheel, making sure that your measurement is perpendicular to the chalk line. Record the measurements (A in the drawing), then measure in like manner from the chalk line to the center (hub) of each rear wheel (B in the drawing) and record the measurements. Study the illustration below, then answer Question 30.

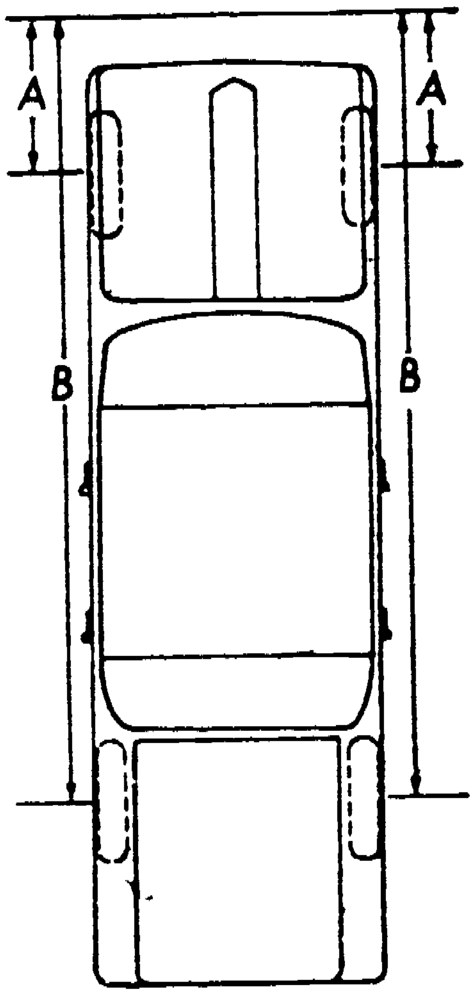


Figure 26.

QUESTION 30.

Does measurement "A" or "B" in figure 26 above check for a shifted rear axle?

Answers to previous questions:

29. If you chose drawing #2 as the correct one you were right. The method illustrated in drawing #1 has too much possibility for error. If the bumper is bent or twisted or installed improperly, or if one of the frame horns is bent or twisted, our chalk line will be out of line, giving us an inaccurate reference line.

30. If you said that "B" is the correct measurement to check for a shifted rear axle, you are right. If you missed, you must have failed to read the question.

Study the measurements of the drawing below.

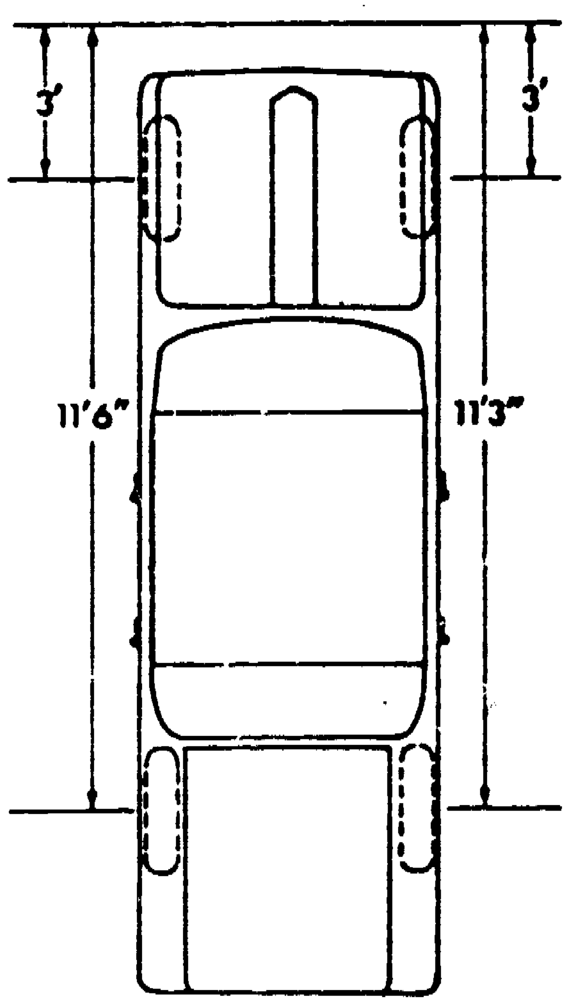


Figure 27.

QUESTION 31.

What is the alignment problem of the vehicle in figure 27?

a. Knee-back.
b. Shifted rear axle.
c. There is no alignment problem.

Frame 35.

31. b. Right! A shifted rear axle condition is the problem. As you noticed, the frame was undamaged. The rear axle was shifted forward on the right side.

There are several possible causes of a shifted rear axle condition. Among these causes are a broken main leaf in the rear spring, a broken center tie bolt in the rear spring, and a missing spring pad. By far the most common cause, however, is the broken center tie bolt.

QUESTION 32.

Which of the following is the correct answer?

a. A shifted rear axle is caused by a broken rebound clip.

b. A broken center tie bolt usually causes a shifted rear axle.

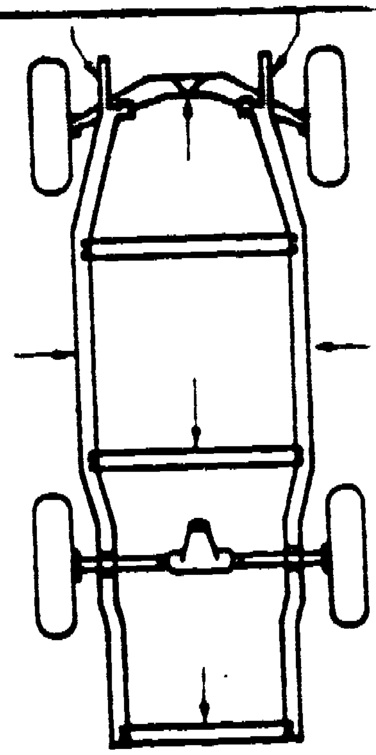
32. The correct answer was choice "b."

You have now completed the program on Vehicle Frame Alignment. If there is any portion that is not clear to you, now is the time to go back and review it. If you feel that you are satisfied, notify your instructor. He will give you another job to do.

PROJECT: Vehicle Frame Alignment

1. ________________

2.



3. (a) (b)

4. (a) (b) (c) (d)

5. ________________

____

____

6. ________________

____

7. ________________

8. (a) (b)

9. (a) (b)

10. ________________

11. (a) (b)

12. (a) (b) (c)

13. (a) (b)

14. (a) (b)

15. (a) (b) (c)

16. (a) (b)

17. (a) (b)

18. (a) (b)

19. (a) (b)

20. (a) (b)

21. (a) (b)

22. (a) (b) (c)

REVIEW TEST

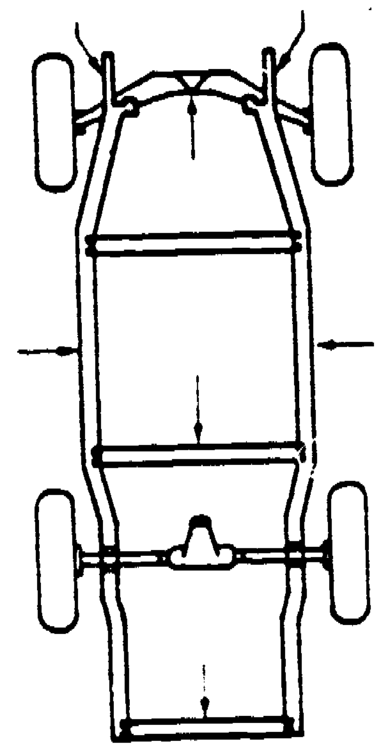
1. ____ Step 1.
   ____ Step 2.
   ____ Step 3.
   ____ Step 4.

2. (a) (b) (c) (d)

3. (a) (b)

4. (a) (b)

5.



23. (a) (b)

24. (a) (b)

25. (a) (b)

26. (a) (b)

27. (a) (b)

28. (a) (b)

29. ________________

30. ________

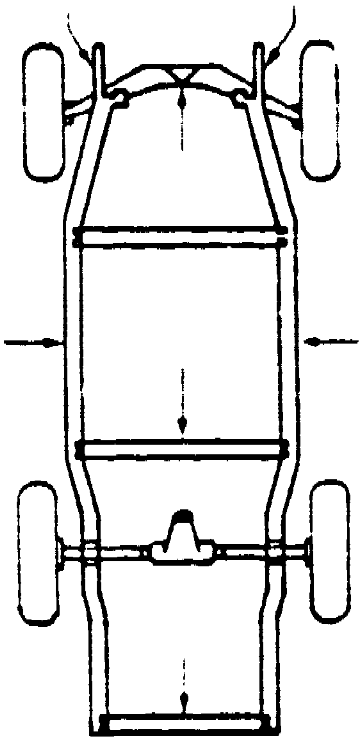
31. (a) (b) (c)

32. (a) (b)

PROJECT: Vehicle Frame Alignment

1. ____________________

2. ____________________



3. (a) (b)

4. (a) (b) (c) (d)

5. ____________________
____
____

6. ____________________
____

7. ____________________

8. (a) (b)

9. (a) (b)

10. ____________________

11. (a) (b)

12. (a) (b) (c)

13. (a) (b)

14. (a) (b)

15. (a) (b) (c)

16. (a) (b)

17. (a) (b)

18. (a) (b)

19. (a) (b)

20. (a) (b)

21. (a) (b)

22. (a) (b) (c)

23. (a) (b)

24. (a) (b)

25. (a) (b)

26. (a) (b)

REVIEW TEST

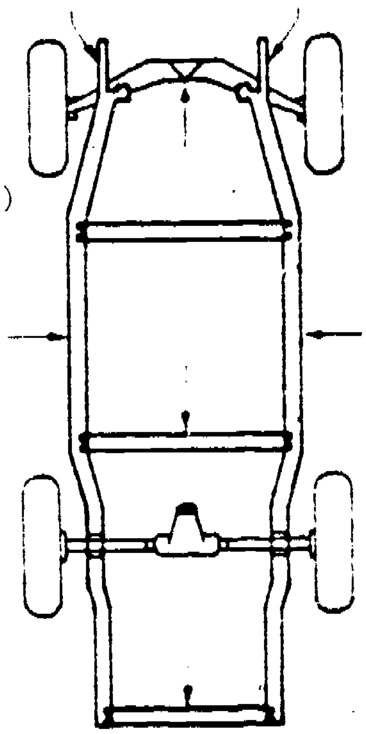
1. ____ Step 1.
____ Step 2.
____ Step 3.
____ Step 4.

2. (a) (b) (c) (d)

3. (a) (b)

4. (a) (b)

5.



27. (a) (b)

28. (a) (b)

29. ____________________

30. ____________

31. (a) (b) (c)

32. (a) (b)

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PREPARE THE MAN

PROGRAMMED TEXT 3ABR47~~330~~232-PT-605A

8-12

Technical Training

General Purpose Vehicle ~~Repairman~~ Mechanic

WHEEL BALANCING

13 August 1974

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-PT-605A, 20 April 1970.
OPR: TWS
DISTRIBUTION: X
TWS - 200; TTOC - 2

INTRODUCTION

The small size wheels with large size tires on today's modern passenger cars and the high speeds with which they travel has increased the need for wheel balance. Unbalanced wheels cause abnormal wear, shimmy, and place considerable stress on front and rear end assemblies.

INSTRUCTIONS

This program is divided into two parts. Part I of the program presents information in small steps called "frames." After each step (frame) you are asked to select the correct answer or fill in a blank. Use a card as a mask over the printed material. Slide this mask down the page until you expose the top of a short line of slashes (/////////////). Read the material presented and make your answer on the Student Response Booklet (SRB). After you have made your answer, slide the mask down until the answer space is exposed. Check your answer against the correct one given in the answer space. If you are correct, go on to the next frame. If you are incorrect, read the frame again and reason out the correct answer. After you have finished Part I check with the instructor to see if you can proceed with Part II, which is a checklist designed to guide you through the wheel balancing procedure. NOTE: DO NOT write in this programmed text!

OBJECTIVES

When you have completed this programmed text you will be able to accomplish the following objectives in accordance with the latest TO:

1. Set up the portable wheel balancer in the correct position for static balancing.

2. Determine the amount of weight required to balance a statically unbalanced wheel.

3. Identify the location where the weight will be placed on the wheel for static balance.

4. Set up the portable wheel balancer in the correct position for dynamic balancing.

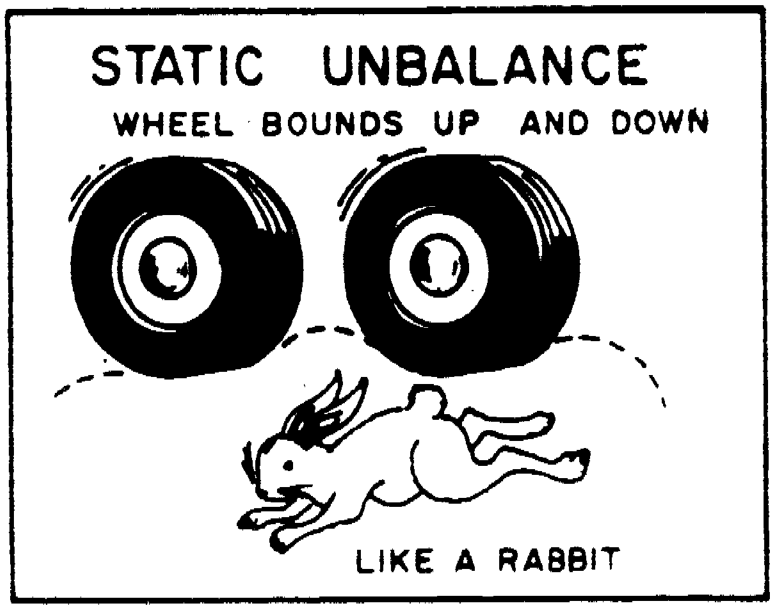
5. Determine the amount of weight required to balance a dynamically unbalanced wheel.

6. Identify he location where the weight will be placed on the wheel for dynamic balance.

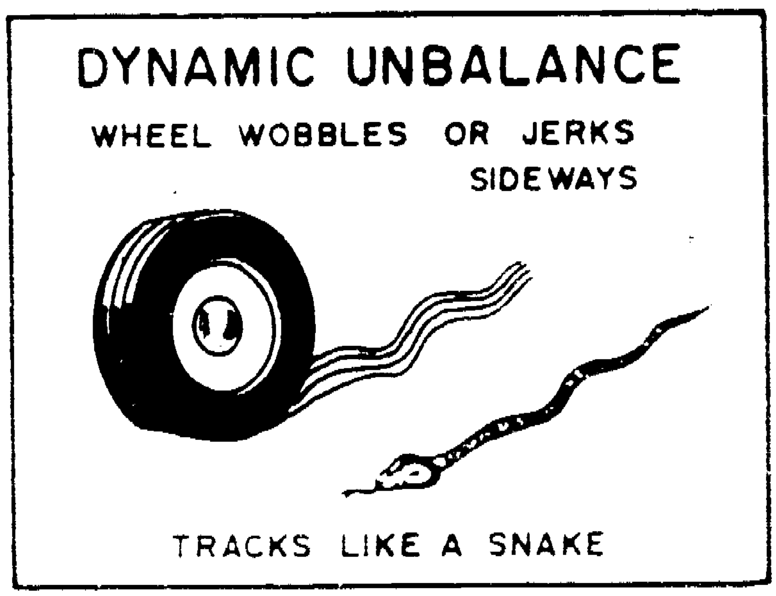
VALIDATION

This programmed text was validated in 1964 with 30 students enrolled in the 3ABR47330 course at Chanute AFB. It has continued to be successful since that time. Approximately 2,500 students have been trained with this text.

In wheel balancing there are two basic unbalanced conditions. They are:



AND



Frame 2

QUESTIONS 1 THROUGH 5.

Supply the missing words to complete the statements given below by writing the missing words in the corresponding numbered space(s) on your Student Response Booklet (SRB).

STATIC and DYNAMIC are the two basic unbalanced conditions encountered in wheel balancing.

1. When the wheel has a tendency to bounce up and down it is called a _______________ unbalanced condition.

2. When the wheel wobbles from side to side or jerks sideways it is called a _______________ unbalanced condition.

3. There are __________ basic unbalanced conditions encountered in wheel balancing. These conditions are called __________ and __________.

4. Static unbalance exists when the wheel has a tendency to bounce __________ and __________.

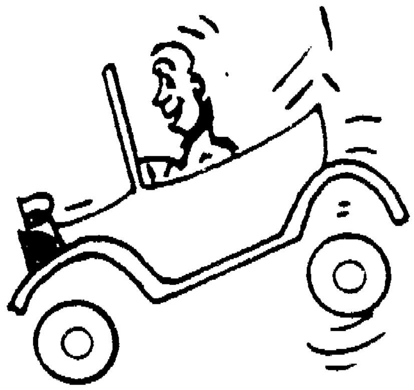
5. Dynamic unbalance exists when the wheel wobbles from __________ and __________.

////////////////////

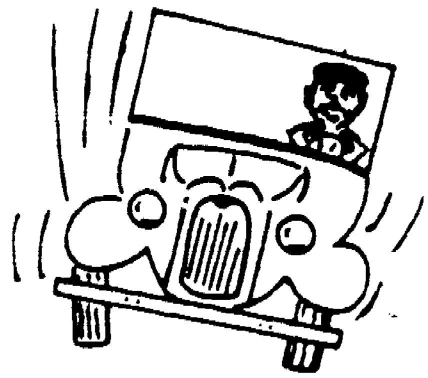
1. static
2. dynamic
3. two or 2, static, dynamic (either order)
4. up (and) down
5. side (to) side

QUESTION 6.

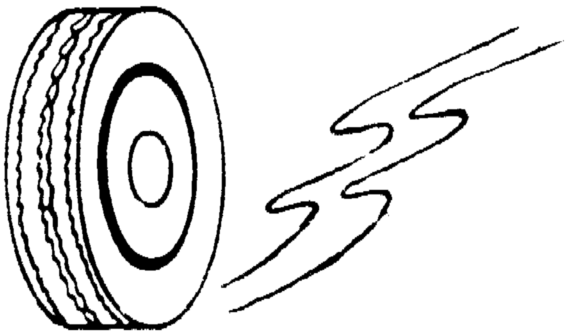
Place the name of the basic unbalanced condition which represents each picture in the space provided in your SRB.



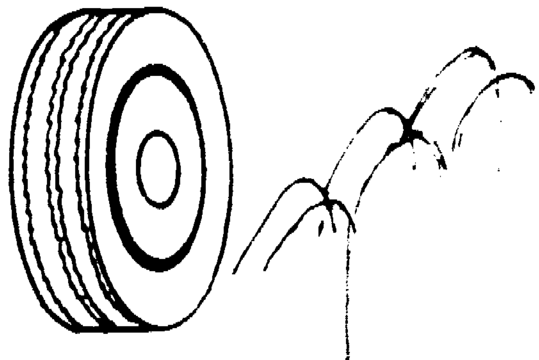
A.



B.



C.



D.

//////////////////////

A. Static
B. Dynamic
C. Dynamic
D. Static

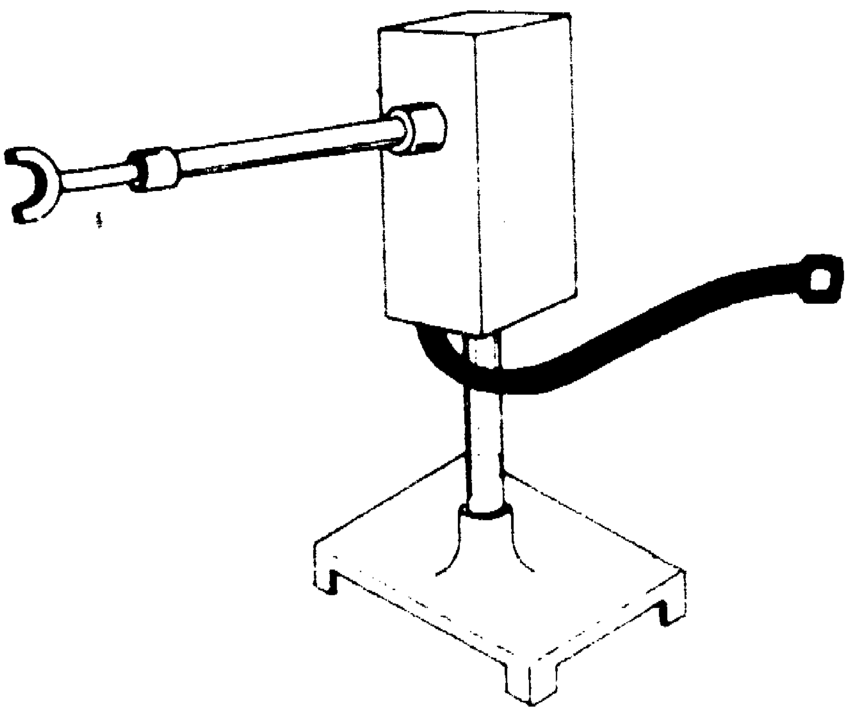
Frame 4

There are several different designs of wheel balancing machines. Some of these machines require removal of the wheel from the vehicle while performing wheel balancing operations. However, with the equipment you will be using, the balancing is accomplished with the wheel mounted on the vehicle.

There are three parts (units) to the portable wheel balancing machine, one of which is illustrated in the drawing shown below, with the other two being illustrated on the next page.

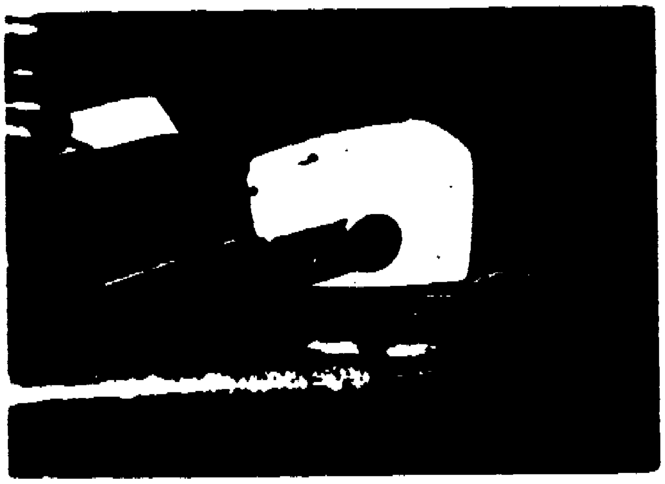
Part 1. The Magnetic Pickup.

The magnetic pickup is a device which is connected to the strobe light. This unit is used to pick up any vibrations of the vehicle or wheel.



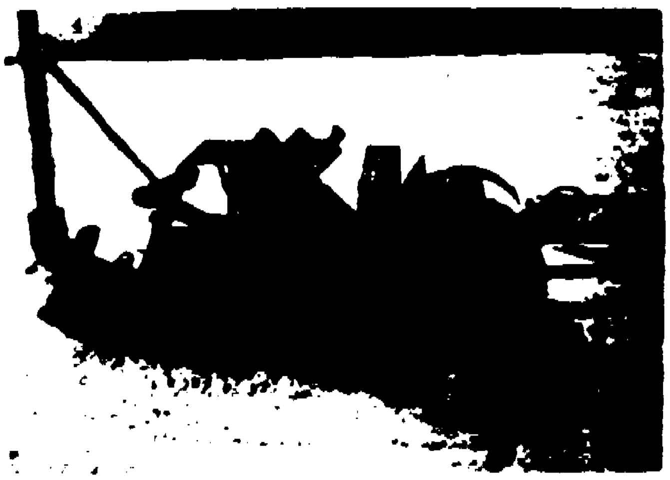
Part 2. The Strobe Light.

The strobe light is a device which will indicate the heavy spot (vibrations from the magnetic pickup) by a flashing light and will indicate the amount of weight to use to counteract the heavy spot on a wheel by use of a scale found on top of the device. The strobe light is illustrated in the drawing below.



Part 3. Wheel Spinner and Brake.

The wheel spinner and brake is an electric motor used to spin the wheel on the vehicle and to stop the rotation of the wheel. The device is illustrated in the drawing shown below.

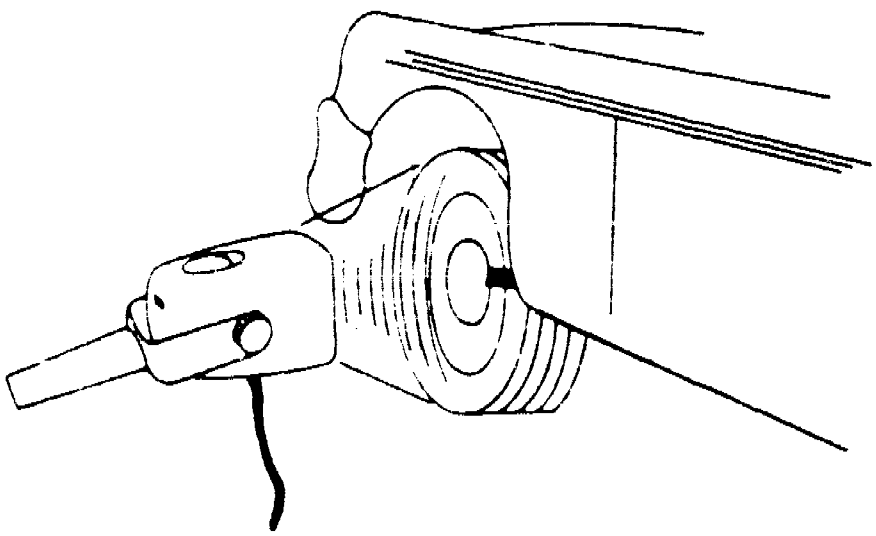


Frame 6

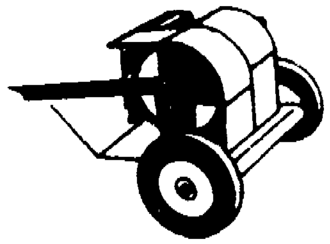
QUESTION 7.

Write the name of the units of the portable wheel balancing equipment represented by the three drawings below in the space provided on your SRB (Student Response Booklet).

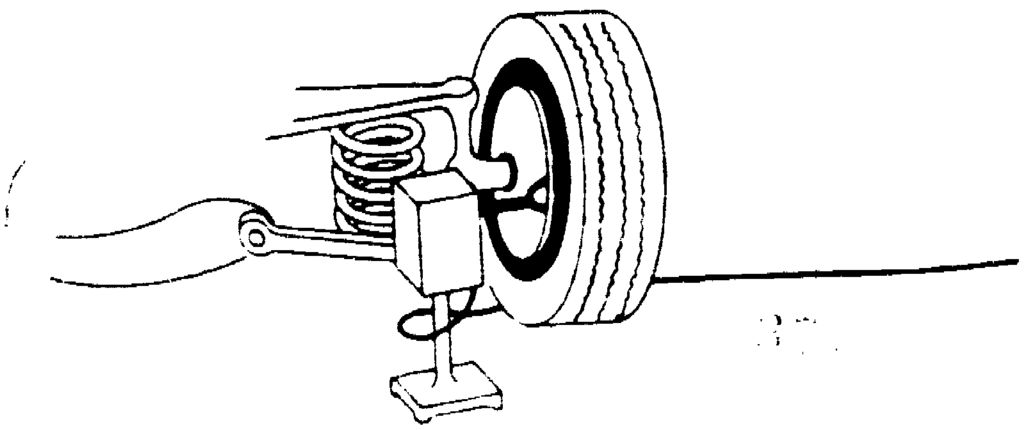
A.



B.



C.

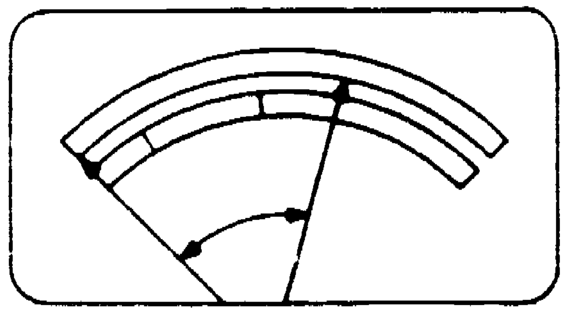


////////////////////////////

A. Strobe light B. Wheel spinner C. Magnetic pickup

There are two scales on the indicator in the strobe light which are controlled by the regular sensitive switch on the strobe light. These scales are used as follows:

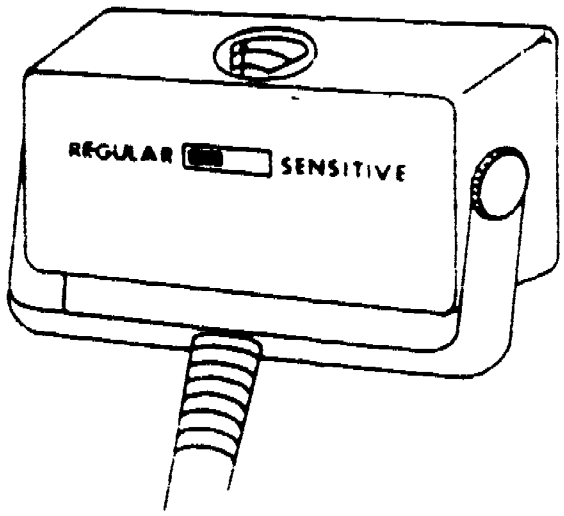
You will use the TOP SCALE when balancing wheels on passenger vehicles.



You will use the BOTTOM SCALE when balancing wheels on heavy trucks.

Frame 8

The regular-sensitive switch on the strobe light has two (2) positions:



When reading the TOP SCALE (for passenger cars) the switch is positioned for regular balancing.

When reading the BOTTOM SCALE (for heavy trucks) the switch is positioned for sensitive balancing.

QUESTIONS 8 AND 9.

8. If you were balancing a wheel on a passenger car, indicate with a checkmark on your SRB which scale you would take the reading from.

   a. TOP SCALE _____ b. BOTTOM SCALE _____

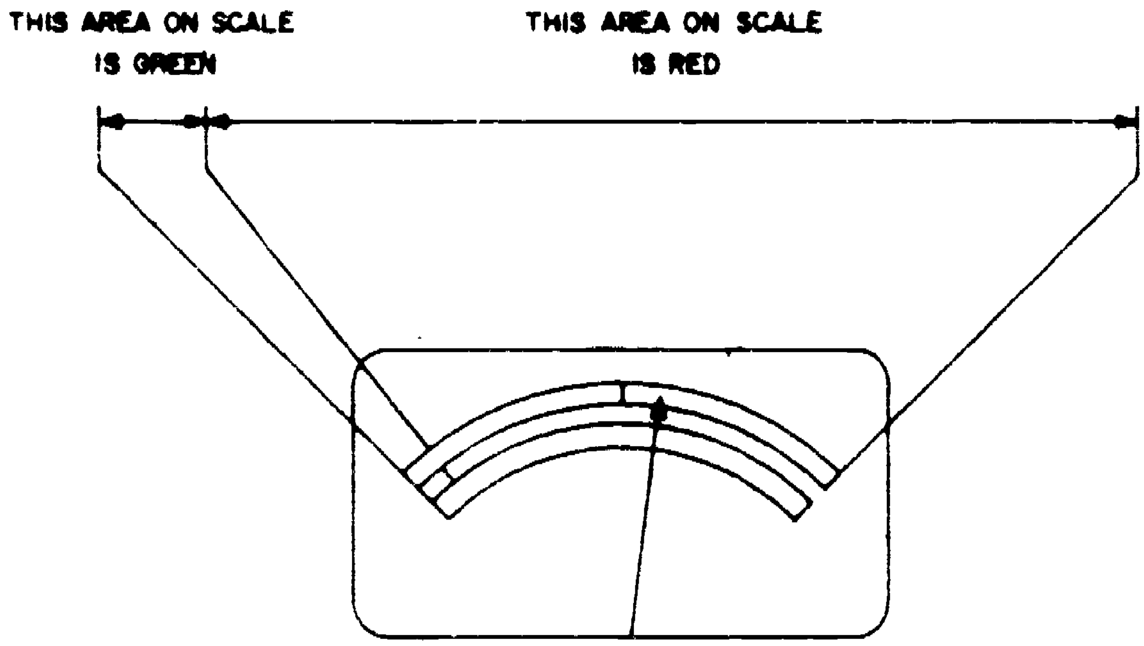
9. If you were balancing a wheel on a passenger car, indicate with a checkmark on your SRB which position should be used, regular or sensitive.

   a. REGULAR _____ b. SENSITIVE _____

//////////////////////

8. TOP SCALE 9. REGULAR

The scales on the strobe light are divided into two (2) sections. If the needle moves to mid position on either scale, approximately three (3) ounces of weight are needed to counteract the heavy spot on the wheel. The scales are color coded, as follows, to assist you:



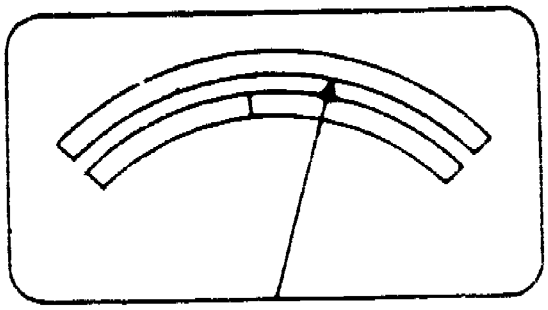
When the needle is in the GREEN area of the scale, the wheel is balanced.

When the needle is in the RED area of the scale, the wheel is unbalanced.

360

Frame 10

QUESTIONS 10 AND 11.

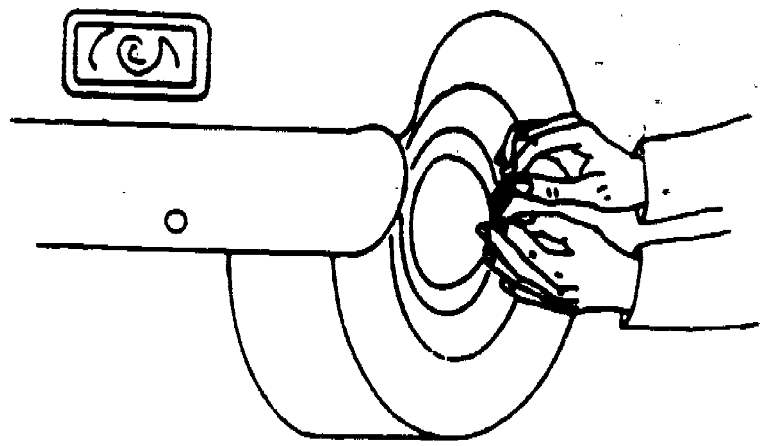


10. In the diagram above, the needle is in the red section. Indicate on your SRB whether the wheel is balanced or unbalanced, according to the illustration above.

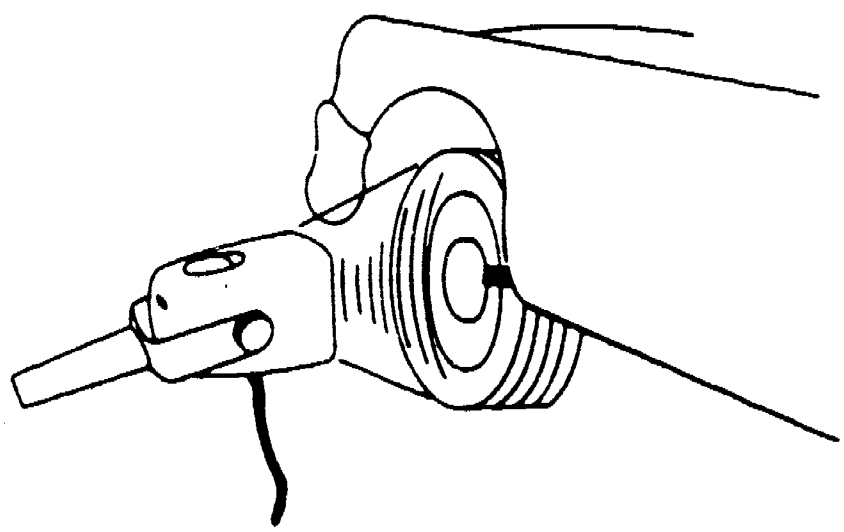
11. If the wheel is unbalanced, according to the illustration above, indicate in the space provided on your SRB, how many ounces of weight are required to balance the wheel.

//////////////////////

10. unbalanced   11. approximately 4 ounces



A reference mark (a piece of tape or a chalk mark) is placed ANYWHERE on the wheel before it is spun. This is illustrated in the drawing above.

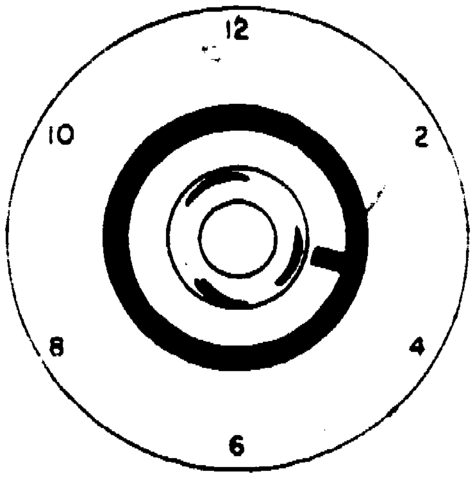


The strobe light is used just like a timing light. When the wheel is spinning, the strobe light will make the reference mark APPEAR TO STAND STILL. This is illustrated in the drawing above.

After the wheel has stopped spinning, place the reference mark in the same position it appeared in when the wheel was spinning. This is done by turning the wheel by hand.

3602

Frame 12



HEAVY SPOT

Think of the wheel as being the face of a clock. When checking a statically unbalanced wheel, the magnetic pickup is placed under the lower control arm. When the heavy spot hits the ground, in relation to the face of a clock, it (the heavy spot) is said to be located at the 6 o'clock position.

QUESTIONS 12 THROUGH 15.

12. Where do you place the reference mark on the wheel?

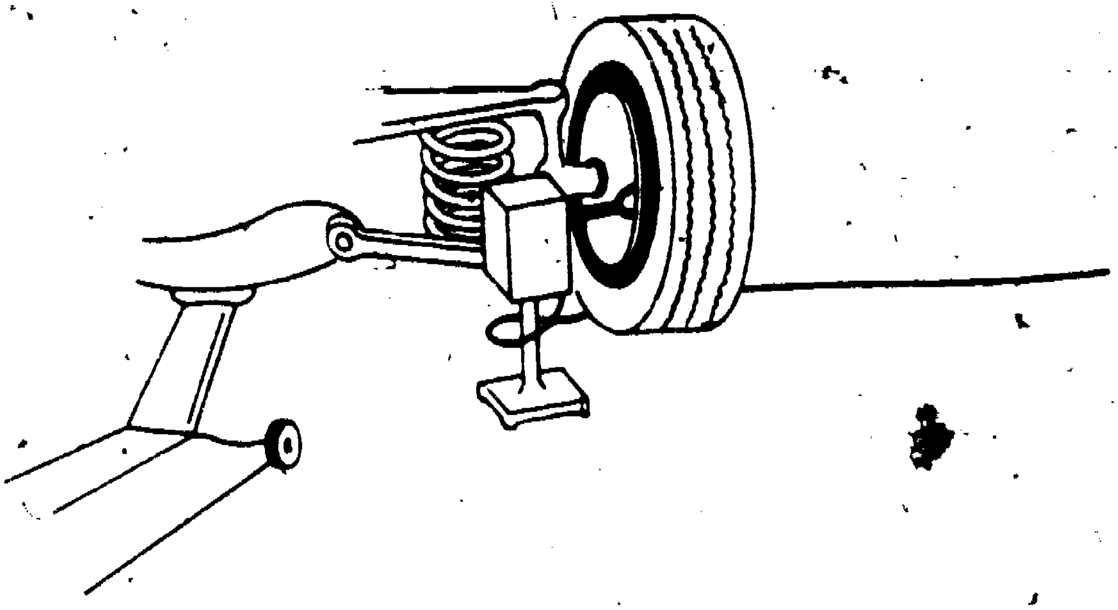
13. What does the reference mark appear to do when the wheel is spinning?

14. Where would you place the reference mark after the wheel has stopped spinning?

15. If, in terms of a clock, the heavy spot is located at the 6 o'clock position on the wheel, where would you place the weight to counteract the heavy spot?

//////////////////////

12. anywhere
13. stand still
14. where it appeared to be when the wheel was spinning.
15. 12 o'clock or top



When checking a dynamically unbalanced wheel, the magnetic pick-up should be placed at the extreme forward edge of the brake backing plate, at spindle height. The strobe light will flash when the heavy spot on the tire forces the wheel inward against the pickup. To offset or counteract this condition, the necessary weight to be installed must be equally divided, placing half of this weight on the inside front of the wheel (next to the pickup) and the other half of the required weight on the outside rear of the wheel (3 o'clock or 9 o'clock position). This will prevent the previously done static balance from becoming unbalanced while correcting dynamic balance.

QUESTION 16.

If, in terms of a clock, the heavy spot is located at the 9 o'clock and 3 o'clock position on the wheel, where would you place the weights to counteract the heavy spot?

//////////////////////

9 o'clock and 3 o'clock position

364

Frame 14

Part II. WHEEL BALANCING

You are about to perform a static and dynamic wheel balancing operation. This booklet is actually a checklist of instructions which requires you to perform a task in small steps and record your progress on a separate SRB. Follow the instructions found in this booklet according to the answers you select for the questions asked. Do not proceed to the next frame in the task until the current frame is accomplished. For all practical purposes you are on your own. However, if you need help do not hesitate to call on your instructor. Record all answers on Part II of the SRB.

When you have accomplished all of the frames in this part of the booklet you will have satisfied the following training objectives:

1. Prepared the vehicle and wheel balancing components for both static and dynamic wheel balancing.

2. Identified the extent of radial and lateral runout of the wheel to be balanced.

3. Identified the wheel balancing equipment components.

4. Operated the wheel balancing equipment.

5. Identified the heavy spot on the wheel.

6. Computed the weight required to offset the heavy spot on the wheel.

7. Installed the weights and determined if the weights are properly placed.

8. Determined if the weights installed are sufficient to counteract the heavy spot on the wheel.

To perform the wheel balancing operation, you will need the following tools and equipment. Normally this equipment should be available at the vehicle. Take an inventory of the equipment to make sure it's all there.

1. Alemite Electronic Wheel Balancer, which includes:

   a. Strobe light.
   b. Wheel spinner.
   c. Magnetic pickup.

2. Jack stand. NOTE: At no time will you put jack stands under the vehicle as a safety measure during the wheel balancing operation. The wheel balancing operation is dependent on vibration. Placing jack stands under the vehicle will reduce or nullify the necessary vibrations.

3. Hydraulic floor jack.

4. Wheel chocks.

5. Assorted weights.

6. Weight installation and removal tool.

QUESTION 1.

Was all of the equipment available at the vehicle?

YES - Proceed to Frame 16.

NO - Ask the instructor to help you obtain the necessary tools or equipment.

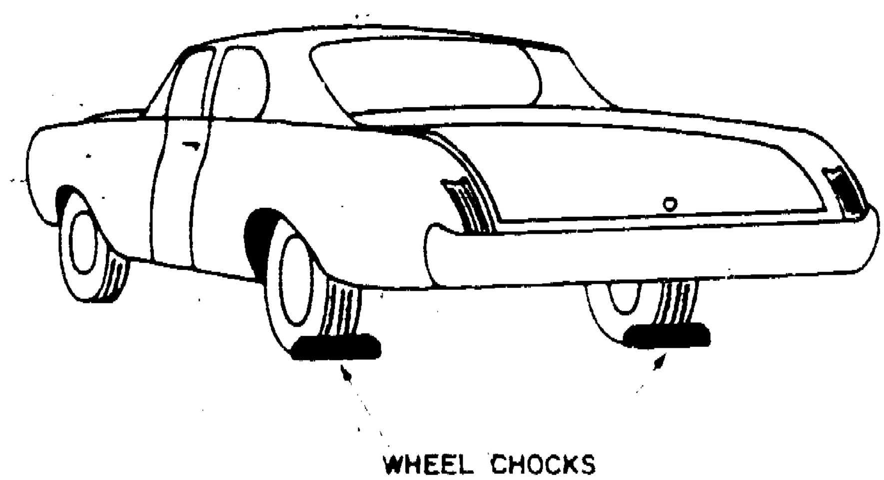
Frame 16

When you have completed the tool inventory, you are ready to proceed with the project. REMEMBER, follow the instructions in this booklet to the letter. Make sure that you record your responses on the SRB as you complete each frame. This will help you keep track of your progress.

Your first objective is to prepare the vehicle and wheel balancing equipment for static wheel balancing.

The illustrations in this booklet refer to the left side of the vehicle in general and to the left front wheel specifically. The procedures for balancing the right front wheel are identical to those for balancing the left front wheel.

Place the wheel chocks under the rear wheels as shown in the drawing below.



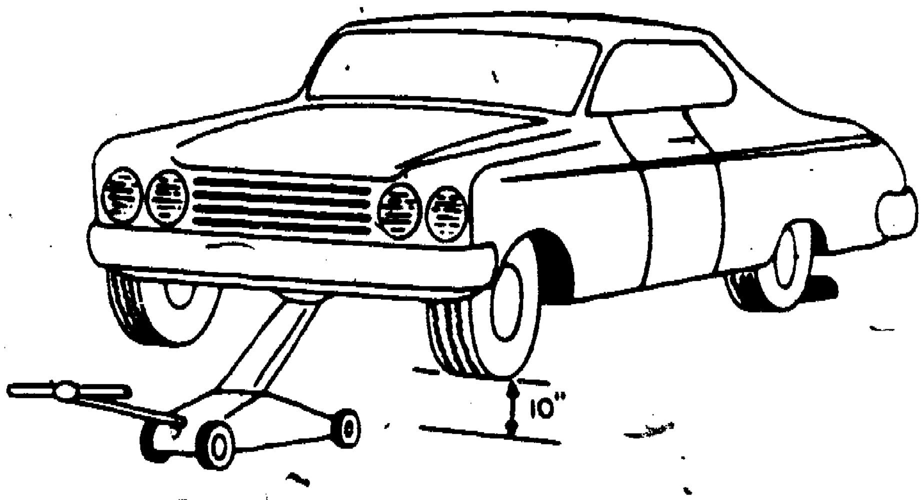
QUESTION 2.

Are the wheel chocks in position?

YES - Proceed to Frame 17.

NO - Chock the wheels as shown in the illustration above. If wheel chocks are not available, inform your instructor.

Center the hydraulic floor jack under the front crossmember of the vehicle as shown in the illustration below. Raise the vehicle until there is at least 10 inches of clearance between the front wheels and the floor.



QUESTION 3.

Are the front wheels at least 10 inches off the floor?

YES - Proceed to Frame 18.

NO - Call an instructor.

Be sure to record your response on the Student Response Booklet (SRB).

Frame 18

Check the tire to be balanced for general condition. Look for any evidence of tread separation, chunks of rubber missing, and for air bubbles between the tire core and tread.

QUESTION 4.

Is the tire in good condition?

YES - Proceed to Frame 19.

NO - Call the instructor. He will assign you to another wheel. If this is the case, you will then have to reaccomplish Frames 16 and 17.

Rotate the wheel to be balanced by hand and remove all nails, rocks, and caked mud. (Use the pointed end of the weight removal and installation tool.)

QUESTION 5.

Is the wheel to be balanced free of nails, rocks, and caked mud?

YES - Proceed to Frame 20.

NO - It is necessary that you accomplish this step for the following reasons:

1. Nails, rocks and caked mud may fly off the wheel when it is rotating at a high speed thereby creating a safety hazard to you.

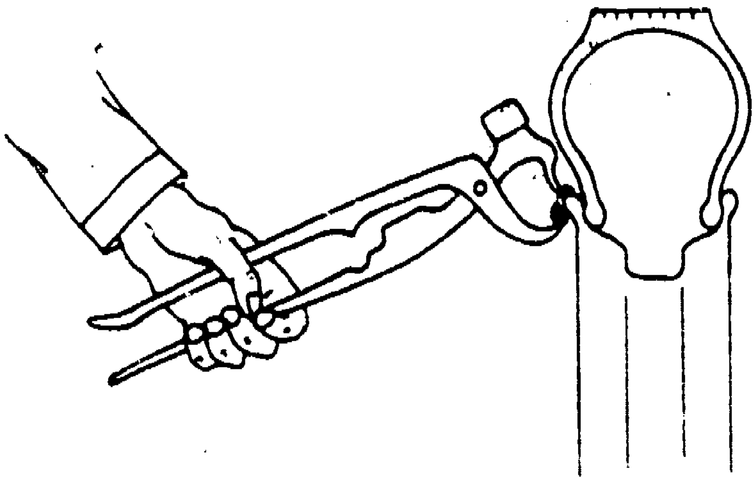
2. Nails, rocks, and caked mud all add weight to the wheel, thereby reducing or nullifying effective attempts at balancing the wheel.

ONLY when your answer to the above question becomes YES may you proceed to the next frame.

Frame 20

Remove all old weights from the wheel to be balanced, both INSIDE and OUTSIDE. All old weights must be removed from the wheel being balanced for the same reasons as nails, rocks, and caked mud are removed.

NOTE: Use the weight installation and removal tool to remove the weights as shown in the illustration below.



It will be easier for you to remove the inside weights if you turn the wheel out at the front.

QUESTION 6.

Have all old weights been removed from the wheel to be balanced?

YES - Proceed to the next frame.

NO - If you are having trouble in removing the old weights, ask your instructor to give you a demonstration.

Rotate the wheel by hand and note if it rotates freely. If the wheel does not rotate freely, then the wheel bearing may be too tight or the brake shoes may be dragging. Readjust either, or both, if necessary.

QUESTION 7.

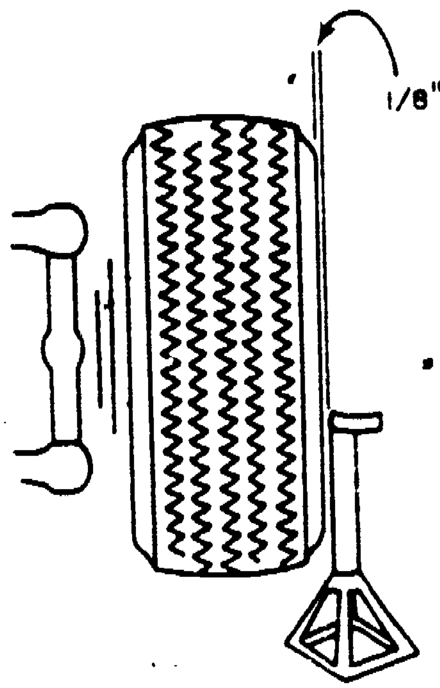
Does the wheel rotate freely?

YES - Proceed to the next frame.

NO - Readjust the brakes or the wheel bearing as the case may be.

Frame 22

Check the lateral runout (side-to-side wobble of the wheel) as follows: First, place a jack stand near the wheel as shown in the illustration below. Then, rotate the wheel and move the jack stand toward the wheel slowly until the jack stand and the wheel make contact. The distance between the point on the wheel that touches the jack stand and the point on the wheel that is farthest away from the jack stand when the wheel is rotated should not exceed 1/8th inch.



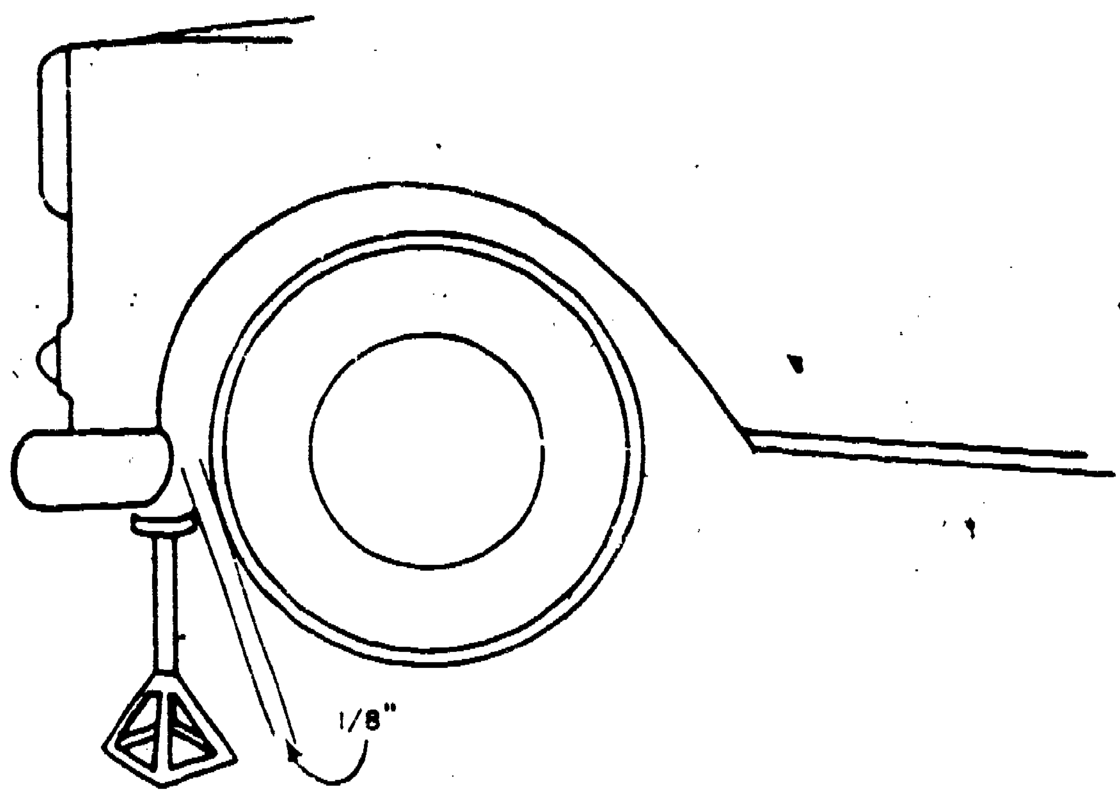
QUESTION 8.

Does the lateral runout of the wheel fall within the 1/8th inch tolerance?

YES - PROCEED TO THE NEXT FRAME.

NO - Call an instructor. He will assign you to another wheel. If this is the case, you will have to repeat Frame 16 through 21 for that wheel.

Check the radial runout (out of roundness) of the wheel as follows: First, move the jack stand to in front of the wheel as shown in the illustration below. Rotate the wheel by hand and slowly move the jack stand toward the wheel until it makes contact with the rotating wheel. The distance between the point of contact and the farthest distance between the wheel and jack stand should not exceed 1/8th inch.



QUESTION 9.

Does the radial runout fall within the 1/8th inch tolerance?

YES - Remove the jack stand, then proceed to the next frame.

NO - Call your instructor. He will assign you to another wheel. If this is the case, you will then have to repeat Frames 16 through 22 for that wheel.

Frame 24

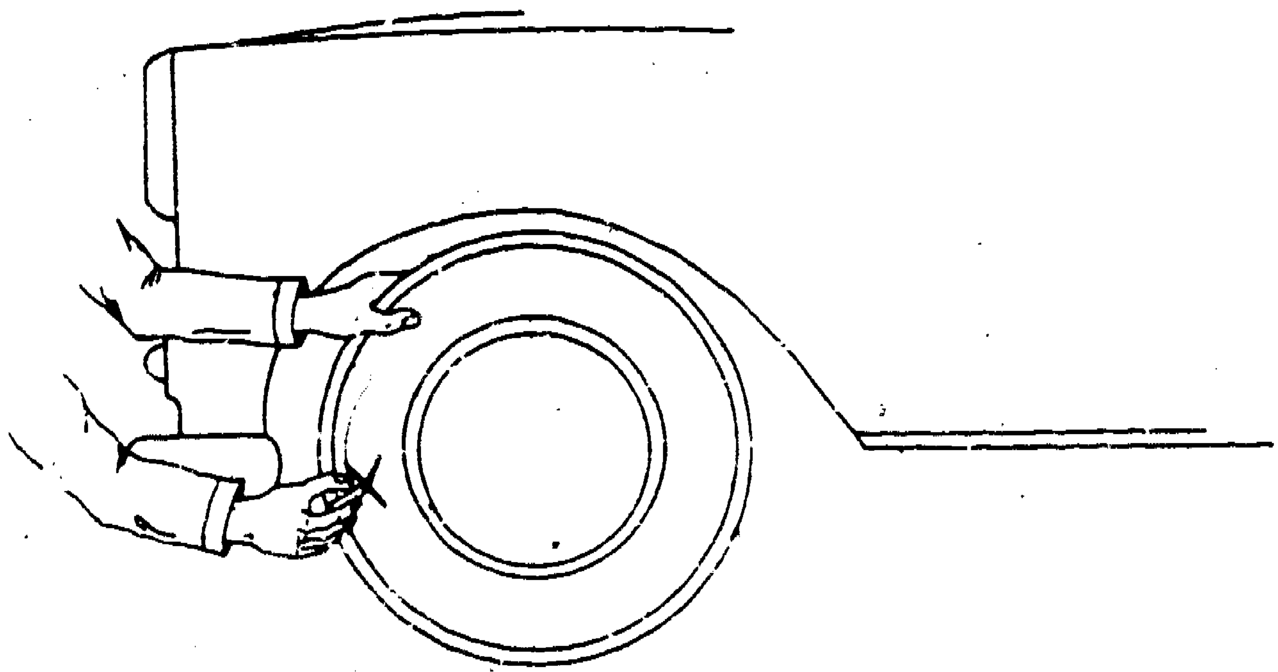
Look the tire over carefully.

QUESTION 10.

Is there a reference mark on the tire already?

YES - Place the same reference mark on the circle listed on the SRB as item 10a.

NO - Place a reference mark anywhere on the tire using crayon, chalk, ~~or~~ masking tape as shown in the illustration below. Then, make the same mark on the circle found on your SRB as item 10a. Then, proceed to the next frame.



Vehicle preparation for wheel balancing is now complete. The following described steps cover the procedure for positioning the wheel balancing units for static balancing.

First, unwind the power cord and connect it to a 220-volt ac power outlet.

QUESTION 11.

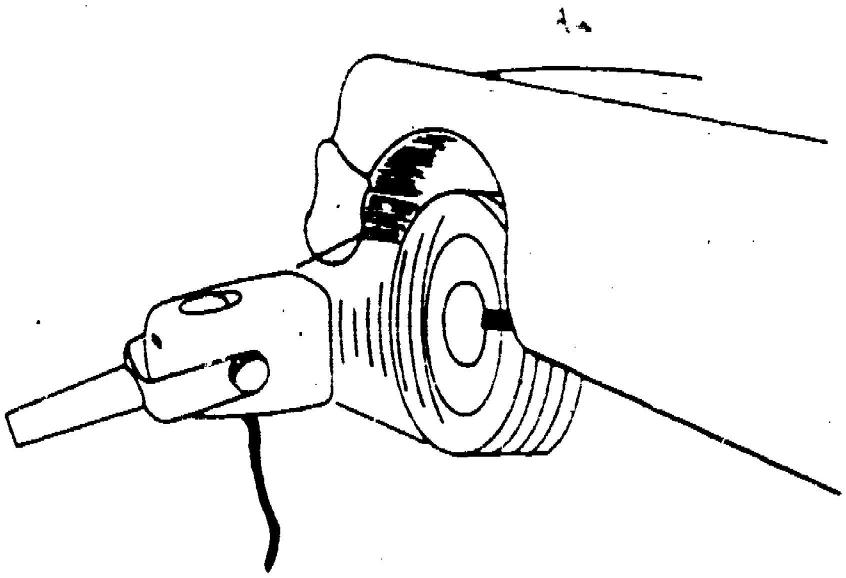
Is the power cord connected to a 220-volt ac power outlet?

YES - Proceed to the next frame.

NO - Call the instructor. He will be able to tell you where the nearest convenience power outlet is located.

Frame 26

Position the strobe light as shown in the illustration below. It must be positioned so that the flashing light beam will strike the wheel in the center. The distance from the wheel to the strobe light should be approximately 12 inches.



QUESTION 12.

Is the strobe light located in the correct position?

YES - Proceed to the next frame.

NO - Position the strobe light in the approximate position as shown in the above illustration. It only needs to be approximate. Call an instructor if you think that you need assistance.

Unwind the power cord. Connect the power cord to the 220-volt ac outlet.

QUESTION 13.

Is the power cord connected to the 220-volt ac outlet?

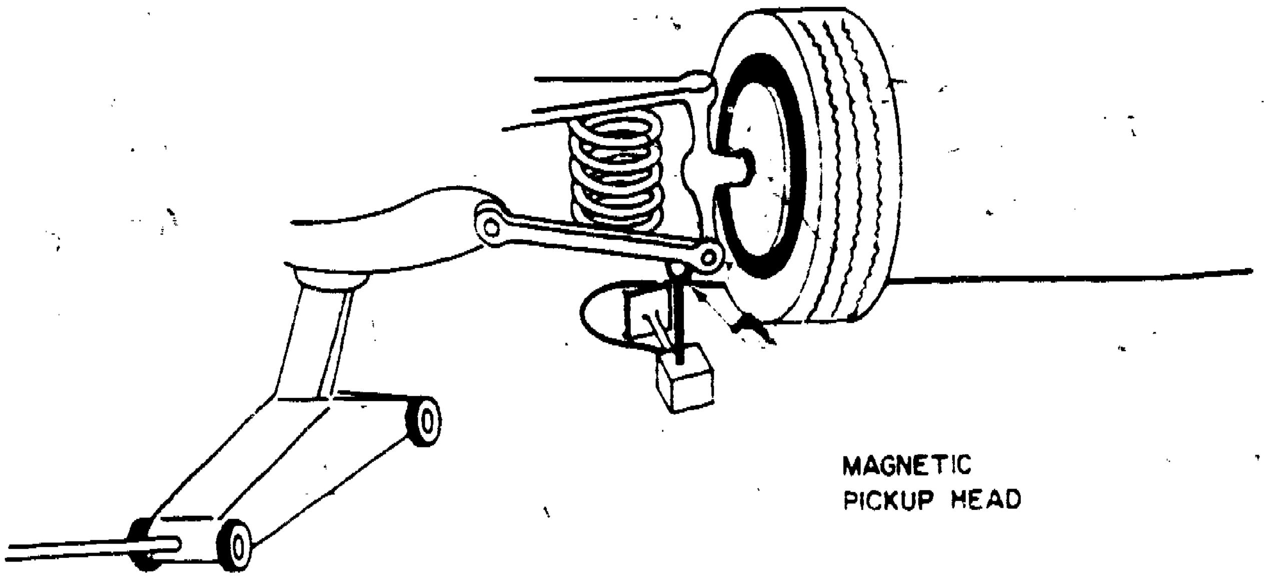
YES - Proceed to the next frame.

NO - There is only one place where the power cord can fit. If you still have trouble, call an instructor.

Frame 28

Caution: Read all the instructions below before performing the task.

Place the magnetic pickup unit under the vehicle as shown in the illustration below. Extend the telescoping stem of the magnetic pick-up until it "sticks" to the lower control arm as near the wheel as possible. Lock the telescoping stem into position by tightening the lock screw on the stem.



MAKE SURE THAT THE POWER CORD IS NOT UNDER THE WHEEL.

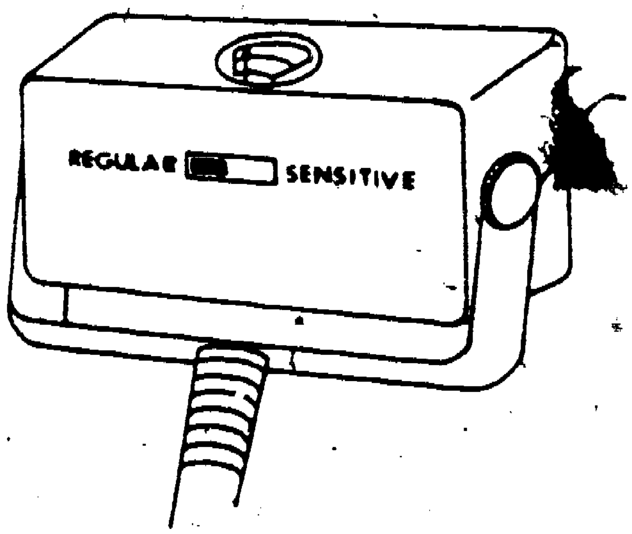
QUESTION 14.

Is the magnetic pickup unit located in the position as shown in the illustration above?

YES - Proceed to the next frame.

NO - Call an instructor for help.

Look at the strobe light switch. It should be in the regular position as shown in the illustration below.



QUESTION 15.

Is the strobe light switch in the "regular" position?

YES - Proceed to the next frame.

NO - Move the switch until it looks like the switch shown in the illustration above.

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Frame 30

Tap the top of the tire with your hand.

QUESTION 16

Did the strobe light flash?

YES - On you go, to the next frame.

NO - Wait about one minute and tap the top of the tire again. If the light did not flash this time, proceed as directed in the procedure outlined below.

Make the following checks if the strobe light still did not flash:

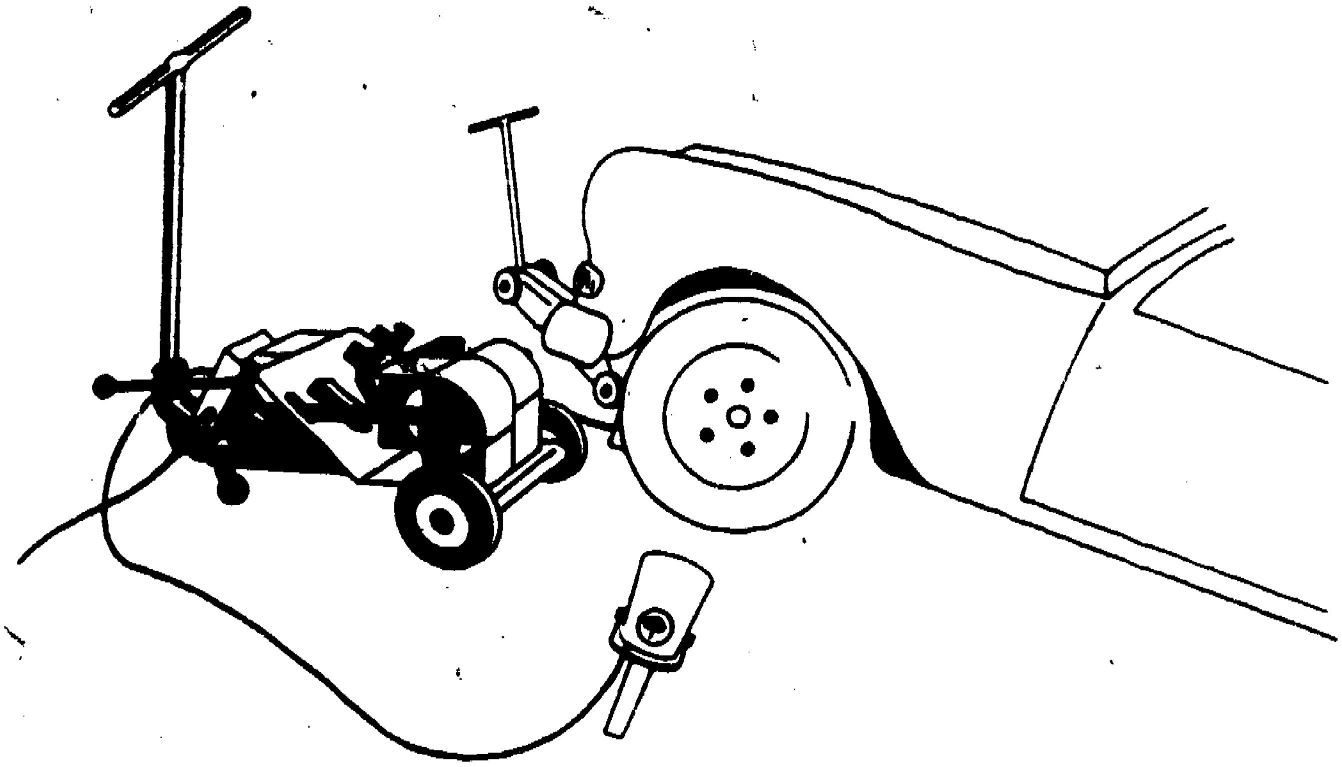
1. Is the strobe light switch in the regular position?

2. Is the strobe light power cord connected to a 220-volt ac power outlet?

3. Is the magnetic pickup in contact with the lower control arm as near the wheel as possible?

4. Call an instructor, you may have a defective unit.

Place the wheel spinner in position as shown in the illustration below.



MAKE SURE THAT THE POWER CORD DOES NOT GET UNDER THE WHEEL.

QUESTION 17.

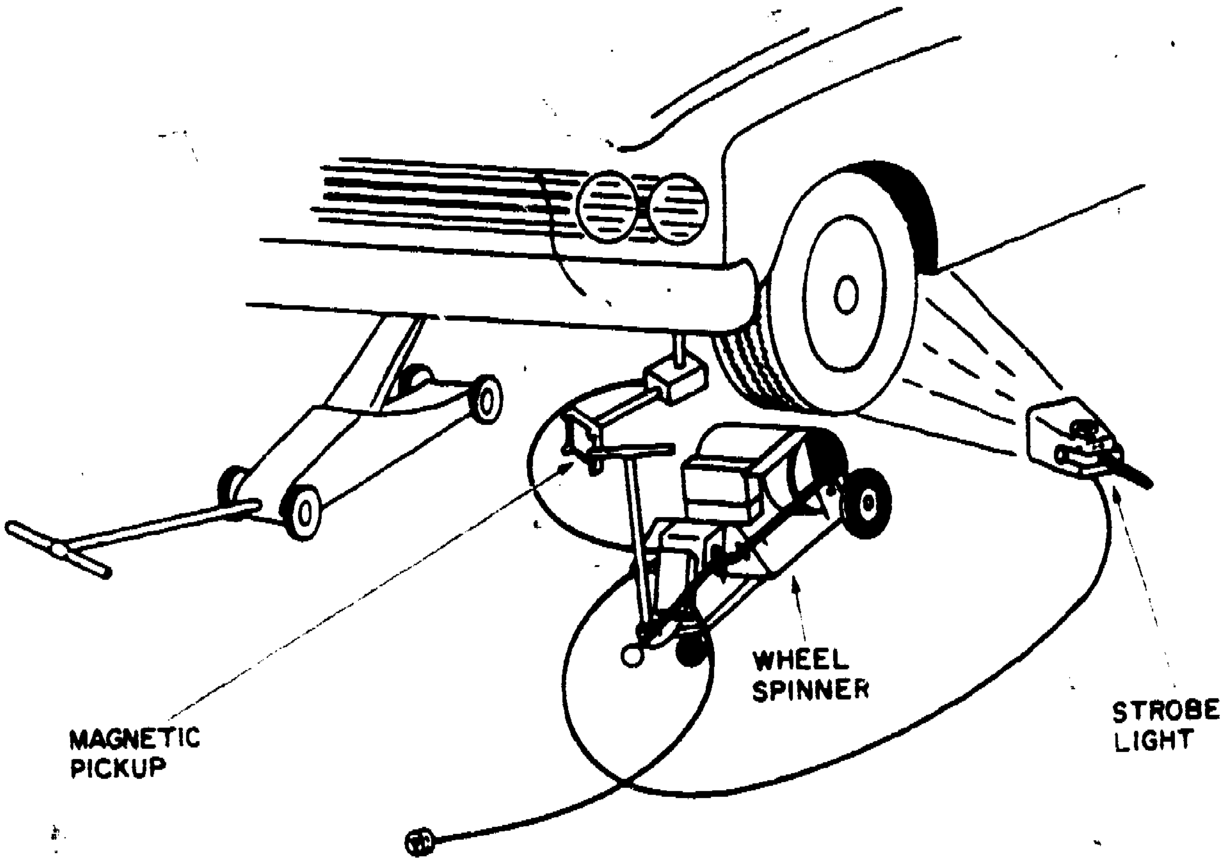
Is the wheel spinner in position and is the power cord connected to a 220-volt ac power outlet?

YES - Proceed to the next frame.

NO - Call an instructor. He will show you where the nearest 220-volt ac power outlet is located.

Frame 32

With this booklet in hand, face the front of the vehicle and compare the equipment position with that shown in the illustration below.



QUESTION 18.

Are all units in the correct positions?

YES - Proceed to the next frame.

NO - Adjust as necessary, or call an instructor if it is not possible to arrange the equipment as shown.

Caution: Read all of the instructions given BEFORE performing the task.

1. Position yourself to one side of the wheel as shown in the illustration below.

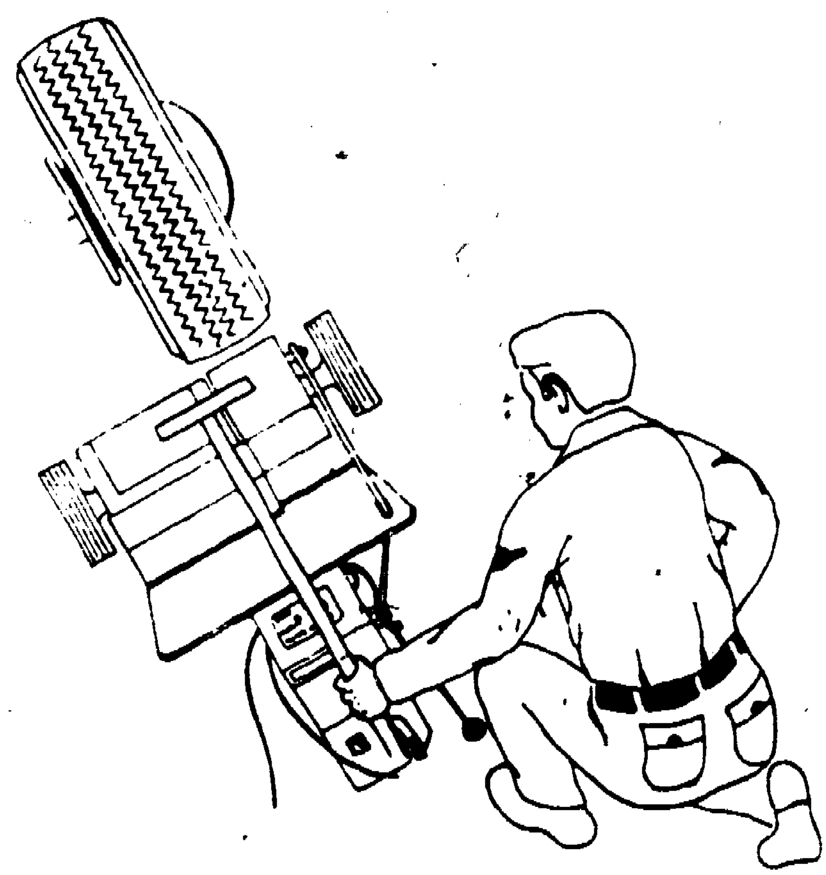
2. Rotate the wheel by hand toward the front of the vehicle (the direction that the wheel would rotate if the vehicle were moving forward).

3. Turn the control switch of the wheel spinner to the ON position and push the wheel spinner toward the wheel until it makes good contact.

4. Allow the wheel spinner to "rev up" the wheel until the spinner has reached maximum speed.

5. Pull the wheel spinner away from the wheel during the time the unbalanced reading is taken.

6. Make sure wheel spinner brake shield covers spinner, then gently apply brake shield to tire with a firm steady pressure until the wheel comes to a complete stop.



Frame 34

QUESTION 19.

Did you spin the wheel and stop it with the wheel spinner?

YES - Proceed to the procedure described below.

NO - Ask your instructor to give you a demonstration.

Caution: Read all the statements below completely before attempting performance of this task.

1. Using the wheel spinner, spin the wheel as you did in the last frame.

2. When the wheel spinner has reached its maximum RPM, pull it away from the wheel and turn it off.

3. While the wheel is spinning, step behind the strobe light and observe the needle. As the wheel loses speed, the strobe light needle will start to descend after reaching a high point. As the wheel continues slowing down, the needle will start to rise a second time. When the needle has reached its highest point the second time, note the position of the reference mark on the wheel. It may appear anywhere around the circumference of the wheel but it will appear to be stationary.

4. Repeat item 3 above. Remember, you are looking for two things:

a. The highest point the needle reached during its second rise.

b. The location of the reference mark on the wheel at the time the needle reached its highest point during its second rise.

5. After you have these two things in mind, record them on the SRB as follows:

a. Mark the position of the reference mark as it appeared on the wheel when the strobe light needle reached its highest point during its second rise.

b. Place an "X" in the division on the illustration on your SRB that represents the highest point the needle reached during its second rise.

6. Use the wheel spinner to stop the spinning wheel.

7. Proceed when you can without referring to these instructions.

QUESTION 20.

Did you make the necessary recording on your SRB?

YES - Proceed to the procedure described below.

NO - Read the instructions again. If you cannot perform the task, call an instructor.

Position the wheel so that the reference mark appears as for frame 34, paragraph 3.

Look at your SRB. Make the necessary entries in the spaces provided for items 19 (5A) and 19 (5B). Do this now.

Look at the scale on item 19 (5B) of your Student Response Booklet.

Remember, mid-position on either scale indicates the need for approximately three (3) ounces of weight. Now, determine from the indication shown during frame 34, how much weight must be added.

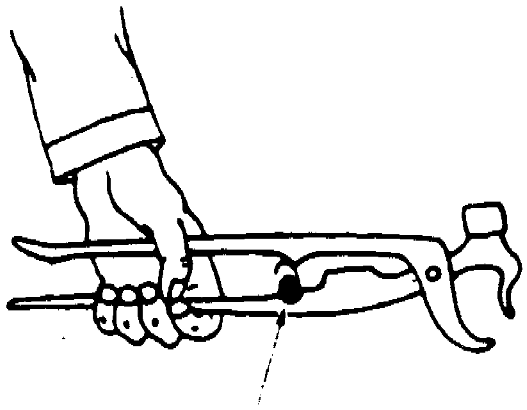
The heavy spot on the wheel when the reference mark is in the position as indicated on frame 34 is at the 6 o'clock position. The weight must be installed at the 12 o'clock position.

Frame 36

If the total weight required is three (3) ounces or more, divide the weight by 2 and install half of the weight on the inside of the wheel rim and half of the weight on the outside of the rim in the 12 o'clock position.

Turn the wheel out at the front when installing the weights on the inside. Return the wheel to its original position after the inside weight has been installed.

Using the weight installation and removal tool, the clip of the weight is crimped as shown in the illustration below.



Now, install the weight(s).

Use the weight removal tool as a hammer and drive the weight clip over the wheel rim in the desired location.

Make certain that the weight is fastened to the wheel rim tight enough so that it will not fly off.

After you have done this, proceed to the next frame.

If the weight should fly off the rim while the wheel is spinning at a high speed it could cause serious injury to the operator of the wheel balancer or to any spectator standing in line with the wheel, so -- go back and hit those weights again to make sure it is securely fastened.

QUESTION 21.

Are the weights on as tight as you can get them?

YES - Proceed to the next frame.

NO - Make certain they are on tight for your own safety.

QUESTION 22.

Have you been recording all of your responses on your SRB?

If the weight should fly off the rim while the wheel is spinning at a high speed it could cause serious injury to the operator of the wheel balancer or to any spectator standing in line with the wheel, so -- go back and hit those weights again to make sure it is securely fastened.

QUESTION 21.

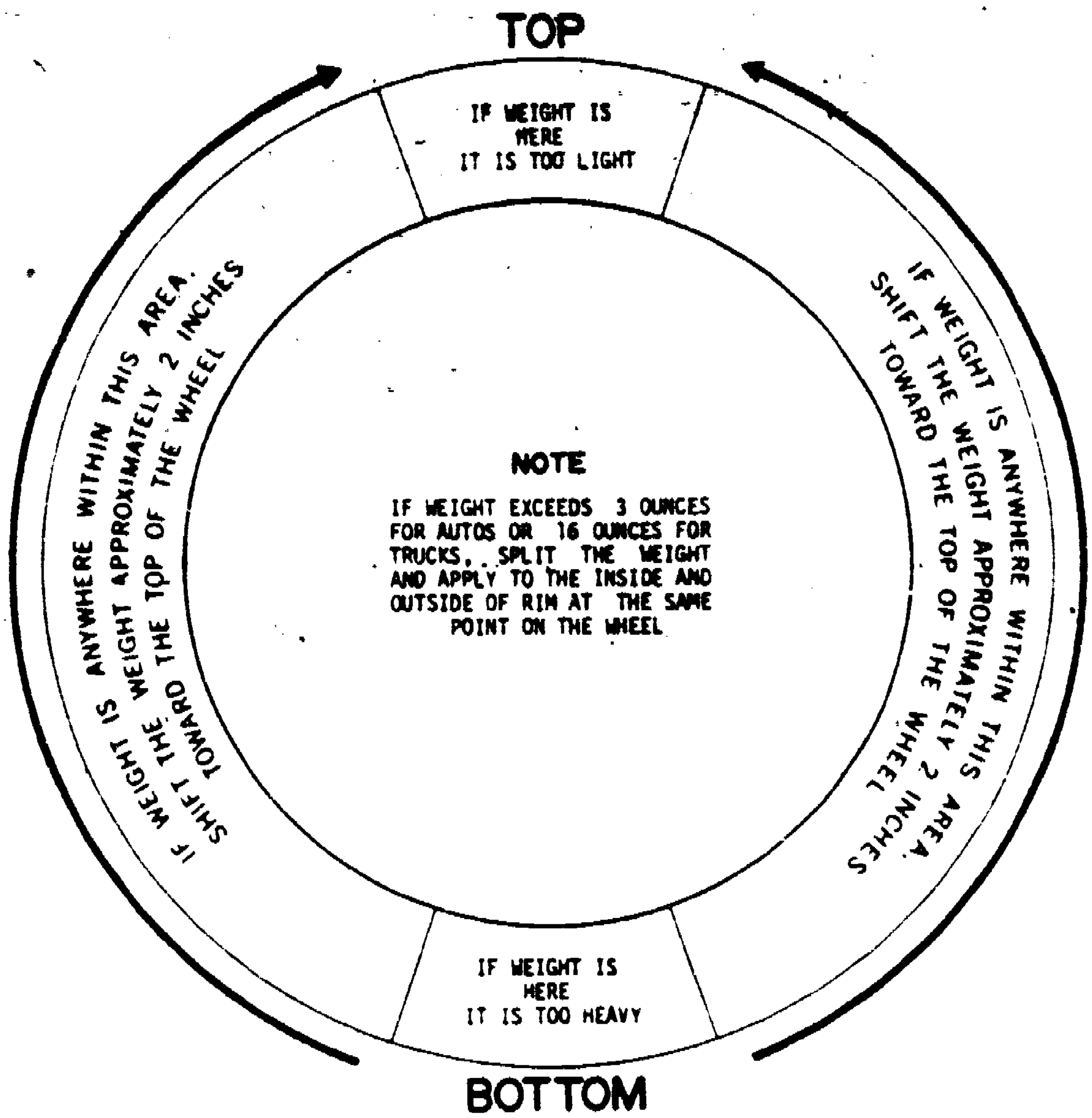
Are the weights on as tight as you can get them?

YES - Proceed to the next frame.

NO - Make certain they are on tight for your own safety.

QUESTION 22.

Have you been recording all of your responses on your SRB?

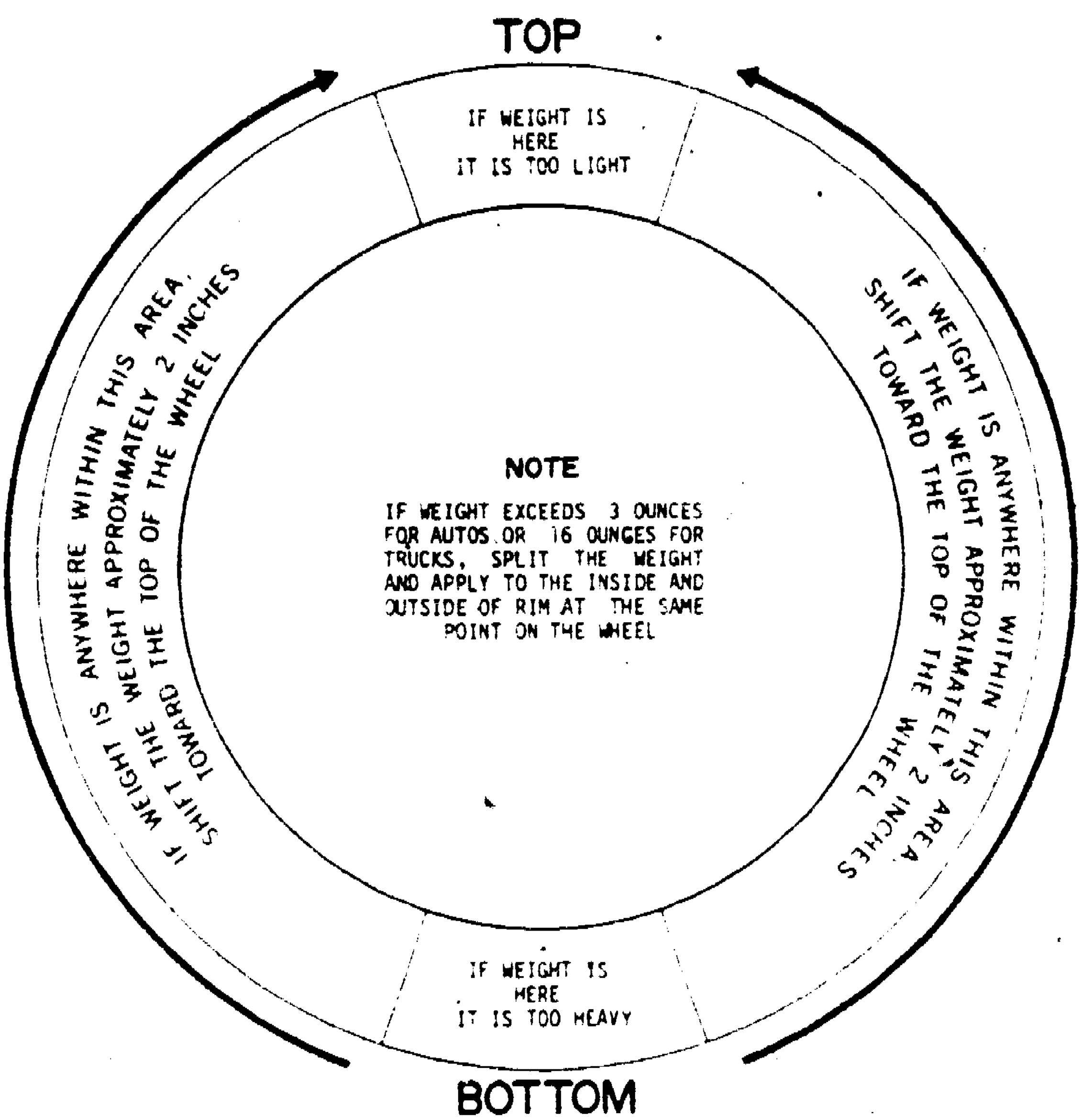


Look at the diagram on item 23a of your SRB and compare the position of the weight with the illustration shown above. Then, proceed to the next frame.

Frame 40

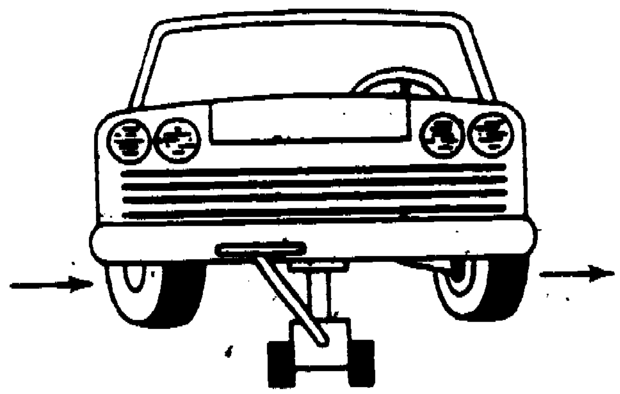
As a result of the instructions contained in the illustration below, you would be shifting the weights and spinning the wheel until that wheel was in balance. This is a time-consuming operation. In actual operations you are allowed to shift the weight(s) only once. After you have shifted the weight you must spin the wheel again. Then, you must note the position of the weight when the strobe light needle reaches its highest point during its second rise.

Remember, you may shift the weight only one time and then you must proceed to the next frame.



The equipment and the vehicle are prepared for dynamic wheel balancing as follows:

First, turn the wheel approximately 20 degrees out at the front, as shown in the illustration below.



QUESTION 24.

Is the wheel to be balanced in the same approximate position as that shown in the illustration above?

YES - Proceed to the next frame.

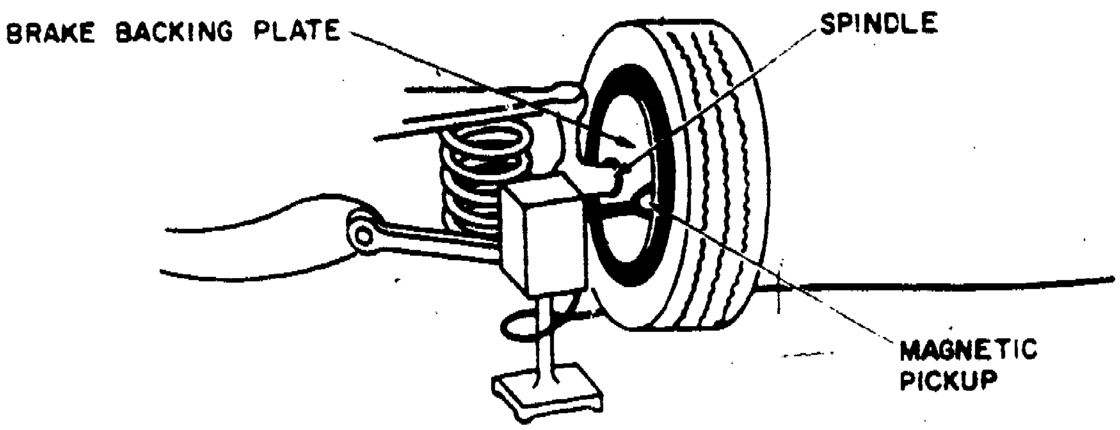
NO - Call an instructor for assistance.

Frame 42

Next, position the magnetic pickup as shown in the drawing below. Make sure that the magnetic pickup is at the same height as the spindle and as near the front edge of the brake backing plate as possible.

SAFETY NOTE: Make sure that the power cord is not under the wheel.

Next, tap the front edge of the wheel.



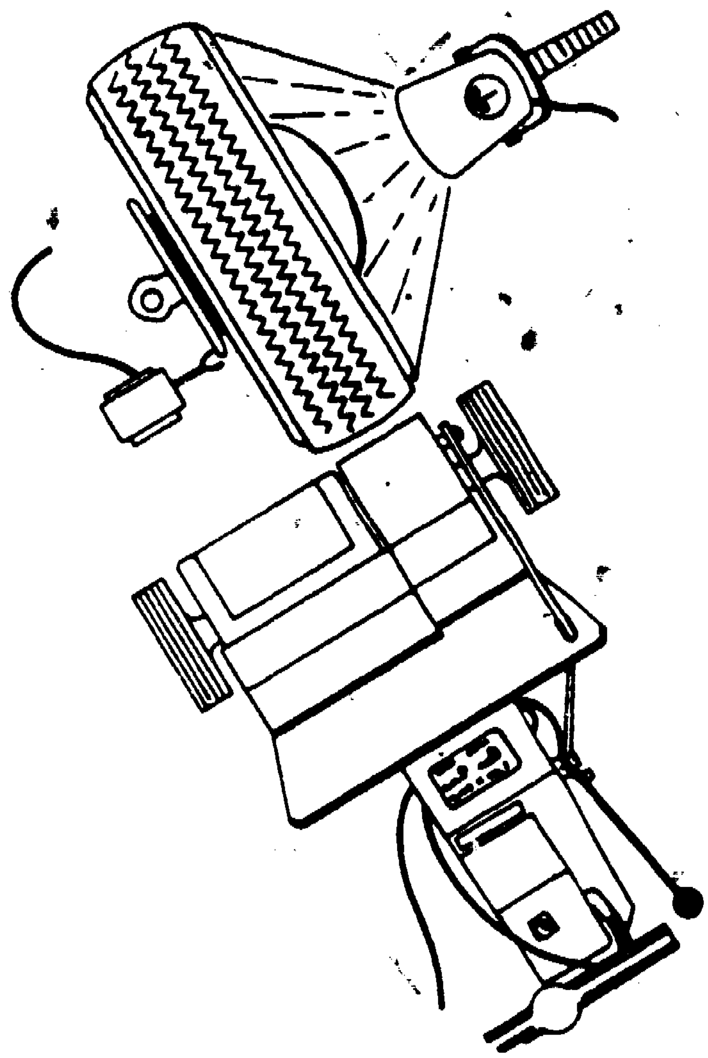
QUESTION 25.

Did the strobe light flash when the front edge of the wheel was tapped?

YES - Proceed to the next frame.

NO - Readjust the magnetic pickup. If you cannot get the strobe light to flash, call an instructor.

Next, align the wheel spinner and the strobe light with the wheel as shown in the drawing below. Make certain that no power cords are left under the wheel.



QUESTION 26.

Are all units in positions as shown in the illustration above?

YES - Proceed to the next frame.

NO - Call an instructor if you are having trouble.

Frame 44

Caution: Read all of the following instructions carefully before attempting to spin the wheel.

The wheel will tend to turn outward when the wheel spinner is applied. It may be necessary, therefore, to apply the wheel spinner at a slight angle, one that is sufficient to counteract the outward wheel movement.

Spin the wheel by hand and get it rotating. Turn the wheel spinner on and apply it carefully to the wheel.

When the wheel spinner has reached its maximum speed, pull it away from the wheel and turn it off. Observe the needle on the strobe light scale. When the needle reaches its highest point during the second rise, note the position of the <u>reference mark</u> on the wheel. Record the position of the reference mark on the wheel in the circle provided on your SRB. Record the highest reading of the needle on the diagram provided on your SRB.

Apply the wheel spinner and stop the wheel.

QUESTION 27.

Did the needle stay in the GREEN area of the scale?

YES - Proceed to frame 49.

NO - Proceed to frame 45.

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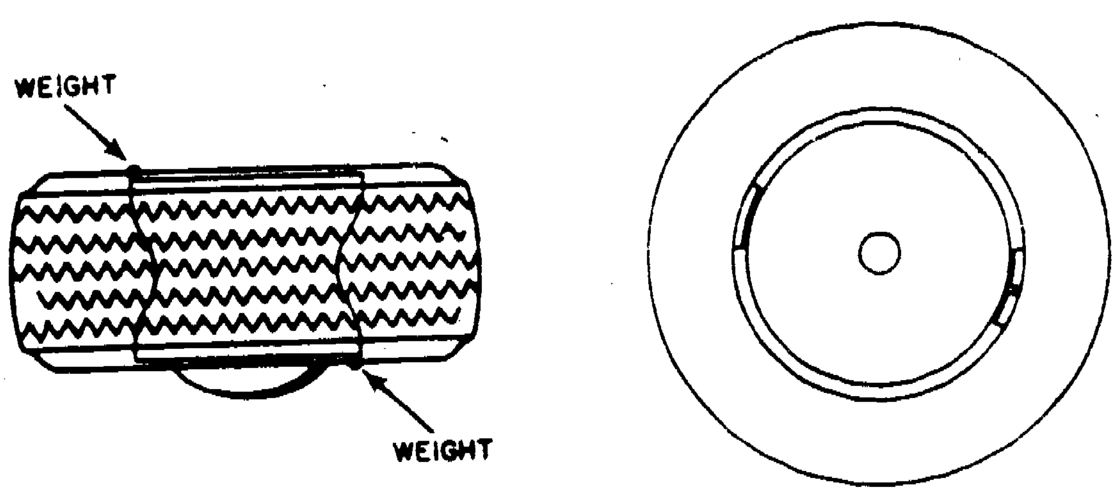
Position the wheel with the reference mark in the position as shown on the circle for 27a on your SRB.

Look at your SRB. Make the necessary entries in the spaces provided for items 27a and 27b.

Look at the scale on item 27b of your SRB. Note the highest reading of the needle on the diagram provided. Determine the amount of weight required to correct the dynamic unbalance condition.

Enter the weight required in the space provided as item 27c on your SRB.

Place one-half of this total weight on the <u>inside front</u> of the wheel and the other one-half of the total weight on the outside rear of the wheel as shown in the drawing below.



QUESTION 28.

Are the weights installed in the positions shown in the drawing above?

YES - Proceed to the next frame.

NO - If you are not sure, call an instructor.

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Frame 46

Now, go back and hit each weight again with the weight removal and installation tool.

MAKE SURE THAT THOSE WEIGHTS WILL NOT COME OFF!!!

QUESTION 29.

Are all those weights on as tightly as you can get them?

YES - Proceed to the next frame.

NO - Call an instructor.

41

Spin the wheel again with the wheel spinner.

Observe the position of the weights when the needle on the strobe light scale reaches its highest point during the second rise.

Record the position of the <u>weights</u> on the diagram on your SRB 30a as it appeared on the wheel when the needle reached its highest point during its second rise.

Apply the wheel spinner and stop rotation of the wheel.

Note: If the needle remained in the GREEN area of the scale, then the wheel is dynamically balanced.

QUESTION 30.

Is the wheel dynamically balanced?

YES - Proceed directly to frame 49.

NO - Proceed to frame 48.

Frame 48

Look at the diagram on your SRB that you filled in from item 30a. Notice the location of the weight and compare that position with the illustration shown below.

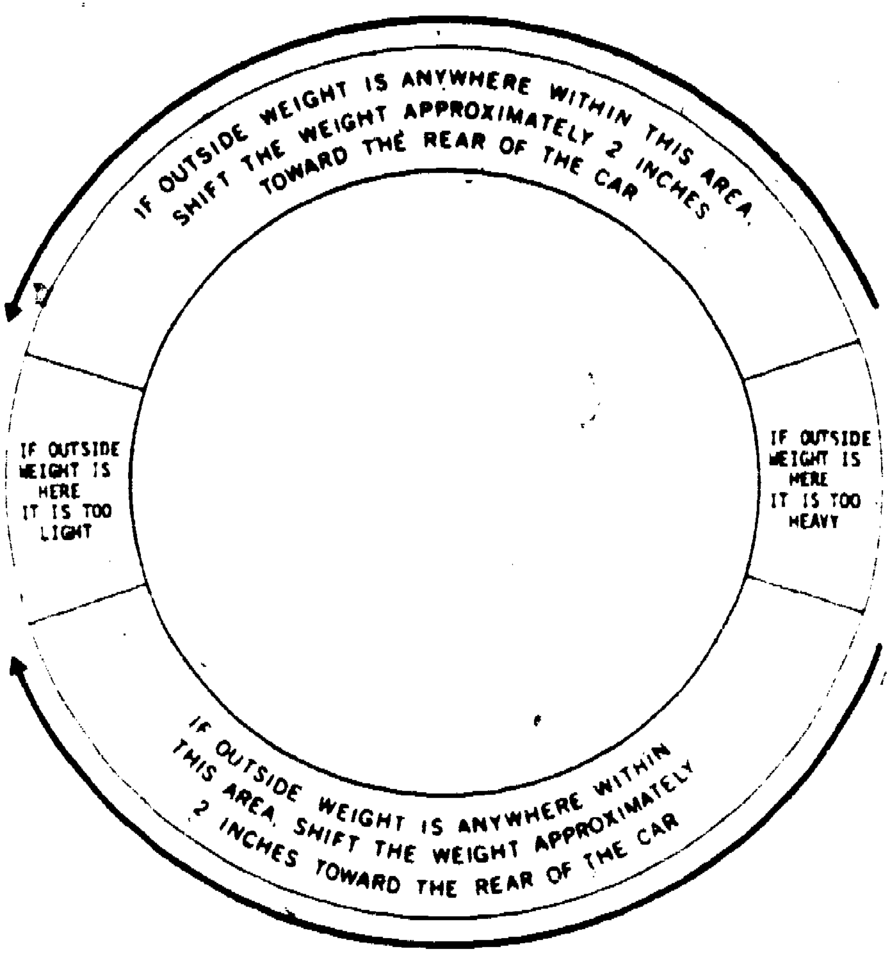
Follow the instructions on the diagram. Depending upon the location of the weight, you may have to shift the weight, install heavier or lighter weights.

In any event, you will have to spin the wheel again to determine if this adjustment affects the scale reading.

Note: If you must add weight or subtract weight, be sure to place the new weights in the same spots as those removed.

Spin the wheel again after making your change and observe the position of the weights as the wheel is spinning.

Apply the wheel spinner and stop the rotation of the wheel.



QUESTION 31.

Did the needle remain in the GREEN portion of the scale?

YES - Proceed to frame 49.

NO - Proceed to frame 49.

IF YOU HAVE NOT STOPPED THE WHEEL, DO SO NOW!

1. Turn the switch to the OFF position.

2. Disconnect the power cord and wind it up in the same manner as you found it at the beginning of this project.

3. Readjust the brake if you had to back it off earlier in the project.

4. Return the strobe light, wheel spinner, and the magnetic pickup to their respective storage areas.

5. Straighten the front wheels.

6. Release the hydraulic jack and return it to its proper storage area.

7. Remove the chocks from the rear wheels and return them to their storage area.

8. Return all tools to their storage area, or to the instructor.

WHEN ALL OF THE ABOVE OPERATIONS HAVE BEEN COMPLETED, RETURN THIS BOOKLET AND YOUR SRB TO THE INSTRUCTOR AND OBTAIN YOUR NEXT PROJECT.

PREPARE THE MAN — PROGRAMMED TEXT 3ABR47330-PT-606 432 400

~~3ABR47231-1-PT-403A~~
3ABR47231A-PT-403A
3ABR47231B-PT-403A
3ABR47231C-PT-403A

Technical Training

8-12

General Purpose Vehicle Repairman
Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)

STEERING FACTORS

3 October 1974

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes PROGRAMMED TEXT 3ABR47330-PT-606, 30 November 1971.
OPR: TWS
DISTRIBUTION: X
TWS - 425; TTOC - 2

FOREWORD

This programmed text was designed for use in the 3ABR47330, Automotive Repairman Course. It was validated by 30 students enrolled in that course in 1964 and has proved to be successful since that time.

OBJECTIVES

Upon completion of this programmed text you will be able to accomplish the following objectives with 85% accuracy.

1. Given a list of steering factors and illustrations of the steering factors, match each steering factor to the correct illustration.

2. Given a list of statements defining steering factors and a list of steering factors, match each steering factor to the correct definition.

3. Given a list of units of measurements and a list of steering factors, match each steering factor to the correct unit of measurement.

INSTRUCTIONS

Read the information in each frame and answer the question or questions following the frame. Write your response on a separate sheet of paper. When you have responded to a question, check your response against the correct response which is usually at the top of the page following the question page. If you make an incorrect response, reread the frame to see why the correct response as given is preferable. Then, change your response to agree with the one given in the program.

Two steering factors deal with the tilt of a wheel. One of these factors is "camber."

Camber is the inward or outward tilt of a wheel at the top. When a wheel tilts inward, this is negative camber. When a wheel tilts outward, this is positive camber.

Look at the illustrations below. In each illustration the line labeled "0" represents the vertical. The unlabeled line represents the center line of the wheel. Determine which way, inward or outward, each wheel is tilting, then answer the questions found below the illustration.

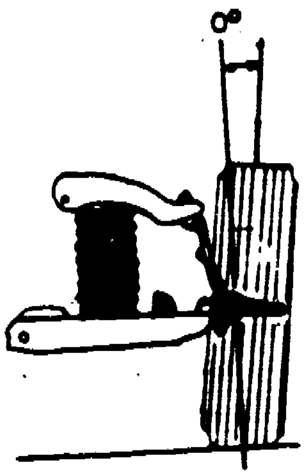


Figure 1

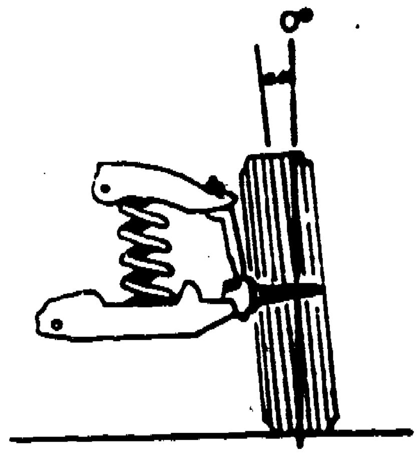


Figure 2

Mark "a", "b", or "c" in the appropriate places to correctly complete the following statements.

1. Figure 1 shows _____ a. negative camber.

2. Figure 2 shows _____ b. no camber.

c. positive camber.

Frame 2

Correct responses to previous questions:

1. c

2. a

Place "a", "b" or "c" in the blank to complete the following statements:

3.	The inward or outward tilt of a wheel at the top is ______	a.	camber.
		b.	negative camber.
4.	The inward tilt of a wheel is _____	c.	positive camber.
5.	The outward tilt of a wheel is _____		

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Note: The answers to the questions on Frame 2 will be found at the top of Frame 3.

Frame 3

Answers to Frame 2:

3. a.

4. b.

5. c.

The other steering factor dealing with the tilt of a wheel is known as "caster."

Caster is the backward or forward tilt of the steering knuckle. When the knuckle tilts backward, this is positive caster. When the knuckle tilts forward, this is negative caster.

Look at the illustrations below. In each illustration the line labeled "O" represents the vertical. The unlabeled line represents the center line of the wheel as drawn through the center of the steering knuckle. Determine which way each wheel is tilting and answer the questions asked below the illustrations.

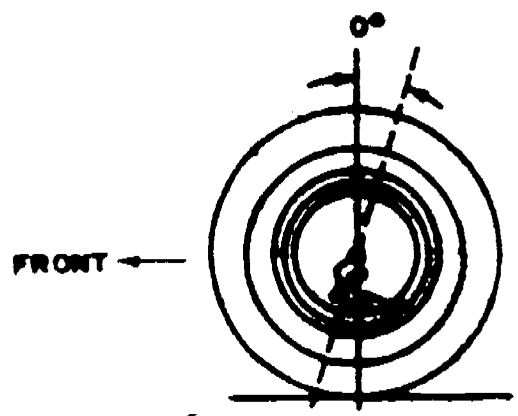

Figure 1

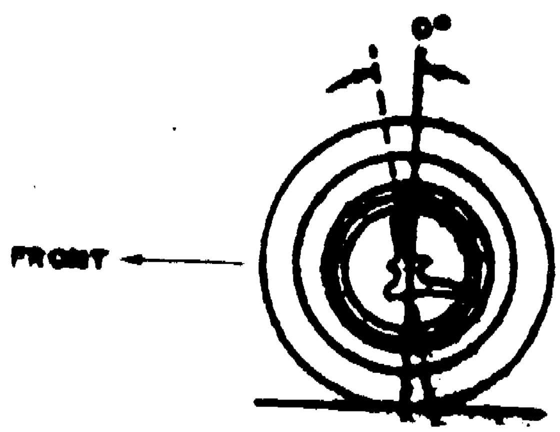

Figure 2

6. Figure 1 shows _____.

7. Figure 2 shows _____.

a. negative caster.

b. no caster.

c. positive caster.

Note: The correct answers to Frame 3 will be found on the top of Frame 5.

Complete the statements below.

8. The backward or forward tilt of the steering knuckle is _____.

9. The inward or outward tilt of a wheel at the top is _____.

a. caster.

b. camber.

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Frame 5

Correct responses for questions 6 through 9:

6. c.

7. a.

8. a.

9. b.

Match the steering factors with the correct illustration by entering the appropriate letter to complete the statements given below the illustrations.

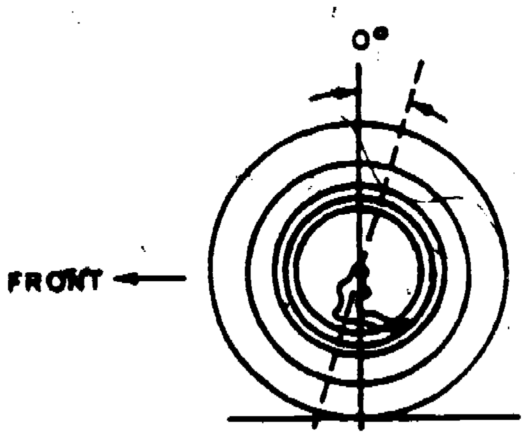

Figure 1

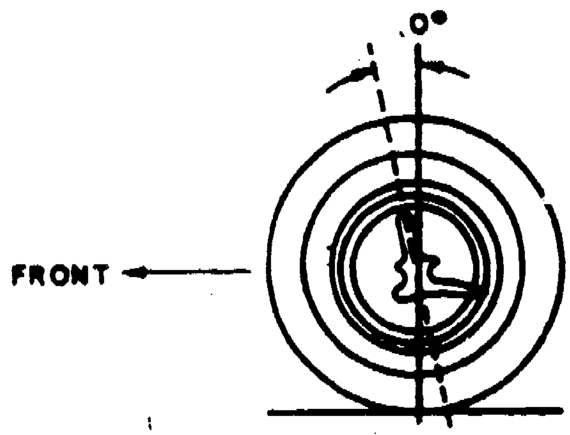

Figure 2

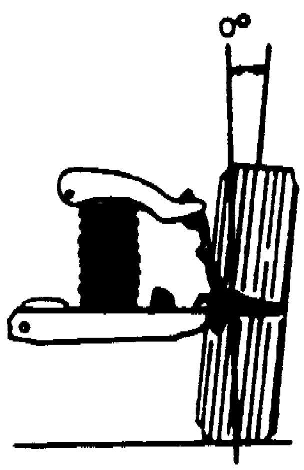

Figure 3

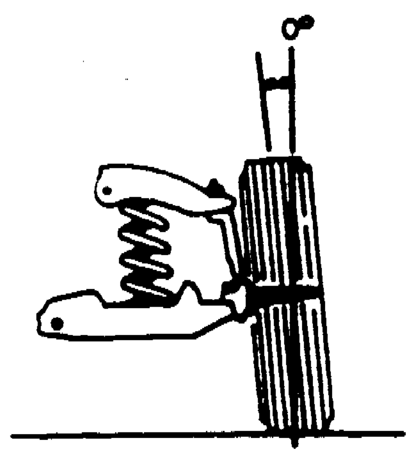

Figure 4

10. Figure 1 shows _____.
11. Figure 2 shows _____.
12. Figure 3 shows _____.
13. Figure 4 shows _____.

a. negative camber.
b. negative caster.
c. positive camber.
d. positive caster.

Frame 6

Match the steering factors with the correct illustration by entering the appropriate letter to complete the statements given below the illustrations.

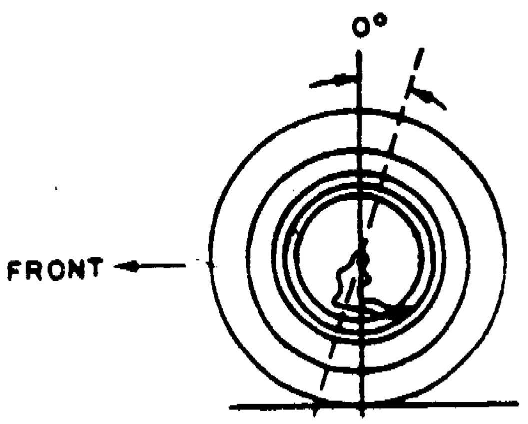

Figure 1

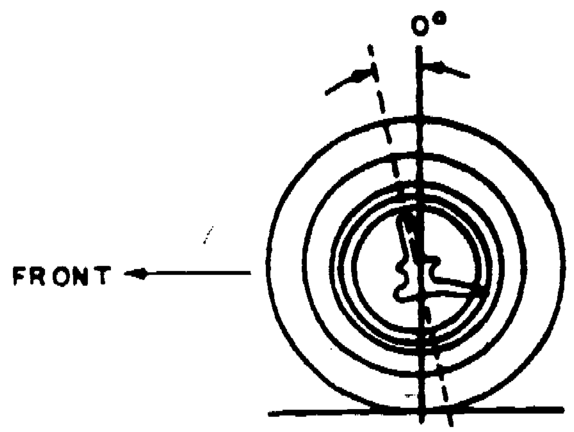

Figure 2

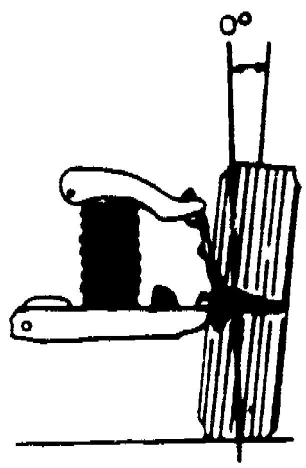

Figure 3

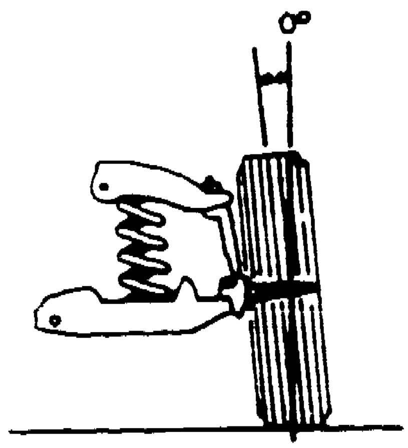

Figure 4

10. Figure 1 shows _____.
11. Figure 2 shows _____.
12. Figure 3 shows _____.
13. Figure 4 shows _____.

a. negative camber.
b. negative caster.
c. positive camber.
d. positive caster.

Match these definitions with the proper term:

16. The backward or forward tilt of the steering knuckle. _____.

17. The difference in distance between the front and the rear of the tires with the wheels straight ahead. _____.

18. The inward or outward tilt of a wheel at the top. _____.

a. camber.

b. caster.

c. toe.

Complete the statements below the illustrations.

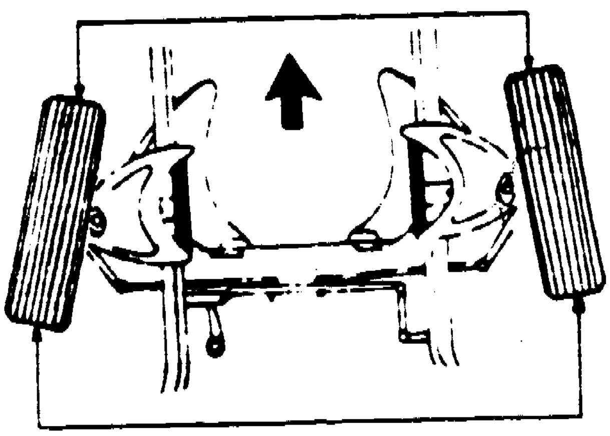

Figure 1

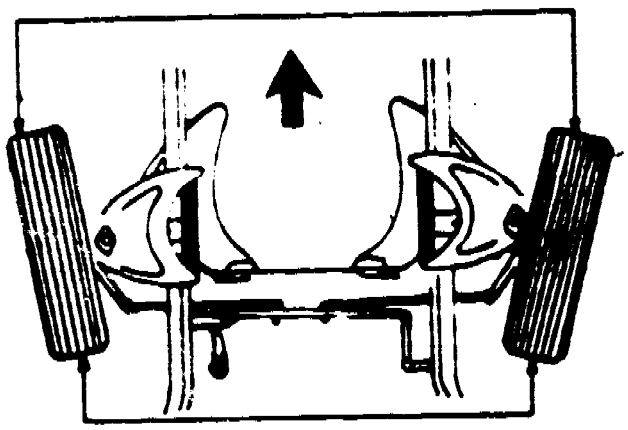

Figure 2.

19. Figure 1 shows _____.

20. Figure 2 shows _____.

a. camber.

b. caster.

c. toe-in.

d. toe-out.

Frame 9

Correct responses for questions 14 through 20.

14. d.
15. c.
16. b.
17. c.
18. a.
19. c.
20. d.

The fourth steering factor is "steering axis inclination." This is the amount (in degrees) that the upper kingpin is tilted inward.

Look at the illustrations below, then answer the question below.

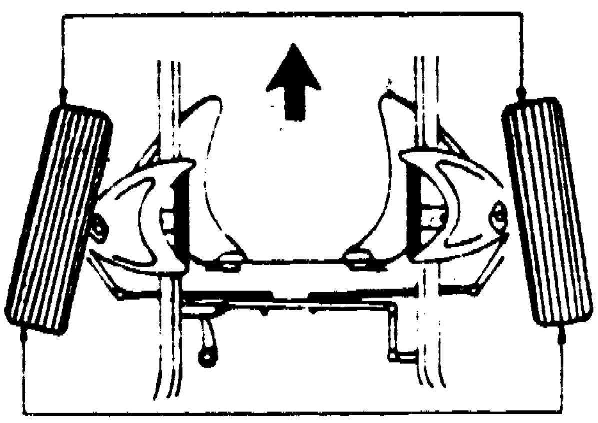

Figure 1

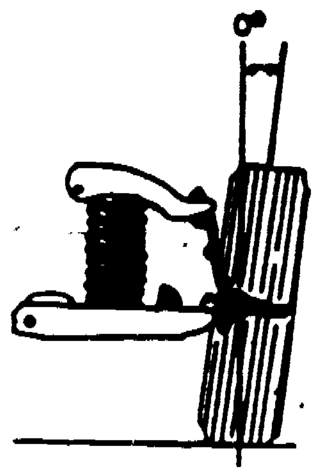

Figure 2

21. Which of the figures above shows steering axis inclination?

    a. Figure 1.

    b. Figure 2.

Correct response to Frame 9.

21. b.

Match the statements below with the term described.

22. The amount, in degrees, that the upper end of the kingpin is tilted inward. _____.	a. camber.
23. The forward or backward tilt of the steering knuckle. _____.	b. caster.
24. The difference in distance between the front and rear of the tires with the wheels straight ahead. _____.	c. steering axis inclination.
25. The inward or outward tilt of a wheel at the top. _____.	d. toe.

Frame 11

Correct response to questions 22 through 25:

a. c.
b. d.
c. d.
d. a.

The last steering factor is "steering geometry." This is the difference in turning radius of the front wheels. Proper steering geometry is achieved when the inside wheel in a turn tends to make a circle smaller than the outside wheel.

For example: If the outside wheel in a turn makes an arc of 24°, the inside wheel should make an arc of about 28°. The larger the number of degrees of arc, the smaller the circle.

Look at the illustrations below, then answer the questions found on the top of the next frame.

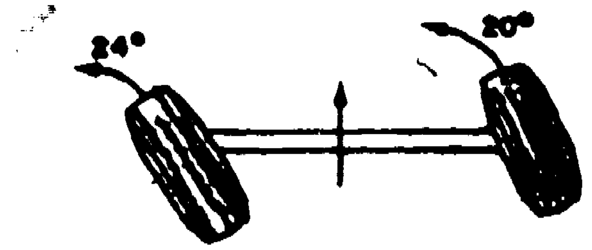

Figure 1

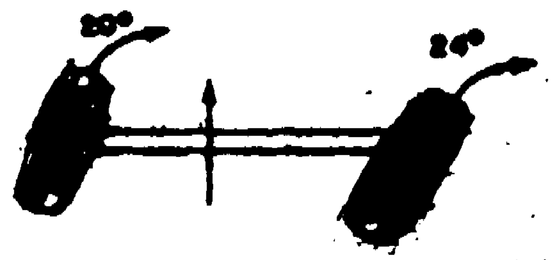

Figure 2

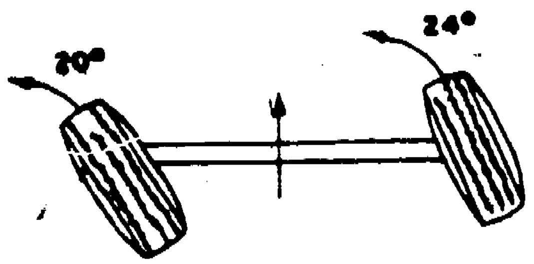

Figure 3

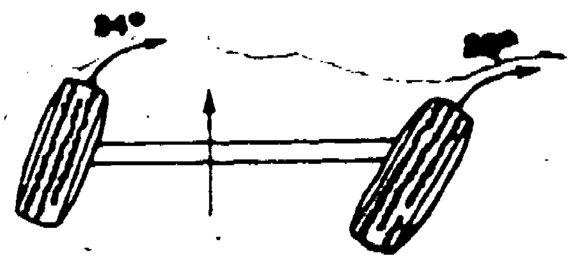

Figure 4

Frame 12

For each of the statements below, mark "a" for proper and "b" for improper in the appropriate space.

26. Figure 1 shows _____ steering geometry.

27. Figure 2 shows _____ steering geometry.

28. Figure 3 shows _____ steering geometry.

29. Figure 4 shows _____ steering geometry.

(Drawings are on page 12.)

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Frame 13

Correct responses to questions 26 through 29.

26. a.
27. a.
28. b.
29. b.

Match the steering factors in the right-hand column to their definitions in the left-hand column.

30. The amount in degrees that the upper end of the kingpin is tilted inward. _____.

31. The backward or forward tilt of the steering knuckle. _____.

32. The difference in distance between the front and the rear of the tires with the wheels straight ahead. _____.

33. The difference in turning radius of the front wheels. _____.

34. The inward or outward tilt of a wheel at the top. _____.

a. camber.

b. caster.

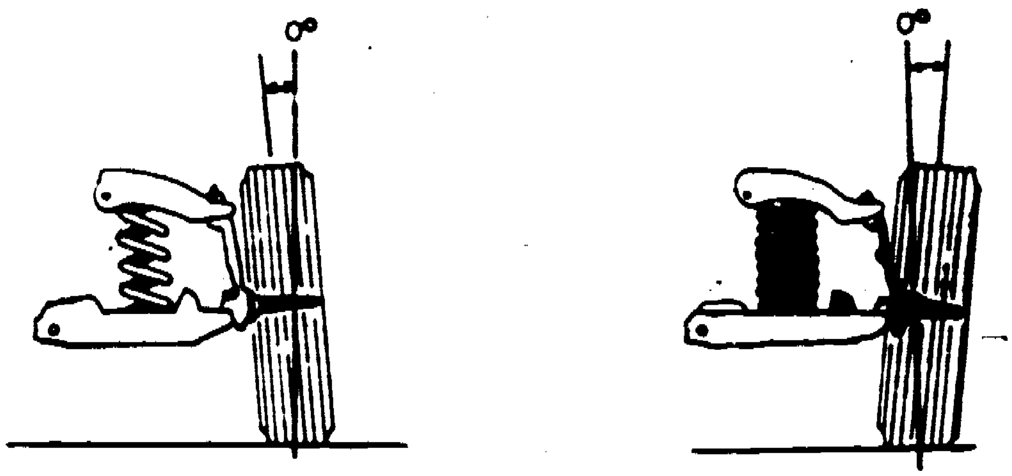
c. steering axis inclination.

d. steering geometry.

e. toe.

Frame 14

The illustrations below show positive and negative camber. The inward or outward movement of the top of the wheel is shown as so many degrees from the vertical. Caster is also measured in degrees, but in this case it is a forward or rearward angle from the vertical. Answer the question below the illustration.



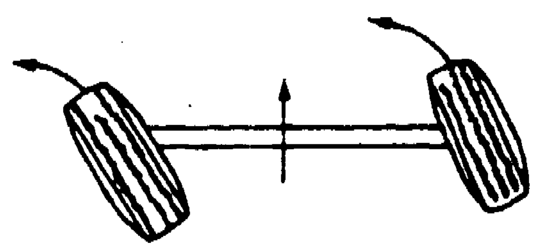
35. Both camber and caster are measured in (circle the correct response).

   a. centimeters or millimeters.

   b. degrees of a circle.

   c. fractions of an inch.

Look at the illustration below then answer the question.



36. Since steering geometry is defined as: "the difference in turning radius of the front wheels, "how would steering geometry be measured? (Circle the correct response.)

   a. In centimeters or millimeters.

   b. In degrees of a circle.

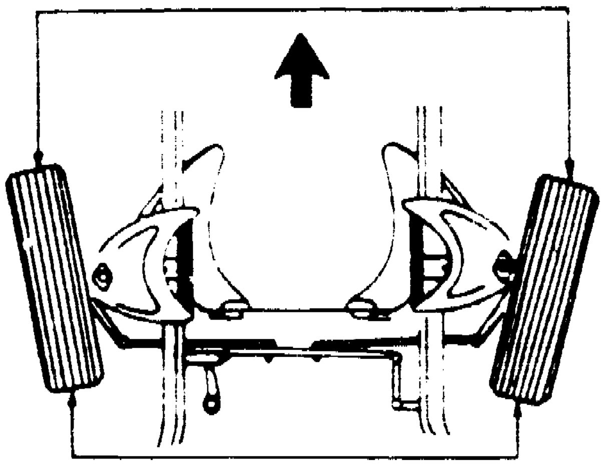
   c. In fractions of an inch.

Frame 15

Correct responses for questions 30 through 36:

30. c.
31. b.
32. e.
33. d.
34. a.
35. b.
36. b.

Look at the illustration below, then answer the question under it.



37. Since toe is the difference in actual distance between the front of the tires and the rear of the tires with the wheels straight ahead, toe is measured in _____.

    a. centimeters or millimeters.

    b. degrees of a circle.

    c. fractions of an inch.

Listed below at the left are the steering factors at the right are units of measurement. Match the steering factor with its proper unit of measurement. Each measurement may be used as many times as necessary. Some measurements may not be used at all.

38. Camber. _____.

39. Caster. _____.

40. Steering geometry. _____.

41. Toe-in. _____.

a. Centimeters or millimeters.

b. Degrees of a circle.

c. Fractions of an inch.

Frame 17

Correct answers for questions 37 through 41:

37. c.
38. b.
39. b.
40. b.
41. c.

Match the steering factors with the correct illustration by entering the appropriate letter to complete the statements below the illustration.

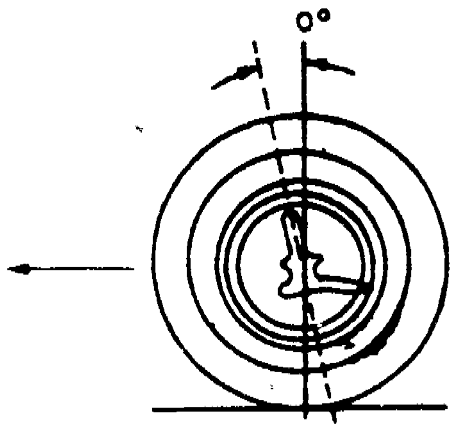


Figure 1

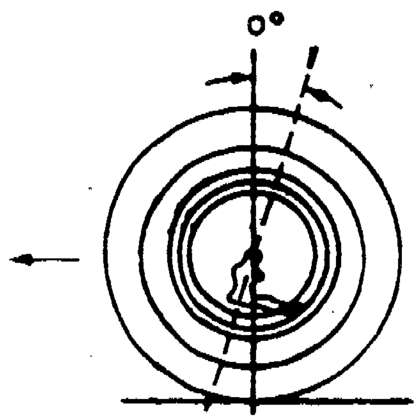


Figure 2

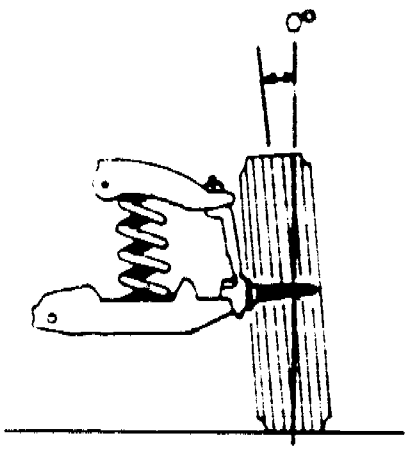


Figure 3

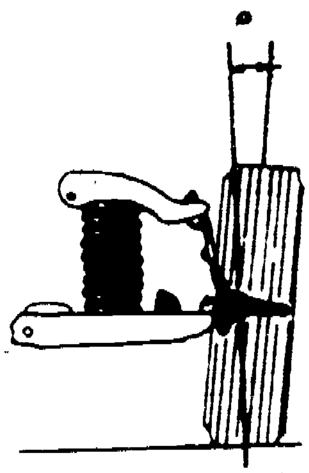


Figure 4

42. Figure 1 shows _____.
43. Figure 2 shows _____.
44. Figure 3 shows _____.
45. Figure 4 shows _____.

a. negative camber.
b. negative caster.
c. positive camber.
d. positive caster.

Match the steering factor in the right-hand column below with the correct definition as given in the left-Hand column. Record your answers in the appropriate space.

46. The amount in degrees that the upper end of the kingpin or steering knuckle support arm is tilted inward. _____.

47. The backward or forward tilt of the steering knuckle pivot pins. _____.

48. The difference in distance between the front and the rear of the tires with the wheels straight ahead. _____.

49. The difference in turning radius of the front wheels. _____.

50. The inward or outward tilt of a wheel at the top. _____.

a. camber.

b. caster.

c. steering axis inclination.

d. steering geometry.

e. toe.

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Correct responses for questions 42 through 50:

42. b.
43. d.
44. a.
45. c.
46. c.
47. b.
48. e.
49. d.
50. a.

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PREPARE THE MAN

PROGRAMMED TEXT 3ABR47~~330~~232-PT-606A
3ABR47231-1-PT-602
3ABR47231A-PT-602
3ABR47231B-PT-602
3ABR47231C-PT-602

Technical Training

General Purpose Vehicle ~~Repairman~~ Mechanic
Special Vehicle Repairman
(Towing and Servicing Vehicles)
(Crash/Fire Vehicles)
(Refueling Vehicles)
(Materials Handling Vehicles)

8-12

SPRINGS AND SHOCK ABSORBERS

23 November 1971

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-PT-606A, 7 May 1970.
OPR: TDWS
DISTRIBUTION: X
TDWS - 800; TTOC - 6

Designed For ATC Course Use
Do Not Use on the Job.

FOREWORD

This programmed text was designed for use in the Automotive Repairman Course, 3ABR47330. It was validated by 30 students enrolled in that course in 1964 and has proved successful since that time.

OBJECTIVES

Upon completion of this programmed text you will be able to accomplish the following objectives with 85% accuracy.

1. List the types of automotive springs.
2. Given a diagram of a leaf spring label the components.
3. List the types of automotive shock absorbers.

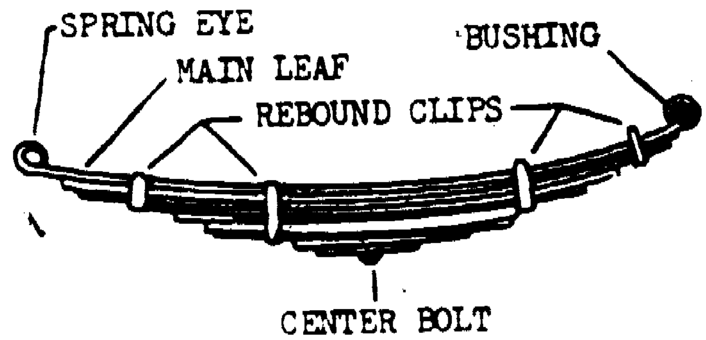
INSTRUCTIONS

This text presents information in steps called "frames." In each step you will be required to respond in some manner: TRUE or FALSE, answer questions, fill in the blanks, etc. Use a piece of paper or a card as a mask to cover the printed material. Slide this mask down the page until you expose the slashes (//////////////////////). One step is now exposed for your viewing. Read the material presented and make your responses to the problems presented. After you have responded, slide the mask down and compare your answer(s) with the correct one(s) given. If your answers are correct, go on to the next frame; if you are wrong, go back and read the part on which you made the mistake and reason out the correct answer. If you have any questions or problems, ask your instructor. After completing one frame, proceed to the next one until you complete this entire text.

Proceed to the frame on the top of the next page.

Springs are required to provide a flexible support for the vehicle and its load. There are several kinds of vehicle springs, but the most common are the "leaf spring" and the "coil spring."

The accompanying figure shows a leaf spring assembly, which is constructed of a number of steel "leaves" strips. The leaves are held together by a center tie bolt and a number or rebound clips. You should notice that the ends of the master leaf are rolled into "eyes" so as to provide a means for attaching the spring to the vehicle frame. These eyes contain a bushing. The center bolt fits into a recess at the axle (housing) to provide the means of "centering" the axle to the spring and hold the two in alignment.



Answer each of the following questions. Refer to the figure above if necessary.

1. What is the purpose of automotive springs? ____

2. What holds the leaf spring assembly together? ____

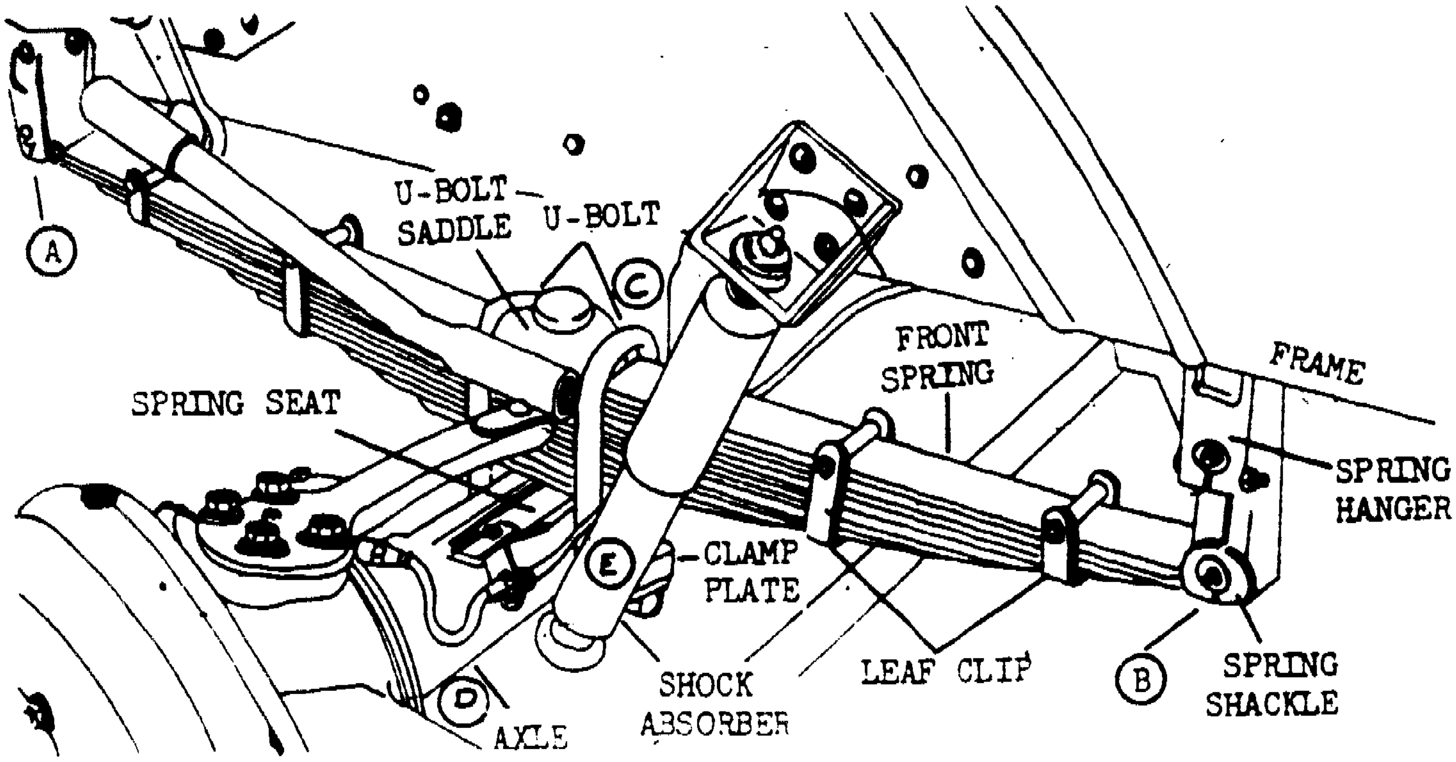
3. What centers (aligns) the leaf spring to the vehicle axle? ____

4. What is the name of the longest leaf of the spring? ____

////////////////////

1. To provide a flexible support for the vehicle and its load.
2. A center bolt and rebound clips.
3. The center bolt.
4. The master leaf.

2.



The figure above shows the typical installation of a leaf spring. Leaf springs could not flex (move up and down) if each eye of the spring were rigidly attached to the frame. At least one end of the spring must be connected to a movable spring shackle (item "B" above) to permit the spring assembly to move up and down (flex). Study each end of the springs (items "A" and "B") and determine the names of the devices that connect the spring eyes to the vehicle frame. The center tie bolt, you will recall, centers or aligns the axle to the spring. Once the spring is properly aligned to the axle it must be tightly secured to the axle. Item "C" above will secure the spring to the axle. Also, notice that the lower end of the shock absorber (item "E" above) is connected to the axle (item "D").

Answer each of the following questions.

1. What kind of bolts secure the spring to the vehicle axle?

 _______________.

2. Name the devices that attach the spring eyes to the vehicle frame.

 _______________.

3. What permits the leaf spring to flex under load and shock?

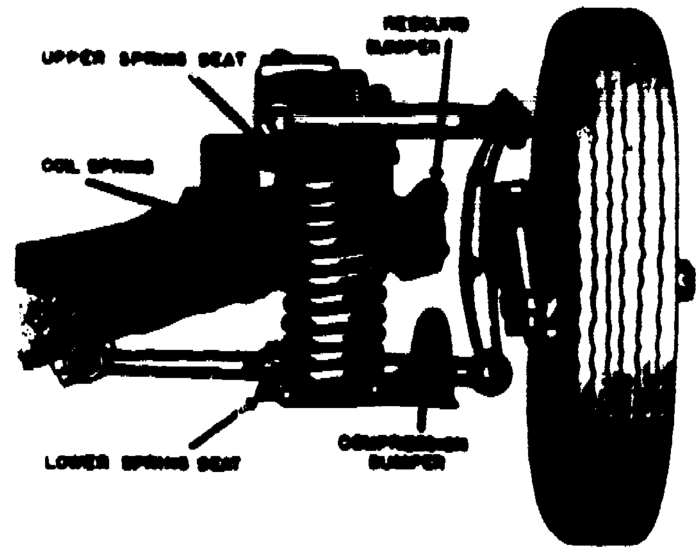
 _______________.

4. The shock absorber is mounted between what two major vehicle members? _______________.

//////////////////////

1. U-bolts.
2. By spring hangers and shackles.
3. The movable shackle.

The accompanying figure shows a front coil spring (this kind of spring provides for independent suspension). One advantage of the coil spring is that there is no friction between the coils. The leaf spring, of course, has a considerable amount of friction between the leaves. Coil springs are much more flexible than leaf springs and therefore they require heavier shock absorbers (heavy duty) than do leaf springs to prevent excessive rebound.



Coil springs can only be used to absorb "up-and-down" movement; they cannot transmit any "side thrust" nor take any "torque reaction." Therefore, when coil springs are used on a vehicle, a stabilizer bar must be used to absorb these loads and to hold the axle in alignment.

Complete each of the following.

1. TRUE or FALSE: Coil springs do not allow for independent wheel suspension.

2. Which type of spring cannot absorb "torque reaction" or transmit "side thrust?" ______________________

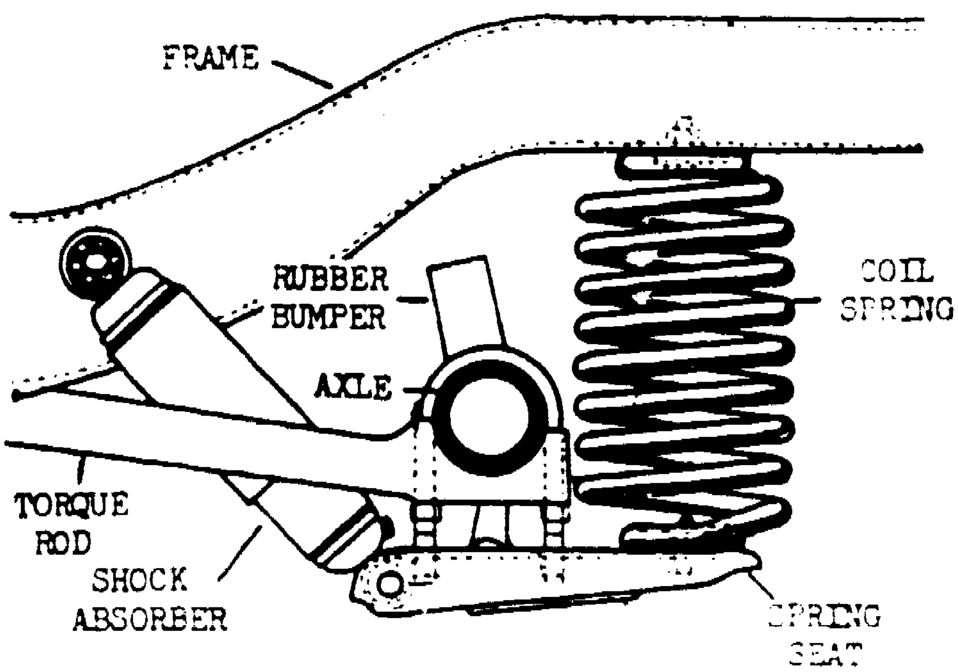
3. Which type of spring can be used in the smallest space? ________

4. Heavier shock absorbers must be used with ____________ springs than with ____________ springs.

////////////////////

1. FALSE
2. Coil
3. Coil
4. Coil leaf

4.



This figure shows a rear coil spring and shock absorber installation. Study the illustration carefully and then answer each of the following questions.

1. The coil spring is mounted between what two major vehicle members? ________
____
____
____

2. The shock absorber is mounted between what two major vehicle members?
____

Overloading a vehicle and driving at excessive speeds over rough roads and terrain often causes suspension problems. The most common spring troubles are: loose or broken rebound clips; broken center tie bolts; and broken spring leaves. Springs must be inspected periodically to determine if any of these three common malfunctions have occurred.

Some manufactureres advocate (recommend) that leaf springs be lubricated and other manufacturers do not recommend the lubrication of springs. Automotive mechanics should always follow the manufacturer's recommendations for lubricating springs.

Answer the following.

1. When should leaf springs be sprayed with oil or lubricated with grease? ____________________.

2. Three common problems encountered with leaf springs are: ____
____
____
____

//////////////////////

1. When and if recommended by the manufacturer
2. Broken leaves, loose or broken rebound clips, and broken center bolt.

There are two types of shock absorbers: the "direct acting" and the "indirect acting" type. The "indirect acting" shock absorbers consist of cams, levers, and extensive linkage. The use of "indirect acting" shock absorbers on modern Air Force vehicles is very limited. The "direct acting" shock absorber, on the other hand, is very compact and simple: it does not require the use of cams, levers, or extensive linkage. The "direct acting" shock absorbers have mounting eyes at each end and rubber bushings are inserted into each eye. The "direct acting" shock absorber is permanently sealed and cannot be overhauled, therefore, maintenance other than required replacement of the entire unit and replacement of worn rubber bushings is not required.

Answer each of the questions asked below the figures.

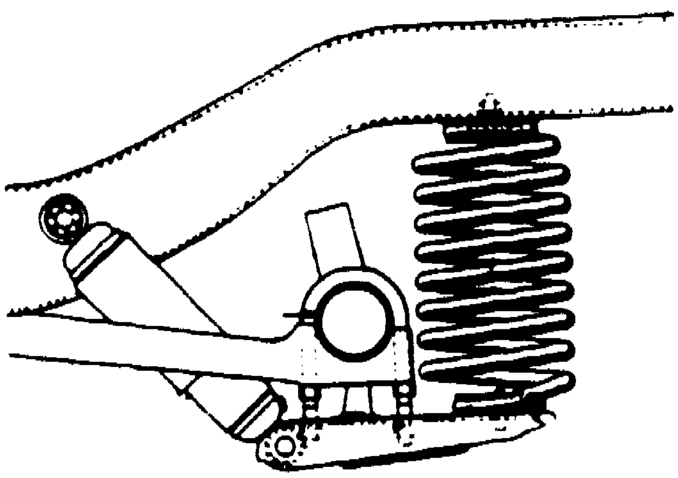


Figure A

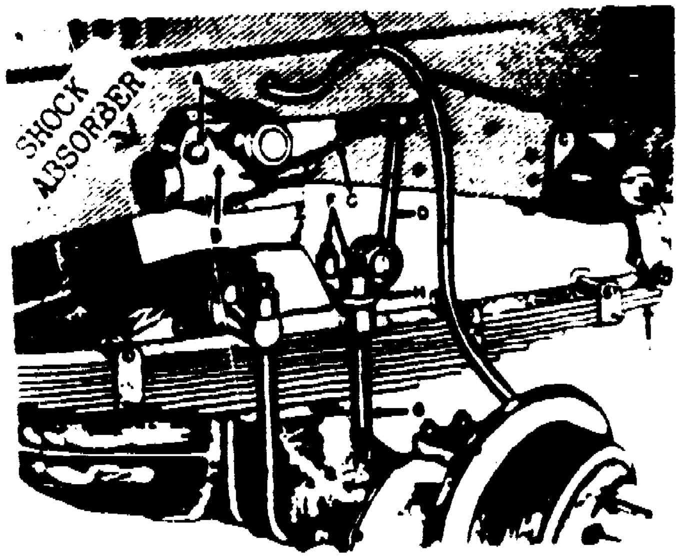


Figure B

1. What type of shock absorber is shown in figure A? ______________

2. What type of shock absorber is shown in figure B? ______________

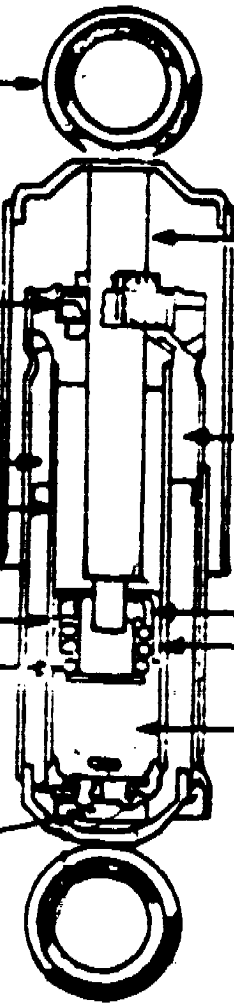
3. What maintenance may be performed on the direct acting type shock absorbers? ______________

4. A shock absorber is mounted between the ______________ and the ______________.

//////////////////////

1. Direct acting
2. Indirect acting
3. Replacement of bushings and entire unit.
4. axle frame (either order is correct)

7.



The figure to the left shows a cross-section view of a direct acting shock absorber. This shock absorber has an "upper" and a "lower" chamber separated by a double acting piston. When the vehicle's spring is compressed, the push rod forces the piston down and the oil below the piston is forced through the one-way compression valve into the upper chamber. When the vehicle's spring "rebounds" the action is reversed. As the piston moves up the oil trapped in the space above the piston is forced through the one-way rebound valve into the lower chamber. By restricting the flow of oil through these one-way valves the shock absorbers regulate the spring compression and rebound rate.

Answer each of the questions below.

1. What is the purpose of shock absorbers? ______________________
____

2. How do shock absorbers dampen road shocks? ___________________
____

//////////////////////

1. To regulate the spring compression and rebound rate.

2. By restricting the flow of oil through one-way valves.

Some passenger cars and trucks use torsion bars in place of springs for front end suspension. Torsion bars take up less space than coil or leaf springs and they are adjustable. That is, they can be used to raise or lower the vehicle's height.

Answer the following question.

What advantages do torsion bars have over coil and/or leaf springs?

____.

////////////////////

They take up less space and are adjustable.

SELF TEST

1. A leaf spring assembly is secured to a vehicle axle by the

    a. center tie bolt.
    b. U-bolts.
    c. rebound clips.

2. A shock absorber dampens road shocks by the

    a. restricted flow of fluid through one two-way orifice.
    b. free flow of fluid through two-way orifices.
    c. restricted flow of fluid through one-way orifices.

3. The longest leaf in a leaf spring assembly is named the

    a. center leaf.
    b. tie leaf.
    c. main leaf.

4. The purpose of shock absorbers is to

    a. support the weight of the vehicle.
    b. control the spring compression and rebound rate.
    c. align the axle of the vehicle.

5. The coil spring

    a. requires heavier duty shock absorbers than do leaf springs.
    b. is less flexible than the leaf spring.
    c. requires more space than the leaf spring.

////////////////////

Answers are to be found on the next page.

9.

ANSWERS TO REVIEW QUESTIONS

1. b.

2. c.

3. c.

4. b.

5. a.

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PREPARE THE MAN

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PROGRAMMED TEXT 3ABR47~~330~~-PT-607A

Technical Training

8-12

General Purpose Vehicle ~~Repairman~~ Mechanic

SCUFF TESTER AND PORTALINER

27 April 1970

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes SG CISDT-PI-47-56, 10 February 1967.

Designed For ATC Course Use

FOREWORD

This Programmed Text was designed for use by students enrolled in the General Purpose Vehicle Repairman Course 3ABR47330. It was validated by 30 students enrolled in that course in 1964 and has proved to be successful since that time.

OBJECTIVES

Given this Programmed Text, a worksheet, and other necessary equipment you will be able to accomplish the following objectives to meet the manufacturer's specifications:

1. Perform a scuff test on the front and rear wheels of a vehicle.

2. Perform a preliminary inspection on vehicle steering mechanism.

3. Prepare the vehicle for checking front end alignment.

4. Check camber and record findings for each wheel.

5. Check caster and record findings for each wheel.

6. Check steering axis inclination and record findings.

7. Check toe-out on turns.

8. Make necessary adjustments using shop manuals.

INSTRUCTIONS

1. Write your name, rank, and class number at the top of your worksheet.

2. Write the name of the vehicle to which you have been assigned. (Ford, Chevrolet, etc.) Also write in the model year of the vehicle.

3. Read each step carefully before starting the task.

4. Perform each step exactly as directed. Do not skip any step.

5. Ask your instructor for help or advice whenever you are in doubt.

6. This task can be accomplished by one man working alone or by two men working together. If you are doing the job alone, you must accomplish each step in each task. If two men are working together, one man can read the task list while the other performs the step; then switch and let the other man perform the next step while the first man reads the task list. When the same task is to be performed on both front wheels, one man should do the left wheel and the other man the right wheel.

7. Make sure that you have a specifications chart and the appropriate shop manual for the vehicle on which you are working.

The purpose of the scuff tester is to give a quick check of wheel alignment to see if the vehicle has toe-out or excessive toe-in. The desired front wheel scuff is 0 to 3 feet per mile IN. The exact amount depends on the vehicle specifications. A vehicle with 1/16 inch of toe-in would read near zero feet per mile scuff, while a vehicle with 3/8 inch of toe-in would read near three feet per mile scuff. The indicator on the scuff tester will reset to zero when the wheels roll over the trip plate and deflect to indicate the amount of wheel scuff when the wheels roll over the scuff blades. It is important that you note whether the indicator reads IN or OUT as most vehicles should have toe-in and a reading of 0 to 3 feet per mile OUT would be an incorrect adjustment.

Perform a scuff test on the front and rear wheels of the vehicle and record the readings as items #1 and #2 on your worksheet.

a. Line up the vehicle with the tester so that both front wheels will strike the tester blades at exactly the same time; then do not turn the steering wheel while the vehicle is on the tester.

b. Drive the front wheels over the platform slowly (3 to 5 MPH) and stop when you are even with the indicator so you can read it.

c. Record the front wheel scuff reading as item #1 on your worksheet and indicate whether it is IN or OUT.

d. Drive the rear wheels across the platform slowly, stop the vehicle in the spot designated for portaliner work, set the parking brake, stop the engine, etc.

e. Record the rear wheel scuff indication as item #2 on your worksheet and indicate whether it is IN or OUT.

QUESTION

? ?

? Did you complete the scuff test and record the readings? ?

? a. YES - Go on to the next step. ?

? b. NO - Ask your instructor for help if necessary. ?

? ?

Frame 2.

Perform a preliminary inspection and place a check mark in the space provided for item #3 on your worksheet to indicate that you have performed the inspection.

a. Check wheel bearing adjustment.

b. Check ball joints or kingpins for looseness.

c. Check steering linkage for looseness.

d. Check to see if the vehicle is level (side to side) and move it to a level spot if necessary.

QUESTION

? ?

? Have you completed the preliminary inspection? ?

? a. YES - Go on to the next step. ?

? b. NO -Try again or ask your instructor for help. ?

? ?

Prepare the vehicle for checking front end alignment.

a. Insure that the front wheels are positioned straight ahead and place them on the turning radius gauges.

b. Lock the wheels with the brake pedal depressor.

c. Use the tire gauge and insure that all tires are properly inflated.

d. Remove the hubcap and dust cap from both front wheels.

e. Wipe off the excess grease and dirt from the end of the spindle and the face of the hub.

f. Remove the lock pins from both turning radius gauges.

g. Bounce the vehicle in the center of the front bumper in order to relieve spring set.

h. Attach the caster-camber SAI gauges to the magnetic adapters and tighten the thumb screws to hold them securely.

i. Attach the gauges to the wheels, insuring that the centering pins fit into the center of the spindles and that the scales face upward.

QUESTION

? ?

? Did you prepare the vehicle for checking front end alignment? ?

? a. YES - Go on to the next step. ?

? b. NO - Ask your instructor for help if necessary. ?

? ?

Frame 4.

⇩

Check camber for both wheels. Record the readings as item #4 on your worksheet, and indicate whether it is negative or positive (- or +).

a. You should already have the camber gauge attached to the wheel with the magnetic adapter.

b. Read camber on the outer scale of the camber gauge at the center of the bubble.

c. Record the readings as directed above.

NOTE: You should never adjust camber until after you have checked and adjusted caster as the caster adjustment will change camber.

QUESTION

? ?

? Did you check and record the camber readings for both front wheels? ?

? a. YES - Go on to the next step. ?

? b. NO - Ask your instructor for help if necessary. ?

? ?

Check caster for both front wheels, record your findings as item #5 on your worksheet, and indicate whether it is negative or positive (- or +).

a. Adjust the turning radius scales so they indicate zero on both turning radius gauges with the wheels straight ahead.

b. Turn the wheel in toward the center of the vehicle until the turning radius gauge indicates 20 degrees.

c. Turn the knob under the caster scale until the bubble centers on the zero (0).

d. Turn the wheel out at the front until the turning radius gauge indicates 20 degrees.

e. Read caster at the center of the bubble on the blue scale.

f. Record the reading as directed above.

Repeat these procedures for the opposite wheel.

QUESTION

? ?

? Did you check and record the caster readings for both front wheels? ?

? a. YES - Go on to the next step. ?

? b. NO - Try again or ask the instructor for help. ?

? ?

Frame 6.

Check steering axis inclination (SAI or kingpin inclination) and record your findings as item #6 on your worksheet.

a. Insure that both turning radius gauges indicate zero with the wheels straight ahead.

b. Turn the wheel in at the front to 20 degrees.

c. Turn the control knob under the SAI scale until the bubble centers on the zero.

d. Turn the wheel out at the front to 20 degrees.

e. Read the steering axis inclination on the blue scale of the SAI gauge at the center of the bubble.

f. Record the SAI reading as indicated above.

Repeat these procedures for the opposite wheel.

QUESTION

? ?

? Did you check and record SAI for both front wheels? ?

? a. YES - Go on to the next step. ?

? b. NO - Ask your instructor for help if necessary. ?

? ?

The next task to accomplish is checking toe-out on turns. This is also known as "steering geometry." As you will recall from the lesson on steering factors, toe-out on turns or steering geometry, is the difference in the turning radius of the two front wheels when making a turn to the left or right.

The right column of the specification chart is titled "Checking Toe-out on Turns." In this column there are two listings titled "When Outer Wheel Turns 20°" and "When Inner Wheel Turns 20."

Determine which group your vehicle is listed in and then proceed as directed.

QUESTION

? ?

? Is your vehicle listed under "When Outer Wheel Turns 20°?" ?

? a. YES - Go on to Frame 8. ?

? b. NO - Skip Frame 8 and go on to Frame 9. ?

? ?

Frame 8.

When a vehicle is making a turn, the left wheel is sometimes the outer wheel and sometimes the inner wheel, depending upon which way the vehicle is turning. The outer wheel is always the wheel on the outside of the turn; therefore, the outer wheel must be turned in toward the center of the vehicle. In order to have toe-out in turns, when the outer wheel is turned in 20 degrees, the inner wheel will be turned out more than 20 degrees.

Use the following procedure to check steering geometry:

a. Write the word "Outer" in the space provided for item #7 on your worksheet.

b. Turn the right wheel in 20 degrees toward the center of the vehicle.

c. Read the steering geometry on the left wheel turning radius gauge.

d. Turn the left wheel in 20 degrees toward the center of the vehicle.

e. Read the steering geometry on the right wheel turning radius gauge.

f. Record the steering geometry readings on your worksheet as item #8.

QUESTION

? ?

? Did you obtain and record the steering geometry readings for both front wheels? ?

a. YES - Go on to Frame 10; skip Frame 9.

b. NO - If you cannot check steering geometry, ask your instructor for help.

? ?

When a vehicle is making a turn, the right wheel is sometimes the inner wheel and sometimes the outer wheel, depending upon which way the vehicle is turning. The inner wheel is always the wheel on the inside of the turn; therefore, the inner wheel is always turned out from the center of the vehicle. In order to have toe-out on turns, when the inner wheel is turned out 20 degrees, the outer wheel will be turned in less than 20 degrees.

Use the following procedure to check steering geometry:

a. Write the word "Inner" in the space provided for item #7 on your worksheet.

b. Turn the right wheel out 20 degrees from the center of the vehicle.

c. Read the steering geometry on the left wheel turning radius gauge.

d. Turn the left wheel out 20 degrees from the center of the vehicle.

e. Read the steering geometry on the right wheel turning radius gauge.

f. Record the steering geometry readings on your worksheet as item #8.

QUESTION

? ?

? Did you obtain and record the steering geometry readings for both front wheels? ?

? a. YES - Go on to the next step. ?

? b. NO - If you cannot check steering geometry, ask your instructor for help. ?

? ?

? ?

Frame 10.

Complete items #9 through #16 on your worksheet. Then, return here and answers the questions asked below. Use the specification chart to look up all specifications.

QUESTION

? ?

? Have you completed items #9 through #16 on your worksheet? ?

? a. YES - Answer the question below and then proceed as directed. ?

? b. NO - If you cannot complete the items, ask your instructor for help. ?

? ?

? ?

QUESTION

? ?

? Is caster within specifications? (Check answer #12 on your worksheet.) ?

? ?

? a. YES - Answer the question asked at the bottom of Frame 11 and then proceed as directed from there. ?

? b. NO - Go on to the next step, Frame 11. ?

? ?

Use your shop manual as a guide while you adjust caster.

a. Obtain the necessary tools, shims, etc., for adjusting caster.

b. Adjust caster to bring the reading within specifications.

c. Insure that caster is within specifications by checking it as outlined in Frame 5 and comparing the reading with the specifications.

QUESTION

? ?

? Have you completed the task of adjusting caster and is the new reading within specifications? ?

a. YES - Answer the question below and proceed as directed.

b. NO - If you cannot accomplish this task, ask your instructor for help.

? ?

QUESTION

? ?

? Is camber within specifications? (Check answer #10 on your worksheet.) ?

a. YES - Skip Frame 12 and go directly to Frame [illegible]

b. NO - Go on to the next step, Frame 12.

? ?

Frame 12.

Use your shop manual as a guide while adjusting camber.

a. Make sure that you have the necessary tools, shims, etc. for adjusting camber.

b. Adjust camber to bring the reading within specifications.

c. Insure that camber is within specifications by checking it as outlined in Frame 4 and comparing the reading with the specifications.

d. Insure that caster is still within specifications by checking it as outlined in Frame 5 and comparing the reading with the specifications.

QUESTION

Have you completed the job of adjusting camber and is the new reading within specifications?

a. YES - Go on to the next step.

b. NO - If you cannot accomplish this task, ask your instructor for help.

Use your shop manual as a guide while checking and making any necessary adjustments on the steering gear or linkage.

a. Make sure that the turning radius gauges indicate zero with the wheels straight ahead.

b. Check to see if the steering wheel is properly centered with the wheels in the straight ahead position.

c. Adjust the steering linkage, if necessary, to center the steering wheel.

d. Check for looseness in the steering gear; adjust if necessary.

QUESTION

? ?

? Did you complete the tasks of checking the steering gear and the steering wheel and making the adjustments as required?

a. YES - Go to the INSTRUCTIONS below.

b. NO - If you cannot accomplish these tasks with the help of your shop manual, ask your instructor for help.

? ?

INSTRUCTIONS

1. Put all of the equipment away in its proper place.

2. When your worksheet is completed, return all training materials to your instructor.

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SCUFF TESTER AND PORTALINER

SUBJECT: Front End Alignment of a Vehicle with Independent Front Suspension.

NAME ____________ RANK ________ CLASS NUMBER ____________

VEHICLE MAKE ____________ YEAR ________ TYPE ____________

1. Front wheel scuff: ________ feet per mile IN OUT
2. Rear wheel scuff: ________ feet per mile IN OUT
3. Preliminary inspection completed: ________
4. Camber reading obtained on the wheel: LEFT ________ RIGHT ________
5. Caster reading obtained on the wheel: LEFT ________ RIGHT ________
6. Steering axis inclination for wheel: LEFT ________ RIGHT ________
7. Steering axis geometry is read when the ________ wheel turns 20°.
8. Steering geometry for the wheel: LEFT ________ RIGHT ________
9. Camber specification from the chart: ________ to ________
10. Is camber within specifications? LEFT ________ RIGHT ________
11. Caster specification from the chart: ________ to ________
12. Is caster within specifications? LEFT ________ RIGHT ________
13. Steering geometry specification from chart: ________
14. Is steering geometry correct? LEFT ________ RIGHT ________
15. SAI specification from the chart: ________
16. Is SAI within specifications? LEFT ________ RIGHT ________

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 26 Feb 75	

COURSE NUMBER	COURSE TITLE
3ABR47330	General Purpose Vehicle Repairman - Part I

BLOCK NUMBER	BLOCK TITLE
VII	Compression-Ignition Engines & Automotive Air Conditioning

LESSON TITLE
Compression Ignition Engine Familiarization, Operation and Servicing

LESSON DURATION

CLASSROOM/Laboratory	XXXXXXXXXX/Complementary	TOTAL
D&D 11 Hrs/Perf 4 Hrs	4 Hrs	19 Hrs

POI REFERENCE

PAGE NUMBERS	PAGE DATE	PARAGRAPH
47, 48	2 JAN. 1975	2

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 68-4038 2. Trainer: 62-7945 3. Trainer: 62-2941 4. Trainer: 61-2835 5. Fuel Injector 6. Fuel Transfer Pump 7. Mechanic's Common Hand Tools (OVER)	None	None	1. 3ABR47330-SG-702 2. 3ABR47330-WB-702 3. 3ABR47330-SG-702A 4. 3ABR47330-WB-702A 5. 3ABR47330-SG-702B 6. T038G1-16-121 7. Film FLC 1-28M8 8. Film: TF 9-3469

CRITERION OBJECTIVES AND TEACHING STEPS (OVER)

a. Without references, identify basic facts and terms pertaining to principles of operation, function and relationship of compression ignition engine systems and components with 70% accuracy.

b. Without references, identify basic facts and terms related to the operating principles and function of compression ignition engine fuel systems components with 70% accuracy.

c. Supplied with tools and equipment, technical orders, engine trainers, and observing automotive personnel and equipment shop safety, inspect, troubleshoot, and service compression ignition engine systems IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770

GPO 1974 779-388/88

450

EQUIPMENT LOCATED
IN LABORATORY

8. Special Tools
9. Hydraulic Governor
10. Fuel Injector Pump

GRAPHIC AIDS AND
UNCLASSIFIED MAT.

9. Chart: 62-62
10. Chart: 62-69
11. Chart: 62-68
12. Chart: 62-67
13. Chart: 62-65
14. Chart: 66-53
15. Chart: 62-63
16. Chart: 74-02
17. Chart: 62-71
18. Chart: 64-402
19. Chart: 74-138
20. Chart: 66-313
21. Chart: 66-317
22. Chart: 66-319
23. Chart: 66-331
24. Chart: 74-22
25. Chart: 66-315
26. Chart: 74-01
27. Chart: 66-329
28. Chart: 74-03
29. Chart: 74-04
30. Chart: 74-05
31. Chart: 74-06
32. Chart: 66-328
33. Chart: 66-326
34. Chart: 66-320
35. Chart: 66-325

INTRODUCTION — Approx 30 Min

1. Attention and Motivation: Gain students' attention by asking questions about the ~~Diesel~~ engine. Relate the importance of the Diesel engine as a means of transportation and as a producer of electrical power. Inform students where the Air Force utilized Diesel engines as a means of moving aircraft.

2. Review: Review and critique questions from student Study Guide 3ABR47330-SG-702. Then briefly review the operation of the gasoline engine in comparison with the Diesel. Relate how the operation differs but the physical make-up is the same.

3. Overview: Today we will describe the construction, operation, and maintenance procedure of the 6-71 GMC Diesel Lubrication, Coolants, and Air System.

BODY — 14 Hrs 15 Min

PRESENTATION:

1. Ref: Para a, Part 1.

a. Type GMC diesel engine — Student Study Guide 3ABR47330-SG-702

(1) 6-71

(2) Two cycle engine

Scavenging	Chart	Number	62-62
Compression	"	"	62-69
Power	"	"	62-68
Exhaust	"	"	62-67

(3) 130 hp - 1800 rpm

(4) Firing order

(a) RH-1-5-3-6-2-4

(5) Compression ratio 17 - 1

(a) Engine will run backward if certain items are changed — Cross. Sect. Chart Number 62-65

b Purpose GMC diesel — Films FIC 1-28M8 ABC of Diesel

(1) Power busses, trucks, aircraft towing tractor MB-2

c. Lubricating System

Lubrication Sys Chart Number 66-53
Capacity: Deep pan - 21 qt
Shallow pan - 31 qt

(1) Oil pan

(2) Oil pump inlet screen

(3) Oil pump

(4) Pressure relief valve — Open at 48 - 53 psi

(5) Oil cooler

(6) Oil cooler by-pass valve

(7) Pressure regulator — Open at 47 psi

(8) Main oil gallery in block

(9) Blower — Drip lubricated; Lubrication Blower Chart Number 62-63

(10) Filters

(a) Primary

1 Full flow

(b) Secondary

1 Part flow

d. Cooling system types — Coolant sys. Chart Number 74138

(1) Radiator and fan — Used on trucks

(a) Radiator

(b) Fan

(c) Water pump

(d) Engine

1 Head

(e) Water manifold

e. Air system

(1) Air cleaner: wet type

(2) Air manifold: Emergancy shut down assembly — Manual or automatic type are used

f. Blower

(1) Rotary type with 2 or 3 lobes

(2) Driven twice engine speed from camshaft gear

(3) Develop 7 psi at max engine speed

g. Air box: Distributes air to all

h. Electric starting system: Insulated and grounded positive ground 12 volts

APPLICATION: Ref: Para b, Part 1. 3ABR47330-WB-702

1. Interspersed throughout the lesson.

EVALUTAION:

1. Check student understanding:

   a. How does the construction of a two cycle engine differ basically from a four cycle engine?

      Ans: Two cycle engine doesn't use intake valves (has intake ports in cylinder sleeve).

   b. What danger is involved if the blower seals leak?

      Ans: Overspeeding of engine.

   c. What is the purpose of the shut-off valve located in front of the primary filter in the lubrication system?

      Ans: Allows changing of filter elements without shutting down engine.

   d. At what speed does the blower operate?

      Ans: Twice the engine speed.

   e. How is the water pump driven in the cooling system?

      Ans: By the blower shaft.

   f. What is the purpose of the air box?

      Ans: Distributes air equally to all cylinders.

   g. When is the oil in the oil cooler heated?

      Ans: When cooling system thermostat is closed during engine warm-up.

END OF DAY SUMMARY

SUMMARY

1. Today we have learned the basic operational principles of combustion ignition engines, including the lubrication coolant, and air system. The students will write out the answers to the daily appraisal in order to evaluate student understanding of the subject matter presented. In order to perform proper maintenance on compression ignition engines on understanding of these system is a must.

1. Restate objectives of the lesson (covered in this day).
2. Emphasize the area of major importance.
3. Use oral questions to determine areas to be retaught.

ASSIGNMENT CTT POI PARA 2a 2 Hrs

3ABR47330-SG-702A

1. We have just completed the Basic Operational principles of combustion ignition engines; tomorrow we will enter the heart of the Diesel engine, the fuel system and components. Read the student Study Guide 3ABR47330-SG-702A and write out answers to the questions at the end of the chapter. Have a good day and we will see you tomorrow morning. Conservation of materials.

1. Identify study materials.
2. Give reasons for student to study assignment.
3. Mention method of study.

INTRODUCTION TO NEW DAY'S WORK

1. Gain students' attention relating a personal experience or analogy to insure they are ready to receive instruction.

2. Review: Check student written answers to questions at the end of student Study Guide 3ABR47330-SG-702A, then briefly review the operation of the lubrication cooling, and air systems. Today we will discuss the Fuel System and Components.

PRESENTATION: Ref: Para b, Part 1.

Use Study Guide 3ABR47330-SG-702A

a. Fuel System & Tune-up

(1) Operating principle of the diesel fuel injection system

(2) Two types

(a) Mechanical

Do not use. Central pump uses central high pressure pump

(b) Hydraulic

(3) Combustion: from heat of compression as fuel is

(4) GMC diesel fuel system mechanical

(a) Through flow system — Fuel Sys. Chart Number CC74-02

1 Cools injector — Purpose

2 Lubricate injector

(5) Fuel system units — Caution: Fuel must be kept clean

(a) Tank: All types used

(b) Primary filter

1 Types: disc, screen, sack disc or screen can be cleaned and replaced

(c) Transfer pump (gear or vane type - pos. displacement) — Maintain 40 psi

Use Bench Item Fuel Injector Pump

1 Driven by blower shaft

(d) Seals

1 Purpose: prevent fuel from entering blower

2 Allowable amount of seepage one drop per minute at 1800 rpm

(e) Secondary filter

1 Type: screen or disc which can be cleaned

2 Should be drained daily to remove dirt and water

(f) Manifold

1 Inlet and jumper lines

2 Outlet and jumper lines - Restriction elbow: Provide back pressure at injector

(g) Fuel injector — Show Bench Item Fuel Injectors

1 Purpose: Meter atomized and inject under pressure

2 Type: Unit injector (G.M. - Old type - H.V. - New type)

Fuel Injector
Chart Number 62-71

H.V. - high valve

3 Different types on GMC engine 50, 60, 70, 80 cubic millimeter

62-2941 Injector
Diesel Fuel Kit

4 Contains two porous material filters

Caution: Must be replaced when dirty

(h) Governor types

Show Hydraulic Governor
Trainer 61-2835 (Woodward)
Show Bench Item Hyd. Governor

1 Mechanical (limited or variable speed)

2 Hydraulic (allows for speed droop)

Chart Number 64-402
Hydraulic Governor

b. PM inspection

Preventive maintenance
Have student use Workbook
3ABR47330-WB-702A

(1) Coolant

(a) Level

(b) Condition

T.O. 38G1-16-121

(2) Belts

(a) Fan

(b) Generator

(3) Fuels

(a) Level always full

(b) Condition

(4) Lubrication

(a) Level

(b) Condition

(5) Control emergency shut down operation

(6) Visual inspection

(a) Leaks

(b) Damaged parts

(c) Missing parts

(7) Electrical starting system

(a) Condition of battery

(b) Cable and connection

c. Removal, inspection and replacement of injector

(1) Remove air cleaner and rocker arm cover

(2) Position engine

(a) Turn engine in direction of rotation only

(b) Remove both jumper lines

(3) Remove rocker arm assembly bolts and swing assembly clear

(4) Remove injector hold down

(5) Remove and clean injector — Use special tool if stuck

(6) Visual inspection

(a) Rack freeness

(7) Clean injector tube and replace injector

(8) Torque hold down nut 20 - 25 ft lbs

(9) Replace rocker assy torque to 90 to 100 ft lbs

(10) Replace jumper line torque to 12 to 15 ft lbs

d. Tune-up

(1) Engine valve adjustment

(a) Position engine with the injector rocker arm down

(b) Adjust push rods

1 Cold setting - .012

2 Hot setting -.009

(2) Time injector

(a) Position engine with the valves rocker arm down

(b) Use timing gauge and adjust push rods until a light snap or drag is felt on top of injector plunger

(3) Governor and fuel control rod adjustment

(a) Setting hydraulic governor with injector

1 Loosen all rack levers

2 Adjust fuel rod to extend 3/16" beyond nut at override button

3 Tighten outer adjusting screw on nr 1 rack lever when control tube moves lock nr 1 rack

4 Check adjustment by pulling out on override button, should move out 1/32 to 1/16 inches

5 If improper movement, re-adjust nr 1 lever

6 Remove pin from clevis and hold control tube in wide open position

e. Procedure for starting the GMC engine

(1) Position engine controls

(2) Override governor in cold weather

(3) Press starter button

Caution: Only 30 sec at a time if engine fails to start, let starter cool 3 - 5 minutes before attempting to start again

(4) After engine starts

(a) Check oil pressure

(b) Set throttle at 450 rpm for warm up

f. Procedure for stopping

(1) ½ throttle for 2 min, no load for cooling

(2) Idle engine for 2 min

Avoid prolonged idling

(3) Close control

(4) Disconnect battery

APPLICATION:

1. Ref: Para, C, Part 1.

TO 38G1-16-121
Provide adequate hand and special tools
Use 62-7945 661 GMC Diesel
Use proper safety precaution when working around engine

END OF DAY SUMMARY

SUMMARY

1. Today we have learned the operational principles of the GMC 6-71 Diesel engine fuel system, and components. We have also learned the importance of this system and its components and adjustment to obtain a smooth and effectively operating engine. The students will write out the answer to the day's daily appraisal in order to evaluate the students' understanding of the subject matter presented. In order to maintain this engine at its peak performance, an understanding of this system is a must.

1. Restate objectives of the lesson (covered in this day).
2. Emphasize the area of major importance.
3. Use oral questions to determine areas to be retaught.

ASSIGNMENT CTT POI PARA 2b 2 Hrs

3ABR47330-SG-702B

1. In order to prepare ourselves for tomorrow's lesson on the six (6) cylinder, four (4) cycle Multi-fuel engine you are to read student Study Guide 3ABR47330-SG-702B. Oral questions will be asked in order to evaluate student understanding. The Multi-fuel engine uses a theory of operation that will be different to you. After having read

1. Identify study materials.
2. Give reasons for student to study assignment.
3. Mention method of study.

this chapter tonight we will discuss any question that you have tomorrow morning - good afternoon and have a good day. Conservation of materials.

INTRODUCTION TO NEW DAY'S WORK

1. Gain student attention by relating a personal experience or analogy to insure that the students are ready to receive instruction.

2. Review: Check student understanding of student Study Guide 3ABR47330-SG-702B by oral questions and answer method then briefly discuss the basic operational principles of the engine which will include air system, lubrication system, coolant-system and fuel system.

PRESENTATION:

1. Ref: Para b, Part 1. — Student Study Guide 3ABR47330-SG-702B Continental LDS-465-1 Multi-fuel engine No. 68-4038

   a. Pertinent data:

      (1) 4 cycle-6 cyl in-line engine — Hypercycle Principle Chart Number 66-313

      (2) Maximum rpm - 3100

      (3) Maximum hp - 205 to 220 at 2800 rpm

      (4) Firing order: RH 1-5-3-6-2-4

      (5) Compression ratio: 23 to 1

      (6) Compression pressure per cylinder 650 lbs

      (7) Clearance between piston and head at top dead center: .040 — Film TF9-3469

   b. Air system

      (1) Dry type air cleaner (wash with mild soap) — Air flow Chart Number 66-317

      (2) Air cleaner indicator

      (3) Turbo-charger — Turbo-charger Chart Number 66-319

         (a) Air is naturally aspirated thru inlet (compressor) side when starting engine

(c) Turbine blades drive compressor blades by a connecting drive shaft, causing compressor to accelerate incoming air

(d) Increases velocity of intake air for combustion

(e) Ineffective when starting or operating engine at low speed

(4) Intake manifold

(a) "Water jacketed" to pre-heat incoming air to improve cold weather starting

(5) Engine head

(a) Contains spiral air intake passages which cause air to "swirl" as it enters the combustion chamber

(b) Produces "tornado" effect on fuel in combustion chamber - initial 5% of injected fuel is atomized, ignited and functions as spark plug for remainder of charge

(6) Manifold flame heater system

Manifold Heater Sys. Chart Number 66-331

(a) Pre-heat intake air in cold weather starting

(b) Fuel leaves vehicle tank at 7 psi from small electric pump

(c) Fuel enters fuel supply pump (side of injection pump) then flame heater filter, manifold fuel pump and finally delivered to spray nozzle and holder assembly

(d) 24 volts from vehicle batteries is stepped up to 35,000 volts by the ignition unit and is delivered to the spark plug at intake manifold

(e) Spring loaded toggle switch is held closed for 5 seconds at a time causing 5 second burning of gasses at spaced intervals

(7) Exhaust manifold

(a) Delivers exhaust gasses to the turbine (drive) side of turbo-charger

c. Lubrication system

Lubrication System Chart Number 74-22

(1) Oil pan with two magnetic drain plugs

(2) Oil pump

(a) Positive displacement - gear type pump

(b) Driven by front of engine crankshaft

(c) Picks up oil through inlet screen in deep front of pan

(3) Oil filters (two)

(a) Replaceable element type

(4) Oil filter by-pass valve

(a) Operates on 15 lb differential pressure

(5) Oil cooler

(a) Heats oil and cools the oil

(6) Oil cooler by-pass valve

(a) Operation is identical to oil filter by-pass valve

(7) Pressure relief valve

(a) Relieves excessive pressure

(8) Pressure regulator valve

(a) Determines normal operating pressure — At 45psi

(9) Piston cooling oil minimum pressure valve

(a) Allows oil passage to piston cooling nozzles as long as system pressure remains above 15 psi

(b) Closes when pressure drops below 15 psi, diverting oil to main, connecting rod, camshaft bearings and valve train

(10) Piston cooling nozzles

(a) Oil sprayed to underside of piston combustion chambers

(b) Prevent excessive heat at pistons

(11) Scavenger oil pump

(a) Driven by engine crank-shaft

(b) Positive displacement gear type pump

(c) Picks up oil from rear of pan when vehicle is on hilly terrain, and deposits oil in front of pan

d. Cooling system

(1) Radiator - 19½ quart capacity — Coolant System Chart Number 66-315

(2) Centrifugal type water pump

(a) Belt driven

(3) Thermostat

(a) Opens at 180°F

(4) Oil cooler

(a) Heats and cools oil

(5) Water manifold

(a) Surrounds intake air manifold

(b) Aids in pre-heating incoming air

e. Multi-fuel fuel system — Fuel Sys. Schematic Chart Number 66-321

(1) Engine will operate without adjustment on any of the following fuels:

(a) Low octane gasoline

(b) Regular octane gasoline

(c) JP-4 jet fuel

(d) Compression ignition fuel

(e) Kerosene

(f) Diesel engine fuel

(2) Fuel system components — Chart 74-01

(a) Fuel tank — Chart 74-02

1 Small electric fuel pump at tank produces 7 psi as source of fuel for system use

(b) Manifold flame heater system

(c) Fuel filters

1 Primary stage filter

2 Final stage filter

f. P.S.B.-6A Bosch fuel pump — Injection Pump PSB-6A Chart Number 66-329

(1) Driven off engine camshaft at crankcase speed

(2) Fuel supply pump — Use Bench Item Fuel Injector Pump

(a) Driven by gear off of the fuel injection pump camshaft worm gear

g. Hydraulic head components

(1) Head block

(2) Plunger

(3) Control sleeve

(4) Plunger drive gear

(5) Delivery valve assembly

(6) Plunger return spring

(7) Plunger movement

(a) Vertical - by means of 3 lobe camshaft

(b) Rotary - worm gear on camshaft drives quill gear causing rotation of plunger drive gear and plunger

Explain the operation of each component in relation with the other

Charts: Pumping Metering I 74-03
Pumping Metering II 74-04
Pumping Metering III 74-05
Pumping Metering IV 74-06

h. Injector (nozzle and holder assy)

(1) Metered quantity of fuel enters the injector nozzle at 350 psi

(2) This pressure acts on an area of the spindle assembly which is 8 times smaller in area

(3) The spindle assembly is held in the closed position over the nozzle orifice until spindle popping pressure reaches 2800 psi, uncovering the orifice, allowing injection and relieving pressure

(a) Popping pressure is adjustable

(b) Tighten adjusting screw to increase spring tension against spindle and vice versa

(c) Excess fuel at injector is routed back to fuel tank thru low pressure lines

Nozzle Holder Assy
Chart Number 66-320

i. Fuel density compensator

(1) Built by Zenith and attached to Bosch injection pump

(2) Fuel density components

(a) Return Spring

(b) Servo Piston

(c) Servo Piston Rod

(d) Stop Plate

(e) Stop Plate Adj Screw

(f) Servo Tap

(g) Servo Tap Adj Screw

(h) Pressure Regulator

Fuel density compensator Chart Number 66-328
Explain the operation of each component in relation with each other

j. Governor (mechanical - variable speed)

Mech. Governor Chart Number 66-326

(1) Operating lever (connected to throttle linkage) moves fulcrum lever

(2) Fulcrum lever

(a) Forward movement raises plunger sleeve in hydraulic head thru linkage

(3) Governor springs (inner & outer)

(a) Spring tension keeps fly-weights

(4) Flyweights and sliding sleeve assy

(a) As speed increases, the flyweights expand, pushing rearward on the sliding sleeve

(b) The sleeve then moves the fulcrum lever against the governor springs

(c) When pressure is equal

on both sides of the lever, the engine speed will stabilize

k. Advance unit (mechanical)

Advance Unit
Chart Number 66-325

(1) Provides up to 9° advance

(2) Advance functions between 1000 and 3000 rpm

(3) Components

(a) Input shaft

(b) Centrifugal Flyweights

(c) Sliding Gear

(d) Return Spring

(e) Advance Hub

(4) Advance occurs when engine rpm increases above 1000 causing the flyweights to expand, pushing the sliding gear off the input shaft onto the camshaft causing the camshaft to twist in the direction of rotation

APPLICATION: Ref: Para c, Part 1.

1. Interspersed throughout the lesson

EVALUATION:

1. Questions:

a. What is the purpose of the turbocharger?

Ans: To increase the velocity of intake air for combustion.

b. How is the system bled?

Ans: No need for bleeding.

c. How many fuel pumps are used?

Ans: Four (4).

d. How many fuel filters are used?

Ans: Four (4).

e. What position is the plunger sleeve in when the engine is stopped?

Ans: Down position or no fuel.

f. How many high pressure pumps are used?

Ans: One (1) plunger.

g. What is the purpose of the fuel density compensator?

Ans: Allow for different viscosity.

h. What does initial PSB mean?

Ans: Pump, single plunger, Bosch.

i. How is the speed and power changed?

Ans: By the amount of fuel.

j. What units are driven by the blower shaft?

Ans: Water pump, fuel pump, blower governor oil pump.

k. How is the blower shaft driven?

Ans: By the camshaft.

l. What does the fuel do beside run the engine?

Ans: Cools and lubricates the injector.

m. What type of fuel pump is used on 6-71?

Ans: Positive displacement gear or vane type.

n. At what speed is the blower driven?

Ans: Twice engine speed.

o. What are the two functions of the limited speed mechanical governor perform?

Ans: Controls the engine idle speed limits the engine maximum speed.

p. What are the disadvantages of the turbocharger?

Ans: Not effective when starting at idle or at low speed.

q. What causes the air to "swirl" as it enters the cylinders?

Ans: The intake ports located in the head.

r. What is the purpose of the manifold flame heater?

Ans: To pre-heat the incoming air as an aid in cold weather starting.

s. What is the purpose of the piston cooling oil minimum pressure valve in the lubrication system?

Ans: Diverts oil to main & connecting rod bearing when system pressure drops below 15 psi.

CONCLUSION 15 Min

SUMMARY AND REMOTIVATION:

1. Today we have learned the basic operational principles of the Multi-fuel engine which included the Air System, Lubrication System, Coolant System and Fuel System. And as in the previous lesson on the GMC 6-71 Diesel engine, we found that the fuel system is one of the most important systems covered. The student will write out the answers to the daily appraisal in order to evaluate student understanding of the subject matter presented. Being able to utilize the information presented today you will be able to operate, service, and perform maintenance on the Multi-fuel engine.

ASSIGNMENT AND CLOSURE:

1. We have just completed the lesson pertaining to compression ignition engines. Our next lesson will pertain to Principles of Refrigeration and Air Conditioning. Read Student Study Guide 3ABR47330-SG-703 and Commercial Manual, Chevrolet Heating and Air Conditioning, pages 10 thru 26. You will have an oral quiz on the Reading Assignment. Have a goodnight's rest and we will see you tomorrow.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 26 Feb 75	

COURSE NUMBER	COURSE TITLE
3ABR47330	General Purpose Vehicle Repairman - Part I

BLOCK NUMBER	BLOCK TITLE
VII	Compression Ignition Engines & Automotive Air Conditioning

LESSON TITLE
Principles of Refrigeration and Air Conditioning

LESSON DURATION

CLASSROOM/Laboratory	~~LABORATORY~~/Complementary	TOTAL
D&D 6 Hrs/Perf 0 Hrs	0 Hrs	6 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
49	2 JAN 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3ABR47330-SG-703 2. Chart: CC72-208 3. Chart: CC72-209 4. Chart: CC72-219 5. Film: TF -5536A 6. Commercial Manual GA-279A

CRITERION OBJECTIVES AND TEACHING STEPS

Without references, identify basic facts and terms pertaining to the principles of operation, function, and relationship of air conditioning systems and components with 70% accuracy.

Teaching Steps are Listed in Part II.

ATC FORM AUG 72 770

☆ GPO: 1972 779-398/23

INTRODUCTION 15 Min

1. Attention and Motivation: Gain students' attention by relating the importance and popularity of Air Conditioning and Refrigeration System.

2. Review: Orally quiz students on the Reading Assignemnt that was given the day before to evaluate their understanding of the Reading Assignment of 3ABR47330-SG-703 and Commercial Manual.

3. Overview and TIE-IN: Inform the students that today's lesson will cover the Basic Principles of Air Conditioning and Refrigeration and how today's modern vehicles are equipped with these units. But in order to be able to repair such units a basic understanding of the principles of refrigeration is a must.

BODY 5 Hrs 30 Min

PRESENTATION:

1. Ref: Para a, Part 1.

   a. Principles of refrigeration — Refer to student Study Guide 3ABR47330-SG-703

      (1) Refrigeration

         (a) The transfer of heat — Commercial Manual GA-279A

      (2) Heat

         (a) Form of energy

         (b) Cannot be created or destroyed

         (c) Can be transferred

      (3) Law of heat transfer

         (a) Hot to cold

         (b) Rate of transfer slows as temperature differential decreases

      (4) Methods of heat transfer

         (a) Conduction — EXAMPLE: Electric blanket

            1 Through a solid from molecule to molecule

         (b) Convection — EXAMPLE: Forced air furnace

            1 Through a gas or liquid the molecules carry the heat

(c) Radiation

EXAMPLE: Sun

1 Transfer by waves or rays

(5) Sensible and latent heat

(a) Sensible heat

1 Can be measured and felt

2 Always causes a temperature change

3 Measured by a thermometer

4 Super heat

a Sensible heat added to a substance above its boiling point

(b) Latent heat

1 Changes state of substance

2 Show no temperature change

(6) Change of state

Air Conditioning System Chart 72-208

(a) Physical states of matter

1 Solid

2 Liquid

3 Gas

(b) Change of state is always accomplished by a gain or loss of heat

(Latent heat is gained or lost)

(c) State can be changed two ways

1 By changing temperature at a constant pressure

2 By changing pressure at a constant temperature

(7) Boiling point (temperature)

Air Conditioning Sys Component Chart 72-209

(a) Temperature at which a liquid starts to vaporize

(b) Controlled by pressure

(c) Boiling rate increases as the temperature increases or the pressure decreases

(8) Condensing point

Air Conditioning Sys Component Chart 72-219

(a) Temperature at which a gas starts to condense

(b) Controlled by pressure

(c) Condensing rate increases as condensing medium temperature decreases

(9) Heat measurement

(a) Thermometer

1 Measures the intensity of heat

2 Expressed in degrees

(b) Thermometer scales

1 Fahrenheit

a $32^{o}F$ freezing point

b $212^{o}F$ boiling point

2 Centigrade

NOTE: Both scales are equal at -40^{o}

a $0^{o}C$ freezing point

b $100^{o}C$ boiling point

(c) British thermal unit

1 Measurement of amount of heat

2 A BTU is defined as the amount of heat required to raise the temperature of one pound of water one degree fahrenheit

(d) Ton of refrigeration

1 12,000 BTU's per hour removed from the load equals one ton

2 Derived from the fact that one ton of 32°F ice melting in a 24 hour period absorbs 288,000 BTU's

(10) Heat Load

(a) Air to be cooled

(b) Total heat load expressed in BTU's or tons

(c) Total heat load depends on

1 Amount of air to be cooled

2 The difference between ambient temperature and the temperature to which the air will be cooled

3 Amount of moisture in the air

(11) Humidity

(a) Moisture in the air

(b) Heat removed to condense moisture causes no temperature change

(c) Temperature at which moisture condenses is called the dew point

(d) Relative humidity is the amount of moisture in the air, compared to the total amount the air could hold at the same temperature

Film TFI - 5536A

476

(12) Refrigerants

(a) A refrigerant is any substance that is used to remove and transfer heat

(b) Types of refrigerants

1 Water

2 Trichloromonofluoromethane (R-11)

3 Dichlorodifluoromethane (R-12) — Most commonly used

4 Monochlorodifluoromethane (R-22)

(c) Desirable properties of a good refrigerant

1 Low boiling point

2 Low condensing pressure and temperature

3 Non-injurious to lubricating oil

4 Non-flammable and non-explosive

5 Non-corrosive

6 Operates on a low to moderate pressure

(d) Undesirable characteristics of refrigerants

1 Frostbite

2 Permanent eye damage

3 Becomes toxic when overheated

4 Skin irritation

5 Damage to lungs — STRESS SAFETY!

(13) Refrigerant cylinder

(a) Do not store refrigerant cylinders in an area above 125°F

(b) Use caution when handling or opening pressurized cylinders

(c) Fusible plug

STRESS SAFETY!

APPLICATION: Ref: Para a, Part 1.

1. Interspersed throughout the lesson.

EVALUATION:

1. Check student understanding.

a. What is the unit of measurement for heat quantity?

ans. B.T.U.

b. What is sensible heat?

ans. Heat that can be measured and felt.

c. What is latent heat?

ans. Heat that will create a change of state.

d. What refrigerant change of state absorbs?

ans. From LPL to LPG.

e. What is the heat load on the Air Conditioner?

ans. The air to be cooled.

f. What two ways can change of state be brought about?

ans. Conduction, convection, radiation.

g. What are the method of heat transfer?

ans. Conduction, convection, radiation.

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h. How does changing the pressure on a liquid affect its boiling point?

ans. It changes the point at which the substance boils.

i. What refrigerant is most commonly used?

ans. Freon R-12.

CONCLUSION 15 Min

SUMMARY AND REMOTIVATION:

1. Today we have learned the basic principles of refrigeration and air conditioning; the theory of heat transfer and the properties and types of refrigerant. With a basic knowledge of these basic principles of air conditioning and refrigeration, you will find that these facts can be applied to any refrigeration system. At this time the daily appraisal will be administered.

ASSIGNMENT AND CLOSURE:

1. We have just learned the basic principles of air conditioning system. Tomorrow we will discuss the air condition system components. By reading student Study Guide 3ABR47330-SG-704 and Commercial Manual GA-279A Pages 14-23, you will be able to discuss and answer orally questions about the system components. Have a good day and we will see you tomorrow.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 26 Feb 75	

COURSE NUMBER	COURSE TITLE
3ABR47330	General Purpose Vehicle Repairman - Part I

BLOCK NUMBER	BLOCK TITLE
VII	Compression Ignition Engines and Automotive Air Conditioning

LESSON TITLE
Construction and Operation of Air Conditioning Components

LESSON DURATION

~~CLASSROOM~~/Laboratory	~~XXXXXXXXX~~/Complementary	TOTAL
D&D 2 Hrs/Perf 3 Hrs	0 Hrs	5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
49	2 JAN 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 72-4288 2. Trainer: 72-4289 3. Trainer: 72-4290 4. Trainer: 74-4362 5. Air Conditioner Equipped Vehicle 6. Kit, Air Cond. Serv. 7. Vacuum Pump (OVER)	None	None	1. 3ABR47330-SG-704 2. Commercial Manual GA-279A 3. Chart: CC72-217 4. Chart: CC72-214 5. Chart: CC72-216 6. Chart: CC72-210 7. Chart: CC72-215

CRITERION OBJECTIVES AND TEACHING STEPS (OVER)

a. Provided with tools and equipment, commercial manual, bench items, and practicing automotive personnel and equipment shop safety, repair or service air conditioning system components IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM 770 AUG 72

GPO: 1972 779-390/33

EQUIPMENT LOCATED
IN LABORATORY

8. Adapter 90° Angle
9. Mechanic's Common Handtools
10. Special Tools
11. Air Conditioning System Components
12. Tester, radiator & cap

GRAPHIC AIDS AND
UNCLASSIFIED MAT.

8. Chart: CC72-218

...Pavon

INTRODUCTION Approx 10 Min

1. Attention and Motivation: Gain students' attention by an appropriate analogy and/or personal experience to insure student are mentally alert.

2. Review: Orally quiz student on the reading assignment that was given the day before to evaluate their understanding of the Study Guide 3ABR47330-SG-704 and Commercial Manual ST-346-71.

3. Overview and TIE-IN: Today's lesson will cover the major components of our Air Conditioning System. The compressor, condensor, Receiver-Dehydrator, Expansion Valve and Evaporator we will learn the function of each unit in our system and also disassemble and reassemble the compressor unit.

BODY Approx 4 Hrs 40 Min

PRESENTATION: Ref: Para a, Part 1.

a. Basic refrigeration cycle components — Use Student Study Guide 3ABR47330-SG-704 and Commercial Manual GA 279A Air Conditioner

(1) Receiver-Drier

(a) Storage Tank — Chart 72-217 Air flow-four season & components

(b) Remove moisture from Refrigerant

(2) Expansion Valve

(a) Meter refrigerant into cooling coils — Chart 72-216 Expansion Valve

(3) Evaporator

(a) Cooling Coil — Chart 72-215 Evaporator Pressure's Control (P.O.A.) Valve

(4) Magnetic clutch Drive the compressor — Types Warner Mech Pitt Elect

(5) Compressor — Compressor Disassembled Chart 72-218 Chart 72-214 Six cyl compressor exploded view

(a) Prepare refrigerant for condensation

(b) Types of Compressor

1 Reciprocating

2 Swash Plate

(c) Servicing compressor

1 Oil Level — Can be checked only after discharging system

a Dipstick

b Must be checked prior to removal or replacement

(1) Must be at least 6 oz

(2) Not more than 8 oz

(3) Excess must be removed

(a) Cause abnormal operating pressure

(b) Reduced performance

(6) Condenser

(a) Transfer heat from the refrigerant to the ambient air

Show Bench Item Condenser

b. High and low side refrigeration cycle

(1) Low side

(a) Provides conditions for cooling

Chart 72-210
Cut-away view of service valves

1 Expansion valve meter refrigerant into evaporator

2 Evaporator receives low pressure liquid refrigerant which absorbs heat as a change of state occurs on the refrigerant

(2) High Side

(a) Recovers and stores refrigerant

1 Compressor transfers refrigerant from evaporator to condenser

2 Condenser receives the high pressure gas and allows a change of state to occur on the refrigerant

Kit Air Conditioning Servicing

3 Receives,accepts and stores refrigerant for reuse

(3) Separation of high and low sides

(a) Expansion valve separation high side from low side

(b) Compressor separates low side from high side

(4) State of refrigerant throughout the refrigeration cycle

(a) Receiver

1 8% HPL and 20% HPG

(b) Expansion valve

Air Conditioning
Show Expansion Valve

1 Inlet HPL

2 Outlet LPL

(c) Evaporator

1 Inlet LPL

2 Outlet LPL

(c) Evaporator

1 Inlet LPL

2 Outlet LPG

(d) Compressor

Show AC Compressor

1 Inlet LPG

2 Outlet HPG

(e) Condenser

1 Inlet HPG

2 Outlet HPL

APPLICATION:

1. Ref: Para 1, Part 1.

Air Conditioning Trainers
Trainer 74-4362
Trainer 72-428?
Trainer 72-428?
Trainer 72-4290

Adapter 90°Angle
Kit Air Condition Servicing
Vacuum Pump
Hand and Special Tools
Tester Radiator & Cap
Use: Student workbook
3ABR47330-WB-704

EVALUATION:

Air Conditioned Vehicle
Check student understanding

1. What component removes any moisture from the refrigerant?

   Ans: Drier.

2. What component where a change of state occur from APG to LPL occur?

   Ans: Condenser.

3. Where does the change of state from HPL to LPL occur?.

   Ans: Expansion valve.

4. How many changes of states occur in one refrigeration cycle?

   Ans: Two.

5. What is the function of the refrigerant compressor?

   Ans: To raise the pressure and temperature of the refrigerant.

6. What safety device is found on the receiver?

   Ans: Fusible plug.

7. What type heat is removed from the refrigerant before it begins to condense?

   Ans: Latent heat.

8. What type of heat is added to the refrigerant before it begins to evaporate?

5??

485

Ans: Sensible heat.

9. What is the state of the refrigerant in the receiver?

Ans: 80% HPL and 20% HPG.

CONCLUSION 10 Min

SUMMARY AND REMOTIVATION:

1. Today we have learned what five basic components make up a refrigeration or air conditioning system. These components are the receiver drier, expansion valve, evaporator, compressor and the condensor. Knowledge of these components are essential to the repairman to be able to troubleshoot and repair an Air Conditioning System. We will now administer the daily appraisal to evaluate student understanding.

ASSIGNMENT AND CLOSURE:

1. For tomorrow you are to read study guide 3ABR47330-SG-705. Also be prepared to answer questions orally on the before mentioned chapter.

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LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 26 Feb 75 [illegible]	
COURSE NUMBER	**COURSE TITLE**
3ABR47330	General Purpose Vehicle Repairman, Part I
BLOCK NUMBER	**BLOCK TITLE**
VII	Compression Ignition Engines & Auto Air Conditioning

LESSON TITLE

Inspection, Troubleshooting, Evacuating, and Charging Air Conditioning Systems

LESSON DURATION

CLASSROOM/Laboratory	~~XXXXXXXXX~~/Complementary	TOTAL
D&D 9.5 Hrs/Perf 6 Hrs	0 Hrs	15.5 Hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
51	2 Jun 1975	6

STS/CTS REFERENCE

NUMBER	DATE
STS 473X0	3 September 1974

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Trainer: 72-4288 2. Trainer: 72-4289 3. Trainer: 72-4290 4. Trainer: 74-4362 5. Air Conditioner Equipped Vehicle 6. Kit, Air Cond. Serv. 7. Vacuum Pump	None	None	1. 3ABR47330-SG-706 2. Chart: CC72-213 3. Chart: CC 72-212 4. Chart: CC 72-211 5. Film: TF 5536B 6. Commercial Manual GA-279A

(OVER)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Supplied with an assigned air conditioning trainer, tools, and equipment, commercial manual, and observing automotive personnel and equipment shop safety, use visual, auditory, operational means, and test equipment to check, adjust, and isolate malfunctions in the air conditioning system IAW technical publications.

Teaching Steps are Listed in Part II.

ATC FORM 770 AUG 72

GPO: 1972 770-390/23

EQUIPMENT LOCATED
IN LABORATORY

8. Adapter 90° Angle
9. Mechanic's Common
   Hand Tools
10. Special Tools

INTRODUCTION 15 Min

1. **Attention and Motivation: Gain students' attention by using an appropriate analogy or personal experience to insure students are mentally alert.**

2. Review: Orally quiz students on their reading assignment that they were given the day before to evaluate their understanding of the material covered in Study Guide 3ABR47330-SG-705.

3. Overview: Today's lesson we'll learn how to use visual, auditory, and operational means to check, adjust and isolate malfunctions in air conditioning system components which include evacuating and charging the air conditioning system.

BODY 14 Hrs 30 Min

PRESENTATION:

1. Refer to Para a, Part 1. — Use Study Guide 3ABR47330-SG-706

   a. Magnetic clutch — Chart magnetic clutch 72-213

      (1) Types

         (a) Warner

            1 Copper wire

            2 Aluminum wire

         (b) Pitts (Electro-Loc)

      (2) Testing

         (a) Short or open circuit

            1 Ammeter

            2 Connect in series

      (3) Disassembly

         (a) New bearing every time clutch is disassembled

      (4) Assembly

         (a) Pulley and hub are mated parts

         (b) Do not replace either unit separately

         (c) May reduce the initial torque of the clutch

b. Gas seal

(1) Types

(a) Cartridge

(b) Unitized

(2) Replacement procedures vary with type of seal used

(a) Special care must be used to prevent damage to the carbon ring

(b) Must be soaked with refrigerant oil

c. Cleaning

(1) Work area

(a) Clean and free of air-borne dust and dirt

(2) Material to be used

(a) Lint-free clothes

(b) Dry compressed air

(c) Clean mineral spirits

d. Safety precautions

(1) Do not use compressed air to dry bearings

(2) Completely discharge system before attempting to perform any disassembly or repair to the compressor

APPLICATION:

Refer Para a, Part 1.

Show Film TFI-5536B

Use Study Guide 3ABR47330-SG-706
Air Conditioning Trainers
72-4288
72-4289
72-4290
74-4362
Mechanics Common & Special Tools

Kit Air Conditioner
Adapter 90°Angle
Vacuum Pump
Air Conditioned Equipped Vehicle

END OF DAY SUMMARY

SUMMARY

1. Today we have learned the servicing (2) 51 a. Restate objectives of the

portion of the air conditioning system components, such as the compressor magentic clutch and gas seal. We have also learned how to check oil level in the compressor and what the effect would be if too much refrigerant oil were placed in the system. It is also important to know what can and cannot be used to clean the system components and how to do the job safely as well as correctly. It is evident that one of the most common areas for a refrigerant leak to occur is at the gas seal and it is equally important for you to develop sound and accurate repair methods and techniques to replace this seal or the leak will re-occur. Students will write out the answers to the Daily Appraisal in order to evaluate student understanding of subject matter.

lesson. (covered in this day).

2. Emphasize the area of major importance.

3. Use oral questions to determine areas to be retaught.

ASSIGNMENT

1. Tonight I want you to study the notes that you have taken during today's lesson and read Study Guide 3ABR47330-SG-705. Oral questions will be asked at the beginning of tomorrow's lesson.

1. Identify study materials.

2. Give reasons for student to study assignment.

3. Mention method of study.

INTRODUCTION TO NEW DAY'S WORK

1. Gain student attention relating a personal experience and analogy to insure that the students are mentally alert

2. Review: Yesterday we learned the importance of using the right type of refrigerant oil and the proper procedure for checking the level of the lubricant. We also learned service and maintenance of air conditioning components such as the magnetic clutch and compressor gas seals and what would be the result if these procedures were not followed. Ask oral questions on yesterday's assignment.

3. Today we will continue with the troubleshooting procedure. Also evacuate and charge an air conditioning system.

PRESENTATION:

1. Refer Para a, Part 1.

a. Procedures of troubleshooting

(1) Simplest to the hardest or most probable to the least probable — Chart Evacuating System 72-212

(2) Common sense

(3) Equipment for troubleshooting — Chart Charging System 72-211

(a) Manifold gauge set

(b) Halite torch

1 Soap and water

APPLICATION:

1. Refer Para a, Part 1. — Air Conditioning Trainer 74-4362; Mechanics Common & Special Tools; Use workbook 3ABR47330-WB-706; Air Conditioning Trainer; Kit Air Conditioner; Adapter 90o Angle; Vacuum Pump; Air Conditioned Equipped Vehicle

END OF DAY SUMMARY

SUMMARY

1. Today we have learned how to effectively troubleshoot and repair the air conditioning system. It is important that we know how to effectively diagnose problem areas that will occur from time to time locating problem areas is the most important part of any repair job. The student will write out the answers to the daily appraisal in order to evaluate students' understanding of the subject matter.

1. Restate objectives of the lesson. (covered in this day).

2. Emphasize the area of major importance.

3. Use oral questions to determine areas to be retaught.

ASSIGNMENT CTT POI Para 6a 2 Hrs — 3ABR47330-SG-705 Commercial Manual GA-279A

1. Tonight I want you to study the notes that you have taken during today's lesson and read Study Guide 3ABR47330-SG-705 oral questions will be asked at the beginning of tomorrow's lesson. Review system troubleshooting in snap on manual GA-279A.

1. Identify study materials.

2. Give reasons for student to study assignment.

3. Mention method of study.

INTRODUCTION TO NEW DAY'S WORK

1. Arouse student attention by asking thought-provoking questions.

2. Review: Yesterday we learned the importance of how to effectively troubleshoot and repair the air conditioning system. We also learned how time saving and economical proper troubleshooting can be. We also learned how one component that is not operating properly could adversely affect another. As oral questions on yesterday's assignment.

3. Today we will continue to troubleshoot and diagnose mechanical malfunctions that occur within an air conditioning system. We will also evatuate and charge an air conditioning system. You will also be given a block test prior to graduation.

APPLICATION:

1. Refer Para a, Part 1.

Use Study Guide 3ABR47330-SG-706
Kit Air Conditioner Service
Adapter 90^{o} Angle
Vacuum Pump
Air Conditioning Trainer 74-4362
Air Conditioned Equipped Vehicle

EVALUATION:

Check student understanding

1. What must be accomplished before attempting to check the refrigerant oil level?

   Ans: Discharge system.

2. What would result from an excess of refrigeration oil?

   Ans: Abnormal pressure and reduced performance.

3. What electrical tests are performed on the magnetic clutch coil?

   Ans: Shorted and open circuit.

4. What test instrument is used to perform the electrical tests on the magnetic clutch coil?

   Ans: Ammeter.

5. What must be replaced each time the magnetic clutch is disassembled?

   Ans: Bearing.

6. What may result if other than mated clutch parts were assembled?

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Ans: Reduced initial torque.

7. What must you do before installing a new gas seal?

   Ans: Soak it with refrigerant oil.

8. What solvent is used to clean refrigeration components?

   Ans: Mineral spirits.

9. What must be installed in the air conditioning system to effectively troubleshoot the system?

   Ans: Manifold gauge set.

10. What would appear in the sight glass if air were present in the system?

    Ans: Bubbles.

11. How would an overcharge of refrigerant be indicated on the manifold gauges?

    Ans: High suction and discharge pressure.

12. What should be checked first if the compressor drive shaft will not turn?

    Ans: Drive belt.

13. What is used to locate a refrigerant leak?

    Ans: Halite torch or soap and water.

14. What safety precaution must be observed when using the Halite torch to locate a leak?

    Ans: Do not inhale the fumes.

CONCLUSION 15 Min

SUMMARY AND REMOTIVATION:

1. Today we have completed the methods of troubleshooting, checking and adjusting air conditioning systems and components, by visual and auditory means.

You have been taught how to evacuate and charge the air conditioning system. I sincerely hope that when you reach your next duty assignment the information that was presented here will help you to perform your assigned duty with maximum efficiency.

PREPARE THE MAN

STUDY GUIDE 3ABR47~~330~~ 432 -SG-700 495
3AZR47350-5-SG-100

Technical Training

8-12

General Purpose Vehicle ~~Repairman~~ Mechanic

COMPRESSION IGNITION ENGINES,
AUTOMOTIVE AIR CONDITIONING

21 February 1974

AIR TRAINING COMMAND

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR47330-SG/WB-700, 21 October 1970; 2ASR47350-3-SG-100, 5 July 1972.
OPR: TWS
DISTRIBUTION: X
TWS - 350, TTOC - 3

Designed For ATC Course Use

DO NOT USE ON THE JOB

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CONTENTS

Note: Copyrighted material is included on figures 7, 59, 60, 61, 72, 74, 75, 76, 81, 82, 83, 84, 85, 87, and 89.

TECHNICAL ORDERS

OBJECTIVES

After completing this unit of instruction, you will have a general knowledge of the purpose and use of the Air Force Technical Order System.

INTRODUCTION

The technical order system is the official means of providing technical instructions in the form of technical orders (TOs). The purpose of technical orders is to provide instructions and information for the safe and efficient operation, maintenance, modification (change), and overhaul of AF equipment. Examples of such equipment are aircraft, missiles, trucks, automobiles, tools, and machines.

Technical orders are also published which contain instructions on subjects such as safety procedures, preparation of maintenance forms, and the handling of AF material.

INFORMATION

Air Force personnel at all levels are faced with a rapidly increasing need to further their knowledge of the AF technical order system. Programmed Text 3ABR47330-PT-103 has been developed to provide a general knowledge of the technical order system as it applies to vehicle maintenance. Carefully read the information and instructions in the text. The instructor will be standing by if you should need help.

COMPRESSION IGNITION ENGINE FAMILIARIZATION, OPERATION, AND SERVICING

OBJECTIVES

After completing this unit of instruction, you will understand the construction of the GMC two-stroke cycle diesel engine and be able to correctly operate, inspect and service the GMC diesel engine.

INTRODUCTION

The first successful diesel engine using liquid fuel was constructed in 1897. The first experimental engine used pulverized coal and fuel but was a failure. After a second engine also failed, liquid fuel was used. The engine then proved successful.

INFORMATION

DIESEL ENGINE FAMILIARIZATION

The diesel engine is mechanically the same as the gasoline engine. For operation they both depend upon fuel, air and ignition. Pistons move up and down in cylinders and connecting rods are fastened to a crankshaft that changes reciprocating motion into rotary motion. There is very little difference in the external appearance. Both the gasoline and the diesel engine extract energy from the burning of an air-fuel mixture inside of a cylinder.

The diesel engine is an internal combustion power unit in which heat of the fuel is converted to work in the cylinders. In the diesel engine, air alone is compressed within the cylinder; after the air has been compressed a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

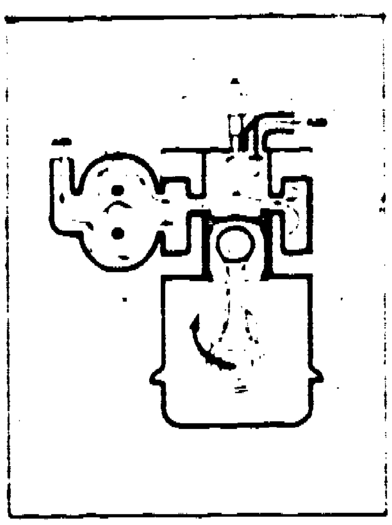


Figure 1. Scavenging.

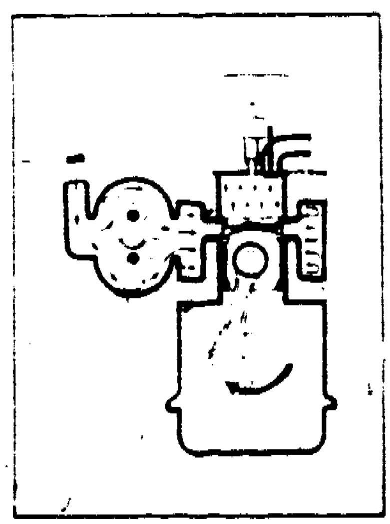


Figure 2. Compression.

THE TWO-STROKE CYCLE PRINCIPLE

Every other stroke in a two-stroke cycle engine is a power stroke. Intake and exhaust must take place during part of the compression and power strokes

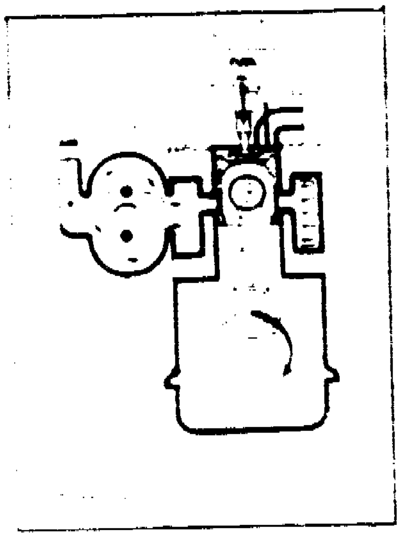


Figure 3. Power.

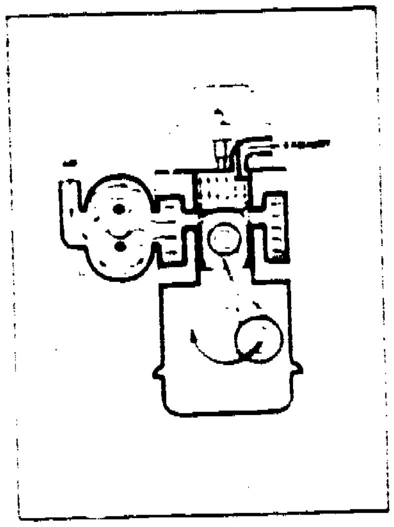


Figure 4. Exhaust.

respectively. This sequence is referred to as scavenging, figure 1; compression, figure 2; power, figure 3; and exhaust, figure 4. In contrast, a four-stroke cycle engine requires four piston strokes to complete an operating cycle. Thus, during one-half of its operation, the four-stroke cycle engine functions merely as an air pump.

In a previous lesson the two-stroke cycle engine was explained as having exhaust and intake ports cut into the cycle walls. The GMC diesel engine has intake ports cut into the cylinder wall sleeves, and utilizes two exhaust valves at the top of each cylinder.

The series of ports cut into the cylinder sleeve are located above the piston when it is at the bottom of its stroke. Air is admitted into the cylinder as soon as the top face of the piston uncovers the ports, figure 1. The flow of air upward toward the exhaust valves, which are open at this time, produces a scavenging effect, leaving the cylinder full of clean air when the piston again covers the inlet ports on its way upward. In order to assure that the cylinders are supplied with an abundance of fresh air and to aid in scavenging the cylinder of burned gases, a blower and air box are mounted on the side of the engine. This blower forces air into the air box, which in turn allows the air to enter the combustion chamber.

Note: The flow of air passing through the cylinder during the time it is being scavenged also cools the valves and injector tips.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression, figure 2. The air being compressed is brought to a very high temperature.

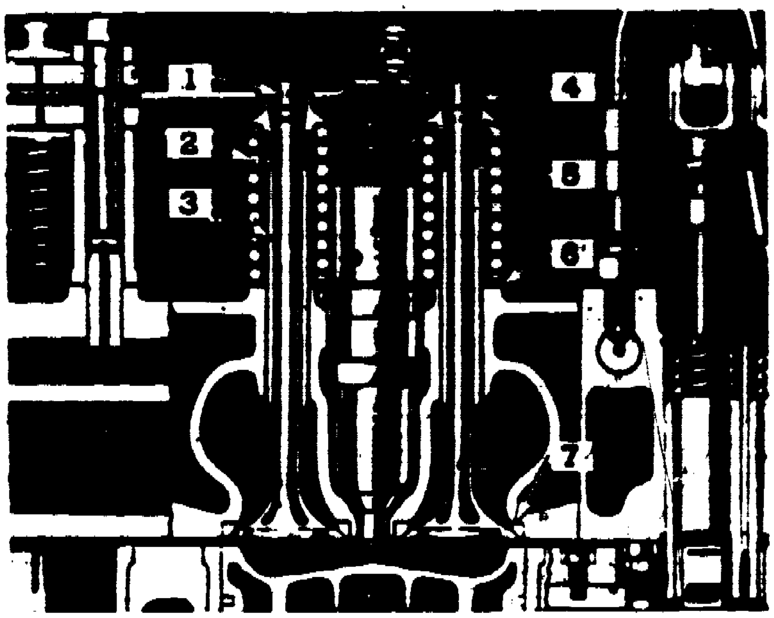
Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion space by the unit fuel injector, figure 3. The intense heat, generated by the high compression, ignites the fine fuel spray. The combustion continues as long as the fuel spray lasts. The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about halfway down, figure 4. Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air, figure 1. This entire combustion cycle is completed for each revolution of the crankshaft, or in other words, two strokes, thus the "two-stroke cycle."

CONSTRUCTION AND OPERATION OF THE GMC DIESEL ENGINE

The previous paragraphs gave you a brief explanation of the two-stroke cycle principles as apply to the GMC diesel engine. The main differences you have encountered between this engine and the ordinary four-stroke cycle gasoline engine are the valve arrangement, the method of mixing the fuel and air, and the manner in which the fuel and air mixture is ignited.

Valve Arrangement

No intake valves are used in the GMC diesel engine. Each cylinder is equipped with two exhaust valves, figure 5, which open and close at the same time. This arrangement assists the burned gases to escape the cylinder with the least amount of delay. The valves are located in the cylinder head and are operated by a camshaft, lifters (cam followers), push rods and rocker arms.



1. **Exhaust Valve**
2. **Exhaust Valve Spring**
3. **Exhaust Valve Guide**
4. **Tapered Seat Lock**
5. **Valve Spring Cap**
6. **Valve Spring Seat**
7. **Hardened Seat Valve**

Figure 5. Assembly of Exhaust Valves and Guides.

Fuel and Air Mixture and Ignition

Air is admitted into the cylinder through a series of ports cut into the cylinder sleeves. As the piston is on its upward stroke the exhaust valves close and the ports are covered by the piston and the charge of fresh air is subjected to compression. This brings the compressed air to a very high temperature. Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion space. The intense heat, generated by the high compression of the air, ignites the fine fuel spray immediately.

The GMC Fuel System, Figure 6

The GMC fuel system, figure 6, is referred to as the mechanical type "through-flow." The purpose of this type is to cool the injectors.

The fuel system used is different from that used on most diesel engines. There are several reasons for this, one being that the fuel is used to help cool the engine. This engine, because of the greater number of power impulse crankshaft revolutions, would otherwise become overheated, except for the additional cooling features built into it.

Included in the fuel system are the injectors, fuel pump, fuel filters and fuel manifolds. Fuel is drawn from the source of supply through the primary filter by the fuel (transfer) pump. This pump is driven from the rear end of the blower lower rotor shaft. From the pump, fuel is pumped through the secondary filter to the fuel intake manifold where fuel is supplied to the

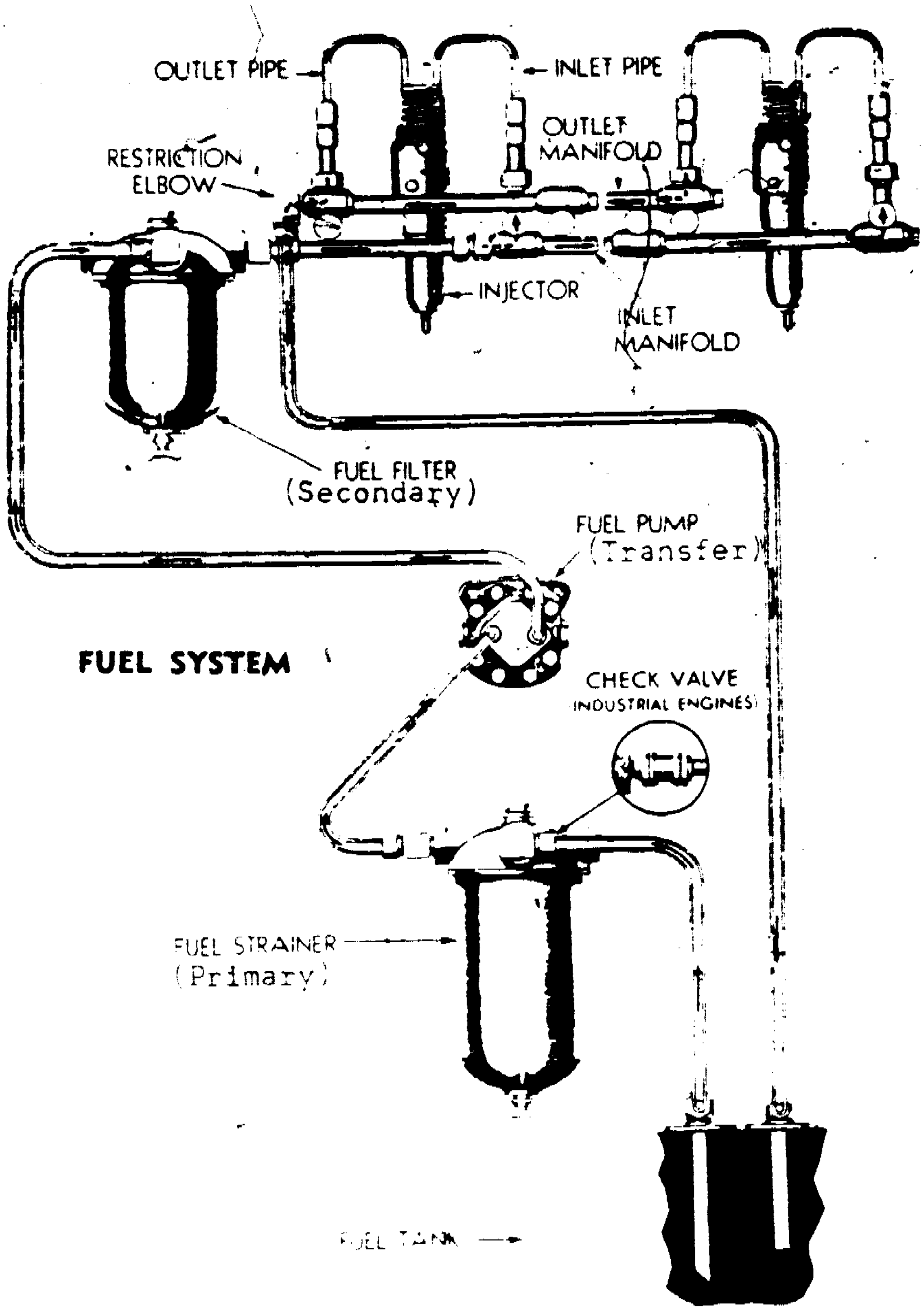


Figure 6. GMC Diesel Fuel System.

injectors. Fuel is filtered when it enters the injectors and also when it leaves them. Surplus fuel flowing through the injectors is returned through the outlet manifold to the supply tank.

As the fuel must be injected into the combustion chamber just before the piston reaches its highest point in the cylinder, the fuel pressure must be higher than the air that is compressed in the combustion chamber. This is accomplished by a high-pressure fuel injection device referred to as the "unit fuel injector." The unit fuel injector combines in a single unit all of the parts necessary to inject, atomize, pressurize, and meter fuel into the combustion chamber. This provides a complete and independent injection for each cylinder.

The fuel necessary for engine operation is used and the excess is returned to the supply tank through an outlet manifold and return lines. Figure 6 shows the GMC fuel system, including the check valve used in the fuel inlet line ahead of the transfer pump. This check valve is necessary when fuel tanks are located lower than the engine. The purpose of this check valve is to prevent fuel from draining back into the tank when the engine is shut down.

The GMC Diesel Engine Starting System

The GMC diesel engine usually uses either a 12- or 24-volt starting system. It is very important to remember that high voltage is used. Shorts or grounds might cause damage to tools or equipment, fires, and injury to personnel. To prevent dangerous arcs, any removed wire or exposed cable ends should be taped.

Two of the common types of electrical systems in use today are the insulated and grounded systems. The starting system used on the GM diesel engine generator set is the insulated type. Neither battery cable is grounded. Both cable terminals located on the starting motor are insulated. The manufacturer of this equipment includes a generator, generator regulator, and the charging circuits as part of the charging system. These units are necessary to keep the starting motor battery charged.

An automatic engaging and disengaging starter drive is mounted directly on the starting motor armature shaft. It is advisable, when starting the engine, not to operate the starter more than 30 seconds at a time. If operated more than 30 seconds at one time; overheating of the starter parts may occur. Several minutes should elapse between cranking periods to permit the starting motor to cool.

Note: Keep all connections clean and tight. Test battery at regular intervals to determine its state of charge. Keep the battery clean and the electrolyte level maintained correctly.

The GMC Diesel Engine Lubricating System

The lubricating oil circulatory system, figure 7, includes an oil pump, oil cooler and oil filter, together with a suitable relief valve in the pump, a bypass valve at the oil cooler and a pressure regulating valve.

The lubricating system provides positive engine lubrication. A gear-type oil pump is used to force the oil through an oil strainer and an oil cooler, figure 7. From the oil cooler it goes to the main gallery in the cylinder block. If the strainer or cooler becomes clogged a spring-loaded bypass valve opens and admits oil to the main gallery.

Note: The strainer has been eliminated on most late models.

A portion of the oil flows continuously from the main oil gallery through an oil filter and through a return line to the crankcase. At the outlet of the filter is a shutoff valve. This valve permits the oil to be shut off so that

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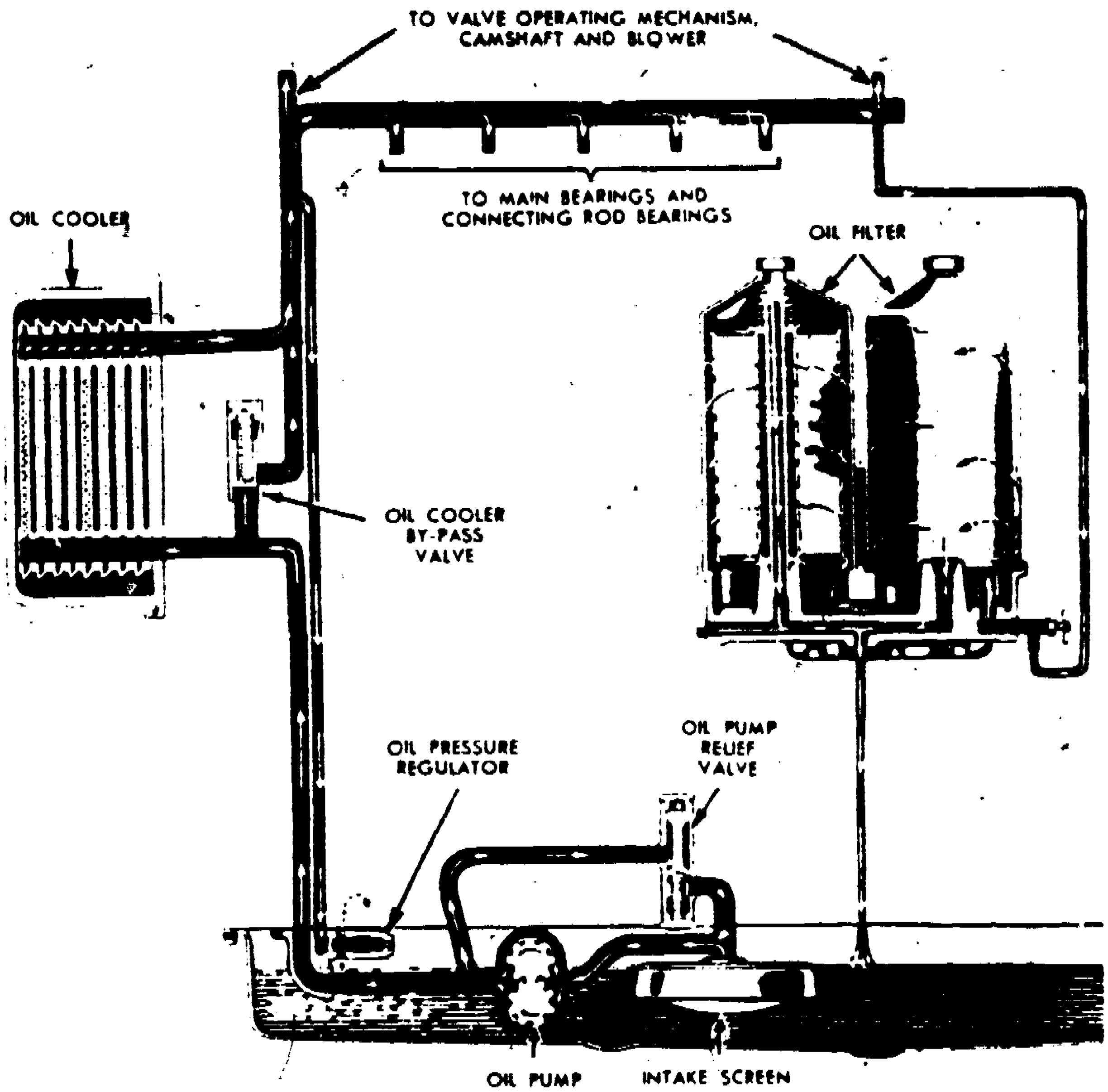

Figure 7. Schematic Diagram of Typical Lubricating System.

the filter can be cleaned while the engine is running. The pressure relief valve, located at the rear of the cylinder block and at the termination of the oil gallery, maintains a stabilized oil pressure within the engine at all speeds, regardless of oil temperature. If the oil pressure at the valve exceeds 45 psi, the valve is lifted off its seat, and oil from the engine gallery is bypassed to the engine crankcase. The connecting rod bearings receive oil from the main bearings through drilled passages in the crankshaft. This oil lubricates the piston pins and sprays against the upper side of the piston head to help cool the engine. The blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block. The hydraulic governor (if used) and the blower bearings also receive their oil from the engine lubricating system.

The oil cooler aids in heating the engine oil when the cooling system thermostats are closed and will aid in cooling the oil when the coolant starts circulating through the radiator. In addition to lubricating the engine parts to prevent wearing and scoring, the lubricating oil also reduces friction and plays an important part in cooling the engine.

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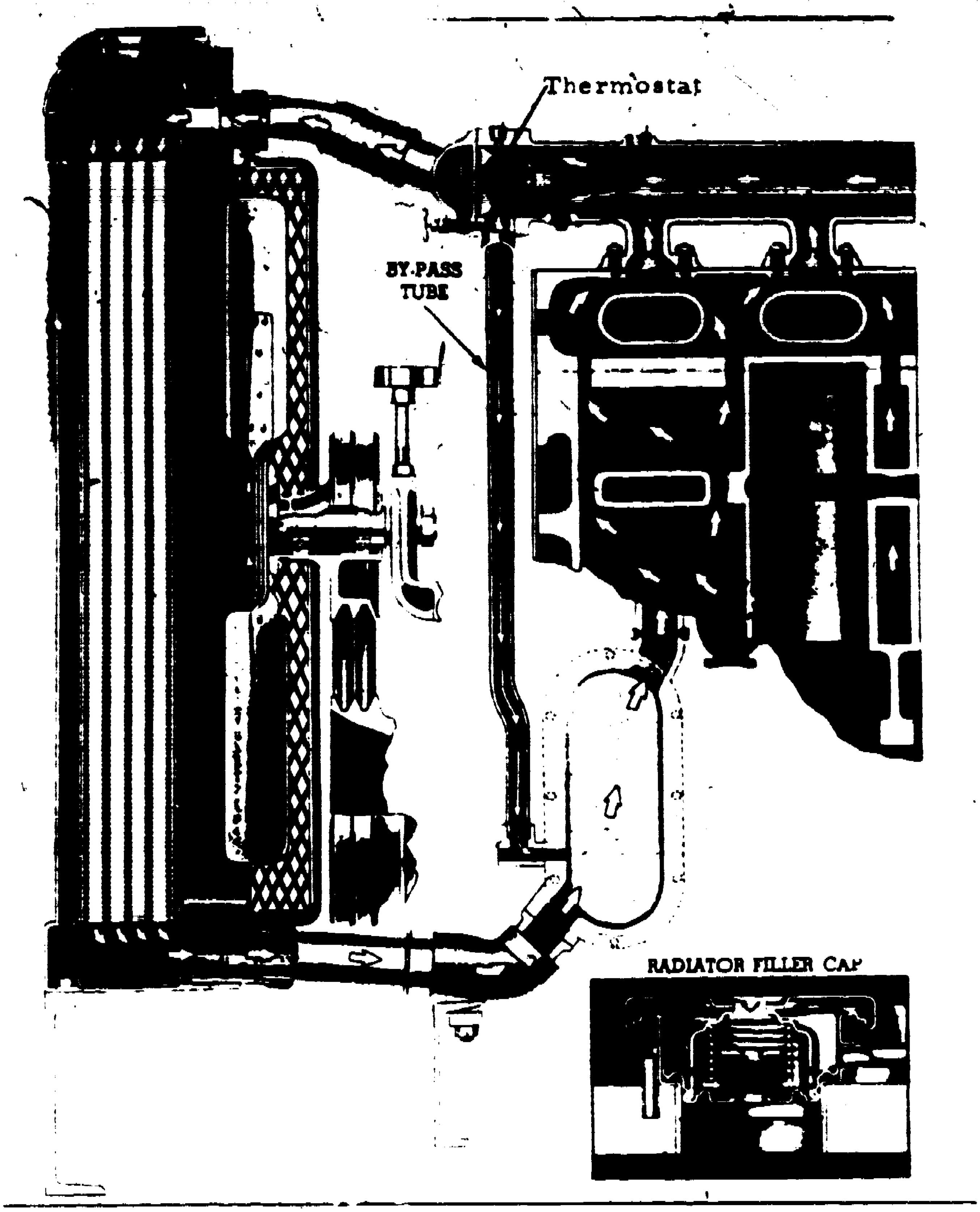

Figure 8. Typical Cooling System with Radiator and Fan.

The Cooling System of the GMC Diesel Engine, Figure 8

One of two cooling systems may be used in these engines. One system has a radiator and cooling fan, figure 8; the other a heat exchanger. In both systems a centrifugal-type water pump draws the water through the air cooler and discharges it into the lower part of the cylinder block. The water pump is attached to and driven from the blower.

The coolant circulates around the cylinder bores, and passes up through openings into the water jacket of the cylinder head, figure 8. In the cylinder

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head it circulates around the valves and fuel injectors. From the cylinder head it then flows into the radiator or heat exchanger. Here the temperature of the cooling liquid is reduced. The cooling liquid gives up its heat to the airstream from the cooling fan or to the colder raw water depending on whether a radiator or a heat exchanger is used.

The water temperature in the engine cooling system is automatically controlled by either a bellows or a spring-type thermostat. These are mounted in a housing between the water manifold and radiator or heat exchanger. With either type of thermostat, the opening to the radiator or heat exchanger is closed during the warmup period. The coolant is permitted to circulate in the cylinder block, cylinder head, and bypass tube or passage. In radiator jobs, the coolant also circulates through the oil cooler before the thermostat starts to open. After the thermostat starts opening and until it is fully open, coolant circulation takes place through the radiator or heat exchanger and the bypass passages. The bellows-type thermostat incorporates a valve which completely blocks the opening to the bypass tube or passage when the thermostat has fully opened. This causes all of the coolant to flow through the radiator or heat exchanger. When the spring-type thermostat is fully open, some water may circulate through the bypass.

In units equipped with a radiator, a tube is used to bypass the coolant from the thermostat housing to the oil cooler, thence to the pump. In units with heat exchangers the bypass passage is incorporated in the heat exchanger tank. By means of bypass circulation, normal engine operating temperatures are obtained in a minimum warmup period. At this time the coolant aids in bringing lubricating oil to normal operating temperature.

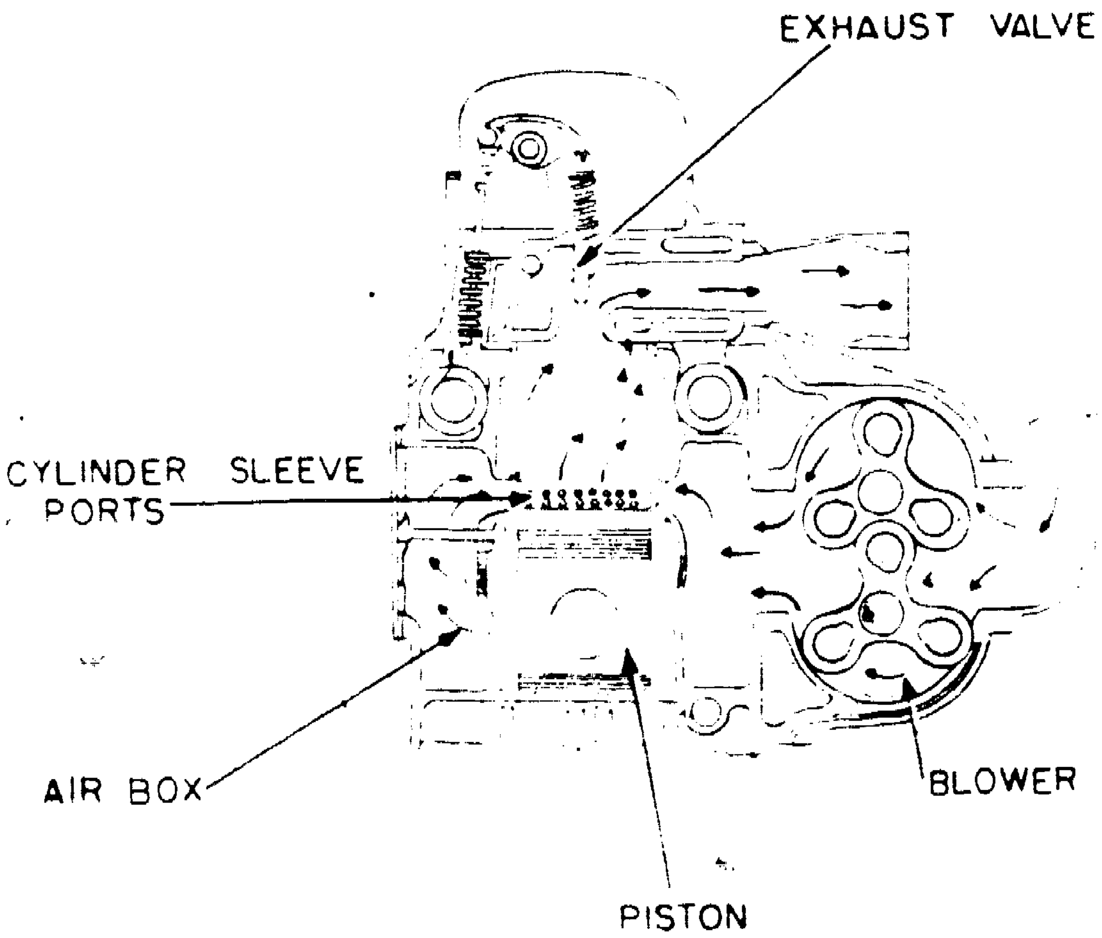

Figure 9. Air Intake System of GMC Diesel Engine.

Intake Air System of GMC Diesel Engine, Figure 9

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Previous paragraphs explained the intake air system and the scavenging process used. The air needed for scavenging and combustion is drawn through the oil bath air cleaner by the blower. It is very important that this air be clean.

Air Cleaner

A heavy-duty oil bath air cleaner and silencer are used on most industrial models. The cleaner and silencer consist of a metal wool element supported inside the housing. Beneath it is the oil bath. Air drawn through the cleaner, by the blower, passes over the oil bath. The oil bath collects the major portion of the dust. The air then flows up through the metal wool where the finer particles of dust are removed. After passing through the metal wool the air passes down the central duct to the blower. Silencing features are incorporated in the design of the cleaner.

Emergency Engine Shutdown Device

This device is located between the air inlet housing and the blower. There may be one of three types used in the Series 71 industrial engines. They are operated as follows: manually through a control wire; automatically by either low oil pressure or high coolant temperature; and, automatically by an overspeed governor trip mechanism.

On a diesel engine, if any combustible liquid is accidentally introduced into the combustion chamber, excessive engine speed will probably occur, resulting in damage to the engine. As there is no ignition system which can be shut off, the only manner in which to shut off the engine is either by shutting off the fuel or the air. If combustible liquid is accidentally introduced into the combustion chamber the engine cannot be shut down by shutting off the fuel. Therefore, the emergency shutdown device provides a means of shutting off the air intake supply. It consists of a flap valve in the air inlet housing at the blower.

> Warning: Never use the emergency shutdown to shut down the engine unless in case of emergency.

Air Blower

The operation of this blower is similar to that of a gear-type oil pump. Two hollow three-lobe rotors, figure 9, are closely fitted in a housing which is bolted to the engine. The construction of the rotors provides continuous and uniform displacement of air as the rotors revolve. The air entering the blower from the air cleaner is picked up by the blower rotors and carried to the discharge side of the blower, figure 9. The continuous discharge of fresh air from the blower creates an air pressure of approximately 4 to 12 1/2 pounds in the air box of the cylinder block. This pressure will vary with the speed of the engine.

Air Box

In normal operation, a slight amount of vapor from the air charge condenses and settles on the floor of the air box. This condensation is drained

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off through cored passages in the ends of the block and openings in the side of the engine block. These openings are below the air box floor. An accumulation of liquid on the air box floor indicates plugged vents. This liquid should be wiped out with rags or blown out with compressed air. If this is not accomplished regularly it could cause the engine to overspeed (runaway).

Operating the GMC Diesel Engine

STARTING THE ENGINE. Starting this engine is as simple as starting the engine of an automobile. Like the gasoline engine, certain routine checks should be made each time the engine is started. These checks are as follows: crankcase oil level, coolant level, fuel level in tank, fuel supply valves, position of controls, and operation of emergency shutdown device. Also, a complete visual inspection should be made of the engine. After the inspection has been completed, open the throttle to idling position and press starter button firmly to start engine.

Caution: Do not operate cranking motor more than 30 seconds at a time to avoid overheating of motor.

If the engine has set for several hours it may be necessary to hold the governor control button in. This button is located on the governor housing (hydraulic governor). Hold the button all the way in until the governor oil pressure builds up to hold the governor in the "RUN" position.

WARM UP OF ENGINE. Immediately after starting, observe the oil pressure on gauge. If no pressure is shown after 10 to 15 seconds, stop the engine. During the warmup period run the engine at part throttle and no load for four or five minutes.

RUNNING THE ENGINE. While engine is running see that oil pressure does not fall below 25 psi at operating speed. (5 psi is satisfactory at idle.) With engine running at operating temperature, check the unit carefully for water, fuel, or lubricating oil leaks. Under normal working conditions the coolant temperature should range between 160° and 185° F with corresponding oil temperature about 40° above the water outlet temperature.

STOPPING. If possible, set throttle at about half speed and allow engine to run without load for about 2 minutes before shutting down. This permits valves and other parts to cool so there will be less danger of warped valves or other damaged parts. To shut down the engine, it is only necessary to turn the throttle to the "NO FUEL" position. Remember, on a diesel engine the method used to shut down the engine is either by closing off the fuel supply or, in case of emergency, shutting off the intake air by the emergency shutdown device.

INSPECTION AND SERVICING OF THE GMC DIESEL ENGINE

There are many things which may affect the operation of this engine. Two items of foremost importance are the presence of sufficiently high compression pressure and the injection of the proper amount of fuel at the right time. The first of these items depends almost entirely on pistons, rings, and valves with their operating mechanisms. The second item depends on the injectors and their mechanisms. Thus, the correct valve adjustment, injector timing, and governor and rack setting are very important for proper engine operation. However, the correct operation of other units mounted on the engine is also very important for proper engine operation.

Air Cleaners

Air cleaners must be serviced regularly to provide sufficient clean air for entrance into the cylinders. Proper servicing of the air cleaner is very important to prevent overspeeding of the engine. The oil level must be maintained and not overfilled. The element in the air cleaner must be allowed to drain thoroughly after it has been cleaned.

Air Box Drains

The service and inspection of these drains are of utmost importance. These drains must be regularly inspected and cleaned. If water vapor as well as a slight amount of fuel and lubricating oil fumes, which condense and settle on the floor of the air box, are allowed to accumulate it may cause the engine to overspeed. If liquid accumulation is found it should be wiped clean and blown out with compressed air.

Engine Ventilation

Harmful vapors which may form within the engine are removed from the crankcase, gear train and valve compartment by a continuous automatic ventilation system. A slight pressure is maintained within the engine crankcase by seepage of a small amount of air from the air box past the piston rings. This sweeps up through the flywheel housing and balance weight cover into the valve compartment. From the valve compartment it is expelled through a vent pipe attached to the governor or a vent attached to the valve cover.

Blower

Always refer to the applicable manual for the service and inspection of the blower. Make sure that all safety precautions are observed at all times.

Exhaust System

A thorough visual inspection should be made of the exhaust system at regular intervals.

Starting System

When inspecting the electrical system, the battery and its connections are the first thing to consider. Cables and connections of the starting motor must be kept in good condition. Standard automotive test equipment may be used for testing the system.

SUMMARY

During this lesson you have had the opportunity to become familiar with the construction, operation, and minor servicing of the GMC diesel engine. The two-stroke cycle diesel engine compares closely to the four-stroke cycle gasoline engine. The main differences being the air intake system, method of ignition, and method of mixing the fuel and air. The following lesson will pertain to the fuel system service and tune up of the GMC diesel engine.

QUESTIONS

1. The GMC two-stroke cycle diesel engine requires no intake valves. How is air intake accomplished in this engine?

2. Two exhaust valves per cylinder are used on this engine. What is the advantage of this arrangement?

3. Since all diesel engines are more or less subject to overspeeding, what safety precautions should be taken before starting the GMC diesel engine?

4. There are precautions to be taken when shutting down diesel engines as well as when starting. What are they?

5. The GMC diesel engine uses an oil cooler. What does this unit do besides aid in cooling the oil?

6. One of the characteristics of the two-stroke cycle diesel engine is to run excessively hot. What added features contribute to cooling these engines?

7. How is the fuel ignited in the diesel engine?

8. Why must the fuel be atomized as it enters the cylinder?

9. Why is a high-pressure fuel injection device used on each cylinder of this engine?

10. When is it necessary that a check valve be used in the fuel inlet line ahead of the transfer pump?

11. What are two common types of electrical systems?

12. The GMC diesel engine uses what is known as a unit-type injector. What characteristics of the injector classify it as this type?

REFERENCES

1. TO 36A-1-76.
2. TO 36AG1 Series.

COMPRESSION IGNITION ENGINE FAMILIARIZATION, OPERATION AND SERVICING

OBJECTIVES

When you have completed this worksheet you will be able to:

Identify units of the diesel engine and explain their purpose.

Operate and service the diesel engine and components.

EQUIPMENT

	Basis of Issue
Diesel Engine, GMC	1/4 students
Mechanic's Tool Set	1/student

PROCEDURE

Using the worksheet as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Perform preoperation inspection, start and stop the diesel engine.

PROCEDURE	IMPORTANT INFORMATION
1. Make a preoperational check of the following:	1. The applicable publication, ______ ________, should be consulted for detailed information. In the appropriate spaces, list items to be checked and answer all of the following questions.
a. Coolant level.	a. Explain any important information concerning the cooling system.
b. Belts.	b. What is maximum permissible slack? List items that belts are checked for:
c. Crankcase oil level.	c. When should oil level be checked?
d. Diesel fuel tank.	d. Why should tank be kept full during storage and between periods of operation?

PROCEDURE		IMPORTANT INFORMATION
e. Battery.		e. What is the battery checked for during the preoperation check?
f. Visual inspection.		f. What is primarily concerned with during inspection?
g. Emergency shutdown control.		g. Why must this control be thoroughly inspected on pre-operational check?
2. Start and operate engine.	2.	All safety precautions should be observed at all times.
a. Position controls.		a. Explain position of controls.
b. Start engine.		b. What is the maximum time that the starter should be operated at one time? What control is held in at the time of starting for quicker starting?
c. Adjust engine speed for warmup period.		c. What engine RPM is desired during this period? How long should this speed be maintained for warmup period? Oil pressure should never be below __________ pounds. Coolant temperature should not exceed __________ in cold weather. What device may be regulated to maintain proper temperature?
d. Operate at 1,200 rpm.		d.
3. Stop the engine. Note: Idle engine for a few minutes after the load has been removed.	3.	Explain why engine should be idled.

Exercise 2

Identify fuel, starting, and lubrication units.

PROCEDURE	IMPORTANT INFORMATION
1. Identify fuel system units.	1. In the spaces provided, list the units that make up the fuel system. What type of fuel transfer pump is used? What size of injector is used? What is the purpose of the restrictor passage in the return line?
2. Identify units of the starting system.	2. In the space provided, list the units that make up the starting system. What voltage is used in the starting system? What type starter pinion is used?
3. Identify units of the engine lubrication system.	3. In the space provided, list the units that make up the lubrication system. Explain the purpose of the oil radiator.

Exercise 3

Remove, clean, inspect, replace, test, and time a fuel injector as assigned by the instructor.

Note: As the injector is one of the most important and carefully constructed parts of the engine, it is recommended that a faulty injector be replaced as a unit.

Caution: Never attempt to repair an injector unless you have a thorough understanding of the injector, and the proper equipment and facilities.

PROCEDURE	IMPORTANT INFORMATION
1. Determine the necessary tools, equipment, and facilities.	1. List special equipment. Note: Emphasize cleanliness at all times. What type of cloth must be used for wiping parts? Caution: Never touch any injector parts with bare hands. Keep parts submerged in clean diesel fuel. How may parts be affected if touched with bare hands?
2. Remove injector from the engine.	2. Refer to applicable publication for procedures.
a. With valve rocker cover removed, position the three rocker arm clevis pins on the assigned cylinder.	a. Pins must be in line at outer end. When positioning engine by hand, what direction should it be turned? Caution: When positioning the engine by hand, make sure battery is disconnected and throttle is in the "OFF" position.
b. Remove fuel jumper lines.	b. What precautions must be taken when lines are removed? Why?
c. Remove rocker arm assembly away from the valves and injector.	c.
d. Remove the injector holddown stud nut, special washer, and injector clamp.	d.
e. Free injector from its seat.	e. What type of tool should be used? Caution: Never pry on the injector rack.

PROCEDURE	IMPORTANT INFORMATION
f. Lift the injector from the cylinder head.	f. Always use two hands when lifting out the injector. Care must be taken not to damage the spray tip of the injector.
g. Clean the injector.	g. Rinse injector in diesel fuel. What type of cloth is used to wipe clean? How is tip cleaned?
3. Make the inspection and tests that do not require a test fixture.	3.
a. Make a visual check.	a. List items to check.
b. Check rack for freeness by rotating the injector from side to side while holding in horizontal position.	b. The rack will fall its full travel by its own weight when the injector is rotated. If the rack does not fall freely, the injector must be ______ ______.

Exercise 4

Adjust the valves and time injectors.

Note: After installing the governor and before the engine is started for governor adjustments, the valve clearance must be carefully checked.

PROCEDURE	IMPORTANT INFORMATION
1. Determine the necessary tools, equipment, and publications.	1. List special tools and equipment required for this job. TO No. ______ is used.
2. List safety precautions to be observed as given by your instructor.	2. List.
3. Prepare engine for valve adjustment.	3. Rocker arm cover is removed and governor control lever is positioned in the "______" position.

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PROCEDURE	IMPORTANT INFORMATION
4. Position engine.	4. Always rotate crankshaft clockwise to position the valve. What may be caused by using a bar and rotating the crankshaft counterclockwise?
5. Measure the valve clearance.	5. The injector rocker arm must be completely depressing the injector plunger of the particular cylinder before measuring the valve clearance. Always refer to the applicable publication for the specified setting and correct procedures. Valve clearance on ________ engine is ______,______.
6. Adjust the valve.	6. What tools are required?
a. Check engine that you are performing the job on and select the proper thickness of gauge.	a. What gauge is used?
b. Place feeler gauge between the end of the valve stem and the rocker arm.	b.
c. Adjust push rod.	c. A smooth "pull" of the feeler gauge should be obtained.
d. Remove feeler gauge and tighten locknut.	d. Make sure push rod is held from turning while tightening the locknut.
e. Recheck clearance (re-adjust if necessary).	e. "Go" feeler gauge should pass through and the "no-go" should not pass through.
7. Adjust the remaining exhaust valves, using the same procedure as given above.	7.
8. Time the injectors.	8. Refer to applicable technical publication for timing procedures, and answer the following questions: When timing the fuel injectors, the governor control lever is in what position? Select the proper tool used to time the injector on the particular engine assigned to you by your instructor.

5/6

PROCEDURE

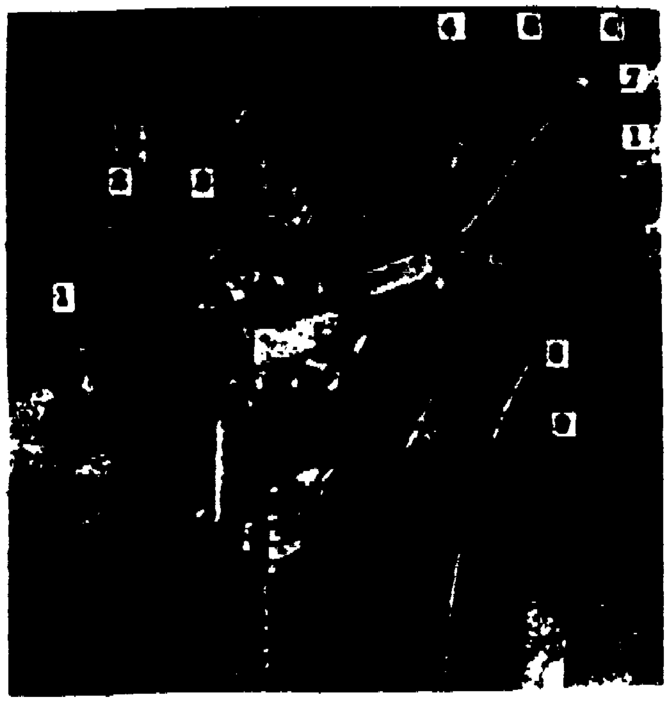
IMPORTANT INFORMATION

Injector designation:
Gauge tool number:
Dimensions?
What is the specified adjustment?

Why is it so important that the correct timing gauge tool be used?

Exercise 5

Adjust the hydraulic governor.



1 FUEL ROD
2 SCREW - COVER AND SUBCAP-TO-CASE
3 LOCKNUT - SHUTDOWN KNOB
4 ADJUSTING SCREW - RACK CONTROL LEVER - INNER
5. ADJUSTING SCREW - RACK CONTROL LEVER - OUTER
6 LEVER - INJECTOR RACK CONTROL
7 LEVER - INJECTOR CONTROL TUBE
8 SUBCAP
9. GOVERNOR CASE

Figure 10. Adjusting Fuel Rod.

PROCEDURE	IMPORTANT INFORMATION
1. Determine necessary tools, equipment, and publications.	1.
2. List safety precautions.	2.
3. Make the fuel rod adjustment, figure 10.	3.
a. Remove the governor cover and replace two screws through the subcap into the governor housing.	a. Late model governors have two additional Allen head-screws holding the subcap in position.

PROCEDURE	IMPORTANT INFORMATION
b. **Place throttle in "STOP" position.**	b.
Note: Rocker arm cover should be off at this time.	
c. Loosen adjusting screws in all injector rack control levers.	c. How many turns should these be loosened?
d. Loosen the fuel rod locknut and remove the shutdown knob.	d.
e. Turn locknut to such a position that 3/16" of the fuel rod extends beyond the nut, figure 10.	e.

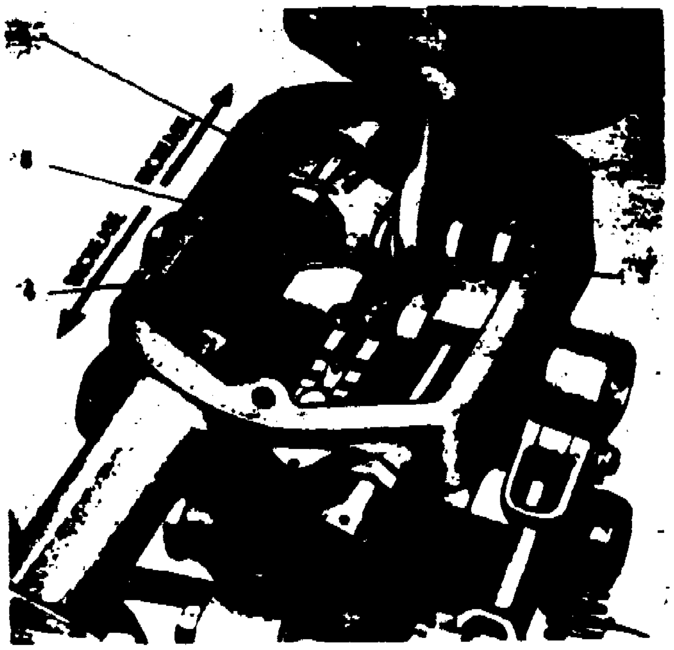
1 SCREW - MAXIMUM FUEL ADJUSTING (LOAD LIMIT)
2 LOCKNUT - MAXIMUM FUEL ADJUSTING SCREW
3 COLLAR - FUEL ROD
4 FUEL ROD
5 SUBCAP
6 TERMINAL LEVER
7 BOSS - GOVERNOR SUBCAP

Figure 11. Setting Maximum Fuel Adjusting Screw, Load Limit.

PROCEDURE	IMPORTANT INFORMATION
4. Position injector rack on No. 1 cylinder.	4.
a. Set the maximum fuel adjusting screw flush with face of boss, figure 11.	a.
b. Set inner rack control adjusting screw.	b. Explain correct adjustment.

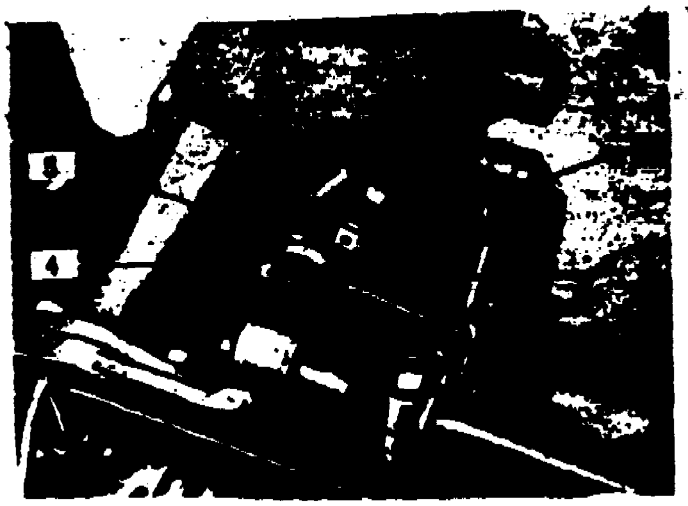
PROCEDURE	IMPORTANT INFORMATION
Note: Refer to figure 11 for locating some of the adjusting points.	
c. Tighten the outer rack control adjusting screw.	c.
5. Make maximum fuel adjustment.	5.
a. Adjust the fuel adjusting screw, figure 11.	a. ____________ space exists between the terminal lever and the collar. What position is the fuel rod held in? What is the purpose of turning the fuel screw in to contact the terminal lever?
b. Tighten the locknut.	b.
6. Position the remaining injector racks.	6.
a. Disconnect the fuel rod from control tube lever.	a.
b. Position the control tube lever to hold No. 1 injector rack all the way in.	b.
c. Adjust the remaining injector racks in turn.	c. Explain procedure.
d. Tighten outer screw and lock the inner screw.	d. After positioning each rack lever, check to see that No. 1 rack has not been moved out. What does it indicate if the No. 1 rack has moved out?
e. Make final check on the rack adjustment.	e. Each rack should be felt with fingertips for any difference in rotating motion. Readjust racks if any difference is felt.

PROCEDURE	IMPORTANT INFORMATION
f. Release control tube lever.	f. In what position will the control tube spring return the racks?
g. Check the distance between the body of the injector and the edge of the rack coupling.	g. What should the distance be? If "NO-FUEL" position cannot be reached, how will the control of the engine be affected?



1 TERMINAL LEVER
2. WRENCH
3 SCREW - DROOP ADJUSTING
4 WASHER - DROOP ADJUSTING SCREW
5. BRACKET - DROOP ADJUSTING

Figure 12. Speed Droop Adjusting.



1 LOCKNUT - MAXIMUM FUEL ADJUSTING SCREW
2 SCREW - MAXIMUM FUEL ADJUSTING (LOAD LIMIT)
3 WRENCH
4 SCREW - MAXIMUM SPEED LIMIT ADJUSTING
5 LOCKNUT - MAXIMUM SPEED LIMIT ADJUSTING SCREW

Figure 13. Setting Maximum Speed Adjusting Screw.

7. Make the speed droop adjustment, figure 12.	7. What is meant by speed droop? Note: Governor droop is adjusted at the factory and further adjustment should not be necessary. However, if the governor has had major repairs, it should be adjusted after governor is installed. Refer to the applicable publication for correct procedures and in the space provided, explain.
8. Make the maximum speed adjustment, figure 13.	8. This adjustment limits the travel of the governor speed adjusting

PROCEDURE | IMPORTANT INFORMATION

shaft. Moving the screw "in" will decrease, and "out" will increase the maximum engine speed. Refer to applicable publication for correct procedures and in the space provided, write a brief explanation.

Exercise 6

Inspect and service the starting system, exhaust system, and air cleaner.

PROCEDURE | IMPORTANT INFORMATION

1. Inspect and service the starting system.

   a. Clean the battery.

1. Remarks:

   a. The terminal posts, battery top, and holddown cover must be kept clean of corrosive formations. Explain the effect of corrosion on the starting system.

   Wash the battery with a strong solution of baking soda and water.

Caution: Do not allow solution to get into the cells. It will react with the acid and weaken the battery.

   b. Test the specific gravity of assigned battery.

   b. List the safety precautions to be observed while testing the specific gravity of the battery.

   Specific gravity reading of from __________ to __________ indicates that the battery is fully charged.

   c. Prepare the terminals and corrosion affected areas for reinstallation of cable clamps and battery cover.

   c. After corrosion is removed, the terminals and other affected areas should receive a ______________________________ ______________________________.

PROCEDURE	IMPORTANT INFORMATION
d. Inspect the battery cable.	d. Remarks:
2. Inspect the exhaust system.	2. The exhaust system consists of the exhaust manifold, exhaust pipe, and muffler or spark arrestor, if used. Remarks:
a. Inspect the exhaust manifold for leaks.	a. Explain how a defective exhaust manifold will affect engine operation.
b. Inspect for cracked or warped manifold.	b. Explain the procedure.
c. Check the manifold bolts for tightness.	c. Explain the proper procedure for tightening the bolts.
d. Inspect the exhaust pipe and muffler, if used.	d. The exhaust system should have the least amount of restrictions possible. If the system has restrictions, it will cause backpressure. Backpressure will cut the engine performance.
3. Inspect and service the air cleaner.	3. Remarks:

COMPRESSION IGNITION ENGINE FAMILIARIZATION, OPERATION, AND SERVICING (FUEL SYSTEM AND TUNEUP)

OBJECTIVES

After completing this unit of instruction, you will be able to explain the purpose, function and construction and identify the various units which make up the fuel system and the governor, inspect, test and troubleshoot the diesel engine.

INTRODUCTION

Included in the fuel system are injectors, fuel pump, fuel filter and fuel manifolds. In the previous lesson you had the opportunity to become familiar with the purpose and location of these units. The following information will further explain the fuel system components and the service and tuneup requirement for satisfactory engine operation.

INFORMATION

FUEL SYSTEM COMPONENTS

The following units make up the fuel system. These units and their working principles will be covered in the following paragraphs.

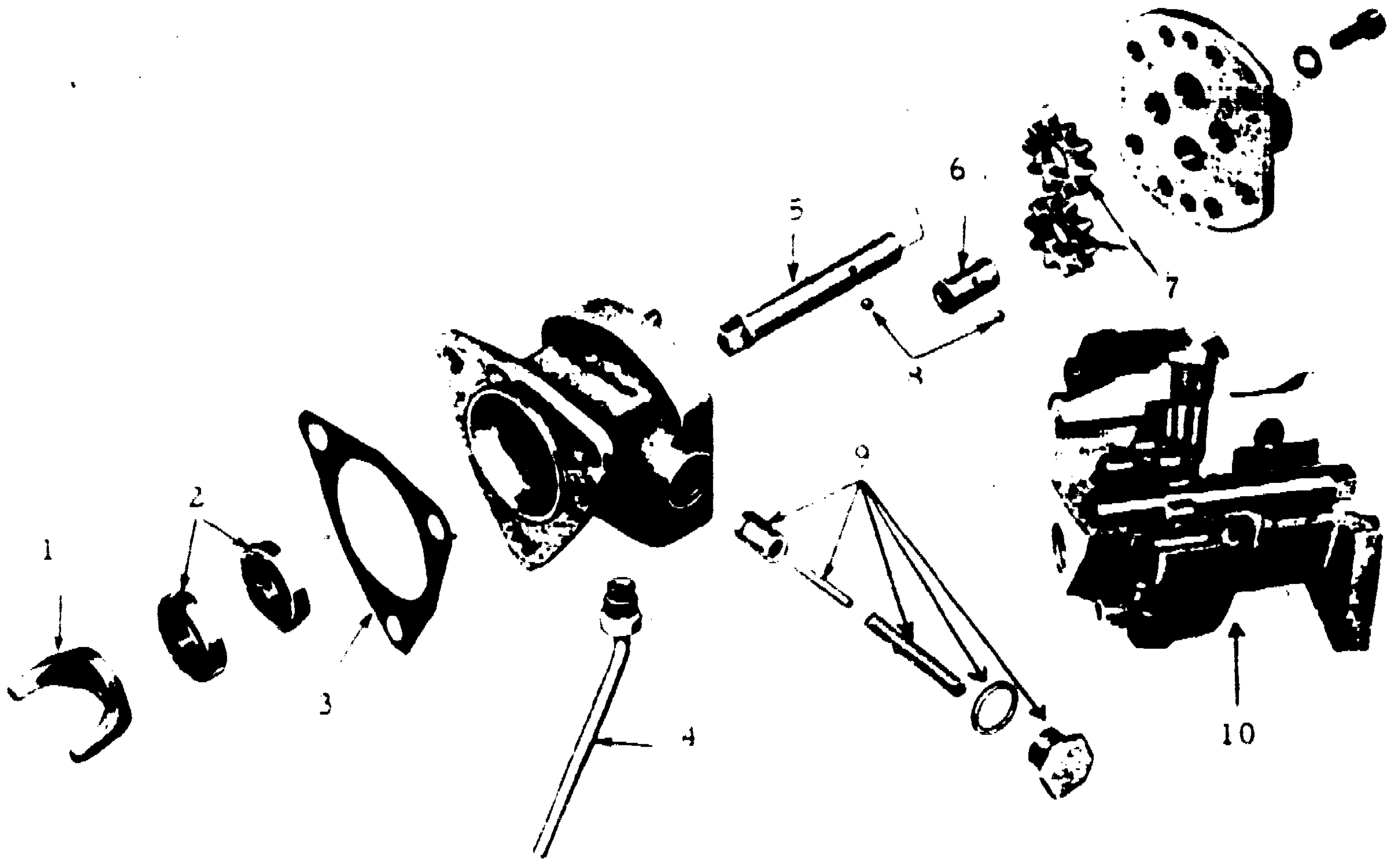
Fuel Pumps

On older model engines, a vane-type pump is mounted on the rear of the blower housing. The pump is driven from the lower blower rotor shaft. On later model engines, a gear-type pump is used.

VANE-TYPE PUMP. This pump has two spring-loaded vanes carried in the rotor. These vanes and rotor revolve inside the eccentric housing and positively displace fuel from the inlet port to the outlet port. Two seals are utilized within the pump. One retains the fuel under pressure, the other prevents the lubrication oil in the blower timing gear compartment from creeping along the pump shaft. A spring-loaded relief valve is located in the cover of the pump. This valve relieves excessive pump pressure should any of the fuel lines or filters become clogged. If pressure exceeds the spring setting, the valve opens and allows fuel flow from the discharge side to the inlet side of the pump.

GEAR-TYPE PUMP. This pump, figure 14, is also a positive displacement pump. It also incorporates a spring-loaded relief valve. This valve will open at a pressure of approximately 42 to 52 psi and returns fuel back to the supply source. Two oil seals are pressed into the bore in the flanged side of the pump body. The feather edge of the seals face away from each other. Two tapped holes in the underside of the pump body, between the seals, are for draining off any leakage.

Note: If leakage exceeds one drop per minute, the seals must be replaced.



1. Fork, Fuel Pump Coupling.
2. Seal, Fuel Pump Oil.
3. Gasket, Fuel Pump to Blower
4. Tube, Fuel Pump Drain.
5. Shaft, Fuel Pump Drive.
6. Shaft, Fuel Pump Driven.
7. Gear, Fuel Pump Drive
8. Steel Ball.
9. Fuel Pump Relief Valve Assy.
10. Cross Section of Pump.

Figure 14. Fuel Pump and Drain.

PUMP ROTATION. Fuel pumps are furnished in either left or right hand rotation, according to engine model. The pumps are stamped and are not interchangeable.

Primary Fuel Filter

This filter, located between the supply tank and the fuel pump, may be referred to as a strainer. Suction from the pump and gravity flow of fuel from the tank causes the fuel to flow through the filter element where the dirt particles are removed. The elements may be screen, disk, canned waste, yarn, or paper type. The screen and disk elements are reusable. The servicing of the filters depends largely on operating conditions. When installing filter after servicing always fill the bowl with clean fuel before securing the bowl to the cover. No gaskets should be used. After installing the filter, run the engine for a few minutes and check the filter for leaks.

Secondary Fuel Filter

This filter is mounted on the side of the engine and is convenient to service. The length of time that this filter may be used before replacing the element should be governed largely by operating conditions and cleanliness of fuel. Low fuel pressure may be the result of a partially clogged filter. This condition will usually cause erratic firing or missing cylinders. The filter element may be the same type used in the primary filter.

Fuel Manifolds

The outlet manifold, to which the fuel flows from the injector, has a restrictor at the discharge end. The restrictor is placed at this point so that the fuel pump can maintain constant pressure on the entire fuel system to this point. This assures ample fuel at the injectors and prevents air entering the system. The fuel manifolds are positioned and locked with tapered seat connectors. Care must be taken when connector is removed. The seats must be clean and properly positioned in the manifold fittings.

Filtering Elements in the Injectors

Beneath each fuel line connector in the injector body are small filtering elements, figure 15. The elements are made of a porous material and as they are very hard to clean, they should be replaced with new ones if they become excessively dirty. If old elements are being reused they should be reinstalled in the same openings from which they were removed because fuel passes through the elements used on the inlet connections in the reverse direction from those used on the outlet connections. Small particles of dirt that may have lodged on the inner surface of the outlet filter may be washed into the injector if it is used on the inlet side.

Unit-Type Injector

As previously explained, the fuel pressure must be higher than that of the air charge in the combustion chamber so that fuel can be injected into the combustion chamber at the specified time. Besides injecting fuel into the combustion chamber at the specified time, some means must be provided so that only a certain amount of fuel is injected at this time. This fuel also must be atomized for proper burning when it is injected into the combustion chamber. The unit fuel injector combines in a single unit all the parts necessary to perform the above functions. Thus, the fuel injector injects the fuel at the correct time, meters the fuel, creates a high fuel pressure, and atomizes the fuel. This provides a complete and independent injection system for each engine cylinder. The cross section of the injector, figure 15, shows the various parts.

Injector Mounting

The injectors are mounted in the cylinder head, with their spray tips projecting below the top of the inside surface of the combustion chambers. A clamp, bolted to the cylinder head and fitting into a machined recess in each side of the injector body, holds the injector in place in a water-cooled copper tube which passes through the cylinder head.

A tight seal is formed between the tapered seat on the lower end of the injector and the copper tube. This will withstand the high pressures inside the combustion chamber. A dowel pin registers with a hole in the cylinder head for accurately locating the injector assembly.

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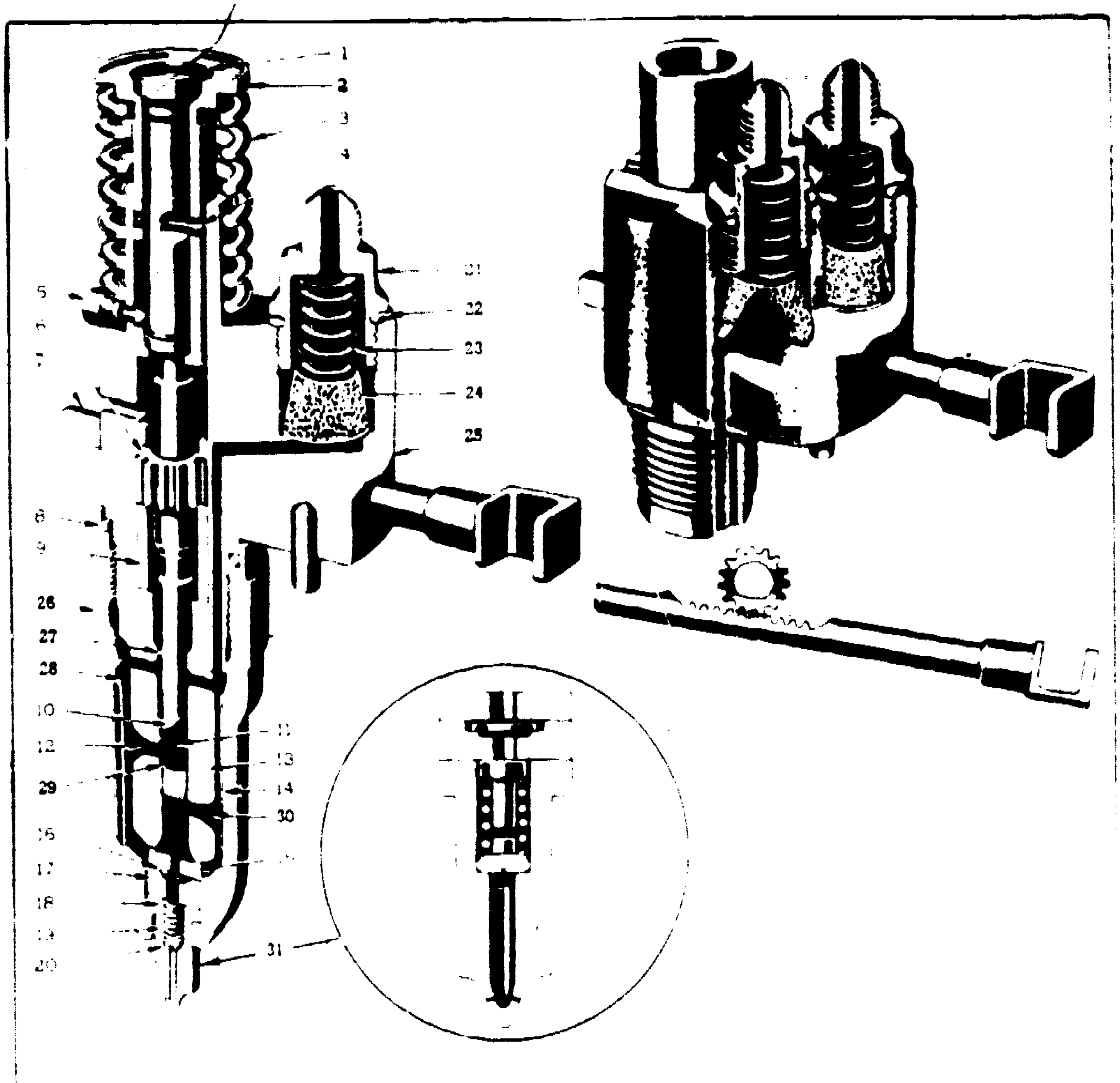

Figure 15. Cross Section of a GMC Injector.

Injector Operation

The fuel oil is supplied to the injector at a pressure of approximately 40 psi. The fuel fills the annular supply chamber between the bushing and the spill deflector, figure 15, item 28. The injector plunger, operated by a rocker arm which is actuated by the camshaft, operates up and down in this bushing. The bore of this bushing is connected to the fuel supply in the annular chamber by two funnel-shaped ports, figure 16. In addition to the reciprocating motion,

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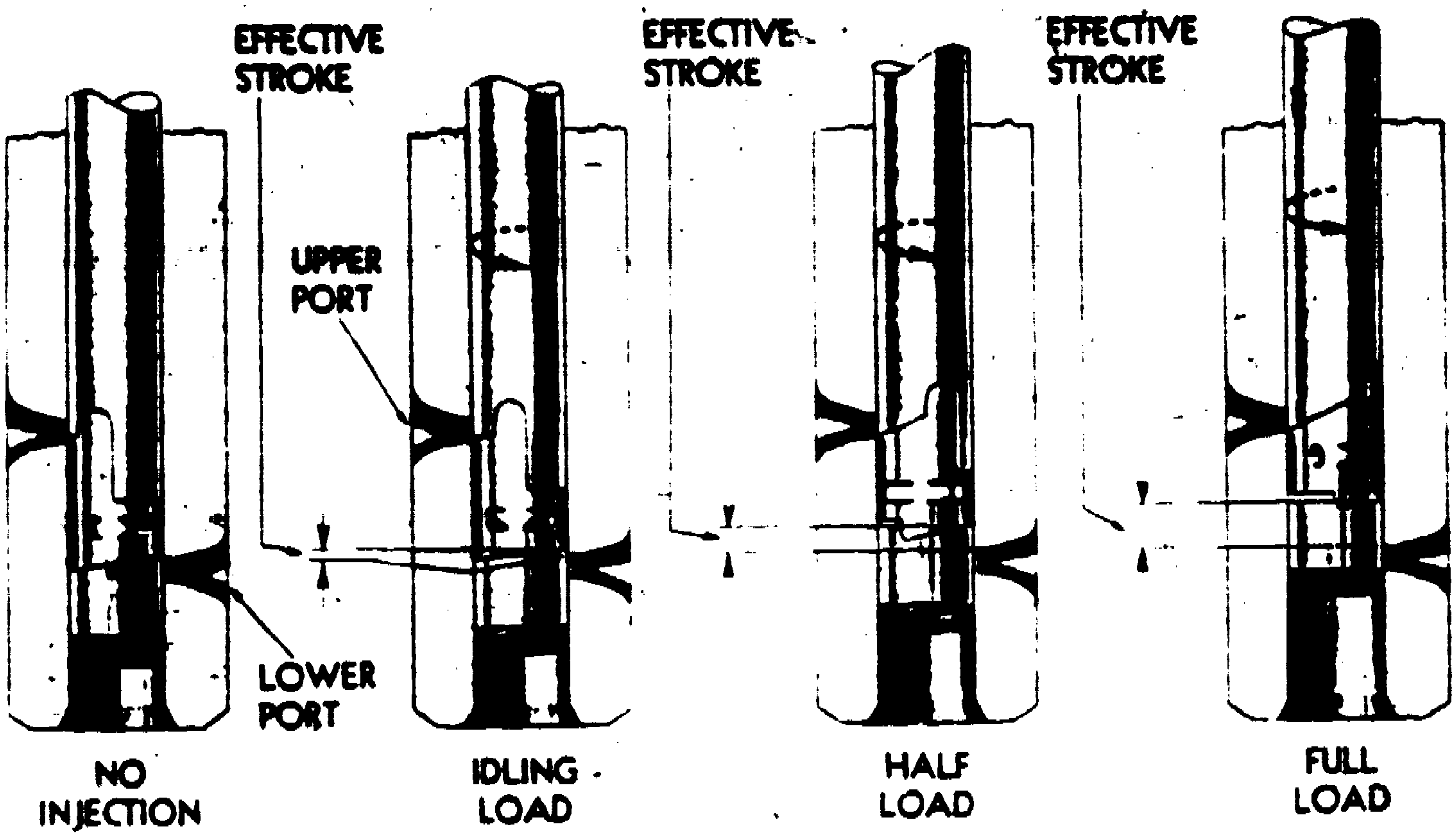

Figure 16. Fuel Metering from FULL LOAD to NO LOAD Produced by Rotating Plunger With Control Rack.

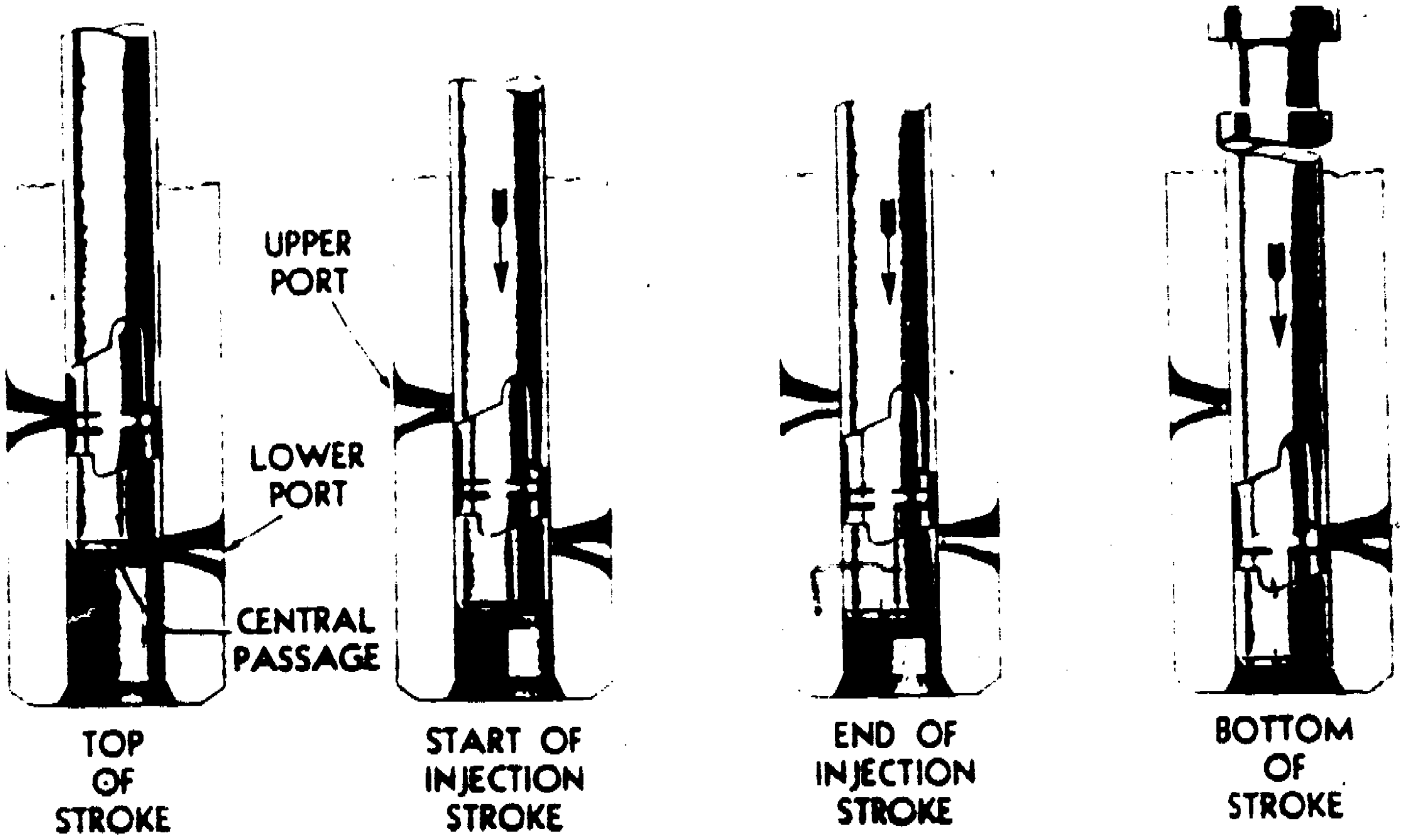

Figure 17. Phases of Injector Operations by Vertical Travel of Plunger.

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the plunger can be rotated in operation around its axis. This is accomplished by the gear, figure 15, which is in mesh with the rack. An upper and lower helix are machined into the lower end of the plunger. These helixes, figures 16 and 17, are for metering purposes. The relation of these helixes to the two ports, changes with relation of the plunger. Changing the position of the helixes by rotation of the plunger, retards or advances the closing of the ports which is the same as changing the beginning and ending of injection or the effective stroke. The longer the effective stroke, the more fuel injected.

> Note: Reference should be made to figures 16 and 17 for positions of the plunger during fuel metering and injector operation.

PLUNGER ON DOWNWARD TRAVEL. As the plunger moves downward, the fuel in the high-pressure cylinder or bushing is first displaced through the ports back to the supply chamber until the lower edge of the plunger closes the lower port. When this takes place, the remaining fuel is then forced upward through the central passage of the plunger into the recess between the two helixes. From this point the fuel can flow back into the supply chamber until the upper helix closes the upper port. The metered amount of fuel is then forced through the valve assembly, check valve, and against the spray tip valve, figure 15. When sufficient fuel pressure is built up, the spray tip valve is lifted off its seat and the fuel is forced through small orifices in the spray tip and atomized in the combustion chamber.

> Note: The check valve prevents air leakage from the combustion chamber into the fuel system in case the spray tip valve is accidentally held open by a small particle of dirt. This allows the injector to continue to operate until the particle works through the valve.

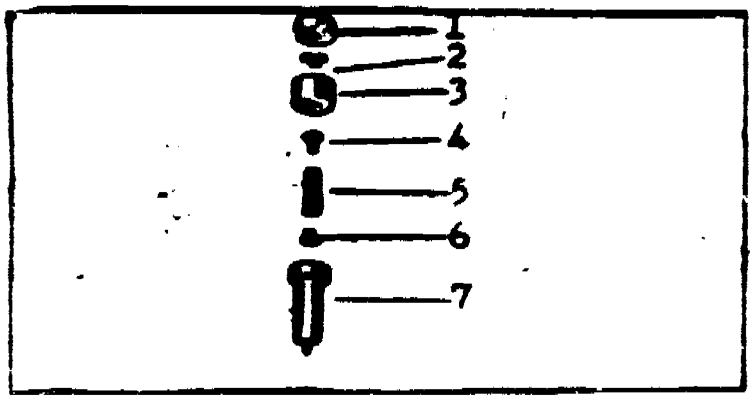
PLUNGER ON UPWARD STROKE. On the return upward movement of the plunger, the high-pressure cylinder is again filled with fuel through the ports. The constant circulation of fresh, cool fuel through the injectors renews the fuel supply in the chamber and helps maintain even operating temperatures of the injectors. This flow of fuel also effectively removes all traces of air. The air might otherwise accumulate in the system and interfere with the accurate metering of fuel. The injector outlet opening which returns the excess fuel supplied by the fuel pump, is directly adjacent to the inlet opening.

Injector Identification

The injectors used in these engines carry an assembly number and a serial number on side of the injector body. An identification plate is carried on the other side. The injector plunger is marked with the letter "A" or a number "[illegible]" to identify its type. The plunger and bushing are both marked with a corresponding serial number so that they may be easily identified as mating parts. Injectors, plungers, and bushings must have these identification markings to insure proper metering of fuel.

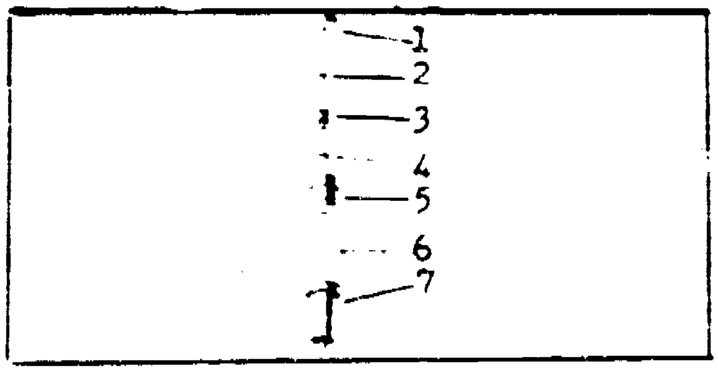
The various injectors are designated by the average number of cubic millimeters of fuel delivered per stroke with the injector operating at a speed of 1000 strokes per minute. The most commonly used injectors are the [illegible] cu mm, [illegible] cu mm, and 80 cu mm.

There is a variation in the construction of the injectors, figures 18 and 19. The older-type injectors are identified by the number "0" following a number. The new type injectors are identified by the letters "HV" preceding the number.



1. Spacer.
2. Check Valve.
3. Valve Seat.
4. Spray Tip Valve.
5. Valve Spring.
6. Valve Stop.
7. Spray Tip.

Figure 18. Injector No. 60 Spray Tip and Valve Assembly.



1. Seat, Injector Valve.
2. Valve, Injector.
3. Spring, Injector Valve.
4. Stop, Injector Valve.
5. Cage, Injector Valve.
6. Valve, Injector Check.
7. Tip, Injector Spray.

Figure 19. Injector No. HV 6-Spray Tip and Valve Assembly.

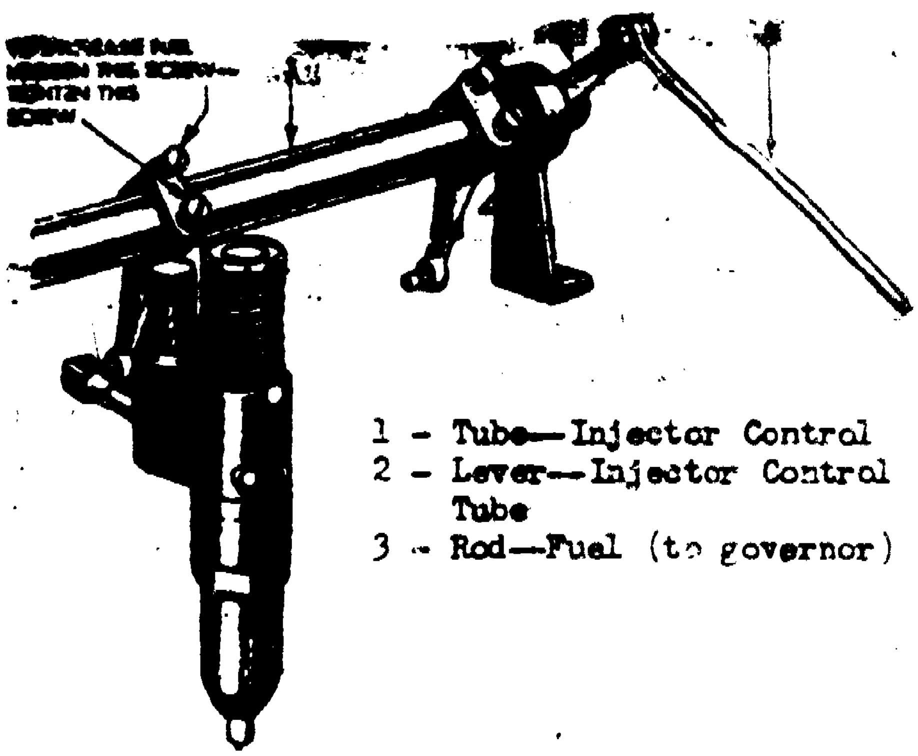
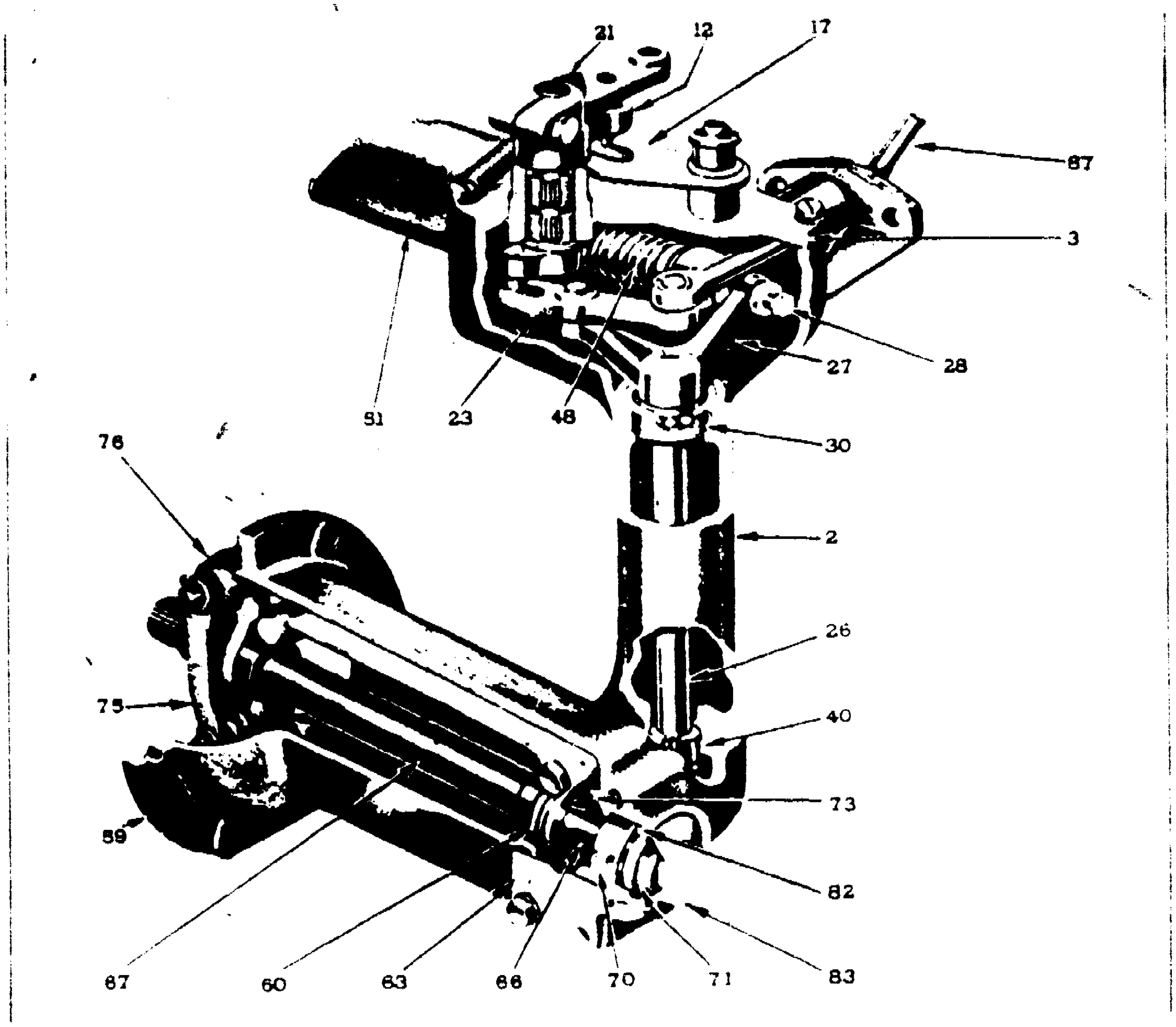


Figure 20. Governor to Injector Linkage.

Injector Controls, Figure 20

Each injector control rack is connected by an easily detachable joint to a lever on a common control shaft. This shaft is linked to the governor and throttle. The levers can be rotated independently on the control tube by the adjustment of two screws, figure 20. This arrangement permits a uniform setting of all injector racks.



2. Housing—Control.
3. Cover—Governor Housing.
12. Lever—Throttle.
17. Cam—Cover.
21. Lever—Operating.
23. Lever—Differential.
26. Shaft—Operating.
27. Lever—Operating Shaft.
28. Screw—Cap Adjusting.
30. Bearing—Operating Shaft (Upper)
40. Bearing—Operating Shaft (Lower)
48. Spring—High Speed.
51. Cover—High Speed Spring
59. Housing—Weight.
60. Bearing—Governor Riser Thrust
63. Cover—Weight Housing
66. Shaft Assy.—Weight
67. Riser—Governor.
70. Bearing—Weight Shaft End.
71. Bolt.
73. Fork—Operating Shaft
75. Carrier—Weight
76. Weight and Bearing Assy.
82. Gasket—Weight Housing Cap
83. Cap—Weight Housing
87. Link—Injector Control Tube to Governor

Figure 21. Limiting Speed Mechanical Governor - Single Weight.

GMC Diesel Engine Governor

The speed of the diesel engine is controlled by the amount of fuel injected; consequently, the injection system is designed to supply the maximum amount of fuel which will enable the engine to operate at full load and reach a predetermined maximum speed. However, if the maximum fuel charge was supplied to the cylinders with the engine running under "Partial Load" or "No Load" the engine speed would increase beyond the critical range and soon cause failure. Thus it can be seen that a governor must be installed to control the amount of fuel injected in order to control the engine speed. The GMC diesel engine may be equipped with either a mechanical governor or a hydraulic governor. The type of governor used will depend on the installation of the engine. There are two types of mechanical governors used on the industrial engines. They are the limiting speed and the variable speed.

LIMITING SPEED MECHANICAL GOVERNOR, FIGURE 21. Applications requiring a minimum and maximum speed control where low droop is not a factor are equipped with this type of governor. The limiting speed governor performs two functions. It controls the engine idling speed and limits the maximum operating speed of the engine.

1. The governor is mounted to the front end of the blower and is driven by the blower upper rotor shaft. It consists of three subassemblies: the weights, shaft and bearing housing assembly; the vertical shaft control mechanism housing assembly; and the cover assembly.

2. The weight, shaft and bearing housing assembly consists of two weights which are pivoted on needle bearings and carried on a horizontal shaft inside the weight housing.

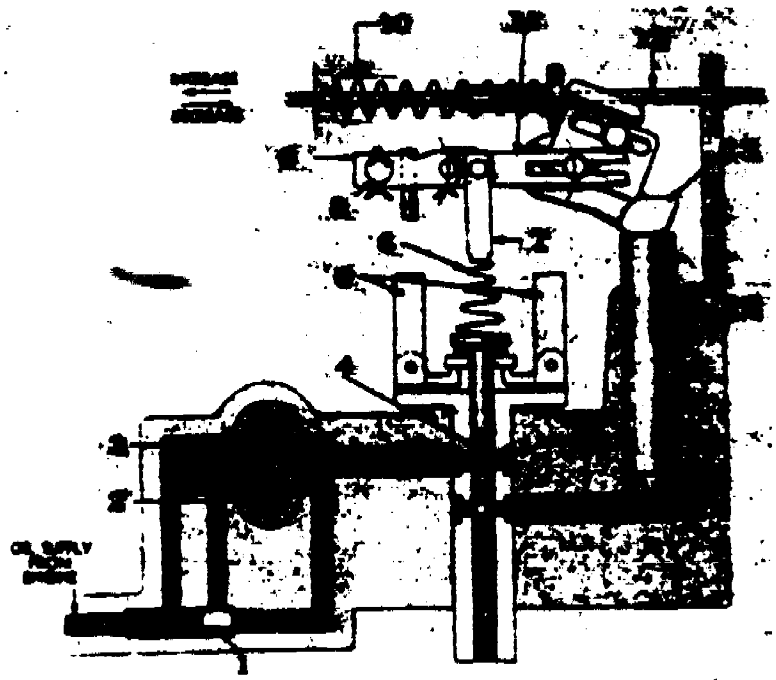
3. The weight carrier shaft is mounted on a ball bearing at the outer end and is supported and driven by the blower rotor shaft at the inner end. A riser and thrust bearing on this shaft transmits the motion of the revolving weights to the vertical operating shaft.

4. Governor control is brought about through the vertical operating shaft and a system of springs and levers in the upper end of the governor housing. The vertical shaft is mounted on a ball bearing at the upper end and a needle bearing at the lower end. Motion of the shaft is transferred to an operating lever at the upper end of shaft. One end of the operating lever is attached to a link leading to the injector rack control shaft and the other end is provided with a slot for the pin of the eccentric lever of the governor throttle shaft. High and low-speed springs with suitable adjustments and retainers restrain movement of the governor weights through an adjustable screw carried in one leg of the operating lever.

VARIABLE SPEED MECHANICAL GOVERNOR. Applications requiring uniform engine speed, which may be varied by the operator, are equipped with this type of governor. This governor is designed to control the engine at a constant speed at any point, within the limitations of the governor spring, that the operator may desire. Such control is made possible by adjusting the idling screw for the low engine speed and imposing more or less tension on the spring by means of the variable speed control lever for higher speeds. The greater the tension on the spring the higher the engine speed. The construction of this governor is very similar to the limiting speed governor. Unlike the limiting speed type, however, only one spring is necessary.

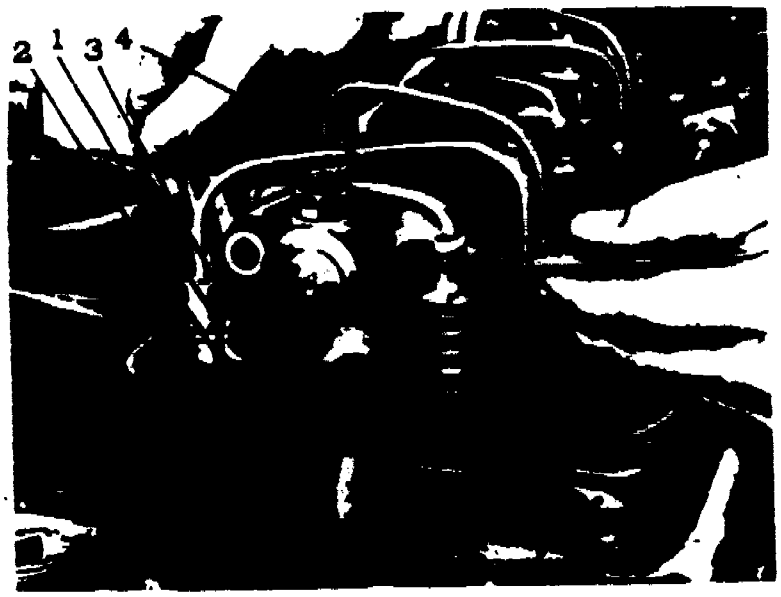
HYDRAULIC GOVERNOR USED ON GMC DIESEL ENGINE. This governor is the hydraulic type with speed droop stabilization. It is used on minimum of governor droop. The hydraulic feature is brought about by oil from the engine lubrication system being admitted, under pressure, to an auxiliary oil pump in the governor The auxiliary pump furnishes the necessary oil pressure to actuate the governor mechanism. Figure 22 shows the working principle of the hydraulic governor.

The governor control is connected to the fuel injectors by linkages and levers. The fuel is decreased by action of a fuel rod spring. It is increased by the opposing action of the hydraulic servo cylinder to which the admission of oil is controlled by a pilot valve. The pilot valve is controlled by the flyweights of the governor. The flyweights are mounted on a vertical shaft and



1. Plunger–Relief valve
2. Gear–Pump drive
3. Gear–Pump idler
4. Plunger–Pilot valve
5. Flyweight
6. Speeder Spring
7. Spring Fork
8. Shaft–Speed adjusting
9. Lever–Speed adjusting
10. Spring
11. Floating Lever
12. Fuel Rod
13. Terminal Lever
14. Servo Piston

Figure 22. Schematic Diagram Showing Working Principle of Hydraulic Governor.



1. Adjusting Wrench–KMO-324
2. Push Rod
3. Lock Nut
4. Feeler Gage–KMO-233-B

Figure 23. Adjusting Valve Lash With Correct Tools.

driven through a pair of miter gears from the upper rotor shaft of the blower. They are driven at twice the speed of the engine. When in rotation, the centrifugal force of these flyweights is opposed by a so-called "speeder spring." The compression of this spring determines the speed at which the governor will control the engine. The compression on the speeder spring is varied by the throttle on the instrument panel.

In order for the governor operation to be stable, "speed droop" is introduced into the governing system. The term "speed droop" means the characteristic of decreasing speed with increasing load. The desired extent of this speed droop may be easily adjusted to suit conditions.

In the previous lesson you were given the opportunity to go through the starting procedures. It was mentioned at that time that when the engine had set for several hours it may be necessary to hold the governor control button in when starting. The reason is that the governor must operate to open the throttle so that the engine can start. After setting for several hours it takes considerable time for the lubricating oil pressure to become great enough to operate the governor. By pressing the control button in, the fuel rod, item 12, figure 22, which connects directly to the injector control tube, takes the control away from the governor.

When the engine is stopped, the fuel rod spring forces the fuel rod, figure 22, and with it the injector racks, to the "FUEL OFF" position. Therefore, regardless of the governor, the engine can be stopped by pulling out on the fuel rod knob. Considerable force must be exerted to do this as the oil pressure against the servo piston must be overcome. The knob thus functions also as a stopping device.

TUNEUP PROCEDURES FOR INDUSTRIAL UNITS USING A HYDRAULIC GOVERNOR

Before changing any settings, you should make sure that the adjustment is necessary. All checks and adjustments must be made only after the engine has reached normal operating temperature. Performance and efficiency of an engine will be governed, to a large extent, by the accuracy with which the tuneup adjustments are made. The mechanic should always perform the operations carefully. The following checks and adjustments must be made.

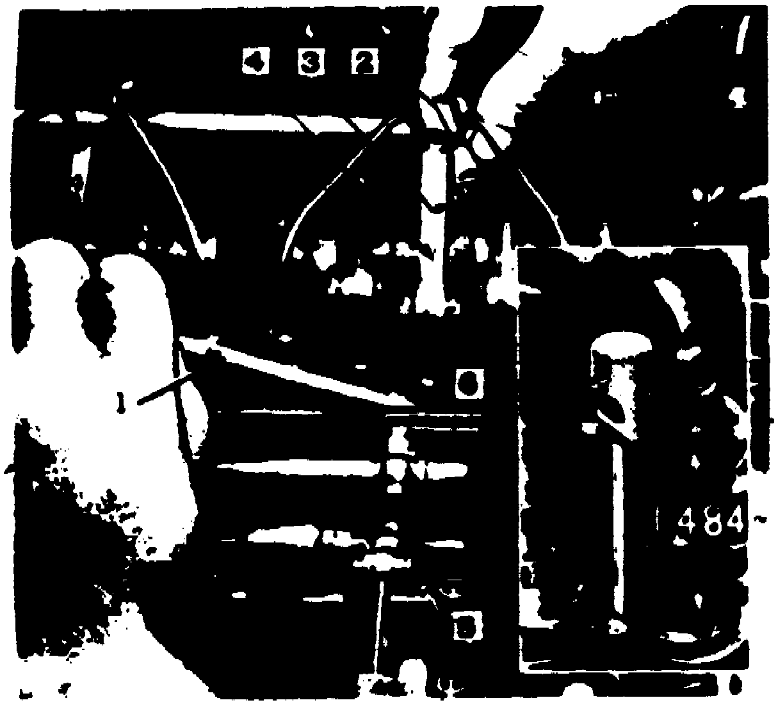
Valve Clearance Adjustment

The valve clearance adjustment is very important. If the correct clearance between the rocker arm and exhaust valve stem is not maintained several troubles could occur such as: loss of compression, misfiring of cylinders, and the eventual burning of the valves and valve seats. Also, since there is very little clearance between the valve and the top of the piston when in a certain position, it is essential that the valves be adjusted properly. Too much clearance results in noisy operation of the engine. The "GO" or "NO-GO" feeler gauge set, figure 23, is used for adjusting valves.

Note: Always refer to the publication pertaining to the engine that you are working on for correct specifications.

Timing the Fuel Injectors

During the time you spent learning about the fuel system and the operation of the diesel engine, the importance of the fuel being injected into the combustion chamber at the correct time was pointed out. In order for the fuel to be injected at the proper time the fuel injectors must be timed. In order for you to properly time the injectors the injector follower guide must be adjusted to a definite height, figure 24. The injector identification was covered in a previous paragraph. It is very important that the timing gauge of the proper height be used. Refer to table 1 for the proper timing tool to be used with various capacity injectors.



1. Wrench—Push rod adjusting
2. Timing Gage J-1242
3. Guide—Injector follower
4. Arm—Injector rocker
5. Injector Body
6. Gage Head

Figure 24. Timing Fuel Injectors Using Proper Tool.

INJECTOR	GAUGE TOOL NO.	TIMING DIMENSIONS
60 mm	J 1242	1.484"
70 mm	J 1853	1.460"
80 mm	J 1853	1.460"

Table 1. Injector Timing Gauge Identification.

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Hydraulic Governor Adjustments

After making the valve clearance adjustments and timing the injectors, the governor adjustments must be checked and adjusted if necessary. The hydraulic governor requires four adjustments. These adjustments are as follows: fuel rod adjustment, maximum fuel (load limit), speed and droop, and maximum speed. The adjustments should be carried out in the order that they are listed above. All of the adjustments, except the maximum speed, are made with the engine stopped. For additional information concerning the procedures for making the adjustments, refer to the worksheet and the applicable technical publication.

Note: The injector rack and control linkage provide a fuel control system by which an equal amount of fuel can be admitted to each cylinder and a minimum to a maximum amount admitted to all cylinders. To do this the entire system must be very accurately adjusted. By the adjustment of two screws on each injector rack a uniform setting of all the injector racks can be made. Because of the interrelationship of the adjustments on the governor and the fuel control system, it is necessary to make all adjustments accurately and in the proper order. The injector racks will be positioned during the time certain adjustments are made on the governor. Make sure that procedures are checked for correct time to set the racks. For further information, refer to the worksheet and the applicable technical publications.

Throttle Control

The throttle control comprises a unique arrangement of rods, levers, and links. This control connects to the throttle knob at the control panel and to the speed adjusting shaft of the governor. The mechanism is connected in the manner it is because of the tension provided by the governor control tension spring.

Two positions, "RUN" and "STOP," are designated on the throttle knob. An arrow shows the correct rotation to attain these positions. Incorporated in the throttle knob is a vernier adjustment. The vernier adjustment provides a fine adjustment for contstant speed which is desirable in governor operation. The vernier adjustment is operated by means of a worm and worm gear.

SUMMARY

The preceding information gives you a brief explanation of diesel engine fuel system service and tuneup. In order for you to accomplish the objective of this lesson it is very important that you thoroughly study this study guide and worksheet.

Note: Always refer to the applicable technical publications or factory manuals for procedures applying to specific engine models. Tuneup and servicing procedures and specifications may vary with different engine models. Tuneup procedures will also be different when the mechanical governor is used.

QUESTIONS

1. It is important that the fuel system control be correctly adjusted. What may be the result of improper adjustment?

2. A unit known as a rack is used on the GMC diesel fuel system. Where is this unit located and what is its purpose?

3. One adjustment of the fuel control system is on the fuel rod. What is the purpose of this rod and where is it located?

4. An adjustment for "speed droop" is sometimes necessary. What is "speed droop"?

5. The limiting speed mechanical governor performs two functions. What are they?

6. What is the principle difference between the limiting speed and the variable speed mechanical governor?

7. On engines using the hydraulic governor, what determines the speed at which the governor will control the engine?

8. Incorrect valve adjustment may affect the engine operation in several different ways. List some of the conditions that may exist from incorrect valve clearances.

9. What is the reason for timing the fuel injectors?

10. How will the overfilling of the air cleaners affect the engine operation?

11. How is crankcase ventilation accomplished on the Series 71 GMC diesel engine?

12. What effect may accumulation of condensation on the air box floor have on the engine operation?

13. What condition usually indicates leaky oil seals in the blower?

MULTIFUEL ENGINE FAMILIARIZATION AND SERVICING

OBJECTIVES

Upon completion of this worksheet you will be able to:

Identify units of the multifuel engine and explain their purpose.

Operate and service the multifuel engine and components.

EQUIPMENT

	Basis of Issue
Multifuel Engine	1/4 students
Mechanic's Tool Set	1/student

PROCEDURE

Using the worksheet as a guide for step-by-step procedures and important information, perform each task as outlined and as directed by the instructor.

Exercise 1

Perform preoperation inspection, start and stop the multifuel engine.

PROCEDURE	IMPORTANT INFORMATION
1. Make a preoperational check of the following:	1. The applicable publication should be consulted for detailed information. In the appropriate space, list items to be checked and answer all of the following questions.
a. Coolant level.	a. Explain any important information concerning the cooling system.
b. Belts.	b. What is the maximum permissible slack? List items that belts are checked for.
c. Crankcase oil level.	c. When should the oil level be checked?
d. Diesel fuel tank.	d. Why should the tank be kept full during storage and between periods of operation?

PROCEDURE	IMPORTANT INFORMATION
e. Battery.	e. What is the battery checked for during the preoperation checks?
f. Visual inspection.	f. What is this inspection primarily concerned with?
2. Start and operate engine.	2. Observe all safety precautions.
a. Position control.	a. Explain position of controls.
b. Start engine.	b. What is maximum time the starter should be operated at one time?
c. Adjust engine speed for warmup period.	c. What engine RPM is desired during this period? How long should this speed be maintained for warmup period? Oil pressure should never be below __________ pounds. Coolant temperature should not exceed __________ in cold weather.
3. Stop engine. Note: Idle engine for a few minutes after a load has been removed.	3. Explain why engine should be idled.

Exercise 2

Identify fuel, starting and lubrication units.

PROCEDURE	IMPORTANT INFORMATION
1. Identify fuel system unit.	1. In the spaces provided, list the unit that make up the fuel system. What type of fuel pump is used? What type injector is used?

PROCEDURE	IMPORTANT INFORMATION
2. Identify units of the engine lubrication system.	2. In the space provided, list the units that make up the lubrication system. Explain the purpose of oil cooler.
3. Identify units of the starting system.	3. In the space provided, list the units that make up the starting system.

Exercise 3

Remove and install the fuel injector pump.

PROCEDURE	IMPORTANT INFORMATION
1. Position engine so that No. 1 charge is on TDC of compression.	1. Refer to applicable publication for detailed information.
2. Remove hydraulic pump from the front of the engine.	2.
3. Remove the two bolts holding the pump bracket to engine block.	3.
4. Remove the two nuts and one bolt holding the pump to the accessory gear housing.	4.
5. Remove pump w/ advance unit.	5.
6. Remove pump bracket.	6.

Exercise 4

Time fuel injector pump.

PROCEDURE	IMPORTANT INFORMATION
1. Remove inspection cover from advance unit to align timer mark with pointer.	1.
2. Align red tooth on plunger drive gear with marker on pump housing.	2.

Exercise 5

Install injector fuel pump by using removal instruction in reverse of items in exercise 3.

Exercise 6

Time cylinder valves.

PROCEDURE	IMPORTANT INFORMATION
1. Place No. 1 cylinder at TDC of compression.	1. Watch pointer and timing mark located on crankshaft pulley.
2. No. 2, adjust following cylinder valves.	2. Rotate crankshaft until No. 1 intake valve is open, then adjust 2, 3, 6 intake valve and 1, 2, 4 exhaust. Rotate crankshaft until No. 6 intake is open, then adjust 1, 4, 5 intake valve and No. 3, 5, 6 exhaust.

MULTIFUEL ENGINE FAMILIARIZATION

OBJECTIVES

Upon completing this unit of instruction, you will be able to locate and identify engine components, describe the operating principles of the multifuel engines, and perform engine tuneup.

INTRODUCTION

The multifuel engine is mechanically the same as the gasoline and diesel engine and the operation is similar to the four-cycle gasoline and diesel engines. It operates on diesel fuel, compression ignition fuel, or gasoline.

INFORMATION

LOCATION OF ENGINE COMPONENTS

In this study guide, the terms defined below will be used to identify the location of engine parts and assemblies.

1. The ends of the engine will be called the "fan end" or "front" and the "flywheel end" or "rear."

2. As viewed from the rear end of the engine toward the front, the side to the right is called the right side. The side to the left is called the left side.

3. The cylinders are referred to as No. 1 through No. 6, viewed from the front of the engine.

4. Starting from the front, the main bearings are numbered 1 through 7.

5. The connecting rods are numbered from the front, 1 through 6, and are identified by matched numbers stamped on the rod and rod cap bosses.

6. Crankshaft rotation is clockwise and camshaft rotation is counterclockwise as viewed from front of the engine.

7. The fuel filter, located at the left rear of the engine has a replaceable element.

8. The two oil filters are located at the left front of the engine and are identical and interchangeable.

9. The two cylinder heads are identical and are interchangeable. The cylinder heads will be referred to as front cylinder head and rear cylinder head in this study guide.

10. The two cylinder head water outlet manifolds are identical and are interchangeable. When mentioned the manifolds will be referred to as the front cylinder head water outlet manifold and the rear cylinder head water outlet manifold.

11. The assembled rocker arms, shaft, and supports are interchangeable. When mentioned, they will be referred to as the front set of rocker arms and the rear set of rocker arms.

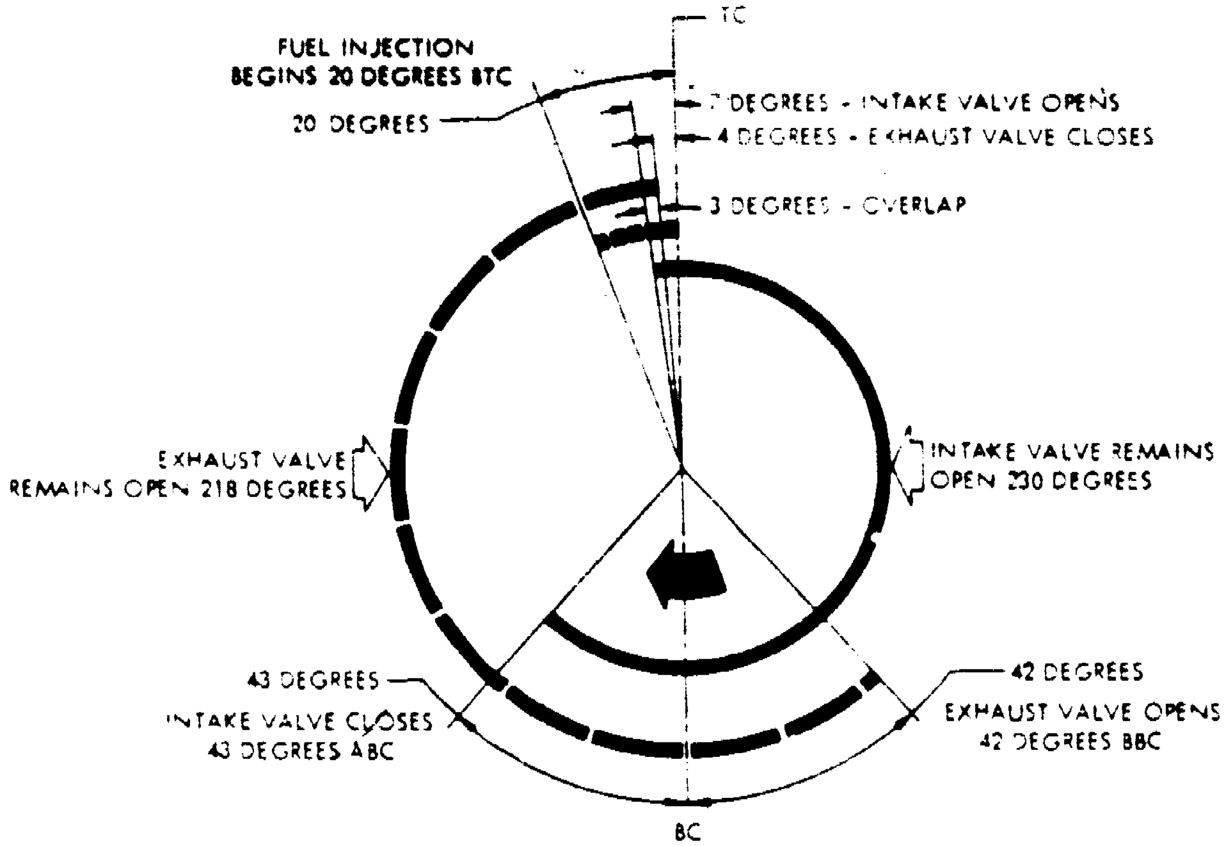

Figure 25. Engine Stroke Cycle and Valve Events.

PRINCIPLE OF OPERATION

The Model LDS-465-1 hypercycle multifuel engine operates on a compression ignition four-cycle diesel principle, figure 25, similar to conventional four-cycle diesel and gasoline engines. A fuel density compensator is provided as a part of the fuel injector pump to automatically maintain constant full power regardless of type or mixtures of fuel being used in the engine. Mechanically this four-cycle compression-ignition engine and the gasoline engine are alike in respect to internal moving parts. The compression ignition principle is explained in the following paragraphs.

Intake Stroke, Figure 26

Air is forced into the cylinder through the open intake valve by atmospheric pressure during cranking, or by the turbocharger during engine operation. The intake passage in the intake manifold and valve port opening are designed to produce an air swirl in the cylinder as air enters the combustion chamber during the intake stroke of the piston.

Compression, Injection, and Power Stroke, Figures 27 Through 29

On the upward movement (compression stroke) of the piston the air swirl continues, raising the compressed air temperature to between 900 and 1000° F. Near the top of the compression stroke, fuel is injected by the fuel injector nozzle. A small amount (five percent) of injected fuel is deposited as a thin film on the walls of the spherical combustion chamber in the head of the piston.

The small amount of fuel charge is atomized into the air space in the spherical combustion chamber in the head of the piston and functions as a spark plug for the remainder of the charge.

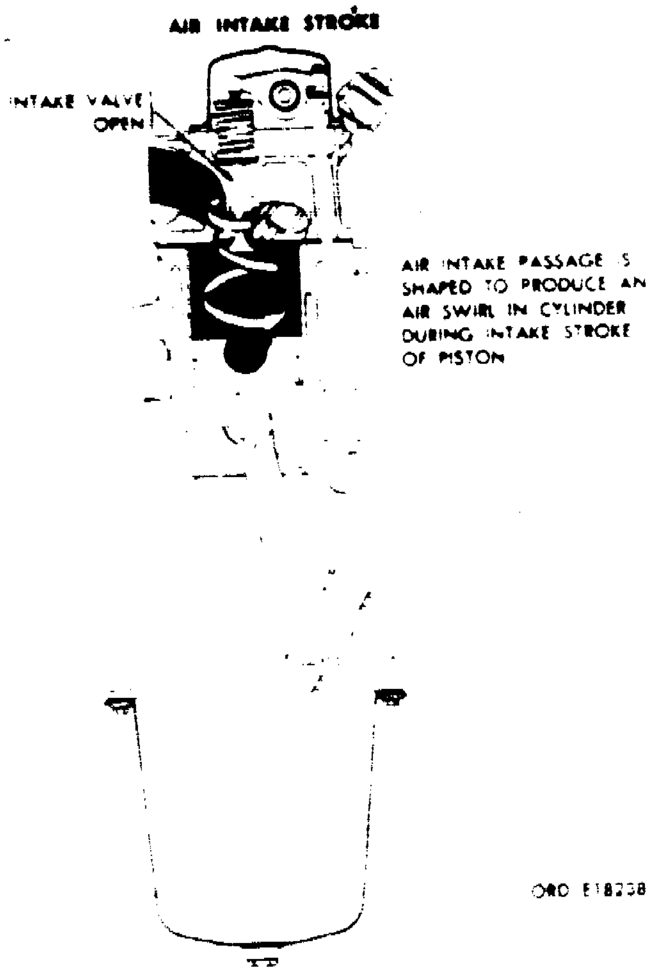

Figure 26. Air Intake Stroke.

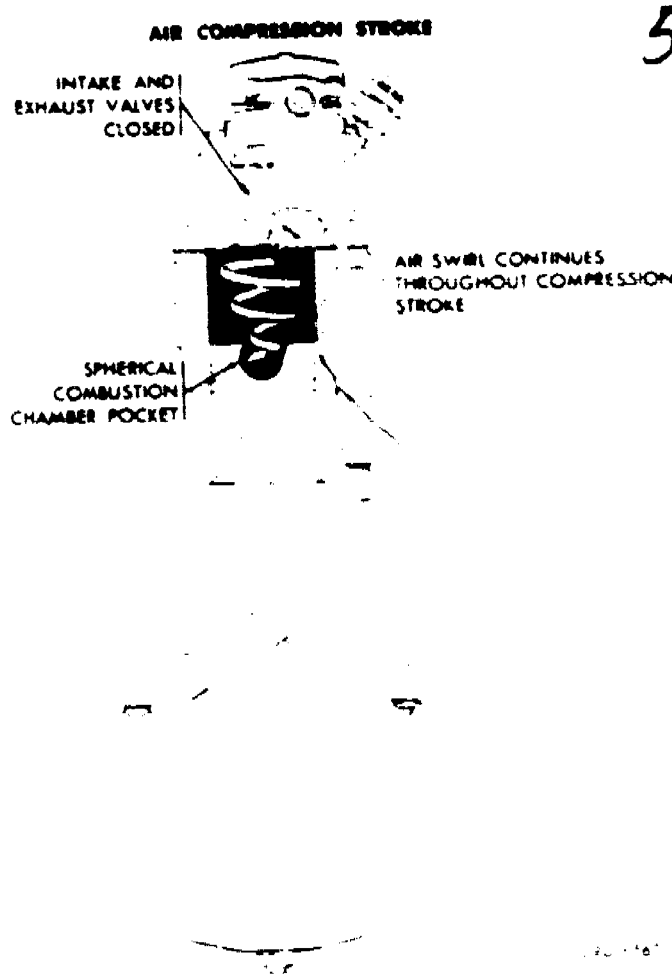

Figure 27. Air Compression Stroke.

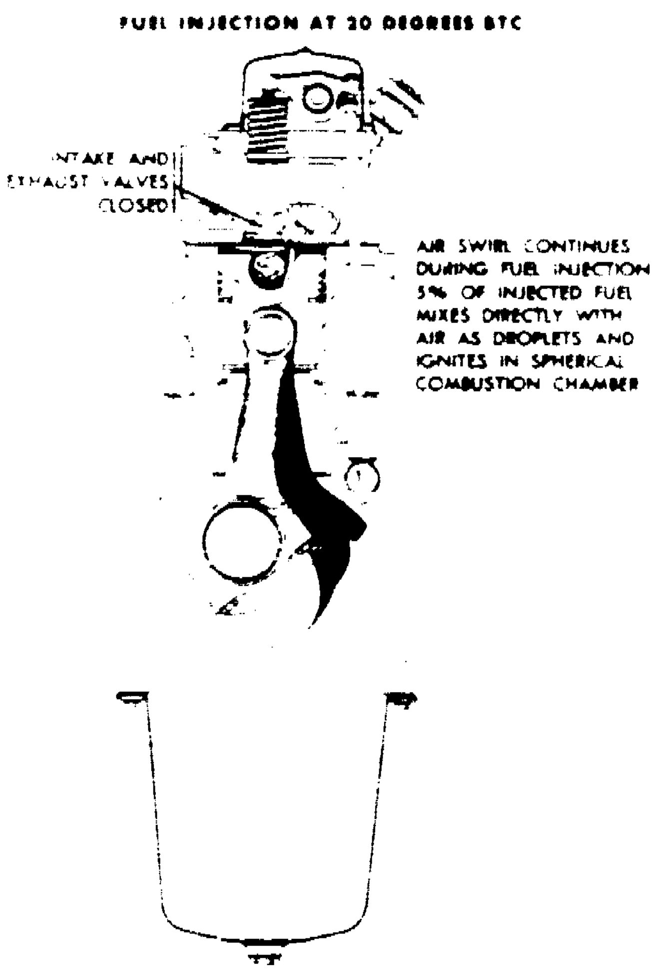

Figure 28. Fuel Injection into Cylinder.

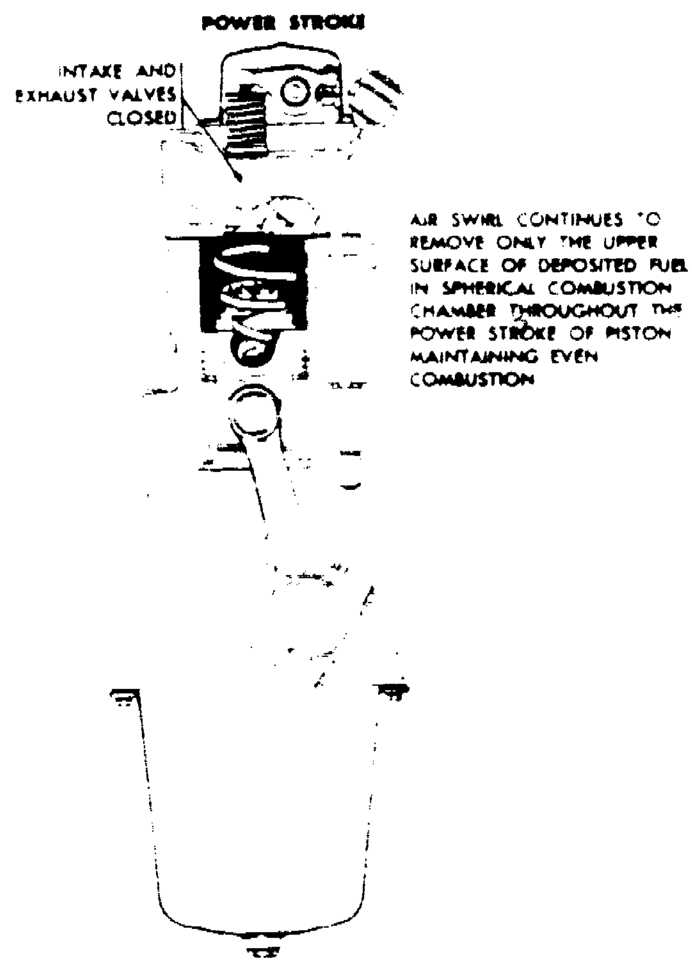

Figure 29. Power Stroke.

During the ignition delay period, the main portion of the charge is exposed to a temperature below its cracking temperature and is undergoing precombustion reactions.

The main portion of the charge is progressively vaporized and swept off the combustion chamber wall by the high velocity rotary air swirl. The air swirl was generated during the intake stroke. The vaporized fuel burns smoothly in the spherical combustion chamber as the fuel is swept by the air swirl from the wall progressively over a period of time.

The following successive portions of fuel also undergo the same sequence of events as they are spread first upon the spherical combustion wall and then gradually removed in vaporized form by the combined action of air swirl and the heat of the fire already in progress in the spherical combustion chamber. The air swirl continues to remove only the upper surface of deposited fuel for combustion expansion throughout the power stroke of the piston, maintaining even combustion and eliminating detonation knock.

Exhaust Stroke, Figure 30

The exhaust stroke is the same as the similar stroke in conventional diesel engines. The piston is pushed up through the cylinder by the crankshaft. The exhaust gases in the cylinder are forced out through the exhaust valve port, which is timed to open on the exhaust stroke.

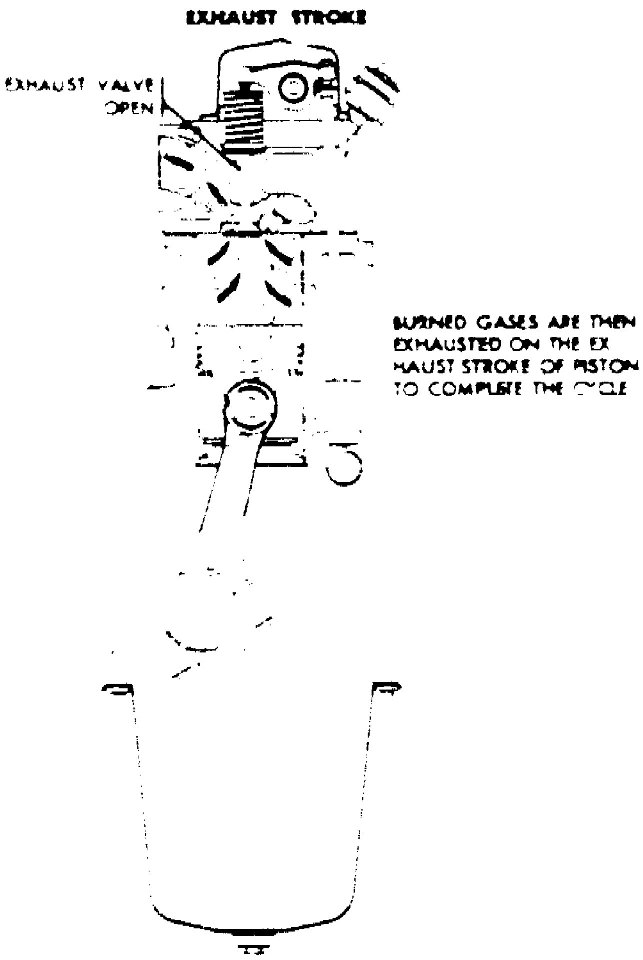

Figure 30. Exhaust Stroke.

GENERAL INFORMATION

The Model LDS-465-1 engine is a four-cycle, in-line, six-cylinder, overhead-valve, turbocharged, liquid cooled compression-ignition engine rated at 210 horsepower at 2600 rpm.

The engine will operate successfully on diesel fuel (VV-F-800), compression ignition fuel (MIL-F-46[illegible]), or regular gasoline (MIL-G-3056A). No modifications or adjustment are necessary when changing grades of fuel.

Engine Accessories

A 24-volt, 25-ampere, direct current generator is located at the right front of the engine. A 24-volt, solenoid operated starter, located at the left rear of the engine, provides power to start the engine.

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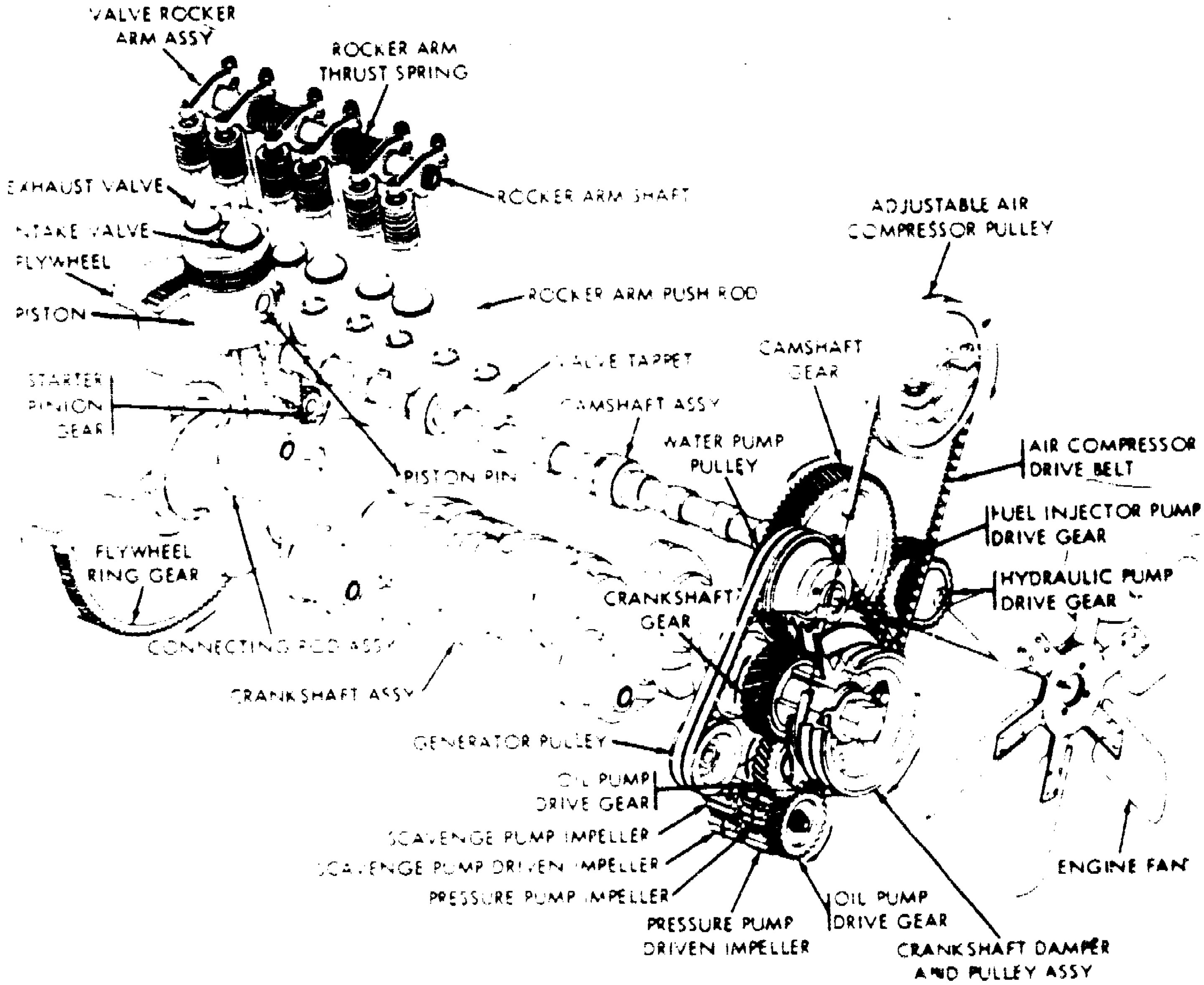

Figure 31. Engine Gear Train.

Cylinder and Crankcase

The cast iron cylinder and crankcase (cylinder block) is of a six-cylinder, in-line design. The cylinder and crankcase have replaceable "dry" cast iron cylinder sleeves which are slip fitted in the cylinder bores. The cylinder head secures the sleeves in the bores of the crankcase. Maximum rigidity for the crankcase is provided by extending the sides of the crankcase below the center line of the crankshaft. Seven main bearing caps provide maximum support for the crankshaft by being recessed into the transverse webs which are cast integrally with the crankcase. The seven main bearing caps are an integral part of the cylinder and crankcase. The cast water jacket provides a uniform transfer of heat to the engine coolant.

Crankshaft Assembly, Figure 31

The crankshaft assembly is a one-piece unit of forged and hardened steel. One end has a flange for mounting the flywheel. The other end has a machined hub with a key slot to mount the crankshaft gear and crankshaft torsional vibration damper and pulley assembly. All crankpin journals are hollow to reduce weight. Holes are drilled diagonally through each main bearing journal and extend through the crank cheek to the no-load side of the crankpin journals

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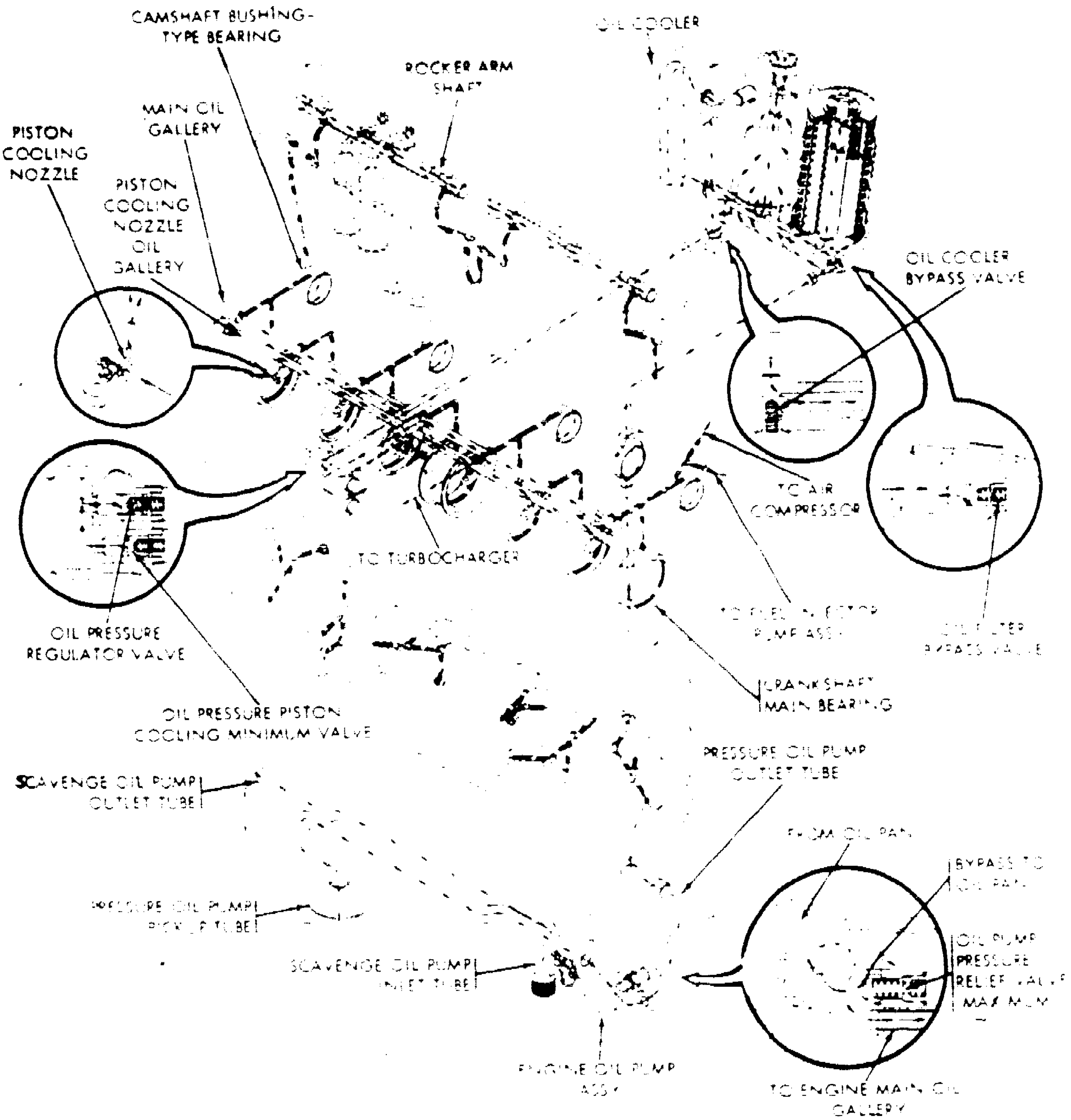

Figure 32. Engine Lubrication System Diagram.

to provide a direct passage for pressurized oil to the connecting rod and crankshaft main bearings. The crankshaft is dynamically balanced.

Main Bearings, Figure 33

The seven main bearings are split, precision type and are steel backed with copper-lead alloy bearing surfaces. The upper half of each main bearing has an oil passage. The center main bearing is double flanged to control crankshaft thrust and end play.

Connecting Rods, Figure 31

The six connecting rods are tapered, I-beam section, steel forgings. The connecting rod bearing caps are joined to the connecting rod at a 45-degree angle to facilitate removal of the piston and connecting rod assemblies through the top of the crankcase cylinder bores. The connecting rods and caps are marked for identification and are replaced only as an assembly. A bronze lined, steel-backed, bushing-type bearing is pressed into the piston pin end of connecting rod. The bushing is diamond bored for precision piston pin fit.

Pistons and Piston Pins, Figure 31

The tin-plated, aluminum-alloy forged pistons are cam-ground to provide an accurate fit in the cylinder bore at operating temperatures. A spherical shaped combustion chamber, figure 27, is machined in the dome of the piston. Each piston accommodates three compression rings and one oil control ring. The piston pins are hollow and are hardened steel to give long service life. The piston pins are held in the piston pin boss by a retaining ring at each end of the pin.

Camshaft Assembly and Bushing-Type Bearings

The camshaft assembly, figure 31, is solid and made of forged steel. The camshaft is supported in the cylinder and crankcase by four steel-backed, copper-alloy, replaceable bushing-type bearings, figure 22. A thrust plate located between the camshaft gear and crankcase is used to control camshaft end play.

Tappets and Push Rods

The 12 tappets, figure 31, are solid and are counterbored to accept the push rods. The bottom of the counterbore is machined to serve as a bearing surface for the pus rods. The tappets are drilled to allow oil drainage. The 12 push rods are tubular with the lower end machine to fit the bearing surface of the tappet. The upper end of the push rod is machined to fit the valve rocker arm adjusting screw bearing surface.

Crankshaft and Camshaft Gears

The steel helical crankshaft gear, figure 31, is pressed on and keyed to the front of the crankshaft. The crankshaft gear drives the camshaft gear. The steel helical camshaft gear is keyed to the end of the camshaft. Two teeth on the camshaft gear and one tooth on the crankshaft gear are punch marked for proper valve timing alignment.

Crankshaft Vibration Damper and Pulley Assembly

The molded rubber-type crankshaft torsional vibration damper and pulley assembly, figure 31, is mounted on the front end of the crankshaft. The triple pulley drives the water pump, generator, and air compressor.

Cylinder Heads

The two cylinder heads are identical and interchangeable as assemblies. They incorporate the overhead valve arrangement. The cast iron heads have replaceable valve guides and valve seats. Each cylinder head covers three cylinder bores and has intake and exhaust valve port openings. The intake port openings in the heads are so designed that an air swirl is created as air enters the combustion chamber. Each cylinder head has openings for the cylinder head water outlet manifolds.

Valves and Valve Springs

The six intake and exhaust valves, figure 31, are constructed of a special steel. Each valve has an outer and inner valve spring and a positive valve rotor. The valve springs are secured in position with a retainer and two keys.

Rocker Arm Shafts and Supports

The two rocker arm shafts, figure 31, are constructed of heat-treated seamless or welded steel tubing. The rocker arm shafts are secured to the two cylinder heads by rocker arm shaft supports. The supports are interchangeable and are drilled to permit oil from the oil pressure pump to pass through to the rocker arm shafts. The shafts are also drilled to distribute oil to the individual rocker arms.

Valve Rocker Arms

The twelve rocker arms, figure 31, are hot-rolled, heat-treated, carbon steel stampings. The steel-backed, bronze-faced, rocker arm bushings are not replaceable. Adjusting screws at the push rod end of each rocker arm permit maintenance of proper clearance in the valve train.

Intake Manifold

The one piece cast aluminum intake manifold is water jacketed. Coolant is circulated through the jacket, and heat thus transferred to the induction air improves the cold weather combustion characteristics of the engine. The thermostat housing is secured to the front flange of the manifold. The intake manifold also houses the water temperature sending unit.

Exhaust Manifold

The exhaust manifold consists of three cast iron sections. The two end sections are joined to the center section by slip joints. To prevent exhaust leaks at these joints, three metal seal rings are used at each center section end.

Cylinder Head Water Outlet Manifolds

The two aluminum cylinder head water outlet manifolds are secured to the two cylinder heads by capscrews and gaskets and are connected to the water jacketed intake manifold by rubber hoses and clamps.

Crankcase Breather Tube

The cylinder head assemblies and crankcase are vented through an adapter and crankcase breather tube. The adapter is located on top of the front and rear cylinder head covers. The crankcase breather tube is attached to the adapter by a rubber hose and clamps and the open end is secured at the turbocharger oil outlet flange.

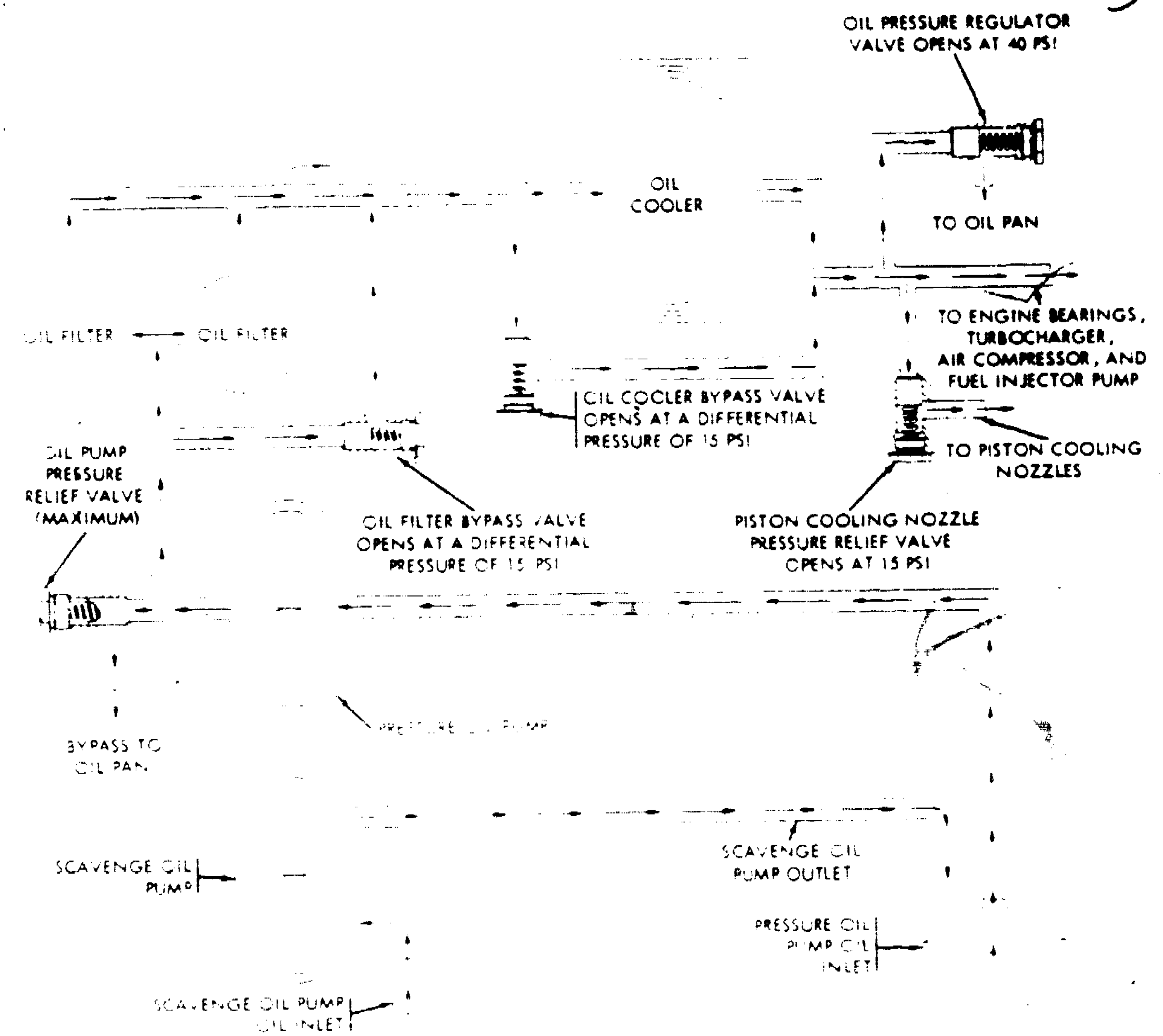

Figure 33. Engine Oil Flow Circuit Diagram.

Lubrication System

The engine has a full-pressure lubricating System, figure 32. The pressure system insures a continuous delivery of oil to all engine moving parts regardless of the angle at which the vehicle may be inclined. The oil flow control is shown on figure 33.

OIL PUMP. The oil pump is a dual unit consisting of a scavenge pump and a pressure pump. The oil pump is gear driven by the crankshaft gear through an oil pump idler gear which is mounted on a shaft extending from the No. 1 main bearing cap. The pressure oil pump picks up oil from the oil reservoir at the rear of the oil pan through a pickup tube and delivers it under pressure to the oil filters, oil cooler, and engine oil galleries. The scavenge oil pump picks up oil from the front of the oil pan via a pickup tube and spills oil back into the rear reservoir.

OIL FILTERS. The engine has two replaceable element-type oil filters, figure 33. Both oil filters are identical and interchangeable. The dual unit filters are mounted on the oil cooler and oil filter housing assembly at the left side of the engine. Pressurized lubricating oil is forced through the filters before entering the oil cooler and engine lubricating system. An oil filter bypass valve is located below the front oil filter. This valve routes oil directly to the oil cooler if the oil filters become clogged. The bypass valve opens at a differential pressure of 15 psi.

OIL PAN. The stamped steel oil pan has a small sump at the front and a large sump at the rear. Each sump is provided with a magnetic drain plug.

OIL COOLER. The oil cooler is located at the rear of the oil cooler and oil filter housing assembly. The jacketed oil cooler performs two functions: to transfer heat to speed warmup of lubricating oil during cold starts, and to maintain lubricating oil temperature at a normal operating level during normal engine operation. The oil cooler bypass valve opens at a pressure differential of 15 psi if the oil cooler becomes clogged, routing the oil directly to the engine oil galleries.

BEARING LUBRICATION, FIGURE 32. The crankshaft and connecting rod split-type bearings, and the camshaft bushing-type bearings are lubricated from drilled passages in the cylinder and crankcase and through the crankshaft journals and cheeks. Oil under pressure from the oil filters and oil cooler enters the main oil gallery in the cylinder and crankcase. Oil flows from the oil gallery through oil passages to the crankshaft main bearings and camshaft bushing-type bearings. Oil lubricating the crankshaft main bearings flows around the bearings to the drilled oil passages in the crankshaft journals and cheeks and to the connecting rod bearings. Excess oil leaving the bearings flows back to the oil pan to be recirculated. The valve rocker arm bearings and other components of the valve train are lubricated with oil fed through a passage leading from the rear camshaft bearing.

PISTON COOLING NOZZLE ASSEMBLIES. [illegible] engine operation depends upon proper piston operating temperature. Oil to cool the pistons is conveyed through an individual oil gallery and directed to the inside of the piston skirts by six cooling nozzle assemblies. [illegible] is controlled by a 15 psi minimum pressure control valve.

FUEL INJECTOR PUMP LUBRICATION. The fuel injector pump is lubricated by the engine oil system. Oil is directed from the main oil gallery to an external flexible hose connected to the fuel injector pump advance unit housing. Refer to TM 9-2910-226-35 for complete description of fuel injector pump lubricating system. Oil leaving the injector pump returns to the engine oil pan through passages in the injector pump advance unit and an external hose from the bottom of governor body to the oil pan. The injector pump driven gear, figure [illegible], is lubricated by oil splashed on the gear by the camshaft gear.

TURBOCHARGER, LUBRICATION. The turbocharger is lubricated by the engine oil from the main oil gallery through an external tube. Oil from the turbocharger is returned to the oil pan. Refer to TM [illegible] for a detailed description of turbocharger lubrication.

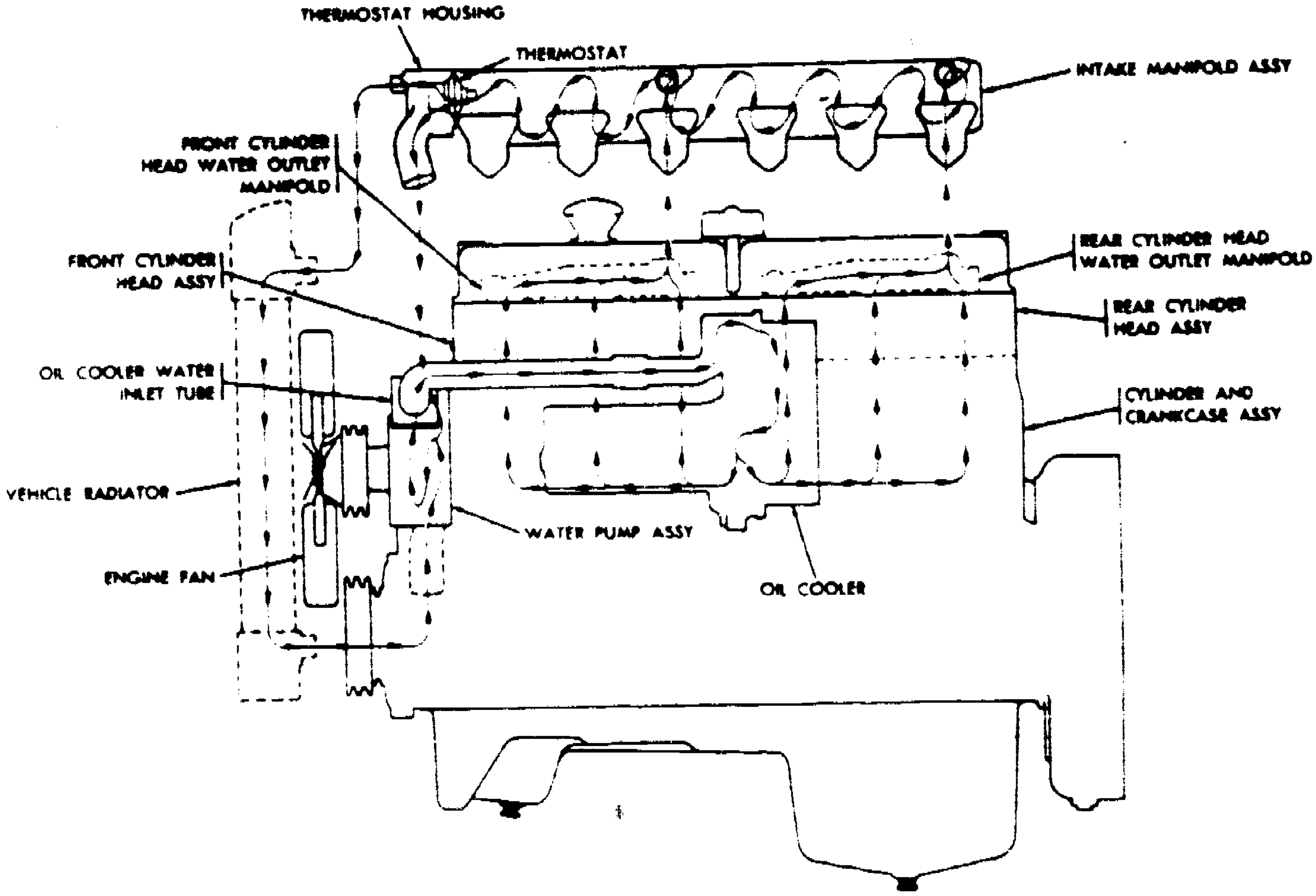

Figure 34. Engine Cooling System Diagram.

Cooling System

The engine is liquid cooled, figure 34. Coolant is circulated throughout the engine cooling system by the belt-driven water pump assembly. Temperature of the coolant is controlled by the thermostat. Front and rear cylinder head water outlet manifolds maintain an equal distribution of coolant around each cylinder head.

WATER PUMP ASSEMBLY. The water pump assembly is mounted on the front of the cylinder and crankcase. The pump is belt driven from the crankshaft damper and pulley assembly. The impeller drive shaft rotates in a sealed double ball bearing housing, and does not require periodic lubrication. The double water pump pulley is pressed on the water pump shaft. The water pump has a bypass connection which allows coolant from the thermostat housing to enter for re-circulation. Coolant bypasses the radiator when the thermostat is closed during engine warmup.

FAN, FIGURES 31 AND 34. The fan has six blades and is attached to the water pump pulley. It provides proper air circulation through the vehicle radiator.

THERMOSTAT. Control of coolant flow from the heated engine to the radiator is maintained by a thermostat installed in a housing at the front of the intake manifold. The thermostat is set to open at 180° F. This closes off the bypass to the water pump.

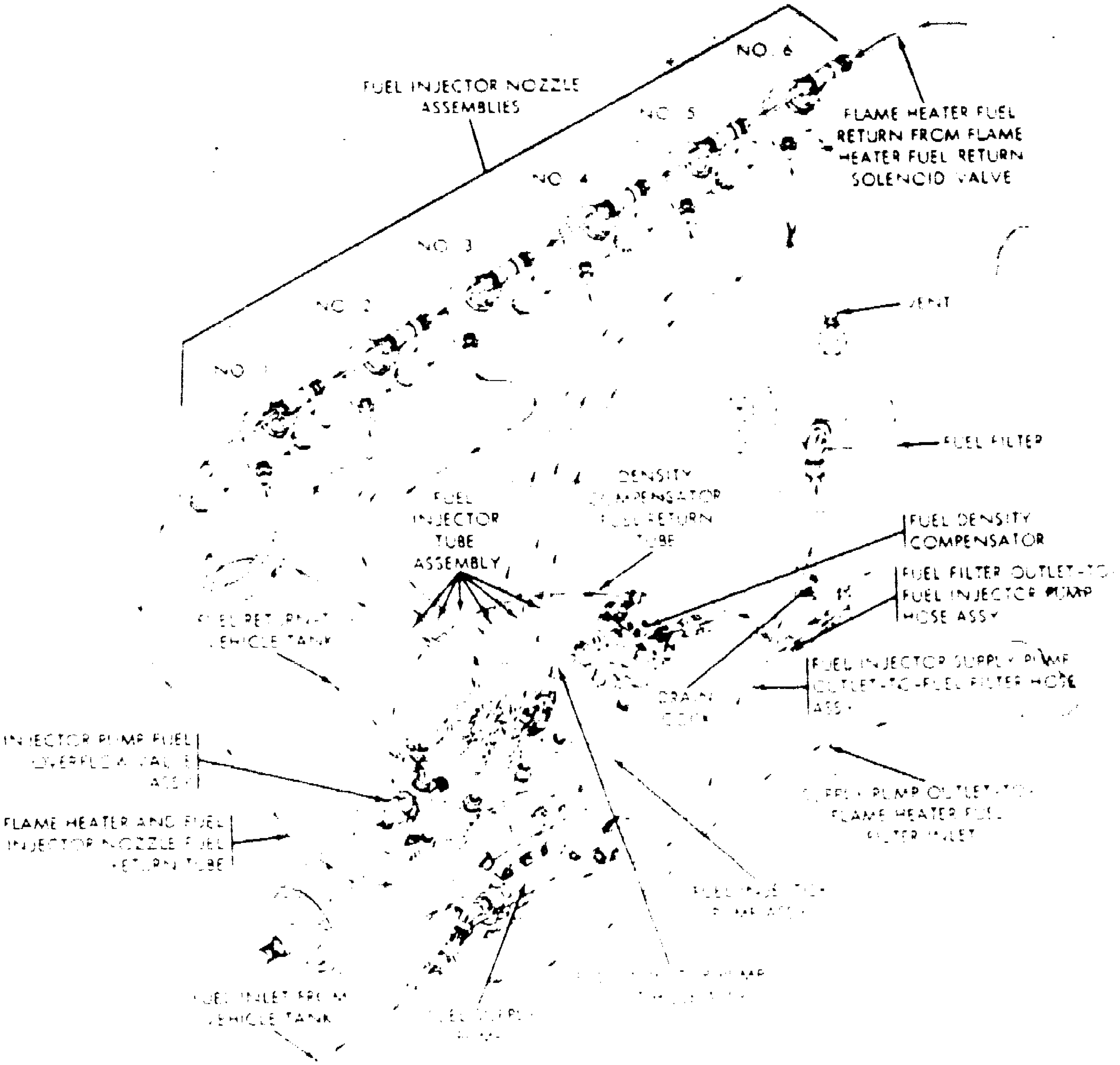

Figure 35. Engine Fuel System Diagram.

Fuel System

The fuel system on this engine, figure 35, allows the engine to operate on various types and grades of fuel without adjusting the fuel injector pump.

FUEL SUPPLY PUMP. The fuel supply pump is part of the fuel injector pump assembly. The supply pump takes fuel from the vehicle fuel tank and delivers it under pressure to the flame heater fuel system filter and pump and to the engine fuel filter and fuel injector pump.

FUEL FILTER. The engine fuel filter is located at the left rear of the engine and has a replaceable element. Dirt is the primary cause of fuel injection system malfunctions. The fuel filter must be properly serviced, and the fuel lines between the fuel filter and fuel injector pump should not be disconnected unless absolutely necessary.

FUEL INJECTOR PUMP ASSEMBLY. The fuel injector pump assembly is driven by the fuel injector pump driven gear which in turn is driven by the camshaft gear, figure 31. The single plunger distributor type pump is used to supply pressurized fuel to each individual fuel injector nozzle and holder assembly in firing order sequence. The fuel injector pump advance unit automatically provides a gradual 8 degrees advance of fuel injection timing over the engine speed range. A fuel density compensator on the pump automatically maintains constant full power fuel flow regardless of the type or mixtures of fuel being used in the engine. For complete description, data, and maintenance of this pump, refer to TM 9-2910-226-35.

FUEL INJECTOR NOZZLE AND HOLDER ASSEMBLIES. The six fuel injector nozzle and holder assemblies are used to inject fuel into the combustion chambers, figure 28. The injector nozzle and holder assemblies are sealed against leakage by copper gaskets. The fuel injector nozzle and holder assemblies are interconnected by fuel return tubes to return excess fuel to the fuel tank. The nozzle and holder assemblies are adjustable to provide the proper opening pressure and spray pattern for economical engine operation and proper performance. Each assembly can be replaced without removing the valve rocker covers.

FUEL HOSES AND TUBES. The fuel supply pump-to-fuel filter inlet hose and the fuel injector pump inlet hose are the flexible rubber composition type. The six fuel injector tubes are subjected to high fuel pressure during operation. These tubes are all ~~the~~ same length, and are fabricated from soft annealed steel tubing, and convey fuel from the fuel injector pump head to each individual fuel injector nozzle and holder assembly. The fuel injector nozzle holder fuel return and fuel overflow tubes are made of plastic tubing.

Intake Manifold Flame Heater and Fuel System

The engine is equipped with a flame type manifold heater, figure 36, for heating the induction air during cold weather starting and warmup operation.

FLAME HEATER ASSEMBLY. The flame heater assembly is composed of a housing, spark plug, and spray nozzle and holder assembly. The spark plug is energized by the flame heater ignition unit, or coil, which is mounted on the intake manifold elbow. The nozzle sprays fuel under pressure into the intake manifold elbow assembly. The fuel vapor is ignited by the spark plug and burns in the intake manifold, heating the air before it enters the engine combustion chambers. The flame heater will operate on all fuels specified for the engine, therefore, fuel is drawn directly from the vehicle fuel tanks.

FLAME HEATER FUEL PUMP ASSEMBLY. The flame heater fuel pump assembly is mounted on a bracket near the lower right front of the engine. The fuel pump is rotary type driven by an inclosed electric motor. The pump is capable of pumping 3.5 gallons of fuel per hour at a pressure of 90 psi. The pump receives fuel from the vehicle fuel tank, through the fuel supply pump and delivers it to the flame heater spray nozzle and holder assembly. The fuel pump is energized by an on-off switch located on the vehicle instrument panel.

FLAME HEATER FUEL FILTER ASSEMBLY. The flame heater fuel filter assembly is mounted on the same bracket as the flame heater fuel pump.

FLAME HEATER SOLENOID VALVES. Two flame heater fuel solenoid valves, figure 36, are used in the flame heater system. The valves, identical and

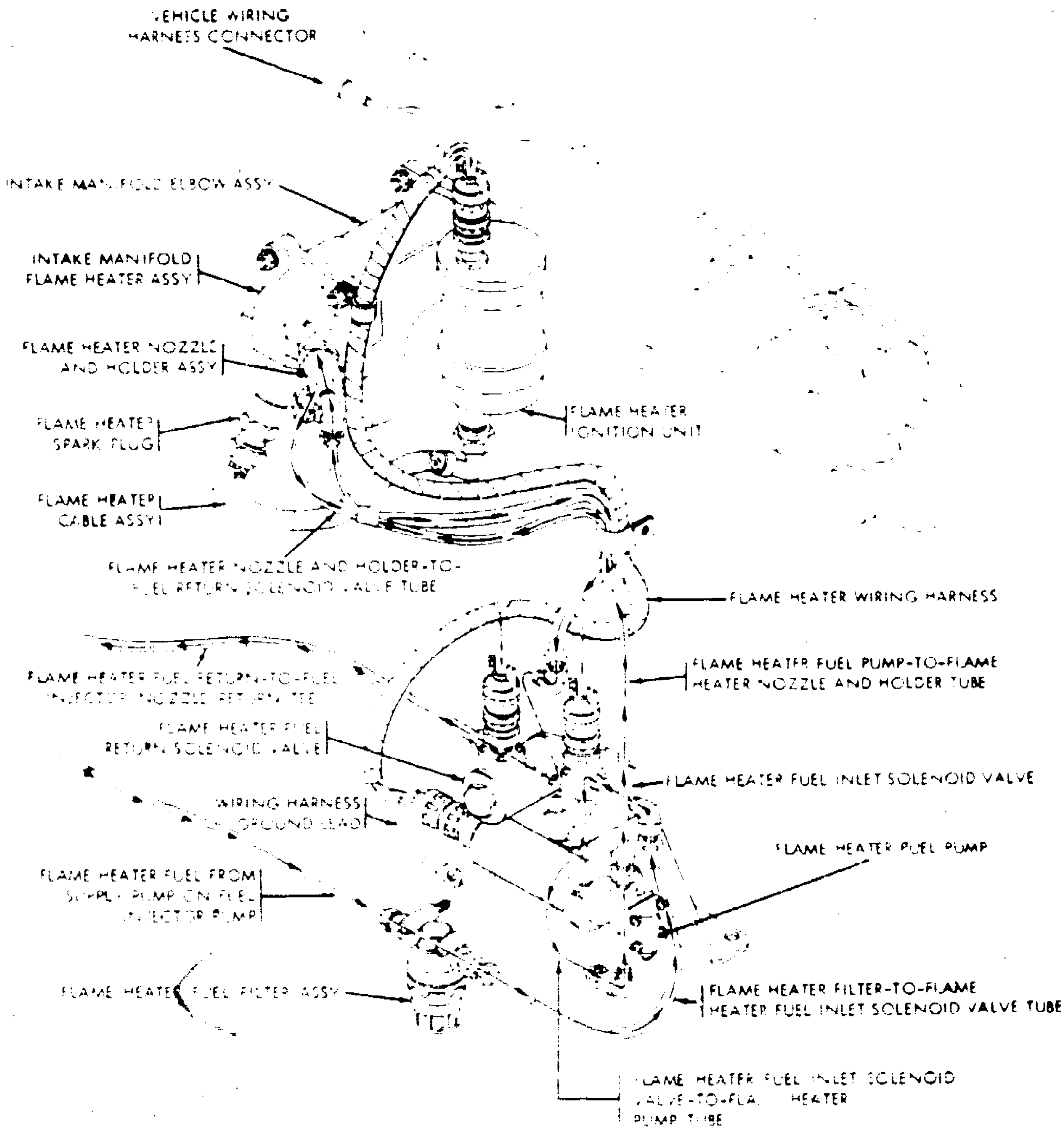

Figure 36. Engine Flame Heater Fuel System Diagram.

interchangeable, are energized (opened) whenever the flame heater assembly and flame heater fuel pump are actuated. These valves insure that fuel is delivered only when the system is actuated, and they stop the flow of fuel the instant flame heater actuation is discontinued.

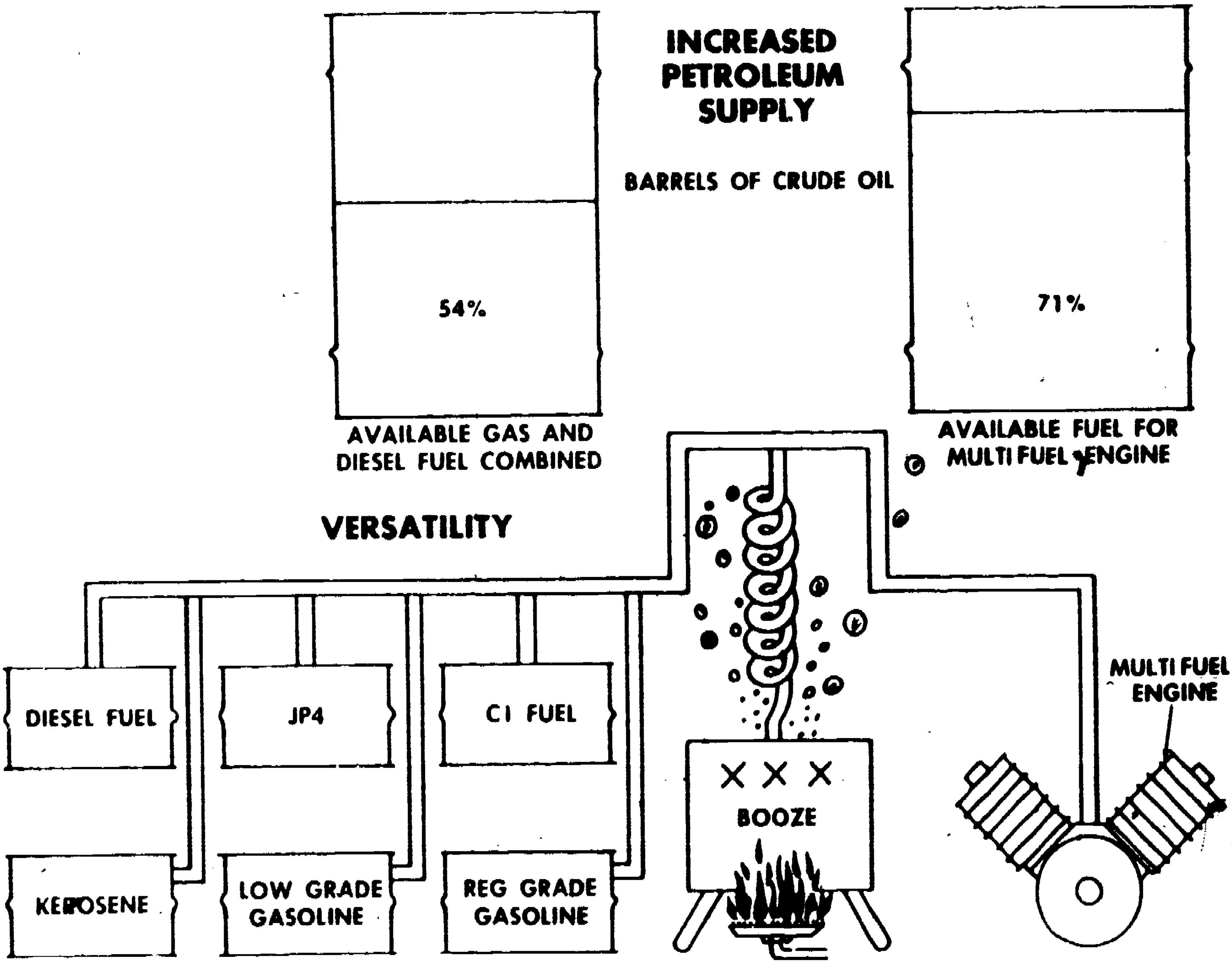

Figure 17. Advantages of Multifuel Compression Ignition Engines.

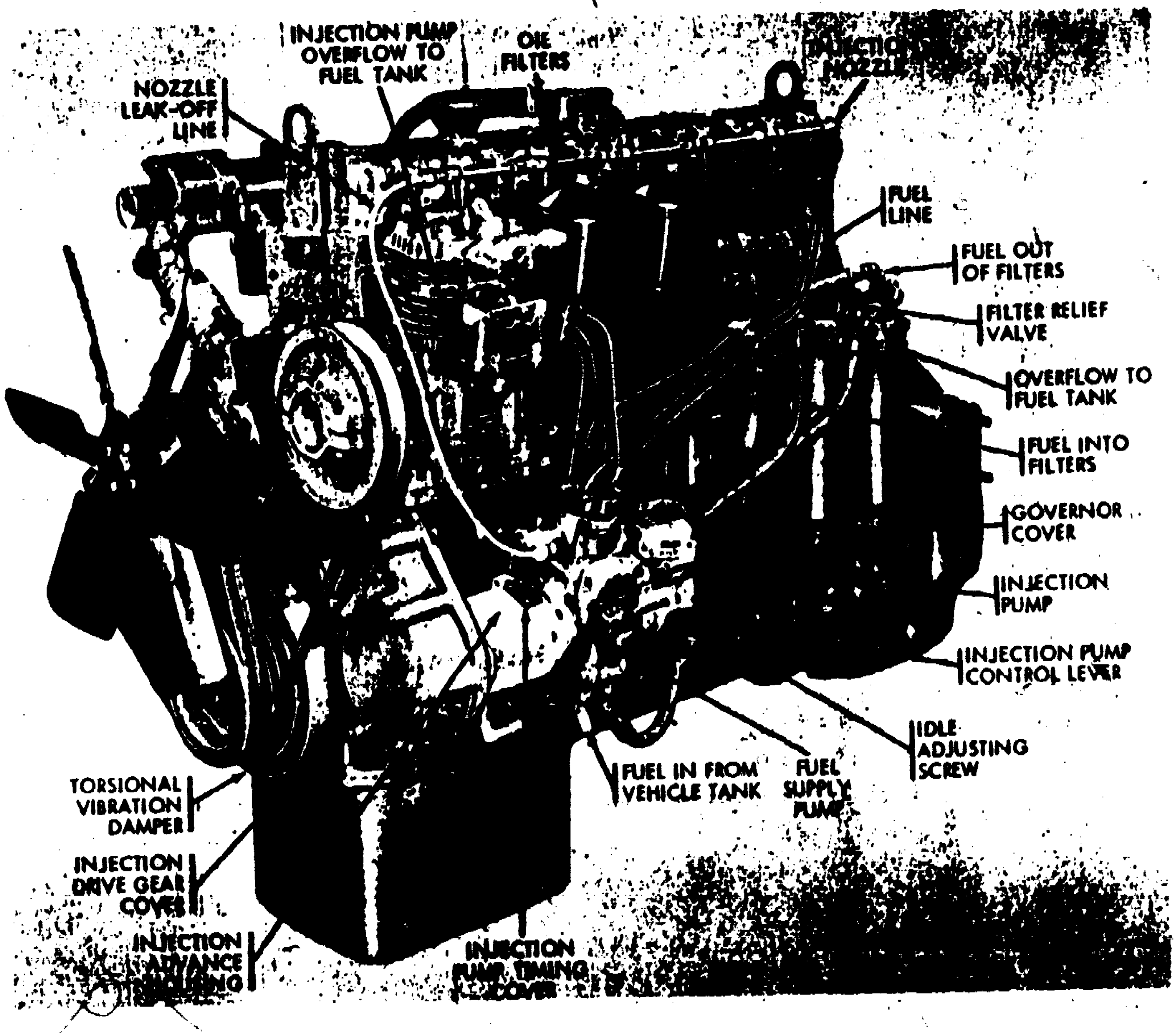

Figure 38. Left Fan End View LDS-465-1 Multifuel Engine.

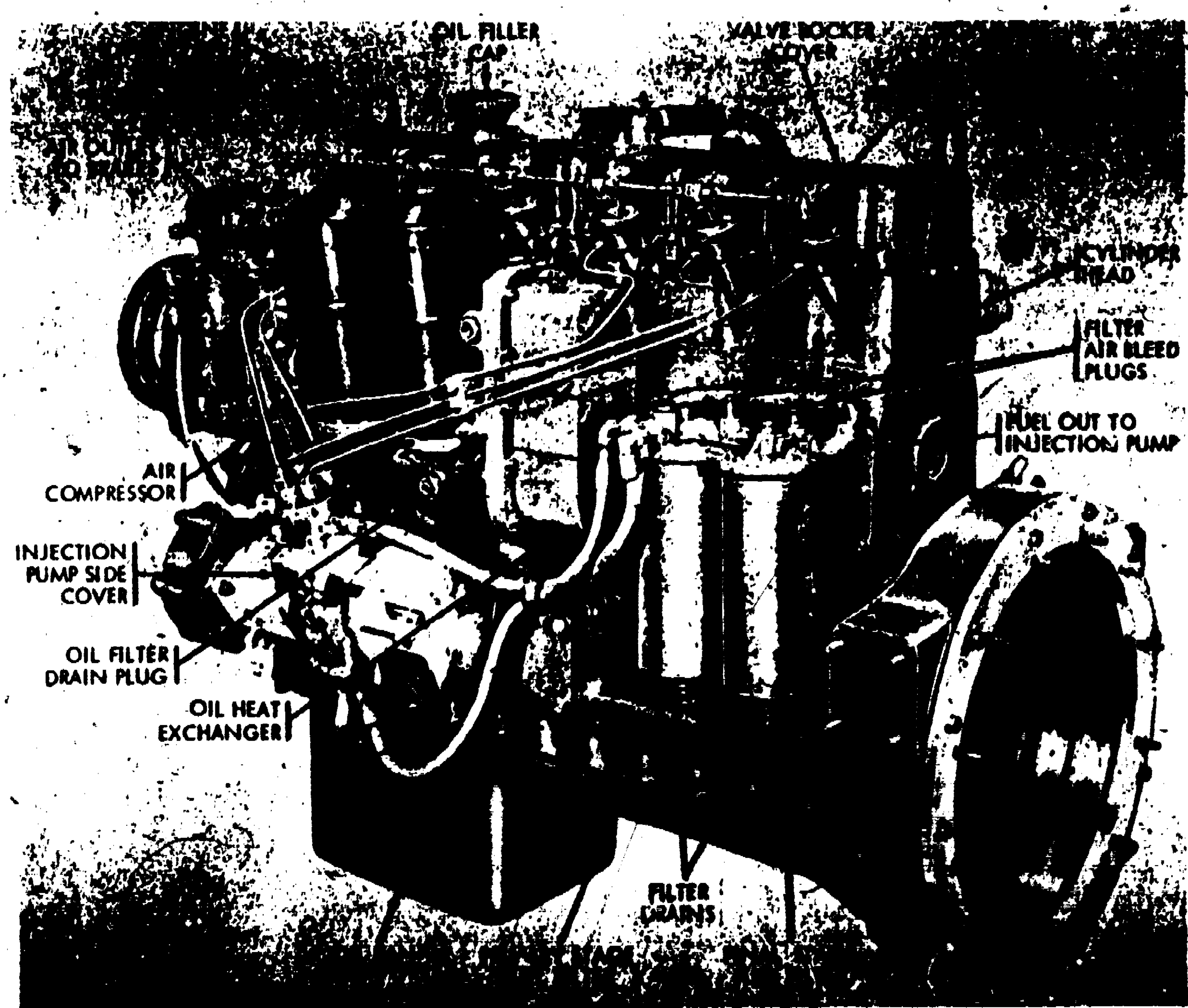

Figure 39. Left Flywheel End View LDS-465-1 Multifuel Engine.

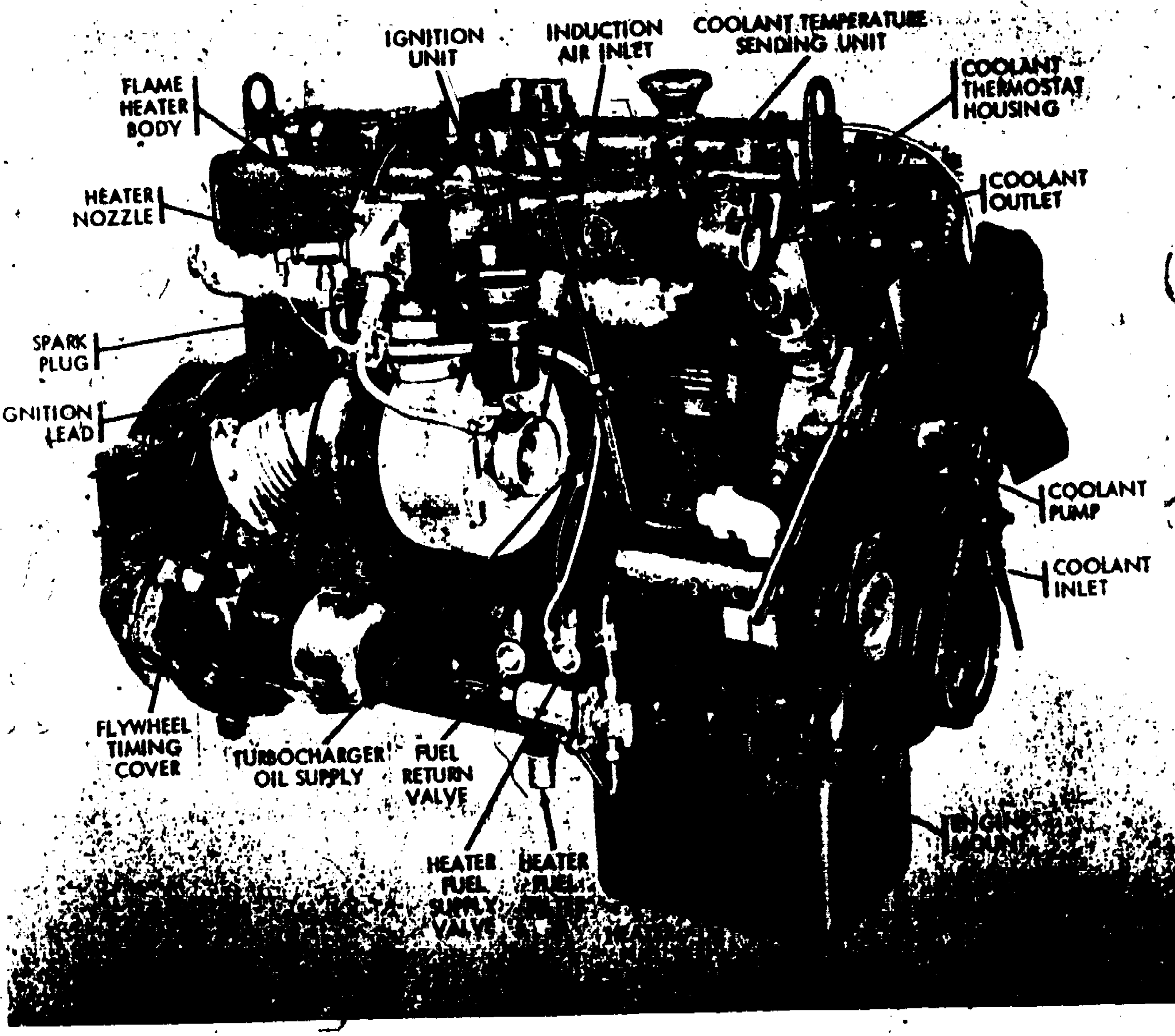

Figure 40. Right Fan End View LDS-465-1 Multifuel Engine.

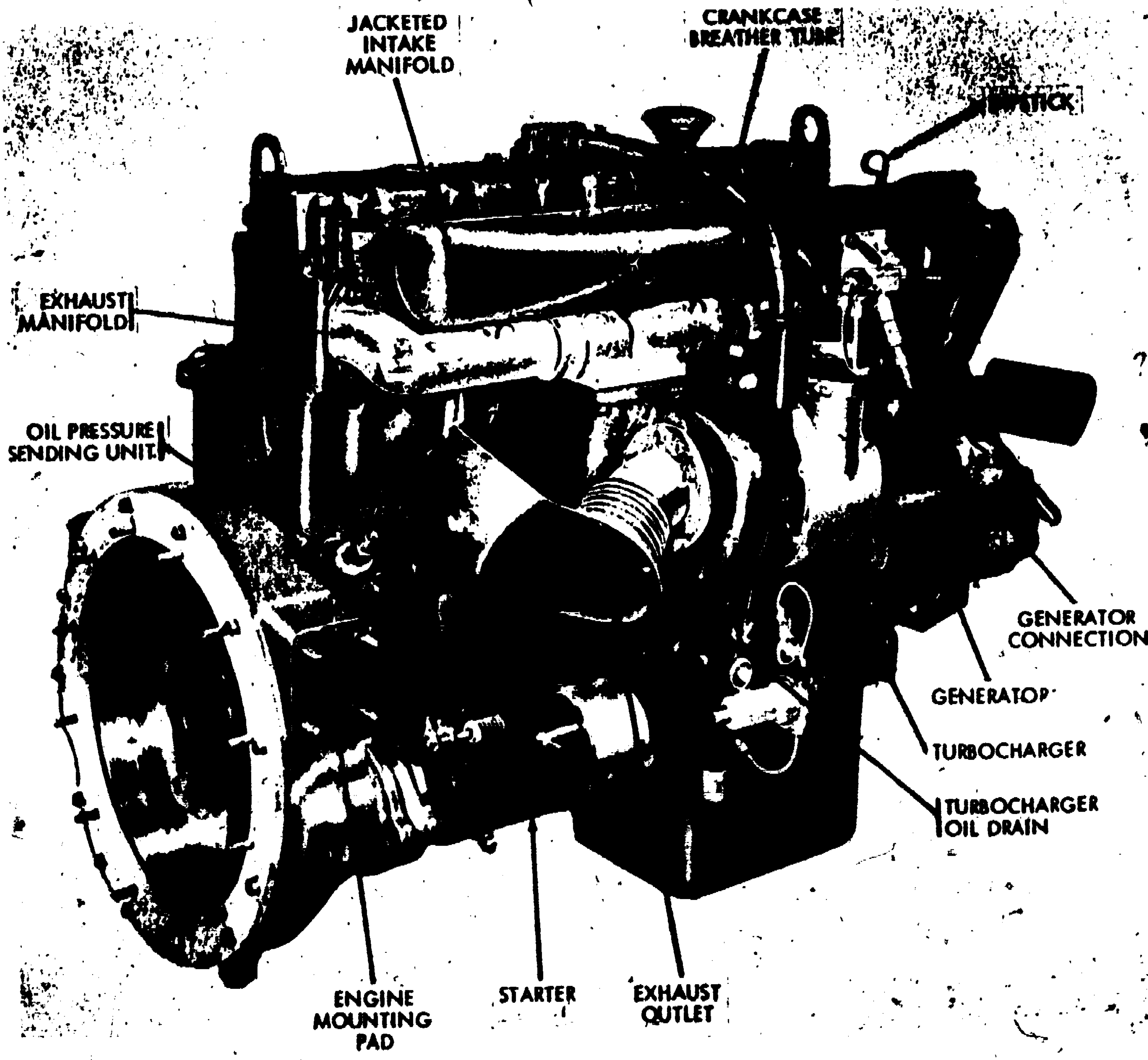

Figure 41. Right Flywheel End View LDS-465-1 Multifuel Engine.

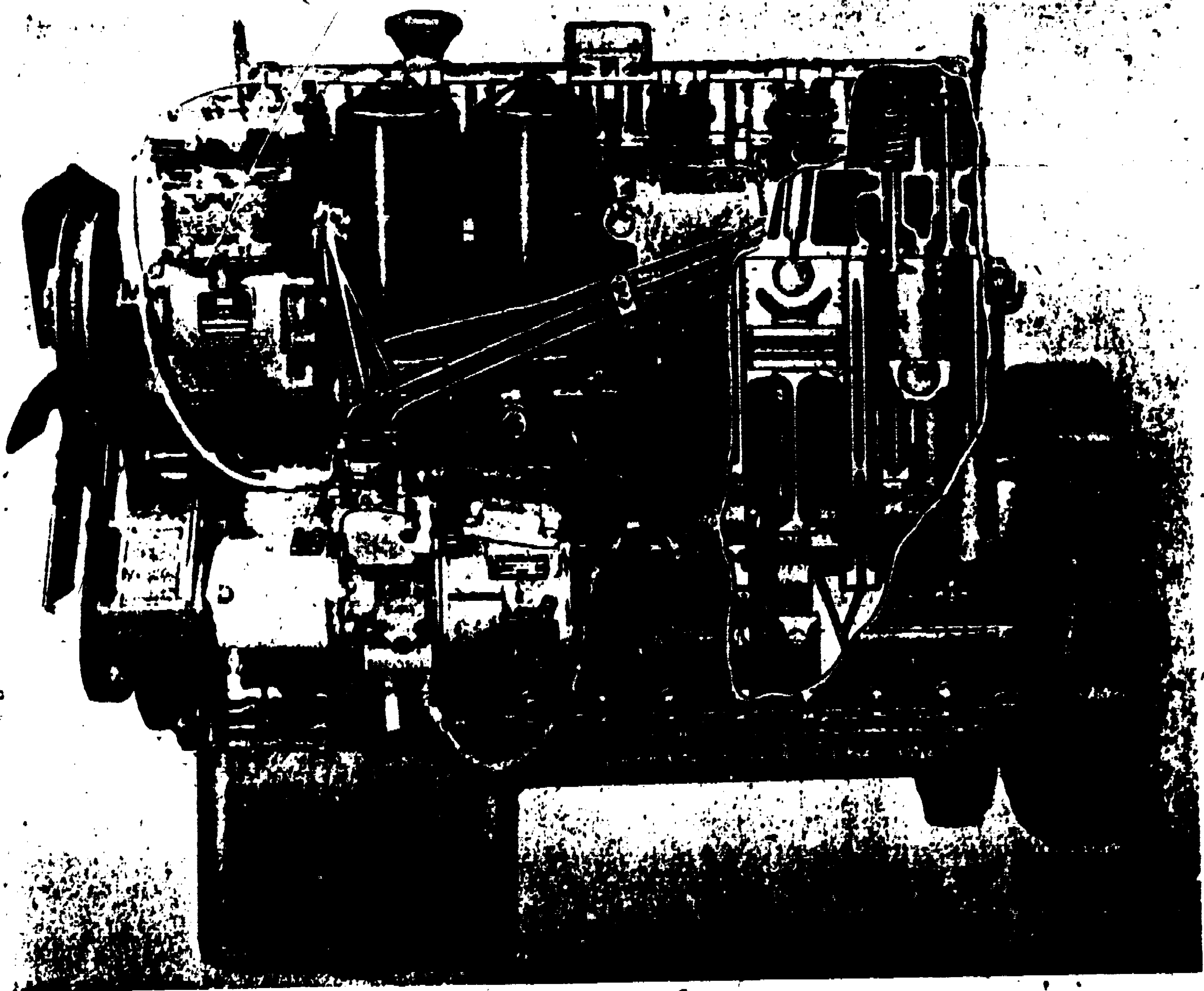

Figure 42. Sectional View LDS-465-1 Multifuel Engine.

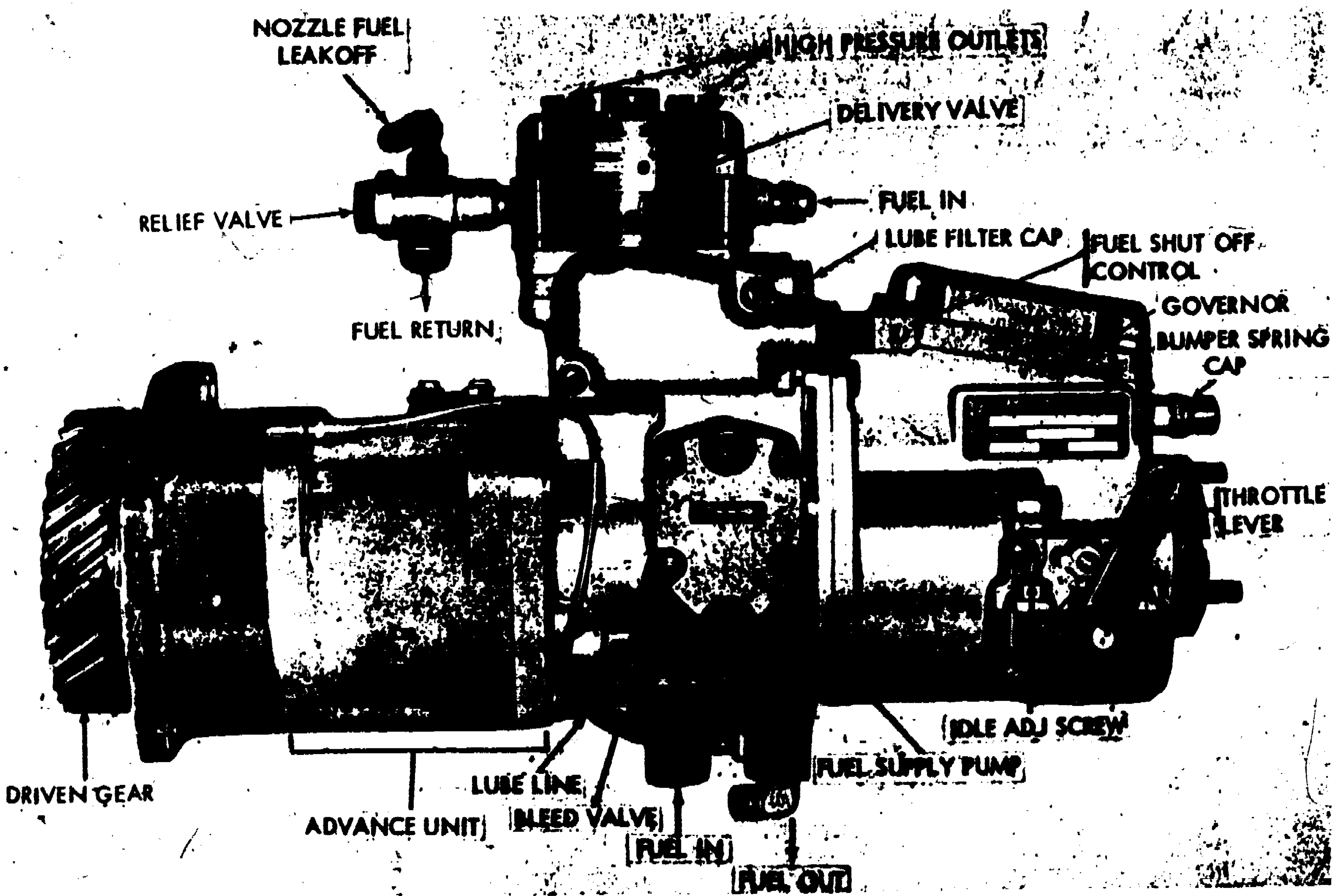

Figure 43. Fuel Injection Pump W/Advance Unit, American Bosch Type PSB-6A LDS-465-1 Engine.

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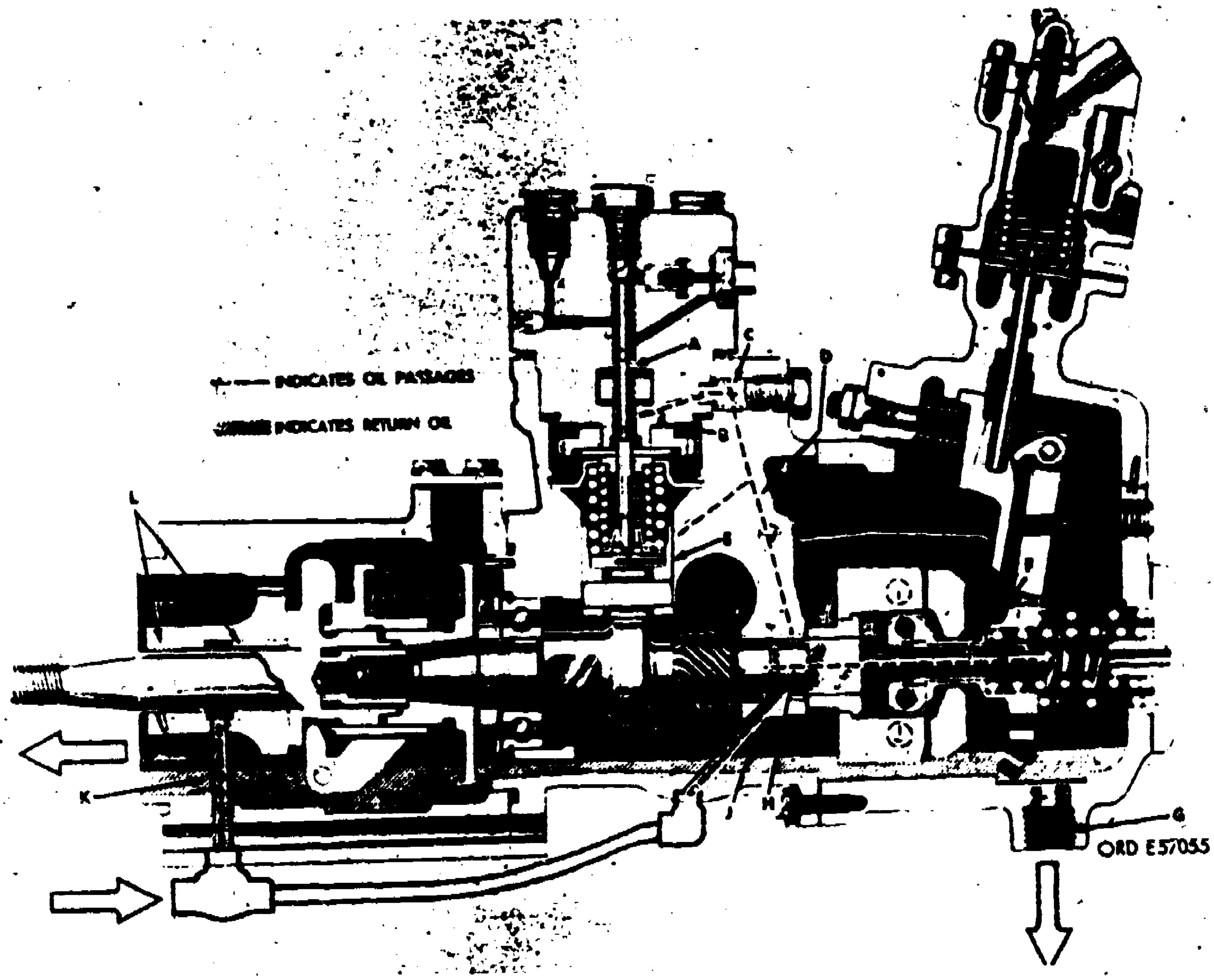
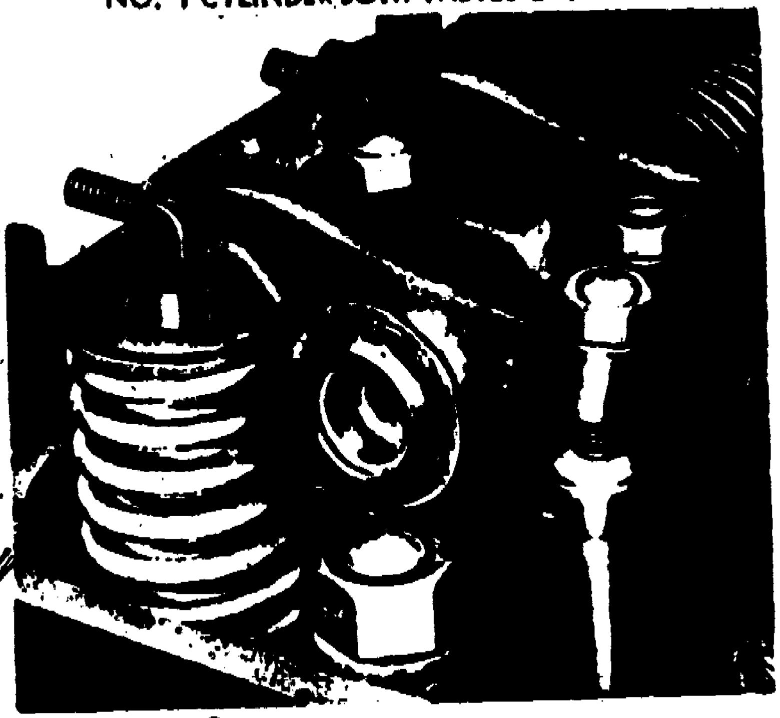


Figure 44. Lubrication System Fuel Injection Pump PSB-6A.

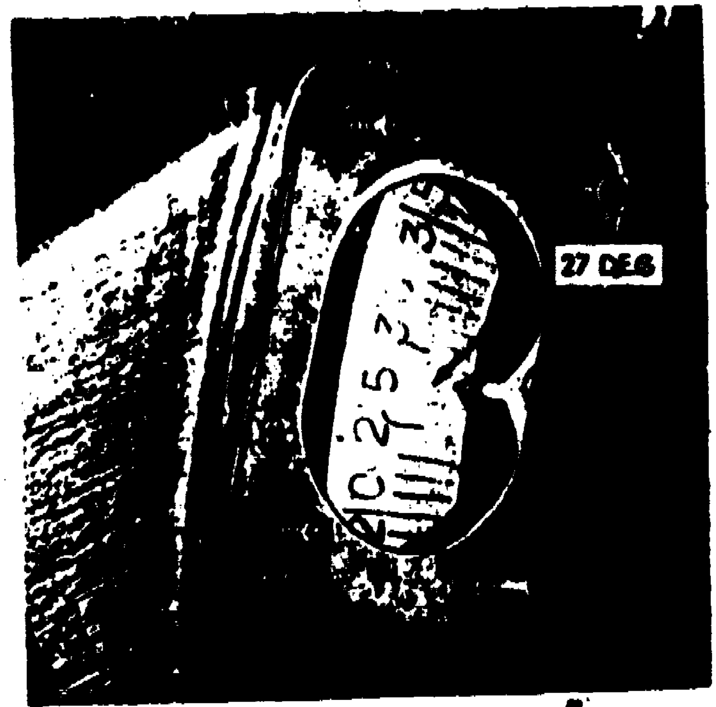
1

NO. 1 CYLINDER BOTH VALVES CLOSED.



2

FLYWHEEL TIMING MARK ON 27° BTC.



3

DAMPER TIMING MARK AND POINTER ALIGNED.

4

INJECTION PUMP TIMING POINTER AND MARK ALIGNED.

5

INJECTION PUMP SCRIBED - PAINTED TOOTH

Figure 45. Injection Pump Installation LDS-465-1 Multifuel Engine.

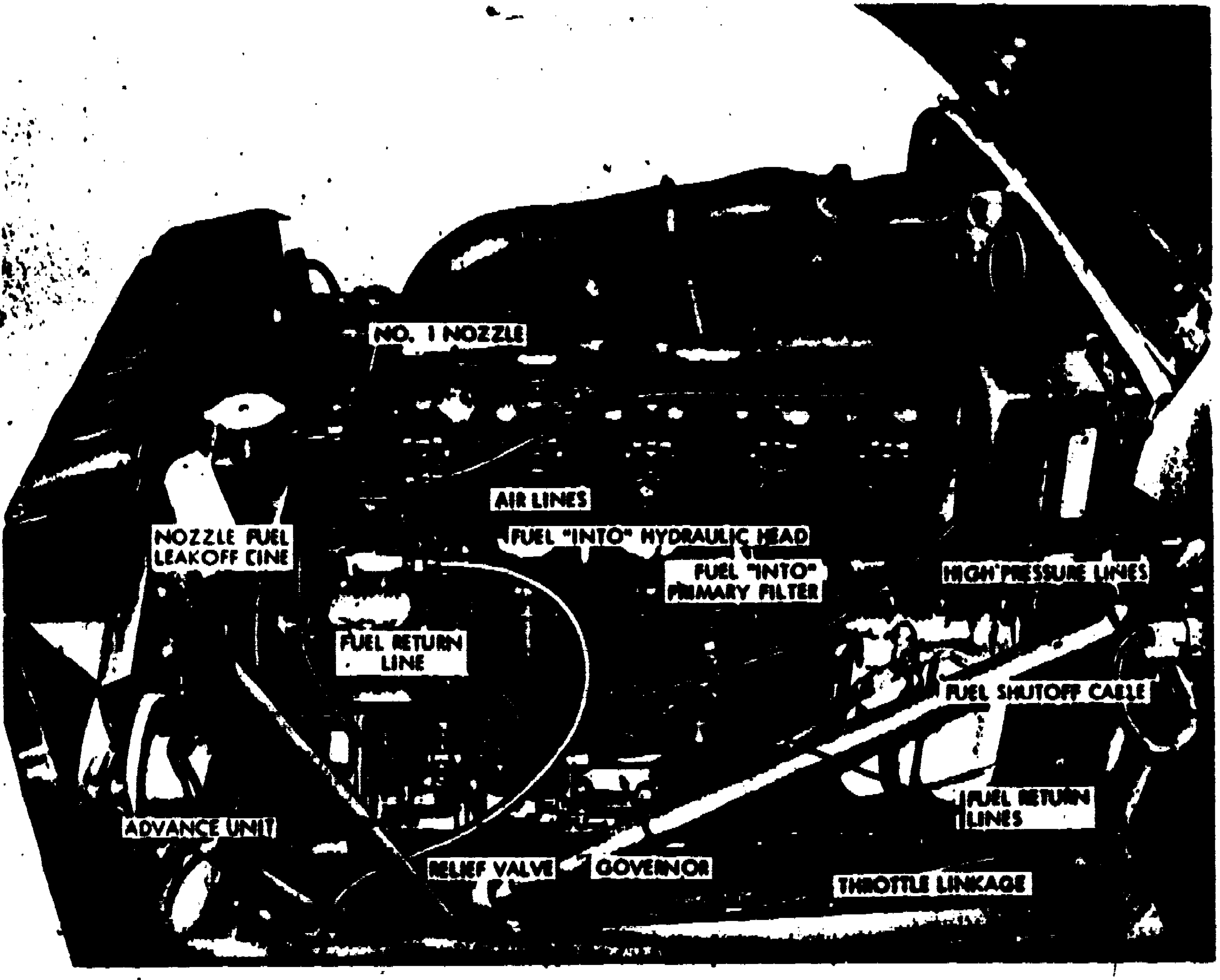


Figure 46. Left Side View of Installed Engine M35E7 Cargo Truck.

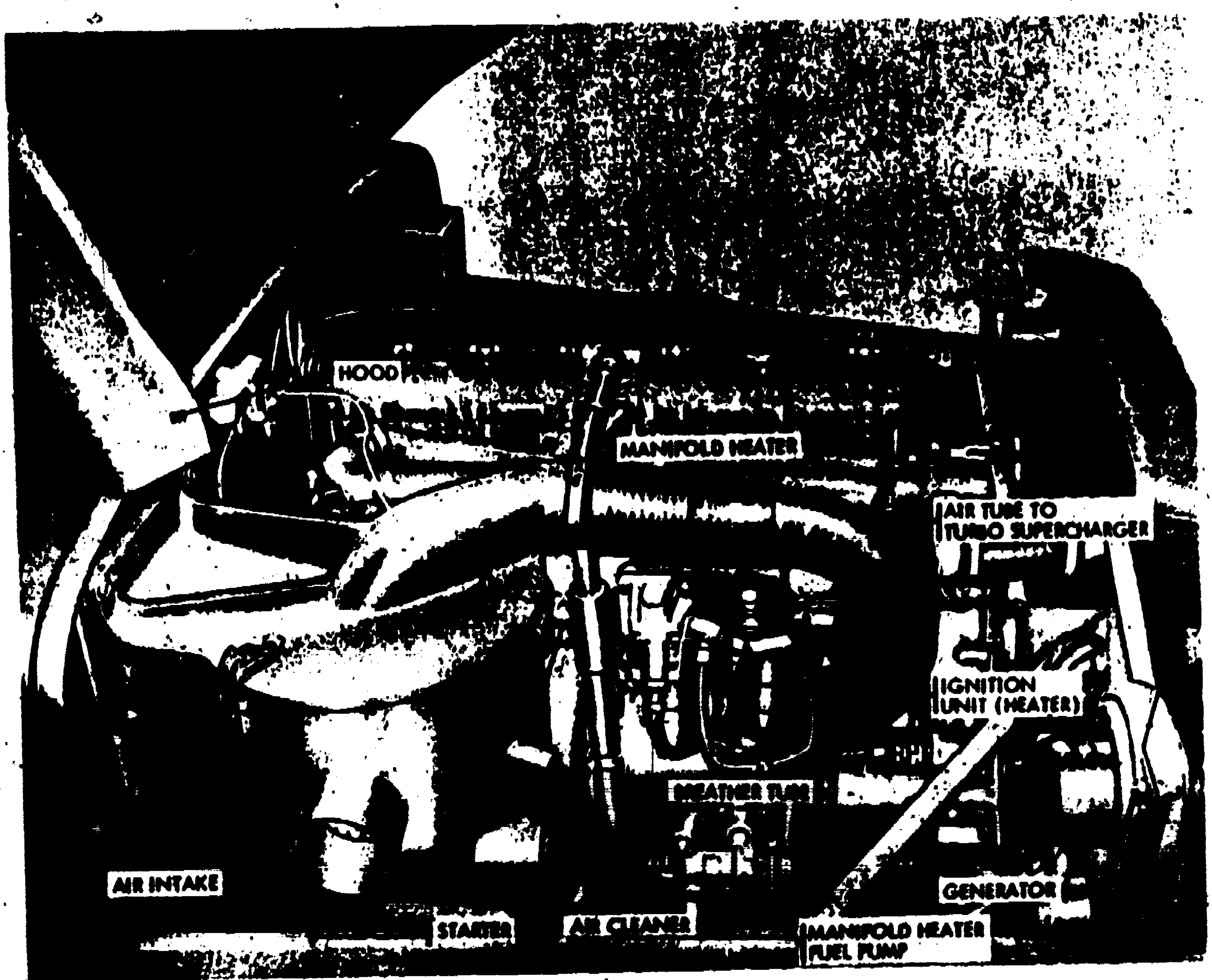


Figure 47. Right Side View of Engine Compartment Truck, Cargo, 2-1/2 Ton, 6x6 M35E7.

Air Induction and Exhaust System (Turbocharger)

The turbocharger increases the velocity and pressure of the intake air, forcing a greater quantity of air into the combustion chambers than is normally obtained on a naturally aspirated, or nonsupercharged engine. Air from the turbocharger is inducted into a jacketed, runner-type intake manifold. Engine coolant, circulated through the jacket, transfers heat to the induction air to improve cold weather combustion characteristics of the engine.

The turbocharger is essentially an exhaust-gas driven blower which utilizes the kinetic energy usually lost in the exhaust gases to compress air into the cylinders. The exhaust gases from the engine enter the turbocharger and are forced around the turbine housing, radially inward, through a nozzle ring. The exhaust gases drive the turbine wheel which in turn drives the compressor wheel. Induction air enters at the center of the compressor wheel and flows radially outward through a diffuser section into the compressor housing. The air then leaves through a tangential outlet on the outside of the compressor housing and enters the intake manifold. The exhaust gases are expelled from the turbocharger into the vehicle exhaust system.

Crankcase Oil Filler and Crankcase Breather

The engine has an oil filter cap in the front cylinder head cover for adding oil to the engine. The oil level gauge is located at the right rear of the engine. The crankcase breather adapter is located on top of, and connected between, the front and rear cylinder head covers. The crankcase breather tube is open to the atmosphere.

Coolant Temperature Sending Unit

The coolant temperature sending unit is located in the front end of the intake manifold above the generator. This unit transmits an electrical interpretation of engine coolant temperature to the temperature gage on the vehicle instrument panel.

Field Maintenance-Multifuel Engines

Figures 37 through 47 are to be used as an aid to instruction throughout the course. These illustrations pertain to the multifuel engines LDS 427-2, LD 465-1, and LDS 465-1. The instructor will explain these illustrations and how they are to be used during the course.

PRINCIPLES OF REFRIGERATION AND AIR CONDITIONING

OBJECTIVES

After completing this study [redacted] your classroom instruction, refer to [redacted] and Air Conditioning, [redacted] you will be able to:

1. Discuss the principles of a basic refrigeration system.

2. Discuss the principles of measurement and transfer of heat.

3. Explain the term "refrigerant."

4. Describe the characteristics of a refrigerant.

5. Describe the safety precautions to be observed when handling a refrigerant.

INTRODUCTION

The increasing demand for a higher standard of living throughout the world is creating a greater necessity for refrigeration. Twenty years ago, a central air conditioned home or an automobile with air conditioning was a very expensive luxury. This increasing requirement for refrigeration has created a need for refrigeration specialists which is not being fulfilled. Every refrigeration unit (whether it is a common household refrigerator, a window air conditioner, or a large, complex air conditioner which is used to cool a high-rise) uses the same principles of operation. You will be introduced to the terms and principles of a refrigeration unit in this text. In studying refrigeration, first, it is important to master the fundamental principles. Much of this basic material will be a review of physics and chemistry for those who have studied these subjects.

INFORMATION

BASIC REFRIGERATION

Mechanical refrigeration is used for domestic refrigeration, commercial refrigeration, air conditioning (comfort cooling), dehumidifying, food freezing, cooling in manufacturing processes, and numerous other applications. Correctly used, the term "air conditioning" means controlling the temperature, circulation, humidity, and purity of the air. A system which performs only one or two functions, but not all of them, is not technically considered a complete air conditioning system. However, by popular usage, these cooling units are still commonly referred to as air conditioners.

How a Mechanical Refrigerator Works

In order to understand the operation of the mechanical refrigerator, it is important to understand the physical and thermal properties of mechanisms and substances used to extract heat. A brief study of the elementary physics involved is provided in this text, in order that all explanations may be made clear.

The operation of a modern mechanical refrigerator (removing heat from inside the refrigerator) might be compared to removing water from inside a leaking canoe. In removing water from a canoe, a sponge is used to soak up the water. The sponge is held over the side, squeezed, and the water is drained into the lake or river. The operation may be repeated as often as is necessary. In this operation, water is transferred from inside the canoe back into the lake.

In a refrigerator, heat is transferred instead of water. Heat leaks into a refrigerator through the insulation and enters when the door is opened. Inside the refrigerator, heat is absorbed, "soaked up," by the liquid refrigerant in the cooling unit (evaporator). The refrigerant, in absorbing heat, changes from a liquid to a gas. After the refrigerant has absorbed heat and turned into a gas, it is pumped outside the refrigerator. It is then compressed and the heat is "squeezed out" by being subjected to high pressure and cooled in the condenser. The refrigerant continues to flow through the refrigerating cycle, absorbing heat inside the refrigerator and releasing it outside the refrigerator, until the desired refrigerating temperature is reached, then the cycle stops. Heat is not destroyed to make the refrigerator cold; it is simply removed from the refrigerated space and released outside the cabinet.

We have seen in the refrigerator that heat is absorbed and carried away by a liquid that evaporates into a gas. You can test this principle by wetting one finger with your tongue and blowing air across the finger. You should feel the coolness that comes over it. It is evaporation, the liquid being transformed into a gas. As the liquid is being transformed into gas, it absorbs heat in the process. If you tried the same experiment with gasoline or rubbing alcohol, it would feel much colder. This is because gasoline and alcohol evaporate at much lower temperatures than does water. The evaporation is also much more rapid, so the heat is extracted faster and it seems cooler. In an air conditioning unit or refrigeration apparatus, the liquid used for cooling is called a "refrigerant," and will be discussed in more detail later in this text.

Pressure Temperature Relationship

We have learned that an evaporating liquid causes a cooling effect and that this principle is used in refrigeration. What is refrigeration? By definition, refrigeration is the removal and transfer of heat from a body or substance. We must remove

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and transfer some of the heat that a substance contains in order to lower its temperature. Heat only transfers from one substance to another when there is a temperature difference between the two substances. It transfers from the substance of higher temperature to the substance of lower temperature. Figure 48 shows a container of refrigerant -12 evaporating at atmospheric pressure. Notice that heat is transferring from the substance at a higher temperature to the substance at a lower temperature. The rate of heat transfer (denoted by arrows) is greater from the water to the refrigerant than from the ice to the refrigerant. The rate of heat transfer always increases as the temperature difference between two substances increases.

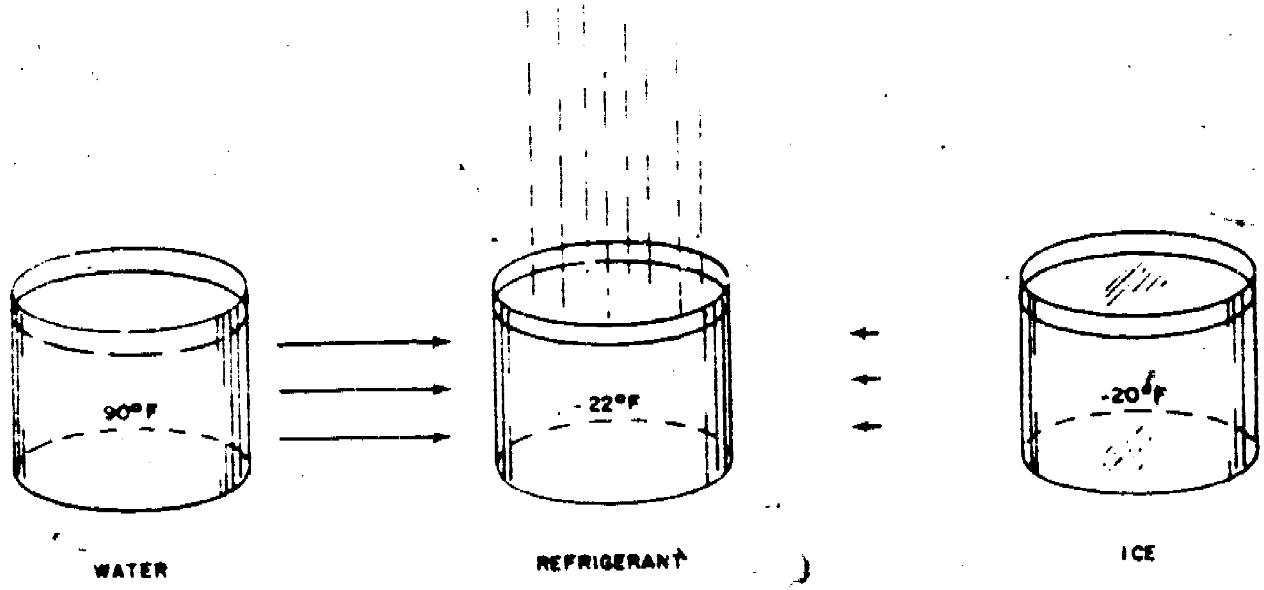

Figure 48. Heat Transfer.

In figure 48, we see heat transferring from the water to the refrigerant. As the heat transfers, the temperature of the water decreases. Will the temperature of the evaporating refrigerant increase? The answer to this question is "NO." The temperature of the evaporating refrigerant will remain at -22°F. The fact that an <u>evaporating liquid can absorb heat and not increase in temperature</u>, is very important in a refrigeration system. This is a characteristic of all liquids. Water, one of the most common liquids, will serve to illustrate this point. A thermometer immersed in water indicates an increase in temperature until the water begins to boil, figure 49. Notice that once the water reaches the boiling point, figure 49B, the thermometer no longer indicates a temperature change. Increasing the flame, figure 49C, has no effect on the temperature. The water boils (absorbs heat) at a faster rate, but the temperature remains constant. The conclusion can be drawn that as a liquid evaporates at a constant temperature, the thermal energy involved in the process is called latent (hidden) heat. Another very important characteristic of all liquids may be equally well demonstrated with water. It is an established fact that water will boil at 212°F at an atmospheric pressure of 14.7 psia. If the pressure on water is decreased, the boiling point is lowered. If pressure is increased (pressure cooker), the boiling point is raised. For example, water under a vacuum of 19 inches of mercury will boil at 165°F. At 10 psig, the temperature must be raised to 240°F before boiling begins. This holds true for all liquids. As pressure increases, the boiling point increases; and, as pressure decreases, the boiling point decreases.

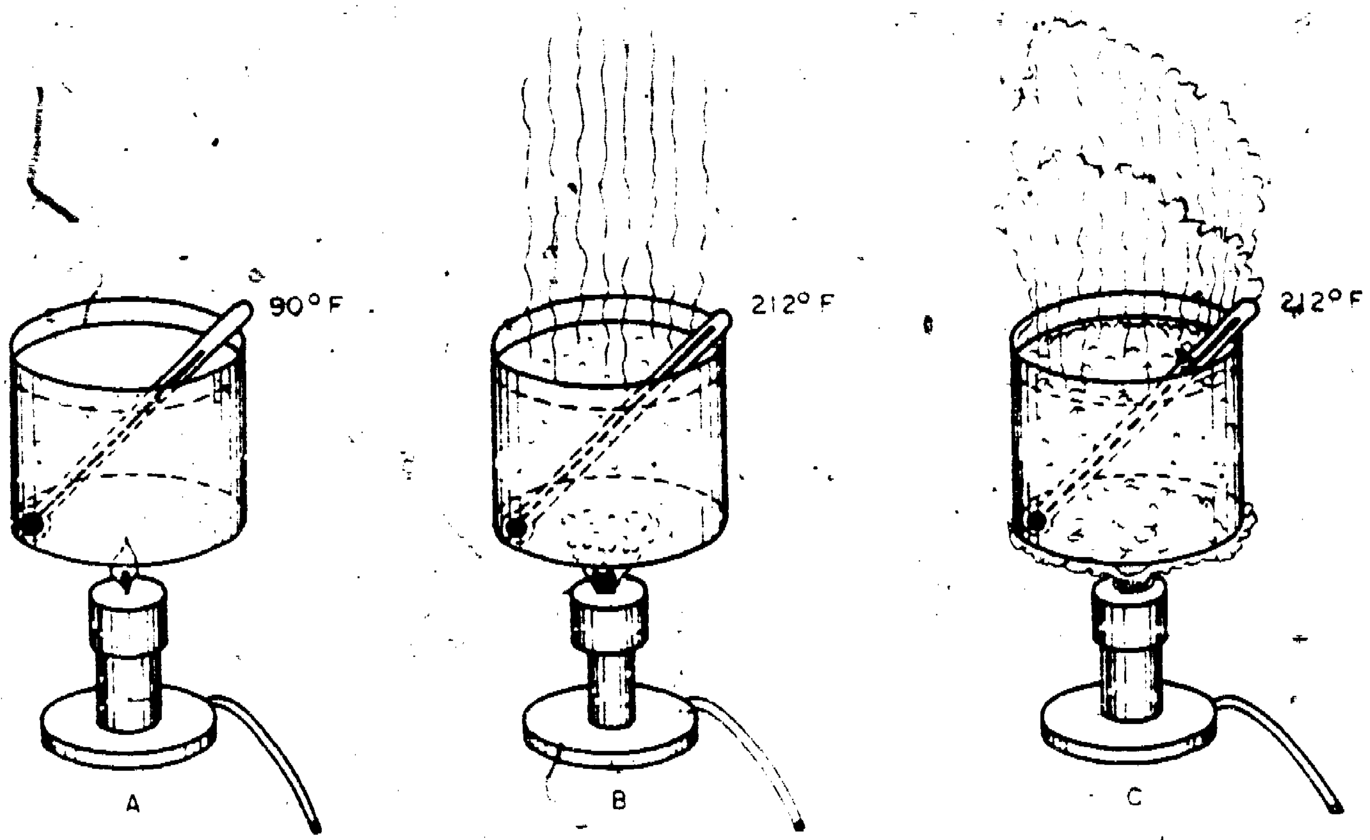

Figure 49. Latent Heat.

Figure 50 shows part of a pressure temperature chart. At .571 psig, Freon 12 boils at -20°F. This temperature is much too low for air conditioning, but by raising to pressure 40.7 psig, the refrigerant boiling point is raised to 44°F. Thus, with every pressure change, there will be a change in boiling point. If the pressure is held constant, the boiling point remains constant. Many of the controls in a refrigeration system are designed to control the evaporation pressure in the system and thereby, control the temperature of the refrigerant. Another important fact is that heat transfer increases as the boiling point of the refrigerant decreases; thus, heat removal is more rapid from substances surrounding the refrigerant. In figure 51, a refrigerant under a low pressure is boiling off at a low temperature in the cooling coils. Ambient (surrounding) air is blown across the cold coils. The temperature of the air decreases as heat transfers to the cold coils. The temperauture of the coil does not increase because the heat absorbed by the refrigerant causes the liquid refrigerant to become a gas (latent heat). As the liquid boils off, more liquid is added to the coils. If the temperature of the coils is lowered, the rate of heat transfer increases. The temperature of the air across the coils decreases as the temperature of the refrigerant and the coils decrease. Any change in pressure on the refrigerant in the coils always results in a change in the boiling point of the refrigerant. This principle is used to control the temperature of the air that is being cooled. If the pressure in the coils is raised, the temperature of the boiling refrigerant increases, and the temperature of the air that is being cooled also increases.

°F	#Pressure	°F	#Pressure
-40	11.0*	50	46.7
-35	8.3*	55	52.0
-30	5.5*	60	57.7
25	2.3*	65	63.7
-20	0.6	70	70.1
-15	2.4	75	76.9
-10	4.5	80	84.1
5	6.8	85	91.7
- 0	9.2	90	99.6
5	11.8	95	108.1
10	14.7	100	116.9
15	17.7	105	126.2
20	21.1	110	136.0
25	24.6	115	146.5
30	28.5	120	157.1
32	30.1	125	167.5
35	32.6	130	179.0
40	37.0	140	204.5
45	41.7	150	232.0

*Inches of Vacuum

Figure 50. Pressure Temperature Chart.

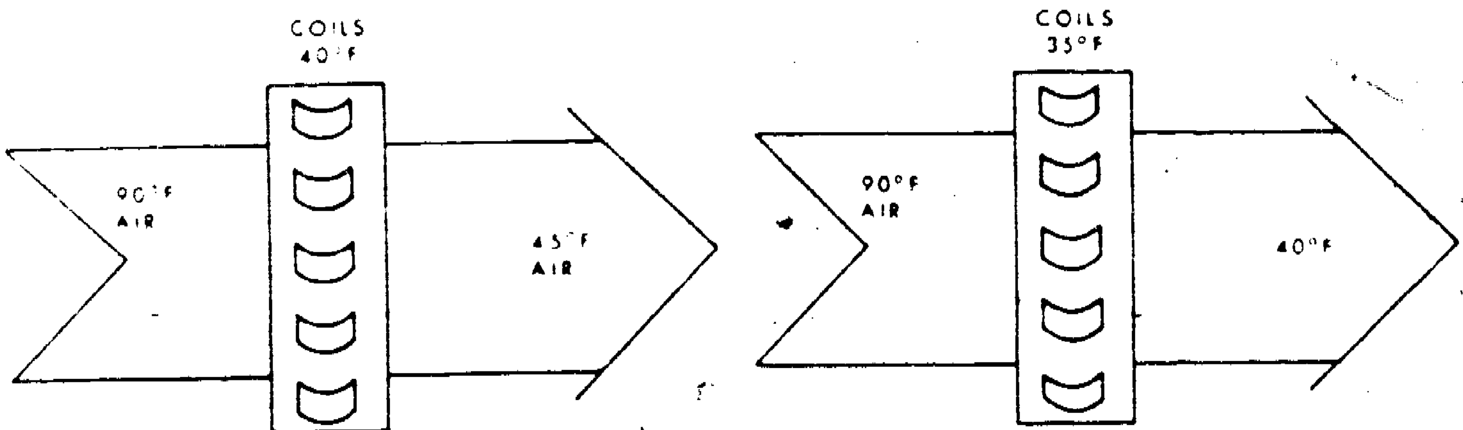

Figure 51. Heat Transfer.

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If the atmosphere surrounding us contained only dry air, the job of cooling would be easy. However, since the air contains various amounts of moisture, refrigeration equipment must be designed to compensate for the effects of this moisture. Under the conditions of high humidity, a refrigeration system must work harder to cool the air to a desired temperature. Figure 52 shows the effects that humidity (moisture in the air) has on a typical air conditioner. Note that at a relative humidity of 54%, the unit is capable of cooling 75 pounds per minute (ppm) of 100°F air to 50°F. When the relative humidity drops to 34%, the unit is capable of cooling 100 pounds per minute of 100°F air to 45°F. As a repairman, you should be aware of the fact that as humidity increases, the load on the air conditioner increases. Humidity can increase to a point where an air conditioner is not capable of cooling the full airflow to the desired air temperature. The technical order for many air conditioners has a chart similar to the one in figure 52. From this chart, you can determine what a unit is capable of cooling under various conditions.

Relative Humidity	Airflow	Ambient Temperature	Discharge Air Temperature
54%	75 ppm	100°F	50°F
34%	100 ppm	100°F	45°F
8%	80 ppm	125°F	45°F

Figure 52. Heat Load.

The amount of heat that an air conditioner is capable of removing is expressed in British thermal units (BTU). A thermometer indicates the degree or intensity of heat in a substance. It cannot be used to measure the amount of heat that a substance contains. As shown in figure 53, a one gallon container of water could be at the same temperature as a ten gallon container, but they would obviously contain a different amount of heat. The BTU is used as the unit measurement for amounts of heat. A BTU is defined as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Water is assigned a specific heat value of 1.00 and is used as the standard of all substances. A substance assigned a specific heat value of .5 means that 1/2 BTU is required to raise a pound of that substance ond degree Fahrenheit (F). Air has a specific heat rating of .24. This means that for each degree of temperature change in one pound of air, then .24 of a BTU of heat will be removed.

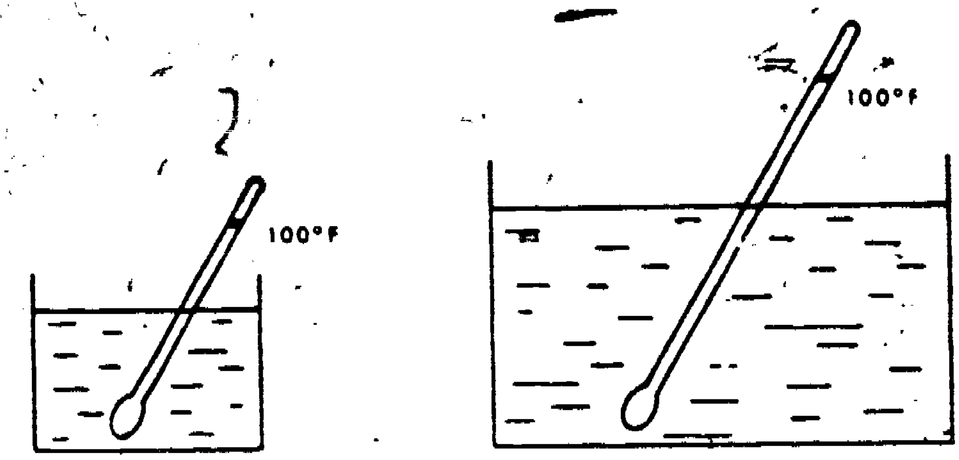

Figure 53. Temperature.

The air conditioner, shown in figure 54, is a two-ton unit. This does not refer to the weight of the unit, but to the amount of heat which the unit is capable of removing. In the previous paragraph, we said that the amount of heat is measured in BTUs. To distinguish between the different cooling capacities of units, tons or BTUs are used for rating. This measuring system is based on one ton of 32°F ice melting in a 24-hour period. One ton of 32°F ice will absorb 288,000 BTUs in the process of melting. Therefore, any unit capable of removing 288,000 BTUs in 24 hours is a one-ton unit. A unit capable of removing three times this much heat in a 24-hour period, is a three-ton unit. As you can readily see, to express this figure in BTUs per 24 hours, would require quite a large number. To reduce the number used, it is normally expressed in BTUs per hour or just simply in tons. For example: If a unit removes 12,000 BTUs per hour, this would be equivalent to 288,000 BTUs in 24 hours; 12,000 BTUs x 24 = 288,000 BTUs; 24 hours = 1 ton.

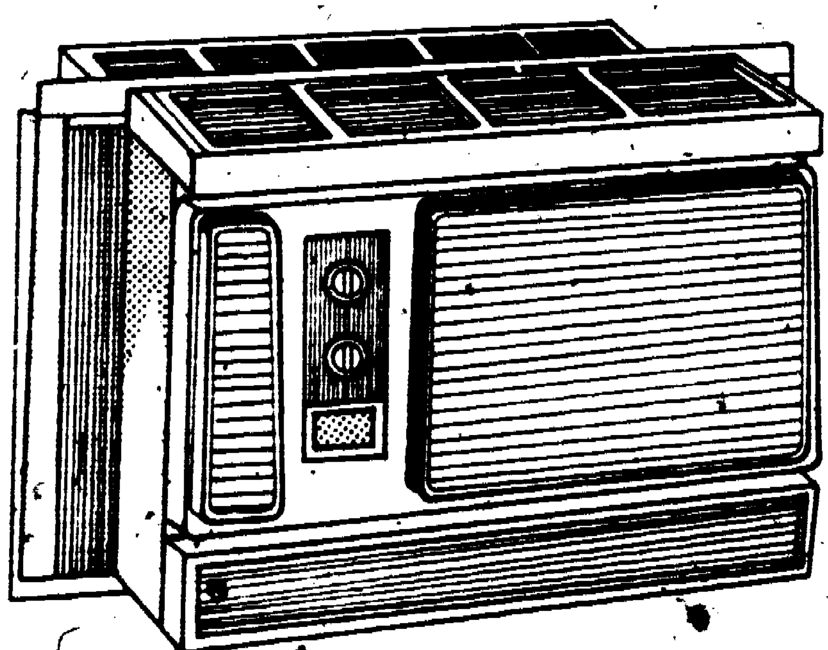

Figure 54. Air Conditioner Two Ton Unit.

Refrigerants

There are many different types of refrigerants. Three of the more popular refrigerants are listed in figure 55. The refrigerant most commonly used in air conditioning systems is refrigerant R-12. It has very desirable operating pressures, and the boiling point, where it changes from a liquid to a gas is 21.7°F below zero.

Refrigerant	Evaporating Temperature (14.7 psia)
Trichloromonofluoromethane (R-11)	75°F
Dichlorodifluoromethane (R-12)	-21.7°F
Monochlorodifluoromethane (R-22)	-41°F

Figure 55. Refrigerants.

Refrigerant R-12 is nonexplosive, nonflammable, noncorrosive, operates on a low to moderate pressure, has a low boiling point, low condensing pressure and temperature, and is noninjurious to lubricating oil which are all good characteristics of a refrigerant. Although it is considered a safe refrigerant and is heavier than air; certain precautions must be observed to protect the parts of the system and the person who is working with it.

Liquid refrigerant R-12, at normal atmospheric pressures and temperatures, evaporates so quickly that it tends to freeze anything it contacts. For this reason, extreme care must be taken to prevent any liquid refrigerant from coming in contact with the skin, and especially with the eyes. To avoid a dangerous explosion, from the buildup of extreme pressures in a sealed system, never weld, solder, or use any excessive amount of heat on any part of the system while it is charged with refrigerant.

Although refrigerant R-12 gas, under normal conditions, is nonpoisonous, the discharge of it near any open flame can produce very poisonous fumes. These poisonous fumes are generated in small quantities when the flame-type leak detector is used. Avoid inhaling the fumes from the leak detector, and always have plenty of ventilation when working with the refrigerant. Goggles should also be worn when opening cylinders or a refrigerant system to prevent a spray of extremely low temperature refrigerant from injuring the eyes.

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The refrigerant is shipped and stored in a cylinder, shown in figure 56. Do not store these cylinders in temperatures above 125°F as the refrigerant is under pressure, and the pressure increases as the temperature surrounding the cylinder increases. This will cause the liquid refrigerant to start boiling, resulting in more pressure in the cylinder. Each cylinder has a fusible plug (safety device) which will melt if the temperature should go to high.

Figure 56. Refrigerant Storage Cylinders.

A liquid-vapor valve, shown in figure 57, is mounted on top of the cylinder. The valve is used to remove either liquid or gaseous refrigerant from the cylinder. A hose can be connected from the valve to a refrigerant system to transfer refrigerant when charging.

Figure 57. Liquid Vapor Valve.

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QUESTIONS

1. As a liquid changes to a gas, it

a. decreases in temperature.

b. absorbs heat.

c. increases in temperature.

d. reduces pressure.

2. Of the following statements, which one is FALSE?

a. All liquids evaporate at the same temperature.

b. As a liquid evaporates, it absorbs heat.

c. Some liquids evaporate at a much lower temperature.

d. As a liquid evaporates, it changes to a gas.

3. Refrigeration is the process of

a. adding heat.

b. destroying heat.

c. transferring heat.

d. putting in cold.

4. Heat always transfers from

a. hot to cold.

b. gas to liquid.

c. liquid to gas.

d. cold to hot.

5. There will be no transfer of heat between two substances when they are at the same

a. temperature.

b. state.

c. pressure.

d. volume.

TRUE OR FALSE

6. A thermometer indicates the intensity of heat in a substance in BTUs.

7. The amount of heat in a substance is stated in degrees.

8. The heat load on an air conditioner increases as the humidity increases.

9. The cooling capacity (amount of heat capable of removing) of an air conditioner is expressed in tons.

10. The liquid used for absorbing heat in an air conditioner is called the refrigerant.

11. The liquid used to absorb heat should have a high boiling temperature.

12. The boiling temperature of refrigerant is determined by controlling the pressure on the refrigerant.

COMPLETE THE FOLLOWING:

13. If pressure is reduced on a boiling refrigerant, its boiling temperature will ________________.

14. As the boiling temperature of a refrigerant is lowered, the rate of heat transferring to the refrigerant will _________.

15. In a refrigeration system, refrigerant in the cooling coils boils at a low temperature under a _____________ pressure.

16. When air is blown across the cooling coils, the rate of heat transfer from the air to refrigerant increases as the _____________ of the refrigerant decreases.

17. The temperature of a boiling refrigerant remains the same as long as the _____________ on it is constant.

REFERENCES

None

CONSTRUCTION AND OPERATION OF AIR CONDITIONING COMPONENTS

OBJECTIVES

G-1229A

After completing this study guide, [redacted] Manual, C[redacted] Conditioning, [redacted] and your classroom instruction, you will be able to:

1. Identify and locate air conditioning system components.

2. Describe the construction and operational characteristics of the air conditioning system components.

3. Partially disassemble, inspect, and reassemble the air conditioning compressor.

4. Apply applicable safety precautions.

INTRODUCTION

We are now going to discuss what makes the typical air conditioning system operate. We will trace the refrigerant flow in the system, and see where and how a change of state occurs on the refrigerant. A firm understanding of this information is a must to effectively troubleshoot the system. This information is applicable to all air conditioning systems from the simplest refrigeration system to the most complex system used to cool the modern high-rise or office building. To ease the learning situation, we will base our discussion around the simple air conditioning system.

INFORMATION

REFRIGERANT FLOW

The condition of the refrigerant as it passes through the system is divided into four phases; these are HPL (high pressure liquid), LPL (low pressure liquid), LPG (low pressure gas), and HPG (high pressure gas). We will be using these terms throughout our discussion of the air conditioning system.

Typical Refrigeration Cycle Components

RECEIVER-DRIER. This unit performs two functions in the car air conditioning system. The receiver is the storage tank for the liquid refrigerant that is necessary for proper operation of the air conditioning system. The drier collects small particles of moisture that may have entered the system. The receiver-drier is located in the line between the outlet of the condenser and the inlet of the expansion valve. A sight glass is usually located in the liquid outlet line of the receiver-drier. The refrigerant in the receiver-drier is 80% HPL and 20%

HPG. This is necessary to allow for expansion of the refrigerant due to perature changes. A pick-up tube or dip tube is installed in the receiver-drier and extends down toward the bottom of the receiver-drier. The lower end of the tube has a strainer attached, whereas the upper end of the tube is attached to the outlet of the receiver-drier. The pick-up or dip tube assures that only HPL is allowed to leave the receiver-drier. A fusable plug is installed in the receiver-drier as a safety device and serves the same purpose as the fusable plug in the refrigerant cylinder. The receiver-driers may be mounted either horizontally or vertically and are shown in figure 58.

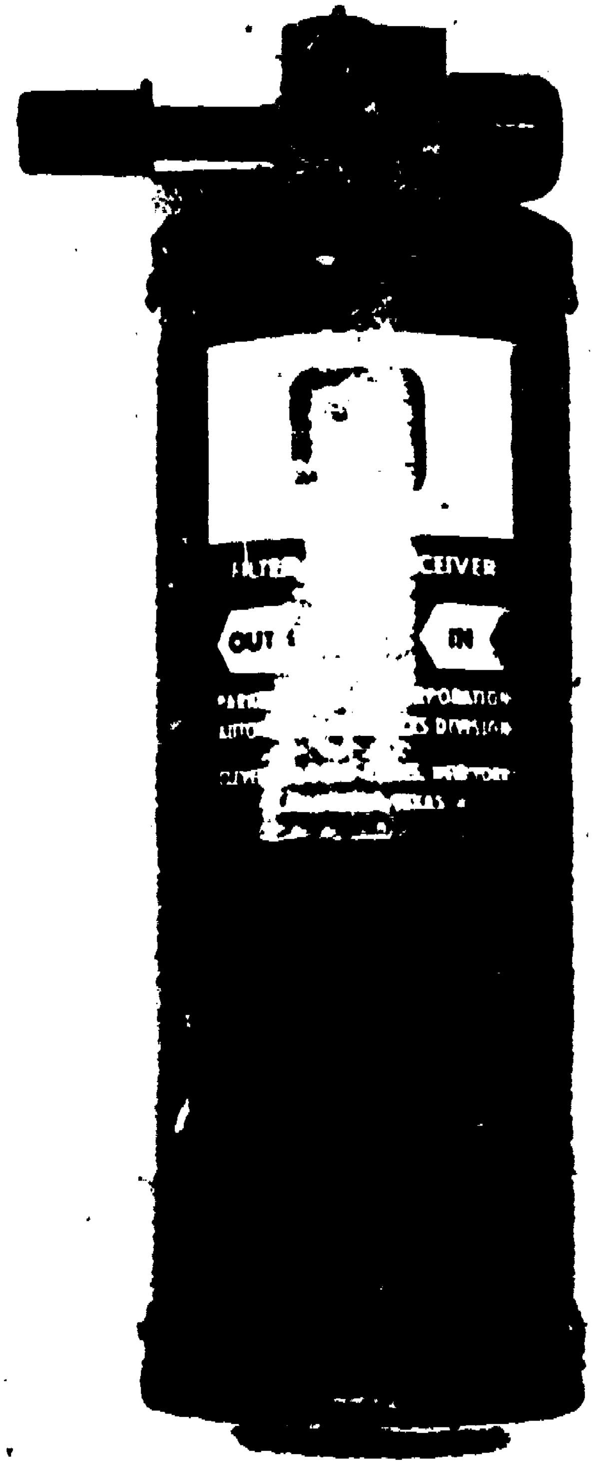

Figure 58. Receiver-Drier.

EXPANSION VALVE. The system must have a reducing device to throttle the high pressure liquid refrigerant to low pressure liquid refrigerant. The device used is the thermostatic expansion valve. This control responds to the temperature of the evaporator outlet as well as the low side (suction) pressure. In operation, the sensing bulb senses the temperature of the refrigerant as it leaves the evaporator. If the refrigerant suction line is quite warm, the captive charge of refrigerant in the sensing bulb expands, forcing pressure on the valve bellows or diaphragm, whichever type is used. The valve opens wider and allows more refrigerant to enter the evaporator. As the refrigerant suction line becomes cooler, the captive charge of refrigerant in the sensing bulb will contract and the expansion valve will close accordingly, decreasing the amount of refrigerant to the evaporator.

Most of the automotive thermostatic expansion valves (TEV) have a pressure equalizer line from the valve body to the outlet of the evaporator. The equalizer is needed because the evaporator coil has enough pressure drop to make it necessary to use the outlet evaporator pressure. This pressure is used only to push against the low side facing of the diaphragm for accurate, consistent operation.

The capacity of this valve (orifice size) must match the capacity of the unit. A valve that is too small will reduce the capacity of the unit, while a valve that is too large will "hunt" or alternately flood and starve the evaporator of liquid refrigerant.

The expansion valve is a very reliable part. It is usually the last part to function improperly or need replacement. If a valve is faulty, it has probably lost its captive charge of refrigerant. The valve cannot be recharged with the average mechanical equipment used by most service men in the field. Some units do have a replaceable power unit, otherwise the valve is considered a replaceable item rather than reparable.

The valve is located on the inlet to the evaporator. It is usually covered with tape insulation to permit it to operate without engine compartment heat affecting it.

A bellows type expansion valve, a diaphragm type (without the equalizer line), and a diaphragm type (with the equalizer line), are shown in figures 59, 60, and 61.

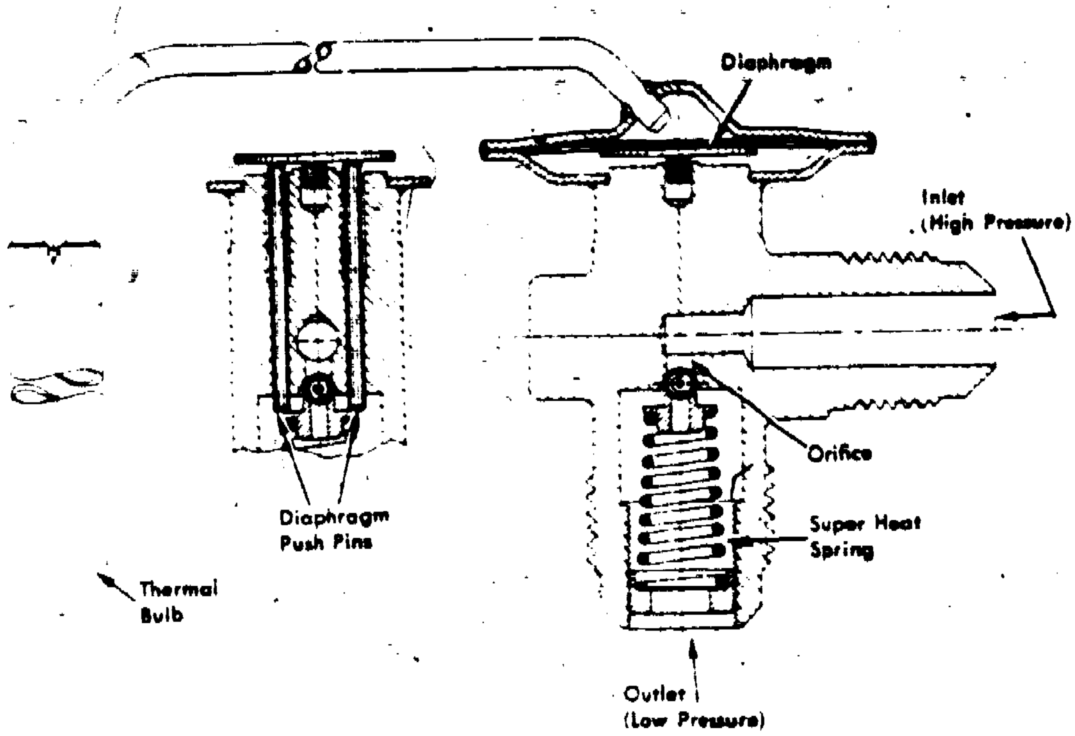

Figure 59. Diaphragm Type Expansion Valve
Without External Equalizer Line.

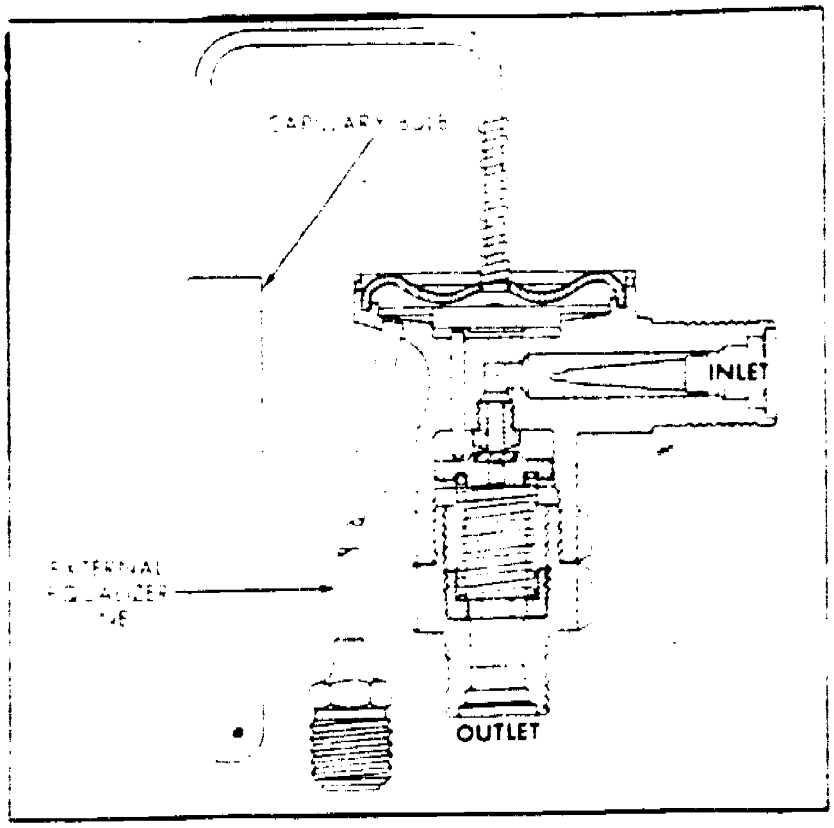

Figure 60. Diaphragm Type Expansion Valve
With External Equalizer Line.

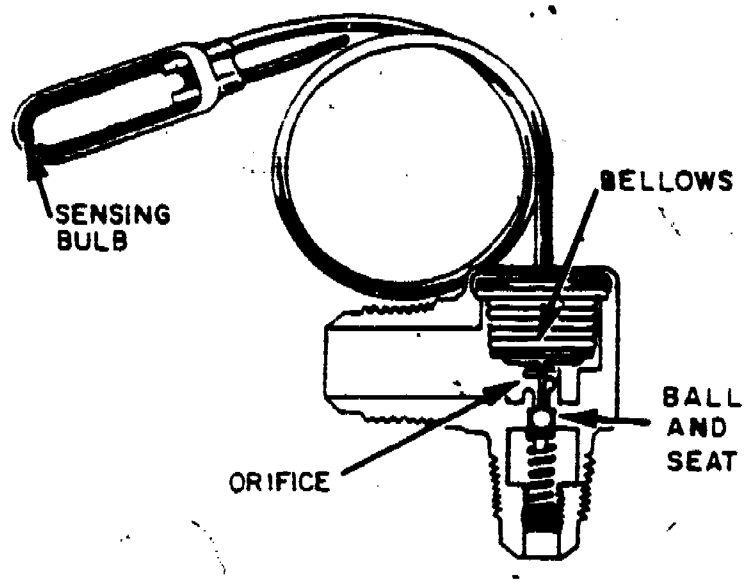

Figure 61. Bellows Type Expansion Valve.

EVAPORATOR. The evaporator can be considered the cooling unit of the air conditioning system. Low pressure liquid refrigerant is metered into the evaporator coils through the inlet (figure 62). The refrigerant boils at a very low temperature as it flows through the evaporator coils. Filtered air is forced by a blower across the evaporator coils. The air passing across the evaporator is cooled when the heat transfers from the warm ambient air to the refrigerant. The evaporator does not make cold air. Instead, it takes the heat out of the air to lower the air temperature in the air conditioning area. The temperature of the refrigerant does not increase, as the liquid vaporizes. Latent heat is being absorbed to superheat the refrigerant. The temperature of the boiling refrigerant only changes if the evaporator pressure is changed. The refrigerant leaves the evaporator through the outlet as a low pressure gas. The refrigerant should be completely vaporized when it leaves the evaporator.

The evaporator coils are usually mounted in a plenum chamber attached to the engine compartment, fire wall, or dashboard. The evaporating coil is of the finned, forced convection type. A moisture drain pan and drainpipe must also be incorporated in the unit to carry away moisture that has been extracted from the air during the conditioning process.

COMPRESSOR. The compressor can be considered the heart of the air conditioning system. In operation, it pumps and circulates the refrigerant through the system. Technically, the function of the compressor is to raise the low pressure, low temperature gas, to a high pressure, high temperature gas.

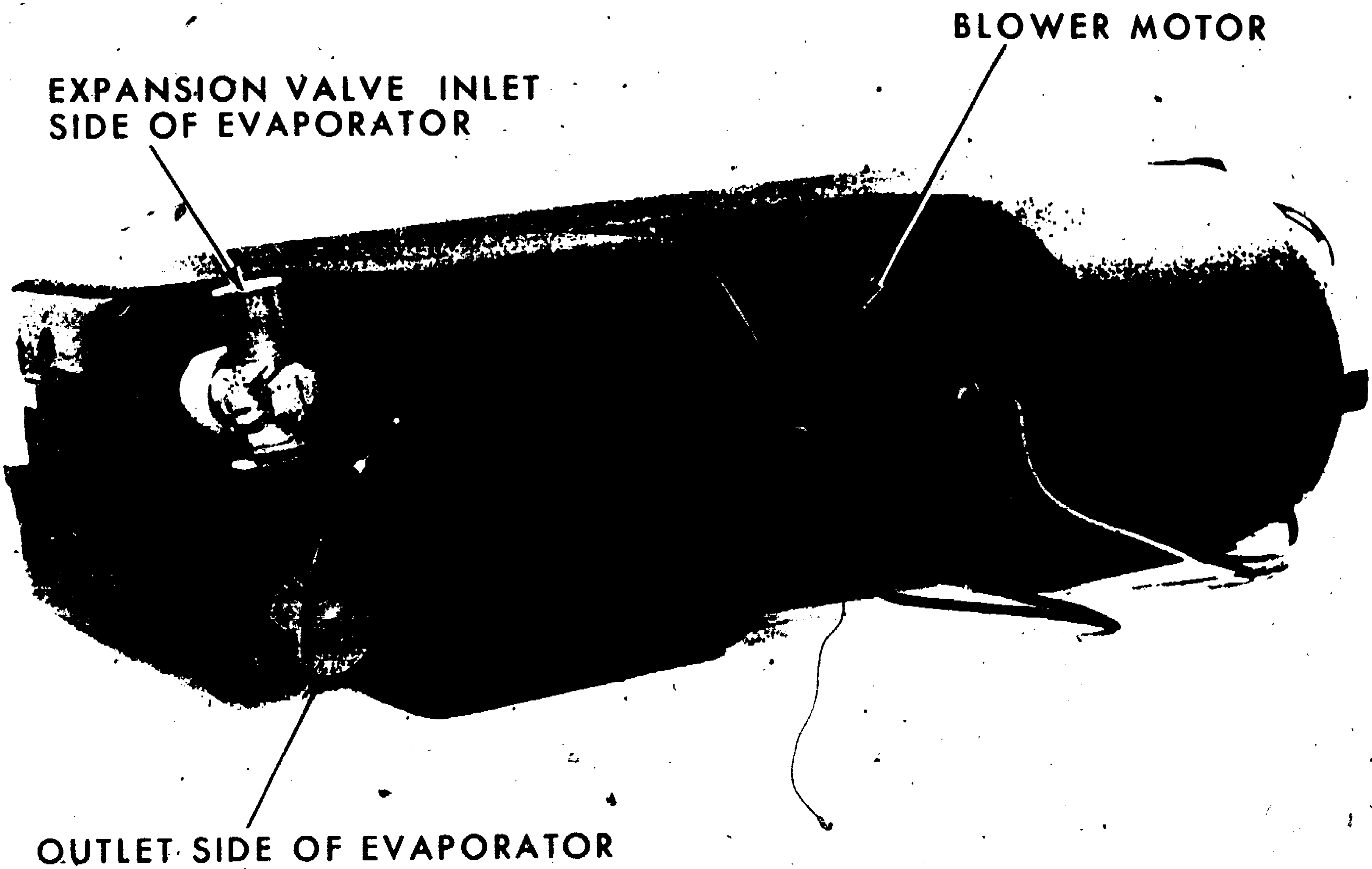

Figure 62. Evaporator.

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Actually, the vapor coming out of the evaporator is very cold. We know the liquid refrigerant boils at temperatures considerably below freezing and that the vapors arising from it are only a shade warmer even though they do contain quantities of heat. Consequently, we can't expect to remove heat from subfreezing vapors by "cooling" them in air temperatures that usually range from 60°F to 100°F. In other words, heat will not flow from a cold object to a warmer one.

But, with the compressor, we can squeeze the heat-laden vapor into a smaller space. And, when we compress the vapor, we also concentrate the heat it contains. In this way, we can make the vapor hotter without adding any heat. Then we can cool it in comparatively warm air. That is the only responsibility of a compressor in an air conditioning system. It is not intended to be a pump just for circulating the refrigerant. Rather, its job is to exert pressure for two reasons. Pressure makes the vapor hot enough to cool off in the warm air. At the same time, the compressor raises the refrigerant's pressure above the condensing point at the temperature of the surrounding air so it will condense.

As the refrigerant leaves the compressor, it is still a vapor although it is quite hot and ready to give up its heat. One of the easiest ways to help refrigerant vapor discharge its heat is to send it through a radiator-like component known as a condenser.

The compressor is driven through a magnetic clutch, which in turn, is driven by the engine. The compressor operates at slightly above engine rpm.

There are two types of compressors in general use today. They are the reciprocating and swash plate. The reciprocating compressor, which was first used and is still popular today, is illustrated in figures 63 and 64. It can be mounted either vertically or horizontally and are in-line or V models. The swash plate compressor, which has been developed by General Motors Corporation is illustrated in figure 65.

CONDENSER. The condenser is the component of the air conditioning system that removes the heat from the refrigerant and dissipates it into the outside air. When the heat is removed from the refrigerant, the refrigerant becomes cooler and condenses from a high pressure gas to a low pressure gas.

The condenser is usually mounted in front of the car radiator. On some independent units, the condenser is mounted back of the radiator. It is firmly fastened to the radiator shell. Air going through the radiator and into the engine compartment usually goes through the condenser first. In most installations, the fan that cools the car radiator also cools the condenser.

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Figure 63. Compressor In-Line.

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Figure 64. Compressor V Model.

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Figure 65. Compressor Swash Plate.

The condenser may be of the one, two, or three pass finned tube type, made of copper or aluminum. A typical condenser is shown in figure 66.

Figure 66. Condenser With Flexible Hose.

VIBRATION ELIMINATOR. A device used to absorb vibrations created by the engine is placed between the compressor and the expansion valve, also between the compressor and the condenser. This may be either a section of flexible tubing surrounded by wire mesh, or a flexible hose. A typical flexible hose is shown in figure 66.

MUFFLER. It is usually located in the high pressure line of the compressor, figure 67. It functions as a surge chamber for HPG to reduce the noise level of the system while in operation.

FAN SLIP CLUTCH. This unit limits the maximum speed of the fan to about 3200 rpm regardless of engine speed. The fluid in the clutch transmits only enough torque to drive the fan at this limited speed, thus avoiding excessive noise and power consumption by the fan at higher engine speeds. The fan slip clutch is shown in figure 68.

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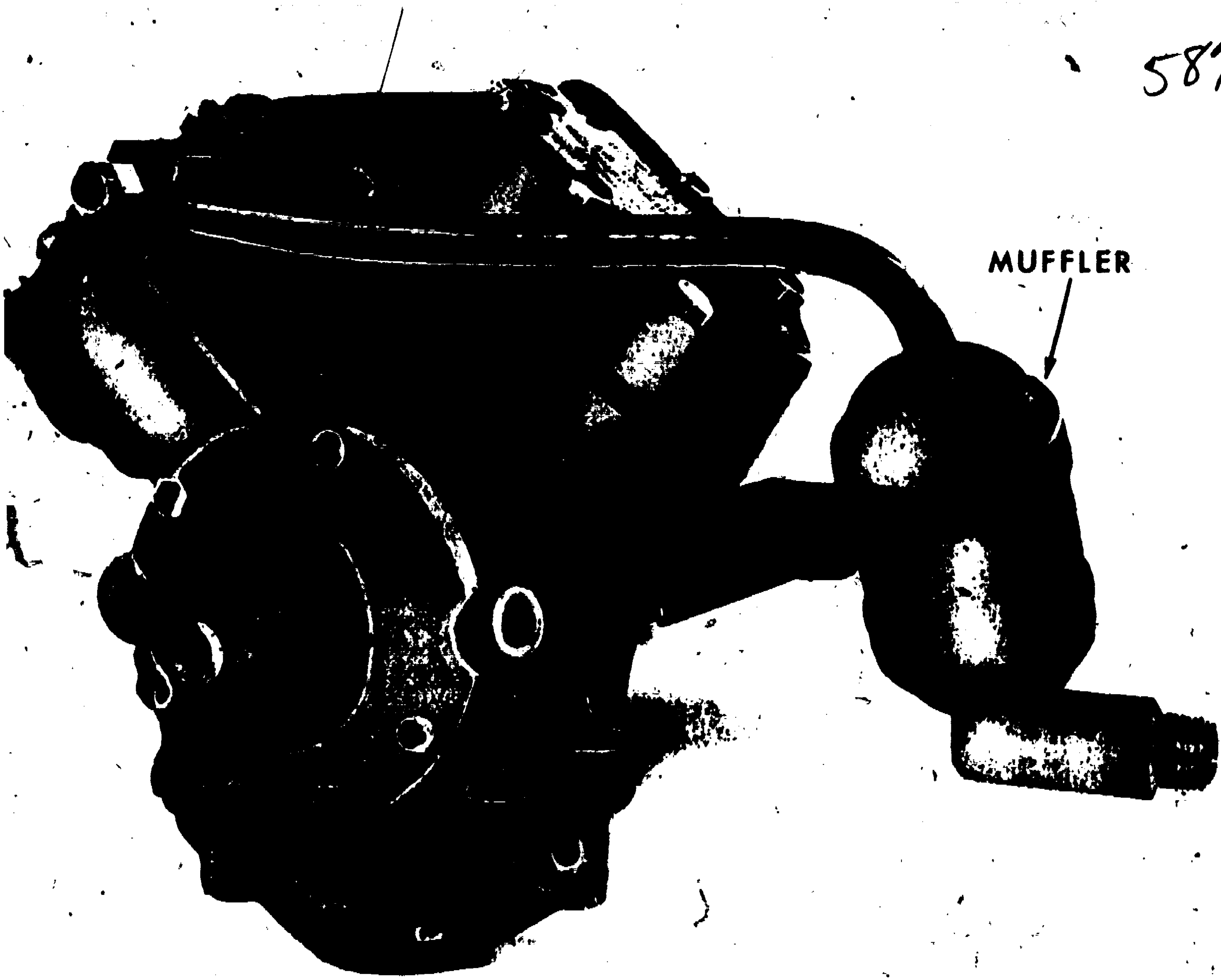


Figure 67. Muffler.

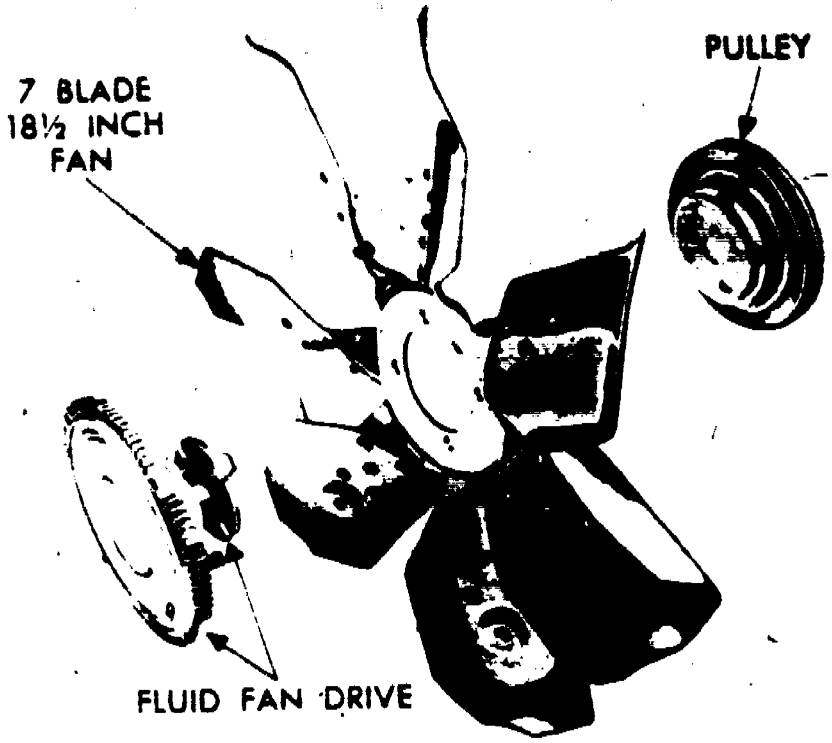


Figure 68. Fan Slip Clutch.

SERVICE VALVES. Various types of service valves, see figure 69, are used in a refrigerant system. Manual shutoff valves, such as those shown in figure 56, are installed at the inlet and outlet of the compressor. During normal operation both valves are open. Some systems use the Schrader valve. These are similar to the valve core used to inflate and deflate tires. They are usually located at the inlet and outlet of the compressor.

SUCTION PRESSURE CONTROL VALVE. Some systems have a suction pressure valve which is used to maintain a certain pressure in the evaporator independent of the compressor low side pressure and independent of the cooling demand. In most cases, a diaphragm or bellows responding only to the pressure in the evaporator opens this valve if the evaporator pressure is above 29 to 31 psi (R-12) and closes the valve if the pressure tends to go below these settings.

Several types of these valves are commonly used:

1. Suction throttling valve (STV).
2. Evaporator pressure regulator (EPR).
3. Pressure operated altitude valve (POA).

Figure 70 shows one type of suction pressure control valve. These valves are located in the low pressure line between the evaporator and the compressor.

Figure 69. Service Valves.

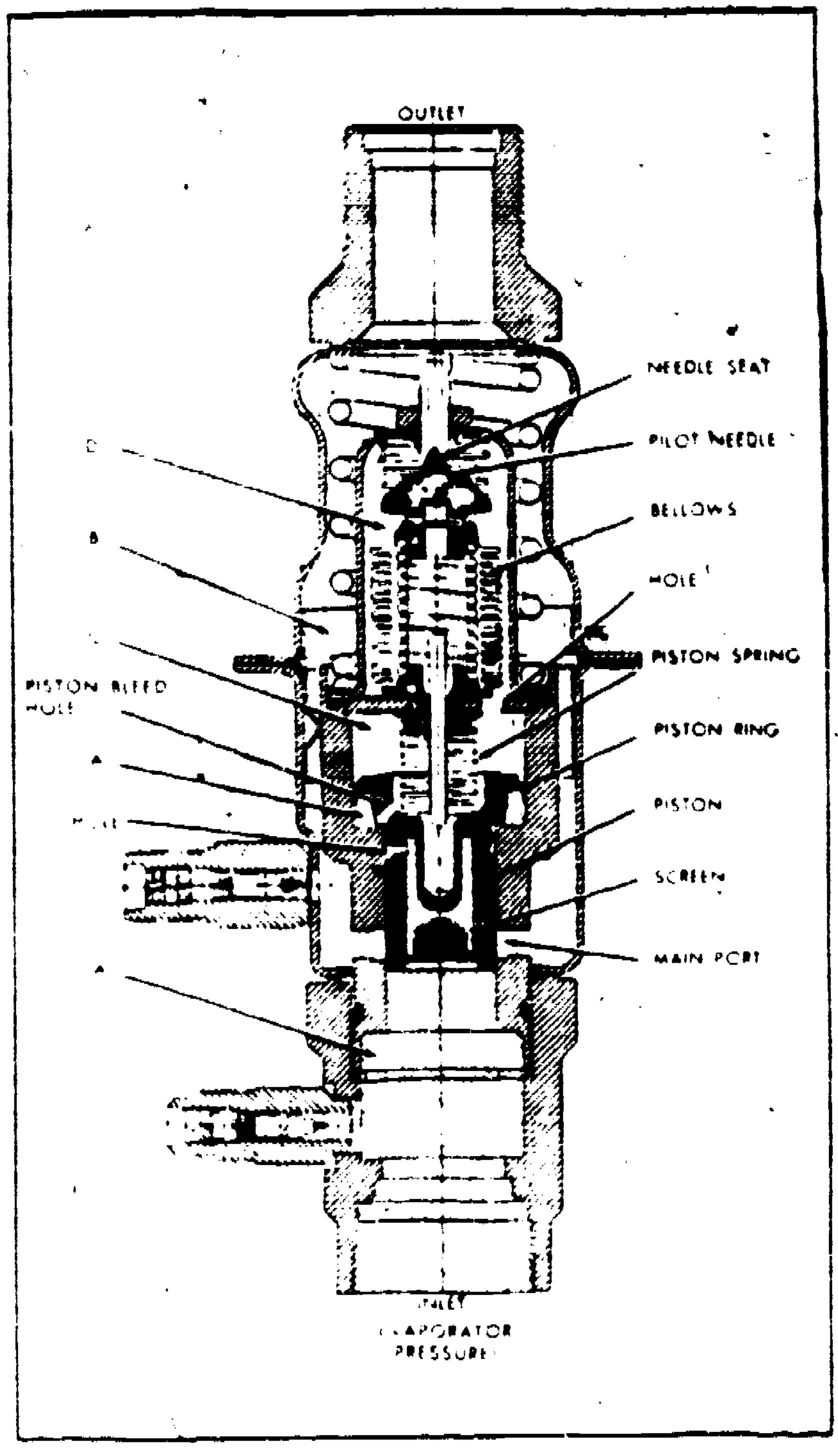


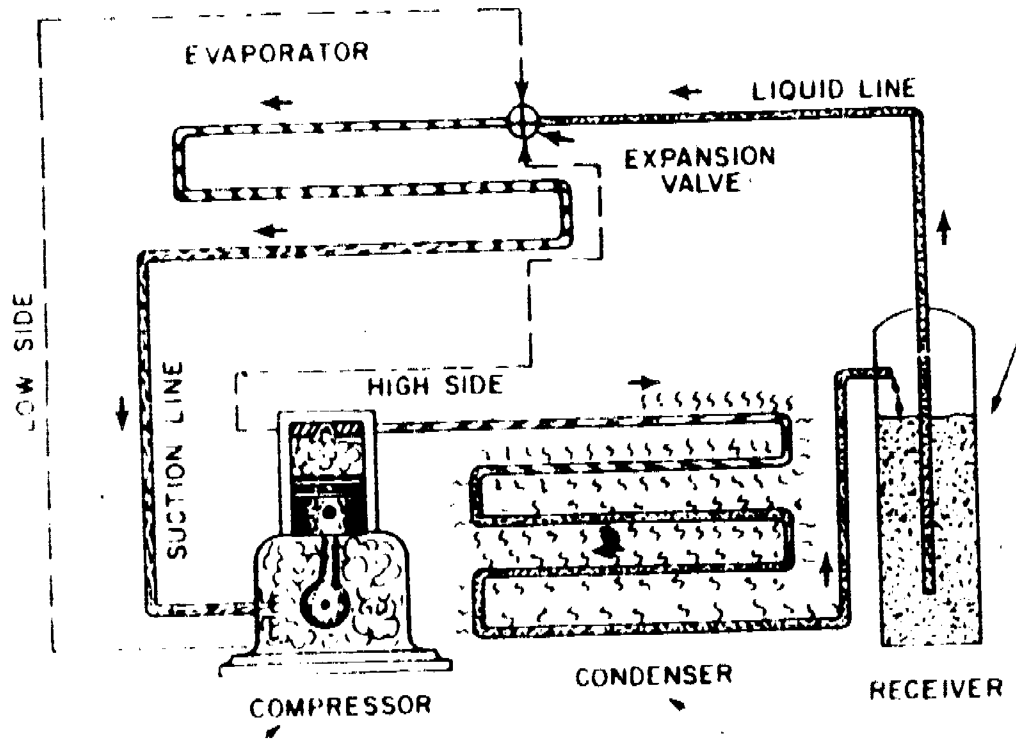
Figure 70. Suction Pressure Control Valve (PCA).

Putting the Components to Work

Now that we have discussed each component separately, let's put them all together into an active air conditioning unit. Figure 71 shows and tells what each component is doing to make this system work. It should be noted that during the refrigeratic cycle, two changes of state occur on the refrigerant. That is where the LPL changes state to LPG, this occurs in the evaporator and where the HPG changes state to HPL, this change occurs in the condenser.

2. In the EVAPORATOR the refrigerant passes through the inside of the tubes of the coils. As the heat from the air inside the car goes into the refrigerant, the refrigerant boils and changes into a gas. From the evaporator, the low pressure low temperature gas goes to the inlet side of the compressor.

1. The Refrigerant enters the EXPANSION VALVE in a liquid state at a high pressure and surrounding air temperature. It passes through the small orifice in the valve where it changes to a wet vapor and is reduced to a lower pressure. The lower pressure is also caused by the compressor sucking the refrigerant out of the evaporator.



5. When the refrigerant leaves the condenser, it goes into the RECEIVER-DRIER where it is stored until such time as the expansion valve calls for more liquid refrigerant. The drier filters out small amounts of moisture that may have entered the system at the time of installation.

3. The COMPRESSOR pumps the refrigerant into a high pressure gas. From the outlet side of the compressor the refrigerant goes to the inlet side of the condenser tubes.

4. In the CONDENSER the heat in the refrigerant gas goes into the air outside the car as this air passes over the condenser coils. As the refrigerant loses the heat, it changes into a liquid state.

Figure 71. Air Conditioning Cycle.

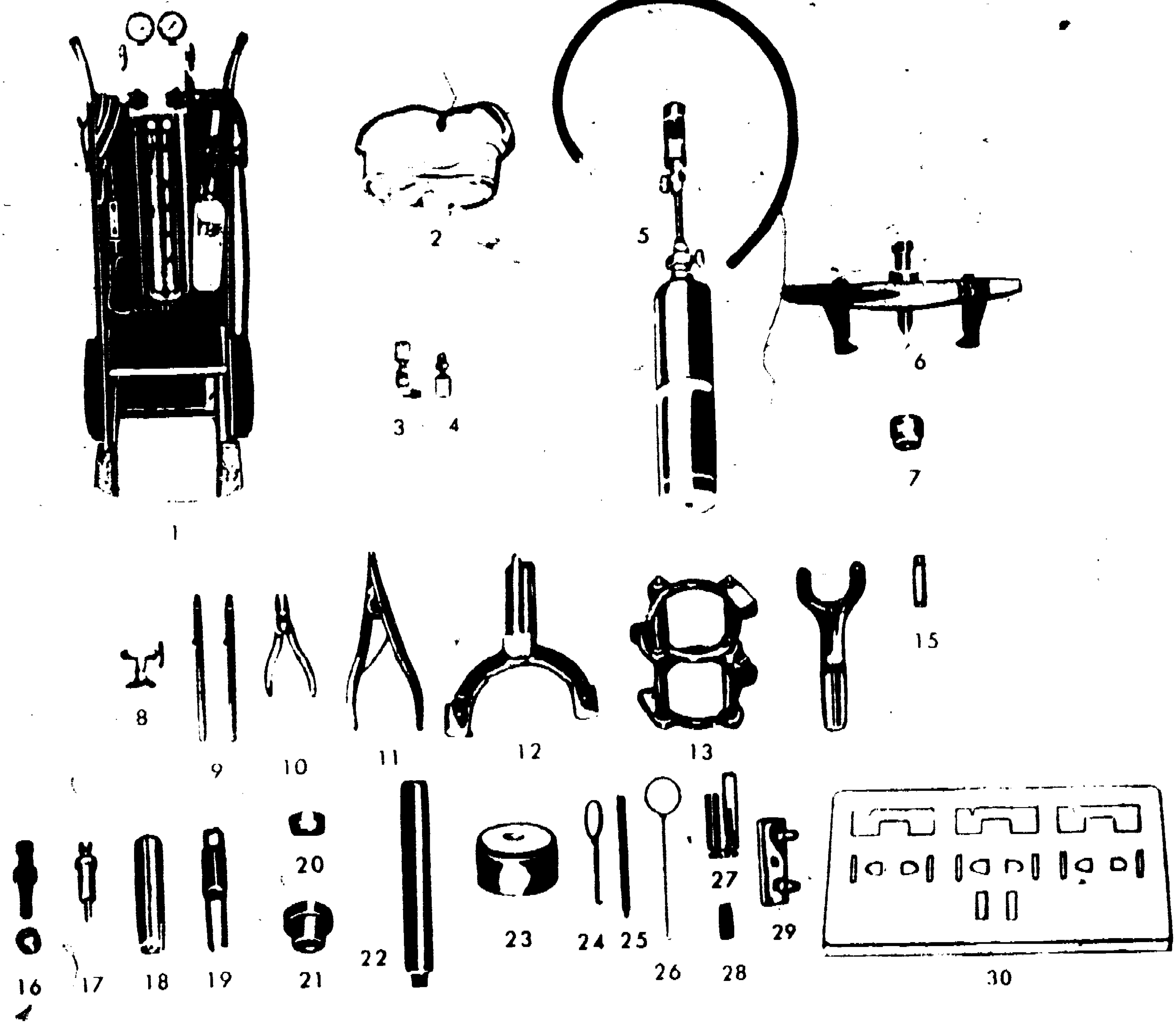


Figure [illegible]. Air Conditioning Special Tools.

1. Charging Station
2. Goggles
3. 90° Gauge Line Adapter
4. Gauge Line Adapter
5. Leak Detector
6. Puller
7. Puller Pilot
8. Fitzall Valve (Single Can)
9. Pocket Thermometers (2)
10. #21 Snap Ring Pliers
11. #26 Snap Ring Pliers
12. Compressor Holding Fixture
13. Compressing Fixture
14. Clutch Hub Holding Tool
15. 9/16" Thin Wall Socket
16. Hub and Drive Plate Assembly Remover
17. Hub and Drive Plate Assembly Installer
18. Seal Remover
19. Seal Seat Remover
20. Pulley Bearing Remover
21. Pulley and Bearing Installer
22. Handle
23. Internal Assembly Support Block
24. Oil Pickup Tube Remover
25. Needle Bearing Installer
26. Seal Seat "O" Ring Remover
27. Seal Seat "O" Ring Installer
28. Shaft Seal Protector
29. Pressure Test Connector
30. Parts Tray

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Minor Maintenance of the Compressor

The majority of the repairs made on the compressor will involve the magnetic clutch or the gas scale. The specific repair procedures for each of these units are described in detail in the appropriate technical publication. Our discussion, therefore, will only be of a general nature.

MAGNETIC CLUTCH. This unit starts and stops the compressor and provides the means of controlling the time the refrigerant is being pumped through the system. The magnetic clutch also allows the compresor pulley to "free wheel" when the air conditioner is not being used. When combined with the thermostatic switch, it will provide positive temperature control.

To remove the clutch from the compressor will require the use of special tools. The hammer and chisel tactics employed by many mechanics cannot be tolerated, so if you don't have the proper tools, see figure 72, don't attempt the repairs. Some of the tools required to remove and reinstall the magnetic clutch, gas seal, and associated parts of the swash plate compressor are shown in figure 72. As the make of the compressor changes, so also will the need for the special tools be changed.

When a leak is detected at the gas seal, removal of the magnetic clutch is required to gain access to the gas seal. The repairs made on the magnetic clutch are considered minor repairs because the system need not be purged. It should be noted also that these repairs may be accomplished without removing the compressor from the unit or system. Figure 73 illustrates this maintenance being accomplished with the compressor removed and mounted on a holding fixture.

Referring to figure 73, use the clutch hub holding tool to keep the drive hub from rotating, then remove the hub locknut using a ratchet and socket. The drive hub can be removed using the special puller, as shown in figure 74.

After the drive hub has been removed, the pulley and bearing retainer ring must be removed. This operation is being performed in figure 75.

With the retainer ring removed, the pulley and bearing can be removed, using the puller shown in figure 76.

With the drive plate and pulley removed, you can perform such other maintenance operations as removing and replacing the clutch coil or pulley bearing. The gas seal can also be serviced but this is considered major maintenance because the system must be purged of the refrigerant before removing the seal.

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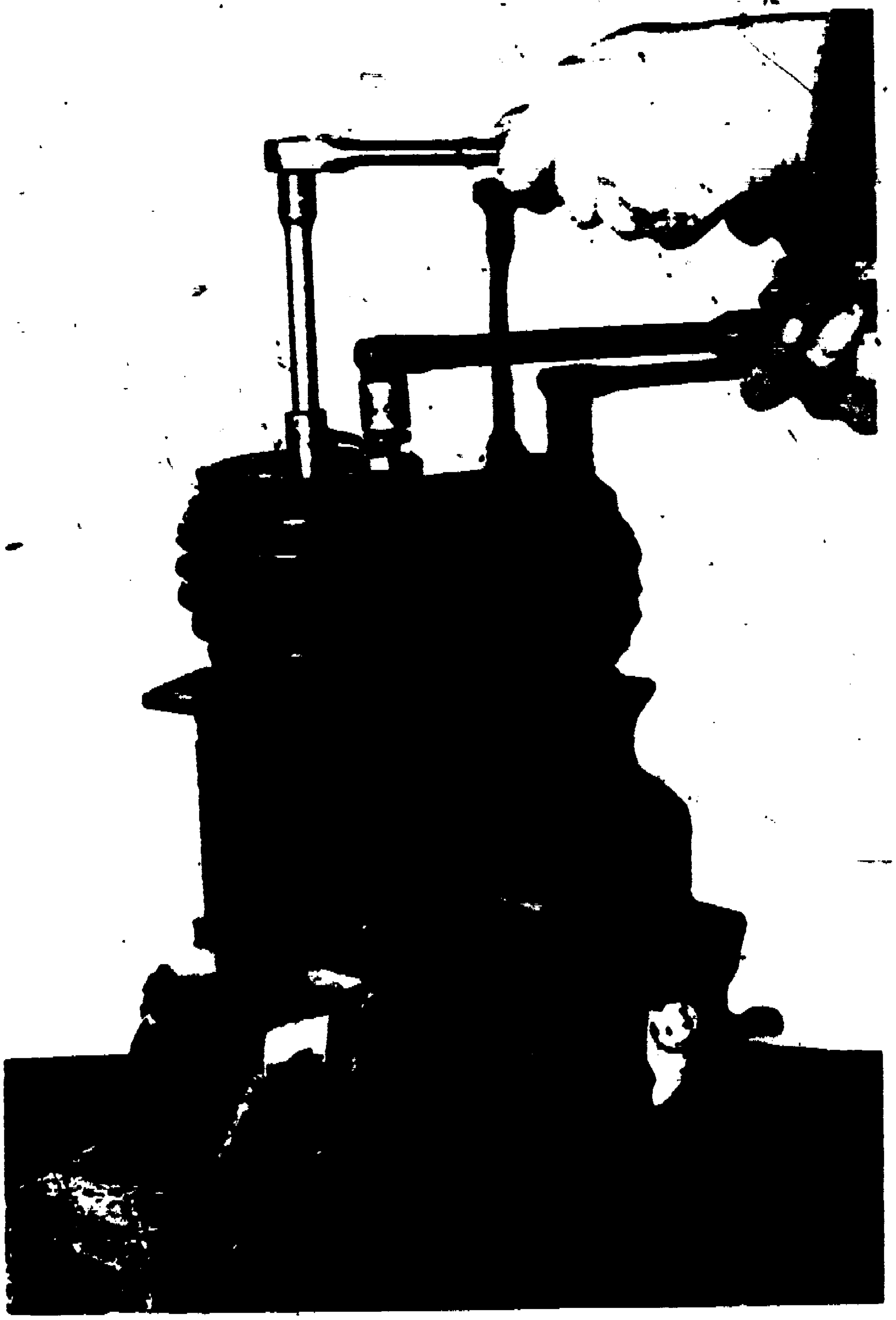

Figure 73. Removing Drive Hub Locknut.

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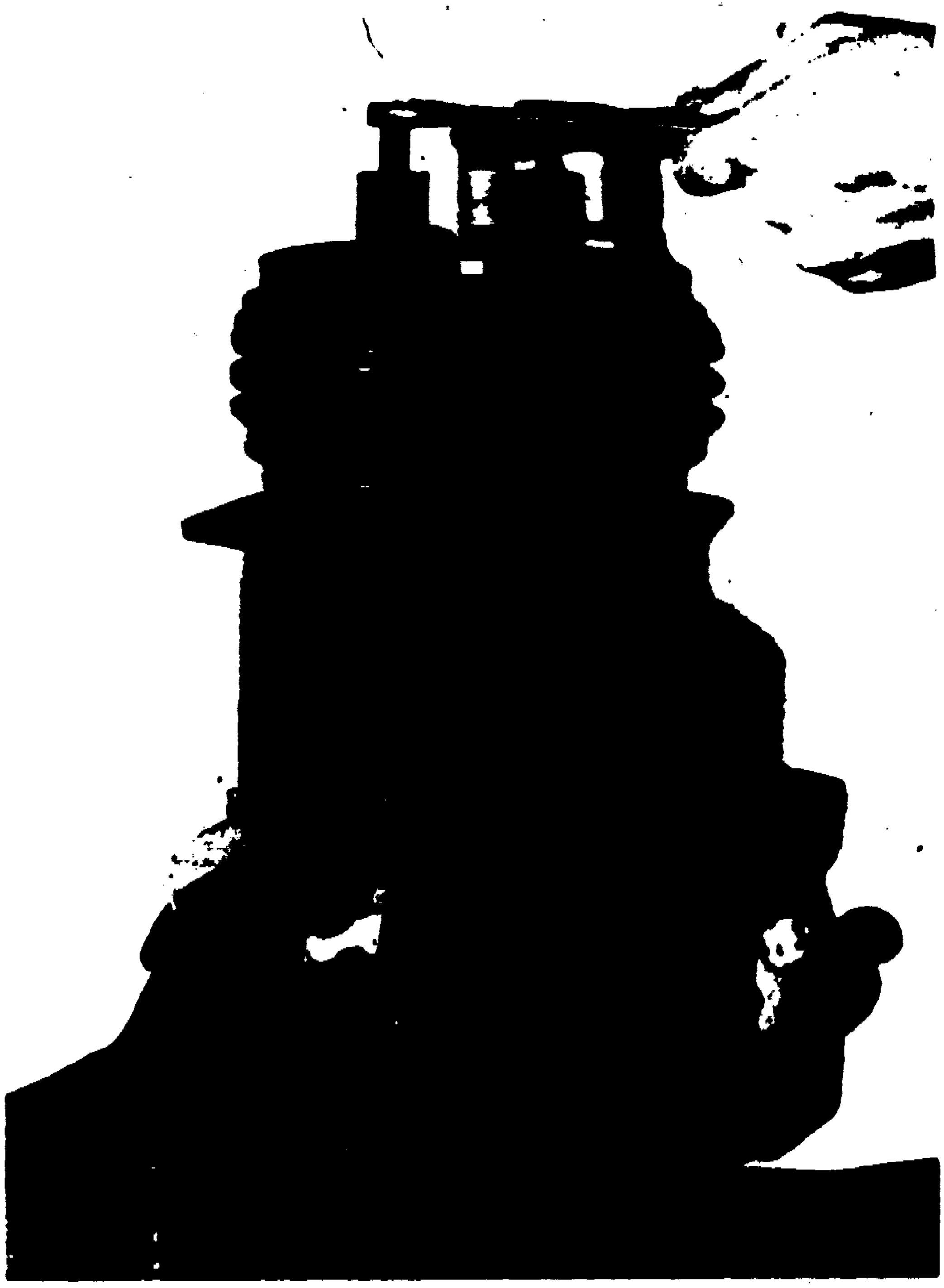

Figure 74. Removing Driving Hub.

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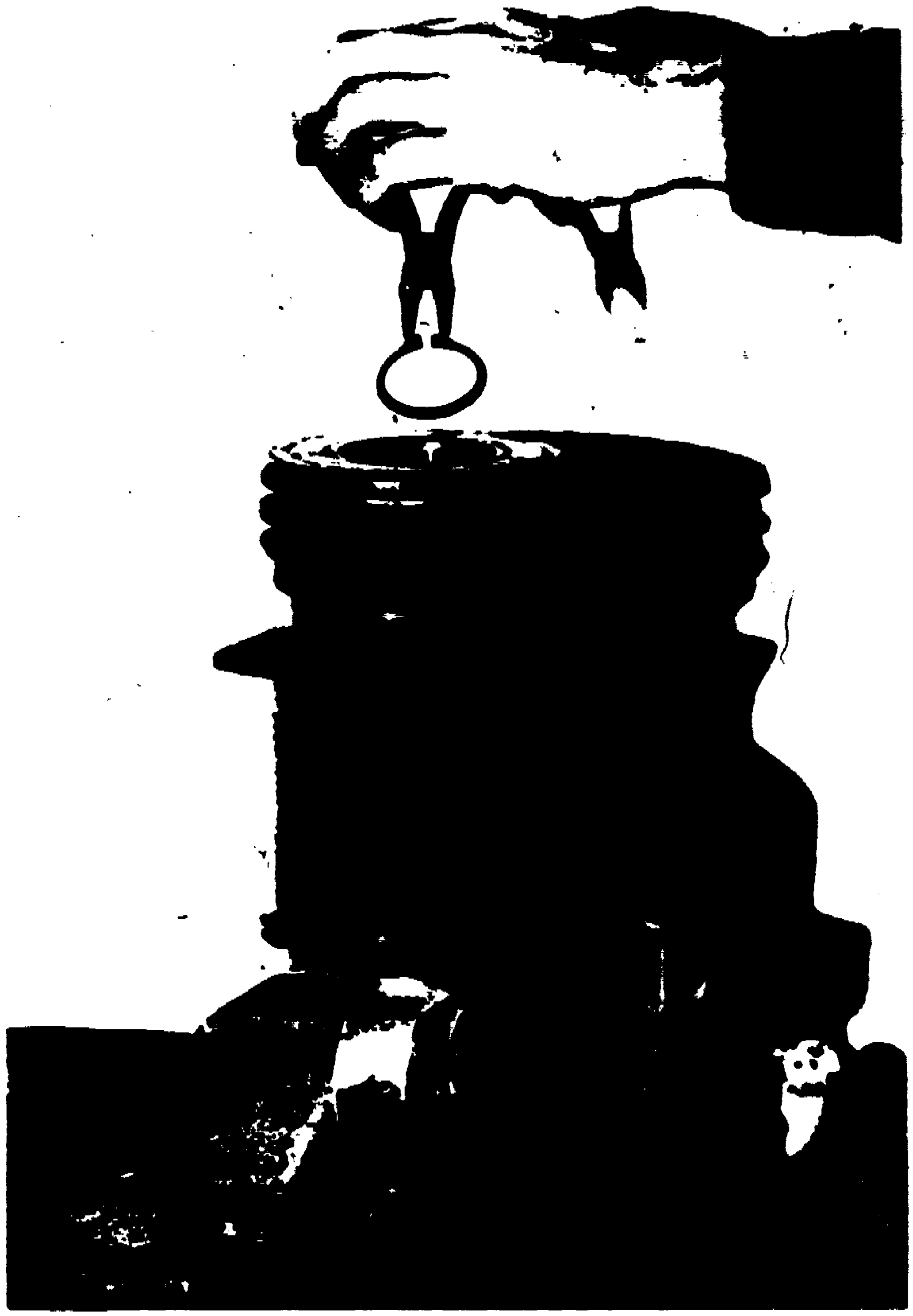

Figure 75. Removing Retainer Ring.

Figure 76. Removing Pulley.

To reinstall the clutch, the disassembly procedure would be reversed and the special tools would be used for the installation of the components.

> Caution: Never pound or drive the hub and drive plate into position. Always use the proper tools when removing or replacing clutch parts. Failure to do so may result in serious internal compressor damage.

QUESTIONS

1. What is the condition of the refrigerant in the receiver-drier?

2. What is the safety device used in the receiver-drier?

3. What are the four phases of the refrigerant?

4. What would be the result if the orifice in the expansion valve were too small?

5. What is the function of the compressor?

6. How many changes of state occur in the refrigerant?

7. Where is the expansion valve located in the refrigeration system?

8. What change of state occurs in the condenser?

9. What controls the opening and closing of the expansion valve?

10. What refrigeration components are necessary to make the system work?

True-False Questions

11. The compressor creates a change of state.

12. The condenser absorbs heat.

13. Gas seal replacement requires that the system be purged.

14. Damage may result to the compressor if a hammer is used to tap the clutch drive plate into place.

15. The evaporator makes cold air.

16. The evaporator takes the heat out of the air.

17. The expansion valve creates a pressure differential.

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18. A typical refrigeration system consists of an expansion valve, evaporator, compressor, condenser, and receiver-drier.

19. The receiver-drier stores refrigerant as LPL.

20. Four changes of state occur during one refrigeration cycle.

Completion Questions

21. Service valves are usually located at the ____________ and ____________ of the ____________.

22. The suction pressure control valve is located in the ________________ between the ____________ and the ____________.

23. The __________ ____________ __________ or ____________ ____________ assures that only __________ is allowed to leave the ____________ ____________.

24. ____________ heat is absorbed to ______________ the refrigerant.

25. The function of the ____________ is to raise the ______________ pressure, __________ temperature gas to a __________ pressure, __________ temperature ___________.

REFERENCES

1. TO 36A2-3-20-2-3, Ford Service Manual.

2. TO 36A2-4-27-2, Chevrolet Service Manual.

3. TO 36A2-4-28-3, Chevrolet Service Manual.

4. TO 36A2-5-9-12, Chrysler Service Manual.

INSPECTION, TROUBLESHOOTING, EVACUATING, AND CHARGING OF AIR CONDITIONING SYSTEM

OBJECTIVES

GA2294

After referring to ~~[illegible] Heating and Air Conditioning~~, ~~pages 84-86~~, and completing this unit of instruction, you will be able to inspect, troubleshoot, evacuate, and charge the air conditioning system.

INTRODUCTION

Air conditioning systems are engineered and constructed to give many years of efficient service. However, there may come a time when a malfunction occurs and you will be required to inspect and troubleshoot the system. Many air conditioner troubles could result from careless practices. This is why it is very important that proper maintenance procedures are followed. There are four important facts to remember when servicing an air conditioning system: (1) Keep dirt out of the system, (2) Keep moisture out of the system, (3) Evacuate the system thoroughly, and (4) Use only refrigeration oil.

INFORMATION

INSPECTION AND TEST PROCEDURES

Satisfactory performance of the air conditioning is dependent upon proper operation and adjustment of all operating controls, as well as proper functioning of all refrigeration system units. The inspections, tests, and adjustments should be used to locate the cause of a malfunction.

Obstructed air passages, broken belts, disconnected or broken wires, loose clutch, loose or broken mounting brackets may be determined by a visual inspection of the parts.

The primary causes of system failures are defined as follows.

Leaks

A shortage of refrigerant causes oil to be trapped in the evaporator. Oil may be lost with the refrigerant at the point of the leakage. Both of these can cause compressor seizure.

Oil circulates in the system with the refrigerant; in solution with the liquid and in globules with the vapor. It leaves the compressor by the action of the pistons and mixes with the refrigerant liquid in the condenser. The oil then enters the evaporator with the liquid and, with the evaporator properly flooded, is returned to the compressor through the low pressure line. Some of the oil returns as globules in the

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vapor but more importantly, it is swept as a liquid along the walls of the tubing by the velocity of the vapor. If the evaporator is starved, the oil cannot return in sufficient quantities to keep the compressor properly lubricated.

High Temperature and Pressure

An increase in temperature causes an increase in pressure. This accelerates chemical instability due to existing contaminants in the system, and initiates chemical instability in a clean system. Other results are brittle hoses, "O" ring gaskets, and bypass valve diaphragms with possible decomposition, broken compressor discharge reeds, and seized compressor bearings.

A fundamental law of nature accounts for the fact that when a substance, such as a refrigerant, is increased in temperature, its pressure is also increased.

Any chemical reactions caused by contaminants already in the system are greatly accelerated as the temperature increases. A 15° rise in temperature doubles the chemical action. Even in a good clean system, heat alone can start a chain of harmful chemical reactions.

While temperature alone can cause the synthetic rubber parts to become brittle and possible to decompose, the increased pressure can cause them to rupture or blow.

As the temperature and pressure increases, the stress and strain on the discharge reeds also increases. This can result in broken reeds. Due to the effect of the contaminants caused by high temperature and pressure, compressor bearings can be caused to seize.

Air In the System

Air results from a discharged system or careless servicing procedures. This reduces system capacity and efficiency and causes oxidation of oil into gum and varnish.

When a leak causes the system to become discharged, the resulting vacuum within the system will cause air to be drawn in. Air in a system is a noncondensable gas and will build up in the condenser as it would in an air compressor tank. The resultant heat produced will contribute to the conditions discussed previously.

Many systems are contaminated and also reduced in capacity and efficiency by servicemen who either do not know or are careless regarding proper servicing procedures.

Too frequently, systems which have been open to the atmosphere during service operations have not been properly purged or evacuated. Air is also introduced into the system by unpurged gage and charging lines. Remember that any air in the system is too much air.

Poor Connections

Hose clamp type fittings must be properly made. Hose should be installed over the sealing flanges and with the end of the hose at the stop flange. The hose should never extend beyond the stop flange. Locate the clamp properly and torque as recommended. Be especially careful that the sealing flanges are not nicked or scored or a future leak will result.

When compression fittings are used, over-tightening can cause physical damage to the "O" ring gasket and will result in leaks. The use of torque and backing wrenches is highly recommended. When making a connection with compression fittings, the gasket should always be first placed over the tube before inserting it in the connection.

Another precaution - inspect the fitting for burrs which can cut the "O" ring.

Restrictions

Restrictions may be due to powdered desiccant or dirt and foreign matter. This may result in starved evaporator and loss of cooling, high temperature at the bypass hose, or a seized compressor.

When the amount of moisture in a system sufficiently exceeds the capacity of the desiccant, it can break down the desiccant and cause it to powder. The powder passes through the dehydrator screen with the refrigerant liquid and is carried to the expansion valve screen. While some of it may pass through the valve screen into the evaporator, it may quickly build up to cause a restriction.

Due to the fact that sufficient oil then cannot be returned to the compressor, it may seize.

Dirt

Dirt, which is any foreign material, may come from cleaner residues, cutting, machines, preserving oils, metal dust or chips, lint, loose rust, soldering or brazing fluxes, paint or loose oxide scale. The following can also cause a seized bearing, abrasion, or wedging, discharge and expansion valve failure, decomposition of refrigerant and oil, or corrosion of metal parts.

Corrosion

Corrosion and its by-products can restrict valve and drier screens, roughen bearing surfaces or hasten fatiguing of discharge reeds. This can result in high temperature and pressure, decomposition, or leaks. In any event, this means a damaged compressor.

From this, we can see the vicious circle that can be produced in a refrigeration system to cause its failure. Corrosion can be the indirect cause of leaks and leaks can be the direct cause of corrosion. We can also see the important role we, as servicemen, play in maintaining chemical stability.

Moisture

Moisture is the greatest enemy of refrigerating systems. Combined with metal, it produces oxide, iron hydroxide, and aluminum hydroxide. Combined with R-12, it produces carbonic acid, hydrochloric acid, and hydrofluoric acid. Moisture can also cause freeze-up of expansion valve and powdered desiccant.

Although high temperature and dirt are responsible for many difficulties in refrigerating systems, in most instances it is the presence of moisture in the system that accelerates these conditions. It can be said, therefore, that moisture is the greatest problem of all. The acids that it produces, in combination with both the metals and the refrigerant, causes damaging corrosion. While the corrosion may not form as rapidly with R-12 as with some refrigerants, the eventual formation is as damaging.

If the operating pressure and temperature in the evaporator is reduced to the freezing point, moisture in the refrigerant can collect at the orifice of the expansion valve and freeze. This temporarily restricts the flow of liquid, causing erratic cooling.

As previously mentioned, moisture in excess of the desiccants capacity can cause it to powder.

TROUBLESHOOTING AND DIAGNOSIS

The following is a description of the type of symptom each refrigerant compound will evidence if a defect occurs.

Compressor

A compressor defect will appear in one of four ways: noise, seizure, leakage, or low discharge pressure.

Note: Resonant compressor noises are not cause for alarm; however, irregular noise or rattles may indicate broken parts or excessive clearance due to wear. To check seizure, deenergize the magnetic clutch and check to see if drive plate can be rotated. If rotation is impossible, compressor

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is seized. If rotation is impossible, compressor is seized. To check for leak, refer to leak testing in the service manual. Low discharge pressure may be due to a faulty internal seal of the compressor, or a restriction in the compressor.

Note: Low discharge pressure may also be due to an insufficient refrigerant charge or a restriction elsewhere in the system. These possibilities should be checked prior to servicing the compressor. If the compressor is inoperative, but is not seized, check to see if current is being supplied to the magnetic clutch coil terminals.

Condenser

A condenser may be defective in two ways: it may leak, or it may be restricted. A condenser restriction will result in excessive compressor discharge pressure. If a partial restriction is present, sometimes ice or frost will form immediately after the restriction as the refrigerant expands after passing through the restriction. If air flow through the condenser or radiator is blocked, high discharge pressures will result. During normal condenser operation, the outlet pipe will be slightly cooler than the inlet pipe.

Receiver-Dehydrator

A defective receiver-dehydrator may be due to a restriction inside the body of a unit. A restriction at the inlet to the receiver-dehydrator will cause high head pressures. Outlet tube restriction will be indicated by low head pressure and little or no cooling. An excessively cold receiver-dehydrator outlet may be indicative of a restriction.

Expansion Valve

Expansion valve defects usually will be indicated by low suction and discharge pressures, and insufficient evaporator cooling. The problem is generally due to malfunction of the power element and subsequent closing of the valve. A less common cause of the above symptom is a clogged inlet screen.

Evaporator

When the evaporator is defective, the trouble will show up as an inadequate supply of cool air. A partially plugged core due to dirt, a cracked case, or a leaking seal will generally be the cause.

POA Valve

If the POA valve is defective, it may cause evaporator pressure (hence air temperature) to be either too high or too low depending on the type of failure. No adjustment is possible on POA valves. If it is determined that a POA valve has failed, it should be replaced. Before replacing the POA valve, check for proper fan operation.

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Refrigerant Line Restrictions

Restrictions in the refrigerant lines will be indicated as follows:

1. Suction Line - A restricted suction line will cause low suction pressure at the compressor, low discharge pressure, and little or no cooling.

2. Discharge Line - A restriction in the discharge line generally will cause the pressure relief valve to open.

3. Liquid Line - A liquid line restriction will be evidenced by low discharge and suction pressure, and insufficient cooling.

Sight Glass Diagnosis

At temperatures higher than 70°F, the sight glass may indicate whether the refrigerant charge is sufficient. A shortage of liquid refrigerant is indicated after about five minutes of compressor operation by the appearance of slow-moving bubbles (vapor) or a broken column of refrigerant under the glass. Continuous bubbles may appear in a properly charged system on a cool day. This is a normal situation. If the sight glass is generally clear and performance is satisfactory, occasional bubbles do not indicate refrigerant shortage. If the sight glass consistently shows foaming or a broken liquid column, it should be observed after partially blocking the air to the condenser. If, under this condition, the sight glass clears and the performance is otherwise satisfactory, the charge shall be considered adequate. In all instances, where the indications of refrigerant shortage continues, additional refrigerant should be added in 1/4 lb increments until the sight glass is clear. An additional charge of 1/2 lb should be added as a reserve after the glass clears. In no case should the system be over-charged.

System Diagnosis

A malfunction in an air conditioning system can be simplified by a logical, systematic procedure which can minimize time and effort. Lack of a logical systematic procedure could complicate determining a relatively minor malfunction or waste time and effort attempting to diagnose a malfunction which does not actually exist.

Before a malfunction in the system can be diagnosed and corrected, an understanding of how the system operates under normal conditions is essential. Always refer to the appropriate manuals for operational procedures.

The most important part of diagnosing a problem is to determine exactly what the complaint is and whether this complaint actually stems from a malfunction in the system. (Without a thorough understanding of how the system is supposed to operate, a complaint stemming from misunderstanding of system operation or improper setting of the control panel lever could result in the search for a malfunction that does not exist.) If the complaint is of a condition that occurs only periodically (intermittent), the malfunction should be observed before diagnosis and repairs are attempted.

A systematic diagnosis before attempting repair or parts replacement will save time and prevent customer dissatisfaction. You must first determine if the problem is in the freon system, the heater, or the control system which includes vacuum and electric.

The main objective when troubleshooting the system is to isolate the problem to either the control head (control panel), the sensors, the vacuum system, the electrical system, or the programmer. After this preliminary isolation is completed, the actual malfunction can then be determined quickly. Figures 77, 78, 79, and 80 will aid you in diagnosing air condition systems malfunctions. Use troubleshooting problem Chart 1 to help determine the malfunction. (Located in back of study guide.)

EVACUATING THE SYSTEM

Hand Operated Service Valves

To evacuate a system, it is necessary to use a vacuum pump. To charge a system properly it is necessary to weigh or measure the amount of refrigerant that goes into the system.

The two service valves that are used to evacuate and charge the system are located on the head of the compressor.

For evacuating an air conditioning system that has hand-operated service valves on the head of the compressor, follow these steps carefully.

1. Remove the two large caps located on the ends of the service valves on the head of the compressor. These caps are approximately 7/8" in diameter.

2. Under the caps there are valve stems. Using a serviceman's refrigeration ratchet, wind the valve stems out (counterclockwise) until they back seat (see figure 81). Back seating the valve stem is usually necessary only when installing a new compressor.

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COMPRESSOR DIAGNOSIS CHART

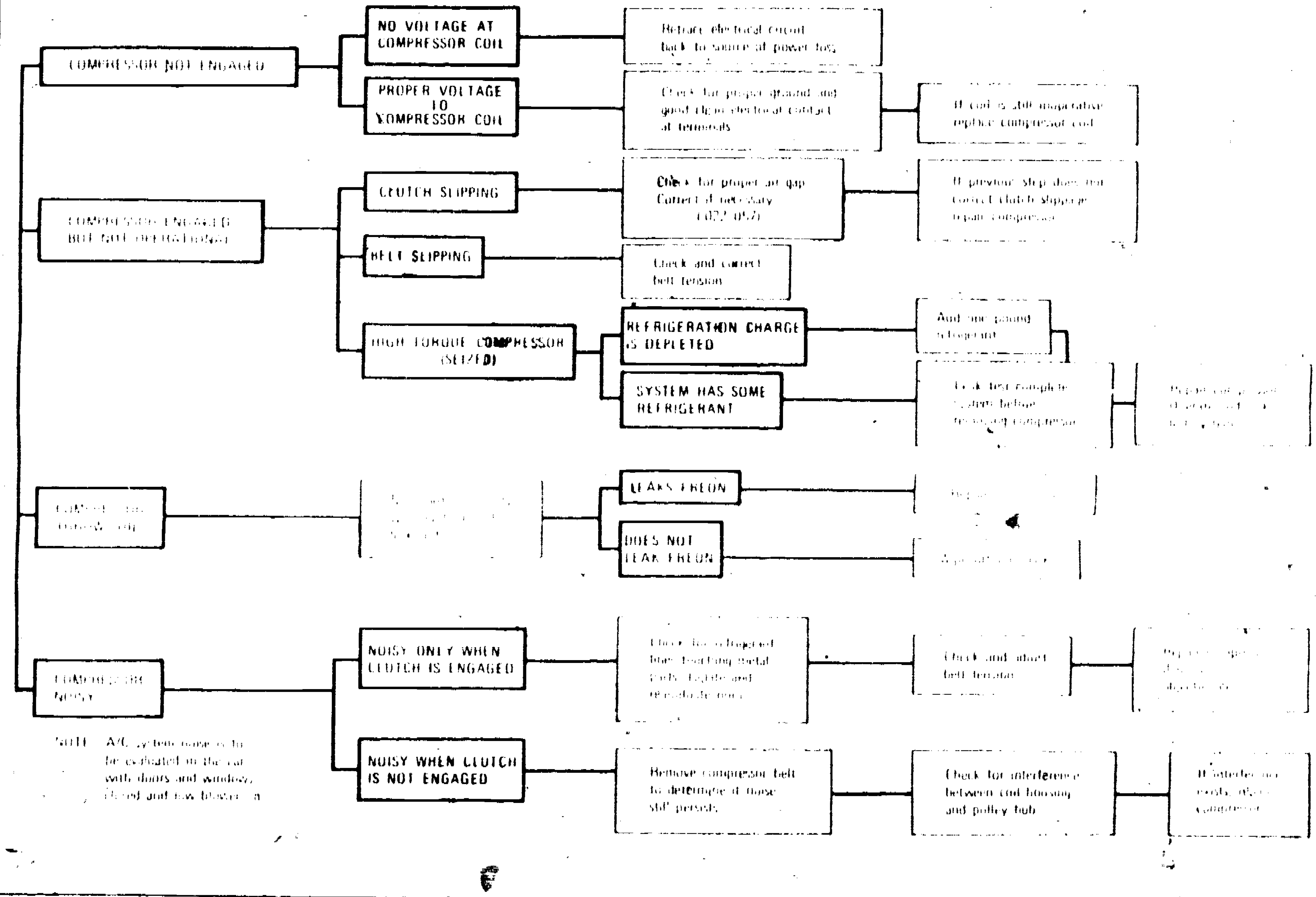

Figure 77. Compressor Diagnosis Chart.

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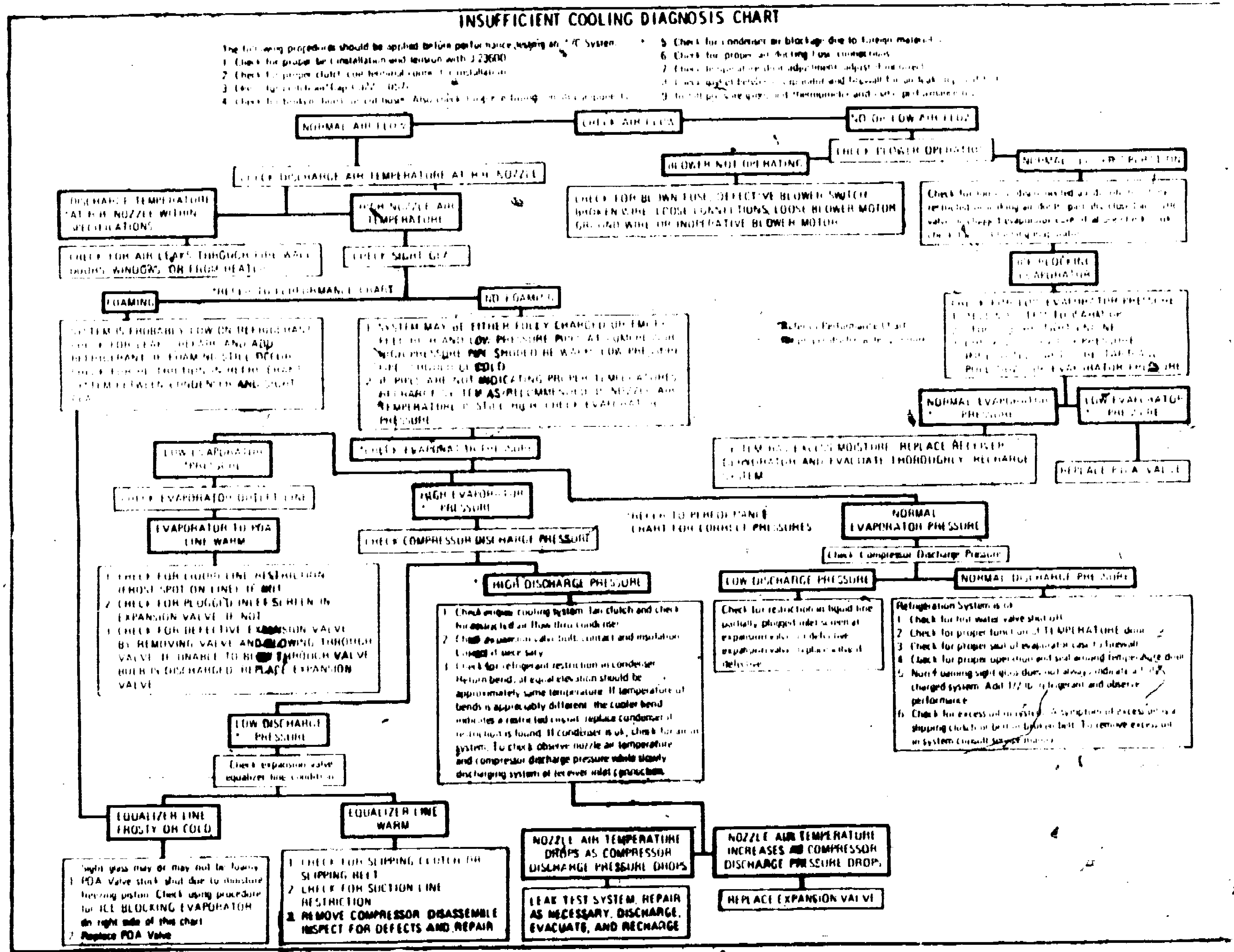

Figure 78. Insufficient Cooling Diagnosis Chart.

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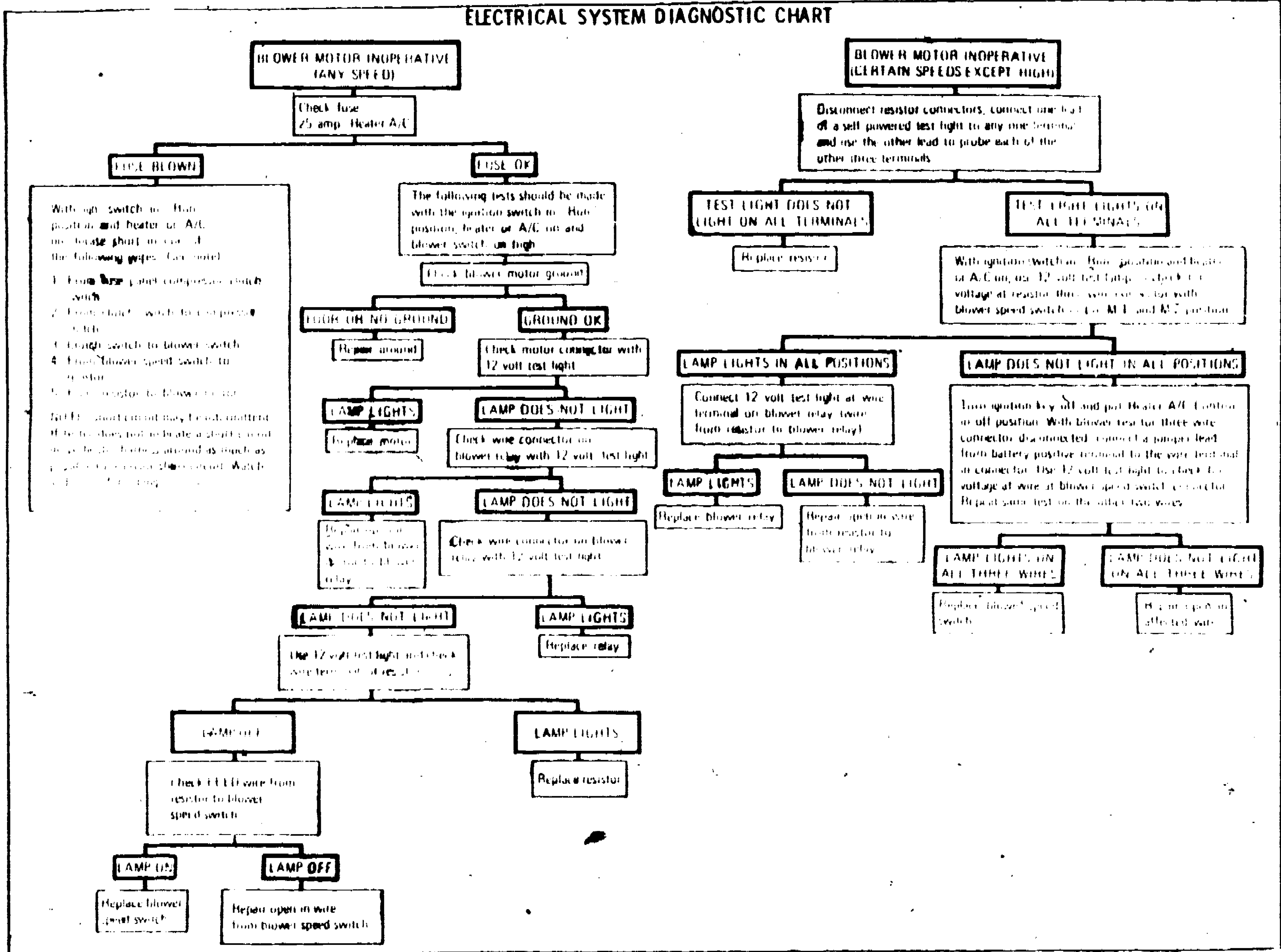

Figure 79. Electrical System Diagnosis Chart.

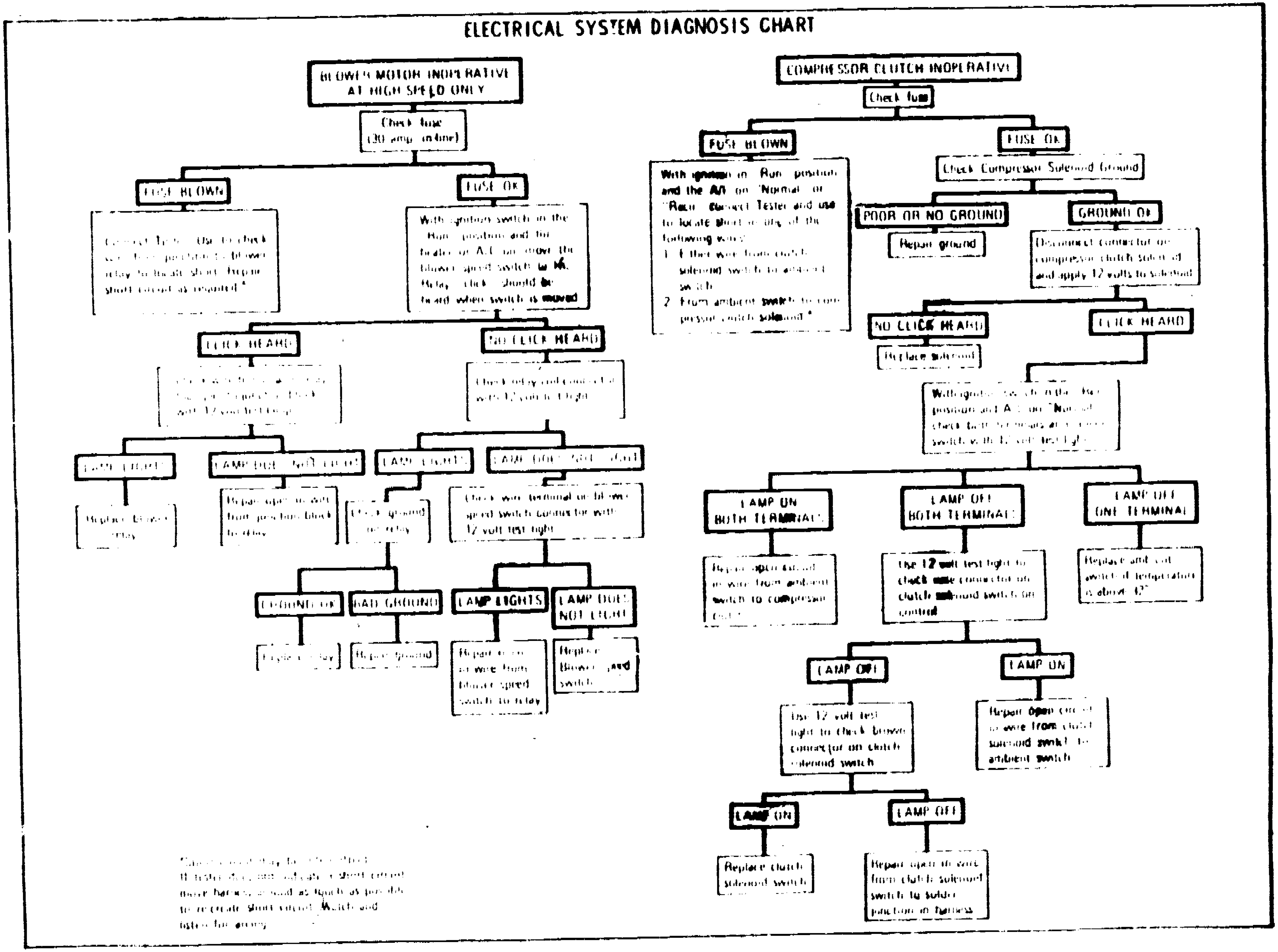

Figure 80. Electrical System Diagnosis Chart.

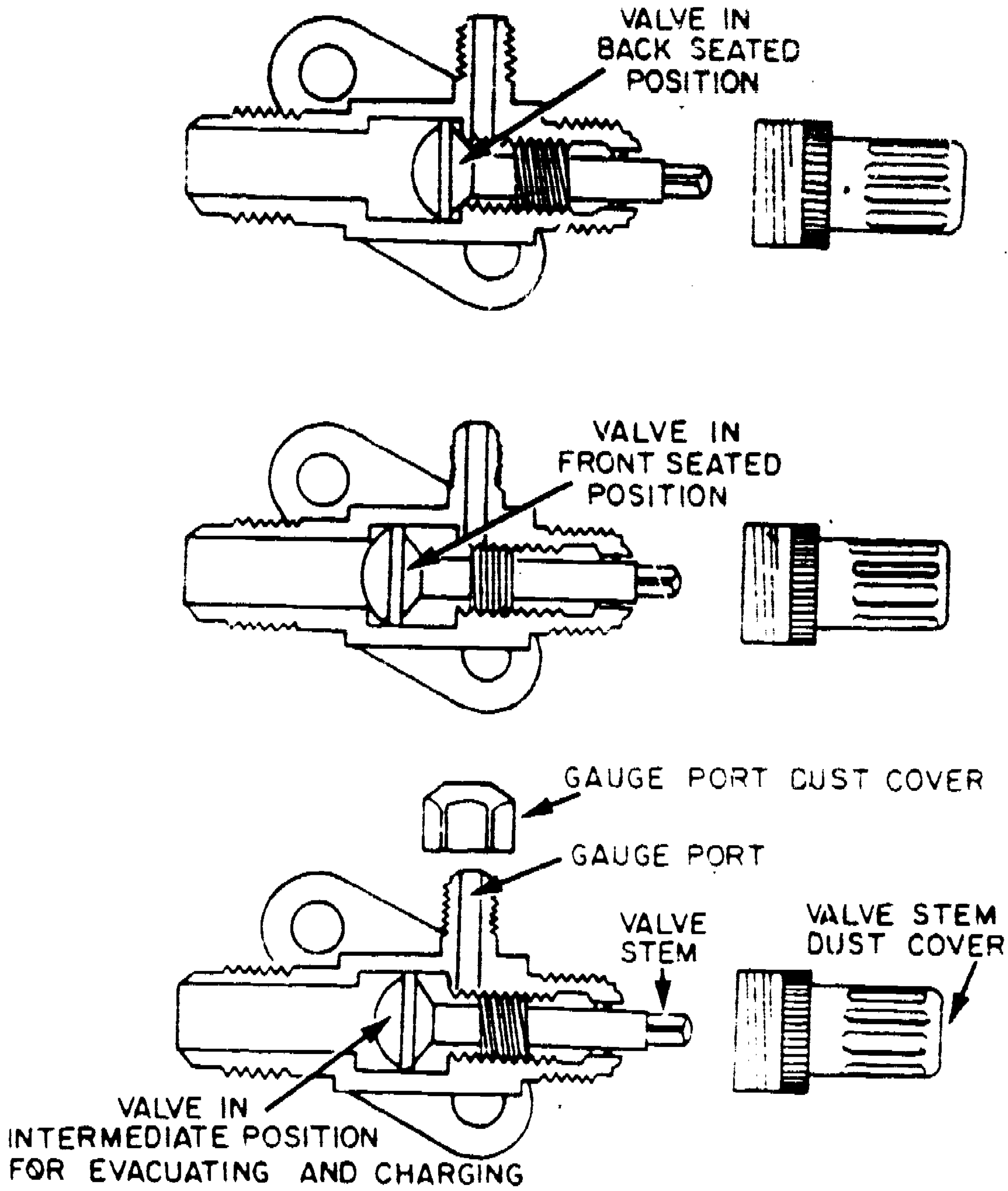

Figure 81. Operating Positions of Valve Stem -- Hand-Operated Valve.

3. Using a 1/2" socket on a ratchet, rotate the clutch shoe and compressor crankshaft ten or twelve turns. Any oil that may be trapped on top of the piston in the compressor will be returned to the crankcase, and at the same time, this oil will lubricate the shaft seal of the compressor.

4. Remove the 9/16" caps that are covering the gauge ports openings on the service valve. Sizes of cap may vary depending on the manufacturer.

5. Connect the <u>high pressure</u> gauge hose of the serviceman's gauge set to the gauge port opening of the discharge valve located on the compressor head, see figure 82.

6. Connect the <u>low pressure</u> gauge hose of the serviceman's gauge set to the gauge port opening of the suction valve located on the compressor head, see figure 82.

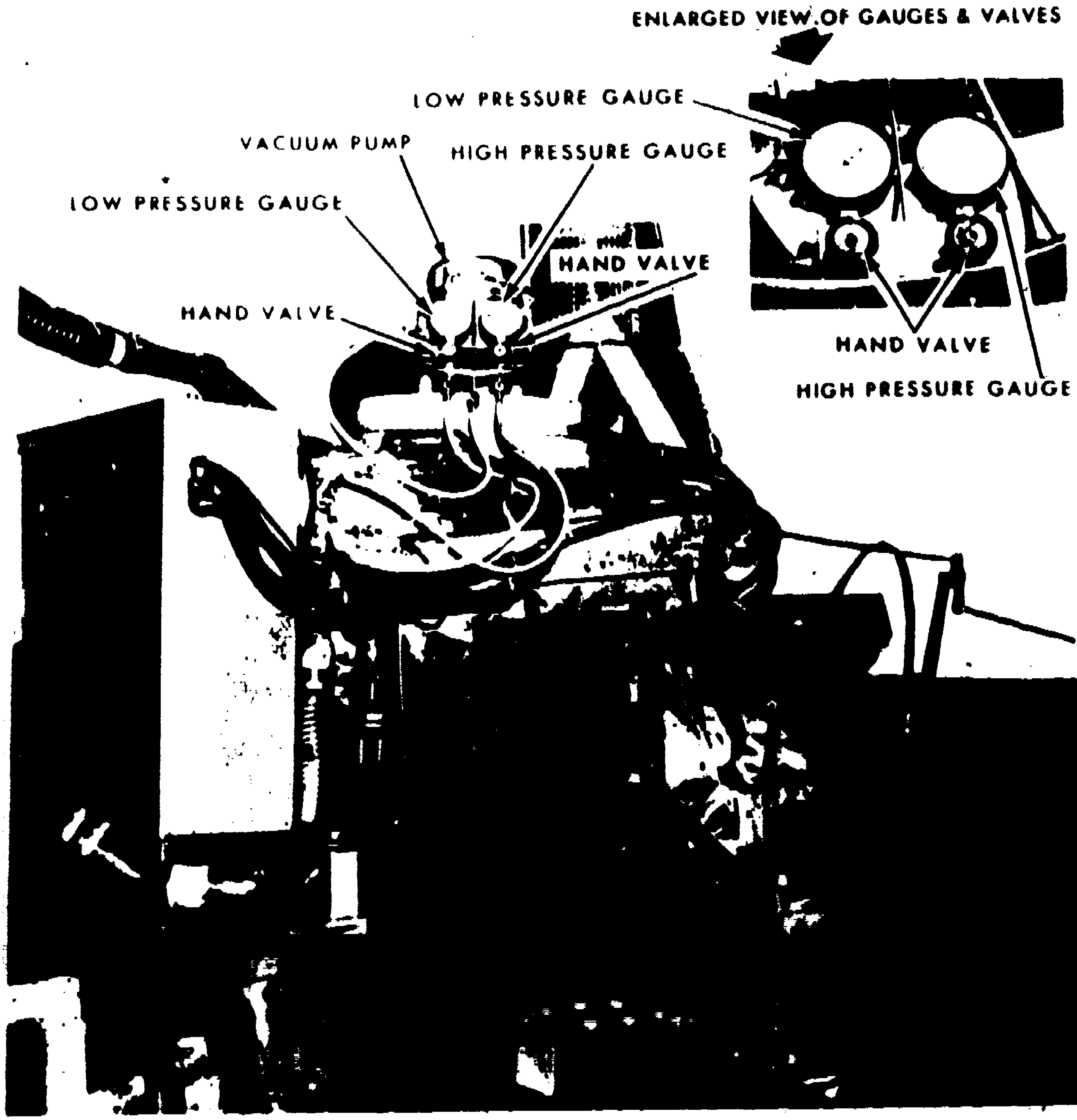

Figure 82. Gauge Set Hookup to Hand-Operated Valves for Evacuating.

7. Close both hand valves located on the serviceman's gauge set by winding the valve stems in.

8. Wind the stem of the suction valve on the compressor in a clockwise motion until the valve is front seated. The valve stem should be all the way in, see figure 81.

9. Connect the center hose from the serviceman's gauge set to a good vacuum pump, see figure 82.

10. Start the pump.

11. Open the high pressure gauge valve on the serviceman's gauge set by winding the valve stem out partway. If the high pressure gauge reads below zero, this means the pump is pumping. If it does not read below zero, check the vacuum pump to be sure it is pumping.

12. Close the high pressure gauge valve on the serviceman's gauge set by winding the valve stem in.

13. Open the suction valve located on the compressor by winding the valve stem out (counterclockwise) five full turns. The valve stem will be about halfway out, see figure 81. The low pressure gauge should read below zero. If it does not read below zero, it indicates one of three things:

a. The system is plugged.

b. The system has leaks.

c. The expansion valve is stuck in the closed position.

First, check the system for plugs. Then, check the system for leaks by inspecting all of the connections. Finally, check the expansion valve to be sure it is in the open position. Also make certain your gauges and the vacuum pump are in good working condition.

14. Continue with the evacuation of the system by opening the low pressure gauge on the serviceman's gauge set by winding the valve stem all the way out (counterclockwise).

15. After the vacuum pump has been running for five minutes, close the low pressure gauge valve on the serviceman's gauge set. Make sure the high pressure gauge valve is also closed. Note the reading on the low pressure gauge. It should be between 25 and 28 inches of vacuum. If this reading stays the same for about seven minutes, it is an indication that the system does not have any leaks. Proceed with the evacuation. If the system does have leaks, do not proceed until they have been repaired.

16. Open both hand valves on the serviceman's gauge set. After the low pressure gauge shows between 25 and 28 inches of vacuum, allow the vacuum pump to run for a minimum of 20 minutes. Preferably, the vacuum pump should run for an hour. <u>You cannot</u> evacuate the system too long a time.

17. Close both hand valves on the serviceman's gauge set by turning them in (clockwise).

18. Stop the vacuum pump and disconnect the center hose of the gauge set from the vacuum pump.

Now that the air conditioning system is completely evacuated, proceed with charging.

> Note: Although the evacuating procedures for all air conditioning systems are similar, steps vary according to the manufacturer. Always refer to the appropriate technical manual for evacuating procedures.

Evacuating the System

DILL CORE SERVICE VALVE. These procedures are to be used when you have the Dill Core type service valve, see figure 83. For evacuating an air conditioning system that has Dill Core type service valves on the head of the compressor, follow these steps carefully:

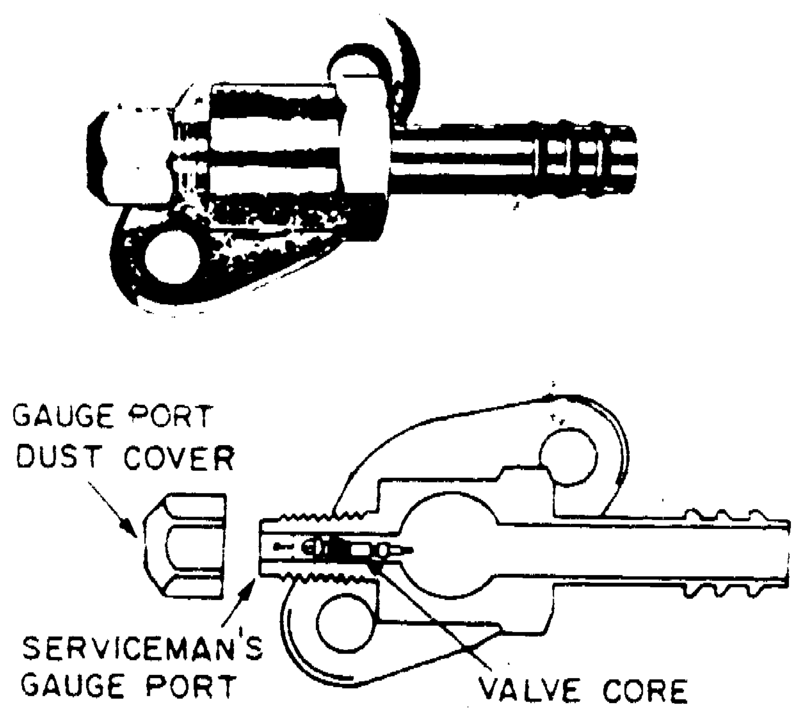

Figure 83. Dill Core Type Service Valve.

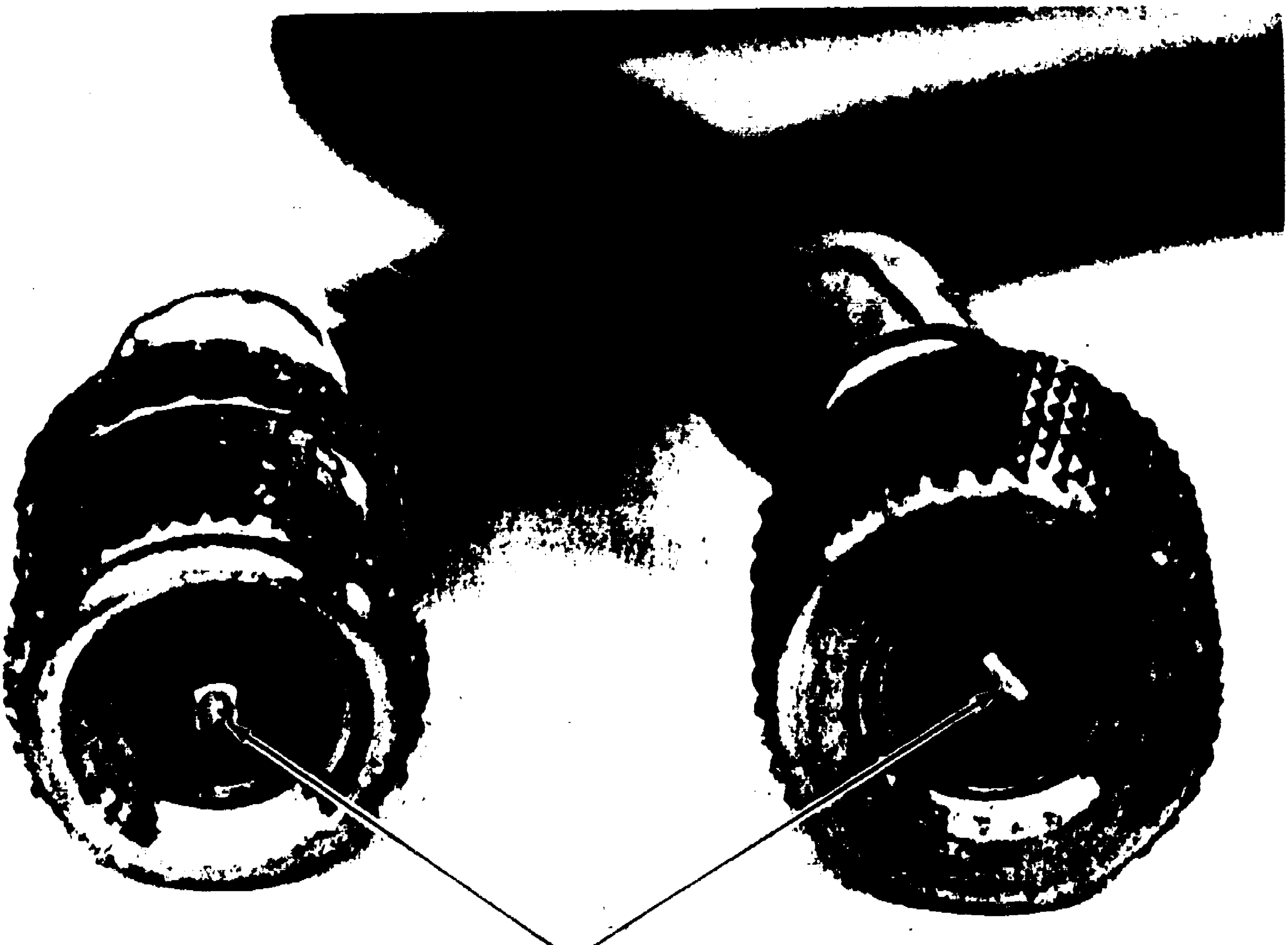

Figure 84. Gauge Hoses with Depression Pins.

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1. Look into the ends of the hoses on the serviceman's gauge set. On one end or the other of the two gauge hoses there must be depression pins, see figure 84. If the hoses do not have the pins in them, you will have to use the adaption shown in figure 85. The depression pins in the hoses or hose adapters are necessary to open the dill core valves on the compressor. Remove caps from Dill valve gauge port openings.

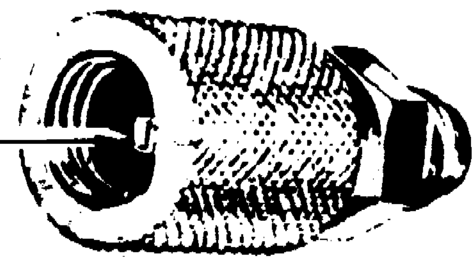

Figure 85. Gauge Hose Adapter.

2. Connect the depression fitting end of the hose from the low pressure gauge of the serviceman's gauge to the Dill suction valve on the compressor.

3. Connect the depression fitting end of the hose from the high pressure gauge of the serviceman's gauge set to the Dill discharge valve on the compressor.

4. Connect the center hose from the serviceman's gauge set to the vacuum pump. See figure 86 for illustration of complete hook-up.

5. Start the vacuum pump.

6. Open the low pressure gauge valve on the serviceman's gauge set by winding the valve stem out.

7. Look at the gauges. If no leaks are present, both gauges will read below zero, as in figure 87. If the high pressure gauge does not read below zero, it indicates one of three things:

a. The system is plugged.

b. The sytem has leaks.

c. The expansion valve is stuck in the closed position.

First, check the system for plugs, then check the system for leaks by inspecting all of the connections. Finally, check the expansion valve to be sure it is in the open position. Also, make certain your gauges and the vacuum pump are in good working condition. Then proceed with the evacuation.

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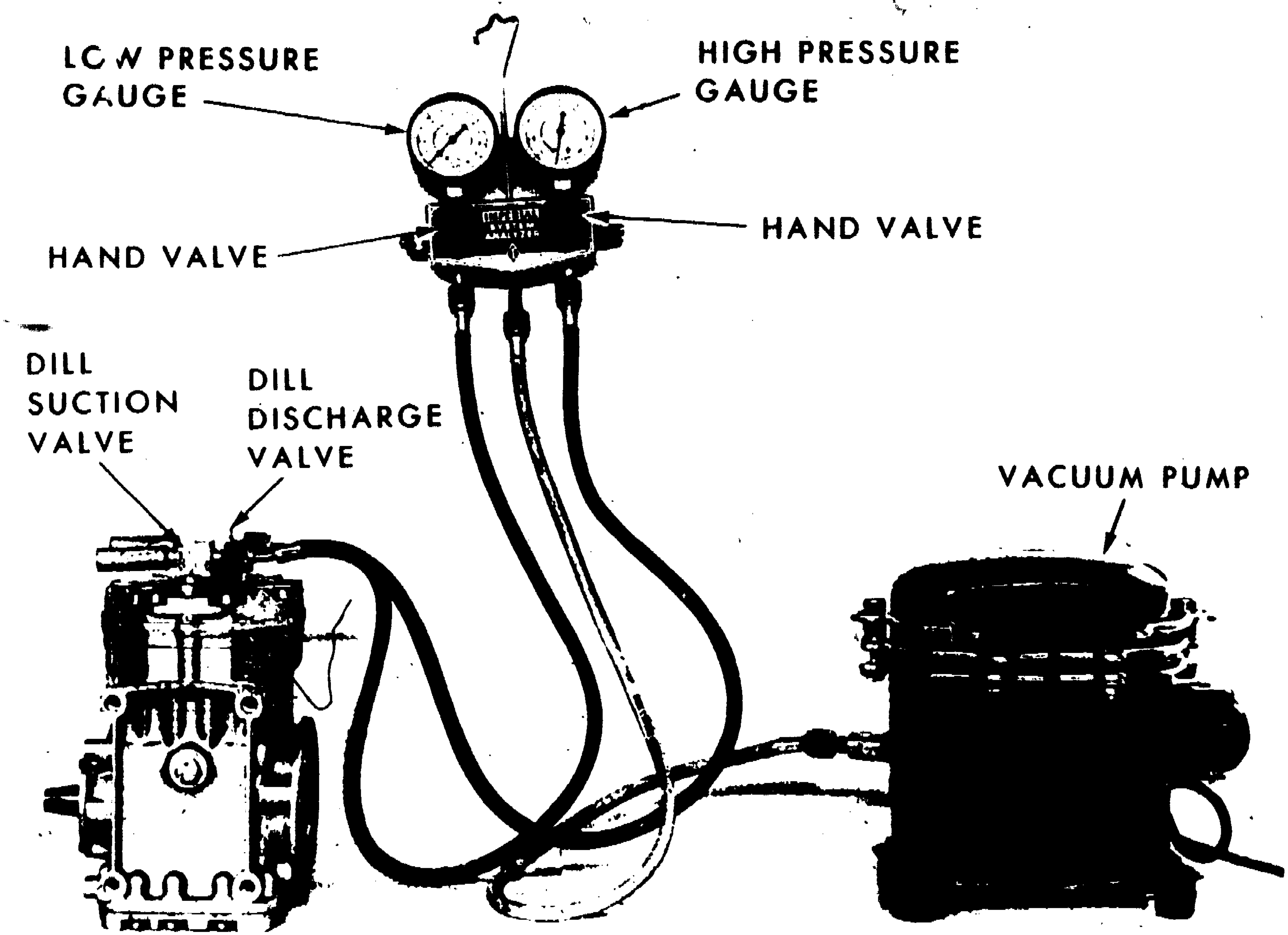

Figure 86. Gauge Set Hookup to Dill Core Valves for Evacuating.

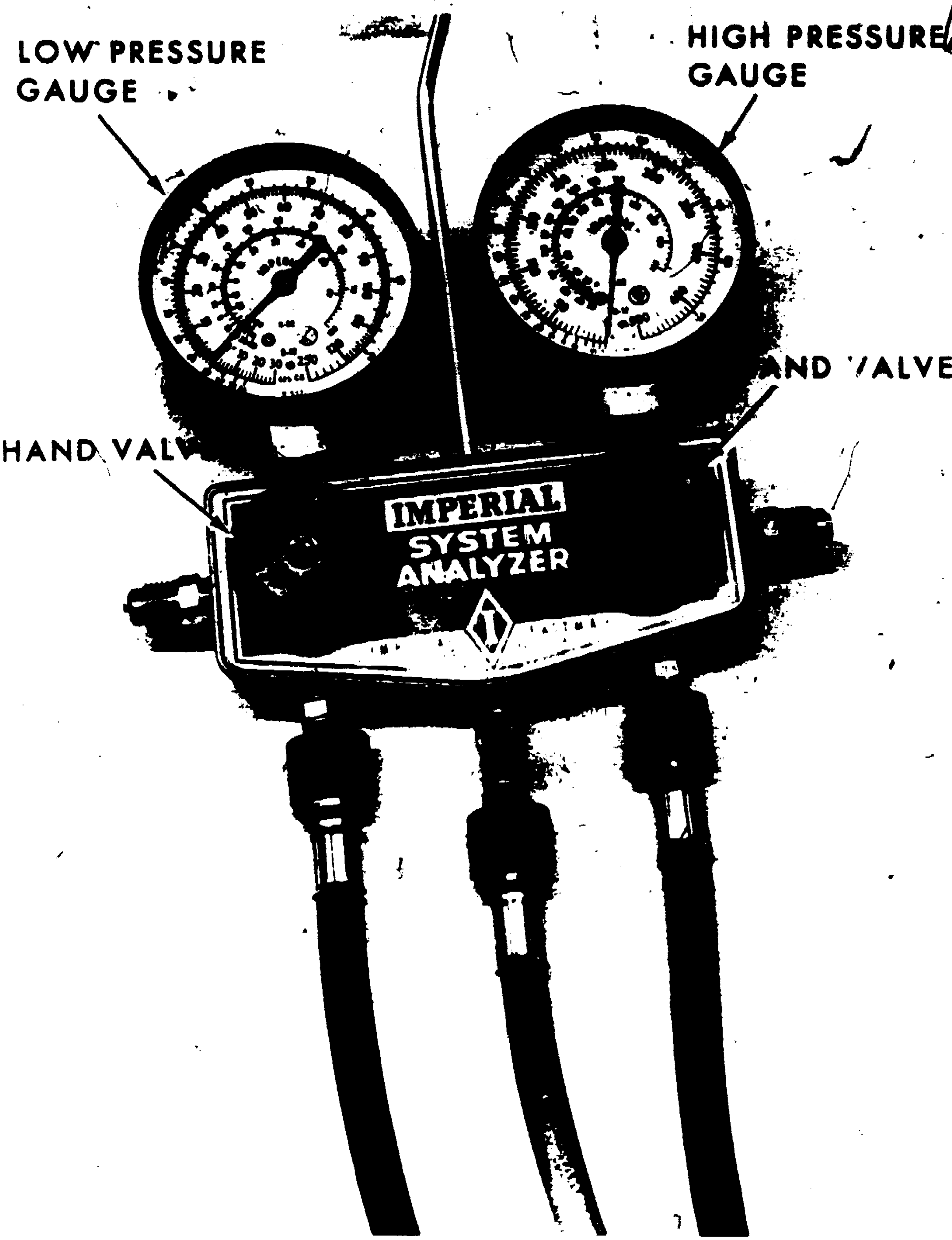

Figure 87. Below Zero Gauge Readings Indicate No Leaks.

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8. Open the high pressure gauge valve on the serviceman's gauge set by turning the valve stem out.

9. After the low pressure gauge shows between 25 and 28 inches of vacuum, allow the vacuum pump to run for a minimum of 20 minutes. Preferably the vacuum pump should run for an hour. <u>You cannot evacuate the system for too long a time</u>.

10. After evacuation has been completed, close both valves on the serviceman's gauge set by turning the valve stems in all the way.

11. Turn off the vacuum pump.

12. Disconnect the center hose of the serviceman's gauge set from the vacuum pump.

> Note: Although the evacuating procedures for all air conditioning systems are similar, steps vary according to the manufacturer. Always refer to the appropriate technical manual for evacuating procedures.

Charging With Refrigerant in Gas State Hand-Operated Service Valves

1. Connect the center hose of the serviceman's gauge set to the can or drum of refrigerant.

2. Make certain the drum or can is in an upright position. Open the valve on the supply source of the drum or can.

3. Look at the low pressure gauge to be certain it is reading below zero and has maintained a vacuum.

4. Loosen the center fitting of the hose at the gauge set to allow a little of the refrigerant to escape. This purges the air from the hose. After about five seconds, retighten the center fitting on the gauge set.

5. Open the low pressure gauge valve on the serviceman's gauge set by turning the valve stem out.

6. <u>DO NOT OPEN</u> the pressure gauge valve at this time!

7. Open the suction valve on the compressor head by turning the valve stem in (counterclockwise) five turns.

8. Open the discharge valve on the compressor head by turning the valve stem <u>in one quarter turn</u>.

9. Look at the gauges. Both gauges should be reading approximately the same pressure.

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10. Turn the evaporator blower switch on high speed and set the temperature control on the coldest position.

11. Start the car engine.

12. Set the car carburetor linkage on the fast idle cam so that the engine will run at about 1000 to 1200 rpm.

13. Allow 2-1/2 pounds of refrigerant R-12 gas to be pumped into the system. This is approximately 2-2/3 cans if you are using the 15-ounce pressure cans.

> Caution: Do not turn the refrigerant drum or can upside down while charging if the compressor is running. A liquid refrigerant cannot be compressed and damage can result to the compressor valve plate.

CAUTION! CAUTION! CAUTION!

14. If the refrigerant gas will not flow into the system fast enough, and the refrigerant supply drum or can becomes too cold, it is possible to warm it by placing it in a pan of warm water not to exceed 110°F, but be sure the supply source valve is still open.

> Caution: DO NOT HEAT THE REFRIGERANT CAN OR DRUM WITH A FLAME OR TORCH. If the can or drum is heated to too high a temperature, it can explode.

15. When 2 to 2-1/2 pounds of refrigerant are in the system, the sight glass will be clear, with the engine and compressor running at 1000 to 1200 rpm.

16. After it is certain that the system is completely charged with 2-1/2 pounds of refrigerant R-12, close the valve on the refrigerant supply drum or can.

> Note: The amount of refrigerant will vary according to manufacturer. Always refer to the appropriate technical manual for servicing procedures.

17. Open the high pressure gauge valve on the serviceman's gauge set to allow the high pressure to bleed into the low pressure side of the system. Both gauges will then read low pressure.

18. Back seat the suction and discharge valves on the compressor by turning the valve stem out (counterclockwise).

19. Stop the car engine.

20. Disconnect the serviceman's gauge set from compressor.

21. Cap the gauge port fittings on the compressor service valves and put the dust caps on the valve stems.

22. Be sure to check the system for leaks.

Charging With Refrigerant in Liquid State - Hand-Operated Service Valves

After the air conditioning system has been completely evacuated, you can proceed with charging the system.

> Caution: When charging with refrigerant in a liquid state, NEVER START THE CAR ENGINE! When the refrigerant is in a liquid state, it cannot be compressed. Starting the engine could cause serious damage to the compressor valve plate assembly.

> Note: The serviceman's gauge set should be connected as at the completion of the evacuating procedure.

1. Connect center hose of serviceman's gauge set to can or drum of refrigerant.

2. Open the supply source valve of the refrigerant drum or can.

3. Loosen the center fitting of the hose at the gauge set to allow a little of the refrigerant to escape. This purges the air from the hose. After about five seconds, retighten the center fitting on the gauge set.

4. Turn the refrigerant supply can or drum upside down so that the liquid refrigerant can be poured into discharge side of the system.

5. Open the high pressure gauge valve on the serviceman's gauge set by turning the valve stem out.

6. DO NOT OPEN the low pressure valve on the serviceman's gauge set at this time.

7. Open the discharge valve on the compressor by turning the valve stem in (clockwise) five full turns.

8. Allow 2-1/2 pounds of refrigerant R-12 to enter the discharge side of the compressor. If you are using 15-ounce pressure cans, this is 2-2/3 cans.

CAUTION! CAUTION! CAUTION!

9. If the refrigerant supply drum or can is too cold and there is not enough pressure to force the liquid into the discharge side, it is possible to build up pressure by warming the can or drum. Place the refrigerant supply drum or can in a pan of warm water not to exceed 110°F.

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Caution: DO NOT HEAT THE REFRIGERANT CAN OR DRUM WITH A FLAME OR TORCH. If the can or drum is heated to too high a temperature, it can explode.

10. Close the valve on the refrigerant supply drum or can when 2-1/2 pounds of refrigerant are in the system.

11. Close the high pressure gauge valve on the serviceman's gauge set by turning the valve stem in until it has seated tightly.

12. Back seat the discharge valve on the compressor by turning the valve stem out (counterclockwise).

13. Start the car engine.

14. In the passenger compartment, turn the evaporator blower switch to the high position, then set the temperature control lever to the coldest position.

15. Open both valves on the compressor by turning the valve stems in approximately one-quarter turn.

16. Set the car carburetor on fast idle cam so car will run at about 1000 or 1200 rpm.

17. After approximately five to ten minutes, the low pressure and the high pressure gauges will indicate normal reading depending on surrounding air temperature. Normal readings on low pressure gauge are 10 to 30 pounds. Normal readings on high pressure gauge are 150 to 220 pounds. If the hand on the high pressure gauge vibrates too fast, slowly turn the discharge valve out but not so far as to completely close the gauge opening. Turn it out just enough to slow the vibration of the high pressure gauge needle so that a reading can be obtained.

18. Back seat both valves on compressor by turning valve stems out.

19. Disconnect gauge set hoses and cap fittings on gauge port openings. Place dust covers on the compressor valve stems.

20. Be sure to check the system for leaks.

Note: Although the charging procedures for air conditioning systems are similar, stems vary according to manufacturer. Always refer to the appropriate service manual for charging procedures.

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QUESTIONS

1. The primary causes of air conditioning system failures are:

a. leaks, dirt, corrosion, and moisture.

b. high temperature and pressure.

c. air in the system, restrictions, and poor connections.

d. All of the above.

2. Which is the greatest enemy of refrigerating systems?

a. Moisture.

b. Dirt.

c. Corrosion.

d. Restrictions.

3. Using the sight glass diagnosis, the appearance of slow-moving bubbles indicate

a. performance is satisfactory.

b. a shortage of refrigerant.

c. a restricted suction line.

d. a restricted discharge line.

4. Before a malfunction in the system can be diagnosed and corrected, it is essential that

a. the exact complaint be determined.

b. a logical, systematic procedure be followed.

c. the repairman have an understanding of how the system operates under normal conditions.

d. the repairman determine if the complaint actually stems from a malfunction in the system.

True or False

5. The main objective when troubleshooting the system is to isolate the problem.

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6. You can never evacuate an air conditioning system too long a time.

7. Always turn the refrigerant drum or can upside down while charging the system.

8. Never heat the refrigerant can or drum with a flame or torch.

9. When charging with refrigerant in a liquid state, NEVER START THE CAR ENGINE!

10. Refrigerant R-12 is the only type of refrigerant you should use in a car air conditioning system.

11. You can use any type of oil in the air conditioning system.

12. Broken belts, obstructed air passages, or disconnected or broken wires may be determined by visual inspection of the parts.

REFERENCES

1. TO 36A2-3-20-2-3, Ford Service Manual.

2. TO 36A2-4-27-2, Chevrolet Service Manual.

3. TO 36A2-4-28-3, Chevrolet Service Manual.

4. TO 36A2-5-9-12, Chrysler Service Manual.

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Problem & Cause	Correction
1. EVAPORATOR NOT COOLING	
Frozen evaporator coil	See Item No. 2
Faulty clutch	Check clutch wires, brush assembly and field coil
Drive belt slipping	Tighten drive belt
Outside air leaks into car	Close heater and air vents
Plugged receiver-drier	Replace receiver-drier
Expansion valve sensing tube broken	Replace expansion valve
Discharge pressure high	See Item No. 3
Suction pressure high	See Item No. 4
Frozen expansion valve orifice	Evacuate system, replace drier, recharge system
Blocked expansion valve	Replace expansion valve and drier
2. EVAPORATOR COIL FROZEN	
Defective thermostatic switch	Replace thermostatic switch assembly
Dirt on evaporator coil fins	Clean evaporator coil fins
3. DISCHARGE PRESSURE HIGH	
Clogged condenser fins	Clean condenser fins
Air in system	Evacuate and recharge system with Refrigerant 12 by weight
System overcharged	Bleed out all refrigerant and recharge by weight
Insufficient condenser air	Install larger fan
Closed discharge valve (for hand operated service valves only)	Open discharge valve (for hand operated service valves only)
4. SUCTION PRESSURE HIGH	
Loose expansion valve sensing bulb	Tighten clamp and make sure bulb is touching suction pipe
System overcharged	Bleed out all refrigerant and recharge by weight
Expansion valve stuck open	Replace expansion valve
Compressor piston and rings worn	Replace compressor
5. DISCHARGE PRESSURE LOW	
Leak in system	Repair leak
Suction valve closed (for hand operated service valves only)	Open suction valve (for hand operated service valves only)

Chart 1. Troubleshooting Problem Chart.

Problem & Cause	Correction
Discharge Pressure Low (Continued)	
Shortage of refrigerant	Check for leaks and add Refrigerant 12
Receiver-Drier plugged or dirt in the expansion valve	Evacuate system, replace receiver-drier, recharge system
Expansion valve stuck closed	Replace expansion valve
Compressor reed valves leaking	Replace compressor valve plate assembly
Compressor piston and rings worn	Replace compressor
6. SUCTION PRESSURE LOW	
Shortage of refrigerant	Check for leaks and add Refrigerant 12
Compressor reed valves leaking	Replace compressor valve plate assembly
Defective expansion valve	Replace expansion valve
Compressor piston and rings worn	Replace compressor
7. COMPRESSOR CRANKSHAFT NOT TURNING	
Broken or slipping drive belt	Replace or tighten drive belt
Broken clutch wire	Replace clutch wire
Broken brush assembly	Replace brush assembly
Thermostatic switch defective	Replace thermostatic switch assembly
Fuse blown	Check for short circuit. Replace fuse
Broken piston or connecting rod	Replace compressor
Defective clutch field coil	Replace clutch
Overcharged system or air in system	Bleed out all refrigerant and recharge by weight
8. ENGINE OVERHEATING	
Leaking head gasket	Replace head gasket
Fan belt slipping	Tighten fan belt
Engine out of time	Tune engine
Damaged radiator cap	Replace radiator cap with pr[illegible] pressure rating
Radiator water low	Fill radiator
Clogged condenser fins	Clean condenser fins
Engine cooling system clogged	Flush radiator and engine
Insufficient air flow over radiator	Install larger fan
Transmission oil low	Check oil level in transmission and add proper amount
Automatic transmission slipping	Replace or repair automatic transmission
Overcharged system or air in system	Bleed out all refrigerant and recharge by weight

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