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ABSTRACT

A model was formulated for developing functional illustrations for text-based competency-based vocational education (CBVE) instructional materials. The proposed model contained four prescriptive steps that address the events of instruction to be provided or supported and the locations, content, and learning cues for each illustration. Usefulness of the illustration design model was evaluated by using the model to illustrate a CBVE procedure and by then comparing the learning effects of use of different versions of the procedure. Three sets of illustration for the same CBVE automotive mechanics assembly procedure were developed: 7 "learner-based" illustrations using the complete model, 10 "developer-based" illustrations using the model without learner data, and 1 "typical" illustration. Random assignments of 173 students to one of three treatments were made; 37 students also performed the assembly procedure. Posttest results indicated few differential effects among the three treatments. Analysis of covariance suggested that students studying the developer-based illustrations performed the assembly significantly better. Results indicated the model seems useful and relevant to designing illustrations, but use of learner input is not necessary. (Appendixes include decision, perception, and memory principles and the three sets of illustrations.) (YLB)

Designing Illustrations for CBVE Technical Procedures

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Abstract

Illustrations are thought to be a critical part of text-based CBVE instructional materials. But procedures for creating instructional text illustrations are not explicit in the literature. Therefore, an illustration design model was developed requiring developers to consider how target learners study illustrated text, to use data regarding learner illustration requirements, and to apply four steps in order to produce illustration specifications. These steps address the events of instruction to be provided or supported, and the locations, content, and learning cues for each illustration. Illustration design principles were derived from recent literature to support these steps.

Three sets of illustrations for the same CBVE automotive mechanics assembly procedure were developed to evaluate the model: seven "learner-based" illustrations using the complete model; ten developer-based illustrations using the model without learner data; and one "typical" illustration. To assess the learning effects of the model's use, 173 students were randomly assigned to one of the three treatments. Students took a vocabulary test, studied their illustrated assembly procedure, completed a multiple-choice posttest, and answered questions about their study of the illustrations (visualization). Thirty-seven students were randomly selected to also perform the assembly procedure.

Few differential effects among the three treatments were found. Students studying the "learner-based" illustrations did no better than the others on the posttest. Analysis of covariance suggested that students studying the "developer-based" illustrations performed the assembly significantly better ($p < .05$). No interactions related to vocabulary or visualization scores were found. Chi-square analyses of individual posttest and assembly items revealed significant differences which could be related to the treatment illustrations. Visualization scores correlated significantly with overall posttest and assembly results. Vocabulary correlated significantly only with overall posttest results.

Based on the results, the model seems useful and relevant to designing illustrations; however, the use of learner input is not necessary. It was also concluded that CBVE technical procedure illustrations should focus on difficult performance aspects; that training in the study of illustrations could improve students' written and performance test results; and that further applications of the revised model should be evaluated.

Designing Illustrations for CBVE Technical Procedures

In CBVE technical training programs, the instructor mainly organizes and manages the learning system and evaluates learner performances. Text materials typically must be responsible for a large proportion of the instructional load, presenting information, concepts, procedures, review and practice, tests, feedback and directions. Many varieties of learning are required, but procedures are central to the competencies being learned. And in the learning of procedures illustrations play a critical role (Butler, 1982).

The design of illustrations for use with text-based CBVE instructional materials should properly be the responsibility of the instructional developer (Duchastel, 1978). But the developer who looks to the various models of design and media selection will not find prescriptive procedures on how to accomplish this task. Instead, models simply state that the developer should "write the prescriptions" in the medium.

Turning to the literature for guidance, the developer can be equally frustrated. There is a paucity of what Briggs (Note 1) terms "culture four" research, i.e. research representing both good experimental and instructional design, from which generalizations regarding illustrations can be drawn. Indeed, the research situation involving illustrations and text seemed so bleak to Duchastel (1980) that he wrote: "if the reseach is taken at face value, it is not difficult to begin believing that illustrations are really not very important in assisting learning" (p. 283).

A comprehensive review and synthesis of the text illustration research by Levie and Lentz (1982) offers a number of generalizations regarding use of illustrations which are not quite as pessimistic. They conclude that "illustrations can help learners understand and remember what they read and can perform a variety of other instructional functions" (p. 226). Not prescriptive but certainly encouraging.

A number of researchers have attempted to categorize illustrations in terms of their functions (Brody, 1982; Duchastel, 1978; Levie and Lentz, 1982; Levin, 1979). Research, they believe, should focus on what an illustration does or is supposed to do in the context of its use with text. The conclusion that illustrations must also be designed with these particular functions in mind is obvious.

What seems to be lacking, therefore, is a procedure or model for developing functional illustrations for both research and practice. The purpose of this research was to formulate such a model for use with instructional text, and then to evaluate its use by designing illustrations for a CBVE automotive mechanics procedure.

The Illustration Design Model

The proposed illustration design model is based on the strategy of using illustrations to support and/or provide the events of instruction (Gagne & Briggs, 1979) in text instructional materials. The model contains four prescriptive steps, as follows:

Step 1: Use the events of instruction to determine the functions that illustrations will support or perform.

Step 2: Identify locations in the text materials where these functions are required.

Step 3: Determine the content of each illustration.

Step 4: Determine the learning cues to be used in and with each illustration.

To help instructional developers accomplish these four steps, series of decision, perception, and memory principles were derived from recent instructional design and development literature (Appendix A). The decision principles are "how-to" statements and are organized by instructional event and, for presenting stimulus material, by learned capability. The perception and memory principles, derived from Fleming and Levie's (1978) Instructional Message Design, focus on mental processes in order to facilitate design of illustrations from which information and skills can be learned and remembered. The three sets of principles were reviewed by a panel of seven instructional designers, who affirmed the principles' relevance to the design of illustrations.

Processes of collecting and using information about and from learners regarding illustrations were also proposed. Guidelines for the processes were based on two ideas. First, collecting data about how the target learners use illustrated text to learn will help the developer produce illustrated text materials generally appropriate to the learner audience. Second, collecting specific learner input about the illustrations required with specific text will facilitate designing an appropriate number of illustrations containing the appropriate content.

<u>Evaluation of the Model</u>

The usefulness of the illustration design model was evaluated by using the model to illustrate a CBVE procedure in automotive mechanics and by then comparing the learning effects of use of different versions of the procedure.

<u>Development of materials</u>. An automotive mechanics procedure was chosen, partially in response to Brody's (1982) criticism of most picture-text research as lacking ecological validity, involving typical materials and situations. The procedure, assembly of a starter motor, was selected, developed, and then evaluated by having students use it to do the assembly. Reading level was checked using the Raygor (Note 2) and Caylor (1973) procedures, and found appropriate for secondary and post-secondary students.

Investigation of how automotive mechanics students study procedures and use illustrations suggested the following strategy for illustrating automotive mechanics procedures. (a) The illustrations should clearly represent the overall procedure. Illustrating all the important steps will facilitate review. (b) To encourage use of the illustration, all steps supported by visuals should reference them. (c) Each illustration should provide sufficient detail and cues so the students can imagine doing the procedure. (d) All the unfamiliar parts and tools used should be identified and labeled in at least one illustration. (e) Cues should be kept simple. (f) Unfamiliar symbols should be labeled or explained.

The development involved preparing three different versions of the assembly procedure--all with the same text. Version I, containing one exploded-view line drawing, represents a "typical" automotive assembly procedure. It served to produce baseline data for comparing the instructional effects of the "designed" Versions II and III.

Version II, termed "designer-based," involved the researcher following the model to make all the illustration decisions on what functions they would serve, where they were located, their content, and their learning cues. Ten line drawings were specified and created, making use of the design strategy described earlier, applying 30 of the perception, memory and decision principles.

Version III, termed "learner-based," also involved using the model. Learner data regarding where illustrations were required and their content and learning cues were collected and used in the decision making process, however. Seven line drawings, including one exploded view, were specified and created, making use of the design strategy, the learner data and 25 of the perception, memory and design principles. The three versions are contained in Appendix B.

Verification of application of the model. Verification of use of the model was necessary to demonstrate that the illustrations in Versions II and III are not idiosyncratic and that differences in results were due to application of the model. Each version was reviewed by three instructional designers who judged the extent to which the illustrations provided or supported the events of instruction claimed and whether proper use of the principles listed was evident in the illustrations. The three reviewers of Version II also rated the extent to which the text associated with each illustration required illustrating. The reviewers of Version III rated the decision rules related to using the learner data and also the decisions made from the data.

The reviewers verified application of the model for both versions. There was some disagreement regarding support or provision of the intended instructional events, but ratings on evidence of application of the principles were quite consistent. In addition, the reviewers of Version III showed basic agreement with the decisions made involving learner data. Thus, Versions II and III represent different applications of the illustration design model.

Development of instruments. To assess the effects of the three versions, a multiple choice posttest, a performance checklist, a questionnaire, a student data form, and a vocabulary test were developed and validated. The reliability was checked as appropriate.

The posttest, containing 20 text and art-related items, was based on a task analysis of the procedure (Dick & Carey, 1978), from which objectives and entry skills were derived. The performance checklist containing 29 items was also based on the task anlysis. The illustration questionnaire assessed attitudes toward the materials (items 1-8) and the extent to which learners took a "visual" approach to studying the assembly procedure (visualization score, items 10-13).

The student data form, was used to select students who had no experience regarding starter assembly and to collect data about them. The vocabulary test was used as a measure of verbal ability.

Where appropriate, the reliability coefficients for these instruments were computed and found to be satisfactory.

Research design and procedures. A posttest-only control group design was used (Campbell & Stanley, 1963). The basic research question was: to what extent did use of the illustration design model result in illustrations which facilitated learning? The three comparisons possible among the three versions (II-I, III-I, III-II) led to 10 hypotheses being proposed regarding visualization scores and total posttest scores, art and text posttest subscores, opinion responses, performance checklist scores, time spent studying, time spent assembling and posttest-visualization-vocabulary interactions.

A total of 173 students from 15 high school, vo-tech center, and community college automotive mechanics classes were selected and randomly assigned to study one of the three versions of the procedure. Students were first given the vocabulary test. They then studied their assigned version, completed the posttest and answered the questionnaire. Randomly selected students (a total of 37) then performed the assembly while being evaluated using the performance checklist. Study time and performance time were recorded for each student.

Experimental results. No significant differences in visualization score (questionnaire items 10-13) were found among the treatment groups which studied Versions I, II, and III. Interesting correlation results were found among a number of variables. Posttest scores corrected significantly ($p < .05$) with vocabulary and visualization scores, study time, and age. Performance checklist scores, however, correlated significantly only with visualization scores and age, and not with vocabulary scores or study time.

Two significant results ($p < .05$) were found among the dependent variables. Based on analyses of covariance, total posttest scores among the treatments were not significant, nor were the text posttest subscores. For the art posttest, significant differences in adjusted means in favor of Versions I and III over Version II were found.

Chi-square analyses of the answers to the Questionnaire items revealed no significant differences. Analyses of variance showed no significant differences among study time and performance time results. Analysis of variance of the posttest scores by version, high-low vocabulary level and high-low visualization score also showed no significant interactions among treatment groups.

An analysis of covariance was also run for performance checklist scores, resulting in a significant treatment F ratio ($p < .05$). Significant differences in adjusted performance checklist means were found in favor of Version II over I and III.

Further chi-square anlayses run on both the posttest and the performance checklist revealed several significant ($p < .10$) results. The significant art subscore result for Version I over Version II was found to be related to significant differences in answering three questions related to parts identification. The difference found in favor of Version II over Versions I and III on the performance checklist was related to significant differences in five checklist items, each of which was in turn related to differences in illustration content and cues.

Discussion and Recommendations

One study can neither completely establish nor refute the usefulness of a model. However, the evidence collected suggested conclusions related to the research questions asked, to the illustration of technical procedures, to the revision of the model, and to future research.

Research questions and revision of the model. Based on the experimental results, use of the illustration design model steps, the principles, and the strategies derived from learner interviews seemed to produce better performance on the assembly but not better posttest results, when compared to the typically illustrated procedure. Use of the specific learner input with the design model, principles and strategies, however, did not produce any significantly different learning results.

The experimental and review results did support the usefulness of the three sets of principles and the use of knowledge of the target learners' processing of illustrated text. The four steps were found to be not discretely applied; the function/location and content/cues steps were often considered together. The collection and use of target learner input regarding their specific requirements for illustrations was not supported, and was therefore dropped from the model. Student input regarding illustrations is probably best obtained during one-to-one formative evaluation of the materials (Dick, 1977).

Technical procedure conclusions. Generalizability of the results to all CBVE technical procedure learning is somewhat limited for two reasons. (a) The study pattern used in the experiment was not quite typical. (b) The starter assembly was an incomplete example, involving little cognitive processing and relatively gross motor skills. Several conclusions regarding illustrating technical procedures may be drawn, however, (a) Exploded-view illustrations may be best for teaching component identification. (b) To facilitate correct first-time performance, complex, difficult steps should be separately illustrated. (c) Illustrations seemed to have greater effects on performance than on posttest results, suggesting illustrations should focus on the procedure rather than on cognitive enabling objectives.

Recommendations for further research. Recommendations include replication, design model research, and learning research. (a) Using both similar and more complex procedures in automotive mechanics or other CBVE technical areas, more data related to illustration--performance effects should be collected. (b) Version II should be revised based on student formative evaluation input and tried with students. (c) Multiple designer use of the model should be attempted in order to understand idiosyncratic effects of use of the model.
(d) Other CBVE technical content areas should be investigated.
(e) Since visualization scores were significantly correlated with both

posttest and performance checklist results, training students to better use illustrations should be researched. (f) Further investigation of how students use illustrations as compared with their intended functions, would provide valuable insight into the extent to which illustrations can really be "designed."

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APPENDIX A

Decision, Memory and Perception Principles

Illustration Decision Principles[1]

Event 1: Gaining and maintaining attention

1.1 Begin with an unusual or incongruous illustration.

1.2 Provide an illustration that relates what will be learned to what already has been learned. (Refer to A-1.)

1.3 Provide an illustration that relates what will be learned to something or someone of importance or interest to the learner.

1.4 Illustrate an incentive for completing the lesson, chapter or unit successfully.

1.5 Choose an illustration size so that the learner can discriminate relevant features and so that the illustration is attractive and maintains interest (Brody, 1982).

1.6 Use learning cues in the illustration (underlining, boxes, arrows, circles, labels, etc.). Refer to B-5.

1.7 Use photos to aid relating to the real world (Merrill & Bunderson, 1981).

1.8 Use as many visual formats (such as photographs, graphics, drawings, cartoons, etc.) as feasible. (Compare with A-6.)

1.9 Use illustrations that contain dynamic rather than static figures (Brody, 1980).

1.10 Use humorous illustrations; be cautious with older learners, however (Sewell & Moore, 1980).

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[1]Adapted from Mengel (1982), except as otherwise noted.

1.11 Use a reference in text to direct learner attention to an illustration "at the point most appropriate for learning" (Brody, 1982). Refer to A-8.

1.12 Use a figure caption to help focus learner interaction with the illustration; a title, description, explanation or question may be used (Brody, 1982).

Event 2: Informing the learner of the objective(s)

2.1 Provide illustrated example(s) of the expected performance(s).

Event 3: Stimulating recall of prerequisites

3.1 Illustrate prerequisite performance(s).

3.2 Use a visual analogy to something already known by the learner.

3.3 Use an illustration to relate what will be learned to the learner's previous experience. (Also Brody, 1982.)

Event 4: Presenting the stimulus material

General

4.1 Use learning cues in the illustration. (See 1.6 and B-5.)

4.2 Use illustrations to support the text content. (See A-12 and B-2.)

4.3 Present a visually appealing layout of text and illustrations.

4.4 Use illustrations that are of interest and relevant to the learner.

4.5 Use illustrations that are technically accurate.

4.6 Use the proper amount of detail in the illustration. (See A-7, A-13.)

4.7 Place illustrations near the related textual content (same or facing page); actual position of illustration (left, right, below, above) probably doesn't matter (Bogusch, 1983).

Verbal information

4.8 Provide a visual analogy to aid comprehension.

4.9 Provide a visual representation of related information (Holliday, 1976).

4.10 Use a schematic to show spatial information (Merrill & Bunderson, 1981). The more spatial the information to be learned, the more the learner will benefit from an illustration (Dwyer, 1978; Levie & Lentz, 1982).

Intellectual skills

4.11 Use illustrations to teach discriminations of objects or symbols. Introduce three to seven at one time, then introduce new objects or symbols with a review of previous learning (Merrill & Bunderson, 1981).

4.12 Use color in an illustration only if the objective requires color discrimination (Dwyer, 1978; Merrill & Bunderson, 1981). Color is expensive.

4.13 Use simplified illustrations to present examples and non-examples for concrete concept learning (Merrill & Bunderson, 1981).

4.14 Use both visual and textual analogies to explain an abstract defined concept, such as electric current (Merrill & Bunderson, 1981).

4.15 Provide illustrations if rule use involves unfamiliar concrete concepts (Merrill & Bunderson, 1981).

Cognitive Strategies

4.16 Provide illustrations if problem situations involve perception of characteristics of unfamiliar objects or events (Merrill & Bunderson, 1981).

Attitudes

4.17 Use illustrations with a human model to demonstrate choice of and/or results of personal action.

Motor Skills

4.18 Use a series of illustrations to show positions or movement with time (pseudo-animation) (Merrill & Bunderson, 1981).

4.19 Provide a series of illustrations with text for a complex procedure with new motor skills (Merrill & Bunderson, 1981).

4.20 Provide pictorial or schematic illustrations showing parts for procedure using known motor skills (Merrill & Bunderson, 1981).

Event 5: Providing learning guidance

NOTE: Many of the Principles listed under Event 4: presenting the stimulus material also contain implicit learning guidance, functioning in an explicative fashion.

Verbal Information

5.1 Use an illustration to provide the learner with links to a larger meaningful context.

5.2 Place the illustration before information to be learned to serve as an overview of the new material (Brody, 1982).

Event 6: Eliciting performance

6.1 Use illustrations for review and practice of identification (concrete concepts) (Olsen & Bogusch, Note 4).

Event 7: Providing feedback

7.1 Use an illustration to show the results of proper performance.

Event 8: Assessing performance

8.1 Use illustrations to test concrete concepts (Szabo, Dwyer & DeMilo, 1981).

8.2 Use illustrations to test procedure sequences (Lee, Note 3).

Event 9: Enhancing retention and transfer

9.1 Provide illustration for learner to use to form mental images for recall (Paivio, 1971) or for mental organization (Bernard, Peterson & Ally, 1981).

9.2 Provide an illustrated mnemonic to aid learner recall of information or a rule (Lc in, 1979).

9.3 Place illustration after verbal information to be learned to facilitate review (Brody & Legenza, 1980; Brody, 1982).

9.4 Use a diagram to summarize and/or show relationships of information presented in text (Holliday, 1976; Lee, Note 3).

Perception Principles[1]

Principle A-1. Include both familiar and unfamiliar content in the illustration, especially content that has been recently seen.

Perception is relative, not absolute (1.1). In particular, a learner's perception of something new is relative to immediate past experience, as well as to how the learner feels, what (s)he seeks and what others think. Using "perceptual relativity" can help the instructional designer predict and control learner perceptions.

Principle A-2. Emphasize important aspects of the illustration to guide selective perception; de-emphasize other aspects to prevent distraction.

Perception is selective (1.2). Only a few visual stimuli can or will be attended to by the learner at one time. In addition, learner perceptual capacity is limited.

Principle A-3. Organize the content of the illustration in a natural or logical way.

A learner's perception is organized (1.3). This organization is determined in part by the organization of the stimulus, and in part by the organization imposed or constructed by the perceiver. The organization of the stimulus affects the speed and the accuracy of the learner's perception (1.3a).

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[1]Adapted from Fleming and Levie (1978) except as otherwise noted. Numbers in parentheses refer to Fleming's and Levie's Principles.

Principle A-4. Be sure what is important in the illustration stands out.

Separation of the field of an illustration into figure and ground is the simplest visual organization done by the learner (1.3b). The important elements of the visual message should be perceived as figure, which are then given more attention (1.21). Characteristics of both figure and ground affect perception (1.22).

Principle A-5. Use simple, rather than complex, sketches and drawings.

Adding the details to an open or incomplete figure is a type of visual organization by the learner (1.3c). Too much simplification in the illustration risks misperception of the designer's intentions by the learner, who may impose the wrong organization.

Principle A-6. Be consistent in the design or style of illustrations.

What the learner expects, i.e. the learner's mental set, influences what is selected, organized and interpreted from an illustration (1.4). Consistency will help control the variety of ways learners will perceive the illustrated messages.

Principle A-7. Use the appropriate amount of complexity in the illustration.

Message complexity tends to draw and hold attention, as long as learner perceptual capacities are not exceeded (1.9). A learner may stop paying attention to material that is perceived as too simple. Optimum levels of complexity depend upon the nature of the learners and their interests. Brody (1978) suggests that increasing illustration complexity to maintain attention must be balanced against simplification to aid in learning from the illustration.

Principle A-8. Use print (verbal) cues to direct learner attention to the illustration.

Attention is directed (1.10). Learner interests, needs and experience are sources of direction. Attention can also be directly influenced.

Principle A-9. Use horizontal and vertical lines in the illustration as anchors to help learners make spatial distinctions.

Verticals and horizontals are more accurately judged for spatial orientation than are diagonals (1.18, 1.51). Vision is better than hearing for making spatial distinctions.

Principle A-10. Use symmetry to minimize potential false interpretations within the illustration.

Different interpretations of the content may be possible within a complex illustration. The learner will likely perceive the simplest and most symmetrical figure (1.25). See A-13.

Principle A-11. Use a linked sequence of illustrations to suggest the passage of time.

Use of any code to suggest passage of time must be known by learners or must be taught to them (p. 48). A standard or frame of reference may be required (1.52).

Principle A-12. Reinforce visual information with verbal information and vice-versa.

During processing, pictorial stimuli can be recoded into mental propositions, and verbal stimuli can be recoded into mental images (1.28b) (also Paivio, 1971) thereby improving memorability.

Principle A-13. Match the information content of the illustration with the capabilities of the learners - neither too much nor too little, neither too complex nor too simple.

Encoding complex stimuli limits other mental processing actions (1.29). The amount of information learners process depends on the amount present and the depth of processing required (1.30). Learners will chunk available information for processing based on the size of the stimulus and their experience and intentions (1.32). If the information is perceived as organized, then more processing is likely (1.33). As learning progresses, more realistic illustrations may be used to approximate the real world environment (Merrill and Bunderson, 1981).

Principle A-14. To foster discriminations within the illustration, use grouping so that relevant differences or similarities are apparent to the learner.

Objects or events perceived as different will be separately grouped (1.39); those perceived as similar will be organized together (1.40). Objects and events encountered in proximity tend to be viewed as related (1.42).

Principle A-15. Represent objects unfamiliar to the learner with more accuracy that familiar objects.

Familiar objects may be minimally represented since they will be perceived to have all the known attributes of the objects (perceptual constancy, 1.43). Representations of unfamiliar objects require more accuracy to be adequately perceived.

Principle A-16. Use a pattern or organization within the illustration to suggest a relationship to the learner.

Perception of a relationship is facilitated when objects or events are seen as part of a common pattern or organization (1.44). Use inclusive devices such as circles, rectangles or free form lines; arrange components in a left-to-right or top-to-bottom manner; accentuate part of the message (1.45).

Principle A-17. Use relative size, linear perspective, texture gradient, upward angular location of grounded objects, interposition and filled space to suggest depth in the illustration.

The listed factors influence perceived depth (1.48). Relative size varies inversely with distance. Linear perspective changes the longitudinal dimension from near to far. Texture gradient refers to the disappearance of texture with increasing distance. Near grounded objects usually touch at the bottom of the illustration, farther objects toward the top. Interposition is the overlap of near objects over far objects. Filled space increases depth perception compared to empty space.

Principle A-18. Use shadows and sharp lines in the illustration to suggest solidity and depth.

Directional lighting produces sharp shadows and influences perception of solidity and depth (1.50).

Principle A-19. Use blurring or streaking of static figures or place limbs in active positions to suggest motion in the illustration.

Motion perception is related to both temporal and spatial factors(1.54).

Principle A-20. Use verbal descriptions plus illustrations to describe motor skill or procedure movements.

Adequate perception of movements will result where the movements are simple, independent and capable of being described simply, and where the learner experiences no orientation difficulties (p. 87).

Memory Principles[1]

Principle B-1. Make the illustration meaningful by using familiar content in an organized way.

Meaningful learning is acquired more easily and retained longer than whatever is percived as meaningless or arbitrary (2.1). Meaningfulness follows from perceived organization. Refer to A-1 and A-3.

Principle B-2. Use the illustration to make the text more concrete.

Concrete things are more easily learned and remembered (2.8). Pictures of objects are better remembered than their names (2.8a).

Principle B-3. For a learner in a new content area, both text and illustrations should begin with the more concrete before becoming more abstract.

As a learner becomes more sophisticated in a subject, he or she will be able to learn more abstract concepts, which will be helped by concrete illustrations (2.9). Learners typically respond less concretely/more abstractly than they perceive (2.10).

Principle B-4. Accentuate criterial features and reduce emphasis on non-criterial features within the illustration, especially where the non-criterial features are more salient (dominant) than the criterial features. (Criterial features are the attributes of the illustration relevant to the learning objective; non-criterial features are not relevant. Refer to Principles A-2 and A-4.)

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[1]Adapted from Fleming and Levie (1978) except as otherwise noted. Numbers in parentheses refer to Fleming's and Levie's Principles.

"Learning is facilitated where criterial (features) are salient" (2.12). Maximizing differences between criterial and non-criterial features facilitates discrimination (2.37).

Learning what is relevant is influenced by the extent to which the instruction controls the stimuli perceived and used in learning (2.11, 2.12). A common instructional designer error is to overlook the distinction between what is presented to the learner (the nominal stimulus) and what is perceived and used in learning (the effective stimulus). Instruction is an attempt to control the effective stimulus by the manipulation of the nominal stimulus (p. 113).

Deciding what illustration features to manipulate and how should result from an adequate analysis of the information, skill or task being learned. Refer to the Illustration Decision Principles.

Principle B-5. Use learning cues in the illustration which are familiar and/or which call attention to criterial features, similarities, differences and relationships.

"Added cues which are familiar and/or direct attention to relationships can facilitate learning" (2.18).

Principle B-6. For initial instruction use illustrations which contain maximally accentuated criterial features or extensive cueing. Reduce accentuation and cueing as the learner becomes more capable. Consider using drawings first, then photographs (see Principle A-13).

Use of accentuation and cueing should be viewed as a temporary crutch during learning; the learner should be moved towards dealing with reality (2.13). Maximum accentuation and cueing helps assure initial correct associations and discriminations (2.37).

Principle B-7. Contrive associations in the illustration to facilitate the learning of relationships between information or concepts. (Compare with Principle A-12.)

Use of an illustration will improve the memory strength of an association (2.22). An illustration also may facilitate generation and retention of a relational mental image (2.31). Levin (1979) suggests that this is "transformation" with the illustration acting as a mnemonic device.

Principle B-8. The organization of the illustration must be apparent to the learner. (See Principle A-3.)

Learning is facilitated when the to-be-learned material is organized and the organization is obvious (2.26).

APPENDIX B

Assembling a GM Starter - Versions I, II, and III

ASSEMBLING A GM STARTER

I

Assembling a GM Starter

Written by Ronald C. Laugen

Illustrations by Gary "Ace" Carroll

Assembling a GM Starter

Learning Objectives

When you finish studying this procedure, you should be able to do the following on a test:

1. Given the names of different parts of the starter, choose the correct drawing of each part.
2. Choose statements that describe how to correctly assemble the starter.
3. Choose drawings that show the proper way to assemble the starter.
4. Match the correct lubricant or sealant with the location or part where it is used.
5. For a given type of part, identify how many are used in the starter assembly.

Performance Objective

When you finish studying this procedure, you should be able to do the following:

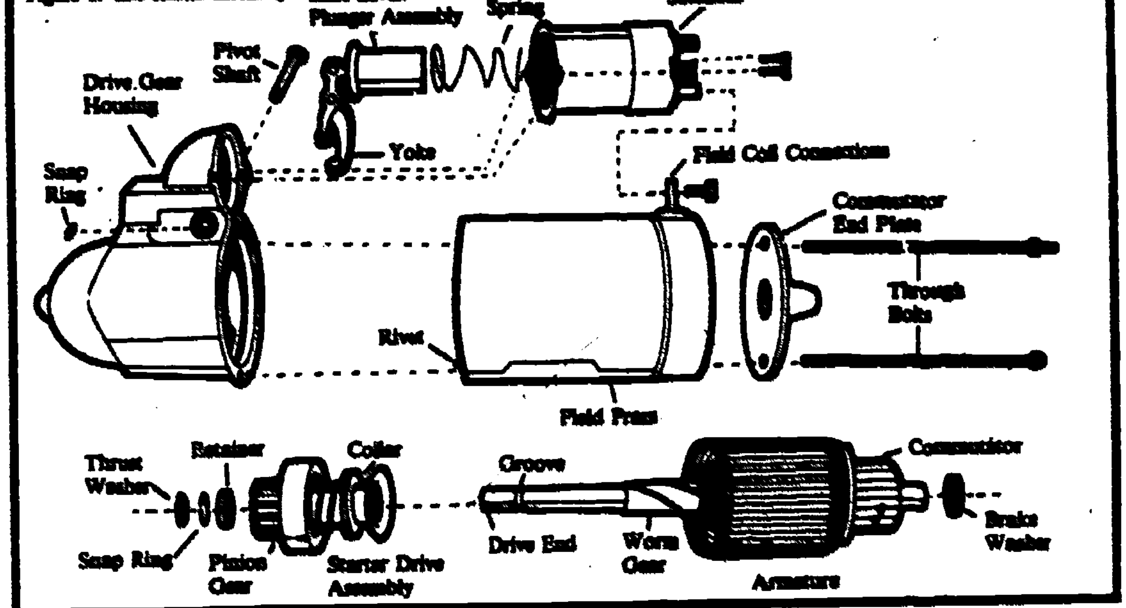
Given a disassembled GM starter and the required tools, assemble the starter, without referring to a service manual or other resources, within 10 minutes. The assembled starter must run properly when connected to a battery.

1

Assembling a GM Starter

After you have disassembled the starter and tested the parts, you must assemble the starter (refer to Figure 1). Replace all defective parts with new ones.

Figure 1. GM starter assembly.



STEP 1 Assemble the starter drive assembly on the armature. To do this:

- 1.1 Wrap a shop rag around the armature to protect it. Then mount the armature, shaft up, in a vise.

CAUTION: TIGHTEN THE VISE JUST ENOUGH TO HOLD THE ARMATURE. OVER-TIGHTENING WILL CAUSE DAMAGE!!

- 1.2 Lubricate the drive end and the worm gear of the armature shaft with lubriplate (white lube).

- 1.3 Install the starter drive assembly onto the armature shaft with the pinion gear away from the armature.

- 1.4 Slide the retainer onto the armature shaft past the groove, with the cupped side away from the pinion gear.

- 1.5 Place the snap ring on the drive end and place a rubber hammer on it. Then tap the rubber hammer with a ball peen hammer to start the snap ring. Slide the snap ring down into the groove.

  NOTE: If the snap ring is not snug in the groove, you should squeeze it with a pliers.

- 1.6 Slide the thrust washer onto the shaft until its shoulder touches the snap ring in the groove.

2

• 1.7 Squeeze the thrust washer and retainer together using two pliers. This will force the snap ring into the retainer.

• 1.8 Remove the armature assembly from the vise.

STEP 2 Assemble the parts in the drive gear housing. To do this:

• 2.1 Lubricate the drive gear housing bushing with lubriplate (white lube).

• 2.2 Position the yoke of the shift lever/plunger assembly on the collar of the drive assembly.

• 2.3 Slide the assemblies into place in the drive gear housing.

• 2.4 Install the pivot shaft through the drive gear housing and shift lever and install its snap ring.

STEP 3 Install the solenoid on the drive gear housing. To do this:

• 3.1 Secure the assembled armature, starter drive assembly and drive gear housing in a vise, with the commutator end up.

• 3.2 Coat the front of the solenoid flange with a suitable sealant (silicone or Permatex #2).

• 3.3 Place the return spring over the plunger.

• 3.4 Install the solenoid over the plunger and hold it in place. Install and tighten the mounting screws.

STEP 4 Install the field frame. To do this:

• 4.1 Note and remember the locations of the threaded holes in the drive end housing for the through bolts.

• 4.2 Carefully lower the field frame over the armature assembly.

• 4.3 Spread the four brushes apart so that they can slide into place on the commutator.

• 4.4 Rotate the field frame until the field coil connections align with the starter terminal of the solenoid.

CAUTION: The rivet of the field frame must drop into the hole in the drive gear housing.

STEP 5 Install the brake washer on the end of the armature shaft.

STEP 6 Lubricate the commutator end plate bushing with lubriplate (white lube).

STEP 7 Install the commutator end plate. To do this:

• 7.1 Place the commutator end plate over the armature shaft and field frame.

• 7.2 Turn the commutator end plate until the holes line up with the threaded bolts in the drive end housing.

• 7.3 Install the through bolts; tighten them evenly and securely.

STEP 8 Attach the field coil connections to the solenoid starter terminal using the connection screw.

3

ASSEMBLING A GM STARTER

II

Assembling a GM Starter

Written by Ronald C. Laugen

Illustrations by Gary "Ace" Carroll

Assembling a GM Starter

Learning Objectives

When you finish studying this procedure, you should be able to do the following on a test:

1. Given the names of different parts of the starter, choose the correct drawing of each part.
2. Choose statements that describe how to correctly assemble the starter.
3. Choose drawings that show the proper way to assemble the starter.
4. Match the correct lubricant or sealant with the location or part where it is used.
5. For a given type of part, identify how many are used in the starter assembly.

Performance Objective

When you finish studying this procedure, you should be able to do the following:

Given a disassembled GM starter and the required tools, assemble the starter, without referring to a service manual or other resources, within 10 minutes. The assembled starter must run properly when connected to a battery.

Assembling a GM Starter

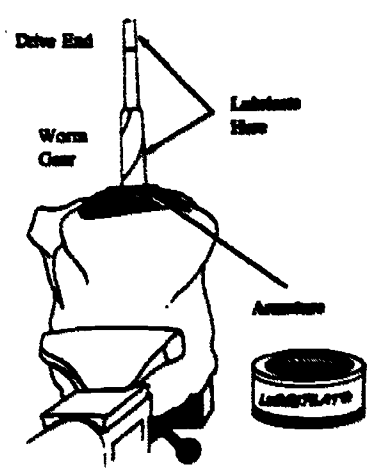
After you have disassembled the starter and tested the parts, you must assemble the starter (Figure 1). Replace all defective parts with new ones.

Figure 1. Assembled starter.

STEP 1 Assemble the starter drive assembly on the armature. To do this:

- 1.1 Wrap a shop rag around the armature to protect it. Then mount the armature, shaft up, in a vise as shown in Figure 2.

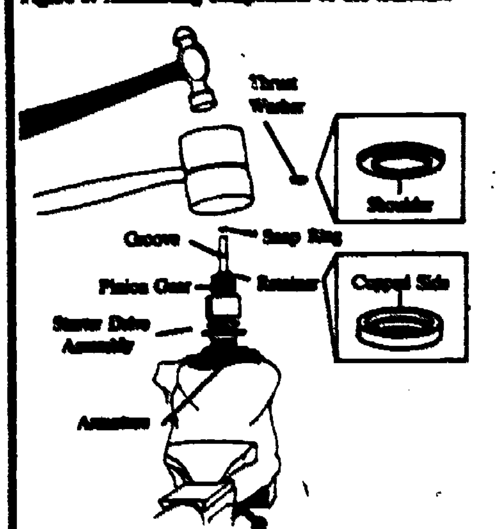
Figure 2. Mounting and lubricating the armature.



CAUTION: TIGHTEN THE VISE JUST ENOUGH TO HOLD THE ARMATURE. OVERTIGHTENING WILL CAUSE DAMAGE!!

- 1.2 Lubricate the drive end and the worm gear of the armature shaft with lubriplate (white lube). See Figure 2.

Figure 3. Assembling components of the armature



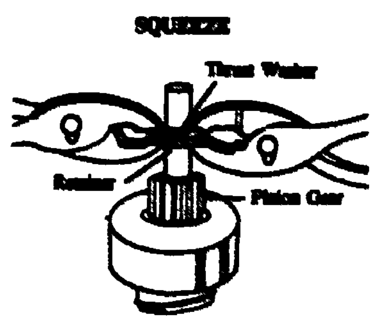
- 1.3 Install the starter drive assembly onto the armature shaft with the pinion gear away from the armature (Figure 3).
- 1.4 Slide the retainer onto the armature shaft past the groove, with the cupped side away from the pinion gear, as shown in Figure 3.
- 1.5 Place the snap ring on the drive end and place a rubber hammer on it. Then tap the rubber hammer with a ball peen hammer to start the snap ring. Slide the snap ring down into the groove. See Figure 3.

2

NOTE: If the snap ring is not snug in the groove, you should squeeze it with a pliers.

- 1.6 Slide the thrust washer onto the shaft until its shoulder touches the snap ring in the groove (Figure 3).

Figure 4. Squeezing the thrust washer and retainer together.



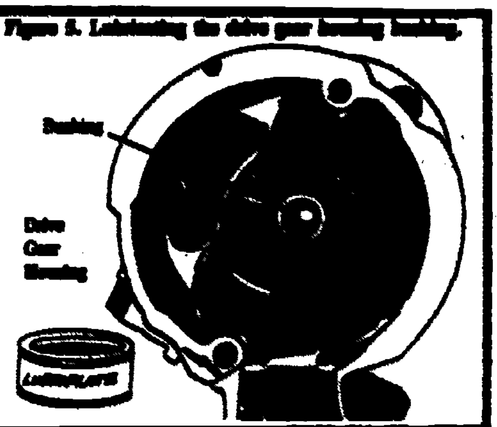
- 1.7 Squeeze the thrust washer and retainer together using two pliers, as shown in Figure 4. This will force the snap ring into the retainer.

- 1.8 Remove the armature assembly from the vise.

STEP 2 Assemble the parts in the drive gear housing. To do this:

- 2.1 Lubricate the drive gear housing bushing with lubriplate (white tube). See Figure 5.

Figure 5. Lubricating the drive gear housing bushing.



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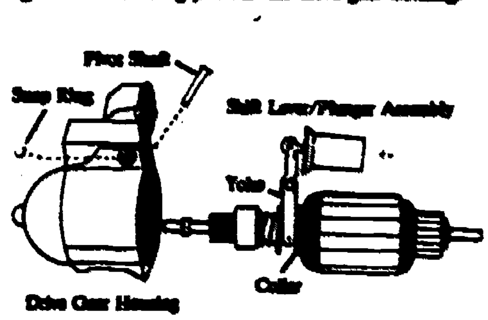
- 2.2 As shown in Figure 6, position the yoke of the shift lever/plunger assembly on the collar of the drive assembly.

- 2.3 Slide the assemblies into place in the drive gear housing.

- 2.4 Install the pivot shaft through the drive gear housing and shift lever and install its snap ring (Figure 6).

Figure 6. Assembling parts in the drive gear housing.

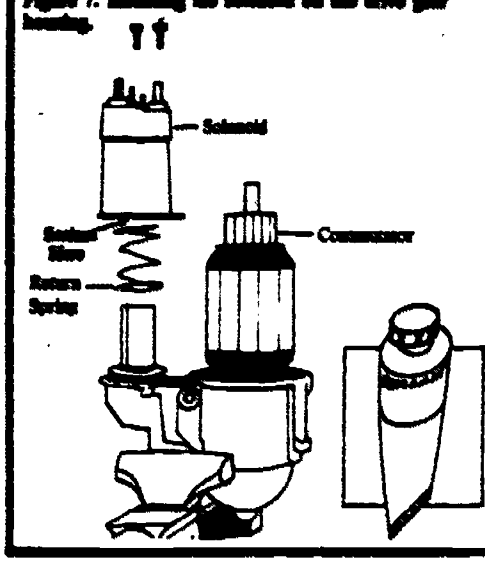


STEP 3 Install the solenoid on the drive gear housing (Figure 7). To do this:

- 3.1 Secure the assembled armature, starter drive assembly and drive gear housing in a vise, with the commutator end up.

- 3.2 Coat the front of the solenoid flange with a suitable sealant (silicone or Permatex #2).

Figure 7. Installing the solenoid on the drive gear housing.

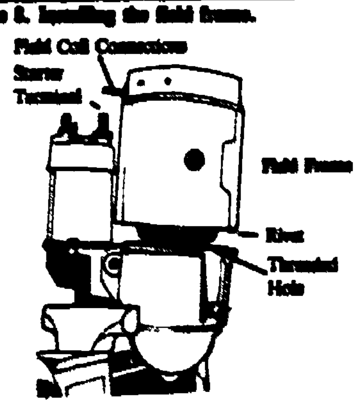


- 3.3 Place the return spring over the plunger.
- 3.4 Install the solenoid over the plunger and hold it in place. Install and tighten the mounting screws.

STEP 4 Install the field frame. To do this:

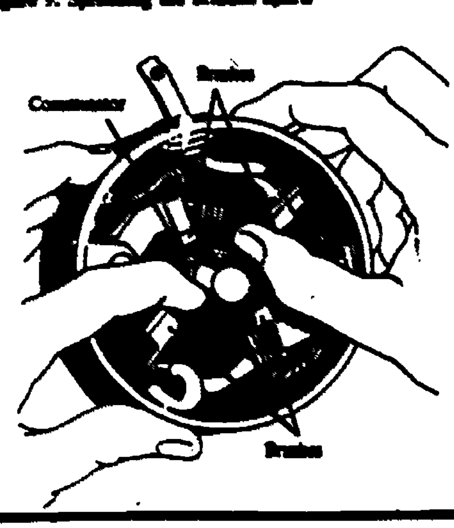
- 4.1 Note and remember the locations of the threaded holes in the drive end housing for the through bolts. See Figure 5.
- 4.2 Carefully lower the field frame over the armature assembly, as shown in Figure 8.

Figure 8. Installing the field frame.



- 4.3 As shown in Figure 9, spread the four brushes apart so that they can slide into place on the commutator.

Figure 9. Spreading the brushes apart.



- 4.4 Rotate the field frame until the field coil connections align with the starter terminal of the solenoid, as in Figure 8.

CAUTION: The rivet of the field frame, shown in Figure 8, must drop into the hole in the drive gear housing.

STEP 5 Install the brake washer on the end of the armature shaft. See Figure 10.

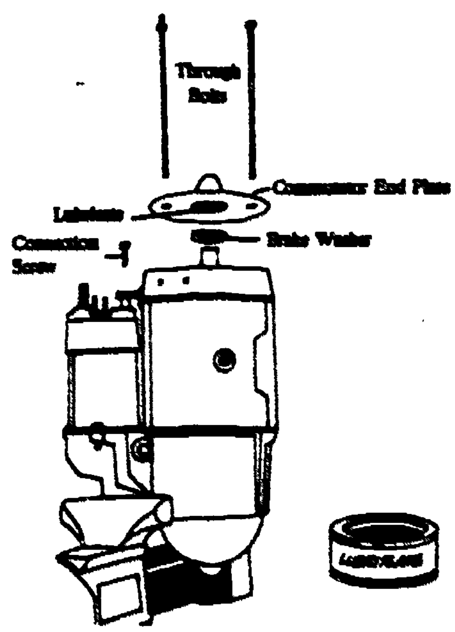
STEP 6 Lubricate the commutator end plate bushing with lubriplate (white lube) as shown in Figure 10.

STEP 7 Install the commutator end plate (Figure 10). To do this:

- 7.1 Place the commutator end plate over the armature shaft and field frame.
- 7.2 Turn the commutator end plate until the holes line up with the threaded holes in the drive end housing.
- 7.3 Install the through bolts; tighten them evenly and securely.

STEP 8 Attach the field coil connections to the solenoid starter terminal using the connection screw (see Figure 10).

Figure 10. Completing the assembly.



ASSEMBLING A GM STARTER

III

Assembling a GM Starter

Written by Ronald C. Laugen
Illustrations by Gary "Ace" Carroll

Assembling a GM Starter

Learning Objectives

When you finish studying this procedure, you should be able to do the following on a test:

1. Given the names of different parts of the starter, choose the correct drawing of each part.
2. Choose statements that describe how to correctly assemble the starter.
3. Choose drawings that show the proper way to assemble the starter.
4. Match the correct lubricant or sealant with the location or part where it is used.
5. For a given type of part, identify how many are used in the starter assembly.

Performance Objective

When you finish studying this procedure, you should be able to do the following:

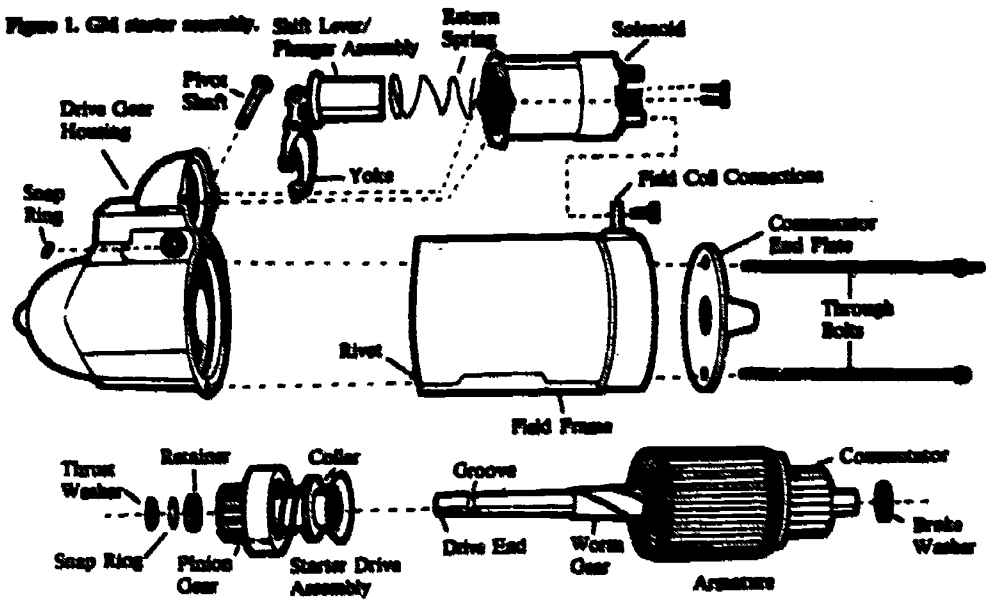
Given a disassembled GM starter and the required tools, assemble the starter, without referring to a service manual or other resource, within 10 minutes. The assembled starter must run properly when connected to a battery.

1

Assembling a GM Starter

After you have disassembled the starter and tested the parts, you must assemble the starter (Figure 1). Replace all defective parts with new ones.

Figure 1. GM starter assembly.



STEP 1 Assemble the starter drive assembly on the armature. To do this:

- 1.1 Wrap a shop rag around the armature to protect it. Then mount the armature, shaft up, in a vise.

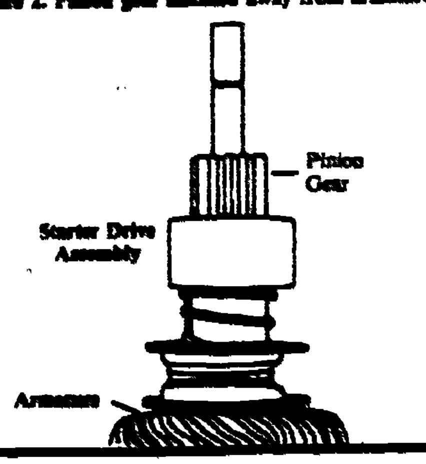
CAUTION: TIGHTEN THE VISE JUST ENOUGH TO HOLD THE ARMATURE. OVER-TIGHTENING WILL CAUSE DAMAGE!!

- 1.2 Lubricate the drive end and the worm gear of the armature shaft with lubriplate (white lube).

- 1.3 Install the starter drive assembly onto the armature shaft with the pinion gear away from the armature, as shown in Figure 2.

2

Figure 2. Pinion gear installed away from armature



- 1.4 Slide the retainer onto the armature shaft past the groove, with the cupped side away from the pinion gear.
- 1.5 Place the snap ring on the drive end and place a rubber hammer on it. Then tap the rubber hammer with a ball peen hammer to start the snap ring. Slide the snap ring down into the groove.

  NOTE: If the snap ring is not snug in the groove, you should squeeze it with a pliers.
- 1.6 Slide the thrust washer onto the shaft until its shoulder touches the snap ring in the groove (Figure 3).
- 1.7 Squeeze the thrust washer and retainer together using two pliers (see Figure 3). This will force the snap ring into the retainer.
- 1.8 Remove the armature assembly from the vise.

STEP 2 Assemble the parts in the drive gear housing. To do this:

- 2.1 Lubricate the drive gear housing bushing with lubriplate (white lube).
- 2.2 Position the yoke of the shift lever/plunger assembly on the collar of the drive assembly, as shown in Figure 4.
- 2.3 Slide the assemblies into place in the drive gear housing.
- 2.4 Install the pivot shaft through the drive gear housing and shift lever and install its snap ring.

STEP 3 Install the solenoid on the drive gear housing. To do this:

- 3.1 Secure the assembled armature, starter drive assembly and drive gear housing in a vise, with the commutator end up.
- 3.2 Coat the front of the solenoid flange with a suitable sealant (silicone or Permatex #2); see Figure 5.
- 3.3 Place the return spring over the plunger (Figure 5).

Figure 3. Squeezing the thrust washer and retainer together.

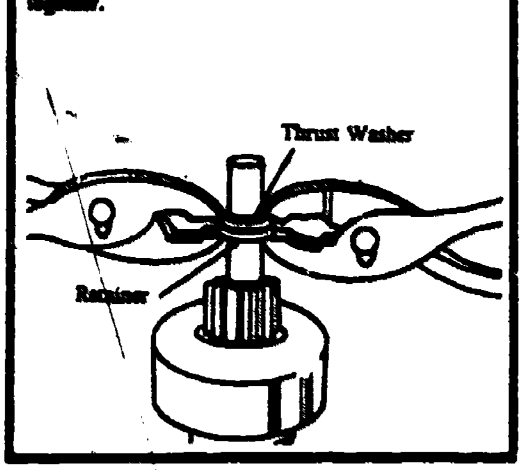


Figure 4. Yoke in position on collar of drive assembly.

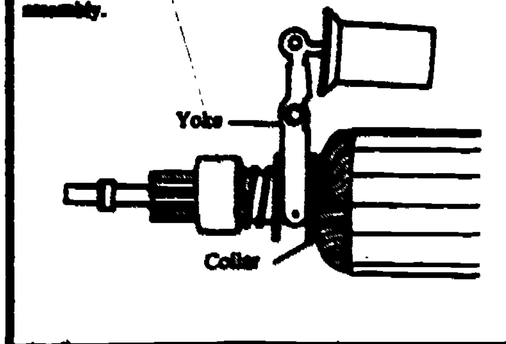
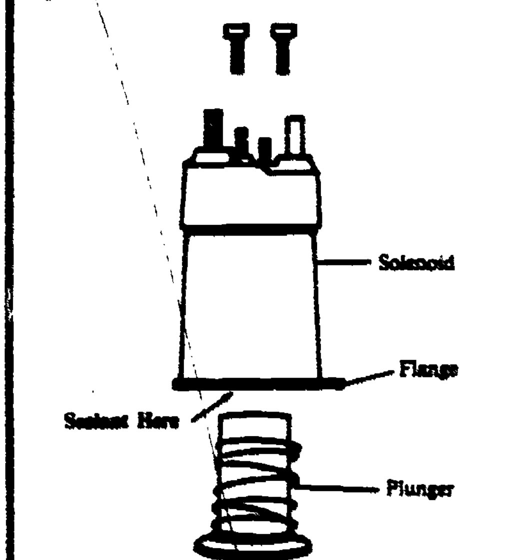


Figure 5. Installing the solenoid.



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- 3.4 Install the solenoid over the plunger and hold it in place (Figure 5). Install and tighten the mounting screws.

STEP 4 Install the field frame. To do this:

- 4.1 Note and remember the locations of the threaded holes in the drive end housing for the through bolts.
- 4.2 Carefully lower the field frame over the armature assembly.
- 4.3 Spread the four brushes apart, as shown in Figure 6, so that they can slide into place on the commutator.
- 4.4 Rotate the field frame until the field coil connections align with the starter terminal of the solenoid. See Figure 7.

CAUTION: As shown in Figure 7, the rivet of the field frame must drop into the hole in the drive gear housing.

STEP 5 Install the brake washer on the end of the armature shaft. See Figure 10.

STEP 6 Lubricate the commutator end plate bushing with lubriplate (white lube).

STEP 7 Install the commutator end plate. To do this:

- 7.1 Place the commutator end plate over the armature shaft and field frame.
- 7.2 Turn the commutator end plate until the holes line up with the threaded bolts in the drive end housing.
- 7.3 Install the through bolts; tighten them evenly and securely.

STEP 8 Attach the field coil connections to the solenoid starter terminal using the connection screw.

Figure 6. Spreading the brushes apart.

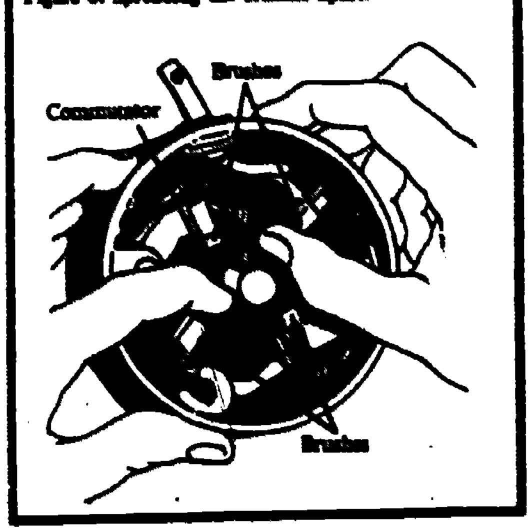

Figure 7. Installing the field frame.