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ABSTRACT

These technical papers by Association members cover a few of the many work functions of physical plants. The authors and their topics are: Thomas E. Shepard, "Opportunities for Controlling the Cost of Electric Power"; Walter W. Wade, "A Different Approach to Parking Structure Construction"; Ronald T. Flinn and Jesse M. Campbell, "Walk -- Through Steam Tunnels at Michigan State University"; Donald Whiston, "Searching for Answers to Refuse Handling"; Raymond Halbert, "Elevator Maintenance Cost Analysis"; R. S. Hollar, "Electrical Demand Study of Campus Buildings at Colorado State University"; Harry F. Ebert, "Physical Plant Organizations in Universities and Colleges"; and Guy Valade and G. M. Gauthier, "Survey of Building Management Centers of North American Universities." (Charts on p. 87, 150-153, and figure on p. 42 may reproduce poorly.) (Author)

TECHNICAL PAPERS

OF

THE ASSOCIATION OF PHYSICAL PLANT ADMINISTRATORS OF UNIVERSITIES AND COLLEGES

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FOREWORD

The Association of Physical Plant Administrators of Universities and Colleges was founded in 1914 for the purpose of aiding its members through the sharing of information and dissemination of mutually useful knowledge. The first papers ever published by APPA were sent out to the membership in 1966. In 1968, another issue followed and in 1969, the very well received "Campus Disorders" was published. This issue marks the first publication of type set pages for said papers. This issue of technical papers was authorized by the Board of Directors of APPA. Publication has proceeded under the stewardship of George O. Weber, President, APPA and Sam F. Brewster, Vice President for Professional Standards, APPA.

Physical plant activities represent a broad spectrum of work functions but only a few are represented herein. The future should hold many interesting topics for the perusal of the APPA membership. Members should be encouraged to prepare and submit papers to their regions and their regional representatives.

Authors and sponsors of articles used in this issue have been extremely helpful in the submission of articles and assisting in the final preparation of the documents. In addition, we wish to acknowledge the assistance of Dennis W. Nelson, who aided greatly in adapting the written and graphic material to the format herewith presented. To each and every one of these persons the editor publicly acknowledges his thanks.

Richard A. Adams
Editor *Newsletter*
August, 1970

OPPORTUNITIES FOR CONTROLLING THE COST OF ELECTRIC POWER

THOMAS E. SHEPHERD, JR., P.E.

Thomas E. Shepherd, Jr., is now Superintendent of Electrical Services at M.I.T. He joined the Physical Plant Staff of M.I.T. in 1967, working as Staff Engineer on utility problems and in the electrical operation of distribution systems and new construction programs. Prior to 1967, he spent 17 years with Jackson and Moreland, Division of H.E. & C., as Project Manager in the Utility Services Department, specializing in utility-industry economics.

He received the B.S. degree from M.I.T. (1950) in Economics and Engineering and subsequently attended Harvard Graduate School of Engineering.

He is a registered professional engineer in Massachusetts and a member of I.E.E.E.

In this technological age vast amounts of time and money are invested in controlling the use of electric energy at all levels of sophistication. I'm sure that you can point to significant contributions on your own campus. Of course, the results of this effort are awesome. It is frequently claimed that the availability of instant energy at reasonable cost is the cornerstone of our present civilization.

On our campus, and probably on yours, electric power costs represent between 15 and 20 percent of our total plant operating budget. With this level of use, it is not surprising that relatively small investments of time and money on the part of plant administrators directed to controlling the cost of this silent but expensive servant can yield high returns measured in reduced power cost.

When I was considering a title for this paper my immediate thought was "Opportunities for Reducing the Cost of Electric Power." I changed from reducing to controlling because reducing the cost has a connotation of achieving a lower total electric power cost next month or next year than you spent this year. In this day of rapidly growing campuses and increasing electric use it is probably not possible to actually lower the total cost of power.

Therefore, reduce cost? Probably not. But increase efficiency, lower the unit cost, get more service for each two dollars you spend for power. Definitely yes! This is possible, and this is what I refer to as controlling the cost of power.

The reference I made to two dollars spent for power is a leading thought to impress you with the fact that electric costs, like good fighters and boy friends, are ambidextrous. That is, you always have two arms to contend with when you are making an electric power decision. Don't spend too much time watching the left hand, say, investment, or you may get clobbered by the right hand, the electric bill or electrical maintenance costs. What you should be looking for are opportunities to control your total campus electric cost; and you should keep in your thinking a balance between fixed costs and operating costs.

The major portion of my talk today will deal with the question of power factor, a very specific electric power cost problem. Power factor improvement is one of the most dramatic opportunities to control the cost of power and it approaches the problem in a free swinging, two fisted manner. But before I get into power factor I would like to give you the general broad check list which we use at the Institute to try to control our cost of power.

First, I might ask, "How often do you talk with your utility representative?" Keep in mind that your utility is your best source of advice and counsel on electric problems. At

M.I.T. we have set up a regular monthly luncheon with our utility company where two or three representatives from each organization sit down for lunch and talk. Occasionally we have an agenda of questions or problems but usually we meet without any pressing needs: invariably we get into a stimulating discussion of mutual problems.

There is a tendency, I think, to avoid discussions with the utility except when it is absolutely necessary, for a new service or for adding load on your present service. This sort of arms length attitude shuts you off from innovative thought and suggestions by a widely experienced consultant.

As a second question I would ask, "How long has it been since you made a serious and fairly comprehensive electric service review?" By review I mean a justification, perhaps better considered an audit, of your electric power cost. If it has been longer than five years our electric use characteristics and our purchased electric costs can change enough so that accumulated deficiencies are costing us money. Enough money annually so that such an audit can be self supporting out of first year's savings. I feel confident that you are in the same situation.

What steps are involved in an electric service review? Such a review falls naturally into two parts: first, getting together your facts and data, and, second, questioning the facts.

The data gathering should include information in the following three items:

Item 1. A list showing in tabular form a fact inventory for every separate service location with as much pertinent statistical information as is available. The list should include the following as a minimum for each location.

a. Rate schedule in use,
b. Maximum demand and time of occurrence,
c. Power factor,
d. Annual KWH energy consumption,

e. Average cost per KWH,
f. Service voltage level and secondary use level.
g. Adjacent services,
h. Transformer and equipment ownership.

Item 2. An up-to-date copy of the published rates of your utility supplier together with copies of his general service agreements and service requirements.

Item 3. A talk with as many other electric customers as possible to determine their rate schedule and their use characteristics together with their average cost.

When you have collected your factual data, the second part of the electric service review involves a critical questioning of as much of your factual data as your resources will permit you to pursue. As a first step, which requires no effort on your part, you should ask your utility to review each service to determine that you are on the proper and most advantageous rate schedule. The utility should be willing to make this analysis and report to you on a semi-formal basis for each separate location. Keep in mind that the utility is also best qualified to advise you as to how you can qualify for a better rate and also make suggestions as to how you can optimize costs on your present rate.

On your part, you should make a critical review of at least one current bill for each of your major services. Ask yourself such obvious questions as:

a. Am I getting my discounts?
b. Is the bill computed properly?
c. Why am I on this rate?
d. Why don't I qualify for a better rate?

Make sure you get a satisfactory answer to each question. Often this routine investigation will turn up obvious errors or oversights on the part of the utility. Don't make the mistake of equating utility bills to bank statements on an accuracy basis.

This investigation is also going to turn up obvious errors and oversights that you have made over the past five years. Correcting your own errors is just as rewarding financially if not egotistically as correcting the utilities errors.

In an electric review conducted this past year, after a five year interval, we discovered that three out of 17 of our separate services which were analyzed in detail were not being billed properly or on the most advantageous rate. The review also disclosed that our major campus totalized service was not being properly billed because of a metering deficiency. The immediate billing corrections for these items more than paid for the entire cost of our formal studies which also included many non-associated electrical analyses.

At this point in the review after you have done some serious questioning undoubtedly you will have raised unanswered questions which require a special study of some type—perhaps technical—perhaps economic or perhaps a full engineering/economic comparison is indicated. Do you hire an engineer? Can the potential benefits justify this expense? Can you handle the study internally and satisfy your administrative officers? I'm sure that you've faced these questions many times. I just add the reminder to exhaust the resources of your utility before you pay for consulting help.

What sort of special studies might be indicated? You will certainly see possibilities for basic changes in your type of service: possibly extension of your own distribution system, a change in voltage level or a change in the ownership of service facilities. You will also find a variety of ideas aimed at improving your load and cost characteristics within the framework of your present rate schedule and physical plant. I don't mean shutting off lights, the idea widely attributed to President Johnson, but by some judicious planning you can frequently add economical off-peak load or move on-peak load to your long-hours use energy block. Or conversely, you can look critically at proposals to add loads which will increase your demand unnecessarily.

Power Factor Improvement

You may find that an awareness of power factor and its effect on your power costs can be very helpful in setting up special studies. Large electric power users frequently have an expensive power factor problem. Most college and university facilities fall into this category. Many college administrators to whom power factor was only an academic problem (pardon the pun) a few years ago are finding it a serious, practical and economic problem today. Growing non-lighting loads, more stringent ventilation requirements, more critical voltage regulation requirements for building equipment and scientific use and even for the more sophisticated devices coming down the line for boiler supervision and control, and of course the rapid growth of air conditioning, all contribute to a power factor problem.

The low, lagging power factor which is characteristic of the connected load of larger commercial, semi-industrial and academic buildings results in hidden or disguised costs which hit the power user twice. First, in his construction cost when he is building, and second, in his operating expenses on each monthly power bill. Low power factor makes it necessary to scale the entire electric system of a building perhaps 20% larger than necessary initially, and, as if that is not enough penalty, the same power factor problem may add a three percent mark-up to the cost of each KWH purchased over the entire life of the building–it has on our campus.

Low power factor can be corrected to eliminate most of these capital and operating cost elements and as a consequence a power factor improvement program will invariably yield dramatic cost reductions. An initial investment is required but, happily, this investment is self amortizing from savings, usually within two years, and the annual savings generated by the equipment then continue, actually increasing in value, each year for the full life of the equipment—estimated at 20 to 30 years.

Who Should Consider Power Factor Improvement?

A power factor improvement program or at least a review of power factor economics is indicated for any institution that purchases at primary level, on a large commercial or industrial power rate or maintains one or more of his own electric substations. More specifically, some power factor improvement will prove to be worthwhile if your electric use meets one or more of the following conditions:

1. If your electric power demand is measured and recorded on your power bill in KVA or if your electric rate has a KVAR or power factor penalty clause,

2. If you have problems anywhere on your distribution system with voltage regulation or chronic low voltage,

or 3. If load growth is eating into the spare capacity of one of your substations or distribution lines and you are faced in the near future with adding additional transformer or feeder capacity.

Power factor improvement will save you money in each of these cases: it will reduce your purchased power cost if you buy on a KVA demand rate; it will improve your voltage regulation and ease any low voltage problems; and it will increase the power carrying capability of your transformers and feeders thereby delaying the need for capital expenditures. These are the areas where power factor is significant because power factor improvement releases locked-up capacity and increases the efficiency with which you use the copper and aluminum both in your electric system and in the utilities' system.

Where do the savings and cost reductions of power factor improvement come from? It is easy to appreciate the actual saving you incur if you increase the efficiency or power carrying capability of your distribution system. Your investment in distribution equipment is smaller for a given power requirement and you can see the saving associated with the avoidance or delay of a major investment in a larger substation.

Similarly, many electric utilities will pay you in reduced power bills for any power factor improvement you make. The utility is willing to pay you because of power factor improvement at the extremities of his entire power supply system, distribution, transmission and generating. He sees these savings as an extension of the saving you see in reduced voltage drop and released capacity.

As you might expect, while power factor improvement is a fairly simple concept in economic terms it becomes fairly complex in engineering and application techniques. There are a wide variety of ways to improve power factor when you get to the detail engineering level. Fortunately, the layman can get good advice in many areas at no cost from the local utility and from the manufacturers who supply the equipment. All that is needed is an appreciation of the problem and, if you feel that you qualify for savings, a call to your utility as a starter.

At M.I.T. we are correcting power factor in a number of ways for each of the reasons noted above, and power factor correction is paying off handsomely on some fairly sizeable investments. For example, within the past year we have invested about $60,000 in equipment for power factor improvement. We are recovering this investment at the rate of $3,000 per month through reduced electric power billing. Our pay-off period for power factor correction is roughly 22 months.

What is Power Factor?

Let me start off by stating that power factor is fundamentally and simply an efficiency ration. Please keep this in mind while I pursue briefly the other things that it is. You probably recall the common formula definition for power consumed in an electric circuit:

$$P(kw) = E\ I \cos \Theta \quad \text{[See Figure 1]}$$

That is, power equals volts times amps (current) times cosine Θ The cosine Θ factor in the equation represents the power factor of the load.

The power factor of a circuit is usually expressed as a percentage which represents the cosine of an angle, usually identified as Θ, which exists between the vector current flowing in a circuit and the vector voltage applied to the circuit. The same angle Θ is the angle which exists between the real power

POWER:

$$P_{(KW)} = E \times I \times \text{Cosine } \theta$$

Real Power = Volts x Amps x Power Factor

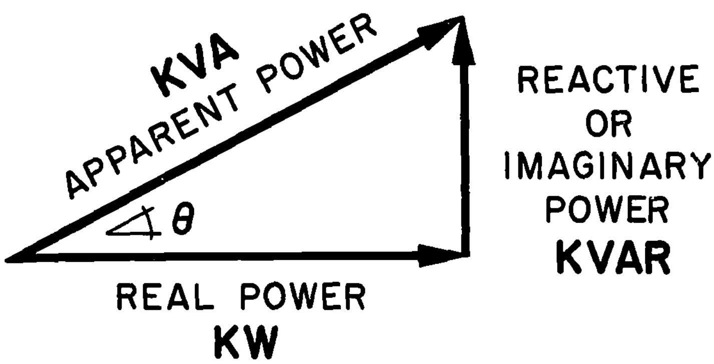


FIGURE 1

vector, the kilowatts (KW) measuring the actual work output of the electric circuit, and the apparent power vector, the kilovolt-amperes, (KVA) measuring the actual voltage and current applied to the circuit. Therefore power factor is the ratio of the KW used to the KVA delivered.

As you note from the geometry of the right triangle on the vector diagram (in Figure 1) the apparent power, KVA delivered, is always larger than the real or useful power KW consumed. For common electric systems the real power will average between 80 and 90 percent of the apparent power. Because apparent power is always somewhat larger than real power and therefore sizes, the electric system, most electrical devices are rated in KVA rather than in KW.

There are three vectors in the power triangle diagram; the real power vector which forms the base of the right triangle, the apparent power vector which is the hypotenuse of the triangle, and a third vector, the imaginary power vector, which is always at right angles to the real power vector and can be either up, as shown, or down.

Real power and apparent power are concepts which I can visualize. Real power I see as the ability to do work and apparent power I can visualize as the product of the current actually flowing in the wires times the voltage applied—forgetting vectors.

Imaginary power or reactive power on the other hand is more difficult to visualize. In physical terms reactive power is the magnetizing and charging currents which must be present in a magnetic device such as a transformer or a motor in order for these devices to do real work. You might relate magnetizing current to blowing up the tires on an automibile so that it may carry a load.

A useful analogy which is frequently applied to the whole power factor problem is the Mug of Beer [see Figure 2]. In this analogy the beer represents the desirable output of an electric system: lighting, pumping, heating, cooling, lifting, all the useful advantages of electric living. But when we buy beer by the mug we get the beer plus a head of foam, symbolic of the reactive power we buy, in an oversized package. Similarly when we buy a KW of power we must buy a KVA package only partially filled with the KW power we want and as a result we must buy a larger package than we really need.

For good beer with life and sparkle we take it with a head on it and accept the low efficiency. You can rate your favorite bartender on his beer factor. If you get eight ounces of beer in a 10 ounce mug his beer factor or efficiency is 80%.

Obviously, buying or transporting beer by the mugful is not efficient. College students, notoriously canny beer buyers, never take a glass full when they can buy it by the pitcher for higher efficiency and the most efficient way to satisfy the thirst of a group is to buy it by the keg. In the keg the beer is under

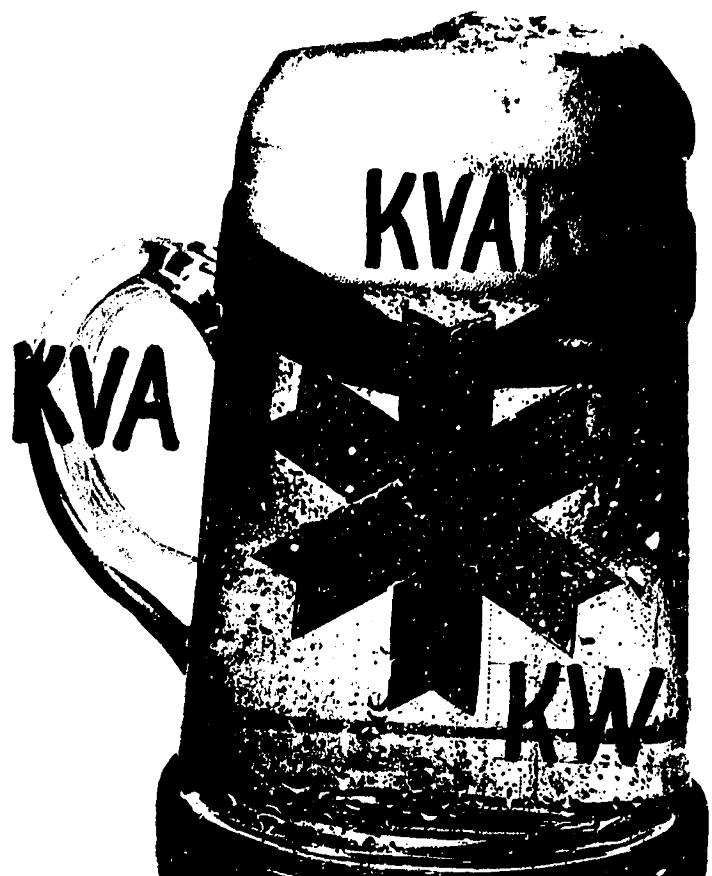


FIGURE 2

pressure with the bubbles dissolved and no foam present and no loss of volume or efficiency is incurred.

This is the secret of power factor improvement, buy your power by the keg, so to speak, without any reactive element and add the reactive power yourself each time you tap the keg.

I should re-emphasize here the fact that we can't do without reactive power. Every magnetic device requires it and the electric system to each device must be sized large enough to KVA to deliver both the KW and KVAR.

The Cause of Low Power Factor

Power factor is low and electric transmission efficiency is correspondingly low when there is a relatively high ratio of magnetizing (imaginary) power to real power. How does this come about?

The equipment which uses imaginary power and which contributes to low power factor are the devices which depend upon magnetic fields for their operation. Transformers, induction motors, welders, induction furnaces and uncorrected fluorescent lamp ballasts all contribute to poor power factor. If you have a relatively high proportion of your total power requirement made up of these devices you will have a low overall power factor. But this problem can be further exaggerated. The magnetizing current for any magnetic device is nearly independent of real power output from no-load to full load. Therefore, the relative imaginary power requirement of a motor, that is its power factor contribution, depends upon the amount of load carried. Lightly loaded motors have a low power factor and the power factor improves as the load on the motor increases. A typical induction motor running at 1/8 of full load will have a 40 percent power factor and will be drawing more than twice as much imaginary current as real current. At 7/8 of full load the power factor will have increased to its peak, say 87 percent. To reach this power factor improvement the real current has increased roughly proportional to load, say seven times, while the imaginary current has less than doubled. This situation is repeated for all the magnetic devices on a system. Therefore, one method of avoiding a poor power factor is to buy and operate your equipment as close as possible to its design level. Do not have an unnecessarily oversized system.

The Effects of Poor Power Factor

A low or badly lagging power factor has some very noticeable ill effects on system operation in addition to the economic losses which are incurred in high power bills and excessive capital costs. The most serious effect is low voltage. Low voltage is reflected in reduced light output and reduced heat from resistance devices. Electric induction motors run hotter because of higher current requirements and motor torque is reduced.

Power Factor Improvement

How can you improve an existing power factor problem?

Power factor improvement comes about by reducing or eliminating the flow of imaginary power through the conductors and transformers of your system. The capacity to deliver power KW's to the loads is limited in conductors and transformers by the total amperes or KVA required. If we eliminate the imaginary power flow and improve the power factor by 20 points say from 80 to 100 percent we increase the power delivering capability and the system efficiency by 25 percent.

This is possible only if we are not required to buy the imaginary power from the utility and deliver it through the distribution system to each magnetic device.

Consequently, if we can inject the imaginary power requirements of the magnetic devices into the system at the point where they are required we relieve the rest of the system of the need to deliver them. This would be comparable to installing a small generating unit adjacent to each load and thereby relieving the circuit conductors of the need to deliver the necessary current.

Local generators would, in fact, be an entirely satisfactory method of improving system power factor. Generators produce the imaginary power required by magnetic devices as well as the real power.

The ability to generate imaginary power is a characteristic of two other electrical devices; the synchronous motor and the static capacitor. These devices produce leading reactive power naturally and when a device of this type is placed electrically adjacent to a magnetic device which requires lagging reactive power there is an interchange of reactive power between them. If the devices are properly sized, the electric circuit looking at them sees no net reactive power requirement. On the vector power triangle we looked at earlier, this is equivalent to adding another imaginary power vector equal in length and in the opposite direction downward to cancel out the original reactive power vector. Then as you see, the KVA will fall down upon the KW vector and their ratio will be 100%.

Large sized synchronous motors can provide dual service, meeting a power requirement and in addition generating extra reactive power to improve the power factor of the circuit serving other inductive loads. The ability to use synchronous motors in this way is limited by economics. In general, synchronous motors in small sizes are substantially more expensive than a comparable induction motor plus a capacitor bank to provide the equivalent high power factor. When motor sizes reach 300 HP the synchronous motor should never be overlooked in preliminary planning.

The other natural generator of reactive power, the capacitor, is the most widely used method of improving power factor. Simple, reliable and relatively inexpensive, with no moving parts and using no real power, the capacitor is an ideal circuit element.

Description of Capacitors

The power factor correcting capacitor is a large scale, high power model of the capacitors we are used to seeing in radio applications. A capacitor consists of two parallel metal plates of large area separated by insulation and sealed within a tank-like container. In manufacturing you would find two long strips of conducting foil separated by a plastic sheet and rolled into cylinder form.

Most of you are probably familiar with capacitors and I'm sure all of you have seen power factor capacitors perhaps without noticing them, mounted in clusters on utility poles in suburban and rural areas. Commonly the individual capacitor unit is a tank about the size and shape of a brief case standing on end with two insulating posts projecting for connections on the top. These units are normally seen in clusters of three to 15 cans in a rack mounted configuration.

For indoor installations the same tank units are built into a standard switchgear enclosure or rack mounted with a sheet metal box enclosing the terminal bushings.

Capacitors for power factor improvement may be thought of as normal electric devices and connected to the electric system in almost exactly the manner that any electric load such as a motor or lighting fixture is connected. As an example, if you wished to correct the power factor of a portable electric motor which was plugged into one side of a duplex receptacle it would be entirely reasonable and good location practice to provide a capacitor unit with a plug and cord and plug it into the other side of the receptacle.

In practice of course, the capacitor installation is permanently mounted like a piece of switchgear and connected to the electric system at a substation bus by a breaker or contactor.

Capacitor Ratings

Thinking of the capacitor basically as a load device is supported by the fact that capacitors are normally rated in KVA reactive or simply KVAX to differentiate leading power from KVAR which is used to identify lagging power.

Capacitors are technically rated in microfarads but in the manufacturers specifications for engineering use, the units are rated in the more realistic terms of system voltage and KVAC.

Availability

Capacitors are available as standard single phase or three phase units at every common distribution and primary voltage from 208 V up. There is an unlimited range of sizes available starting at units as small as two KVAX for voltages under 600 volts and starting at 15 KVAC for primary voltage levels at 2400 and above.

The current rating of the capacitor unit determined in the same manner as any KVA load, that is for a three phase unit.

$$KVAC = \sqrt{3}\ V \times I \text{ and}$$

$$I = KVAC \text{ Rating} / \sqrt{3} \times V$$

Conductor and fuse sizes are predicated on this current rating. Safety switches and circuit breakers for capacitor circuits are normally underrated to 60% to 70% of their normal load rating because of the possibility of high transient switching currents.

How Much Reactive Capacity Should You Install?

If you undertake power factor improvement, how much reactive capacity do you install and where do you install it; equally important, how much will it cost and what will you save?

The amount of KVAC to install is dependent on three factors; the present power factor, the power factor you want to achieve, and the circuit or system load measured in either KW or KVA. When you have these pieces of information the sizing of a capacitor bank to give you the desired power factor has been made very simple. All that is required is a reference to a "Power Factor Correction Table" or a simple nomograph where the cross index of present and desired power factor reads out a multiplier in percent form. This percent factor is multiplied by the present load to give the necessary KVAC. Since the relationship between KW, KVA and KVAR is trigonometric and therefore complicated, each manufacturer has published the necessary unit relationships in table form for simplicity in computation.

Of the three input factors needed for this decision, two—the present power factor and the present load— are known or can be determined easily by metering. The third item, desired power factor, is somewhat deceptive. What level of final power factor do you want: 85%, 95%, unity (100%)?

If for billing purposes your electric rate gives you a power factor target of say 85% or 95%, this is what you want as a minimum. It is usually desirable when you are correcting power factor to go to a higher power factor than your minimum level. This is suggested for two reasons;

First, the incremental cost of capacitors is very low. The unit cost to add one more KVAC to an existing bank of capacitors is usually less than half of the average cost installed. This is true because the fixed costs of switching and mounting structures in a capacitor bank are major cost items.

Second, normal load growth results in a falling power factor. If you correct power factor to the minimum this year, next year, with normal load growth, your power factor will have declined and you will again be deficient and faced with the same correction problem at higher cost.

This philosophy says reach out for a good improvement with some cushion above the minimum. How high should you go? You are limited on the upper end of correction by the effectiveness of added KVAC. As shown in Figure [3], the corrective ability of a KVAC decreases rapidly as you approach unity power factor. Thus, you are faced with the law of diminishing returns on your investment if you try to correct to much over 95% to 97%.

For a rule-of-thumb, which is supported by many studies, plan to correct to 97% or more, regardless of your purpose.

And Where Should You Install It?

After you have estimated the total amount of reactive capacity in KVAC, which can be utilized on your system, you can consider the problem of where to locate this amount of KVAC. Will you install it in one large block or in several small blocks? At what voltage should the installations be made if you have a choice?

If your major incentive is to reduce your power bill, either by meeting a utility standard or by reducing your billing

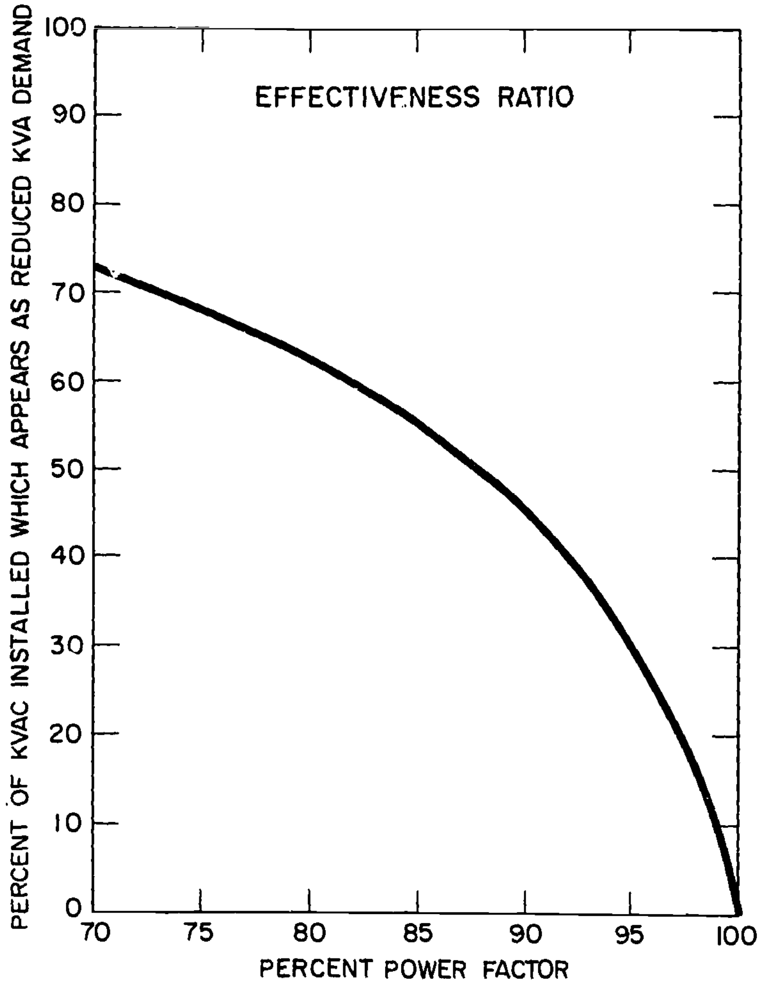


FIGURE 3

21

demand, you should be looking at large blocks of capacitors, at the highest voltage you own and as close to the utilities meter point as you can get. If on the other hand your major concern is distribution efficiency, delay of new investment in transformers or feeders or improved voltage regulation, you should be looking at smaller units at lower voltages located at the extremities of your system.

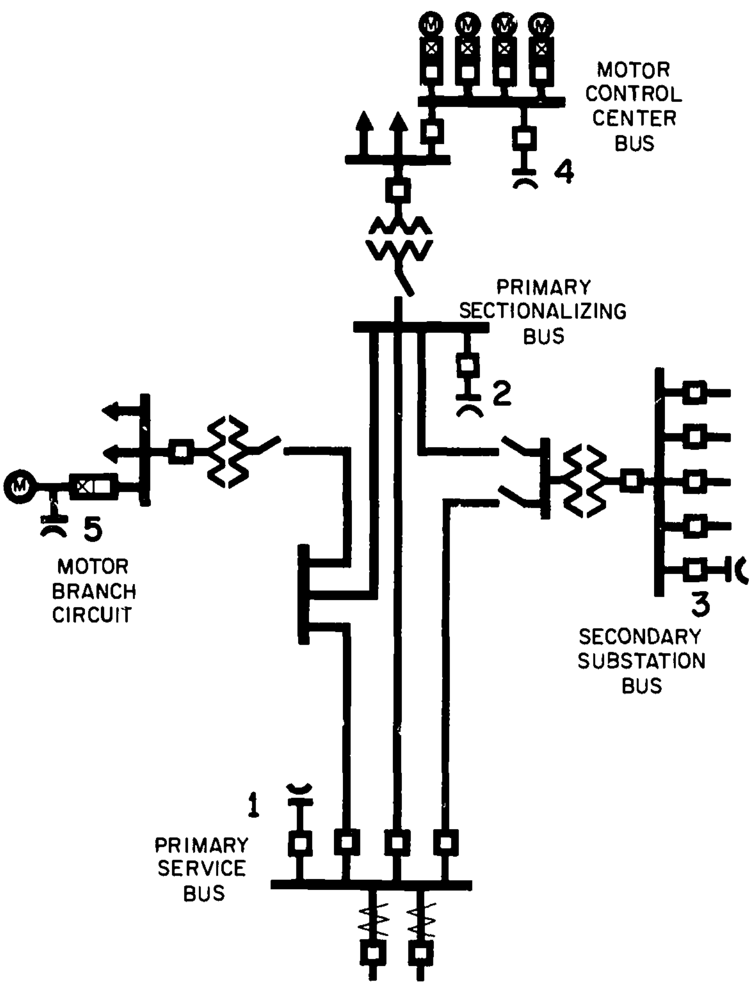
To illustrate these extremes, consider the simplified one-line diagram in Figure [4,] which looks something like a tree. For purchase power economies add large capacitors at the roots or on the trunk of the tree, points 1, 2, or possibly 3: for distribution economies add several smaller capacitors at the branches or at the leaves, points 3, 4, or 5.

We can simplify the question of unit size and location in this manner because the cost of capacitor units follows a very predictable pattern. Large blocks of capacity operating at high voltages are cheap and small blocks of capacity operating at low voltages are expensive. Figure [5] demonstrates these conditions graphically. Large blocks are cheap because of the low incremental cost of the actual capacitor units. High voltages are cheap because capacitor efficiency increases as the square of the voltage.

Since your potential savings are usually fixed once you decided on the total amount of KVAC you plan to add, your over-all economic incentive depends on how cheaply you can add the KVAC. To maximize benefits, climb down the tree as far as you can.

Power Factor Improvement at M.I.T.

To illustrate some of these principles in practice, let me use some examples of power factor correction at M.I.T. To put our personal problems in context I will briefly outline the M.I.T. power supply and distribution system as it stands today.



MOTOR
CONTROL
CENTER
BUS
4
PRIMARY
SECTIONALIZING
BUS
2
5
MOTOR
BRANCH
CIRCUIT
3
SECONDARY
SUBSTATION
BUS
1
PRIMARY
SERVICE
BUS
POWER COMPANY

FIGURE 4

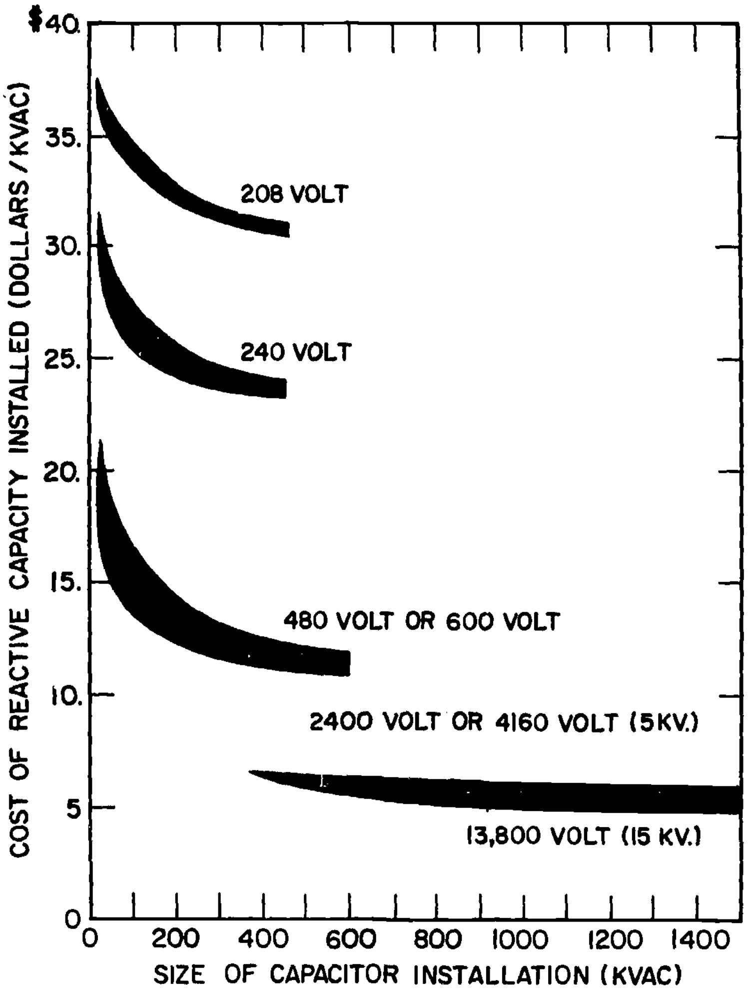

$40.
35.
30.
25.
20.
15.
10.
5
0
COST OF REACTIVE CAPACITY INSTALLED (DOLLARS / KVAC)
208 VOLT
240 VOLT
480 VOLT OR 600 VOLT
2400 VOLT OR 4160 VOLT (5KV.)
13,800 VOLT (15 KV.)
0 200 400 600 800 1000 1200 1400
SIZE OF CAPACITOR INSTALLATION (KVAC)

FIGURE 5

We have a central urban campus in the shape of a broad triangle which comprises most of our teaching, research and dorm facilities. All the buildings on the main campus are interconnected by a 13.8 KV selective primary loop underground distribution system anchored at three service points within the campus. Figure [6] One station is located at the middle apex and two other stations at points close to the other ends of the triangle. The original portions of the campus, now a small fraction of our load, are interconnected at 2,300 volts. The balance, the major portion, is operating at 13,800 volts. We have connected on the 13,800 volt system 55 individual substations serving buildings on the campus at secondary voltage. All of our power is purchased and we take delivery at the three bulk delivery service substations. The utility feeds each of these substations with two 13,800 volt feeders. Our maximum demand for our main campus load is totalized for three separate services. The maximum load in 1968 was 16,000 KVA and our annual use was 85,000,000 kwh. Our normal uncorrected power factor is 86%.

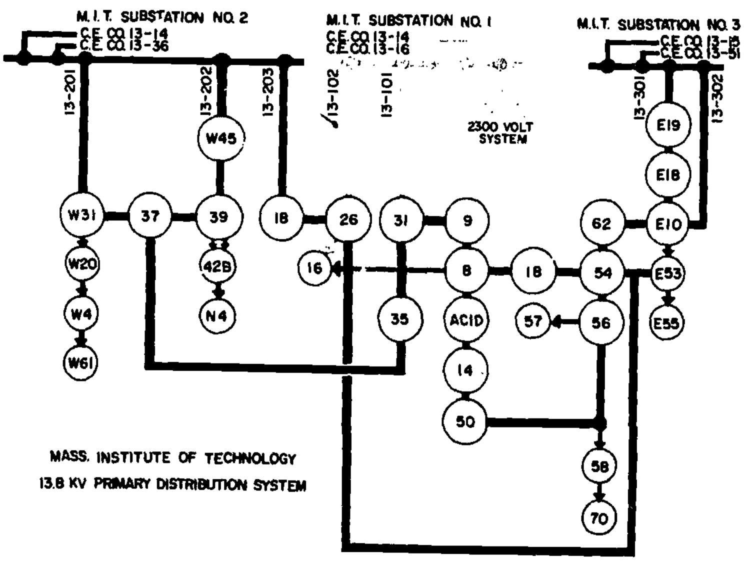


FIGURE 6

In addition to the central contiguous campus system, we are responsible for electric service to some 30 additional buildings close to the central campus which are not interconnected and are separately served by our utility. These loads, range up to 1,000 KVA in individual size and account for another 7,000 KVA of demand and 30,000,000 kwh in annual use. Many of these loads, former industrial properties, have uncorrected power factors between 80 and 90 percent. These separate locations are normally served at primary voltage if they are large enough to qualify; otherwise at the available secondary level.

In our "Large General" and "Primary Light and Power" rates from the utility we have a well defined economic incentive for power factor improvement. We pay for power on a two-part demand and energy rate with a long-hour use provision. Our billing demand is computed on a KVA basis. As a consequence, it is fairly easy for us to estimate the savings in the monthly power bill which will result from any power factor correction. On the main campus rate for example, for each KVA we reduce our demand, our demand charge pays us $1.22 per month or $14.65 per year. On the smaller, individual services off-campus, our savings run as high as from $1.56 per KVA per month for some services to $2.10 per KVA per month or $25.20 per year for smaller loads with service at secondary voltage. When we compare these potential savings with the per unit cost of capacitors, roughly $10 to $20 per KVAC, it is fairly easy to justify even a substantial capital outlay with a short pay-off period. Referring back to Figure [3] which showed the KVA reduction per KVAC added, we note that the "effectiveness" drops off rapidly as the initial power factor increases over 90%. This "effectiveness ratio" multiplier must be used to discount the savings for comparison with the cost of capacitors.

Examples of Capacitor Installations

To give some practical examples of the form that power factor correction can take, I have prepared capsule descriptions of four of our installations. The first three installations are at low voltage, at 480 volts or 550 volts. The final example is our most recent and ambitious installations at 13,800 volts.

While our incentive for power factor improvement is generally for lower billing, we have recently installed a capacitor bank at a separately served building—a converted industrial property off-campus, which is a classic example of released capacity. It happened this way. When we took over this property it had a 1,000 KVA transformer substation and an 800 KVA load. Over a three year period we progressively occupied and upgraded the building substantially. The maximum demand on the substation gradually grew in this three year period to a 1,245 KVA summer peak and showed signs of increasing still further beyond safe limits. This condition was coupled with a low power factor averaging 80 percent. We were faced with an expensive step-up in transformer capacity.

We found that by adding enough capacitors on the transformer secondary side to raise the power factor to an economic level, purchase power wise, that the KVA peak load dropped from the excessive levels of 1,245 KVA in 1967 to a safe level of 960 KVA with added capacity for growth in 1968. To reach this condition we added a 450 KVAC bank at 550 volts.

By extending the substation pad slightly and utilizing a spare breaker position to tie the bank to the secondary bus, we added this equipment at a cost of $4,600. This unit has reduced our power bill by $3,025 in the first 9 months of its operation and we see a payoff period on our investment of 14 months from billing alone. Of course we also have avoided a new transformer and substation installation which saved us over $10,000 immediately. This savings alone exceeded the cost of the units twice over.

Low voltage capacitor units are very compact and easy to fit into existing electrical equipment space. This is demonstrated by the next two examples.

Another low voltage capacitor bank, a minimum type installation also in an off-campus building was installed in 1961. In this installation, a 80 KVAC unit corrected an 80% power factor condition to 97% on a 200 KVA load. This unit at an original cost of $1,200 in 1961 has been saving us billing of $960 per year for seven years.

As a third example of power factor correction added at secondary voltage, we have made a similar installation this year in a converted semi-industrial building. This compact unit of 150 KVAC at 550 volts is installed to improve power factor on a load of 400 KVA at a saving of $1,120 per year. Total cost of the installation was about $1,700.

Note that the capacitor is not as large as breaker panel. These units have illustrated the technique of correcting power factor at the secondary voltage level. This type of power factor improvement is very beneficial for the entire electric system since it covers all of the desirable features of power factor improvement. It frees capacity, improves voltage, and results in purchase power saving. It doesn't, however, maximize savings. These units we have seen cost an average of $12 to $20 per KVAC, depending on voltage and size, and yet they each reduce billing at the rate of roughly $10 per KVAC per year. By inspection of the unit cost chart we see that we can buy this equivalent reactive capacity for less than $10 per KVAC and achieve the same savings if we install the units at primary voltage, 2,300 or 13,800 volts.

This conclusion led us to the consideration of large bulk capacitor installations. In past years we tended to look at the power factor problem on an individual building or substation basis. If we planned to upgrade the power supply to a building or add a substation we would check the local power factor and, if indicated, we would add a power factor correcting bank with the installation.

This past year we faced the power factor problem on a system wide basis. Our studies of loads, locations and savings relationships convinced us that in our position we would maximize our benefits on our campus system by installing our system power factor improvement in large blocks, at primary voltage, the cheapest possible installation. As a result we have installed two large indoor metal enclosed capacitor banks on our side of the metering equipment at two of our substation ties to the utility. We have under construction a unit for the third station and it will be in service within two months.

With our primary sectionalizing equipment we provide a dual feed to each of our 55 individual substations. We can select the active feeder to each substation from any one of the three bulk substations by use of the eight primary loop feeders. This configuration made it desirable for us to go to capacitor locations close to the delivery points because we cannot guarantee that any one location we might choose out on the system will always be at the end of a feeder.

Since our load is fairly well balanced between our three delivery points under normal conditions, we have settled on a typical capacitor bank design for each of the three bulk units. We have installed a specially designed package unit of 2,250 KVAC initial capacity with an add-on feature to an ultimate capacity of 3,600 KVAR per unit. We intend to increase the capacity of each unit in increments of 450 KVAC as our load increases and on this basis to keep our power factor close to unity. The incremental cost of capacitors at the 13,800 volt level is less than $2.00 per KVAC and even at 99% power factor each KVAC we add will save us $1.50 per year.

Each of the three bulk capacitor banks has a design payback period of 22 months. They will do somewhat better than this in practice because our system load continues to grow at a 10 percent annual rate and this growth amplifies our savings.

We expect that these banks will carry our power factor improvement needs on the main campus for at least six years based on our current growth projections. Before these units are used to capacity, load growth and feeder capacities may force us to turn to the dispersal method of adding our additional capacitor needs. Also, we intend to look more carefully at synchronous motors for large power needs and capacitors directly at the motor for our intermediate size motor needs.

A DIFFERENT APPROACH TO PARKING STRUCTURE CONSTRUCTION

WALTER W. WADE

Walter W. Wade is a 1941 engineering graduate of Purdue University. After four and one-half years service in the Navy as an engineering officer, and a brief period of employment with Commonwealth Edison Company, he joined the staff of the Construction Division of the Physical Plant Department of Purdue University in 1946. His current title is Director of Physical Plant. During his period of service at Purdue, over $200,000,000 of new construction contracts have been completed at Purdue's five campuses.

Through a combination of circumstances, a parking structure construction procedure evolved at Purdue which might be of use to other universities as well as others in need of parking structures. The major advantage of the procedure is that the buyer is able to select the design he prefers at a known price. In Purdue's case we were able to select an economical, low maintenance structure designed to our program requirements by a specialist in parking structure design.

The procedure is quite simple, yet there are certain pitfalls to be avoided.

The procedure is as follows:

1. Performance specifications are prepared.
2. The project is advertised for bids.

3. Bids are received from designer-builder teams.
4. The Owner selects the most advantageous design at a known bid price and awards the contract.
5. The designer submits working drawings as shop drawings for the Owner's approval.
6. Construction proceeds with inspection of the work a joint responsibility of the Owner and designer.
7. Final acceptance procedures are those of normal construction practices.

Having outlined the total procedure, I will go into more detail as to how each item has been handled at Purdue and pitfalls that may be encountered.

The preparation of performance specifications must be done in detail by qualified personnel, in that, having described what is acceptable to you, the designers will provide a design just meeting your minimum requirements. For the designer to provide more than the minimum requirements will insure that his team is not the low bidder for the particular material combination used in his design.

Fortunately, our personnel in our Planning and Engineering Section have the necessary qualifications. Undoubtedly many other universities have such qualified personnel also.

Our specifications were quite detailed and contained the normal "front end" as well as the design requirements. The index was as follows:

Advertisement for Bids
Wage Rates
Instructions to Bidders
Combination Bid Bond and Bond for Construction
Principal Subcontractor Questionnaire
Subcontractor and Material Questionnaire
Proposed Design and Construction Progress Schedule
Supplemental Bid Form
Alternate Proposals

General Conditions

Special Conditions
Scope of Project
The Site
Design Requirements
Field Log for Soil Boring

Each university undoubtedly has a "front end" to its specifications that is designed to meet its own particular needs. Therefore, I will not dwell in any detail on that part of our specifications.

We included a section on alternate proposals to permit the designer to propose alternative solutions of accomplishing any phase of the work which he felt might be to the Owner's advantage. Examples of the kind of items a designer-builder team might submit alternate proposals on are:

(1) Cor-Ten steel structure in place of painted steel structure.
(2) An alternate facade treatment in place of the proposed with the base bid.
(3) An alternate safety barrier assembly.
(4) An alternate drainage or water proofing method.
(5) An alternate stair style or construction.

Our general conditions were the same general conditions as used on all Purdue work. Our section headings are:

(1) Definitions
(2) Intent of the Contract Documents
(3) The Architect and the Superintendent
(4) Construction Progress Schedule
(5) Materials, Workmanship and Equipment
(6) Specifications and Drawings
(7) Changes in the Work
(8) Access to Work and Correction of Work
(9) Correction of Work
(10) Payments to Contractor
(11) Insurance
(12) Owner's Right to Let Other Contracts
(13) Contractor's Superintendent and Supervision
(14) Subcontractors and Manufacturers

(15) Protection of Work and Property
(16) Contractor's Guarantees
(17) The Owner's Right to do Work
(18) Owner's Right to Terminate Contract
(19) Assignment
(20) Waiver
(21) Cash Allowances
(22) Permits and Regulations
(23) Codes and Ordinances
(24) Royalties and Patents
(25) Use of Premises
(26) Cleaning Up
(27) Cutting, Patching and Digging
(28) Gross Income Tax–Non-Resident Contractors
(29) Nondiscrimination Provisions
(30) Open Competition

Special general conditions are needed to fit the requirements of a particular site and project. The headings used in our special general conditions were:

Additional Definitions
Tests and Inspection of Materials
Delivery and Storage of Materials
Manufacturer's Instructions or Specifications
General Conditions of the Contract (Revisions)
Indiana Sales and Use Tax
Time of Completion
Liquidated Damages
Owner's Use or Occupancy
Cooperation of Contractors
Parking Regulations
Maintaining Traffic
Temporary Offices
Sanitary Conveniences
Locations and Grades
Protecting Public

In the Scope of the Project we covered the preliminary design submittal; the working drawings and specifications to be submitted if awarded a contract; demolition; State and Owner's approvals required; permits; quality of construction; shop drawing approval; field inspection; progress schedule; "As-Built Drawings"; quality standards; and Owner's evaluation of all bids.

To permit the Owner to select the solution best meeting his requirements, he must not be forced to accept the low dollar bid. In this portion of the specifications we informed the design-builder team that we would evaluate all bids on the basis of (1) economy, (2) traffic flow, (3) structure, (4) aesthetics, both exterior and interior, (5) and maintenance. We did not indicate what weight we would assign to each item.

This award evaluation section is one which reaps the greatest benefits to the Owner but also creates some of his post-award headaches. Each designer and material supplier of course considers his design and material the best. Once you select a design and its associated materials, you are open to criticism for having chosen what you selected.

To adequately explain to your governing board why you recommend a particular design, it is necessary to make a detailed comparison of all bids submitted. When this is done, some bids are eliminated because of poor traffic patterns; others because of first cost; others because of high maintenance cost. This same detailed comparison will be of value in explaining to bidders why their bid was not selected. To a limited extent, it will also be of use in placating unsuccessful material suppliers.

A site plan and description needs to be supplied to the bidding team for their use in preparing a design and bid. Ours covered the following items concerning the site: size, grades, adjacent streets and alleys, points of ingress and egress to the parking structure, existing utilities, sidewalks, curbs and gutters, protection of adjacent property, storage area, set-backs, demolition and soil boring, plot plan and log.

Finally, we get to the Design Requirements of the parking structure. Our paragraph headings (capitalized) and subheadings were:

General Description
Building Code

Usage, primary, secondary
Capacity
Traffic Flow: entrance, exit one way traffic, pedestrian traffic, parking spaces, vertical clearance, slant parking, module width, ramp slopes, buried spaces, ramp widths, turning radii, curbs and dividers and crossover lanes.
Type of Structure: footings, framework, structural steel, reinforced concrete, concrete decks, safety barriers, live loads, finishes, codes and concrete requirements.
Drainage and Waterproofing
Stairways: treads and risers, non-slip nosing, handrails, enclosure and fire extinguishers.
Striping and Marking: parking spaces and warning signs
Exterior Treatment
Excavation, Backfill and Grading
Concrete Paving
Sidewalks, Curbs and Gutters
Standpipes
Electrical System: lighting fixtures and light levels, convenience outlets, distribution system, exit light system and fire alarm system.

Although the above list is long, subheadings were omitted in some instances where none are listed.

The advertisement for bids is the normal one we use with the exception that sufficient time must be allowed for the designers, builders, and material suppliers to form "teams" to bid upon the work. In my opinion a minimum of two months should be allowed from the time of advertising and the receipt of bids.

Bids should be received at least two weeks before presenting your recommendation to your governing board to allow sufficient time for analysis and comparison of the designs and bids.

Following the above procedures, we received eight bids which are summarized below:

Bid Information	Features of Design
Bid No. 1—Base Bid: $580,000 (390 car garage complete) $1488/space; $5.09/sq.ft.	Short span steel framework with reinforced concrete decks. Interlocking helix w/90° parking, 9' stalls, one-way traffic, 60' module width, 4 stories high, 4% crown ramp (w/2.5% slope in parking spaces).
Bid No. 2—Base Bid: $622,000 (391 car garage complete) $1592/space; $5.10/sq.ft.	Long span steel framework with reinforced concrete decks. Interlocking helix w/70° slant parking, 9' stalls, one-way traffic, 55' module width, 4 stories high, 4% crowned ramp (w/2.5% slope in parking spaces).
Bid No. 3—Base Bid: $640,000 (391 car garage complete) $1638/space; $5.29/sq.ft.	Long span post-tensioned concrete w/ post-tensioned concrete decks. Interlocking helix w/70° slant parking, 9' stalls, one-way traffic 55' module width, 4 stories high, 4% crowned ramp (w/2.5% slope in parking spaces).
Bid No. 4—Base Bid: $660,000 (391 car garage complete) $1690/space; $5.45/sq.ft.	Long span precast (double tee) concrete w/3" reinforced topping deck. Interlocking helix w/70° slant parking, 9' stalls, one-way traffic, 55' module width, 4 stories high, 4% crowned ramp (w/2.5% slope in parking spaces).
Bid No. 5—Base Bid: $680,000 (391 car gargage complete) $1740/space; $5.61/sq.ft.	Long span precast (single tee) concrete w/3" reinforced topping deck. Interlocking

helix w/70° slant parking, 9' stalls, one-way traffic, 55' module width, 4 stories high, 4% crowned ramp (w/2.5% slope in parking spaces).

Bid No. 6–Base Bid: $772,730 (424 car garage complete) $1824/space; $5.68/sq.ft.	Long span precast concrete w/3" post-tensioned deck over 9' tees at 9' o.c. Ramped floors (full length) w/90° parking, 9' stalls, two-way traffic 62' module width, 4 stories high, 2.5% ramp slope throughout.
Bid No. 7–Base Bid: $914,576 (422 car garage complete) $2170/space; $6.50/sq.ft.	Long span precast concrete framework w/post-tensioned concrete decks. Interlocking helix w/90° parking, 9' stalls, one-way traffic, 60' module width, 4 stories high, 3.73% crowned ramp (w/2.5% slope in parking spaces) and a 8.3% slope crossover ramps at ends.
Bid No. 8–Base Bid: $997,457 (417 car garage complete) $2390/space; $6.50/sq.ft.	Long span steel framework w/reinforced concrete decks. Interlocking helix w/60° slant parking, 9' stalls, one-way traffic, 55' module width, 5 stories, 4% crowned ramp (w/2.5% slope in parking spaces).

We selected Bid No. 3 on the basis of good traffic flow, low maintenance cost and reasonably low first cost. Having made the selection of poured in place post-tensioned concrete, I am no longer as well thought of by structural steel and precast concrete suppliers as I once was.

Once the award is made, another delay period occurs during which the working drawings are prepared by the designer and submitted as shop drawings to the Owner for approval. As part of our requirements, we require the designer to obtain the necessary approvals from the various State agencies.

Once the working drawings are approved, construction proceeds with the designer now a member of a second team. He now joins forces with the Owner to inspect to see that his design is carried out. At Purdue we provide the day to day inspection with the designer visiting the job on a weekly basis for progress review and necessary interpretation of his plans and specifications.

I have gone into some detail in listing the points covered in our performance specifications in that the design will be responsive first to what you require, and secondly to the designer's thoughts. To permit the designer as much freedom as is possible to utilize his own talents, the performance specifications should concentrate on results desired and not on how these results are to be achieved.

Having gone through this procedure on one parking structure, I feel we have discovered a procedure that will bring us the latest thinking in design concepts and material utilization as future parking structures are built. As evidence of this, I was visited by representatives of one of the major steel manufacturers subsequent to our awarding our contract. Their purpose in visiting us was to have their design criticized so that flaws in it could be eliminated in future work.

With designers, builders and material suppliers working together to achieve the most economical, functional, maintenance-free design, I feel certain that lower cost per space structures will be available to Owners who follow this suggested procedure.

WALK-THROUGH STEAM TUNNELS AT MICHIGAN STATE UNIVERSITY

RONALD T. FLINN
and
JESSE M. CAMPBELL

Jesse M. Campbell is now employed as a Consultant to the Utility Services Department at the Physical Plant Division–Michigan State University. He was formerly Superintendent of Power Plants, preceded by a full time teaching assignment as Professor of Mechanical Engineering. He has a B.S. degree in Mechanical Engineering from Mississippi State University and an M.S. degree from the University of Minnesota. He is a member of the American Society of Mechanical Engineers (A.S.M.E.) and the American Society of Electrical Engineers (A.S.E.E.), and has been active in other organizations.

Ronald T. Flinn is currently Associate Director of Physical Plant Division at Michigan State University, and has charge of engineering planning, construction and all technical services related to Physical Plant activities. He is a Registered Professional Engineer, has a B.S. degree in Civil Engineering from Michigan State University, and an A.A.S. (Associates of Applied Science) degree from Erie County Technical Institute in Buffalo, New York. Mr. Flinn is active in professional organizations and numerous community activities.

Introduction

Michigan State University has 34.4 miles of steam and condensate return pipes and this system includes 5.0 miles of walk-through steam tunnels. Prior to 1939, steam tunnels were constructed; from that time until 1960, all construction of steam distribution was of the direct burial type. Since 1960, 3.3 miles of steam tunnels have been built.

The older section of steam tunnels carries 90 psi and 5 psi steam mains and vacuum condensate return mains, while the new section carries 90 psi steam mains and 25 psi condensate return mains.

The tunnels carry steam pipes varying from 2-1/2" to 30" diameter and accompanying condensate return lines vary in size from 1" to 18" diameter. The steam tunnels have reserve space for future pipes and in certain areas, parallel steam mains have been installed to provide additional capacity for reliability. Chilled water pipes have been installed to air condition one building from machinery installed in another. Figure [1] displays the campus steam distribution system.

Construction

The steam tunnels have been constructed with various widths and heights, but the most common have inside dimensions of 6'9" width and 6'2" height. The tunnel structure is constructed in three steps: 1. floor slab; 2. wall erection; 3. roof slab. The pipe is normally placed in the tunnel between step 2 and 3. Inserts and anchors are placed in the form work, before the concrete placement. The steam tunnels are built in sections with lengths no longer than 40 feet; thus, the tunnel is essentially a group of concrete boxes, 40 feet long. The placement of a vinyl water stop between each section of tunnel allows for slight linear expansion and contraction. Steam vaults are placed at interconnection points in the piping, and especially at expansion joint locations. Each steam vault has a minimum of two access and ventilation manholes. The concrete tunnel and vaults receive a two-ply felt and pitch waterproofing coat.

The lowest pipes in the tunnels are supported with pipe saddles and rollers placed on concrete pads. The spacing of these supports is dictated by pipe size, but it is normally 15 to 20 feet. Good results have been obtained by using galvanized metal strut inserts in the walls and the support pads. The support rollers are bolted to the strut cast in the support pad and the wall strut, which extends from floor to ceiling, is used to support future pipe. The wall strut is also employed to receive rollers at guide locations. Anchors in the tunnel section usually consist of three structural steel channels cast in the concrete tunnel wall. Anchors within steam vaults employ a vertical structural steel column or columns. Pipe guides have a structural steel column next to the walkway to provide resistance to pipe movement in that direction. The anchors and guides are, therefore, capable of receiving future pipe located above the first pipe installed. All steel, in contact with the floor, is encased in concrete for corrosion protection.

The packed slip sleeve type of expansion joint has been the most widely used. Maintenance on these joints require ease of accessibility and occasionally require additional manholes or ladders to allow the men to get to the side of the expansion joint opposite the walkway. See Figures [2 and 3] for typical details of tunnels and piping arrangements.

The steam tunnels have 100 watt electric light bulbs placed 25' apart. Main tunnel runs are switched from a master panel in one of the power plants. Branch tunnels have two-way switches to control lights.

Operation

Steam tunnels provide an unexpected problem of security, especially with an inquisitive university community. Since safety of maintenance personnel is a foremost thought, it was necessary to develop a system of control which would allow the rapid exit of maintenance personnel in case of emergency, but would also prevent entry by unauthorized personnel. The solution was to chain down each manhole cover with a quick release load binding device and to have doors at buildings unlocked on the tunnel side. This requires very close security control, whenever construction requires an opening into the existing tunnel system. A steel bulkhead, with a locked door erected in the tunnel, has been the best solution. During the summer, the temperature in the steam vaults can become quite high and a cooling fan greatly aids the maintenance men in performing their work. A gasoline driven mobile fan is illustrated in Figure [4] and has been very successful. In steam tunnels, the men usually drape tarpaulins over the tunnel opening to force the cool air down through the manhole opposite the manhole on which the fan is setting. The fan has been extremely beneficial, when a steam leak has developed. The fan is capable of exhausting enough air to clear a vault of steam when a 3/4" nipple on a 90 psi steam line has broken, and allow maintenance men to enter safely.

Steam tunnels are susceptible to flood therefore adequate floor drainage is essential; occasionally, this requires the installation of sump pumps.

Economics

From the historical sketch presented in the Introduction, it can be seen that there was a period of time when steam tunnels were considered too expensive at Michigan State University. When the large expansion began, during the early sixties, it was necessary to construct steam lines in the 20" diameter class. Estimates of the various types of steam line construction indicated that steam tunnels could be economically feasible. At the time, the possibility of extending a parallel steam main for future capacity could not be ruled out. This eventually would require the installation of a second large diameter steam pipe, initially or in the future, in any buried type installation.

The history of direct burial distribution systems reveals fairly frequent failures of condensate return pipes installed in granular fill insulating materials and failures of asphalt coated steel conduits, especially if buried in corrosive soils. The most recent direct burial systems used have a steel conduit which is coated with epoxy resin and fiberglas cloth. Installation of uninsulated direct burial ductile iron pipe with mechanical joints for condensate return lines has been used in recent years.

The mechanical joints, by not butting the pipe sections tightly together, eliminates the need for expansion joints, since the mechanical joints will absorb the expansion and contraction. A failure by corrosion has not been experienced on the ductile iron; however, a time elapse of 10 years is too short to provide a decisive conclusion. Figure [5] displays a graph which compares steam tunnel cost versus a direct burial system using epoxy-coated conduits on the steam line, and epoxy-coated conduit or ductile iron pipe for the return line.

Steam tunnels will allow delaying the installation of the future pipes, when needed; whereas, a buried system will require their installation during the initial construction, if economy is to be gained for the excavating and backfilling operation.

Conclusion

Walk-through tunnels are the most maintenance free system for steam transmission mains. When long life and low maintenance costs are important factors in selecting the type of pipe encasement, tunnel costs should be closely analyzed against costs of alternate systems. The larger the pipe diameter, the more competitive tunnel costs will be as compared to alternate systems.

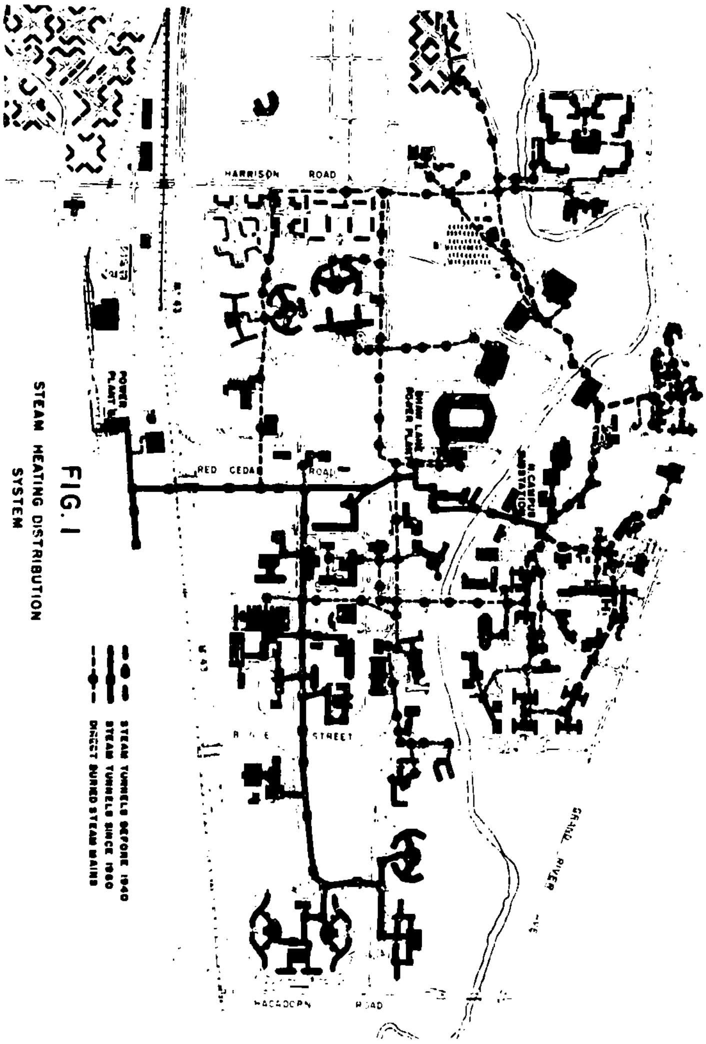
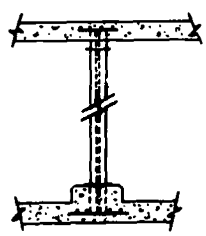
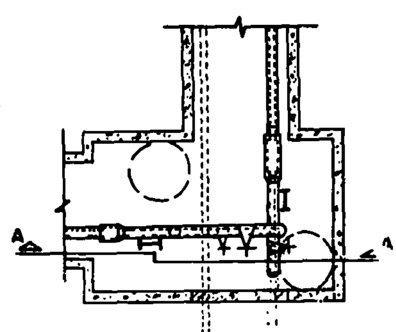


FIG. 1
STEAM HEATING DISTRIBUTION SYSTEM

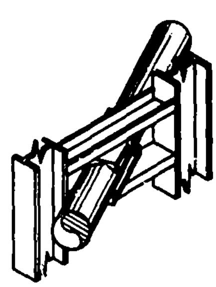
FIG. 2
STEAM TUNNEL
DETAILS



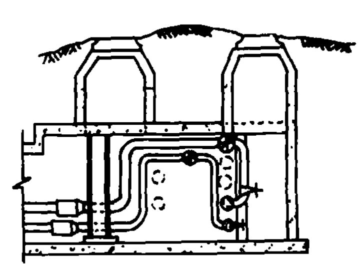
TYPICAL VAULT
ANCHOR CONSTRUCTION



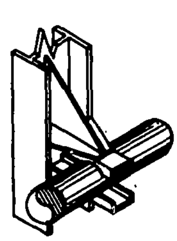
TYPICAL VAULT PLAN



TYPICAL TYPE II
VAULT ANCHOR

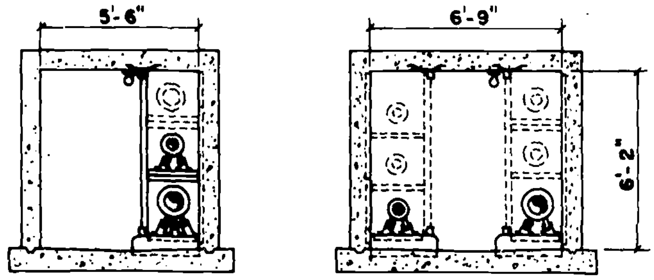


SECTION A-A

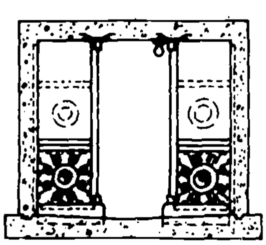


TYPICAL TYPE I
VAULT ANCHOR

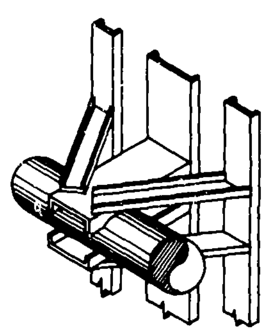
FIG. 3
STEAM TUNNEL DETAILS



TYPICAL CROSS SECTIONS
AT PIPE SUPPORTS



TYPICAL CROSS SECTION
AT PIPE GUIDES



TYPICAL TUNNEL
ANCHOR

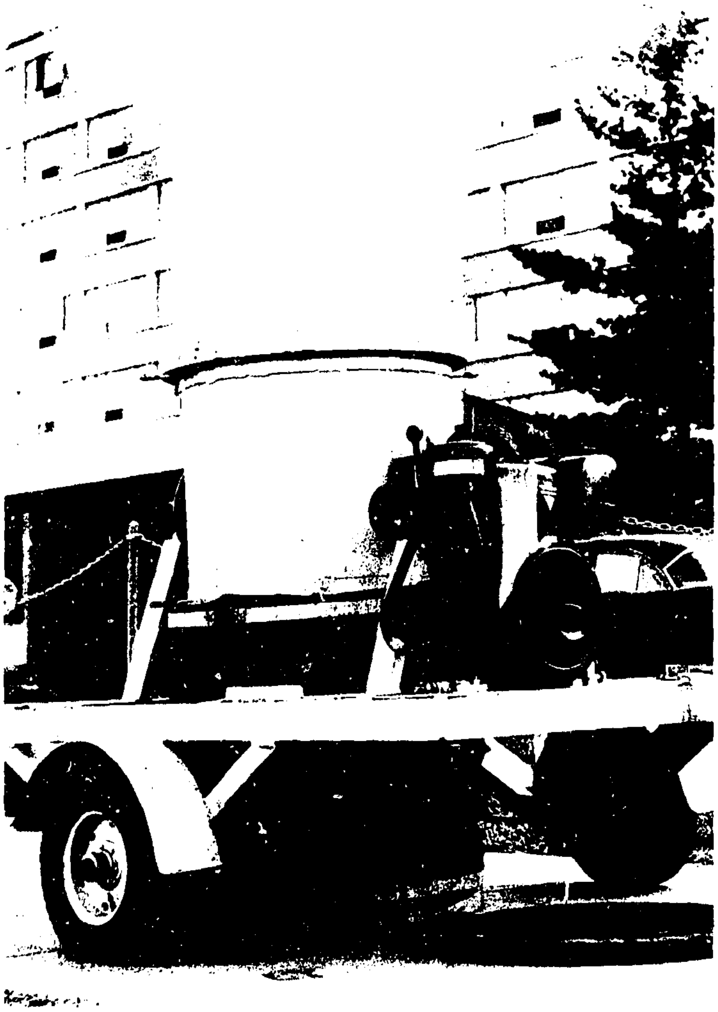
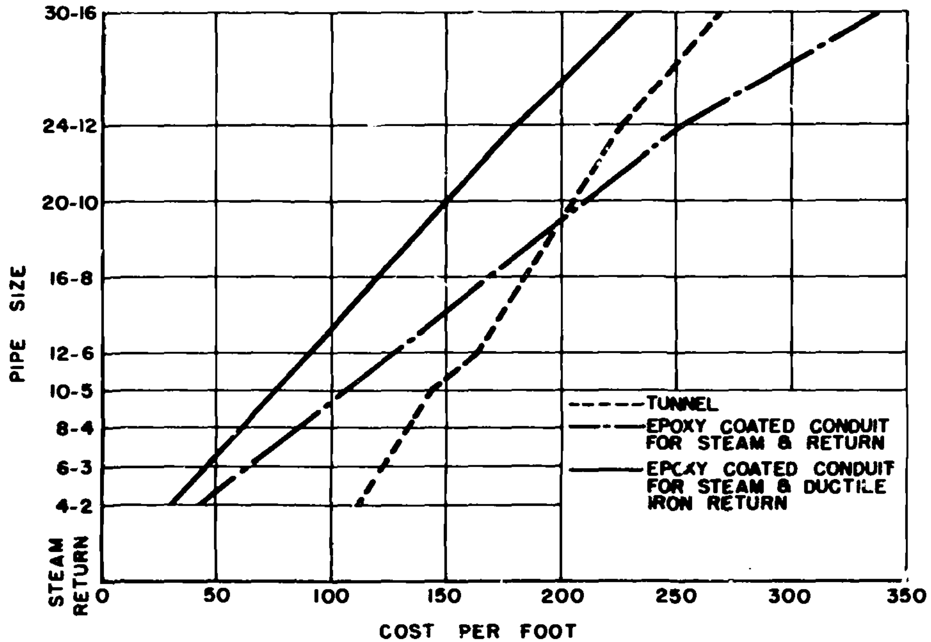


FIG. 4 MOBILE TUNNEL EXHAUST FAN

FIG. 5
COST COMPARISON OF ENCASEMENT SYSTEMS



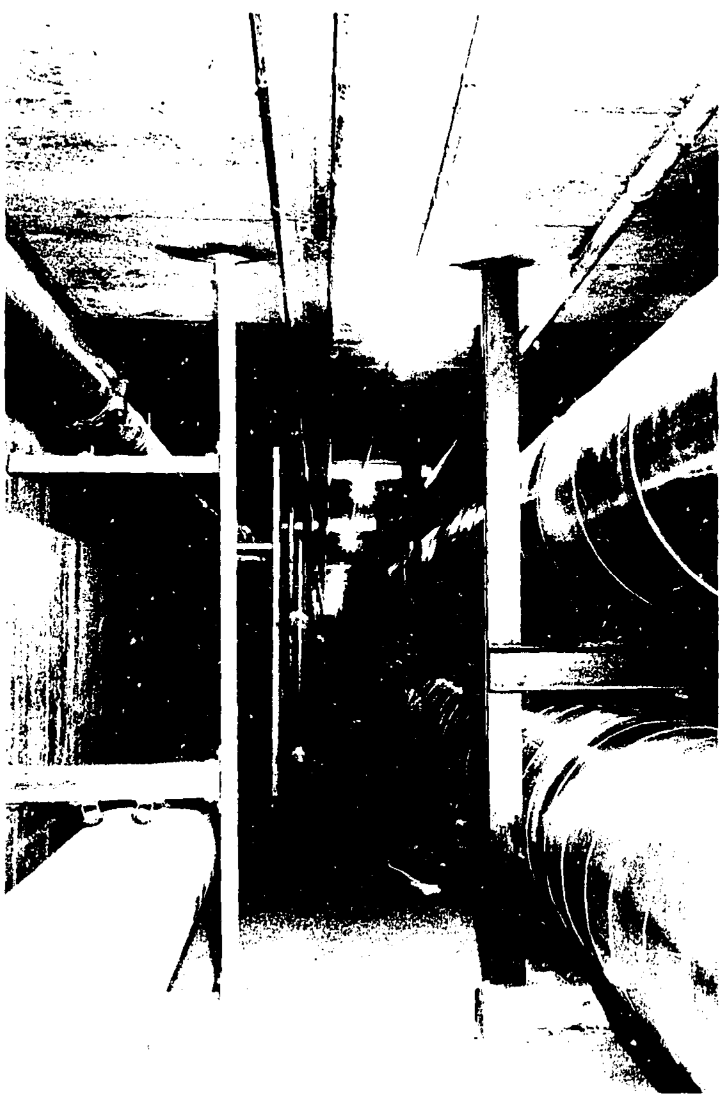


FIG. 6 9 'TUNNEL WITH TWO 30 " STEAM LINES, 18 " RETURN LINE AND 6 " DEMINERALIZED WATER LINE

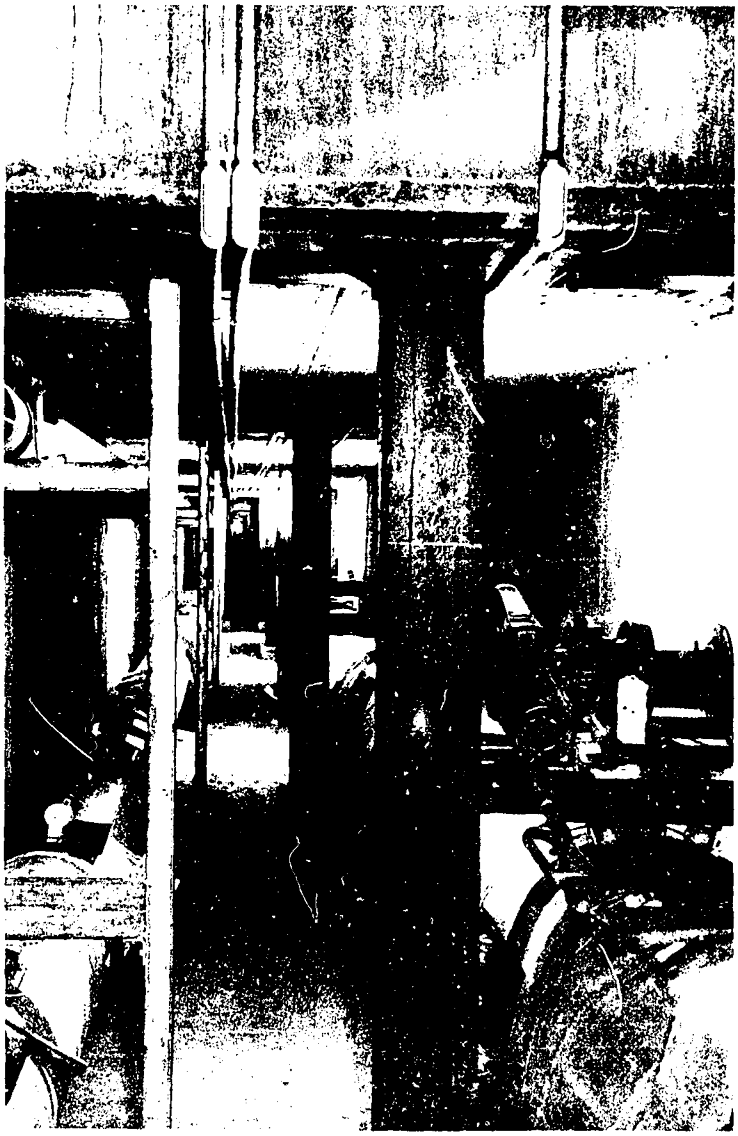


FIG. 7 7 'X 7 'TUNNEL READY FOR 2ND 24 " STEAM LINE

FIG. 8 8 'DIAMETER CROSSING UNDER RAILROAD

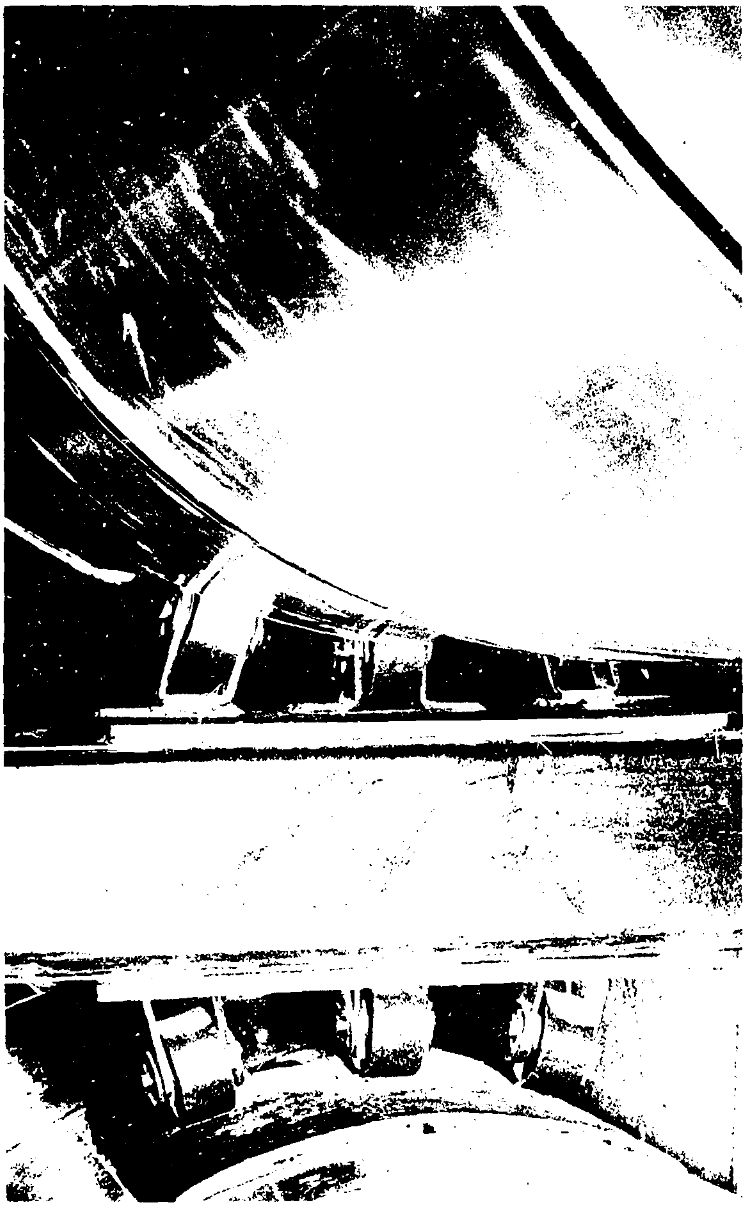


FIG. 9 ROLLER SUPPORT FOR UPPER PIPE

FIG. 10 PIPE GUIDE ASSEMBLY–HORIZONTAL STRUT WILL BE REPLACED BY STRUCTURAL STEEL FOR COMPLETION

SEARCHING FOR ANSWERS TO REFUSE HANDLING

DONALD WHISTON, P.E.

Donald Whiston graduated from M.I.T. in 1932 with S.B. degree in Building Engineering and Construction. He taught for two years at the Central China College; designed and supervised construction of several buildings, including Radiation Laboratory facilities at M.I.T. while employed in private industry. He shifted into maintenance with assignment as Plant Engineer for the Radar School and in 1946 to Buildings and Power Department, M.I.T., as Assistant Superintendent.

He was Construction Manager of the Raw Materials Division of A.E.C. for two years, and then for 1 1/2 years with American Cyanimide Company, as General Superintendent of the Chemical Construction Corporation's Construction Division.

He returned to M.I.T. in 1954, in the Physical Plant Department as successively Executive Officer, General Superintendent and presently Associate Director.

The rug wore out and exposed the sweepings. So now with dirt in the sky, everyone is suddenly aware of air pollution and the problem of solid waste disposal. Legislators are busy making laws controlling the output of incinerators and the water effluent of industrial complexes. Citizens are protesting against dumps and landfills. Still there is no final answer as to the form refuse should take, whether in its original form scattered into a convenient hole in the ground, whether compacted to eliminate the voids which breed flies and rodents, whether shredded to feed an incinerator, pulverized for mixing with dirt as landfill, or as a gas devoid of solid particles and odours, whether encased and sunk in the ocean depths, or kicked off the earth's surface to burn off in an orbit about the sun.

Physical Plant administrators are, however, faced with an interim decision closer to home, how to handle the proliferation of trash in the building space provided and what to do if the regular refuse outflow ceases because of strikes of sanitation workers or by other uncontrollable events. This, then, is the problem—what system, which machine, how much storage?

Late in 1965, the problem of refuse collection particularly at the central rubbish room of the main M.I.T. campus became so troublesome, action had to be taken. To this rubbish room every night some 120 cleaners brought their refuse pickup from the offices, classrooms, and laboratories in the 1,615,000 gross square feet they serviced. The collection was made into 42 gallon fibre barrels which were trundled by means of four wheel dollies to this room and the contents dumped loose on the floor. Often the quantity was such that more than one trip was necessary, the distance traveled varying from a few hundred yards to one-quarter mile. Imagine the time spent in this traveling, let alone the stopping to chat with dear friends!

By morning, this rubbish filled the floor of the room to a depth of three to four feet. Sometimes it overflowed into the corridor, since the last comers were not about to tramp through the waste to dump near the exterior door. Open doors allowed the wind to scatter pieces of paper down the corridor inside and up and down the alley outside.

Quoting from the brochure of an incinerator manufacturer "And this brings up a blind spot toward waste disposal costs which afflicts many an organization highly knowledgeable in production costs and business accounting. All they see is the contract hauler's fee to remove waste from the premises. Few, if any, recognize that, for every $1 spent to haul away trash, they spend some $3 collecting, transporting and storing it right on their own property. As trash generation proliferates, its disposal demands a rethinking on a systems basis." [1]

Around eight in the morning the rubbish contractor brought in two open trucks which were loaded by means of a payloader or by hand. During this operation still more papers were wafted up and down the alley and on to adjacent roofs. Professors teaching in nearby classrooms complained not alone on the appearance of the grounds but on the noise of the operation.

The answers come, not from refuse management consultants, but from a careful step by step examination of the procedure by the physical plant supervisors.

The first answer–Contain the waste. Paper or plastic bags were bought to insert in the rubbish collection barrels. Also, ties were furnished to secure the top of the filled bag. Result: no scattered rubbish, bags could be piled two or three high if needed. Odours and rodents went to near zero, and the room was no longer a haven for rubbish pickers.

The second answer: Contain the noise. The rubbish contractor parked a packer-truck at the door of the rubbish room each evening with a man to operate. Bags were deposited in the truck tail-piece as they came to the room, were compacted, and by 7:00 A.M. at the end of the shift the truck was full and ready to drive to the dump as the first load of the day. Results: no noise to disturb the day classes, and the rubbish room clear, clean, and ready to receive the minor amount of refuse brought over during the day.

The overall result: Cleaner's time for rubbish room trips controlled, and complaints down to a minimum. (The blue-green color of the plastic bag clashed with the decor of a traveling art exhibit, so a change was made on the next purchase to a cream colored bag).

Although in M.I.T.'s case the plastic bag (of 0.0135" thickness) seemed most desirable by reason of lower costs and ease of use, paper bags may be the container of the future. Plastic does smoke during incineration, has an unpleasant odour when burnt, will tear with punctures, and may not pass thru certain pulverizers. Its stretching qualities, which permits retention of irregular shaped objects, is a fault when disposed of in small single bag compactors. Plastic does have some compaction effect due to its elasticity. The use of bags, however, with their neater and cleanlier appearance, has brought out a change of attitude toward refuse, for what is not seen fails to offend. Presently at M.I.T. some 160,000 bags are used per year as against 50,000 the first year.

The cost proved worth it, but its excessiveness warranted continued efforts. The budget for rubbish hauling for this area of the campus has tripled in the last five years. Part of this increase is the cost of bags, from $3600 in 1965-66 to $8600 during 1968-69. Other factors are: A. The difference in cost between the previous open air disposal method and the present rent on the packer-truck and operator for 12 hours a night, five nights a week. B. Inflationary costs effecting the contractor's rates, about three to four percent per year, and C. Costs of special handling of demolition and construction wastes caused by extensive space alterations to existing buildings.

Space Planning

During this same period (1965 to 1969) M.I.T. was adding to its building facilities. With each building came the question from the space planners on the amount of space to allow for building service functions, including that of rubbish storage. Early space forecasts were based on the assignment of 12,000 to 15,000 gross square feet to each cleaner-custodian, and that each such cleaner would produce 1 1/2 to 1 42-gallon rubbish barrels per night. With the gross square feet of the building known as well as the nature of the occupancy the area of a rubbish room could be determined, using rented two yard containers to contain at least three day's waste.

Waste Per Capita

In reviewing the literature on solid waste disposal, it was found that the figure for the amount of waste generated per person varied with the author. European consultants, analyzing the United States waste problems, came up with a figure of 0.66 tons of waste per person per year or 3.62 pounds per day per person. [2] Other authors in the Proceedings of the 1968 National Incinerator Conference give values ranging from four to five pounds per day per person. From the M.I.T. report of 1968 comes a figure of 1000 lbs./year/person or 2.7 lbs./day/person.

A more useful table for physical plant use is that shown in Table I compiled by the Incinerator Institute of America. [4] However, personal observation showed that even these figures were out of line with actual values. Some of the difference probably comes from the use of net square feet figures in the Table I values, but in keeping with the standards of APPA (Association of Physical Plant Administrators of Universities and Colleges) [5] gross square feet of a building is used in the data to follow.

Table 1. Data for Estimating Incinerator Capacity

Building Types	Quantities of Waste Produced Per Day
Industrial	
Factories	Survey required
Warehouses	2 lb. per 100 sq. ft.
Commercial	
Office buildings	1 lb. per 100 sq. ft.
Department stores	4 lb. per 100 sq. ft.
Shopping centers	Study of plans or survey required
Supermarkets	9 lb. per 100 sq. ft.
Restaurants	2 lb. per meal
Drug stores	5 lb. per 100 sq. ft.
Banks	Study of plans or survey required
Residential	
Private	5 lb. basic plus 1 lb. per bedroom
Apartment	4 lb. per sleeping room
Schools	
Elementary	10 lb. per room plus 1/4 lb. per pupil
High schools	8 lb. per room plus 1/4 lb. per pupil
Universities	Survey required
Institutions	
Hospitals	8 lb. per bed
Nurses or interns homes	3 lb. per person
Homes for the aged	3 lb. per person
Rest homes	3 lb. per person

Building Types	Quantities of Waste Produced Per Day
Hotels	
First class	3 lb. per room plus 2 lb. per meal
Medium class	1 1/2 lb. per room plus 1 lb. per meal
Motels	2 lb. per room
Trailer camps	6-10 lb. per trailer

In one set of observations covering the rubbish room servicing two buildings some six cubic yards of partially pressed rubbish in bags were deposited on the average each day. Invoices of the rubbish contractor confirmed this. These two buildings, occupied by the Biology, Bio-chemistry and Earth Science Departments, aggregated 269,000 gross square feet, (231,000 net), and 848 spaces. With each bag weighing between 25 and 30 pounds and a volume of 5 to 5 1/2 cubic feet, the density is then about five pounds per cubic foot, and for this occupancy waste will be generated at 0.30 pounds per day per 100 gross square feet or one pound per space per day.

At another location, where refuse from four buildings is gathered, the unit is higher–0.40 pounds per day per 100 gross square feet or 1 1/2 pounds per space per day. In this case the four buildings totaled 297,000 gross square feet, (247,000 net), with 746 spaces, and serviced space for aeronautical, servomechanism, space study and computer work.

At the present time studies are being made on rubbish generation in dormitories, but to check Table I values observations were made at several New York City apartments. These were middle-class income apartments with an average of four persons per apartment. The figure was 1 1/4 to 1 1/2 lbs./day/person, varying evidently with the relative income.

A calculation of the waste generation at the M.I.T. Student Center Building, using 4 lbs./day/100 gross sq. ft. for the store area, one pound per meal for the dining service, and 1/2 lb./day/100 gross sq. ft. for the student organization's offices and the general area, gave a value for waste volume of 20 cubic yards per day. This agreed with personal observation as well as invoice figures of 20.3 cubic yards per day over a three month period.

Rubbish Room Requirements

Allowances must be made in any waste analyses for wide variations in waste input. Such material as computer punched cards at 48 lbs. per cubic foot or telephone books at 36 lbs. per cubic foot can change materially density figures for average wastes at five pounds per cubic foot. Charges at dumps and landfills are sometimes based on weight and sometimes on volume. With increased use of compactors the trend will be to charges based on weight.

In setting aside rubbish room area, include allowances for variations in waste input during the year. Stores at the start of the school season, the Christmas per period throughout office areas, new furniture, all these and more effect the normal waste generation. Any such room should also include area for maneuvering containers as well as room for future compactors.

Other room requirements include water connection for cleaning, floors sloped to floor drains, power, ventilation to exhaust odours and smoke, and sprinklers. With a need for an occasional wash-down, concrete floors should be sealed and walls and ceilings should be covered with a hard gloss paint.

Stationary Compactor Study

It was obvious early in the study of M.I.T. waste problems that regardless of the ultimate resting place of the wastes, the logistics of picking up, transporting within our buildings, and assembling for pickup were the items for study. By the use of paper or plastic bag barrel liners the pickup became orderly with custodians placing filled bags at convenient points in their area for later transport at the end of the shift. However, the deposit of these bags in open containers and the later handling by the rubbish hauler seemed inefficient as well as unsightly.

In certain buildings with incinerators a review of the time taken to fire up, the feeding of waste through a hot open door, and the later removal of ash and unburnables all seemed inefficient, costly and an excessive use of manpower. Where the use of the incinerator was a necessity because of laboratory animal wastes, it was best to assign the incinerator to a laboratory technician or animal caretaker designated by the academic department. The sole function of physical plant maintenance was the removal of the ash daily and the occasional check of gas controls.

With the advent of more rigid air pollution regulations, the obvious difficulties attending labor disputes in the rubbish field, and the closing of dumps by citizen demand, it was evident that steps must be taken to put the waste in a more condensed and contained form. [9] This led to a detailed study of the various types of compactors during the spring and summer of 1969.

Stationary Compactor Requirements

The compactor for use inside a building rubbish room basement corridor, or previous incinerator space must be small in physical dimension. The hopper size must receive one or more bags of waste at a time and take an average sized cardboard carton. Its container should handle wastes collected by cleaner-custodians during the evening and night shifts. Yet the container must be small enough to pass through doors, down corridors, and into elevators for transit to shipping rooms. The degree of compaction must be sufficient to warrant the expenditure. Compactor and/or containers must not only look neat but be designed to withstand the pressures and abuse to which they are subjected.

Compactor Types

It was found on examination of the trade literature that most emphasis was given to the larger compactors. These are eminently suitable at an industrial site where interior routes of waste pickup can terminate at a suitable loading platform, or for transfer sites as an end terminus before trucking to a distant landfill. The application of compactors as a substitute for small building in nerators is a recent development, pushed particularly by the air pollution regulations enacted by New York City early in 1968. [6] The industry is in the throes of having a demand market without a true and tried product to deliver. Many times during survey inspection trips to see the operation of seemingly suitable compactors it was found that they had been withdrawn, were in the process of modification, or were the figment of a salesman's hopeful prediction of a sale and/or delivery promise. The practice of manufacturers in bringing out newly designed compactors for trial at the customer's location is a nuisance that should be discouraged.

Nevertheless there is progress, many models are now in use and satisfactory to the building owner. Others are installed and useable, but not in use by reason other than machine fault.

To list all compactors available is not the task of this report. Those listed are typical of the type and are the product of manufacturers known in the trade. They may or may not be presently available for purchase. Only one model of any one type of any one manufacturer is listed. The data given is that provided or calculated from values furnished in brochures furnished by the maker or his agent. See compactors listed in the Sanitation Industry Yearbook [8].

Medium Size Stationary Compactors   Table II

Medium size compactors are those up to 1 1/4 cubic yards nominal size for use with six cubic yard containers or larger and are usually a smaller version of larger industrial-type compactors. These require the use of a platform for deposit of the wastes into the hopper and trucking area for handling the container. There are some arrangements putting the compactor and hopper inside the building with the container outside. The planner must, in this case, think of how to conceal the container in some fashion and provide for truck loading of the container. There should be sufficient waste volume to warrant a pickup at least twice a week. Longer storage of compacted material could cause odours and health hazards.

Small Stationary Compactors   Table III

Small compactors are mini-versions (less than one cubic yard nominal size) for use with one to five cubic yard containers. These containers are small enough to permit moving from an interior location to a suitable shipping location. Although the compactor units are relatively trouble free, the containers are subject to considerable abuse during unloading into the packer-truckers. Loose, unfastened lids, bulging sides and cracked welds of the containers destroy the ability of the compactor to concentrate the refuse. The degree of compaction is thus reduced to possibly three to one or less as against its rating of five to one. Casters on these containers are sometimes undersized for the weight to be handled. The contractor's personnel frequently have difficulty in hooking up the container to the packer-truck for unloading. Building management, renting such equipment, should put the burden of container repair on the contractor. Management should watch the entire sanitation operation that untrained, unsupervised, lackadasical sanitation workers do not effect the prices quoted by the contractor.

Small Special Compactors Table IV

The small special compactors, intended to replace apartment building incinerators, are fairly new in concept. These have been brought out by the industry by reason of certain New York City requirements [7], as well as a need for small containers of the ash can type and no more than 80 pounds in weight when filled. Some of these units fill one paper bag container at a time, and require an up-righting of the bag after filling, tying and replacement with a new bag. Building management having captive help, or a janitor with spare time at the right time of day can consider this type machine, but it is certainly not automatic in operation

Other compactors in this table, having compaction from two directions, produce a denser material, and use a carousel to automatically place an empty ash can or bag in position when the previous receptacle is full. This type, with several patented variations, may prove outstanding once the bugs have been licked. The practice of the manufacturers in bringing out newly designed compactors for trial at the customer's expense should, however, be discouraged. Compactors of this type are not now listed in the Sanitation Industry 1970 Yearbook. [8]

Compactor Data

The data listed in Tables II, III and IV are fairly self explanatory, but there are some precautions in comparing the values given.

The value for the ram force is usually the maximum available, and puts the hydraulic system at its top-limiting pressure. The machines are customarily run at lower pressures dependent on the safety factor desired, the type of refuse and the desired degree of compaction. It is unfortunate but most compactors are not furnished with pressure gauges, a feature that would be most desirable for the operator.

Some values do not reflect the entirety, as for instance the weight given is usually that of the compactor and would not include the weight of the hydraulic system or control panel.

The design for the cylinder of the hydraulic system is an important feature, and the cylinder used should be of reputable manufacture. The diameter and stroke should not be so excessive as to cause distortion of the tube or rod. One problem of maintenance is the replacement of the seals and gaskets of the cylinder and for this reason the cylinder should be protected with covers from dirt and grit as far as possible.

Attention is called to the Force Factor, [Table III Item 19] (the ram force divided by the charging box volume) which is more pertinent than the ram face area stress. Often manufacturers increase the dimensions of the charging box without increasing the available force. Research is needed to determine the best value for this factor for various types of refuse.

Like the auto industry, compactor models sometimes are delivered with certain controls or with controls as an extra to the price. These can vary from a lever or push button to an electric eye or sonic sensor in the hopper. Many compactors have a forward and back stroke limit switches as well as a pressure limit switch. Others are evidently hopeful that no one will drop in any refuse (such as a bolt) that the machine cannot shear off. The building management must make a judgement on the joining of a particular compactor to the particular trash expected from the building. In no case should physical plant management make a choice of compactor from an evaluation of these tables. Rather they should examine the reputation of the manufacturer, the simplicity of the machine, the built-in safety, the availability of reliable repair service, and the relation of cost to weight. Here is a machine where the cost/weight ratio can be an important factor.

TABLE II

DATA ON MEDIUM SIZE STATIONARY COMPACTORS FOR 6 CU. YD. OR LARGER CONTAINERS

ITEM NO.	DATA ITEM	UNIT				
1.	Nominal Size	CY	3/4	3/4	1	1 1/4
2.	Ram Force	lbs.	70,000	20,000	39,000	42,405
3.	Ram Face Area	in.	648	1,220	1,008	1,490
4.	Ram Face Area Stress	psi	108	16	38	28
5.	Weight	lbs.		1,730	3,000	
6.	Power	HP	3	3	3	5
7.	Cylinder Dia.	in.	2 1/4"sc		2-5"	6
8.	Cylinder Stroke	in.	48			30
9.	Hydraulic Pressure	psi	Non		2,000	1,500
10.	Pump Capacity	GPM		3 1/2	12	7 1/2
11.	Oil Capacity	Gal.			10	22
12.	Compactor Width	in.	57	46	48 1/2	97 1/2
13.	Compactor Length	in.	108	75	75	51 1/4
14.	Compactor Height	in.	56	44		52
15.	Charging Box-Width	in.	36	36	42	
16.	Charging Box-Length	in.	40	31	34	
17.	Charging Box-Depth	in.	23	34	30	39
18.	Displacement/Cycle	C.F.	19.2	22.0	24.8	32.8
19.	Force Factor	lbs/CF	3,450	925	1,450	1,310
20.	Time of Cycle	sec.	30	50	26	45
21.	Controls		Non-Hyd Button	Button	Button	S@onic
22.	Manufacturer		McMearty Equip. Co.	Perfection Coby Co.	Auto-Pak Company	Dempster Bros.
23.	Model Name		Pac-King	Station-Pac	Dual-Pak	Power-Mite
24.	Model No.		150	SP8	DP10	SP10-42

TABLE III

DATA ON SMALL STATIONARY COMPACTORS FOR 1-5 CUBIC YARD CONTAINERS

ITEM NO.	DATA ITEM	UNIT					
1.	Nominal Size	CY	1/4	1/4	1/3	1/3	3/4
2.	Ram Force	lbs.	10,000	40,000	10,000	25,000	7,350
3.	Ram Face Area	in.	207	480	467	540	345
4.	Ram Face Area Stress	psi	49	83	21	46	21
5.	Weight	lbs.		2,100	1,500	1,800	1,600
6.	Power	HP	1	2	3	2	1
7.	Cylinder Dia.	in.	1 1/2"sc		2 3/4	4	2 1/2
8.	Cylinder Stroke	in.	31		39		31 1/2
9.	Hydraulic Pressure	psi	Non		1,650	2,000	1,500
10.	Pump Capacity	GPM			2 1/2	7	1 1/2
11.	Oil Capacity	Gal.			5	3	1
12.	Compactor-Width	in.	28	28	43 1/2	42 1/2	32
13.	Compactor-Length	in.	71	61	87	73	69
14.	Compactor-Height	in.	42	31	72 1/4	66	57
15.	Charging Box-Width	in.	23 1/2	24		30	26
16.	Charging Box-Length	in.	27	20		28	26
17.	Charging Box-Depth	in.	15	20		21	48
18.	Displacement/Cycle	C.F.	5.0	5.5	9.3	10.2	18.8
19.	Force Factor	lbs/CF	1,850	7,250	1,050	2,500	390
20.	Time of Cycle	sec.	30	26	30	26	20
21.	Controls		Non-Hyd Eye	Button	Sonic	Button	Sonic
22.	Manufacturer		McMearty Equip. Co.	Nat'l Compactor & Tech Syst's	Heil Co.	Auto-Pak Co.	E-Z Pack Co.
23.	Model Name		Pac-King		Keil-Pac	Pitch'N'Pak	Ap't Packer
24.	Model No.		100	2024			

TABLE IV

DATA ON SMALL COMPACTORS FOR CAN AND/OR BAG CONTAINERS

ITEM NO	DATA ITEM	UNIT				
1.	Nominal	CY	1/4	1/4	1/4	1/4
2.	Ram Force	Max.lbs.	37,600	42,000	39,300	53,000
3.	Ram Face Area	in.2	200	177	176	
4.	Ram Face Area Stress	Max.psi	187	238	223	
5.	Weight	lbs.	600	1,500	2,300	2,200
6.	Power	HP	7 1/2	3	7 1/2	2
7.	Cylinder Dia.	in.	4"H,4"V		5",4",2"	2-3 1/2"
8.	Cylinder Stroke	in.	24"H,30"V			
9.	Hydraulic Pressure	Max.psi	3,000	2,500	2,000	3,000
10.	Pump Capacity	GPM	5.6		7.	6.
11.	Oil Capacity	Gal.	25		20	
12.	Compactor-Width	in.	24	26	42	37
13.	Compactor-Length	in.	74	94	95 3/4	111
14.	Compactor-Height	in.	91	26	83 1/2	69
15.	Charging Box-Width	in.	24	24	24	
16.	Charging Box-Length	in.	24	24	38	
17.	Charging Box-Depth	in.	18	19 1/2	15	
18.	Displacement/Cycle	CF	6.0	6.5	6.7	7.5
19.	Force Factor	Max. lbs/CF	6,300	6,460	6,100	7,680
20.	Time of Cycle	sec.				39
21.	Controls		Hydr.	Button	Button or Eye	Eye
22.	Manufacturer		Combustion Equip.Assoc.	Compactor Corp.	Research-Cottrell,Inc.	Auto-Pak Co.
23.	Model Name		Hydra-Pak	Waste-Pactor	Pak-Trell	Gobbler
24.	Model No.		Mark I	157		16

INCINERATOR VS. PULVERIZER VS. COMPACTOR

All three of these machines serve to concentrate solid waste, with the incinerator properly controlled giving the smallest end result. The incinerator must have the proper high temperature, even to using additional fuel in a secondary burner, which makes its use costly and calls for control equal to a chemical plant. When one examines the variation in refuse composition and moisture contents of typical home and industrial wastes, [10] the instances of smoke and vapor clouds can be appreciated. It is thus obvious that an incinerator must be large enough in capacity to warrant the excessive cost of erection and that a volume of waste be available equal to that from one to one and one half million people. [2]

Pulverizers are beginning to gain attention as a means of feeding incinerators, to permit a greater degree of compaction; or to mix with dirt for compositing or controlled landfill. Further development of these machines are needed to prove their advantages as against their higher costs in comparison with compactors "In Great Britain as a whole 80 per cent of refuse is disposed of by "controlled" tipping, (landfill) 16 per cent by incineration and four per cent by composting and pulverization." [1]

Compactors have met the challenge of present day needs, in furnishing types to meet the demands of any waste, be it autos, tin cans, or confetti. Waste in the compacted form does present difficulty to the incinerator operator, for its low burning rate. Waste, when compacted properly, can be hauled to landfill sites at cost comparable to the removal of non-combustibles and by-products of incineration. On costs there is no question that compactors have large advantages over incinerators. [9]

And here finally is the point of departure, what is the necessary ultimate form of our solid wastes? To meet this problem an extensive federal research program [12] has been started. Hopefully, some answers will be forthcoming before it becomes an unsolved problem for physical plant administrators.

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ELEVATOR MAINTENANCE COST ANALYSIS

BY

RAYMOND HALBERT

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In looking through the minutes of previous National Association of Physical Plant Administrators' Meetings and Central States Regional Association Meetings, I do not find any papers pertaining to elevator maintenance or history of elevators.

Before going into the matter of maintenance of elevators, I thought perhaps it might be well to consider a brief history of elevators. The history of vertical transportation parellels the new development of civilization. As nations grew economically, materially, and intellectually, there is a closely allied growth in the field of vertical transportation and the designs and construction of monumental types of structures.

We read that Louis XIV and Napoleon I were familiar with an elevator composed of a chair that employed the use of a counterweight.

The first commercial power elevators for vertical transportation were powered by steam. It was applied in a crude way and was used almost exclusively for freight elevators as these elevators were not considered safe for passenger service.

In 1853, G. E. Otis, the inventor, reportedly brought a platform equipped with a safety device to a safe stop after a "free-fall" demonstration. This eventful date begins the era of modern elevator industry. There have been many major improvements and refinements made in elevators in ensuing years. Development of a practical wire rope had a strong influence on the progress of elevator design and operation.

In its beginning, the elevator industry was one in which a few individuals set up workshops to fabricate elevators piecemeal. Today, there are hundreds of highly organized elevator companies in all parts of the world. At present, elevator engineering is a highly specialized industry combining application of the newest developments in the electrical, chemical, and mechanical fields. A look at the skyline of any large city will easily show the absolute dependency placed by the public on vertical transportation. If vertical transportation had not been made available, building structures would have remained at their 1850 height.

The year 1861 saw an improvement in roped elevators consisting of the use of multi-ropes rather than only one or two. Each rope was capable of sustaining the full weight of the car. The use of multi-ropes was satisfactory and is still common practice.

The hydraulic elevator was first developed and installed in 1867. Hydraulic elevators can operate at 600 and 700 feet per minute, but are very expensive. Elaborate pumping equipment is required with this type since a pressure of 1000 pounds per square inch or higher is necessary. With the use of hydraulic elevators, the hole must be drilled below the pit floor as deep as the rise is high. Think of the cost of sinking a 300 feet deep by 12 inch diameter hole in New York City where bedrock starts on the surface. Aside from the high initial cost and extensive maintenance expense, there are two other objectionable features of hydraulic elevators which arise from the passenger viewpoint. First, there is a considerable difference in up and down speed, especially under extreme load conditions. Second, such cars often give unpleasant bouncing sensations on starting and stopping if air pockets exist in the cylinders.

One of the most important developments of the 1870's was the introduction of the overspeed safety and governor. This safety device was designed to automatically cause the car safety to grip the guide rails if the elevator attained a predetermined speed, thereby stopping and holding the car in case of overspeed due to any cause. Present day safeties fall broadly into three general classifications. They are the broken rope safety, the roll safe and the gradual safe. The first two are instantaneous types but differ in concept, depending on rope breakage and overspeed respectively to operate the safety devices.

In America, the commercial use of the electric elevator began in 1899 with the installation of two electric elevators by Otis Brothers and Company in New York. These elevators were direct current shunt motor driven. Several years elapsed before alternating current motors were developed to the extent where they could be applied to elevator machines.

The traction elevator, or gearless traction, was developed in 1903. Today, most cable elevators around the world are traction driven. The advantage of the traction machine can be listed as, A. a given machine can be used for almost any rise as compared with drums which must have capacity for enough rope to accommodate the rise, and B. when either the car or counter-weight ceases to move because of some obstruction in the shaft, the ropes lose their traction allowing the drum to spin without moving the car. The last mentioned item constitutes an important safety feature. With the advance of the traction machine, the days of the hydraulic car appeared to be numbered.

In the past few years, however, the plunger electric elevators have again become quite popular in certain applications. Most plunger electric units today are "closed circuit" installations where the fluid passes from a storage tank to a piston or pistons and returns. On the up direction, a pump forces the fluid from the tank to the cylinder lifting the car. To descend, a valve is electrically opened and the fluid is forced back to the storage tank by the weight of the elevator and load. Most units today use oil rather than water as actuating fluid. Probably the greatest number of plunger electric elevators installed today are of limited rise type.

The manner of elevator controls is quite important. The early elevators were hand rope controlled which involved a rope running over shafts in the overhead structure and fit into a shipper wheel on the controller. This wheel revolves in the direction the hand rope is moving, turning the shaft which opens and closes the directional switches by means of a cam.

Later, car switch controls were developed. This system involves a switch which energizes electric magnetic switches on the controller which supplies power to the motor in the chosen direction. These two types of controls are becoming obsolete throughout the world.

An improved signal control system was developed in the early 20's whereby an individual would signal the need for an elevator at a given floor and the elevator operator would take the elevator to the floor that had signaled. The individual would then be taken to his desired floor. This control was very popular for approximately 25 years. This type control required an elevator attendant. Many of these elevators are still in operation; however, most of the elevators have been converted to automatic operation.

A single automatic push-button control has been developed and by means of a push button at any landing the passenger calls a car to him. Having entered the car, he indicates the level desired by pressing a marked car button. This type control is unsatisfactory in that someone may take the car away from the original rider and he may be delayed in getting to his desired floor.

About 15 years ago, the selective collective automatic push-button control system was developed. This type of operation permits any number of landing buttons to register calls concurrently. This has a great advantage over single automatic push-button controls where only one passenger or group of passengers can be served at a time. A passenger entering a collective control elevator at the first landing might register his stop as point six. Other passengers might send or call the car by pushing their landing buttons in the car or in the halls. The elevator will automatically stop at these indicated intermediate stations answering in sequence all calls in one direction irrespective of the sequence in which the buttons are pressed. It will after its last call in one direction, reverse itself and answer all calls in the opposite direction in the same manner.

Refinement of signal control systems as used by a number of companies, has been one of the several reasons for the development of the so-called "operatorless elevators." These controls have been developed to a point where they are quite reliable and permit elevators to run up to speeds of 1600 feet per minute with safety in heavily populated high rise buildings.

While the elevator manufacturers were developing newer types of drives and control mechanisms, they were also conscious of the need for greater safety imposed by the higher speed and by the operation of the elevators by passengers. Some European countries regard safety of elevators in a different light than do the Western Hemisphere countries. For example, self service passenger elevators in Europe are permitted to operate without car gates. At the other extreme, until recently, Australia insisted on drop safety tests without hoist rope on all completed elevators. They still require double sets of contacts on all hoistway doors so the elevator will not run with the door open. The elevator code authorities in all areas try to the best of their ability to insure safe conditions for passengers.

As a result of engineering advances, appreciation of responsibility on the part of labor and management, as well as cooperation between codes and other governing authorities and industries, today's elevator is the safest form of public transportation. The elevator carries more passengers per day than any other individual system in most of the world's major cities.

With the many advances in automation and controls, it can readily be seen that special skills are required in the maintenance of elevators throughout our many buildings. No single mechanical trade is involved in elevator maintenance. It involves mechanical trades as well as electrical trades. The day of the maintenance man with the screwdriver and pliers is past. Electronic equipment as well as a thorough understanding of the electronic equipment is necessary today for the modern elevator maintenance man.

The public has accepted "operatorless elevators" and they expect them to operate flawlessly. and only through proper maintenance will this occur.

For the elevator maintenance man to do his job properly and the owner to have a safe and satisfactory elevator, some items must be "built in" when the elevator is ordered. Some of the paragraphs under each of the following major items which should be included in your specifications are:

1. Codes: All work in connection with the installation of the elevator shall be done in accordance with National Electric Code and American Standard Safety Code for Elevators, Dumbwaiters, and Escalators.

2. Power Supply: Elevator motor and controls will be designed to operate at minimum speed specified under full load conditions in up direction with a 10% reduction in the specified voltage.

3. Multi-Speed Leveling: Car will approach landing at reduced speed from either direction of travel.

4. Car Position and Direction Indicator: As a paragraph under this heading you should state, "If "Nixie" tubes are used for elevator position indicators at hall push buttons, the tube shall be 15,000 hour life tubes. These tubes shall be B-50313 as manufactured by Burroughs Corporation or approved equal."

5. Main Line Strainer: On hydraulic elevators, a main line strainer and shut-off cock assembly of the self-cleaning type, equipped with a 100 mesh element and a magnetic drain plug, shall be furnished and

installed in the oil line. The unit shall be designed for 300 p.s.i. working pressure, compact in design and with easy access for cleaning.

6. Instruction Manuals: Prior to the acceptance of the elevator covered under this contract, the contractor is to furnish owner with three complete bound instruction manuals for operation and maintenance of the elevator equipment. These manuals are to include complete description of systems, complete parts list showing all parts by name, identifying number, function and source of supply if such is other than the manufacturer of the elevator installed, detailed maintenance instructions with copy of complete electrical dircuit diagram as installed, complete lubrication schedule and lubrication instructions.

This is by no means a complete list of all of the paragraphs you will have in your specifications, others would be: Shop Drawings, Travel, Capacity, Car Platform and Sling, Car Guides and Shoes, Car Enclosure, Car Doors, Hoistway Doors, Door Operation, Signal Type (Selective Collective Automatic Push Button), Alarm Bell, Automatic Control of Standing Time, Directional Arrows, Jackunit if Hydraulic, Jackhole if Hydraulic, Power Unit, Buffers, Wiring and Piping, Painting, Maintenance, Special Conditions and Guarantee.

I will list some of the types of elevator service agreements available:

1. Oil and Grease Examination Service: This service agreement provides cleaning and oiling of machine, lubrication of bearings, and minor adjustments at time of examination. This agreement does not give the owner much in the way of preventive maintenance. You pay for all parts and call-back service. This would be the least expensive form of elevator maintenance if you can tolerate frequent periods of service interruptions. This maintenance program should not be used unless you have light use of the elevators.

2. Parts, Oil and Grease Examination Service: This service agreement provides for cleaning and oiling of machines, lubrication of bearings, minor adjustments at time of examination and only minor parts such as motor brushes, contact springs, cotton wastes, et cetera are furnished. This, like the one above, does not give the owner much in the way of preventive maintenance. You pay for all but minor parts and all costs in connection with call-back service. This is next to the least expensive form of elevator maintenance. You can expect frequent periods of service interruptions. This maintenance program should not be used unless you have light use of the elevator.

3. Full Maintenance Service: This type service covers all items connected with elevator service except abuse and misuse. Good preventive maintenance is performed and excellent service and long life should be expected from equipment covered by this type maintenance agreement.

4. Full Maintenance Service Plus a Charge for Metered Elevator Mileage: The same maintenance service is received as under item three above, but the cost is adjusted in accordance with the number of times the elevator is used. Elevators with light use will cost less, but the elevator having heavy use will cost more. This is a fair arrangement since you should expect to pay for the service received. The Full Maintenance Service Plus a Charge for Elevator Car Mileage is a relatively new type agreement and will probably become more popular in the future.

By using either agreement, number three or four, the cost will be much more than number one or two, but you should have a minimum of service interruptions. Either number three or four should be used if you have a heavy use of the elevators and depend on the elevator for emergency use unless you do the maintenance work on the elevators with your own personnel.

You can accept a standard form of maintenance service agreement which any reliable elevator company will furnish you or you can write your own specifications, depending on your needs.

In 1956, we started a 440 bed Teaching Hospital and Medical School on our campus at Columbia. No elevator firm had a serviceman in Columbia, and we were 125 miles from Kansas City or St. Louis. We did not have men in our employment with experience in elevator maintenance service, and we elected to have an outside elevator contractor perform our elevator maintenance service. We wrote our own specifications due to our location and special conditions we had to meet. We set forth our needs and requirements and in addition specified that the successful bidder for our work would establish a service office in Columbia and have stationed in Columbia at least one serviceman with five or more years experience in the servicing of elevators of the selective collective control system.

Due to the critical need for elevators in hospital service and the Regional Handicapped Program, we specified the firm had to have a serviceman at our elevators that needed service within thirty minutes after we phoned his office in Columbia. We secured Haughton Elevator Company, Inc. as our original successful bidder. We have bid this service contract twice since then, and our same requirements still apply except the firm was required to have three men available in Columbia to be an acceptable bidder. The firm is permitted to do work for other firms in Central Missouri if they have as many as four servicemen stationed in Columbia. As buildings are completed on our campus which have elevators in them, these elevators are added to the contract by Change Order. The elevator maintenance company doing our elevator maintenance work can cancel if they are not satisfied and we can do the same. The company has asked that the agreement be cancelled once, and the University cancelled once due to technicalities. The price can only be changed when our elevator maintenance work is rebid as we have no provision for price change in the contract.

At the Rolla campus, they do not have a need for thirty minute service. We have a twenty-four hour reporting time after we call the elevator maintenance company for the serviceman to report. We modified our specifications for Columbia elevator maintenance work and bid the elevator maintenance service at Rolla. It has proven acceptable at Rolla. The one form at each campus is required to perform full maintenance service on all makes of elevators at Columbia and Rolla campuses. I believe we have all makes of elevators at our campuses. The firms are to use genuine replacement parts manufactured by the manufacturer of the elevator they are repairing. A $50.00 penalty for each twenty-four hours an elevator is out of service is to be charged if any elevator is not placed back in service within forty-eight hours after the trouble is reported. The University is not liable for premium time which the contractor may incur to meet this deadline. A long delay in placing an elevator back in service should only be exprienced when a motor burns out or some other major item fails. To date, we have had only short periods of elevator service outage.

In Kansas City and St. Louis, where each elevator manufacturer has a serviceman available, we have issued a Full Service Maintenance Agreement with each company to maintain the elevators of their company on each campus. We have used their standard form of maintenance agreement. Their cost per elevator opening is higher than ours at Columbia.

We have not made an effort to employ our own elevator maintenance men as this is specialized work. We would have sickness, vacation and other scheduling problems. Everyone is happy with the results of our present system, and no one has time to take on the added responsibility of elevator maintenance.

We all realize that companies are in business to make money. If you want to save the 10-15% the company hopes to make and you want to compete with them for the qualified man to do competent elevator maintenance work, you may be able to save some money.

You should realize you are assuming responsibility for safe operation of frequently used equipment. You will be relying on someone or several men to do proper and competent work. The men must be reliable as trouble will not show up for many years in a little used elevator. You may have difficulty placing responsibility for failure of parts due to lack of maintenance, as more than one employee will be doing this work because of vacations, sickness, change of personnel, et cetera. Your school should have liability insurance which will protect it and you from damage suits which may result from an accident in connection with elevator use.

Each Director or Superintendent should consider his need for availability of elevator service on his campus and choose to do the elevator maintenance service with his own personnel or with his own personnel and services of a reliable elevator firm for special maintenance service, or use a service agreement as discussed previously in this paper.

I had a good response to my questionnaire regarding elevator maintenance throughout the colleges of Central States Regional Association of Physical Plant Administrators. I am including a summary of the returns for your information and guidance. Each of you can compare your own operation with the data given in this summary. If you are in doubt as to your school, I will give you the number used to identify each school.

I tried in several ways to compare these figures and finally decided to use the comparison of costs based on "cost per month for each opening served."

1. Maintenance by Own Personnel and Contract—For Oil, Grease and Examination Service: Seven schools reported that they did the minor work on elevators, but oil, grease and inspection work was contracted. These schools also contracted on a per item basis for major items of repair. These schools reported costs ranging from $2.59 to $18.01 per month per opening served. The average cost for 208 elevators on this type maintenance at seven different schools was $6.81 per month per opening served for hydraulic elevators and $5.34 for electric cable elevators. On this basis, cost for hydraulic elevators over electric cable elevator maintenance was $1.47 per month per opening served. It might also be noted that there were 67 hydraulic elevators with 222 openings and 141 electric cable elevators with 1,070 openings. Costs might be grouped under this heading, combining

hydraulic and electric cable elevators, as follows:

12 elevators over $2 but under $3 per month per opening
34 elevators over $3 but under $4 per month per opening
10 elevators over $4 but under $5 per month per opening
32 elevators over $5 but under $6 per month per opening
102 elevators over $6 but under $7 per month per opening
18 elevators over $7 per month per opening.

This would indicate substantial savings can be made if you have the proper manpower to do this type of maintenance. Three of the seven schools with this type maintenance listed one or more of their elevators as critical.

2. Maintenance by Own Personnel and Contract for Parts, Oil, Grease and Examination Service: There were four schools reporting on this basis. Two schools stated some of their elevators were critical. Costs on this basis averaged $2.24 for hydraulic and $2.46 for electric cable per month for each opening served. This group covered a total of 45 elevators. This is too few a number to establish a fair cost. Forty-five elevators with 178 openings were involved at schools reporting on this basis.

3. Maintenance by Contract—Full Maintenance Service: On this basis, there were 15 schools reporting an average cost of $12.54 per month per opening served with 102 hydraulic elevators involved. Also on this basis, there were 18 schools reporting an average cost of $12.21 per month per opening served with 228 electrical cable elevators involved. It should be noted that it costs $.33 less per opening served by the use of electric cable elevators over electric hydraulic. Costs might be grouped under this heading, combining hydraulic and electric cable elevators, as follows:

9 elevators under $5 per month per opening
119 elevators over $5 but under $10 per month per opening
70 elevators over $10 but under $15 per month per opening
101 elevators over $15 but under $20 per month per opening
29 elevators over $20 but under $25 per month per opening

There were 328 elevators covered by this type maintenance in the report received. Seven of the schools, where elevators were located, listed one or more of their elevators as critical. If you pay more, you should expect and can insist on fewer and shorter outage of elevator service.

4. Maintenance by Contract–Full Maintenance Service Including Monthly Mileage Charge: Two schools reported that they had this type maintenance. One at a cost of $8.62 per month per opening served for hydraulic elevators with eight elevators involved and the other at a cost of $7.80 per month per opening served for hydraulic elevators with five elevators involved. One school with electric cable elevators reported this type of maintenance service. Their cost was $9.84 with five elevators involved. Each of these schools are located in large cities. Two schools reported that their elevators were critical. The mileage charge feature of this type agreement must result in a lesser charge than the average for the full maintenance agreement type service.

5. Maintenance by Own Personnel: One school reported they did all of their elevator maintenance work. They use two men, part time, at an annual cost for labor and parts of $2,486. They have four hydraulic and six electric cable elevators. None of the elevators is listed as critical. Average cost per opening served at this school is $4.41.

The survey also indicated that,

at 35 colleges we have 216 elevators less than five years old;

at 25 colleges we have 162 elevators over five years old, but under 10 years old;

at 27 colleges we have 114 elevators over 10 years old, but under 15 years old;

at 19 colleges we have 106 elevators over 15 years old, but under 25 years old;

at 17 colleges we have 73 elevators over 25 years old.

Twenty-five schools indicated a total of 219 elevators covered by this survey were listed as critical. A total of 143 of the 219 elevators were located at three colleges. They have contract elevator maintenance service at two of these schools and one school does have maintenance by oil, grease, and examination service with four men spending 75% of their time on elevator mainteance service.

I have not covered all of the factors involved in establishing a comparison of maintenance costs. Others which you should consider are: (1) Location of the elevator, big city or urban area; (2) Speed of the elevator—100' per minute would not require a motor generator set—at 300' per minute, you should have a M-G set; (3) Capacity—large units require larger cables, a larger motor and all items would be more expensive to replace; (4) Controls—a selective collective system is, by its nature, more expensive than a push-button type control; and if you use group supervision, this will be more expensive to install and maintain than the selective collective system.

I have only scratched the surface on this subject. I doubt if we have a proper number of various types of elevators with the many variations in size, speed, control, et cetera to arrive at a definite cost for elevator maintenance.

Considering the various types of elevators, the location of the installation, the speed at which elevators travel, our many and various types of controls, the capacity of our elevators, and the service we expect them to perform, our prime consideration in connection with elevator maintenance should be, "How can I get the elevator maintenance work performed with the greatest economy and in a quality manner without injury to workmen or passengers?" Safety should be your foremost consideration in elevator maintenance service. If you cannot do your elevator maintenance safely and economically, you must have a competent elevator firm do it for you.

From the questionnaires I received, it would appear that the most economical way to have maintenance work performed on elevators is to do the routine inspection and maintenance including oiling and greasing and replacement of minor parts with your own personnel, if you have qualified maintenance men, who understand electronics and the operation and maintenance of elevators. You should have such work as cable replacement and safety checks done by an outside reliable elevator firm.

		1	1a	2	3	4	5 How is Maintenance Performed		6 If By Outside Contract-Basis Of Proposal				7	8	9	10 Total Annual Cost of Hydraulic Elevator Maintenance Agreements Based On:			
							5a	5b	6a	6b	6c	6d				10a	10b	10c	10d
College Identification	Do You Have Elevators or Dumb-waiters on Campus?	No. of Buildings with Elevators	No. of Buildings without Elevators	Total No. of Elevators (Hydraulic)	Total No. of Elevators (Electric Cable)	Total No. of Elect. Cable Dumb-waiters	By Your Own Forces	Outside Contract	Oil & Grease Exam. Service No. Units Involved	Parts, Oil & Grease Exam. Serv. No. Units Involved	Full Maintenance Agreement No. Units Involved	Full Maint. Agree.+ Month Mile Charge - No. Units Involved	Total Openings Served by Hydraulic Elevator	Total Openings Served by Electric Cable Elevators	Total Openings Served by Dumb-waiters	Oil & Grease Examination Service	Parts, Oil & Grease Examination Service	Full Maintenance Agreement	Full Maintenance Agreement Including Monthly Mileage Charge
1	yes	44	120	26	42	5		X			72		87	265	27			$21,876	
2																			
3	yes	14	1	16	21	2		X			39		43	120	7			$37,450	
4	yes	12	4	10	18	5		X			all		32	107	15			$33,588	
5	yes	3	7		3			X			3			15					
6	yes	8	34	12	2	2		X	14				41	6	9	$ 5,892			
7	yes	17	16	8	19	4		X			31		42	109	17				$ 4,344
8	yes	5		1	13	7	X dumb.	X all other			13		5	1hnd				$ 600	
9	yes	38	100	12	34	5	X	X	14		2		36	132	17	$ 1,119			
10	yes	49	73	14	51	5		X	56				31	350	14	$ 6,700			
11	no																		
12	yes	5	28	2	3		X	X		1		7	7	2					
13	yes	8	26	4	5	5	X	X	X				13	24	16				
14	yes	4	5	9				X			9		34					$ 1,308	
15	yes	3	19	1	1	1		X	1		1		3	4	2	$ 168			
16	yes	10	40	4	6		X						15	32					
17	yes	9	21	4	5			X			9		11	19				$ 1,583	
18	yes	4			8	2		X			X								
19	yes	1	20		1			X			1			2					
20	yes	2	15	2				X			X		10					$ 1,032	
21	yes				-			X											
22	yes	7	20 aprx.	4	10	1	X	X	3 hyd		9 cbl		12	100	2	$ 80			
23	yes	12	25	7	15			X					14	45					
24	yes	20	14	4	21	1	X	X		11			7	89	4				
25	yes	3	14	1	2			X			X					$ 360			
26	yes	4	1	2	7			X	X				4	48					
27	yes	9		5	4	4	in part	in part		2			15	19	13				
28	yes	12	3	11	6		X			17			66	43		$ 2,160			
29	yes	2	7		2			X		X				4					
30	yes	6	12	5	4		X	X		X			14	28			$ 387		

3	yes	14	1	16	21	2		X			39		43	120	7			$37,450	
4	yes	12	4	10	18	5		X			all		32	107	15			$33,588	
5	yes	3	7		3			X			3			15					
6	yes	8	34	12	2	2		X	14				41	6	9	$ 5,892			
7	yes	17	16	8	19	4		X			31		42	109	17				$ 4,344
8	yes	5		1	13	7	X dumb.	X all other			13		5	1hnd 2				$ 600	
9	yes	38	100	12	34	5	X	X	14		2		36	132	17	$ 1,119			
10	yes	49	73	14	51	5		X	56				31	350	14	$ 6,700			
11	no																		
12	yes	5	28	2	3		X	X		1		7	7	2					
13	yes	8	26	4	5	5	X	X	X				13	24	16				
14	yes	4	5	9				X			9		34					$ 1,308	
15	yes	3	19	1	1	1		X	1		1		3	4	2	$ 168			
16	yes	10	40	4	6		X						15	32					
17	yes	9	21	4	5			X			9		11	19				$ 1,583	
18	yes	4			8	2		X			X								
19	yes	1	20		1			X			1			2					
20	yes	2	15	2				X			X		10					$ 1,032	
21	yes							X											
22	yes	7	20 aprx.	4	10	1	X	X	3 hyd		9 cbl		12	100	2	$ 80			
23	yes	12	25	7	15			X					14	45					
24	yes	20	14	4	21	1	X	X		11			7	89	4				
25	yes	3	14	1	2			X			X					$ 360			
26	yes	4	1	2	7			X	X				4	48					
27	yes	9		5	4	4	in part	in part		2			15	19	13				
28	yes	12	3	11	6		X			17			66	43		$ 2,160			
29	yes	2	7		2			X		X				4					
30	yes	6	12	5	4		X	X		X			14	28			$ 387		
31	yes	4	16	3	2		minor calls						10	20					
32	yes	4	22	2	4	2		X			X		8	10	4			$ 455	
33	yes	23	23	4	37	2		X		1	42		10	180	9				
34	yes	1	27			1		X				1			2				
35	yes	4	12	4	1	4		X			X		8	4	12			$ 5,700	
36	yes	37	32	21	45	20	X						61	521	65	$ 1,500			
37	yes	7	20	2	5	1	elec.	hydr.			2		7	15	2			$2,326	
38	yes	3	14	1	2		yes						2	6		Own Crew			
39	yes	18	14	5	27	3		X				X	11	163	11				$ 16.279 + elect.
40	yes	2	31	2		1		X	2	2	2		9		6			$ 1,872	
41	yes	2	10	1	1	4	prev. maint	major		X			3	3	13		$ 50		
42	yes	7		9				X			9		8					$ 6,300	
43	yes		4	2	2	5		X	1	2	1		6	5	12	$80.00 Month		$1.25 Month	
44	yes	2	21	1	2			X			3		3	16				$ 540	

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	11 Total Annual Cost of All Electric Cable Elevator Maintenance Agreements:				12	13	14	15	16	16a	16b	17	18	19 Average Age of Elevators					20
	11a	11b	11c	11d										19a	19b	19c	19d	19e	
College Identification	Oil & Grease Examination Service	Parts, Oil & Grease Examination Service	Full Maintenance Agreement	Full Maintenance Agreement Including Monthly Mileage Charge	Average Cost of Additional Outside Maintenance per Year for Last 10 Years	Average Length of Downtime on Elevators (Unscheduled)	After Call Placed, Length of Time Before Maintenance Man Arrives	Hourly Rate Maintenance Men Are Paid	Number of Men Involved	% of Men's Salaries Who Do Elect. Maint. Work Chargeable to Elevator Maintenance	If Men Are Not Involved 100% of Time, What Other Trade Involved In	If Own Forces Perform Maint. How Long Wait For Delivery of Parts	Average Length Time Required To Receive Replacement Parts	Under Five Years Old	Over Five, Under Ten Years	Over Ten, Under 15 Years	Over 15, Under 25 Years Old	Over Twenty-Five Years Old	No. of Elevators Which Are Critical
1			$43,649		None	45 min.	15 min.							16	20	3		5	68
2						2 hrs.	30min 2 hrs	$4.35	1			2 wks.	2 wks	3	1	1	1		
3						30 min.	15 min.						3 wks	21	7	6	5		
4					None	3call month	30 min.							10	11	12			11
5			$ 4,698		None	5 hrs.	4 hrs.							3					
6					$ 4,238	2 hrs.	1 hr-30min							8	4	1	1		8
7				$10,008.00		3 hrs.	1 hr.							8	10	5	8		1
8			$21,605			4 hrs.	30 min.							1	5	8			5
9	$ 5,005			$ 2,271.00	$ 6,000	30 min.	10 min.	$3.52-$4.73	2	75%	Elec. Repair	2 wks.	2 wks.	12	6	9	12	12	3
10	$28, 300					2 hrs.	30 min.							20	24	7	8	12	20
11																			
12					Not Available	2 hrs.		$3.00	2	.3%	Electrician	2 wks.	2 wks	2	1	1	1		1
13	$ 285				$ 1,200	12 hrs.	6 hrs.	$4.00	1	5%	Electrician	12 hrs.	½ day	5	2	2			
14					$ 746	2 hrs.	1 hr.							7		2			1
15			$ 623		Unknown vry little		24 hrs.							1	1	1			
16						1 hr.	30 + or -	$3.05	2 part time	25%	Gen. Mech.	2 wks		1	2	1	4	2	
17			$ 2,242		$ 1,350	30 min.	10-20 min.							3	0	3	1	2	
18			$ 9,000		$ 200	30 min.	45 min.								6		2		3
19				$ 64.57			24 hrs.								1				1
20						3-4 hrs.	2-3 hrs.							X					
21																			
22			$ 1,164			4 hrs.	2 hrs.	$2.72		.1 of 1%	Elect. Refri.	2 months	2 month	13	1				
23					$ 3,000	1 hr.	30 min.							6	12	4		4	
24		$ 750			$ 600	2 hrs.	30 min.	$2.20	3	5%	Electric		2 days	7	5	7	5	2	
25							2 hrs.							2				1	
26	$ 793				$ 1,000	2 hrs.	2 hrs.	$5.75	2										2
27		$ 1,420					1 day	hy Elect.						4	1	1	3		3
28	$ 1,080				$200/year per elev.	30 min.	15 min.	$3.30	2	None	Electric		3 days	4	7	3	2	1	all
29			$ 100			1 hr.	6 hrs.							1	1				1
30		$ 456				2 days	2 days	$3.00	2	None	Gen.Elec mt		5 days	5	4				2
31					$100/year	3 days	12 hrs.		1					2	1	1		1	3
32			$ 5,460		None	30 min.	30 min.							4		3	2	1	2
33		$ 481	$18,308		$ 2,319	40 min.	20 min.							5	8	7	21		2
34		$ 50			$ 50.00 5 years		3 hrs.												
35					$ 4,000	1 hr.	1/2 hr.							3	3	2		1	1
36	$12,000				$ 500	30 min.	20 min.	$3.50	4	75%	Gen. Maint.	3 weeks	3 weeks	21	16	18	20	11	55
37	249	$ 94					Less 22 hr.	$4.25	1	None		2 days	2 days	3	2		2		2
38						3-5 hrs.	1-2 hrs.	Month	2			Short Time	1-3 days	1		2			
39						2 hrs.	30 min.							6	4	3	7	12	
40						12 hrs.	1 day												
41		$ 10			Minimal	1/2-1 hr.	2-4 hrs.	$4.25	1	None	Electrician		1 day-1 week		3	1		2	1
42							2 hrs.								5			4	3
43			$ 1.25			8 hrs.	1 hr.							3			1		
44			$2,088			20 min.	15 min.							3					3

ELECTRICAL DEMAND STUDY OF CAMPUS BUILDINGS AT COLORADO STATE UNIVERSITY

R. S. HOLLAR, P.E.

R. S. Hollar graduated in 1951 from Colorado State University with a B.S. degree in electrical engineering. After graduating he joined General Electric developmental division in Fort Wayne, Indiana.

He joined the staff of the Colorado State University Physical Plant Department in 1953, as Assistant University Engineer. His present title is Manager of Utilities. In addition to his operational and maintenance duties he is responsible for the design and development of the primary electrical distribution systems of the campus.

He has been a registered professional engineer in the state of Colorado for over ten years.

Colorado State University Physical Plant Department, Fort Collins, has completed the first phase of a study aimed at correlating building types and connected load characteristics with maximum electrical demands.

We have found (and not too surprisingly) that in sizing a transformer it is not sufficient to know the demand of a "similar" building without first establishing the degree of similarity between the two buildings.

The data are presented to provide a base of facts and a point of departure for design engineers. The information is sufficiently complete to allow the interested user to formulate his own use and method of application.

Many Colleges and Universities receive electrical power from the supplier at primary distribution voltage and thereby assume the role of electrical distributor. The distribution lines and transformers are thus the property of the institution and as a general rule the new building transformers are sized by a consulting electrical engineer. We have reason to pity the typical consultant at this point: he may use a formula of his own making, data from the last similar building (doubtful), the National Electric Code, his intuition, or a combination of any number of these methods to arrive at the "proper" transformer size. He must consider not only the probable maximum demand for today but he feels he must also provide some capacity for the future. If the transformer is large and hard to remove from the building or is a part of a load center, the consultant will want to oversize the unit to provide for unforseen changes in building use and not burden the owner with unnecessary transformer changes. Thus the consultant might rigorously apply his knowledge and come up with a "properly" sized transformer. Furthermore, the conscientious consultant will readily offer "proof" of the validity of his calculated maximum demand. So be it. The consultant's task of sizing the transformer is more nearly a job for a magician.

Simple economics does not demand that the transformer be sized "exactly" even if it were possible, so long as sufficient capacity is made available and so long as the sizing was based on available facts properly applied.

The campus buildings selected for study are broadly categorized in the table according to use: academic, residence, research, and service. Seventy-five percent of the buildings listed have permanently installed watthour meters with fifteen minute demand registers. Recording ammeters were used where no watthour meters existed and a power factor of 90% was assumed. These buildings may be easily identified in the table, as no kilowatt hour consumption figures appear. We feel there is no significant loss in accuracy in cases where measurements were taken via recording ammeters.

Both physical and electrical building characteristics most likely to affect the electrical load are listed for each building. These include the gross square feet, building use, date of construction, lighting loads and types, mechanical loads, and heating and cooling system characteristics.

Connected load calculations, however arrived at, are always based on numerous assumptions. Most variable among the assumptions is the watts or current assigned to convenience outlets and outlets for special equipment. The most often assigned load value and the one used in this study for a common convenience outlet is 1.5 amps or 180 watts at 120 volts assuming unity power factor.

"Special" outlets with unknown loads were assigned a 400 watt load. Where outlets were designed for a known piece of equipment, the full value of that load was used in arriving at the connected load.

Admittedly, most assigned loads to outlets of any sort are intelligent guesses and are fair subjects for discussion, particularly in commercial or industrial buildings not governed by home building codes. The judgment of the designing engineer is recognized, but values other than those used in this text must be adjusted to correlate with the data presented if comparisons are to be valid.

Residence halls listed are complete living units with central lounge areas and kitchen and dining facilities. Kitchen equipment energy may be steam, from a central station, gas, or electric, with a fair degree of each in a typical unit listed.

Most central air conditioning is accomplished via steam absorption units receiving steam from a central station; however, some of the research facilities as noted have total electric air conditioning equipment.

It should be noted that one horse power is equated to one kilowatt in arriving at the connected load. It is felt that such a "rounding off" does not compromise the accuracy of the study so long as the fact is known and the reader adjusts his thinking accordingly.

To use the data to aid in the design of a new structure, the engineer will first categorize the proposed building according to use and size and select a building from the data which has a recent date of construction. If the buildings are similar in size and use (refer to "percent of gross square feet" column), multiply the "gross square feet" by the "watts per gross square feet" for a ball park figure on what the demand might be. At this point the engineer must review carefully the elements of his connected load figure to be certain of the correlation between the proposed building load and the load shown in the table. To establish a correlation other than unity, the engineer must look at the lighting loads, method of arriving at convenience outlet load, total motor load, special outlet loads, etc. In other words, he must carefully analyze the example offered and in a similar fashion and with the same end in mind carefully compare the proposed building characteristics and adjust the "watts per gross square feet" figure up or down according to the degree of similarity.

Buildings dating back to early 1900 are included in the study for their interest and for use by Colorado State University engineers in their overall planning of distribution.

Many buildings used for study are typical or represent an average found throughout the area, while others may not be typical. A careful study of the building characteristics is necessary if the reader hopes to successfully use the data presented.

If the data presented fails to support the reader's previous information or reassumed methods we can but sympathize. This presentation does not presume to draw conclusions, but only to record the facts as they appear.

BLDG NO.	BUILDING NAME	YEAR CON-STRUC-TED	GROSS AREA SQUARE FEET	CONNECTED LOADS — LIGHTING KW LOAD	% FLOR	% INCAN	% HG	MOTORS HP 3 LOAD	MAX HP	C.O. @ 180W KW LOAD	OTHER KW LOAD	DESCRIP.	GRAND TOTAL KW LOAD
	ACADEMIC												
1	Agriculture	1939	46,550	93	82%	18%	--	--	--	66	22	c.o.@ 100	181
2	Ammons Hall	1921	23,704	30	13%	87%	--	5	5	9	--	--	44
3	Animal Science	1960	38,600	116	70%	30%	--	141	10	70	76	Lab.Equip.	403
4	Aud/Gym	1966	260,332	539	28%	48%	24	478	30	174	--	--	1,191
5	Biophysical Science	1948	72,600	168	70%	30%	--	104	10	164	20	Spec.c.o.	456
6	Chemistry	1922	54,002	127	13%	87%	--	--	--	108	19	Spec.c.o.	254
7	Engineering Center	1957	120,304	211	67%	33%	--	102	25	138	32	Spec.c.o.	483
8	Engineering Center (Math)	1966	31,076	84	71%	29%	--	132	25	65	69	Computer	350
9	Geology	1905	14,084	28	18%	19%	--	--	--	19	4	Spec.c.o.	51
10	(Home Ec) Guggenheim	1910	15,767	33	39%	61%	--	4	3	29	152	Ranges	218
11	Home Ec Annex	1919	18,519	38	79%	21%	--	--	--	27	11	Spec.c.o.	76
12	Humanities	1964	40,670	82	78%	22%	--	112	15	49	--	--	243
13	Industrial Arts Shops	1925	19,740	47	11%	89%	--	145	75	9	75	Wldrs & Spec.c.	276
14	Liberal Arts	196[illegible]	66,234	152	83%	17%	--	83	10	106	54	Co.& Elec Equip	395
15	Morgan Library	1964	140,356	335	70%	30%	--	342	90	85	41	Heaters/c.o.	803
16	Music Bldg.	1927	31,150	70	30%	70%	--	13	10	20	--	--	103
17	Physiology	1966	61,122	165	88%	12%	--	284	100	70	89	C.o.& heaters	608
18	Plant Science	1960	78,768	205	73%	27%	--	85	20	200	10	Spec Lab Equip	500
19	Social Science Unit A	1968	102,101										
20	Social Science Units B & C	1967	151,859	429 KVA	92%	8%	--	449 KVA	40	435 KVA	--	--	1,313 KVA
21	University Headhse/Grnhse	1959	28,450	50	10%	90%	--	46	2.5	31	160	Grth Chmbrs	287
22	Veterinary Science	1920		43	70%	30%	--	9	1.5	31	25	C.O. & Elec Micro	108

MAXIMUM MO. 15 MIN. KW DEMAND	AVERAGE MO. KWH CONS.	LOAD FACTOR (MONTHLY 15 MIN)	CAL. UNIT DEMAND W/FT^2 GSF	PERCENT OF GROSS SQUARE FEET											
				CLASS ROOM	OFFICE	OFFICE SERVICE	RESEARCH LABORATORY	TEACHING LABORATORY	RESEARCH TEACHING LAB	LABORATORY SERVICE	INSTRUCTION SERVICE	FOOD SERVICE	LIVING QUARTERS	BUILDING SERVICE	OTHER
ACADEMIC															
115			2.46	10	20	4	11	17		10				28	
22			0.93	2	6	3		29		29				15	15
125			3.24	2	15	2	7	8	3	22	17			24	
630	248,000	.55	2.42	1	2	1		33		12				30	19
211			2.91	2	10	1	2	7	11	18				26	2
180	45,500	.35	3.34	16	10		9	22	6	17				17	2
216			1.80	15	15	1	9	24	2	8				27	
200	77,000	.53	6.45	24	23	3		3						30	17
29			2.07	18	18	3	5	18		16				20	3
38			2.43		16	4	2	50		6				19	4
32			1.73	20	14	1	9	14	8	3				28	2
112	36,000	.45	2.76	3	13	6	3	25		7	13			29	1
54			2.74		1			81		16				2	
156			2.36	24	26	5		4						37	3
600	340,057	.79	4.27	1	15	2								19	62
60	15,800	.37	1.93	9	2	6		49		9				26	1
230	104,000	.63	3.77	6	6		20	11		18				34	4
187			2.36	8	14	2	20	13		12				29	1
120	50,500	.58	1.18	24	3	2	5			5				46	15
270	96,600	.89	1.78	17	27	4	4	5		3	2			38	
150	50,000	4.64	5.30		2		3	3		11				15	68
77	25,000	.45	5.35		8	2	8	35		36				9	3

* Totally air conditioned with electrically driven equipment

BLDG NO.	BUILDING NAME	YEAR CONSTRUCTED	GROSS AREA SQUARE FEET	CONNECTED LOADS: LIGHTING KW LOAD	% FLOR	% INCAN	% HG	MOTORS HP LOAD³	MAX HP	C.O. @ 180W KW LOAD	OTHER KW LOAD	DESCRIP.	GRAND TOTAL KW LOAD
	RESIDENCE HALL												
1	Aylesworth Hall	1956	84,990	114	11%	89%	--	35	2	115	--	--	264
2	Braiden Hall	1963	109,256	151	26%	74%	--	92	7.5	190	148	Kitch Equip	581
3	Corbett Hall	1965	221,412	368	25%	75%	--	470	25	556	--	--	1,394
4	Edwards Hall	1964	96,839	133	42%	58%	--	76	5	195	56	Kitch Equip	460
5	Ingersoll Hall	1964	98,840	144	39%	61%	--	82	7.5	188	54	Kitch Equip	468
6	Lory Hall & Faculty Apts.	1950	70,014	54	0	100%	--	--	--	158	36	Wshrs & Dryrs	248
7	Newsom Hall	1955	101,984	139	7%	93%	--	40	3	157	--	--	336
8	Parmelee Hall	1962	108,877	147	27%	73%	--	65	5	189	147	Kitch Equip	548
	RESEARCH												
1	Atmospheric Science	1967	33,175	103	87%	13%	--	95	40	87	11	Spec c.o.	296
2	Communicable* Disease Center	1967	40,916	138	84%	16%	--	448	47	83	164	Snowmelter Equip&Steril	833
3	Radiology *	1964	13,500	37	70%	30%	--	57	37.2	35	23	Spec.LabE[illegible]	152
4	Surgical Metabolic	1964	17,139	62	67%	33%	--	105	10	40	74	Heatng Systm	281
5	Environmental Stresses Lab*	1966	14,502	51	67%	33%	--	75	46.7	69	31	Xray & SpecEq	226

MAXIMUM MO. 15 MIN. KW DEMAND	AVERAGE MO. KWH CONS.	LOAD FACTOR (MONTHLY 15 MIN)	CAL. UNIT DEMAND W/FT^2 GSF	PERCENT OF GROSS SQUARE FEET											
				CLASS ROOM	OFFICE	OFFICE SERVICE	RESEARCH LABORATORY	TEACHING LABORATORY	RESEARCH TEACHING LAB	LABORATORY SERVICE	INSTRUCTION SERVICE	FOOD SERVICE	LIVING QUARTERS	BUILDING SERVICE	OTHER
RESIDENCE	HALLS														
125	39,718	.44	1.475												
264	72,000	.38	2.42									10	66	23	
420	175,000	.58	1.90									8	61	30	
152	65,000	.59	1.78									9	59	32	
148	66,000	.62	1.50									9	60	30	
62	20,500	.46	0.87									66	12	23	
125	42,417	.47	1.23												
208	70,000	.47	1.92									10	66	23	
RESEARCH															
115	40,000	.48	3.48		19	10	14			26				30	
196	85,000	.60	4.80		9	5	19			27				41	
67	15,666	.32	4.96		7	4	23			40				26	
105	45,000	.59	6.15		6	3	30			43				18	
118	25,000	.29	8.14		8	2	33			30				27	

COLORADO STATE UNIVERSITY

BLDG NO.	BUILDING NAME	YEAR CONSTRUCTED	GROSS AREA SQUARE FEET	CONNECTED LOADS: LIGHTING KW LOAD % FLOR	% INCAN	% HG	MOTORS HP LOAD[3] / MAX HP	C.O. @ 180W KW LOAD	OTHER KW LOAD / DESCRIP.	GRAND TOTAL KW LOAD
	SERVICE BUILDINGS									
					19		553		--	
1	Heating Plant	1915	13,734	8%	76%	16%	250	9	--	581
	(Without Add.)				294		480		46	
2	Student Center	1962	124,924	40%	60%	--	100	90	Kitch Appl.	910
	(With Addition)				687		772		416	
3	Student Center	1962	253,731	54%	46%	--	100	214	Kitch Appl.	2,089
					86		66		15	
4	Student Health	1964	38,458	41%	59%	--	10	50	Spec.Equip.	217

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MAXIMUM MO. 15 MIN. KW DEMAND	AVERAGE MO. KWH CONS.	LOAD FACTOR (MONTHLY 15 MIN)	CAL. UNIT DEMAND W/FT2 GSF	PERCENT OF GROSS SQUARE FEET											
				CLASS ROOM	OFFICE	OFFICE SERVICE	RESEARCH LABORATORY	TEACHING LABORATORY	RESEARCH TEACHING LAB	LABORATORY SERVICE	INSTRUCTION SERVICE	FOOD SERVICE	LIVING QUARTERS	BUILDING SERVICE	OTHER
SERVICE	BUILDINGS														
280	117,400	.58	20.4		1	1								5	93
496	227,000	.64	3.97		3	3						22		23	51
1200	400,000	.22	4.75												
93	40,000	.59	2.42	14								7		34	44

PHYSICAL PLANT ORGANIZATIONS IN
UNIVERSITIES AND COLLEGES

By

Harry F. Ebert

Harry F. Ebert has been a member of APPA since 1961. He is a member of the Central States Regional Association. He is editor of the Central States Regional Association Newsletter.

He holds membership in the American Association Mechanical Engineers, American Association Refrigeration and Air Conditioning Engineers, Texas Association of Professional Engineers, National Association of Professional Engineers and the Honorary: Pi Tau Sigma.

Since 1961 he has presented 17 papers to various organizations concerning Physical Plant Organization, Plant Maintenance, Plant Operation and Budget Preparation. In addition to these accomplishments he has also served with distinction on several APPA committees.

Management of physical plant organizations is a frequently and rather thoroughly discussed subject. It is necessary to research only briefly in the literature to find this is a very general subject and that a great store of information has been published even in the specific field of university and college physical plant management. It is necessary to do only equally brief research in the same literature to realize that there exists a variety of definitions, principles, terms and graph symbols for which there is no universal agreement. However, these variations appear to reflect only different points of view or different background and experiences rather than conflicting conclusions.

In order to establish a premise for the following, it should be stated for purposes of this discussion that *the art of administration is the direction, coordination, and control of many persons to achieve some purpose or objective.* That is, an administrator is one who directs, coordinates and controls the activities of others. These definitions may seem too elementary for this occasion, but it is felt they bear repetition to emphasize the goals and objectives of college and university physical plant administrators.

An administrative system deals with organization, certain aspects of management in action, fiscal management, personnel management, forms of action by which some persons in other jurisdictions are regulated and with the responsibility to which the system is subject. The term "organization" may be used to point out an existing arrangement of the parts of a whole. The term may also be used to point out the process of establishing or rearranging relationships among parts. Since every college or university physical plant department in existence has an arrangement, however good or bad, it then is preferable here for purposes of clarity to refer to "organization" as an arrangement of the parts of a whole and to "reorganization" as the process of establishing a different relationship.

It is one of the most important tasks of an administrator to apply skill and good judgment in an organization to secure an arrangement of parts that will attain maximum achievement with available resources. A good organization and smooth operation are inseparably connected with the effectiveness with which personnel can work. A poor organization is one in which the parts are not properly laid out, where there may be duplication of effort, misunderstanding of responsibility, poor coordination and supervision, ineffective delegation, imbalance, confused purpose and responsibility and restricted achievement. Even though competent personnel may make any organization work, there is no sense in requiring them to work with a poor one. The point has been admirably made by Prof. John M. Gaus:

> "Organization is the arrangement of personnel for facilitating the accomplishment of some agreed purpose through the allocation of functions and responsibilities. It is the relating

of efforts and capacities of individuals and groups engaged upon a common task in such a way as to secure the desired objective with the least friction and the most satisfaction to those for whom the task is done and those engaged in the enterprise.

"*The vital point is that structure* (organization) *is an arrangement of the working relationships of individuals,* not merely an impersonal process of putting blocks together to make a building."[9]

This, the continuing need and desire for better physical plant organization seems soundly justified. This continuing need and desire for better organization presents a very complex situation. The complexity would appear to be somewhat intensified in view of a changing situation. It is in order for a good physical plant administrator to examine perpetually the questions in his own situation:

(1) What is the mission of the physical plant department?
(2) Which changes are occurring?
(3) How are they occurring?
(4) What is their magnitude and direction?
(5) Should an attempt be made to influence these changes; and if so, why?

The overall problem of every administrator may be simply visualized if he can imagine himself a marksman. When the marksman is to fire one shot from a stationary platform to a fixed target through a clear range, he has a relatively simple situation. On the other hand, it is not so simple if he is on a roughly moving platform firing continuously at an erratically moving target that is changing range rapidly. It isn't likely in the latter case that all the shots will be on target, but good marksmen do make high scores if they don't run out of bullets before the end of the contest.

It is not within the scope of any single presentation to examine in detail all of the static and dynamic factors that affect organization. At least one reason for not attempting such an investigation is that all of the factors are not yet known even though studies in administration and organization are recorded in history to have begun prior to the days of the Roman Empire with continuing progress in the meantime. A scholarly statement was made in 1885 by one of the first American writers in the field of management that bears repeating here:

"If there be a science correlative to the art of administration, it must, like every other physical science, be founded on the comparison of accumulated observations. Since the accuracy of the knowledge sought can be no greater than the exactness of the data from which it is derived, in order to make a proper comparison it is important that the observations be as free from error as possible, and that they be measured by a common standard. Whatever be the standard of measurement, it suffices for comparison if it be generally accepted, if it be impartially applied and if the results be fairly recorded."[7]

While this occasion is more oratory than scientific, some comparison of accumulated observations having a common, generally accepted base are useful even if applied to only a limited number of factors.

To limit the scope of this paper, it was somewhat arbitrarily determined that the size of institution would be used as a common base of comparison. Previous investigations have variously used building square feet, building cubage, student enrollment and other measurables as a base. More recently the term F.T.E. Enrollment has come to common usage. Full Time Equivalent Enrollment is generally agreed to be determined by dividing total undergraduate semester hours by 15 and graduate semester hours by nine. F.T.E. was selected as a base here because it is believed to be the most readily available at this time.

A superficial review of the overwhelming volume of data currently available to determine indices of change shows the most radical measurable changes are occurring in enrollment and capital investment in physical plant. A correlation between these factors and changes in organization would be extremely useful in organizational planning and administration if such correlation exists and can be identified. To provide current data for study, inquiries were sent to eighty-five universities and colleges. An attempt was made to get approximately equal geographical distribution and a spread in sizes of schools offering a general curriculum. Usable data was received from forty of those contacted. Since specific authority for republication was not requested from the respondents, the data is represented here symbolically. A period of only the last 10 years was used. It is felt that changes more than 10 years old would be of little immediate significance. It was presupposed that the sponsorship of the school and the ultimate authority to whom the physical plant administrator reports would have a significant affect on the organization. Therefore, inquiries were made regarding these. The effort involved here makes one further assumption. That is, there is a common mission of all university and college physical plant organizations. A definition of this common mission was well stated in a recent publication by Mr. M. F. Fifield, Director, Physical Plant Department, University of New Mexico:

> "The mission of a physical plant organization is to provide the best possible facilities and climate to support the instruction and learning program for the entire university."[6]

It is worth restating that the mission of a physical plant organization is solely one of support, one that is to serve the teaching and learning function.

Many of the studies made in the field of management and organization present data in statistical and numerical forms. One of the most extensive of such studies was made by Mr. Sam Brewster, Director Physical Plant Department, Brigham Young University, Provo, Utah. A complete and detailed report of this gigantic effort is recorded in *Minutes Of The Forty-Sixth Annual Meeting,* The National Association of Physical Plant Administrators Of Universities And Colleges, May 11, 1959. Another extensive study was reported by L. L. Browne in a paper recorded in *Minutes Of The Fortieth Annual Meeting,* The National Association Of Physical Plant Administrators Of Universities And Colleges, May, 1953.[4] Anyone interested in the intimate details of plant operation would be well advised to include these reports in his bibliography. Since organizational changes and functional arrangements do not lend themselves readily to numerical expression, a graphic and pictorial scheme was selected here.

The graphic information given in Figure [1] illustrates, in general terms, the F.T.E. growth rates in different size institutions. While it is commonly accepted that almost every school is experiencing an increase in enrollment, there is one factor shown here that may not be common knowledge. That is, in general, the larger schools are growing at a greater rate, percentage-wise, than are the small schools. If this is a self-regenerative process, then our growth patterns are unstable and will bear watching in relation to long-term plans. The significance of this criteria is not yet clear, but it seems worthwhile to know that the larger an institution becomes, the more rapidly it is likely to grow.

Figure [2] is a reflection of expenditures for new construction in two consecutive five year periods. In general, and as one might suspect, the expenditures were greater more recently by some 25%. The causes for this increase are many. The most common of these are the escalation of unit construction costs, increased complexity of facilities, and increased sophistication. Probably the most significant conclusion one might draw from Figure [2] is that the investment in schools of 8,000 or less is quite radical whereas above this size it is reasonably stable at a current level of approximately $2,000 per F.T.E. for a five year period. While no information is given here in support of such a conclusion, there are other data available to indicate that the extensive federally-controlled participation in new construction financing will establish a fairly uniform per capita investment during the life of the federal program.

If an administrator is to attempt control and direction of the efforts of others, it would be useful if he could anticipate how many others there will be. Figure [3] is an illustration of average data regarding the number of physical plant employees versus F.T.E. for a span of 10 years. The single significant factor shown in the figure is that the F.T.E. enrollment per physical plant employee has remained nearly constant for 10 years in all sizes of schools at approximately 48.

Of all the organization charts that became available during this study, no two were identical nor even close thereto. Each has certain common elements and some had predominating

FIGURE I.

AVERAGE F.T.E. ENROLLMENT vs CALENDAR YEARS
FOR FIVE SIZE GROUPS OF VARIOUS
UNIVERSITIES & COLLEGES

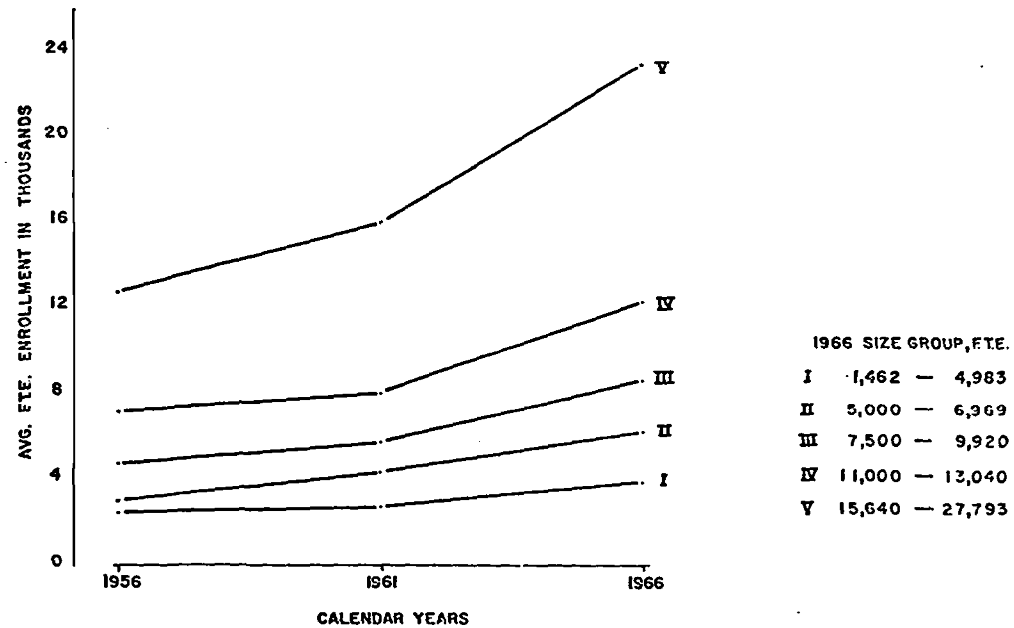


FIGURE 2.

NEW CONSTRUCTION EXPENDITURE PER F.T.E.
VS
1966 F.T.E. ENROLLMENT

A – AVERAGE EXP. PER STUDENT 1956–61 / 1961 F.T.E.
B – AVERAGE EXP. PER STUDENT 1961–66 / 1966 F.T.E.

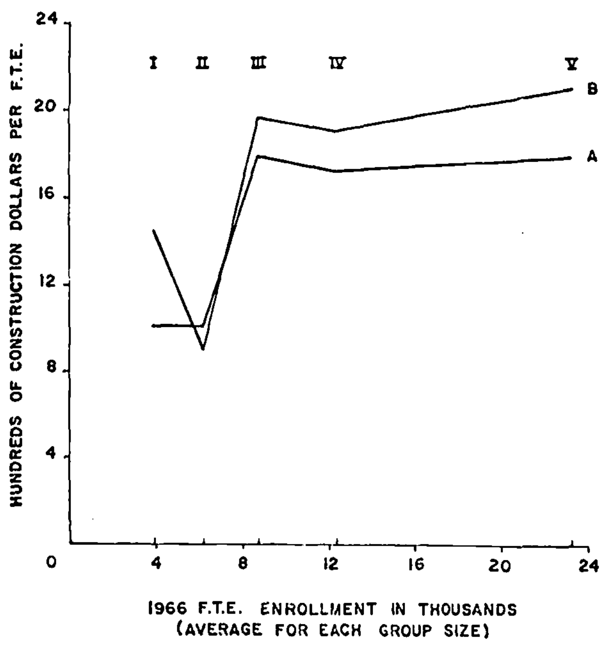
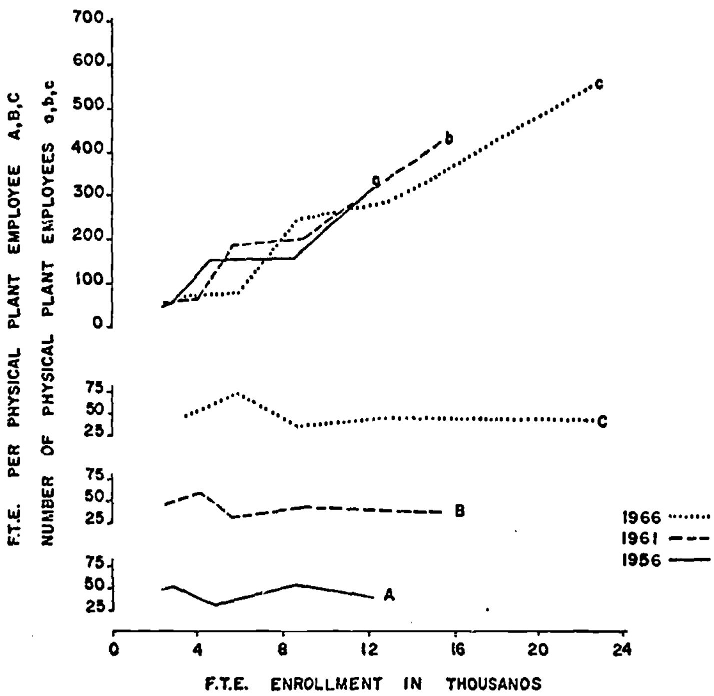


FIGURE 3.

PHYSICAL PLANT EMPLOYEES

VS

F.T.E. ENROLLMENT



portions similar to some others, but no two could be considered the same. In order to keep the scope of this collection within practical limits, only illustrative examples are included. A study of all the charts available will support the general statement that all physical plant departments, irrespective of size, have approximately the same fundamental responsibilities and vary only in the degree of detail. Further support for this statement can be found in the several *C.S.R.A.* and *N.A.P.P.A. Standards Committee* reports and in the survey conducted relative to the report on *Organizations and Functions of Physical Plant Departments* by Sam Brewster and in other publications. During a question and answer period following a paper presented at the 1949 N.A.P.P.A. Meeting by Mr. Henry Pearson on *Organization of the Buildings and Grounds Department at Indiana University*, the following question and answer were recorded:

"Ries-Oberlin—'I think that in order to understand the problem better we should have some measure of the size of your plant, something that would give us some notion as to the magnitude, such as floor area.'

"Pearson-Indiana University—'It makes very little difference how big the organization is. It would make a difference of course in the number of personnel, but the system would work the same for a large or small organization'."

In this particular regard little, if anything, has changed in the last 16 years.

If it can be accepted that all physical plant departments do have essentially the same fundamental responsibilities, then why is every organization different? *The organization must be influenced by other than plant needs.* The influence is primarily one of people. This influence is of two kinds: one external to the organization and another within the organization. These influences, regardless of the direction, cause distortions away from the ideals. Some of the more readily apparent influences are:

A. External To The Department

1. Institutional attitude and policy toward the department.
2. Personalities and background of other departmental or administrative officers.
3. Role and scope of the institution.
4. Local labor markets and organizations.
5. Available community services and facilities.
6. Source of funds.
7. Competition for funds.
8. Miscellaneous other.

B. Internal To The Department

1. The inherited organization.
2. Tenure
3. Personalities
4. Availability of talents.
5. Attitudes
6. Competence and intellect.
7. Complexity of facilities.
8. Communication and transportation.
9. Miscellaneous

Anticipation of some distortions in any ideal organization chart is set forth in a statement by M. F. Fifield. He says, "No matter how intelligently and carefully you plan your organization it's not going to work quite that way because of the people in it."[6] In summary of this point it can be said that each situation presents a different set of circumstances and an organization must be specially designed within the local guidelines to fit as nearly as possible the particular situation.

An examination of existing organization charts is not likely to produce one acceptable for copy and application to a second situation. Neither does it disclose anything approaching a standard. However, such an examination will provide an opportunity to share experiences of others and can provide a basis for better understanding fundamentals necessary for the planning and developing the desired organization structure. The charts shown on pages 19 to 42 are typical of some currently in use. Those presented are only typical and not proposed as good nor bad. It may be useful to point out some features of each.

I/2 Director assumes direct line contact with three functional and one staff unit, and has delegated all related maintenance functions to a single authority.

I/3 Similar to 1/2 except a "methods engineer" is retained at top .taff level.

I/4 A somewhat unusual combination of staff positions is retained.

I/6 Three managerial levels superimposed on a general line organization with staff support at lowest manager level only.

I/7 A conventional organization but contains the unique staff position "space planning analyst".

I/8 Organization chart does not indicate a responsibility for utilities and is strongly oriented to design and construction. The campus is less than five years old.

I/9 Contains a line function for property development.

II/10 Does not provide for any building maintenance by physical plant staff.

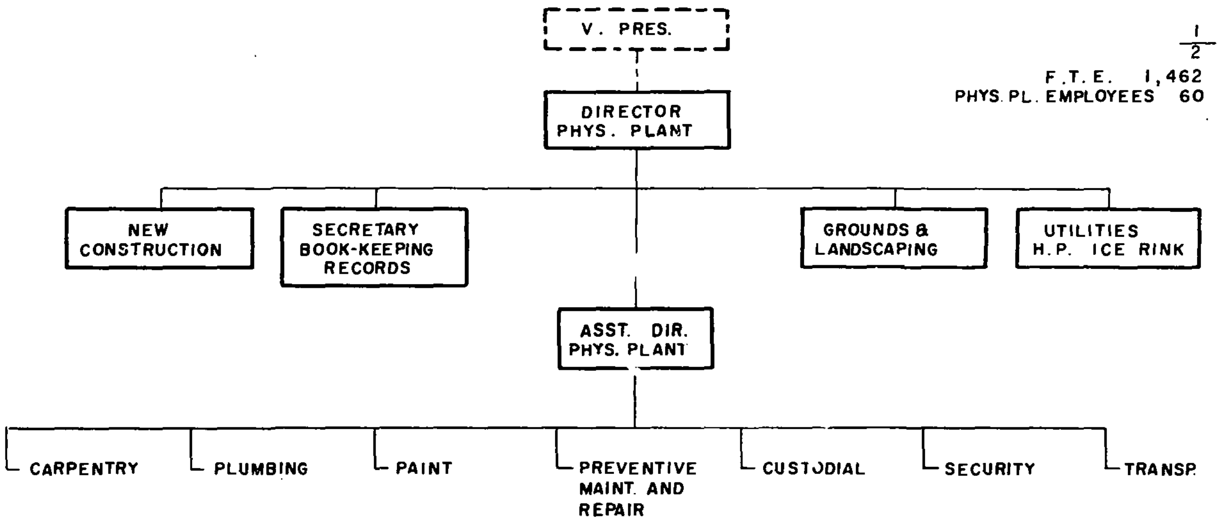
II/11 Mechanical trades are under separate jurisdiction from building trades below second level of responsibility.

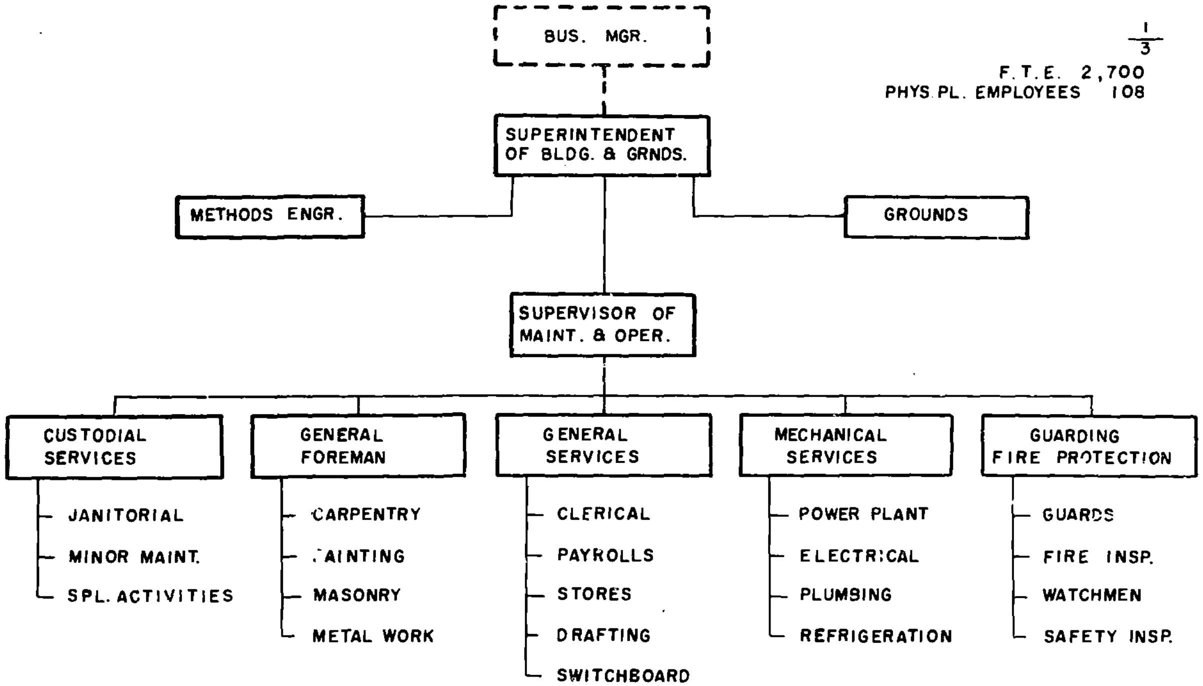
II/12 Top level administrator serves dual function and performs in line function.

II/13 Each third level supervisor has three parallel lines of responsibility to top level.

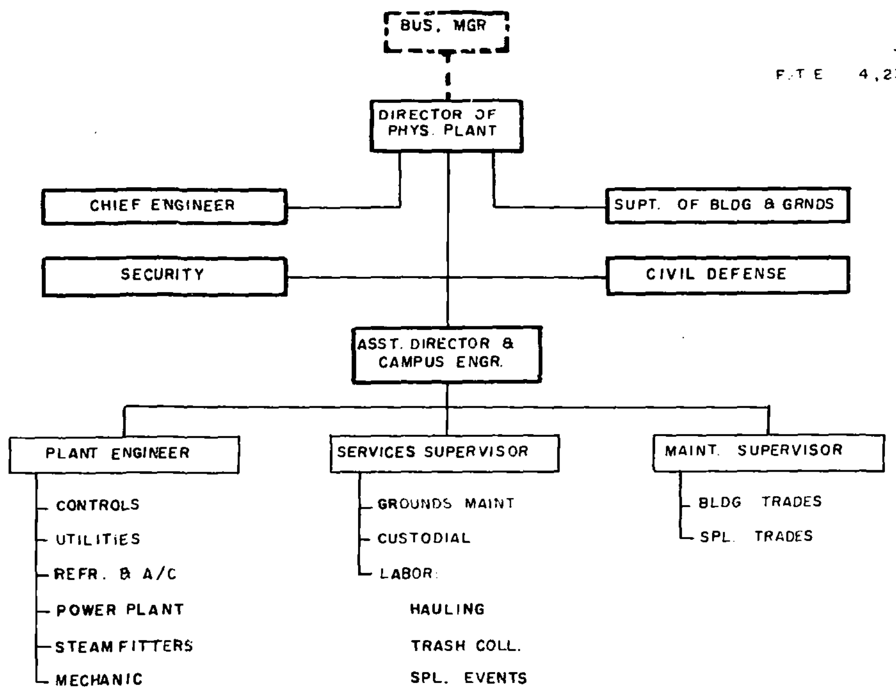
II/14 Physical Plant in operational line of student housing.

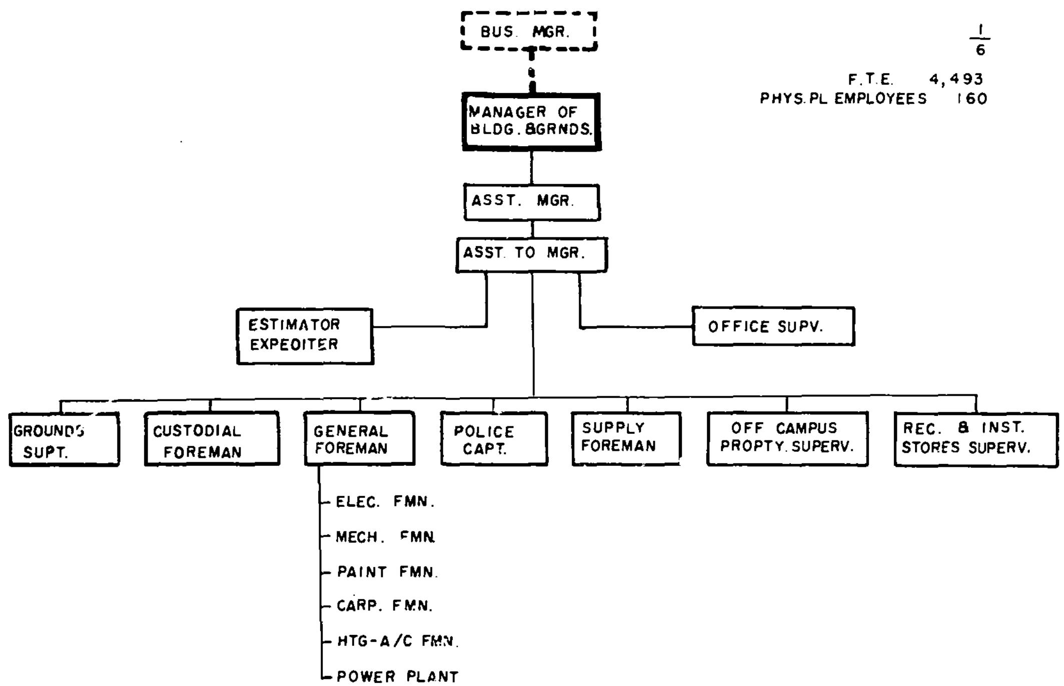
II/16	Staff positions also perform line functions.
III/17	Top level supervision serves dual position and performs as staff to non-physical plant department.
III/18	All building trades and mechanical trades under same superintendent with custodial also in same jurisdiction as a shop.
III/19	Exceptionally clear separation of line and staff functions. However, Director is in direct communication with nine subordinate positions.
III/20	An arrangement for operating two campuses under one superintendent of buildings and grounds.
IV/23A	Remodeling carried as a major function. Campus Architect responsible for coordinating federal fund project.
IV/24	Physical Training faciiities under joint responsibility with physical plant.
V/26	Director of Physical Plant, through an assistant is in direct line with 13 supervisors.
V/27	Safety Engineer functions as a line officer.
V/28	Plant Planning is function of an engineering service instead of architect as in usual case.
V/30	All of plant operation and maintenance line functions are separated into architectural and engineering, each under an assistant director.


1/2
F.T.E. 1,462
PHYS. PL. EMPLOYEES 60
V. PRES.
DIRECTOR PHYS. PLANT
NEW CONSTRUCTION
SECRETARY BOOK-KEEPING RECORDS
GROUNDS & LANDSCAPING
UTILITIES H.P. ICE RINK
ASST. DIR. PHYS. PLANT
CARPENTRY
PLUMBING
PAINT
PREVENTIVE MAINT. AND REPAIR
CUSTODIAL
SECURITY
TRANSP.

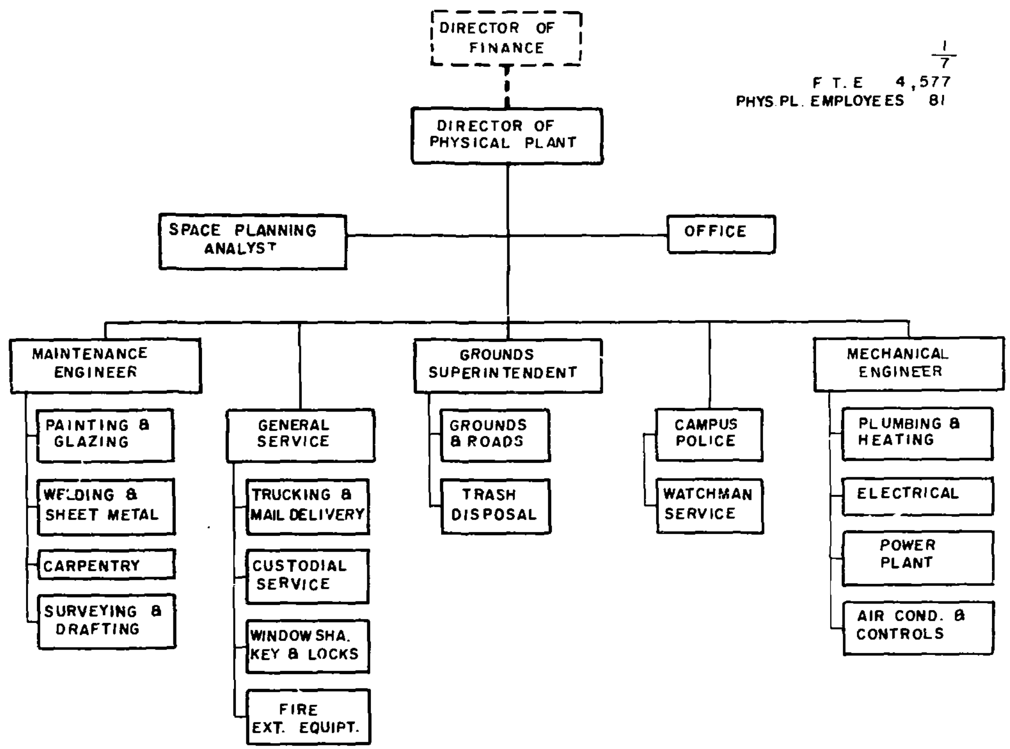

1/3
F.T.E. 2,700
PHYS. PL. EMPLOYEES 108
BUS. MGR.
SUPERINTENDENT OF BLDG. & GRNDS.
METHODS ENGR.
GROUNDS
SUPERVISOR OF MAINT. & OPER.
CUSTODIAL SERVICES
JANITORIAL
MINOR MAINT.
SPL. ACTIVITIES
GENERAL FOREMAN
CARPENTRY
PAINTING
MASONRY
METAL WORK
GENERAL SERVICES
CLERICAL
PAYROLLS
STORES
DRAFTING
SWITCHBOARD
MECHANICAL SERVICES
POWER PLANT
ELECTRICAL
PLUMBING
REFRIGERATION
GUARDING FIRE PROTECTION
GUARDS
FIRE INSP.
WATCHMEN
SAFETY INSP.

F.T.E 4,232 $\frac{1}{4}$

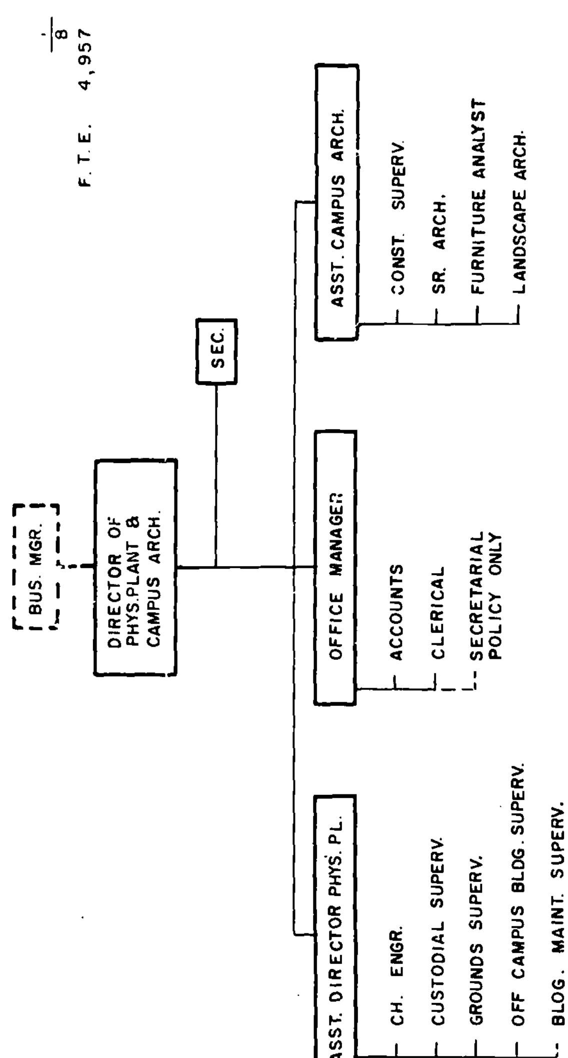


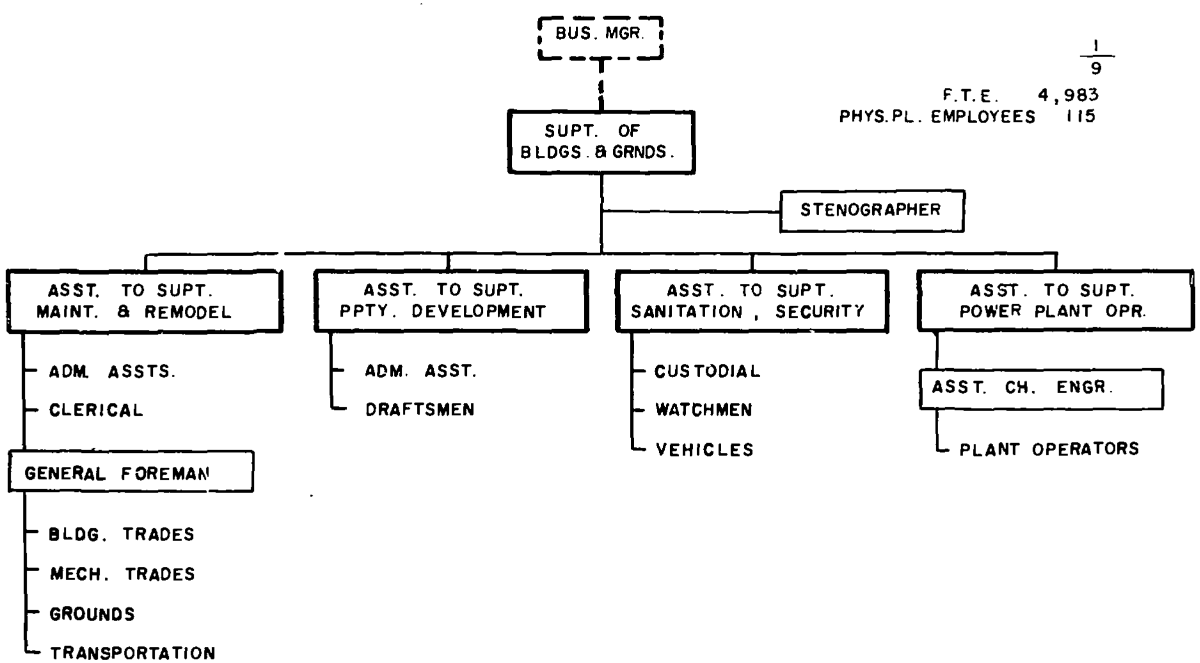


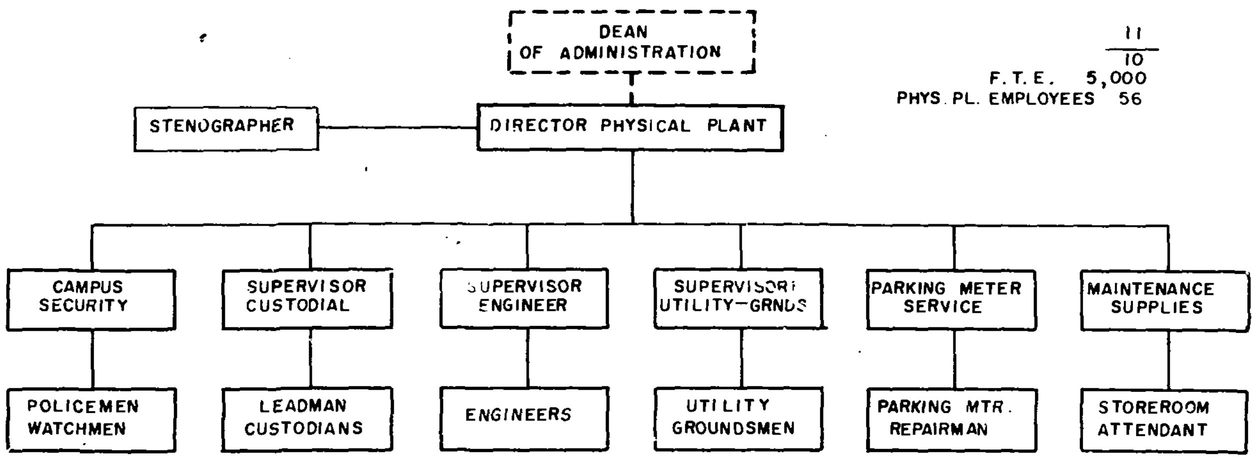
1/6
F.T.E. 4,493
PHYS. PL EMPLOYEES 160
BUS. MGR.
MANAGER OF BLDG. & GRNDS.
ASST. MGR.
ASST. TO MGR.
ESTIMATOR EXPEDITER
OFFICE SUPV.
GROUNDS SUPT.
CUSTODIAL FOREMAN
GENERAL FOREMAN
POLICE CAPT.
SUPPLY FOREMAN
OFF CAMPUS PROPTY. SUPERV.
REC. & INST. STORES SUPERV.
ELEC. FMN.
MECH. FMN.
PAINT FMN.
CARP. FMN.
HTG-A/C FMN.
POWER PLANT



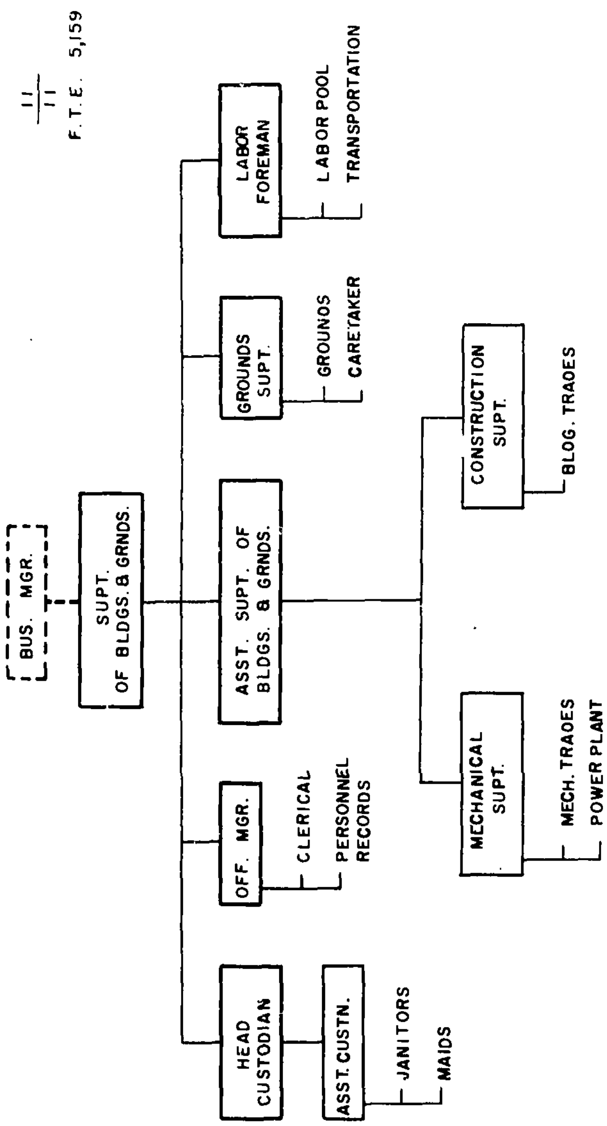
I/7
F T. E 4,577
PHYS. PL. EMPLOYEES 81
DIRECTOR OF FINANCE
DIRECTOR OF PHYSICAL PLANT
SPACE PLANNING ANALYST
OFFICE
MAINTENANCE ENGINEER
PAINTING & GLAZING
WELDING & SHEET METAL
CARPENTRY
SURVEYING & DRAFTING
GENERAL SERVICE
TRUCKING & MAIL DELIVERY
CUSTODIAL SERVICE
WINDOW SHA. KEY & LOCKS
FIRE EXT. EQUIPT.
GROUNDS SUPERINTENDENT
GROUNDS & ROADS
TRASH DISPOSAL
CAMPUS POLICE
WATCHMAN SERVICE
MECHANICAL ENGINEER
PLUMBING & HEATING
ELECTRICAL
POWER PLANT
AIR COND. & CONTROLS


F.T.E. 4,957
8
BUS. MGR.
DIRECTOR OF PHYS.PLANT & CAMPUS ARCH.
SEC.
ASST. DIRECTOR PHYS. PL.
CH. ENGR.
CUSTODIAL SUPERV.
GROUNDS SUPERV.
OFF CAMPUS BLDG. SUPERV.
BLDG. MAINT. SUPERV.
OFFICE MANAGER
ACCOUNTS
CLERICAL
SECRETARIAL POLICY ONLY
ASST. CAMPUS ARCH.
CONST. SUPERV.
SR. ARCH.
FURNITURE ANALYST
LANDSCAPE ARCH.

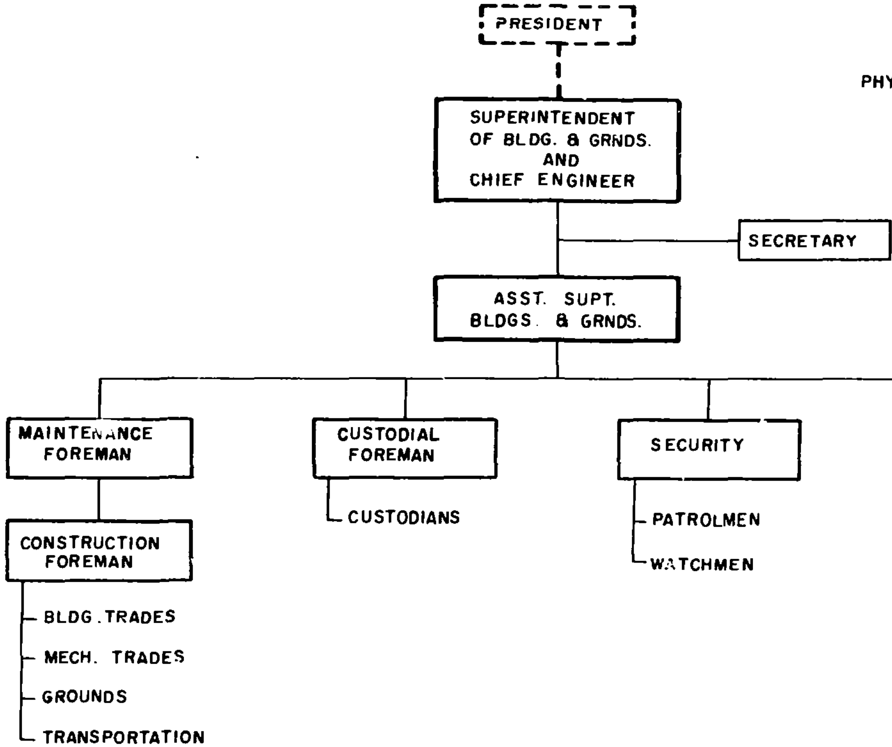

BUS. MGR.
SUPT. OF BLDGS. & GRNDS.
STENOGRAPHER
1/9
F.T.E. 4,983
PHYS. PL. EMPLOYEES 115
ASST. TO SUPT. MAINT. & REMODEL
ADM. ASSTS.
CLERICAL
GENERAL FOREMAN
BLDG. TRADES
MECH. TRADES
GROUNDS
TRANSPORTATION
ASST. TO SUPT. PPTY. DEVELOPMENT
ADM. ASST.
DRAFTSMEN
ASST. TO SUPT. SANITATION, SECURITY
CUSTODIAL
WATCHMEN
VEHICLES
ASST. TO SUPT. POWER PLANT OPR.
ASST. CH. ENGR.
PLANT OPERATORS



11
10
F. T. E. 5,000
PHYS. PL. EMPLOYEES 56

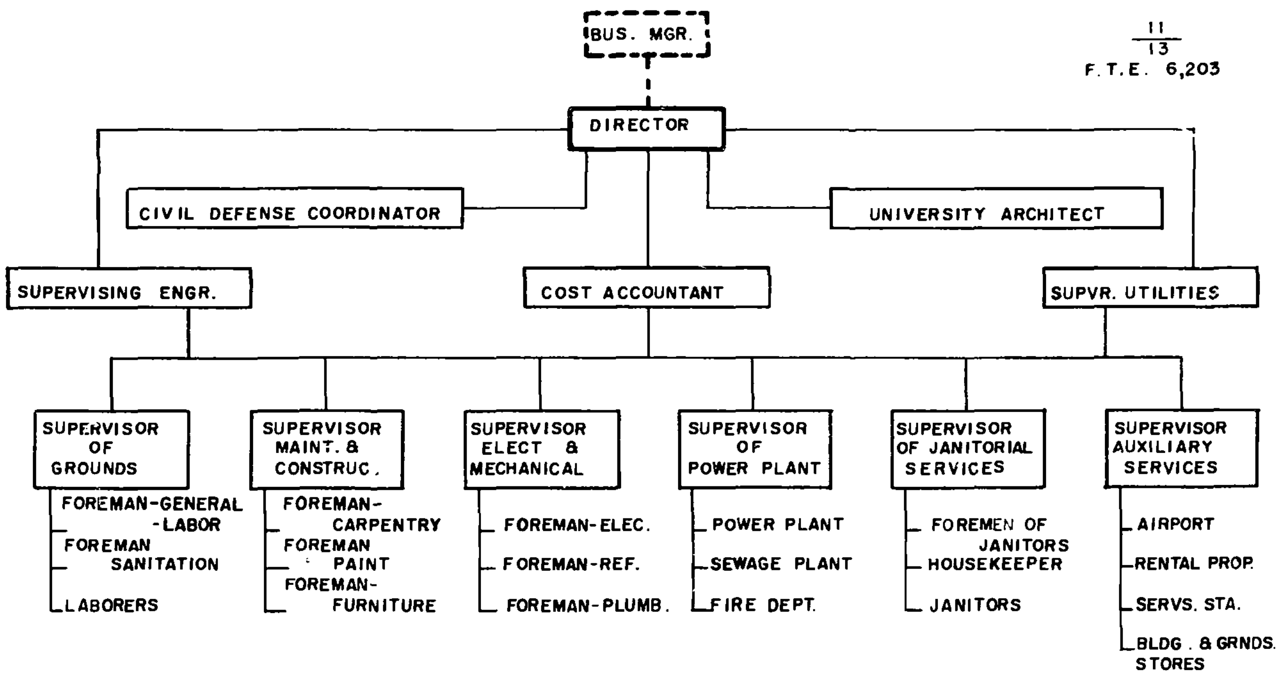


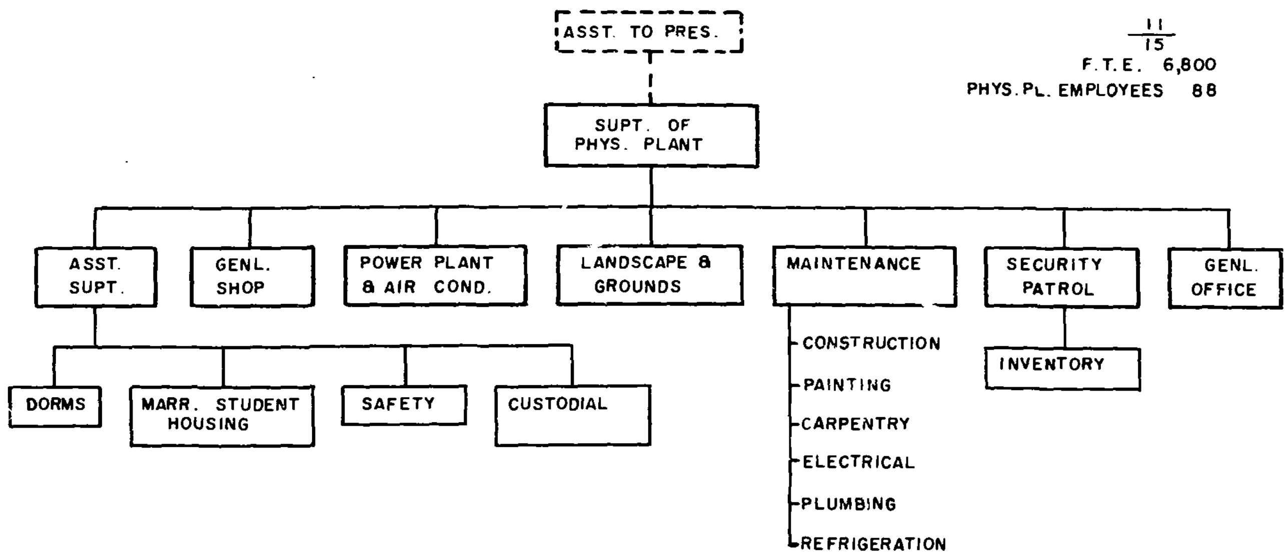
11/11
F.T.E. 5,159
BUS. MGR.
SUPT. OF BLDGS. & GRNDS.
HEAD CUSTODIAN
ASST. CUSTN.
JANITORS
MAIDS
OFF. MGR.
CLERICAL
PERSONNEL RECORDS
ASST. SUPT. OF BLDGS. & GRNDS.
MECHANICAL SUPT.
MECH. TRADES
POWER PLANT
CONSTRUCTION SUPT.
BLDG. TRADES
GROUNDS SUPT.
GROUNDS
CARETAKER
LABOR FOREMAN
LABOR POOL
TRANSPORTATION

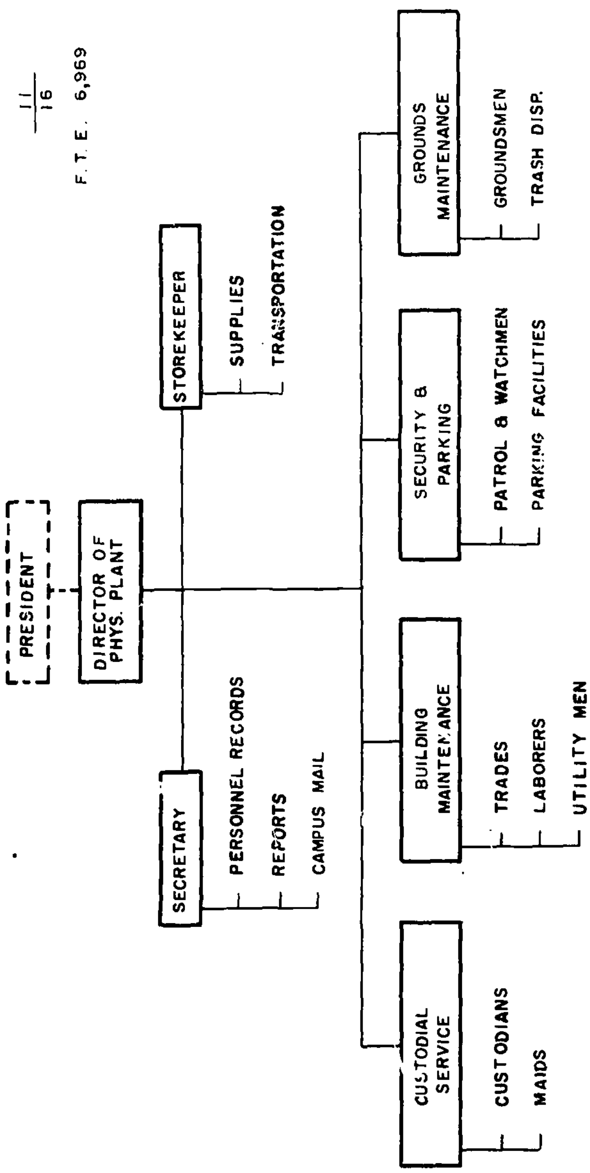


11/12
F.T.E. 5,571
PHYS. PL. EMPLOYEES 47

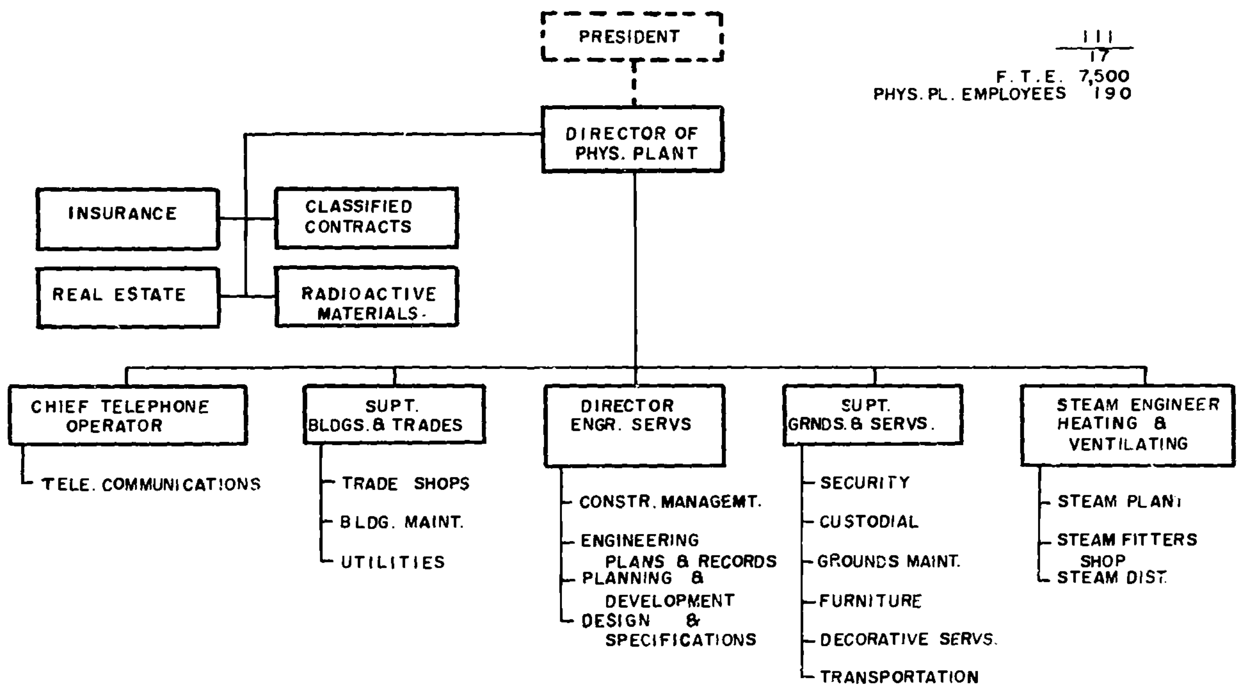
$\frac{11}{13}$
F.T.E. 6,203

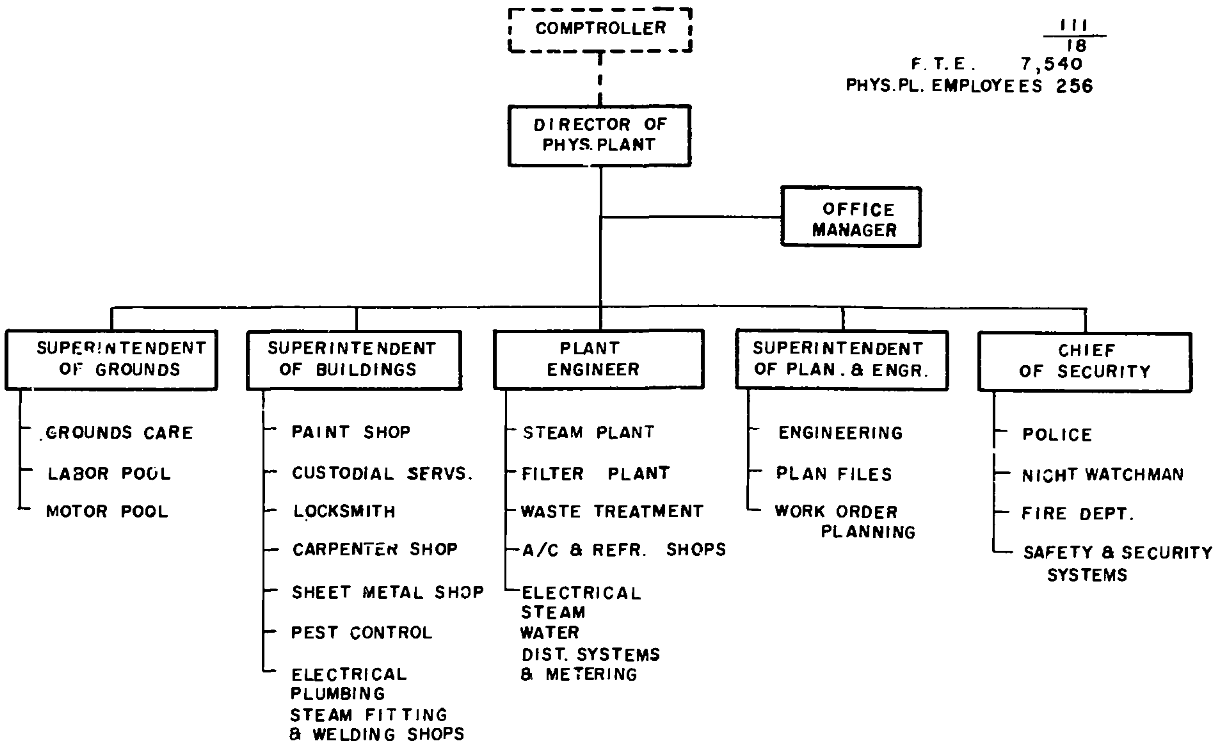


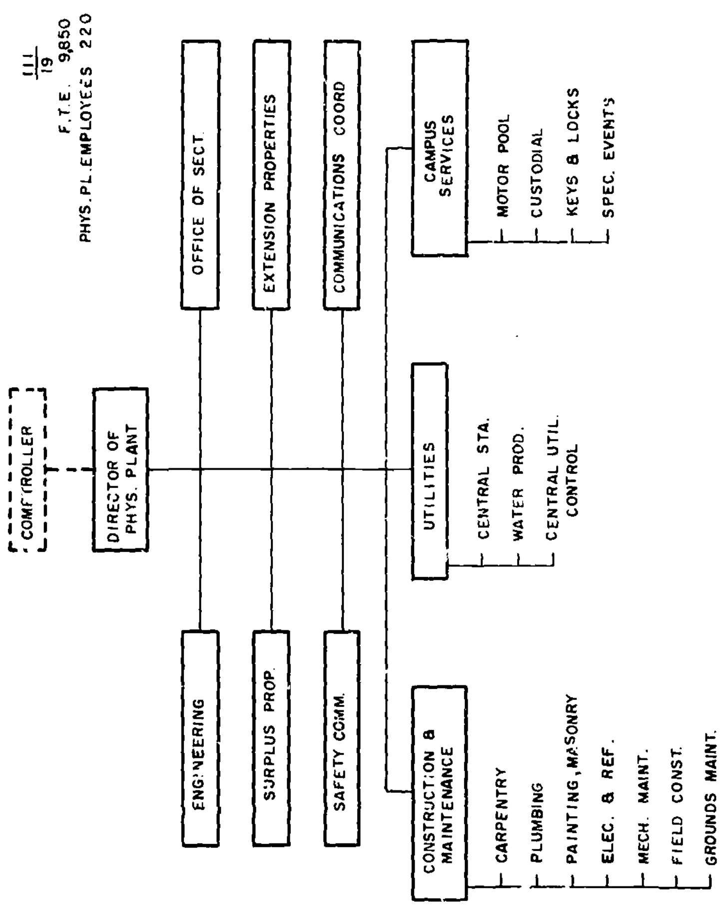

ASST. TO PRES.
SUPT. OF PHYS. PLANT
11/15
F.T.E. 6,800
PHYS.PL. EMPLOYEES 88
ASST. SUPT.
GENL. SHOP
POWER PLANT & AIR COND.
LANDSCAPE & GROUNDS
MAINTENANCE
SECURITY PATROL
GENL. OFFICE
DORMS
MARR. STUDENT HOUSING
SAFETY
CUSTODIAL
CONSTRUCTION
PAINTING
CARPENTRY
ELECTRICAL
PLUMBING
REFRIGERATION
INVENTORY

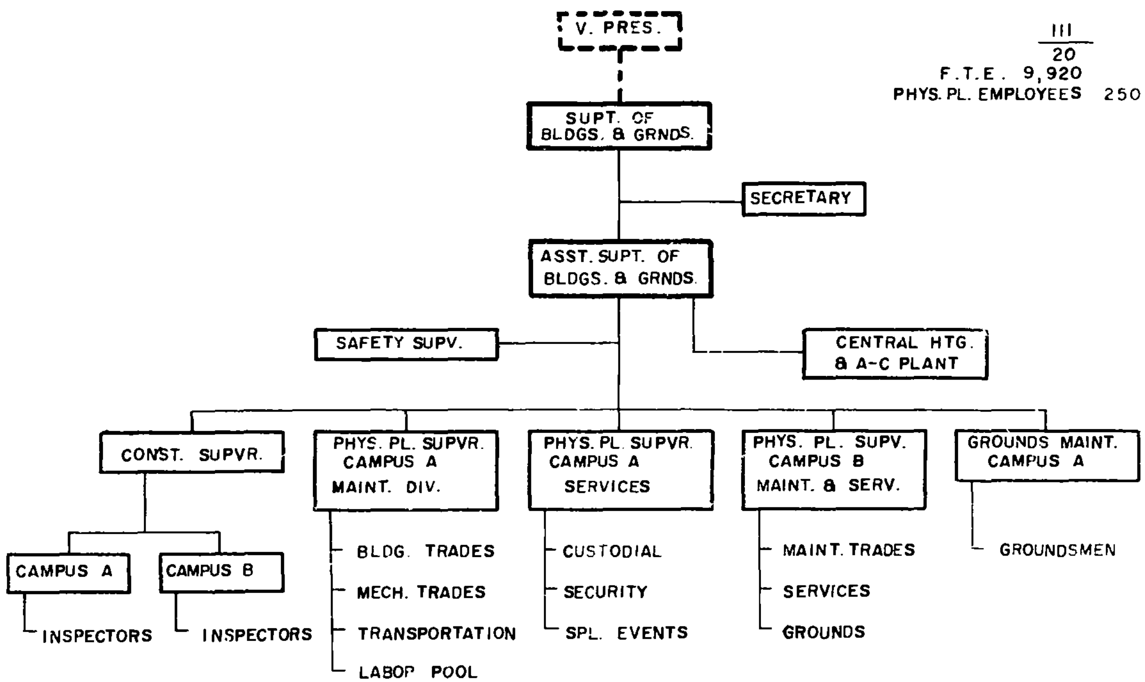


11/16
F.T.E. 6,969
PRESIDENT
DIRECTOR OF PHYS. PLANT
SECRETARY
PERSONNEL RECORDS
REPORTS
CAMPUS MAIL
STOREKEEPER
SUPPLIES
TRANSPORTATION
CUSTODIAL SERVICE
CUSTODIANS
MAIDS
BUILDING MAINTENANCE
TRADES
LABORERS
UTILITY MEN
SECURITY & PARKING
PATROL & WATCHMEN
PARKING FACILITIES
GROUNDS MAINTENANCE
GROUNDSMEN
TRASH DISP.

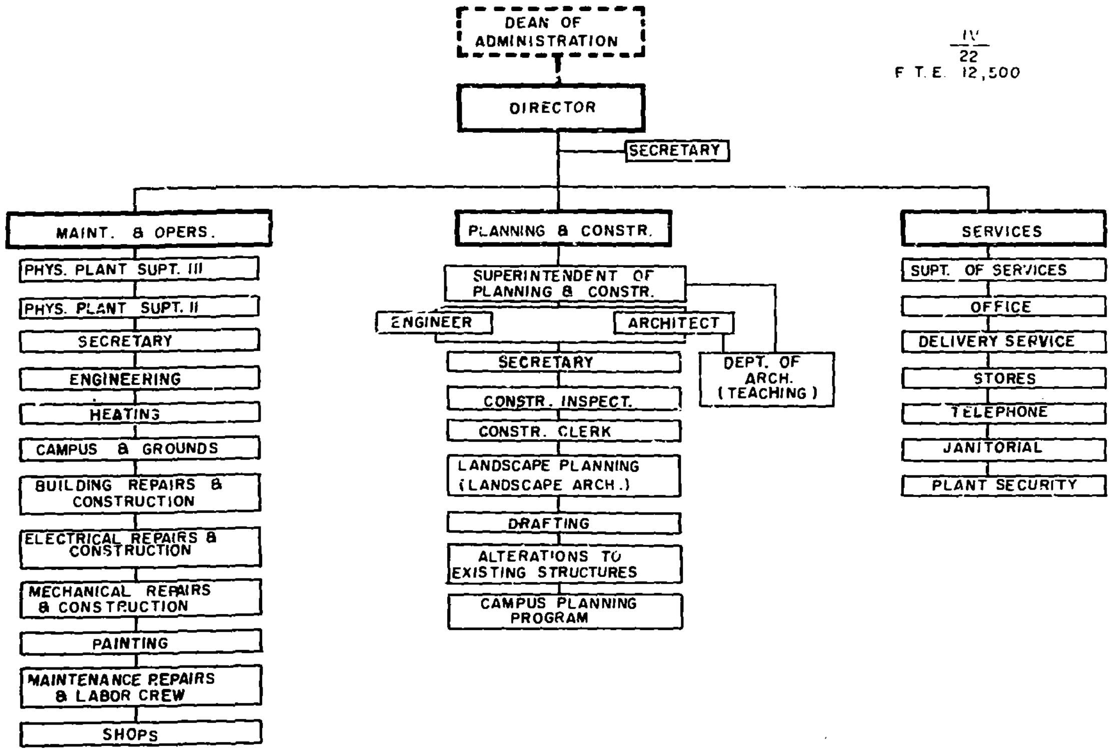

111
17
F.T.E. 7,500
PHYS. PL. EMPLOYEES 190
PRESIDENT
DIRECTOR OF PHYS. PLANT
INSURANCE
CLASSIFIED CONTRACTS
REAL ESTATE
RADIOACTIVE MATERIALS
CHIEF TELEPHONE OPERATOR
TELE. COMMUNICATIONS
SUPT. BLDGS. & TRADES
TRADE SHOPS
BLDG. MAINT.
UTILITIES
DIRECTOR ENGR. SERVS
CONSTR. MANAGEMT.
ENGINEERING PLANS & RECORDS
PLANNING & DEVELOPMENT
DESIGN & SPECIFICATIONS
SUPT. GRNDS. & SERVS.
SECURITY
CUSTODIAL
GROUNDS MAINT.
FURNITURE
DECORATIVE SERVS.
TRANSPORTATION
STEAM ENGINEER HEATING & VENTILATING
STEAM PLANT
STEAM FITTERS SHOP
STEAM DIST.

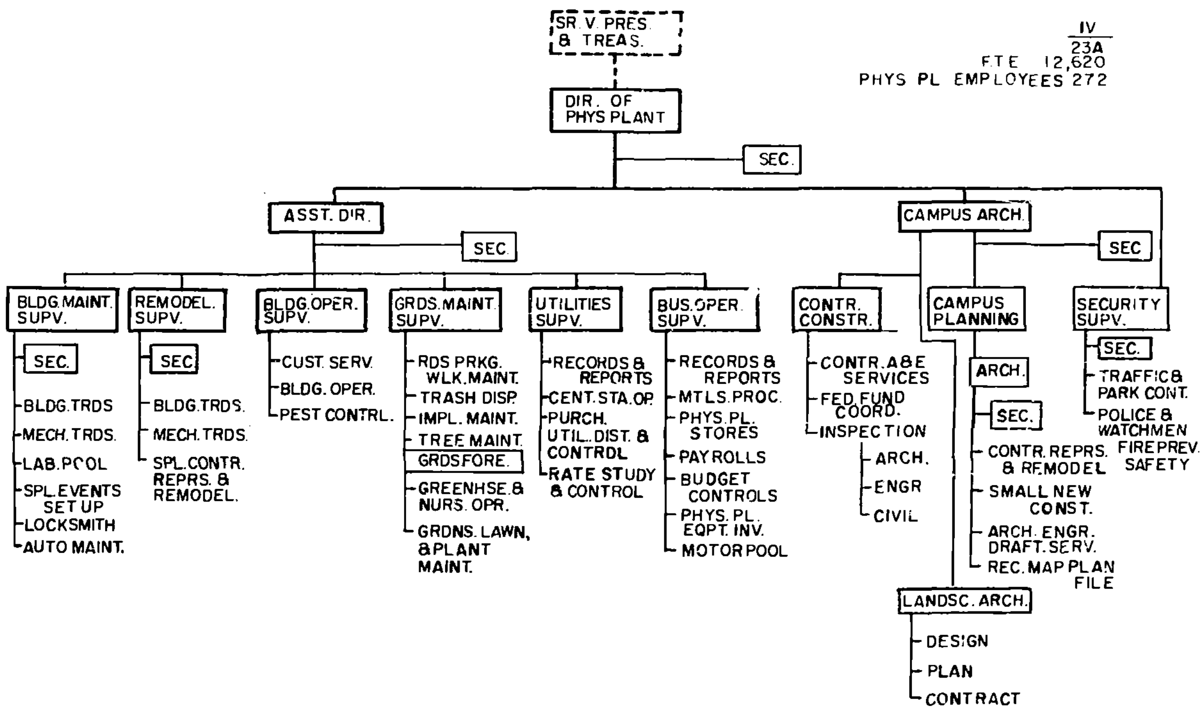

111
18
F. T. E. 7,540
PHYS.PL. EMPLOYEES 256
COMPTROLLER
DIRECTOR OF PHYS. PLANT
OFFICE MANAGER
SUPERINTENDENT OF GROUNDS
GROUNDS CARE
LABOR POOL
MOTOR POOL
SUPERINTENDENT OF BUILDINGS
PAINT SHOP
CUSTODIAL SERVS.
LOCKSMITH
CARPENTER SHOP
SHEET METAL SHOP
PEST CONTROL
ELECTRICAL PLUMBING STEAM FITTING & WELDING SHOPS
PLANT ENGINEER
STEAM PLANT
FILTER PLANT
WASTE TREATMENT
A/C & REFR. SHOPS
ELECTRICAL STEAM WATER DIST. SYSTEMS & METERING
SUPERINTENDENT OF PLAN. & ENGR.
ENGINEERING
PLAN FILES
WORK ORDER PLANNING
CHIEF OF SECURITY
POLICE
NIGHT WATCHMAN
FIRE DEPT.
SAFETY & SECURITY SYSTEMS

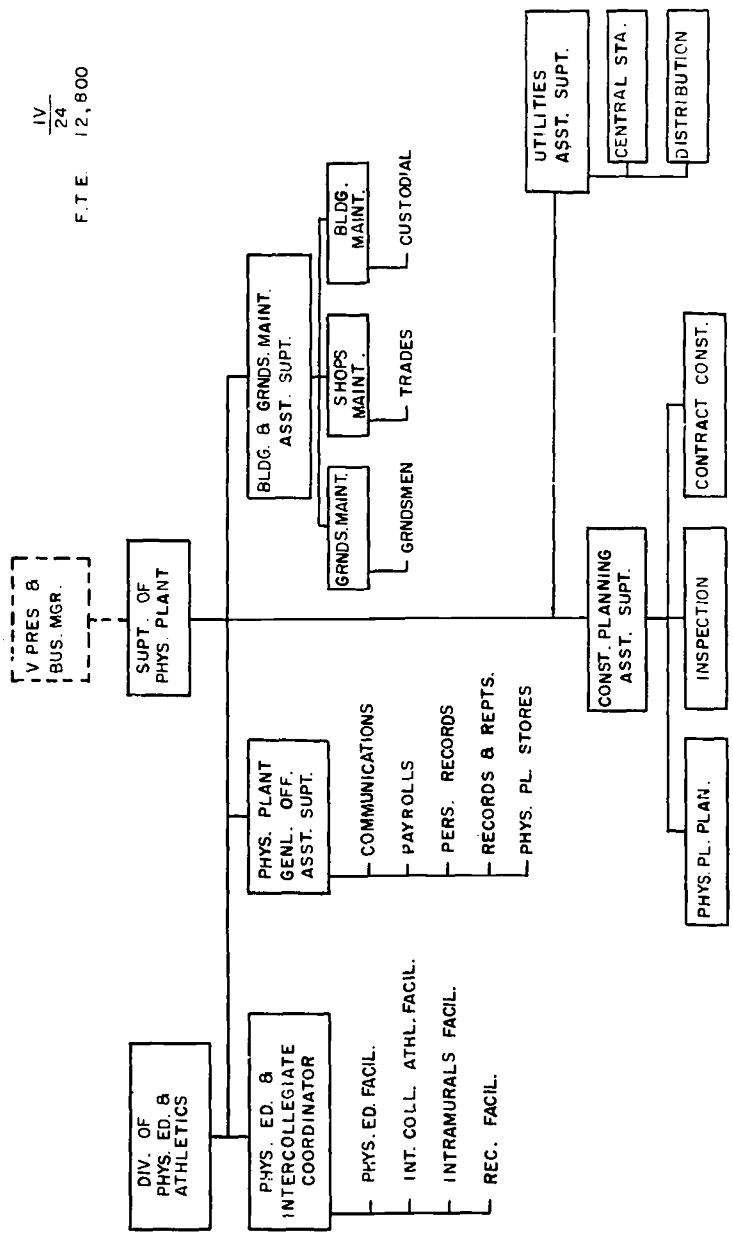

III
19
F.T.E. 9,850
PHYS. PL. EMPLOYEES 220
COMPTROLLER
DIRECTOR OF PHYS. PLANT
ENGINEERING
OFFICE OF SECT.
SURPLUS PROP.
EXTENSION PROPERTIES
SAFETY COMM.
COMMUNICATIONS COORD
CONSTRUCTION & MAINTENANCE
CARPENTRY
PLUMBING
PAINTING, MASONRY
ELEC. & REF.
MECH. MAINT.
FIELD CONST.
GROUNDS MAINT.
UTILITIES
CENTRAL STA.
WATER PROD.
CENTRAL UTIL. CONTROL
CAMPUS SERVICES
MOTOR POOL
CUSTODIAL
KEYS & LOCKS
SPEC. EVENTS


III
20
F.T.E. 9,920
PHYS. PL. EMPLOYEES 250
V. PRES.
SUPT. OF BLDGS. & GRNDS.
SECRETARY
ASST. SUPT. OF BLDGS. & GRNDS.
SAFETY SUPV.
CENTRAL HTG. & A-C PLANT
CONST. SUPVR.
CAMPUS A
INSPECTORS
CAMPUS B
INSPECTORS
PHYS. PL. SUPVR. CAMPUS A MAINT. DIV.
BLDG. TRADES
MECH. TRADES
TRANSPORTATION
LABOP POOL
PHYS. PL. SUPVR. CAMPUS A SERVICES
CUSTODIAL
SECURITY
SPL. EVENTS
PHYS. PL. SUPV. CAMPUS B MAINT. & SERV.
MAINT. TRADES
SERVICES
GROUNDS
GROUNDS MAINT. CAMPUS A
GROUNDSMEN

IV
22
F.T.E. 12,500




IV
23A
FTE 12,620
PHYS PL EMPLOYEES 272
SR. V. PRES. & TREAS.
DIR. OF PHYS PLANT
SEC.
ASST. DIR.
SEC.
CAMPUS ARCH.
SEC
BLDG.MAINT. SUPV.
SEC.
BLDG.TRDS
MECH.TRDS.
LAB.POOL
SPL.EVENTS SET UP
LOCKSMITH
AUTO MAINT.
REMODEL. SUPV.
SEC
BLDG.TRDS.
MECH.TRDS.
SPL.CONTR. REPRS. & REMODEL.
BLDG.OPER. SUPV.
CUST. SERV.
BLDG. OPER.
PEST CONTRL.
GRDS.MAINT. SUPV.
RDS PRKG. WLK.MAINT.
TRASH DISP.
IMPL. MAINT.
TREE MAINT.
GRDSFORE.
GREENHSE.& NURS. OPR.
GRDNS. LAWN, & PLANT MAINT.
UTILITIES SUPV.
RECORDS & REPORTS
CENT. STA. OP.
PURCH.
UTIL. DIST. & CONTROL
RATE STUDY & CONTROL
BUS.OPER. SUPV.
RECORDS & REPORTS
MTLS.PROC.
PHYS.PL. STORES
PAYROLLS
BUDGET CONTROLS
PHYS. PL. EQPT. INV.
MOTOR POOL
CONTR. CONSTR.
CONTR. A&E SERVICES
FED.FUND COORD.
INSPECTION
ARCH.
ENGR
CIVIL
CAMPUS PLANNING
ARCH.
SEC.
CONTR. REPRS. & REMODEL
SMALL NEW CONST.
ARCH. ENGR. DRAFT. SERV.
REC. MAP PLAN FILE
LANDSC. ARCH.
DESIGN
PLAN
CONTRACT
SECURITY SUPV.
SEC.
TRAFFIC & PARK CONT.
POLICE & WATCHMEN
FIRE PREV. SAFETY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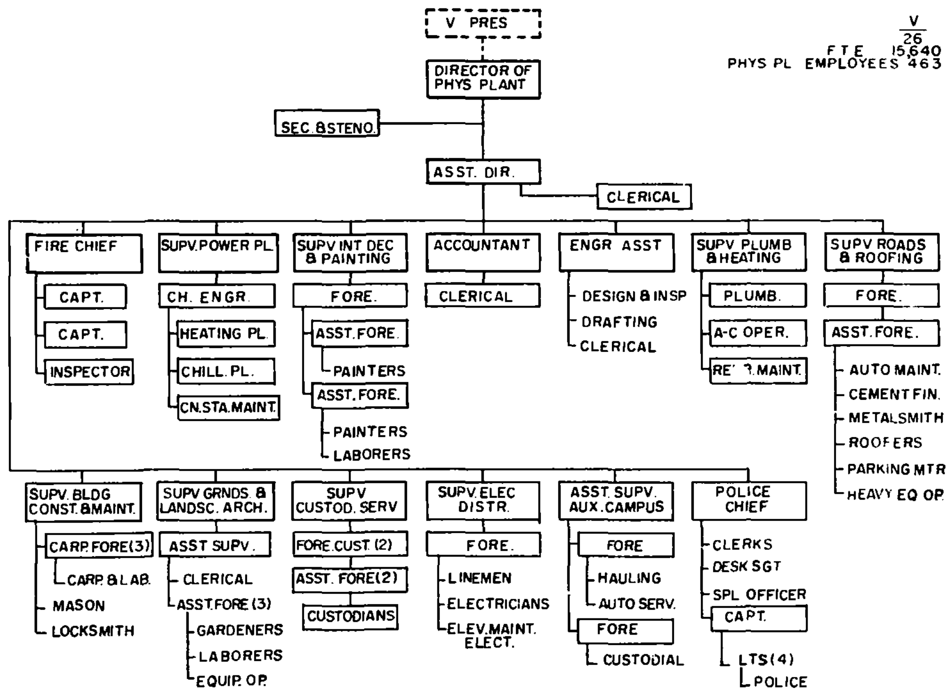
24
F.T.E. 12,800
V PRES & BUS. MGR.
SUPT. OF PHYS. PLANT
DIV. OF PHYS. ED. & ATHLETICS
PHYS. ED. & INTERCOLLEGIATE COORDINATOR
PHYS. ED. FACIL.
INT. COLL. ATHL. FACIL.
INTRAMURALS FACIL.
REC. FACIL.
PHYS. PLANT GENL. OFF. ASST. SUPT.
COMMUNICATIONS
PAYROLLS
PERS. RECORDS
RECORDS & REPTS.
PHYS. PL. STORES
BLDG. & GRNDS. MAINT. ASST. SUPT.
GRNDS. MAINT.
GRNDSMEN
SHOPS MAINT.
TRADES
BLDG. MAINT.
CUSTODIAL
CONST. PLANNING ASST. SUPT.
PHYS. PL. PLAN.
INSPECTION
CONTRACT CONST.
UTILITIES ASST. SUPT.
CENTRAL STA.
DISTRIBUTION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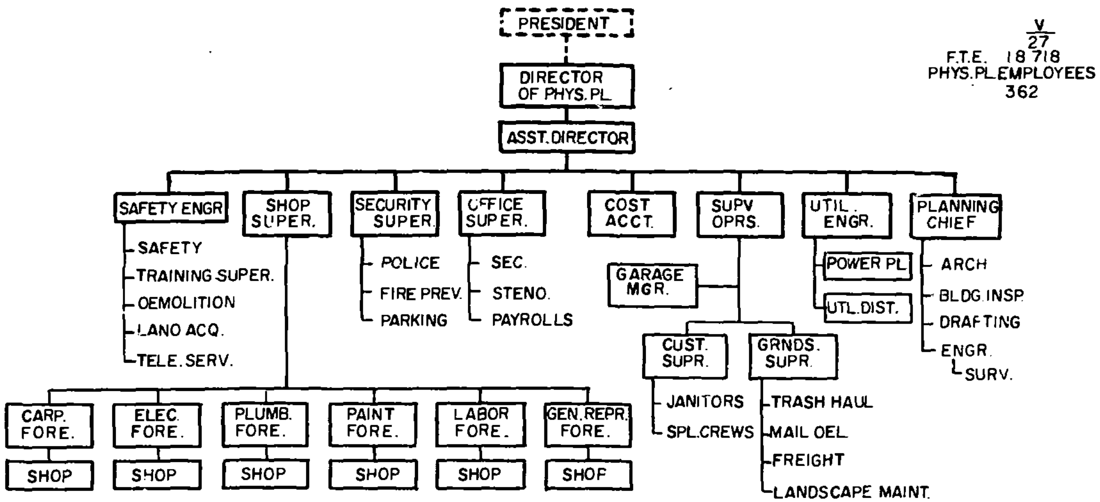
26
PHYS PL FTE 15,640
EMPLOYEES 463
V PRES
DIRECTOR OF PHYS PLANT
SEC & STENO.
ASST. DIR.
CLERICAL
FIRE CHIEF
CAPT.
CAPT.
INSPECTOR
SUPV.POWER PL.
CH. ENGR.
HEATING PL.
CHILL. PL.
CN.STA.MAINT.
SUPV INT DEC & PAINTING
FORE.
ASST. FORE.
PAINTERS
ASST. FORE.
PAINTERS
LABORERS
ACCOUNTANT
CLERICAL
ENGR ASST
DESIGN & INSP
DRAFTING
CLERICAL
SUPV PLUMB & HEATING
PLUMB.
A-C OPER.
SUPV ROADS & ROOFING
FORE.
ASST. FORE.
AUTO MAINT.
CEMENT FIN.
METALSMITH
ROOFERS
PARKING MTR
HEAVY EQ OP.
SUPV. BLDG CONST. & MAINT.
CARP. FORE(3)
CARP. & LAB.
MASON
LOCKSMITH
SUPV GRNDS. & LANDSC. ARCH.
ASST SUPV.
CLERICAL
ASST. FORE (3)
GARDENERS
LABORERS
EQUIP. OP.
SUPV CUSTOD. SERV
FORE. CUST. (2)
ASST. FORE(2)
CUSTODIANS
SUPV. ELEC DISTR.
FORE.
LINEMEN
ELECTRICIANS
ELEV. MAINT. ELECT.
ASST. SUPV. AUX. CAMPUS
FORE
HAULING
AUTO SERV.
FORE
CUSTODIAL
POLICE CHIEF
CLERKS
DESK SGT
SPL OFFICER
CAPT.
LTS (4)
POLICE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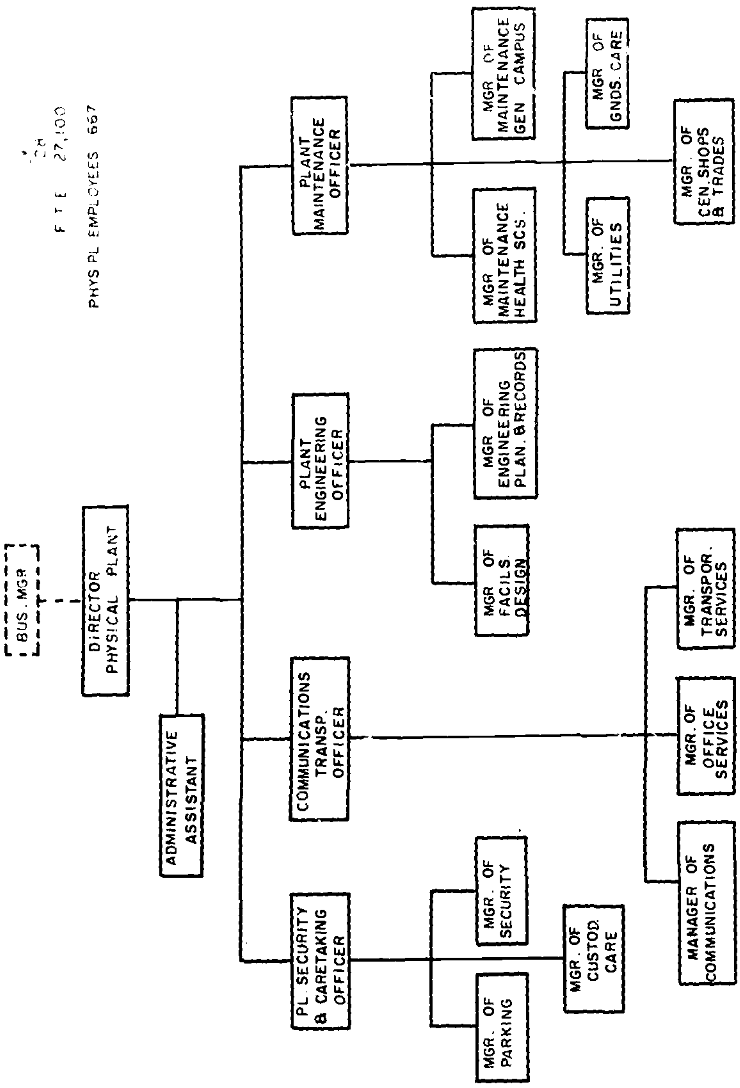
27
F.T.E. 18 718
PHYS.PL.EMPLOYEES
362
PRESIDENT
DIRECTOR OF PHYS. PL.
ASST. DIRECTOR
SAFETY ENGR
SAFETY
TRAINING SUPER.
OEMOLITION
LANO ACQ.
TELE. SERV.
SHOP SUPER.
CARP. FORE.
ELEC. FORE.
PLUMB. FORE.
PAINT FORE.
LABOR FORE.
GEN. REPR. FORE.
SHOP
SHOP
SHOP
SHOP
SHOP
SHOF
SECURITY SUPER.
POLICE
FIRE PREV.
PARKING
OFFICE SUPER.
SEC.
STENO.
PAYROLLS
COST ACCT.
SUPV OPRS.
GARAGE MGR.
CUST. SUPR.
JANITORS
SPL. CREWS
GRNDS. SUPR.
TRASH HAUL
MAIL OEL
FREIGHT
LANDSCAPE MAINT.
UTIL. ENGR.
POWER PL.
UTL. DIST.
PLANNING CHIEF
ARCH
BLDG. INSP.
DRAFTING
ENGR.
SURV.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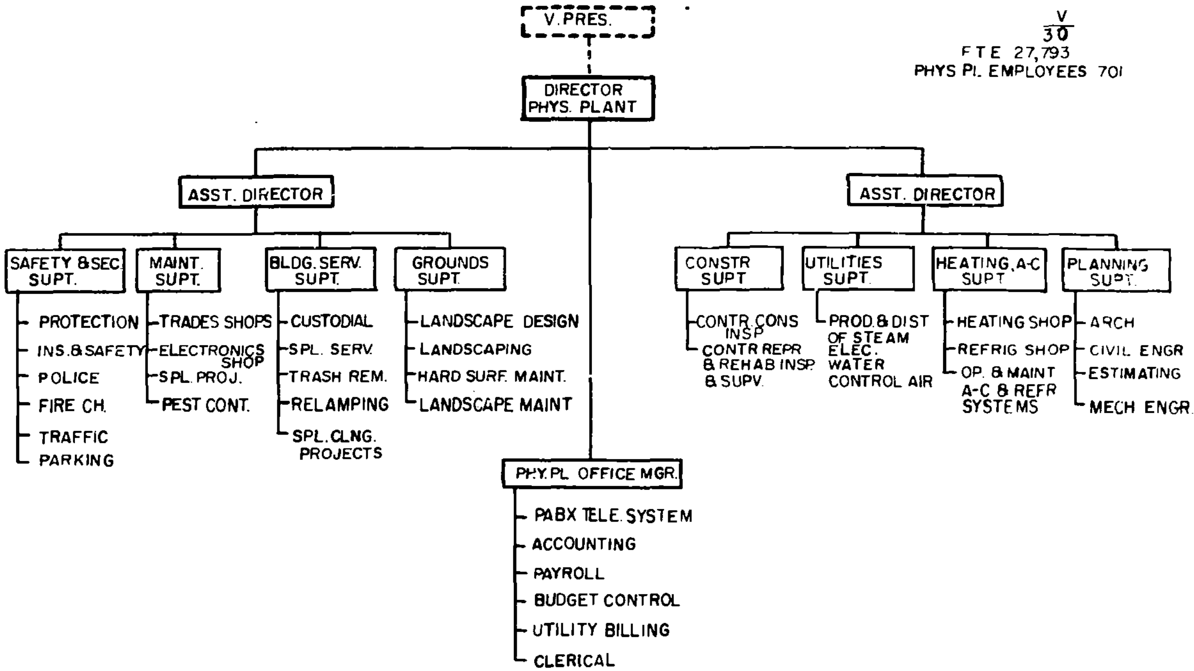
BUS. MGR.
DIRECTOR PHYSICAL PLANT
ADMINISTRATIVE ASSISTANT
PL. SECURITY & CARETAKING OFFICER
COMMUNICATIONS TRANSP. OFFICER
PLANT ENGINEERING OFFICER
PLANT MAINTENANCE OFFICER
MGR. OF PARKING
MGR. OF SECURITY
MGR. OF CUSTOD. CARE
MANAGER OF COMMUNICATIONS
MGR. OF OFFICE SERVICES
MGR. OF TRANSPOR. SERVICES
MGR. OF FACILS. DESIGN
MGR. OF ENGINEERING PLAN. & RECORDS
MGR. OF MAINTENANCE HEALTH SCS.
MGR. OF MAINTENANCE GEN. CAMPUS
MGR. OF UTILITIES
MGR. OF GNDS. CARE
MGR. OF CEN. SHOPS & TRADES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30
FTE 27,793
PHYS PL. EMPLOYEES 701
V. PRES.
DIRECTOR PHYS. PLANT
ASST. DIRECTOR
ASST. DIRECTOR
SAFETY & SEC. SUPT.
PROTECTION
INS. & SAFETY
POLICE
FIRE CH.
TRAFFIC
PARKING
MAINT. SUPT.
TRADES SHOPS
ELECTRONICS SHOP
SPL. PROJ.
PEST CONT.
BLDG. SERV. SUPT.
CUSTODIAL
SPL. SERV.
TRASH REM.
RELAMPING
SPL. CLNG. PROJECTS
GROUNDS SUPT.
LANDSCAPE DESIGN
LANDSCAPING
HARD SURF. MAINT.
LANDSCAPE MAINT
PHY. PL. OFFICE MGR.
PABX TELE. SYSTEM
ACCOUNTING
PAYROLL
BUDGET CONTROL
UTILITY BILLING
CLERICAL
CONSTR SUPT
CONTR. CONS INSP
CONTR REPR & REHAB INSP. & SUPV.
UTILITIES SUPT.
PROD. & DIST OF STEAM
ELEC.
WATER
CONTROL AIR
HEATING, A-C SUPT
HEATING SHOP
REFRIG SHOP
OP. & MAINT A-C & REFR SYSTEMS
PLANNING SUPT.
ARCH
CIVIL ENGR
ESTIMATING
MECH ENGR.

Individual reactions to information given here are almost certain to vary widely. These variations are almost with equal certainty to be a reflection of different circumstances of individuals rather than fundamental disagreements. In any event, the information is presented for individual study with the intention that it may contain some helpful and thought provoking suggestions.

1. Because of the demand for growth in every institution, there is a recent increase in campus planning effort but fewer than half of the physical plant departments participate in design and planning of facilities.

2. Even though many contract maintenance services are currently available, there is still no extensive use of them in universities and colleges.

3. There are some physical plant departments now providing highly technical services such as electronic and instrument repairs, elevator maintenance, business machine repairs, research and prototype shops where these were almost non-existent 10 years ago.

4. Approximately half of the institutions separate maintenance forces into two general categories of building trades and mechanical trades, each under separate supervision. The other half combines them under single line supervision. This appears to be an area of management that has not been sufficiently mastered as to produce a singularly preferred arrangement.

5. There appears to be a trend toward removal of campus security from physical plant jurisdiction.

Some of the conclusions that may be drawn from this survey are:

1. There is no apparent relationship between the organizational charts and school sponsorship (i.e. state, church, private, other).

2. A large majority of the physical plant administrators report to a university official whose primary concern is finance. Only a small per cent report to the senior university administrator.

3. There are some readily available and measurable change indices in university growth patterns, but the ones used here do not correlate with any specific patterns of organizational structure.

4. As long as organizational structure continues to be framed around people, and more specifically around individuals, it is not likely that a generally applicable or standard organization chart will be possible.

As a general summary and conclusion, it is indicated that the demand for technical and professional competence in physical plant administration is greater than ever before. These demands are accentuating the managerial and administrative phases. If present trends continue, the physical plant administrators of the future will be more oriented to the management of people and money, and will supplement his needs for technical competence by employment of specialists. In any event, the future in this field is certain to be dynamic, interesting and a tremendous challenge.

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SURVEY OF BUILDING MANAGEMENT CENTERS OF NORTH AMERICAN UNIVERSITIES

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AND
G. M. GAUTHIER

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G. M. Gauthier, Engineer, is chief automation engineer with Surveyer, Nenniger, Chenevert Inc., a major international engineering consultant with its head office in Montreal. Mr. Gauthier received his Bachelor of Arts degree from University of Montreal in 1951, and graduated from McGill University in 1956 with a B.A. Sc. degree, majoring in communications. Subsequently, Mr. Gauthier held many responsible positions allied to the field of automation. In 1966 he joined the consulting firm of Surveyer, Nenniger, Chenevert, Inc. to set up an automation group. He is a member of numerous engineering societies.

Editor's Note: This paper was obtained for publication through the courtesy and thoughtfulness of O. Jean Gratton, Directeur, Service Technique des Immedubles, Universite de Montreal, C.P. 6128. Montreal 3, Quebec, Canada. We believe that Mr. Gratton was responsible for having the compilation made and for forwarding the initial documents to the editor. We are grateful for the opportunity to publish this survey.

INTRODUCTION

The growing complexity of mechanical, electrical and auxiliary services of buildings, as a consequence of the requirements of usage, comfort and safety of the premises, has created a great number of specialized tasks to insure the best possible use and control of the required equipment. The proper organization and performance of these various tasks may be improvised manually until such time when the magnitude and complexity of the installations make this operation uneconomical and inefficient. It is then that the application of the principles of automation become essential in order to insure the optimum operation of the systems.

Nowadays, automation is in general use in the great majority of commercial and industrial complexes where the most efficient and economical operations are the basic criteria for a successful venture.

Automation has also found favor in the public sector, such as governmental and institutional complexes. However, the importance of this trend is not too well known.

University of Montreal authorities are deeply interested in the subject of automating its campus and it was thought that some knowledge on this subject would be helpful in arriving at a decision. To this end, they decided to make a survey among North American universities, members of APPA. A questionnaire was sent to more than 600 members, requesting information on the size of physical plant, number of buildings involved, the type of services and controls, the number of monitor and control points, economical results, etc.

RESULTS OF SURVEY

Response from APPA membership was very encouraging and we take this opportunity to convey our gratitude.

A total of 223 answers were received. Their compilation and analysis gave the following results:

52	(23%)	institutions are equipped with a centralized control system.
11	(5 %)	institutions are presently installing a centralized system.
74	(33%)	institutions have undertaken a feasibility study on the subject and are planning in view of its implementation.
18	(8 %)	institutions indicated a genuine interest and propose to undertake a study.
68	(31%)	institutions have answered negatively. This group however, comprises the smaller institutions and generally do not have centralized services.

As a complement to this survey, we have compiled separate lists of 13 Canadian and 75 American universities presently enjoying the benefits of a centralized control system. Among this group are many members of APPA, from whom no answer was received.

Thus, from a total of 311 universities, 140 possess a "building management center", 11 have reached the installation stage, 92 have definite plans or are genuinely interested; only 68, for the specific reasons mentioned above, are not interested at this time.

A further regrouping of the answers, on the basis of size and equipment, has been made, in an attempt to show more clearly the actual trend to automation in university complexes.

Group I comprises universities having centralized services coordinated through a centralized control system or management center.

GROUP I
CENTRALIZED SERVICES–BUILDING MANAGEMENT CENTER

Total Area Million Sq. Ft.	Institutions No.	%	Computer	Control Points
Up to 1/2 M.	3	(5.5)	-	Less than 1000
1/2 M. to 1 M.	9	(17)	-	Less than 1000
1 M. to 2 M.	14	(27)	2	1000
2 M. to 3 M.	8	(15.5)	1	1300 Average
3 M. to 4 M.	8	(15.5)	2	1500 Average
4 M. +	10	(19)	1	1500 Average
	52		6	

To this group should be added 75 American and 13 Canadian universities, not included above, but similarly equipped. Lack of information as to size of campus did not permit their inclusion in the above table.

There is a definite relation here between the size of campus and the use of computerized automation. The six campuses so equipped have a floor area of over one million square feet. This figure has been confirmed by equipment manufacturers as the present day economical limit.

The total number of control points varies widely among similar size campuses; it obviously depends on the number of buildings actually connected to the control network and the specific building services monitored and controlled. A study of the survey shows:

Control Point Range	Institutions	%
Up to 1000	25	48%
1000–2000	18	34%
2000–4000	4	8%
4000–10000	2	4%
10000 +	3	6%

The survey indicated an average of 30 buildings on campus, one third of which are controlled from a building management center, the remainder being gradually integrated to the control system as soon as yearly budgets will permit.

With regard to benefits resulting from automation, 80% of those who answered to this question report savings of 10% to 30% in such areas as operation and maintenance personnel, fuel and electrical bills and an average reduction of 15% in emergency calls. One particularly enthusiastic report indicated that the investment was paid in three years and expects total savings to reach $ 1 million in 10 years.

Group II includes university complexes equipped with centralized services but without management center.

GROUP II

CENTRALIZED SERVICES–WITHOUT MANAGEMENT CENTER

Total Area	Institutions		Proposed Installation of Management Center			Degree of Interest	
Million Sq. Ft.	No.	%	Under Construction	Planned	Interested	No.	%
Up to 1/2 M.	4	(4)	1	1	1	2	50
1/2 M. to 1 M.	22	(22)	2	9	1	10	55
1 M. to 2 M.	29	(29)	-	12	5	12	59
2 M. to 3 M.	14	(14)	2	6	3	3	79
3 M. to 4 M.	9	(9)	-	6	3	-	100
4 M. +	22	(22)	3	13	-	6	73
	100		8	47	12	33	67

Comments

It is obvious from this tabulation that the degree of interest grows with the size of the physical installations. Note that of 33 negative answers, 24 are from small campuses of less than one and a half million sq. ft.

Group III includes 70 institutions equipped with local building services, and no management center.

GROUP III

NON CENTRALIZED BUILDING SERVICES–NO MANAGEMENT CENTER

Total Areq	Institutions		Proposes Installation of Management Center			Degree of Interest	
Million Sq. Ft.	No.	%	Under Construction	Planned	Interested	No.	%
Up to 1/2 M.	12	(17)	-	2	3	7	41
1/2 M. to 1 M.	21	(30)	1	7	1	12	43
1 M. to 2 M.	19	(27)	-	9	1	9	53
2 M. to 3 M.	9	(13)	1	4	-	4	55
3 M. to 4 M.	3	(4)	-	3	-	-	100
4 M. +	6	(9)	1	2	1	2	67
	70		3	27	6	34	51

It is understandable that the existence of localized mechanical and electrical services is not conducive to automation because of its more expensive installation costs, which in turn inhibits possible savings, specially for the smaller installations. It is remarkable that in spite of these objections, more than 50% are either thinking about it or have taken initial steps towards its implementation.

CONCLUSIONS

From an analysis of the answers to the present survey, the following conclusions can be drawn:

a) Existence of a definite trend to automation of building services of University Campuses.

b) Trend is obviously stronger on larger campuses i.e. over one million sq. ft., as expressed by the so-called degree of interest, tabulated in Groups II and III.

c) For economical reasons, computer application is restricted to the larger installations, upwards of 2 million sq. ft., where the number of monitoring and control points justify its use.

d) In the majority of cases reported, rate of return on investment was favorable; answers indicate savings of 10% to 30% in such areas as operation and maintenance personnel, fuel and electrical billing. In addition, there is a marked decrease (15%) in the number of emergency calls.

May we say, in conclusion that the survey has been very helpful in determining the primary aims for which it was launched, namely;: a) determine the trend to automation on university campuses, and b) locate installations already automated among APPA membership comparable to the University of Montreal Campus as to size, operational conditions and equipped with centralized services.

Its present floor area of 3.5 million sq. ft., to be expanded to 6.5 million in 1977, places the University of Montreal Campus among the larger institutions in North America.

The successful experience gained by others, together with the resulting tangible and intangible benefits, should be a strong incentive to undertake the necessary steps for a more efficient and economical building management.

RESULTS OF SURVEY OF
BUILDING MANAGEMENT CENTERS OF
NORTH AMERICAN UNIVERSITIES

ABBREVIATIONS

M : MONITOR
M-C: MONITOR AND CONTROL
B : BAILEY
BC : BARBER COLMAN
H : HONEYWELL
J : JOHNSON
P : POWERS
R : ROBERT SHAW
SI : SIMPLEX

UNIVERSITY CODE NUMBERS

Harvard University, Cambridge	1	Carleton Ottawa	28
Southern Illinois Univ., Carbondale	2	Brown University	29
Health Sciences Division	3	University of Alaska	30
Virginia Commonwealth Univ.	4	Clemson University	31
Skidmore College	5	Centre Hospitalier University	32
Trent University	6	Pennsylvania State University	33
State Univ.of New York, Stony Brook	7	SUNY Upstate Medical Center	34
Southern Illinois Univ., Edwardsville	8	Northern Arizona University	35
Bennington College	9	University of Arizona, Tucson	36
University of Massachusetts	10	Tulane University	37
York University	11	Midwestern Univ., Wichita Falls	38
Ottawa	12	Univ. of Tennessee Medical Units	39
University of Northern Iowa	13	Hofstra University	40
University of New Mexico	14	Southern Methodist University	41
Pan American College	15	Texas Technical University	42
Illinois State University, Normal	16	Queens College	43
Gustavus Adolphus College	17	University of Idaho	44
Hollins College, Virginia	18	State Univ.of New York, Plattsburg	45
U.S. Military Academy, Westpoint	19	Univ. of Texas Medical School	46
Harvard University, Allston	20	University of Guelph	47
Southern Texas State University	21	University of Washington	48
U.C.L.A., Los Angeles	22	SUNY, Fredonia	49
University of California, Irvine	23	University of Utah	50
California Institute of Technology	24	Laval University	51
University of Nebraska	25	University of Calgary	52
Oklahoma City University	26	SUNY at Albany	53
Austin College	27		

UNIVERSITIES WITH CENTRALIZED CONTROL SYSTEM (BUILDING MANAGEMENT)

UNIVERSITY CODE	NO. OF BUILDINGS ON CAMPUS	TOTAL AREA	NO. OF BUILDINGS WITH AREA LARGER THAN 50,000 S.F.	AGE OF BUILDINGS			NO. OF BUILDINGS WITH SERVICES					
							CENTRALIZED			LOCAL		
				0-10 YEARS	10-20 YEARS	20-30 YEARS	HEATING	REFRIGERATION	ELECTRICAL	HEATING	VENTILATION	AIR CONDITIONING
1	40	4,000,000	20	-	-	-	10	PROP	10	10	10	10
2	40	3,000,000-4,000,000	10-20	10	5-10	5-10	10	-	-	10	10	10
3	40	2,000,000-3,000,000	20	5-10	5-10	10	10	-	-	-	10	10
4												
5	10-20	500,000-1,000,000	5-10	10	-	-	10	10	10	10	-	5-
6	5-10	500,000-1,000,000	5-	5-10	-	-	-	-	5-10	5-10	5-	5-
7	-	3,000,000-4,000,000	10-20	10	-	-	10	-	10	-	-	-
8	5-10	1,000,000-2,000,000	5-10	5-10	-	-	5-10	5-10	5-10	5-10	5-10	5-10
9	40	500,000-1,000,000	5-	5-10	-	-	10	-	-	5-	-	5-
10	160	4,000,000	20	10	10	10	10	-	-	5-	10	10
11	10-20	2,000,000-3,000,000	20	5-	-	-	10	10	10	10	10	10
12	10-20	1,000,000-2,000,000	10-20	5-	5-10	10	10	-	-	5-	5-	5-
13	20-40	1,000,000-2,000,000	10-20	10	5-	-	10	-	10	5-	10	10
14	40	2,000,000-3,000,000	10-20	10	10	10	10	10	-	-	-	-
15	20-40	500,000-	5-	10	10	10	-	10	-	-	-	10
16	40	3,000,000-4,000,000	10-20	10	10	10	10	-	-	10	-	-
17	20-40	1,000,000-2,000,000	5-	5-	10	5-	10	-	-	-	-	-
18	40	500,000-	5-	5-10	10	5-	10	5-	-	10	5-	5-
19	40	4,000,000	20	5-	5-10	10	10	-	10	10	10	10
20	40	4,000,000	20	10	10	10	10	10	5-10	10	10	10
21	40	2,000,000-3,000,000	-	10	10	10	10	-	-	10	10	10
22	40	4,000,000	20	10	10	10	10	5-	-	10	10	10
23	10-20	500,000-1,000,000	5-10	10	-	-	10	10	10	5-10	5-10	5-10
24	40	1,000,000-2,000,000	10-20	10	10	10	10	10	10	10	10	10
25	40	4,000,000	20	10	5-10	5-10	10	10	-	5-	10	5-10
26	20-40	500,000-1,000,000	5-10	5-	5-	5-10	10	5-10	-	10	5-10	5-10
27	20-40	500,000-1,000,000	5-	5-	10	10	5-10	5-10	-	10	5-	10
28	10-20	1,000,000-2,000,000	10-20	10	-	-	10	-	-	10	-	-
29	40	2,000,000-3,000,000	10-20	5-10	5-10	10	10	-	-	10	10	5-
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31	20-40	2,000,000-3,000,000	10-20	10	10	10	10	10	10	-	- -	-
32	5-	1,000,000-2,000,000	--	-	-	-	5-	-	-	5-	5-	5-
33	40	4,000,000	20	10	10	10	10	-	10	10	-	-
34	5-10	1,000,000-2,000,000	5-	5-	-	5-	-	-	-	-	-	-
35	40	500,000-1,000,000	10-20	10	10	5-10	10	-	10	5	-	5-
36	40	4,000,000	20	10	10	10	10	10	10	10	10	10
37	40	2,000,000-3,000,000	10-20	5-10	10	10	10	10	-	10	10	10
38	20-40	500,000-1,000,000	5-10	5-10	10	5-10	10	10	-	-	-	-
39	20-40	500,000-1,000,000	5-10	5-10	10	10	-	-	-	10	10	10
40	40	1,000,000-2,000,000	20	5-10	10	5-	5-10	5-10	-	5-10	5-10	5-10
41	40	2,000,000-3,000,000	10-20	10	10	10	10	10	10	-	-	-
42	40	3,000,000-4,000,000	20	10	10	5-10	10	10	-	-	-	-
43	20-40	1,000,000-2,000,000	5-10	5-10	10	10	10	-	-	10	5-	5-
44	40	3,000,000-4,000,000	10-20	10	10	10	10	-	-	5-	10	5-10
45	20-40	1,000,000-2,000,000	10-20	10	10	10	10	-	-	-	-	5-10
46	5-	500,000-	5-	5-	-	-	5-	5-	-	-	-	-
47	40	3,000,000-4,000,000	5-10	10	10	10	10	5-10	10	5-	10	5-
48	40	4,000,000	20	10	10	10	10	10	10	10	10	10
49	20-40	1,000,000-4,000,000	10-20	5-10	5-10	5-	10	-	10	5-	10	5-10
50	40	4,000,000	20	10	10	10	10	-	-	10	10	10
51	10-20	3,000,000-4,000,000	10-20	10	10	10	10	5-10	10	5-	5-	5-
52	10-20	1,000,000-2,000,000	10-20	10	5-	-	10	10	-	10	10	10
53	48	3,000,000-4,000,000	10-20	48	-	-	48	-	..		-	-

UNIVERSITIES WITH CENTRALIZED CONTROL SYSTEM (BUILDING MANAGEMENT)

UNIVERSITY CODE	NO. OF BUILDINGS WITH CONTROL SYSTEM											TOTAL NO. OF POINTS
	LOCAL CONTROL		CENTRALIZED CONTROL									
	HEATING VENTILAT. AIR COND.	FIRE	MANUFACT.	HEATING		VENTILATION		AIR CONDITION		ELECTRIC M	FIRE M	
				M	M-C	M	M-C	M	M-C			
1	10	-	H	10	10	10	10	10	10	10	10	1,000-2,000
2	10	-	P	10	10	10	10	10	10	10	10	1,000-2,000
3	10	10	V	5-	-	5-	-	5-	-	-	-	1,000-2,000
4												
5	-	-	H	10	10	10	-	5-	-	-	-	1,000-
6	-	5-10	H	-	5-10	-	?-10	-	5-	-	5-10	1,000-
7	-	10	H	5-10	5-10	5-10	5-10	5-10	-	5-	5-10	10,000
8	5-10	5-10	J	-	5-10	-	5-10	-	5-10	-	-	10,000
9	-	-	P	5-	5-	-	-	-	-	-	-	1,000
10	10	5-	H	-	5-	-	5-	-	5-	-	-	1,000
11	10	10	H	10	-	10	-	10	-	10	10	800
12	5-	-	J	5-	5-	5-	5-	5-	5-	5-	5-	1,000
13	10	5-10	R	-	5-10	-	5-10	-	5-10	-	-	4,000-10,000
14	-	-	J	-	10	-	10	-	10	-	-	2,000-4,000
15	10	-	B	-	-	-	-	10	10	-	-	1,000-
16	5-	5-	P	5-	5-	5-	5-	5-	5-	5-	5-	1,000-
17	-	-	H	-	10	-	10	-	5-	-	-	1,000-
18	5-	5-	H	5-	5-	5-	5-	5-	5-	-	5-	1,000-
19	10	10	J	5-	5-	5-	5-	5-	5-	5-	5-	?,000-
20	10	10	H	10	10	10	10	10	10	10	10	1,000-2,000
21	10	10	SI	10	-	10	-	-	-	-	-	1,000-
22	10	10	H	-	5-	-	5-	-	5-	-	-	1,000-
23	5-	5-	H	5-	10	5-	10	5-	10	5-	5-	1,000-
24	10	10	H	10	10	10	10	10	10	-	10	1,000-
25	10	10	J	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	1,000-2,000
26	5-10	5-10	H	5-10	5-10	5-10	5-10	5-10	5-10	-	10	1,000-2,000
27	10	5-10	J	5-	5-	5-	5-	5-	5-	-	-	1,000-
28	10	10	H	-	10	-	10	-	10	-	-	2,000-4,000
29	5-	5-	H	-	10	-	10	-	10	-	-	900
30	10	10	H	-	10	-	10	-	10	-	10	---
31	-	-	H	-	10	-	10	-	10	-	-	1,000-2,000
32	5-	-	H	-	-	-	-	-	-	-	-	---
33	5-	-	-	-	5-	-	5-	-	5-	-	-	---
34	5-	5-10	H	5-	5-	5-	5-	5-	5-	-	5-10	1,000-
35	5-	5-	J	5-10	5-10	-	-	-	-	-	-	1,000-
36	10	10	H	10	10	10	10	10	10	-	10	1,000-
37	10	-	H	10	10	10	-	10	10	-	-	1,000-2,000
38	-	-	B.C.	-	10	-	10	-	10	-	-	1,000-2,000
39	10	10	H	10	10	10	10	10	10	10	10	1,000-2,000
40	5-10	5-10	H	-	5-10	-	5-10	-	5-10	-	-	1,000-
41	-	-	P.P.D	10	10	10	10	-	10	-	-	---
42	-	-	J	10	10	10	10	10	10	-	10	10,000-
43	5-	10	-	-	-	-	-	-	-	-	-	---
44	5-10	10	H	5-	5-	5-	5-	5-	5-	5-	5-10	1,000-
45	10	-	H	10	-	-	-	-	5-	-	10	1,000-
46	5-	-	J	-	5-	-	5-	-	5-	-	-	1,000-
47	10	10	J	-	10	-	10	-	10	-	-	4,000-10,000
48	5-10	10	H	5-10	5-10	5-10	5-10	-	-	-	10	1,000-
49	10	10	SI	10	-	10	-	5-	-	-	10	1,000-
50	10	10	H	10	10	5-10	5-10	5-	5	-	10	1,000-
51	5-	-	B	5-10	5-10	5-10	5-10	5-10	5-10	5-10	5-10	2,000-4,000
52	10	10	B	10	-	10	-	10	-	10	10	1,000-
53	-	-	J	48	48	48	48	13	13	-	48	1,000-2,000

UNIVERSITIES WITH CENTRALIZED CONTROL SYSTEM (BUILDING MANAGEMENT)

UNIVERSITY CODE	COMPUTER		ECONOMIES %							PROPOSED INSTALLATION OF CENTRALIZED CONTROL SYSTEM			
			PERSONNEL		OPERATION		MAINTENANCE CALLS	ACTUAL SAVINGS In ACCORDANCE WITH FORECAST					
	YES	NO	OPERATION	MAINTENANCE	FUEL	ELECTRICAL		NO	YES	NO	YES	UNDER STUDY	UNDER CONSTRUCT
1		X										X	
2		X											
3	X		30	30			20-30		X				
4													
5		X							X				
6		X											
7		X							X				
8		X											
9		X								X			
10		X							X				
11		X							X				
12	X										X		
13		X							X				
14		X							X				X
15		X											
16		X							X				
17		X	10-	10-20	20-30	10-20	10-						
18		X											
19		X											X
20	X												
21		X	10-	10-	10-			X					
22		X											
23		X											
24		X											X
25		X											X
26		X											
27		X											
28		X											
29		X											X
30		X											X
31		X											X
32			30	30		10-20	10-20	X					
33												X	
34										X			
35		X	10-20	20-30	30-	10	10						X
36		X	10-	30	10	10-20	10						
37		X											
38		X											
39		X	20-30	10-20	20-30	10-	10-	X					
40	X		30	30	30			X			X		
41		X	10										
42	X												
43													
44		X											
45		X											X
46		X	20-30	10-[illegible]	30	10-20	10-						
47	X												
48		X								X		X	
49		X											
50		X											
51		X											
52		X											
53		X	10-20	10-	10-	10-	10	X					