THESIS

Electric power distribution

ELECTRICAL DISTRIBUTION

A Thesis Submitted to

the Faculty of

Michigan State College

of

Agriculture and Applied Science

by

Ingwald Halvorsen Gronseth

Candidate for the Professional Degree of

Electrical Engineer

June 1931

THESIS

INTRODUCTION

In the last few years electric utility companies have begun to realize that one of their most important problems is that of the economical delivery of the energy produced at the generating plant to the ultimate consumer and that improvements in the methods of distribution may be as productive of savings as the application of fuel saving devices and more efficient generating equipment. That this trend toward improvement of economics in the distribution is well justified may readily be understood when it is realized that fifty per cent or more of the ultimate cost of the electrical energy is accumulated after it leaves the power house. It is also realized that such improvements in the economics must be coupled with betterment of service to the consumer whose full and continued use of the product depends upon the assurance he has that his demands will be met when required.

While, perhaps, the major portion of future savings will continue to be made at the generating plants through the continual improvement in boilers and generators and their auxiliary equipments, considerable savings may be effected by the more intelligent use of existing distribution systems and by the replacement of inefficient methods by those more efficient and more adaptable to the continual demand for improvements in service standards. More careful planning in the construction of extensions to the system and in the replacement of the older and inadequate portions will result in an appreciable decrease in the obsolescence and maintenance expense. Line load factors may be improved by more intelligent use of lines and the system power factor increased by a more careful attention to transformer loadings. Depreciation as well as maintenance may be cut down by systematic and close periodic inspections of the whole system.

It is not the purpose of this thesis to treat the whole subject of distribution in detail, but rather to point out certain methods and ideas which the writer has applied in practice and which have proven satisfactory in reliability, simplicity, and economics.

Ingwald Halvorsen Gronseth

Ingwald Halvorsen Gronseth

METHODS OF DISTRIBUTION

Direct-current

The distribution of electrical energy by means of direct-current systems is fast disappearing and need not be touched upon in detail. It is used here merely as a means of comparison with the present accepted method of alternating-current distribution.

The cost of manufacture and distribution, and the law of supply and demand are the factors which determine the sale of an article and its worth to the buyer. If a merchandiser should wrap similar articles in two different packages and make a difference in their prices, the purchaser would probably demand the one of lesser price if he knew that the articles were the same and that they would give him equal satisfaction. So it is with electrical energy in the forms of direct-current and alternating-current. They do the same work but their cost to the consumer is vastly different due to their difference in cost of manufacture and distribution and this cost is greatly in favor of alternating-current.

The transmission of great bulks of power by low voltage direct-current is very costly due to the large size and number of conductors that are necessary in order to overcome excessive voltage drops and so insure satisfactory regulation. Due to this necessarily great number of conductors of large cross-sectional area, the use of pole lines is precluded and it is necessary to use the more expensive underground construction of conduits and lead covered cables. In the high density load areas, in the larger cities, this construction of conduit lines of sufficient numbers of ducts for direct-current distribution is well nigh impossible. The streets and thoroughfares that are available are usually crowded with pipes and conduits of every nature and description. There will be found sewer pipes, gas and water mains, conduits for the use of telephone companies and for street railway and street lighting purposes, street car tracks, and so many other obstacles that expensive tunneling at depths of fifty feet or more blow the surface is often resorted to in order to provide the necessary room. In alternating-current distribution, using higher voltages, the number of ducts needed is materially reduced and their facility of installation is greatly simplified with a corresponding decrease in cost.

Due to the short transmission distances of direct-current a great number of substations or converter stations with costly switch gear and expensive rotating machinery must be used. Also, in the more densely loaded areas, these systems are generally provided with storage-battery reserve amounting to from 50 to 75 per cent of the load served.

Studies are constantly being made by central station companies throughout the United States towards the elimination of direct-current distribution, and reductions in the direct-current areas are made each year. The cost of change-over of customer's equipment is the main deterrent towards final elimination, but in many cities this change-over must necessarily be spread over a long period of time and the costs, in many instances, are being taken care of by agreements between the central station company and the consumer whereby each pay a certain portion. Some companies are taking care of all the expenses involved including changing the customers equipment, while others have adopted a policy of watchful waiting - allowing no extensions to the system and eliminating customers from time to time through the voluntary discontinuance on the part of the customer or by the customer's replacement of worn-out equipment with alternating-current equipment. Statements of the policies adopted by some central station companies will be found in Appendix "A".

In the changing over of any system the problem is one of pure economics and, while in many cases the costs involved are large, savings can be made by both the central station company and the consumer. The lower rates for alternating-current energy will usually more than pay for the change of customer's equipment and the central station companies will be benefitted by the better use of their alternating-current distribution systems which are now, in most cases, paralleling and supplementing the direct-current system.

Lansing has for some time permitted no extension to its direct-current system and while this system has never been very large the policy adopted several years ago has had the result that at the present time only about forty customers remain.

The following is an example of the analysis to be made in any proposed change-over and although the system analysed is very small, the same problem must be handled by all companies contemplating such change.

Analysis of Proposed Change-over
of
Direct-current System
of the
XYZ Electric Co.

<u>Extent of survey</u>

Statement showing what was covered in the survey such as direct-current generating equipment, switchboards, switches and other auxiliary equipment, underground and overhead lines used for direct-current distribution, availability of alternating current, equipment now used by the customer and alternating-current equipment required, etc.

<u>Method of survey</u>

Statement showing what was done and how.

<u>Condition of equipment</u>

Statement of basis for determining percentages of condition of equipment.

<u>Selection of Alternating-current equipment</u>

Statement of reasons for the selection of types and kinds of replacement equipment. Sources of bids and labor costs, etc.

<u>Territory involved</u>

Statement showing territory covered and reasons.

EQUIPMENT

D. C. Generating Equipment

	Costs	Dep.%	Present value
1 - Westinghouse steam turbine exciter set, 2750 RPM, serial #2534, direct connected to Westinghouse D.C. generator, 75 KW, 125 volts, 600 amps,	$4050.00	50	$2025.00
1 - M.G. set consisting of 1 - Westinghouse D.C. generator, 125 KW, 600 V, 208 amps, 690 RPM, ser. #640287, direct connected to 1 - Westinghouse motor, 200 HP, constant speed Ind., 4000 V., 3ph., 60 cy, ser. #640285	3690.00	50	1845.00
1 - M.G. set mounted on Cl base, consisting of 2-GE D.C. generators, 25 KW, 200 amps., 120/125 V, 1200/1160 RPM, compound wound, ser.#447026, 447027. and 1 - GE ind. motor, 75 HP, 60 cy., 4000 V, 1200 RPM, NL, 1160 RPM FL, ser. #781184	1700.00	50	850.00
1 - M.G. set mounted on Cl base consisting of 1 - GE syn. motor, 125 HP, 900 RPM, 3 ph., 60 cy., ser.#301396, direct connected to 1 - GE D.C. gen. 75 KW, 125 amps, 125 volts, 900 RPM, ser. #500691, and 1 - GE D.C. gen, 75 KW, 600 amps, 125 volts, 900 RPM, ser. #500690	2540.00	50	1270.00
D. C. Switchboard & equipment			
1 - 9 panel switchboard including meters, bus bars, etc.	1600.00	50	800.00
	$13,580.00		$6,790.00

D. C. Distribution lines

Salvage value of itemized wire and cable	$2,355.00	
Less removal costs	720.00	
Total or net salvage value ------------------------------------		$1,635.00

Customers Equipment

Itemized statement of customers equipment, equipment required for replacement, cost less salvage	$ 36,000.00

EVALUATION AND COSTS

Generating costs

The cost of generating electricity at the Ottawa St. Plant (cost of energy delivered to the switchboard) or the charges which the Electrical Department pays the Steam Heat Department for the energy - 1.25¢ per kwh-is approximately double the cost of energy delivered to the switchboard by the electric plant. Also, the conversion equipment is only about 50 per cent efficient, so that only half of the energy that is delivered to the machines is delivered to the customer. These conversion losses occur after the power is delivered to the switchboard so that the total cost of the energy delivered to the customer is 2.5¢ per kwh. The total energy delivered to direct current customers during 1929 was 172,750kwh approximately.

Distribution costs

The average cost of furnishing electricity to alternating-current customers from the switchboard to the customer's meter, and which includes cost of billing, general and miscellaneous and other expenses, is .752¢ per kwh. This cost, for direct current, may be taken as slightly higher, or approximately 1.0¢ per kwh. Inasmuch as alternating current lines are available for use at all direct current customers and the majority of these customers are already supplied with alternating current of the type which will have to be used for the replacement equipment, the cost of furnishing the added alternating current service will be so small that it may be neglected. The existing cost of furnishing direct current service will therefore constitute a saving and will amount to 172,750 x .01 - $1,727.50. Cost of distribution of alternating current based on .752¢ per kwh would be $1,299.08

Total Energy

The total cost of the energy delivered to the customer would be the generating cost plus the distribution cost or 3.5¢ per kwh and amounts to 172,750 x 3.5 = $6,046.25

Revenue

The net revenue (less the prompt payment discount) from the sale of direct current energy during the year 1929 was approximately $8,983.00 - $6,046.00 = $2,937.00.

The gross revenue (less the prompt payment discount) which would be received from these customers if they were using alternating current instead of direct current would be 172,750 x .024 - $4,146.00. The cost of delivering this energy is .01405 ¢ per kwh, making a total cost of 172,750 x .01405 - $2,427.50. The difference between these two is $4,146.00 - $2,427.50 - $1,739.00 approximately, which would be the net revenue from alternating current.

Plant Costs

The floor space which the D.C. equipment occupies at the

Ottawa St. Plant will become available for other purposes if this direct current equipment is removed. The cost of buildings, plus land, amounts to $248,964.54 and 22% of this is used for electric generation. The total kwh in electricity generated at this plant during 1929 was 9,835,886 kwh of which approximately 345,500 kwh was for D.C. use. Twenty-two per cent of $248,964.54 or $54,772.00 is the share of the buildings to be apportioned to the electrical use and from this the cost to be apportioned to direct current is found to be (54,772 x 345,500) ÷ 9,835,886 = $1,925.00.

Evaluating this at 6%, we get a yearly saving of $115.00

Plant Equipment

The existing equipment at the Ottawa St. Plant used for furnishing direct current service was purchased in 1918 at 1914 prices with a 10% discount. This equipment will have to be replaced in a few years if we are to continue to furnish this type of service and the cost of this replacement - estimated at $15,000.00 less $5,000.00 for salvage of old equipment - may be evaluated at about 12% which includes interest on the investment, maintenance, and depreciation. This would amount to $10,000.00 x.12 = $1,200.00

Distribution Equipment

With the growth of the system, the demand for conduit space will increase and the conduit now used for direct current lines will be needed for alternating current cables. The number of feet of conduit used for direct current is about 8000 and at a cost of 55¢ per duct foot, this space is worth $4,400.00. The wires and cables can be salvaged and will amount to approximately $1,635.00. The wire and cable used for direct current will not be needed for alternating current distribution, and could not be used due to the fact that the insulation is not suitable for primary distribution voltage. This cable, as well as the wire, can be salvaged, and capitalizing its salvage value of $1,635.00 at 6% the yearly revenue from this will be $98.00, approximately.

Conclusion

The cost of changing the customers' equipment to alternating current operation will be approximately $36,000.00 and inasmuch as the existing direct current equipment is, in general, in a bad or worn-out condition, necessitating excessive expenditures for maintenance, such change will be to the customer's benefit, not only in that these excessive maintenance costs will be eliminated, but also through the realization of lower operating costs due to the lower rate for alternating current service. The saving effected by the lower energy charge of alternating current service alone is estimated to be $4,837.00 per year.

The change-over will affect the customer and the XYZ Elec. Co. as follows:

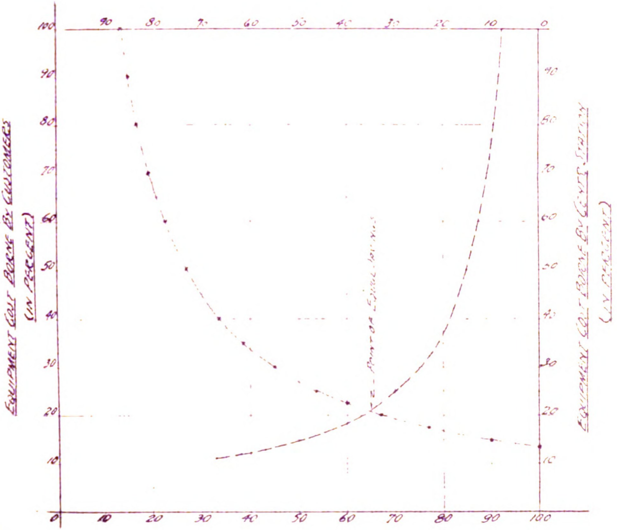
Total amount paid by direct current customers	$8,983.00
Total amount customers would pay for equivalent alternating current	4,146.00
Yearly savings to customer	$4,837.00
Net revenue from direct current customers	$2,937.00
Net revenue if customer is furnished A. C.	1,727.00
Loss in revenue	$1,210.00

Net cost of D. C. delivered to switchboard	$4,318.75	
Net cost of A. C. delivered to switchboard	1,128.50	
Savings due to lower generating costs		$3,190.25
Net distribution cost of D.C.	$1,727.50	
Net distribution cost of A.C.	1,299.00	
Savings in distribution costs		428.50
Savings from salvage of distribution lines		98.00
Savings from duct space		265.00
Future savings in replacement costs of plant equipment		1,200.00
Savings from floor space		115.00
Total yearly saving to company		$4,087.00

Maps showing the direct current area and the direct current distribution lines, curve of equipment cost plotted against savings to customers and to the company and which shows point of equal saving, together with copies of letters from several electric utility companies who have experienced the problems involved in this change-over, are attached.

(Signed)

CENTRAL STATION SAVINGS
ON INVESTMENT IN CUSTOMERS NEW EQUIPMENT
(IN PERCENT)



CUSTOMERS SAVINGS
ON INVESTMENT IN NEW EQUIPMENT
(IN PERCENT)

NOTE:

THE ABOVE CURVE IS CONSTRUCTED FROM COSTS AND SAVINGS INVOLVED IN CHANGING THE DIRECT-CURRENT SYSTEM IN THE CITY OF LANSING TO ALTERNATING-CURRENT. DATA AS FOLLOWS:

COST OF CHANGING EQUIPMENT FROM D.C. TO A.C.	$36,000.00
SAVINGS TO CUSTOMERS THROUGH LOWER ENERGY CHARGES (YEARLY)	$4,837.00
SAVINGS TO CENTRAL STATION CO. (YEARLY)	$4,087.00

FIG. 1

Alternating -current

The development of the transformer is primarily responsible for the rapid growth of the electrical industry and the present efficiency and economy of the distribution of electrical energy. Before its advent, the radius of distribution was confined to narrow limits because of the excessive costs of direct-current distribution. The transformer, however, made it possible to transmit the energy at higher voltages, reducing these voltages at any point on the system to that required by the customer. This permitted an enormous saving in the cost of distribution and transmission because of the increased load carrying capacities of the feeders and the reduction in substation equipment. The production costs could also be reduced due to the fact that these higher voltages permitted reduction in the size and cost of generators and other equipment and to savings of conversion losses. The apparatus and equipment of utilization kept in step with this important change so that at the present time, alternating current motors are almost exclusively used and the control for this type of motor has been so highly developed that, except in rare instances, the use of direct-current for motor drives has been eliminated.

Although the scheme of alternating-current distribution is fundamentally the same now as at its inception, many changes and readjustments have taken place. The frequencies and voltages of generation and distribution have varied greatly among the companies engaged in the industry, and although 60 cycles has become the accepted standard, many 25 and 30 cycle systems are still in operation.

Generation and distribution voltages were also chosen without regard to standardization. Distribution voltages run the gamut of from 2200 to 6600 volts and all the known methods of distribution are still in use. The three phase 3-wire, and three phase 4-wire systems predominate at present and the systems at variance with this will eventually be changed over.

Standards of secondary voltages are also lacking and the secondary systems of today vary from 110/220 to 120/240 volts single phase for lighting, with voltages for power purposes of 230 and 460, three phase. Two phase systems, both primary and secondary, are still being used in many parts of the country, but they will probably entirely disappear within the near future.

The lack of standardization of frequencies and voltages and the absence of coordination between the electrical manufacturer and the central station companies, which prevailed during the early days of the industry, have been detrimental to both the producer and the consumer of electrical energy. Much of the equipment and apparatus used must necessarily be made for the one particular system and the cost of manufacture will naturally be greater than if the same could be used on all systems. Many central station companies have changed or will be forced to change their systems from the lower frequencies to the accepted 60 cycle standard and the enormous cost of such change in a very large system may become nearly prohibitive. In the district of Grand Rapids, Michigan, containing approximately 50,000 customers and with a maximum demand of less than 70,000 kwh, the Consumers Power Co., is at present engaged in changing over the old 30 cycle system to 60 cycle. It is estimated that the cost of this change-over will be approximately $5,000,000.00 which will amount to more than $70.00 per kwh of maximum demand or about $100.00 per customer. (Number of customers and demand is estimated)

The evolution of the primary distribution system, beginning with single phase, has been to two phase, four wire, to two phase three wire, and to three phase, with the three phase connection either Y or Delta. Single phase distribution proved quite satisfactory during the early days of the industry when lighting was the principal load. Small motors operated on these single phase lines did not prove very objectionable but with growth of the demand for electric motor drives it became necessary to change the system to polyphase operation. Two phase was the logical step as no change had to be made in the existing single phase lines which were combined for two-phase operation of motor equipment. The first system, two-phase four wire, evolved later into the two-phase three wire system which had the advantage of being more economical due to the fact that the amount of conductor material required was reduced to seventy-five per cent of that required for the four wire system.

The three phase three or four wire system universally used at the present time, though designed primarily for power distribution has the advantage that it may be readily used for single phase service and is more economical in that it uses only seventy-five per cent of the copper used in an equivalent single phase circuit. Either two or three transformers may be used to supply power loads.

Three phase systems may be operated as an isolated delta or as a grounded Y system. In either system the neutral is at ground potential and the voltage from line to ground is the line voltage divided by 3. In the isolated delta system, however, the capacity current of the line balances the voltages against ground and thereby keeps the neutral at ground potential. Therefore, in this system, line troubles will give an increased voltage but do not materially affect the operation of the system. In the grounded Y system, line troubles immediately affect the operation due to the difference of potential between phase and neutral or ground.

The choice of system to use has been in favor of the grounded Y by the majority of operating companies. Distribution is normally at 4000 volts, phase to phase, with the grounded neutral brought out and used for single phase connection of transformers and for open delta connection of power transformers.

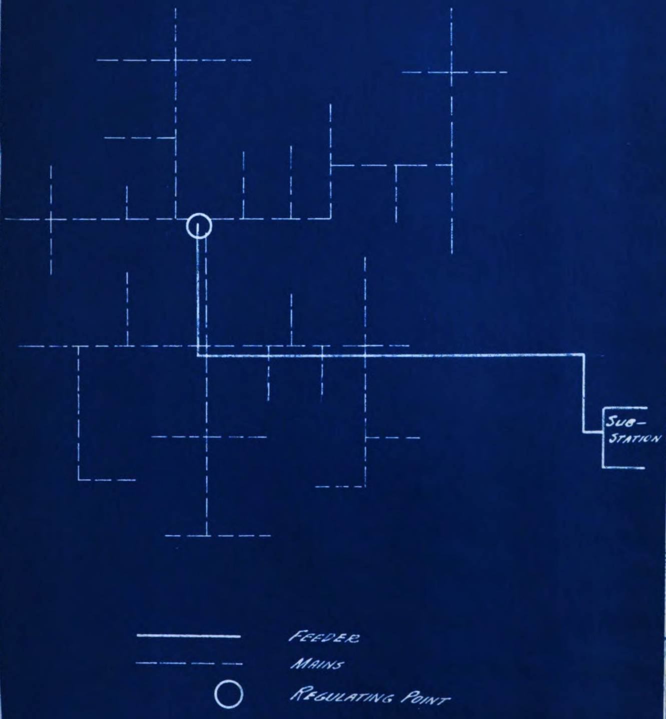
Several schemes of primary distribution are being used and the merits of each depend upon several factors, such as the distances covered, density of load, service requirements, etc. For lighting service especially, where requirements exist for certain limits of voltage regulation, which requirements may be prescribed by State Utilities Commissions such as in Michigan (allowable variation of 3% below to 5% above the normal standard voltage) or by the company's own desire to keep within certain limits, the system to be used must lend itself most readily to such regulation.

The feeder and main system, shown in Fig. 2, has the disadvantage that the mains, in many cases, are backfeeding from the center point of distribution thus using more wire than is necessary as well as occupying much valuable pole space. The regulation is to the center of the section and its effectiveness depends upon the load on the mains and their distance from the feeder point.

Figure 3 shows a modified feeder and main system in which regulation is provided to the load center of the feeder, but with branch leads tapped off from the feeder back of the center of regulation. This method provides good regulation to any part of the circuit if the necessary amount of boost required at the far end is not too great for the closer loads. This system is excellent for condensed load areas and for loads located close to the stations.

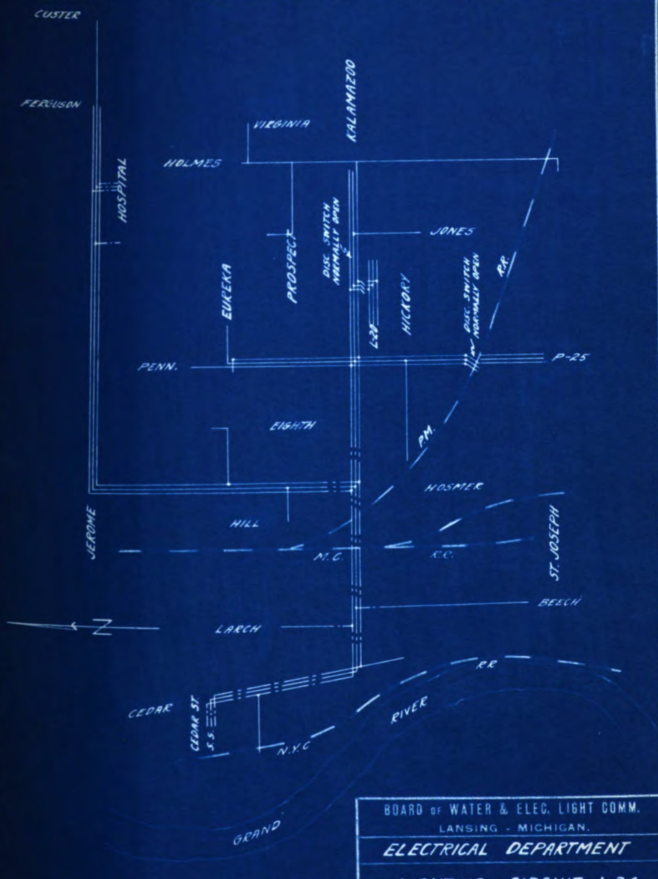
A third method, shown in Fig. 4, is used principally for lighting purposes and is especially adapted for three phase four wire grounded neutral. Here, the three phase feeder is treated as three single phase circuits, individually regulated and usually separately controlled, though the individual circuit breakers may be provided with mechanical interlocks where it is desired to use the feeder for supplying miscellaneous power loads. This method is the best means for providing regulation in the outlying and less densely loaded districts and may cover a large extent of territory. It also has the advantage that feeder troubles are easily located as troubles occurring on the feeder will be confined to one relatively small area or along the feeder proper. Its simplicity of installation, ease of regulation and economy of operation make it the more favored for general lighting feeder purposes.

FEEDER & MAIN SYSTEM



5/23/31

IMPERIAL TRACING CLOTH



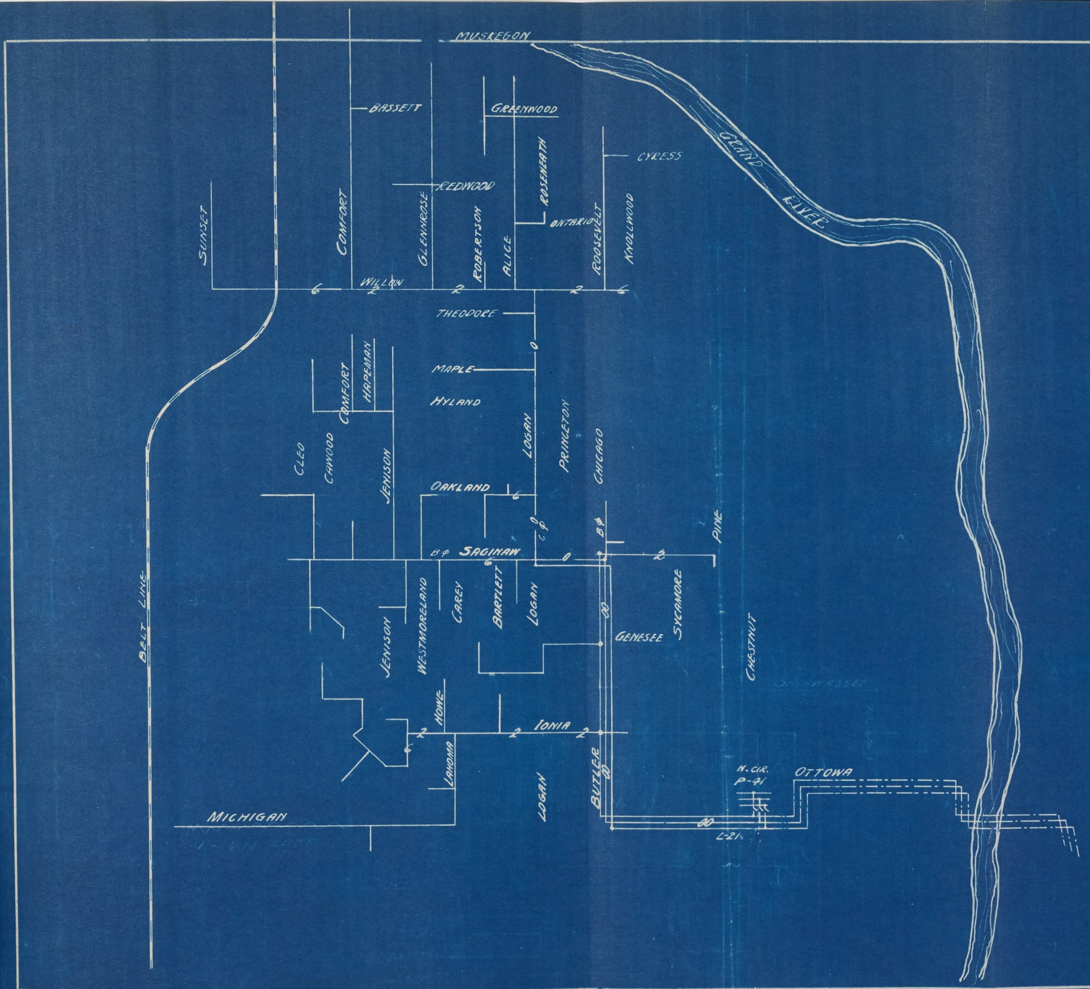
BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN.

ELECTRICAL DEPARTMENT

LIGHTING CIRCUIT L-24

DR'N BY H.W.S. | SCALE 1" = 660'
CHECKED | DATE 9-21-30
APPROVED WHG

FIG. #3



BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN.

ELECTRICAL DEPARTMENT

LIGHTING CIRCUIT L-21

DR'N BY I.H.G.	SCALE	FIG. 4
CHECKED	DATE	~~255.23~~
APPROVED	12-27-26 4-13-29 1-23-30	

"IMPERIAL" TRACING CLOTH
K & E CO., N.Y.

fir

tio

mor

by

Lar

tic

fes

an

ra

gr

an

eq

pl

ab

ns

I

II

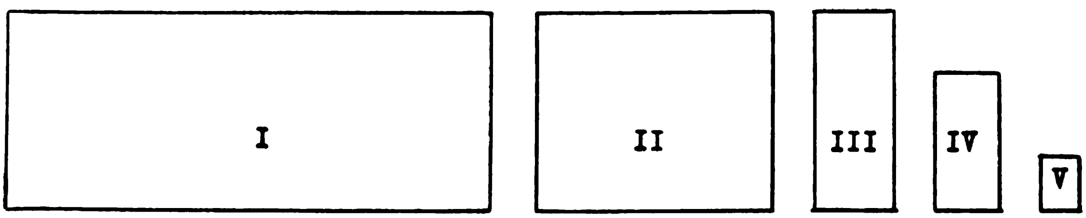
III

IV

V

Most companies employ both of the last two methods, the first for lighting in condensed load areas and for power distribution with or without voltage regulators, the second for serving the more outlying districts or more lightly loaded areas. Both are used by the Board of Water and Electric Light Commissioners of the City of Lansing and have proven satisfactory in providing excellent regulation and in general operation. Diagrams of both lighting and power feeders of this system are appended.

In comparing the relative amount of loads that can be supplied by 4160 v, three phase and direct current at 240 v, the ratio is found to be approximately 35 to 1. The following diagrams, taken from the Electrical World, issue of Oct. 25, 1930, give an indication of the relative savings of duct space for transmitting equal amounts of power at different voltages. Comparing the three phase 4160 v. system to 240 v. direct current it is seen that only about 1/6 of the duct space required for 240 v. direct current is needed for the three phase 4160 v. system.



I - Direct current, 240 volts---------------------------------- 19.31 Sq. Ft.

II - Alternating current, two phase, 2,400 volts ------------- 8.26 Sq. Ft.

III - Alternating current, three phase, 4160 volts ------------ 3.43 Sq. Ft.

IV - Alternating current, three phase, 6,600 volts ----------- 2.25 Sq. Ft.

V - Alternating current, three phase, 27,000 volts ---------- .376 Sq. Ft.

notes

any o

being

defi

where

thei

comp

rec

tir

to

te

ar

or

a

ALTERNATING-CURRENT NETWORKS

The term, network, as used in electrical distribution denotes an interlacing or interconnection of lines and does not refer to any one individual, isolated system, which is not so or is not capable of being so interconnected. The National Electric Light Association has defined a low voltage network as "Any alternating-current installation where transformers located on different premises have their secondaries tied together".

The network principle has been used by central station companies since the beginning of the electrical industry, first in direct-current distribution and then in its most simple form in alternating-current distribution by providing interconnection from one feeder to another which could be used in cases of emergency. This first system depended upon manual operation for completing the interconnection and although this took a certain amount of time, the service given was, on the whole, deemed quite satisfactory and except in the larger cities and very heavy load areas it will continue to be used as the principal method of interconnection.

The installation of the networks system with elaborate and expensive control equipment may be economically justified in the larger cities where the character and the density of the load warrant the expense involved or where continuity of service is all important. The dependence of man upon electricity for his comfort and well-being is apparent to all and the failure of generating plants and distribution lines to properly function may be the means of stopping all normal and necessary operations in that particular locality.

slo

com

sec

may

swi

cen

rea

fee

wit

equ

per

vis

tie

be

sec

bec

cus

sep

ina

cap

age

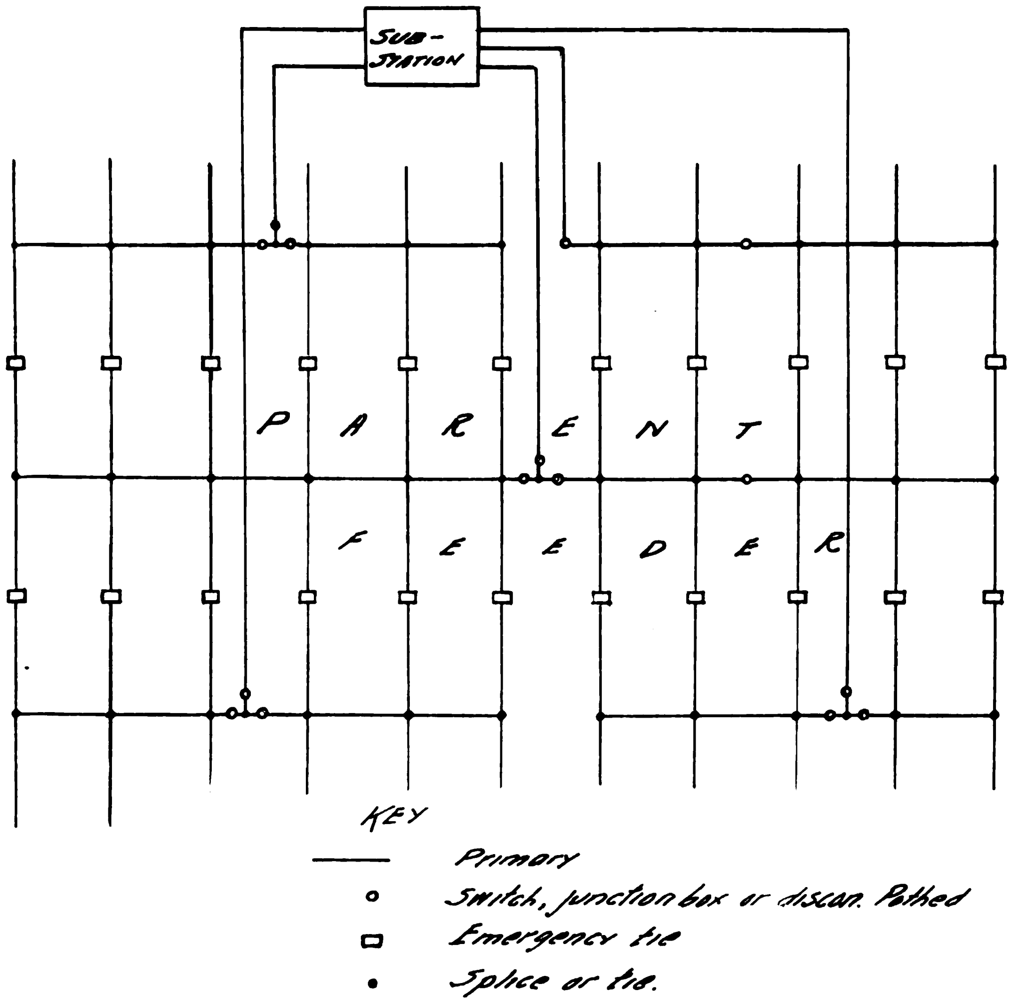
The manual interconnection of lines, while somewhat slow in operation has demonstrated its usefulness to all operating companies. This scheme has been further perfected by the use of sectionalizing switches in the feeders themselves so that any section may be cut out of service in cases of emergency. These sectionalizing switches make it possible to transfer any section of a feeder to adjacent feeders in cases of overload of that section or if for any other reason such transfer should become necessary.

To eliminate the possibilities of overload, the parent feeder system shown in Fig. 4-a is used. The parent feeder is laid out with this end in view and enough spare capacity in copper and station equipment is allowed to prevent its becoming overloaded. Normally, the parent feeder carries as much load as any feeder in its group.

In the duplicate feeder system, shown in Fig. 4-a, provision may be made to tie any primary section to the one opposite or to tie any secondary section to the one opposite. The primary feeders should be run back to the station along different routes. Either primary or secondary should be designed to take over all the load in case this should become necessary.

In the cities of large size there are found individual customers using several thousands of kva. These should be treated as separate substations and served by independent feeders, preferably originating at separate substations and differently routed. Enough feeder capacity should be provided to maintain service in cases of feeder outage. These large loads are not difficult to serve and manual throw-

PARENT FEEDER SYSTEM



DUPLICATE FEEDER SYSTEM

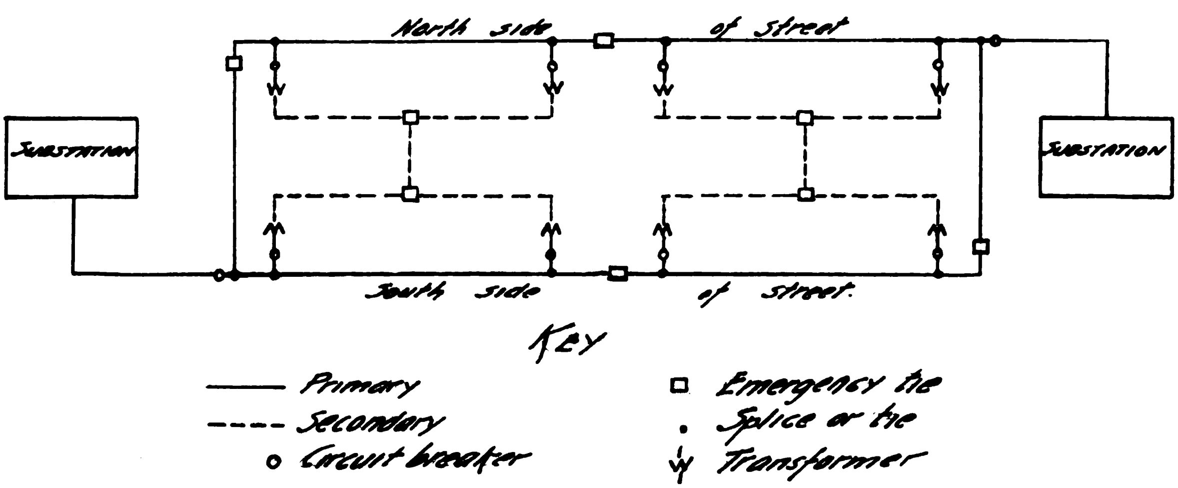


FIG. 4a

over equipment may be used as these large loads usually have an electrician handy who can operate this equipment and any outage would therefore be only of brief duration.

Business districts, however, should be more carefully considered. Here, service should be of paramount importance because of the fact that during business hours, large numbers of people are congregated therein and the greater the number of people affected the greater the amount of good-will the operating company will lose. The transformer installation serving these areas should not only have plenty of feeder capacity but throw-over equipment from one feeder to another should be automatic instead of manually operated. The larger the cities, of course, the more important this service becomes, but justification may exist for this higher degree of service in the smaller cities as well. Careful studies should be made of each particular area in order to determine whether or not such service is warranted.

The automatic throw-over equipment used for this purpose should be selective, i.e., normally operate on its own feeder but in case of failure of such feeder, to throw the load over to the other. When its own feeder is placed service again it should automatically get back on it. Circuit breakers of such design are made by several manufacturers and may be bought at prices ranging from about $1,000.00 and up, for 4,000 volts operation.

This network principle applied to the primary feeders is particularly applicable to the business areas of cities of average size. Its use presupposes spare feeder capacities and except for the additional

ost i
ne t

esig
uch
by t
Elec
syst
are
for
the
ser
em
in
pe
C
u
c

cost involved in this spare capacity the percentage increase in cost due to employment of automatic throw-over equipment is relatively small.

The transformer installation shown in Fig. No 5 is so designed that an automatic vault unit may be installed at any time without much additional expense in labor. This installation was designed by the writer and is typical of several in use by the Board of Water & Electric Light Commissioners, Lansing, in their undergound distribution system throughout the business section of the city. These installations are so designed that for normal operation the lighting and power transformers are fed from separate feeders. In cases of emergency, all of the load can be thrown over to either feeder. During several years of service these installations have given excellent service and in cases of emergency (this has not yet been experienced) all of the load on a cable in trouble may be transferred to other cables within the relatively short period of one-half hour. Distribution engineers of the Detroit Edison Co. who have inspected these installations have indicated that they may use the same design in installations in Ann Arbor and other medium sized cities on their system.

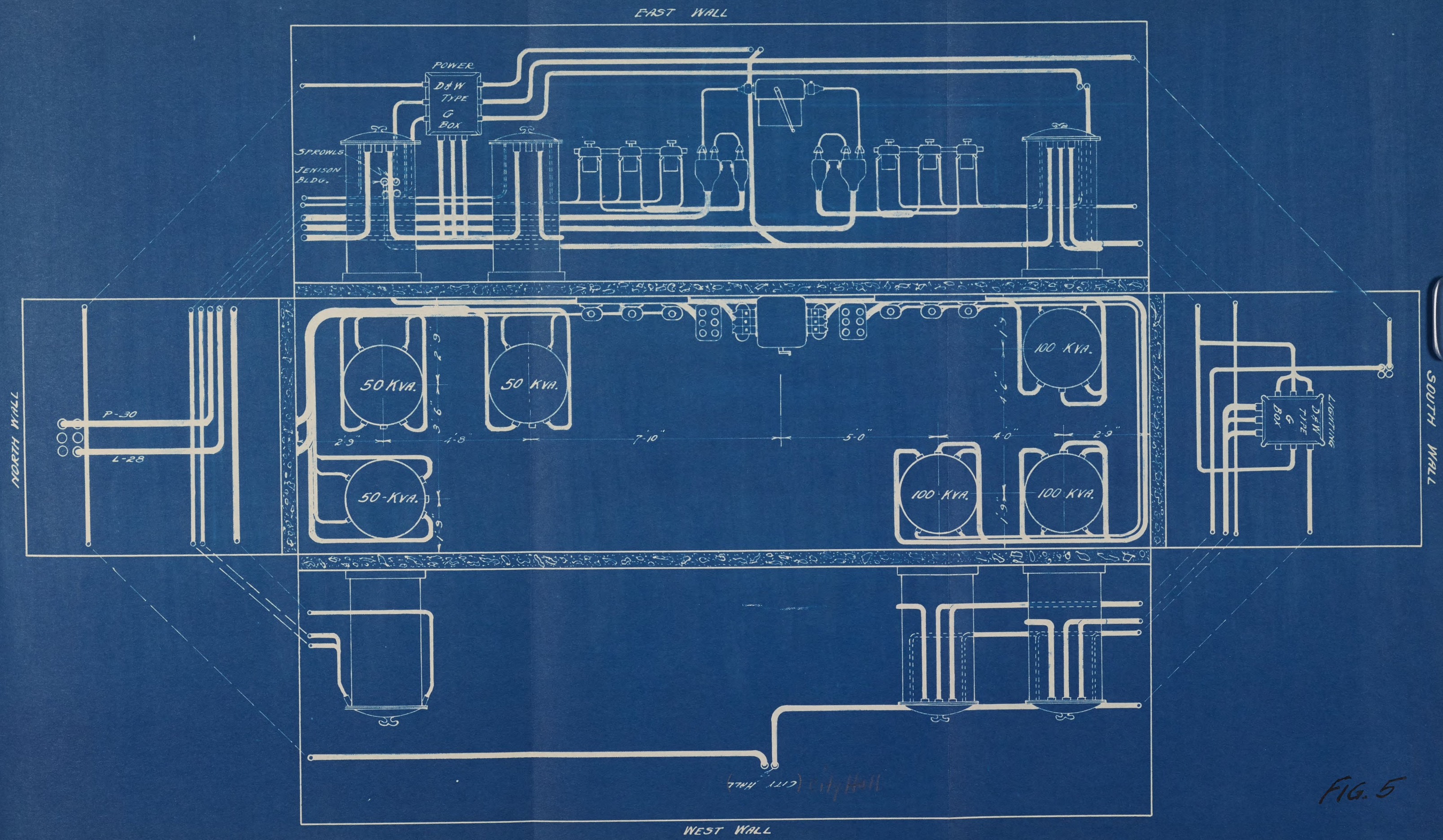
In order to approximate the reliability of the direct-current system much work has been done in recent years in the development of the secondary network. This method of paralleling transformers is not new, however, as many operating companies have used the scheme of banking all the transformers on the same single phase feeders for many years with varying success. One of the disadvantages of the method as practiced before the introduction of the later methods of networks protection laid in the fact that constant inspection of transformers and of transformer fuses as well as of sectionalizing fuses (if these were used) was necessary in order that the transformers would not become overloaded to such an extent that they would burn out due to failure of other transformers on the network to carry their proportionate share of the load. The writer had occasion to eliminate several such networks in Lansing about ten years ago when investigations revealed that transformer failures and poor service conditions were due to transformers being disconnected from the system by reason of open fuses thus throwing an overload on other transformers. This has been of common occurrence with many operating companies and for the reason that sufficient regularity of inspections cannot be made without excessive costs many companies do not permit the paralleling of transformers. On the other hand, by the use of this network system, the transformer capacity installed may be much smaller due to the advantage derived from diversity of load.

The later developments, however, have eliminated most of the disadvantages of the old system of parallel operation. With the use of automatic networks units the stability of the network approaches that of the direct-current system. Short circuits on any one feeder will cause the units on that feeder to open and when the feeder is repaired these units will automatically reclose when the feeder circuit breaker at the substation is closed. They will not reclose on reverse phase or when the ratio of the feeder voltage to the network voltage is less than normal and in case feeder voltages are out of synchronism the units of one feeder will open and will reclose again when voltages are in step.

The substation operator may take advantage of light load periods and take units out of service by opening feeder circuit breakers. Also, the secondaries of the network may be so designed that faults occurring on them will burn clear without interrupting service. The costs of network units as quoted by one manufacturer in Jan. 1927, were as follows:

Amps.	Non-Submersible	Submersible
250	$ 500.00	$ 890.00
500	550.00	940.00
1200	1,050.00	1,550.00

The following diagram, taken from Westinghouse Elec. & Mfg. Co. Instruction Book I.B.5374, shows schematic diagram of an alternating-current secondary network using network units.



EAST WALL
POWER
D&W TYPE G BOX
SPROWLS
JENISON BLDG.
50 KVA.
50 KVA.
50-KVA.
100 KVA.
100 KVA.
100 KVA.
2'9"
3'6"
4'8"
7'10"
5'0"
4'0"
2'9"
1'9"
4'6"
P-30
L-28
NORTH WALL
SOUTH WALL
LIGHTING D&W TYPE G BOX
CITY HALL
City Hall
WEST WALL

FIG. 5

DISTRIBUTION IN CONDENSED LOAD AREAS

Some of the problems encountered by distribution engineers in the location and the economic construction of lines, though seemingly simple, are not always easily solved. The question of time - the maximum life of the line with respect to future load growth-is, of course, of major importance but there are others such as routing, choice between overhead and underground, etc. that must be given most careful consideration. Proper routes are not always available for overhead lines nor is it always possible to build conduit lines where they are most desired. Each particular part of the problem must be considered in its relation to the whole and the solution must be based upon sound judgment and economic facts.

The writer recently had occasion to study and make recommendations regarding the reinforcement of lines, of the Board of Water & Electric Light Commissioners of Lansing, now serving East Lansing and the report is quoted herein in order to show some of the problems that must be considered. Quote:-

"At the present time we have one No. 4/0, three phase, four wire overhead circuit feeding East Lansing from our Cedar Street substation, this circuit being connected to the Michigan State College Power Plant through a bank of 4000 to 2300 volts step-down transformers. The load on this circuit has been as high as 200 amperes per phase or about 1,400 kw for the circuit. The normal load is approximately 1,000 kw which is the maximum that should be carried without excessive voltage drop. The construction of this line is in good condition except for that section along Michigan Avenue from Clippert Street to Harrison Road.

that o

badly

slight

in th

finai

as fa

Michi

this

park

tens

subi

not

fir

pos

cer

sys

in

is

on

b

so

t

Basing the future growth of the load in East Lansing on that of the past ten years it is found that the present load will probably double in the next ten years. The load center will shift slightly to the west due to the higher type of subdivision properties in this direction. The growth in this direction will probably be confined to the territory between Saginaw Street and West Michigan Ave., as far as Ranney Park. There will be no development south of Michigan Ave. due to the lowness of the ground and to the fact that most of this land is owned by the State and by the City of Lansing and used for park purposes. The growth south of the Cedar River will not be extensive because much of this land is State property and will not be subdivided. The growth in a north-easternly direction will probably not go much beyond Saginaw Street.

Construction of lines to East Lansing presents a more difficult problem than any encountered in other parts of our system. The possible routes - Michigan Ave., Saginaw St., and Mt. Hope Ave., have each certain disadvantages which must be considered in their relation to the system and to the general public.

In the consideration of routes, Michigan Avenue is of first importance as it is the location of the existing circuit and because it is the shortest route to our generating plants and substations. Additional circuits (overhead) along this route, however, will necessitate rebuilding the pole line on Michigan Avenue from Clippert Street to Harrison Road which is not recommended due to the fact that the completion of the boulevard project may force abandonment of pole lines on this street.

Another influence against additional circuits here is the fact that our pole line on Kalamazoo Street is already loaded to such an extent that additional load on these poles is not advisable. No direct route other than Kalamazoo Street exist south of Michigan Avenue and lines east from the Cedar Street substation must therefore use this street.

Saginaw Street from Larch Street east provides another route to East Lansing, but lines constructed here would have to pass over Grand River Avenue from its intersection with Saginaw Street to Hillside Street, East Lansing. Overhead lines along here would be very objectionable because of the high class subdivisions which lie along both sides of this street and because of the fact that it is a much traveled State and National highway. Considerable underground cable would also be necessary from the Cedar Street substation to Saginaw Street. This would occupy duct space that may be more needed for future circuits to the northern part of the city.

Although lines could be constructed along Mt. Hope Avenue to Harrison Road and North on Harrison Road to reach East Lansing, the use of this route would be prohibitive due to the fact that over most of the distance the reconstruction of existing lines and construction of new over that portion that has no pole lines at present would be uneconomical because of the light load conditions which now exist along this route and which will not change materially for years to come.

Another route that has been considered is along Main Street from River Street to McCullough Street, then over private right-of-way along the Pere Marquette Railway to Sheppard Street and over Shields Avenue to a point opposite Foster Street. At this point an underground cable

right-

pole

Camp,

Golf

com

and

be

kw

era

pas

4,0

vol

pr

cable dip would be required under the Pere Marquette Railway Company's right-of-way to the Francis Street pumping station. From here pole lines could be constructed to Clippert Street opposite the Tourist Camp, and underground cable construction from there across the Red Cedar Golf Course for a distance of about 1,500 feet. This line could be connected to one of the circuits of HL-1 at Main and River Streets and fed 13,200 volts from the Moores Park station.

In the construction of lines to East Lansing, it should be borne in mind that the load at East Lansing will probably reach 3,000 kw or more within the next ten years and that the distance from our generating plant to the load center is nearly five miles which distance is past the point of economical distribution of this amount of load at 4,000 volts. Any new construction should therefore be made for 13,200 volts, whether or not operation at this higher voltage is immediately provided or deferred to a later period.

In considering 13,200 volts construction it should also be remembered that this voltage is above the maximum allowed by the Michigan Bell Telephone Company for joint use. The operation of 13,200 volts circuits on pole lines would therefore mean duplicate pole lines over the major part of the distance. Much of our efforts during the past few years has been towards the elimination of such duplicate pole lines.

Direct feed of this load from the Moores Park Plant is not recommended for the reason that no additional transformer or 13,200 volts line capacity will be required at the Cedar Street substation. This is due to the fact that the load in East Lansing is essentially a lighting load, its maximum demand coming on at times when the demand on the substation is falling off; i.e., in the evening hours. Thus, advantage is taken of the diversity in load which will improve the substation load factor. If it should be desired at any future time to feed this load direct from Moores Park, these circuits can readily be transferred to feeders from Moores Park at Cedar and Kalamazoo Streets.

Distribution over overhead lines has many advantages over underground distribution where no obstacles to the construction of such lines exist. The first cost of overhead construction is much less than for underground and maintenance is considerably simplified. The maintenance cost is high, however, and in the long run underground construction may prove the least expensive, even though duplicate circuits are required in underground, in order to take care of possible interruptions on the cables. Where construction of adequate overhead lines is difficult as in this particular case, underground construction is greatly favored.

Any extension of our underground conduit system east of Holmes Street should not be considered as any addition to the distribution system as the territory east of Holmes Street is not likely to require distribution of this type for many years, if ever. Underground construction of circuits to East Lansing should therefore be planned for this purpose alone and no consideration should be given to other distribution circuits along the route.

Conduit construction throughout the portion of the route that will not require future undergound distribution may be dispensed with by the use of parkway cable (steel armored) laid in a trench of sufficient depth to go below the frost line. The cable would need no protection other than a creosoted plank laid on top of the cable as a protection against mechanical injury. Manholes for splicing should be provided about every 700 feet. Cables of smaller circular mill areas may also be used by placing them directly in the ground instead of in conduits as the carrying capacities are increased due to better heat radiation. The attached reprint from the Electrical World describes the use of this method of underground construction in Omaha, Nebraska, and which resulted in a considerable saving to the operating company.

The attached estimates are based on an ultimate load of about 4,000 kw. and double circuits are provided in order that interruptions to service may be minimized.

SUMMARY OF COSTS

Estimate #1

Construction of overhead line	$30,000.00

Estimate #2

Standard undergound construction	$79,000.00

Estimate #3

Undergound trenchlay cable construction	$55,000.00

Estimate #4

Substation installation including land and buildings	$40,000.00

Difference in cost between standard undergound and trenchlay underground construction	$24,000.00

The attached schematic diagram of the 4,000 volts distribution system of the Board of Water and Electric Light Commissioners covering the main business section of Lansing illustrates the simplified primary networks used, and for the design and construction of which the writer has been principally responsible. This system was begun in 1922 and extensions have been made from time to time. It has given no trouble during this time and there has been no cases of feeder outages by reason of failure of any part, except in one instance. This one failure was due to the breakdown of a primary tap box which was used experimentally and in which moisture crept in by reason of the cover being not sufficiently tightened. Wiped joints are used throughout for both main splices and taps.

As can be seen from this diagram, feed is had over five 4,000 volts circuits from the Cedar Street substation. In addition to these circuits, one small portion (north on Grand Ave.) may also be fed from the Ottawa Street plant or the Moores Park plant direct. This circuit is a tie circuit from the Ottawa Street plant to the Moores Park plant through the Durant 13,200 volts substation. Tie through the Ottawa Street plant bus to the Cedar Street substation is had through four 500,000 CM 3/conductor cables which is used for emergency service from the Ottawa Street plant in cases of breakdown at Moores Park.

As explained on page 22, for normal operation, the lighting and power transformers are connected to their own individual circuits but all the load at any one of these installations may be transferred to either feeder if necessary or desired. In addition to this, the two feeders serving the installation may be tied together at this point. The operation of the installations on pole structures is similar to that of the underground vault installations except that on pole structures selective type disconnects are used instead of oil circuit breakers.

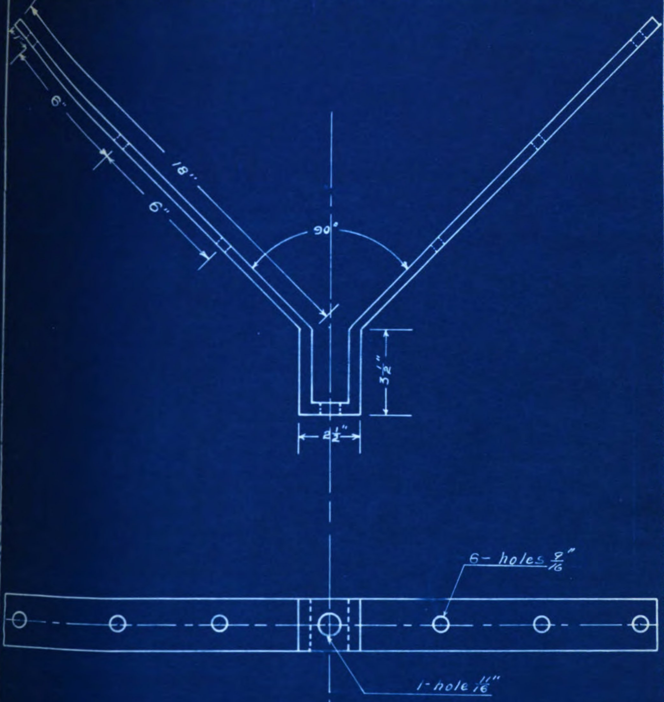
Each particular transformer installation used in the Lansing distribution system, including the business districts is a separate system and no attempt has been made to use the secondary network scheme because the business blocks are, as a rule, not provided with any alleys or thoroughfares running through the entire length of the blocks. In only a few cases is it possible to run conduit lines through more than one block in any direction. If networks were employed it would also be necessary to use one for each of light and power as the secondary power voltage, now being 460 volts, could not readily be changed without considerable expense in rewiring customers' services and in reconnecting and changing their equipment if the more economical scheme of 3 phase, four-wire secondary distribution scheme for serving both light and power were to be used.

A rather unique method of secondary distribution for use in the business districts has been developed in Lansing because of the small amount of space which may be had in the rear of the business blocks. The use of poles has been found unsatisfactory as these poles were constantly being run into by truck bodies and wheel hubs of trucks and which caused excessive maintenance costs of poles and wire lines. When the undergound system was first started it was therefore decided to place the transformers underground in those blocks which afforded least space for overhead mounting, and in order to avoid the use of poles for secondary distribution, these secondaries were fastened.

to the rear of the buildings by the use of steel racks. The first of the blocks treated in this manner (in 1922) has had no maintenance cost since this time except for that incurred by reason of periodic inspection of equipment. In order to make the work of running the wires on the rear of the buildings as neat and substantial as possible several supporting fixtures were designed by the writer and which fixtures are now being manufactured and sold as standard line equipment. Figures 6 and 7 show two of these fixtures which are used for supporting secondary racks on corners.

The cost of a standard vault installation as used in Lansing is approximately $2,200.00. This covers all labor and equipment with the exception of the transformers, the cost of which would vary with the size of the installation. With the use of three fifty kva transformers for power and three one-hundred kva transformers for lighting the total cost will be nearly $5,000.00. By using automatic throw-over equipment instead of manual this cost would be increased to approximately $6,000.00., or by about 20 per cent. This increase may not be justified where the service with the use of manual equipment is satisfactory. Figure 8 shows part of the interior of a standard vault on the Lansing system.

The use of pole structures for transformer installations of this type is very satisfactory where sufficient space can be obtained. The cost involved in such installations will be materially less than for underground and should not exceed $750.00 including all labor, material and equipment except transformers.



BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN.

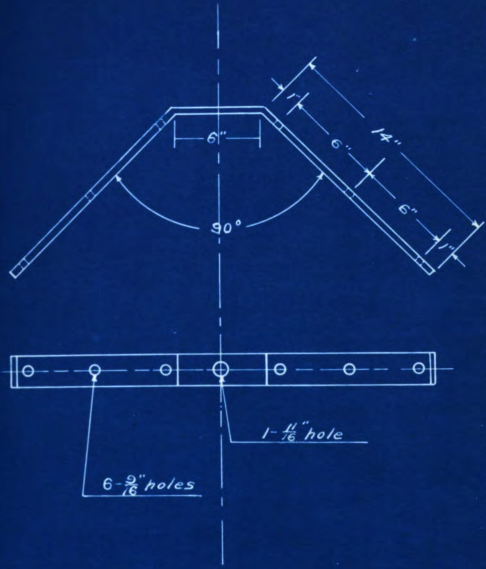
ELECTRICAL DEPARTMENT

CORNER STRAP FOR
SECONDARY RACKS

DR'N BY T.H.G. CHECKED APPROVED	SCALE $\frac{1}{4}$" = 1" DATE 1-30-26	FIG. 6

$\frac{3}{16}$" X $1\frac{1}{2}$" STRAP IRON

FIG. 6



$\frac{3}{16}$" X $1\frac{1}{2}$" STRAP IRON

BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN.

ELECTRICAL DEPARTMENT

CORNER STRAP FOR SECONDARY RACKS

DR'N BY T.H.G. CHECKED APPROVED	SCALE $\frac{3}{16}$" = 1" DATE 1-30-26	FIG. 7

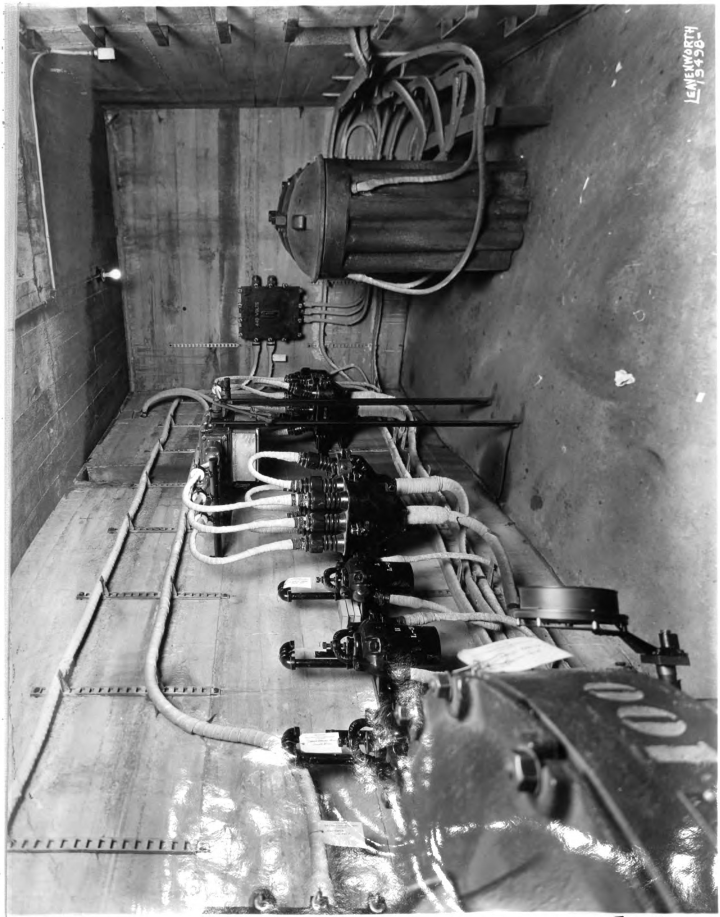


FIG. 8

DISTRIBUTION IN RESIDENTIAL AREAS

Due to the tremendous growth of the electrical industry during the past decade distribution systems have necessarily been called upon to supply an increasing and diversified load, and the increase in the residential areas has been of more concern to the distribution engineer than that of the industrial load. Large, concentrated loads are relatively easy to serve and original lines are usually planned for the addition of load and extra capacity may readily be installed.

The increase in residential load, however, has been more difficult to take care of. Here, there are two separate problems - primary line capacity and secondary line capacity. While primary lines for lighting purposes, like industrial distribution lines, may be planned in advance to take care of a certain load increase or may readily be reinforced if necessary, the secondary distribution lines serving one small group of customers are more difficult to plan in advance for maximum economy.

Until the heating of homes by the use of electicity becomes economically possible or electric cooking becomes universal, the bulk of the demand of residential customers will continue to be caused by the lighting load. The ordinary appliances such as sweepers, toasters, washing machines, ironers, etc., while adding to the total amount of energy used does not add to the demand upon the distribution system as their uses occur mainly while the lighting load is low. Ranges, however, where they are of sufficient numbers, may affect the whole lighting distribution system and replace lighting as the mainstay of the residential demand and change the time of peaks of demands.

The curve in Fig. 9, plotted from current readings of lighting feeders at the Cedar Street substation, Lansing, shows that the existing peak demand occur about 7:00 o'clock in the evening. If range loads should replace lighting as the principal creator of the demand the peak will be advanced to about 6:00 o'clock.

The curves in Fig. 10, plotted by the writer from data contained in the Electrical World, issue of November 27, 1926, shows the individual and group demands of electric ranges. These curves show that where one range on the system creates a demand of 3.75kw the individual demands of a number of ranges on the same system decreases very rapidly up to fifteen ranges. At forty ranges the individual demand is only 1.0 kw and at eighty ranges this demand is reduced to 0.9 kw. The curve will probably not go below 0.75 kw for any number.

Radio receiving sets have been the largest single residence load builder in recent years and have been the principal means of bringing the residence lighting demand up to nearly double that of ten years ago. The average receiving set uses approximately one-hundred watts and this, coupled with the fact that it is used for long periods of time each day until late in the evening hours and that more people stay at home now than they formerly did in order to enjoy the radio programs - and this more often with more than the usual amount of illumination turned on - it may well be said that this piece of apparatus has done more towards increasing the revenues of the operating companies than any other apparatus used in the home. It has been the most desirable addition to the load building apparatus as it has not increased the demand to such an extent that extensive rebuilding of

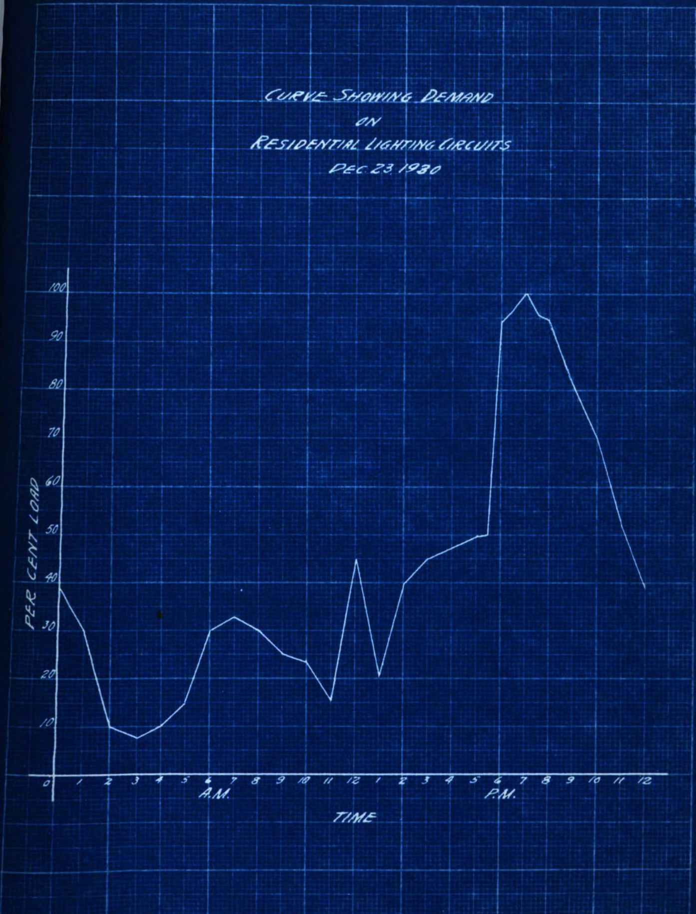

CURVE SHOWING DEMAND
ON
RESIDENTIAL LIGHTING CIRCUITS
DEC. 23. 1930
PER CENT LOAD
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
A.M.
P.M.
TIME

FIG. 9

the secondary distribution systems has become necessary, which has been the case with the electric range load.

In order to take care of the constantly growing residential demand, operating companies have been forced to spend huge sums in the reconstruction of secondary distribution systems. Where formerly No. 6 and No. 4 wires were of sufficient size to carry the load and No. 2 wire was considered quite large, the present demands call for the use of wire sizes as large as No. 4/0 and with smaller limits of distribution.

In planning the change or reconstruction of any secondary distribution system, distribution engineers must carefully consider not only that particular system but also those adjoining in order that such reconstruction will fit in with the future development of those adjoining sections. They must take into account the possible future growth of the whole and apply the most economical methods, consistent with the proper degree of service, in making these necessary changes. Very often, secondary systems may most economically be bettered by cutting them into two or more separate parts and installing transformers for each and at other times the needs may best be taken care of by combining two or more independent systems with only a small amount of work involved. The diversity of demand should also be known so that the transformer and wire sizes, which materially affect the fixed charges, may be reduced to the minimum. Conditions, such as existing pole lines, primary lines, interference from trees to primary line extensions, etc., must also be taken into account. There is no hard and fast rule by which one may be guided in planning secondary systems as each locality and system has its own method of proper solution.

In the larger cities it is very often the case that large districts may be found in which the demand of residential customers may vary considerably. In the smaller cities, however, the entire area is of comparatively uniform demand. Lansing, particularly, has no one section where the demand will differ materially from that in others and the normal demands have therefore been fairly easy to determine.

Figure 11 shows the demand that any number of customers will place on the secondary distribution system. The data for this curve was obtained by the writer during the months of December, 1930 and January, 1931. Several individual transformers of various sizes and with various numbers of customers connected were tested by means of recording ammeters, and the minimum demand was checked from readings of several primary lighting circuits. From these primary readings, covering approximately one thousand customers per circuit, the maximum individual demand for this number was found to be about .175 kw.

This curve has been embodied in the "Instructions for Determining Sizes of Transformers and Secondary Wires" which have been prepared by the writer for use of the electric distribution department of the Board of Water and Electric Light Commissioners of Lansing, in the planning of secondary distribution systems. These instructions follow:-

INSTRUCTIONS FOR DETERMINING SIZES OF SECONDARY MAINS AND LOCATIONS AND SIZES OF TRANSFORMERS

I GENERAL

A - In laying out secondary distribution systems the economics of the undertaking must be carefully considered and thought must be given to its relation to the system as a whole and the wire and transformer sizes must be selected which will fit in with the ultimate scheme.

B - In the extension and the reconstruction of secondary distribution, the fact that tree conditions and other interferences often make the extension of primary lines difficult and costly, must not be lost sight of. Extensions of primary lines, where extremely high poles are necessary, is often not economically justified and in many cases it will be found that proper rearrangement of the existing secondary system will provide the desired degree of service.

C - In general, secondary mains shall not be extended more than five spans on either side of the transformer unless conditions are such that primaries are difficult to install, in which case, extensions beyond five spans may be permitted.

D - Only one transformer shall be connected to any secondary system and parallel operation shall be resorted to only in cases of emergency.

E - Secondaries on rear lot service shall not cross intersecting streets except where the transformer is located on the street in which case they may run into the blocks in either direction.

. Ver

bloc

ate

over

tems

ably

. The

getl

PROCE

A. Est

ser

ing

to

wil

in

bl

B - Ma

of

C - Pr

be

or

D - C

t

E - F

k

F - Where it is possible to do so, secondaries in two to three block squares shall be grid connected and the transformer located as near the center of the grid as possible. Blocks of over 500 feet in length shall not be included in gridded systems, nor shall the number of customers on such grids appreciably exceed 200.

G - The neutral wires of secondary systems shall be connected together as far as practicable.

II PROCEDURE

A - Establish the physical limits of the distribution required to serve the territory, taking into account its relation to existing secondary systems which may need rebuilding and its relation to future distribution in new and adjoining territory. Ordinarily, consideration will be confined to rear lot lines between intersecting streets, street service within the limits of long blocks, four-way distribution on streets, and grids.

B - Make a map of the territory showing the locations of poles and of poles to be set. Number each pole.

C - From the physical limits of the territory involved and the number of spans to be built for the ultimate development, determine which type of system is best suited and establish the limits of each. Select the locations of transformers.

D - Compute the existing load, probable future load, combine these two and set down opposite their respective pole numbers.

E - From the transformer as a starting point compute the load in kw as follows:-

E -

1 - For Straight Sections (Refer to Fig. 12)

(a) Using the demands from curve in Fig. 11, multiply the load at each pole by the number of spans between it and the transformer pole. Do this for both present and probable future loads. Use these totals to determine the transformer size and the size of wire to be used. Use table No. 1 for wire size.

<u>Note:</u> The transformer size to be selected according to the present and future loadings, 5.3 kw and 8.9 kw respectively would be $7\frac{1}{2}$ kva. The wire size may also be determined from the method shown for gridded sections.

2 - For Gridded Sections

(a) Total the kw load of the grid using the curve in Fig. 11 for the demand of services. For the demand of electric ranges use the curves in Fig. 10. For stores and other places, not single residences, use table No. 2.

(b) Divide the grid up into sections with approximately equal load on each sections. Compute the new load on each section from Figures 10 and 11. For a uniformly distributed load use the total section load for two-thirds of the distance in selecting the wire size to be used from Figures 14, 15, and 16, depending upon the per cent voltage drop to be allowed.

<u>Note:-</u> Until more detailed information has been obtained relative to the diversity of range loads in relation to lighting loads, the range load may be omitted from any section where it amounts to less than one-half of the lighting load.

E -

2 - For Gridded Sections, cont'd.

(c) The following example is used to illustrate the method of solution stated in (b). Refer to Figure 13.

Total number of services on the grid = 186

Individual demand from Figure 11 = .175 kw, approximately.

Store demand from Table No. 2 = .500 kw.

Total demand = 186 x .175 - .500 = 33.0 kw.

Load each way from tranformer = 33/2 = 16.5 kw.

Distance = 200 feet.

Wire size from Figure 16 = 3/0 - Use 4/0.

Next, take either side of the transformer, as Olds Avenue. Compute the load on this half of the grid, omitting that part of Max Avenue south of the transformer and the pole at the intersection of Max and Olds Avenues.

Total number of services = 70

Individual demand from Figure 11 = .200 kw, approximately.

Total demand = .200 x 70 = 14.0 kw.

Distance each way from transformer = 325 feet.

Demand on each section = 14/2 = 7.0 kw.

Wire size from Figure 16 = 1/0.

Now, from Olds Avenue south, the total load is connected to a loop circuit and the total load may therefore be divided by two and carried half the distance. This load is fairly well concentrated towards the middle of the loop and no allowance will be made for load distribution.

E -

2 - For Gridded Sections, cont'd.

(c) continued.

Total number of services = 33

Individual demand from Figure 11 = .275 kw.

Total demand = .275 x 33 = 9.0 kw, approximately.

Range demand - Omitted.

Total distance of loop = 1200 feet.

One-half the load or 4.5 kw will be carried one-half the distance of the loop or 600 feet.

Allowing $1\frac{1}{2}$ per cent voltage drop the wire size may be found from Figure 14. Wire size = 1/0.

Note:-

Inasmuch as the secondary voltages at the transformers are usually slightly in excess of 120 volts (varies from 120 to 122 volts) the total drop may exceed 3 per cent. Voltage drops are cumulative, however, and as a general rule shall not exceed 4 volts.

TABLE NO. 1

Kw. spans one way from transformer	Size of Secondaries Outer wires	Neutral
6	#6	#6
8	#4	#6
10	#3	#6
12	#2	#4
18	#0	#3
30	#4/0	#0

TABLE NO. 2

Kind of Load	Kilowatt Demand
Small Apartments	.250
Large Apartments	.350
Small Neighborhood Stores	.500
Charging Sets	2.000
For each H. P. of motor rating	1.000

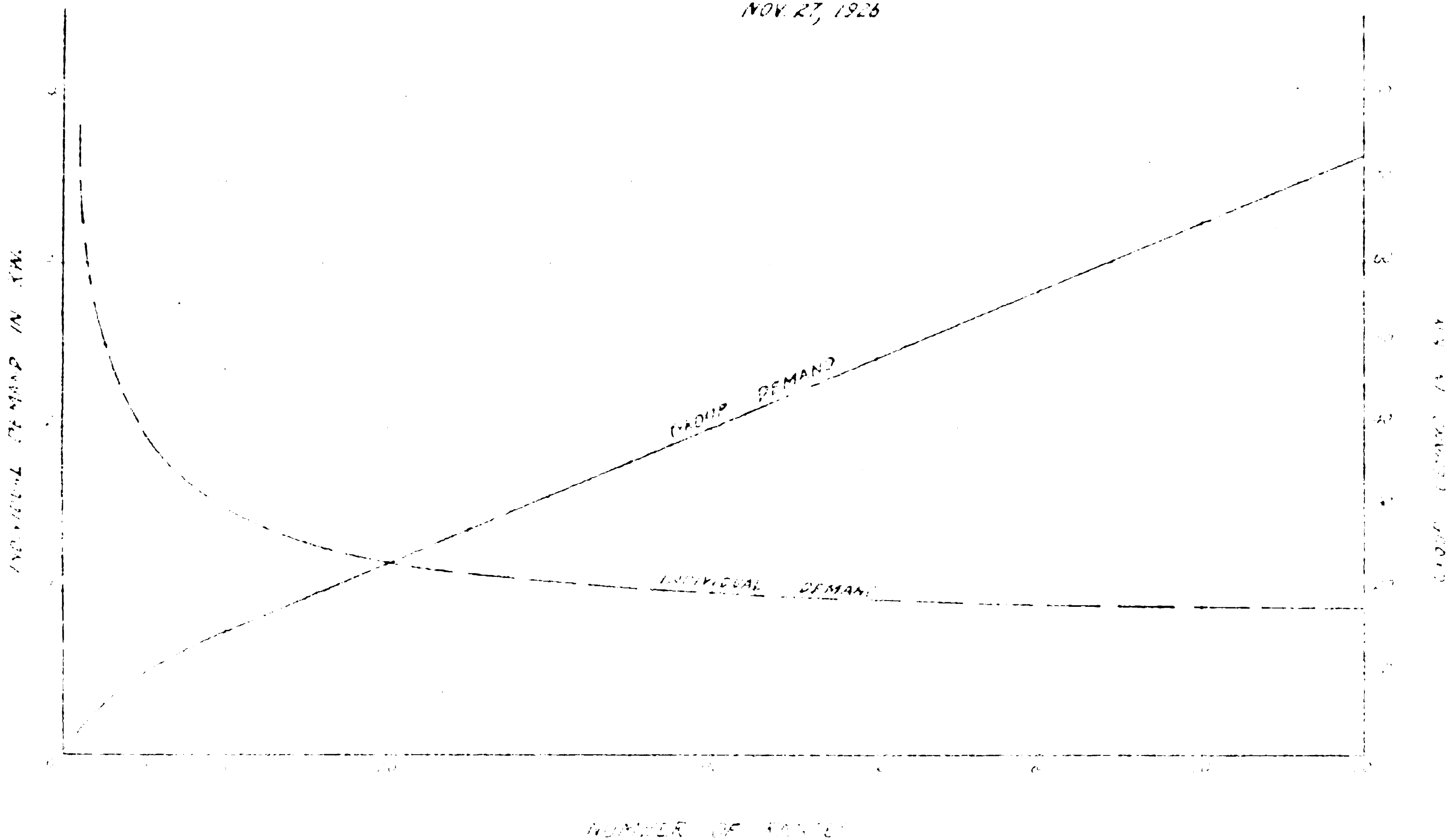
DEMAND OF ELECTRIC RANGES

FOR DOMESTIC USE

MODIFIED DATA FROM

THE ELECTRICAL WORLD

NOV. 27, 1926



CURVE SHOWING
DEMAND PER CUSTOMER
ON SECONDARY LIGHTING SYSTEMS
IN RESIDENTIAL AREAS

4/9/31

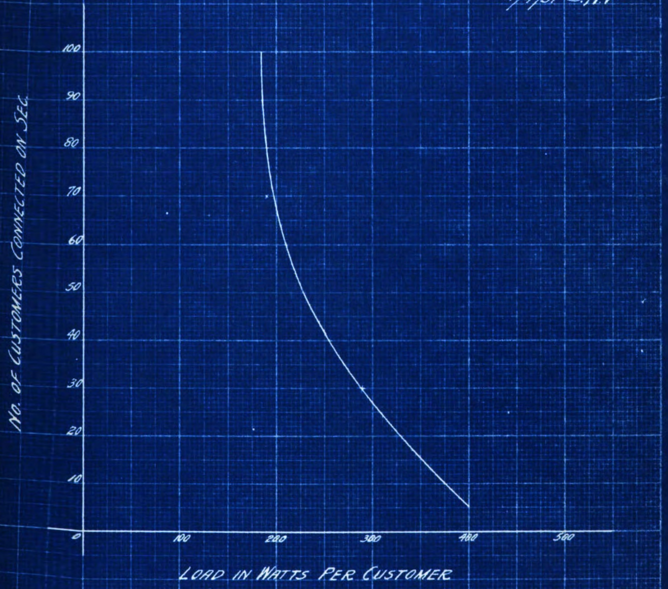
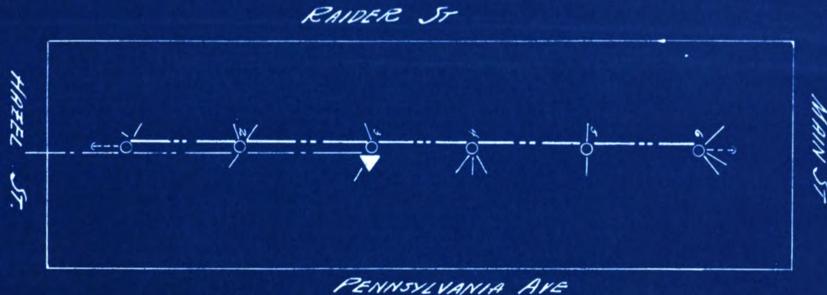


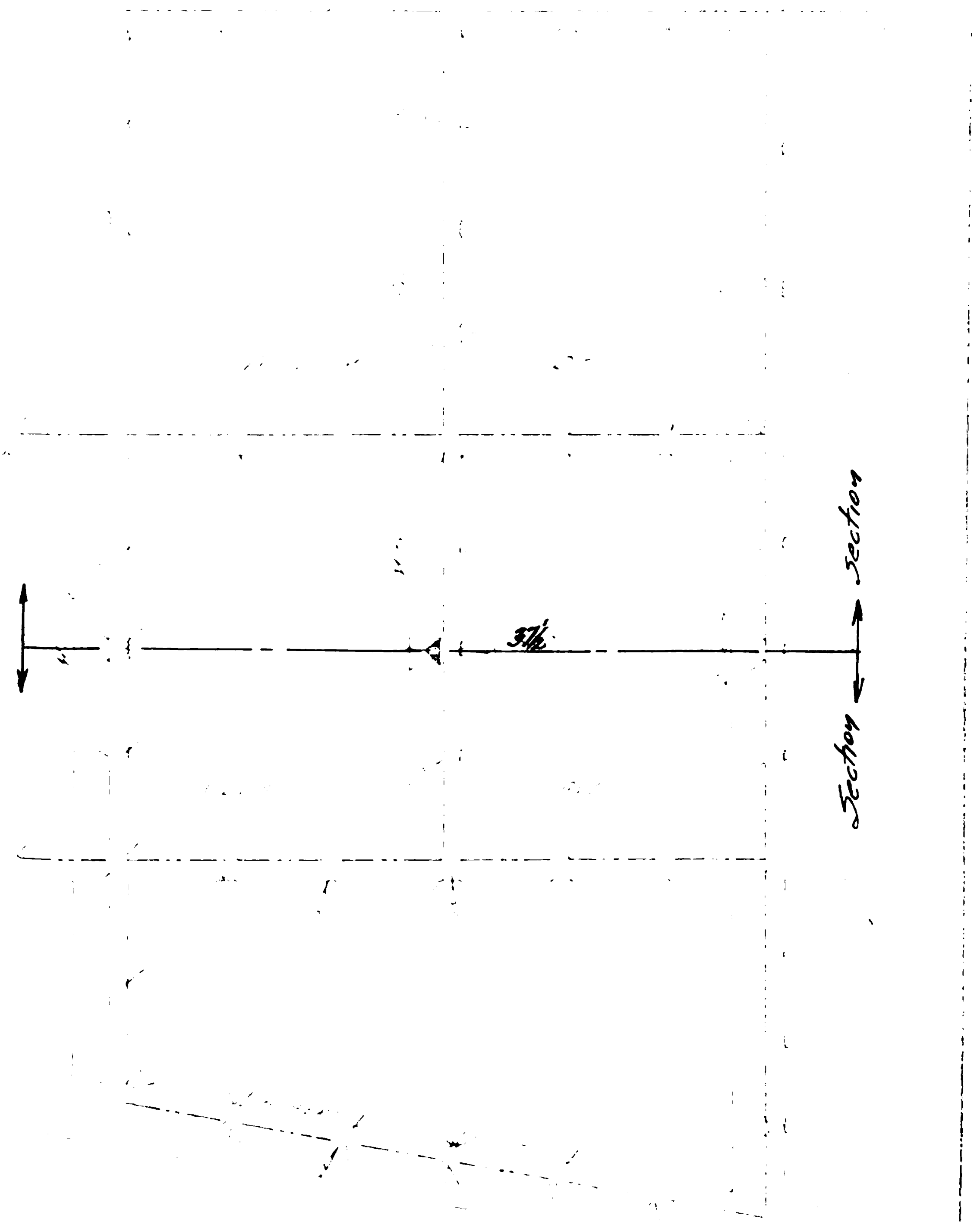
FIG. 11

Pole No.	Customers Present	Customers Future	Loadings Present	Totals	Loadings Future	Totals
1	1	3	1 × .4 = .4 KW		3 × .375 = 1.135 KW	
2	3	4	3 × .4 = 1.2 "	1.6 KW	4 × .375 = 1.5 "	2.635
3	2	4	2 × .35 = .7 "		4 × .350 = 1.4	
4	3	5	3 × .375 = 1.135 "		5 × .350 = 1.75 "	
5	2	4	2 × .375 = .75 "		4 × .350 = 1.4 "	
6	3	5	3 × .375 = 1.135 "	3.0 KW	5 × .350 = 1.75	4.9
	TRANSF. SIZES		5.320		8.935	

KW SPANS			
SOUTH		NORTH	
Present	Future	Present	Future
2 × .4 = .8	2 × 1.135 = 2.275	3 × 1.135 = 3.4	3 × 1.75 = 5.25
1 × 1.2 = 1.2	1 × 1.5 = 1.5	2 × .75 = 1.5	2 × 1.4 = 2.8
Totals 2.0	3.775	1 × 1.135 = 1.135	1 × 1.75 = 1.75
		Totals 6.035	9.80

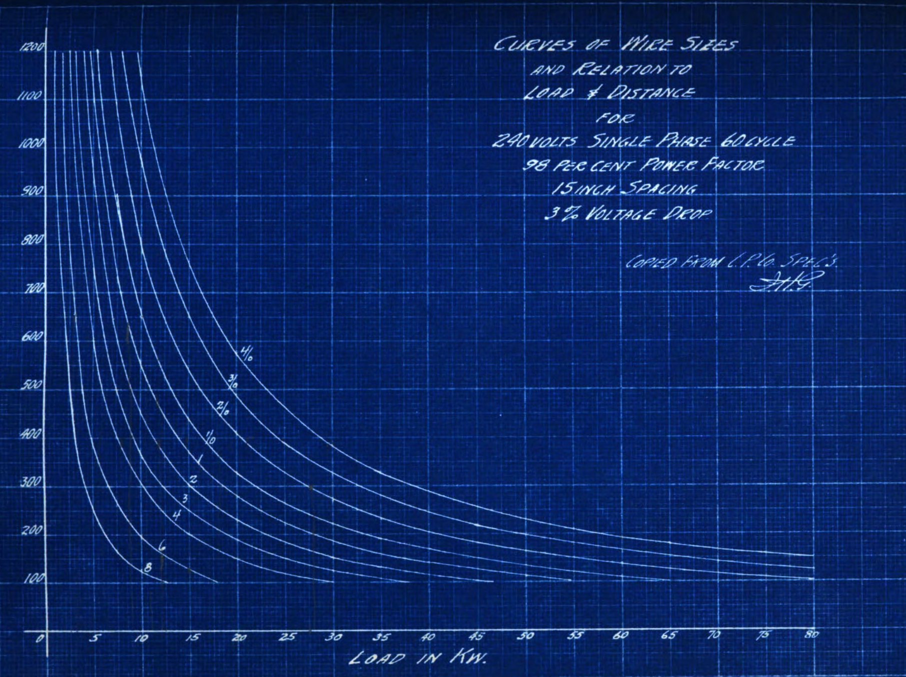


H.G. 5/18/31



TYPICAL SECONDARY GRID

FIG 13



CURVES OF WIRE SIZES
AND RELATION TO
LOAD & DISTANCE
FOR
240 VOLTS SINGLE PHASE 60 CYCLE
98 PER CENT POWER FACTOR
15 INCH SPACING
3% VOLTAGE DROP
COPIED FROM C.P.Co. SPEC'S.
DISTANCE IN FEET
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
LOAD IN KW.
4/0
3/0
2/0
1/0
1
2
3
4
6
8

FIG. 14

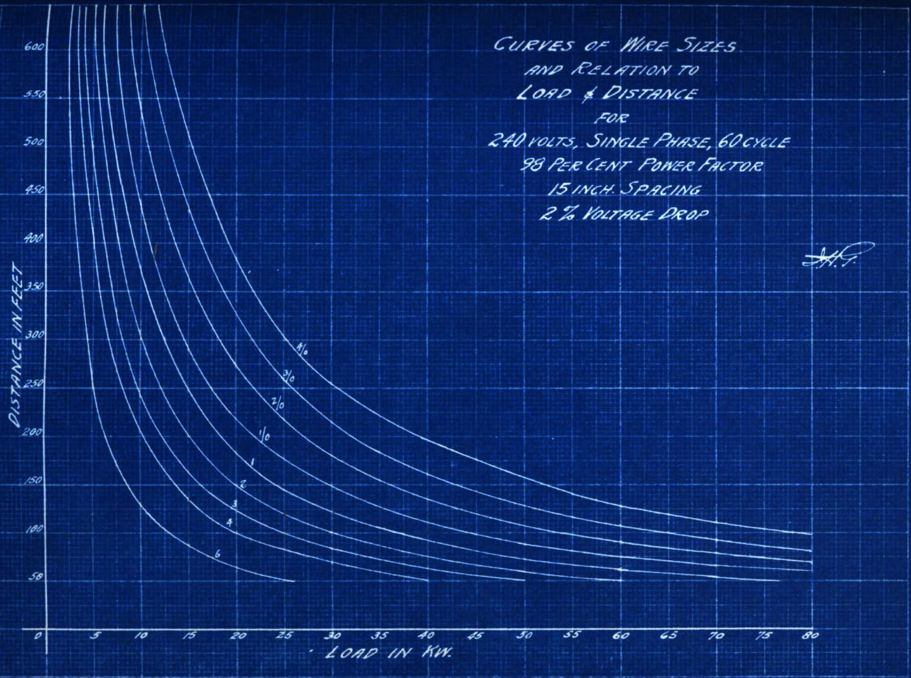

CURVES OF WIRE SIZES
AND RELATION TO
LOAD & DISTANCE
FOR
240 VOLTS, SINGLE PHASE, 60 CYCLE
98 PER CENT POWER FACTOR
15 INCH. SPACING
2 % VOLTAGE DROP
DISTANCE IN FEET
LOAD IN KW.
4/0
3/0
2/0
1/0
1
2
3
4
6
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
100
150
200
250
300
350
400
450
500
550
600

FIG. 15

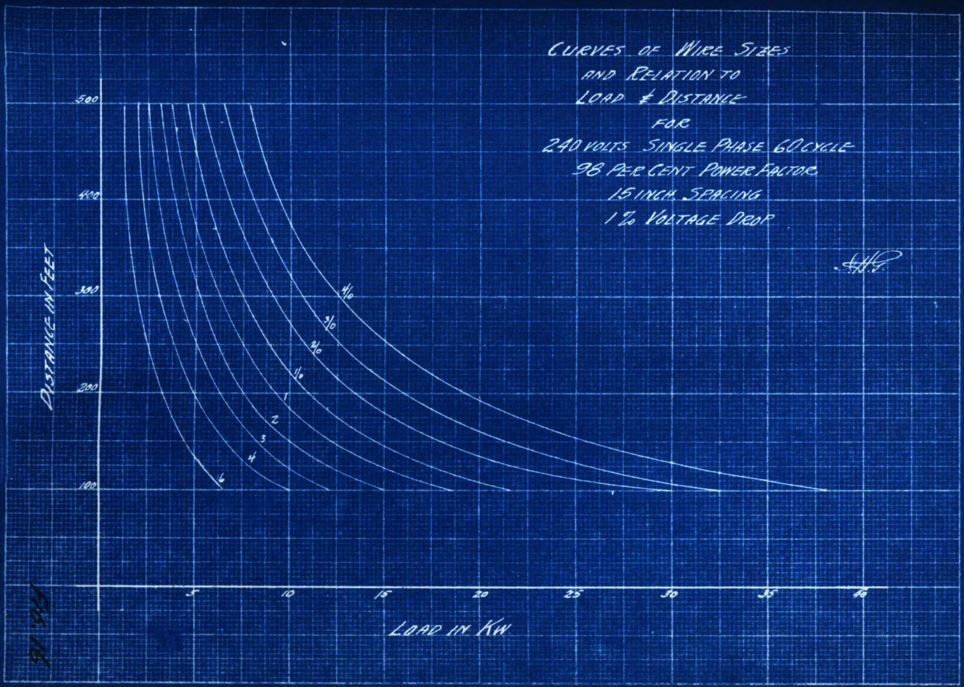

CURVES OF WIRE SIZES
AND RELATION TO
LOAD & DISTANCE
FOR
240 VOLTS SINGLE PHASE 60 CYCLE
98 PER CENT POWER FACTOR
15 INCH SPACING
1% VOLTAGE DROP
DISTANCE IN FEET
500
400
300
200
100
LOAD IN KW
5
10
15
20
25
30
35
40
4/0
3/0
2/0
1/0
1
2
3
4
6

FIG. 16

In recent years electric utility companies have done much to reduce the hazards and the unsightliness resulting from overhead pole lines on the streets and main thoroughfares. On the main streets and especially in the business sections where the load density warrants it, it has been to the companies' own advantage to place its lines underground, but in the residential sections, where economic justification does not exist for placing the lines underground, other means must be used to appease public clamor and to remove the service hazards caused by tree interferences, etc. Sometimes, alleys are available where pole lines may be constructed and where they will be more inconspicuous and at other times it will be necessary to procure private right-of-way on rear lot lines.

In the newer and more up-to-date subdivisions easements are usually provided on rear and side lot lines for the construction of pole and other utility lines but even so, difficulties arises at times in their construction. Lot lines, along which utility lines have been planned or have already been constructed as along side lot lines to be used for crossing from one block into another, may become obliterated by the purchase by one person of the two lots adjoining this lot line and the construction of a dwelling on these two lots. In such cases the moving of lines to other locations may become costly and sometimes nearly impossible of execution without private right-of-way.

This sort of trouble has been experienced by the Board of Water and Electric Light Commissioners of Lansing as well as by all

other operating companies, and it is a coincidence that the writer had occasion to receive a complaint from a lot owner in the subdivision which is used as an illustration in this thesis and which had already been prepared before receiving the complaint. This particular complaint was that the 4,000 volts mains were damaging the trees along this owner's lot line. In this instance the line was constructed in this particular location because of the objections of the owner of the lot along which the line had been originally planned and where it should have been constructed. For reference see map of the subdivision in Figure 17. The line from the north edge of the subdivision south should have been constructed along the lot line of lots 7 - 8 and 109 - 110 but was instead constructed along lot line of lots 15 - 16 and 106 - 107.

In a talk before a meeting of the Lansing Real Estate Board about three years ago the writer pointed out some of the difficulties which utility companies experience in the construction and maintenance of their lines and suggested that certain provisions be made in the laying out of subdivisions which would make for better satisfaction of the property owner and result in better service from the utility companies.

One of the things brought out was the objection by the real estate people to running the lines over head from one block to another. It was suggested at that time that this could be avoided by the employment of certain methods of underground construction which should be at the expense of the owners of the subdivision. The type of construction which the writer had in mind at that time was lead

covered cables placed in conduit and which, in the average subdivision, would amount to approximately $25.00 per lot. Since that time, however, the cheaper type of trenchlay cable has been perfected so that they may be used with entire satisfaction for this kind of work. For the purpose of showing the difference in cost between total overhead construction and partial underground with the use of trenchlay cable, the following estimates of costs have been made:-

OVERHEAD CONSTRUCTION

Poles, installed, 41 @ $20.00 --------- $820.00

Crossarms, complete with pins and insulators

and installed 60 @ $2.10 -------- 126.00

Anchor guys, complete and installed

35 @ $10.00 ---------------------- 350.00

Wire, #3, W. P. , 3600 feet

720 # @ $ .15 ------------------ 108.00

Wire, #6, W. P., 2700 feet

308# @ $.15 ---------------------- 46.00

Installing wire, 6300 feet @ $ .01 --------- 63.00

Total cost, not including supervision and overhead ---------- $1,513.00

PARTIALLY UNDERGROUND CONSTRUCTION

Poles, installed, 34 @ $20.00 -------- 680.00

Crossarms, complete with pins and insulators

and installed, 35 @ $2.10--------------- 73.50

Anchor guys, complete and installed,

23 @ $10.00----------------------------- 230.00

Wire, #3, W.P., 3600 feet

720# @ $.15 ------------------------------ 108.00

Wire, #6, W.P., 800 feet

90# @ $.15--------------------------------- 13.50

Trenchlay cable, 3/condr. #6,

1350 feet @ $ .20------------------------ 270.00

Excavating and backfill, 1075 ft @ $.25---------- 268.75

Potheads, 8 @ $20.00 ----------------------- 160.00

Iron conduit, 250 ft @ $ .20----------------- 50.00

Installing cable, 1350 ft @ $ .075-------------- 101.25

Installing potheads, 8 @ $5.00 ----------------- 40.00

Total cost, not including supervision and overhead -------- $ 1,995.00

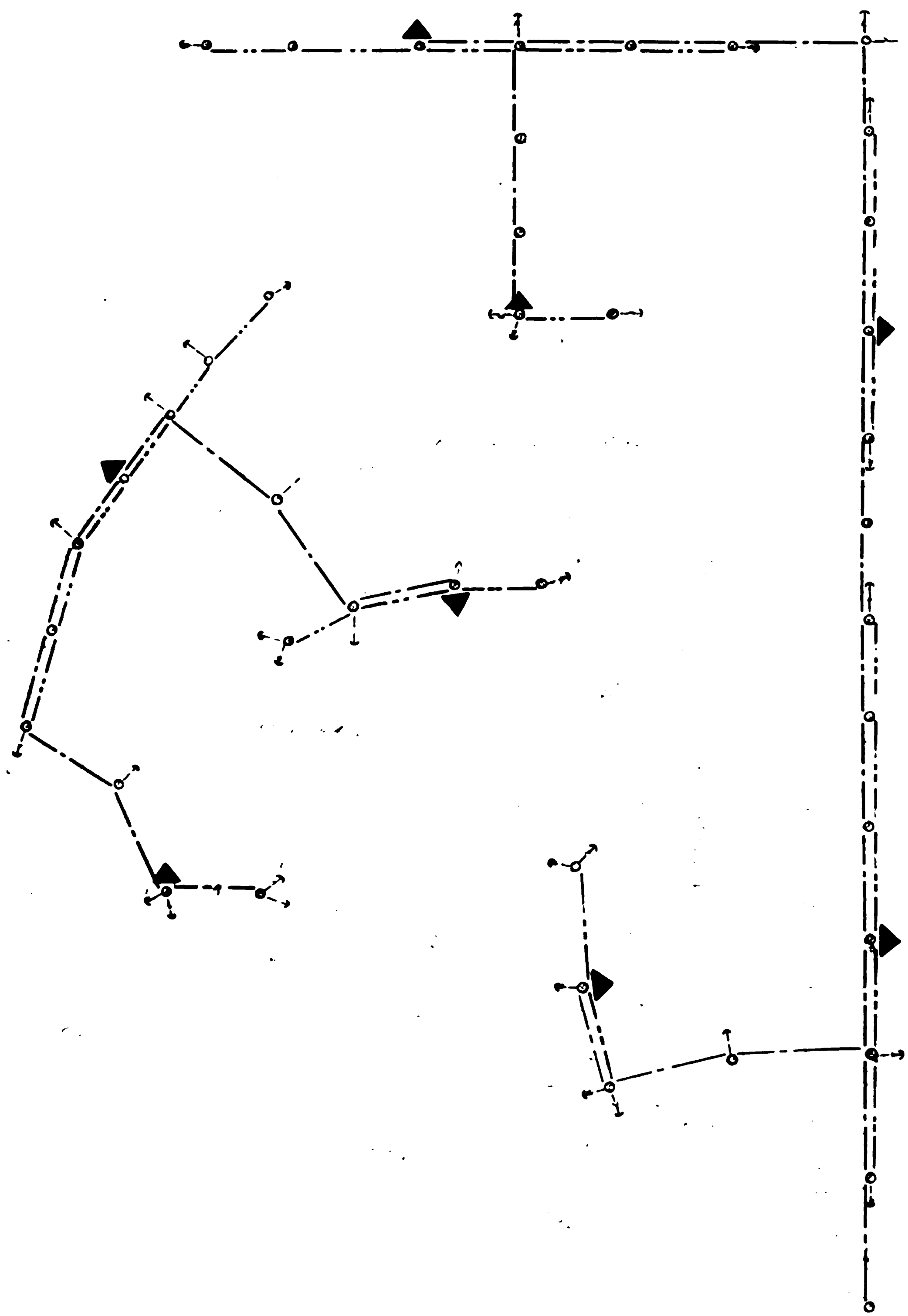
Difference in cost between overhead construction and partial underground construction -- $ 482.00

Additional cost per lot of partial underground constr. ---- $ 4.35

In order to compare the cost of serving this subdivision with the cost of serving the same acreage laid out with the same number of lots but with straight lot lines and streets we will assume that it is composed of thirty-three more lots than shown in the subdivision. This is to allow for lots adjoining the subdivision on the north and east. We will assume that the depth of these lots is 125 feet. The approximate area of the territory to be served would then be 1,200,000 square feet (1000' x 1200') including the streets. This could be laid out in rectangular blocks with 8 blocks to the section and each block composed of 18 lots. The length and depth of the blocks from the center line to center line of streets will be 300 x 500 feet.

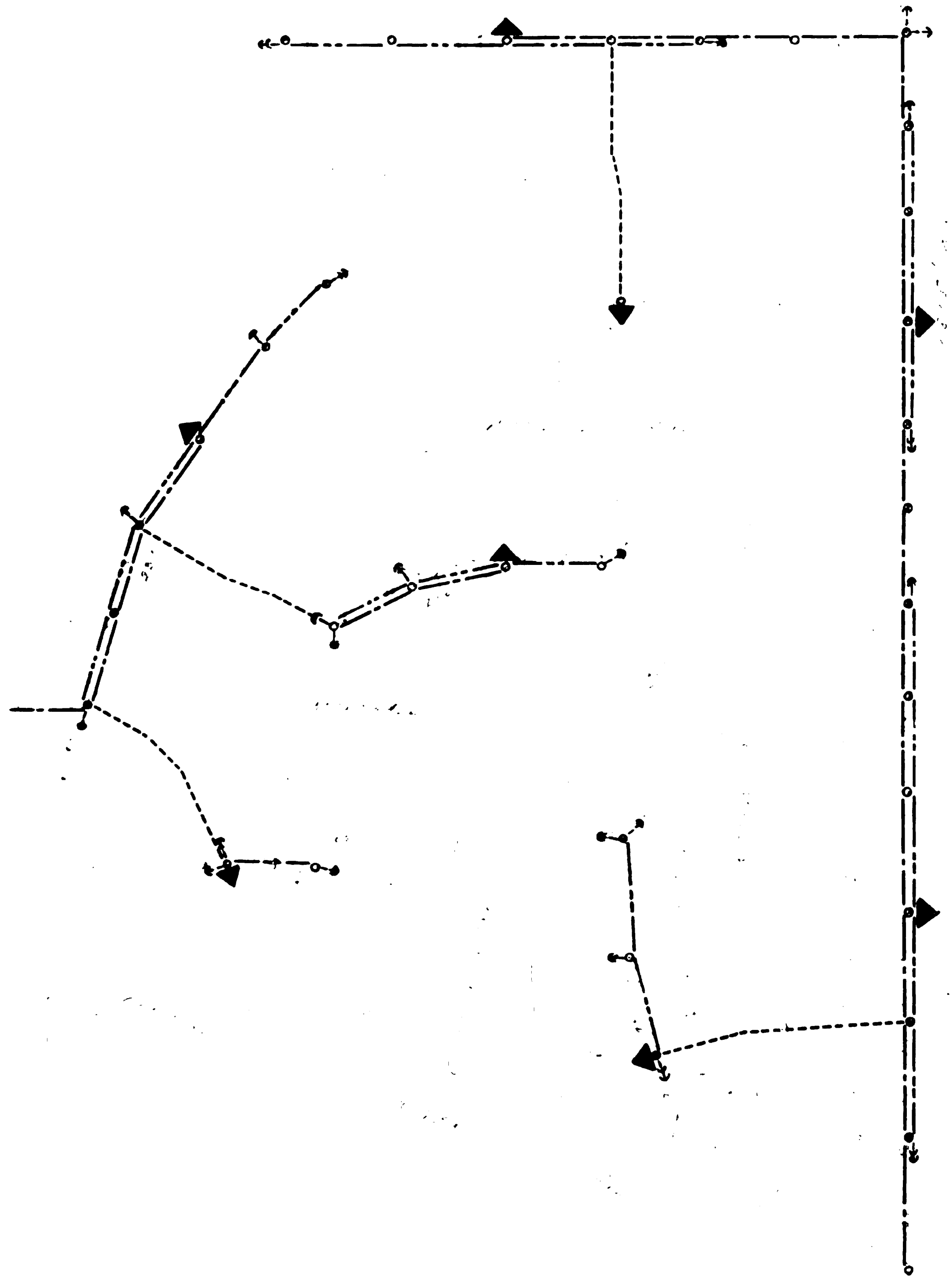
Assuming a pole spacing of 125 feet there would be required approximately 36 poles including the poles on the cross streets. Guying would be reduced to a minimum and would be required only for each secondary dead-end plus an additional allowance for contingencies such as dead-ending cross-leads. About 12 guys will be required. The number of transformer installations could be reduced to four, one for each of two blocks. The saving to the electric utility company would then be as follows:-

5 poles @ $20.00 -------------	$100.00
23 guys @ $10.00 -------------	$230.00
40 crossarms @ $2.10 ------------	84.00
4 Transf. installations @ $35.00	140.00
Saving in transformer capacity	
20 Kva @ $6.00 ----------	120.00
Total saving --	$674.00
Saving per customer --	$ 4.68



OVERHEAD CONSTRUCTION

FIG 17



PARTIAL UNDERGROUND CONSTRUCTION

FIG. 17

SPECIFICATIONS

As in the standardization of voltages and frequencies and electrical utilization equipment a considerable saving may be made by the utility companies by the use of certain "standard" methods of construction. These standard methods should be embodied in and issued as "specifications" covering the particular type of installation. By the use of such specifications construction practices will be standardized and any one type of installation will be done in the same manner at all times and their appearance will be uniform, no matter which crew should do the work.

These specifications should describe in general each particular piece of work and should be accompanied by prints showing installation as well as by such detailed prints and material lists as are necessary in order that the foreman or person responsible for carrying out the project may plan the work with the least amount of difficulty. The use of such specifications will aid greatly in the expeditious completion of the work and may result in a considerable saving through the more efficient use of material and equipment and labor.

The larger operating companies usually have such specifications printed and bound in booklet form which are issued to their foremen and inspectors for use, but for the few copies of such specifications as are needed by the smaller companies the cost of preparation, printing, and binding may be too expensive. These smaller companies, however, may obtain a sufficient number of copies of specifications from one of the larger companies whose construction practices are similar to their own or after whose practices they may wish to pattern their own.

Inexpensive specifications may also be made by the use of typewritten and mimeographed instructions, accompanied by blue printed drawings of the installations, bound in loose leaf covers. These may readily be supplemented from time to time by the additions of such special installations as are deemed advisable. Figures 18 to 22 inclusive are typical examples of such specification drawings.

In dealing with the general public it is necessary that operating companies formulate and publish rules and regulations setting forth their requirements as to customers installations based upon the rules of the National Electric Safety Code and such additional rules as are prescribed by the governing bodies of the particular locality in which they are operating. Each type of installation should be covered in detail or referred to the sections of the Safety Code or municipal or state regulations as are governing. Special rules covering certain specific requirements should be made whenever the general rules are not of sufficient detail and are apt to be misconstrued. A typical example of such special rules follows:

RULES AND SPECIFICATIONS COVERING THE INSTALLATION OF UNDERGROUND ELECTRIC SERVICE

L. GENERAL

(a) These specifications shall govern the installations of all conduits and cables which may be connected directly to the distribution system of the X Y Z Electric Company without intermediate circuit breakers or other automatic disconnecting devices.

(b) Secondary services may be installed by any licensed electrical contractor and will be connected to the system provided that the specifications embodied herein and pertaining to the particular type of service have been complied with.

(c) All primary underground services shall be installed by the X Y Z Electric Company and the actual cost plus ten percent (10%) of all labor and material shall be billed the party authorizing the installation.

(d) Any plans for the construction of underground services shall be submitted to the Electrical Engineering Department of the X Y Z Electric Company for approval before construction is commenced.

(e) Inspection of material and workmanship of secondary service installation will be made by the X Y Z Electric Company without charge.

II. COST OF INSTALLATION

(a) Where primary and secondary services are to be connected to the existing underground system, the X Y Z Electric Company will bear all expense of such installation from its nearest manhole or other point of connection and to the customer's property line, provided that such property abutts upon a public street or alley and that the particular block in which the customer is located is being served by an underground distribution system. The customer shall bear any other expense incident to such installation.

(b) Where primary or secondary underground services are desired in districts not served by the underground distribution system, such services may be installed and connected to the overhead lines. In such cases, the customer shall bear all expense of labor and material involved in such installation including conduits and cable used for pole risers together with the necessary cable terminals and protecting equipment.

(c) Contractors bidding on jobs involving primary underground construction will be furnished with an estimate of the cost of such installation upon application to the X Y Z Electric Company.

III. MATERIAL AND EQUIPMENT

(a) All material and equipment used for underground electrical services shall be as approved by the X Y Z Electric Company for each particular installation and as detailed in these specifications.

IV. METHODS OF CONSTRUCTION

(a) General

1. All underground installations shall be run in as straight a line as possible and without undue bends. If for any reason it becomes necessary to change the direction of the run, a manhole or pullbox may be required at this point. This, however, will depend on the length of the run and the degree of bend and instructions may be obtained from the X Y Z Electric Company for each particular case. The run shall be so located that they will be free from possible injury or damage which may be caused by future excavations or other causes.

(b) Trenching

1. The trench shall be dug at such a depth that a minimum cover on top of duct shall be (a) Under lawns and places not subject to vehicle traffic, 18", (b) Roadways and places subject to vehicle traffic, 24".

2. The trench shall be of such a width that it shall permit the easy installation of the conduit.

IV. (continued)

3. All conduit installations shall be so constructed that no gas or water pockets are formed and shall be given a slope of not less than one half of one percent. Where the conduit is attached to poles or other structures, the slope shall be away from such pole or structure. In general, the conduit run shall drain into basements or into pull boxes constructed for this purpose.

4. In backfilling trench, the dirt shall be thoroughly tramped in place and sod replaced on top of the dirt. Where the sod cannot be saved, good dirt should be placed on top of trench to a depth of six inches and shall be seeded with approved lawn grass seed.

(c) Length of Runs

1. On the pole end of the run, the distance of cable pull shall not exceed 300 feet. If the run is greater than 300 feet, a pullbox or manhole shall be installed. The location of such pullbox or manhole shall be specified by the X Y Z Electric Company for each individual case.

2. The distance between pullboxes or manholes shall not exceed 500 feet.

(d) 1. Except as hereinafter provided, fiber conduit shall be used for all underground services and shall be of a size as specified by the X Y Z Electric Company for each particular installation. The conduit shall be provided with a sleeve joint for joining the ends together. In general, fiber conduit shall be equivalent to that manufactured by the Brown Company under the trace name of "Bermico".

2. The joint of the conduit shall be painted with hot compound before being jointed together.

3. The conduit shall be encased in a concrete protective covering to a depth of 3 inches on all sides of the conduit. Where more than one conduit is used, the duct shall be separated by not less than 1 inch, which space shall be filled with concrete. All multiple conduit formations shall be encased with concrete to a depth of 3 inches.

4. Under certain conditions, the concrete covering may be omitted if a timber of 2" x 6" size is placed on top of the conduit as a means of protection from mechanical injury. This should apply to secondary services only, but in all cases where they are constructed under streets and driveways, they shall be protected by a concrete covering as specified in d (3).

5. The conduit joint shall be made as tight as possible to avoit water seeping through the joint. In joining ducts, tap the end of the duct being installed with a

short piece of 2" x 4" to drive it back well into the sleeve. Care must be used so that this driving back does not crack the coupling or sleeve.

6. Where conduits for both electric and telephone services are laid in the same trench they shall be separated by a minimum of 6 inches of concrete or 12 inches of dirt.

V. SERVICE CABLES

(a) 1. Cables for primary services shall be varnished cambric insulated and lead covered. The thickness of insulation and lead shall be equivalent to that used by the X Y Z Electric Company.

2. For voltages less than 600, trenchlay cable may be used without the use of conduit but if so installed the customer will be required to maintain same in proper condition.

3. In general, all service cables shall be designed for the proper operating voltages and of sufficient carrying capacity for the ultimate current demand.

VI. PROTECTIVE EQUIPMENT

(a) Where secondary service cables are connected to overhead lines, they shall terminate in an approved weatherproof fuse box and shall be fused for the carrying capacity of the cable. (Noark Water Tight Service Boxes, Cat. #3871, 31-60 amps and Cat. #3661, 61-100 amps or equivalent are recommended). (#5871 for 60 amp, 3 phase and #5774 for 100 amp, 3 phase.)

(b) Where primary service cables are connected on to overhead lines, such cables shall terminate in pothead of approved shape and equipped with disconnecting connectors.

(c) On customer's premises, primary cable shall terminate in the same manner as stated in (b) above.

VII. MANHOLES AND PULLBOXES

(a) The dimensions of manholes and pullboxes will depand upon the number and size of service cables. For the ordinary residence service a small manhole or pullbox may be used and shall be 4 ft x 4 ft x 4 ft inside.

(b) Manholes and pullboxes shall be provided with a sewer drain, if possible, and a ball trap used in the manhole. If a sewer drain cannot be had without excessive cost, a sump of 12 inches in diameter and 12 inches deep shall be placed in the center of the manhole. The bottom of the manhole shall slope towards the drain or sump.

(c) The covers of manholes and pullboxes shall provide an opening of 30 inches and frames and covers shall be

equivalent to those used by the X Y Z Electric Company for manholes.

VIII. Any point not covered in these specifications shall be taken up with the X Y Z Electric Company and shall be treated separately for each particular installation.

FIG. 18

ELECTRICAL DIAGRAM
STREET LIGHTING
TRANSFORMER ASSEMBLY

FIG. 19

Designed by I. H. Gronseth

NOTE

WELD ALL JOINTS

Designed by I.H. Gronseth

FIG. 20

FIG. 21

Designed by W.H. Collins

FIG. 22

Designed by W. H. Collins

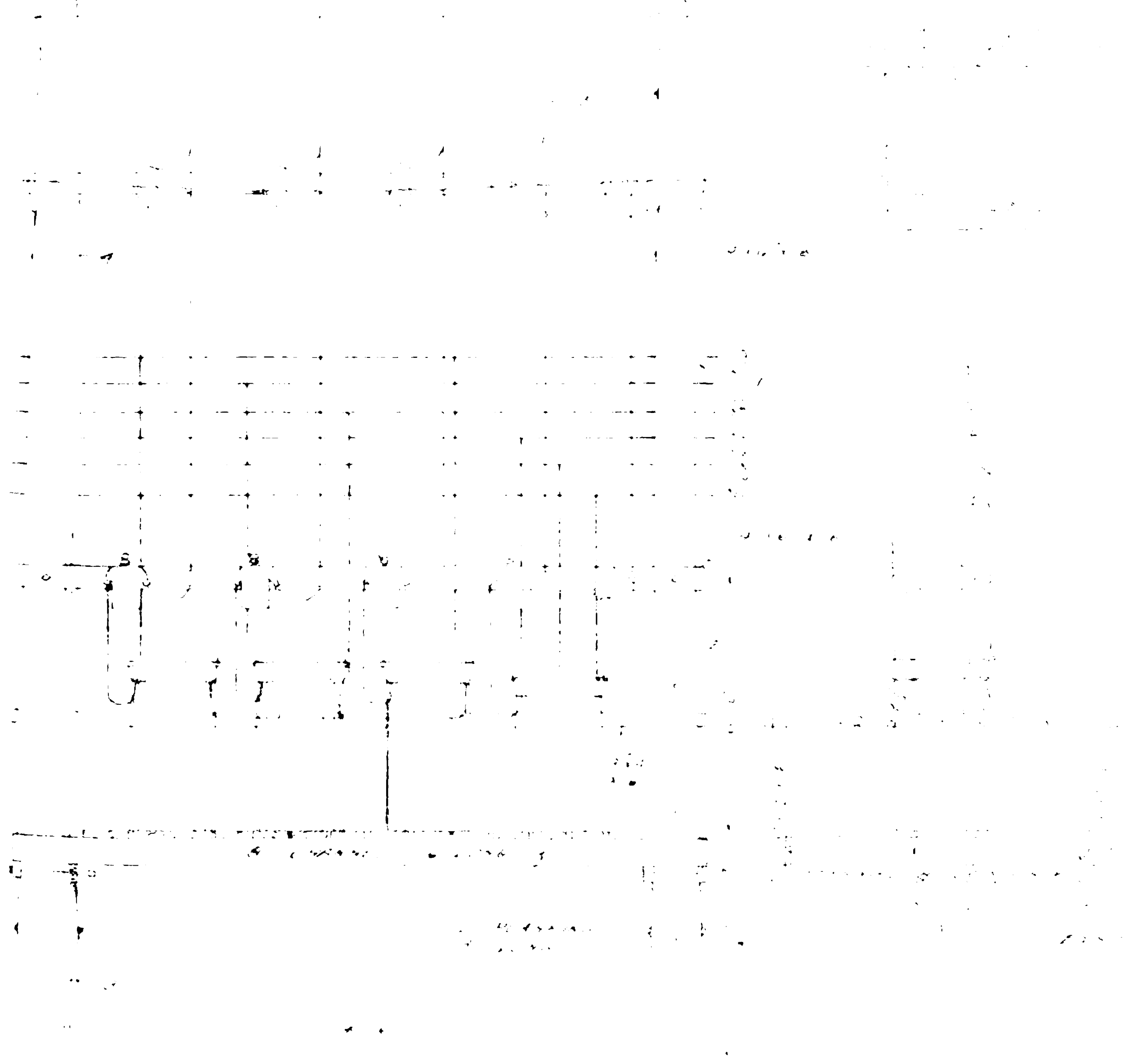


FIG. 21

Designed by W.H. Collins

WIC

FIG. 22

Designed by W.H. Collins

APPENDIX "A"

COMMONWEALTH EDISON COMPANY

EDISON BUILDING

72 West Adams Street

Chicago, Illinois Jan. 29, 1930

Bd. of Water & Light Comm'rs,

Lansing, Michigan.

Gentlemen: Attention Mr. W. H. Collins

Our Company has for several years been employed in changing over quite a large area from direct to alternating current. Our first move was to establish our alternating current lines in as large a part of this area as possible so as to be able to furnish new customers with alternating current service as soon as they moved in.

We also made a field survey of the entire area so as to obtain a record of of the nature of the load in every customer's premises. We listed the horsepower, speed and application of all motors, size, type, make of all fans, washing machines, radios, etc. When we made this survey about eight years ago, we found quite a number of customers who could be cut over to the alternating current lines at little or no cost and this was done.

In our Company, all requests for final bills are handled by our Application Bureau and we attach a small special card to the customer's record card with the following notation: "When final bill or successor application is requested, please notify the cutover division at once, because this is alternating current territory." If a final bill is requested, the meter is removed and if there are no other customers in the same building, the direct current service is also cut off on the outside. If a successor application is made, the applicant is notified that his application can be approved for alternating current service only, but it has frequently occurred that the applicant was either taking over some direct current equipment or had some which he wished to move into the premises and did not wish to be put to the expense of making the change at that time. Whenever possible in such cases, we have accomodated the new customers with direct current service under a special form of agreement, a copy of which I am inclosing.

A decision was rendered by the New York Commission holding that it was not discriminatory to refuse to take on new business on direct current lines, where all applicants are treated the same, and I am inclosing an excerpt of that report.

When the service of old customers is changed over, an appraisal is made on their equipment, as well as an estimated cost of the replacement. Our Company then submits the customer a proposition in which we agree to assume a portion of the cost which will represent the remaining useful life of the equipment to be changed, less junk value. In other words, if a customer has received $60.00 worth of use from a motor for which he paid $100.00, we pay $40.00 towards the cost of replacement and take the old motor. We also place a junk value on the motor and allow him to keep it at that price, if he wishes. The junk value on this equipment averages about $2.00 a horsepower.

Owing to the difficulty of obtaining the actual cost of the original equipment, we base our percentage allowance on the cost of replacing it with new AC equipment. This, in most cases, amounts to practically the same as if the percentage allowance had been made on the origional cost. On these replacements, everything is taken into consideration. That is, the estimate is made up to include wiring, as well as apparatus, and the same percentage allowance applies on an average estimated depreciation of the entire installation.

There is a question in the minds of some attorneys as to whether the Public Utility is legally abligated to stand any portion of the cost of making replacement of equipment on the customer's premises, which was furnished and installed by the customer. The supreme court of Arkansas is the only court of last resort which has rendered a decision directly bearing upon the question and that was in the case of Hunt et al versus Marianna Electric Company 1914 170 S. W. 96. An excerpt from this decision is as follows: "The pleadings conceive the duty of the users of the electricity to furnish their own appliances, but this, they say, they have done, and they call upon the Company to make such adjustments as are necessary to adapt their fixtures to the new system, or to furnish them with new appliances and we conceive the question in the case to be whether or not the Company is under any duty to perform this service or whether that expense should be borne by the plaintiff. In our judgment, it not having been alleged that the charges were needlessly or capriciously made, we think this expense should be borne by the plaintiff. Otherwise, having become a part of the operating expense of the Company, this would be an item to be considered in fixing the rates to be charged all consumers of electricity and would be an expense to be borne at least by the public generally rather than by those owners who were required to supply themselves with new appliances.

The state commissions have looked with favor upon such cases which have been brought before them where the Public Utility agreed to stand a portion of the cost based on the depreciation of the customer's equipment. Of course, it is assumed that the changes are being made in the interest of the customers as a whole or as someone has already expressed it "in the nature of public improvement." In answer to your question regarding cost, we find that they vary to such an extent that it is necessary to make up a detailed estimate in each case, which sometimes involves obtaining quotations from dealers in special equipment such as meat grinders, coffee mills, etc. in which the motor is only a part of the unit. We have found the average cost, however, to be in the neighborhood of $40.00 to $45.00 a kilowatt of customer's maximum demand to our Company and since we have not been approving any direct current equipment within the areas to be changed, for the past eight years, the average depreciation of the equipment to be replaced runs in the neighborhood of 65 per cent.

If the customers feel that we have given them an unfair appraisal, we stand ready to jointly employ a disinterested appraisor, pay one-half of his charges and accept his appraisal as final. We have only had one case, however in seven years where our appraisals were not accepted. We also make up an estimate on the cost of replacement, submit it to the customer, and allow him to choose between giving us the job and having it done by someone else and if he elcts the latter, we reimburse him for our percentage of the cost, based on our figures.

This, of course, is our general plan and if I can be of assistance in furnishing any further details, please write me for same.

Yours very truly

A. F. Bronwell

November 29, 1929

P. U. R. 1929 E 257 (N. Y.)

The New York Commission has held that it is not discriminatory for an Electric Company engaged in substituting alternating for direct current in certain city areas to refuse to take on any new business on a direct current basis, where all new applicants for service are likewise required to take alternating current. Schroder and Koppel versus New York Edison Company.

THE DETROIT EDISON COMPANY

2000 SECOND AVENUE

DETROIT, MICHIGAN

January 22, 1930

Bd. of Water and Electric Light Comm'rs

Lansing, Michigan

Attention Mr. W. H. Collins

Gentlemen:

In response to your letter of January 14 concerning our policy in changing certain of our districts from direct to alternating current supply.

We have for many years been narrowing in our direct-current district, and in doing this have always stood the full expense of making the change, and the customers have never been put to any money outlay because of it. The changes have been made for betterment of service and general public good, so that it has appeared to us that we ought to carry the cost. Of course, in residence districts which involve the greatest number of customers, the average cost is low, the cost to us being merely the changing of small motors on domestic electrical appliances.

In commercial districts, however, this expense has been much higher. We cut over quite a large territory in 1928, in fact the largest we have ever undertaken at one time. It involved a total of over 2000 customers, 700 of which required changes in equipment; 385

of these customers were commercial customers and many of them had three phase installations. The average cost for the residence customer ran about $21.00 and the commercial customer $100.00

Yours truly

S. M. Sheridan

Vice Pres. and Sales Manager

OHIO POWER COMPANY

216 N. ELIZABETH ST

LIMA, OHIO Jan 16, 1930

Mr W. H. Collins, Elec. Engineer,

Bd. of Water & Elec, Light Comm'rs,

Lansing, Michigan.

Dear Sir:

We wish to acknowledge receipt of your letter of January 14 wherein you make inquiry as to methods used in changing our D.C. customers to alternating current operation.

In connection with this request, we wish to advise that practically all of the equipment of our D.C. customers was from twenty to thirty years old and could easily be considered as obsolete. The proposition offered to these customers in connection with our portion of the cost of the changes was 40 percent of the total cost which included not only the equipment but the necessary wiring for 3 phase, 220 volt, A.C. service.

We have been successful in getting the customers to consent to making the change and at the present time, we have only six direct current installations left.

Trust that the above information answers your inquiry in a satisfactory manner, we are

Very truly yours

THE OHIO POWER COMPANY

I. A. Wagoner,

Power Engineer

PUBLIC SERVICE ELECTRIC AND GAS COMPANY

Newark, New Jersey
January 21, 1930

Mr. W. H. Collins, Elec. Engineer,

Bd. of Water and Elec. Light Comm'rs,

Lansing, Michigan

Dear Sir:

Your inquiry of the 14th instant addressed to the Trenton Public Service Company has been refered to the writer.

The changeover involves the replacement, on the customers' premises, of all direct current motors and other devices, with equipment of the alternating current type and consequent changes or reconstruction of the interior wiring on the customers' premises. We are obliged to make necessary changes in our distribution lines and withdraw from service direct current generating equipment, switchboard apparatus and materials.

The Company, in addition to bearing the cost of its own changes, stands part of the net cost of the necessary changes in the equipment and wiring on the premises of the customer. This proration of the expense of the changeover on customers' premises is in the main based upon the expired life of the direct current equipment replaced, using an average of twenty years as the full life of the equipment, the price paid for the new alternating current equipment to be considered as the basis of all costs. The cost of changing the wiring on the customers' premises, as well as the cost of the labor installing the new alternating current equipment is on a 50 - 50 basis between the customer and the Company. Of course the cost of any necessary change in service from the Company's main feeder lines to the customers' meter boards is assumed entirely by the Company.

The Company will handle the entire matter for the customer and furnish new alternating current motors and devices of modern and efficient design, and make the necessary changes in the wiring on the customers' premises, based on a careful estimate made by the Company of the cost of the changeover. The customer is given the privilege of getting an estimate from his own contractor. We permit the customer, if he so elects, to furnish all the material and do the work himself, he to advise us as to how much he could have the entire job done for and we would allow him the same percentage of that cost as we would be obliged to assume providing we did the work ourselves.

As we progressed with the changeover work, our experience suggested a more liberal treatment of strictly <u>elevator</u> changeovers as compared with straight motor installations and we decided to amend our original plan.

For DC electrical elevator equipment from ten to twenty years old, the proportion of the cost of replacement to be borne by the Company will be 50 per cent of the cost of the new AC electrical elevator equipment, providing the new AC electrical equipment installed duplicates the replaced DC equipment as to operating characteristics, i.e. horsepower, car speed, carrying capacity, etc.

When the replaced DC electrical elevator equipment is over twenty years old, the proportion of cost of replacement to be borne by the Company will be 33 - 1/3 per cent of the cost of the new AC electrical equipment, providing the new AC electrical equipment installed duplicates the replaced DC equipment as to operating characteristics, i.e., horsepower, car speed, carrying capacity, etc.

In addition to the 33 - 1/3 per cent of replacement cost borne by the Company of DC electrical elevator equipment over twenty years old, and in those instances where the customer has been put to an expense in renewing the life of the DC electrical equipment subsequent to the twenty year life period, and where the customer presents authentic records covering such expenditures, in addition to the 33 - 1/3 per cent (as outlined above) an amount equal to 50 per cent of the amount expended by the customer for upkeep for the period subsequent to the twenty year life of the DC electrical equipment. This additional amount plus the 33 - 1/3 per cent contribution shall, however, in no case be greater than 50 per cent of the replacement cost of each individual DC electriccal elevator equipment.

I trust the foregoing general outline will assist you.

Yours very truly,

Franklyn Heydecke, Gen. Auditor,

Electrical Department.

BIBLIOGRAPHY

Blake, D. K. ---------- Fundamentals of the Medium-voltage Network

Reyneau and Seelye --- Economics of Electrical Engineering

Seelye --------------- Electrical Distribution Engineering

Sanderson ------------ Electric Systems Handbook

N. E. L. A. ---------- Overhead Systems Reference Book

General Electric Co.-- Low-voltage A-C Networks

General Electric Co.-- Technical Letters 336A and 339A

Westinghouse Elec. &
Mfg. Co. ---------- Instruction Book I.B.5374

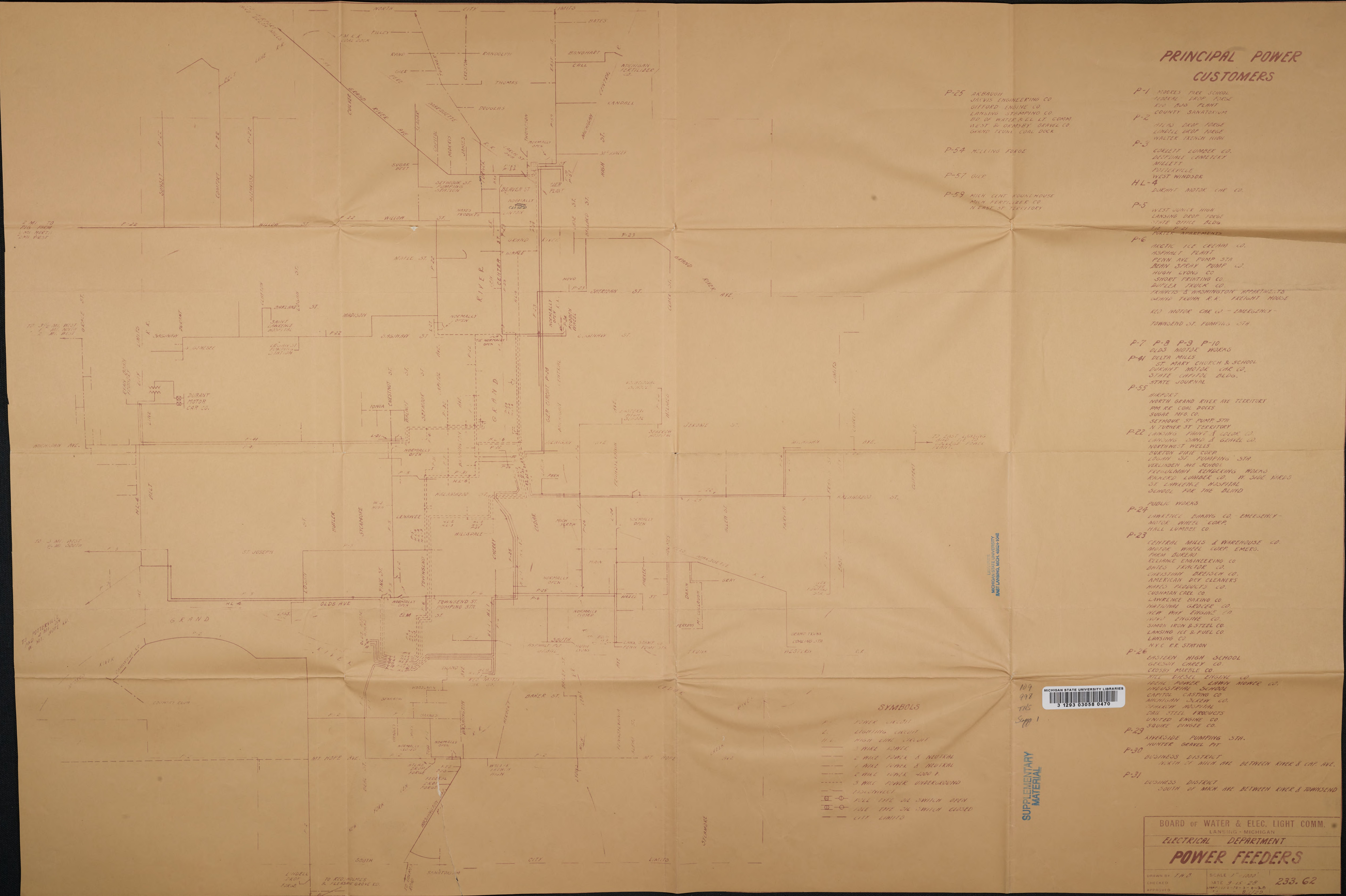
Michigan Public Utilities Commission Order #1692

Standard Handbook for Electrical Engineers

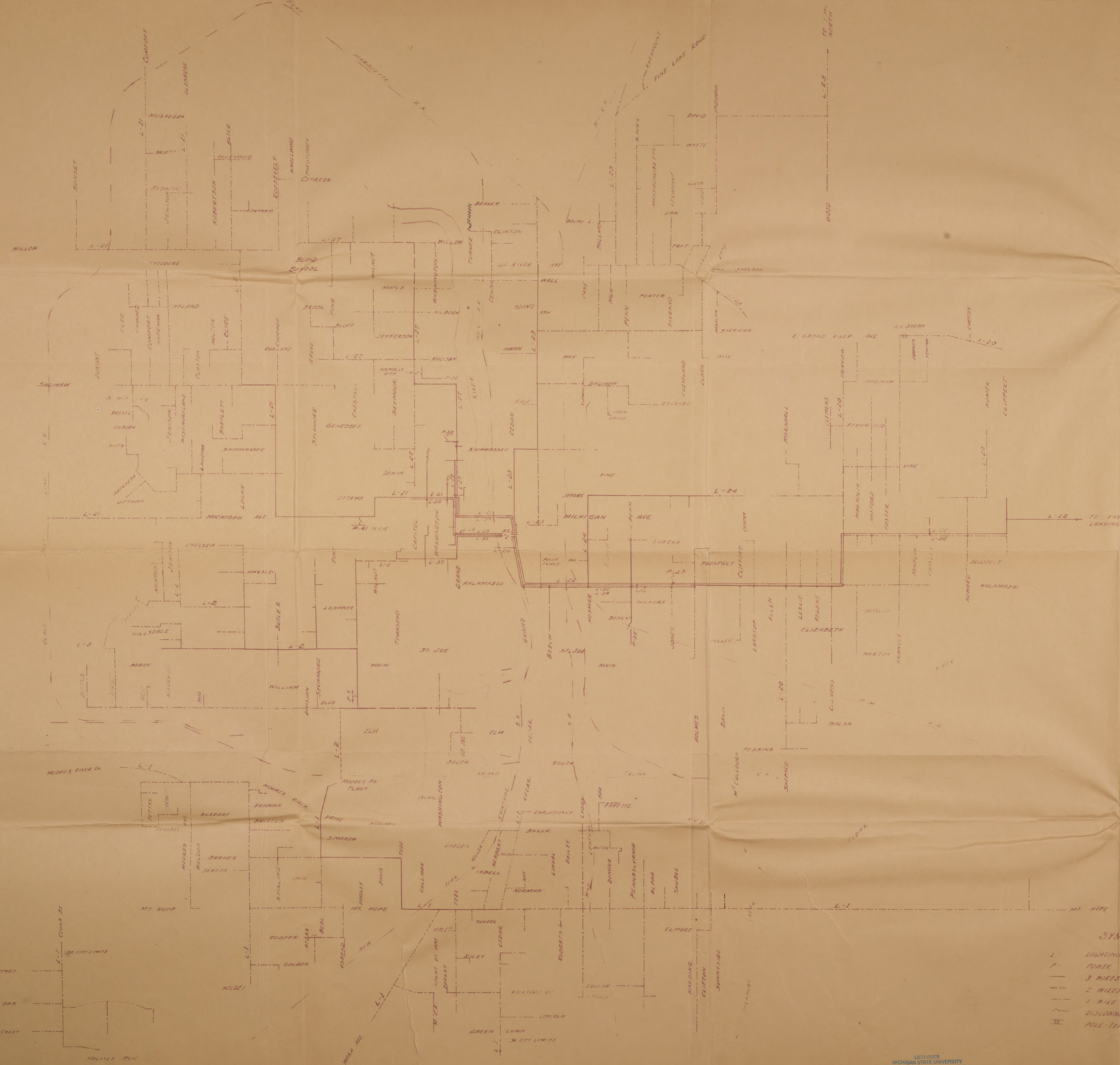
Electrical World

Electric Journal

Pocket has: 3 Supplements



PRINCIPAL POWER CUSTOMERS
P-1 MOORES PARK SCHOOL
FEDERAL DROP FORGE
REO BUS PLANT
COUNTY SANATORIUM
P-2
ATLAS DROP FORGE
LINDELL DROP FORGE
WALTER FRENCH HIGH
P-3
CORLETT LUMBER CO.
DEEPDALE CEMETERY
MILLETT
POTTERVILLE
WEST WINDSOR
HL-4
DURANT MOTOR CAR CO.
P-5
WEST JUNIOR HIGH
LANSING DROP FORGE
STATE OFFICE BLDG.
TIE P-21
PORTER APARTMENTS
P-6
ARCTIC ICE CREAM CO.
ASPHALT PLANT
PENN. AVE PUMP STA
BEAN SPRAY PUMP CO.
HUGH LYONS CO
SHORT PRINTING CO.
DUPLEX TRUCK CO.
FRANCIS & WASHINGTON APPARTMENTS
GRAND TRUNK R.R. FREIGHT HOUSE
REO MOTOR CAR CO. - EMERGENCY -
TOWNSEND ST. PUMPING STA.
P-7 P-8 P-9 P-10
OLDS MOTOR WORKS
P-41 DELTA MILLS
ST. MARY CHURCH & SCHOOL
DURANT MOTOR CAR CO.
STATE CAPITOL BLDG.
STATE JOURNAL
P-55
AIRPORT
NORTH GRAND RIVER AVE TERRITORY
P.M. R.R. COAL DOCKS
SUGAR MFG. CO.
SEYMOUR ST PUMP. STA.
N. TURNER ST TERRITORY
P-22 LANSING PAINT & COLOR CO.
LANSING SAND & GRAVEL CO.
NORTHWEST WELLS
BURTON DIXIE CORP.
LOGAN ST. PUMPING STA.
VERLINDEN AVE SCHOOL
PREGULMAN RENDERING WORKS
RIKERD LUMBER CO. W. SIDE YARDS
ST. LAWRENCE HOSPITAL
SCHOOL FOR THE BLIND
PUBLIC WORKS
P-24
LAWRENCE BAKING CO. - EMERGENCY -
MOTOR WHEEL CORP.
HALL LUMBER CO.
P-23
CENTRAL MILLS & WAREHOUSE CO.
MOTOR WHEEL CORP. EMERG.
FARM BUREAU
RELIANCE ENGINEERING CO
BATES TRACTOR CO.
CHRISTIAN BREISCH CO.
AMERICAN DRY CLEANERS
HAYES PRODUCTS CO.
CUSHMAN CARL CO
LAWRENCE BAKING CO
NATIONAL GROCER CO.
NEW WAY ENGINE CO
NOVO ENGINE CO.
SIMON IRON & STEEL CO.
LANSING ICE & FUEL CO.
LANSING CO
N.Y.C. R.R. STATION
P-26
EASTERN HIGH SCHOOL
GERSON CAREY CO.
CROSBY MARBLE CO.
HILL DIESEL ENGINE CO.
IDEAL POWER LAWN MOWER CO.
INDUSTRIAL SCHOOL
CAPITOL CASTING CO
MICHIGAN SCREW CO.
SPARROW HOSPITAL
DAIL STEEL PRODUCTS
UNITED ENGINE CO.
SQUIRE DINGEE CO.
P-29
RIVERSIDE PUMPING STA.
HUNTER GRAVEL PIT
P-30
BUSINESS DISTRICT
NORTH OF MICH. AVE BETWEEN RIVER & CAP. AVE.
P-31
BUSINESS DISTRICT
SOUTH OF MICH. AVE BETWEEN RIVER & TOWNSEND
P-25 ARBAUGH
JARVIS ENGINEERING CO
GIFFORD ENGINE CO.
LANSING STAMPING CO.
BD OF WATER & EL. LT. COMM.
WEST & ORMSBY GRAVEL CO.
GRAND TRUNK COAL DOCK
P-54 MELLING FORGE
P-57 GIER
P-59 MICH. CENT. ROUNDHOUSE
MICH. FERTILIZER CO.
N. EAST ST TERRITORY
SYMBOLS
P- POWER CIRCUIT
L. LIGHTING CIRCUIT
H.L. HIGH LINE CIRCUIT
3 WIRE POWER
2 WIRE POWER & NEUTRAL
1 WIRE POWER & NEUTRAL
2 WIRE POWER 4000 V.
3 WIRE POWER UNDERGROUND
DISCONNECT
POLE TYPE OIL SWITCH OPEN
POLE TYPE OIL SWITCH CLOSED
CITY LIMITS
BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN
ELECTRICAL DEPARTMENT
POWER FEEDERS
DRAWN BY T.W.B.
CHECKED
APPROVED
SCALE 1" = 1000'
DATE 9-15-28
233.62



PRINCIPAL LIGHT CUSTOMERS

L-1
CHRISTIANCY ST. SCHOOL
BARNES AVE. SCHOOL
MAPLEWOOD SCHOOL
WALTER FRENCH JUNIOR HIGH
ST. CASIMIR SCHOOL

L-2
MAIN ST SCHOOL
AMERICAN STATE SAVINGS BANK (Branch)
TOWNSEND ST. SCHOOL
WASHINGTON APARTMENTS
GRAND TRUNK R.R. STATION
FIRE STATION #3
FRANCIS APARTMENTS

L-20
ALLEN ST. SCHOOL
CITY HOSPITAL
FOSTER AVE SCHOOL

L-21
FIRE STATION #7
GENESEE ST. SCHOOL
ST. LAWRENCE HOSPITAL
WARNER ST. SCHOOL

L-23
AMERICAN STATE SAVINGS BANK (Branch)
CEDAR ST. SCHOOL
SOCIAL CENTER
EAST PARK SCHOOL
FIRE STATION #6
FRANKLIN AVE. SCHOOL
HIGH ST. SCHOOL
HOTEL DIGBY
LARCH ST. SCHOOL
P.M. R.R. STATION

L-24
AMERICAN STATE SAVINGS BANK (BRANCH)
BINGHAM ST. SCHOOL
PATTENGILL JUNIOR HIGH
FIRE STATION #4.
PENFIL APARTMENTS
SPARROW HOSPITAL

L-27
DR LANGE SANATARIUM
CENTRAL TEMPLE HOUSE
FIRE STATION #2
ROOSEVELT HOTEL
SENIOR HIGH SCHOOL
WALNUT ST. SCHOOL
SCHOOL FOR THE BLIND

L-28
CAPITOL THEATRE
CITY HALL
CITY NATIONAL BANK BLDG.
DETROIT HOTEL
GARDEN THEATRE
GLADMER THEATRE
JENISON BLDG.
JURY ROWE
MICH. BELL TELEPHONE CO.
ORPHEUM THEATRE
POST OFFICE
TUSSING BLDG.
WESTERN UNION TELEGRAPH CO.
Y.M.C.A.

L-29
AMERICAN STATE SAVINGS BANK
BUILDING AND LOAN ASSOCIATION
LANSING THEATRE
FIRE STATION #1
KERNS HOTEL
BLANDING'S GARAGE

STRAND HOTEL
STRAND THEATRE
VANDERVOORT HARDWARE CO.

L-30
AMERICAN LAUNDRY
BAUCH BLDG
CAPITOL NATIONAL BANK BLDG.
Y.W.C.A
DANCER BROGAN BLDG.
DOWNEY HOTEL
HOTEL OLDS
KNAPPS
KRESGE
LANSING LAUNDRY
MASONIC TEMPLE
MILLS
THOMAN BLG.
UNITED BLG.

109
997
THS
Supp. 2

SYMBOLS

L-	LIGHTING CIRCUIT
P-	POWER CIRCUIT
——	3 WIRES LIGHTING & NEUTRAL
— —	2 WIRES LIGHTING & NEUTRAL
—·—	1 WIRE LIGHTING & NEUTRAL
	DISCONNECT
	POLE TYPE OIL SWITCH OPEN

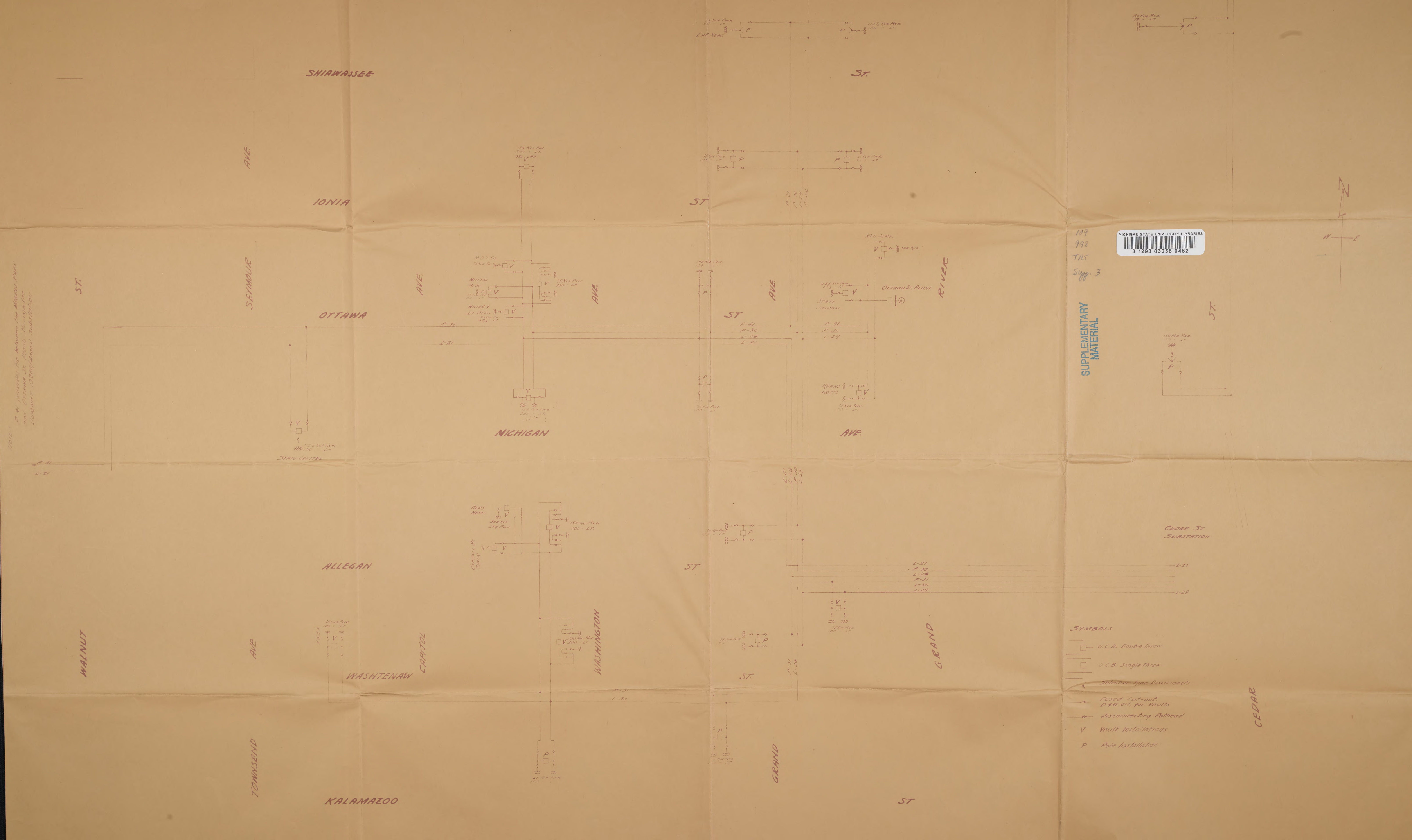
Revised 1-7-'31 WHB.

BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN.

ELECTRICAL DEPARTMENT

LIGHTING FEEDERS

DRAWN BY T.W.B.	SCALE 1" = 1000'	233.66
CHECKED	DATE 2-26-27	
APPROVED	REV. 9-15-28	



BOARD OF WATER & ELEC. LIGHT COMM.
LANSING - MICHIGAN

ELECTRICAL DEPARTMENT

DIAGRAM OF U.G. 4000V DISTR. CIRCUITS AND TRANSFORMER INSTALLATIONS IN BUSINESS SECTION

DRAWN BY I.H.G.
CHECKED
APPROVED WHG
SCALE
DATE 6-4-30