SURVEY OF THE ELECTRIC DISTRIBUTION SYSTEM FOR THE UNIVERSITY OF TENNESSEE

by

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and

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INTRODUCTION

This thesis is intended to give a general survey of the present electric distribution system at the University of Tennessee. Its faults and advantages are discussed. It includes a comparison of the present system's connected load and the connected loads for the years 1920 and 1924. It also includes a detailed description of the present equipment of the distribution sub-stations. It should be read with the idea of gaining accurate knowledge concerning the load centers, connected load, possibilities, necessities, advantages, and disadvantages of the present system.

Chapter I

GENERAL SURVEY OF THE FIELD

In the year 1924 the present system was put into operation. The change-over was very gradual. As the demand for power increased, the generating capacity of the power plant was increased. New sub-stations were added to take care of new buildings.

At present the generating capacity of the power plant is adequate for the connected load. The distribution centers are logically located. The duplicate arrangement at the sub-stations for switching from underground to overhead eliminates to a large degree the possibility of failure of service. The sub-station equipment is very economical and the design of the sub-stations tend toward strict economy.

The general design and arrangement of all sub-stations is similar. The transformers are connected in delta-delta. The two middle legs of the middle transformer are combined and brought out for the neutral of the lighting load. The lighting load is taken off the middle transformer. All lighting loads are served with a single-phase, three-wire system. All power loads are served with a three-phase, three-wire system. Each transformer in the bank forms one phase of the three-phase system. It can be seen that the middle transformer must be larger than the other two transformers.

Some of the newer sub-stations have a very well designed bus layout work for the secondary, while in the older sub-stations the secondary is simply racked around the vault.

All sub-stations have a manually operated knife switch for switching from underground primary to overhead primary in case of trouble on the underground circuit. Five of the main sub-stations have automatic circuit breakers on the primary circuit.

There is a necessity at present for several of the sub-stations to be re-designed. Estabrook sub-station should be re-designed and a better arrangement of circuits should be installed. The transformers at the Home Economics sub-station are obsolete and should be replaced with new ones. The sub-station at Ferris Hall should be re-designed. Due to a lack of space, the transformers are crowded together and the wiring is badly jumbled together. The Reese Hall sub-station is in need of a better drainage system. The sub-station at Chamberlain House should be done away with and the building should be supplied from the New Girls' Dormitory sub-station.

In the years 1920 and 1924, a survey was made to obtain data from which a design for an underground distribution system for the University of Tennessee could be made. A presentation of this data together with that obtained from the present survey will give an idea of the expansion of the system during this period.

SURVEY FOR YEAR 1920

Connected Load

Name of Building	Light Load K.W.	Power Load K.W.
Barbara Blount	5.9	
Carrick Hall	3.7	
President's Hall	1.0	
Morrill Hall	12.2	6.0
Science Hall	10.3	
South College	4.8	
Humes Hall	3.5	
Ayres Hall	45.4	20.0
Library	6.0	
Reese Hall	4.0	
Y.M.C.A.	4.2	
Sub-Totals	101.0	26.0
Total	127.0	

SURVEY FOR YEAR 1924

Connected Load

Name of Building	Light Load K.W.
Ayres Hall	34.0
Estabrook Hall	28
Science Hall	13.5
Jefferson Hall	9.5
Morrill Hall	8.7
Library	6.8
Carrick Hall	5.8
South College	5.0
Barbara Blount	4.8
Y.M.C.A.	4.2
Humes Hall	3.8
Reese Hall	3.8
Infirmary	2.5
Ayres House	1.8
Turner House	1.0
Total	133.2 K.W.
Street Lights	1.5 K.W.

SURVEY FOR YEAR 1931

Connected Load

Name of Building	K.W. Lights	K.W. Power	Total K.W.
1. Science Hall	20.565	2.984	23.549
2. New Chemistry Building	22.350	12.824	35.174
3. Physics Building	42.750	27.565	70.315
4. Morril Hall	34.715	8.763	43.478
5. New Gym	6.095	5.680	11.775
6. Stadium	0.800	0.000	.800
7. Carrick Hall	9.385	0.000	9.385
8. Estabrook Hall	47.180	114.689	161.869
9. Chamberlain	4.310	0.000	4.310
10. Practice House	3.545	10.119	13.664
11. Cafeteria	17.120	4.010	21.130
12. New Strong	12.030	0.000	12.030
13. New Girls' Dorm.	17.980	4.316	22.296
14. South College	6.450	.600	7.050
15. Barbara Blount	7.460	1.518	8.978
16. New Library	77.335	18.617	95.952
17. Humes Hall	4.780	0.000	4.780
18. Old Strong	4.460	.400	4.860
19. Ferris	30.810	280.176	310.986
20. Y.M.C.A.	11.250	1.244	12.494
21. Reese Hall	8.860	1.592	10.452

SURVEY FOR YEAR 1931 (cont'd)

Connected Load

Name of Building	K.W. Lights	K.W. Power	Total K.W.
22. Infirmary	6.925	20.247	27.172
23. Ayres Hall	50.425	.373	50.798
24. Jefferson Hall	9.950	2.238	12.188
25. Home Economics	42.460	23.156	65.616
26. Green House	1.035	0.000	1.035
27. Power Plant	3.815	45.200	49.015
28. Farm	25.000	37.300	62.300
29. Street Lights	2.000	0.000	2.000
Total	531.840	623.611	1,155.451

The chief disadvantages resulting from unbalanced load conditions are: (a) poor voltage regulation, (b) unequal voltage stresses in the several phases and (c) unequal heating in the circuits. The more common cause for unbalanced load conditions is the operation of essentially single-phase loads, as incandescent lamps or single-phase motors, on polyphase systems.

Tests were made at all sub-stations with a voltmeter and ammeter. Line voltage of the power circuits and lighting circuits were measured. With the use of a split-core transformer and an ammeter the phase currents and line currents were determined in every case possible.

The connected load was found for each building connected to the system. The power load was recorded separate from the lighting load.

Chapter II

STATEMENT OF PURPOSE

The purpose of this work was to make a study of the present system as regards the following:

1. Voltage regulation,
2. Connected load,
3. Equipment,
4. Facilities for operation
5. Demand factor
6. Schematic diagram of the distribution system.

Chapter III

GENERAL THEORY

According to the A.I.E.E. definition, the connected load of a system is the combined continuous rating of all the receiving apparatus on consumer's premises, which is connected to the system under consideration.

The demand factor of any system is the ratio of the maximum demand of the system to the total connected load of the system under consideration.

All transformer banks at the sub-stations are connected delta-delta. This type of connection is illustrated in Figure I.

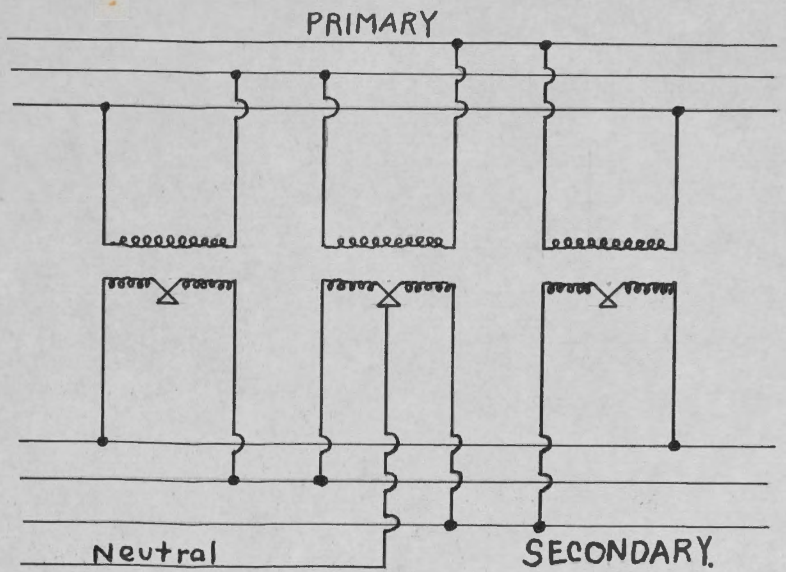

Figure 1

Assuming a balance load the current and voltage relations of a delta-connected transformer are as follows:

$E_L = E_p$ and $I_L = \sqrt{3}\, I_p$

E_L = voltage between lines

E_p = voltage per phase

I_L = current flowing in each line

I_p = current flowing in each phase

It is, therefore, apparent that each phase of delta-connected transformers must be wound for full line voltage. On the other hand the current-carrying capacity of each phase is only 58 per cent of the line current.

Assuming that three delta-connected transformers have the same ratios and impedance, it follows that the resultant voltage acting around the closed delta must be zero, since the three-phase voltages are 120 electrical degrees apart. It is also apparent that the vector sum of any two voltages is equal to the third voltage; hence it follows that a delta-connected transformer will continue to deliver power in case one phase is omitted. If, however, the ratios or impedance of the three phases are not alike, there will be a circulating current in the closed delta, and the load will, therefore, not be equally divided among the three phases. The advantage of the delta connection is that if one transformer goes bad the bank will continue to deliver power using only two transformers. Thus, continuity of operation is assured.

Stock was taken of the equipment of all sub-stations.

As regards the schematic diagram of the distribution system, a sketch was first drawn showing the location of the circuits. There with the use of a pantograph a map was drawn to a reduced scale from a large map of the campus showing the location of all the buildings. Then the circuits were drawn in on this map in their approximate locations.

Chapter IV

DESCRIPTION OF THE METHOD AND APPARATUS USED

Due to the fact that the service could not be interrupted the split core transformer method was the only practical method that could be used. Also this method was very convenient.

The ammeter was calibrated for the split core transformer used; therefore, the error in the reading in the test on the sub-stations was reduced to a minimum. There was a possibility of a small error in the connected load due to possible chance of missing a few lights.

Chapter V

CONCLUSIONS

In conclusion it can be said that the present generating plant is of sufficient capacity for the connected load. The power plant has two 500 K.W. alternating current generators. The total connected load amounts to approximately 1200 K.W. However, the maximum demand on the plant is a small percentage of the total connected load. Much of the connected power load is never on the line, due to the fact that the equipment is obsolete and is only used for very special tests. Then, too, such buildings as the Home Economics, the Library, Ferris Hall, and practically all of the administration buildings are never on at night. To balance the load in the day time, the dormitories are usually off during the day.

According to the tests made at the substations, it was found that the voltage was practically constant and varied very little. The current in the different lines were necessarily unbalanced due to the transformer hook-up. However, this unbalancing of currents did not cause unbalanced voltages. The currents carried by the two outside transformers of the bank were divided fairly equally.

The growth of the system has been comparatively rapid. In 1920 the total connected load was 127 K.W., and as compared with 1155 K.W. for 1931 the rapid increase in load is apparent. With the addition of new buildings in the future, the connected load will increase still more.

The final analysis brings us to these brief statements:

1. Generating capacity is adequate for the present, but will have to be increased in the future.
2. The voltage regulation is good.
3. Currents and voltages are balanced.
4. The sub-stations in several cases should be re-designed.
5. The equipment in some of the sub-stations is obsolete and should be re-placed.

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APPENDIX

SUB-STATIONS

No. 1 Power Plant

	Power and Lights			
	Line	Line	Line	Neutral
Current	57.5	50.0	47.5	10.5

	Power				Lights	
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	218	218	220	110	220	110

No. 2 Estabrook

	Power and Lights			
	Line	Line	Line	Neutral
Current	32.5	31.5	34.5	

	Power				Lights	
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
	218	218	220	109	218	109

No. 3 Ferris Hall

	Power and Lights			
	Line	Line	Line	Neutral
Current	4	6	21	

	Power				Lights	
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	228	223	225	112	228	112

SUB-STATIONS

No. 4 — Barbara Blount

	Power and Lights			
	Line	Line	Line	Neutral
Current	27.5	50	75	

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	224	220	110	220	110

No. 5 — Humes

	Power			Lights		
	Line	Line	Line	Line	Line	Neutral
Current	12.5	12.5	12.5	48.5	50	12.5

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	218	216	108	218	109

No. 6 — Reese

	Power					
	Line	Line	Line	Line	Line	Neutral
Current	0	0	0	57.5	12.5	44.5

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	218	220	109	220	110

SUB-STATIONS

No. 7 Home Economics

	Power and Lights			
	Line	Line	Line	Neutral
Current	21	17.5	39	

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	220	219	109	218	109

Library

No. 8

	Power and Lights			
	Line	Line	Line	Neutral
Current	72.5	6	80	

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	218	220	218	108	214	108

New Girls' Dormitory

No. 9

	Power and Lights			
	Line	Line	Line	Neutral
Current	21.5	22	20	

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	223	223	223	116	224	118

SUB-STATIONS

Chamberlain

	Power and Lights			
	Line	Line	Line	Neutral
Current				

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage				114	228	114

New Strong

	Power and Lights			
No. 11	Line	Line	Line	Neutral
Current	15	44.5	70	23.5

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	220	220	109	109	218

Farm

	Power and Lights			
	Line	Line	Line	Neutral
Current	22	33	53	17

	Power			Lights		
	Line	Line	Line	Line to Neutral	Line to Line	Line to Neutral
Voltage	220	220	220	109	218	109

SUB-STATION EQUIPMENT

No. 1 Power Plant

2 G.E. 15 K.V.a. Transformers 2300 - 110/220

1 G.E. 25 K.V.a. Transformers 2300 - 110/220

No. 2 Estabrook

3 - 15 K.V.a. 2300 - 110/220 G.E. Transformers

1 - 15 K.V.a. 2300 - 110/220 W.E. Transformer

1 - 7.5 K.V.a. 2300 - 110/220 G.E. Transformer (spare)

1 - 10 K.V.a. 2300 - 110/220 G.E. Transformer (spare)

No. 3 Ferris

3 - 37½ K.V.a. 2300 - 110/220 Westinghouse Transformers

1 - oil circuit Breaker 50 Amperes 2500 volts

No. 4 Barbara Blount

1 - 50 K.V.a. 2300 - 110/220 Westinghouse Transformer

2 - 10 K.V.a. 2300 - 110/220 G.E. Transformers

Autom-oil circuit Breaker Amperes 200 v 2500

No. 5 Humes

2 - 10 K.V.a. 2300 - 110/220 Allis Chalmers Transformers

1 - 150 K.V.a. 2300 - 110/220 Westinghouse Transformer

No. 6 Reese

1 - 10 K.V.a. 2300 - 110/220 G.E. Transformer

1 - 25 K.V.a. 2300 - 110/220 G.E. Transformer

1 Changeover Switch

No. 7 Home Economics

1 - 10 K.V.a. 2300 - 110/220 Westinghouse Transformer

1 - 10 K.V.a. 2300 - 110/220 Allis Chalmers Transformer

1 - 37.5 K.V.a. 2300 - 110/220 Allis Chalmers Transformer

No. 8 Library

2 - 10 K.V.a. 2300 - 110/220 G.E. Transformers

1 - 15 K.V.A. 2300 - 110/220 G.E. Transformer

No. 9 New Girls' Dormitory

1 - 15 K.V.a. 2300 - 110/220 G.E. Transformer

2 - 1½ K.V.a. 2300 - 110/220 G.E. Transformers

Automatic Switch on Main Line

No. 10 Chamberlain

1 - 7½ K.V.a. 2300 - 110/220 Allis Chalmers Transformer

Changeover Switch for Overhead

No. 11 New Strong

2 - 10 K.V.a. 2300 - 110/220 G.E. Transformers

1 - 37½ K.V.a. 2300 - 110/220 G.E. Transformer

1 - oil circuit Breaker Amperes 60 Volts 2500

1 Changeover Switch

No. 12 Farm

1 - 37.5 K.V.a. 2300 - 110/220 G.E. Transformer

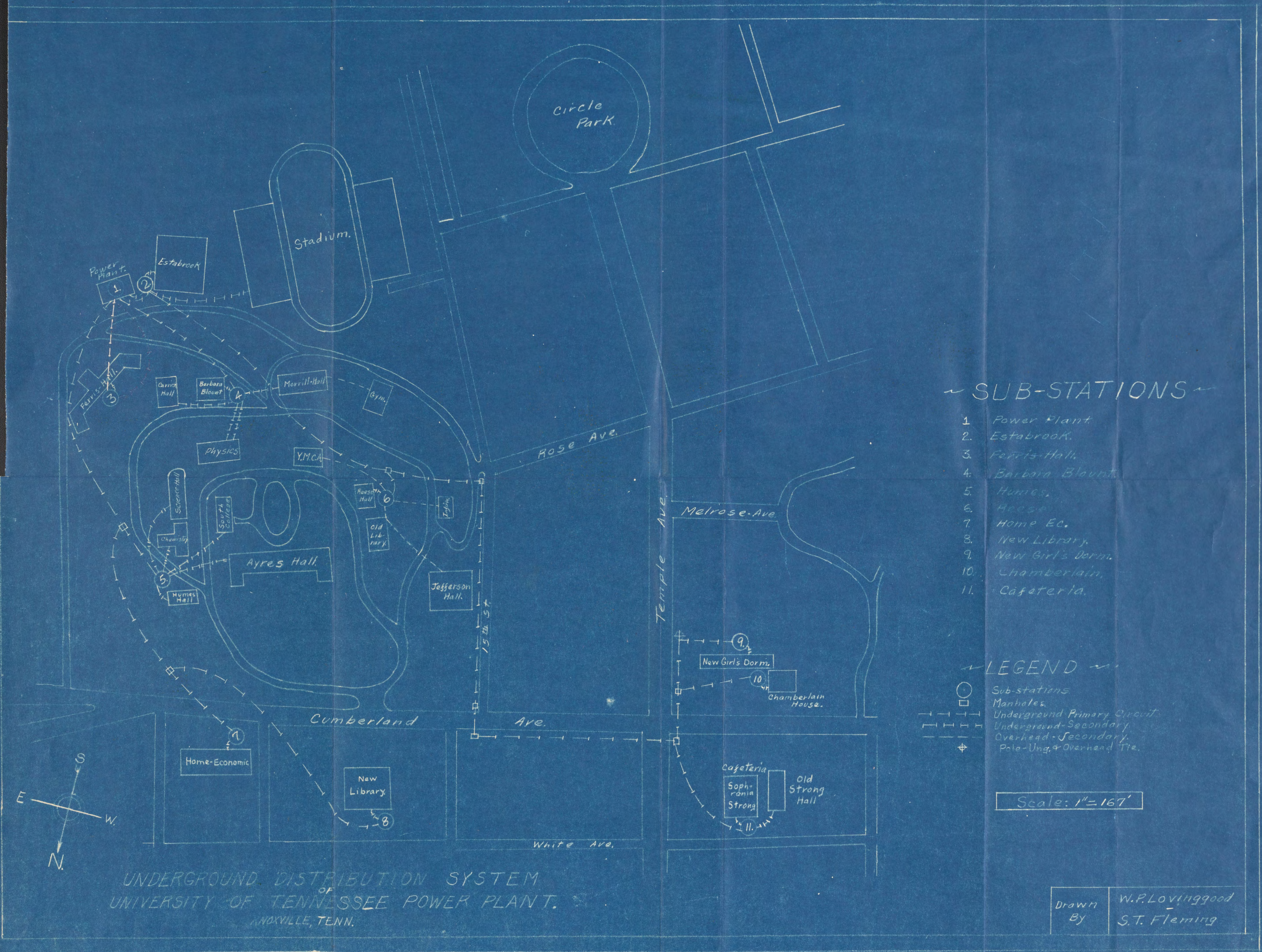
2 - 25 K.V.a. 2300 - 110/220 G.E. Transformers

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name J. G. Tarboux

Title Prof. Elec. Eng.



Circle Park
Stadium
Power Plant
Estabrook
Ferris Hall
Carrick Hall
Barbara Blount
Morrill Hall
Gym
Physics
Y.M.C.A.
Science Hall
South College
Reese Hall
Old Library
Chemistry
Ayres Hall
Humes Hall
Jefferson Hall
15th St.
Rose Ave.
Melrose Ave.
Temple Ave.
New Girl's Dorm.
Chamberlain House.
Cumberland Ave.
Home-Economic
New Library
Cafeteria
Sophronia Strong
Old Strong Hall
White Ave.
S
E
W.
N.
SUB-STATIONS
1. Power Plant
2. Estabrook.
3. Ferris Hall.
4. Barbara Blount.
5. Humes.
6. Reese.
7. Home Ec.
8. New Library.
9. New Girl's Dorm.
10. Chamberlain.
11. Cafeteria.
LEGEND
Sub-stations
Manholes.
Underground Primary Circuit.
Underground Secondary.
Overhead Secondary.
Pole-Ung. & Overhead Tie.
Scale: 1" = 167'
UNDERGROUND DISTRIBUTION SYSTEM OF UNIVERSITY OF TENNESSEE POWER PLANT.
KNOXVILLE, TENN.
Drawn By
W. P. Lovingood
S. T. Fleming