A

CENTRAL HEATING SYSTEM FOR CONGESTED DISTRICT

OF

KNOXVILLE

by

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A THESIS SUBMITTED FOR THE DEGREE

OF

BACHELOR OF SCIENCE

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INTRODUCTION

The problem of introducing a central heating system for the congested section of Knoxville involves two peculiarities entirely its own. Unlike other projects undertaken in a course of Mechanical Engineering this required an actual survey of the field instead of a theoretical survey. By actual survey is meant the canvassing of the congested portion of the city and the determining of radiation requirements, while by theoretical survey is meant the survey of previously recorded information along lines relative to the subject at hand.

The brevity of the heating season consisting of approximately 200 operating days as compared to 365 operating days for other public utilities, leaves a little doubt in the minds of some as regards the expediency of the proposed development.

It is the purpose of this paper to outline a plan by which this Central Heating System will compete favorably with individual heating systems now in use. To do this it was necessary to obtain data and costs on the present systems in order to make accurate comparison with the cost of a Central Heating Plant. Further aims are to show that the proposed system has a greater efficiency, introduces the smokeless plant, utilizes less installation space for heating equipment and allows utilization of basement space for storage which formerly was taken up by heating equipment. It reduces the fire hazzard, especially in newspaper offices, merchandise buildings, and shops containing material of a very inflammable nature.

HISTORY OF CENTRAL HEATING STATIONS

Northern

Distribution system of the Terminal Heating and Freezing Company of Baltimore, Maryland

The Terminal Heating and Freezing Company of Baltimore, Maryland is very conservative in both its storage and heating business.

Their charges of heating are:

First 100,000# of condensation ...... $1.75 per 1,000#

Next 200,000# of condensation ...... $1.44 per 1,000#

Next 300,000# of condensation ...... $1.10 per 1,000#

In addition to the above they make a service charge of $.07 per square foot of radiation per season, and a minimum bill of $4.50 per month for the eight heating months.

The 12" feeder line about to be installed will cost about $30.00 per foot installed complete. They are using book tile construction. This plan does not return its condensate. All lines are of welded construction. The expansion joints are all A. D. S. guided type, and the meters are all A. D. S. Simplex meters.

At this plant they read about 150 every other day. This is done to keep a close check on all meters.

The lines are kept hot all summer with exhaust steam from the ice plant auxiliary. This is done to keep down the corrosion within the pipes.

This plant has had a great amount of trouble with lines flooded from the exterior. Many of their lines have had to be renewed because of external corrosion. They are correcting all of this now by proper drainage, and by locating their pipe lines a safe distance from the city water and sewer lines.

Most of the lines installed are 10" lines with 40 pounds of steam leaving the plant, and no reducing valves on the service connections. The steam goes out one and one-half miles from the plant, and a pressure indicator at the end with a recorder at the plant is maintained. It is kept as near two pounds on the end as practical.

Distribution System of Ashburn Steam Company of Baltimore, Maryland (Residence Heating)

This company was started by a contractor who built some 125 houses and heated them from a Central Heating Plant. Later the plant was reorganized, and a number of the residences were placed on the Board of Directors to act as advisors and consultants. The Company is now mutual, permitting a 1% return on investment for the first year, then increasing annually until it reaches an annual return of 6%.

The rate is open and they establish the rate each year to net the required returns on the investment. For the year 1926-27 it cost them $1.50 per 1,000 pounds of condensation. Each customer pays a minimum of $120.00 per year and makes a deposit of $37.50 for good faith. The average radiation is 225 square feet per house. They serve 175 houses, and the average house heating cost is $165.00 per year.

Distribution System of Harrisburg, Pennsylvania

The plant at Harrisburg, Pennsylvania has a number of novel features. The coal burned is dredged from the bottom of the river. The Susquehannah River has been receiving the wash from the Pennsylvania coal fields for many years. There are thousands of tons of slack coal from the mine dump washed down each year. The Power Company maintains a fleet of dredges in the river and dredge their own coal. It is usually about 20% sand, but has a heat value of about 11,000 B. T. U. It costs the Company about $1.80 to $2.00 per ton to reclaim this coal.

A zone system of rates is in force. The section near the plant pays a slightly lower rate than those further away. The rates range from $.85 to $1.10 for consumers at a distance and $.75 to $.90 for close consumers.

Distribution Plant of Lockport, N. Y.

The Lockport Plant is the parent Plant of the United States.

This plant has about 400 customers buying steam as follows:

First 25,000 lb.	$1.20 net
Next 25,000 lb.	$1.10 net
Next 400,000 lb.	$1.00 net
All excess	$ .95 net

This plant burns powdered fuel at $5.40 per ton using Aero pulverizers. The boiler plant is equipped with some 350 H. P. water tube boilers and some 750 H. P. boilers. The smaller units are equipped with Taylor stokers.

Southern

Now, getting down in the South where the rates will compare favorably with Knoxville rates, we find the following conditions:

Rate of Atlanta, Georgia

Minimum Guarantee: To and including 5,000 square feet of radiation on basis of 200 pounds of steam per square foot of radiation per season; $1.25 per thousand pounds of condensation;all over 5,000 square feet, $1.00 per thousand pounds.

First 10,000# condensed steam per month	$1.75 per 1000 lbs.
Next 10,000# condensed steam per month	1.55 per 1000 lbs.
Next 10,000# condensed steam per month	1.40 per 1000 lbs.
Next 20,000# condensed steam per month	1.20 per 1000 lbs.
Next 20,000# condensed steam per month	1.10 per 1000 lbs.
Next 30,000# condensed steam per month	1.00 per 1000 lbs.
Over 500,000# condensed steam per month	.55 per 1000 lbs.

Rate of Birmingham, Alabama

First 10,000# steam or part thereof plus	$1.10 per 1000 lbs.
Next 10,000# steam or part thereof plus	1.00 per 1000 lbs.
Next 10,000# steam or part thereof plus	.90 per 1000 lbs.
Next 20,000# steam or part thereof plus	.85 per 1000 lbs.
Over 100,000# steam or part thereof plus	.70 per 1000 lbs.

DESCRIPTION OF THE METHOD AND APPARATUS USED

It was necessary in order to obtain the data to calculate the size of pipe and the amount of pipe to make a survey of each building and obtain the following data:

1. Square feet of radiation

2. Amount of coal consumed

3. Cost of coal per ton

4. Cost for operations

To obtain the amount of radiation each radiator was measured as to height, number of columns and number of sections, the square feet being taken from a table by American Radiator Corporation. The radiation of each block was determined in this manner. Thereby the radiation for necessary for that particular block was obtained. The other data was given the writer and his associates.

To determine the location and size of pipe line it was necessary to map out the section of the city that is to be heated by this Central System to scale and scale the length of pipe. To obtain the size of the pipe the following equation was taken from Woolrich and Biggs Handbook of Steam Engineering. Assuming a velocity not exceeding 6,000 feet per minute W = 8D where W is the weight of steam per minute and D is the diameter of the pipe. Assuming 100 feet of radiation = 1 H. P. and 1 H. P. = 30 pounds of steam per hour or one-half pound of steam per horse power minutes 100 feet radiation = .5 pounds of steam; 1 foot radiation = .005 pounds of steam. Knowing the required amoung of radiation for the whole system the feeder pipe can be calculated, and the size of the branch pipe can be calculated. The cost of connection is to be born by the consumer. The cost of the valves and the meters is included in the assumed value of installation. The cost of labor for piping and excavating of material was assumed in one lump sum. The cost was proportional to the size of pipe installed, and the traffic condition under which the excavating and trenching was performed. The highest costs were on Gay Street and other similar streets where the traffic would be a material handicap. For side streets the cost would be relatively smaller. For every 2,000 feet of radiation on the average a meter was charged at the rate of $40.00 each. This would mean that for a large building like the Tennessee Terrace Hotel, which has 16,667 square feet, only one meter would be used, leaving six to be distributed among buildings of radiation less than 2,000 feet.

The cost of the power plant was the summation of individual elements, such as boilers, stacks, pumps, etc. These costs were given to the writer by Professor W. R. Woolrich based upon his previous dealings with power plant costs. The cost of the three different locations for a permanent plant are assumed to be the same, while the cost of the temporary one on East Clinch and Central varied due to the smaller degree of installation.

There are four general methods of laying the pipe line which are to be considered. A drawing of each will be found in the appendix.

The first method considered is that which is used on all of the piping on the campus of the University of Tennessee. It consists of piping insulated and surrounded by glazed crock split tile. The pipe rests on rollers and is allowed ample room for expansion by using expansion joints placed in the man holes. The rollers are of the manufactured type very similar to John Mansville Company's rollers. The drawing will show that there is ample space for drainage which is very essential in the insulation of the pipe line. The advantage of this system is that in case of a leak the top can be removed without destroying the whole part of the system.

Another method of installing steam pipe lines very similar to the above described differs only in the use of the rollers. This method is very applicable to owners who wish to install at lowest cost. Two holes are drilled in the side of the T joint of the tile and a rod passed through. Upon this rod is a short piece of one-half or larger galvanized pipe to act as a roller. The size of the pipe depends upon the side of the rod inserted. The T is then placed in a concrete base flush with the bottom of the pipe, thus imbedding the rod and making a secure joint. The other construction is analogous to the previous description.

Yet another method presents itself, Figure 3. This method consists of laying a foundation on grade as required, leaving rests or shoulders containing steel plates about a foot long and the width depending upon the size of pipe to be installed. The pipe rests upon rollers and is insulated as shown in the drawing. The whole is then covered with concrete to prevent leakage which saps the heat from the line. This method is very efficient as far as insulation is concerned, but should it become necessary to make a repair job it is necessary to destroy the concrete in order to gain access to the steam line.

DESCRIPTION OF PROJECT LOCATIONS

It is well to consider the different probable locations of the power plants. They will be discussed in order: Project No. 1, Project No. 2, Project No. 3, and lastly, Project No. 4. The advantages due to locations, costs, etc. will be considered.

Project No. 1 is located at the intereection of East Church Ave. and First Creek, either adjacent to Henderson Milling Company or on the south side of Clinch Ave. The costs will be approximately the same for each. In chosing a location to act only temporarily as a site for a Central Heating System the first motive is a cheap location as regards real eatate and at the same time a location near the congested district of Knoxville. This location has both these features. If it is thought necessary water from the First Creek is available for feed water for the boilers. Fuel will entail no difficulties as it must be hauled only a short distance. The largest amount of required radiation can be commanded from thislocation, and in the future, when a permanent location is deemed necessary, the pipe line will remain the same. The only salvage will be the plant. To comply with the surroundings no majestic building will be required, only a minimum priced building with just enough room to operate the boilers being necessary. This property can be purchased at a fair price and should make an ideal location for a temporary heating plant.

Project No. 2 is located on Western Avenue just north and under the Viaduct on the property formerly owned by the Knoxville Iron Works. This location has been chosen as a permanent location for a Central Heating Plant. Second Creek, which flows on one side, will furnish adequate water supply for the boilers. The Southern and Louisville and Nashville railroad are close at hand for delivering the coal. It is probable that there will be two plants, an Ice and Cold Storage Plant and a Central Heating Plant. Should it be necessary, the entrance from Western Avenue is ideal for a Cold Storage Plant entering on the second floow. One disadvantage at first is the length of the pipe line up to Gay Street, but considering that the city is likely to grow westwardly due to the proposed highway to take the place of Henley Street, it adjusts this seeming disadvantage.

Project No. 3 is the location of a Power Plant at the south end of Gay Street at the river on the east side of the bridge. The advantages of this location are abundant supply of water, which can be secured from the river, relatively low cost for real estate and spur railroad track for securing coal. Again, the plant will be closer to the congested district than any other Permanent Project mentioned. In case of co-operations with a cold storage plant this is ideal due to the upper entrance from Gay Street Bridge. The cost of this plant is less than any other considered. The whole Project is based on a non-return steam line, thus embodying a large cost for water, and since the river is available this cost will be almost negligible. This location is perhaps the ideal location for a Central Heating Plant for the City of Knoxville.

Lastly, Project No. 4, located at the intersection of Cumberland and Second Creek. This property is owned by the Atlantic Ice Company at present. The elevated track is ideal for coal hauling. The creek will furnish an abundant supply of water for the boilers and cooling water for the Cold Storage Plant, if considered. The great disadvantage of this location is its great distance from Gay Street, but the same disadvantage may be over-ruled if the city grows westwardly due to the proposed highway. Another objection is that the present company is planning a new development of a Cold Storage Plant on this site and should this be the case the property could not be purchased at a nominal price.

CALCULATIONS

TEMPORARY PLANT NO. I

Cost of Power Plant

Real Estate	$10,000
Building	16,000
Four Boilers	12,000
Stack	2,500
Piping (in plant)	2,000
Fan	1,500
Feed Water Heater	1,500
Bunkers	2,000
Coal Conveyer	2,000
Feed Water Pumps	2,000
Instruments	2,000
Tools and Service Equipment	2,500
Stokers	8,800
Total for Power Plant	$72,300

Pipe Line Cost for Plant No. I

Total Radiation = 159,250 square feet as equivalent to 1,593 H. P. Assuming 2,000 of radiation to each meter, number of meters = 80 @ \$40 = \$3,200

Pipe Size Inches	Cost Per Foot, Dollars	Length of Pipe, Feet	Total Cost of Pipe, Dollars	Cost of Installation Dollars per Ft.	Total Cost of Installation
8	1.47	410	630	20	12,600
6	1.03	1490	1535	20	30,700
4	.59	1060	626	15	9,400
Total			$2791		$52,700

Cost of Pipe	$ 2,791
Cost of Pipe Installation	52,700
Cost of Meters	3,200
Total Cost of Pipe Line	58,691
Total Cost of Power Plant	72,300
Total Cost of Project	$130,991

PERMANENT PROJECT NO. 2

Cost of Power Plant

Four 350 H. P. Bent Tube Boilers	$24,000
Four Settings	12,800
Four Stokers (Biggs Type E)	12,000
One Chimney (12' x 200')	12,000
One Feed Water Heater and Softner	4,500
Two Feed Water Pumps	1,000
Breeching	1,100
Four Runways	600
Piping (power plant)	8,000
One Coal Conveyer (Bunker Type)	5,400
Building	25,000
Real Estate	18,000
Instruments	800
Total for Power Plant	$125,200

Pipe Line Cost for Plant No. 2

Total Radiation = 231,188 square feet equivalent to 2,312 H. P. Assuming 2,000 feet radiation per meter, number of meters = 116 @ $40.00 = $4,640

Pipe Size Inches	Cost Per Foot, Dollars	Length of Pipe, Feet	Total Cost of Pipe, Dollars	Cost of Installation Dollars per Ft.	Total Cost of Installation
10	1.98	880	1750	22	19,360
8	1.47	480	705	20	9,600
6	1.03	2570	2645	20	51,400
4	.59	1960	1155	15	28,400
Total			$7255		$108,760

Cost of Pipe	$ 7,255
Cost of Pipe Installation	108,760
Cost of Meters	4,640
Total Cost of Pipe Line	120,655
Total Cost of Power Plant	125,200
Total Cost of Project.................	$245,855

PERMANENT PROJECT NO. 3

Cost of Power Plant

Four 350 H. P. Bent Tube Boilers	$24,000
Four Settings	12,800
Four Stokers (Biggs Type E)	12,000
One Chimney (12' x 200')	12,000
One Feedwater Heater and Softner	4,500
Two Feed Water Pumps	1,000
Four Breechings	1,100
Four Runways	600
Piping (power plant)	8,000
One Coal Conveyer (Bunker Type)	5,400
Building	25,000
Real Estate	18,000
Instruments	800
Total for Power Plant	$125,200

Pipe Line Cost for Plant No. 3

Total amount of radiation = 231,188 equivalent to
2,312 H. P. 116 meters @ $40.00 = $4,640

Pipe Size Inches	Cost Per Foot, Dollars	Length of Pipe, Feet	Total Cost of Pipe, Dollars	Cost of Installation Dollars per Ft.	Total Cost of Installation
10	1.98	740	1466	22	16,300
8	1.47	570	840	20	11,400
6	1.03	1680	1730	20	33,600
4	.59	1780	1050	15	26,700
	Total		5086		88,000

Cost of Pipe	$ 5,086
Cost of Pipe Installation	88,000
Cost of Meters	4,640
Total Cost of Pipe Line	$ 97,726
Total Cost of Power Plant	125,200
Total Cost of Project	$222,926

PERMANENT PROJECT NO. 4

Cost of Power Plant

Four 350 H. P. Bent Tube Boilers	$24,000
Four Settings	12,800
Four Stokers (Biggs Type E)	12,000
One Chimney '12' x 200')	12,000
One Feedwater Heater and Softner	4,500
Two Feedwater Pumps	1,000
Four Breechings	1,100
Four Runways	600
Piping (power plant)	8,000
Coal Conveyer (Bunker Type)	5,400
Building	25,000
Real Estate	18,000
Instruments	800
Total for Power Plant	125,200

Pipe Line Cost for Plant No. 4

Total amount of radiation - 231,188 square feet.
Assuming 2,000 square feet radiation for each
meter, 116 meters @ $40.00 = $4,640

Pipe Size Inches	Cost Per Foot, Dollars	Length of Pipe, Feet	Total Cost of Pipe, Dollars	Cost of Installation Dollars per ft.	Total Cost of Installation
10	1.98	1050	2080	20	21,000
8	1.47	510	750	20	10,200
6	1.03	1700	1750	20	34,000
4	.59	2640	1560	15	39,600
	Total		6140		104,800

Cost of Pipe	$ 6,140
Cost of Pipe Installation	104,800
Cost of Meters	4,640
Total Cost of Pipe Line	$115,580
Total Cost of Power Plant	125,200
Total Cost of Project	$240,780

A P P E N D I X

PROJECT NO. 1

View showing buildings
that must be removed.
On north side of East
Clinch between Central
Avenue and First Creek.

Henderson Milling Co
adjacent to location
for Project No. 1.

Western Avenue Viaduct
above Project No. 2.

PROJECT NO. 2

View showing location for Power Plant and Southern Railroad.

View showing creek for water supply, also L. and N. Railroad.

View showing Plant site and storage yard for fuel and Southern Railroad.

PROJECT NO. 3

View from west side of Gay Street Bridge looking north. Plant location in foreground.

View from east side of Bridge looking north. Plant location in foreground. Tennessee Terrace Hotel in background.

View looking south from west side of Bridge on plant location.

PROJECT NO. 4

View showing plant of Atlantic Ice Company with creek used for water supply.

Ye Olde Mill Wheel at Henderson Milling Co. Location of Project No. 1.

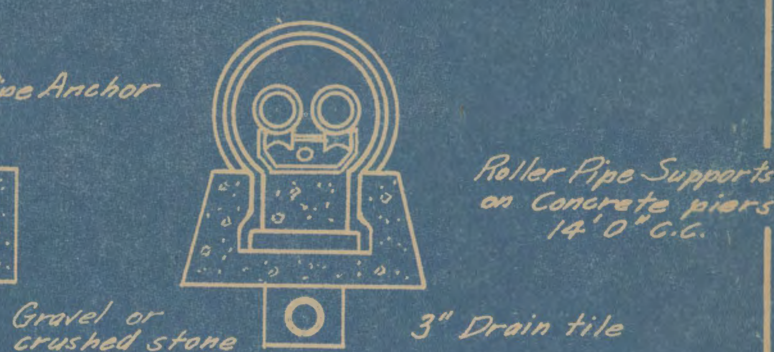
Henderson Milling Co.

ACKNOWLEDGMENT

I wish to express my appreciation to Professor W. R. Woolrich for the able assistance he has rendered during the making of the survey as contained in this thesis, and for much valuable information he contributed toward making the project possible.

A. V. Heoderick

Cross-Section thru. H.P. Steam Return and trap-dischargelines at Anchor.
Scale 1/2" = 1'0"

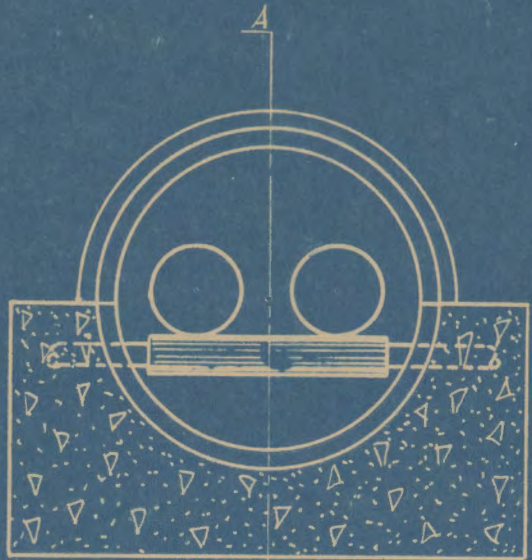


Cross-Section thru H.P. Steam Return and trap-discharge lines at Support
Scale 1/2" = 1'0"

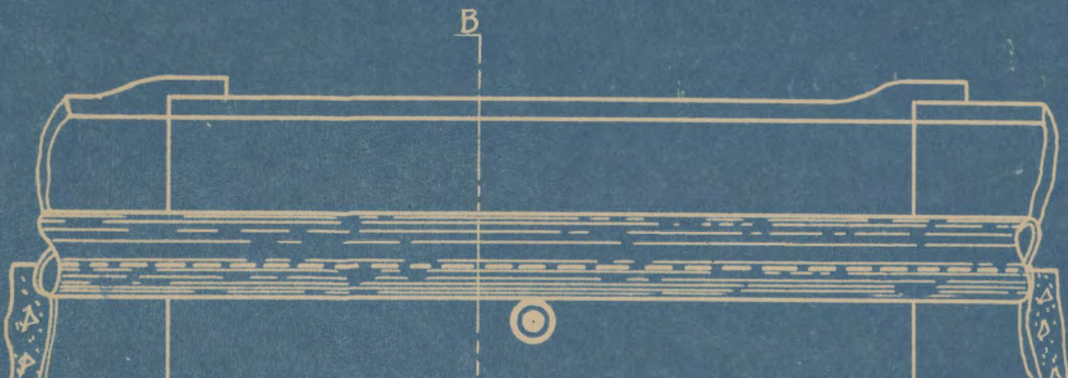
Longitudinal Section through H.P. Steam Return and trap-discharge Lines at Support
Scale 1/2" = 1'0"

Fig. 1

ANCHOR BASE



ROLLER BASE
SECTION B-B



LONGITUDINAL VIEW OF ROLLER BASE
SECTION A-A.

FIG 2

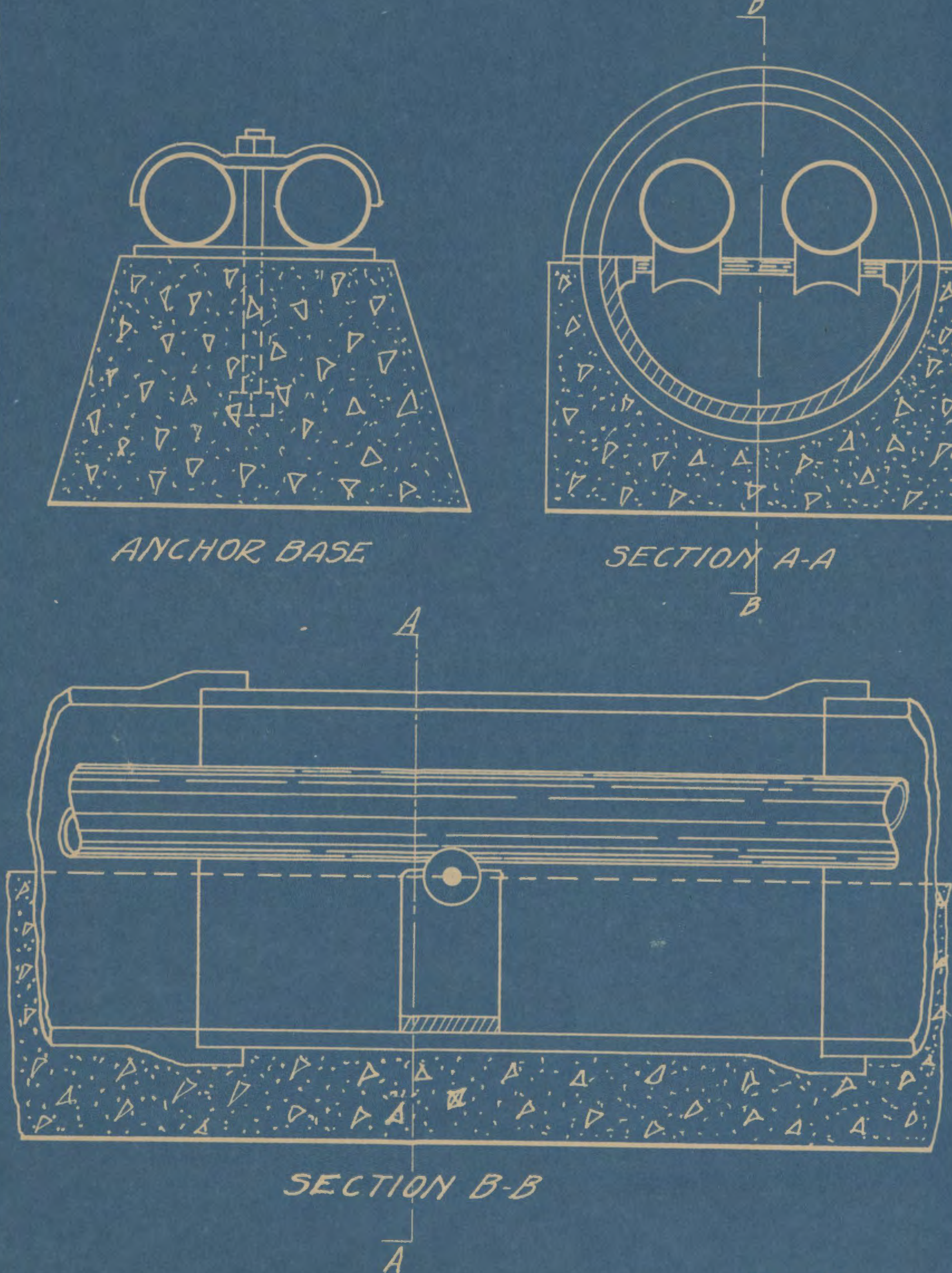


FIG 4.

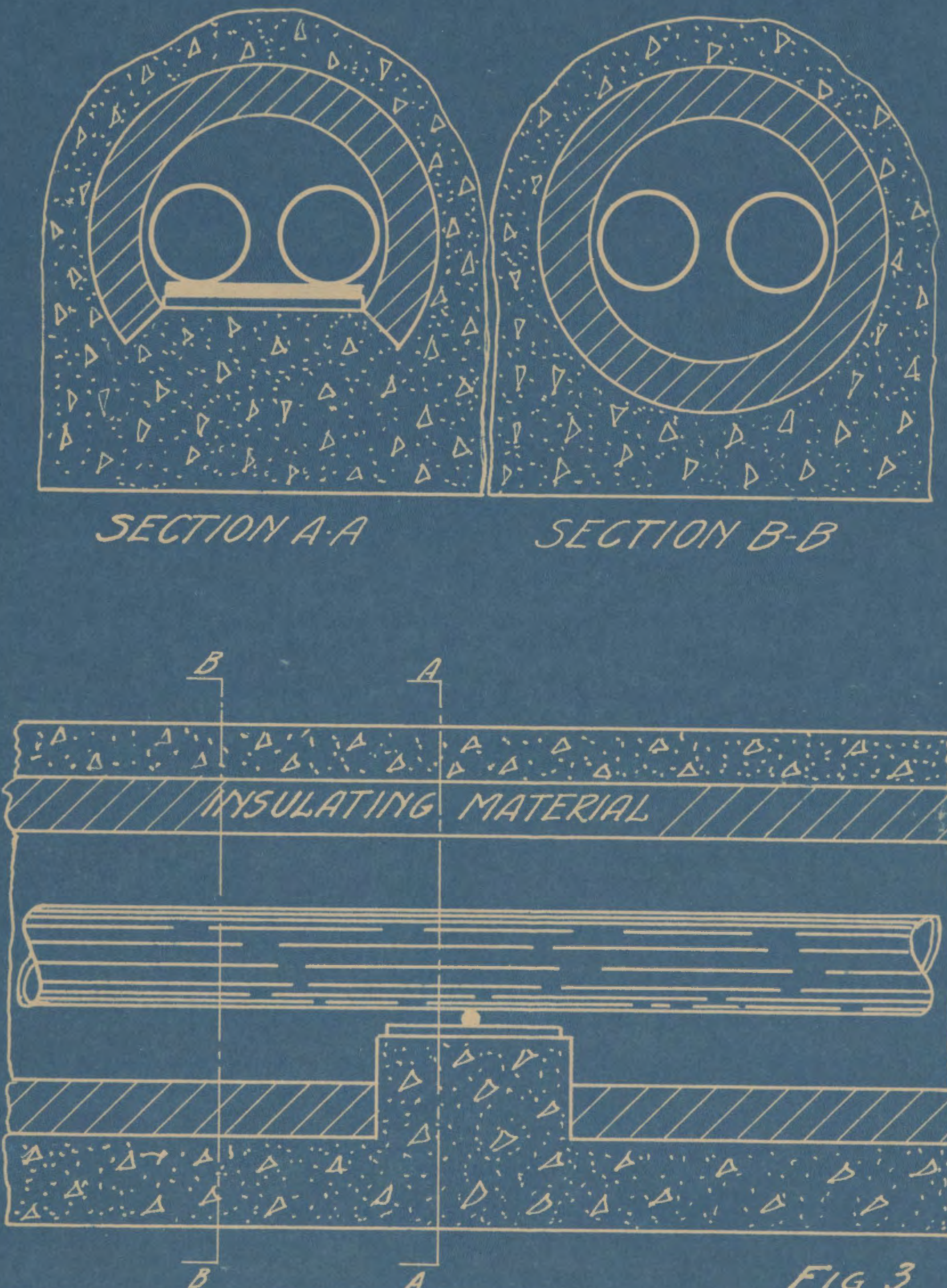


FIG 3

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 of approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

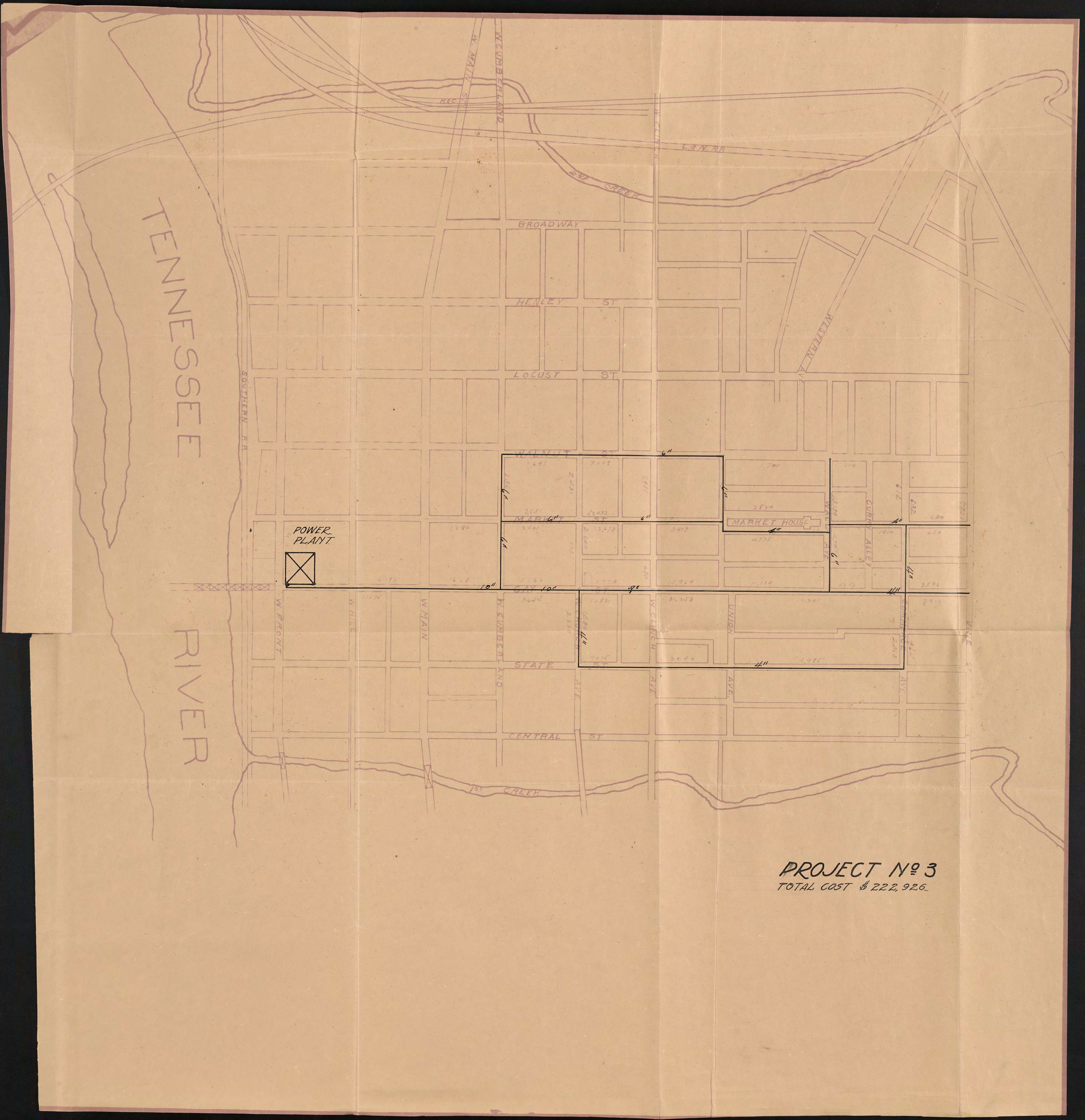
Name W. R. Woolrich

Title Prof. Mech Eng.

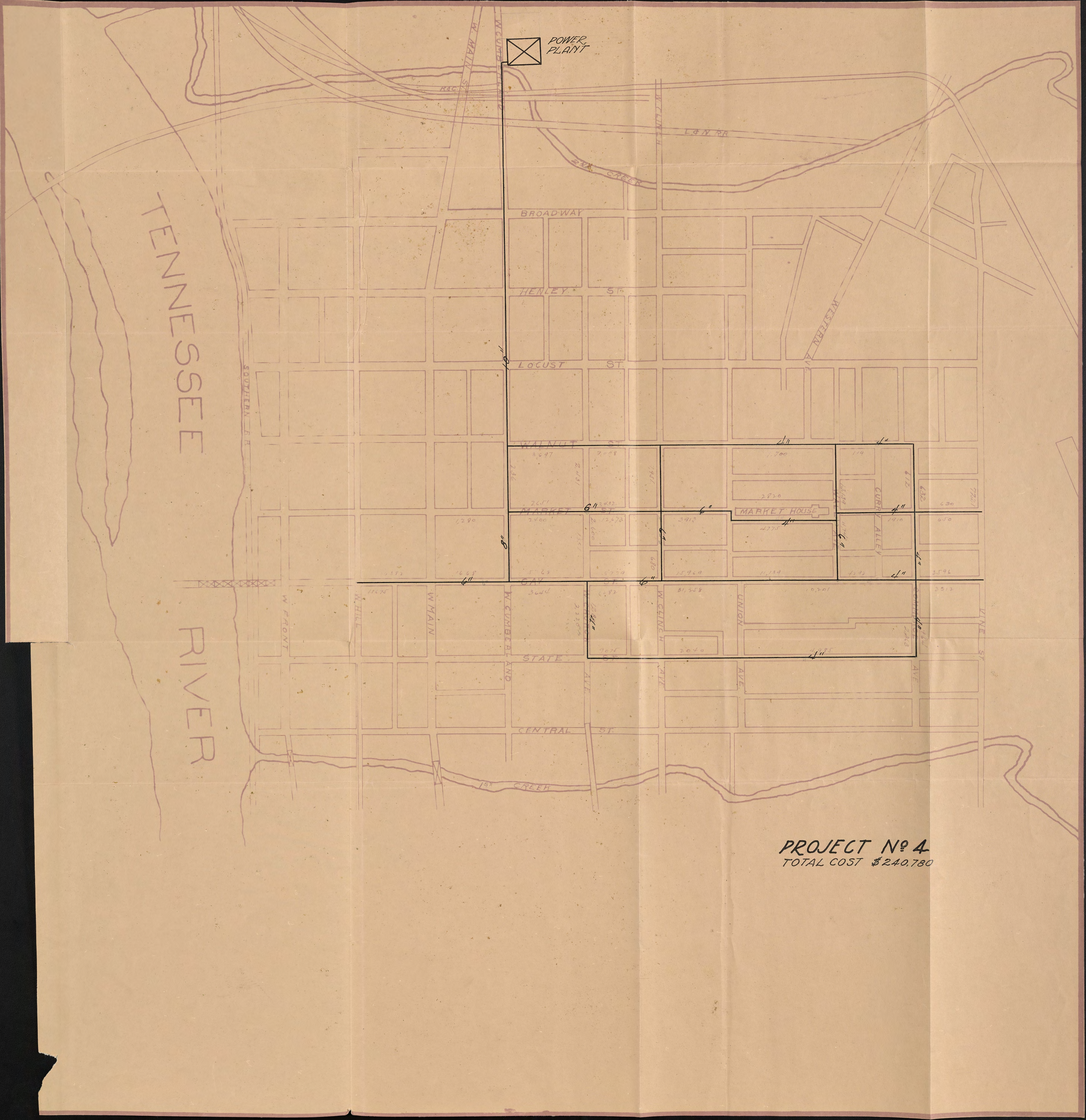

TENNESSEE RIVER
BROADWAY
HENLEY ST.
LOCUST ST.
WALNUT ST.
MARKET ST.
GAY ST.
STATE ST.
CENTRAL ST.
W. MAIN
W. CUMBERLAND
W. CLINCH
W. FRONT
W. HILL
W. CHURCH AVE.
UNION AVE.
COMMERCE AVE.
VINE ST.
CURRY ALLEY
WESTERN AVE
SOUTHERN R.R.
L&N RR
2ND CREEK
1ST CREEK
MARKET HOUSE
POWER PLANT
6"
4"
PROJECT No 1
TOTAL COST $131,000.

PROJECT No 2

TOTAL COST $ 245,855.



PROJECT Nº 3
TOTAL COST $ 222,926


POWER PLANT
TENNESSEE RIVER
BROADWAY
HENLEY ST
LOCUST ST
WALNUT ST
MARKET ST
MARKET HOUSE
GAY ST
STATE ST
CENTRAL ST
W MAIN ST
W CUMBERLAND
W CLINCH AVE
UNION AVE
WESTERN AVE
CURRY ALLEY
VINE ST
W FRONT
W HILL
SOUTHERN R.R.
L&N RR
2ND CREEK
1ST CREEK
PROJECT No 4
TOTAL COST $240,780