REPORT ON CAMPUS HEATING

for

BENNINGTON COLLEGE

Bennington Vermont

June 27 1958

FROM

LOCKWOOD GREENE ENGINEERS, INC.

New York
Montreal

41 EAST 42ND STREET
NEW YORK 17, N. Y.

Boston
Spartanburg

R E P O R T

ON

CAMPUS HEATING

FOR

BENNINGTON COLLEGE

BENNINGTON, VERMONT

June 27, 1958

LOCKWOOD GREENE

TABLE OF CONTENTS

PURPOSE OF REPORT

The purpose of this report is:

1. To study the adequacy and condition of the present individual heating boilers and their auxiliary equipment.

2. To present recommendations and cost estimates for present equipment requiring replacement.

3. To investigate the feasibility of a central heating plant and steam distribution system.

4. To present preliminary schemes and cost estimates for a central heating plant and steam distribution system.

5. To compare oil with other possible fuels.

6. To determine whether the present system of individual heating plants should be continued in the new library and other future buildings.

RECOMMENDATIONS AND CONCLUSIONS

Our recommendations are:

1. That a central heating plant and steam distribution system be constructed at the earliest possible time.

2. That this plant should have minimum facilities costing $258,390., but that capacity for future expansion and space for central maintenance shops be added if funds are available.

3. That the new library be provided with a temporary or rental heating unit.

Our conclusions on which these recommendations are based are given below. The body of the report developes the reasons for these conclusions.

1. a. The existing individual boiler plant equipment is in bad condition and is approaching the end of its useful life.

   b. There is no spare equipment to provide heat in case of emergency breakdown.

c. Operating costs are high due to low efficiency and high labor costs.

d. Maintenance and repair costs are high because of the age and diversity of the equipment, but are not adequate to keep it in good condition.

2.a. All of the present boilers, burners, controls and pumps should be replaced. It is likely that the #6 fuel oil tanks will have to be replaced in the near future.

b. If the present system of individual heating plants is to be continued the estimated replacement cost will be $100,610.

3.a. A central heating plant is feasible. Such a plant will reduce direct operating costs by $9,582 per year, provide spare capacity for emergency breakdown, and can economically be arranged to provide for the future growth of the college.

4.a. The cost of a minimum central plant will be approximately $258,390.

b. The plant building should be increased in size over the minimum scheme to include space for central maintenance shops and a future boiler at an additional cost of $15,445. if funds are available.

c. The boilers of the central plant should be oversized by an amount suitable for planned future expansion of the college.

d. The cost of the central plant can be written-off by direct operating expenses in 27 to 28-1/2 years.

5.a. No. 6 fuel oil is the most economical fuel for a central plant.

6.a. The new library will be constructed before a central heating plant can be designed and built. The library must have an individual heating plant for the interim period. This can be a temporary or rental unit.

DESCRIPTION OF PRESENT HEATING PLANTS

The 22 major campus buildings are heated by 10 separate boiler plants. The size, type, burner data, fuel, age and condition of each boiler plant are tabulated at the end of this section. Faculty houses are heated by individual heating plants but the fuel cost is borne by the tenants. These houses are not considered in this report.

Six large boilers in Commons, The Barn, and the east and west residence groups, burn cold #6 oil. This practice results in inefficient combustion, excess smoke and soot, and tube failure. The burner fires observed were poorly adjusted and sparky. A sizeable back-puff was noticed upon start up of one of these units indicating oil leakage and poor control operation.

The two International steel water tube boilers (Commons and west residence group) lose an average of 20 tubes per year. In the opinion of the insurance company boiler inspector, this tube failure is caused by corrosive attack from the outside due to poor combustion conditions and cold oil. In the case of three failed tubes that we inspected, this was true.

There does not appear to be serious water side corrosion. The quality of the water is excellent. However, the insurance inspector has noted pitting in the water legs of the Kewanee fire tube units. This is to be expected in units of this age and is the commonest cause of failure of this type of boiler.

The burners and controls are in bad condition. Most are incapable of being properly adjusted. Many of the control relays are without covers and were noted to be dusty and dirty. Short cycling was noticed on several units operating on light hot water loads.

Even though some control components and wiring have been replaced, the control systems as a whole have passed the point of efficient useful life. This is evidenced by inability to bring the oil-air ratios into proper adjustment for efficient operation, short cycling and wear of parts.

The Nash vacuum and condensate pumps are leaking badly and some are operating erratically. Nash services these pumps once a year, but they appear to be near the replacement point.

None of the large boiler rooms except the Commons have a proper means of ventilation. Even though there is a supply fan in Commons, all of the boiler rooms firing #6 oil were too hot. This has caused deterioration of electric wire insulation on the control systems. Without a source of supply air, the burner fans must draw against negative pressure in the boiler rooms throwing out fuel-air adjustment and stack draft.

Another consideration is the safety hazard due to carbon monoxide in the unventilated boiler rooms caused by bad flame adjustment and poor stack operation. This was observed in several of the boiler rooms.

TABULATION OF PRESENT HEATING PLANT EQUIPMENT

Building No.	Building Name	Boiler Mfr.	Boiler Type	Boiler Rating (edr.)	Boiler Date	Burner Mfr.	Burner Type	Burner Oil	Burner Date	Fuel Tank Size (Gals.)	Fuel Tank Date	Plant Condition
1	Commons	International	Steel W.T.	8000	1932	Ray	#3	#6	1939	10,000	1939	Unsatisfactory
		Kewanee	Steel F.T.	6340	1932	Ray	#3	#6	1939			Poor
5	Booth											
6	Kilpatrick											
7-8	Leigh-McCullough	Kewanee	Steel F.T.	4454	1932	Ray	#3	#6	1939	15,000	1939	Poor
9	Bingham	International	" W.T.	6000	1932	Ray	#3	#6	1939			Unsatisfactory
10	Welling											
11	Dewey											
12	Canfield											
13-14	Swan-Woolley	Kewanee	Steel F. T.	14,705	1933	Ray	#5	#6	1938	15,000	1938	Poor
15	Stokes-Sanford											
16	Franklin											
18	The Barn	Kewanee	Steel F.T.	7225	1931	Ray	#3	#6	1939	11,400	1931	Poor
19	Cricket Hill	Am.Std.	C.I.	1450	1944(?)	Am.Std.	-	#2	1944(?)	-	1944(?)	Fair
20	Nursery School											
21	Ceramic Studio	Am.Std.	C.I.	3700	-	Arco	-	#2	-	(1) 1,000	-	Poor
22	Sculpture Studio									(2) 2,000		
23	The Brooder											
25	Shingle Cottage	Pierce Butler	C.I.	423	-	-	-	#2	-	550	-	Unsatisfactory
26	Presidents House	International Heating Co.	Hot Air	224,000 BTU/hr	-	-	-	#2	-	-	-	Good
27	Jennings Hall	Am.Std.	C.I.	7600	1902	Gilbarco	-	#2	-	2,000	-	Fair
28	Recreation	Am.Std.	C.I.	1680	-	Arco	L-1	#2	-	(2) 550	-	Fair
	Garage	Am.Std.	C.I.	595	-	Arco	#11	#2	-	-	-	Poor

ANALYSIS OF PRESENT STEAM LOADS

The steam requirements of the various college buildings are tabulated on a following page. Where records are available, the steam loads given are based on actual installed radiation. Where such information is not available, the loads given are based on heat loss calculations.

The totals in the summary are sustained peak loads for winter and summer. The winter figures include heating, hot water and kitchen steam use. Summer loads include hot water and kitchen use only.

All buildings have full occupancy from September to mid-December, and from March through June. During the last two weeks of December, January and February the student body leaves the college and the buildings are dropped to approximately 50° F holding temperature except for certain administrative offices and faculty apartments.

The college operates on a partial occupancy basis in the summer. Steam is required for hot water heating and operation of the kitchen.

The closely grouped buildings of the south campus represent 82.5% of the total steam load. The arrangement and magnitude of this load group makes it well suited for central plant operation. Jennings Hall and Recreation on the north campus, and Shingle Cottage and the President's House to the east are generally small loads, far removed from the south campus group. The high cost of the distribution piping to serve them cannot be justified by any fuel or labor savings which might result.

The comparisons of central versus individual heating plants given in the following pages of this report deal only with south campus buildings. Jennings Hall, Recreation, Shingle Cottage and the President's House have not been included.

FUTURE LOADS

The only known future load is the new library. Construction of this building will start this summer. This load has been included in sizing the central plant.

A theater arts building has been considered but is not actually planned at present. It is likely that this building, if built, would be located in the open area west of the Barn.

Planning studies made in the 1930's show additional residence buildings south of Welling and Franklin Houses, but these are not planned for at this time.

Because of the concentration of major facilities and activities in the south campus group, it is likely that any buildings constructed in the foreseeable future will be in this area. A central heating plant and distribution system designed to serve the south campus can be enlarged to provide steam for such future buildings.

TABULATION OF BUILDING STEAM REQUIREMENTS
SUSTAINED PEAK LOADS

Building No.	Name		Winter Load Heating	Hot Water	Total #/hr.	Summer Load Total #/hr.
1	Commons	Heating	1560	270	2130	570
		Kitchen	300			
5	Booth		325			
6	Kilpatrick		325			
7-8	Leigh-McCullough		640	330	2480	330
9	Bingham		450			
10	Welling		410			
11	Dewey		325			
12	Canfield		325			
13-14	Swan-Woolley		640	330	2480	330
15	Stokes-Sanford		450			
16	Franklin		410			
18	The Barn		1420	50	1470	50
19	Cricket Hill		300	60	360	60
20	Nursery School		165			
21	Ceramic Studio		40	50	600	50
22	Sculpture Studio		80			
23	The Brooder		265			
25	Shingle Cottage		85	25	110	25
26	President's House		190	--	190	--
27	Jennings Hall		1500	100	1600	100
28	Recreation		310	50	360	50
	Garage		100		100	
	New Library		650	50	700	50
					12,580#/hr	1,615#/hr

COMPARISON OF CENTRAL VS INDIVIDUAL HEATING PLANTS

The major advantages of a central heating plant over scattered individual plants are lower operating costs due to higher efficiency, and reduced labor and maintenance. Other advantages are easy provision for emergency spare capacity and expansion.

Efficiency

The higher operating efficiency of a central plant over the present low operating efficiencies will result in reduced fuel consumption.

Fuel distribution records are available for the buildings burning #6 oil. By comparing calculated heating and hot water loads (adjusted for the mid-winter turn down) against fuel oil actually used, the approximate seasonal efficiency can be determined.

Calculated efficiencies for the heating year July 1956 through June 1957 are given below:

Commons	57.0%
B-1 (west residence group)	56.0%
B-2 (east residence group)	58.7%
The Barn	59.4%
Average	58.0%

No records are kept on the boilers burning #2 oil. The manufacturer of these units estimates that their seasonal efficiency would be approximately 65% because of age and poor control adjustment.

If the individual boilers are replaced with new units, they should be considered on the basis of average operating efficiency expected over their lifetime. The efficiencies for the old units above are minimums at near the end of useful life. Oil pre-heaters will also improve the over-all efficiency of the new units. For purposes of comparison, new units on #6 oil will be figured at 65% and units on #2 oil at 70%.

New oil burning boilers in a central heating plant fitted with automatic combustion controls can be expected to have a peak efficiency of 80% to 82% and a seasonal efficiency of 75%. New coal fired boilers with controls will have peak efficiency of 75% and a seasonal efficiency of 70%.

<u>Labor</u>

Labor cost for a central plant will be less than present heating plant labor cost.

The present boiler plants are run and maintained by a four man crew responsible for operating the college utilities. It is estimated that more than one half of their time can be charged against boiler operation. Wage, overtime and insurance costs for this crew have increased uniformly since 1954 at 2% per year. Negotiations for wage increases are currently under way. It is reasonable to assume that increases of approximately 10% will result. A graph of present heating plant labor costs is given in the Appendix.

For purposes of comparison it is estimated that a central heating plant on fully automatic controls, elimination of #2 oil handling by college personnel and reduction of boiler maintenance work will reduce heating plant labor charges by 50%.

For the heating year 1957-58, wages now chargeable to the heating plants total $6900 ± . For the central plant study labor has been taken at approximately $3450 ±.

Repairs and Maintenance

The cost of repairs and maintenance for a single central plant will be lower than for the several individual plants.

There are no records showing the extent or cost of repairs and maintenance for the several present heating plants. An estimate of $600 for maintenance work by outside contractors in 1957 has been made by the superintendent but this figure does not appear realistic considering the extent and age of the present equipment. No figures are available for equipment or parts drawn from inventory for maintenance use.

For purposes of this report based on our experience, the maintenance costs of present equipment are taken at $4000 per year. This figure is low and represents minimum possible repair to keep equipment operating. It should be twice this amount to keep the equipment in good, efficient condition.

These maintenance costs can be expected to increase each year until complete replacement of each item of mechanical equipment is forced by breakdown.

For a new central plant cost of maintenance and repairs may be expected to average 3% for mechanical equipment, 1/2% for distribution piping and 1% for the boiler plant building.

Spare Capacity

A serious drawback of the present system of individual heating plants is the lack of spare capacity. Each boiler plant is sized for design heating load plus pick-up of the building(s) served. In the event of complete failure of extended breakdown, the building(s) involved would be without heat and hot water until replacement or repair could be made. If such a breakdown occurred in sub-zero weather, it is probable that the building(s) would have to be vacated. Unless the plumbing and heating piping systems could be completely drained, damage and loss of piping could result. It is not possible to estimate the extent of such damage but it could run to many thousands of dollars.

Minor breakdowns are much more likely. While these may not cause contingent damage,they can cause considerable inconvenience to the building occupants. The frequency of such breakdowns can be expected to increase because of the age and condition of the present equipment.

A major design condition of a central heating plant is spare capacity. Where the cost can be justified, it is usual to install 150% of the connected steam load in three generating units. Two of the units can handle loads up to the peak demand while the third is held in reserve. Any active unit can be taken off the line for service or repair without reduction of plant output. The regular rotation of active and idle units for inspection, cleaning and preventative maintenance extends the life of all.

As a less costly alternative,100% of the connected load may be installed in two units. In the event of emergency breakdown of one unit, 50% of the plant output is still available. This will normally be adequate for all but the few minimum temperature winter months. In this period, the occupied areas of all buildings can still be held at reasonable holding temperatures by local thermostat and radiator control of unoccupied spaces.

Expansion

The boilers of a central plant should be oversized to provide for expansion.

It is reasonable to plan for expansion of the college steam requirements. This need not be caused by an increase of the student enrollment. Many educational institutions are finding it necessary to provide additional buildings for activities and services not dependent on enrollment. Examples of this at Bennington are the new library and the projected theater. Typical of the magnitude of such load increases are 35% at Williams and 25% at Amherst within the last six to seven years.

If such expansion is accompanied by the construction of additional individual boiler plants rather than a central plant, the disparity in operating costs, labor and maintenance will be increased. The total installed cost of this diversified heating capacity will be greater than the equivalent central plant capacity because of the multiplicity of auxiliaries such as stacks, pumps, oil storage facilities, controls etc.

Provision for expansion can be economically provided for in a central plant by oversizing the boilers by whatever percentage is desired. The additional capacity costs less as the size of the unit increases. This is illustrated by a graph of the cost per boiler horsepower for units of various sizes in the Appendix. We recommend that the boilers be oversized by some percentage determined by the college to cover predicted expansion. This should be based on an analyses of expansion plans and the funds available.

Smoke

A minor advantage of a central plant is the concentration of smoke at a single point rather than the many chimneys now located on all sides of the campus.

OIL VERSUS OTHER FUELS

Heavy fuel oil (#6) should be used in the central heating plant.

The fuels presently used are #2 and #6 fuel oils. Other fuels which might be considered are gas and bituminous coal. Anthracite coal is not considered because of its premium cost.

Gas may be eliminated immediately because natural gas is not available and bottled ~~gas is~~ not competitive with oil or coal.

Not true

Of the coals considered, Fairmont slack is typical of the inexpensive bituminous coals that can be burned on either underfeed or spreader stokers. This coal has a heating value of 13,500 BTU per pound. A comparison of this coal against present oil use on a heat value basis is given below. Also shown is a comparison of present oil cost against #6 oil used in a central plant.

Oil purchases for the heating season July 1956 to June 1957 are used as the basis of this comparison, plus fuel to be used for heating the new Library. Fuel costs are taken at present day prices, not as actually billed. Efficiences are as previously developed. Anticipated fuel consumption of the new Library has been estimated at a seasonal efficiency of 70%.

Total fuel consumed - 1956-57:

#6 oil	220,356 gals.
#2 oil, South campus buildings..............	33,200 gals
New Library	21,900 gals.
Total #2	55,100 gals.

BTUs available:

$$220{,}356 \times 150{,}000 \times .58 = 19.20 \times 10^9 \text{ BTU}$$
$$33{,}200 \times 140{,}000 \times .65 = 3.02 \times 10^9 \text{ BTU}$$
$$21{,}900 \times 140{,}000 \times .70 = 2.15 \times 10^9 \text{ BTU}$$
$$24.37 \times 10^9 \text{ BTU}$$

Equivalent coal (central plant):

$$\frac{24.37 \times 10^9}{13{,}500 \times .70}$$ = 1287 tons of coal equivalent to oil purchased in 1956-57 plus Library

Equivalent #6 oil (central plant):

$$\frac{24.37 \times 10^9}{150{,}000 \times .75}$$ = 216,500 gallons equivalent to 1956-57 oil plus Library.

Equivalent fuel for new individual boilers:

#6 oil, 220,356 x $\frac{.58}{.65}$ = 200,500 gallons

#2 oil, 33,200 x $\frac{.65}{.70}$ = 30,850 gallons

#2 oil for Library	21,900 gallons
Total #2 oil	52,750 gallons

Costs:

Oil - #6	$.0698 + .0082 =	$.0780/gal.
#2	$. 195 + . 117 =	$. 102/gal.

Coal - Fairmont slack	$10.75/ton at Siding
Trucking to College	1.75
Ash Handling	.50
	$13.00/ton

Cost Comparison:

a. Present system 220,356 @ $.078 = $17,187.
55,100 @ $.102 = $ 5,620.
$22,807.

b. Coal (central plant) 1287 tons @ $13.00 = $16,731.

c. Oil (central plant) 216,500 @ $.078 = $16,887.

d. Oil (individual plants) 200,500 @ $.078 = $15,639.
52,750 @ $.102 = $ 5,381.
$21,020.

e. Advantage of coal over present oil cost $ 6,076.

f. Advantage of oil in central plant $ 5,920.

g. Advantage of new individual boilers $ 1,787.

This comparison deals with fuel consumed only. A coal burning plant cannot be made fully automatic. At least one watch fireman would be required on each shift adding the wages of 4 additional men to the cost of coal firing.

There are other drawbacks to coal firing for a college such as Bennington. Bulk storage of coal is unsightly. Facilities would have to be arranged for disposal of ashes.

Fly ash and dust nuisance from the stack is likely.

The fuel cost for central plant will be approximately $6,000 less than present fuel cost but #6 oil is ahead of coal because of added wages required for coal fired boilers.

COST OF REPLACING PRESENT EQUIPMENT

The age and consition of the present heating plant equipment makes its replacement in the foreseeable future likely. Replacement of the boilers will require much associated work including piping and insulation changes, new breechings, foundations, etc. Because of the age of the present burners, new burners and controls should be installed with each new boiler. Since access to the existing boiler rooms is limited, most of the new boilers will have to be field erected.

The condition of the existing underground fuel oil tanks is not known. Such tanks usually fail due to internal corrosion at approximately 25 years of age. The cost of new oil storage tanks is included in the replacement cost.

The cast iron boilers in the Brooder, Cricket Hill and the Garage can probably be rebuilt by the installation of new burners and controls, and repair of insulation and breechings.

If the equipment is operated until it fails, the replacement cost may be spread out over many years. It is possible, however, that several units may fail in the same year. The total replacement cost is used in studying the feasibility of a central plant.

The estimate following covers total replacement cost for all present steel boilers and the rebuilding of the cast iron boilers. Burner and fuel tank replacement is also included.

The present high pressure boiler generating 50 psig steam for kitchen use in the Commons is greatly oversized. The replacement cost is based on a unit sized for the kitchen load of 500 pounds per hour. A high temperature hot water heater and tank are also included for kitchen service to eliminate the direct steam-water blender which requires a high percentage of boiler make-up water. A similar arrangement has been charged against the cost of a central plant. No allowance is made for a new fuel oil tank in the Barn. If the present #6 tank fails, the #2 oil tank can be converted to suit.

SUMMARY OF REPLACEMENT COST OF PRESENT HEATING EQUIPMENT

(Refer to Appendix for Detailed Estimate)

BUILDING	ITEM	COST
1. Commons:		
	Heating Boiler with auxiliaries and associated work.	$13,830.
	Kitchen boiler with auxiliaries and associated work.	10,820.
	10,000 gallon oil tank with heater and piping	3,000.
2. B-1 (West Residence Group)		
	Heating boiler with auxiliaries and associated work.	17,850.
	15,000 gallon oil tank with heater and piping.	4,000.
3. B-2 (East Residence Group)		
	Heating boiler with auxiliaries and associated work.	16,350.
	15,000 gallon oil tank with heater and piping.	4,000.
4. Barn		
	Heating boiler with auxiliaries and associated work.	13,260.
5. Cricket Hill Brooder, Garage		
	Rebuild burners, controls insulation and breechings.	3,250.
	Allowance for small oil tank replacement	1,000.
		$87,360.
	15% of Contingency Allowance	13,250.
	Total Replacement Cost.	$100,610.

SCHEMES FOR A CENTRAL HEATING PLANT

The size, arrangement and equipment of the central heating plant are dependent on the winter and summer operating loads, the type of boiler and the fuel used, provisions for future expansion, building construction, and whether the boiler plant is to be used for associated operations such as maintenance shops.

The equipment will be fully automatic requiring only periodic checking by the day maintenance crew and the night watchman.

Operating Load

Summer and winter loads for the south campus building group are given in the steam load tabulation. The summary below shows the total steam output for the central plant using these steam loads, 5% losses for the distribution piping system, 10% for staggered pick-up and 5% for boiler plant losses including feed water heating.

	Winter	Summer
Net steam demand for south campus	10,320#/hr	1440#/hr
Distribution losses - 5%	516	72
	10,836	1512
Pick-up - 10%	1,084	----
	11,920	1512
Boiler plant losses - 5%	600	75
Total steam output	12,520#/hr	1587#/hr
Equivalent boiler horsepower	362BHP	46.0BHP

Boiler Size

Two 200 boiler horsepower units will be adequate to handle the winter load of 362 BHP. With this arrangement the minimum spare capacity scheme described previously is provided. There will be 38 BHP (1310#/hr) of excess capacity for expansion. This would be suitable for two buildings comparable to the new library.

The minimum output of boilers of this size is about 1 to 4, or 1870#/hr. The summer load of 46 BHP (1587#/hr) is actually a peak condition. During the night and at times during the day this load will drop almost to zero. Thus special provision for summer heating must be made.

The existing individual boilers still have a few years of useful life. The most economical point at which to retire them will be after this life has been used up. They can be used as installed spares to provide better than the minimum spare capacity scheme referred to above, and they can be operated during the summer for hot water heating. When they must be retired from service, a separate summer boiler must be installed in the central heating plant. Space for this unit is now provided in the new Boiler Room.

Additional spare capacity and provision for expansion of the campus steam load can be installed in the future by adding another 200 BHP boiler in a new bay at the end of the building.

<u>Fuel Storage</u>

One month's supply of fuel during mid-winter operation is deemed to be adequate for oil storage requirements. Pro-rated for the coldest month (December) on a degree day basis, this is calculated to be 38,900 gallons. Two 20,000 gallon tanks holding a total oil quantity of 40,000 gallons are recommended.

Boiler Types

Several types of boilers are available in the size required. In selecting the best type for institutional central heating, expected length of service life and conservative design are paramount. We recommend water tube boilers with large water capacity, low furnace heat release, large diameter tubes and drums. Typical of this type is the longitudinal drum boiler offered by many of the major manufacturers. This boiler is of an established design with numerous existing installations. A cut of this boiler is included in the Appendix. Another type is the newer cross drum boiler. Generally, the longitudinal drum units are less expensive. Such boilers, conservatively sized, can be expected to give 35 to 40 years of active service.

We strongly recommend against the packaged fire tube steam generator type. These units are quite inexpensive and are widely used in industry. They are of light construction and have very high values of heat release per cubic foot of furnace volume and per square foot of exchange surface. The design is new, the oldest units being about 15 years old. Expected life is problematical, but 20 to 25 years appears likely.

The cost estimates and plant layout in this report are based on the longitudinal drum boiler.

Central Plant Building

A proposed layout for a central heating plant, Drawing #2, is enclosed in the Appendix. This layout is based on minimum space requirements. No provision has been made for future expansion or shops. The building shown would be a minimum cost structure with a steel frame, masonry walls, concrete roof deck and industrial sash. Stacks will be the low stub type.

The appearance of the building can vary greatly. By proper use of colors, textures, sash and door shapes, its architectural treatment can be made much more imaginative than the usual boiler plant structure. A perspective sketch of such a building is bound in the Appendix.

For greatest utility, the building should be enlarged to include central maintenance shops, so that the campus operating and maintenance crew could be based at the boiler plant. The additional bay for the future third boiler should be constructed at this time to save the expense of the end wall which must be demolished to extend the building at a future time.

The estimate following is based on the minimum scheme. Two more 15 foot bays built at the present time to house shops and a future boiler will add $15,445 to the building cost including contingency allowance. This space should be provided if funds are available.

Location of Central Plant

Drawing #4 in the Appendix shows the buildings of the south campus group. The calculated center of the steam load is shown midway between the new Library and Commons. This point is the best theoretical location for a central heating plant. The nature of the plant building and the possible smoke nuisance actually requires it to be on the outer edge of the area, preferably concealed by trees on the east or southeast side. The cost of the distribution piping will increase in direct proportion to the distance from the center of load.

The sloping open field north of the Brooder appears to be a very favorable location. The plant can be recessed into the hill shielded from the major campus buildings. Prevailing west winds will carry smoke away from the campus. The distance from the load center is reasonable.

Fuel oil storage tanks can be buried in the bank to the north of the plant, delivery of oil being made from a short extension of the road south of the Barn. Access to the plant would be effected by extending the road which now turns north past the east end of the Brooder.

COST ESTIMATE OF CENTRAL PLANT

The estimated cost of a minimum central heating plant as described above and as shown on Drawing #2 is given on the next page.

COST ESTIMATE OF CENTRAL PLANT

Item		Cost
1. Boiler Plant Building, 32'w.x 63'l.x 20'h. @ $.70 per cu. ft.		$28,200
2. Equipment		
a. 2-Keeler CPK W.T. boilers, 200 HP, in place with settings and insulation @ $12,460	$24,920	
b. 2-Ray #7 burners, in place, wired and piped @ $4,565	9,130	
c. 2-Wing induced draft fans @ $775	1,550	
d. Duplex #6 oil pump and heater set	4,200	
e. Condensate receiver	1,000	
f. 2-Condensate pumps @ $300 ea.	600	
g. Feedwater heater, Graver "SSC", size 7	2,810	
h. 2-Boiler feed pumps @ $485	970	
i. 2-Stub stacks @ $575	1,150	
j. Misc. machinery setting and erection	1,000	
k. Foundations	1,000	
l. Piping work	18,000	
m. Electric power	4,000	
n. Lighting	2,040	
o. Thermal insulation	5,000	
p. Electric starters and electric controls	1,000	
q. Combustion controls, meters & instruments	5,000	
r. Painting piping & equipment	1,500	
s. Start-up, test, etc.	1,000	
	$85,870	$85,870
3. Oil storage, 2-20,000 tanks, installed		7,000
4. Water main, storm drain & septic tank		2,375
5. Roads and walks		1,000
		$124,445
15% for Contingencies and Engineering		18,655
Total cost of Minimum Central Plant		$143,100

In the section on Comparison of Costs both the minimum scheme above and the larger building with space for shops and a future boiler are compared.

STEAM DISTRIBUTION SYSTEM

Distribution Pressure

The most common steam distribution pressures for central heating systems are in the range of 35 to 50 psig. Below this range the size and cost of the distribution piping becomes very high. At higher pressures the maintenance cost of the piping system increases and the active life of the system is reduced. This report is based on generating steam at 40 to 45 psig and distributing at 35 to 40 psig.

The State of Vermont has no limits on the pressure of fully automatic boiler plants and generation of steam at 40 psig or requirements for the pressure or licensing of firemen.

Piping Arrangement

Drawing #4 in the Appendix shows the proposed arrangement of the steam distribution piping. This layout is arranged to provide for future expansion of the campus in any direction around the south campus building group. Basically, the system is a branch system for the initial stage, but it may be converted into a loop system, as shown, by closing the ends of the branches to the east and west residence groups. While the piping is new, there is little need for the breakdown protection afforded by a loop system. As it nears the end of its expected life and failures begin to occur, the loop closure can be installed to insure heating of all buildings while piping repairs are made. For the same reason, few divisional valves are provided. If the loop closure is installed, divisional valves will be required on both sides of each building branch.

The pipe sizes shown are based on maintaining conservative steam velocities in the mains. This is a major factor in obtaining long life from the system and eliminating noise.

With the pipe sizes shown, the steam loads may be doubled due to expansion without limiting the expected 50 year life of the system.

An important consideration in the location of the main runs shown is to keep disturbance of landscaping and planting to a minimum. No major trees would be disturbed and interference with minor trees, shrubs and planting beds would be slight.

Insulation and Protection

There are many methods of insulating and protecting buried steam piping. The method offering high insulating efficiency and good corrosion protection at lowest cost is preferable.

Tunnels are the best answer on a performance basis but the cost is prohibitive. Recent cost studies for another New England College showed that the cost of the tunnel structure alone in a system of comparable length was $100 per foot exclusive of piping and insulation. For Bennington, this would increase the distribution cost by $219,500 for main runs only. Tunnels obviously cannot be considered.

There are several protected metal conduit systems on the market of which Ric-wil is typical. While these systems are excellent, their cost is 30 to 40% higher than the granular asphaltic insulating materials described below. Tile conduit and porous concrete systems are not thought to be comparable in performance and have not been considered.

For about 10 years a granular asphaltic insulating material called Gilsulate has been available for underground piping systems. The bulletin in the Appendix describes the physical characteristics of Gilsulate and its method of application. The cost of a Gilsulate protected piping system is lower than any other type. The thermal efficiency and corrosion resistance are excellent. Although the material is relatively new, it has had wide acceptance by colleges and similar institutions as well as industry and the Federal Governmant.

We have used Gilsulate for steam line protection at approximately 6 colleges and universities and many industrial plants based on discussions and investigations with present users, other consulting engineers and various Federal agencies. The cost estimates for this report are based on its use.

Piping Modifications in Present Buildings

Steam received at the buildings at 35 to 40 psig must be reduced in pressure for use in the heating systems. The 30 psig steam for the kitchen must be regulated for constant pressure. Instantaneous steam hot water heaters will be required to serve the present H.W. storage tanks.

The direct steam-water blender in the kitchen should be eliminated to save condensate and reduce boiler make-up water. A high temperature hot water storage tank and heater will be required to replace this blender.

The estimate of cost for the distribution system shows the costs of the piping and equipment in the various buildings served by the steam distribution system tabulated separately.

COST ESTIMATE OF STEAM DISTRIBUTION SYSTEM

In the estimate below the letter designations for the various piping runs, refer to Drawing #2.

Distribution Piping

1. Mains

Run	Length in ft.	Pipe Sizes	Cost per Foot	Total
a. AB	280	8-2-1/2-1	$42.80	$12,000
b. BC	265	6-1-1/2	27.16	7,200
c. CD	195	6-1-1/2	27.16	5,300
d. BE	310	4-1-1/2	17.77	5,510
e. BF	365	8-2-1/2-1	42.80	15,650
f. FG	215	8-2-1/2-1	42.80	9,210
g. GI	565	6-1-1/2	27.16	15,330

2. Branches to Bldgs.

a. Barn	165	3-1	16.00	2,640
b. Cricket Hill	150	2-1/2-1	14.55	2,190
c. Library	40	2-1/2-1	14.55	580
d. B-2	50	4-1-1/2	17.77	890
e. Commons	115	4-1-1/2	17.77	2,050
f. Garage	110	1	10.00	1,100
g. B-1	50	4-1-1/2	17.77	890
h. Brooder	75	2-1/2-1	14.55	1,090

3. Misc.

a. 3 Manholes @ $500	1,500
b. 3 Drip assemblies @ $250	750
c. 2 Fitting assemblies in 8" steam lines in Manholes @ $500	1,000
d. 1 8" Gate with flanges @ $500	500
e. 2 6" Gate with flanges @ $400	800
f. 1 4" Gate with flanges @ $300	300
	$86,480
15% for Contingencies and Engineering	13,000
Total cost of Distribution Piping	$99,480

Piping Modifications in Present Buildings

Building	Item	Cost
1. Commons	2 instantaneous heaters 1-800 gal. H.W. tank Piping with PRV's, Control Valves, Traps, Relief Valves, Vents and Insulation. 1 condensate return Unit	$5,000
2. B-1	1 instantaneous heater Piping with Valves and Specialities 1 condensate return Unit	2,500
3. B-2	Same as for B-1 above	2,500
4. Barn	Similar to B-1 above but smaller capacity	2,000
5. Cricket Hill	" " " "	750
6. Brooder	" " " "	750
7. Garage	Small piping assembly only	250
		$13,750
15% for Contingencies and Engineering		2,060
Total Cost of Building Piping Modifications		$15,810

COMPARISON OF COSTS

Capital Expenditures

1.	Replacement of Present Equipment		$100,610.
2.	Minimum Central Plant		
	a. Heating Plant	$143,100.	
	b. Distribution Piping	99,480.	
	c. Piping Modifications	15,810.	
		$258,390	258,390.
3.	Central Plant with Shops and Space for Future Unit		
	a. Total from 2 above	$258,390.	
	b. Additional Building Cost	15,445.	
		$273,835.	273,835.

Direct Operating Costs

1.	Present Operating Cost		
	a. Fuel	$22,807.	
	b. Labor	6,900.	
	c. Maintenance and Repairs	4,000.	
		$33,707.	33,707.
2.	New Individual Boilers		
	a. Fuel	$21,020.	
	b. Labor	6,900.	
	c. Maintenance and Repairs @ 3%	3,018.	
		$30,938	30,938.
3.	New Central Heating Plant		
	a. Fuel	$16,887.	
	b. Labor	3,450.	
	c. Maintenance & Repairs; Equip.@3%	2,963.	
	Dist. Piping @ 1/2%	500.	
	Plant Buildings @ 1%	325.	
		$24,125.	24,125.

Savings and Period to Write Off Capital Cost

1. New Individual Boilers
   a. Savings, $33,707 = 30,938 = $2,769.
   b. Period, $\frac{\$100,610}{\$2,769}$ = 36.4 years

2. Minimum Central Plant
   a. Savings $33,707 - 24,125 = $9,582.
   b. Period $\frac{\$258,390}{\$9,582.}$ = 27.0 years

3. Central Plant with Shops
   a. Savings, same as 2 above $2,958.
   b. Period, $\frac{\$273,835}{\$9,582.}$ = 28.5 years

Discussion

The operating savings for the new individual boiler plants do not write off their installation cost in the expected 30 year service life of the equipment.

For the central plant schemes, the expected life of the boiler plant equipment is 35 to 40 years. The piping is expected to remain in service for 50 years, and the plant building, 50 years plus. In both of the two schemes, the operating savings return the capital cost in less than their expected life time.

Depreciation and the Cost of Capital

None of the schemes above amortize their investment cost if analyzed on an industrial basis where an annual depreciation reserve charge and the interest cost of the capital are applied as costs. This matter is the source of much debate on the part of private college and school administrators.

Where schools have large endowments received as gifts, the endowment income can be considered as free income against which a capital use cost (interest) need not be applied. Similarly, capital received as gifts through fund raising drives for specific projects can also be considered interest free.

If these funds could be invested they would return an income. Technically the loss of this income represents a cost or charge paid for using the funds for capital construction. Since the endowment income or gift funds are intended only for capital construction and operating expense of the institution, the question of interest becomes academic. The money is not raised for purposes of investment.

Equipment depreciates over the length of its useful life until it must be replaced because of failure or obsolescence. In industry, the annual depreciation cost is charged as an operating expense and a reserve fund is developed for replacement. This is an accounting device to offset the cost of industrial capital (interest) and to reduce taxes. Similar arguments apply for colleges as those used above in discussing interest. If interest free capital is available for equipment replacement, the depreciation reserve is not required.

Bennington does not charge depreciation as a yearly cost at the present time. If a depreciation charge is applied to the schemes above, the savings in operating costs would be wiped out.

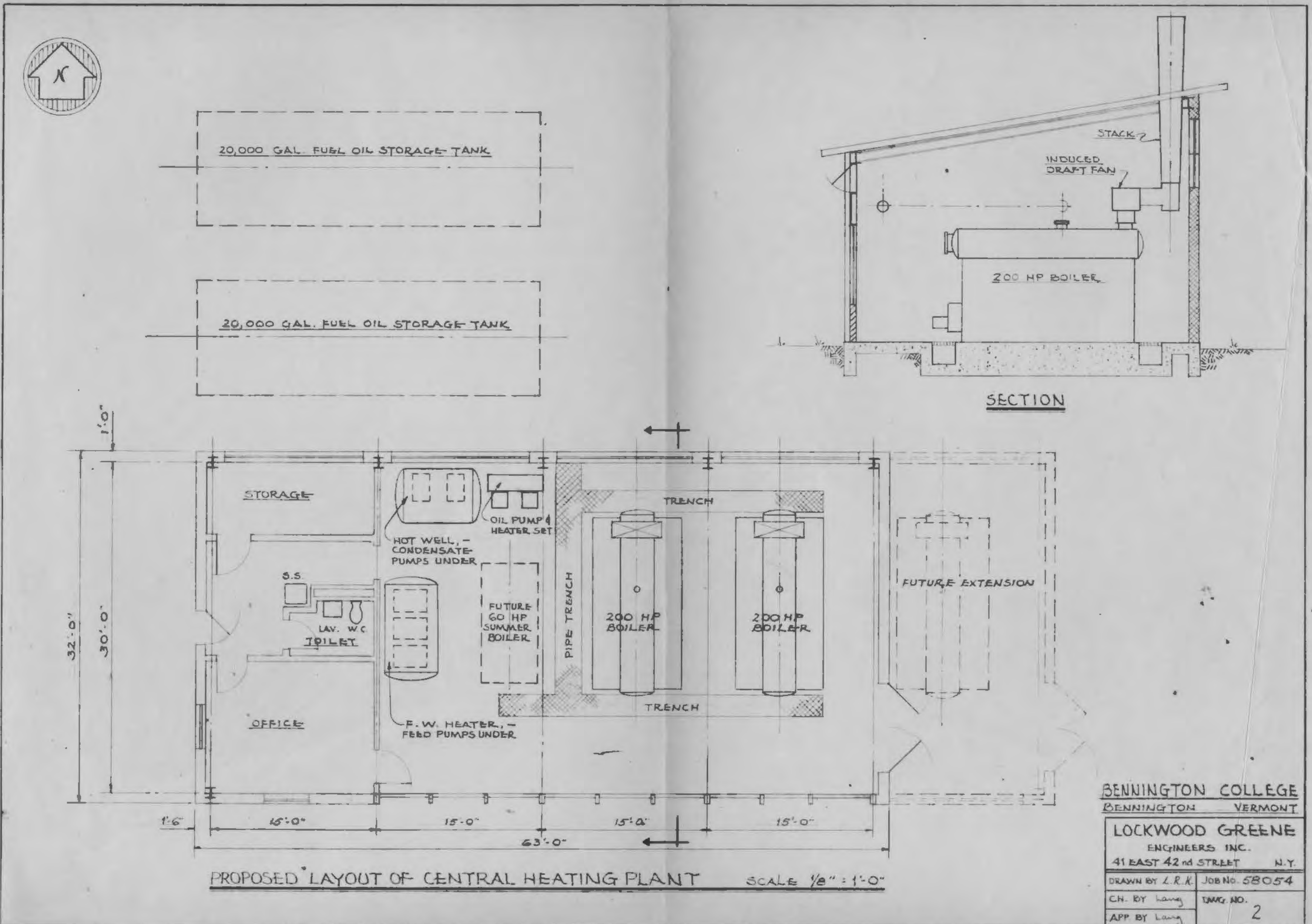
LIST OF APPENDICES AND DRAWINGS

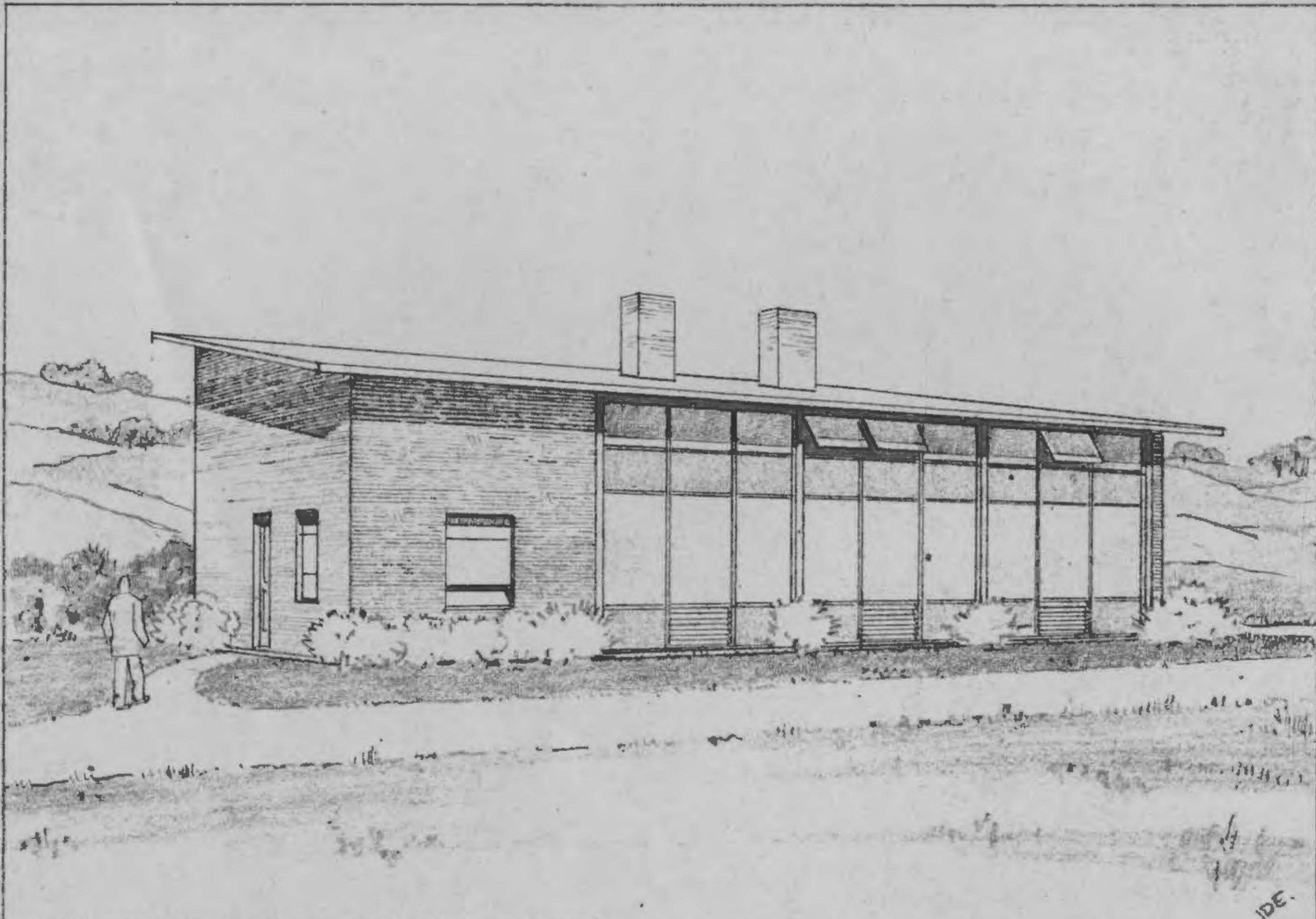
BUILDINGS	
1	COMMONS
5	BOOTH HOUSE
6	KILPATRICK HOUSE
7	LEIGH HOUSE
8	Mc CULLOUGH HOUSE
9	BINGHAM HOUSE
10	WELLING HOUSE
11	DEWEY HOUSE
12	CANFIELD HOUSE
13	SWAN HOUSE
14	WOOLLEY HOUSE
15	STOKES-SANFORD HOUSE
16	FRANKLIN HOUSE
18	THE BARN
19	CRICKET HILL
20	NURSERY SCHOOL
21	CERAMIC STUDIO
22	SCULPTURE STUDIO
23	THE BROODER
24	FACULTY HOUSES
25	SHINGLE COTTAGE
27	JENNINGS HALL
28	RECREATION

PLOT PLAN OF CAMPUS
BENNINGTON COLLEGE
BENNINGTON VERMONT

SCALE 1":400'-0"

LOCKWOOD GREENE ENGINEERS INC. 41 EAST 42nd STREET N.Y.	
DRAWN BY LRK	JOB No 58054
CH. Lang	DWG No
APP. Lang	1

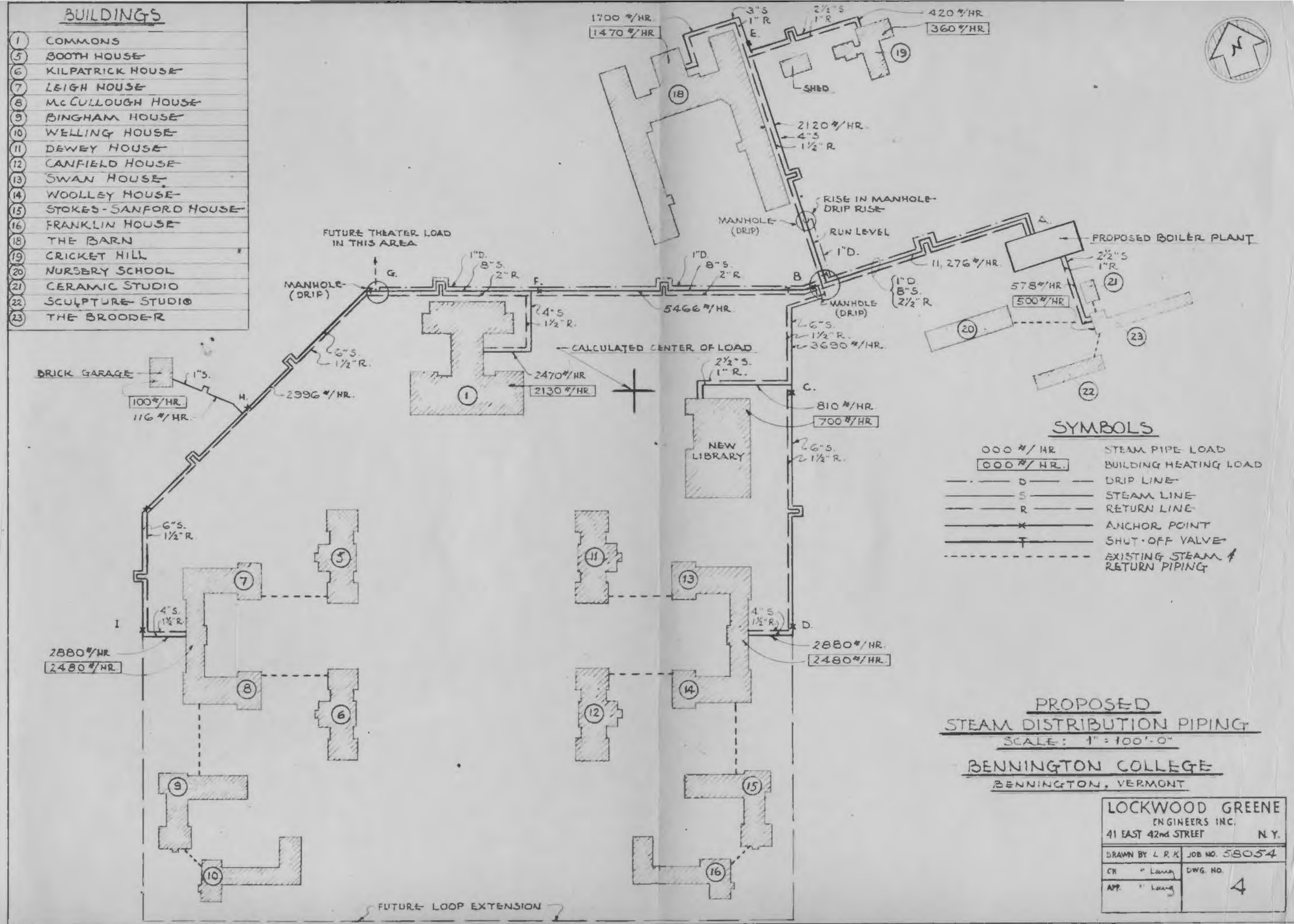

20,000 GAL. FUEL OIL STORAGE TANK
20,000 GAL. FUEL OIL STORAGE TANK
STACK
INDUCED DRAFT FAN
200 HP BOILER
SECTION
STORAGE
OIL PUMP & HEATER SET
HOT WELL, - CONDENSATE PUMPS UNDER
TRENCH
S.S.
LAV. W.C.
TOILET
FUTURE 60 HP SUMMER BOILER
PIPE TRENCH
200 HP BOILER
200 HP BOILER
FUTURE EXTENSION
TRENCH
OFFICE
F. W. HEATER, - FEED PUMPS UNDER
1'-0"
32'-0"
30'-0"
1'-6"
15'-0"
15'-0"
15'-0"
15'-0"
63'-0"
PROPOSED LAYOUT OF CENTRAL HEATING PLANT
SCALE 1/8" = 1'-0"
BENNINGTON COLLEGE
BENNINGTON VERMONT
LOCKWOOD GREENE
ENGINEERS INC.
41 EAST 42 nd STREET N.Y.
DRAWN BY L.R.K.
JOB No. 58054
CH. BY Lang
DWG. NO. 2
APP. BY Lang
16"-11"



NEW BOILER HOUSE FOR BENNINGTON COLLEGE

Lockwood Greene Engineers, Inc. '58

DRAWING No. 3



BUILDINGS

1	COMMONS
5	BOOTH HOUSE
6	KILPATRICK HOUSE
7	LEIGH HOUSE
8	McCULLOUGH HOUSE
9	BINGHAM HOUSE
10	WELLING HOUSE
11	DEWEY HOUSE
12	CANFIELD HOUSE
13	SWAN HOUSE
14	WOOLLEY HOUSE
15	STOKES - SANFORD HOUSE
16	FRANKLIN HOUSE
18	THE BARN
19	CRICKET HILL
20	NURSERY SCHOOL
21	CERAMIC STUDIO
22	SCULPTURE STUDIO
23	THE BROODER

SYMBOLS

000 #/HR	STEAM PIPE LOAD
[000 #/HR.]	BUILDING HEATING LOAD
—·— D —·—	DRIP LINE
—— S ——	STEAM LINE
—— R ——	RETURN LINE
——×——	ANCHOR POINT
——T——	SHUT-OFF VALVE
- - - - -	EXISTING STEAM & RETURN PIPING

PROPOSED STEAM DISTRIBUTION PIPING

SCALE: 1" = 100'-0"

BENNINGTON COLLEGE

BENNINGTON, VERMONT

LOCKWOOD GREENE
ENGINEERS INC.
41 EAST 42nd STREET N.Y.

DRAWN BY L R K	JOB NO. 58054
CH " Lang	DWG. NO. 4
APP. " Lang	

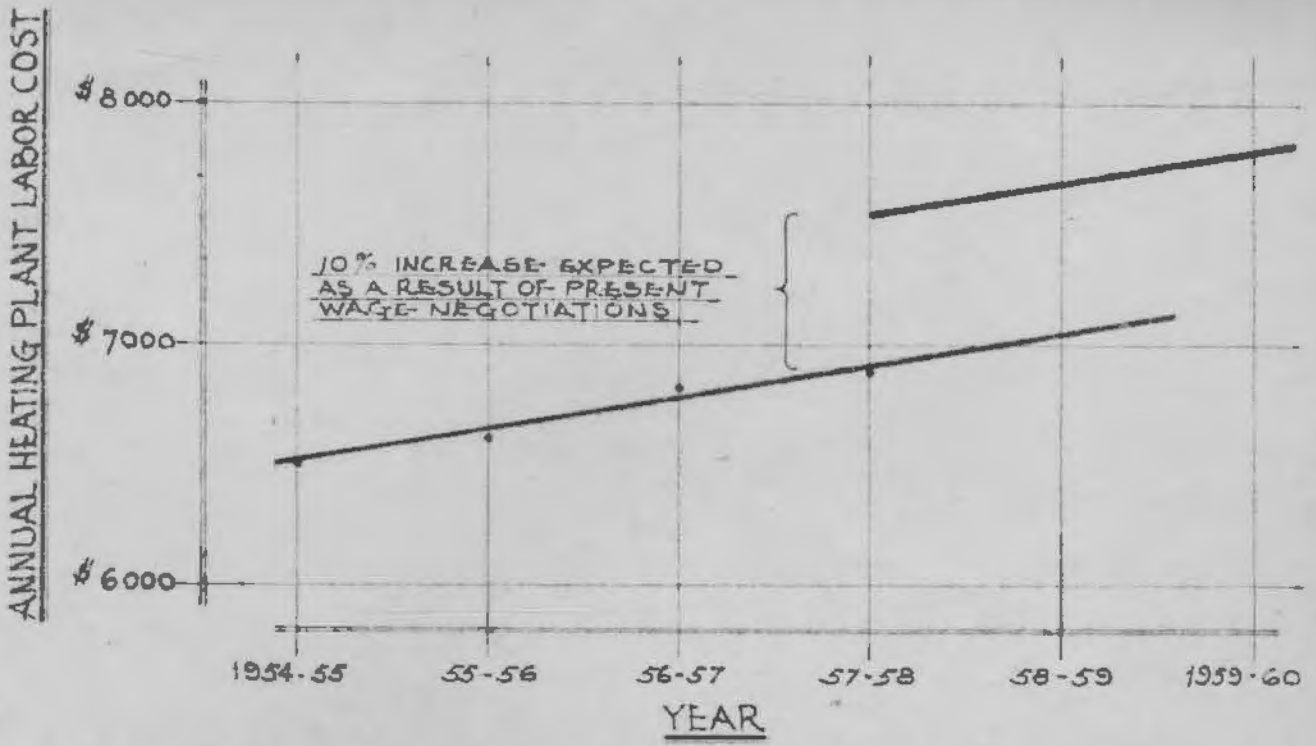
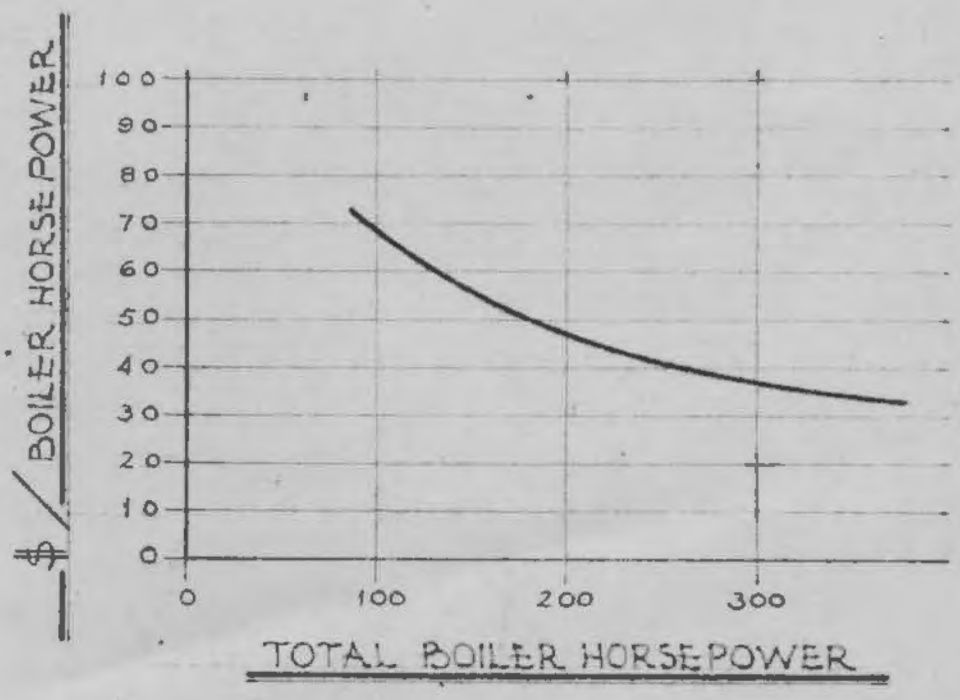


CHART OF ANNUAL HEATING PLANT LABOR COST SINCE 1954

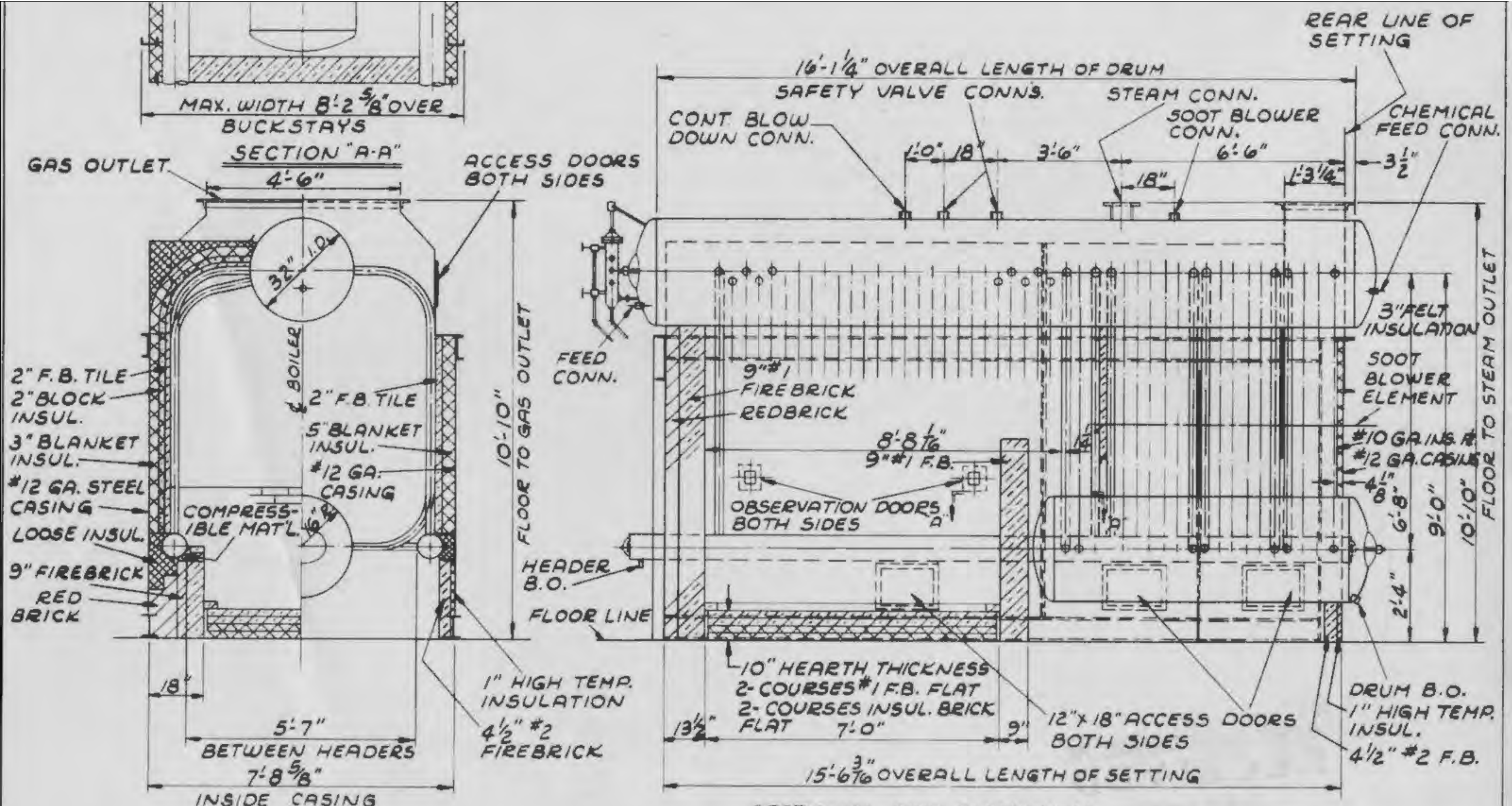


TYPICAL CURVE OF
BOILER UNIT COST REDUCTION
WITH INCREASE IN SIZE

DETAILED ESTIMATE OF
REPLACEMENT COST OF PRESENT HEATING EQUIPMENT

Building	Item	Cost	Total Cost
1. Commons			
	Heating boiler - Kewanee 1781 JB	$2,730.	
	Freight, trucking, rigging, fabrication and testing	2,450.	
	Burner - installed	2,950.	
	Controls	500.	
	New Breeching	400.	
	Electrical work	500.	
	Piping	2,000.	
	Insulation (piping, boiler & Breeching)	1,500.	
	Concrete work	300.	
	Removals	500.	
		$13,830.	$13,830.
	Kitchen boiler, Kewanee KP-18S-125	2,400.	
	Freight, trucking, rigging	750.	
	Burner, installed with controls	1,570.	
	Hot water tank and heater	1,500.	
	New Breeching	400.	
	Electrical work	500.	
	Piping	1,500.	
	Insulation (piping, HW tanks, breeching)	1,500.	
	Concrete work	200.	
	Removals	500.	
		$10,820.	$10,820.
	10,000 gallon oil tank with suction heater and piping		3,000.
2. B-1 (West Residence Group)			
	Boiler (to replace two existing units) Kewanee 1784 JB	$4,200.	
	Freight, trucking, rigging, fabrication and testing	3,100.	
	Burner, installed	3,850.	
	Controls	500.	
	New breeching	400.	
	Electrical Work	500.	
	Piping (modify for one boiler)	2,500.	
	Insulation (boiler, piping & breeching)	1,500.	
	Concrete work	300.	
	Removals (two boilers)	1,000.	
		$17,850.	$17,850.
	15,000 gallon oil tank with suction heater and piping		4,000.

Building	Item	Cost	Total Cost
3. B-2 (East Residence Group)			
	Boiler, Kewanee 1784 JB	$4,200.	
	Freight etc., as above	3,100.	
	Burner, installed	3,850.	
	Controls	500.	
	New Breeching	400.	
	Electrical Work	500.	
	Piping	2,000.	
	Insulation (boiler, piping & breeching)	1,000.	
	Concrete Work	300.	
	Removals	500.	
		$16,350.	$16,350.
	15,000 gallon oil tank with suction heater and piping		4,000.
4. Barn			
	Boiler - Kewanee 1780 JB	2,560.	
	Freight, etc. as above	2,450.	
	Burner, installed	2,950.	
	Controls	500.	
	New Breeching	300.	
	Electrical Work	500.	
	Piping	1,500.	
	Insulation (piping, boiler & breeching)	1,500.	
	Concrete Work	200.	
	Removals	500.	
	Suction heater for existing oil tank	300.	
		$13,260.	$13,260.
5. Cricket Hill, Brooder, Garage			
	3-burner and control units installed with new wiring & piping	2,500.	
	Repair of breechings and insulation	750.	
		$3,250.	3,250.
	Allowance for small oil tank replacement		1,000.
			$87,360.
	15% contingency allowance		13,250.
	Total Replacement Cost		$100,610.



SECTIONAL SIDE ELEVATION

HALF SECTION THRU FURNACE

HALF SECTION THRU LAST PASS

340 CU. FT. FURNACE VOLUME

1000 SQ. FT. TOTAL HEATING SURFACE

E. KEELER CO.
WILLIAMSPORT PA.

PRELIMINARY PLANS OIL FIRED
8500 #/HR. TYPE "CPK" BOILER

FOR ______________________

DATE ____________ DRAFTSMAN ____________

DRAWING P-17255-S-300 NO SCALE


The answer to all-around protection for hot buried piping
Protects against external corrosion ...heat loss ...electrolysis
A. F. HINRICHSEN, INC.
50 CHURCH ST.
NEW YORK 7, N. Y.
REPRESENTATIVE
The insulation that can be buried in the ground without deteriorating
GILSULATE®
TM Reg. U. S. Pat. Off. U. S. Patent No. 2,668,125
The Triple-Zone System for complete lifetime protection of hot underground pipes

UNIVERSITY INSTALLATION at Albert Einstein College of Medicine, N. Y. This is an 845 foot steam line, using 138 tons of Gilsulate.

GILSULATE has been tested, tried, proven and is now in use at:

Refineries

Railroads

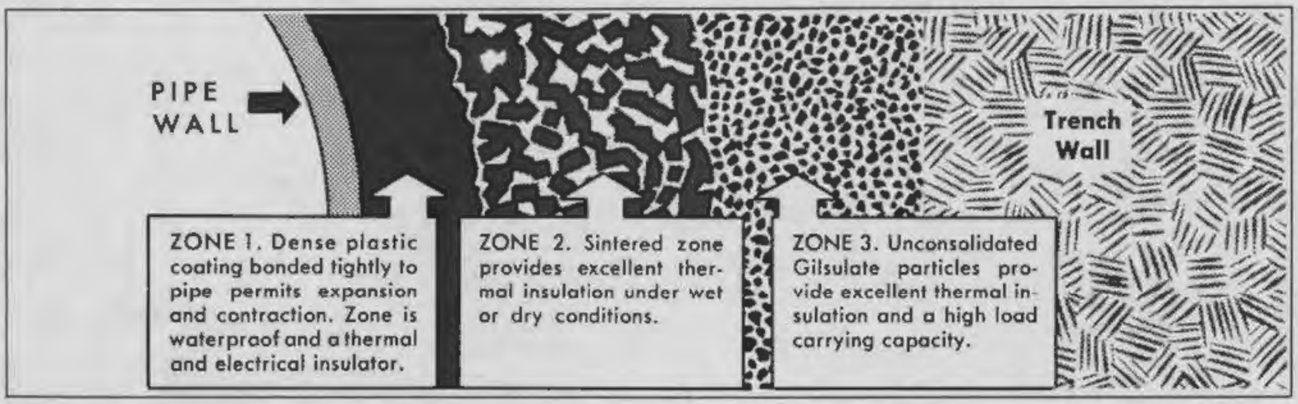
Schools

Colleges

Public Utilities

Industry

MUNICIPAL INSTALLATION on the West C
Trenches in paved streets are often deep
narrow. Gilsulate's resistance to heavy t
vibration, convenient packaging and electr
protection make it ideal for this type of se



TECHNICAL DATA TABLE

Density	In Shipping Sacks: Approximately 40 lb. per cu. ft.	In Trench: approximately 44 lb. per cu. ft.	
Flash Point	Cleveland open cup method—600 F		
Specific Heat	at 300 F = 0.52 Btu/lb. (°F)	at 500 F = 0.61 Btu/lb. (°F)	
Three Types Available:	Type A for 220°-300° F. temp. range	Type B for 300°-385° F. temp. range	Type C for 385°-520° F. temp. range

Thermal Coefficients of Transmission (U) from field data

Pipe Size, I. P. S.	1"-4"	5"-6"	8"	10"-12"	16"
Recommended Gilsulate Thickness	4"	5"	6"	8"	11"
Approx. U in Btu/(hr) (sq. ft.) (°F)	0.20	0.15	0.12	0.08	0.055

See your local distributor for a Gilsulate demonstration

AMERICAN GILSONITE COMPANY

134 West Broadway, Salt Lake City 1, Utah [redacted]

The Agents Building, 3537 Lee Road, Room 37, Shaker Heights, Ohio

(L-102-F-56) 5/57 15M—LITHO