A DESIGN OF A SEWAGE SLUDGE GAS COLLECTOR, AND A HOT WATER HEATING SYSTEM FOR THE EAST LANSING MICHIGAN SEWAGE TREATMENT PLANT

Thesis for the Degree of B. S.

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SUPPLEMENTARY
MATERIAL
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C. A. S.

A view of the Imhoff tank

INTRODUCTION

The city of East Lansing Michigan and Michigan State College jointly constructed a sewage treatment plant in 1928 to care for the sewage from the city and the College. This plant consists of a bar rack, a pump station, and an Imhoff sewage treatment tank. A brick building houses the pump station and the bar rack.

The sewage flows through the Imhoff tank, during which time suspended solids settle to the bottom of the tank. These settled solids accumulate in the bottom part of the tank, and together with its contained water is known as sludge. This sludge is held in the tank for a period of several months. The organic solids of the sludge undergo digestion, during which process combustible gases, largely methane, are given off. At present these gases rise to the surface of the tank through four gas vents, and escape to the atmosphere. It is proposed to cover these gas vents and collect and utilize the gases. These gases when burned will be used to heat water, which will be circulated through radiators to heat the pump station. During the summer months the gas will be wasted by burning it in a waste burner.

A typical analysis of sewage sludge gas shows:

Methane	76.6%
Carbon Dioxide	14.7%
Nitrogen	8.2%
Oxygen	0.5%

Experience at other plants has shown that the amount of gas collected is from 0.36 - 0.44 cu. ft. per capita per day. The average is 0.40 cu. ft. per capita per day. On the basis of the present population this will amount to 3,520 cu. ft. per day, and on the basis of the year 1950 population this will amount to 5,280 cu. ft. per day. Corresponding heat values are 650 to 750 B. T. U. per cu. ft. of gas.

It will be shown later that the present estimated amount of gas is more than sufficient to heat the pump station building.

PROCEDURE

The design has the estimated population of 14,200 persons for the year 1950 as its' basis. The amount of gas produced is assumed to be 0.4 cu. ft. per capita per day. Using these assumptions the amount of gas produced will be 5,680 cu. ft. per day.

The four gas vents of the Imhoff tank will be covered with a 4" reinforced concrete cover, and each cover will be fitted with a gas collecting dome. In the outside gas vents the five pillars, which are spaced at regular intervals, extend from the surface of the tank to the top of the sludge hoppers. In order to construct the cover a section of the pillar will have to be removed. The underside of the ends of the covers will be built 1 foot below the level of the water surface in the flowing through chambers, and the highest point on the covers will be at the water level. The covers are sloped upward from the ends to the gas domes so the gas will collect at these points. The covers are below the water level so the scum will not rise to the surface of the water in the vents and form a hard mat. If the scum is kept wet it will settle to the sludge hoppers. To prevent clogging, a scum barrier made of boards set loosely is placed at the bottom of the gas domes.

In order to get a good bond between the old concrete, and the cover, a portion of the old concrete will have to be

removed. A strip of concrete 6" wide and 2" deep will be removed from each side of each vent along the line of the cover. The joint between the vent, and the cover will have to be water tight.

The gas collecting domes will be made of 3/8" steel plates. Details of the cover and of the dome are shown on the blue print.

The gas burner that will be used is a Basmor 25 - W - 6 boiler. This boiler has an input rating of 165,000 B. T. U. per hour and an output or available B. T. U. rating of 132,000 B. T. U. per hour. This boiler is made by the Premier Heater Division of the Crane Co. LaPorte, Indiana.

There are three rooms that will require heat. They are ; the motor room, and the room adjoining, both of which are on the first floor; and the pump room, which is in the basement below the motor room.

The amount of radiation surface required in sq. ft. for each room was obtained by following the procedure given by H. A. Thrush and Co. of Peru, Indiana in Sweet's Catalog File for 1936. The temperature to be maintained will be 70 degrees Fahrenheit.

The size of the pipe used for piping the gas from the Imhoff tank to the burner will be 2" in diameter. The size of the pipe for the hot water flow to the radiators will be 2" and 1¼" in diameter, and the return pipe to the boiler will be 2" in diameter. All sizes of pipe were taken from other designs.

DESCRIPTION OF THE LAYOUT

The gas which rises to the surface of the tank is collected in the gas collecting domes. The pressure due to the rising gas forces the gas in the domes through pipes 2" in diameter to the pump station. The gas goes through a condensate trap, and then a meter records the amount of gas produced. For safety measures the gas passes through a pressure relief and a flame trap. The pressure relief is connected to the waste burner which is placed outside of the building. From the flame trap the gas goes to the burner. The water which is heated to 180 degrees Fahrenheit is circulated through pipes 2" and 1½" in diameter to the radiators, and is returned to the boiler through pipes 2" in diameter by means of an electric circulating water pump.

A water tank is installed near the ceiling above the boiler to care for the expansion and contraction of the water being heated. A pipe is connected from the flow line to this tank. A two pen temperature recorder records the temperature of the flow to the radiators and the return water. A 10 foot chimney 10 inches in diameter is used to carry away the products of combustion.

CALCULATIONS

Gas Pipe from Gas Collecting Domes to Boiler

Formula from the Textbook,

Sewerage and Sewage Disposal by Metcalf and Eddy

page 633

$$S = \frac{1.848\ Q^{1.852}\ t}{1{,}000\ p^{4.873}\ d^{5}}$$

S = drop in pressure per 1,000 feet of pipe in lb. per sq. in.

Q = cu. ft. of gas per minute

t = recorded temperature in degrees F + 459.6

p = gage pressure + 14.7

d = diameter of pipe in inches

Try d = 2" assume p = 20

$$S = \frac{1.848 \times 3.94^{1.852} \times (70 + 459.6)}{1{,}000 \times 20^{4.873} \times 2^{5}}$$

S = 0.0105 lb. per sq. in./1,000 ft.

The length of the gas pipe from the gas collecting domes to the boiler is 30 feet. Therefore the drop in pressure is,

S = 0.0003 lb. per sq. in.

It is alright to use a pipe 2" in diameter, for the drop in pressure is less than 1.0 lb. per sq. in.

The drop in pressure in inches of water pressure is,

0.0003 x 2.31 ÷ 12 = 0.000115 inches

Small Room - size 30' x 9' x 12'

Heat loss through all exposed or cold surfaces.

Exposed wall - brick wall coefficient = 0.46

30 x 12 + 2(9 x 12) - (7 x 3)(doors) -

3(3 x 3)(windows) = 523 sq. ft.

Loss per hour = 70 x 0.46 x 523 = 17,000 B. T. U.

Single window (3 x 3) - coefficient = 1.35

Loss per hour = 70 x 1.35 x 3(3 x 3) = 2,550 B. T. U.

Ceiling - coefficient = 0.60

Loss per hour = 70 x 0.60 x (9 x 30) = 1,134 B. T. U.

Floor - assume temperature in basement to be

45 degrees in zero weather

Temperature difference is 25 degrees (70 - 45)

Coefficient = 0.62

Loss per hour = 25 x 0.62 x (9 x 30) = 4,190 B. T. U.

Door (3 x 7) - coefficient = 0.69

Loss per hour = 70 x 0.69 x (3 x 7) = 1,012 B. T. U.

Air entering room by infiltration

Two air changes every hour

Volume of room = 30 x 9 x 12 = 3,240 cu. ft.

Coefficient = 0.033

Loss per hour = 70 x 0.033 x 3,240 = 8,150 B. T. U.

Total B. T. U. loss per hour = 34,035 B. T. U.

Pump Room - size 30' x 15' x 18'

Assume temperature to be 45 degrees in zero weather

Temperature difference is 25 degrees (70 - 45)

Concrete wall coefficient = 0.44

30 x 18 + 2(18 x 15) + 2(15 x 30) = 2,070 sq. ft.

Loss per hour = 25 x 0.44 x 2,070 = 22,800 B. T. U.

Air entering room by infiltration

One air change every hour

Volume of room = 30 x 15 x 18 = 8,100 cu. ft.

Coefficient = 0.009

Loss per hour = 25 x 0.009 x 8,100 = 1,820 B. T. U.

Total B. T. U. loss per hour = 24,620 B. T. U.

Radiation Requirements for Each Room

Using water with a temperature of 180 degrees F there will be a heat emission of 170 B. T. U. per hour from each sq. ft. of radiating surface.

Motor Room	76,642 ÷ 170	= 451 sq. ft.
Small Room	34,045 ÷ 170	= 200 sq. ft.
Pump Room	24,620 ÷ 170	= 145 sq. ft.

Total radiating surface = 796 sq. ft.

Total B. T. U. requirement per hour = 135,297

GAS REQUIRED FOR HEATING

An estimate of the gas consumption following the procedure given by the Premier Heater Division, Crane Co., LaPorte Indiana.

With an average B. T. U. value of gas of 700, the amount of gas necessary for heating the water will be 0.1 cu. ft. per degree day per sq. ft. of radiation.

Detroit Michigan has 6,494 degree days

Grand Rapids Michigan has 6,534 degree days

Using the average value of these two cities the number of degree days for East Lansing Michigan would be 6,514.

The total radiation is 796 sq. ft.

Assume 210 heating days

Average cu. ft. of gas per day

$$\frac{6,514 \times 0.1 \times 796}{210} = 2,470$$

Approximately 3,000 cu. ft. of gas will be wasted in the year 1950, if the present type of treatment plant is still in use. On the basis of the present population of 8,801 persons, approximately 1,050 cu. ft. of gas will be wasted.

With an outdoor temperature of -10 degrees F and an inside temperature of 70 degrees F the amount of gas required is as follows:

difference in temperature, 80 degrees

Maximum consumption in cu. ft. per day

$0.1 \times 80 \times 796 \times 0.875 = 5,575$

At present there is available only 3,530 cu. ft. of gas per day. The temperature that can be maintained is:

$$\frac{3,530}{\frac{70 \times 9.1 \times 776}{27}} = 17 \text{ degrees F}$$

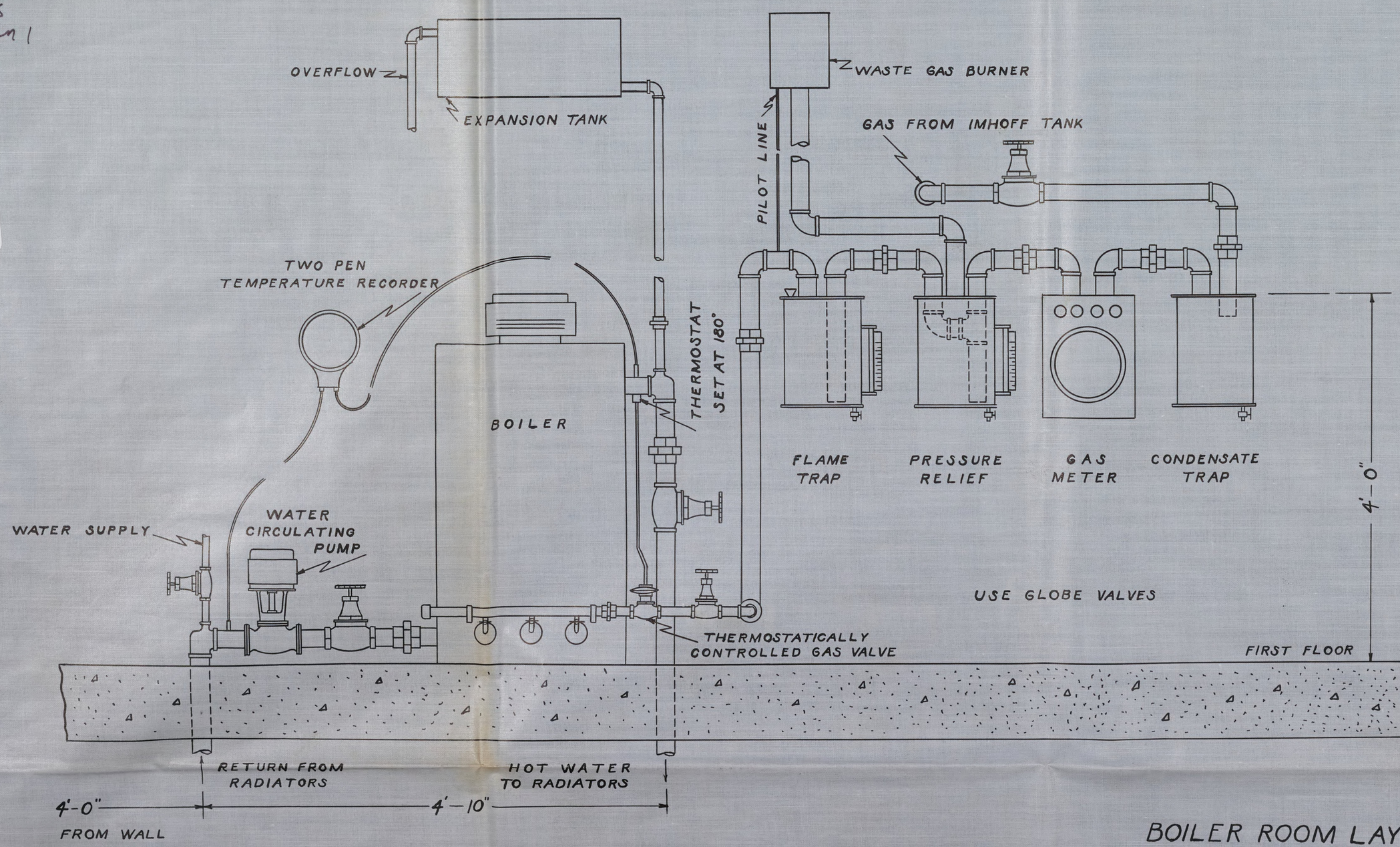
ESTIMATED TOTAL COST

Basmor 25 - W - 6 Boiler $235.00 + freight ($2.79)			$237.79
Flame Trap			10.00
Pressure Relief			10.00
Condensate Trap			10.00
Wrought Iron Pipe			
233 ft.	2" diameter @	$0.19	44.30
92 ft.	1¼" diameter @	0.12	11.05
20 ft.	¾" diameter @	0.04	0.80
Globe Valve			
7 - 2"	@	$3.50	24.50
6 - 1¼"	@	1.75	10.50
1 - ¾"	@	0.50	0.50
Tees			
7 - 2"	@	$0.50	3.50
4 reducers			
2" - 1¼"	@	0.50	2.00
Ells 90 degree			
20 - 2"	@	$0.40	8.00
12 - 1¼"	@	0.20	2.40
2 - ¾"	@	0.05	0.10
Radiators			
796 sq. ft.	@	$0.35	278.50

Gas Vent Covers 3.61 cu. yd. of concrete	
Cement	
5.33 bags per cu. yd. x 8.61 @ $0.458	$20.50
Fine Aggregate	
0.584 tons per cu. yd. x 8.61 @ 1.20	6.03
Coarse Aggregate	
1.17 tons per cu. yd. x 8.61 @ 1.30	13.13
Reinforcing Steel	
3/8" ϕ wt. = 0.376 lb. per ft.	
307 ft. @ $2.20 per 100#	7.50
Lumber	
2,000 ft. B. M. @ $24.00 per 1,000 ft. B. M.	48.00
Gas Domes Steel Plates	
77 sq. ft. wt. = 15.3 lb. per sq. ft. @ $0.08	94.35
Carpenters	
Assume 40 hours for job with 4 men	
@ $1.00 per hour	160.00
Common Labor	
Assume 80 hours for job with 3 men	
@ $0.55 per hour	352.00
Extra Work	200.00
Total Estimated Cost	$1,585.37

CONCLUSION

The amount of gas assumed to be generated is a minimum, also the coefficients used in determining the B. T. U. losses are conservative. Consequently on the coldest day there will probably be enough gas to maintain the desired inside temperature of 70 degrees F.



BOILER ROOM LAYOUT

EAST LANSING MICHIGAN

SEWAGE TREATMENT PLANT

SCALE 1"=1' CLAIR A. SHALER