FINAL TECHNICAL REPORT

GRANT FUNDED PROJECT FOR DIGESTER GAS UTILIZATION AT WEST SOUTHWEST SEWAGE TREATMENT WORKS

DOE GRANT NUMBER FG02-79R510110.A000
MSD CONTRACT NUMBER 78-M01-W

Grantee's Legal Responsibility: The Metropolitan Sanitary District of Greater Chicago was formed in 1889 to protect the water supply of people living in the Chicago and Calumet river basins. Flow of these rivers was diverted from Lake Michigan to prevent contamination of the Lake. In 1930, construction of sewage plants and intercepting sewers became necessary to adequately treat wastewater from a growing population.

At that time, it became evident that the Upper Illinois River System, which acts as a number of interconnected lagoons, could not take combined sewage and storm overflows without severe upset. Permitted diversion of lake water was drastically reduced from 1935-1940 by decree of the U.S. Supreme Court. This required concurrent improvements in treatment methods of District plants.

Presently, the District is charged with responsibility to adhere to stricter water quality standards and plan for the possibility of still less lake water diversion for effluent dilution. These standards, adopted by the State of Illinois and approved by the federal government, require that canals and waterways be upgraded to where they can be used for water supply and recreation by a population approaching six million and an industrial equivalent of four million covering over 850 square miles.

Physical Site and Operation of the West Southwest Sewage Treatment Works: The site of the project is the MSDGC's West Southwest Sewage Treatment Works. The plant is located just west of the City of Chicago, in Stickney, Illinois. It consists of a West Side facility utilizing Imhoff treatment of sewage sludge, placed in operation in 1930, and a Southwest facility, operating since 1939 with activated sludge processing. The following page is a map of the plant layout, showing locations of project work;

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Project Equipment and Installation: Two 35,000 lb/hr low pressure steam generators were installed, along with 3000 feet of 12-inch pipe for digester gas. Auxiliary items consist of two digester gas booster pumps and controls, a building to house the booster pumps and various valves, fittings, and accessories to make the steam generators compatible with treatment plant process flows and ensure reliable service.

The Grantee (MSDGC) undertook this work and committed its own funds without a general election. Preparation of the WSW STW installation site was performed by MSDGC employees. Installation of the generators and other equipment proceeded with the aid of tradesmen hired under a subcontract. Professional personnel from the Districts M & O Department supervised the work.

Photographic slides of project equipment have been forwarded to the U.S. Department of Energy. See following page for a table of slide descriptions.

Project Operation: The basic principles of sewage treatment are well established and widely practiced. Although the WSW STW handles over a billion gallons of sewage per average day, making it the world's largest sewage treatment plant, the process is quite simple. Influent is screened to remove large debris, flows through preliminary settling tanks to separate most suspended and floating scum solids, passes through aeration tanks which assist bioligical decomposition of remaining impurities, and is allowed to settle again before chlorination and/or discharge to the waterway. Sludges collected during the process are mixed with scum and ground screenings, concentrated by gravity or mechanical means, and, in the case pertinent to the subject project, are fed to digestion tanks where the action of anaerobic bacteria generates heat and combustible gas, primarily methane. Digested sludge can be further concentrated and disposed of by application on strip mined land.

Gas generated during anaerobic digestion has averaged approximately 2.7 million standard cubic feet per day. Of this amount, 1.7 million SCF per day is used keeping the digesters heated to the proper temperature for the bacteria to thrive. The excess 1.0 million SCF per day is piped from the digesters and burned to supply power for low pressure steam generator.

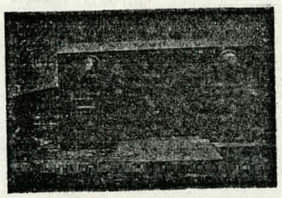
The booster (gas pump) system was put into operation on March 20, 1980 and has operated continiously from that date with the exception of down time for minor maintenance and alterations to the system. Booster No. 1 has been in operation for 1001 hours, whereas Booster No. 2 has logged 1273.4 hours as of June 25, 1980. For the month of April 1980, metering equipment indicates that 23,050,000 cubic feet of digester gas was pumped by the system. Readings indicate that 27,865,000 cubic feet was pumped in May, measured at an average pressure of 5.0 psig and 75° F. Volume pumped in June is currently not available, but estimated to approach the volume pumped in May. Therefore, for the 96 days the system has been in operation, total pumpage is within the range of 85 to 90 million cubic feet.

TABLE OF

PHOTOGRAPHIC SLIDES

Slide No.	Description
1	Booster building housing boosters 1 and 2
2	Boosters 1 and 2 and associated piping
3 & 4	Booster No. 1, Robicon motor controller and moisture removal equipment.
5	Booster No. 1, suction and discharge piping, and monitoring gauges.
6	Booster No. 1, silencer, and moisture removal equipment (aftercooler and separator)
7	Moisture removal equipment for Boosters Nos. 1 and 2, associated piping and valves.
8,9,10 & 11	Installation of the 12 inch diameter wrapped and cathodically protected underground line which conveys digester gas to steam generators
12,13 & 14	Boiler #1 breeching and exhaust stack.

Slide no. 1



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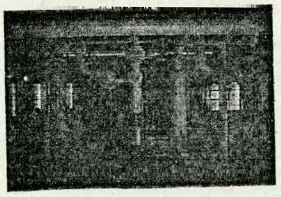

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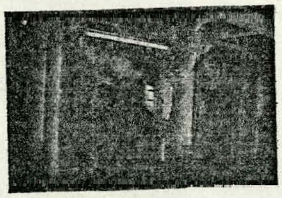

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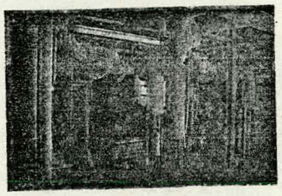

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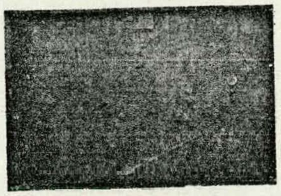

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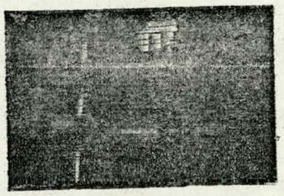

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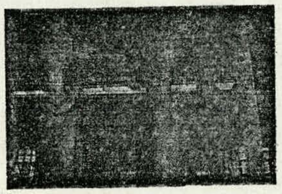

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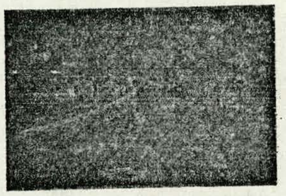

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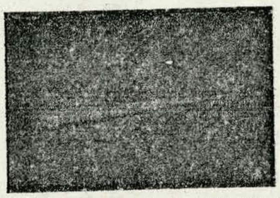

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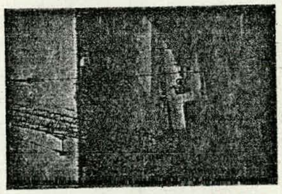

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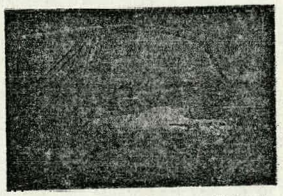

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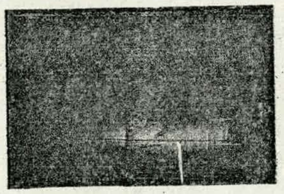

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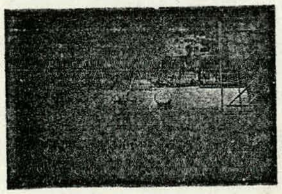

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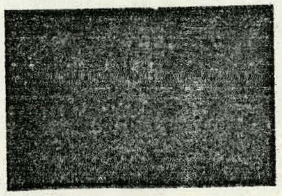

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Future Enhancement: Installation of a larger motor will double nominal gas pumping capacity. This will allow the handling of increased flows as the West Southwest Sewage Treatment Works treats more sewage from the Chicagoland area.

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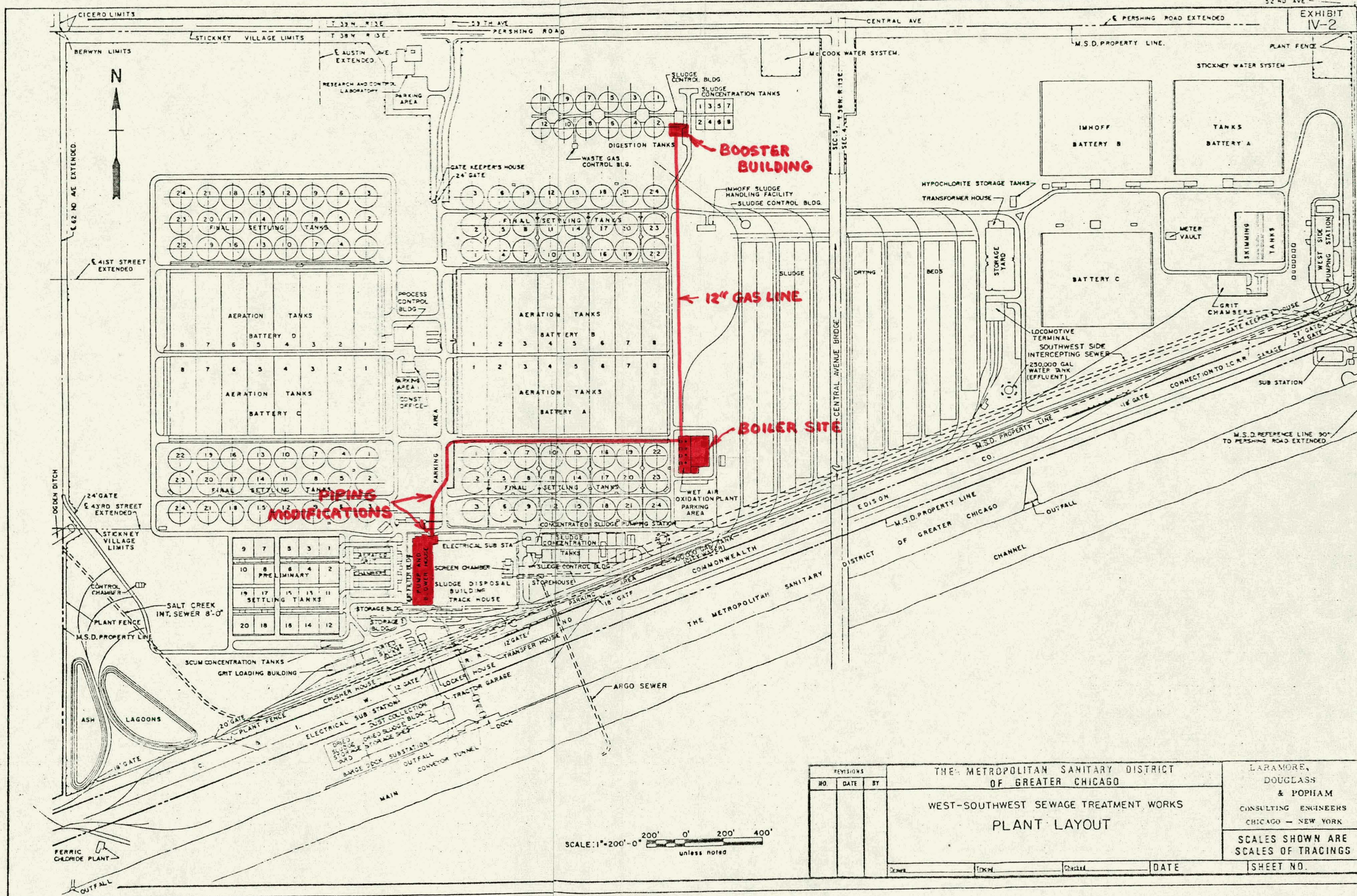


EXHIBIT IV-2
BOOSTER BUILDING
12" GAS LINE
BOILER SITE
PIPING MODIFICATIONS
PUMP AND BLOWER HOUSE
CICERO LIMITS
STICKNEY VILLAGE LIMITS
BERWYN LIMITS
PERSHING ROAD
CENTRAL AVE
PERSHING ROAD EXTENDED
M.S.D. PROPERTY LINE
PLANT FENCE
STICKNEY WATER SYSTEM
McCOOK WATER SYSTEM
AUSTIN AVE. EXTENDED
RESEARCH AND CONTROL LABORATORY
PARKING AREA
SLUDGE CONTROL BLDG
SLUDGE CONCENTRATION TANKS
DIGESTION TANKS
WASTE GAS CONTROL BLG.
GATE KEEPER'S HOUSE
24' GATE
IMHOFF SLUDGE HANDLING FACILITY
IMHOFF BATTERY B
TANKS BATTERY A
HYPOCHLORITE STORAGE TANKS
TRANSFORMER HOUSE
METER VAULT
SKIMMING TANKS
WEST SIDE PUMPING STATION
BATTERY C
GRIT CHAMBERS
STORAGE YARD
LOCOMOTIVE TERMINAL
SOUTHWEST SIDE INTERCEPTING SEWER
250,000 GAL WATER TANK (EFFLUENT)
SUB STATION
CONNECTION TO I.C. R.R.
M.S.D. REFERENCE LINE 90° TO PERSHING ROAD EXTENDED
62 ND AVE EXTENDED
41ST STREET EXTENDED
FINAL SETTLING TANKS
AERATION TANKS BATTERY D
AERATION TANKS BATTERY C
AERATION TANKS BATTERY B
AERATION TANKS BATTERY A
PROCESS CONTROL BLDG.
PARKING AREA
CONST. OFFICE
SLUDGE DRYING BEDS
CENTRAL AVENUE BRIDGE
WET AIR OXIDATION PLANT
CONCENTRATED SLUDGE PUMPING STATION
OGDEN DITCH
24' GATE
43RD STREET EXTENDED
STICKNEY VILLAGE LIMITS
PRELIMINARY SETTLING TANKS
ELECTRICAL SUB STA.
SCREEN CHAMBER
SLUDGE DISPOSAL BUILDING
TRACK HOUSE
SLUDGE CONCENTRATION TANKS
SLUDGE CONTROL BLDG
STOREHOUSE
STORAGE BLDG.
CONTROL CHAMBER
SALT CREEK INT. SEWER 8'-0"
PLANT FENCE
M.S.D. PROPERTY LINE
SCUM CONCENTRATION TANKS
GRIT LOADING BUILDING
CRUSHER HOUSE
ELECTRICAL SUB STATION
DUST COLLECTION
DRIED SLUDGE BLDG.
DRIED SLUDGE STORAGE SHED
BARGE DOCK SUBSTATION
OUTFALL
CONVEYOR TUNNEL
LOCKER HOUSE
TRACTOR GARAGE
TRANSFER HOUSE
DOCK
ARGO SEWER
ASH LAGOONS
FERRIC CHLORIDE PLANT
OUTFALL
COMMONWEALTH EDISON CO.
THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO
MAIN CHANNEL
SCALE: 1"=200'-0" unless noted
REVISIONS
NO. DATE BY
THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO
WEST-SOUTHWEST SEWAGE TREATMENT WORKS
PLANT LAYOUT
LARAMORE, DOUGLASS & POPHAM
CONSULTING ENGINEERS
CHICAGO — NEW YORK
SCALES SHOWN ARE SCALES OF TRACINGS
DATE
SHEET NO.

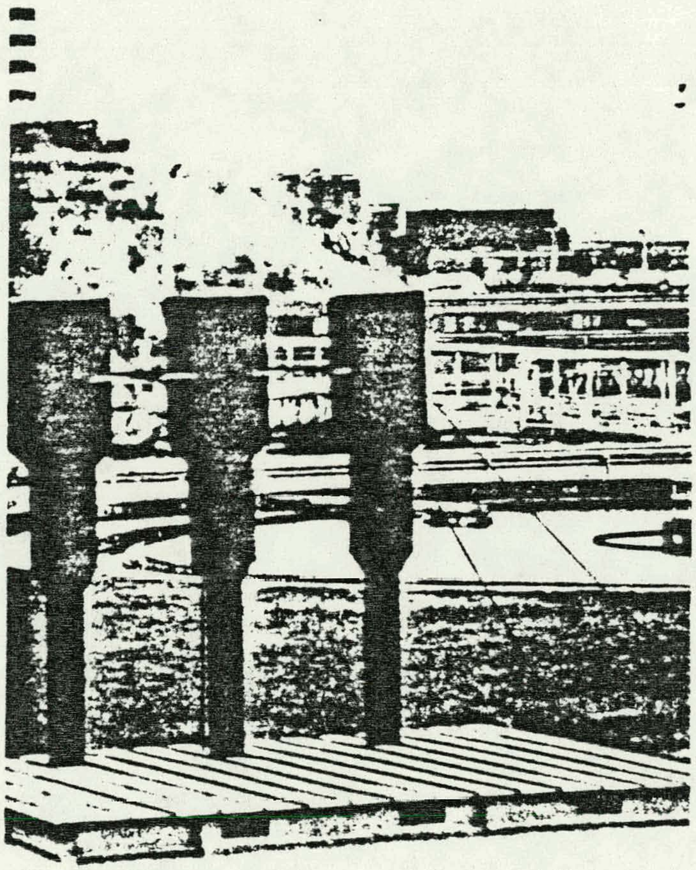
AMERICAN SOCIETY

OF CIVIL ENGINEERS

ANNUAL CONVENTION

DIGESTER GAS UTILIZATION PROGRAM

R.R.Rimkus J.M.Ryan A.Michuda



Atlanta, Ga. October 22-26, 1979

Al Michaud
5901 W. Pershing

DIGESTER GAS UTILIZATION PROGRAM

by

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INTRODUCTION

This paper will describe the preliminary studies and final design at the Chicago Metropolitan Sanitary District West-Southwest Sewage Treatment Works for a digester waste gas utilization program. The studies and design were done in-house by staff engineers.

The first four digesters at the West-Southwest were built and placed into service in 1964. At that time, the use of digester gas consisted only of that amount required to maintain Mesophilic conditions in the digesters and to provide heat for the digester building. The economics at that time indicated that the excess digester gas be flared off in waste gas burners. Two additional

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[2]Assistant Chief Engineer, West-Southwest Sewage Treatment Works, MSDGC

[3]Engineer of Treatment Plant Operations, West-Southwest Sewage Treatment Works, MSDGC

sets of four digesters each were subsequently built in 1969 and 1973 and again the waste gas was flared off.

Since 1974, with the Middle East oil embargo and the shortage of domestic energy, the cost of energy has skyrocketed and made the utilization of this waste gas not only economical but mandatory.

DESCRIPTION OF PLANT

The West-Southwest Works is a 1200 MGD activated sludge plant with an anaerobic digestion complex consisting of twelve 2.5 million gallon floating cover highrate digestion units. Each digestion unit is rated at 25 dry tons/day at a 3.3% solids feed. Sludge heating and mixing is accomplished by continually circulating the sludge through water tube heat exchangers. Hot water is supplied to the heat exchangers from digester gas fired fire-tube boilers. There are sixteen boilers for twelve digesters. Feed to the digesters is 100% waste activated sludge.

Sixty per cent of the main sewage pump capacity and 100% of the blower capacity is supplied by turbo-driven equipment. In addition, the Southwest Works has 3 turbo-generators capable of producing 20,000 KV. The large 10,000 KV generator is an extraction unit from which low pressure steam is extracted for plant heating and boiler feed water treatment. Approximately

80% of the plant's low pressure steam is obtained by extraction from the generator's turbo-drive. The remaining 20% is obtained from a pressure reducing station where 430 psig, 700°F steam is reduced to 18 psig and 200°F. The low pressure steam is distributed throughout the 600 acre complex through service tunnels and utility conduits. The Research and Development Laboratory which is located on the plant property uses low pressure steam winter and summer. Summer cooling of the laboratory is provided by two 150-ton absorption units that use approximately 10,000 lbs./hour of low pressure steam.

DIGESTER GAS PRODUCTION AND DOLLAR VALUE

The gas produced in each digester is metered and recorded by chart and totalizer, and the average total gas production is 2.7×10^6 ft.^{3} per day. Fig. 1 shows the gas produced on a monthly basis and the gas utilized to maintain the digesters at 95°F. The difference between the two is the digester gas wasted or the amount of gas available for further utilization. An average of 1.0×10^6 ft.^{3} per day of digester gas is available for additional utilization.

Digester gas is composed of approximately 65% methane, 30% carbon dioxide and 5% of varying amounts of nitrogen, hydrogen, carbon monoxide and oxygen. This gas is capable of supplying

DIGESTER GAS

PRODUCTION AND UTILIZATION FOR 1977.

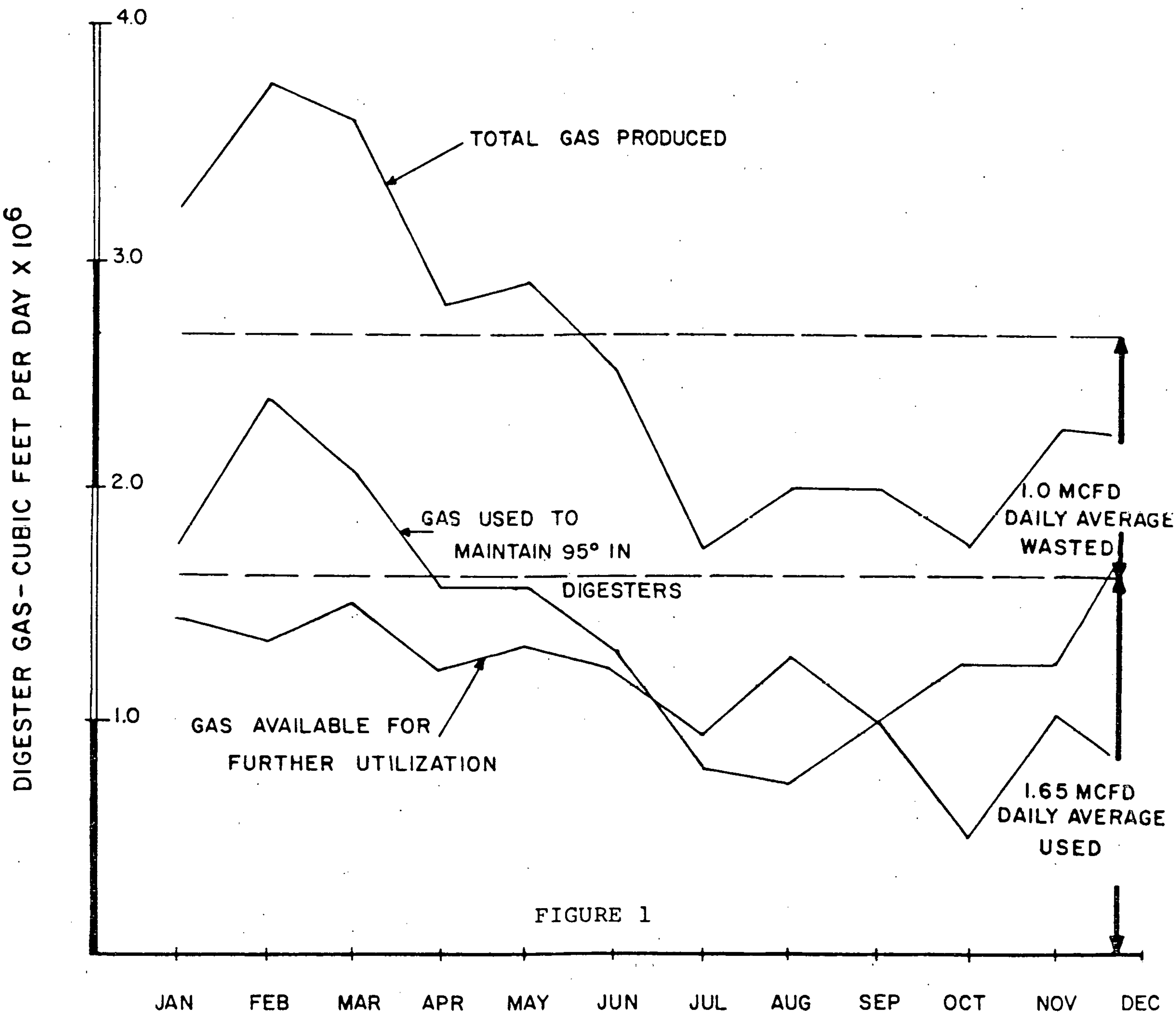


FIGURE 1

650 BTUs per standard cubic feet. Thus 1.0×10^6 $ft.^3$ per day of digester gas @650 BTU per standard cubic feet is the energy equivalent of 650×10^6 BTU/day and since 100,000 BTUs equals one therm, the amount of digester gas wasted or available for utilization is 6,500 therms per day. Since the major fuel source at the plant is natural gas, the digester gas will replace an equivalent amount of therms of natural gas. For the first six months of 1979, the average price of natural gas at the West-Southwest Plant was $0.24 per therm. The 6,500 therms of unutilized digester gas is worth (6,500 therms x $0.24/therm) $1,625.00 per day, or annually, this comes to $593,125.00.

METHOD OF UTILIZATION

Some of the methods of utilizing digester gas studied at the West-Southwest Plant were gas turbine-generators, internal combustion engines and water tube boilers.

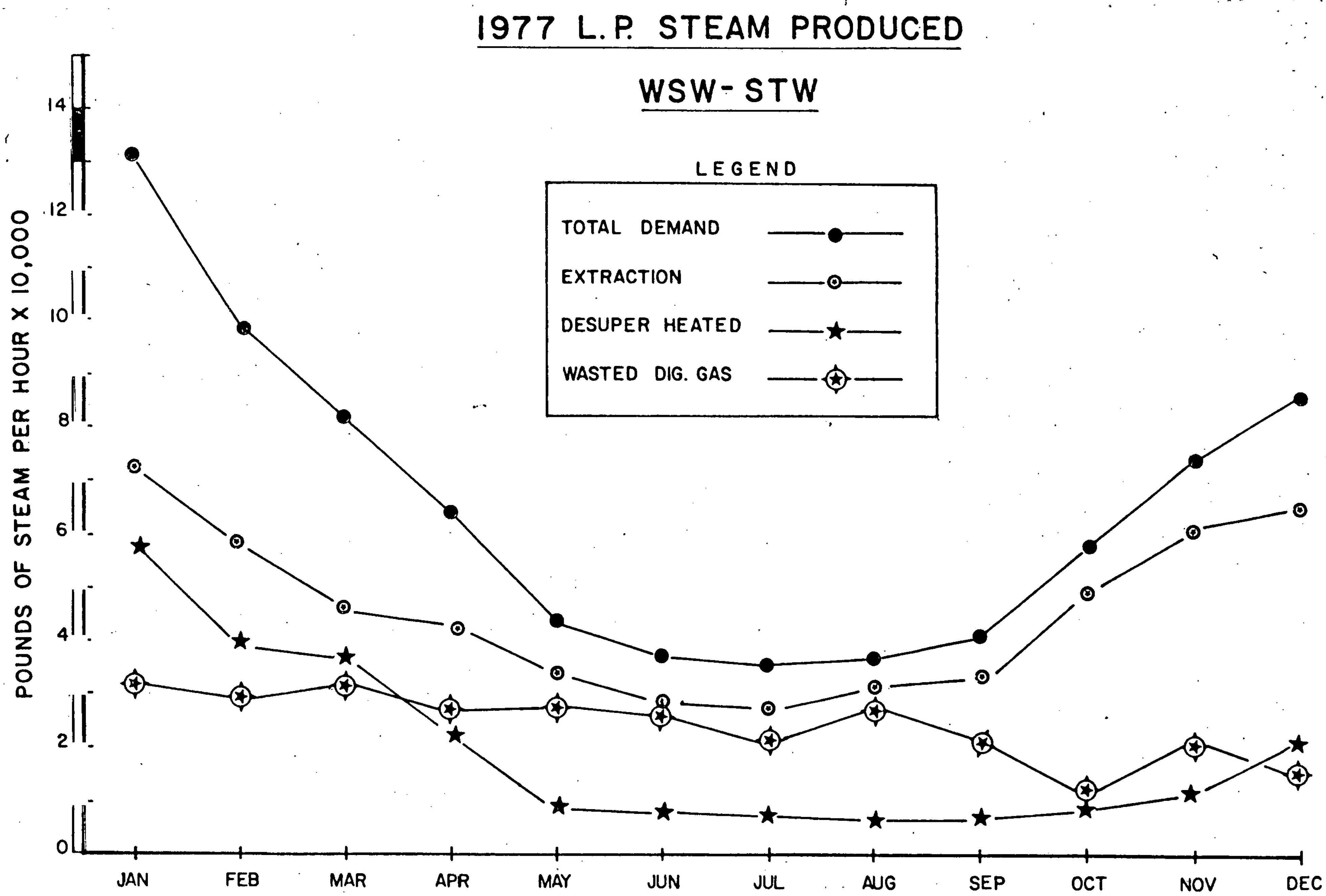
Gas turbine generating systems require a large capital investment. In our particular case, this meant $2,500,000 to $3,000,000. Also there was much concern about cleaning the digester gas which is a necessity for keeping the combustion chamber clean.

Internal combustion engines as observed in other plants had high noise levels and an abundant amount of supporting equipment such as lubrication, ignition, carburation and cooling systems. It appeared that there would be a problem using digester gas on an internal combustion engine since some plants had to redesign component parts of the engine to deal with the corrosive nature of the gas. Additionally, there was no convenient direct application to a pump or blower in the plant.

The third alternative, water tube boilers was studied and became our first choice for three reasons:

1. Low capital cost and quick return on investment. It was estimated that the cost of material and labor to complete the project would be $830,000.00. The cost of operation is estimated at $150,000.00 per year. It was calculated that the project cost would be amortized in less than three years.

2. Complete utilization of low pressure steam. The low pressure steam requirements and the source of steam were studied along with the amount of steam generated from the excess digester gas. Fig. 2 shows this study on an average monthly basis for one year. It can be seen that at no time does the amount of low pressure steam available from the excess digester gas exceed the demand for low pressure steam. The fact that the Research and Development Laboratory is cooled during the summer months by two 150-ton absorption units that use approximately 10,000 lbs./hr. of low pressure



1977 L.P. STEAM PRODUCED
WSW-STW
LEGEND
TOTAL DEMAND
EXTRACTION
DESUPER HEATED
WASTED DIG. GAS
POUNDS OF STEAM PER HOUR X 10,000
0
2
4
6
8
10
12
14
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

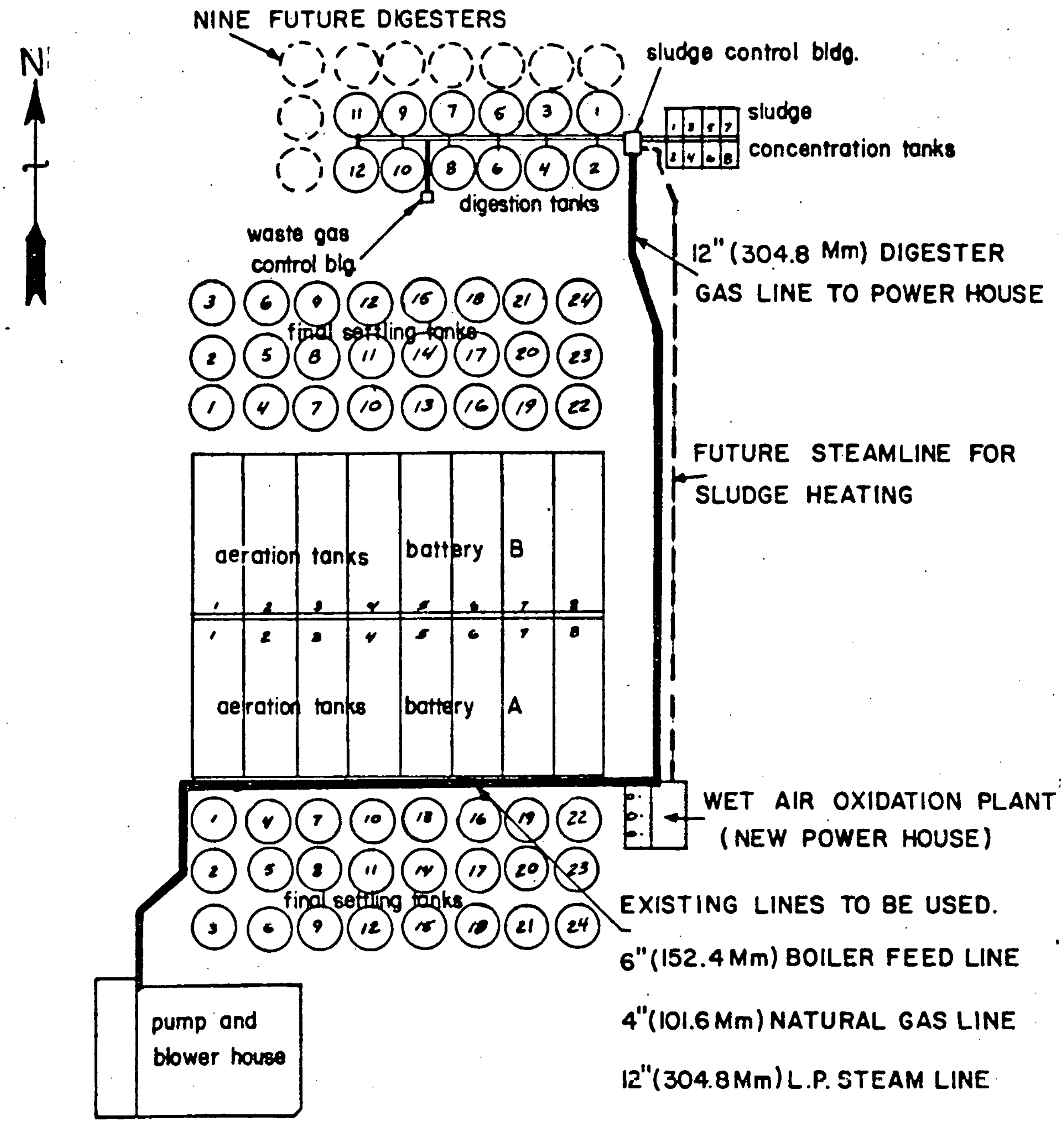
FIGURE 2

steam helps this situation come about. Since the demand for low pressure steam is present, a consistent boiler operation is expected.

3. By 1985, the plant expects to replace six turbo-pumps and seven turbo-blowers with electric drives. This equipment is being phased out along with seven high pressure steam generators due to their age and high cost of maintenance and operation. Coinciding with this program, the plant will be expanded by the addition of two aeration batteries and additional digesters. Elimination of the high pressure steam generators along with the plant expansion necessitates new steam generators located centrally.

Fig. 3 shows the chosen site for the new steam generating equipment. The existing building, completely equipped with utilities such as water, electricity, telephones, etc., formerly housed the wet air oxidation process for sludge processing. As the process was terminated several years ago, the building became available for the steam power house. The utilization of an existing building such as this allowed a considerable capital savings. For the minimal cost of removing some equipment, this building became the location for the digester gas utilization boilers.

Additionally, the sixteen hot water generators presently in use



UTILIZATION OF DIGESTER GAS

WSW PLANT PARTIAL LOCATION PLAN

FIGURE 3

at the digester complex will be phased out. They will be replaced by new high pressure steam boilers capable of being fired with digester gas which will also be located in the new steam generating building. The steam will be transported back to the digester complex where sludge heating will be accomplished by means of hot water converters.

PIPING CONSIDERATIONS

The distance between the digester complex and the steam boilers is 1800 feet. It was calculated and determined that a 12" coated steel pipe with sacrifical anode cathodic protection was necessary. The pipe was installed underground, below the frost level where possible, and sloped to permit moisture to flow to traps for release. The gas line was intentionally oversized because as previously mentioned, the plant expects to increase the digester facility by 50% and future planning call for the total gas production from the digesters to be utilized at the new steam generating plant.

As shown in Fig. 3, a 6" high pressure steam line, a 4" natural gas line and 12" low pressure steam line were already in existence between the Wet Air Oxidation Plant and the main building of the plant. Again, in order to keep the capital expenditure as low as possible, it was decided to use the 6" high pressure steam line to transport boiler feed water from the main to the new boilers. In order to do this, steam traps had to be removed from the steam line and connections to the boiler feed water at the main building had to be made. The boiler feed water in the main building is 600 psig and 210^{o}F. Since the new boilers are rated 260 psig, a reducing station for the feed water was installed in the main building. The boiler feed water treatment and feed system will be moved to the new steam generating building when the seven high pressure boilers are phased out.

The 4" natural gas line will provide an alternate fuel for the new boilers. The 12" low pressure steam line will be used to transport the generated steam back to the low pressure steam system in the main building.

BOILER SELECTION

Once it was decided to utilize the excess digester gas by producing steam, the next step was to determine the size and type of boiler best suited to our needs.

An average of 1.0 x 10^6 ft.^{3}/day of wasted digester gas at 650 BTU/ft.^{3} equals 650 x 10^6 BTU/day or 27.08 x 10^6 BTU/hour. The steam generator efficiency for this type of operation is 80% and, therefore, 27.08×10^6 BTU/hour x .80 = 21.67×10^6 BTU/hour which are available for actual steam production. The heat required to raise the feed water temperature 210°F to saturated steam at 100 psig is found in the steam tables to be 977 BTU/hour/lb. Then 21.67×10^6 BTU ÷ 977 BTU/hour/lb. = 22,200 lbs./hr. of steam would be the average output of the boiler required to burn all the excess digester gas. The maximum and minimum loads were calculated to 32,000 lbs./hr. and 10,000 lbs./hr., respectively. From this it was decided to use two 35,000 lbs./hr. steam generators. Two units were chosen to provide the plant with a back-up unit to be used during repairs and because there is a plan to increase the digester complex by 50%. The two units finally selected were manufactured by Cleaver Brooks. They are rated at 35,000 lbs./hr., 100 psig operating pressure and are the water tube type. In addition to being a packaged unit (for easy installation) their burners are designed to burn digester gas.

MOTOR CONTROL AND COMPRESSOR SELECTION

There is a varying amount of excess digester gas produced that is now being flared off. It has been determined that the daily range of gas flow is from 250 to 700 cfm. However, in the near future, the digester complex is to be expanded by 50% and since methods are being studied to produce more gas, it was decided to obtain a compressor with a capacity range of 250 to 1400 cfm. Two compressors were ordered so that one could remain on stand-by. The gas conditions which the compressors must handle are:

Inlet conditions

Specific gravity of gas:	.86 to .89
Temperature :	95°F
Pressure :	4.75" to 5.75" water column
Relative humidity :	100%

Discharge conditions

Pressure :	7 to 12 psi
Temperature :	250°F maximum

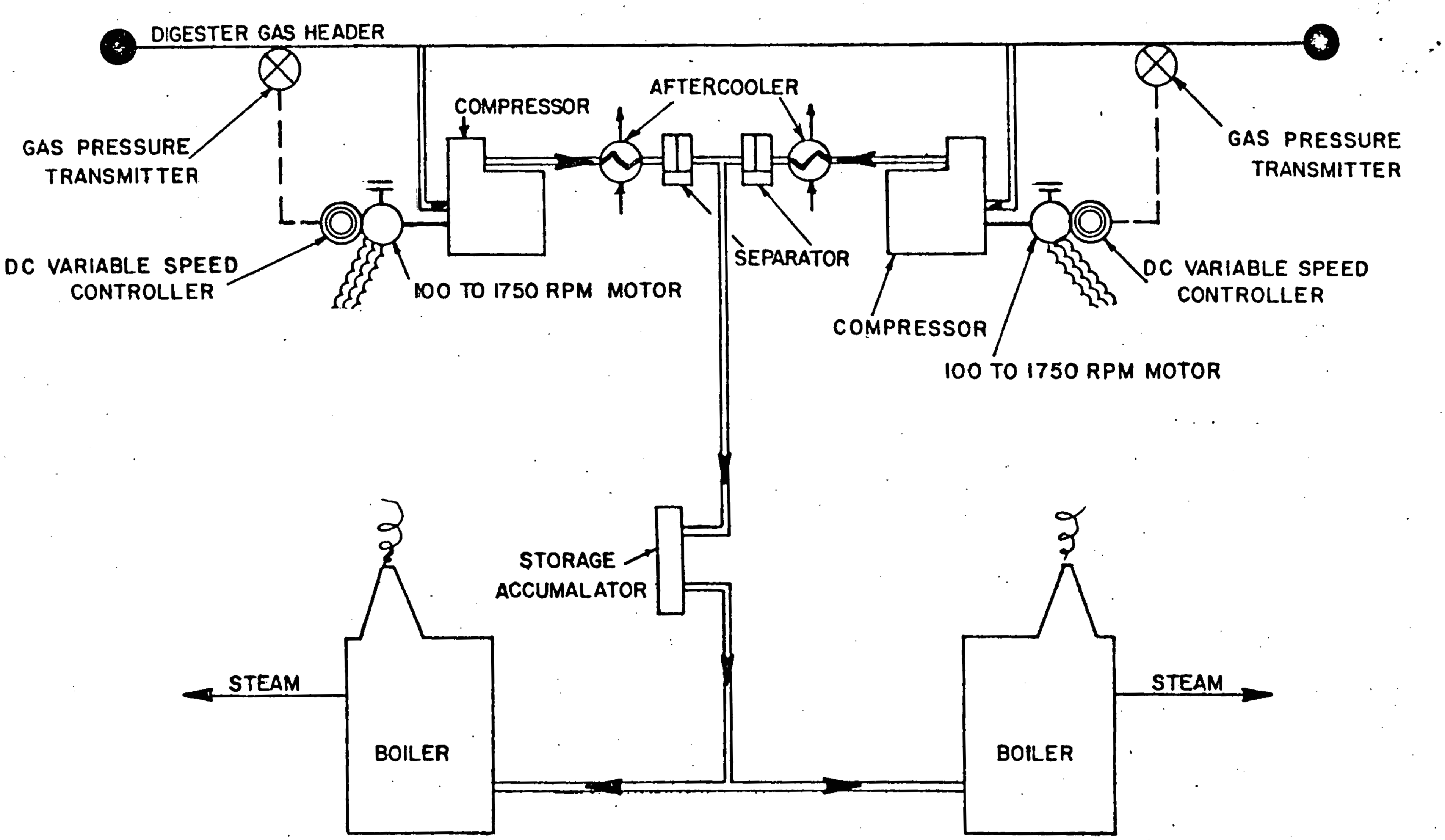
Given these conditions, the compressors selected for this system are positive displacement, lobe type with ductile iron impellers that operate without rubbing and without liquid seals or lubrication. A double seal arrangement around the shafts prevents inward air leakage and outward gas leakage. The compressor suction is connected directly to the digester gas header as it is expected that no cleaning of the gas is necessary. After compression, the gas passes through a cooler to remove as much moisture as possible.

Since the only storage capacity for the gas is in the interconnecting piping and a pressure vessel (2000 $ft.^3$) on the site of the boilers, the gas must be removed and utilized at almost the same rate that it is produced. This means that the compressors must be driven by an adjustable speed, direct current motor.

A schematic of the overall system and the associated pressure control system designed to control this system is shown in Fig. 4. Two gas pressure transmitters are installed in the gas header, one for each compressor. The transmitter puts out electrical signals (4 to 20 milli-amps) to the D.C. variable speed controller which regulates the speed of the motor in a manner that maintains the pressure in the digester gas header at 5.25" water column plus or minus 0.5".

At the steam generating end, the gas at line pressure is stored in the 2000 $ft.^3$ vessel which will function as a buffer for the system. Due to the variable rate of gas production, it was felt that this vessel would dampen the fluctuations in fuel supply to the boilers, thereby having a more uniform steam output from the boilers.

Incorporated into the controls is an alarm system designed to provide safety to the operation. The alarms, visual and audio, monitor such things as low gas header and compressor suction pressure, high discharge pressure and temperature and the presence of methane gas in the area. In these situations, the compressors are automatically shut down.



SCHEMATIC DIGESTER GAS UTILIZATION

FIGURE 4

SUMMARY

The cost of energy has increased greatly during the past few years. This, in turn, has increased the value of digester gas to the point where maximum utilization is mandatory. A million cubic feet of digester gas is worth $593,125.00 in an equivalent amount of therms of natural gas costing $0.24 per therm. A comparison to the price of oil would further increase the value of digester gas.

There are many methods and systems that can be employed to utilize digester gas. Several important considerations that should be taken into account in determining a system are capital expenditure, return on investment, compatibility with existing systems and maximum utilization of digester gas. These were the considerations that determined the West-Southwest Plant would use digester gas fired water tube boilers to fully utilize digester gas.