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The Energy-Exchange Project

April 1982

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Prepared for:
U.S. Department of Energy
Assistant Secretary, Conservation and Renewable Energy
Federal and Community Programs Division
Under Contract No. DE-AC01-78CS20468

MASTER

The New York City, 26th Ward Water Pollution Control Plant
and the Starrett City Total Energy Plant

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Preface

This volume, a companion to volume I, is intended for the technically oriented reader and plant operator who is interested in the investigative procedures used to support the conclusions described in volume I. Its scope, however, goes beyond the findings expressed in the proposed energy exchange strategies: it addresses those tasks of the statement of work dedicated to data acquisition, analysis and energy conservation strategies internal to the Starrett City Total Energy Plant and the community it supplies as well as to the 26th Ward Water Pollution Control Plant; it presents methods applicable to the future design and operation of cogeneration and wastewater treatment plants; it will provide assistance to the cogeneration plant operator in the preparation of a data acquisition format and its interpretation, and in the exploration of plant systems and equipment flexibilities and their limits. It will assist the wastewater treatment plant manager to find markets for the plants' byproducts.

Further, the technical development report compares actual measured seasonal energy consumption patterns of the Starrett City housing development as supplied from its Total Energy Plant with a computer simulation program output. The computer program models building energy consumption independent of energy source. The difference between the observed and modeled quantities is significant, the explanation for it exploratory and tentative.

The reader should realize that the Total Energy Plant has to be responsive to greater fluctuations than the wastewater treatment plant. The former is subject to hourly, diurnal and seasonal load changes caused by widely varying ambient temperature changes and distinctive energy consumption tendencies that depend on the individual lifestyle of the residents; the latter, which serves a mature community, is subject only to fluctuations due to rain or snow-falls and attendant variations in stormwater disposal. Also, the Starrett City Total Energy Plant which was brought on line in 1974 has supplied utilities to a growing tenancy which reached 93% apartment occupancy level only in 1979. It had, therefore, no history of a numerically stable community's systematized record accumulation. The 26th Ward Wastewater Treatment Plant, on the other hand, had available many years of historical records. This accounted for the much greater need to monitor, record, aggregate, and analyze data at the cogeneration plant than at the Wastewater Treatment Plant which had done this as a routine matter for a long period of time.

Finally, a word about the organization of the technical report. Conclusions, recommendations and hypotheses involving exchange options shared by both plants are treated as common subjects and are so described in Chapters 1 and 3A. The methodology for reaching these conclusions are recommendations as well as energy conservation options and planning considerations peculiar to each facility are treated separately for each one in chapters 3B through 3D. This is intended to facilitate topic selection for those who are involved in wastewater treatment plant technology and those whose interest is in the total energy plant/community utilities supply area.

It is hoped that this report presents a contribution to the state-of-the art of communities' energy planning and conservation.

William Diskant, PE
Technical Director

June 1981

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List of Abbreviations

amp	- amperes	mg/l	- milligrams per liter
avg	- average	mo	- month
bhp	- brake horsepower	MMBh,	- millions of Btus per
BOE	- Barrels of oil equivalent	MMBtuh	hour
Btu	- British thermal units	mw	- megawatts
°C	- degrees Centigrade	No.	- number
cfm	- cubic feet per minute	NYC	- New York City
cp	- coefficient of performance	NYC DEP	- New York City Department of Environmental Protection
cu	- cubic	O.R.	- overflow rate
DFE	- Dual Fuel Engine	PASNY	- Power Authority of the State of New York
DOE	- Department of Energy	PC	- Professional Corporation
D.T.	- detention time	ph	- phase
DTW	- Dual Temperature Water	PI	- pressure indicator
elect	- electric, electrical	pph	- pounds per hour
°F	- degrees Fahrenheit	psig	- pounds per square inch, gage
FE	- flow element	rpm	- revolutions per minute
ft	- foot, feet	scfh	- standard cubic feet per hour
gal	- gallon, gallons	scfm	- standard cubic feet per minute
gpd	- gallons per day	SWD	- side water depth
gpm	- gallons per minute	Δt	- temperature difference
GSF	- gross square feet	TDH	- total dynamic head
HE	- heat exchanger	TEP	- Total Energy Plant
hp	- horsepower	TG	- turbine generator
hr	- hours	TI	- temperature indicator
HTW	- high temperature water	TOD	- time of day
HV	- heating and ventilating	tpd	- tons per day
Hz	- Hertz	tpw	- tons per weeks
kv	- kilovolts	Whp	- Water horsepower
kva	- kilovolt amperes	WHRB	- waste heat recovery boiler
kw	- kilowatts	WPCP	- Water Pollution Control Plant
kwh	- kilowatt-hours	W.R.	- wound rotor
lb; #	- pounds	yr	- year
max	- maximum		
MBh,	- thousands of Btu per		
MBtuh	hour		
MBtu	- thousands of Btu's		
MCU	- modular combustion unit		
mgd	- millions of gallons per day		

Chapter 1

Conclusions and Recommendations

The terms energy conservation, resource recovery, and alternative fuels, are commonly used today among environmental engineers. Energy sources are often described as fossil or solar, as derived from biomass, or with reference to any one of several conversion technologies. This project, the Starrett/New York City Energy Exchange Project, does not focus on a specific technology but on an approach to energy conservation. Its purpose was to determine what energy savings can be achieved by coordinating the resources and requirements of two facilities which are currently operated independently of one another.

The study area is located in New York City, Borough of Brooklyn, on the shore of Jamaica Bay. One facility is the 26th Ward Water Pollution Control Plant (WPCP) which is owned and operated by the New York City Department of Environmental Protection (NYC DEP). Across the street from the 26th Ward WPCP is a housing development named Starrett City. A Total Energy Plant (TEP) provides Starrett City with all its electricity, hot water, heating and air conditioning. Both of these plants consume energy in providing necessary services to the public, and both emit certain products or waste streams as a result of their processes.

The organization of the project involved a partnership between Starrett City and NYC DEP. Hazen and Sawyer, P.C. was retained as a consultant for the study of the 26th Ward, and American Hydrotherm Corporation for the study of the TEP/Starrett City Complex.

The overriding objective of the project was to demonstrate that the use of fossil fuels can be reduced by using currently wasted energy resources in an environmentally and economically acceptable manner. In order to produce a thorough description of how wasted energy

resources could be used, the specific objectives included both technical and non-technical areas.

The technical objectives were straightforward: establish a data base at both plants to thoroughly understand the energy use and availability at each, and develop exchange options which could conceivably lead to energy savings. Early in the project, as many as seven forms of energy exchange were hypothesized. By energy exchange is meant the transfer of any resource—gas, liquid, or electrical power—which has an inherent Btu value. Engineering analysis, design, and cost evaluation would determine which exchange options should be implemented to attain optimum energy savings.

The non-technical objectives focused on developing an implementation plan for a project unique in its public/private sponsorship. The project, the first of its kind funded by the Department of Energy, Division of Buildings and Community Systems, had to identify legal and institutional restraints inherent in the utilization of publicly generated waste-derived energy by the private sector under a barter arrangement whereby the private sector “exchanged” its energy resource with the public facility. The economic and environmental factors which affected implementation were also analysed. The analyses and recommendations involved in the development of the project implementation plan can be used in evaluating other existing facilities and for planning new communities where energy exchange systems could be successfully constructed.

Three energy exchange options were determined to be feasible and cost-effective and are recommended for implementation: Digester Gas, Thermal Energy and Effluent Water.

Digester Gas—It was determined that transmitting all digester gas produced at 26th Ward, including

that generated from raw sludge pumped from the Jamaica WPCP, to the Starrett TEP, was more cost effective than utilizing a portion of the digester gas in the 26th Ward boilers. This conclusion obviously depended on the feasibility of obtaining substitute thermal energy from Starrett City, an option discussed below. Including Jamaica sludge, approximately 600,000 scfd of digester gas is available for transmission. This gas represents about 9% of the Starrett City Total Energy Plant fuel requirement.

The digester gas exchange is shown schematically in Figure 1. The facilities required for this transfer include new compressors, a 22.5' diameter spherical storage tank for damping flow variations, a six-inch diameter pipeline and a new burner train in two of the Starrett City Total Energy Plant boilers.

The entire gas production from 26th Ward will be used to supplement the natural gas or fuel oil supply. The quantity of natural gas or fuel oil will be automatically modulated to meet the boilers total fuel requirements.

Thermal Energy—It was determined that transmitting thermal energy from Starrett to 26th Ward was more cost-effective than either continuing to utilize digester gas in the 26th Ward boilers or purchasing fuel oil for the boilers. The primary reason for this cost-effectiveness is the efficiency and low incremental cost at which thermal energy can be produced by a co-generation facility such as the Starrett City Total Energy Plant.

The thermal exchange is shown schematically in Figure 3 along with the design parameters. Facilities required for the exchange include a steam/hot water heat exchanger, supply and return piping from Starrett City to 26th Ward and new circulating pumps. The 26th Ward boilers will be taken out of service but kept operational to serve as standby.

Effluent Water—It was determined that pumping treated effluent from 26th Ward to the Starrett TEP for cooling was less expensive than continuing to operate the Starrett City cooling tower. Not only is the large electrical demand of the

tower's fans eliminated but 77 million gallons per year potable makeup water would no longer be needed. This latter consideration is important not only economically but also because water transmission facilities in the Starrett City 26th Ward area frequently have low main pressure problems. The elimination of this demand is expected to improve the low pressure problems, as well as help to alleviate the impact of periodic droughts.

The effluent water exchange is shown schematically in Figure 2 along with design criteria. Physical facilities required are a pumping station with variable speed pumps to accommodate the great range of cooling water flows required, 36-inch diameter supply and return pipelines and new strainers. The Starrett City cooling tower will be taken out of service but kept operational for standby. The effluent will be drawn from the final tank effluent channel prior to chlorination and

reintroduced just downstream of the withdrawal point so that the entire plant flow will be disinfected as required. The higher effluent temperatures expected to result from this exchange are within the New York State Environmental Conservation Law standards for thermal discharges to receiving waters.

Energy conservation both at 26th Ward and at Starrett City was investigated during this study. It was

found that the easily accomplished, cost-effective conservation measures had already been implemented at 26th Ward as part of several, city-wide energy conservation programs. The only significant savings which remain to be realized would result from the cost-effective elimination of infiltration and inflow. A previous infiltration/inflow study estimated possible electrical energy savings of about 7% due primarily

to decreased raw sewage pumping and aeration requirements.

At Starrett City, significant reductions in the energy demands and improvements in operating efficiencies have already been accomplished or are proposed. For example, conservation measures include thermostatic controls for air conditioning fans in apartments and many reductions in lighting levels in areas where unnecessary lighting was originally designed and installed. Increased Total Energy Plant efficiency can be brought about by: 1) improving boiler efficiencies through mechanical and control modifications, 2) more efficient utilization of dual fuel engines in lieu of steam boilers to better match energy demands. Should all of the measures identified and recommended be implemented, the fuel requirements of the Total Energy Plant could be reduced by about one third. Starrett City also organized a tenant incentive program in the form of a conservation contest. The effort expended by Starrett City in its energy conservation programs has brought it the distinction of receiving the President's Award for Energy Efficiency, presented in January, 1981.

Two additional exchange options were considered but were determined to be not feasible at this time:

Transmitting electrical energy from Starrett to 26th Ward was not pursued for two reasons — cost and available generation capacity. The current Power Authority of the State of New York (PASNY) rates are lower than the incremental cost of generating power at Starrett. As long as the PASNY rates remain low and available to New York City's Department of Environmental Protection to operate their water pollution control plants, no other outside sources of electrical energy need be considered. Even if the incremental cost of generating electrical energy at Starrett should become competitive, there is no excess generating

FIGURE 3

Thermal Requirement:

Hot Water Temperatures:

Extraction Steam Proposed:

26th Ward WPCP

avg. — 4.2×10^6 BTU/hr.
 peak — 15×10^6 BTU/hr.
 supply — 215° F
 return — 185° F

TEP

avg. — 4,200 lbs. 130 psi
 peak — 15,000 lbs. 130 psi

capacity which could be devoted to 26th Ward needs. Seasonal and diurnal variations in demand at Starrett are reasonably regular and predictable, but the periods of low demand there do not match 26th Ward requirements, which depend to a very great extent on precipitation.

The digested sludge produced at 26th Ward represents a significant energy resource. This resource was the subject of a separate study which identified possible cost-effectiveness facilities for its development. This separate study is Appendix D of this report, published in a separate volume. Implementation of this resource development has been deferred because the facilities proposed were considered unproven and because New York City's plan for management of the sludge generated at all wastewater treatment plants is still being developed.

The total capital cost of the energy exchange project is estimated to be about \$5.7 million. Operating cost savings realized by implementing the project are predicted to be \$1.1 million in the first year of operation. The annual savings are expected to rise to about \$5 million by the year 2000. The estimated 1981 capital costs are shown in Table 1. The payback period for the facilities proposed for this project is approximately 4.5 years.

This energy study recommends three energy exchange options using conventional technologies for final design and construction. The recommended energy exchange system consists of:

- Digester gas produced from sludge of two NYC water pollution control plants, Jamaica and 26th Ward, to be transferred to the Starrett City Total Energy Plant.
- Hot water produced more efficiently at the TEP to be transferred to 26th Ward WPCP for space and process heating.

Table 1
STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

<u>CAPITAL COSTS</u>	
Installed capital costs - New York City property	(\$ Thousand)
Gas flow damper tank	55
Gas blowers	175
Gas transmission piping	44
Sludge pumps and piping	165
Sludge screens	110
Hot water circulation pumps	48
Hot water transmission piping	97
Effluent pump house	149
Effluent circulation pumps	605
Effluent valves	121
Effluent transmission piping	305
Electric cable for effluent pumps	102
Effluent tie-in piping and valves	60
Other	281
	2,317
Installed capital costs - Starrett City property	
Boiler modifications	571
Gas transmission piping	34
Heat exchanger	48
Hot water transmission piping	217
Control valve	48
Effluent strainer	97
Effluent transmission piping	240
Effluent tie-in piping and valves	110
Other	79
	1,444
Engineering, legal, and administrative expenses	664
Construction management	188
Contingency	375
Interest during construction	660
Total Investment	5,648

- Effluent from the 26th Ward WPCP to be transferred to the TEP to meet cooling needs now provided by an energy intensive cooling tower using NYC potable water.

The operation of the proposed system will achieve a projected energy savings equivalent to the use of 25,000 barrels of oil annually.

In the non-technical areas, the energy project has demonstrated:

- Energy exchange systems are economically feasible; with an initial investment of \$5.7 million, the expected pay back period is 4.5 years for this project.
- Federal, state, and local subsidies for Starrett City can be reduced as a direct result of reducing operating costs.

- A data base is available for evaluating other decentralized energy systems of existing facilities or new communities where energy exchanges might be successful.
- Energy exchange options can contribute to the reduction of dependence on foreign oil imports in an environmentally acceptable manner.
- The public and private sector can cooperate on projects of this kind which are mutually beneficial.
- Legal and institutional constraints can be reduced by addressing issues early in the project.
- Energy exchange systems will become more common with the growing awareness of their contributions to energy conservation.

Summary

Task Description	Estimated Saving In BOE/Year	Recommendation
Digester Gas Transfer from 26th Ward Water Pollution Control Plant (WPCP) to Starrett City Total Energy Plant (TEP) and Hot Water Transfer from TEP to WPCP	15,125	Implement
Effluent Transfer from WPCP to TEP	9,670	Implement
Supply Electricity from TEP to WPCP	—	Do not Implement. a) Not Cost Effective. b) Insufficient excess capacity at TEP
Supply Steam to TEP from Refuse/Sludge co-disposal facility	17,000	Do not Implement - absence of comparable operating experience.
Improved Boiler Efficiencies at TEP	30,696	Implement
Improved Operation of Variable Speed Pumps at TEP	1,700	Implement
Dual Fuel Engine Operation at TEP	15,643	Implement
Heat Pumps at TEP	2,802	Do not Implement Not Cost Effective
Heat Recovery from Lube Oil Coolers at TEP	—	Do not Implement Temperature levels too low
Hydro-Ejector in Starrett City Garages	—	Not Technically Feasible
Thermostatic SCR Controllers on Fan Coil Units	21,271	Implement
Additional Wall Insulation	24,086	Do not Implement Not Cost Effective
Direct Use of Solar Energy at Starrett City	645	Do not Implement Not Cost Effective

Summary

Task Description	Estimated Saving In BOE/Year	Recommendation
Equipping of Existing Refrigeration Units with Free Cooling at TEP	—	Not Technically Practical
Apartment Window Treatment at Starrett City	2,058	Do Not Implement Not Cost Effective
Energy Conservation Measures in Progress at Starrett City		
a. Disconnect high speed fan switch on fan coil units	2,075	Implement
b. Deactivate Lobby & Canopy Lights	900	Implement
c. Deactivate Garage Perimeter Lights	686	Implement
d. Deactivate Selected Hallway Lighting Fixtures	1,936	Implement
e. Install timers for Laundry Room Lighting	341	Implement
f. Deactivate Miscellaneous Motors, Lights & Heaters	37	Implement
g. Change Kitchen & Bathroom Lights from Incandescent to Fluorescent	11,292	Implement

Chapter 2 Background of Facilities

Part A Starrett City Background

The Site

Starrett City is a privately owned, federally and state subsidized middle income housing community located in the Borough of Brooklyn, City of New York. It ranks among the largest residential complexes in this city and overlooks, to its south, the busy Belt Parkway spanning the city circumferentially, and faces Jamaica Bay and Gateway National Park. When approached from this and on its broad Pennsylvania Avenue thoroughfare, its 153 acre site with its wide open lawns and tall, well maintained and attractive buildings, many of them having terraces, the complex and its ancillary facilities present an impressive sight, contrasted by its surrounding, essentially low rise apartment buildings. Its eastern boundary, separated by Van Siclen Avenue, borders the 26th Ward Water Pollution Control Plant, the synergetic source and partner for this energy exchange project.

A site plan is shown to orientate the reader.

What distinguishes this complex from many others is not only its size but also its complete independence and self sufficiency from the local public utility. Its essential utilities, power, heat, domestic hot water, and air conditioning are supplied from a single, central, total energy or cogeneration plant. This kind of plant, widely found in residential housing in West European countries, Japan, and, on a vast scale, in the U.S.S.R. and its behind-the-Iron-Curtain located satellites, delivers these total services at a much higher average combined annual thermal efficiency than if each one of them was delivered separately.

The Residential Complex

The Starrett City development contains 5,881 dwelling units which

house approximately 20,000 people. Its construction was completed in 1974 and it became fully occupied in 1979. Its apartments are distributed among forty-six buildings having a gross area of 7,500,000 sq. ft. and net rentable space of approximately 6,375,000 sq. ft. There are fifteen, twenty-story buildings, twenty, seventeen and eleven, eleven story structures. The apartment mix consists of 13 studio apartments, 2,293 one-bedroom, 1,994 two bedroom, and 1,581 three-bedroom units. There are 8 apartments set aside for managerial and custodial staff.

Ancillary Facilities

Community Center

A club and community center having 90,000 sq. ft. of floor area provides a place for community meetings, lectures, sports and multiple cultural and leisure activities. It contains a large gymnasium, game rooms, meeting rooms, two auditoriums (each accommodating 500 people), kitchens, a gleaming Olympic size swimming pool, a children's pool, a swim club, and, above all, an open, airy, country-club like atmosphere. An alert security staff and a well appointed glass walled lobby overlooking the pool with a manned reception desk and information center conveys a feeling of physical comfort and well being.

Adjacent to the community center is a tennis bubble containing four indoor tennis courts, with six outdoor tennis courts next to the bubble.

Schools

A 141,000 square foot public school was constructed by the City of New York on land transferred to it by Starrett City. This school is served by its own heating system, and electric power for it is supplied by the local utility company.

A 40,000 square foot intermediate school for 750 pupils is located on

the street floor of two garage structures in spaces leased by the housing company to The Board of Education.

In addition, a 16,000 square foot nursery school and summer camp with facilities for 400 children is located within the development.

Shopping Center

The shopping center has a floor area of approximately 110,000 square feet, and offers a variety of retail shops, essential service stores, restaurants, banking facilities and a sizable parking lot for ease of accessibility.

Health Services

The shopping center houses a 20,000 square foot medical facility. It provides a full range of private doctors and dentists and is affiliated with a nearby medical and surgical hospital.

Garages

There are eight, four story high separate garage buildings accommodating approximately 4,000 automobiles and having a total floor area of about 520,000 sq. ft. of which close to 300,000 sq. ft. are fully enclosed. Some of the latter areas house administrative spaces, property managers' offices, storage rooms, maintenance and repair shops, supply rooms and locker rooms. Partial basements are given over to mechanical equipment rooms which serve the primary/secondary district heating and cooling pumping system, and accommodate the motor control and cable vaults, transformer rooms and fire pump.

The Total Energy Plant (Cogeneration Plant)

The complex described in the previous sections receives its life line of essential utilities from the total energy plant, located in a self con-

tained building with an adjacent plot to the northeast on which stands the three cell cooling tower and the main, 400,000 gallon No. 6 fuel oil tank. A refuse collection and maintenance equipment yard to its East has, in a designated area, four 20,000 and one 10,000 gallon No. 2 fuel oil tanks set on concrete pads buried below ground.

The distinguishing feature of this 18 mw capacity plant is that it has both automatic extraction type turbines and dual fuel Diesel engines with heat recovery mufflers as prime movers, thus providing an operational flexibility not too often encountered in such facilities. There are, in New York City, several similar plants serving large residential complexes which were developed under the auspices of a single pioneering developer, Mr. Abraham E. Kazan of United Housing Foundation.

The main operating floor of the plant, some 30,000 sq. ft. of area, houses the prime steam generating and power generating equipment, as well as the chilled water producing refrigeration machines. In its center is the soundproof control room with four prominent instrument panels and a data acquisition and monitoring system which is primarily security oriented.

The steam power boiler bay, an area of 4800 sq. ft. and approximately 55 ft. high, contains four Combustion Engineering, Inc., natural gas or No. 6 fuel oil fired power boilers, each having the capability to generate 110,000 pounds of superheated steam at 875 psig and 825 °F. They provide the power for the principal prime movers, two 6 mw automatic extraction, condensing type General Electric Company turbine-generators which, due to their operational reliability and thermally advantageous cogenerative features, are the key power and heat producers of

the facility. The turbine steam extraction pressure is set at 130 psig. The reason for this relatively high pressure was the designer's intent to drive the three 2500 ton York refrigeration compressors with condensing steam turbines, to furnish steam to the steam ejectors for the turbine condensers, and to satisfy the generation of hot water for space heating purposes and domestic hot water for year-round use. The latter two loads, though, could have been accommodated at considerably lower steam pressures.

The main operating floor, then, contains, in addition to the above-mentioned equipment, three Nordberg dual-fuel Diesel engine driven generators equipped with waste heat recovery units, each having a capacity of 2 mw. Though originally intended to serve principally as standby equipment, these units, in our era of escalating energy costs and because of their high thermal efficiencies, are now operated during the spring and fall seasons when neither space heating nor air conditioning is required. The 130 psig steam generated in the waste heat boilers, though amounting only to about 8500 pounds per hour, is fed into the main 130 psig steam header to aid in the production of domestic hot water, if needed.

The high pressure boilers feed into an 875 psi steam supply header, and two pressure reducing/desuperheating stations from this header decrease the boiler pressure to 130 psig. The reducing stations' purpose is to furnish supplemental steam for space heating or emergency use in the event the steam extracted from the turbines fails to meet the heating demand or there is a turbo-generator failure. It is interesting to note that so far these pressure reducing stations have not been used, and that all steam demands have been satisfied entirely by turbine extracted steam.

The auxiliary equipment to the prime movers is also located on the main operating floor, notably the turbine condensers which, due to the soil conditions - the plant is built entirely on fill - are placed adjacent to, rather than below, the turbines.

The 4160 volt, 23 unit main 5 KV switchboard receives its power from the turbine and Diesel generators, transfers part of it via two feeders to the 480 volt TEP substation while 10 feeders furnish power to the complex. The 480 volt substation feeds 10 motor control centers which serve the auxiliary or parasitic plant equipment. The switchboard and substation together, about 100 feet long, stand behind the main turbo-generators.

A pump bay houses three Ingersoll Rand Company dual temperature circulating water pumps with variable speed drives, each capable of handling 6850 gpm of either hot or chilled water. These pumps feed into an underground distribution pipe grid and supply the space heating and cooling needs of the complex; also three high temperature water pumps of 1000 gpm capacity each, with variable speed drives which supply domestic hot water via an extensive below-ground circulating loop to the buildings.

The four power boilers receive feedwater from three (two operational, one standby) multistage boiler feed pumps (also Ingersoll-Rand Company) each capable of delivering 355 gpm against a pressure of 1030 psig, driven by 350 hp electric motors.

In addition, twelve condensate transfer pumps, condenser hotwell pumps, two air compressors, and a sizable chemical treatment, demineralizing and neutralizing tank section, make-up water storage tank and atmospheric condensate drain tank as well as a Diesel oil day tank with transfer equipment and a No. 6 fuel oil pump and preheater set

make up the principal equipment located on the main operating or first floor.

Offices, a gas meter room, a water metering area, a foam room for fire fighting purposes, a personnel locker room and lounge and a maintenance shop and storage complete the first floor. A twenty five ton capacity overhead crane at an elevation of 18 ft. moving on rails extending the entire length of the machinery bay, 244 ft., serves to maintain the heavy equipment.

A mezzanine floor contains two dual temperature water heat exchangers and two high temperature water heat exchangers. The former provide space heat to the entire complex and operate during the winter season only. They are each supplied with steam from the 130 psig extraction steam header via a control valve activated by a temperature control instrument which monitors the hot water supply temperature to the complex. The heated water then flows to the suction side of the dual temperature water pumps on the main operating floor which raise the water pressure sufficiently to pump the hot water to the buildings through a large recirculating underground distribution system. The dual temperature water pumps, being equipped with variable speed drives, can be adjusted to regulate the flow in accordance with outdoor temperatures, thus saving energy on warmer days by reducing the hot water flow, and meeting even the coldest winter day requirements by increasing the hot water flow.

Each of the steam-to-hot water dual temperature heat exchangers have a capacity of 67.5 million Btu per hr. and can raise the temperature of 3375 gallons of water per minute from 100° to 140°F.

The high temperature water heat exchangers provide the complex with domestic hot water through a separate loop and are arranged similar to the dual temperature

system circuit, equipped with their own high temperature, variable speed hot water pumps, and, of course, operate continuously throughout the year. Primary domestic hot water is distributed at 275 °F to mechanical equipment rooms located in the garages where a primary/secondary hot water converter-pump-control valve system supplies the individual buildings.

Also located on the mezzanine floor is a 60 ft. long by 18 ft. wide motor control center room whose multi-cubicles serve the boiler plant, refrigeration plant, turbo-generator plant, dual-fuel engine-generator plant and the miscellaneous equipment comprising the total energy facility.

A platform at 21 ft. elevation makes the forced draft fans and economizers for each boiler accessible. The large deaerator storage tank, dual temperature and high temperature water expansion tanks are supported off the top floor and columns of the building at 31 ft. height. At the highest point the plant roof is 54 ft. off ground or main floor level and the top of the four steel stacks, set directly on top of each boiler, reach a height of 99 ft.

Finally, a partial basement, 11 ft. deep, located below the turbo-generators and the switchgear, provides a separately walled-in cable vault, the turbo-generator drain tanks and the turbine condenser hotwell pumps.

Figure 4 is a simplified flow diagram of the Total Energy Plant. A detailed breakdown of its principal equipment is shown in Attachment 2.

Energy Supply and Distributions Systems

The TEP boilers' dual-fuel burners are designed to use natural gas, supplied on an interruptible

FIGURE 4

Starrett City TEP Major Equipment

basis from the local gas company, as the primary fuel for steam generation. Natural gas is also the prime fuel for the dual-fuel Diesel engines. No. 6 oil is used as a boiler standby fuel and No. 2 for Diesel engine standby.

Natural gas is also supplied by the local utility on a firm basis to the apartments for cooking and to the shopping center for space heating and domestic hot water production.

An extensive two-pipe dual temperature closed, recirculating underground pipe distribution system supplies hot water for space heating during the winter season and chilled water for air conditioning during the summer season. In the spring and fall seasons when neither space heating nor cooling is required the water temperature of the closed circuit distribution system's contents are adjusted for the following season. This is done by recirculating the water, at the end of the heating season, through the chillers to cool it

for air conditioning purposes to approximately 42°F. Similarly, at the end of the cooling season, the cool water is circulated through the dual temperature steam-to-water heat exchangers to raise its temperature to 140° to 150°F. The water contained in the system is thus used over and over again —recirculated— except for small losses at pump packings or glands, such losses being made up by treated make-up water being introduced into the system. The ultimate users of the hot/cold water carrier are the fan coil units located in each apartment.

The domestic hot water is also supplied from a separate recirculating two pipe underground system which, as previously mentioned, supplies hot water to the individual distribution centers located in the garages whence it is pumped to the final users.

Electrical power is supplied from the TEP's 5 KV switchboard via 10 sets of 4160 volt feeder cables to 56

apartment building, garage, community and shopping center substations. Two sets of cables supply each of 5 apartment building groups and their associated garages and community and shopping centers. Each substation, in turn, contains two switches, one 4160/480 volt transformer, and a number of 480 volt distribution switches furnishing power to building risers. The two switches enable the building load to be automatically transferred from one cable to the other in the event of a cable failure.

Annual energy consumption data at the Starrett City Complex are summarized below:

- 40,000 Btu per gross sq. ft. for heating
- 16,000 Btu per gross sq. ft. for cooling
- 18,000 Btu per gross sq. ft. for domestic hot water
- 29,350 Btu per gross sq. ft. for electrical power.

STARRETT CITY SITE PLAN

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Chapter 2

Part B

26th Ward Background

The 26th Ward Water Pollution Control Plant represents only a small portion of New York City's wastewater treatment facilities. At present there are twelve main plants and one supplementary plant in operation throughout the five boroughs. Two additional plants are projected for completion by 1987. The location of each plant is shown on Figure 5.

History Of The 26th Ward Project

The 26th Ward Water Pollution Control Plant is located on the north shore of Jamaica Bay about three miles west of John F. Kennedy International Airport. Wastewater treatment at this site dates back to a plant constructed in the 1890's to handle three million gallons per day (mgd) of sewage. The sewage was treated with lime, the resultant sludge with chlorine.

After extensive studies, the plant was converted to a fine screening operation in 1916. In 1949, an expansion program that had been interrupted by World War II was completed, providing secondary treatment for a design flow of 60 mgd from a population of 480,000. Treatment processes included screening, grit removal, preliminary settling and activated sludge. Sludge treatment included gravity thickening and digestion with provisions for disposal to drying beds, sludge vessels or landfill.

In 1970, Hazen and Sawyer Engineers completed the design for the expansion and upgrading of the original plant. Construction of the upgraded facilities was completed in 1975.

Collection System

The 26th Ward plant is served by a combined sewer system covering approximately 6,000 acres, all in the borough of Brooklyn. During times of storm runoff, flows in excess of the plant peak hydraulic capacity of

170 mgd are diverted at sewer system regulator chambers directly to Jamaica Bay, with the exception of storm overflows at the Autumn Avenue Regulator which are treated by sedimentation and chlorination at the Spring Creek Auxiliary Water Pollution Control Plant. Figure 6 is a schematic representation of the regulator and interceptor system.

Plant Facilities

The upgraded and expanded plant provides screening, preliminary settling, activated sludge treatment by step aeration, and chlorination. Figure 7 shows the plant layout. Sludge treatment includes gravity thickening followed by digestion and disposal of digested sudge at sea.

Influent to the plant is divided between high and low level sewers because of a 10 ft. elevation difference in the collection system. Flow enters two separate screen chambers with similar equipment. There are three screen channels in each level. Screenings are moved by means of belt conveyors to containers in the garage area for truck disposal to sanitary landfill. Sewage flows by gravity from the screen chambers to separate wet wells. Three vertical, main sewage pumps serve each wet well level. Sewage is pumped from the wet wells to the four preliminary settling tanks where suspended sewage solids are settled out, scraped to central hoppers and pumped to degritters. All tanks are provided with scum removal facilities. Scum and grit are removed in containers for disposal in a sanitary landfill.

The settled sewage flows by gravity to two aeration tanks where it is distributed and mixed in all four passes of each tank. Filtered air is supplied to the aeration tanks through porous diffuser tubes. Spray water is provided to suppress foaming.

Aeration tank effluent flows by gravity to seven final settling tanks where solids are settled, collected and wasted to the thickeners or returned to the aeration tanks. Scum removal facilities are provided on all final settling tanks.

Final tank effluent is chlorinated and detained in two identical chlorine contact tanks. Chlorinated effluent discharges into the Hendrix Street Canal through a 10' x 10' out-fall conduit.

Four gravity thickeners are available to receive sludge from the waste sludge well where solids from the settling and aeration tanks are collected. Four digesters have been provided to which thickened sludge is pumped. The digester overflow is piped to the influent conduit of the preliminary settling tanks.

The sludge flows by gravity from the digesters to two domed circular sludge storage tanks. Sludge is pumped from the storage tanks to vessels at the loading dock for ocean disposal. A more detailed summary of unit processes and parameters is found in Attachment 2.

Energy Consumption and Resources

The operation of the 26th Ward WPCP consumes energy in two forms. Electrical energy is required to power the great number of motors necessary for the hydraulic and process functioning of the plant as well as for auxiliary systems such as lighting, instrumentation and control. Thermal energy is required for space heating throughout the plant as well as heating sludge to maintain efficient digester operation.

Energy resources generated by the plant include digester gas, a by-product of sludge digestion and plant effluent. Plant effluent would not normally be considered a resource but because of the relatively large cooling requirements of the

Starrett TEP, its value becomes important in this project.

Electrical Energy Consumption—The entire electrical energy demand of the WPCP is met by purchasing power. Power is distributed through the Consolidated Edison network but the rates paid are the much lower ones of PASNY (Power Authority of the State of New York). The current rate schedule is shown in Table 2.* For the pattern of electrical power usage at 26th Ward, the combined consumption and demand charges average approximately 4½¢ per kwh.

Average and maximum daily power consumption as well as peak demands are presented in Figure 8.*

Because the 26th Ward WPCP treats flow from combined sanitary and storm sewers and because the main sewage pumps represent essentially the only large, variable electrical load, the peak electrical demands occur during heavy rain-falls and cannot be controlled or reduced except by by-passing combined sewage into Jamaica Bay.

The high voltage electrical power is transmitted to and throughout the plant. Power is supplied by Consolidated Edison and introduced into the main substation from three 26.4-4.33 kv transformers. Second contingency design is provided enabling the entire plant load to be maintained if any two Con Edison transformers fail, any two Con Edison 26.4 kv service feeders fail, or if any combination of a single feeder and Con Edison transformer fails.

A breakdown of the major motor loads of the various distribution centers is shown on Table 3.* Normal operating demand ranges and extremes for various distribution centers are shown on Table 4.*

Thermal Energy Consumption—The thermal energy requirements for space heating, hot water and digester heating are met with a hot water system utilizing

three boilers. The boilers are fired by digester gas when available and fuel oil when digester gas production is not adequate.

Maximum, minimum and average daily thermal demands for 1976 are plotted monthly on Figure 9.* These data are derived from plant records covering a period when fuel oil only was being used to fire the boilers. Confirming data was taken during special collections in June and August 1979, when digester gas alone was meeting the plant's thermal demand.

The heating system is a closed dual pipe forced hot water system designed to operate at 215 °F. supply and 185 °F. return temperature. A hot water circulating loop consisting of separate supply and return piping serves the Main Building. A branch loop leaves the Main Building via a system of underground piping conduits to serve all outlying buildings. Figure 10* is a schematic diagram of this hot water piping system.

The circulated hot water is a heat source for space heaters, radiators, cleaning hot water, and tempering ventilating air units.

Individual ventilating systems are designed to maintain the proper working atmosphere throughout the plant. Most process areas are continuously ventilated with tempered (heated) air to prevent fogging and hazardous conditions.

Hot water for the heating system is supplied by three horizontal firetube updraft package boilers rated at 11,716 MBh or 350 hp each. Under normal operating conditions two boilers can handle the peak heating load. Pumps, boilers, supply and return lines are all manifolded so that a single boiler or any combination thereof may be put onto the system. Boiler exhaust piping is also manifolded and connected to a single exhaust stack. The boilers may be fired either with digester gas or No. 4 fuel oil through combination gas and oil burners.

Digester gas is piped from the digesters to the gas compressor room in the Main Building where it is compressed to the required pressure by a system of three motor driven gas compressors.

Space heating is mainly provided by integrated heating and ventilating (HV) units. Fresh air is drawn through the HV units, filtered and tempered through hot water coils with thermostatic controls, distributed through a duct system, and discharged through registers. The HV units are supplemented by unit heaters, floor radiators, baseboard radiators, hot water coils and cabinet heaters.

The boiler hot water serves as the heat source for heating and maintaining temperature of the digester contents. To prevent contamination of the boiler hot water, hot water for the sludge heat exchangers is heated through a separate system of water-to-water heat exchangers.

Digester Gas Production—Sludge digestion is the process whereby the raw, putrescible sludge removed in the treatment of sewage, is decomposed by anaerobic bacteria to form a stable, non-objectionable sludge suitable for disposal. During the digestion process, the bacteria produce a gas consisting mostly of carbon dioxide and methane with considerable heating value.

At 26th Ward, four fixed-cover high rate digesters are provided. External sludge heating is provided by recycling a portion of the digester contents through the sludge heating loops. Thickened raw sludge, pumped into the heating loops, is mixed with the heated digester sludge which is fed to the digesters.

Continuous mixing is provided by the recirculation of compressed digester gas through the digesters. Two of the digesters have sufficient capacity to process the sludge currently generated at the 26th Ward plant. The remaining two digesters are not in service.

Digested sludge is pumped to sludge vessels for final disposal at sea near Ambrose Light, some eleven miles from Sandy Hook. Digested sludge from similar facilities at the Jamaica WPCP located near JFK International Airport is pumped to 26th Ward for loading onto the sludge vessels because water access is much easier at 26th Ward than at Jamaica.

During the winter months most of the gas produced is used as the primary fuel for building and process heat. At other times, when the entire gas production is not needed as fuel for the boilers, the excess gas is burned off in the waste gas burners. However, the waste gas burners have a capacity for wasting the entire peak hourly gas production in the event of complete breakdown of the gas utilization system.

In addition to direct gas consumption in the boilers, a portion of the digester gas production is continuously recirculated through the digesters for maintaining a uniform sludge mixture, which enhances gas production.

The present gas utilization facilities are depicted schematically on Figure 11.*

Maximum, minimum and average daily gas production from plant logs are plotted monthly in Figure 12.* Equivalent data for waste gas and boiler feed gas are plotted on Figure

13* for the year 1976. The gas wasted and used in the boilers shown on this figure are computed data based on fuel oil consumption, which was used as fuel exclusively in 1976. This computation was made necessary because the waste gas and boiler feed gas flow meters were inoperative until they were repaired for the data collections undertaken during this project.

It is also possible to recover most of the gas currently wasted at the Jamaica WPCP by pumping raw Jamaica sludge to 26th Ward for processing in the unused digesters. Although actual gas production data for Jamaica is not available, it is calculated that an average of 200,000 cubic feet per day is available.

Effluent Water—Plant effluent is currently being used at the 26th Ward WPCP as dilution water for hypochlorite feeding, for spray water (foam control) in the aeration and chlorine contact tanks, for ring flushing water in the main sewage pumps, and for maintaining a constant sludge thickener overflow rate. The maximum effluent water usage is currently less than 5,000 gpm.

Minimum plant flows in the order of 30,000 gpm at temperatures ranging from 41 °F to 77 °F are available for cooling or other purposes. Plant effluent flows and temperatures are shown on Figures 14* and 15,* respectively. Effluent grease concentrations and pH, data routinely collected at the WPCP are shown in Table 5* and Figure 16*, respectively. Effluent suspended solids concentrations and the results of other special analyses performed by NYC-DEP are presented in Table 6.*

Note: Figures 8 through 16 and Tables 2 through 6 are at the end of Chapter 3, Part C.

WATER POLLUTION

CONTROL PLANTS

- ① WARDS ISLAND
- ② NORTH RIVER
- ③ HUNTS POINT
- ④ NEWTOWN CREEK
- ⑤ 26TH WARD
- ⑥ CONEY ISLAND
- ⑦ RED HOOK
- ⑧ OWLS HEAD
- ⑨ TALLMANS ISLAND
- ⑩ JAMAICA
- ⑪ BOWERY BAY
- ⑫ ROCKAWAY
- ⑬ PORT RICHMOND
- ⑭ OAKWOOD BEACH

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 5

Diagram illustrating the Sewage Collection & General Lay for the Flatlands area, showing the flow of sewage from various sources into a central system.

Key components and flow paths include:

- Top Section:** FRESH CREEK flows into TIDE GATES, leading to a STORM OVERFLOW and a COMBINED TRUNK SEWER (252").
- Right Side:** The COMBINED TRUNK SEWER (252") runs vertically, passing MANHOLE "C" and receiving input from the FLATLANDS INTERCEPTOR.
- Central Section:** The sewer turns left, passing a SCREENING WING OF MAIN BLDG. (L.L. and H.L. tanks) and R-1 and R-2 structures. It then passes TIDE GATES and a STORM OVERFLOW before entering the HENDRIX ST. CANAL.
- Bottom Section:** The sewer continues down, receiving input from SANITARY SEWERS FROM FRESH CREEK MENTAL HYGIENE CENTER and VANDALIA AVE. INTERCEPTOR (60"). It then receives COMBINED TRUNK SEWER FROM QUEENS (156") and TREATED STORM OVERFLOW from SPRING CREEK AUXILIARY POLLUTION CONTROL PLANT.
- Bottom Right:** The system terminates at R-3 and R-4 structures, with COMBINED TRUNK SEWERS FROM BROOKLYN (174" and 126") joining the main line.

Legend:

- R-1
- R-2
- R-3
- L.L.
- H.L.

SEWAGE COLLECTION & GENERAL LAY

LEGEND

R-1 WILLIAMS AVE. REGULATOR (L.L.)

R-2 AUTUMN AVE. REGULATOR (L.L.)

R-3 HENDRIX ST. REGULATOR (H.L.)

L.L. LOW LEVEL SYSTEM

H.L. HIGH LEVEL SYSTEM

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 7

Chapter 3

Part A

Hypothesis of Exchange Options

General

In order to determine the adequacy of existing data and develop data collection programs to supplement that data, hypothetical energy exchange options were defined. Initially, these options were very general but became more specific as the existing data were reviewed and new data collected.

Digester Gas

Two basic digester gas exchange hypotheses were developed:

1) Transfer the gas being wasted at 26th Ward to Starrett City and continue to use as much as possible in the 26th Ward boilers.

2) Transfer all the gas produced at 26th Ward to Starrett City and provide the plant's thermal requirements either by purchasing alternate fuels for the boilers or by transfer of thermal energy from Starrett City.

Later in the project, the NYC-DEP suggested increasing the gas production at 26th Ward by pumping the raw sludge not required for digestion at the Jamaica WPCP to 26th Ward. This modification was applied to both previously mentioned options.

Data required to develop gas exchange options were determined to be hourly gas flow quantities as follows:

Gas produced in each 26th Ward digester

Gas utilized in the 26th Ward boilers

Gas produced at Jamaica

Gas utilized at Jamaica

In addition to these gas quantities, qualitative data were required to determine the suitability of the digester gas for burning in the TEP boilers. Also, quantities of supplementary fuel used at both pollution control plants had to be determined.

At the TEP diurnal patterns of fuel usage were required to evaluate

the potential savings using digester gas.

Thermal Energy

Only one thermal energy transfer hypothesis was defined: supplying the entire 26th Ward thermal energy requirement from Starrett City.

Data required to develop the thermal energy transfer option was determined to be the overall and sludge heating thermal demands of the 26th Ward plant on an hourly basis for summer, winter and intermediate seasons. The magnitude of the sludge heating load was required to determine the additional thermal requirements should Jamaica sludge be digested at 26th Ward.

Data for diurnal plots of throttle steam, turbine extraction steam and electrical load were required to evaluate the TEP's ability to meet the thermal load requirements of the 26th Ward.

Effluent

Again, only one effluent transfer hypothesis was defined which was pumping effluent through the Starrett City TEP condensers and heat exchangers on a once-through basis. The hypothesis of using WPCP effluent as cooling tower makeup was never given serious consideration because of obvious drawbacks including fouling the cooling tower, the generation of dangerous aerosols by the cooling tower and the fact that little or no electrical energy would be saved.

Data required to develop effluent transfer options were available flows and temperatures of 26th Ward treated effluent and the seasonal variation in TEP cooling requirements. Also qualitative data were required to determine compatibility with materials in the TEP heat exchange equipment.

Electrical Energy

Three basic electrical energy transfer hypotheses were defined, all involving the Starrett City TEP furnishing power to 26th Ward:

1) To meet all the 26th Ward electrical energy requirements.

2) To furnish service to selected portions of the 26th Ward plant.

3) To provide stand-by power to the WPCP in the event of a power failure.

Data required to develop electrical energy exchange options were determined to be hourly variations in the overall plant electrical usage and the usage at each of twelve

separate distribution centers including the blowers and main sewage pumps.

Data required at the TEP were the total kw generated on an hourly basis and which generators were on line.

Sludge/Solid Waste

Four alternatives were investigated for an energy-recovery system using Starrett City's refuse and 26th Ward WPCP's sludge:

1) Co-disposal of Starrett City's residential and commercial refuse with an equal amount, by weight, of pre-dried 26th Ward WPCP raw or

digested sludge producing high pressure steam for use in the TEP.

2) Identical to 1) but producing medium pressure steam for use the TEP.

3) Disposal of Starrett City's refuse only, producing medium pressure steam.

4) Disposal of Starrett City's refuse with an equal amount, by weight, of NYC solid waste, producing high pressure steam.

Data required to develop these options were available quantities and quality of refuse at Starrett City and sludge at 26th Ward WPCP.

Chapter 3

Part B

Hypothesis of Conservation Options

AT TEP

Conservation options hypothesized for the TEP all centered on recovering heat from the condenser water. These options would be valid whether or not effluent is used as the cooling medium.

Recovery of heat from the Dual Fuel Engine lube oil coolers and jacket water coolers was considered. These are closed loop systems which discharge their heat gain to condenser water in water to water heat exchangers. Instrumentation to evaluate this option was available. Jacket water and lube oil temperature readings were required. Flow rates, though not measured, were available from manufacturer's data and were considered to be sufficiently accurate to evaluate the option.

Another option considered was use of a heat pump to recover heat from condenser water and use it to supply part or all of the space heating and/or domestic hot water load. Instrumentation was in place to evaluate this option. Dual and High Temperature Water temperatures and flow rates were continuously recorded. This information was needed to determine the magnitude of the loads. Cooling Tower inlet and discharge water temperatures are also recorded continuously. Although there is no provision to monitor condenser flow we could keep data on the number of condenser pumps in operation and determine flow from manufacturer's data.

A third conservation option considered was incorporation of "Free Cooling" with the existing chillers. To evaluate this option chilled water supply and return temperatures and flow rates were required. In addition, condenser water supply temperature and flow were necessary. Instrumentation to measure or calculate these parameters was in place.

At Starrett City Buildings

All of the conservation options for the buildings were hypothesized at the start of the program. Equipment and material data were readily available from manufacturers and technical literature and it was deemed unnecessary to instrument any of the buildings for this study. As is common practice, the buildings have no instrumentation in place.

Many of the conservation options showed such significant energy savings for minimal dollar expenditure that they were immediately incorporated. These are listed under the subtitle of "Energy Conservation Measures in Progress."

The conservation options hypothesized were:

- a) Use of Hydro-ejectors to replace the secondary Dual Temperature Water Pumps in the garages.
- b) Incorporate thermostatic control in all fan coil units.
- c) Add wall insulation.
- d) Use solar energy to supply domestic hot water or space heating loads.
- e) Addition of storm windows or sun screens to existing windows.
- f) Removal of high speed fan position on all fan coil units.
- g) Conversion of kitchen and bathroom lights from incandescent to fluorescent.
- h) Reduction of garage lighting.
- i) Reduction of lobby lighting.
- j) Reduction of corridor lighting.
- k) Control of laundry room lighting with timers.

AT WPCP General

Because of the high and rising costs of all forms of energy, the obvious and easily achievable conservation measures had been implemented on a City-wide basis at all

water pollution control plants before the energy exchange project began. Most of these measures consisted of operating procedures designed to reduce the electrical demand charge.

Since by far the greatest energy demand at 26th Ward is represented by the blowers and main sewage pumps, our attention was directed to those sets of machines. Two additional conservation programs were hypothesized.

Reduction of Infiltration and Inflow

A significant amount of the plant influent which must be pumped and treated is infiltration or inflow. Infiltration is flow which leaks into the sewer from the surrounding soil during high groundwater periods. Inflow is flow which enters the sewer due to illegal connections or improperly constructed or operating facilities. No data collection was required for this option since the cost-

effective removal of infiltration inflow was the subject of a study issued in 1977 under which the necessary data was collected.

Automatic Control of Aeration

Theoretically it would be possible to reduce electrical energy required to operate the blowers by controlling their output to maintain a minimum dissolved oxygen content in the aeration tank effluent. Since the analysis of this option is theoretical, no data collection was required.

Chapter 3

Part C

he Analysis— Exchange Options

The relative treatment in the following sections emphasizes the operational and historical differences between the TEP and 26th Ward WPCP.

The reader should realize that the Total Energy Plant has to be responsive to greater fluctuations than the wastewater treatment plant. The former is subject to hourly, diurnal and seasonal load changes caused by widely varying ambient temperature changes and distinctive energy consumption tendencies that depend on the individual lifestyle of the residents; the latter, which serves as a mature community, is subject only to fluctuations due to rain or snow-falls and attendant variations in stormwater disposal. Also, the Starrett City total energy plant which was brought on line in 1974 has supplied utilities to a growing tenancy which reached 93% apartment occupancy level only in 1979. It had, therefore, no history of a numerically stable community's systematized record accumulation. The 26th Ward wastewater treatment plant, on the other hand, had available many years of historical records. This accounted for the much greater need to monitor, record, aggregate, and analyze data at the cogeneration plant than at the wastewater treatment plant which had done this as a matter of routine for a long period of time.

For The TEP

Data Collection

At the outset of the study it was known that the data collection effort would be a major task. The first step taken was to prepare a list of all the data that would be required to calculate an energy balance for the TEP under various modes of operation. Once the list of required data was completed it was easily seen which data were available from existing instrumentation and which data would require the installation

of new instrumentation or the use of manufacturers' data. The rationale for installing new instrumentation or using manufacturers' data is discussed below.

Prior to this program, TEP personnel recorded turbine data on a turbine log sheet and electrical power used by the various outgoing feeders in an electrical log. The existing logs, although sufficient for daily plant operational purposes, were insufficient for the mass of data we required to calculate an energy balance for the TEP. Therefore, new data sheets were designed. However, to enable plant personnel to maintain existing logs, the turbine log was kept intact and the electrical log was changed very slightly.

New data sheets were organized by areas. In areas such as the control room, they were further divided into groupings such as boiler panels and generator panels. They were then further subdivided into readings that had to be taken from meters and gauges and data taken from recording charts. The purpose in separating readings and data transcribed from recording charts was to allow someone not normally associated with the power house to collect the recording charts every few days and transcribe the readings onto the data sheets in an area away from the noise and activity of the power plant. It also meant that person could work only 2 or 3 days per week while the people taking data had to work every day. This resulted in significant manpower savings.

For ease of handling and duplicating, the data sheets were standard legal paper size (8½" × 14").

Besides the data already being recorded at the TEP such as pressure, temperature and flow, much new data were taken concerning equipment operation. For example all motors were logged hourly as to whether they were "Off" or "On"; if they were variable speed, the speed and amps

FIGURE 17

DATE: 1-15-79

STARRETT CITY POWER STATION

G GARAGE

AM, PM		8	9	10	11	12	1	2	3	4	5	6	7
OUTSIDE AIR TEMP. °F		14	16	16	20	22	26	22	22	18	20	18	18
CONTROL AIR PRESS. PSIG BUTTERFLY		N 8 S 11	N 8 S 11	N 8 S 11	N 9 S 10.5	N 7.5 S 10.5	N 7.5 S 10.5	N 8.5 S 10.5	N 8 S 10.5	N 8 S 10.5	N 8 S 11	N 7.5 S 11	N 9 S 11
DUAL TEMP SYSTEM	PRIMARY SUPPLY TEMP. °F	158	158	158	158	158	158	158	158	158	158	158	158
	PRIMARY RETURN TEMP. °F	132	132	132	132	132	132	132	132	136	134	134	136
	PRIMARY SUPPLY PRESS. PSIG	115	115	115	115	115	115	115	115	115	115	115	115
	PRIMARY RETURN PRESS. PSIG	115	115	115	115	115	115	115	115	118	115	115	115
	PRIMARY SUPPLY FLOW, GPM	N 30 S 32	N 30 S 32	N 30 S 30	N 30 S 32	N 30 S 32	N 30 S 32	N 30 S 32	N 30 S 32	N 32 S 28	N 30 S 30	N 30 S 28	N 32 S 30
	NORTH	SECONDARY SUPPLY TEMP. °F	122	122	122	122	122	122	122	122	122	122	122
		SECONDARY RETURN TEMP. °F	110	110	110	110	110	110	110	110	110	110	110
		SECONDARY PUMP SUCT. PRESS. PSIG	95	95	95	95	95	95	95	98	95	98	95
		SECONDARY PUMP DISCH. PRESS. PSIG	205	205	205	205	205	205	205	203	200	205	200
		SECONDARY RETURN PRESS. PSIG	110	110	110	110	110	110	110	110	115	115	115
		SECONDARY SUPPLY FLOW, GPM	30	30	30	30	30	30	30	34	32	32	32
	SOUTH	SECONDARY SUPPLY TEMP. °F	122	122	122	122	122	122	122	124	124	124	124
		SECONDARY RETURN TEMP. °F	112	112	112	112	112	112	112	116	116	116	114
		SECONDARY PUMP SUCT. PRESS. PSIG	105	105	105	105	105	105	105	105	100	105	105
		SECONDARY PUMP DISCH. PRESS. PSIG	135	135	135	135	135	135	135	135	135	135	135
		SECONDARY RETURN PRESS. PSIG	110	110	110	110	110	110	110	115	115	115	115
		SECONDARY SUPPLY FLOW, GPM	40	40	38	40	40	38	38	38	34	38	38
HIGH TEMP. SYSTEM	SUPPLY WATER TEMP. °F	245	245	245	245	245	245	245	245	245	245	245	245
	RETURN WATER TEMP. °F	220	220	220	215	220	220	220	220	225	220	215	210
	SUPPLY WATER PRESS. PSIG	140	140	140	140	140	140	140	140	140	140	140	140
	RETURN WATER PRESS. PSIG	110	110	110	110	110	110	110	110	110	110	110	110
	SUPPLY WATER FLOW, GPM	50	52	52	52	50	52	52	52	52	48	50	52
DOMESTIC HOT WATER	SUPPLY WATER TEMP. °F	136	138	134	140	140	140	144	144	140	138	136	134
	RETURN WATER TEMP. °F	L 104 R 106 98 102	L 98 R 102 96 98	L 102 R 106 96 98	L 102 R 106 96 98	L 102 R 106 96 98	L 102 R 106 96 98	L 102 R 106 96 98	L 102 R 106 96 98	L 104 R 108 100 102	L 102 R 106 96 98	L 102 R 106 96 98	L 102 R 106 96 98
	PUMP DISCH. PRESS. PSIG	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 156	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 150	N 150 S 150
	PUMP SUCTION PRESS. PSIG	N 85 S 88	N 85 S 86	N 85 S 86	N 85 S 88	N 85 S 86	N 85 S 88	N 85 S 80	N 85 S 81	N 85 S 86	N 85 S 86	N 85 S 86	N 85 S 86

(if available) were recorded; if two-speed, slow or fast was recorded. This kind of information would supply detailed information on plant operation.

The initial layout of the data sheets, copies were used for an actual run-through by engineers working on the project. Changes resulting from the "dry run" were incorporated and the revised sheets were submitted to the Starrett City Energy Project Manager for review and approval.

Upon approval by project management, data sheet masters were drawn on mylar by computer. An example of a final data sheet for water flows in the G Garage is shown in Figure 17.

Since neither funds nor time allowed for a protracted data collecting period, we attempted to "stretch" the available funds and still collect meaningful data. Data were collected on a twenty-four hour per day basis for the first seven days. This was followed by fourteen days of taking data for one eight-hour shift per day. The shift was rotated each day so that over the fourteen day period each shift was covered at least twice. This procedure enabled the data collecting period to be spread over a three week span so that changes in weather could be picked up if they occurred. It also minimized the manpower requirement thereby "stretching" the available funds for data collection.

Data collection took place in the spring, summer and winter seasons. During the spring collection neither heating nor cooling was being supplied to the tenants. Data was not taken during the fall period because we considered that there would be no significant difference from the spring data since the TEP does not supply heating or cooling in the fall.

The actual data collection started in the winter and summer

seasons was determined by reviewing weather data and selecting that period where summer highs and winter lows were most likely to occur. Winter collection started January 15, 1979. Summer collection started July 7, 1979.

Spring collection started May 13, 1979. This was basically determined by Starrett City management's decision to turn off the heat supplied to the tenants on that date.

Data were collected by apprentices from a union operated training program. Prior to each actual data run the apprentices took several practice runs for familiarization. This was done for each data collection period since the same apprentices were not available for more than one collection period. These practice runs were very valuable since it eliminated potential problems from occurring during the actual runs. By the time the actual run started, the apprentices knew where the equipment was (in the TEP as well as outlying buildings), which meters or gauges to read and how to operate portable meters that were required.

As data were collected in each run, it was spot checked so that errors were picked up and corrected very early in the data run. While data were being collected, a student from a local engineering school was used to transcribe data from recording charts to data sheets.

Selection and Specification of Additional Instrumentation

Where possible, if proper instrumentation was not already in place in the TEP, manufacturer's data was used instead of installing expensive instrumentation where we considered the manufacturers information to be sufficiently accurate. An example was the condenser supply flow. Two lines were involved; one being 24 inches in diameter and the other 36 inches. In this case, we used

pump curves supplied by the manufacturer to determine flow, because they were sufficiently accurate and the cost of installing flow measuring and recording devices was very high.

In some cases such as the measurement of deaerator steam flow manufacturer's data was insufficient for our purposes and in some cases the data needed were specific to the operation of the TEP such as the steam temperature and pressure to the High Temperature Heat Exchangers and therefore were completely unavailable. In these cases, rather than make assumptions which might compromise the accuracy of the results, we recommended the installation of new instrumentation, including pressure, temperature and flow measuring devices, which would be useful not only for this study, but also for the continued efficient operation of the plant.

Based on these considerations, it was determined that the bulk of the new required instrumentation was to determine total extraction flow and extraction flow to the various heat exchangers for the heat balance calculations.

Also, flow meters on the Dual Fuel Engine Waste Heat Recovery Boilers were required to evaluate each WHRB's performance, as well as temperature sensors on the DFE heat exchangers to supply information on the availability of usable heat presently being wasted.

A required "Additional Instrumentation List" was generated that included the instruments, manufacturers, model numbers, equipment cost and installation cost. The list is shown in Appendix B. Specifications for each instrument were written (Appendix B) to make competitive bidding possible. Finally, a specification for the installation of the instrumentation was written (Appendix B) and drawings (Appendix B) showing

installation details were generated. Bids were then obtained from several companies and a contractor selected.

Data Reduction and Evaluation

The initial data gathering program at Starrett City TEP was performed between January and July 1979 and provides the bulk of the data available to use for evaluation. This has all been tabulated and much of it translated into diurnal plots. A sample plot created in part from Figure 17 is shown in Figure 17A.

The data which follow have been grouped into data sets of related information, the titles of which are listed beneath the name of the pertinent TEP system.

Data listed as "Measured" were directly measurable or immediately inferred from directly measured data such as flow rates from the pressure drop across an orifice, or fuel input in Btu's from fuel oil input in gallons.

"Calculated Data" has been obtained from measured quantities, equipment manufacturer's design data, theoretical and empirical relationships among the variables and various assumptions about all the aforementioned when exact data were not available; necessary assumptions are noted. Actual methods of calculation are described in the Appendix B.

Between June and August 1980 additional instrumentation was installed as we recommended and is now available to collect further data and for refining or corroborating previous calculations. The newly available measurements for each system are included in the following description. The list of available data for each TEP system is followed by a general discussion of how this information was used to help in our evaluation of energy transfer options with the 26th Ward WPCP.

Space Heating And Cooling System

Initial Data Set

Titles of Data Sets

1. Water flow through and temperature difference across Dual Temperature Heat Exchanger (DTHE) No 1 and Ambient temperature vs. Time of Day (TOD).
2. Same for DTHE No. 2.
3. Steam and water flow through DTHE No.1 and Ambient Temperature vs. TOD.
4. Same for DTHE No. 2.
5. Heating load - Dual Temperature Heat Exchangers Nos. 1 and 2.
6. Total cooling load, North and south zone flow, North and south zone supply temperatures, North and south zone ΔT , Ambient temperature.
7. E Garage — Primary and secondary water flows and Temperature vs. TOD.
8. G Garage - Same as above. (Two among eight garage mechanical rooms were chosen for data readings as being typical).

Measured Data

1. Ambient Temperature, °F.
2. Flow rates of heating water through DTHE 1 and 2, gallons/min.
3. Inlet and outlet temperatures of water through DTHE 1 and 2, °F.
4. Flow rates of cooling water to the north and south zones of Starrett City, gallons/minute.
5. North and south zone cooling water, supply and return temperatures, °F.
6. Primary and secondary water flow rates in Garages E and G, gallons/minute.
7. Primary and secondary water supply and return temperatures in Garages E and G, °F.
8. Refrigeration turbine throttle steam flow rates, pounds/hour.

9. Dual Temperature System water pump characteristics—amps, rpm, flow rate.

Calculated Data

1. Steam flows to DTHE 1 and 2, pounds/hour

The energy transmitted to the heating water through each DTHE can be calculated with water flow rates and temperature increases across the heat exchanger. Assuming design inlet conditions for the steam as given in equipment specifications, saturated condensate at the outlet and heat exchanger efficiency as given by the manufacturer, steam flow can be calculated.

2. Total heating load, Btu/hour

This is the sum of the energy increases seen by the heating water across DTHE 1 and 2 which is equivalent to the energy needed to heat the buildings plus losses.

3. Total cooling load, tons

The temperature increases between supply and return chilled water lines and their respective flow rates for the North and South zones yield cooling load for the Starrett City complex plus losses.

Data Application

These data sets establish steam requirements for the heating and cooling system.

Profiles of steam flow and its relationship to ambient temperature will help determine whether or not thermal energy can be supplied to the 26th Ward and if there will be limitations on the availability of the thermal energy.

This data was also required to perform heat balance calculations for the TEP.

Additional Instrumentation

- Steam flow rates to Dual Temperature Heat Exchangers FE-HE1, FE-HE2.

This is an important quantity ... TEP heat balance calculations and

Figure 17A G - Garage Primary and Secondary Water Flows versus Time of Day

North Primary Flow (North Primary Flow is Typical of South Primary Flow)
 North Secondary Supply Temp. is Typical of South Secondary Supply Temp.

this data would be more accurate and reliable than that calculated which depended on a number of assumptions.

In addition it will help the plant operator to determine whether or not the heat exchanger performance is deteriorating.

Hot Water System

Initial Data Set

Titles of Data Sets

1. Total high temperature water (HTW) system supply flow, North zone flow, South zone flow, North and south zone ΔT and Total steam flow to the HTW heat exchangers.

2. E Garage - HTW supply flow and temperature, HTW ΔT , Domestic hot water supply temperature and Δ vs. TOD.

3. G Garage - Same as above.

Measured Data

1. Flow rates of heating water to the north and south zones, gallons/min.

2. Supply and return temperatures for north and south zones, $^{\circ}F$.

3. Domestic Hot Water (DHW) and HTW flow rates at the heat exchangers in Garages E and G, gallons/min.

4. DHW and HTW inlet and outlet temperatures at the heat exchangers in Garages E and G, $^{\circ}F$.

5. HTW pump characteristics - flow rates, rpm, Amps.

Calculated Data

• Total HTW system steam supply flow, pounds/hour.

The energy transmitted to the primary water through each HTW heat exchanger can be determined from our knowledge of primary water flow rates and temperature increases. Assuming that the steam inlet conditions are as given in the equipment specifications and exits as a saturated liquid, and using the manufacturer's value for the heat

exchanger efficiency, we can calculate the steam flow.

Data Application

This data establishes steam requirements for the High Temperature Water heat exchangers, which is necessary to perform heat balance calculations and determine the availability of thermal energy for the 26th Ward WPCP.

Additional Instrumentation

• Inlet temperatures and pressures, outlet temperatures $^{\circ}F$, steam to high temperature heat exchangers - TI-HE3(2), TI-HE4(2), PI-HE3, PI-HE4.

Steam flow rates must still be calculated, but they no longer have to be based upon assumptions about inlet and outlet conditions. Just as for DTHE steam rates, this data is needed for accurate heat balance calculations.

In addition, once all instrumentation is in place, the steam flow rate H.T.W. Heat Exchanger can be determined by subtracting all measured flows from the total extraction flow.

Condenser Water System

Initial Data Set

Title of Data Set

Condenser water supply temperature and ΔT , Number of condenser water pumps and cooling tower fans "On" vs. TOD.

Measured Data

1. Supply and return temperatures of condenser water, $^{\circ}F$.

2. Number of condenser water pumps running.

3. Number of cooling tower fans running.

Data Application

The operation of this entire system is to be reviewed to quantify savings possible by substituting WPCP effluent as the cooling

medium. The present system must be maintained for standby use however, in the event of insufficient effluent flow or mechanical breakdown.

Dual Fuel Engines and Waste Heat Recovery Boilers

Initial Data Sets

Titles of Data Sets

1. Dual Fuel Engine (DFE) - Fuel Input, Efficiency, Power Output and parasitic load vs. TOD.

2. DFE No. 2 - Same as above.

3. DFE No. 3 - Same as above.

Measured Data

1. Fuel oil supply, Btu/hour

2. Power output, Btu/hour

3. Parasitic load, Btu

Calculated Data

• Dual Fuel Engine Efficiency, Percent.

This is the ratio of the power output to the heating value of the fuel.

Data Application

This information is necessary to perform heat balance calculations and to compare the relative merits of DFE versus boiler-turbine operation. It also helps establish the total cost of supplying electrical power to the 26th Ward WPCP.

Additional Instrumentation

1. Steam flow rates from individual WHRB's - FE-WH1, FE-WH2, FE-WH3.

2. DFE jacket water heat exchanger - cooling water outlet temperature - TI-DF1, TI-DF2, TI-DF3.

Steam flow rates from each WHRB can now be monitored even if more than one DFE is running which was not previously possible.

The DFE generates heat which is transferred, first, to the jack cooling water and then to the condenser water and wasted. Tempera-

ture measurements of the condenser water return will indicate whether or not this heat can be used.

Boilers

Initial Data Sets

Titles of Data Sets

1. Total steam flow and total fuel input to boilers vs. TOD.
2. Percent load vs. efficiency of Boiler No. 1
3. Same for Boiler No. 2
4. Same for Boiler No. 3
5. Same for Boiler No. 4
6. Steam flow and efficiency of Boiler No. 1
7. Same for Boiler No. 2
8. Same for Boiler No. 3
9. Same for Boiler No. 4

Measured Data

1. Steam flow from each boiler, pounds/hour.
2. Fuel input to each boiler, Btu/hour.

Calculated Data

- Efficiency of each boiler, percent.

This is the ratio of the energy added to the feedwater by the boiler to the heating value of the fuel.

Data Application

This data is necessary to determine the impact of using digester gas at the TEP, specifically what percentage of fuel requirements would be displaced and how many boilers could be thus supplied.

The cost of supplying steam to the WPCP can also be evaluated through use of this information.

Turbine Generators

Initial Data Sets

Titles of Data Sets

1. Power generated and parasitic load vs. TOD.
2. Turbine Generator No. 1 Throttle steam flow, Extraction steam flow, Condensate flow and kw Generated vs. TOD.

3. T.E. No. 2 - Same as above.
4. Power usage - Groups 1 through 5.
5. Throttle steam flow, Demineralizer water flow, City water flow and Ambient temperature vs. TOD.
6. Total Megawatts generated.

Measured Data

1. Power generated by each Turbine Generator, kw
2. Parasitic load, kw
3. Throttle steam flow, pounds/hour.
4. Power usage - Medium Voltage Switchgear, Groups 1-5, kw.
5. City water flow, gallons/hour
6. Demineralizer water flow, gallons/hour

Calculated Data

- Condensate and Extraction Steam Flow, pounds/hour.

It is necessary to perform a heat balance calculation to obtain this data and verify turbine performance curves supplied by the manufacturer.

At a particular power level, throttle flow rates are available as well as condensate temperature and data for the Dual Fuel Engines and Waste Heat Recovery Boilers if used.

Using recorded values for throttle steam flow rate and design values for Dual and High Temperature Heat Exchangers' and deaerator's steam and condensate parameters, we can perform heat balance calculations to determine steam flow to the deaerator.

With the above calculation we then know flow rates for all equipment using extraction steam. We could then determine turbine extraction steam and condensate flow rates.

Data Application

This data is necessary to evaluate the basic operation of the plant technically and economically. Efficiency

can be calculated at various power levels, extraction steam and throttle steam rates and actual performance curves can be compiled.

The data allows internal power conservation measures to be translated into fuel savings and helps establish the costs and availability of energy for transfer to the 26th Ward WPCP; it is also necessary for analysis of augmented DFE operation to increase the overall plant efficiency.

City water and demineralizer water flows are a measure of the water required for makeup in the condenser and feedwater systems respectively, allowing the calculation of savings, in water use as well as dollars, by using WPCP effluent as condenser water.

Additional Instrumentation

1. Extraction steam flow from each turbine - FE-TE1, FE-TE2.
2. Steam flow and temperature to the deaerator - FE-DEA, TI-DEA.
3. Condensate flow and temperature from atmospheric drain tank - FE-ATD, TI-ADT.

This data would replace that previously calculated or assumed and provide a much more reliable basis for an accurate heat balance as well as the possibility for a detailed analysis not previously possible. Steam flow can now be tracked along virtually its entire cycle, establishing increased accountability for every process and piece of equipment so that continued optimum plant operation can be maintained.

Operational Changes at Starrett City TEP Resulting from Data Analysis

The information obtained from the original data collection of January, May and July 1979 is listed in Appendix B. The application of this data to the evaluation of TEP performance is outlined below for each system. The application of additional instrumentation installed subsequent to these tests is also

discussed. The newly measured quantities are listed with the instruments' tag numbers.

Aside from these additional instruments, collection and analysis of data continued after the initial program to help evaluate aspects of TEP operation. Data thus obtained to date is listed as "Subsequent Data" for the applicable TEP system and the test dates are given. Following each test is a brief description of the reason for the additional testing.

Finally, based upon all available data, the operation of each TEP system is evaluated. Observations from the data are indicated. In some cases, our suggestions have been implemented. These are noted, along with the results. Further suggestions and conclusions are also described, with estimates of the financial impact of these steps. Table 7 summarizes the financial savings realized through measures already taken and lists estimated savings through the implementation of further conservation measures.

Space Heating and Cooling System Data Application

The data gathered here helps us evaluate the operation of the entire heating and cooling system. For example:

a) Flows and temperature differences through the heat exchangers allow us to determine if equipment is being used properly, and will specifically identify pumps which may be incorrectly sized and wasting power or otherwise be running inefficiently.

b) The energy required by various systems can be quantified to determine if there are any variations between actual and design values so as to pinpoint areas for further investigation. Along those lines, a computer model (discussed in detail in the section on conservation) of Star-

TABLE 7

STARRETT CITY TEP ENERGY CONSERVATION PROGRAM - RESULTS SUMMARY		
SYSTEM	MEASURES IN EFFECT	SUGGESTED FURTHER MEASURES
A) Space Heating & Cooling	Run one DTW pump during heating season rather than two. <u>Savings:</u> \$65/day \$13,650/7 mo. heating season	Reduce flow rates for heating and cooling seasons. <u>Savings:</u> depends on results of tests at TEP.
B) Hot Water System	Run one HTW pump rather than two. <u>Savings:</u> \$25,432/yr	1) Lower flow rate to 1250 GPM. <u>Savings:</u> \$4786/yr. 2) Replace a pump with one single speed pump. <u>Savings:</u> \$513/mo, \$5643/yr, based on 11 mo. operation
C) Condenser Water System		Reduce pump and fan operation to run system closer to design temperature.
D) Dual Fuel Engines, Waste Heat Recovery Boilers		1) Improve WHRB to provide design steam flow <u>Savings:</u> Gas - \$5020/mo (2 DFE's), Oil - \$11,100/mo 2) Use less pilot oil during gas operation. <u>Savings:</u> \$378/mo (2 DFE's). Total - \$26,990 over 5 mos.
E) Boilers	Replace damper controls, O ₂ analyzers. <u>Savings:</u> \$60,000/mo for one boiler at 70,000 lb steam/hr Based on 7 mos boiler operation at 200,000 lb steam/hr and 5 mos operation at 120,000 lb steam/hr, proportional savings = \$171,000/mo x 7 mos + \$103,000/mo x 5 mos = \$1,712,000	

Continued Next Page

rett City provided theoretical values for energy consumption which were compared to actual values yielding insights into where consumption may be too high (as well as into the program's deficiencies) thereby identifying potential areas for further examination.

c) The relationship between the water temperature difference across the heat exchanger and ambient temperature can help establish what the thermal lag in the system is. This can be used to operate the pumps more effectively.

d) Data obtained from the equipment in Garages E and G supplies information relating to the effectiveness of the control system for the Dual Temperature System. It will also help in determining time lags, if any, between changes in ambient temperature and changes in secondary supply and return and primary supply and return temperatures, which is useful in establishing pump operating procedures. These data also would help to identify and locate possible losses in the distribution system.

Subsequent Data

- DTW operating with one pump - 4/14/1980 - Water flow rates, supply and return temperatures for DTHE Nos. 1 and 2; flow rates, supply and return temperatures to north and south zones.

Here we are investigating the possibility of using one DTW pump at higher flow rather than two at lower flows in heating operation. This could result in power savings in pump operation without affecting other system characteristics.

Additional Instrumentation

- Steam flow rates to Dual Temperature Heat Exchangers - FE-HE1, FE-HE2

The need for this was discussed elsewhere.

Table 7 Continued

SYSTEM	MEASURES IN EFFECT	SUGGESTED FURTHER MEASURES
F) Turbine Generator		Use one T.G. plus 2 DFE's rather than 2 T.G. during non-heating seasons. Savings: \$84,000/mo x 5 mos = \$420,000
<hr/>		
TOTALS:	\$1,751,082 per year	\$ 457,419 per year (plus likely savings for Dual Temperature System, Condenser Water System and extension of fraction of year where one T.G. + 2 D.F.E. operation is feasible).

Observation

Data taken of the water temperature difference across the Dual Temperature Heat Exchangers during the heating season showed values which were often substantially lower than those for which the heat exchanger was designed. This indicated that similar quantities of heat could be transferred at lower flow rates, which could result in power savings to the pumps which circulate the heating water. Table 8 gives pump data for four representative heating days in January, including the average DTHE ΔT over each 24 hour period. These values, ranging from 22-30°, can be compared to the DTHE design Δ of 40°F.

Water supply flows now handled by two pumps are within the capacity of one pump at winter volumes. This was confirmed by a subsequent test running one pump (see test data in Appendix C) at 780 rpm which gave substantially identical system performance to two pumps running at 625 and 560 rpm.

Similarly, the temperature differentials of cooling water to the north and south zones, from 3 to

8°F in our sample, is smaller than the design value of 13.4°F. In this case, two pump operation was judged to be necessary, as it was feared that failure of the single pump would lead to freeze-up and damage to the chillers.

Conclusions and Recommendations

Our recommendation to run one rather than two pumps during heating season has been enacted. The results have shown that system performance is unaffected, and financial savings are realized by drawing less power for pump operation. These data show a power savings of 48 kw, with a daily savings of 1152 kwh or \$65 at a fuel oil price of \$.70/gal, or \$.057/kwh; this adds up to \$13,650 over a seven month heating season.

Lowering the water flow rate to take advantage of higher allowable Δ across the DTHE is another approach likely to lead to pump power savings. A procedure has been drawn up for collecting data to determine optimum flow rates (Appendix C). At present, the pumps are run at a constant speed for the

entire heating or cooling season. The test procedure calls for decreasing the pump speeds from the maximum down to much lower values for two pump and one pump operation. Readings will be taken at each rpm level, over a 24 hour period, of pump data, DTHE flows and inlet and outlet water temperatures and pressures and characteristics for primary and secondary flows in Garages E and G. These data should allow us to choose the pump operating procedure which would supply heating needs at lowest power usage.

That further savings are possible can be seen by inspecting the January and July, 1979 and April, 1980 data. A typical temperature increase across the DTHE for January is 28°F. At 7.7 lb/gallon (140°) and the flow rate of 6850 gpm, the energy transfer rate is:

$$\frac{28 \text{ Btu.}}{\text{lb.}} \times 7.77 \frac{\text{lb.}}{\text{gal.}} \times 6850 \frac{\text{gal.}}{\text{min.}} \\ = 1,476,860 \frac{\text{Btu.}}{\text{min.}}$$

The design ΔT across the DTHE is 40°F; for a more modest increase in the ΔT to 35°F, the reduced flow rate would be:

$$\frac{1,476,860 \text{ Btu.}}{\text{min.}} \times \frac{1 \text{ lb.}}{35 \text{ Btu.}} \times \frac{1 \text{ gal.}}{7.7 \text{ lb.}} \\ = 5480 \frac{\text{gal.}}{\text{min.}}$$

at the same rate of heat transfer. Based on manufacturers data this would require a pump speed of 611 rpm, a substantial decrease from the original speed of 780 rpm, based upon direct proportionality between pump speeds and flows.

The temperature increase of water across the DTHE in April is even lower due to lower space heat demand. Therefore, possible flow reductions are greater. For an

average ΔT of 11°F and flow of 7480 gpm at a speed of 780 rpm, calculations similar to those above yield a flow of 2351 gpm or 262 rpm at a ΔT of 35°F.

Similar flow reductions appear possible during cooling season. Based on a typical ΔT of 5°F, flow of 13,400 gpm at a pump speed of 1000 rpm and water density of 8.3 lb per gallon (50°F), we can compute the flow rate for the same energy transfer at a ΔT of 10°F (the design value is 13.4°F). The necessary flow rate is 6700 gpm or 3350 gpm for each of two pumps at a speed of 500 rpm.

These calculations given an indication of the magnitude of excess levels of pump operation in effect the year around. Savings will depend on how closely the system can run to design temperatures, efficiency of the pump and drive at low

TABLE 8

STARRETT CITY POWER STATION - DUAL TEMPERATURE SYSTEM - OPERATION DATA

		<u>HEATING</u>				<u>AIR CONDITIONING</u>					
		<u>JANUARY</u>				<u>JULY</u>					
		<u>15</u>	<u>17</u>	<u>19</u>	<u>21</u>		<u>8</u>	<u>10</u>	<u>12</u>	<u>13</u>	
DTHE 1	supply flow	GPM	3,400	3,400	3,400	3,400	N.Zone	6,700	6,600	6,850	6,400
DTHE 2	" "	GPM	3,450	3,450	3,450	3,450	S.Zone	6,800	6,800	6,550	6,250
Total flow		GPM	6,850	6,850	6,850	6,850		13,500	13,400	13,500	12,650
Supply Temp.		°F					N. S.	48 52.5	46 44	46 44.5	48 43
DTHE 1	Δ t	°F	28	26	33	22	N.Zone	3	3.5	3.7	6
DTHE 2	Δ t	°F	28	26	33	22	S.Zone	5.5	6	6.8	8
P7	amps		120	120	120	120		340	335	335	340
	rpm		560	560	560	560		990	990	990	990
P8	amps		115	112	112	117		-	-	-	
	rpm		565	562	560	560		-	-	-	
P9	amps		-	-	-	-		325	320	325	325
	rpm		-	-	-	-		1,070	1,070	1,070	1,070

rpm and how well the entire system operates at low flows.

The suggested test program should be implemented several times during the year at different seasonal conditions — at least at midwinter, mid-summer, and when there are low heating and low cooling requirements. During the low heat requirement periods, single pump operation could probably be reduced further than suggested.

Data from the suggested test program would provide the information required to decide the levels at which the pumps could be run for various seasonal conditions, or whether an automatic control system would be a cost effective way to operate the Dual Temperature System pumps.

Hot Water System

A report, entitled "Recommendations for Energy Saving High Temperature Water System Operation", dated May 1, 1980, details our analysis of the HTW system and is included in Appendix C. A summary of its findings follows with some modifications based on new information acquired in the subsequent data collection.

Data Application

The high temperature water data relates to the system providing domestic hot water to the residential buildings and includes the space heating system (when needed) for the Community Center.

With the diurnal graphs of the HTW system we can compare actual equipment operation to equipment specifications. The graphs also help determine whether or not equipment is being used to take advantage of its capabilities.

Profiles of steam flow help determine when, and under what conditions, thermal energy can be supplied to the 26th Ward.

Among other numerous data a computer simulation of Starrett City

energy needs predicted domestic hot water use which could be compared to measured values and used to monitor residential consumption and identify possible waste. Data obtained from the heat exchangers in Garages E and G could help refine any conclusions on this matter and provide information on system controls leading to further energy savings.

Subsequent Data

HTW system operating under lower flow and single pump conditions — 2/6-14/1980 — north and south zone flow rates and supply and return temperatures; pump characteristics — amps, r.p.m., suction and discharge pressures.

Savings are possible through the use of lower water flow rates, use of fewer pumps or acquisition of a different type of pump. Operation in different modes and levels was tested so that a determination could be made as to how the Hot Water System operates under these conditions.

Additional Instrumentation

Inlet temperatures and pressures and outlet temperatures of the steam to the high temperature heat exchangers — TI-HE3 (2), TI-HE4 (2), PI-HE3, PI-HE4.

These measurements allow a calculation of steam flows to the HTHE's which is not based upon assumptions as to steam and condensate flow conditions, yielding more accurate data than previously possible. Steam flows are necessary for heat balance calculations which are needed for the evaluation of plant performance.

Observations

An inspection of High Temperature Water System (HTWS) data reveals that normal operation was with two pumps on line operating at maximum volume

during the heating season (2,000 gpm) and approximately 75% maximum flow the rest of the year. At the same time, the temperature drop, ΔT , of the heating water across the High Temperature Heat Exchangers is somewhere between the north zone ΔT and south zone ΔT (depending upon relative flow rates) which average less than 25 °F, a small fraction of the design HTHE ΔT of 150 °F. Substantial reductions in water flow rates appear possible with consequent energy savings realized through reduced pump operation.

Conclusions and Recommendations

Using logged test data, the system head curve was drawn allowing the estimation of pump rpm for any given flow rate.

Further system tests were performed (see Appendix C) in which much lower flow rates were maintained during winter operation, down to 1050 gpm with two pumps and then 1260 gpm with one pump. North and south zone temperature drops increased to values ranging up to 80 °F, still far below the design value.

Our first recommendation was to run a single HTW pump rather than two. The plant has accepted this suggestion and, at last inspection, is running one pump at 1625 rpm, 1330 gpm total flow and 100 amps.

Compared with previous pump operation, savings are computed as follows:

Present operation — $100a \times 465 v. \times 3 \times .85$ (power factor) $\times 24$ hours/day = 1643 KW hr/day @ \$.057/kwh.

For one year, pump costs are \$34,183.

Previous operation

• winter — $190a \times 465 v. \times 3 \times .85 \times 24$ hours/day = 3122 kwh/day @ \$.057/kwh.

For the seven month heating season, pump costs were \$38,118.

• summer — $150a \times 465 \text{ v.} \times 3 \times .85 \times 24 \text{ hours/day} = 2465 \text{ kwh/day @ } \$0.057/\text{kwh}.$

Based on present levels of operation being maintained for the entire year and a fuel oil price of \$.70/gal., savings come to \$25,432 per annum. This number differs from those calculated in the report because actual present operating data is used here and no credit is taken for lower operating levels during non-winter operation, as no data is available. Higher flow rates are maintained during the winter because high temperature water is used to heat the Community Center. Assuming the plant will continue to lower flow in the summer, spring and fall seasons actual savings can be expected to be higher.

Recommendations for further reducing HTWS pump costs are the following:

(1) At present, the one HTWS pump is being run at near maximum speed with a flow rate of 1330 gpm and HTHE ΔT of 40°F. The system has already been successfully tested at lower flow rates and there seems to be no reason why the flow rate could not be reduced to 1250 gpm based on past knowledge.

This could reduce pump amperage to the test level of 86a, which would reduce daily power consumption to 1413 kwh/day. The financial savings compared to present operation would be:

$$\$34,183 - \$29,397 = \$4,786 \text{ per annum.}$$

(2) Noting the still sizable differences between actual and design HTHE ΔT 's, it has been postulated that flows of 1000 gpm for winter and 800 gpm for non-winter operation would be sufficient to serve Starrett City. Based upon performance and head curves, pump speeds at these flow rates would be 1300 and 1200 rpm respectively.

We suggest decreasing the pump speed until 1000 gpm is reached (or complaints start coming in), logging system data as the test progresses.

Similarly, flow should be decreased to 800 gpm after the heating system ends. Results of these tests will help indicate whether the system can be run at these levels.

(3) Assuming successful system operation at 1000 gpm, further savings are possible by replacing one of the existing variable speed pumps with a high efficiency single speed pump. A $4 \times 6 \times 13$ HOC Ingersoll Rand pump having an efficiency of 82% when delivering 1000 gpm against a total head of 126 feet was selected for comparison.

From present test data, we choose a data set showing flow to be 1280 gpm at a speed of 1450 rpm, current 86a and a head (from pump curves) of 140 feet.

$$\text{Water horsepower (Whp)} = \frac{1280 \text{ gpm} \times 140 \text{ ft}}{4302} = 41.7$$

(The discrepancies between these figures and those in the report are attributable to the denominator in the above equation which is based on a water specific gravity of .92 (7.67 lb/gal.), while that in the report is based upon a s.g. of 1.0.)

The input hp based on 86 amps and 465 volts is 78.8 hp, yielding a pump efficiency of 53%.

At 1000 gpm and 120 ft. head, the required Whp would be 27.9, which, for the present pump, would require an input of 52.6 hp, from:

$$\frac{1000 \text{ gpm} \times 120 \text{ ft.}}{4302} = 27.9 \text{ WHP,}$$

$$\text{hp} = \frac{27.9}{.53} = 52.6$$

The new pump, with a 95% efficiency motor, has an overall efficiency of

$$.82 \times .95 = .78$$

and a required input hp of

$$\frac{27.9 \text{ Whp}}{.78} = 35.8 \text{ hp}$$

for savings of 16.8 hp or 12.5 kw. At a fuel oil price of \$.70/gal, the new pump would save \$513 per month at these flow rates. Given the pump price of \$3,172, the payback period would be a little over six months.

Condenser Water System

Data Application

Although the 26th Ward WPCF effluent will replace condenser water for TEP cooling, the present system must remain operational in the event of insufficient effluent or mechanical breakdown. This system, therefore, may be called upon to run for extended periods, and should be operated as efficiently as possible.

Observations

The flow and temperature of the condenser water is controlled by the three condenser water pumps, the cooling tower fans and the number of operating cooling tower cells, all of which are under manual operation from the control room.

The cooling tower is designed to produce a condenser water temperature of 85°F, but data taken from January 15-21, 1979 (Table 9) shows that cooling tower fans were turned on at condenser water temperatures as low as 74°F and as high as 90°F. Two condenser water pumps are operated continuously, with the third, apparently, turned on most evenings between 5 and 6 o'clock, regardless of system conditions.

Conclusions and Recommendations

Based simply upon horsepower ratings, at \$.057 per kwh, nominal costs of operation for the condenser water pumps are \$102 per day (100 h.p.), for the cooling tower fans \$38 and \$150 per day for low (37.5 h.p.) and high (150 h.p.) speed operation, respectively.

Proper operation of the condensers is based upon a cooling water temperature of 85°F, which is often exceeded under the present system of manual control. On the other hand, cooling tower fans are turned on at temperatures far below 85°F, consuming power unnecessarily.

Ordinarily, the costs of running

TABLE 9
OPERATION OF COOLING TOWER FANS AND CONDENSER WATER PUMPS
JANUARY 15-21, 1979

	Time of Day	Ambient Temp °F	Condenser Water Temp, °F	Condenser Water ΔT , °F
Conditions under which one cooling tower fan was turned <u>on</u> (originally none on)	2 pm	30	90	12
	8 pm	21	74	13
	7 am	10	76	12
	12 N	34	90	15
	11 am	25	85	22
	1 pm	26	79	13
	6 pm	33	86	15
	3 am	29	75	12
	8 am	5	73	10
	6 pm	28	92	13
Conditions under which one cooling tower fan was turned <u>off</u> (originally one on)	3 pm	30	73	6
	10 am	27	70	3
	5 am	22	77	10
	12 N	26	80	10
	5 pm	32	85	8
	9 am	28	79	13
Conditions under which one condenser water pump was turned <u>on</u> (originally two on)	10 am	27	69	4
	8 pm	32	80	11
	8 pm	14	81	12
	5 pm	17	82	10
	6 pm	28	92	13
	6 pm	45	81	8
Conditions under which one condenser water pump was turned <u>off</u> (originally three on)	One pump was turned off between 11 pm and Midnight each day, Wednesday through Sunday.			

this equipment as computed above would justify the installation of a simple control system, based on condenser water temperature, initiating a sequence of equipment starts (perhaps fans low, then fan high, then additional pump) as the temperature rises. The system would be on minimum operation of one or two pumps as long as this temperature was below, say, 80°F.

With the likelihood that 26th Ward WPCP effluent would be used as cooling water, it is not cost effective to install such controls. The system will, however, remain operational for standby use and should be run efficiently in such an eventuality.

During winter operation, ambient temperature is low and system response is fast. Condenser water temperature can be allowed to come close to 85°F before activating the

fans. The apparently routine activation of the third condenser water pump may not be necessary — only once during the test period was the condenser water temperature higher than 85°F when this was done. In any case, consideration should be given to turning a cooling tower fan on first on low speed, as this consumes much less power than a water pump.

During the week of data collection in May, 1979, the plant operated continuously with one fan and one pump on. For much of the time, the condenser water temperature varied between 75-80°F; the system may have maintained an adequate temperature without the fan on.

Data taken from July 8-13, 1979 shows a similar pattern of operation. Two pumps were on constantly, with two or three fans. The

third fan was activated at midweek, when the condenser water temperature was only 70°F and left running for the rest of the week during which period this temperature varied from 68-77°F. It seems evident that some of this equipment was being run unnecessarily.

In general, condenser supply water temperature is the most significant variable to be monitored. Manipulating the available equipment so that this temperature runs as close to 85°F as is reasonably possible would ensure proper operation of the condensers as well as minimize unnecessary power consumption by the system's mechanical equipment.

Dual Fuel Engines and Waste Heat Recovery Boilers (DFE and WHRB) Data Application

This data is required to verify the proper operation of the engines for greatest efficiency. Comparison with manufacturers tests help in this determination.

An important variable in TEP operation is the relative overall efficiency of running the DFE's rather than one Turbine Generator at different seasonal and load conditions. Accurate DFE data is necessary for these calculations.

Subsequent Data

(a) Individual DFE operation at different power levels; oil and gas modes — 11/79-2/80 — Fuel consumption, WHRB steam production.

(b) Normal usage DFE operation; gas mode 10/23-30/1980 — Fuel consumption, power output.

This data was necessary to supplement that taken during the initial tests which was spotty and incomplete because the DFE's were run for only short periods of time. Comparisons can be made between gas and oil as a fuel, and efficiencies

computed at different power levels to compare with manufacturers test data.

A steam flow meter was originally installed only on the steam header common to all three WHRB's. Individual tests were required to measure steam production, a prerequisite to obtaining WHRB efficiencies which can then be compared to design data for determination of proper operation. WHRB data which is also needed for heat balance calculations is a factor in calculations concerning DFE vs. boiler-turbine operations and for determination of heat available for transfer to the 26th Ward WPCP.

Additional Instrumentation

Steam flow rates from individual WHRB's—FE-WH1, FE-WH2, FE-WH3.

DFE jacket water heat exchanger—cooling water outlet temperature—TI-DF1, TI-DF2, TI-DF3.

Steam flow rates from each WHRB can now be monitored even if more than one DFE is running which was not previously possible.

Observations

The DFE's were tested by the manufacturer in 1971; this data presumably reflects optimal conditions and serves as a basis of comparison for later, on line, testing.

Tests performed in December, 1979, and January, 1980, (Table 10) showed operating DFE efficiencies which compared favorably with those from the manufacturers tests; for example, in the gas mode, operating values ranging from 35-45% versus the original test range of 33-39% at similar loads. Data for DFE #3, however, is suspect, showing fuel flow rates widely different from those of the other two DFE's.

The operating data shows higher rates of pilot oil injection in the gas burning mode than the manufacturers tests do. The latter shows a fairly constant oil injection rate of

TABLE 10

STARRETT CITY - DUAL FUEL ENGINES - EFFICIENCY

	hrs.	Av Watt kw	Avail. Energy		Ft ³ Gas x 1000	Gal. Oil	Total Htg Value x 10 ⁶ Btu	Effic.
			kwh	Btux10 ⁶				
DFE #1	7	1128	7896	26.9	--	527	75.9	35.4
11/20/79	6	1500	9000	30.7	--	543	78.2	39.3
Fuel Oil	3	2000	6000	20.5	--	330	47.5	43.2
DFE #2	6	1000	6000	20.5	--	416	59.9	34.2
11/19/79	5	1592	7960	27.2	--	533	76.6	35.5
Fuel Oil	5	1983	9915	33.8	--	661	95.2	35.5
DFE #3	5	1028	5140	17.5	--	392	56.4	31.0
1/22/80	6	1507	9042	30.9	--	648	93.3	33.1
Fuel Oil	5	2000	10000	34.1	--	604	87.0	39.2
DFE #1	5	1033	5165	17.6	41	55.9	49.0	35.9
1/28/80	5	1580	7900	27.0	57	53.5	64.7	41.7
Gas & Oil	3	2000	6000	20.5	50	34	54.9	37.3
DFE #2	6	1000	6000	20.5	46	53	53.6	38.2
1/26/80	5	1500	7500	25.6	53	32	57.6	44.4
Gas & Oil	4	2000	8000	27.3	58	34.2	62.9	43.4
DFE #3	6	1014	6084	20.8	78	7	79.0	26.3
1/27/80	5	1617	8085	27.6	79	8	80.2	34.4
Gas & Oil	5	1967	9835	33.6	149	9	150.0	22.4

approximately 4.5 gallons per hour, independent of load; the operating oil injection rates range from 8 to 17 gallons per hour.

These tests were run operating one DFE at a time so that steam flow rates from the WHRB's could

be measured. At full load, steam flow rates were erratic, but mostly well below the design rate of 2820 lb-steam per hour (see Table 11). Operation in the gas mode produced higher stack temperature and higher steam rates.

TABLE 11

WASTE HEAT RECOVERY BOILER - STEAM PRODUCTION

Design value at full load = 2820 $\frac{\text{lbs. steam}}{\text{hour}}$

	$\frac{\text{lb/hr}}{\text{Steam at 2000 kw}}$	
DFE	OIL	GAS + OIL
1	1133	1986
2	2000	2050
3	1560	2720

These results are based on steam integrator readings from November 1979 and January 1980 tests.

The manufacturers' tests show similar DFE efficiencies whether burning oil or gas, with perhaps a slight dropoff at lower loads, in the 50% range, for gas operation.

Another set of tests were performed in October, 1980, while two DFE's were on line simultaneously. Efficiencies generally were 15-20% lower than those of previous tests, while, once again, values for DFE #3 were erratic. WHRB data were unavailable as individual boiler steam flow rates could not be measured. Since that time individual steam flow meters have been installed.

Oil consumption data, especially that for DFE #3 are suspect and all three oil flow meters have been replaced. The October, 1980 tests show much more reasonable pilot oil flow rates, reflecting this replacement.

Conclusions and Recommendations

Due to the apparent unreliability of some of the data, and unavailability of others, our first recommendation is to collect a new set of on-line data similar in format to that of the December, 1979 - January, 1980 tests. This time, there would be no constraint of running only one DFE at a time to collect a complete data set.

The conclusions and recommendations which follow are contingent upon the further validation of present data.

It is impossible to know for certain what is the cause of incongruous data for DFE #3. Both on-line tests for gas show low efficiencies, but whether this is actually the case or merely the result of a faulty meter cannot be judged. Significantly higher WHRB steam flow rates for this DFE indicate that gas flow rates may, indeed, be higher than in the other DFE's, since higher exhaust flows in the stack would produce more steam. The operation of the gas flow meter should be checked, perhaps by rotation with the other

two, to determine where the discrepancy lies. If the meter is accurate, needless to say, the engine is not running properly.

With oil costs per Btu higher than that for gas, it would be advantageous to inject less pilot oil in the gas burning mode of operation and make up the energy loss with more gas. From 3.5 to 13.5 gallons of oil could thus be replaced per hour to bring amounts down to that used during the manufacturers' tests which was 4.5 gallons per hour.

Based upon a 5% differential in cost per Btu between oil and gas, operation of the Dual Fuel Engines in the gas mode and a decrease of an average of 7.5 gallons per hour of pilot oil per DFE, the use of oil will be decreased by 10,800 gallons per month. The replacement of this quantity of oil with gas results in savings of \$378 per month, operating two DFE's.

The highly variable pilot oil flow rates, as opposed to the nearly constant rates for the manufacturers' tests, indicates that there is some control problem. These excessive and fluctuating pilot oil flow rates are confirmed on the new meters.

Steam flow rates from the WHRB's being generally much lower than the design value at full load, an inspection of the boilers is called for. Accretions on the heat transfer surfaces could be the cause of low steam flow rates. Additionally, it appears that the DFE's were run for several years with the WHRB's dry. Although done supposedly with the manufacturer's blessings, the extremely high temperatures of the exhaust, without the cooling effects of the water, could have damaged the equipment.

Test data for oil burning operation show a total steam output for three WHRB's, with DFE's at full load, of 4693 lb-steam per hour. During gas operation, the total is 6756 lb-steam per hour.

The approximate cost of energy

from the main boilers can be computed from the average steam production per gallon of fuel oil, the enthalpy increase of the steam and the price of the oil. From the most recent boiler data:

$$105 \frac{\text{lb-steam}}{\text{gallon oil}} \times (1359.1 - 252.74) \frac{\text{Btu}}{\text{lb-steam}} \times \frac{1 \text{ gallon oil}}{70 \text{ ¢}} = 166,000 \text{ Btu/¢}$$

which is about \$.006 per 1000 Btu. This calculation takes feedwater and steam enthalpies as 252.74 and 1359.1, respectively, fuel oil price as \$.70 per gallon and a typical value for steam production of 105 lb per gallon oil.

Assuming two DFE's in operation, the amount of steam which falls short of the design value is equivalent to the following energy loss for gas operation:

$$\frac{2}{3} (8460 - 6756) \frac{\text{lb-steam}}{\text{hour}} \times (1276.2 - 252.74) \frac{\text{Btu}}{\text{lb-steam}} = 1,162 \times 10^3 \frac{\text{Btu}}{\text{hour}}$$

using the design value of 2820 lb-steam per hour per WHRB and steam enthalpy of 1276.2 Btu per lb. at 500°F and 130 psi. The cost of replacing this energy, therefore, is

$$1162 \times 10^3 \frac{\text{Btu}}{\text{hour}} \times \frac{.006 \text{ ¢}}{1000 \text{ Btu}} \times 24 \text{ hours} \times 30 \text{ days} = \$5020 \text{ per month.}$$

For oil operation, the cost is

$$\frac{2}{3} (8460 - 4693) \frac{\text{lb-steam}}{\text{hour}} \times (1276.2 - 252.74) \frac{\text{Btu}}{\text{lb-steam}} \times \frac{.006 \text{ ¢}}{1000 \text{ Btu}} \times 24 \text{ hrs} \times 30 \text{ days} = \$11,100 \text{ per month.}$$

These costs justify bringing in the manufacturers' service representative if plant personnel cannot significantly improve WHRB performance.

Boilers Data Application

These data provide the operating efficiency of the boilers and could be compared with the efficiency indicated by the boiler manufacturer to see whether or not they are running properly.

The data also provide informa-

tion on efficiency changes with load which is required for evaluating the possibility of increased Dual Fuel Engine operation.

The more efficient boilers should be run more frequently in normal operation if significant differences are found.

Subsequent Data

Boiler characteristics using steam flow as a parameter, boilers 1 through 4, gas and oil modes -12/79-2/80 - steam flow rates, fuel consumption, steam temperatures and pressure, feedwater temperature.

These data are more systematic and cover the entire boiler load range unlike the original data set; also, they reflect the addition of improved damper controls and new ox-

ygen analysers, the effects of which are now evaluated. Therefore, these new data should be used in future calculations, and the initial set disregarded.

Observations

Although boiler data from the initial TEP testing were incomplete, there was sufficient indication of low efficiencies to warrant inspection of the equipment (see Table 10). This inspection disclosed that the combustion air flow controls did not work properly and led to the replacement of the damper mechanisms for air intake and new oxygen analysers on the exhaust.

The subsequent data collection (December, 1979, and February, 1980) showed marked improvement.

Note that values here refer to combustion efficiency only; overall boiler efficiency includes heat added to the feedwater in the economizer. Unless otherwise noted, "efficiency" will refer to the former.

Conclusions and Recommendations

The typical steam production per gallon of oil from our data is approximately 105 lb-steam/gallon. At a price of \$.70 per gallon, the cost of a pound of steam from the TEP boilers is about \$.0067, after boiler improvements.

For a typical flow rate of 70,000 lb-steam per hour, fuel cost, therefore, is \$469 per hour, reflecting an efficiency of 81.5% (Table 12, Boiler #3).

TABLE 12
STARRETT CITY
BOILER COMBUSTION EFFICIENCIES

	STEAM FLOW RATES x 1000 lb/hr	BEFORE IMPROVEMENTS			AFTER IMPROVEMENTS	
		JAN 1979 OIL	MAY 1979 GAS	JULY 1979 GAS	DEC 1979 GAS	FEB 1980 OIL
BOILER #1	>100	-	-	-	82.8	76.2
	60 - 70	56.1	-	-	83.2	77.1
	55 - 60	54.0	-	-	83.9	77.1
	45 - 55	51.3	66.6 *	-	81.6	78.2
BOILER #2	>100	-	-	-	83.5	70.8
	60 - 70	-	-	-	84.4	72.1
	55 - 60	-	-	-	83.0	72.2
	45 - 55	-	62.0 *	-	81.7	72.2
BOILER #3	>100	-	-	-	79.4	78.6
	60 - 70	68.7	-	78.7	84.4	81.5
	55 - 60	67.8	-	79.9	84.5	82.6
	45 - 55	65.8	-	79.2	84.5	82.8
BOILER #4	>100	-	-	-	80.7	71.1
	60 - 70	74.6	-	81.8	84.8	72.0
	55 - 60	73.7	-	83.5	93.8	75.7
	45 - 55	72.5	72.5 *	90.5	89.1	75.9

DESIGN COMBUSTION
EFFICIENCIES:

OIL FIRED - 85.6%
GAS FIRED - 82.5%

* MAY READINGS ARE AT FLOW RATES
OF APPROX. 30,000 lb/hr STEAM

At the efficiency prevailing before the repairs, 68.7%, fuel costs would be 18.6% higher, or \$556 per hour. Savings generated by the repairs, for this *single* boiler, are on the order of \$60,000 per month, assuming operation at the given flow rate.

At the full steam flow rate of 110,000 lb. per hour, a one percent reduction in efficiency, from a base level of, say, 80%, would result in additional fuel costs of \$6,686 per month, for each boiler.

These results emphasize the importance of monitoring boiler operation. Efficiency calculations should be performed regularly and decrements investigated as to the cause. The more efficient boilers should be run more often; even slight differences lead to considerable savings.

Sample boiler performance curves, comparing efficiencies before and after boiler improvements, are in Appendix C.

Turbine Generators

A report entitled "Starrett City Total Energy Plant Operation Analysis" has been prepared and is included in this report (Attachment 3) and Appendix C.

Data Application

These data are necessary to evaluate the basic operation of the plant technically and economically. Efficiencies can be calculated at various power levels, extraction steam and throttle steam rates and actual performance curves can be compiled.

The data allow internal power conservation measures to be translated into fuel savings and are necessary for analysis of augmented DFE operation to increase the overall plant efficiency.

Parasitic load and power usage data help keep track of electrical consumption, identifying areas of unusual use and describing load cycles so that conservation measures can be implemented and checked.

TABLE 13

STEAM REQUIREMENTS AND EFFICIENCIES

a. Spring and Fall

2 T.G. Operation			1 T.G. + 2 DFE Operation		
Steam Flow to HTHE X 1000#/hr	Throttle Steam Rate X 1000#/hr	Eff'y %	T.G. Throttle Steam X 1000#/hr	TTL Throttle Steam X 1000#/hr	Eff'y %
20	120	29.3	64	67.5	38.4
40	135	37.4	77.8	81.5	47.7
60	149	43.9	91.6	95.5	55.0
80	163	49.3	105.3	109.0	60.9
100	177	54.0	119.5	122.5	65.5

b. Summer

2 T.G. Operation			1 T.G. + 2 DFE Operation		
Steam Flow to HTHE + RM X 1000#/hr	Throttle Steam Rate X 1000#/hr	Eff'y %	T.G. Throttle Steam X 1000#/hr	TTL Throttle Steam X 1000#/hr	Eff'y %
40	135	38.8	77.8	83.4	48.9
60	149	45.3	91.6	97.2	55.5
80	163	52.2	105.3	110.9	62.4
100	177	57.0	119.5	125.1	66.9

Additional Instrumentation

Extraction steam flow from each turbine — FE-DEA, TI-DEA.

Steam flow and temperature to the deaerator — FM-DEA, TI-DEA.

Condensate flow and temperature from atmospheric drain tank — FE-ADT, TI-ADT.

Observations

Due to lack of proper instrumentation installed at the time of data taking, this analysis was prepared on the basis of TEP equipment design of the report. Operation of both turbines was compared with operation of one turbine plus Dual Fuel Engines for various operational levels during heating, cooling and "in-between" seasons.

The method of analysis used to compute flow rates was to perform a heat balance calculation on steam and condensate flows into the deaerator. This allowed the computation of steam flows to the heat exchangers

and condenser as a function of extraction steam flow rate, which is itself dependent upon throttle steam flow rates as given by the Turbine Generator Extraction diagram.

Overall power plant efficiency can now be calculated for various operating levels knowing these flow rates, efficiencies of individual pieces of equipment and steam and condensate enthalpies.

Winter heating required more steam for the Dual and High Temperature Heat Exchangers than could be supplied by one Turbine Generator plus two (or three) Dual Fuel Engine Waste Heat Recovery Boilers. There is no choice but to continue the present operation of running both TG's plus a DFE for peak load, at least during mid-Winter. Data and calculations from the January 1978 tests indicate that maximum HTHE and DTHE steam requirements are around 160,000 lbs per hour, while the highest extrac-

tion steam flow from one turbine generator plus three WHRB's equals 118,460 lbs per hour.

Steam requirements are lowest during the Spring and Fall, extraction steam being needed only for domestic hot water through heat exchange in the HTHE. Table 13 is a summary of the results of efficiency calculations for different HTHE requirements, along with corresponding throttle steam flows according to the T.G. extraction diagram. Overall plant efficiencies can be compared for two turbine and one turbine plus two DFE operation, and throttle steam flows for the one turbine are given assuming WHRB steam rates of 2820 lbs per hour each. It can be seen that the one turbine and two DFE operation is preferable at all extraction levels. Data from the May 1978 tests indicate that the maximum HTHE steam requirement is about 36,000 lbs per hour.

Although steam requirements are greater in the cooling season, it is expected that the one T.G. plus two DFE operation will meet the requirements. The highest recorded steam flow rate to the HTHE over the week of July 7-13, 1978 was 25,000 lb/hr. With the design steam flow rate to the refrigeration machinery (RM) at 74,000 lb/hr, it is unlikely that the steam production capacity will be exceeded, even at low electrical load, for most of the cooling season. Similarly to the in-between season, operation of the single T.G. plus DFE's is more efficient.

Conclusions and Recommendations

Table 12 summarizes the savings possible through the use of Dual Fuel Engines for a typical summer day. The data chosen is from June 8, 1979, 10 P.M. — the peak load for that day. Although savings will be somewhat less for lower loads, the peak was chosen to demonstrate

the adequacy of the power and steam supply.

Daily fuel savings, at \$.70 per gallon fuel oil, are over \$2800, or \$84,000 for each month of cooling operation. Figures 13 and 14 (in attachment 3) demonstrate how the load is presently being taken up by the two Turbine Generators and how, ideally, the TEP should be run to generate the savings estimated above.

As mentioned previously, all calculations were based upon design data and assumptions about TEP operation. Accuracy is sufficient to demonstrate the advantage of using the Dual Fuel Engines whenever possible to replace one Turbine Generator.

There is little doubt that such operation is possible for the Spring and Fall seasons; extraction steam requirements are low and could be met under any conceivable circum-

stance including the steam needs of the 26th Ward WPCP.

It also appears likely that single Turbine Generator plus DFE operation is sufficient for at least the bulk of the summer period. Although design data for steam flows to the HTHE and refrigeration turbines indicate requirements higher than that which can be supplied by one TG plus two DFE's, data from the various tests which were performed show actual needs to be much lower (see Table 14.)

Instrumentation since installed, especially extraction steam flow and flows to the heat exchangers and deaerator, allow a more accurate, and far simpler, calculation of steam requirements than was possible when the report was written. This is very important if there is any doubt about the adequacy of the steam supply when running in the more efficient one turbine mode.

TABLE 14

COMPARISON OF TEP OPERATION IN TWO MODES
FOR JUNE 8, 1979, 10 P.M.

	Two Turbines	One Turbine + 2 DFE
Power Output	TG1 = 4600 kw TG2 = 4600 kw	TG1 = 5000 kw DFE1 = 2100 kw DFE2 = 2100 kw
Extraction Steam Flow	TG1 = 25,000#/hr TG2 = 19,000#/hr	TG1 = 40,000#/hr DFE1 = 2,000#/hr DFE2 = 2,000#/hr
Throttle Steam Flow	121,000#/hr	74,500#/hr
Fuel Input	170X10 ⁶ Btu/hr	TG1 = 105 x 10 ⁶ Btu/hr 2 DFE = 41 x 10 ⁶ Btu/hr Total = 146 x 10 ⁶ Btu/hr
Fuel Oil Req'd	1181 gal/hr = 28,344 gal/day	1014 gal/hr = 24,336 gal/day
Fuel Cost (\$.70/gal)	\$19,841/day	\$17,035/day
Savings	\$2,806/day = \$84,180/mo.	

The substantial savings realized when operating one Turbine Generator is an incentive to maximize the proportion of annual operation performed in this mode. While this is feasible for 'in-between' and, most likely, for summer seasons, the high steam requirements of mid-winter exceed the capacity of this mode. The heating season for Starrett City, though, is much longer than the few mid-winter months, generally extending from October into April. During the times of marginal heating requirements, at the beginning and end of the period, it is very likely that demands could be met running one Turbine Generator and DFE's. Energy conservation measures being implemented at the Starrett City complex are expected to lower demand and make such operation still more feasible.

To maximize the period over which the TEP could operate on one T.G., we need to keep a more accurate watch over demand which is now possible with the newly installed instrumentation. A program of measurements taken over the heating and cooling seasons will allow us to define the conditions for which such operation is possible.

Develop Options

Digester Gas Transfer

Data supplied by the 26th Ward showed an average percentage of methane in the digester gas was 60% (Attachment 4). Values varied from the average by +10% to -3%. These values were obtained from samples taken daily over a 2-week period. Calculated Btu value of the gas, based on the 60% methane average, was 608 Btu/ft³.

A sample of the gas was given to U.S. Testing Company for detailed analysis and determination of Btu value. Their result (Attachment 4) indicated a thermal value of 636 Btu/ft³ dry and 624 Btu/ft³ wet. For the purpose of this study a value of 600 Btu/ft³ was used which was felt

to be a conservative value.

Data taken over a three-year period at the 26th Ward (Fig. 8) shows an average daily production of 400,000 ft³/day of digester gas. This value was used in all calculations to determine the economics of using the gas.

Total energy consumption at Starrett City was approximately 1440 X 10⁹ Btu. Digester gas could account for 87.6 X 10⁹ Btu/year or 6% of the total Btu requirement. Additionally, it is assumed that another 200,000 ft³/day of digester gas can be obtained by digesting sludge from Jamaica WPCP at the 26th Ward. This increases the total Btu supplied by digester gas to 131.4 X 10⁹ Btu/year or 9% of the total Btu requirements. This represents a significant portion of the fuel used at the TEP and is therefore considered a potential option.

Thermal Transfer

Based on a three-year summary of data at the 26th Ward the maximum thermal load was 11.5 MMBh. Data taken at the 26th Ward for the project showed that at peak loads the portion of heat supplied to the two active digesters was 60% of the total load. Therefore, if two additional digesters are used for Jamaica sludge, the peak load would be 19 MMBh.

On an average, the thermal load at the 26th Ward was 4.24 MMBh (based on a 3-year data summary). Increasing this by 60%, to take into account the operation of two additional digesters, makes the average load 7 MMBh.

At a constant kw output, increasing the turbine extraction by 18,267 pph (equivalent to 19 MMBh) increases throttle steam to the turbine by 11,500 pph. Since a minimum of two boilers are always on line, the increase per boiler is 5,750 pph. The boilers are rated at 110,000 pph and the maximum load recorded has been 60% rated or 66,000 pph.

Therefore, the addition of another 6,000 pph can easily be handled by the boilers. The fact that even at peak loading the boilers can supply the thermal requirements of the 26th Ward WPCP obviated the need to consider diurnal patterns of the thermal load at the 26th Ward. This option could satisfy all the heating requirements of the 26th Ward thus displacing the equivalent of more than 9,000 BOE used there. We therefore consider this as a potential option.

Effluent Transfer

From data collected during the program, maximum condenser flow during the Winter is 7,600 gpm and 30,000 gpm during the Summer. Minimum average summer flow at the 26th Ward amounts to 90 mgd (million gallons per day). From data taken over a three-year period, the minimum instantaneous flow was 45 mgd which occurred during the Spring. During the Summer months flow peaks at the treatment plant as it does at the TEP. Average flows at the 26th Ward do not fall below 80 mgd. In addition, the effluent temperature is consistently lower than the cooling tower water at the TEP. On the basis of quantity and temperature, the effluent from the 26th Ward could replace the cooling tower water at the TEP and its associated power consuming equipment. It is therefore considered a potential transfer option.

Electrical Transfer

Total electrical generation capability at the Starrett City TEP is 16 mw consisting of two steam turbine generators of 5 mw each and three dual fuel engines of 2 mw each.

Normal operation at the TEP is to operate the two steam turbine generators to handle the electrical load and supply extraction steam for domestic hot water and space conditioning. During peak load periods which occur between 5:00 p.m. and

11:00 p.m. the two turbines plus one dual fuel engine generator are operated. Therefore, the TEP has the potential of supplying 4 mw to the 26th Ward.

Select Options

Digester Gas Transfer

The transfer of digester gas from the 26th Ward to Starrett appeared to be a good possibility. However, before its selection as a viable option the technical feasibility and cost had to be determined.

Assuming the energy consumption at Starrett City is divided equally between the four boilers, the digester gas total Btu content represents 36.5% of the Btu input to a single boiler. It is therefore apparent that the digester gas will have to be co-fired with either oil or natural gas.

Coen Company, the original burner and burner control manufacturer, was contacted. They have extensive experience in co-firing fuels including low Btu waste gases. Coen Company suggested several constituents that the digester gas should be analyzed for. The list of items was incorporated into the specification given to U.S. Testing. A copy of the analysis was given to Coen and they stated that there was no problem in co-burning the digester gas and either natural gas or oil.

The burner assembly proposed is a single assembly consisting of three burners, one each for digester gas, natural gas and oil. A new windbox to accommodate the new burner plus a new control system are also required. The new control system will regulate the flow of digester gas and oil or natural gas to supply the boiler's thermal requirements. A new burner safety system is also required and is included in the control package.

Burner controls will be designed so that all available digester gas will be burned and oil or natural gas will supply the remainder of the Btu demand of the boiler.

Variations in the heating value of the gas can be tolerated up to $\pm 10\%$. Variations above this tolerance will require the addition of instrumentation to measure the heat content of the gas and modify the control circuits accordingly. This equipment would cost approximately \$20,000. To insure proper operation of the new burner train this equipment will be included in the design.

Aside from the $\pm 10\%$ tolerance on the Btu value of the gas, the burner manufacturer's only other requirement is that the gas be supplied at $1\frac{1}{2}$ psig to the burner train. Present design of the gas booster and storage system calls for a minimum of 2 psig at the burner train.

Instrumentation will be installed in the digester gas line to monitor flow, pressure, temperature and Btu value of the gas. Flow and Btu value will be recorded for a permanent record. The control system will be designed to give priority to burning digester gas. Natural gas and oil will essentially be used as supplementary fuels to supply the total Btu requirements of the boiler. All three burners will have a 10-to-1 turndown ratio. The digester gas flame is self-sustaining so that an auxiliary fuel does not have to be injected into the line to maintain the flame.

The digester gas line will be a 6" steel line. Construction, installation and testing of the line will be per Brooklyn Union Gas specifications for low pressure gas lines.

Aside from the ability to co-burn digester gas and either natural gas or oil, the burner is capable of supplying the entire boiler thermal load on natural gas or oil alone. Thus, the only need for storage of digester gas is to dampen fluctuations in flow. For this reason and to increase the safety of the system and reduce the complexity of the equipment, digester gas will be stored at low pressure (10 psig) in a spherical tank located at the 26th Ward.

Detailed cost estimates for instal-

led cost on the TEP side of the boundary are shown in Appendix A. Installed cost at the TEP is approximately \$605,000. Potential fuel savings (75¢/gal oil) are approximately \$684,000. Therefore, this option warrants further investigation.

Thermal Transfer

There is no technical obstacle to the TEP's supplying the thermal requirements of the 26th Ward. The necessary equipment is readily available and, as shown previously, the TEP has the extra capacity required.

Control requirements for this option are relatively simple. Water supply temperature to the WPCP will be sensed and will control a valve in the steam supply to a heat exchanger. Inlet and outlet temperatures and pressure gauges will be placed in both the water and steam lines. Steam and water flow will be recorded. These measurements will enable plant operators to determine whether or not the system is functioning normally.

Although the maximum load expected is 19 MMBh, the heat exchanger will be designed for the maximum load for which the 26th Ward heating system was originally designed. Those conditions are 30 °F difference between supply and return temperatures and 2,000 GPM. The design load therefore is 30 MMBH. Since this load included the operation of four digesters, it is not necessary to increase the load for digesting Jamaica WPCP sludge. We should note that should the thermal load ever reach 30 MMBh, the TEP boilers would be able to supply the Starrett City and 26th Ward peak loads and still operate at less than 75% of full load.

This option is based upon the premise that the TEP will receive all of the gas generated at the 26th Ward. Because of the advantages of cogeneration the TEP can get more work from a given amount of fuel than the WPCP can. Therefore, it is

more advantageous to burn all the digester gas at the TEP and have the TEP supply the WPCP's thermal load.

The advantage of burning the digester gas at the TEP is described by Carnot's maxim: "Heat should be added at the highest possible temperature and rejected at the lowest possible temperature if the greatest amount of work is to be gained and the highest thermal efficiency is to be realized."

Carnot's maxim can be demonstrated by a brief example using actual system conditions. The example will demonstrate that more available energy is realized when the digester gas is fired in the TEP boilers rather than the WPCP boilers. We must mention here that the TEP is a cogeneration plant. Steam is extracted from the turbine at 130 psig and used in a heat exchanger to generate space heating and domestic hot water. The heat exchangers are designed to condense the steam, thereby recovering the heat of vaporization.

System conditions are as follows:

NOTE: The ultimate heat sink for the TEP and WPCP is the atmosphere. Assumed average temperature is 60°F.

TEP

Throttle Steam at 820°F, 850 psig

$$h_g = 1407.9 \text{ Btu/lb} \quad s_g = 1.598 \text{ Btu/lb}$$

Condensate at 212°F, saturated liquid

$$h_f = 180 \text{ Btu/lb} \quad s_f = 0.312 \text{ Btu/lb}$$

$$Q_A = \Delta h = 1407.9 - 180 = 1227.9 \text{ Btu/lb}$$

$$E_u = \Delta s T_o = (1.598 - 0.312)(520) = 668.72 \text{ Btu/lb}$$

$$E_a = Q_A - E_u = 1227.9 - 668.72 = 559.18 \text{ Btu/lb}$$

Assuming a boiler efficiency of 80%, the Btu value of the fuel fired is:

$$Q_F \frac{1227.9}{.8} = 1534.88 \text{ Btu/lb}$$

$$\begin{aligned} \% \text{ of available energy} &= \frac{E_a}{Q_F} \times 100 \\ &= \frac{559.18}{1534.88} \times 100 = 36.4\% \end{aligned}$$

26th Ward WPCP

Water is heated from 185°F to 215°F

$$\text{at } 214^\circ\text{F } h_f = 183 \text{ Btu/lb } s_f = 0.3164 \text{ Btu/lb}$$

$$\text{at } 185^\circ\text{F } h_f = 152.9 \text{ Btu/lb } s_f = 0.2708 \text{ Btu/lb}$$

$$Q_A = 183 - 152.9 = 30.1 \text{ Btu/lb}$$

$$E_u = (0.3164 - 0.2708) 520 = 23.7 \text{ Btu/lb}$$

$$E_a = 30.1 - 23.7 = 6.4 \text{ Btu/lb}$$

Assuming a boiler efficiency of 80%, the Btu value of the fuel fired is:

$$Q_F = \frac{30.1}{.8} = 37.63 \text{ Btu/lb}$$

$$\begin{aligned} \% \text{ of available energy} &= \frac{E_a}{Q_F} \times 100 \\ &= \frac{6.4}{37.63} \times 100 = 17\% \end{aligned}$$

Therefore, 19.4% more available energy is obtained from the digester gas when burned at the TEP than when burned at the 26th Ward WPCP.

Symbol definition:

h = enthalpy subscripts f = fluid

s = entropy g = gas

Q_A = heat added

E_u = unavailable energy

E_a = available energy

T_o = degrees Rankine

Q_F = Btu value of fuel fired

Since the thermal transfer option is actually linked to the gas transfer option it, too, will be investigated further.

Details of the installed cost at the TEP are shown in Appendix A. Total installed cost (at the TEP) is approximately \$265,000. Savings accrued to the 26th Ward are discussed elsewhere.

Effluent Transfer

As noted previously, there is am-

ple volume of effluent at acceptable temperature levels to allow substitution of effluent water for the TEP condensers in place of cooling tower water.

What is questionable, however, is the effect of the water (effluent) on the piping and condensers at the TEP. A review of literature describing the use of effluent disclosed systems that use effluent for cooling tower makeup only. Our proposal is to use it on a once-through basis which we believe is less of a problem than using the effluent as makeup.

Chemical analysis of the effluent indicates that the average pH is slightly alkaline; average grease is about 12.6 mg/l and total solids are about 2,000 mg/l. The results are a mixture of good and bad. Being alkaline is a potential corrosion problem. However, it will also inhibit the formation of algae. The high grease content could foul the condenser tubes but the high total solids may tend to scrub the tubes clean and a flow rate of 2 feet per second should keep the solids from settling out and clogging lines.

New York City Water Pollution Control Plants have extensive experience with effluent used as cooling water (Figure 18). They use the effluent in blower coolers, engine coolers, oil coolers and air conditioning condensers. Their only treatment is to pass the effluent through a self-cleaning strainer. The operators of the various plants indicate that the only time they have problems is if the strainer is not maintained, that is, holes develop which are not repaired. It should also be noted that corrosion due to the effluent does not appear to be a problem.

A major strainer manufacturer was contacted (Zurn) to obtain strainer information and to learn what experience they had with effluent used for condenser cooling. The local office experience was primarily that of New York City's experience and they confirmed that, to their

knowledge, no problems were encountered using the effluent.

To attempt to evaluate the corrosive characteristics of the effluent a test was set up at the 26th Ward. Effluent, prior to cleaning by an effluent strainer, was passed through a small heat exchanger and corrosion coupons. The heat exchanger tubes were Admiralty metal, as are the condenser tubes in the TEP. Coupons of Admiralty metal, copper and steel were installed. These coupons represent the range of material the effluent would be in contact with at the TEP. Two sets of coupons were used. One stayed in service for 30 days, and the other for 90 days.

Results indicated that the Admiralty metal and copper were unaffected by the effluent. Steel showed a moderate to severe corrosion rate. Corrosion rate of the steel coupon after 90 days was half the rate indicated after 30 days. This would seem to indicate that once corrosion starts it forms a protective layer over the metal and inhibits further corrosion. This might be further indicated by the fact that other WPCP facilities using effluent for cooling for many years have not experienced corrosion problems.

For the preliminary cost estimates chemical treatment of the effluent to inhibit corrosion was included. Costs were estimated to be the same as current costs for treating the cooling tower water.

Another problem indicated by the test was that of a buildup of sludge in the end bells of the heat exchanger but not in the tubes. Apparently the fluid velocity in the tubes prevented the solids from settling out. As noted previously, the effluent for the test was taken before the effluent strainer at the 26th Ward. A small simplex basket type strainer was used in upstream of the heat exchanger. Since this was not a self-cleaning strainer it quickly became loaded and of little use.

Another test run was started using

a centrifugal separator upstream of the heat exchanger. Analysis of water in and out of the separator indicated a 96% solids removal rate. Analysis of coupons left in for periods of 30 and 77 days with the separator in place showed the same pattern of corrosion as previously noted. Admiralty metal and copper were unaffected. The steel coupon left in the line for 77 days showed a 30% lower rate of corrosion than the 60-day coupon. The level of corrosion of the 77-day coupon was termed "slight." Test reports are shown in Figures 19, 20, 21.

Our preliminary study incorporates a self-cleaning strainer in the effluent line because it is a proven device for flows of the magnitude required. Also, a great deal of experience has been obtained at treatment plants with self-cleaning strainers. In the initial design stage centrifugal separators will be investigated and evaluated in comparison to self-cleaning strainers.

Automatic condenser tube cleaning systems have been investigated. However, in view of the results at the treatment plants and the test at the 26th Ward, these systems were not included in the preliminary design. They remain as an option if further investigations indicate they are required.

Instrumentation for the system will deal primarily with sensing and recording flow rates. If for any reason flow from the 26th Ward falls below a predetermined level, the TEP will automatically switch over to the cooling tower. Motor operated butterfly valves will be used to isolate the effluent line and activate the cooling tower. Of course, this implies that the cooling tower will always be maintained in an operational state. Motor operated butterfly valves will be used to proportion flow between the refrigeration and turbine condenser lines in the Summer.

All the butterfly valves and the

automatic strainer will be located in an underground, concrete vault near the cooling tower. Access to the vault will be via manhole covers at the surface.

Fuel and water savings at the TEP are approximately \$372,000 (1980 fuel and water costs). Installed costs at the TEP are approximately \$385,000 (1980 dollars). Therefore, this option will be considered for further study.

Electrical Transfer

Although the TEP has the basic capability, if it were to supply power to the 26th Ward, the dual fuel engines would have to be operated almost continually. This would significantly increase maintenance. Consequently, in determining the amount of power the TEP could deliver, we must assume one engine out of service for maintenance. This would leave one engine on standby and one available for service. In other words, the TEP could supply 2 mw during off peak hours at Starrett City and zero power during peak hours.

Demand load at the 26th Ward has reached 2,400 kw. Therefore, the TEP could not supply the entire 26th Ward load. In addition, if any problems occurred at the TEP, they would have to immediately disconnect the 26th Ward.

To receive power from the TEP the distribution system in the 26th Ward would have to be sectionalized so that sections could be switched to or from PASNY as power at the TEP became available or unavailable. Preliminary estimates are that the equipment and installation costs would be on the order of \$750,000 to one million dollars.

Another consideration is that PASNY power presently costs \$0.045 per kwh while the TEP generates power at \$0.063 per kwh (assuming 75 cents per gallon of oil).

Because of the low PASNY rate structure the economics show that

Figure 18

The City of New York

DEPARTMENT OF ENVIRONMENTAL PROTECTION

AIR RESOURCES - WATER RESOURCES - ENERGY

2358 MUNICIPAL BUILDING, NEW YORK, NY 10007

Telephone 566-4124/5

Francis X. McArdle, Commissioner

Mr. William Diskant
American Hydrotherm Corporation
470 Park Avenue South
New York, NY 10016

August 30, 1979

Dear Mr. Diskant:

The following is in response to your list of equipment and materials at the TEP, and results of investigating the effect plant effluent might have on them.

The enclosed information and specifications were supplied by Mr. Kenneth Graefe, Chief of Instrumentation Section, who can be contacted at 860-9357.

	Heat Exchangers-Use and Maintenance		
NYC WPCP	Effluent Application	Effluent Strainer	Maintenance
Newtown Creek	engine cooler (see spec. pg. 816, 817)	Elliott Rotary (see spec. pg. 1028-1030)	punch the tubes, once or twice a year
	blower cooler oil cooler air conditioner condenser		
Tallman Island	engine cooler blower cooler	Zurn Rotary and basket	None
Owls Head	engine cooler blower cooler	Zurn Rotary	cleaning of tubes every 6 months due to holes in the strainer

The attached specifications, taken from the Newtown Creek Water Pollution Control Project Contract work, 1962, are those applicable to existing NYC treatment plants

FIGURE 19
CORROSION COUPON EXPOSURE RESULTS REPORT

FROM: STARRETT CITY POWER PLANT
ADDRESS: 165 ELMIRA LOOP
BROOKLYN, NEW YORK 11239

DATE: August 28, 1980

Attn: Mr. Al Muir, Director of Engineering

COUPON NO.	COUPON METAL	COUPON LOCATION	EXPOSURE PERIOD DAYS	TYPE OF CORROSION	CORROSION RATE/MPY	COMMENTS
AA	Admiralty Brass	26th Ward Sewage Effluent	29	Negligible	1.48	Excellent
493	Copper	" "	29	Negligible	1.20	Excellent
1052	Steel	" "	29	Severe	18.00	Requires water to be conditioned

TREATMENT

SIGNED:

FIGURE 20
CORROSION COUPON EXPOSURE RESULTS REPORT

FROM: STARRETT CITY POWER PLANT
ADDRESS: 165 ELMIRA LOOP
BROOKLYN, NY 11239

DATE: Sept. 26, 1980

Attn: Mr. Al Muir - Director of Engineering

COUPON NO.	COUPON METAL	COUPON LOCATION	EXPOSURE PERIOD DAYS	TYPE OF CORROSION	CORROSION RATE/MPY	COMMENTS
CC	Admiralty Brass	26th Ward Sewage Effluent	60	Negligible	0.9	Water treatment not required
494	Copper	" "	"	Negligible	1.2	" " "
1053	Steel	" "	"	Moderate-severe	9.7	Water treatment required

TREATMENT

SIGNED:

CHEMICAL TESTING CORPORATION

Creative Chemistry to Conserve Energy

November 14, 1980

Mr. Al Muir, Director of Utilities
Starrett City
165 Elmira Loop
Brooklyn, N.Y. 11239

Dear Mr. Muir:

This will report on the results obtained on the last two samples of 26th Ward sewage effluent to determine the effectiveness of the experimental centrifugal separator for the removal of suspended solids.

Influent - 475 mg/liter	Suspended Solids
Effluent - 16 mg/liter	Suspended Solids
% Removal - 96.6%	

The above results indicate that the separator was producing a good quality effluent at the time of sampling especially as it was also observed that the suspended solids were of a very flocculent nature.

Again we thank you for the opportunity to be of service.

Very truly yours,

CHEMICAL TESTING CORPORATION

G. Harvey Saunders
Director of Laboratories
cc: J. Jennings

FIGURE 21 (sheet 2 of 2)
CORROSION COUPON EXPOSURE RESULTS REPORT

FROM: STARRETT CITY POWER PLANT
ADDRESS: 165 ELMIRA LOOP
BROOKLYN, NEW YORK 11239

DATE: NOVEMBER 21, 1980

COUPON NO.	COUPON METAL	COUPON LOCATION	EXPOSURE PERIOD DAYS	TYPE OF CORROSION	CORROSION RATE/MPY	COMMENTS
510	Copper	26th Ward	29	Negligible	1.1	No treatment required.
1082	Steel	Sewage	29	Moderate-Severe	10.5	Treatment would be required.
BB	Admiralty Brass	Effluent	77	Negligible	0.85	No treatment required.
492	Copper		77	Negligible	0.66	" " "
1054	Steel		77	Slight-Moderate	6.9	Treatment would be required.

TREATMENT

SIGNED:

this option would operate at a permanent loss. In addition, due to the limitations that would be imposed on the transfer of power, PASNY is a more reliable source of power for the 26th Ward. Therefore, this option was dropped from consideration.

Preliminary Design

General

Preliminary design drawings and cost estimates are included in Appendix A as well as a copy of the following text.

Digester Gas Transfer

An average of 600,000 cubic feet per day is to be transferred from the 26th Ward to the TEP where it will be burned in the boilers.

Equipment

Existing boilers at the TEP are capable of burning oil or natural gas. New burners will replace the existing ones in two boilers and will be capable of burning digester gas and either natural gas or oil. Co-burning of digester gas and natural gas or oil is necessary because the digester gas can supply only 25% of the thermal requirements of one boiler at average loads (approximately 60,000 pounds per hour).

The new burner assembly will consist of three concentric burners. Outermost will be a scroll type burner suitable for low btu gases. Center ring will be a standard ring type natural gas burner and the inner ring will be a standard oil burner.

A new wind box will have to be

mounted on the boiler to accommodate the new burner arrangement.

Two boilers will be modified to burn digester gas to allow for routine maintenance or downtime of one while still maintaining the ability to burn all available digester gas on the second unit.

Controls

Burning of all available digester gas is the basic parameter in the design of the control system. Digester gas flow rate and Btu content will be measured and fed to a controller along with inputs from load sensing elements. The controller will operate gas or oil (operator's choice) fl valves to satisfy the load requirements. If digester gas flow is interrupted for any reason, the system

will automatically switch to the secondary fuel previously selected. Both the natural gas and oil burners will have the capability of supplying the full load thermal requirements of the boiler. Therefore, an interruption in digester gas flow will not cause the boiler to shut down or operate at a reduced load.

Thermal Energy Transfer Equipment

Hot water for all of the 26th Ward's thermal requirements will be supplied by a single 30 MMBh two pass, steam to hot water heat exchanger. Maximum hot water flow will be 2,000 gpm with 185 °F inlet and 215 °F outlet temperatures. Maximum steam flow will be approximately 30,000 pound per hour.

The heat exchanger will be mounted in the same area as the existing Dual Temperature and High Temperature Heat Exchangers.

Existing boilers at the 26th Ward will remain operational so that a back-up heat exchanger is not necessary.

Controls

The outlet temperature of the heat exchanger will be monitored. A temperature transmitter will supply an input signal to a steam control valve on the inlet side of the heat exchanger. This valve will increase or reduce steam flow to maintain the outlet water temperature.

Effluent Transfer Equipment

The major unit, on the TEP side, for this option is a 36 inch, self-cleaning strainer on the incoming effluent line.

In addition, there are five new motor operated butterfly valves whose function is to isolate the existing cooling tower from the effluent system and vice versa. By maintaining the cooling tower operational it will serve as the back-up to the new effluent cooling system.

Controls

Temperature of the effluent returning to the 26th Ward will be monitored. If the temperature varies from a preselected temperature setting, a signal will be sent to the variable speed effluent pumps at the 26th Ward and they will increase or decrease flow as required.

Should effluent flow fall below a predetermined level, the system will automatically switch to the cooling tower mode of operation.

For the WPCP Analysis-Data Collection General

The 26th Ward WPCP instrumentation system monitors and controls process and environmental conditions throughout the entire plant including the inlet sewer system. Measured data are used for plant operating records, automatic process controls and safety warnings. Interlocks with the motor controls provide equipment overload protection and malfunction alarms on instrument panelboards in various areas.

Parameters monitored for major process control are: sewage flow and main sewage pump operating conditions, sludge flows, air flows, digester gas flows, wet well and tank levels, and digester temperature. In addition, combustible gas and oxygen levels are measured in enclosed areas for safety. Pressures are gaged locally at pumps.

Existing instrumentation provides enough data to control the treatment processes. It did not, however, provide enough information to determine the energy balance of the plant. It was determined that certain modifications and additions were needed to quantify energy use and production. Water flow meters were installed, gas meters were serviced and thermometers were calibrated and placed throughout the hot water system.

Data collection was performed in three parts. Existing records covering a three-year period were reviewed to obtain a "historical" perspective of the 26th Ward WPCP operations and process. Daily records routinely kept at the plant were used to generate certain information required. Where no data or not enough detail was available, special data collection periods were established.

Data Sheets

Data collection for these special periods was performed by union apprentice electricians, New York City CETA employees, and regular WPCP operating personnel. To simplify the collection and assure accuracy, special data collection sheets were prepared. Copies of these sheets are included in Appendix B.

Figure 22 shows the sources of data for the various parameters associated with the exchange options. Table 15 lists the various time periods and parameters for the special data collection programs. Seasonal temperature variation was the main factor which determined the schedule of special data collection programs. Plant energy requirements were established during temperature ranges from warm to cold. The schedule of data collection was also dependent upon new instrumentation being installed and functioning.

Digester Gas

Gas production and utilization flows are measured at the digesters, waste gas burners and boiler compressor room. The meters (Hagen ring balance, differential pressure type) display instantaneous flows and totalize. The meter in the boiler room area was out of service. This meter was put into operation to record the gas supplied to the boilers.

Difficulties balancing the gas flows were traced to problems with all meters. Meters were recalibrated

DATA SOURCES

DIGESTER GAS OPTIONS

DATA AVAILABILITY

0% 50% 100%

CU. FT. DIGESTER GAS PRODUCED

CU. FT. DIGESTER GAS USED

CU. FT. DIGESTER GAS WASTED

CHEMICAL ANALYSES

ELECTRICAL OPTIONS

TOTAL POWER USAGE, KWH

DISTRIBUTION OF POWER
WITHIN PLANT
(KW, AMPS, HRS., ON/OFF)

THERMAL OPTION

FUEL USE IN BOILERS
(CU. FT. GAS, GALS., OIL)

DIGESTER HEATING LOAD
(TEMPERATURE, PRESSURE,
HOT WATER RECIRCULATION)

EFFLUENT OPTION

EFFLUENT FLOW, MGD

EFFLUENT ANALYSES

EXISTING DATA

EXPANSION OF EXISTING
DATA

NEW DATA REQUIRED
SPECIAL COLLECTION
PROGRAM

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 22

and some were serviced by manufacturer's representatives. It was also found that incorrect conversion factors had been used in reporting gas production since the meters were installed. After repair and calibration, the gas production meters were determined to be accurate to within plus or minus 2%.

The waste gas meter is of the same type as the gas production meters. Its range, however, is 800,000 ft.³/day. Hourly readings showed that the waste gas meter did not indicate any gas flow when flaring was obviously taking place. After further attempts at recalibration did not correct these discrepancies, it was concluded that the meter could not register flows of gas below 100 ft.³/min. or 144,000 ft.³/day. Thus, the digester gas profiles used for the options are based on data recorded for gas produced and gas used by the boilers. The amount of gas wasted was determined by subtraction.

The plant was recording the gas produced every four hours, and gas wasted once a day. This did not produce sufficient data to generate the daily and seasonal profiles of gas flows required for this project. Hourly gas flow data were collected for dates as shown on Table 15.

A factor affecting the meter accuracy was accumulation of condensation in the gas lines. To limit this the lines were drained once every 8-hour shift. Intermittent low pressures below 3 inches of water were also thought to affect accuracy of readings.

Special Laboratory Analyses

Data were compiled on the quality of the 26th Ward WPCP digester gas. It was necessary to determine how the digester gas, when used at the TEP, might affect existing equipment and materials.

It had to be determined whether the constituents of digester gas could adversely affect the integrity and operation of the TEP boilers. These boilers operate at higher temperature and pressure than 26th Ward boilers, so it could not be assumed with confidence that the TEP boilers would perform as well.

Laboratory analysis of digester gas is not included in the daily sampling requirements of a treatment plant. Intermittent sampling of digester gas is performed in order to observe the proper functioning of the plant digesters as part of process control. The gas consists of methane (CH₄) and carbon dioxide (CO₂) with traces of hydrogen sulfide,

nitrogen, carbon monoxide and moisture. At the Jamaica WPCP, grab samples of digester gas were collected from once a month to once a week for one year (April, 1979 to March, 1980). The results for carbon dioxide content ranged from 22.2% to 39.5%, and averaged 34.6%. The corresponding values for methane content ranged from 77.8% to 60.5% range, and averaged 65.4%. These are typical values for digester gas composition, since the gas is formed through a biochemical reaction and the components are relatively fixed. The heating value is approximately 630 Btu cubic foot.

26th Ward digester gas was sampled daily for seventeen days (2/26/79 - 3/20/79) and analyzed by gas chromatography and mass spectroscopy to obtain information on all constituents. These analyses were performed at the NYC-DEP, Division of Plant Operations Laboratory. A composite sample was also collected and analyzed by U.S. Testing Co. which verified the heating value and trace elements. These results are shown in Attachment 4.

Thermal Energy (Space and Process Heat)

The 26th Ward WPCP uses dual

TABLE 15

26th WARD/STARRETT CITY ENERGY EXCHANGE

SPECIAL 24 HOUR DATA COLLECTIONS

DATE	GAS PRODUCTION	GAS WASTED	GAS FEED TO BOILERS	OIL USE BOILERS	BOILER HOT WATER FLOW AND TEMP.	SLUDGE HEATING HOT WATER AND TEMPERATURE	SLUDGE HEAT EXCHANGER TEMPERATURES	MAIN SEWAGE PUMPS MAIN BLOWERS, SWITCHGEAR AMPS, KWATT
2/12/79-2/26/79	x							
4/17/79-4/30/79	x	x	x	x	x			
6/7/79-6/19/79*	x	x	x		x			x
8/8/79-8/22/79	x		x			x		x
12/3/79-12/18/79	x	x	x	x	x	x	x	
2/19/80-3/8/80*			x	x	x	x	x	

*Preceded by 2 day - daytime hourly readings to establish parameters for 24 hour surveys.

fuel boilers to produce hot water which circulates in a closed loop to provide process, space heating and hot water for washing equipment. The three main hot water circulation pumps are in the boiler room. Two others are in the digester building near the sludge heat exchangers and serve a separate sludge heating loop. Although the main circulating pumps are constant speed, the flow can vary with system demand. In order to measure flow, an "Annubar" flow measuring device was installed near the boilers in the main return header.

Oil supply flow is measured at each boiler. Oil not fired in the boilers is returned to the fuel tanks. The return flow was not previously measured. Meters were installed on the return lines so oil consumption and boiler efficiency could be calculated. Plant records were also examined for previous years' oil purchases.

Profiles of the heating needs of the WPCP on a daily and seasonal basis had to be generated so the TEP could determine their capability for supplying the thermal requirements of the 26th Ward plant. Temperature ranges and average thermal needs for 26th Ward were determined. When the concept of digesting Jamaica WPCP sludge at 26th Ward to produce more gas came under consideration, additional detail was required. A scheme of data collection was developed which would determine the amount of thermal energy used by the digesters versus space heating. The additional heat load of operating additional digesters could then be determined. The approach was to record the total Btu/hr output of the boilers and the Btu/hr transferred to the sludge heat exchangers, the balance being the amount used for space heating. No existing instrumentation could give this data. For close accounting of heat transfer to the sludge, thermometers were cali-

brated and additional units installed. Manometers were connected to the orifice plates in the hot water circulating pump discharge lines to determine flow.

Hourly readings of the hot water temperature and pressure were taken to calculate the Btu transfer out of the boiler room, and to the sludge heat exchangers. Some difficulties were encountered, since the hot water circulation from the boiler room is continuous, and the sludge heating hot water circulation is intermittent. Sludge heating hot water pump operation is controlled manually according to the temperature of the sludge.

For the boiler output, water temperature was measured in supply and return lines. The temperature gages on the heating control panel are divided in ten degree (°F) increments which was not accurate enough for close monitoring of the system. New thermometers were installed which read in 1°C increments, providing more accurate data. Temperatures were verified by thermometers in other locations throughout the plant.

Effluent

Sewage flow data were gathered from existing plant records. No additional equipment or modifications were needed for this phase of the study. Continuous flow recording strip charts were obtained from the plant to correlate flow variations with time and weather. Since sewage temperature does not change quickly, daily readings routinely taken were considered sufficient.

The effluent at 26th Ward is of high quality in terms of wastewater treatment. For the past several years the effluent has consistently met secondary standards of less than 30 mg/l suspended solids (SS) and biological oxygen demand (BOD). These analyses are performed daily. Figures 15 and 16 show the average annual temperature and pH varia-

tions for three years of data. These parameters are also measured daily. Concentrations of twelve metals, determined from monthly composite samples are listed in Table 6 for years 1976 through 1978. Effluent grease content is also analyzed monthly and is compiled in Table 5.

Special Laboratory Analyses

Additional effluent analyses were required to determine constituents which may have adverse effects on TEP equipment when effluent is used as cooling water. These analyses were performed by the Division of Plant Operations laboratory. Total solids were analyzed daily for two-week long periods, May 6 to June 7, and July 21 to August 7, 1979. During the latter sampling period hardness, conductivity, and chlorides were also tested.

Influent chlorides are recorded daily. Effluent chloride tests were done to verify that the influent values do not change through the treatment process. The results corresponded to samples collected in March 1979 and analyzed by the Bureau of Water Supply laboratory. The results are shown in Table 6.

Electric

Electrical power at the 26th Ward WPCP is supplied by PASNY via Consolidated Edison and introduced into the main substation from three 26.4 Kilovolt (kv) service feeders. Nominal 4160 V service is supplied to the plant by use of three 26.4-4.33 kv transformers. Record-ers monitor the electric use by the plant at the main substation at 15 minute intervals. A computerized listing of this data and the conversion to kilowatt-hours was supplied for the year 1978. The Main Building houses a substation fed from the high tension 4.16 kv switchgear, which consists of two 1500 4.16kv-480 V transformers and 480 V switchgear.

The hypothesized options for electrical exchange included the selective supply of electricity to operate certain equipment on a stand-by basis for emergencies. Further system information was compiled to determine the feasibility of this option. A complete list was made of all motors 7.5 horsepower and larger in the plant. They were summarized according to the distribution centers supplying the electricity. This information is included in Table 3.

In order to determine the distribution of power to various major motors and distribution centers, a data collection program was developed. For two, one-week periods, 24 hourly readings were taken at the distribution centers. Six distribution centers are in the main building and four others are in the former chlorine building. For these distribution centers, amperes and kilowatts were recorded. Each distribution center has duplicate switchgear and instruments. The hourly readings were taken from both sets of instruments and compared.

For the main sewage pumps, blowers and transformers in the Main Building, kilowatt-hours as well as amperes and kilowatts were recorded.

The kilowatt-hour meters have the multiple dial faces (similar to the standard water meter). A separate data sheet was supplied with blank dial faces in which the data collector would draw the needle location. This reduced the potential for error. The technician taking the readings converted the dial readings to their corresponding numbers in the period between hourly readings. Daily electric power demand is shown on Figure 8.

Data Reduction and Evaluation

General

Readings were taken hourly for

dates and parameters shown on Table 15. Vast quantities of raw data were generated. Hand processing these data included such repetitive operations as subtracting hour 2 data from hour 1, multiplying by the same conversion factors and calculating the desired parameters. A program was written for desktop programable calculator which processed the raw data. Data sheets were collected daily, and raw data was input to the calculator. Results were generated with significantly less effort than with hand processing.

Most data were plotted producing diurnal curves of the various parameters monitored. These diurnal curves are included in Appendix B.

Also, many summary curves and tables were produced both from data routinely collected at the plant and from data obtained during special collections. These summaries are included where appropriate in this volume and are repeated in Appendix B.

Digester Gas

Two of the four digesters at 26th Ward WPCP are required for handling the present solids loading to the plant. The gas produced in the digesters is sent to the boilers as fuel or flared in waste gas burners when gas production is in excess of boiler demand.

An initial attempt was made to obtain a balance of gas produced, gas used, and gas wasted by taking hourly readings of the three flows during one week. The initial data could not be balanced, and consequently, a thorough check was made of the system.

The gas pressure operates regulator valves and pressure switches to send gas to the boilers or flares. If there is heating demand, the gas will be sent to the boilers. A pressure of 2 inches of water will start the lead compressor which feeds the boilers. If the pressure still continues to build, a second compressor will

switch on. If pressure continues to rise, the first waste gas valve will open and flare the waste gas. When there is no boiler demand, all gas is flared and valves open sequentially at 7, 8 and 9 inches of water allowing as many as three flares to operate. If there is a line blockage or extreme high pressure, a relief valve will open on the digester dome and vent the gas.

It was found that the boilers were not using gas due to low pressures. Boiler controls were checked and found to be operational. The relief valves on the digesters were found to be set to maintain too low a digester pressure. Additional loading was applied and the valve seats were repaired, thereby increasing gas pressure. Another malfunction was discovered at the waste gas burner where gas was bypassing the regulator valves through auxiliary piping. This situation was corrected and the regulator valves were adjusted to a higher pressure. Line pressure was increased so boilers were cycling regularly and using gas preferentially.

The daily gas production figures for 26th Ward are shown on Figure 12. These are derived from data logs regularly kept at the WPCP and verified during special data collections undertaken during this project in February, April, June and August, 1979. Analysis of the hourly gas production data taken during these special collection periods shows that diurnal peaks 150% of the daily average can be expected. Digester gas utilization is shown on Figure 13. The gas produced and gas used in boilers are based on measured quantities, the balance represents the gas wasted (flared).

Analyses show that the gas heating value will range between 580 to 650 Btu's per cubic foot. Results of physical and chemical analyses performed by NYC-DEP and U.S. Testing Corp. are shown in Attachment 4.

Since the Jamaica WPCP gas pro-

duction meters were inoperative, gas production was computed using plant records of the weight of volatile solids added to the digesters and data from other New York City treatment facilities relating gas production to volatile solids. By subtracting thermal requirements, also developed from plant records, it is calculated that an additional 200,000 cubic feet per day of digester gas can be generated for transmission to the Starrett TEP. Assuming the variations in production which were observed for 26th Ward digester gas apply to the combined 26th Ward/Jamaica production, daily quantities are expected to vary between 150,000 to 1,200,000 cubic feet per day or 105 to 835 cubic feet per minute. Diurnal peaks 150% of the daily average gas production should still be accommodated.

Additional gas produced by processing Jamaica sewage is expected to have the same heating value as that measured for 26th Ward gas, i.e., between 580 and 650 Btu's per cubic foot. It is considered quite likely that the total gas production will exceed the 600,000 scfd used in the option evaluations.

Thermal Energy

The 26th Ward thermal energy requirements were determined from plant records and verified by the special data collections undertaken in June, August, October and December, 1979, and February, 1980. Daily average thermal demands are shown on Figure 9. The average ranges from a low of 2 million Btu/hr. in the summer to a high of 8 million Btu/hr. in winter. Diurnal variations in thermal demand for the critical cold weather months are shown in Appendix B.

The proportion of thermal demand required for digester heating versus space and hot water heating were determined during the special collection periods. Results averaged from a 40%-60% split to 50%-50%

split between space heating and digester heating. During a two-week cold period of testing in February-March, 1980, ambient air temperature ranged from 16°F to 44°F and remained below freezing over eight consecutive days. The boiler output average was 6.5 million Btu/hr. and average daily maximum was 9.5 million Btu/hr. during this testing period.

The temperature data collected in the hot water system averaged 185°F supply and 165°F return. This is lower than the design of 215°F supply and 185°F return. This variance is reasonable, since the system was designed to supply heat to four digesters and only two are being used. These results support the hypothesis that obtaining hot water at 215°F from the TEP and operating an additional digester would increase overall system efficiency.

Effluent

Three years of plant flow data were summarized from monthly summary sheets. The average flow treated is 90 mgd. The plant is designed to handle a peak loading of 120 mgd during storms. Since the significant flow variations occur during rainfall, plots of daily dry weather and hourly flow variations yielded little useful data. This is typical of a plant served by a combined sanitary and storm water collection system.

The three year summary plots show metered flow by month including minimum and average daily flows. Flows peaked during the summer months. Effluent temperature data averaged over three years were also plotted. Flows and temperatures are shown in Figures 14 and 15, respectively.

Minimum flow was compared to maximum TEP demand to assure availability of cooling water. Flow is divided among seven final settling tanks but effluent will normally be withdrawn from only four. Under

all expected flow conditions, cooling requirements will be met. Water surface elevations in the final tank effluent channel were observed for use in pump station design.

Effluent pump sizing was based on data obtained from TEP data collection. Cooling tower temperatures and flows were used to determine heat rejected to the cooling water. It was then compared with sewage temperatures. The required effluent flow to the TEP was determined based on removing an equivalent amount of heat (Btu's) from the condensers and heat exchangers. Diurnal and seasonal variations were examined to gauge the required effluent pump flow range.

Electric

Electric data gathered at the plant and from Con Edison were plotted versus time. Daily profiles were drawn to determine peak load and maximum usage. All equipment with motors 7-½ hp and larger were tabulated. Power use at the main pumps and main blowers was also plotted, as these are the largest power consumers in the plant. Motor ratings are shown on Table 3. The electrical distribution system was traced to determine which switchgear fed which equipment. Hourly peaks and usage were plotted for each distribution center. These diurnal plots are shown in Appendix B.

It was determined that the TEP does not have sufficient excess capacity to supply 26th Ward with electrical power on any certain basis. Also, there was no feasible method of supplying partial or peak shaving power to 26th Ward. Diurnal and seasonal variations of power consumption at Starrett and 26th Ward are determined by independent factors. Power use at 26th Ward varies mainly with rainfall, while at Starrett City it varies hourly with temperature, population and use of lighting appliances, and seasonally with heating and cooling requirements.

Balancing power production between demand for 26th Ward and Starrett City would be extremely difficult.

Also the incremental cost of generating power at the TEP is higher than the PASNY rates currently paid at 26th Ward. This circumstance makes the electrical energy transfers uneconomical.

Develop Options

General

The development of options was a step in the study which consisted of defining the quantities of energy resources to be exchanged and identifying the equipment and other facilities necessary for the exchange.

Digester Gas

Three of the four digester gas exchange options hypothesized were developed. For the purposes of this analysis the quantities of gas to be transferred under the three options was assumed to be 200,000 scfd, 400,000 scfd and 600,000 scfd as shown:

	SCFD
Transmitting excess 26th Ward gas	200,000
Transmitting all 26th Ward gas	400,000
Transmitting all 26th Ward gas plus excess Jamaica gas	600,000

The operation of the gas transfer option would be the same for any of the flow quantities. The operation of the digesters including gas mixing would remain as at present. Control of the process is arranged to maximize gas production. Gas currently transmitted to the boilers and waste gas burners would be intercepted and directed to new compressors.

The initial evaluation of alternative gas transfer options was based providing a new compressor building. During the latter stages of the study it was determined that

compressors could be located in the existing gas compressor room. Four gas compressors would be provided to pump gas from the digesters into a flow damping tank and from there to the TEP. Three of the compressors would handle the peak flow allowing for one standby unit. Compressor control would be accomplished by maintaining the proper operating pressure in the digesters (compressor suction pressure).

The gas flow damping tank would be a steel tank 22.5 feet in diameter storing gas at 10 psig.

The tank's outlet pressure would be regulated down to a constant level as required by Starrett TEP facilities.

Gas from the storage tank would be transmitted to the Starrett TEP in a 6-inch diameter steel pipe approximately 500 feet long.

A list of major equipment and facilities follows:

Option	200,000 SCFD	400,000 SCFD	600,000 SCFD
Number of Compressors	2	3	4
Capacity of Compressors SCFM	450	450	450
Compressor Discharge Pressure PSIG	10	10	10
Compressor Motor Horsepower	40	40	40
Storage Tank Capacity SCF	10,000	10,000	10,000
Pipeline Diameter Inches	6	6	6

An engineering judgment was made to size the tank and pipeline for the 600,000 scfd alternative in case it was decided to change to that capacity in the future. The incremental cost of this oversizing is very small when compared with the flexibility provided and the cost of increasing equipment sizes in the future.

Thermal Energy

The thermal energy exchange option developed for the project required all 26th Ward heating requirements to be supplied by the

TEP. Hot water would be piped from the TEP and enter the heating loop at 26th Ward.

Initially it was thought that very little new equipment would be required for the transfer of hot water. The only modifications would be new piping to the TEP, connection to the 26th Ward heating loop and a boiler bypass. Boilers would be shut down and existing circulating pumps continue to operate. It was later found that, since the hot water will be introduced in the rear of the plant in the thickener gallery, new circulating pumps and expansion tanks will be needed. Pumps and tanks will be installed in the thickener gallery. There will be three pumps, 920 gpm each, with total dynamic head of 130 feet. The expansion tanks will be 1150 gallons each.

The existing circulating pumps and boilers will be shut down but will be kept operational to serve as stand-by. A constant supply of 215°F water will be supplied from the TEP. One or two circulating pumps will be operated as heating requirements vary. Hot water will be transferred between the plants in prefabricated insulated piping.

Effluent

The effluent transfer option was developed for preliminary design. Cooling water from the cooling tower will be replaced with effluent from 26th Ward. The cooling tower, circulating pumps and fans will be shut down but maintained in operating order as stand-by. The quantity of effluent transferred will equal the cooling capacity of the existing system, between 3,500 and 39,000 gallons per minute.

Effluent was to be withdrawn from the chlorine contact tanks and pumped to the TEP. Concern was expressed about the corrosive properties of chlorinated effluent on condenser piping and heat exchangers. The withdrawal point was relocated to the final tank effluent

channel, where unchlorinated effluent is available.

Four vertical turbine transfer pumps are required to meet the varying cooling needs of the TEP. They will be 12,500 gpm each, driven by 350 hp variable speed motors. The TEP will control pump speed and number of pumps in service. Effluent will return to 26th Ward for chlorination and discharge. Transfer piping will be 36 inches in diameter. A pump station will be built adjacent to the digesters and thickeners to house the pumps and electrical switchgear.

Electrical Energy

None of the three electrical energy transfer options was developed. The TEP does not have sufficient excess capacity to supply 26th Ward with electricity. In addition, capital and operating costs were high for these options.

Sludge/Solid Waste

The Refuse/Sludge Coincineration Study prepared by Camp Dresser & McKee is included in its entirety in Appendix D of this report. Preliminary cost estimates for these options are given in Tables 16 and 17. Four hypothesized options were developed:

- Case I. Codisposal of Starrett City residential and commercial refuse with an equal amount, by weight, of 26th Ward WPCP thickened raw sludge, centrifuged to 18% solids and predried to 80% solids. Case I-A considers the economic impact of using digested sludge as a feed to the dryer (at 18% solids). This system produces high pressure steam for delivery to the TEP turbine inlet.
- Case II. Codisposal of Starrett City residential and commercial refuse with an equal amount by weight, of 26th Ward WPCP thickened raw sludge, centrifuged to 18% solids and predried to 80% solids. This system produces medium pressure steam, which would be used to offset extraction steam at the TEP, allowing the TEP turbines to be run with less extraction, and less throttle steam.
- Case III. Disposal by incineration of Starrett City residential and commercial refuse only. This would produce 130 psig steam for use at Starrett City.

TABLE 16

Capital Cost Estimates
(1981 Construction Start)

	Case I	Case IA	Case II	Case III	Case I
MCU's & Boilers	\$1,902,000	\$1,902,000	\$1,143,000	\$ 718,000	\$1,902,000
Scrubber System	121,000	121,000	121,000	-	-
Dewatering System	575,000	876,000	575,000	-	-
Drying System	802,000	802,000	802,000	-	-
Building	1,314,000	1,314,000	1,314,000	697,000	801,000
Loader	25,000	25,000	25,000	25,000	25,000
Scale	25,000	25,000	25,000	25,000	25,000
Inside Piping	24,000	24,000	24,000	6,000	6,000
Outside Piping (1)	48,000	48,000	48,000	-	-
Conveyors	42,000	42,000	42,000	-	-
	\$4,878,000	\$5,179,000	\$4,119,000	\$1,471,000	\$2,759,000
Engineering & Legal Fees, 15%	\$ 732,000	\$ 777,000	\$ 618,000	\$ 221,000	\$ 414,000
Contingencies, 10%	488,000	520,000	412,000	147,000	276,000
Interest During Construction (12% per annum)	732,000	777,000	618,000	221,000	414,000
TOTAL CAPITAL COSTS	\$6,830,000	\$7,253,500	\$5,767,000	\$2,060,000	\$3,863,000

¹Includes sludge feed line and chlorinated effluent line for scrubber and dryer condensers.

Case IV. Disposal by incineration of Starrett City residential and commercial refuse with an equivalent amount, by weight, of waste delivered by the City of New York. This system produces high pressure steam for delivery to the TEP turbine inlet.

The quantity of solid waste generated at the Starrett City complex consists of approximately 21 tons/day commercial waste. An additional bulky waste of 1.3 tons/day was not planned for use. The refuse is 80% combustible and 20% non-combustible based on New York City solid waste characteristics.

The raw and digested sludge produced at 26th Ward is 31 and 18 dry tons/day respectively. The sludge from Jamaica WPCP is 61 and 36 dry tons/day. The volatile content is about 70% in the raw sludge and 58% in the digested sludge. These are projected 1980 figures.

The energy conservation options under consideration draw on three areas of technology: (1) systems for

combustion of solid waste and, potentially, sewage sludge, (2) systems to dewater the dilute (3-5% solids) sewage solids generated at the 26th Ward WPCP and (3) systems to dry the dewatered sludge to 80 to 85% solids for co-combustion with refuse.

This study (Appendix D) is based upon the application of "modular combustion units" (MCU's), often called "starved air" or "controlled air" incinerators. This equipment is built on a production basis by several American manufacturers, and is sold as factory-assembled package units. Sizes available range from about 10 to 50 tpd (70-350 tpw), and options include choices as to the degree of mechanical handling to be provided for refuse feed and residue removal, and the energy recovery method to be used, if any. The equipment has demonstrated capability to thermally reduce the volume of waste material; to recover

TABLE 17

ANNUAL OPERATING COST ESTIMATES
(1983)

	Case I	Case IA	Case II	Case III	Case IV
Variable Costs					
Fuel	34,900	34,900	34,900	17,500	34,900
Electricity	151,600	151,600	151,600	42,100	151,600
Water	9,600	9,600	9,600	700	1,400
Dryer Steam	374,000	374,000	374,000	-0-	-0-
Residue Disposal	87,800	103,000	87,800	41,800	83,500
Semi-Variable Costs					
Maintenance	158,600	168,400	134,000	47,900	89,800
Labor (6 days, 24 hr. operation)	276,300	276,300	276,300	245,600	276,300
Fixed Costs					
Annual Debt Service (12%, 15 yrs.)	1,002,800	1,064,900	846,700	302,500	567,200
TOTAL ANNUAL COST	2,095,600	2,182,700	1,914,900	698,100	1,204,700
Revenues					
MP Steam	-	-	867,000	342,600	-
HP Steam	1,096,700	956,000	-	-	888,600
Comm'l. Hauler Fees	4,300	4,300	4,300	4,300	4,300
NYC Refuse Fees	91,700	91,700	91,700	91,700	183,400
Revenue Total	1,192,200	1,052,000	963,000	438,600	1,076,300
Net Cost	903,400	1,130,700	951,900	259,500	128,400
Break-even Refuse Tipping Fee					
	-	-	-	\$50.18	\$26.68
Break-even Sludge Tipping Fee \$/T (dry)					
	\$164.02	\$205.28	\$172.82	-	-

heat energy, as steam or hot water; and to operate in compliance with emission regulations. It has been pilot-operated in a sludge-refuse co-disposal mode, and has shown its capability in this area as well.

In summary, the proposed system includes centrifuges for dewatering digested sludge from 26th Ward WPCP at 3% solids. Centrifuge cake at 18-20% solids is conveyed to "porcupine" dryers, where steam, available from the Starrett City TEP, dries the material to 80% solids. At 130 psig and 340°F, the steam consumption rate will be 1.2 to 1.4 lb of steam per lb of water evaporated in the dryer.

The dried sludge and refuse are to be fed into two 25-ton per day MCU's in equal amounts, by weight, of approximately 22 tons/

day. The refuse acts as a bulking agent for the sludge and must be charged first so air can flow properly in and around the sludge-refuse mixture after charging to the incinerator.

Steam is to be generated either at 875 psig and 825°F (superheated) or at 135 psig and 350°F (saturated). The high pressure superheat steam will be piped to the existing TEP distribution system for use in the turbo-generators whereas the medium pressure steam would feed the medium pressure steam header. Steam production is estimated to average about 12,000 lbs/hr.

Auxiliary fuel is required to fire the primary chamber during startups and for the secondary chamber during normal operation in order to assure complete burnout of the off-

gases and particulates. Digester gas from the 26th Ward WPCP will be available as an auxiliary fuel source, backed up by (interruptable) natural gas and fuel oil.

Residue from the combustion process would be trucked to the nearest landfill, or other approved disposal site. Overall volume reduction is expected to be approximately 75-85% in view of the characteristics of the ash derived from sludge-refuse mixture.

The proposed system was not selected for implementation as part of the Starrett City/26th Ward Energy Exchange Project for these reasons:

- MCU operating experience to date has been almost exclusively in the combustion of municipal refuse or industrial solid waste. Significant operating experience in the co-incineration of solid waste and sewage sludge in MCU incinerators is lacking. A similar co-incineration facility is planned for the Linden-Roselle (N.J.) Sewerage Authority. Operating data from that plant would be valuable in determining co-incineration capability and performance of MCU's at a future time, but not soon enough for present evaluation.
- The New York City Local air pollution control code has very restrictive limits for mercury and cadmium emissions. Further study is required to determine if these limits could be met.
- The proposed facility is adjacent to the TEP. Issues of spatial constraints, tenant acceptability and environmental compatibility would have to be resolved with Starrett City.
- The proposed system is innovative, using porcupine dryers for drying sludge, co-combusting refuse and sludge in MCU-type equipment, and in generating very high pressure superheated steam from flue gas produced by the MCU's. The

selection of energy exchange options was based on ease of implementation including knowledge of operating characteristics of processes and equipment, and short pay-back period. Sufficient operating knowledge does not now exist to make confident judgments on feasibility of the MCU system.

- A concurrent New York City Sludge Management Study was evaluating the treatment and disposal alternatives for City-wide sludge production at the time this report was prepared. Its recommendations could pre-empt conclusions drawn by the specialized Starrett City study using sludge from 26th Ward WPCP only.

Select Options

Three options identified in the study have been selected for implementation: digester gas, effluent and thermal energy transfer.

Digester Gas

Transfer of 600,000 scfd of digester gas was the selected option. Average production of 400,000 scfd at 26th Ward will be supplemented by digesting raw sludge from Jamaica WPCP at 26th Ward, producing the balance of the gas.

This quantity of gas represents the maximum amount of gas available utilizing existing structures and some new equipment. This option is most cost-effective, as it displaces the greatest possible quantity of purchased fuels at Starrett. The incremental capital expenditure required to transfer the largest quantity of gas was slight when compared to the total capital cost of transferring 200,000 or 400,000 scfd.

Thermal Energy

The TEP will provide all 26th Ward's thermal energy requirements by transferring hot water to the 26th Ward heating loop. This selected option is cost-effective and will pro-

vide more efficient operation than if the WPCP were to continue operating the boilers on digester gas or purchased fuel oil. Since all digester gas is transferred to the TEP under the gas exchange, 26th Ward would have to fire oil in their boilers for space and process heat, a very costly alternative. As the TEP is a cogeneration facility it can produce hot water more efficiently and with a low incremental fuel requirement when compared to ordinary boilers. The operating cost is therefore lower.

The hot water will enter the heating loop in the thickener gallery, the closest point to the TEP within 26th Ward. Since the sludge heaters are in this area, most of the heat will be used here and distribution line heat losses will be minimized.

Effluent

Supplying all cooling water for the TEP using effluent pumped from 26th Ward was the selected option. The operating cost for this option will be significantly less than present cooling tower operating costs. The quantity of water pumped will be less than presently pumped because effluent is cooler than recycled cooling tower water. Makeup water will no longer be required because effluent will be pumped on a once-through basis. In addition, electric power costs are lower for 26th Ward than the incremental cost of generating power at the TEP.

The effluent withdrawal point was moved from the chlorine contact tank to the final tank effluent channel. Using chlorinated effluent in the TEP was thought to have harmful corrosive effects. A structure was provided to house the pumps and electric gear for noise control and to ease foul weather equipment servicing.

Cost

Costs for all selected options are shown on Table 18.

Preliminary Design

General

Preliminary design drawings and cost estimates are included in Appendix A. The following text is also included in that appendix to make it a meaningful document on its own. A summary cost estimate is shown in Tables 18 and 19.

Digester Gas Transfer

All digester gas produced at the 26th Ward WPCP will be transferred to the TEP and fired in multi-fuel boilers. 600,000 cubic feet per day will be transferred. Average production of gas at 26th Ward is 400,000 cubic feet per day which will be augmented by the transfer of raw sludge from the Jamaica WPCP. Jamaica sludge will be digested at 26th Ward, increasing gas production to the projected average of 600,000 cubic feet per day.

Existing Equipment

26th Ward has four gravity sludge thickeners, four anaerobic digesters and two sludge storage tanks. Gas produced in the digesters is used to mix digester contents. Also, since the gas has a heating value of about 600 Btu's per cubic foot it is piped to the head of the plant where it is fired in boilers currently providing space and process heat. Excess gas is wasted to flares at the rear of the plant.

Gas Transfer

Digester gas will be withdrawn from the main gas header. Ahead of this new tap are gas production meters and a gas recirculation system which provides digester mixing. Other than relocating gas meter instruments and minor piping modifications, the new equipment will not interfere with existing digestion operation.

Four new gas compressors will be

Table 18

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

CAPITAL COSTS

Installed capital costs -
New York City property

(\$ Thousand)

Gas flow damper tank	55
Gas blowers	175
Gas transmission piping	44
Sludge pumps and piping	165
Sludge screens	110
Hot water circulation pumps	48
Hot water transmission piping	97
Effluent pump house	149
Effluent circulation pumps	605
Effluent valves	121
Effluent transmission piping	305
Electric cable for effluent pumps	102
Effluent tie-in piping and valves	60
Other	<u>281</u>

2,317

Installed capital costs -
Starrett City property

Boiler modifications	571
Gas transmission piping	34
Heat exchanger	48
Hot water transmission piping	217
Control valve	48
Effluent strainer	97
Effluent transmission piping	240
Effluent tie-in piping and valves	110
Other	<u>79</u>

1,444

Engineering, legal, and administrative expenses

664

Construction management

188

Contingency

375

Interest during construction

660

Total Investment

5,648

TABLE 19

STARRETT CITY/26TH WARD
ENERGY EXCHANGE PROJECT

OPERATING COST SAVINGS

1983

FUEL	\$1,290,000
CITY WATER	85,000
MAKE-UP WATER TREATMENT	12,000
EFFLUENT TREATMENT	(12,000)
ELECTRICITY	(90,000)
INSURANCE	(65,000)
NYC PROPERTY TAX	(138,000)
NET OPERATING SAVINGS	\$1,082,000

INCREASED SAVINGS DUE TO
ESTIMATED FUEL COST ESCALATION

1990	\$ 2,433,000
2000	\$ 5,016,000

() Indicates Increased Cost

installed in the existing gas compressor room. Although equipment spacing will be close, there will be enough room to service equipment and walk through the building. All equipment will be explosion proof.

The compressors will be rotary liquid piston type, requiring a water seal and moisture separator. Gas will be drawn off the digesters at a low pressure of three to ten inches of water and compressed to ten psig. Effluent water from the transfer pumps will be mixed with the gas on the inlet side of the compressors. The gas-water mixture, once the gas is compressed, will enter a gravity moisture separator, the effluent discharging to a plant drain. There is a back up water seal system using city water with backflow preventers for cross-connection protection.

Dependent on gas production, one, two or three compressors will be used. There is one full standby compressor.

As the gas is at elevated temperatures and is saturated, condensate traps are installed at several points in the system.

Compressed gas is carried in a 6-inch main to a flow damping tank. The tank is a spherical steel structure, 22.5 feet in diameter. Its functions are to dampen fluctuations in gas production and provide some gas storage in case of system shutdown. The sphere will be located west of Thickener #4. All piping connections will be on top or bottom of the sphere, minimizing both stress points and number of disruptions in the skin of the tank. Gas will enter and exit at the top of the sphere, condensate will drain from a tap at the low point. Manhole access will also be provided.

The 6-inch line will continue from the sphere, crossing Van Siclen Avenue to the TEP. Gas will be burned if it is produced, since even at maximum production, the gas will only supplement the primary gas or fuel oil boiler feed.

Controls

Pressure regulating valves, switches and indicators will make the control of the gas transfer automatic. Manual operation will also be possible at all control points.

The gas compressors must start with no load. A bypass valve will open prior to energizing the compressor allowing the discharge to flow back to the suction. This bypass will remain open for 30 seconds, then slowly close. As the bypass closes, a back pressure valve will open into the main header.

The compressors run at constant speed and produce a constant volume of gas at a fixed discharge pressure. Since the gas production and use are variable, a second bypass on each compressor will recycle the quantity of gas equal to the difference between the compressor capacity and the digester production. Bypass and transfer valves are automatic, pressure or motor operated.

As digester gas production increases beyond one compressor's capacity increasing suction line pressure, a pressure switch will bring a second compressor on line. The same start-up and transfer sequence will operate. If peak production is reached, three compressors will be on line. As production falls off and pressure drops, compressors will shut down in sequence.

Backflow preventers and check valves are installed at all control points to prevent pressurizing lines improperly. Drawing a vacuum on the digesters is also prevented. If suction line pressure drops too low, all compressors will shut down. Pressure will be maintained in the storage sphere between four and ten pounds. A pressure reducing valve will be installed upstream of the TEP burners to provide proper operating pressure. If pressure builds beyond ten pounds due to line blockage or other malfunction, alarms will sound at the TEP and 26th Ward control center. If mal-

functions cannot be corrected quickly, the waste gas flares will be activated and sphere isolated or emptied of gas.

Jamaica Sludge Transfer

Digested sludge produced at the Jamaica WPCP is normally transferred to 26th Ward via a 4-mile-long 12-inch pipeline. It is stored at 26th Ward prior to being pumped to a tanker for disposal at sea. Gas produced at Jamaica is burned in their boilers as required for space and process heating. Excess gas is flared.

It is planned to transfer raw sludge from Jamaica through the existing pipeline and digest it at 26th Ward to supplement the gas transfer to the TEP. 26th Ward has sufficient excess digester capacity to process the additional Jamaica sludge.

Sufficient quantities of sludge will be digested at Jamaica to produce gas to meet their local needs. This digested sludge will continue to be piped to 26th Ward for disposal. Piping changes will be necessary at both plants. Normal operations will continue, but scheduling changes will be necessary to coordinate transfer of both raw and digested sludge. Up to 50% of Jamaica sludge will be transferred.

Jamaica Equipment Modifications

A set of secondary screens will be installed on the discharge side of the primary sludge degritters. As rags and other solid debris pass through the primary screens, pump clogging has become severe. The new screens should remove the debris and prevent downstream problems. The screens have no moving parts, and debris falls into containers below. A fork lift will pick up these containers and empty them into the large grit containers for disposal at a landfill.

There is a 6-inch thickened sludge pump discharge line from the thickeners to the digester gallery. It is planned to extend this line to the

west end of the gallery where a new suction well will be constructed outside, adjacent to the gallery wall. The existing thickened sludge plunger pumps will be installed in the west end of the gallery. These will be used to transfer raw sludge from the suction well to 26th Ward.

Operations will probably alternate on a daily schedule, pumping raw sludge or digested sludge to 26th Ward as required to transfer the quantities of each material being produced. In order to segregate raw and digested sludges in the same pipeline, provision will be made for inserting and recovering a pipeline pig.

Digested sludge will be transferred using existing pumps. When raw sludge is to be transferred, operations will change. The pig will be inserted in a special "launcher." Thickened sludge will be pumped to the suction well. Existing digested sludge transfer pumps will be shut down, and new raw sludge transfer pumps started. The pig will enter the pipeline, pushing digested sludge ahead of the raw sludge. A mechanical signal will indicate the pig's entering the pipeline.

A short section of new 12-inch pipeline will be required from the new transfer pumps to the sludge force main where the existing line reduces to 8 inches. A pig designed for liquid separation in a 12-inch line will not pass through an 8-inch line.

As operations change back to transfer digested sludge, the procedure will be reversed. The raw sludge suction well will be drained to limit odor problems.

26th Ward Equipment Modifications

The digested Jamaica sludge currently enters 26th Ward digester gallery and flows to the storage tanks. A new tee will be installed there to allow transfer of sludge to other process areas. A new pipeline will be installed along the digester

gallery to the thickener tunnel. Here, valved connections will be made allowing very flexible operation. Raw sludge may enter any of four heating loops which feed the digesters. It may also enter the thickener feed header. This latter will be the expected mode of operation. Raw sludge from Jamaica will be processed in the 26th Ward thickeners, enter the heating loop and be fed to the digesters.

Only one sludge transfer operation will be possible at any time. When the pig arrives at 26th Ward, visual and audible alarms will sound, locally and at the plant control center. Required valve changes will be manual. Digested sludge will enter the sludge storage tanks as occurs now.

The pig will be retrieved here in the thickener feed, flow splitter box. Complex signal and valve controls have been avoided. Sludge controls have a history of fouling easily. Although this system could be automated, its reliability would be low. It was determined that manual controls on this system are preferable.

Thermal Energy Transfer

26th Ward currently produces hot water for space and process heating in three boilers. Fuel is digester gas or #4 fuel oil. Since all digester gas will be transferred to the TEP, a new hot water source is needed.

The TEP will install a new steam to hot water heat exchanger to provide the 26th Ward WPCP with hot water. The boilers and circulating pumps will be shut down at 26th Ward, but maintained for use as standby. Hot water will be piped across Van Siclen Avenue, entering the heating loop of 26th Ward in the thickener gallery.

A new set of circulating pumps will be installed there. The heating loop will need no major changes other than new intake and discharge taps from the new pumps. Existing valves will be closed to isolate the

boilers and existing circulating pumps. Though the existing heating loop is pumped in one direction, the new system will split the flow at the point of injection. New expansion tanks will be installed next to the new pumps.

Efficiency will increase with the new system. The sludge heat exchangers are in the thickener gallery, near the new circulating pumps. These heat exchangers account for 50% of the plant's heating load. Since it is closer to the heat source, less distribution line loss can be expected.

Return water will flow back to the TEP heat exchanger to be reheated. Exterior piping will be prefabricated and insulated to minimize heat loss. The 26th Ward system will have to be re-balanced once the new heat source is on line. Each unit heater must be adjusted to draw the proper flow for its most efficient operation.

Control

The TEP will supply hot water to 26th Ward at a constant temperature. Circulating pumps at 26th Ward will be manually controlled. Thermostatically controlled valves supply hot water to unit heaters, while hot water supply to the sludge heat exchangers is controlled manually. As heating requirements increase at 26th Ward, an additional circulating pump will be brought on line. Should any equipment fail, the other plant will be informed via telephone to shut down or modify equipment.

Effluent Transfer

A portion of the sewage flow which has passed through the secondary treatment processes will be intercepted and pumped to the Starrett City TEP. The cooling tower, fans and pumps at the TEP will be shut down but maintained in operating order to serve as standby. The effluent water will be used as condenser and heat exchanger cooling

water. It will circulate through the TEP on a once-through basis, and return to 26th Ward for discharge with the balance of the sewage effluent.

The water will be taken from the effluent channel of Final Tanks 1 through 4. Flow through these tanks will be great enough to serve the cooling requirements of the TEP under all expected conditions. Worst case conditions are maximum effluent temperature and maximum TEP cooling demand, a situation which occurs during the summer. If one of Final Tanks 1 through 4 is out of service, minor thermal short circuiting will occur. This condition will not be serious since it should be of very short duration. If more than one final tank is out of service, flows might be inadequate and the cooling tower might have to be brought on line.

Flow will be intercepted at a drop manhole constructed adjacent to the effluent channel for tanks 1 through 4. A 42-inch diameter gravity line will carry the flow to the suction well of a pumping station. This line will run south of the final tanks to the west road, then run west of the digesters. It will be buried next to the roadway, crossing it once. Small existing pipelines will be relocated.

The 36-inch pump discharge line will leave the pump station, turn underground and cross Van Siclen Avenue to a valved connection into the TEP cooling tower pump discharge lines. The return pipeline will run parallel to the supply line and on the 26th Ward property it will run parallel to the 42-inch diameter gravity line feeding the pump station. Used cooling water will discharge to the final tank effluent channel and combine with the rest of the sewage flow for disinfection. The discharge will be about 20 feet from the drop manhole where it was withdrawn.

The pump station will be situated between Digester #4 and Thickener

#4. This area has steep earth embankments around the digesters and thickener building. There is also a temporary access road to the thickener building here.

To maintain slope stability during construction, temporary sheet piling will probably be necessary. A permanent retaining structure will also be required around the pump station. The earth embankment acts as insulation for the digesters, and it must be maintained. Precautions must also be taken to avoid erosion and caving during construction.

The existing roads are crossed only once at the southwest corner of the final tanks. Other roads can be maintained or repaired as construction proceeds. The existing temporary access road to the thickener building will be eliminated by the pump station and a new road will be constructed on the east side of the thickeners. Design of this road has taken into account avoidance of severe slopes, ice prevention, traction for heavy trucks and turn around areas for large vehicles.

The pump station will house four variable speed vertical turbine pumps, 12,500 gpm each, with 350 hp motors. Continuous flow from the final settling tank effluent channel will be directed to the suction well below the pumps. The water surface elevation in the suction well will vary slightly with pump station flow. The maximum water surface elevation will be several feet below the underside of the pump station operating floor. The suction well will have a sluice gate at its entrance to interrupt flow from the final tanks if necessary. There will also be a drain from the suction well to an existing plant drain. Flow can also be stopped at the final tank effluent channel by insertion of stop logs. Access to the suction well is provided by a removable grating at the pump station. This grating and similar one at the effluent channel connection also serve to vent the suction

line. If shock chlorine dosage is necessary for slime control, it can be applied at either of these points.

A 4-inch line will be tapped on the discharge side of the effluent transfer pumps, leading to the gas compressor room. The digester gas compressors transferring gas to the TEP require a water seal flow of 10 gpm each. The effluent will be used in the compressors, then wasted to a plant drain. This flow will not affect the effluent transfer for TEP cooling because, at worst case conditions, the flow required by the gas compressors is only one percent of required cooling water flow.

The pump station will be a brick and cinder block structure, with architectural treatment to blend in with the surrounding buildings. The retaining wall will have similar aesthetic treatment. Electrical controls for the variable speed motors will be housed in the same structure, but in a separate room. The pumps will be housed in an adjacent room and removable skylights will be installed above the pumps. As the pumps are large units, major overhaul will require their removal. The skylights will have to be removed, and a crane brought in to pull the pumps out. With proper maintenance, removal of a pump is unlikely for many years.

The structure will be sound-proofed so that motor or pump noise will not be heard beyond the plant boundary. Ventilation, lighting, fire protection and other safety items will be incorporated in the design to meet all applicable codes.

Controls

An automatic control system for the effluent cooling pumps will not be provided at the specific request of TEP operating personnel. Under normal operating circumstances, the number of operating pumps and their speed will be controlled manually from the TEP. Effluent flows will be controlled through pump

speeds to maintain a maximum condenser or heat exchanger exit water temperature. If the temperature exceeds the desired maximum, the number of operating pumps and/or their speed will be increased. If the

temperature falls below the desired maximum, flow will be decreased to save electrical energy. The operating status of the pump station, which pumps are running, and their speed will be telemetered to the TEP con-

trol room.

For reasons of safety, there will be local controls at 26th Ward to allow for overriding the TEP remote controls.

DAILY ELECTRICAL POWER DEMAND
(FROM PLANT TREATMENT LOGS, JANUARY 1976 THROUGH DECEMBER 1978)

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 8

THERMAL ENERGY DEMAND
(1976 FUEL OIL CONSUMPTION BASIS)

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 9

HOT WATER SYSTEM

APRIL 1974

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 10

- C1 - C6 GAS COMPRESSORS (FOR DIGESTER MIXING)
- CB1 - CB3 BOILER GAS COMPRESSORS
- PLUG VALVE
- PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
- ORIFICE PLATE & FLOW METER

DIGESTER GAS UTILIZATION SYSTEM

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 11

DAILY DIGESTER GAS PRODUCTION
(FROM PLANT TREATMENT LOGS, JANUARY 1976 THROUGH DECEMBER 1978)
STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 12

DIGESTER GAS UTILIZATION
1976-1978

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 13

TREATMENT PLANT FLOW
(FROM PLANT TREATMENT LOGS, JANUARY 1976 THROUGH DECEMBER 1978)

**STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 14**

PLANT EFFLUENT TEMPERATURE

(FROM PLANT TREATMENT LOGS, JANUARY 1976 THROUGH DECEMBER 1978)

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT
FIGURE 15

◇ ONE DAY, ISOLATED, EXTREME READING

PLANT EFFLUENT pH

(FROM PLANT TREATMENT LOGS, JANUARY 1976 THROUGH DECEMBER 1978)

STARRETT CITY/28th WARD
ENERGY EXCHANGE PROJECT
FIGURE 16

TABLE 2

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

New York City Power Rate Structure

There is a special rate which applies to treatment plants only, due to the magnitude of their consumption. NYC deals directly with PASNY in receiving and paying electric bills. PASNY in turn deals with Con ED which is responsible for reading meters, maintaining equipment, and transmitting the electricity.

There are two rates: Demand and Consumption. The peak demand is calculated by taking the sum of the two highest consecutive 15-min. periods of demand (for the month) and multiplying by two. This is the peak demand kilowatt-hours. The charge consists of:

\$4.73/kw	Basic demand
\$1.18/kw	Wheeling charge via Con ED
6.1%	Surcharge on wheeling amount

Total Demand Rate is \$5.98

Consumption Rate is a flat charge: \$.0123/kw-hr.

Rates vary with PASNY fuel cost.

Information received from Electrical Section, Division of Plant Operations, Wards Island, 3/79.

Electrical Rates, Fiscal Year 79-80

<u>Month</u>	<u>Consumption \$/KwH</u>	<u>Demand, \$/Kw</u>
July 79	0.0135	6.84
Aug. 79	0.0135	6.79
Sept. 79	0.1160(?)	6.93
Oct. 79	0.0191	6.84
Nov. 79	0.0309	6.97
Dec. 79	0.0346	6.79
Mar. 80	0.0416	9.46
Jun. 80	0.0245	9.75

Recommended rates for FY 81: 3¢/KwH, \$9.75/Kw*

For estimated consumption at 26th Ward WPCP of 2200 Kw demand and 1,500,000 KwH consumption/month, overall rate becomes \$.0443/KwH.

* Information from NYC Dept. of General Services, Energy and Conservation Unit.

TABLE 3

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

MAJOR MOTOR LIST

This list tabulates all motors 7-1/2 Hp or larger, their location, quantity, and equipment driven. Numbers in parentheses indicate the number of units operating during normal plant operations. Where no parentheses appear, assume all units are operating during normal plant operation.

A. Distribution Center 1N - Pump and Blower House

1. Wear Ring Flushing Water Pumps - 6 Units @ 10 Hp (4)
2. Air Compressor - 2 Units @ 7-1/2 Hp (1)
3. Oil Pump (Sluice Gate Operators) - 2 Units @ 10 Hp (1)
4. Air Cooled Compressor (ACC2, ACC3) - 2 Units @ 16 Hp

B. Distribution Center 2N - Boiler Room, Main Building

1. Boiler Blowers - 3 Units @ 15 Hp
2. Heating Hot Water Pump - 3 Units @ 75 Hp (2)
3. Boiler Gas Booster Pump - 3 Units @ 25 Hp (2)

C. Distribution Center 3NE - Pump and Blower House

1. Heating & Ventilating Unit #6 - 1 Unit @ 75 Hp
2. Exhaust Fan #25 - 1 Unit @ 100 Hp
3. Emergency Ventilation Fan - 2 Units @ 7-1/2 Hp (0)

D. Distribution Center 3NW - Pump and Blower House

1. Heating & Ventilating Unit #7 - 1 Unit @ 75 Hp
2. Exhaust Fan #26 - 1 Unit @ 100 Hp
3. Emergency Ventilation Fan - 2 Units @ 7-1/2 Hp (0)

E. Distribution Center 4N - Service and Storage Wing

1. Air Compressor - 2 Units @ 50 Hp (1)
2. Passenger Elevator - 1 Unit @ 10 Hp
3. Freight Elevator - 1 Unit @ 25 Hp

F. Distribution Center 5NE - Preliminary Sludge Gallery

1. Sludge Transfer Pump - 3 Units @ 50 Hp (2)
2. Auxiliary Pump - 1 Unit @ 20 Hp

G. Distribution Center 5NW - Preliminary Sludge Gallery

1. Sludge Transfer Pump - 3 Units @ 50 Hp (2)
2. Auxiliary Pump - 1 Unit @ 20 Hp

H. Distribution Center 6 - Return Sludge Gallery

1. Return Sludge Pumps - 4 Units @ 40 Hp (2)
2. Spray Water Pump - 4 Units @ 7-1/2 Hp (3)

I. Distribution Center 6N - Return Sludge Gallery

1. Waste Sludge Pump - 2 Units @ 125 Hp (1)

J. Distribution Center 7N - Digester Gallery

1. Vessel Loading Pump	-	2 Units @ 300 Hp (1)
2. Sludge Transfer Pump	-	2 Units @ 40 Hp (1)
3. Digester De-Watering Pump	-	1 Unit @ 20 Hp
4. Spray Water Pump	-	1 Unit @ 7-1/2 Hp

K. Distribution Center 10N - Thickener Building

1. Thickened Sludge Pump	-	8 Units @ 20 Hp (4)
2. Sludge Recirculating Pump	-	6 Units @ 60 Hp (4)
3. Seal Water Pump	-	2 Units @ 7-1/2 Hp (1)
4. Air Compressor	-	2 Units @ 15 Hp (1)
5. Heating & Ventilating Unit #1, 2	-	2 Units @ 7-1/2 Hp
6. Hot Water Recirculation Pump	-	2 Units @ 10 Hp (1)
7. Monorail	-	1 Unit @ 7-1/2 Hp
8. Ozonator	-	1 Unit @ 12 Hp (approximate)

L. Main Sewage Pumps

All Units variable speed	-	2 Units @ 300 Hp (1)
	-	2 Units @ 350 Hp (1)
	-	1 Unit @ 400 Hp
	-	1 Unit @ 500 Hp

M. Main Blowers

All units variable speed	-	4 Units @ 800 Hp (2)

TABLE 4

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

ELECTRICAL DISTRIBUTION CENTER LOADS
11:00 A.M., 6/7/79 TO 10:00 A.M., 6/15/79

June, 1979

<u>Center</u>	<u>Normal Range KW</u>	<u>Extremes, KW</u>		<u>Comments</u>
		<u>Minimum*</u>	<u>Maximum*</u>	
1N	15-45	10(4)	60(6)	Peaks caused by intermittent service equipment, cannot be avoided.
2N	70-100	70(N/A)	115(3)	Peaks caused by intermittent service equipment, cannot be avoided.
3N	0-30	0(N/A)	40(2)	Possible high loads not recorded during test period.
4N	0-40	0(N/A)	100(2)	Peaks caused by intermittent service equipment, cannot be avoided.
5N	135-150	80(3)	150(N/A)	-
6N & 6	160-185	95(1)	185(N/A)	-
7N & 9N	40-55	25(1)	405(6)	Peaks caused by sludge vessel loading pumps, cannot be avoided or substantially reduced
10N	120-145	105(4)	170(4)	Peaks caused by intermittent service equipment, cannot be avoided
Blowers	390-830			

*Numbers in parentheses indicate the number of values below or above the range.

TABLE 5
STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

GREASE ANALYSIS
1976 to 1978
March 1979

<u>Month</u>	<u>Effluent Grease (mg/l)*</u>		
	<u>1976</u>	<u>1977</u>	<u>1978</u>
Jan.	13	12	10
Feb.	11	14	14
March	13	20	10
April	6	16	19
May	21	25	15
June	19	35	13
July	5	6	11
Aug.	10	12	4
Sept.	7	-	8
Oct.	4	11	19
Nov.	16	1	14
Dec.	4	15	10
Avg.	11	15	12
Min.	4	1	4
Max.	21	35	19

*By hexane extraction

TABLE 6

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

FINAL EFFLUENT ANALYSES

TOTAL SOLIDS IN PLANT EFFLUENT
DAILY COMPOSITE SAMPLES

June, 1979

<u>Date</u>	<u>Composite Sample</u> <u>Total Solids</u> <u>Plant Effluent</u> <u>mg/l</u>
5/26/79	4,500
5/27/79	5,700
5/28/79	5,000
5/29/79	3,500
5/30/79	2,900
5/31/79	3,200
6/1/79	-
6/2/79	3,000
6/3/79	2,300
6/4/79	2,100
6/5/79	3,300
6/6/79	3,800
6/7/79	3,000

THE CITY OF NEW YORK
DEPARTMENT OF WATER RESOURCES
BUREAU OF WATER SUPPLY

WATER ANALYSIS REPORT (A)

Series 1979 No. Subject Special Samples - Bureau Water Pollution

Prepared by R. Popper, Acting Director Mar. 28, 1979

Source of Samples	26 Ward Sewage Plant	Date:	Coll.	Rec'd
3468	Plant effluent		3/15	3/22
3469	Plant effluent		3/16	3/22

Sample Number	3468	3469						
Temperature °F								
Turbidity (u)	10	8						
Color (u)	17	20						
Odor/Taste	0/-	0/-						
Nitrogen (mg/L N)	.36	.50						
Albuminoid "								
Free Ammonia "	6.30	7.50						
Nitrite "								
Nitrate "	.20	.20						
Sp. Conductance (M Mhos)	1900	2300						
Solids: Total (mg/L)								
Chloride "	500	650						
Hardness (mg/L CaCO ₃)	252	292						
Alkalinity " "	100	110						
pH								
Iron (mg/L)								
Copper (mg/L)								
Chlorine resid. (mg/L)								
Fluoride (mg/L)	.93	.93						
Bacteria per ml.								
Coliforms per 100 ml.								
Microscopical Exam.								
Total organisms s.u.								
Important genera								
Amorphous matter								

Coliforms expressed according to Most Probable Number (M.P.N.) Index

TABLE 6 (Cont'd)

STARRETT CITY/26th WARD
ENERGY EXCHANGE PROJECT

FINAL EFFLUENT ANALYSES

<u>1979 DATE</u>	<u>ppm Total SOLIDS</u>	<u>ppm* HARDNESS</u>	<u>mmhos** CONDUCTIVITY</u>	<u>ppm CHLORIDE</u>
7/21	1300	284	1800	520
7/22	1300	276	1850	440
7/23	1500	276	1800	620
7/24	1500	280	1900	720
7/25	1400	280	1800	520
7/26	1400	256	2000	520
7/28	1600	316	1950	660
7/29	1700	304	2150	660
7/30	2100	396	2950	820
7/31	1900	360	2900	720
8/1	1800	320	2400	740
8/2	1600	296	2400	620
8/4	1600	288	2300	560
8/5	1700	316	2550	580
8/6	1700	308	2300	620
8/7	1800	328	2300	600

*ppm CaCO₃ by EDTA titration

**millimhos by meter

TABLE 6 (Cont'd)

CONCENTRATIONS OF METALS

26th WARD EFFLUENT

CONCENTRATIONS IN mg/l

Year		Copper Cu	Chromium Cr	Nickel Ni	Zinc Zn	Lead Pb	Iron Fe	Cadmium Cd	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Mercury Hg
1979	J	0.07	0.022	0.080	0.14	0.010	0.4	0.0730	37	48	360	22	0.0009
	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	0.06	0.031	0.080	0.12	0.049	0.30	0.0140	37	26	495	23	0.0010
	A	0.04	0.030	0.300	0.12	0.067	0.30	0.0030	42	75	450	22	0.0009
	M	0.04	0.026	0.030	0.12	0.022	0.40	0.0082	43	95	620	28	0.0013
	J	0.04	0.012	0.060	0.05	0.020	0.20	0.0032	31	62	490	21	0.0007
	J	0.06	0.016	0.060	0.06	0.010	0.30	0.0056	33	64	570	26	0.0005
	A	0.04	0.015	0.015	0.04	0.011	0.20	0.0005	35	48	300	16.5	0.0008
	S	0.04	0.070	0.060	0.07	0.053	0.40	0.0010	29	46	470	17.5	0.0006
	O	0.04	0.030	0.100	0.06	0.044	0.35	0.0120	33	54	560	21	0.0004
	N	0.04	0.023	0.080	0.06	0.052	0.20	0.0490	35	40	390	14	0.0003
	D	0.04	0.028	0.060	0.11	0.175	0.45	0.0193	27	44	325	16	0.0001
1976	AVG	0.046	0.028	0.084	0.086	0.0466	0.32	0.0172	35	55	457	21	0.0007
1977	J	0.060	0.040	0.020	0.07	0.0640	0.35	0.0088	26	72	680	16	0.0023
	F	0.080	0.050	0.060	0.08	0.0720	0.20	0.0160	45	70	560	35	0.0006
	M	0.040	0.025	0.129	0.17	0.0100	0.60	0.0130	48	75	580	21	0.0001
	A	0.080	0.022	0.130	0.13	0.0330	0.40	0.0022	35	120	430	19	0.0003
	M	-	-	-	-	-	-	-	-	-	-	-	-
	J	0.060	0.001	0.088	0.25	0.0120	0.52	0.0094	12	35	398	16	0.0011
	J	0.015	0.021	0.027	0.13	0.0003	0.15	0.0032	37	68	573	26	0.0008
	A	0.170	0.019	0.067	0.15	0.0032	0.21	0.0072	43	62	613	25	0.0030
	S	0.048	0.024	0.001	0.09	0.0016	0.28	0.0120	22	66	545	22	0.0040
	O	0.059	0.007	0.065	0.10	0.0028	0.20	0.0052	48	76	613	25	0.0012
	N	0.035	0.045	0.062	0.16	0.0077	0.17	0.0052	29	65	477	21	0.0001
	D	0.050	0.020	0.050	0.12	0.0600	0.28	0.0088	29	62	470	20	0.0001
1977	AVG	0.063	0.025	0.064	0.13	0.0242	0.305	0.0083	34	70	540	22	0.0012
1978	J	0.037	0.110	0.075	0.100	0.0820	0.28	0.0060	34	46	424	20	0.0001
	F	0.041	0.030	0.074	0.100	0.0041	0.23	0.0110	39	49	369	18	0.0004
	M	0.036	0.022	0.089	0.072	0.0160	0.43	0.0140	34	59	495	21	0.0006
	A	0.034	0.041	0.094	0.067	0.0074	0.23	0.0150	42	52	450	19	0.0001
	M	0.150	0.051	0.051	0.071	0.0066	0.24	0.0150	27	58	478	19	0.0016
	J	0.020	0.002	0.040	0.064	0.0036	0.21	0.0074	37	67	623	26	0.0008
	J	0.045	0.004	0.049	0.069	0.0045	0.34	0.0210	25	43	376	17	0.0041
	A	0.076	0.016	0.140	0.098	0.0013	0.27	0.0070	48	163	799	36	0.0001
	S	0.044	0.005	0.089	0.073	0.0120	0.15	0.0092	44	90	775	33	0.0007
	O	0.049	0.016	0.100	0.090	0.0090	0.37	0.0056	35	98	723	33	0.0003
	N	0.046	0.031	0.066	0.038	0.0044	1.10	0.0062	40	56	497	21	0.0002
	D	0.090	0.006	0.065	0.077	0.0120	0.35	0.0090	36	56	498	23	0.0002
1978	AVG	0.056	0.028	0.078	0.077	0.0136	0.35	0.0105	37	70	542	24	0.0008
3 YEAR	AVG	0.055	0.027	0.075	0.098	0.028	0.325	0.012	35	65	513	22	0.0009

Chapter 3

Part D

Analysis— Conservation Options

For Starrett City For the TEP Data Collection

Data required to analyze any conservation options is the same data as are required to obtain the operating levels and efficiencies of the TEP and its subsystems. Refer to the section entitled "The Analysis-Exchange Options."

Data Reduction and Evaluation

The same comments apply here as in the previous paragraph.

Develop Options Heat Recovery from Lube Oil Coolers.

The concept here is to recover heat presently wasted in cooling the lubricating oil and jacket water of the dual fuel engines.

At present, condenser water cools the lube oil and jacket water then dissipates it in the cooling tower. Condenser water could be passed through an intermediate heat exchanger where the heat could be recovered for useful purposes.

Data collected during the program indicated two things:

1. The dual fuel engines were only operated a few hours each day, primarily in the winter. In other words, the engines were run only as peaking units.

2. The temperature level of the cooling water is too low for use in the TEP water systems. Cooling water return from the water jacket cooler is typically 155°F. The Dual Temperature Water supply is 160°F and the High Temperature Water supply is 250°F.

Therefore, even if the dual fuel engines were operated for longer periods of time, the low temperature level of the recoverable heat is of no practical use at the TEP. For this reason, this option was dropped from further consideration.

Heat Pumps

Heat pumps used in the condenser

water line could recover approximately 40 MMBh presently dissipated in the cooling tower. This could supply approximately 60% of the average heat requirements at Starrett City.

This was selected as an option for further consideration.

Equipping Refrigeration Units with Free Cooling

Free cooling is a method of chilling water for air conditioning without operating the centrifugal compressor and its driver. It is a factory packaged accessory added to the centrifugal chiller. The system works by circulating cold cooling tower water through the free cooling unit's condenser and chilled water return through the unit's cooler. Refrigerant evaporates in the cooler, cooling the chilled water, and migrates to the condenser. In the condenser cooling tower water condenses the refrigerant which then flows by gravity through a bypass to the evaporator.

Free cooling can be employed when the cooling tower water temperature is lower than the chilled water supply. Chilled water temperature is allowed to rise as a function of the cooling load and condenser water temperature.

At Starrett City, during the cooling season, the cooling tower condenser supply water does not drop below 70°F according to data taken in the field. Similarly, if effluent from the 26th Ward is used for condenser water, the average temperature does not fall below 65°F. In either case, the condenser water temperature is too high to initiate a free cooling cycle. Consequently, further study of free cooling was abandoned.

Select Options Heat Pumps

Two applications for heat pumps were considered at the TEP. Both

applications used condenser water as the heat source.

First, using heat pumps to supply the space heating load was considered. Discussions with Westinghouse Templifier Division disclosed that three 1200 horsepower units could handle all loads except peak loads. Installed cost would be \$765,000 (1979 dollars). The difference in fuel costs between operating heat pumps or generating steam for the heat exchangers was forty-two (42) cents per MMB in favor of the heat pumps. Payback would take approximately 10 years. In addition to the relatively poor payback, the additional 2.7 mw required for the heat pumps would severely tax the generating capability of the TEP.

Another consideration is that having the heat pumps supply all space heating requirements would drastically reduce the amount of extraction steam required from the turbines. For all practical purposes the turbines would be operating in the condensing mode, thereby greatly reducing the efficiency of the TEP. Plant efficiency would drop from approximately 60% to 30%. This would then increase payback to approximately 13 years. For this reason and the fact that the electrical energy required for the heat pumps would severely tax the TEP's ability to supply normal loads, this option was dropped from consideration.

A second proposal was to generate high temperature hot water with heat pumps. However, heat pump equipment capable of the 300°F required is not available. In addition, lowering the water temperature to 220°F (the maximum temperature the heat pumps can produce) would require a heat pump with a cp of 4.27 to break even based on fuel alone. The cp's available at this output temperature are only 2.1 to 2.3. Therefore, this option was considered not feasible and was dropped from consideration.

During discussions with heat

pump manufacturers, the heating loads at the 26th Ward were discussed. A computer analysis run by a heat pump manufacturer (Westinghouse) indicated heat pumps might be suitable for application at the 26th Ward.

For the Buildings Data Collection

The same comments apply here as in the TEP section above.

Data Reduction

The same comments apply here as in the TEP section above.

Develop Options Apartment Energy Audit and Computer Analysis

A properly conducted energy conservation program begins with an energy audit. The audit serves two prime functions: it provides the quantitative data needed to identify the more significant energy consumption areas so that those most productive of the energy conservation potentials can be addressed first and it serves as an index against which the effectiveness of the various conservation measures can be evaluated.

There are a number of inputs to the Starrett City Energy Audit:

- a) Logging of Energy Use Data at various points in the Starrett City System.
- b) Reviewing fuel billings to determine consumption.
- c) Computer Modeling.

Logging of Energy Use Data

Energy use data were logged for several weeks during mid-winter, in the spring and again in mid-summer. A representative sample is shown in Figure 23.

Logging and surveying the energy use at Starrett City serve several useful purposes:

- a) Provides operating data for the various systems.
- b) Provides for the development

of energy use profiles based on measured, not theoretical or "typical," values.

c) Renders information on system operation and performance.

Sample use profiles are included with this section of the report

The significant finding resulting from acquiring and logging energy use data is the excess energy use for the heating of domestic hot water. Assuming an incoming cold water temperature of 70°F (very conservative) and an average temperature rise in the domestic hot water of 70°F, the energy input to the high temperature water system during July would heat 117.5 gallons per day per apartment. This figure is approximately 3-1/3 times the anticipated consumption (35 gpd per apartment) for apartment complexes with more than 200 apartments.

The domestic hot water use figure used for comparison (35 gpd/apartment) was taken from empirical data published by ASHRAE. See Reference No. 1.

The data used in this analysis included the average energy input to the high temperature water system (the heating medium for domestic hot water) for July 8, July 12 and July 13, 1979. Apartment use calculations were based on 94% occupancy during the month of July (5528 occupied apartments).

The consumption of energy at this rate by the domestic hot water system cannot be reconciled on the basis of excess use by tenants who feel no direct incentive to conserve. Such energy consumption is indicative of system losses either through leaks or excessive heat loss in the underground distribution system.

Fuel Consumption Data

All calculations were based on a total apartment building gross floor area of 7,500,000 square feet.

The fuel consumption data, for No. 6 fuel oil, interruptible gas and

the firm gas used for cooking and clothes dryers, were obtained from the owner, reviewed and used to determine the actual energy consumption of the Starrett City apartment buildings. At the outset of the study complete fuel consumption and occupancy data were available for 1978—the year used for consumption analysis.

Based on the fuel consumption, the estimated unit energy consumption for the Starrett City apartment buildings was 143.7 MBtu/GSF/yr. This estimate is based on an average occupancy rate of 81% during 1978. Additional adjustments had to be made for the temporary schools, the shopping center, the Community Center and differences in degree days. The adjustments made for the differences in degree days between 1978 and a typical year are:

Degree Day Comparison

	1978	Typical Year	Correction Factor
Winter	5168	4838	-0.06
Summer	1042	795	-0.24

Correction factors were applied to estimated energy consumptions for heating and cooling. As such, the corrections are approximate and are intended only to refine the billing data.

All calculations were based on a total apartment building gross floor area of 7,306,000 sq. ft.

Computer Modeling

Four buildings, buildings A3-Z1-20, B1-Z2-17, F3-L2-11 and H4-L2-17 were selected as being representative of the various apartment building types, heights and orientations.

Building A3 is a 20-story Z-type with long, glazed walls facing northwest and southeast. Building A-3 has balconies on the top five floors.

There are two groups of balconies on each major exposure of the building, located at the mid-point of

each wing. Building B-1, also a "Z" type, is a 17-story structure with long walls facing northeast and southwest. Building B-1 has balconies, similar to those described above on the 7th through 17th floors. Buildings F-3 and H-4 are both "L" type buildings. The apex of the "L" on building F-3 points to the southeast while the apex of the "L" on building H-4 points northwest. The "L" type buildings each have four major wall exposures facing northeast, northwest, southeast and southwest. Since building F-3 and H-4 are 180° out-of-phase with one another, their shading patterns are different. Building F-3 is an 11-story structure with balconies on both sides of each wing from the third through the eleventh floors. Building H-14, a 17-story building, has no balconies.

It was assumed that analysis of these four buildings would serve to extrapolate the needed data for all of the apartment buildings at Starrett City.

Computer Program and Analysis

The computer program used for the modeling of the Starrett City apartment buildings was the AXCESS Program developed by the Edison Electric Institute for building energy consumption/conservation study and evaluation.

With the necessary input information, the program will calculate hourly loads for:

- Heating
- Cooling
- Lighting
- Appliances
- Elevators
- Environmental System Loads (Fans, Pumps, etc.)
- Domestic Hot Water
- Utility Usage per Occupant

The computer prints out a load for each hour of the day for every third day and displays the various loads individually. In addition, the

computer sums the various loads and fuel and energy consumption monthly and annually. The computer printout for this study is in Appendix C.

Input Data

Climate data used for the computer calculations are for Kennedy Airport and were secured from the National Climatic Center of the National Oceanic and Atmospheric Administration in tape form. The data used are for the year 1951 which was selected by the National Climatic Center as being closest to a typical year for the Kennedy Airport and its environs.

The energy use profiles used in the computer analyses were secured from various sources (See References 4 & 5). Some profiles, such as the operation of ventilation fans, were derived from data provided by the owner. Other profiles were evident by virtue of the nature of the load. For instance, corridor and lobby lighting is in operation 24 hours a day; exterior lights are operative from dusk until dawn. Other profiles like the apartment appliance profile were generated by comparison with established profiles covering similar time spans. For the apartment appliance profile, load and use information was drawn from Reference No. 3.

The computer evaluation of heating and cooling loads utilized "U" factors determined from data contained in Reference No. 2. Appropriate response factors were used so that the program could simulate mass effects.

A factor of 0.8 was used for internal window shading. This factor is based on 50% of the glass being shaded by medium colored venetian blinds set at a 45° angle. The 50% figure for use of internal shading is subject to the action and desires of the tenants and cannot be given definitive support. Visual examination of the building on a clear sum-

mer day indicates that interior shading is used on approximately half of the apartment windows.

The various building types feature balconies in several configurations. These balconies provide external shading in varying degrees depending on the building orientation and balcony configuration. Further, the perpendicular wings of the "L" buildings provide shade for one another. The AXCESS program is not at present equipped to consider external shading. Based on the average shaded areas, the computer derived loads were corrected to reflect the effect of exterior shading.

The apartment buildings are, in general, sufficiently far apart so that shading by adjacent buildings would not have an effect greater than the range of accuracy of the computer calculations.

Computer Outputs

The computer outputs indicate a modeled energy use dramatically less than the actual energy consumption at Starrett City.

The loads and energy consumptions produced by the AXCESS program differ substantially from the actual consumptions measured at Starrett City.

Energy Use Comparison

Energy Consumer	Computer Model (Avg of 4 Bldgs)	Starrett City (1978)
	MBtu/GSF/yr	MBtu/GSF/yr (adjusted)
Total Energy	84	143.7
Electric Power	38.2	32.
Domestic HW	5.07(6.0)*	20.1 (estimated)
Heating	16.5	85.56 — heating & cooling
Cooling	15.8	
Cooking Gas	6.1	6.04

*Estimated Correct Value

In the matter of heating and cooling, based on one ton per 800 gross sq. ft. and 1000 equivalent full load operating hours, the annual energy consumption for cooling, determined by the AXCESS

program, does not depart substantially from what might be expected for a facility like Starrett City. The energy consumption for space heating is a far different matter.

The AXCESS program is based on the assumption that the space heating is under thermostatic control. Such is not the case at Starrett City — the fan-coil units (terminal heating units) are provided with 3-speed fan switches, the operation of which is totally at the discretion of the tenants.

The apartment buildings are arranged in clusters with the center of each cluster being a garage. Within the garage equipment rooms there are secondary pumps and mixing valves which serve the apartment fan-coil units. The secondary systems supply temperatures are adjusted in response to the outside air temperature. This temperature reset does not, however, provide for exposure zoning. Much of the time there is substantial overheating in the apartments. Some tenants control the temperature in their apartments by opening windows, even in 20°F weather.

For the infiltration load, the computer program used half an air change per hour—typical for structures like the Starrett City apartment buildings. With open windows the infiltration rate is certain to be much higher. See Figure 24 for the effect of infiltration on energy consumption.

The net effect of all of the above differences between the energy consumption at Starrett City and the computer modeling effort is not sufficient for total resolution of the model with reality. It is obvious that the energy consumption data produced by the computer is somewhat low.

The Starrett City Domestic Hot Water energy consumption indicates that there may be substantial energy losses in the site distribution system. There also may be similar problems

with the Dual Temperature Water System.

Profiles generated by the AXCESS program do not relate to the way the systems operate at Starrett City. The apparent excessive energy demand for heating displaces the total energy peaks so that there is no match between the computer generated profiles and the real consumption profiles. In addition, the AXCESS program assumes that the buildings are individual and it cannot consider system mass or "fly-wheel" effects. With extensive site distribution systems, like those at Starrett City, the mass of water in the systems slows the reaction of energy conversion equipment and tends to flatten thermal load peaks. This phenomenon is illustrated by Figure 25.

Without a great deal of refinement, it is not likely that available computer programs, and the AXCESS program in particular, will be able to produce a really meaningful model of the energy use at a facility like Starrett City. By adjusting all of the profiles and factoring the building "U" and infiltration factors, such computer programs could probably be made to produce a model approaching reality but at present the "off-the-shelf" program is far too limited.

Conclusions

The tentative conclusions drawn from the audit and modeling follow:

a. There is a potential savings of 20 to 25% of the annual energy costs with the conservation measures described herein and with a workable incentive plan for the tenants.

b. Search out and resolve energy loss in the underground distribution systems.

1. Review make-up water use.

2. Have thermographs made of the site to locate hot spots in the underground dual temperature high temperature water distribution systems.

FIG 23

January 18 to 21, 1979

3. Perform "no-load" tests of the High Temperature Water and Dual Temperature systems.

4. Computer modeling, at least with the AXCESS Program, is not completely satisfactory for analysis of a campus-type facility like Starrett City. The AXCESS Program cannot properly handle uncontrolled loads nor modify peak loads for "flywheel" (mass effects).

Reference No. 1—ASHRAE Handbook and Product Directory, 1976 SYSTEMS, Chapter 37.

Reference No. 2—ASHRAE Handbook and Product Directory, 1977 FUNDAMENTALS

Reference No. 3—Producing Your Own Power, Carol H. Stoner, Vintage Books, Page 40.

Profile References

Reference No. 4—Cooking Load Profile: - Multi-Family Dwelling Units - Economic Evaluation of Total Energy, HUD,

1973, as presented in Advanced Coal-Using Community Systems, Energy Consumption Analysis, Volume 1, Mathtech, Inc., Princeton, N.J.

Reference No. 5—AXCESS Profiles from AXCESS Program Input Data

Hydro-Ejector

One of the requirements of the "Statement of Work" was to consider using a Hydro-Ejector to replace the secondary pumps in the Dual Temperature Water System.

The principle of the Hydro-Ejector is based on Bernoulli's Theorem which states that the total energy of a fluid consists of the sum of the velocity head $V^2/2g$; the pressure head (P/δ); and the potential head (Z). Also, since energy can be neither created nor destroyed, the total head is constant (neglecting losses) at any point in the system. Bernoulli's Theorem is written as:

$$H = P/\delta + V^2/2g + Z$$

H = Total Head

P/δ = Pressure Head = P_1

$V^2/2g$ = Velocity Head = P_2

Z = Potential Head

If we assume a horizontal pipe, then Z becomes a constant. Now, if the velocity head is increased by reducing the pipe diameter, then the pressure head must decrease because the total head must remain constant (neglecting losses). This is the principle on which the Hydro-Ejector works.

Referring to Figure 26, the high static pressure (P_1) of the motive fluid is converted to velocity head by reducing the flow area by means of the nozzle shown in the figure. Design of the nozzle is such that the pressure (P'_1) of the emerging fluid is lower than the pressure (P_2) of the return fluid. This difference in pressure creates a suction that not only draws the return fluid into the mixing chamber but mixes the return and motive fluids. In addition, the

FIG. 24

FIG. 25

COOLING LOAD VS. TIME OF DAY
JULY 24, 25, 28 & 29, 1979

FIG. 26

PRESSURE & VELOCITY IN A CONTROL-EJECTOR AT MAXIMUM TRAVEL

G_1 : MOTIVE FLOW G_2 : SUCTION FLOW $G_3 = G_1 + G_2$

P_1 : MOTIVE PRESSURE P_2 : RETURN PRESSURE $P_3 = P_2 + h$

h : SECONDARY (SUPPLY) PRESSURE DROP

FINAL WHEN STAMPED AS FINAL AND SIGNED BY PROJECT ENGINEER

PROJECT NO.:	DATE:	SCALE:	DWG. NO. A-
DRAWN BY:	CHECKED BY:		
SUBMITTED:	APPROVED BY:		

motive fluid (G_1) imparts some of its velocity to the return fluid (G_2) and the two velocities are equalized in the diffuser at some level between their original velocities at the entrance of the mixing chamber. The velocity head of the supply fluid (G_3 , which is the sum of G_1 and G_2) is then changed to pressure in the diffuser by enlarging the cross section of the flow area.

In the controlled Hydro-Ejector the motive flow, and therefore the return flow, is controlled by a needle that alters the flow area of the motive nozzle. Motion of the needle is controlled by two sensors. One measures outside ambient and the other the outlet temperature of the ejector.

When the Hydro-Ejector was considered for use at Starrett, where it would replace the secondary pumps in the garages, calculations showed that the secondary head was too high for the use of a Hydro-Ejector. This was due to the fact that the secondary pumps in the garages serve several buildings while the Hydro-Ejector application is generally for a single building.

However, because it was felt that in certain applications the Hydro-Ejector would be cost effective, we took a hypothetical case and went through the Hydro-Ejector selection and cost analysis to demonstrate how it could be done. See Appendix C for these calculations.

Thermostatic Controllers on Fan Coil Units

The Starrett City Apartments are provided with fan coil units for heating and cooling. The fan coil units are equipped with 3-speed fan switches so that the tenants can exercise some control of the heating and cooling within the apartments. Some of the apartments are unoccu-

1 for portions of the day with the unit fans running at maximum speed. In other cases, tenants elect to draw the maximum heating and

ESTIMATED SAVINGS WITH FAN-COIL CONTROL RETROFIT

UNIT	ANNUAL HEATING SEASON SAVINGS	ANNUAL COOLING SEASON SAVINGS	ANNUAL POWER SAVINGS
201	2671 MBtu	375 MBtu	112 kwh
202	2521.5 MBtu	330 MBtu	112 kwh
203	2353.4 MBtu	300 MBtu	112 kwh
301	3719.2 MBtu	480 MBtu	211.5 kwh
302	3304 MBtu	420 MBtu	211.5 kwh
303	3088.3 MBtu	380 MBtu	211.5 kwh
401	4348.8 MBtu	620 MBtu	195 kwh
402	4558.9 MBtu	500 MBtu	195 kwh
403	3529.5 MBtu	450 MBtu	195 kwh
601	No precise data available		302.8 kwh
602	but capacities proportional		302.8 kwh
603	to those above - (approx, twice the savings of the 300 series units)		302.8 kwh

References: McQuay Unit Shop Drawings and Performance Data

cooling capacity from the central system while using the window for ventilation and temperature control. Manual fan speed control, requiring tenant intervention, is not as efficient as some form of automatic control.

The fan coil units can be retrofitted with a thermostatic fan speed control, a manual heating-cooling switch, and a new control box cover. The thermostat, with its sensing element located in the fan coil unit return air inlet, would turn fans off when it is satisfied and cycle the fan on when there is a demand for heating or cooling. The fan would cycle regardless of the speed setting of the fan switch.

The thermostat dial and summer-winter switch would be located in the cover of the fan control box. Since all of the control system com-

ponents would be located within the fan coil units, there would be no work required outside the fan coil units. Fan coil units produce 5 to 8% of their heating-cooling effect through gravity circulation without the fans running; therefore, there will always be sufficient air passing over the thermostat bulbs to function properly. Figure 27 shows the controller arrangement.

Based on an estimated energy saving of 20% during the heating season and 10% during the cooling season, the unit with the least capacity (the worst case) would pay out the control system retrofit described above in less than 4.5 years, based on energy cost figures used in this study of 65 cents/gal. of Number 6 oil. The larger units would pay out in less time resulting in an overall payback of less than 3 years for in-

SUMMARY OF ESTIMATED
FAN COIL UNIT SAVINGS
(BASED ON 1978 FUEL COSTS)

		No. of Units	X	Load	X	Cost	
200	Heating	5979	x	2521.5	x	\$0.0038	= \$57,289
	Cooling	5979	x	330	x	0.038	= 6,241
	Power	5979	x	112	x	0.055	= 36,744
						subtotal	100,274
300	Heating	11,181	x	3304	x	0.0038	= 140,377
	Cooling	11,181	x	$\frac{420}{12}$	x	0.038	= 14,859
	Power	11,181	x	211.5	x	0.055	= 129,766
						subtotal	285,002
400	Heating	6041	x	4558.9	x	0.0038	= 104,652
	Cooling	6041	x	$\frac{500}{12}$	x	0.038	= 9,560
	Power	6041	x	195	x	0.055	= 64,699
600	Heating	368 (estimated)	x	6608	x	0.0038	= 9,240
	Cooling	368	x	$\frac{1000}{12}$	x	0.038	= 1,163
	Power	368	x	302.8	x	0.055	= 6,114
						subtotal	16,517
						GRAND TOTAL	\$580,704
						Approximate installation cost	\$1,661,615

corporation in all fan coil units. Payback period will decrease proportionally to the increase in the price of oil.

Power savings were based on fans running at no higher than medium speed since the owner is currently eliminating the high speed option on the fan coil units.

Additional Wall Insulation

The addition of wall insulation for apartment interior walls was examined.

Our analysis was based on the addition of 3-1/2 inches of fiberglass insulation and 1/2-inch thick sheet rock as an interior finish.

Such a procedure would result in a change in the average wall "U" from 0.29 to 0.06 Btu/sq.ft./°F.

Using charts and methods described in Reference No. 6, it was determined that the average unit savings in heating and cooling energy expenditures would be 18,000 Btu/sq. ft./yr and 2000 Btu/sq. ft./yr respectively. At 65 cents per gallon of oil, this is equal to savings of 9 cents per year per square foot. The cost of adding insulation plus the additional work or resetting sinks, gas ranges and fan coil units, as well as adding new trim around windows and balcony door would be approximately \$1.56 per square foot. This

results in a simple payback of 17 years.

In addition, major renovations like this would be very disruptive tenants and might be extremely difficult to schedule satisfactorily. This would also result in the tenant losing 4 inches off the room length or width which could cause some discontent.

As a result of the long payback period and other negative aspects, we have abandoned this area of study.

Use of Solar Energy

The direct use of solar energy was examined for application at Starrett City. The areas considered were space heating and domestic hot water. With approximately 170 acres of occupied building area, it becomes immediately apparent that the installation of solar collectors with sufficient area to provide a significant portion of the space heating requirement would dramatically alter the character of the Starrett City site. Domestic hot water heating was selected as the direct solar energy application offering the greatest promise. The roofs of the garages were chosen as being the locations most suitable for the installation of solar collectors. The area of collector considered in the study was limited to the area that could be installed on one selected garage roof.

The analysis was performed using the simplified manual calculation method published by the Copper Development Association, Incor-

1978 ENERGY COSTS

kwh	\$0.055
Ton-Hr. Refrig.	0.0377
MBtu - Heating	0.00377
Fuel cost	65¢/gal. (#6 oil)

Reference:

6. "Manual of Energy Savings in Existing Buildings & Plants" — Vol. 2 — Facility Modifications, by Stephen L. Baron, P.E.

FIG. 27

FAN COIL UNIT
RETROFIT CONTROL SYSTEM

FINAL WHEN STAMPED AS FINAL AND SIGNED BY PROJECT ENGINEER

	PROJECT NO.:	DATE:	SCALE:	DWG. NO. A-
	AM - 1986	9/26/79	NONE	
	DRAWN BY: SAL	CHECKED BY: GEH		
	SUBMITTED:	APPROVED BY:		

porated. The method is known as the Copper Development Association Sun-Chart Hand Calculation Method and is fully described in Reference No. 7.

An analysis was made for solar heating of domestic hot water with collectors mounted on the roof of Garage G-H and furnishing hot water to the buildings served by this garage. The analysis was based on a hot water demand of 35 gallons per day per apartment, supplied at 130°F. The collectors used in the analysis were flat plate type, copper, with a selective surface and two glass covers.

Other parameters used in the analysis are:

Collector Tilt angle - 35°

Latitude - 41° N

Collector Surface Azimuth Angle South (180°)

Collector Area (Garage G-H) - 10,656 sq. ft.

Collector Flow Rate - 1 gpm per collector

Installed Cost - \$40.00/sq. ft. of Collector (not including basic heating system)

Fuel Cost - \$4.51 per Million Btu Heating System and Distribution Efficiency - 70%

The analysis indicates that the amount of domestic hot water heating that could be accomplished with solar heating is approximately 2,738 x 10⁶ Btu per year. Translated into dollars, it represents \$17,640 of equivalent oil (645 bbls/year).

Considered on a simple payout basis, it would take 24 years of fuel savings to cover the cost of the solar system.

A more detailed analysis does not make solar heating of domestic hot water more viable. Without a grant, tax incentives, low interest loans and

other incentives, solar heating of domestic hot water cannot be justified for the Starrett City Project.

Apartment Window Treatment

Windows in the Starrett City Apartments are aluminum, single glazed, double hung units. The operable window units permit the tenants to use the windows for ventilation.

A number of window treatments were considered as energy conservation measures:

a. Addition of internal supplementary glazing units at \$135.00/window installed. "U" factor equals 0.5, including existing window.

b. Addition of internal double glazed supplementary units at \$162.00/window installed. "U" factor equals 0.39 including existing window.

c. Installing external shading devices at \$40.00/linear ft. installed.

d. Installing miniature louvered sun screens at \$97.50/window unit, installed.

NOTE: Awnings, both fixed and retractable types, were excluded because of their cost and susceptibility to wind damage.

The utilization of storm or supplemental windows at Starrett City is more complex than similar applications at another facility. The use of fixed external storm window units is not practical at Starrett City. The tenants must utilize the operable window sash for ventilation and exterior storm window installation on high rise buildings is expensive.

To retain the utility of the present windows it would be most practical to install supplemental windows inside the existing prime windows. The supplemental windows would have to be almost identical to the prime windows, duplicating all of the required window functions. Double glazing could be provided in the supplemental windows.

The estimates of unit fuel savings

with retrofit, supplemental windows are:

1. Single glazed retrofit supplemental window unit.

- north exposure - 775.1 MBtu/window/Yr.

south exposure - 848.9 MBtu/window/yr.

2. Double glazed retrofit supplemental window unit.

- north exposure - 1020.2 MBtu/window/yr.

- south exposure - 1450.1 MBtu/window/yr.

Analyses indicate that the installation of supplemental windows is not economically viable for the foreseeable future. Assuming distribution losses of 10%, savings for the single glazed supplementary window are \$3.40 per year and for the double glazed supplemental window are \$5.20 per year. Payback periods are 40 and 31 years respectively. Further, replacing the existing prime window with one meeting current energy standards would be even more expensive and no more effective than the installation of supplemental windows and, as a result, does not merit consideration at this time.

External Shading

Among the energy conservation measures applicable to windows in an air conditioned building is external shading. Two of the more common methods of shading windows from the outside are: the installation of fixed louvered, "eyebrow" type sun screens over the windows and the use of miniature louver sun screens applied directly to the windows.

The "eyebrow" type units would be affixed to the exterior of the building, above the windows and would be run to form continuous overhangs. Among the advantages of this type of sun control device is their ability, when properly designed, to prevent the sun's rays from entering the windows during the cooling season, yet permitting them

Reference:

7. Copper Brass Bronze Design Handbook, Solar Energy Systems, Copper Development Association, Inc.

to enter during the heating season when some benefit can be gained from the passive solar heating. The selectivity of the overhead louver units is achieved by careful positioning of the louvers. The angle at which the louvers are set excludes the rays from the sun at the higher solar altitudes during the summer while passing the sun's rays when the solar altitude is lower during the heating season.

The miniature louvered sun screens would be applied directly to the window frames on the outside of the building. These sun screens are quite effective in excluding unwanted solar energy. They do not, however, admit the rays of the winter sun as effectively as the overhead "eyebrows," although they tend to reduce conduction heat loss. Further, the miniature louvered sun screens interfere with window washing and reduce visibility. They have an additional undesirable property in that they are reflective on the inside at night while permitting full view from the outside. An additional positive feature of the miniature louvered sun screen is that it also functions as an insect screen.

Neither of the shading schemes described above offers an economically feasible energy conservation retrofit option. To provide fixed louvered sun shades above the windows on the south exposures of a typical 17-story apartment building at Starrett City would cost approximately \$148,000.00. The energy saved would amount to approximately 270,650 MBtu/Yr. or \$1134 per year.

The miniature louver sun screen at \$97.50 per window unit would save 601 MBtu or \$2.27 per year for each south facing window so protected. (See Reference No. 8).

Reference:

8. Window Design Strategies to Conserve Energy. U.S. Department of Commerce, National Bureau of Standards, Pages 2-4.

In the matter of the energy conservation measures described herein for the apartment windows at Starrett City, it is evident that double glazing and external shading could be feasible if included as part of the original structure. Retrofitting makes these measures sufficiently expensive and they cease to be cost effective.

Energy Conservation Measures in Progress

The Starrett City Energy Project, with assistance from the maintenance staff, has begun instituting some significant energy conservation measures. The prime focus to date has been on conservation of electrical energy — lighting and power. Some of the conservation efforts have been completed, while others are still in progress.

The conservation efforts include:

Eliminating the High Fan Speed on Fan Coil Units

Implementation of this conservation option involves disconnecting the fan motor connections to the high speed fan switch position. The fan coil units were selected using heating and cooling capacities at medium fan speed so that the only consequence of the elimination of the high fan speed will be to deny tenants the option of using high air circulation rate within the apartments.

Eliminating the high speed position involves merely disconnecting a wire. This was done during normal yearly maintenance of the fan coil units and represented no capital costs and no additional labor costs.

Changing Apartment Kitchen and Bathroom Lights from Incandescent to Fluorescent

As designed, the kitchen and bathroom lighting is with single fixture units with each unit designed for four 60-watt bulbs. It is known that a large percentage of tenants

changed to 100-watt bulbs.

Changing the fixtures to two 40-watt fluorescent lamps in the kitchen and two 20-watt lamps in the bathroom results in an overall savings of 5605×10^3 kwh per year (including ballast losses). This represents 11,417 barrels of oil per year.

Estimated costs for parts and labor to effect this changes is \$250,000.00. The payback period, assuming 65 cents per gallon for oil, is less than one (1) year.

The lighting level, using the fluorescent lamps, will be sufficient for the kitchen and bathroom. Both are small rooms. We do not anticipate any objections by the tenants.

Reduction of Lighting and Miscellaneous Equipment Use

(a) Deactivation of lobby and canopy lights. This conservation measure is accomplished by removing lamps from the fixtures being deactivated. Canopy and lobby illumination is maintained at or above levels needed for safety and security even with the deactivated fixtures.

(b) Deactivation of garage perimeter lights, like the deactivation of corridor and lobby lights, involves removing lamps from fixtures and/or interrupting the flow of current to the perimeter light fixtures. Deactivation of the perimeter fixtures has no discernible effect on the illumination within the garages.

(c) The deactivation of corridor lights consists of deactivating two light fixtures in each corridor wing on each apartment floor. While the illumination level in the corridors is reduced by application of this procedure, security and safety have not been affected.

(d) The addition of timers to laundry room lighting will turn the laundry room lights off for nine hours during the early morning hours when use of the laundry facilities is minimal.

(e) The deactivating of miscellaneous unclassified lights, heaters, motors and other electrical apparatus amounts to 50 kw at present. Further reductions in the use of unclassified electrical loads are anticipated.

We should note that at the outset of the project submetering was an obvious method of reducing energy usage. However, at the time the study was undertaken regulatory controls prevented its serious consideration.

A summary (Table 20) of the above energy conservation measures follows:

Select Options

As can be seen in the previous

paragraphs, the cost effective options in the area of conservation are the incorporation of thermostatic controllers in the apartment fan coil units and the group of options discussed under the title "Energy Conservation Measures in Progress."

For The WPCP

As noted in Part B of this chapter, the readily implemented and cost-effective conservation measures have already been taken at 26th Ward as part of several city-wide, water pollution control plant, conservation programs. Possibilities for further energy conservation at the plant include elimination of some of the infiltration/inflow and automatic control of blower speed to

maintain a fixed dissolved oxygen level in the aeration tanks.

Previous Conservation Programs

In May, 1976, the Mayor issued an Executive Order in regard to energy conservation throughout the city. The Division of Plant Operations developed procedures for all the WPCP's in order to comply with this order. Continuous monitoring of electric power use was instituted; recording kilowatt hours, monthly peak demand and total energy cost. The largest energy use and demand peaking at the 26th Ward WPCP occurs from operation of pumps and blowers. 60-70% of the total power load consists of main sewage pumps and blowers. Less than 10%

Table 20

ENERGY CONSERVATION MEASURES

<u>CONSERVATION MEASURE</u>	<u>Annual Electric Power Saving KWH x 10³</u>	<u>Annual Energy Savings as MBTU x 10³</u>	<u>Annual Energy Savings per Gross sq. ft. of Apartment Area MBTU</u>	<u>Total Annual Saving Bbl. No. 6 Oil</u>	<u>Total Annual Power Savings (oil at 65¢/gal)</u>
a. Disconnect High Speed Switch Option on Fan Coil Units	1,030	3,515	0.48	2,075	\$ 56,648
b. Deactivate Lobby and Canopy Lights	446.8	1,525	0.21	900	24,570
c. Deactivate Garage Perimeter Lights	340.6	1,162	0.16	686	18,728
d. Deactivate Selected Hallway Lighting Fixtures	960.7	3,279	0.45	1,936	52,853
e. Adding Timers for Laundry Room Lighting	169.2	578	0.08	341	9,309
f. Deactivating Misc. Motors Lights & Heaters	18.2	62	0.008	37	1,010
g. Changing Kitchen Lights in Apartment from Incandescent to Fluorescent Units	3,737	12,757	1.75	7,529	205,542
h. Changing Bathroom Lights from Incandescent to Fluorescent Types	1,868	6,375	0.88	3,763	102,730
	<u>8,571</u>	<u>29,253</u>	<u>4.02</u>	<u>17,267</u>	<u>\$471,390</u>

TABLE 20A

ENERGY CONSERVATION MEASURES

<u>CONSERVATION MEASURE</u>	<u>ANNUAL PER UNIT ELECTRIC POWER SAVINGS</u>	<u>SIMPLE PAYBACK</u>
a. Disconnect High Speed Switch Option on Fan Coil Units	43.7 watt-hrs/unit/yr	immediate*
b. Deactivate Lobby and Canopy Lights	9713 watt-hrs/bldg/yr	immediate*
c. Deactivate Garage Perimeter Lights	394 watt-hrs/fixture/yr	immediate*
d. Deactivate Selected Hallway Lighting Fixtures	336 watt-hrs/fixture/yr	immediate*
e. Adding Timers for Laundry Room Lighting	3678 watt-hrs/room/yr	6 months
f. Deactivating Misc. Motors, Lights & Heaters	N/A	N/A
g. Changing Kitchen Lights in Apartment from Incandescent to Fluorescent Units	794 watt-hrs/fixture/yr	1 year
h. Changing Bathroom Lights from Incandescent to Fluorescent Types	397 watt-hrs/fixture/yr	1 year

*No costs were incurred in carrying out these measures.

of all power consumed is made up of electric heating, lighting and ventilating.

The peak demand charge makes up a significant portion of the monthly energy cost. This demand was monitored and steps were taken toward its reduction. Some of those steps were:

- Run fewer variable speed pumps at top speed rather than more units at lower speeds.
- When alternating units into service, stop one unit first, then start the replacement unit.
- Delay nonessential power uses such as sludge transfer operations until low peak demand periods.
- Install demand monitoring equipment.

In addition, the plant modulates blower operation during high sewage flow conditions.

In the last 5 months of 1976, these procedures reduced 26th Ward's peak demand by 18% and total electric power consumption by 18%. Monthly costs dropped an average of \$11,500 or 18.8%.

Extraneous flow entering the collection system results in unnecessary pumping and aeration requirements. A major source of extraneous flow was the tide gate at the Williams Avenue regulator. Inflow varied from one to twenty mgd depending on the height of the tide. These tide gates were repaired, greatly reducing this source of inflow and its subsequent pumping.

Further Conservation Opportunities

The most effective methods of further reducing power consumption at the plant are to further reduce infiltration/inflow and to fine tune aerator operations.

An infiltration/inflow report* identified nearly ten mgd of extraneous flow which could be cost-effectively eliminated, i.e., operating cost savings would outweigh the cost of the required remedial work. The remedial work recommended consisted of sewer repairs and a plumbing inspection program. Many water distribution system and building plumbing leaks find their way to the sewage collection system. Not only is the water resource wasted, but it must be pumped and treated at the water pollution control plant.

Fine tuning the aeration system would reduce blower power requirements. Dissolved oxygen probes in the aeration tanks would be linked to the blower controls allowing the proper level of dissolved oxygen to be maintained. To date, however, no probes are available which operate reliably in sewage. This project may merit future consideration with the development of reliable probes.

***Study of Excessive Wastewater Flows 26th Ward Water Pollution Control Plant, Hazen and Sawyer, July, 1977.**

Engine generators capable of producing power on-site were removed from the 26th Ward in the late 1960's. These engine generators operated on digester gas or fuel oil. At that time, oil prices and purchased power costs were low and maintenance of the generators took considerable manpower and materials. It was decided to remove the engines as they were not cost-effective.

A study by the Division of Plant Operations in June, 1977, compared on-site generation at Newtown Creek to purchased power and found on-site generation cost-effective. Further, it recommended on-site generation for ten city plants including 26th Ward. Implementing this recommendation would save 8 million gallons of oil per year overall and 700,000 gallons at 26th Ward. This study recommended seeking federal funds to construct new facilities at the ten plants. Since there appears to be no current funding for this project and because we have proposed using the digester gas very efficiently at the Starrett Total Energy Plant, consideration of installing engine generators at 26th Ward should be deferred.

We recommend continued attention be given to these conservation opportunities. They are likely to become more attractive in the future as the cost of electric power and fuel increases relative to the cost of implementing the conservation opportunities.

Chapter 4

Environmental Review

An environmental review of the selected options indicates negligible effects of air, water, and other pollution. Positive secondary effects are predicted in the conservation of energy resources and potable water.

Air Effects

The 26th Ward boilers are operated under a permit issued pursuant to the NYC Air Pollution Control Code. The Starrett City Total Energy Plant has a similar permit to operate under the Air Pollution Control Code.

The air quality in the vicinity of Starrett City is predicted to improve slightly. The TEP will have lower fuel requirements and the proportion of gas fuel used will increase. Natural gas burns cleaner than oil with lower emissions. None of the constituents in the digester gas (maximum 9% of the total fuel requirement) is expected to add any new stack emissions. The cooling tower will be shut down, eliminating evaporative losses forming "clouds."

At the 26th Ward WPCP, the boiler operation will be discontinued, eliminating stack emissions, and digester gas will no longer be flared in the open atmosphere except in emergency situations.

Water Effects

The 26th Ward WPCP operates under an effluent discharge permit issued in compliance with the State Pollutant Discharge Elimination System. The effluent option was studied to determine the extent of increased thermal discharge which will occur when the effluent is used for cooling in the TEP. The "worst case" of maximum cooling requirement and minimum plant flow predicts an effluent temperature increase of 8.2°F. The more prevalent conditions of average effluent flow with maximum and average cooling requirements yield increases of 5.5°F and 4.5°F respectively. The effluent used for cooling will be

returned to the plant and diluted with the remaining effluent before discharge.

The effluent is discharged into Hendrix Creek, a narrow tidal inlet connecting to Jamaica Bay. The average maximum temperature increase expected in Hendrix Creek in the vicinity of the plant outfall is 2°F to 2.5°F. This is below the thermal discharge limit of 4°F set forth in the New York State Environmental Conservation Law governing estuaries. Temperature data is collected in Jamaica Bay annually, providing sufficient background data to monitor any changes that might occur. No environmental effects due to thermal discharge are expected.

Noise

The design of the pump station will take into account noise control. Construction will take place in Van Siclen Avenue, a street with minimal traffic, located away from the dense residential areas of Starrett City.

Need to Expand the TEP

To evaluate the need for expansion of the TEP, two areas must be investigated. One is additional loads resulting from the energy exchange, and the second is projected loads due to increases in occupied apartments or additional structures and general increases in power usage by tenants as they become more affluent.

If all three exchange options are carried out, the peak load at the TEP will decrease by almost 1 megawatt. In all three options (digester gas, thermal exchange, effluent) the power supplied by the TEP is only used for control purposes; therefore, it is negligible. However, the use of effluent from the 26th Ward for condenser cooling results in significant energy savings at the TEP. Cooling tower fans, turbine condenser pumps and refrigeration condenser pumps will no longer be required. They will, however, be

maintained on a standby basis. Effluent, digester gas and hot water pumping equipment will all be located at the 26th Ward and be operated on PASNY power.

Supplying hot water to the 26th Ward will require an increase in extraction steam and, therefore, an increase in throttle steam. Assuming that the 26th Ward received Jamaica sludge for its digesters, a peak load of 20 MMBh is predicted. This represents 20,000 pph of extraction steam which, in turn, is an increase of 13,000 pph of throttle steam.

Energy balances calculated for the TEP for various loads show that the plant's overall efficiency improves as extraction steam is increased. Therefore, the increase in extraction steam is not a problem for the TEP.

The additional 13,000 pph of throttle steam required can be easily supplied by the TEP boilers. At present, no boiler has ever operated over 70,000 pph but they are capable of 110,000 pph. In addition, present operating procedure is to always have a minimum of two boilers on line. Therefore, we can see that the

additional load is well within the capabilities of the present TEP equipment.

An area that might require expansion is the electrical generation capability of the TEP. As of September, 1979, the peak load was 11.2 megawatts and the occupancy rate was 93%.

Since that time management at Starrett City has started an intensive program of conservation. Items such as reducing exterior and garage lighting, changing bathroom and kitchen incandescent lights to fluorescent lighting, reducing hall lighting and eliminating high speed on the fan coil units will save approximately 2 mw when fully implemented. Changes in operating procedures such as better use of variable speed pumps can reduce power plant loads by up to 1 mw.

In addition, an intensive campaign of tenant education in conservation has been undertaken. This has included contests for energy consumption reductions in which cash prizes were given to the winning apartment buildings. Reduc-

tions have been on the order of 10% which actually represents a 15% to 20% reduction in the power the tenants control. Consolidated Edison of New York estimates that the tenant controlled power can be reduced by 40%.

Another point is that since the peak load of 11.2 mw in 1979, the project has become 100% occupied. However, since the conservation program has started, the peak demand has been approximately 10 mw. If tenants continued to use power as they did in 1979 when the project was 93% occupied, the new peak would have been about 12 mw.

Assuming the peak load does not exceed 10 mw, it could be handled by one turbine-generator and two dual fuel engine-generator sets. This allows one turbine and one engine to be "down" and is hopefully a worst case condition.

An intensive program of energy conservation by management and tenant, bolstered by energy savings resulting from the exchange options, will obviate any need for expansion of the TEP.

Attachment 1
Statement of Work
Background and Objectives

The primary role of DOE's Division of Buildings and Community Systems (BCS) is to assume the national technical leadership for research, development, and demonstration (RD&D) activities related to energy conservation in buildings and community systems; accelerate and complement private sector efforts; foster acceptance of energy-saving technology; maximize the effectiveness of energy use, and minimize adverse socioeconomic and/or environmental impacts.

Starrett City is a self-contained residential community in Brooklyn, New York, of approximately 24,000 people, in addition to shopping and community centers, parking garages, schools, and recreational facilities. Currently, a total energy (TE) plant supplies the electrical, heating, cooling, and domestic hot water needs for the entire complex. The Division of Buildings and Community Systems is interested in analyzing energy conservation potential in community energy systems. This site offers the potential for examination of several alternatives. The possibility exists to explore the potential feasibility of integrating the local municipal wastewater treatment system with the total energy plant at Starrett City for co-generation of energy services. The possibility exists to adapt the total energy plant to burn methane recovered from the nearby New York City 26th Ward Water Pollution Control Plant (WPCP). In turn, because of the close proximity of the two plants, the total energy plant would supply electricity and thermal energy to the 26th Ward plant. The low-grade heat transfer to be considered can only be viable over distances less than one mile. In addition, utility franchise restrictions will not apply since in this case no public right of way is involved. In undertaking the feasibility analysis of this concept, Starrett City, Inc., would also evaluate the potential for using sludge

and solid waste as a supplemental energy supply for the Starrett TE plant and conduct a detailed energy conservation analysis. In addition, it would study the feasibility of using water from the WPCP treatment in the TE plant and on-site TE plant treatment process.

The proposed concept offers DOE the opportunity to develop and test the feasibility of using currently wasted energy sources to generate energy for a self-contained community. Of equal program importance in this effort is the possibility to compare the energy conservation impacts of this approach to an internally focused load balancing, insulation, thermal storage concept tied to the TE system. The information gained in this technical research/feasibility effort will form the basis for proposing the institutionalizing of energy conservation concepts in communities. Basically, we will be able to analyze and compare the external and internal energy conservation systems and make judgments on policy for both TE systems and cogeneration systems. If technical viability can be illustrated, the Division of BCS intends to begin an effort to foster acceptance of the selected approach through existing institutional frameworks.

Task 1: Prepare Detailed Work Plan

Initially, the contractor shall meet with DOE/BCS representatives to discuss the proposal, any questions of emphasis, and the necessary degree of detail. The contractor shall then prepare a detailed work plan covering the entire 18-month study period. Because of the size of the project and the number of subcontractors, the work plan shall include a detailed schedule showing the timing and completion point of individual components of the project.

The contractor shall transform the detailed project work plan into a

CPM type display. This CPM format will be used to track the monthly progress of each subcontractor.

During the first progress review the work plan shall be presented DOE. Any modifications suggested by DOE shall be incorporated following this meeting.

Task 2: Collect Engineering Data

Following approval of the project work plan, the contractor shall design and implement a plan for collecting data from the 26th Ward WPCP and the Starrett TE plant. Three steps will be performed:

Step 1: Review Data Already Being Collected

Step 2: Determine Additional Data Requirements

Step 3: Assign Responsibilities for Data Collection and Summary

Step 1. Review Data Already Being Collected

A significant amount of data is already being collected at both the 26th Ward WPCP and the Starrett TE plant. The contractor and his subcontractors shall review this data and itemize the monitoring equipment already in place at both plants.

Step 2. Determine Additional Data Requirements

To determine additional data requirements, the contractor and subcontractor shall hypothesize a range of energy recovery systems that could be considered for use in either the 26th Ward WPCP or the Starrett TE plant. The contractor shall then determine the basic data requirements that would be needed to evaluate each option. If more frequent monitoring or additional detail is required, the operators in each plant shall be requested to modify their procedures.

For example, data on electrical heating, and cooling demands on a hourly, daily, and seasonal basis, and fuel and water consumption will

be needed to evaluate all options. Information on the quality and quantity of digester gas will also be required.

Step 3. Assign Responsibilities for Data Collection, Evaluation and Summary

After preparing a comprehensive list of data requirements, the contractor shall determine the need for additional monitoring instruments.

The contractor shall prepare data collection forms to be used for each item and assign a specific individual the responsibility for completing these forms. On a selective basis, the contractor shall collect these forms, and summarize and review the data to ensure that the equipment is operating properly. The data will be made available for use in later tasks.

Task Descriptions

The contractor, Starrett City, Inc., will perform eight basic tasks:

Task 1: Prepare Detailed Work Plan

Task 2: Collect Engineering Data

Task 3: Develop and Evaluate Alternative Energy Conservation, Recovery, and Exchange Options

Task 4: Analyze Starrett City Energy Conservation Options

Task 5: Select Systems for Further Analysis

Task 6: Prepare Preliminary Engineering of Selected Systems

Task 7: Develop Financial/Institutional Alternatives

Task 8: Prepare Project Implementation Plan

Task 9: Prepare Comprehensive Report for Technology Transfer

In addition, if the analysis of energy conservation options demonstrates the possibility of substantial conservation, the contractor is prepared to undertake an additional

task (Design and Implement a Consumer Motivation Plan for Energy Conservation). This task would require additional funding at a level to be determined after a specific conservation plan is selected, and is specifically not included in this statement of work.

Task 3: Develop and Evaluate Alternative Energy Conservation, Recovery, and Exchange Options

In this task, the contractor shall develop conceptual designs and approximate cost estimates for the alternative energy recovery options. The task shall be undertaken in four steps:

Step 1: Develop Conceptual Designs and Cost Estimates for Energy Conservation and Recovery Options at the 26th Ward WPCP.

Step 2: Develop Conceptual Designs and Cost Estimates for Energy Conservation and Recovery Options at the Starrett TE Plant.

Step 3: Analyze the Feasibility of Using the Sludge Disposal Plant to Supply Energy to the Starrett TE Plant.

Step 4: Develop Conceptual Designs and Cost Estimates for Transporting Energy and Water Between the 26th Ward WPCP and the Starrett TE Plant.

Step 1: Develop Conceptual Engineering and Cost Estimates for the 26th Ward WPCP

The contractor shall develop conceptual designs and cost estimates for all modifications within the 26th Ward WPCP required to accommodate the identified energy conservation and recovery options.

Step 2: Develop Conceptual Designs and Cost Estimates for Energy Conservation and Recovery Options at the Starrett TE Plant

The contractor shall develop conceptual designs and cost estimates

for all required modifications within the Starrett TE plant necessary to accommodate the identified energy recovery and conservation options. A determination will be made as to whether the methane gas from the 26th Ward WPCP is acceptable to the current boiler configurations. This determination shall be based on the heating value of the gas and its specific constituents (e.g., water content).

In addition, the contractor shall identify any necessary boiler or burner modifications and develop preliminary costs. To ensure that potential modifications would be feasible, the contractor shall evaluate the plant's physical structure. For those options requiring delivery of heated water to the 26th Ward WPCP, the contractor shall conceptualize cost-out methods for handling the requisite water flows. The contractor shall also prepare conceptual designs for all water treatment and handling systems required to transmit treated sewage effluent for use in the TE plant and at the site of the housing development.

The contractor shall prepare an analysis of the need to expand the total capacity of the Starrett TE plant. This analysis shall be based on a series of energy balances for the plant that cover the entire range of options under analysis. These energy balances shall include projections of future energy requirements for both Starrett City and the 26th Ward WPCP.

Step 3: Analyze the Feasibility of Using the Sludge Disposal Plant to Supply Energy to the 26th Ward WPCP and/or to the Starrett TE Plant

In conjunction with New York City's preparation of an environmentally acceptable sludge management plan, the contractor shall determine the feasibility of using sludge and/or solid waste as supplemental energy for WPCP and/or

the Starrett TE plant. In particular, the contractor shall assess the feasibility of using energy from the sludge disposal system in the existing plant boilers and prepare conceptual designs and preliminary costs for any required modifications. The contractor shall also prepare conceptual designs and preliminary cost estimates for any sludge storage, processing, and handling systems required.

In addition, the contractor shall determine the feasibility of supplying waste heat and/or electricity from the Starrett TE plant for use in the sludge-drying process. In conjunction with the analysis in Step 2 above, the contractor shall prepare a conceptual design and cost estimates for any necessary plant modifications.

Step 4: Develop Conceptual Designs and Cost Estimates for the Exchange of Energy and Treated Effluent Water Between the 26th Ward WPCP and the Starrett TE Plant

For each option being analyzed, the contractor shall prepare an initial design and estimate the costs for facilities needed to exchange digester gas, electricity, water, and thermal energy between the two plants. In preparing these estimates, the contractor shall consider the appropriate capacity for each facility, site-specific installation requirements (e.g., the need for piling supports), and any property modifications required.

Task 4: Analyze Starrett City Residential Buildings Energy Conservation Options

In this task, the contractor shall conduct an analysis of the potential energy savings available to the Starrett City complex. The analysis shall be conducted in two steps:

Step 1: Identify Potential Energy Conservation Strategies.

Step 2: Estimate the Costs and Energy Savings for Each Strategy.

Step 1: Identify Potential Energy Conservation Strategies

The contractor shall conduct an energy audit of selected typical residential buildings at Starrett City. The audit will establish energy use per unit area, population, and dwelling unit type for the selected buildings. This information will be correlated with load profiles of the TE plant to identify peak and off-peak periods for key activities.

Corresponding energy conservation strategies shall then be devised. At a minimum, the contractor is expected to consider the use of a hydro-ejector as a substitute for pumps in the secondary heat distribution system.

The contractor shall also determine the feasibility of metering energy usage at selected locations subject to PSC rulings (e.g., individual apartments).

Step 2: Estimate the Costs and Energy Savings for Each Strategy

After identifying energy conservation alternatives, the contractor shall estimate the potential energy savings and implementation costs for each option. These cost estimates shall include capital expenditures for equipment, installation, and operation maintenance.

Task 5: Select System for Further Analysis

The contractor shall summarize the major attributes of each energy recovery and conservation option, rank the options, and, on the basis of a cost-benefit analysis, select a preferred system for further analysis.

This task shall require three steps:

Step 1: Summarize Energy Recovery and Conservation Alternatives

Step 2: Prepare a Cost-Benefit Analysis for Each Alternative and Perform a Sensitivity Analysis of the Cost-Benefit Alternatives

Step 3: Select a System for Further Analysis.

Step 1: Summarize Energy Recovery and Conservation Alternatives

For each alternative energy recovery system involving the 26th Ward WPCP and the Starrett TE plant, as well as each energy conservation alternative, the contractor shall prepare a summary of the system attributes. For example, the contractor shall itemize capital costs for equipment installation, the increase or decrease in each plant's operating costs, and the estimated energy savings.

Step 2: Prepare a Cost-Benefit Analysis for each Alternative

After assembling the relevant data, the contractor shall perform a cost-benefit analysis for each alternative. This analysis will result in a single net benefit or cost for each alternative. The contractor shall also test the sensitivity of the results to key assumptions, such as the cost of capital for Starrett City, the future prices of alternative fuels, and the probability of realizing the projected energy savings.

Step 3: Select a System for Further Analysis

The completed cost-benefit analysis will suggest a ranking of alternatives that could be used directly to choose a specific alternative for in-depth analysis. However, the contractor shall review all projects with a net positive benefit to incorporate subjective factors not included in the quantitative ranking.

Based on this analysis, the contractor shall recommend to DOE/BCS a specific system for further analysis.

Task 6: Prepare Preliminary Engineering of Selected System

The contractor shall prepare a conceptual design for the most promising energy recovery conservation and exchange system alternative selected in Task 5. The focus of this task will be to refine the conceptual design of this alternative from Tasks

3 and 5 to produce a cost estimate that can be used for designing a financial plan.

At this stage the contractor shall conduct a preliminary environmental review to identify any design features that may require special environmental consideration. It is anticipated that a more detailed environmental assessment will be required if a decision to proceed with project implementation is made.

Task 7: Develop Financial/Institutional Alternatives

In conjunction with preparing the preliminary engineering, the contractor shall identify alternatives for financing the selected system and develop a range of institutional strategies for implementation.

Two steps will be conducted:

Step 1: Identify Financing Alternatives

Step 2: Identify Institutional Issues.

Step 1: Identify Financing Alternatives

The contractor shall prepare a financial plan specifying the timing and amounts of necessary funding and identify all potential sources of funds. At a minimum, the following sources will be investigated:

- New York State Housing Finance Agency
- Federal loan guarantee programs
- State loan guarantee programs
- State DOE grant
- EPA construction grant
- Private financing

For each potential source of funds, the contractor will identify the amounts of capital available, its likely cost, and required terms.

Step 2: Identify Institutional Issues

A number of complex institutional issues will probably arise during the evaluation of the selected system. The contractor will determine those institutional barriers that

could impede the successful implementation of the system and suggest mechanisms for overcoming these constraints.

Task 8: Prepare Project Implementation Plan

Following the conceptual engineering of the selected plan and the identification of financial and institutional alternatives, the contractor shall prepare a detailed plan for project implementation. This plan shall detail the remaining work to be undertaken, who is responsible for each option, when it must be completed, and how much each remaining activity will cost. A secondary purpose of the plan will be its use as a sales tool in obtaining financial commitments from various parties.

Task 9: Report

Step 1: Prepare an Interim Report after Task 5

Step 2: Prepare a Final Report at the Conclusion of Task 8.

Attachment 2
EQUIPMENT SUMMARY

TEP Equipment Data & Characteristics

Boilers

Number of units: 4 Type 28-VP-12W
Manufacturer: Combustion Engineering, Inc.
Fuel: Primary Fuel: natural gas
Alternate Fuel: No. 6 oil

Predicted Performance:	Nat. Gas	No. 6 Oil
Evaporation	110,000 lb/hr	110,000 lb/hr
Feedwater Temperature	280 °F	280 °F
Superheater Outlet Temperature	825 °F	780 °F
Superheater Outlet Pressure	875 psig	875 psig
Efficiency	82.5%	85.6%
Fuel Fired	156,000 scfh	7,850 lb/hr
Fuel Higher Heating Value	1,000 Btu/scf	18,550 Btu/lb

Boiler Auxiliaries

Forced Draft Fans

Number of units: 4 Type: Airfoil, single inlet, single width (one fan per boiler)
Manufacturer: Chicago Combustion-Air Corp.
Fan Size: 4900 Design 1904
Capacity: 34,700 cfm, 36.4" static pressure
Fan rpm 1770, bhp at design capacity 236

Fan Drive: Squirrel cage induction motor
Manufacturer: Various
Capacity: 350 hp, 460-V, 3 ph, 60 Hz, 1800 rpm

Boiler Feed Pumps

Number of units: 3 Type 3HMTA - 7 stage pumps connected to common header, two operating at max. load, one stand-by
Manufacturer: Ingersoll-Rand Company
Capacity: Rated 355 gpm at 1030 psig discharge pressure
Pump drive: Squirrel cage induction motor Allis-Chalmers Corp.
350 hp, 460-V, 3 ph, 60 Hz, 3600 rpm

Turbine-Generators

Number of units: 2 Single automatic extraction condensing, Single-flow exhaust
Manufacturer: General Electric Company
Steam conditions: 850 psig, 825 °F, Back pressure 3" Hg.
Extraction pressure: 130 psig design pressure
166/117 operating pressure range
Generator: 7500 kva, 6000 kw, 4160 Volts, 3 ph, 60 Hz, 3600 rpm, 0.8 power factor.

Diesel Engine Generators

Number of units: 3 Type FSG-138-TSC
Manufacturer: Nordberg Div. of Rex Chainbelt, Inc.
Fuel: Dual fuel: Natural gas, No. 2 oil
Rated horsepower: 2805 bhp

Rated speed: 514 rpm
Number of cylinders: Eight
Generator: Portec Inc., Electric Products Div.
2500 kva, 2000 kw, 4160/2400 Volts, 514 rpm, 3 ph,
60 Hz, 0.8 power factor

Waste Heat Recovery Boilers

Number of units: 3 Model WT-418.3 using diesel engine exhaust gas,
one unit for each engine
Manufacturer: Vaporphase Systems, Engineering Controls, Div.
Pott Industries, Inc.
Maximum capacity: 2820 lb/hr steam
Operating pressure: 140 psig
Feedwater temp: 280°F

Dual Temperature Heat Exchangers

Number of units: 2 Shell and tube type heat exchangers
Manufacturer: Yula Corporation
Rating: Capacity to heat 3375 gpm of water each from
120°F to 160°F through the tubes, using 130 psig
steam in the shell

High Temperature Water Heat Exchangers

Number of units: 2 Shell and tube heat exchangers
Manufacturer: Cochrane Division/Crane Co.
Rating: Capacity to heat 950 gpm of water each from 150°F
to 300°F through the tubes using 130 psig steam in
the shell

Pumps

Dual Temperature Pumps

Number of units: 3 Type 14 ALV centrifugal pumps
Manufacturer: Ingersoll-Rand Company
Capacity: 6850 gpm at 168 ft. total head Pumping temp, 35°F
to 150°F (rated), Pump speed 1140 rpm
Pump drive: Squirrel cage induction motor
Allis-Chalmers Corp.
350 hp, 1200 rpm, driving a variable speed magnetic
coupling

High Temperature Water Pumps

Number of units: 3 Type 6x19A centrifugal pumps
Manufacturer: Ingersoll-Rand Company
Capacity: 1000 gpm at 242 ft. total head
pumping temperature 300°F, pump speed 1710 rpm
Pump drive: Squirrel cage induction motor
Allis-Chalmers Corp.
100 hp, 1800 rpm, driving a variable speed magnetic
coupling

Chilled Water System

Number of units: 3 Model 238A6, 2-stage centrifugal compressors
Manufacturer: York Division Borg-Warner Corp.
Capacity: To cool 4500 gpm of water each from 54.4°F to 41°F; water in tubes, R-22 in shell. Evaporator temp. 35.2°F
Design tonage 2500 tons each
Condenser capacity: 7500 gpm of cooling water (each) entering at 85°F, leaving at 94.6°F. Water in tubes, refrigerant in shell.
Compressor drives: 3 Type K condensing steam turbines
Manufacturer: Murray Iron Works Company
Rated capacity: 2268 bhp at 5360 rpm
Inlet steam pressure 125 psig
Inlet steam temp. 550°F
Exhaust steam pressure 3½ " Hg. Abs.

Condenser Water Pumps

Refrigeration Machine Condenser Pumps

Number of units: 3 Single stage Model OLS 18HH turbine pumps
Manufacturer: FMC Corp., Hydrodynamics Division, Peerless Pumps
Capacity: 7500 gpm at 90 ft head, 1785 rpm, 196 bhp
Pump drive: Squirrel cage induction motor
General Electric Co.
250 hp, 1800 rpm, 460 V, 3 ph, 60 Hz

Turbine Generator Condenser Pumps

Number of units: 3 Single stage Model OLS 16HxB turbine pumps
Manufacturer: FMC Corp., Hydrodynamics Division, Peerless Pumps
Capacity: 3800 gpm at 80 ft head, 1760 rpm
Pump drive: Squirrel cage induction motor
General Electric Co.
100 hp, 1800 rpm, 460 V, 3 ph, 60 Hz

Cooling Tower

Number of cells: 3 Cell Model 653-0-03S
Series 600 steel double flow cooling tower
Manufacturer: The Marley Company
Fan drives: Two-speed motors, 150/37.5 hp, 1800/900 rpm, 460 V, 3 ph, 60 Hz
General Electric Co.

Fuel Oil Storage Tank

Number of units: 1 No. 6 fuel oil storage tank
Size: 55 ft dia × 22 ft high
Capacity: 400,000 gallons
Fuel heating value: Varies between 142,000 Btu/gal and 146,000 Btu/gal

Summary of Unit Processes and Equipment 26th Ward WPCP

1. Screening Facilities — Six heavy duty, front raked, mechanically cleaned bar screens are provided, three in the low level and three in the high level system. All units are 5'-6" wide with 7/8" clear openings using 2-1/2" × 3/8" rectangular bars.

2. Main Sewage Pumps — Six vertical, variable speed, centrifugal, mixed-flow type pumps are provided as follows:

High Level System:	2 at 36 mgd utilizing 300 hp W.R. motors
	1 at 42.5 mgd w/400 hp W.R. motor
Low Level:	2 at 32 mgd utilizing 350 hp W.R. motors
	1 at 42.5 mgd w/500 hp W.R. motor

3. Preliminary Settling Tanks — Four rectangular tanks are provided and equipped with sludge and scum handling equipment. Design data are listed below:

Single tank dimensions	— 162' × 67' × 12'
Net total tank volume	— 500,000 cu. ft.
D.T. at design flow (85 mgd)	— 1.0 hr.
Total surface area	— 43,400 sq. ft.
O.R. at design flow (85 mgd)	— 1,960 gpd/sq. ft.

4. Preliminary Sludge Pumping and Degritting — The mixture of sludge and grit collected in the preliminary settling tanks is pumped to four 24-inch cyclone degritters by six 50 hp two-speed centrifugal (torque-flow) pumps, rated at 450/250 gpm. Two triplex heavy duty plunger pumps rated at 160 gpm vs. 100 psi are also provided for clearing clogged sludge hoppers as required to facilitate the movement of the sludge-grit mixture.

5. Aeration Facilities

a. Air Filters — Four electrostatic, dry plate agglomerator filters with disposable fiberglass filter cartridges are provided, designed to remove 97% of particulate matter from atmospheric air. Each of the four units is rated at 25,000 cfm.

b. Air Blowers — Four units each rated at 17,500 scfm vs. 7.75 psig.

c. Aeration Tanks — Two tanks are provided and equipped with air distribution piping and ceramic diffuser tubes. Design data are listed below:

Single tank dimensions	— 404' × 30' × 15'
Net total volume	— 1,380,000 cu. ft. or 10.4 mg
D.T. at design flow (85 mgd)	
w/o R.S.	— 2.92 hrs.
w/25% R.S.	— 2.34 hrs.

Design BOD₅ loading — 49 lb/100 cu. ft.

d. Air Diffusers — 2½" diameter by 24" long ceramic diffusers rated at 5 cfm are installed on double header pipes.

3. Return and Waste Sludge Pumping

R.S. Pumping Units	— Four pumps are provided
Rated Pump Capacity	— 8,400 gpm vs. 11 ft. TDH
Motor Horsepower	— 40 hp
Waste Sludge Pumping Units	— Two units are provided
Rated Capacity	— 8,750 to 4,370 gpm vs. 39 to 30 ft. TDH
Motor Horsepower	— 125 hp (variable speed)

6. Final Settling Tanks — Seven rectangular tanks are provided, equipped with heavy duty sludge collectors and dipping pipe scum collectors. Design data are as follows:

	Remolded Tanks 1, 2, 3 & 4	New Tanks 5, 6 & 7
Number of tanks (4 bays each)	4	3
Single tank dimensions	232' × 70' × 12'	200' × 70' × 12'
Surface area — all tanks		107,000 sq. ft.
O.R. at design flow (85 mgd)		800 gpd/sq. ft.
Net volume — all tanks		9.61 mg
D.T. at design flow (85 mgd)		2.7 hrs.

7. Chlorination Facilities — Disinfection of plant effluent is by the use of sodium hypochlorite (15% solution NaOCl) injected at the influent end of two chlorine contact tanks sized as follows:

Single tank dimension	— 275' × 54' × 8.8'
Net volume (both tanks)	— 1.94 mg
D.T. at 85 mgd (both tanks)	— 30 minutes
D.T. at 170 mgd (both tanks)	— 15 minutes

8. Sludge Handling Facilities

a. Sludge Thickeners — Four covered, circular, reinforced concrete, gravity thickeners are provided and sized as follows:

Tank diameter (I.D.)	— 70 ft.
SWD	— 10 ft.
Center cone depth	— 17 ft.
Surface area (all tanks)	— 15,000 sq. ft.
Volume (all tanks)	— 197,640 cu. ft.
O.R. at design flow (85 mgd)	— 800 gpd/sq. ft.
D.T. at design flow (85 mgd)	— 2.9 hours
Design sludge loading (all tanks)	— 4.0 lb/day/sq. ft.

b. Sludge Digesters — Four fixed cover high rate digesters equipped with external sludge heaters and gas recirculation systems for continuous mixing. Design data are listed below:

Tank diameter (I.D.)	— 86 ft.
SWD. - Primary Digesters	— 30 ft.
- Secondary Digesters	— 29 ft.
Depth of center cone	— 9 ft.
Sludge volume - primary digester	— 191,500 cu. ft.
- secondary digester	— 186,000 cu. ft.
Total sludge volume (3 primary plus 1 secondary digester)	— 760,500 cu. ft.
Total sludge volume provided at design population (500,000)	— 1.52 cu. ft./cap.
Design sludge loading (peak month in 2015)	— 135,800 lb/day
Volatile solids at 75%	— 102,000 lb/day
V.S. loading (prim. dig. only)	— 0.177 lb/day/cu. ft.

c. Sludge Heaters — Four external, tube type heat exchangers are provided, each having an estimated capacity of 1.8×10^6 Btu/hr. under the following operating conditions:

	Sludge	Hot Water
Flow per heater - gpm	600	150
Inlet temperature - °F	95	150

d. Sludge Recirculation — Digested sludge is recirculated through the sludge heaters by means of six torque-flow pumps each rated at 600 gpm vs. 98' TDH.

e. Sludge Transfer and Storage — The system is designed for gravity transfer of digested sludge from primary to secondary and then to storage. In addition, two triplex plunger pumps are provided for unblocking lines and for transferring sludge between digesters, and from the digesters to the sludge storage tanks. These are rated at 325 gpm vs. 100 psi. Two digesters have been converted to sludge tanks with fixed domes. Design data are as follows:

Tank diameter	86 ft.
Max. sludge level	Elev. 27.5
Max. SWD.	29.5 ft.
Depth of center cone	9 ft.
Total storage at max. sludge level	376,000 cu. ft.
Sludge load at peak month production in 2015	42,000 cu. ft./day
Min. storage provided	9 days
Sludge load at average month production in 2015	33,500 cu. ft./day
Average storage provided	11 days

In addition to the sludge produced at 26th Ward, digested sludge from the adjacent Jamaica Plant will be pumped to the 26th Ward storage tanks for ultimate disposal at sea. The maximum sludge load from Jamaica is estimated at 60,000 cu. ft./day (450,000 gpd at 2.8% solids). The combined maximum sludge load from both plants is therefore 102,000 cu. ft./day, which reduces the minimum storage at 26th Ward to 3.7 days.

f. Sludge Disposal — Digested sludge is pumped from the storage tanks to the loading dock in Jamaica Bay using two 300 hp centrifugal variable speed pumps each rated at 5,000 to 8,600 gpm vs. 25' to 108' TDH. Each pump is designed to fill one of the larger sludge vessels (100,000 cu. ft. capacity) within 90 minutes. Digested sludge is ultimately disposed at sea near Ambrose Light (some 11 miles from Sandy Hook).

g. Digester Gas Utilization — Gas withdrawn from the digesters is utilized in three 350 hp dual fuel (digester gas and No. 4 fuel oil) boiler units. Waste gas will be burned through 6-inch diameter waste gas burners designed to burn the entire peak hourly gas production estimated at about 50,000 cu. ft./hr.

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Attachment 3
Starrett City Total Energy Plant —
Operation Analysis

Background

In order to establish the most favorable TEP operation in terms of efficiency, specific plant operation should be analyzed for the summer, winter, spring and fall (in-between) seasons. For lack of actual operating data, the power plant equipment design characteristics (Table 1) were used and the operation with and without dual fuel engines analyzed.

From the manufacturer's turbine generator diagram (Fig. 1) a curve for extraction versus throttle steam flow rate was developed, for 5000 kw_e output (Fig. 2), simplifying further calculations.

As stated above, this analysis was performed for the following conditions:

1. Spring and fall (in between) season operation (Fig. 3).
 - 1.1 without dual fuel engines.
 - 1.2 with dual fuel engines.
2. Winter season operation (Fig. 4).
 - 2.1 without dual fuel engines
 - 2.2 with dual fuel engines
3. Summer season operation (Fig. 5).
 - 3.1 without dual fuel engines
 - 3.2 with dual fuel engines.

This theoretical data was compared to the actual operating data and, consequently, recommendations were made.

TABLE 1

TEP EQUIPMENT DESIGN CHARACTERISTICS

1. Turbine Generators	2 units	
Power Output	5000 kw	
Maximum Throttle Flow per unit	126,000 lbs/hr.	
Steam Pressure	850 psi	
Steam temperature	825 F	
2. Boilers	4 units	
Steam Flow Rate	110,000 lbs/hr.	
Minimum efficiency		
-No. 6 oil fired	85.6%	
-Natural gas fired	82.5%	
3. Dual Fuel Engines	3 units	
Power Output	2000 kw	
4. Waste Heat Recovery Boilers (WHRB)	3 units	
Maximum steam flow	2820 lbs/hr.	
Operating pressure	140 psi	
5. High Temperature Heat Exchangers (HTHE)	2 units	
	Steam	Water
Maximum flow rate	61,000 lbs/hr.	423,200 lbs/hr.
Temperature in	320 F	150 F
Temperature out	160 F	300 F
6. Dual Temperature Heat Exchangers (DTHE)	2 units	
	Steam	Water
Maximum flow rate	69,559 lbs/hr.	1,687,500 lbs/hr
Temperature in	350 F	120 F
Temperature out	212 F	160 F

7. Refrigeration Machines

3 units

Design Tonnage	2500
Chilled Water Flow Rate	4500 gpm
Temperature in	54.4 F
Temperature out	41.0 F
Compressor Performance	.9 bhp/ton
Steam flow rate of 100% load	11.0 lbs/bhp hr.

Technical and Economic Analysis

1.1 Spring and Fall (in between) season operation without dual fuel engines (Fig. 3a).

Assume the rate parameters for the operating equipment as follows:

Turbine generator power output	2×5000 kw
HTHE Steam flow rate	2×61000 lbs/hr
HTHE condensate temperature	160°F
HTHE efficiency	99.5%
Boiler efficiency (natural gas fired)	82.5%
Average parasitic load	1500 kw

Considering the flow diagram (Fig. 3a) and applying the energy conservation law to the deaerator (Fig. 3b) for the above conditions results in Equation 1:

$$249.2 = 83 X + 128 Y + 1147 \times (1 - (X + Y)) \quad (1)$$

Where:

X = steam flow rate to the condenser

Y = steam flow rate to the HTHE

Hence,

$$Y = .881 - 1.044 \times X \quad (2)$$

With the throttle steam flow rate varying from 60,000 lbs/hr to the maximum of 126,000 lbs/hr, the total extraction would increase from 18,460 lbs/hr up to 120,000 lbs/hr (Fig. 2), and therefore the steam flow rate to the condenser (X) would drop correspondingly from 41,540 lbs/hr to 6,000 lbs/hr. For those values, the steam flow rate to the HTHE (Y) would vary consistent with Equation 2, from 9,540 lbs/hr to 104,700 lbs/hr (Table 2). The corresponding extraction curve is shown in Figure 2.

We now calculate the power plant overall efficiency as shown in Equation 3:

$$e_{pp} = \frac{3413 (E_t^{TG} - E_p^{TG}) + W_{HTHE} (h_s - h_c) e_{HE}}{G (h_{ts} - h_f) \times 1} \times 100 \quad (3)$$

e_B

Where:

e_{pp} = Power plant efficiency (%)

E_t^{TG} = Turbine generator output (kw)

E_p^{TG} = Parasitic load (kw)

W_{HTHE} = Steam flow rate to the HTHE (lbs/hr)

h_s = HTHE steam enthalpy (Btu/lb)

h_c = HTHE condensate enthalpy (Btu/lb)

G = Throttle steam flow rate (lbs/hr)

h_{ts} = Throttle steam enthalpy (Btu/lb)

h_f = enthalpy of feedwater entering the boiler (Btu/lb)

Table 2

STEAM EXTRACTION TO HTHE
FOR A POWER OUTPUT OF 5000 kw

THROTTLE STEAM FLOW RATE	TOTAL EXTRACTION	STEAM FLOW RATE TO THE CONDENSER X		STEAM FLOW RATE TO THE HTHE Y	
lbs/hr	lbs/hr	lbs/hr	% (1)	lbs/hr	% (1)
1	2	3	4	5	6
60,000	18,460	41,540	69.2	9,540	15.9
70,000	33,850	36,150	51.6	23,940	34.2
80,000	49,230	30,770	38.5	38,200	47.9
90,000	64,620	25,380	28.2	52,830	58.7
100,000	80,000	20,000	20.0	67,200	67.2
126,000	120,000	6,000	4.8	104,700	83.1

e_B = Boiler efficiency

e_{HE} = Heat exchanger efficiency

Assuming the steam flow rate to the HTHE varies from 20,000 lbs/hr to the maximum amount of 122,000 lbs/hr, extracted at a power output of 10,000 kw, the overall power plant efficiency would increase with extraction, ranging from 29.29% up to 58.43% (Fig. 6) as follows:

TABLE 3

Steam flow to HTHE* (lbs/hr)	e_{pp} %
20,000	29.29
40,000	37.37
60,000	43.94
80,000	49.34
100,000	54.01
122,000	58.43

* The throttle steam flow rates corresponding to the above extracted steam amounts were taken from the turbine diagram (Fig. 2).

1.2 Spring and fall (in between) season with Dual Fuel Engines (Fig. 3c).

Assume the following design parameters for the operating equipment:

Turbine generator power output	5000 kw
Average Parasitic load	1500 kw
Dual Fuel engine power output	2×2000 kw
WHRB steam flow rate	2×2820 lbs/hr
HTHE steam flow rate	$2 \times 61,000$ lbs/hr
HTHE condensate temperature	160°F
HTHE efficiency	99.5%
Boiler efficiency (natural gas fired)	82.5%
Dual fuel engine parasitic load	1.5%

Dual fuel engine fuel consumption (Table 4) was calculated from the manufacturer's test data, assuming the generator efficiency to be 95.6%. At nominal output, the average specific fuel consumption is was .496 lbs oil/kwh (19,350 Btu/lb).

TABLE 4

DUAL FUEL ENGINES FUEL CONSUMPTION

(lbs #2 oil/kw hr)

ENGINE NO. LOAD	DFE 1 1278	DFE 2 1280	DFE 3 1279
100%	.497	.498	.494
75%	.489	.492	.489
50%	.494	.502	.495
25%	.554	.560	.544
110%	.504	.506	.504

Power plant overall efficiency was calculated using Equation 4:

$$e_{pp} = \frac{3413 (E_t^{TG} - E_p^{TG}) + W_{HTHE} (h_s - h_c) e_{HE} + 3413 (E_p^{DF})}{G (h_{ts} - h_f) \times \frac{1}{e_B} + H.R.DF \times E_t^{DF}} \times 100 \quad (4)$$

where:

E_t^{DF} = Dual fuel engine output (kw)

E_p^{DF} = Parasitic load (kw)

H.R.DF = Dual fuel engine heat rate (Btu/kwh)

E_t^{TG} , E_p^{TG} , W_{HTHE} , h_s , h_c , e_B , e_{HE} , G , h_{ts} , h_f have the same definitions as those in the previous case.

Assuming the steam flow rate to the HTHE varies from 20,000 lbs/hr. to 100,000 lbs/hr and the WHRB delivers a constant 5640 lbs/hr, the overall power plant efficiency (Fig. 7) would be as follows:

TABLE 5

Steam flow to the HTHE (lbs/hr)	e _{pp} %
20,000	38.35
40,000	47.73
60,000	54.96
80,000	60.93
100,000	65.51

2.1 Winter season operation without dual fuel engines (Fig. 4a).

Assume the design parameters for the operating equipment to be as follows:

Turbine generator power output	2 × 5000 kw
Average parasitic load	1500 kw
HTHE steam flow rate	2 × 61,000 lbs/hr
HTHE condensate temperature	160°F
DTHE steam flow rate	2 × 69,559 lbs/hr
DTHE condensate temperature	212°F

For the above conditions, the condensate enthalpy before entering the deaerator would be

$$180.2 \times 0.533 + 128 \times 0.467 = 155.8 \text{ Btu/lb.}$$

Applying the energy conservation law to the deaerator (Fig. 4b),

$$249.2 = 83 X + 155.8 Y + 1147 (1 - X - Y). \quad (5)$$

Hence,

$$Y = .906 - 1.073 X, \quad (6)$$

where X and Y have the same definitions as those in Equation 2.

Assuming the throttle steam flow rate varies from 60,000 lbs/hr to 126,000 lbs/hr for a constant power output of 5,000 kw, consistent with Equation 6, the steam extraction for the dual and high temperature heat exchangers goes up to 107,600 lbs/hr (Table 6).

Table 6
STEAM EXTRACTION TO HTHE AND DTHE
FOR A POWER OUTPUT OF 5000 kw

THROTTLE STEAM FLOW RATE	TOTAL EXTRACTION	STEAM FLOW RATE TO THE CONDENSER X		STEAM FLOW RATE TO THE HTHE AND DTHE	
lbs/hr	lbs/hr	lbs/hr	% (1)	lbs/hr	% (1)
1	2	3	4	5	6
60,000	18,460	41,500	69.2	9,840	16.4
70,000	33,850	36,150	51.6	24,640	35.2
80,000	49,230	30,770	38.5	39,440	49.3
90,000	64,620	25,380	28.2	54,270	60.3
100,000	80,000	20,000	20.0	69,100	69.1
126,000	120,000	6,000	4.8	107,600	85.4

The extraction curve for the above conditions was plotted on Fig. 2.

The maximum extracted steam flow rate to the high and dual temperature heat exchangers, at a T.G. power output of 10,000 kw is then

$$2 \times 107,600 = 215,200 \text{ lbs/hr.}$$

Since this flow is shared between HTHE and DTHE in proportion to their design steam flow ratio, we calculated the power plant overall efficiency consistent with Equation 3, obtaining

$$e_{pp} = 71.41\%$$

with a Boiler efficiency of 82.5% and parasitic load of 1500 kw.

For a decrease in extraction, the overall efficiency dropped consistently, as shown below (Table 7, Fig. 8):

TABLE 7

Steam flow to HTHE and DTHE (lbs/hr)	e_{pp} %
215,200	71.41
200,000	69.71
180,000	67.49
160,000	64.69
140,000	61.70
120,000	57.61

2.2 Winter season operation with dual fuel engines (Fig. 4b)

Taking into account the extraction requirements during the Winter season, there appeared to be no possibility to run only one turbine generator.

In order to estimate how the dual fuel engines would affect the power plant overall efficiency, we assume the following:

Turbine generator power output	$2 \times 5000 \text{ kw}$
Average parasitic load	1500 kw
Dual fuel engine power output	$3 \times 2000 \text{ kw}$
WHRB steam flow rate	$3 \times 2820 \text{ lbs/hr}$
HTHE steam flow rate	$2 \times 61,000 \text{ lbs/hr}$
DTHE steam flow rate	$2 \times 69,559 \text{ lbs/hr}$
HTHE condensate temperature	160°F
DTHE condensate temperature	212°F
DFE heat rate	9598 Btu/kwh
DFE parasitic load	1.5%

The power plant overall efficiency consistent with Equation 4 for the above data then was calculated to be:

$$e_{pp} = 67.72\%$$

Therefore, winter operation with dual fuel engines lead to an overall efficiency drop against the operation without dual fuel engines. The explanation is that the turbine generator with the maximum extraction flow rate has a better efficiency than that of the dual fuel engine with waste heat recovery boiler.

3.1 Summer season operation without dual fuel engines (Fig. 5a).

The design parameters for the operating equipment was assumed to be:

Turbine generator power output	2×5000 kw
Average parasitic load	1500 kw
HTHE steam flow rate	$2 \times 61,000$ lbs/hr
Refrigeration machines tonnage	3×2500
Refrigeration compressor performance	.9 bhp/ton
Murray Turbine steam consumption	11.0 lbs/bhp hr.

Hence,

$$\text{Murray Turbine design steam flow rate} = 11.0 \times .9 \times 7500 = 74,000 \text{ lbs/hr.}$$

For the above conditions, the condensate enthalpy before entering the deaerator would be:

$$122 \times .622 + 88.5 \times .378 = 113 \text{ Btu/lb.}$$

Applying the energy conservation law to the deaerator (Fig. 5b) results in the following:

$$249.2 = 83 X + 113 Y + 1147 (1 - X - Y) \quad (7)$$

therefore,

$$Y = .868 - 1.029 X \quad (8)$$

where X and Y were defined as in Equation 2.

Consistent with Equation 8, for the throttle steam flow rate varying from 60,000 lbs/hr to 126,000 lbs/hr (for a power output of 5000 kw), the steam extraction (4) increases from 9360 lbs/hr to 103,190 lbs/hr (Table 8).

Table 8

STEAM EXTRACTION TO HTHE AND
REFRIGERATION SYSTEM
POWER OUTPUT - 10,000 kw)

Throttle Steam Flow Rate	Total Extraction	Steam Flow Rate to the Condenser		Steam Flow Rate to the HTHE and Refrigeration Machine	
lbs/hr	lbs/hr	lbs/hr	%*	lbs/hr	%*
<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
60,000	18,460	41,540	69.2	9,360	15.6
70,000	33,850	36,150	51.6	23,590	33.7
80,000	49,230	30,770	38.5	37,760	47.2
90,000	64,620	25,380	28.2	52,020	57.8
100,000	80,000	20,000	20.0	66,200	66.2
126,000	120,000	6,000	4.8	103,190	81.9

*% of throttle steam flow rate.

The extraction curve plotted using the values shown in Table 8 is shown in Figure 2.

The overall power plant efficiency can be calculated from Equation 9:

$$e_{pp} = \frac{3413 (E_t^{TG} - E_p^{TG}) + W_{HTHE} (h_s - h_c) e_{HE} + 12000 \times \frac{W_{RM}}{S.C.MT \times C.P} \times 100}{G (h_{ts} - h_p) \times \frac{1}{e_B}} \quad (9)$$

where:

W_{RM} = Steam flow rate to the refrigeration machine (lbs/hr)

$S.C.MT$ = Murray turbine steam consumption (lbs/bhp hr)

$C.P$ = Compressor performance (bhp/ton)

E_t^{TG} , E_p^{TRG} , W_{HTHE} , h_s , h_c , h_{ts} , h_f , G , e_B , e_{HE} have been previously defined in Equation 3.

For the design parameters, the computed overall efficiency consistent with the above equation (9) was:

$$e_{pp} = 71.4\%$$

This value decreased consistently as the hot water and cooling load drop, the power output having been kept constant (Table 9, Figure 9).

TABLE 9

Steam flow to HTHE and RM (lbs/hr)	e_{pp} %
196,000	71.40
150,000	65.36
120,000	60.15
90,000	53.66
60,000	45.31
30,000	34.36

3.2 Summer operation with Dual Fuel Engines (Fig 5c).

The following design parameters were assumed for the operating equipment:

Turbine generator power output	5000 kw
Average parasitic load	1500 kw
Dual fuel engine power output	2×2000 kw
WHRB steam flow rate	2×2820 lbs/hr
HTHE steam flow rate	$2 \times 61,000$ lbs/hr
Refrigeration machines tonnage	3×2500
Refrigeration compressor performance	.9 bhp/ton
Murray turbine steam consumption	11.0 lbs/bhp hr.
Dual fuel engine parasitic load	1.5%
DFE average specific fuel consumption	.496 lbs oil/kwh

The Murray turbine steam flow rate is $11.0 \times .9 \times 7500 = 74,000$ lbs/hr.

Power plant overall efficiency was calculated using Equation 10:

$$e_{pp} = \frac{3413(E_t^{TG} - E_p^{TG}) + W_{HTHE}(h_s - h_c)e_{HE} + 12000 \times \frac{W_{RM}}{S.C.MT \times C.P} + 3413(E_t^{DF} - E_p^{DF})}{G(h_{ts} - h_f) \times \frac{1}{e_B} + H.R^{DF} \times E_t^{DF}} \times 100 \quad (10)$$

where all the terms were previously defined for Equations 4 and 9.

Varying the steam flow rate to the HTHE and refrigeration machines from 40,000 lbs/hr to 100,000 lbs/hr, increased the overall efficiency (Fig. 10) as follows:

TABLE 10

Steam Flow to the HTHE and R.M. lbs/hr	e_{pp} %
40,000	48.91
60,000	55.49
80,000	62.39
100,000	66.94

For further calculations, the useful steam extraction to the heat exchangers was needed for various power output levels. In order to obtain it, Equation 2 (considering the HTHE condensate temperature to be 160°F) and Figure 1 was used. The results, calculated for 4500, 4000 and 3500 kw (Table 11) have been plotted on a diagram (Figure 11) which could also be used by the TEP personnel.

TABLE 11
TEP - STEAM FLOW TO HTHE FOR
DIFFERENT POWER OUTPUTS

Throttle Flow Rate lbs/hr.	TOTAL EXTRACTION (from manufacturer's diagram) lbs/hr.			STEAM FLOW RATE to the CONDENSER (X) lbs/hr.			STEAM FLOW RATE to the HTHE (Y) lbs/hr.		
	4500 kw	4000 kw	3500 kw	4500 kw	4000 kw	3500 kw	4500 kw	4000 kw	3500 kw
60,000	23,850	30,000	34,600	36,150	30,000	25,400	15,120	19,740	26,340
70,000	39,350	45,380	52,300	30,650	24,620	17,700	29,680	35,980	43,190
80,000	55,380	61,540	67,700	24,620	18,460	12,300	44,800	51,200	57,600
90,000	70,770	77,690	83,000	19,230	12,310	6,000	59,220	66,420	72,179
100,000	86,150	93,080		13,850	6,920		73,700	80,900	
Max. Flow	105,380			6,620			91,840		

Assuming an electrical load of 7500 kw (annual average power output), we calculated the overall efficiencies for various extractions (up to 100,000 lbs/hr to the HTHE), for operations with and without the dual fuel engines.

A. Operation without the DFE

TG1 — 4000 kw

TG2 — 3500 kw

B. Operation with the DFE

TG1 — 5000 kw

DF1 — 1250 kw

DF2 — 1250 kw

WHRB1 — 1500 lbs/hr

WHRB2 — 1500 lbs/hr.

Consistent with Equations 3 and 4, and using the diagrams from Figs. 2 and 11 to obtain the throttle steam flow rates, the overall efficiencies were as follows (Table 12):

TABLE 12

Steam flow to the HTHE lbs/hr.	e _{pp}	%
	TG1 + TG2	TG1 + DFE1 + DFE2
100,000	58.22	65.96
80,000	52.94	61.35
60,000	46.62	56.07
40,000	39.11	47.84
20,000	29.67	37.84

The results, plotted in Fig. 12, proved the net advantage of operating with the DFE due, on one hand to the increased turbine extraction rates (and the correspondingly increased TG efficiency) and, on the other hand, to the higher efficiency of the DFE + WHRB.

In order to estimate the potential savings by operating during the Summer with the DFE, we arbitrarily picked a day (June 8, 1979) with the load profile plotted in Fig. 13.

At 10 pm (the peak load), the operating data was as follows:

Power output	TG1 = 4600 KW
	TG2 = 4600 KW
Extraction steam flow	TG1 = 25000 lbs/hr
	TG2 = 19000 lbs/hr
Throttle steam flow	121,000 lbs/hr
Fuel input	TG1 + TG2 = 170×10^6 Btu/hr

Running only one turbine and two dual fuel engines (Fig. 14), with the same extraction flow rate, the fuel input would have been as below:

Power input	TG1 = 5000 kw
	DFE1 = 2100 kw
	DFE2 = 2100 kw
Extraction steam flow	TG1 = 40,000 lbs/hr
	WHRB1 = 2000 lbs/hr
	WHRB2 = 2000 lbs/hr
Throttle steam flow (see Fig. 1)	74,500 lbs/hr

We calculated the TG fuel input using Equation 11:

$$B^{TG} = W_{ts} (h_{ts} - h_f) \times \frac{1}{e_B} \quad (11)$$

where:

W_{ts} = throttle steam flow (lbs/hr)

h_{ts} = throttle steam enthalpy (Btu/lb)

h_f = Feedwater enthalpy (Btu/lb)

e_B = boilers efficiency (%)

Assuming $e_B = 82.5\%$ (on gas), the turbine generator fuel input was

$$B^{TG} = 74500 \times (1410.5 - 249.2) \times \frac{1}{.825} = 104.9 \times 10^6 \text{ Btu/hr}$$

For the DFE fuel consumption calculation, we used the manufacturer's test data (Table 4) as follows:

$$B^{DFE} = 4200 \text{ kwh} \times .504 \text{ lbs oil/kwh} \times 19,350 \text{ Btu/lbs oil} = 41 \times 10^6 \text{ Btu/hr}$$

Hence, the total fuel input of the operation with the DFE + WHRB was:

$$B^{TG+DFE+WHRB} = 104.9 \times 10^6 + 41 \times 10^6 = 145.9 \times 10^6 \text{ Btu/hr}$$

Compared to the actual operation, the savings were as follows:

$$\Delta B = 170 \times 10^6 - 145.9 \times 10^6 = 24.1 \times 10^6 \text{ Btu/hr.}$$

Assuming 144,000 Btu/gal oil, the fuel saved was be 167.4 gal/hr, or 4017.6 gal/day.

For \$.70/gal, the dollar savings would be

$$4017.6 \text{ gal/day} \times \$.70/\text{gal} = \$2812/\text{day.}$$

Conclusions and Recommendations

For electrical loads up to 9000 kw and steam extraction flow rates up to 120,000 lbs/hr, the most economical operation is that with one turbine generator and one or two dual fuel engines on line. Compared to the "two turbines" operation, this operating procedure might save an average of 150 gal/hr #6 oil, which at a fuel price of \$.70/gal, would equal \$2500/day.

Analyzing the 1979 operation data (Table 13), we recommend this method of operation for most of the Spring, Fall and Summer seasons.

TABLE 13
STARRETT CITY TOTAL ENERGY PLANT - OPERATION DATA - 1979

	SPRING & FALL OPERATION			SUMMER OPERATION		
	May 14	H T H E May 16	May 19	TOTAL July 10	TOTAL July 12	TOTAL July 13
Avg. Steam Rate pph	16,000	15,000	25,000	39,000	47,000	40,000
Max. Steam Rate pph	22,500	22,500	36,000	45,200	53,200	57,700
Avg. Power Output kw	6,240	5,610	6,250	8,000	8,300	8,300
Max. Power Output kw	8,200	7,800	7,950	9,850	10,100	10,050
TG1 Avg. Output kw	4,500	4,400	4,500	4,200	4,200	4,000
Max. Output kw	4,900	4,700	4,800	4,700	4,600	4,500
TG2 Avg. Output kw	-	-	-	3,800	4,000	4,200
Max. Output kw	-	-	-	4,500	4,600	4,600
DFE1 Avg. Output kw	370	630	210	-	100	100
Max. Output kw	-	1,300	-	650	900	950
DPE2 Avg. Output kw	850	550	940	-	-	-
Max. Output kw	1,700	1,500	1,600	-	-	-
DPE3 Avg. Output kw	520	30	600	-	-	-
Max. Output kw	1,600	300	1,550	-	-	-

In order to get more information about the maximum turbine generator power output, (which, from the manufacturer's data should be in the range of 6000 kw_e), tests are required. Data should be recorded for throttle, extraction and condenser flows for each power output level.

Considering the energy conservation measures which are to be taken in the near future (especially changing kitchen and bathroom lights from incandescent to fluorescent types), the electrical peak is going to be lowered by 2500 kw, which reinforces the case that summer operation with one or two dual fuel engines and one turbine would be the most efficient operating procedure.

It should be noted that there are other considerations besides efficiency in determining what line-up of equipment to operate. Equipment maintainability, reliability, and speed of bringing equipment on line are such considerations. The method of operation, therefore, becomes a managerial decision. At present, Starrett City is opting for what they feel is a more reliable operation using turbines. This is based on the potentially longer outage of services in the event of diesel engine failure and the lengthier and more complex operation in bringing the turbine system on line. This decision is not a final one but may be revised as more operating experience is gained with the diesels.

For the winter season, the high extraction flow rates require both turbines running on line almost all the time, despite the better efficiency operating with the dual fuel engines.

Figure 1

5000 kw

850 PSIG - 825 FTT - 3.0" Hg.A.

A.E. @ 130 PSIG

FIG. 2 TURBINE GENERATOR - POWER OUTPUT - 5000 kw
EXTRACTION DIAGRAM

FIG. 3 SPRING AND FALL SEASON OPERATION
 a. Flow diagram without DFE
 b. Heat balance of deaerator
 c. Flow diagram with DFE

FIG. 4. WINTER SEASON OPERATION
 a. flow diagram without DFE
 b. heat balance of deaerator
 c. flow diagram with DFE

FIG 5. SUMMER SEASON OPERATION
 a. Flow diagram without DFE
 b. Heat balance of deaerator
 c. Flow diagram with DFE

FIG. 6 POWER PLANT EFF. FOR 10,000 KW OUTPUT
without desulf.

FIG. 7 POWER PLANT OVERALL EFFICIENCY

vs. STEAM FLOW RATE TO HTHE

POWER OUTPUT

TG = 5000 kw

DFE = 2 x 2000 kw

FIG. 8

POWER PLANT OVERALL EFFICIENCY

vs. STEAM FLOW RATE TO HTHE and DTHE

POWER OUTPUT = 10,000 kw

FIG. 9 POWER PLANT OVERALL EFFICIENCY
vs. STEAM FLOW RATE TO HTHE and
REFRIGERATION SYSTEM

FIG. 10

POWER PLANT OVERALL EFFICIENCY

vs. STEAM FLOW RATE TO THE HTHE and
REFRIGERATION SYSTEM

POWER OUTPUT TG = 5000 kw

DFE = 2 x 2000 kw

FIG. 11 TEP - STEAM FLOW TO HTHE FOR
DIFFERENT POWER OUTPUTS.

FIG. 12

TEP OVERALL EFFICIENCY

vs. STEAM FLOW TO THE HTHE

-POWER OUTPUT 7500 kw

KW

FIG. 13

STARRETT CITY POWER PLANT -

ACTUAL SUMMER OPERATION (JUNE 8, 79)

(without DFE)

10000

9000

8000

7000

6000

5000

4000

3000

2000

1000

TG 2

TG 1

12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM PM

KW

FIG. 14 STARRETT CITY POWER PLANT

IDEAL SUMMER OPERATION (JUNE 8, 79)

(with DFE)

Attachment 4
Digester Gas Analysis

United States Testing Company, Inc.
Environmental Sciences Division

REPORT OF TEST

Hazen & Sawyer Engineers
360 Lexington Avenue
New York, New York 10017

August 6, 1979

TEST REPORT NO. 04289

SIGNED FOR THE COMPANY

BY

David L. Hansen

David L. Hansen

DLH

8/6/79

SUBJECT:

Samples of digester gas were collected at the 26th. Ward Water Pollution Control Plant in Brooklyn on 7/17/79 by the United States Testing Company, Inc.

PROJECT:

The digester gas indicated above was analyzed for the following parameters: Oxygen, Hydrogen, Total Hydrocarbons, Chlorides, Particles, Sulfur, Hydrogen Sulfide, Carbon Dioxide, Carbon Monoxide, Moisture (H₂O), Nitrogen, BTU value, Ammonia, Grease and Methane.

PROCEDURE:

Samples of digester gas were collected in five layered non-contaminating non-permeable gas sampling bags. These gas samples were returned to the United States Testing Company lab located in Hoboken, New Jersey and were analyzed for Oxygen, Hydrogen, Total Hydrocarbons, Carbon Dioxide, Carbon monoxide, Methane, Nitrogen and BTU value via gas chromatography and infrared spectroscopy. Ammonia and Hydrogen sulfide were analyzed at the sampling site via Drager detector tubes. Chlorides, grease and sulfur were collected via midget impinger technique and analyzed via Standard Methods. Particulate was collected on a PVC filter and analyzed gravimetrically. Moisture was determined via condensation in an ice bath.

RESULTS:

<u>Parameter</u>	<u>Concentration</u>
1) Oxygen	<0.2%
2) Hydrogen	<0.01%
3) Total Hydrocarbons	None Detected *
4) Ammonia	<5 ppm
5) Chlorides	0.5 µg/l
6) Particulate	<0.1 mg/l
7) Grease	<0.01 mg/l
8) Sulfur	<1 ppm **
9) Hydrogen Sulfide	100 ppm
10) Carbon Dioxide	36.1%
11) Carbon Monoxide	1480 ppm
12) Moisture (H ₂ O)	1%
13) Methane	62%
14) Nitrogen	0.97%
15) BTU value	636 BTU/ft ³ dry @ 60°C
	624 BTU/ft ³ wet @ 60°C †

NOTES:

- < = less than the value shown, this indicates that the concentration was below the lower detection limit of the method used.
- * = No hydrocarbons above Methane (CH₄) were detected in the sample. Methane was analyzed separately.
- ** = This number represents sulfur in the sample other than that combined as hydrogen sulfide.
- † = BTU values are calculated from known values of the constituents of the digester gas which were determined by gas chromatography and Mass Spectroscopy.

COPY

Hazen and Sawyer
360 Lexington Ave.
RECEIVED

JAN 20 1981

COPY

September 20, 1979

Mr. Jan M. Gasparec
Hazen and Sawyer, P.C. Engineers
360 Lexington Avenue
New York, New York 10017

Dear Mr. Gasparec,

Pursuant to our telephone conversation on September 20, we are confirming the conversion of 100 ppm of H₂S to 6.0 grains/100 cu. ft.

$$1 \text{ ppm} = 0.00139 \text{ mg/l}$$

$$100 \text{ ppm} = 0.139 \text{ mg/l}$$

$$0.139 \text{ mg/l} \left(\frac{28.3 \text{ l}}{\text{cu. ft.}} \right) (100 \text{ cu. ft.}) = 393.4 \text{ mg/100 cu. ft.}$$

$$\left(\frac{393.4 \text{ mg}}{100 \text{ cu. ft.}} \right) \left(\frac{1 \text{ gram}}{1000 \text{ mg}} \right) \left(\frac{1 \text{ lb.}}{454 \text{ grams}} \right) \left(\frac{7000 \text{ grain}}{1 \text{ lb.}} \right) = 6.01 \text{ grains/100 cu.ft.}$$

Yours truly,

UNITED STATES TESTING COMPANY, INC.

David L. Hansen
Manager

DLH/br
esd.

THE CITY OF NEW YORK
Intradepartmental Memorandum

To: SEYMOUR L. KIRSCHNER, PH.D., DIRECTOR OF LABORATORIES, DIVISION OF PLANT OPERATIONS
From: Joseph Blackman, Assistant Chemist
Wards Island, Laboratory
Date: March 29, 1979
Subject: Methane, Carbon Dioxide, and
Hydrogen Sulfide Content in Digester
Gas at the 26th Ward W.P.C.P.
(Feb. 26 March 16, 1979).

Methane, carbon dioxide, and hydrogen sulfide content of digester gas (Digesters 1 and 2 combined at the 26th Ward W.P.C.P. were determined from February 26 to March 16, 1979.

The Hewlett-Packard Model 5934 Gas Chromatograph/Mass Spectrometer/Data System was used for the analyses of methane and carbon dioxide. Carbon Dioxide and Hydrogen Sulfide was analyzed by the Orsat and Iodometric methods at 26 Ward W.P.C.P. by John Ward, Supervising Chemist of Jamaica Laboratory. Within experimental error, the average value for methane is 60% and the average value for carbon dioxide is 40%.

Mass Spectrometer Conditions for Methane and
Carbon Dioxide Determinations

Column - Silica gel, 60/80 mesh
12 feet x 1/8 inch, stainless steel

Injector temperature - ambient, oven 120°C
Sample size - 0.5 ml. (gas syringe)

Mass spectrometer ran in Select Ion, the ions monitored were 16 (methane), 44 (carbon dioxide), 32 (oxygen), and 28 (nitrogen and carbon monoxide)

Samples were taken in gas sampling bulbs supplied by Fisher Scientific Company.

Carrier Gas = Helium gas flow rate 20 ml./min.

GAS CONTENT OF 26th WARD DIGESTERS
1 and 2 COMBINED

SAMPLE DATE	LAB NO.	% CH ₄	% CO ₂	H ₂ S	Remarks
2/26/79	79-P-11	60	38.5 (39.2)	0.0148 grains 0.0034 mg/l <small>100 ft³</small>	
2/27/79	79-P-13	60	40	-	
2/28/79	79-P-14	60	34	-	6% Air
3/1/79	79-P-15	66	34	-	
3/2/79	79-P-16	(71)	(44) (39.6)	0.222 grains 0.005 mg/l <small>100 ft³</small>	
3/5/79	79-P-17	62	38	-	-
3/8/79	79-P-18	60	40 (36.9)	0.296 grains 0.006 mg/l <small>100 ft³</small>	
3/9/79	79-P-19	63	37	-	-
3/12/79	-	-	(37.4)	22 grains/100 ft ³ 0.065 mg/l	-
3/13/79	79-P-21	(70)	(41)	-	-
3/14/79	79-P-22	60	40	-	-
3/15/79	79-P-23	(46)	(47)	-	7% Air
3/16/79	79-P-24	60	40 (36.3)	0.296 grains/100 ft ³ 0.007 mg/l	
2/28/79	79-P-14	65	30		
3/1/79	79-P-15	60	41		
3/19/79	79-P-25	60	41 (38.0)	0.518 grains/100ft ³	
3/20/79	79-P-26	58	40	-	-

Unreliable data is encircled

(1) H₂S analysis done by John Ward

() CO₂ values obtained by John Ward using an Orsat-type gas analyzer

Joseph Blackman
Asst. Chemist
Wards Island Laboratory

cc: John Ward

Joseph Blackman

ADDENDUM TO TASK 2.3.4, Additional Data Collection

A. Methane Analyses-

Heating Value (Gross):

From Perry's Chemical Engineering Handbook, second ed.,
p. 2378, Table 29:

Methane, 1,013.2 Btu/cu. ft.

Based on an average of 60% methane in digester gas (see memo,
Blackman to Kirschner)

digester gas: 607.9 Btu/cu. ft.

B. Nitrogen and Oxygen-

Except for two samples listed below, values were negligible.

<u>Date</u>	<u>Sample No.</u>	<u>%Air</u>	<u>%N₂*</u>	<u>%O₂*</u>
2/28/79	79-P-14	6	4.8	1.2
3/15/79	79-P-23	7	5.6	1.4

(*calculated, based on %air)

W. Pressman, P.E.
April 11, 1979

UNITED STATES
DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585

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