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MASTER

CASE STUDY OF TOTAL ENERGY AT
ROCHDALE VILLAGE

ARGONNE NATIONAL LABORATORY

**ENERGY AND ENVIRONMENTAL SYSTEMS
DIVISION**

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CASE STUDY OF TOTAL ENERGY AT
ROCHDALE VILLAGE

by

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ABSTRACT

This report details the dual-fuel energy system installed in Rochdale Village at the former site of the Jamaica Race Track in New York City. Providing 100% of the development's heating, hot water, air conditioning, and electricity, it is estimated that the Rochdale Plant conserves the annual equivalent of over 561,000 gal of oil. This study covers item relating to the planning and construction stages and current status of the central power plant.

1 EXECUTIVE SUMMARY

Rochdale Village is a 5,860-dwelling unit cooperative (tenant owned) development consisting of twenty 14-story apartment buildings, two shopping centers, totaling 300,000 ft², and a 90,000 ft² community center. Rochdale Village, located on a 170-acre parcel of land (formerly the site of the Jamaica Race Track) in the Jamaica section of the County of Queens in the City of New York, is within several miles of John F. Kennedy International Airport.

Rochdale's on-site, dual-fuel energy system provides 100% of the heating, hot water, air conditioning, and electricity with no local electric utility grid backup.

It is estimated that an annual reduction of the equivalent of over 561,000 gal of oil usage is achieved by the Rochdale plant when compared with the purchase of fossil-fuel-generated electricity from the local utility company. Dollar savings to Rochdale are estimated at over \$1.8 million per year compared to the next best system.

The study team was headed by The Brooklyn Union Gas Company, supplier of primary fuel to the complex. Day & Zimmermann, Inc., design engineers of the power plant, performed a two-year technical efficiency analysis and provided technical information. Other sources of information were: Rochdale Village Management; Allied Maintenance Corporation, maintenance operators of the plant; and Herman J. Jessor, Architect.

The findings in Volume 1 cover items relating to the planning and construction stages, operation, and present status of the central power plant. Major components of the central power plant are:

- Four dual-fuel Union Iron Works packaged boilers, 650 psig, 650°F, steam 110 Mlb/h;
- Two Westinghouse steam turbine generators, 7500 kVa, 0.8 P.F., 4160V, 60 Hz, with auto-extraction at 20 psig;
- Two Worthington dual-fuel diesel engine generators, 450 rpm, 3750 kVa, 0.8 P.F., 4160V, 60 Hz;
- Twelve 1000-ton Trane absorption chillers, single shell, low-pressure steam.

The primary fuel for the complex is natural gas supplied on an interruptible basis. Secondary fuels are Number 6 oil for the boilers and Number 2 oil for the diesel engines.

The entire facility, placed into operation in 1963, has, without design change, been dependably supplying the energy needs of Rochdale Village for more than 13 years.

Rochdale Village has had a professional maintenance service contract with Allied Maintenance for more than two years. The complex has been able to realize a dramatic reduction in fuel consumption, more than enough to offset the cost of maintenance service.

- Technical Efficiency. The technical efficiency study showed that *maximum plant thermal efficiency is reached during peak heating and cooling seasons because of the beneficial use of waste heat for space heating, air conditioning, and water heating.* Thermal efficiencies as high as 71.9% have been reached and are considerably higher than from utility-generated power.
- Electrical Requirements. Rochdale Village annual electric requirements were originally estimated at 44 million kWh in 1964. With the average American family now using more convenience and leisure-time appliances, the projected 1977 use of electricity has grown to 50.8 million kWh. Despite this increase, the power plant installed capacity of 18 MWe has been more than adequate to meet the peak demand experienced to date (9.8 MWe).
- Methodology. The methodology used to obtain the required information included interviews with pertinent sources; acquisition of drawings, prints, and schematics; and performance of the technical efficiency study calculations.
- Conclusion. The major conclusion that can be drawn from this case study is that if it had to be done over, Rochdale Village Management would have again opted for a total energy plant.

The major effect of this study, in conjunction with the others contracted by USDOE, will be to revive interest in efficient on-site energy systems. Equipped with the knowledge gained from the past, future Total Energy/Selective Energy systems -- properly conceived, designed, and operated -- will be assured the chance to succeed.

2 FINDINGS

2.1 INTRODUCTION

This report is a case study of the total energy system at Rochdale Village, located in the Jamaica section of the County of Queens in the City of New York. The purpose of the study is to provide a data base of guidelines to ensure reasonable success for future industrial, commercial, or residential on-site total energy systems. Covered in this data base are fuel savings, economics, consumer benefits, and interface information for future commercialization and technology transfer of total energy systems.

Rochdale Village is unique among total energy installations in the United States. It serves a large (over 25,000 persons) integrated, residential development with self-contained, commercial support facilities. As one of the first major total energy plants constructed in the early 1960's, its success provided inspiration for the construction and operation of many other such plants across the country. Having been in operation since 1963, Rochdale's total energy plant has received wide publicity in technical circles, both here and abroad. The Brooklyn Union Gas Company has been closely associated with the Rochdale Village total energy plant since its inception, and has been its primary energy supplier.

Rochdale Village (shown in Fig. 2.1) is a 5,860-dwelling unit cooperative (tenant owned) development consisting of twenty 14-story apartment buildings, two shopping centers, totaling 300,000 ft², and a 90,000 ft² community center. Located on a 170-acre parcel of land (formerly the site of the Jamaica Race Track) in the Jamaica section of the Queens County in the City of New York, it is within a few miles of John F. Kennedy International Airport.

The project, owned by the cooperative's tenants, is a self-contained community. Shopping centers provide entertainment (theaters), restaurants, and other shopping services. The community center includes a medical facility. The size and diversity of Rochdale may be typical of future Integrated Community Energy System (ICES) projects.

The Rochdale total energy plant supplies all of the heating, cooling, domestic hot water, and electrical requirements of Rochdale Village. The total energy plant has an 18-MWe electrical capacity and an installed air conditioning capacity of 12,000 tons. Electric, hot water, chilled water, and steam

FIG. 2.1.: ROCHDALE VILLAGE, COOPERATIVE HOUSING DEVELOPMENT, CONSISTING OF TWENTY 14-STORY APARTMENT BUILDINGS CONTAINING 5,860 COOPERATIVE DWELLING UNITS, A COMMUNITY CENTER, AND TWO SHOPPING CENTERS. THE PROJECT SITE, FORMERLY OCCUPIED BY THE JAMAICA RACE TRACK, IS SPREAD OVER AN AREA OF 170 ACRES WHICH IS EQUIVALENT TO 122 CITY BLOCKS.

distribution systems to all buildings are underground. Hot or chilled water is distributed through a two-pipe system to all apartment buildings and to the community center, thereby providing heating/cooling according to the season. Domestic hot water is produced by low-pressure steam through converters in each building. The shopping centers utilize steam for heating and are equipped with local electrically driven cooling systems. These commercial buildings have a longer cooling season than do the apartments. The electric equipment allows cooling the commercial spaces when the two-pipe central system is providing hot water for residential heating.

The 18-MWe total energy plant at Rochdale is an interesting design in that it utilizes both condensing single automatic extraction steam turbine generators and dual-fuel diesel engine generators as prime movers.

All heating, cooling and domestic hot water requirements are met with recovered heat extracted from the turbines and/or directly from the boilers when needed.

The Rochdale boilers generate steam at high pressure to drive the steam turbine electric generators. Heat is recovered through the turbines' automatic extraction feature which allows electric generation at unusually low water flowrates. Dual-fuel diesel engine generators serve as standby units for the steam turbine generators and are utilized during periods of low thermal load in the spring and fall. No interconnection exists between the Rochdale total energy plant and the local electric utility.

The principal equipment at Rochdale Village includes:

- (1) Four Union Iron Works package boilers - 650 psig - 650 degrees F - 110 M lbs/h - gas/oil burners;
- (2) Two Westinghouse single automatic extraction condensing steam turbines - 7500 kVa - 0.80 P.F. - 4160 V - 60 Hz;
- (3) Two Worthington 16-cylinder, dual-fuel diesel (gas/oil) engine generators - 450 rpm - 3750 kVa - 0.80 P.F. - 4160 V - 60 Hz;
- (4) Twelve Trane 1000-ton steam absorption water chillers - single shell; and
- (5) Two 3-cell Foster Wheeler cooling towers - 20,000 gpm per tower.

The Rochdale Village plant began operations on November 28, 1963 and has been operating continuously since that time. It has had a very successful history of operation. The savings derived from the operation of the total energy plant have far exceeded original projections because of increases in the cost of purchased electricity.

Rochdale Village was built by the United Housing Foundation. The cooperative tenants are the owners of the project. After an initial down payment, each owner pays a monthly carrying charge that covers operating expenses (including the cost of operating the total energy plant) and repayment of outstanding debt. The Rochdale Village total energy plant is not subject to Public Service Commission regulation. Major financing for Rochdale was provided by tax abated, low interest loans via the New York State Mitchell-Lama Act.

The study team for this project consisted of:

The Brooklyn Union Gas Company, Brooklyn, New York and
Day and Zimmermann, Inc., Philadelphia, Pennsylvania.

Brooklyn Union headed the project team and coordinated the research effort, conducted interviews and collected data from appropriate sources. Three major sources providing information, other than Brooklyn Union and Day & Zimmermann were:

Rochdale Village Management;
Herman J. Jessor, Architect; and
Allied Maintenance Corporation, maintenance operators
of the power plant.

All three are headquartered in New York City.

Day & Zimmermann, Inc., the consulting engineering firm responsible for the original design of the Rochdale Village total energy plant, was retained to provide engineering assistance and to collaborate on certain aspects of the study. This firm provided: supplementary information on many questions posed to Rochdale Management regarding the planning stages and present operating status of the complex and the technical and engineering information contained in the report. Technical efficiency studies of turbine heat rate and overall plant efficiency were calculated monthly over a two-year period.

2.2 PLANNING STAGES

2.2.1 Total Energy Concept

Rochdale's early preliminary planning included the concept of a Total Energy System (TES).

Motivation was provided by United Housing Foundation, the sponsor of Rochdale and other cooperative low-and middle-income housing. The United Housing Foundation had just completed a 2500-unit development (Penn Station South) which included a central heating and air-conditioning plant. Day & Zimmermann was commissioned to study the feasibility of adding electric generation to a similar plant conceived for Rochdale.

The sponsors, who were interested in reducing the total operating cost of the development, including heating, air conditioning, domestic hot water, and electricity, believed that the cost of heating and air conditioning with oil and natural gas would be reasonably stable due to the competitive market and Rochdale's capability to operate on either fuel. However, the purchase of electricity from the local utility offered no such market constraint. One way to alleviate this condition was to by-pass the customary purchase of electric power from Consolidated Edison (whose rates the builders regarded as too high) and erect its own on-site power plant.

The Day & Zimmermann study of 1961 investigated two basic methods of providing electricity, heating, and air conditioning to the complex:

Plan A - central heating and air conditioning with purchased electricity, and

Plan B - electric generation with central heating and air conditioning.

Comparison of the prevailing electric utility rates with the costs of a total energy plant revealed that annual operating costs of approximately \$400,000 could be realized. The 1964 estimate of annual electric requirements of Rochdale Village was 44 million kWh and the cost per kWh with onsite generation was estimated at 1.24 cents. This showed a direct saving of one-half cent per kWh against the cost of purchased electric power and was a key factor in influencing the decision in favor of an onsite plant.

Another consideration that influenced the decision to provide the development with its own generating plant was the prevalent opinion in the 1960's that air conditioning was no longer a luxury, but was as necessary to living comfort as heat and hot water. It appeared to the planners that if the development had its own onsite power plant, central air conditioning could be offered as a basic utility. It was also recognized that central air conditioning would enhance future property value.

For these reasons, the concept of total energy was a part of the early planning. By incorporating electric generation, Rochdale Village has been able, over the years, to provide electric power at less than local electric utility prices.

The major factor that made a total energy system attractive was the high cost of purchased electricity. An economic analysis indicated it would be practical to build an onsite power plant. The net annual savings of self electric generation using available fuels (gas and oil) vs the cost of purchasing electricity were very attractive.

Legal and regulatory considerations were regarded as neither advantageous nor disadvantageous to the selection of a total energy system. As will be explained later, the operations of the power plant at Rochdale Village would not be subject to Public Service Commission regulation. Moreover, the purchase of utility power would cause no special legal and regulatory problems. Therefore, legal and regulatory considerations did not play a major role in the decision-making process.

Because the total energy system would not be subject to regulation by the Public Service Commission, there was little management trepidation about becoming a "utility". The Commission regulates only companies that transport electricity in public thoroughfares for sale to others. However, electric power can be metered and sold by Rochdale on its own property without being legally considered a "utility". Currently, Rochdale does have individual electric meters for each apartment. However, the meters are not used because the cost of the electricity is included in the overall monthly carrying charges to the tenant-owners.

Nevertheless, the Rochdale Village power plant is a "utility" in the sense that it provides an entire complex with essential utility services. Because of this, the responsibilities or risks assumed by owners of self-electric-generation plants were considered, but the potential for economic benefit more than compensated for what were considered to be reasonable risks.

Because there would be no external electric utility connection, planning for system reliability was paramount. Ample standby equipment was included in the original design so that failure of the largest electric generating unit could be fully compensated for by operation of other onsite equipment. This degree of equipment redundancy is seldom practiced by electric utilities today.

Because adequate fuel availability was considered vital, full provision for dual-fuel capability was made. The total energy plant was designed to use either gas or No. 6 fuel oil in the boilers, and gas or No. 2 fuel oil for operation of the dual-fuel diesel engines. A tank farm was installed to provide the plant with a one-month fuel oil supply during normal operating periods.

Proper manning of the plant was another area that required evaluation. The risks -- such as strikes, excessive absenteeism; etc. -- of plant operating personnel were fully considered. Again, the potential for economic benefit outweighed these risks.

2.2.2 Financing

Financing of the total energy system was included in the Rochdale mortgage financed under the New York State Mitchell-Lama Law.

An objective was established during preliminary financial planning that monthly carrying charges would not exceed \$21 per room per month. Any financing package negotiated would have great impact on the carrying charges and the sponsor's ability to meet this goal.

Arranging a mortgage to finance a development the size of Rochdale Village presented considerable problems to the sponsor. Many financing plans were carefully considered. Initially the mortgage was arranged with the New York State Division of Housing providing \$19,000,000 and the New York State Teachers Retirement System and New York State Employees Retirement System each providing \$28,500,000 from their pension funds. When financing became available through the New York State Housing Finance Agency the Teachers and Employees Retirement Systems graciously withdrew.

A 40-year mortgage of \$68,406,000 was granted by the State Housing Finance Agency. This agency was created by Governor Rockefeller in 1960 for the sole purpose of lending money at low interest rates to developers of middle-income housing built under the State's Limited Profit Housing Law. As a housing company organized under that law, Rochdale Village benefited by the loan policy of this new agency. Another mortgage, one for 50 years, was underwritten by the State of New York for \$22,815,000. Equity received from Rochdale co-op purchasers accounted for \$10,488,000 of the over-all development figure of \$101,709,000. The City of New York granted a 30-year tax abatement of 50% on the residential properties of the development.

With the major financing problem solved through the implementation of State, City, and private resources, the dream for a housing development on the site of the Jamaica Race Track was on its way to becoming a reality.

The assumed life for depreciation and amortization of the total energy system used in the original Day & Zimmermann study was 30 yr.

2.2.3 Preliminary Engineering

This section discusses the system engineering planning, covering the original Day & Zimmermann study of 1961 and emphasizing fuel and utility back-up considerations. Other engineering aspects that might be considered part of the planning stages, including schematics of system components, design specifications, and component descriptions are contained under Sect 3.3, *Construction Engineering*.

The original *Study and Report of Economics of Power Generation for Rochdale Village*, was dated July, 1961. The purpose and scope of this earlier study were as follows:

- (1) to estimate the quantities of basic utilities required, namely: electricity, heat, domestic hot water, and air conditioning;
- (2) to develop various plans for supplying these basic utilities as an integrated operation;
- (3) to estimate the required investment and operating costs for each plan for purposes of comparison to determine whether it is more economical to generate electricity or to purchase it from the local public utility; and
- (4) to estimate the incremental costs of generating electricity in a central plant already designed to supply heat, domestic hot water and air conditioning to the apartment buildings and shopping centers.

The following five separate plans were developed for supplying utilities to the Housing Development:

<i>Plan A-1</i>	purchase of electricity at a single metering location and use of central turbine-driven centrifugal water chilling units;
<i>Plan A-2</i>	purchase of electricity at a single metering location and use of central, motor-driven, centrifugal water chilling units;
<i>Plan B-1</i>	generation of electricity and use of central absorption water chilling units;
<i>Plan A-1 Alternate</i>	purchase of electricity at individual buildings and use of central, turbine-driven, centrifugal water chilling units;

Plan C-1 purchase of electricity at a single metering location and use of turbine-driven, centrifugal, water chilling units in individual groups of buildings.

Each of the five plans is described in detail in the 1961 Day & Zimmermann study. An outline of the equipment required for each plan, the capital investment, and the basic operating costs are presented. From the study, it was felt that Plan B-1 -- a central power plant housing the boiler and refrigeration equipment -- would be preferable. Annual savings from onsite generation of \$400,000 were estimated, based on comparison with a conventional No. 6 oil-fired central heating-cooling plant.

Oil was considered as the primary fuel in the 1961 study until Brooklyn Union Gas approached the United Housing Foundation and offered to supply Rochdale Village with gas on an interruptible basis. Day & Zimmermann recalculated operating costs, incorporating interruptible fuel gas as primary fuel with No 6 fuel oil and No. 2 fuel oil as secondary energy sources.

An additional saving of over \$170,000 per year was projected by using gas on an interruptible **basis** rather than straight oil. Therefore, it was decided that interruptible gas would be used as primary fuel. The total energy plant was designed to use gas or No. 6 fuel oil in the boilers, and gas or No. 2 fuel oil in the dual-fuel diesel engines. Provision was made for sufficient oil storage to allow a full month of plant operation without resupply.

Initially, little consideration was given to possible fuel cost escalation, because the price of oil had been relatively stable during the 1950s and early 1960s. However, increases in fuel cost affect the cost of producing electricity for both the fossil-fueled public utility and the onsite total energy plant. Historically, an increase in fuel cost to the electric utility company is passed on to the consumer in the form of higher rates. For onsite cooperative plants, the increased cost results in higher monthly carrying charges. The impact is generally at least as severe for the utility customer as for the cooperative tenant.

Electric utility connection as backup to the onsite system was investigated and considered impractical. The power company tariff prohibited the parallel operation of electric equipment or set an exorbitantly high price for connection of service. Without the production from the total energy plant at Rochdale, estimated at 44 million kWh/yr, a sizable added annual revenue would

have been realized by the local power company. The power company, therefore, had no interest in providing standby service at low cost to Rochdale but did have an interest in discouraging the self-generation concept. In the October, 1963 issue of *Electric Light and Power*, Con Edison released its own story on Rochdale Village's self-generated power. The story states that the savings derived from the total energy plant would be minimal and that the plant was designed with little or no reserve capacity.

3 CONSTRUCTION

3.1 PERMITS

Copies of all available construction permits and documents related to certification of construction are available. Some of the items presented in this list are:

- (1) Applications and approvals for permits to commence construction work;
- (2) Applications and approvals for equipment installation;
- (3) Building permits;
- (4) Applications and approvals of plans and specifications for construction;
- (5) Applications and approvals for alteration of buildings;
- (6) Applications and certifications of Workmen's Compensation Insurance;
- (7) Restoring and repaving permits;
- (8) Sewers and Drains permits;
- (9) Applications and approvals for amendments in construction;
- (10) Fire hydrant use permits; and
- (11) Certificates of inspection for welding.

3.2 SITE PLANNING, CONSTRUCTION, AND SITE PLAN

Following acceptance of the basic concept of the facility, the United Housing Foundation, in the name of Rochdale Village, proceeded with pre-purchase of the equipment components, so that the detailed design would reflect, as accurately as possible, the specific equipment to be installed. This pre-purchased equipment included:

steam generating units (boilers),
boiler feed pumps,
steam turbine generator units,
surface condensers,
absorption refrigeration units,
cooling towers,
large circulating pumps,
diesel driven electric generator units, and
overhead cranes for equipment maintenance.

A major concern during design was the limited space available for the powerhouse structure. The assigned property was bounded by a street line on one side and the Long Island Railroad right-of-way on the other. This resulted in a relatively long and narrow building which, at time of construction, supported the world's largest roof top cooling tower.

Construction proceeded on schedule, and electric power was available for the occupants as they moved into their new residence. The entire facility was placed in operation with no design changes and has been supplying heat, air conditioning, domestic hot water, heating, and electric light and power without connection to external power sources for more than 13 years.

3.3 CONSTRUCTION ENGINEERING

General schematics of the heat flow system and electric system at Rochdale Village are shown in Figs. 3.1 and 3.2, respectively.

The HVAC system in the apartments is a two-pipe, chilled and hot water distribution system with individual room fan coil units. These units are supplied with either hot or chilled water, depending upon the season, with the occupant selecting fan speed to obtain desired room temperature. The circulating water temperature is controlled in both the power plant and the individual apartment building pump rooms to meet system load.

Steam originally was furnished to the apartment buildings at 80 psig for domestic water heating. This steam system subsequently was lowered to 20 psig.

Detailed design specifications and the bid package for the system provided by Day & Zimmermann comprise the following:

(1) *Specifications for Rochdale Village Power Plant*

- (a) Circulating Pumps and Boiler Feed Pumps;
- (b) 4.16 kv Switchgear & Control Board;
- (c) Two 3000 kVa Indoor Double-Ended Substations 4160/480 Volt, 3 Phase, 60 Cycle;
- (d) Substations for Apartment Buildings;
- (e) Motor Control Centers for Circulating Water Pumps;
- (f) Motor Control Centers for Power Plant Auxiliaries;
- (g) Steam Generating Units for Power Plant;
- (h) Steam Turbine Synchronous Generator Units for Power Plant;

FIG. 3.1. HEAT FLOW SYSTEM -- ROCHDALE VILLAGE

FIG. 3.2. ELECTRICAL SYSTEM -- ROCHDALE VILLAGE

- (i) Condenser Units and Auxiliaries for Power Plant;
 - (j) Cooling Towers for Power Plant;
 - (k) Dual Fuel Diesel-Electric-Generator Units and Emergency Engine Generator Set for Power Plant;
 - (l) Steam Absorption Refrigeration Units for Power Plant;
 - (m) Traveling Cranes for Power Plant.
- (2) *Specifications for Rochdale Village Power Plant Construction*
- (a) General Conditions for Electrical Contractor for the Power Plant;
 - (b) Specifications for Electrical Contractor for the Power Plant;
 - (c) General Conditions for Mechanical Contractor for the Power Plant;
 - (d) Specifications for Mechanical Contractor for the Power Plant.
- (3) *Specifications for Rochdale Village Power Plant (Distributing System)*
- (a) The Main Distributing System of High Pressure Piping, Pump Discharge & Chilled and/or Hot Water Piping;
 - (b) Electrical Distributing System 4160 Volts, 3 Phase, 60 Cycle;
- (4) *Specifications for Rochdale Village Housing Project*
- (a) Air Conditioning and Heating;
 - (b) Electrical Work and Materials;
 - (c) Ventilation Work.

Major pieces of plant equipment for Rochdale Village are listed below:

- (1) Gas supply - 16" diameter service, 7 psig - 2 Roots Connorsville meters, 270 Mcf/h each - telemetered to the Brooklyn Union Dispatcher;
- (2) No. 6 oil storage - sixteen 20,000 gal tanks; No. 2 oil storage - two 20,000 gal tanks;
- (3) Boiler feedwater - deaerated, chemically treated, pumped to boilers at 850 psig;
- (4) Four Union Iron Works packaged boilers - 650 psig 650°F Steam - 110 M lbs. per hour - dual-fuel economizers - Bailey controls - two burners each - 1 boiler is standby;
- (5) Two Westinghouse steam turbine generators, each 7500 kVa-0.8P.F. - 4160V - 60 Hz 40% condensing auto extraction at 20 psig - 20 lb/kW at full extraction;
- (6) Two Worthington dual-fuel diesel-engine generators - 450 rpm - 3750 kVa-0.8P.F. - 4160V - 60 Hz Fuel gas at 30 psig;

- (7) One Worthington reciprocating gas compressor 65MCFH boosted to 30 psig;
- (8) Heating system - 5 heat exchangers - 18 psig extraction steam - circulating hot water 175°F to buildings;
- (9) Domestic hot water - 18 psig extraction steam converters in each building;
- (10) Twelve Trane 1000-ton absorption units - single shell - low pressure steam - Cochrane condensate pumps;
- (11) Cooling towers - 2 Foster Wheeler, 38' x 48' x 72', 3 cells each - 20,000 gpm per tower - one winterized for turbine condensing steam;
- (12) Switchgear - 16 Westinghouse, indoor metal clad, drawout type, 250 MkVa, interrupting duty, electrically operated breakers - 4 generator circuits - 11 feeders - 1 spare.

The principal source of "waste heat" energy is extraction steam from the turbine generator units. Extracting steam from the turbine at a useful low pressure level prevents the energy loss that occurs if this steam is condensed in the surface condenser. Using the heat of condensation (vaporization) of the steam for heating and air conditioning after useful energy has been extracted for electric power generation provides maximum utilization of the heat energy in the steam.

There are no waste heat energy recovery systems on the diesel units because of their infrequent use, low heat rate, and the low cost of fuel at time of construction. Moreover, there is no electric utility backup to this generating system. It is a self-contained power facility with instrumentation provided to permit paralleling of generators on a single electrical bus without phase imbalance.

The acceptance testing periods for the equipment in the plant proceeded without incident. Raisler Corporation, the contractor responsible for installation of the heating and air conditioning equipment, reported that the plant met specifications without problem. Although standard equipment and boiler tests were employed, there are no written records of these tests because of the length of time that has transpired since the acceptance period (1963). Raisler generally discards records that are over ten years old.

3.4 CONSTRUCTION COSTS

Capital costs for the Rochdale Village complex power plant totalled \$10,208,955. Rochdale Village did not plan or require any expansion of existing

buildings or any increase in electric power generation capacity. Since the first day of operation, there have been no major capital cost expenditures for the power plant.

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4 OPERATION AND PRESENT STATUS

4.1 OPERATING PERMITS

By law, all operating permits required by State, Federal and City Governments must be posted in plain view of any visitor to the power plant. Rochdale Village has these permits posted in the main office of the power plant. The permits present are:

- (1) Boiler and burner permits plus amendments from the Department of Air Resources and the Department of Air Pollution Control;
- (2) Application and certificate of occupancy plus amendments from the Department of Buildings;
- (3) City of New York Fire Department.

4.2 GOVERNMENTAL REGULATIONS

The sources of any citations from the EPA or other related bodies are:

- (1) Department of Air Resources;
- (2) Fire Department;
- (3) Department of Air Pollution Control; and
- (4) Department of Buildings.

According to Rochdale Village Management, any state and federal OSHA inspections are done on an informal basis. Therefore, inspection reports were not available for inclusion in this report.

One regulatory cost that has resulted from owning a total energy system is related to Environmental Protection Agency action. The power plant must use oil which has a sulfur content less than 0.3%. There is a difference in price between low- and high-sulfur oil. To calculate the difference in price, reference can be made to the *Journal of Commerce Daily Petroleum Prices*. Calculations revealed that low-sulfur oil with a sulfur content of 0.3% retails for an average price of 35.2 cents per gallon. One percent sulfur oil retails for an average price of 32.3 cents per gallon, yielding an average difference of almost 3 cents per gallon. Calculations can be made from the monthly oil consumptions to determine how much "regulatory cost" has accrued as a result of this NYC Department of Environmental Protection regulation.

However, the less expensive high-sulphur oil has corrosive effects and increases maintenance costs; whereas, the more expensive low-sulphur oil increases equipment life.

Another regulatory cost to Rochdale Village stems from a New York City Fire Department regulation. Originally, Rochdale oil deliveries were in 7000-gal tank wagons. The Fire Department prohibits this size truck in certain areas including Rochdale Village. Smaller 5400-gal tank wagons must be used, and the number of deliveries and costs have therefore increased.

4.3 MAINTENANCE

Allied Maintenance Corporation is the maintenance operator of the Rochdale Village power plant. Included in the general personnel agreement or contract between Allied's management and the union are the schedule of union personnel's hourly rates and a copy of the personnel benefits package. Also included is the agreement between Allied Maintenance and Rochdale Village. This agreement indicates the number of people required to run and maintain the plant and their titles or labor classifications.

Also available for inspection is a summary of manpower requirements, preventive maintenance costs, weekly power plant personnel costs, and a list of overtime manhours from August, 1975 to July, 1977.

Overtime manhours are 7089, 2108, and 1042, respectively, for the periods August, 1975 to March, 1976; April, 1976 to March, 1977; and April, 1977 to July, 1977. These overtime manhours which are broken down on a monthly basis, are not a true reflection of the overtime associated with normal preventive maintenance. As explained in the "Reflection and Commentary" section, Allied did not find the plant equipment in top condition when they started working for Rochdale in 1975. Since that time, Allied has been engaged in routine preventive maintenance plus restoration of equipment to efficient operating condition. To reduce costs, items in this latter category, which normally might be subcontracted were handled by Allied in overtime hours.

Included in the plant preventive maintenance program for major components of the system are: (1) items to be inspected and/or serviced, (2) frequency of inspection, (3) time standards for each inspection, (4) total annual manhour chart broken down by weeks of the year, and (5) record-keeping samples.

Moreover, the manufacturers' recommended preventive maintenance for the Westinghouse steam turbines, the Worthington diesel engines, and the Trane absorption chillers are also available for inspection. Maintenance of the Union Iron Works boilers is prescribed in the Building Codes, Local Law. No. 76 of the City of New York, effective December 6, 1969.

A copy of the spare parts and tool inventory system and the costs of these items at the time they were purchased is available for inspection along with a breakdown of total monthly inventory costs from November, 1976 to July, 1977.

4.4 OPERATIONAL ENGINEERING

Operators can adjust and balance loads between turbine generators and diesel generators to achieve minimum fuel consumption. The objective is to obtain as much power by steam extraction as the steam load permits. As steam load decreases, diesel electric generation becomes more economical. Steam condensing power generation should be kept to a minimum. It is not practical to switch loads frequently between diesels and turbines; therefore, changes are made on a seasonal basis, with the diesels carrying loads only during periods of low steam demand (spring and fall).

Load shedding is not required because of the "firm power" design capability to carry peak loads even with the largest electric generating unit out of service. Under absolute emergency conditions, individual distribution breakers could be tripped in each apartment building to selectively maintain elevator service at minimum power generation.

The control equipment used includes: 16 Westinghouse, indoor metal clad, drawout type, 250-MkVa, interrupting duty, electrically operated breakers with four generator circuits and 11 feeders. One feeder is used as a spare.

The daily electrical and thermal load profiles for the peak summer thermal load, peak winter thermal load, and minimum yearly thermal load are shown in Figs. 4.1, through 4.3. Only one day type was graphed because of the residential nature of the load. Fig. 4.4 graphs the seasonal thermal and electrical load profile.

* BECAUSE OF RESIDENTIAL NATURE OF TENANTS THERE IS NO
SIGNIFICANT DIFFERENCE BETWEEN WEEKDAYS, WEEKENDS
AND HOLIDAYS

PEAK ELECTRIC LOAD - 9500 kW
PEAK THERMAL LOAD - 160 million Btu/hr

FIGURE 4.1 DAILY ELECTRICAL AND THERMAL LOAD PROFILE

AT PEAK WINTER THERMAL LOAD
JANUARY 17, 1977

FIGURE 4.2 DAILY ELECTRICAL AND THERMAL LOAD PROFILE

FIGURE 4.3 DAILY ELECTRICAL AND THERMAL LOAD PROFILE

AVAILABILITY OF FLEXIBLE THERMAL LOADS:

THERMAL LOAD - June thru Sept. - due to steam absorption refrigeration units furnishing chilled water to fan coil units in each room.

- Nov. thru April - due to steam heat exchangers furnishing hot water to fan coil units in each room.

ELECTRICAL LOAD - varies with number of fan coil units operating in addition to normal lighting loads etc.

FIGURE 4.4 SEASONAL ELECTRICAL AND THERMAL LOAD PROFILE

4.5 SYSTEM OUTAGES

A record of system outages from August, 1975 to July, 1977 causing customer downtime is as follows:

No indications of a total "blackout" of the Village and power plant were found, and in no case was it indicated that the use of the emergency generator was required to get the plant back on line. Only three types of problems were noted:

- (1) boiler "flame out": reducing power generation capability;
- (2) electrical feeder failure: resulting in substations transferring automatically to an alternate feeder with no apparent loss of power;
- (3) boiler "flame out" with no apparent loss of power generation.

The following paragraphs report on the details of three types of failures.

- *Boiler "flame out" with apparent loss of power:* Two events were noted in this category: (1) there was a system "brown out" on April 25, 1976 at 9:00 a.m. when a boiler "flame out" occurred and power to unidentified preselected feeders was dropped for 20 min. Some of the buildings did not pick up the load immediately as feeders were reenergized; and (2) A partial "brown out" was reported on October 31, 1975 from 10:40 a.m. to 12:30 p.m. because of a boiler flame-out. Only two feeders (S-1-2 and S-1-6) were tripped.
- *Electrical Feeder Failures* were reported on feeder S-1-2 at 9:00 a.m. on December 25, 1975 and again at 6:05 p.m. on January 11, 1975. Repairs on the circuit were completed January 25, 1976, and the circuit was placed into service at 9:30 p.m. on January 26, 1976. A similar episode occurred on feeder S-2-16 on June 14 and 20, 1977. It was presumed that the automatic transfer of feeders at the apartment building substations prevented any loss of customer service during these episodes.

Maintenance of electrical switchgear and feeders was reported on a continuing basis during August and September, 1975 when feeders were selectively tripped. Again,

automatic transfer or possibly pre-transfer of load to parallel feeders is believed to have prevented loss of customer service.

- *Boiler Flame-Out without report of feeder tripping* occurred several times during 1977. The following episodes were noted:

February 8 at 2:30 p.m.
 February 27 at 5:30 p.m.
 March 28 at 9:30 a.m.
 April 2 at 8:30 a.m.
 April 16 at 4:30 p.m.
 April 24 at 10:10 p.m.
 May 17 (no time indicated).

Most of the above events appeared to result from air in oil lines, unstable combustion or control system malfunction. Because of the relatively close grouping of these events, a malfunction in the control system is suspected.

Review of the above events indicates that the automatic starting of the diesel engines has, in most cases, provided adequate system backup to ensure continuity of power when boiler flame-out occurs.

4.6 PLANT CAPACITY

Even though the development plan initially was fixed in size, energy needs have continued to expand. The average American was consuming more electricity in 1977 than in 1964 when Rochdale first opened its doors for occupancy. The American home is using more convenience and leisure-time appliances (televisions, microwave ovens, hairdryers, etc.). Rochdale was estimated to need 44 million kWh in 1964. For 1977, generation of power at the plant was projected at 50.8 million kWh. This increase in energy usage was not forecast in 1961. However, the system has been able to accommodate the greater load because of the large reserve capacity built into the power plant. The Rochdale Village power plant has installed capacity of 18,000 kW; whereas, the largest electrical demand experienced to date has been only approximately 9500 kW.

4.7 TECHNICAL EFFICIENCY STUDY

The technical efficiency study done by Day & Zimmermann, Inc. is summarized in Tables 4.1 and 4.2. The two major derivations of this study are the turbine efficiencies based on turbine heat rate and the overall plant efficiency based on total useful work. These efficiencies were calculated from January, 1975 to July, 1977 on a monthly basis. Average annual efficiencies were weighted according to the fuel consumed each month. These efficiencies are lower for 1975 and 1977 because all higher efficiency months were not tabulated for these years.

From this analysis it can be seen that maximum thermal efficiency was reached during peak heating and cooling seasons. Minimum efficiency was experienced during the low thermal load periods in spring and fall. When little or no thermal load is present, the steam must flow directly to the condenser rather than being applied to useful work. When a thermal load is present, however, the steam can be extracted and put to work. This results in a higher efficiency during times of greater extraction.

During peak thermal loads, efficiencies close to 70% were calculated for the Rochdale Village power plant. Efficiencies for large electric utility power plants, where "waste" heat is not applied beneficially is usually less than one half of that achieved by Rochdale.

Actual calculations made for the technical efficiency study are available for inspection. The methodology used to derive these results, i.e., assumptions and calculations made, is shown in Sect 7, *Methodology*.

4.8 OPERATING COSTS

A complete breakdown of the Rochdale power plant operating expenses for their Fiscal Years 1975, 1976 and 1977 are available. Total operating costs for the power plant were as follows:

<u>YEAR</u>	<u>COST</u>
1975	\$4,483,805
1976	\$4,620,338
1977	\$4,594,388

Fuel costs from April, 1975 to March, 1976, April, 1976 to March, 1977 and April, 1977 to July, 1977 were \$3,273,880, \$3,411,937, and \$976,639 respectively.

TABLE 4.1. TECHNICAL DATA FOR ROCHDALE VILLAGE

Day & Zimmermann Inc.

COMPANY Brooklyn Union Gas Co. P.O. No. DATE Sept. 14, 1977
 LOCATION Rochdale Village SHEET No. 33* OF 33
 SUBJECT Efficiency Calculation Summary

COMPUTED BY WTC CHECKED BY

EFFICIENCIES %				
YEAR	MONTH	BOILERS	TURBINES	USEFUL WORK
1975	JANUARY	79.00	41.50	65.23
	FEBRUARY	79.00	42.50	66.59
	MARCH	79.00	42.46	66.13
	APRIL	79.00	35.13	59.20
	MAY	79.00	31.79	50.16
	JUNE	78.89	35.10	56.10
	JULY	78.00	49.98	69.06
	AUGUST	75.00	39.70	59.61
	SEPTEMBER	75.00	29.67	42.83
	OCTOBER	76.71	33.23	47.84
	NOVEMBER	77.22	32.08	49.91
	DECEMBER	79.00	46.91	69.00

Average Annual Weighted Efficiency = 57.4**

1976	JANUARY	79.00	50.03	71.04*
	FEBRUARY	79.00	46.84	69.18
	MARCH	79.00	43.09	65.82
	APRIL	79.00	31.18	52.47
	MAY	75.00	25.57	32.37
	JUNE	75.00	38.05	57.35
	JULY	75.00	40.08	60.15
	AUGUST	75.00	41.76	61.70
	SEPTEMBER	75.00	30.56	46.42
	OCTOBER	75.00	31.44	42.00
	NOVEMBER	78.80	61.53	71.54
	DECEMBER	79.00	50.53	70.55

Average Annual Weighted Efficiency = 59.9

1977	JANUARY	79.00	52.15	71.85
	FEBRUARY	79.00	40.92	64.46
	MARCH	79.00	30.98	48.85
	APRIL	78.60	30.85	49.25
	MAY	76.05	30.27	39.64
	JUNE	75.00	30.69	43.23
	JULY	75.00	38.87	58.55

Average Annual Weighted Efficiency = 55.9***

*Revised 9-27-77

**Based on April to December 1975

***Based on January to July 1977

TABLE 4.2. SUMMARY OF CALCULATIONS -- ROCHDALE VILLAGE EVALUATION

Brooklyn Union Gas Company
Rochdale Village Evaluation
Summary of Calculations

Average Hourly Conditions

Average Monthly Summary																			
Year	Month	K.W.	# 6 Oil Gas Gallons Cu FT	#2 Oil Gallons	Turbine Factor	Boiler Eff.	Steam Gener- ated	Boiler Plant Loss	Turbine Eff.	Turbine Plant Loss	Con- denser Flow	Extrac- tion Flow	Reducing Station	Deaera- ting Heater	Domestic Water	Loss L.P. Steam	H-AC Flow	Plant Eff.	
1975	Jan	5984	1217		3.8	2.00	79.0	124742	4000	41.5	6000	24742	100000		16540	4200	1800	67460	65.2
	Feb	5824	1229		0.2	2.00	79.0	125972	4000	42.5	6000	21972	104000		16704	4200	1880	71216	66.6
	Mar	5659	1188			2.00	79.0	121770	4000	42.5	6000	21770	100000		16147	4200	1800	67853	66.1
	Apr	5390	1084			2.00	79.0	111110	4000	35.1	6000	30110	81000		14733	4200	1420	50647	59.2
	May	4657	742		26.0	1.42	79.0	76055	4000	31.8	4260	29905	46150		10085	4200	758	22847	50.2
	June	5359	875	3388	31.0	1.60	78.9	91985	4000	35.1	4800	28785	63200		12197	4200	1088	36915	56.1
	July	6769	1038	49328	3.7	2.00	78.0	139845	4000	50.0	6000	19845	120000		18543	4200	2200	85057	69.1
	Aug	6733		191774	1.1	2.00	75.0	130046	4000	39.7	6000	32046	98000		17244	4200	1760	64796	59.6
	Sept	5327	19	125152	3.2	1.57	75.0	86717	4000	29.7	4710	42757	43960		11498	4200	705	18847	42.8
	Oct	4748	298	57083	24.9	1.00	76.7	69254	4000	33.2	3000	30254	39000		9183	4200	640	17977	47.8
	Nov	5259	507	58055	2.3	1.60	77.2	91335	4000	32.1	4800	36935	54400		12111	4200	912	28377	49.9
	Dec	6115	1280		1.6	2.00	79.0	131200	4000	46.9	6000	19200	112000		17397	4200	2040	78363	69.0
Average Annual Weighted Efficiency = 57.4*																			
1976	Jan	6337	1439		3.2	2.00	79.0	147497	4000	50.0	6000	17000	120000	10,497*	19558	4200	2410*	94329*	71.0*
	Feb	6229	1312		2.0	2.00	79.0	134480	4000	46.8	6000	19480	115000		17832	4200	2100	80868	69.2
	Mar	5862	1160		19.6	2.00	79.0	118900	4000	43.1	6000	20900	98000		15766	4200	1760	66274	65.8
	Apr	5374	963	1553	14.7	2.00	79.0	99817	4000	31.2	6000	35817	64000		13236	4200	1080	35484	57.5
	May	4803		111586	0.7	1.74	75.0	75669	4000	25.6	5310	47349	28320		10034	4200	380	4396	32.4
	June	6027		166390	0.8	1.77	75.0	112832	4000	38.1	5310	31412	81420		14961	4200	1442	51507	57.4
	July	6709		193375	0.1	2.00	75.0	131131	4000	40.1	6000	31131	100000		17388	4200	1800	66612	60.2
	Aug	6812		199193	0.5	2.00	75.0	135076	4000	41.8	6000	29076	106000		17911	4200	1920	71969	61.7
	Sept	5727		147097	1.9	1.83	75.0	99749	4000	30.6	5490	43019	56730		13226	4200	945	28869	46.4
	Oct	5102		107647	3.7	1.00	75.0	72997	4000	31.4	3000	38997	34000		9679	4200	540	12581	42.0
	Nov	5708	983	2597	70.8	1.03	78.8	102352	4000	61.5	3090	8240	83430	10,682	13572	4200	1740	67510	71.5
	Dec	6293	1274		9.4	1.87	79.0	130585	4000	50.5	5610	16514	114070		17316	4200	2089	80855	70.6
Average Annual Weighted Efficiency = 59.9																			
1977	Jan	6527	1430		0.6	2.00	79.0	146575	4000	52.2	6000	16000	124000		19436	4200	2411	94528	71.9
	Feb	6366	1256			2.00	79.0	128740	4000	40.9	6000	27740	101000		17071	4200	1820	67909	64.5
	Mar	5760	1080		0.1	2.00	79.0	105546	4000	31.0	6000	41546	64000		13995	4200	1080	34725	48.9
	Apr	5109	858	389	13.7	1.73	78.6	87776	4000	30.9	5190	35876	51900		11639	4200	854	26017	49.3
	May	4542	171	68521	7.4	1.00	76.1	63993	4000	30.3	3000	35993	28000		8485	4200	420	7895	39.6
	June	5381		125694	1.2	1.43	75.0	83879	4000	30.7	4290	41694	42185		11122	4200	678	17895	43.2
	July	6844		190376	1.4	2.00	75.0	129098	4000	38.9	6000	34098	95000		17118	4200	1700	61982	58.6
Average Annual Weighted Efficiency = 55.9***																			

*Revised 9-27-77

**Based on April to December 1975

***Based on January to July 1977

4.9 EXTRAORDINARY MAINTENANCE

With the procurement of the professional maintenance services supplied by Allied Maintenance Corporation, several extraordinary maintenance needs were discovered. The cost was estimated at \$120,300 and \$75,500 for fiscal years ending March 31, 1977 and March 31, 1978, respectively.

4.10 ESTIMATED SYSTEM BOOK VALUE

Rochdale's estimate of the system book values for the last two years, dated March 31, 1976 and March 31, 1977 are \$8,612,701 and \$8,315,686, respectively. The capital cost of the power plant through March 31, 1967 was \$10,208,955.

4.11 RATE STRUCTURE

Initial customer rates were determined in the following manner: Robert Moses, then Chairman of the Slum Clearance Committee, and City Construction Coordinator, initially had the vision of erecting a large housing development on the 170-acre site of the Jamaica Race Track. Mr. Moses turned to the United Housing Foundation whose experience in the low-cost housing field extended over many years. Close examination of the Moses plan for a Jamaica Race Track development by the directors of the United Housing Foundation failed to satisfy them with regard to the suggested \$25 per room monthly carrying charges. United Housing contended that housing on the site, which was in a mass transit two-fare zone and in a somewhat unattractive neighborhood, would not support a \$25 per room monthly carrying charge. Experience told them that, to populate a development of this proportion, it would be necessary to draw people from other boroughs by offering very attractive apartments and equally attractive carrying charges and equity payments. In short, they felt the Moses \$25 per room estimate was too high for this type of housing.

After numerous discussions among Mr. Moses, the United Housing Foundation, and banking and financing institutions, the proposal for housing on the Jamaica Race Track reached a stalemate.

But Robert Moses again approached the United Housing Foundation and urged it to undertake the housing development. This time the board of directors agreed to sponsor the housing cooperative if monthly carrying charges could be kept at \$21.00.

There is no present rate structure for customer HVAC and electric charges *per se*. These costs are included in monthly carrying charges, determined by the number of rooms owned by the tenant. Roughly 30% of the monthly charges are used by Rochdale Village to cover operating costs of the power plant.

Increased fuel costs are passed on to the tenant, but not automatically. The increase in fuel has been passed on to the cooperative owner in the form of carrying charge increases. Hearings are held regarding proposed increases, and each member of the co-op is allowed to express an opinion. Increases have occurred in 1971, 1974, 1975, and 1976.

In 1974, the rates increased 56% mainly because the price of oil had quadrupled. In 1964, when Rochdale Village was designed and advertised, the average cost per room was \$21. This average cost has risen to \$46.87 per room which is still low compared to other similar housing in New York City. Rochdale management has reported that current monthly per-room carrying charges at Co-op City in the Bronx, New York City are \$51.37. Co-op City (15,372 dwelling units) is larger than Rochdale and is a purchaser of preferentially priced power company electricity.

A copy of a "typical lease" (at Rochdale an Occupancy Agreement) between Rochdale Village and its tenants is available for inspection. Contained in the lease are:

- (1) Rochdale Village Inc. Occupancy Agreement;
- (2) Rider to Occupancy Agreement;
- (3) Commercial Rider to Occupancy Agreement; and
- (4) Application of Rochdale Village, Inc. for an Increase in the Maximum Average Monthly Room Rental.

5 ESTIMATED VS ACTUAL ENERGY REQUIREMENTS AND COSTS

5.1 ENERGY REQUIREMENTS

The total energy requirements, as originally estimated, were accurate for the first several years of operation. However, in later years, actual electrical consumption increased and is still growing. Because households are now using more convenience appliances (TV's, toaster ovens, electric percolators, microwaves, etc.) they are consuming more electricity than the average American in 1964. The estimated annual electrical requirements of Rochdale Village for 1964 were 44 million kWh. By comparing this estimate with records of generated kWh for 1976, the increased use of electricity in the American home is easily seen. For 1976, the power plant generated 48.2 million kWh, and for 1977 the projected generation requirement was 50.8 million kWh.

However, this increase is insignificant because no new capital costs have been incurred as a result. There is sufficient equipment to handle the added demands that have been put on the plant. The installed capacity of the power plant is 18,000 kW. To date, the peak demand on the system has been approximately 9500 kW. The installed air conditioning capacity is 12,000 tons. The maximum demand to date has not exceeded 8000 tons. Guidelines at the time of building required that this excess cooling capacity be installed. The plant now stands as it was originally designed and built in 1963.

Because of the reserve capacity built into the system, there is potential for selling electric power to the local electric utility. However, because the local electric utility's requirements are enormous compared with the available power from the Rochdale plant, it would be more feasible to supply smaller loads located near Rochdale. Satellite loads could further increase the plant's efficiency and productivity without incurring significant transmission and distribution losses.

Current thinking of Rochdale's management is to study the possibility of becoming an emergency supplier of power to Kennedy Airport in the event of a city-wide blackout.

5.2 ESTIMATED VS ACTUAL COSTS

Before 1975, costs for operators, preventive maintenance, and parts inventory were not projected adequately; nevertheless, spending was kept within an allocated budget. Recently, more money has been budgeted for such items.

In the recent past, the power plant chief was in a staff position on the maintenance crew. These men moved up through the ranks and eventually someone became chief engineer. Although they were good engineers and could operate from day to day, they were not administrators. Therefore, the preventive maintenance program fell behind somewhat, and the men were mostly occupied with just keeping up the plant on a day-to-day basis. Regular preventive maintenance that should have been done in the past had not been done. Moreover, money needed for such preventive maintenance was not always available. In the past, certain monies were needed for improvements, but when brought to Rochdale Village management, it was not always possible to allocate such money for improvement.

In subsequent years, the power plant operators finally claimed they could not operate if not given adequate funds for improvements. Before the past 2 1/2 years, Rochdale Village power plant was run on a day-to-day basis, and minimal preventive maintenance was performed. This is one of the reasons for the power plant operating under budget. Now the plant is being run with the expertise of a professional maintenance company. Adequate preventive maintenance is being performed, and the plant is being restored to peak operating condition. It is this extra work that has resulted in the higher-than-usual budget allocations in recent years.

Current general inflationary pressures also have contributed to the recent increases in operating budget.

6 REFLECTIONS AND COMMENTARY

The following are commentaries from the management of Rochdale Village, Inc.; Allied Maintenance Corporation, maintenance operators of the plant; Day & Zimmermann, Inc., design consulting engineers; and the Brooklyn Union Gas Company, supplier of primary fuel.

6.1 ROCHDALE MANAGEMENT COMMENTARY

"Rochdale Village is pleased to participate in this national power plant study. We should appreciate receiving a copy of the final report, and for the future, hope that our input will be of value to those planning construction of on-site power plants.

"Given the benefit of hindsight, we would do it over again and build our own total energy plant, although we now know that we would have done some things differently.

"First and foremost, we would have turned over control of the plant to a professional service company, such as Allied Maintenance, from the beginning. This is not to level criticism at the former Chief Engineers, both of whom were excellent technical engineers, competent to run the plant on a day to day basis. Unfortunately, they came through the ranks, and as such, they were not administrators, nor could they be described as visionary, although it must be said that they constantly reminded the administrators of the shortage of funds to make the needed repairs and do preventive maintenance. Their pleas went largely unheeded.

"As a result, it required crisis and breakdown to pry loose minimum funds for obvious Power Plant needs. Severe problems arose a few years ago with the air conditioning system. A professional firm was called in to take over the operation. They have done a commendable job, as the fuel consumption figures will show.

"Things learned along the way included the need to meter incoming oil from the trucks to the tanks; the need for a temperature correction gauge, automatic control in the Power Plant of the pumps in the residential buildings and the inverse variation between consumption and preventive maintenance. If possible, natural gas should be the year-round fuel. Market conditions require us to use oil for six months of the year.

"For those considering construction of a total energy plant, we would say that from the technical standpoint, the engineering is basically the same everywhere. However, geographic location will have an impact on the total picture. Examples are, proximity to or distance from sources of supply, presence or absence of labor unions, population density, and climate. All told, there will be no substitute for careful planning and vision.

"For the future, we see a potential problem with the water supply. Right now we are tied into only one water supply company and if anything were to happen to it, the Power Plant would be out of business. There is another source of supply some distance from the Plant which could serve as an alternate source. We are studying the feasibility of this. We are also considering the possibility of providing our own well water, for the use of the **Power Plant**.

"On a different vein, we would welcome a feasibility study of the possibility of being an emergency supplier of power to Kennedy Airport in the event of a city-wide blackout. As you know, during the two blackouts of 1965 and 1977, Rochdale Village had power all day and night. If another blackout occurs and it turns out to be a long one, the vital functions of the Airport could be kept open, using Rochdale's excess power, with the joint assistance of Consolidated Edison and the Port Authority of New York and New Jersey. We are certain that such a standby back-up system could become a reality.

"The engineers and others who conducted the study were knowledgeable and personable. We are certain that the completed report will reflect their competence. Our relationship with Brooklyn Union Gas has been good over the years and we have no reason to suppose that it will be otherwise in the future."

6.2 ALLIED MAINTENANCE COMMENTARY

"On August 1, 1975, Allied Maintenance Corporation assumed the responsibility of operating and maintaining the power plant at Rochdale Village. At that time an in-depth analysis of the condition of the equipment was made and the following conditions were found to exist.

"(1) *Fuel Oil Tanks*

The fuel oil tanks had a large accumulation of sand and grit. All tanks needed to be stripped and cleaned. There were no meters on the fuel lines to the tanks and from the tanks to the boilers.

- "(2) *Fuel Oil Pumps*
4 fuel oil transfer pumps and 4 fuel oil service pumps needed a complete overhaul.
- "(3) *Boilers*
The 4 boilers were capable of steaming only to 60% of their maximum capacity.
- "(4) *Feed Water Pumps*
The feed water pumps needed an overhaul (4 pumps).
- "(5) *Steam, Water and Air Valves*
All these valves were in need of packing and reseating.
- "(6) *Diesel Generators*
The air starting system and the governors needed a complete overhaul, windings cleaned, and two coats of insulating varnish.
- "(7) *Turbo-Generator Units*
The two turbo-generators were due for their semi-annual inspections and cleaning. We also found that they were overdue for their 5 year overhaul.
- "(8) *Atmospheric Valves*
We found these valves with springs broken and leaking to atmosphere.
- "(9) *Pump Rooms*
The 28 pump rooms throughout the site were in need of repair - pumps needed a complete overhaul - thousands of feet of insulation were in need of repair or replacement - valves were leaking and controls were in need of repair.
- "(10) *Absorption Units*
5 of the 12 absorbers were operational. One was beyond repair (left open for 5 years) - 2 had tubes leaking and 4 had weak solution.
- "(11) *Cooling Towers*
4 cells of the cooling tower needed a complete overhaul.

"The following outlines Allied's progress in the effort to rehabilitate the plant over a two year period.

"Because of the cost of rehabilitating all the equipment in the plant, and the unavailability of money to do this work at one time, the decision was made to effect the rehabilitation over a period of several years, or as money became available.

"During the first two years of Allied's involvement at Rochdale Village, the following items have been completed:

- "(1) Cleaned all fuel oil tanks and installed meters in filling lines;
- "(2) Cleaned and renewed insulation varnish on diesel generators;
- "(3) Purchased a panel truck;
- "(4) Painted cooling tower superstructures, stacks, and diesel engine mufflers;
- "(5) Rebuilt two cooling tower cells;
- "(6) Upgraded the 4 boilers;
- "(7) Inspected and repaired diesel engines and purchased needed spare parts;
- "(8) Installed one high pressure air compressor for diesel start system;
- "(9) Rehabilitated one 1000 ton absorber and purchased two solution pumps;
- "(10) Overhauled 4 fuel oil transfer pumps and 4 fuel oil service pumps;
- "(11) Repaired valves on feedwater and replaced defective valves on two heat exchangers.

"Total cost for completing the 11 items was \$216,805.00. A large amount of this work was done using in-house mechanics in order to hold the cost to a minimum.

"The following are projected improvement items which fall into two groups: (1) items that have been approved and money allocated to them, and (2) items that are presently under consideration by the Rochdale Board of Directors.

"These items are partially completed:

- "(1) Overhaul controls on 25 ton crane;
- "(2) Clean, inspect and overhaul turbo-generators;
- "(3) Rehabilitate three 1000 ton absorption units;
- "(4) Install cooling tower catwalks for safety of personnel.

"Estimated cost-\$106,500.00. This cost is based on the fact that a large portion of the work will be done by the in-house personnel. Items proposed and under consideration by the Rochdale Board of Directors:

- "(1) Install remote control system so power house personnel can shut off chilled water and hot water pumps in pump room throughout the site when not required during night time hours or weekends;
- "(2) Install steam and condensate meters on turbo-generators, domestic hot water system, and absorption units. This will make it possible to analyze steam and water consumption in different areas for better control;
- "(3) Replace fill and drift eliminators in three cooling tower cells and overhaul fan units;
- "(4) Purchase and install 3 valves on dual-temp piping so each zone can be isolated if necessary;
- "(5) Modify main steam header so work can be done on boiler main stop valves without a complete shutdown of steam plant;
- "(6) Improve power plant security system;
- "(7) Purchase two truck mounted portable generators to be used if and when feeder cables fail or in other emergencies.
- "(8) Replace present combustion controls with modern and more efficient controls. This would result in approximately 5% fuel savings.

"Total estimated cost - \$465,000.00."

6.3 DAY & ZIMMERMANN COMMENTARY

"The Rochdale Village Total Energy Plant is a self-contained facility designed to supply heating and air conditioning, heat for domestic hot water and all electric requirements to a 5860-unit low income housing facility from the generation of steam in gas/oil fired boilers. Standby and peaking electric power is available from diesel engine driven electric generators contained within the facility. Adequate standby equipment is provided to meet peak load conditions if any major item of equipment is removed from service for maintenance or due to equipment failure.

"The system was installed to obtain the benefit of low cost electric generation using controlled extraction steam turbines. The selection of absorption refrigeration units using low pressure steam was based on analysis of the relationship between electric generation requirements and low pressure steam loads. Although the turbines have the ability to carry peak electrical loads in the straight condensing mode, more efficient operation (energy conservation)

is obtained by operating the diesel units during periods of extremely light low pressure steam demand.

"The facility has operated on a continuous basis since its original operation in 1963 and has provided light and power to the tenants of the facility during two major extended power blackouts of the local electric utility.

"Looking back on the design after more than a decade of operation there does not appear to be any areas adaptable to changes in the design concept. Operation has indicated the refrigeration capacity required by the New York Housing Authority has never been required, so that a reduction in installed chiller capacity would be considered valid.

"The design study for this facility involved an analysis of electrical loads and steam loads for the entire year. It was determined that due to the highly residential character of the project there was little change in the daily electrical load curve except as influenced by the weather. Electrical loads were established for each hour of an average day for each month of the year. Corresponding steam loads were established for each hour of the average weather day for each month and then turbine throttle, extraction and condensing steam flows were determined from characteristic curves of a representative controlled extraction turbine. Prior to the detailed study on an hour by hour basis, a preliminary analysis was made to establish a turbine throttle pressure compatible with capital costs and required steam flows.

"The individual hourly steam flows as established by the detailed analysis on a month-by-month basis were used to determine annual fuel consumption.

"It must be recognized that a study based on peak summer and winter load conditions would not reflect the less economic operation that occurs at part load."

6.4 BROOKLYN UNION GAS COMMENTARY

"Brooklyn Union Gas was actively involved in the very planning for the Rochdale complex dating back to early 1961 and has since that time been promoting the concept of highly reliable, highly efficient and economically sound on-site generating systems. A variety of customer types in the Brooklyn Union service area are served with such systems including industrial plants, large commercial facilities and large residential developments such as Rochdale.

"The keys to the reliability of this plant are its excellent design utilizing amply sized quality machinery and its dual-fuel (oil and gas) capability. No electric service is provided by the local electric company.

"The economic success of Rochdale is partly attributable to the fact that a major portion of the annual energy cost, the amortization of investment in the Total Energy plant, is fixed and therefore not subject to inflationary pressures.

"Many millions of dollars in saved energy costs have accrued to the co-operators since start up of the Rochdale facility 14 years ago.

"In November 1965, when the entire northeast region of the country was plunged into darkness by a massive power failure and again in July of 1977 when New York City was without electric utility service, the lights from Rochdale's 50,050 windows were a glowing oasis in a blacked-out city. See Figs. 6.1 and 6.2.

FIG. 6.1.: VIEW OF SOUTH JAMAICA AT NIGHT WITH ROCHDALE VILLAGE IN BACKGROUND.

FIG. 6.2.: SAME VIEW OF SOUTH JAMAICA AT NIGHT DURING THE FAMOUS 1965 NORTH-EAST BLACKOUT. ROCHDALE VILLAGE REMAINED UNAFFECTED BECAUSE OF TOTAL ENERGY.

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7 METHODOLOGY

7.1 GENERAL INFORMATION

Major sources from which documents, memos, prints, or other portions of the study were obtained included:

- (1) Rochdale Village Management;
- (2) Day & Zimmermann, Inc., power plant design engineers and engineering consultants;
- (3) Herman J. Jessor, architect;
- (4) Allied Maintenance Corp. maintenance operators of the power plant; and
- (5) The Brooklyn Union Gas Company.

Rochdale Village Management provided information through several recorded interviews and meetings. Answers to questions regarding the planning stages of the complex, such as the original total energy concept, financial planning, and the engineering design were obtained. Moreover, operating procedures were discussed including such topics as regulatory bodies, past and present maintenance service, costs, and rate structure. Various supporting documents were acquired at the meetings which are presented in the report, such as the capital project request with a financial analysis relating to the implementation of the installation of the system, the contract agreement between Rochdale and Allied, fuel and inventory costs, additional capital project requests for capital improvements, a "typical lease" (Occupancy Agreement) between Rochdale and its tenant owners, and the specific commentary on the management's thoughts and feelings on the past, present and future operations of Rochdale Village.

Day & Zimmermann, Brooklyn Union's subcontractor for the study, provided supplementary information to many of the questions posed to Rochdale Management. In addition, they provided much of the necessary technical and engineering information, such as construction and equipment specifications, generator loading information, and electrical and thermal load profiles. A large portion of the work contracted to Day & Zimmermann was the technical efficiency study in which, over a two-year period, the turbine heat rate and overall plant efficiency were calculated on a monthly basis. The calculation procedure and assumptions used by Day & Zimmermann in the study are presented in Sect 7.2, *Technical Efficiency Study*.

Herman J. Jessor, architect, provided some of the major prints needed for the study, including a scaled site plan of the Village and the electric and HVAC distribution system. In addition, copies of various construction permits were provided by the architect.

Allied Maintenance also provided some of the major prints, particularly the schematics of the system components (electric and HVAC) showing the turbines, diesels, chillers, boilers, and cooling towers. Moreover, they provided a sample of their preventive maintenance program, a list of the components served on the program, a list of personnel needed to operate the plant, the costs needed to upgrade the system, inventory items and costs, copies of operating permits, and finally, a commentary on past, present, and future operations.

In addition to obtaining all data and providing supplementary information to the data acquired from the sources mentioned above, Brooklyn Union Gas was responsible for overseeing, compiling, writing, editing, and binding the final report.

7.2 TECHNICAL EFFICIENCY STUDY

7.2.1 Assumptions

To perform the technical efficiency study, it was necessary to make some assumptions because complete detailed plant operating data were not available. An explanation of assumptions made is included in the following paragraphs.

Boiler efficiencies were estimated for gas and oil firing at 75% and 79% respectively following analysis of data at no load (heating or air conditioning) conditions in May of 1976 and 1977. This study also resulted in the following fixed steam flows:

Domestic water heating	4200#/h
Boiler & Piping losses	4000#/h
Turbine losses	3000#/h
	per turbine

Considered as useful work were, heat energy to the heating and air conditioning systems, to the deaerating heater, to domestic hot water and the direct heat equivalent (at 3413 Btu/kWh) of electric power generated. A two percent loss was assumed and deducted from the useful steam flow.

The turbine efficiency is the thermal efficiency of the turbine only and, therefore, does not include boiler losses. If a comparison is made between the turbine and the dual-fuel diesel engine, one should incorporate a factor for boiler efficiency in the turbine analysis.

Gas fueled diesel power was indeterminate; therefore, the only diesel power credited was for oil fired power. All gas delivered to the plant was charged to steam generation resulting in a higher turbine condenser heat loss than would have actually occurred during dual-fuel diesel operation.

All calculations were done on an hourly basis based on the averages of data tabulated on the monthly summary sheets. It was presumed the daily figures for kilowatt hours, gas and oil consumption are of an accuracy suitable for these calculations. Kilowatt loads and steam generation figures were divided by a "turbine factor" (indicating the average number of units in operation over the entire month) to obtain extraction steam flows from throttle flows at a given generator load.

7.2.2 Calculation Procedure

Inspection of copies of the daily and monthly summary log sheets from Rochdale Village Power Plant indicated a significant lack of valid steam flow data. The data for steam generated and fuel consumed indicated the boilers were operating well above their peak design efficiencies. It was concluded the only valid log data was kW generated and fuel consumed, combined with daily entries of number of units operating.

In order to proceed with suitable calculations, the original design boiler efficiencies, turbine extraction curves and climatological data were utilized.

Using the above information, preliminary calculations on an average hourly basis were made for periods of zero heating or air conditioning during selected dates in May of 1976 and 1977. Fuel consumption was used to establish high pressure steam flow based on design boiler efficiencies. This flow was assumed to go to the turbine generators. The turbine extraction curve for this throttle flow and kW load established the average hourly steam flow to the extraction nozzle with the balance going to the condenser.

From the extraction flow data and from a turbine expansion curve on a Mollier diagram, steam flow conditions (enthalpies) were established for the deaerating heater. The excess extraction steam over deaerating heater requirements was charged against domestic water heating and plant losses.

Analysis of the first set of calculations using the design boiler efficiencies (including blowdown) of 85% on oil and 81.1% on gas indicated high levels of plant steam loss. After analysis of several trial calculations, the following were established as reasonable:

- (1) Boiler efficiency - 79% on oil
75% on gas
- (2) Higher heating values
 - A. Gas 1000 Btu/ft³
 - B. #6 Oil 143,500 Btu/gal
 - C. #2 Oil 139,000 Btu/gal
- (3) Turbine auxiliary steam (ejectors, seals) - 3000 lb/h per unit.
- (4) General plant steam losses-constant at 4000 lb/h.
- (5) Domestic hot water steam load-constant at 4200 lb/hr.
- (6) Deaerating heater steam was assumed to represent useful energy since all of the heat is returned to the energy cycle. (Heater radiation and vent losses are included in plant steam losses.)
- (7) Variable unaccounted for losses of useful work steam were assumed to be a constant two percent.

It must be recognized that all monthly average calculations were determined by dividing monthly totals by the number of hours in the month to obtain a monthly average for kW generated and fuel consumed. This results in the selection of a single value for turbine average extraction flow and average condenser flow for the month. The relationship between turbine extraction flow, kWh generated and condenser flow is not linear; however, there is no other reasonable way to approach the desired data without accurate and highly detailed log data on an hourly basis. The equipment necessary to measure throttle flow, extraction flow and condenser flow was not installed in the plant due to capital cost considerations.

Monthly average calculations were made using the above procedure and assumptions. Due to the approximations used in the calculations, the accuracy of the second significant figure in the efficiency results is probably question-

able; however, the trends as displayed appear highly representative of the performance of the plant. All data presented in these calculations should be rounded off to two significant figures.

The reason that 5000 apartments at 35 GPD for domestic hot water was used is as follows: ASHRAE indicates a reduction in flow of domestic hot water per dwelling unit as the number of units increases; however, their tabulations do not go above 200 units. The 35 GPD specified by ASHRAE is higher than actual Rochdale usage and therefore the number of apartments used in the study was reduced to a more realistic figure, based on analysis of total plant steam flows.

The specific value of steam consumption for domestic water is not significant insofar as the efficiency results are concerned. Plant efficiency was determined based on total beneficial use of extracted steam which included steam for domestic hot water.

The assumptions for turbine and plant losses may be higher than actually experienced. However, lower assumed turbine and plant losses would have resulted in unreasonably high boiler efficiencies and subsequently higher turbine and plant efficiencies.

Due to relatively limited operation of the diesel generators, no attempt was made to evaluate their gas consumption while on dual-fuel operation. This gas energy was charged against steam turbine generation.

The average annual weighted plant efficiencies were calculated by taking the summation of the product of each monthly efficiency and the Btu content of the fuel consumed for each month, divided by the total Btu content of the fuel used for the period.

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8 CONCLUSIONS & RECOMMENDATIONS

Because of its long history of successful operation, Rochdale has been a standout in the field of total energy. Thorough analysis of the Rochdale experience will provide motivation for the further development and application of Total Energy/Selective Energy Systems to the Integrated Community Energy System Program.

According to the various contractors and sub-contractors, the Rochdale Village residential-commercial complex is an excellent example of sound engineering principles that can be equally well applied to nurture and develop the concept further to help meet our National Goal of Energy Independence.

One of the first conclusions which can be drawn from the study is the amount of energy and savings which are realized with a total energy system. Day & Zimmermann's original study of 1961 compared the operating costs of a total energy plant with other means of providing basic utilities to its tenants. The next most economical system was purchasing electricity with central turbine driven centrifugal water chilling units. Translating 1961 figures into 1977 figures and taking into account the increased usage of electricity, annual savings between the two systems are over 561,000 gallons of oil and \$1.8 million. These figures are based on the system operating at maximum design efficiency.

Rochdale's Management was cooperative in providing necessary information. They have been interested in maximizing the efficiency of plant operation and expect this report will help them gain insight into current problems and future improvements.

From experience Rochdale's Management is convinced that a proper maintenance program is critical to the successful operation of a total energy system. This program should include both routine maintenance and planned preventive maintenance and be implemented by a professional maintenance company.

Since 1975 Rochdale has employed such a professional maintenance company. Comparing present operating costs with those prior to this time, a dramatic savings has been realized. This savings has offset the cost of the professional service. To maximize the favorable economics available from such a power plant, it is imperative to maintain the plant to operate close to design conditions.

Another recommendation which Rochdale considers important is the inclusion of oil meters with temperature correction to check deliveries from oil trucks to the tank farm. Such metering would ensure a more accurate record of oil received.

Presently the chilled/hot water circulating pumps in each residential building are manually controlled. The addition of automatic on/off control with outdoor temperature sensors would result in lower operating costs and electrical consumption.

The technical efficiency study done by Day & Zimmermann showed how efficiently the Rochdale Village system is operating. Average annual plant efficiencies of 55 to 60% were calculated.

Maximum thermal efficiency was reached during peak heating and cooling seasons. Lower efficiencies were experienced during the low thermal load conditions in spring and fall. When little or no thermal load is present, the steam flows to the condenser and is not applied to useful work. When a thermal load is present, however, the steam can be extracted and utilized. Therefore, higher efficiencies are experienced during times of greater extraction.

To obtain maximum annual efficiency Day & Zimmermann recommends the following actions:

- (1) Monitor turbine operation to assure minimum steam flow to the condenser. Analysis of peak electrical loads indicates only one turbine should be used with peak shaving provided by dual-fuel diesels. The operating data indicates two turbines were running 88% of the time from January 1975 to July 1977. This results in extremely high condenser losses. (Compare May and November 1976.)
- (2) Operate a single boiler, instead of two in parallel, to maintain boiler operation above the 50% capacity level.
- (3) Check boiler excess air using O_2 or CO_2 analyzer and adjust for maximum combustion efficiency.
- (4) Check boiler flue gas temperature to optimize internal heat transfer.
- (5) Check all steam ejectors, gland seals, etc., to minimize steam losses.
- (6) Utilize diesels during off peak seasons, even to the extent of shedding some non-essential load to minimize condenser heat loss.

Day & Zimmermann also stressed the need for high quality calibrated meters to monitor steam flow. Meters should be checked for accuracy and logged

on a regular basis. To maintain high plant efficiency it is necessary to know how and where energy is being consumed.