NYO-10719

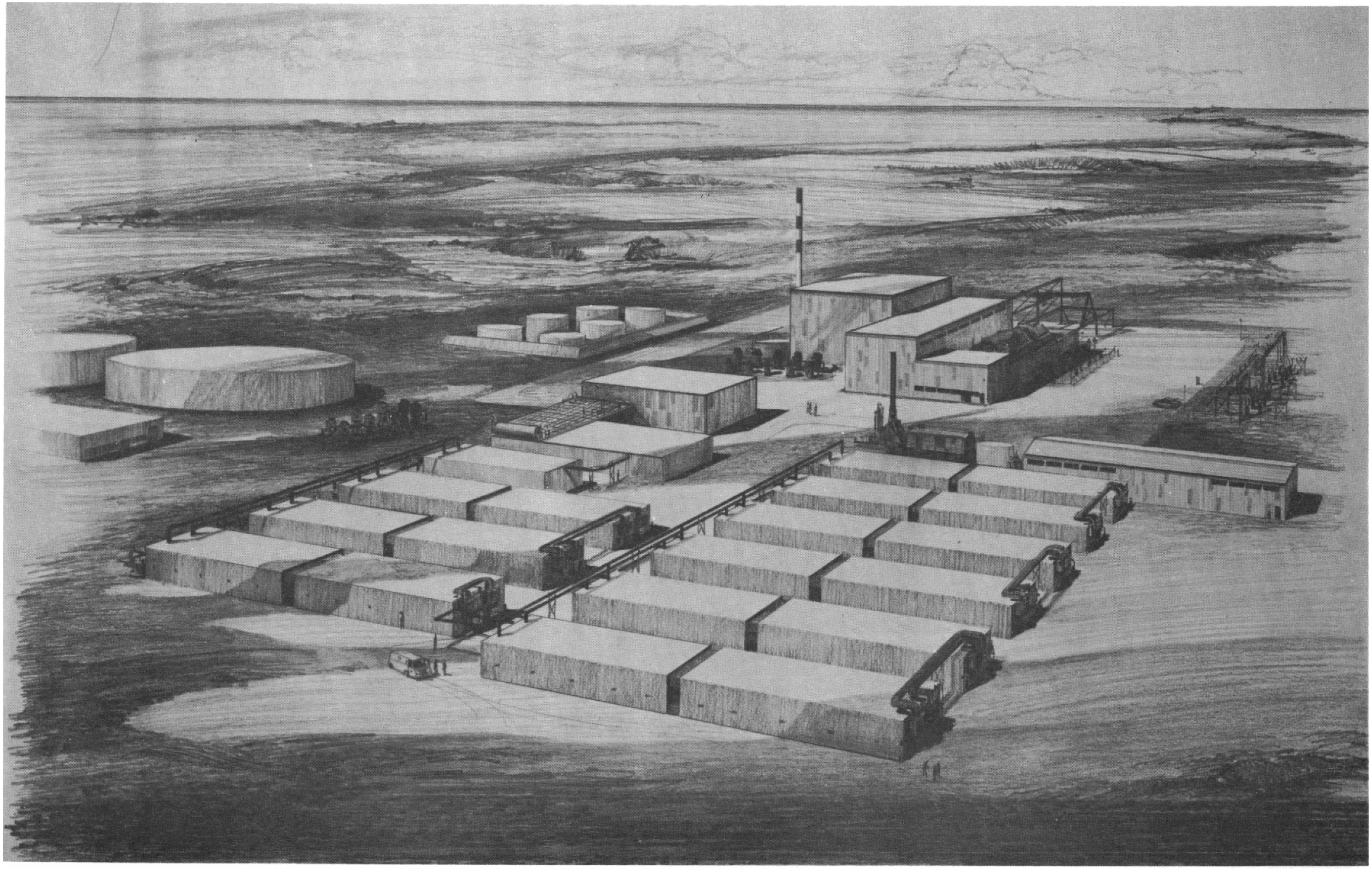
FEASIBILITY STUDY
OF A
DUAL-PURPOSE
NUCLEAR REACTOR POWER PLANT
FOR THE
FLORIDA KEYS

MARCH, 1964

Prepared For The
ATOMIC ENERGY COMMISSION

BY

BURNS AND ROE, INC.



Feasibility Study - Florida Keys
Proposed Dual-Purpose Nuclear Power and Water Desalination Plant

NYO - 10719

A NUCLEAR REACTOR SYSTEM FOR GENERATING POWER AND SUPPLYING STEAM TO A WATER DESALINATION PLANT IN THE FLORIDA KEYS

Prepared for:

ATOMIC ENERGY COMMISSION
Contract No. AT (30-1)-3277

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March, 1964

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FOREWORD

The results of an engineering study directed toward the evaluation and selection of a nuclear reactor system designed to produce electricity and furnish steam to a water desalination plant in the Florida Keys are given in this report. Emphasis was placed during the course of the study on the development of sufficient design and cost information to permit calculation of meaningful unit costs for power and for steam. Similar costs were also determined for fossil-fueled power plants of comparable net capacities, and a significant dual-purpose economic advantage was indicated for the recommended nuclear reactor system.

The study was conducted in compliance with U.S. Atomic Energy Commission Contract AT (30-1)-3277.

ACKNOWLEDGMENTS

For their cooperation in making operating data and other records available, as well as for helpful discussions on the general problems of water and power supply and distribution, the engineers wish to express their appreciation to Mr. J. J. Pinder, Chairman, Florida Keys Aqueduct Commission, Mr. E. R. McCarthy, Florida Keys Aqueduct Commission, Mr. M. E. Rosam II, City of Key West Electric System, Mr. J. H. Phillips, Florida Keys Electric Cooperative Association, Inc., Mr. H. Klein, United States Geodetic Survey, Mr. R. H. Dunlap, Executive Director, Florida Nuclear and Space Commission, Captain C. H. Neel, CEC, USN, Resident Officer in charge of Utility Contracts, United States Naval Station, Key West, Florida, and Mr. Hamilton Treadway, Bureau of Yards and Docks, United States Navy.

Thanks are also due to Messrs. R. H. Jebens and E. N. Sieder of the Office of Saline Water and Mr. L. J. Connery of the Atomic Energy Commission for providing guidance and support during the course of this study.

I. SUMMARY

The application of nuclear energy to the desalination of water is an area where there is much promise for a near-term economically competitive situation with fossil-fueled heat sources. Nuclear reactors can be used in one of two ways to produce the process steam needed for desalting sea water. The possibilities are: (1) design a reactor with minimum capital and fuel costs to produce low-pressure steam exclusively and directly, or (2) design a reactor system which will produce electricity by a turbine generator, either backpressure or extraction, and use the backpressure or extraction steam as the heat source for the water desalination plant. This investigation concentrated on the second possibility because the first approach would have no economic advantage over a fossil-fuel-fired single-purpose water plant in the applicable water capacity ranges.

Based on steam and electrical requirements determined from studies of combined desalination and power plant installations in the Florida Keys conducted for the OSW under a parallel contract, it was established that reactor power levels in the range 120 to 220 MWt would be required.

To obtain valid information for comparison of boiling- and pressurized-water reactor systems in the selected size range, proposals were requested and received from five reactor manufacturers. Two of these proposals were based on the boiling-water concept and the remaining three utilized pressurized-water reactor designs. All of the proposals were evaluated on a uniform basis, insofar as practicable. Where such items as auxiliary systems or steam generators for brine steam (in the case of the boiling-water designs) were not included in the quoted costs, adjustments were made accordingly. This brought each bid to the same degree of completeness and thus normalized the overall installed costs. Features considered, in addition to costs, were reliability, proven design, operability and maintainability, efficiency and safety and vendor experience.

From a comparison of all the factors considered it was concluded that the proposals from Vendor A met the design requirements and were best suited economically for furnishing electricity and steam, in a dual-purpose combined power and water desalination plant. To verify quoted figures, detailed fuel cost calculations were made and compared with the figures given by Vendor A. Fair agreement was found; our costs were 24.3 cents/million Btu as compared to the Vendor A estimate of 21 cents/million Btu.

Among the factors which account for the differences are the allowances for fuel processing, the estimated batch size charged to the reactor per refueling operation and the daily separation plant charges. Since the fuel cycle data submitted by Vendor A are estimates (and most likely conservative) for proposal purposes, a more detailed and precise determination of differences would not be warranted for this study. However, to ensure adequate margins in calculating nuclear power costs, nuclear fuel costs of 24.3 cents/million Btu were used throughout this report.

Using the Vendor A designs producing 412 and 700 psia steam, preliminary studies were made of the steam costs to a desalination plant producing 6,000,000 gallons per day of fresh water, which was the basis used prior to the final selection of the water plant capacity. These initial calculations showed that the 700 psia steam reactor design gave the lower power costs of the two pressures offered. Further, the incremental increase in power costs resulting from a power plant designed to meet combined needs, as compared to an unassociated power plant, were smaller for the nuclear system than for a fossil-fueled plant. It was found, after developing costs for brine heater steam extracted at pressures of 37.9, 49 and 67 psia, that the lowest-pressure steam had the least cost.

While the initial studies were based on a water plant capacity of 6,000,000 gallons per day, detailed present worth analyses of six water supply patterns, performed for the Office of Saline Water, showed that 10,000,000 gallons per day of fresh-water production was the optimum plant capacity. Similarly, it was determined that a single power plant, rated at a net output of 50 MWe and designed to furnish electricity to both the Upper and Lower Keys, was the most economical unit to install initially. Finally, studies of site characteristics showed that Sugarloaf Key was best suited for the installation of the nuclear dual-purpose facility.

The results of the calculations for the recommended combined plants are summarized on Table I-1, page I-4, with the fossil-fueled units included for comparison.

As can be seen from Table I-1, steam costs from the nuclear plant are lower than the corresponding costs from fossil plant. This situation, which is unusual for nuclear plants of comparatively low outputs, is largely due to four factors:

a. The compact Vendor A primary system design combined with the pressure suppression containment building arrangement results in a nuclear plant of low first cost.

b. Use of municipal financing with its lower fixed charge rate than industrial financing decreases the disadvantage of the higher nuclear plant first cost compared to fossil-fuel plants.

c. The nuclear fuel costs for the selected reactor design are comparatively low at 24.3 ¢/10^6 Btu.

d. The fuel oil cost of 42 ¢/10^6 Btu at the Florida Keys is relatively high.

The analyses of electric power costs are based on normal economics, i.e., no subsidies or monies for research and development assistance or for design support have been assumed for the nuclear reactor system. Further, fuel costs include fuel use charges as well as all other factors. For the nuclear reactor systems the fixed charge items were based on municipal financing and were established as 7.30 percent per year for depreciating capital and 5.17 percent per year for nondepreciating capital.

For fossil-fuel plants the insurance allowance was reduced to 0.35 percent, thus yielding 7.15 percent and 5.02 percent for depreciating and nondepreciating capital respectively.

The results of this study indicate an economic advantage for a dual-purpose nuclear power and water desalination plant, as compared to a fossil-fuel-fired unit with similar capacities and functions. Because of the economic savings shown, and the anticipated advancements in the state-of-the-art attendant to the application of combined nuclear power and large-scale water desalination, the reactor system described in this report is recommended as the basis for detailed engineering designs of dual-purpose plants in the Florida Keys.

TABLE I-1

FEASIBILITY STUDY - FLORIDA KEYS

RESULTS OF POWER AND ENERGY COST CALCULATIONS

	Fossil-Fueled Power Plant, Unassociated	Fossil-Fueled Power Plant for Dual-Purpose Operation with 10-MMGPD Water Desalination Plant	Nuclear Power Plant, Unassociated	Nuclear Power Plant for Dual-Purpose Operation with 10-MMGPD Water Desalination Plant
Steam Temperature/Pressure	1000° F/1465 psia	1000° F/1465 psia	572° F/700 psia	572° F/700 psia
Boiler Capacity	4.55×10^8 Btu/hr	6.05×10^8 Btu/hr	-	-
Reactor Power Level	-	-	170.6 MWt	221.8 MWt
Steam Flow to Brine Heater	-	246.9×10^3 lb/hr	-	246.9×10^3 lb/hr
Power Produced,				
Gross	52,630 kw	56,840 kw	53,190 kw	57,450 kw
Net	50,000 kw	50,000 kw	50,000 kw	50,000 kw
Estimated Capital Investments,				
Nuclear Island	-	-	$ 7,723,000	$ 8,362,000
Total Power Plant	$ 9,948,000	$11,686,000	14,514,000	16,938,000
Unit	199 $/net kw	234 $/net kw	290 $/net kw	339 $/net kw
Net Plant Heat Rate(1)	10,570 Btu/kwhr	14,040 Btu/kwhr	11,760 Btu/kwhr	15,290 Btu/kwhr
Unit Power Costs,				
Fixed Charges(2)	2.01 mills/kwhr	2.36 mills/kwhr	3.02 mills/kwhr	3.53 mills/kwhr
Fuel(3)	4.44 mills/kwhr	5.91 mills/kwhr	2.86 mills/kwhr	3.72 mills/kwhr
O and M, Interest on Working Capital, Nuclear Insurance, Administrative and General	1.54 mills/kwhr	1.57 mills/kwhr	2.05 mills/kwhr	2.12 mills/kwhr
Total	7.99 mills/kwhr	9.84 mills/kwhr	7.93 mills/kwhr	9.37 mills/kwhr
Difference in Total Unit Power Costs (Dual-Purpose Less Unassociated)	-	1.85 mills/kwhr	-	1.44 mills/kwhr
Cost of Steam at Water Desalination Plant Brine Heater(4)	-	23.9 ¢/1000 lb	-	15.5 ¢/1000 lb

Notes: (1) Includes allowance for 87% boiler efficiency for fossil-fueled units and 1% increase over design net plant heat rate for all units.

(2) At 7.15% for fossil-fueled units and 7.30% for nuclear units; 80% capacity factor (7008 hr/yr).

(3) At 42 $¢/10^6$ Btu for fossil-fueled units; 24.3 $¢/10^6$ Btu for nuclear units. Fuel costs for dual-purpose plants reflect increases in steam generation to meet water desalination requirements as well as power.

(4) $$\text{Steam cost} = \frac{\text{Difference in total unit power cost x net power - unit power cost x difference in gross power generation}}{\text{Mass flow rate of steam to brine heater}}$$

II. INTRODUCTION

A. Authorization for Study and Scope of Work

Burns and Roe, Inc., was retained on August 1, 1963, by the United States Atomic Energy Commission to prepare a preliminary design, cost estimate and outline functional specifications for a nuclear reactor power plant designed to meet electrical needs in the Florida Keys, and to furnish steam for a sea water desalination plant.

In accordance with the terms of the contract the following services were performed:

1. Steam and electrical requirements were determined under a parallel study conducted for the Office of Saline Water, Department of the Interior. The Florida Keys Aqueduct Commission, Utility Board of the City of Key West, and Florida Keys were consulted for necessary data.

2. A site was selected which could meet reactor safety requirements and which would provide a location most favorable, from an economic standpoint, to a sea water desalination plant using nuclear energy as the source of steam.

3. Information on boiling- and pressurized-water reactor systems in the approximate size range needed to meet the power and water requirements was obtained.

4. The two systems were compared and the system which gave the lowest costs over the life of the plant was determined.

5. Based on the system selected, a reactor system capable of supplying the electric power requirements, and the steam required for a sea water desalination plant sized for the needs of the Florida Keys, was designed and costs were estimated. The reactor system was designed using condensing extraction turbines as required by the type of reactor and steam cycle selected. A curve of steam cost, crediting electricity at the value of power, versus brine heater steam requirements was drawn. This information was used to select the proper steam conditions to yield lowest water production costs over the life of the plant.

6. The plant was redesigned for the optimum steam conditions

selected and adjusted to the specific requirements of adequately sized power and water plants.

7. The plant operating characteristics under the anticipated load variations were analyzed.

8. Sufficient information on capital, fuel and operating costs was developed to permit others to check the calculations and to study the effects of varying items of cost.

9. Outline functional specifications were provided for the reactor system so that they may be used as a basis for inviting reactor manufacturers to bid for supplying the dual-purpose nuclear steam supply system and power conversion equipment.

B. Historical Background

The Florida Keys area is presently dependent upon a Navy-owned aqueduct system for its supply of potable water under an agreement which terminates in 1967. This system is now operating at close to its maximum capacity and, based on even the most conservative population forecasts, would be soon overtaxed, even if the Navy were to extend the present agreement to furnish water to civilian consumers. However, under the current contractual arrangement the Navy is not obligated to furnish water beyond 1967 to the Florida Keys Aqueduct Commission, which is a Florida state agency empowered to distribute and sell water throughout the Florida Keys area.

In view of these circumstances, the Office of Saline Water, Department of the Interior, has authorized a feasibility study (Contract 14-01-001-337) which has as its objectives an examination of the engineering and financing considerations for providing the Florida Keys area with a system for supplying potable water at lowest cost and designed to form the basis for meeting future population demands to the year 2010. Under the OSW study, electric power and water requirements were established based on consultations with officials of the following agencies: Florida Keys Aqueduct Commission, Utility Board of the City of Key West, Florida Keys Electric Cooperative and the Bureau of Yards and Docks, Department of the Navy.

These electric power and water requirements establish the criteria for this parallel study conducted for the AEC, specifically concerned with developing design information and cost data on boiling- and pressurized-water reactor systems, evaluating this information and selecting that system which gives the lowest power and water costs.

The results of the AEC study leading to the determination of the capital, fuel and operating ocsts of a nuclear reactor system designed to generate electric power and furnish steam to a sea water desalination plant in the Florida Keys area are given in this report.

C. Review of Existing Water and Power Supply Facilities

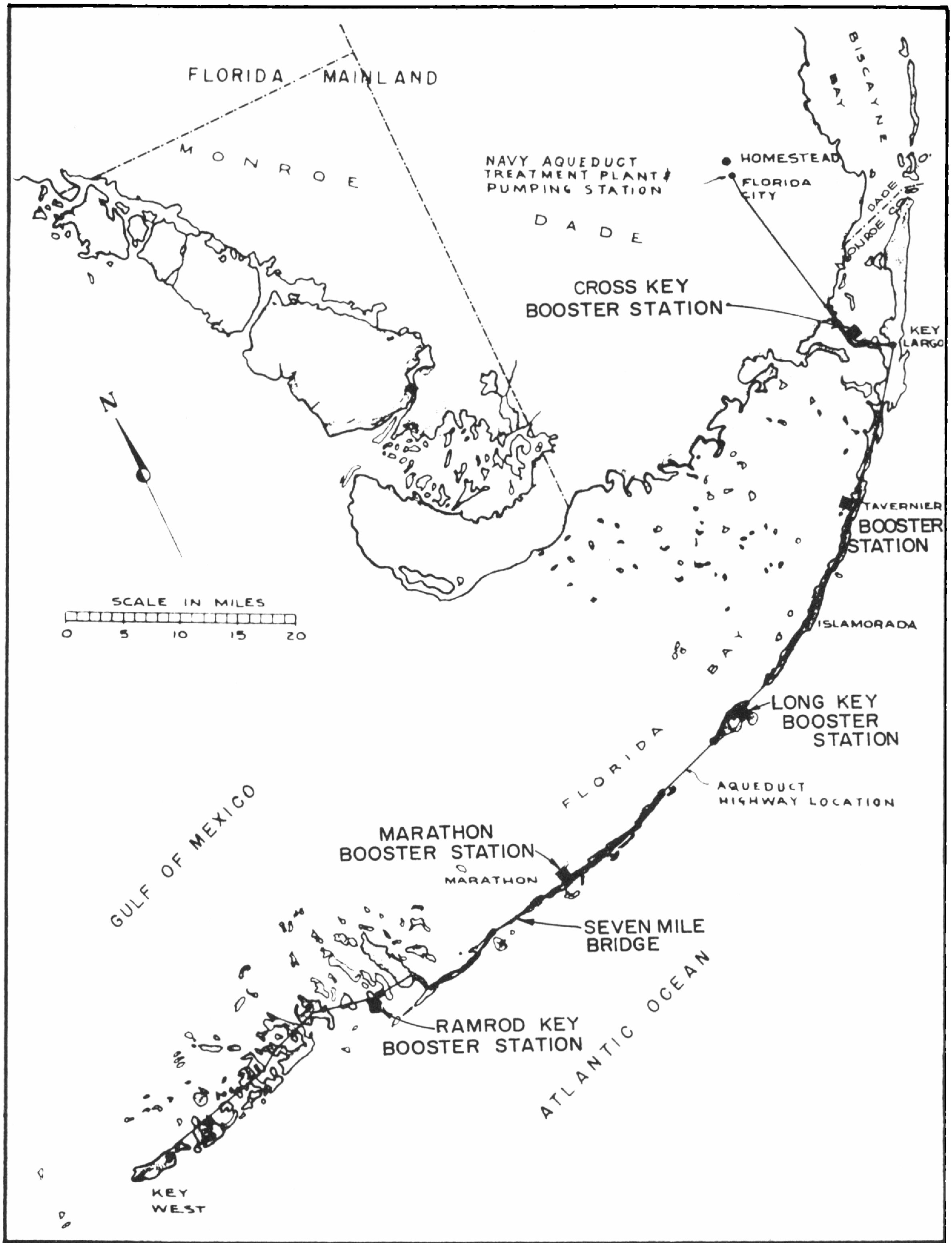
1. Water

The initial water supply facilities consisted of two 12-inch wells, a collection well, two diesel-driven high-service pumps located at Florida City, Florida, and the 18-inch pipeline from Florida City to Key West. These facilities had a firm capacity of 2,300,000 gallons per day. In 1945 and in 1954 additional facilities consisting of a lime softener water treatment plant at Florida City and booster pumping stations constructed at Marathon Key and Tavernier served to increase the capacity of the aqueduct system to 4,800,000 gallons per day.

In 1957 the water demands approached the available delivering capacity of the aqueduct and three additional booster pumping stations were constructed by the Florida Keys Aqueduct Commission at Cross Key, Long Key, Ramrod Key and Stock Island. Modifications to improve capacity were also made to the existing pumping stations. Locations of all the present pumping stations along the route of the aqueduct are shown on Exhibit II-1, page II-4.

The capability of the present system of water supply to the aqueduct is not limited by the availability of raw water. Further, the quality of the well water is satisfactory considering that average demands of 6,012,000 gallons per day are being made on water treatment facilities rated at 4,800,000 gallons per day. However, the quantity of the present water supply to the Navy, the City of Key West and the entire Keys area is severely limited by the capacity of the existing 18-inch O.D. steel

EXHIBIT II-1



BURNS AND ROE, INC. - NEW YORK, N.Y. AND REYNOLDS, SMITH AND HILLS - JACKSONVILLE, FLA	VICINITY MAP —— EXISTING AQUEDUCT AND BOOSTER STATIONS
DATE	FEASIBILITY STUDY - COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS ENGR. W.O. Nº 2270-01, PROJ. Nº 63143

pipe transmission main. This is the limiting factor insofar as the quantity of water delivered by the system is concerned. During the first nine months of 1963, the Florida City well field and pumping station pumped an average of 6,102,000 gallons per day into the 18-inch pipeline. Allowing for 662,000 gallons per day line loss and 2,010,000 gallons per day Navy usage, the total amount of water delivered to the FKAC averaged 3,340,000 gallons per day. Of this amount, the Upper Keys area used about 1,360,000 gallons per day and the Lower Keys area received the balance of 1,980,000 gallons per day.

Under these conditions the present peak demand on the system exceeds the present peak delivery capacity. The average monthly peak is involved, not just the peak day or peak hour demand. The normal growth pattern of water usage of the area has already been affected by the shortage of delivery capacity and the high price of $1.52 per thousand gallons, to civilian users. Without additional potable water supply, growth is impossible.

As a result of the study reported herein and the companion effort, conducted for the OSW (under Contract No. 14-01-001-337), the most economically advantageous method for supplying this needed water is with combined nuclear power reactor and water desalination plants having design capacities of 50 mw of electricity (net) and 10,000,000 gallons of water per day.

2. Power

An on-site investigation was made of the present electric power facilities serving the Florida Keys, particularly with respect to the physical size of the plants and systems and their adaptability to future expansion. The Florida Keys are divided geographically and electrically into two parts, separated by approximately 10 miles of open water, spanned by causeway and bridge. Each territory, Upper and Lower Keys, is served by a separate electric system, with no interconnection between them.

a. Lower Keys

The Lower Keys, encompassing all of the territory extending essentially west of Pigeon Key, are served electrically by a locally owned municipal system operating as the "City of Key West, Florida, Electric System." The headquarters for the municipal system is located in the City of Key West, Florida, on the island of Key West. Electric power for the Key West system is generated in two generating stations. The prime station is a modern, well-kept steam-turbine electric plant which carries the base load. The secondary station is an older, well-kept diesel-electric plant which is used for occasional peaking purposes and standby emergency power.

The net capability of the steam-turbine and diesel plants of 45,000 kw and 4980 kw each totals 49,980 kw. With the largest unit of 16,580 kw out of service, the remaining net firm capability is 33,400 kw. Peak system load for 1963 was 28,500 kw.

Electric power is transmitted to the distribution substations at 69 kv and 13.8 kv. The 69-kv transmission line extends approximately three miles from the steam-electric generating station to a 69/13.8-kv step-down substation near the east end of Key West.

This 69-kv, two-circuit line conveys approximately one half of the system load, and the substation serves to strengthen the remote end of the 13.8-kv system. One circuit is now in operation; the second circuit is under construction, and will serve to supplement the needs of the expanding load on the east side of the system.

The main transmission circuits are 13.8 kv, encircling the island with supplementary cross-tie circuits and sectionalizing switches for maintenance and emergency operations. The 13.8 kv is arranged so that the major substations have at least two lines for power source. Transmission along the Keys to the northeastern extremity of the system is 13.8 kv, single circuit.

A previous study made for the City of Key West indicated that the present generating facilities are adequate for supplying power requirements for approximately the next three years. Beyond 1966 a critical area will probably be reached in which requirements for short-time winter heating peak loads could be expected to exceed firm generation facilities.

Studies conducted on land development show that of the total land area possible for development at the present time approximately 10 percent is actually developed. The bulk of the undeveloped land is on Upper Sugarloaf, Cudjoe and Big Pine Keys.

Future expansion at the existing steam-electric generating plant presents problems due to limited area of the plant site and the transmission of power to expected load development in the Cudjoe and Big Pine Key area.

b. Upper Keys

The Upper Keys, extending from Pigeon Key west and north to the Florida mainland, are served electrically by a locally owned REA system operating as the "Florida Keys Electric Cooperative Association, Inc." with headquarters in the city of Tavernier on the island of Key Largo.

Electric power for the Cooperative System is generated in one power station. The station is a modern, well-kept diesel-electric plant with a net capability of 11,000 kw, and a net firm capability of 8000 kw with the largest unit out of service. Peak system load for 1963 was 17,500 kw.

At the present time, a part of the electric power necessary to meet peak loads and to assist in maintaining satisfactory load and voltage conditions is purchased from the Florida Power & Light Company.

Electric power is transmitted on two operating voltages -- a 69-kv tie line to Florida Power & Light Company system and combination transmission-distribution circuits operating at 14.4/24.94 kv.

Network analyzer studies show that for 1963 with a system peak of about 17,500 kw and a firm capacity of 8000 kw generated at Marathon (one 3000-kw unit out of service) system voltage conditions and reactive transfer are unsatisfactory.

Further analyzer study with 11,000 kw of firm generating capacity available at Marathon shows system operating conditions to be satisfactory.

The study results point up the urgent need for additional firm generating capacity at Marathon.

In recognition of the needs of expanding power requirements, plans have already been formulated by the Florida Keys Cooperative System to extend the 69-kv transmission line from Tavernier to Upper Matecumbe Key. At Upper Matecumbe Key a step-down substation is planned to supply power at 14.4/24.9 kv to the distribution system. This strengthening of the system is to be accomplished within the next two years. Plans are also under consideration to extend within five years the 69-kv transmission line to the diesel-electric generating station at Marathon. Additional diesel-electric generating capacity is under consideration by the Florida Keys Electric Cooperative, and it is expected that within 10 years the system growth will necessitate the installation of a new steam-electric generating plant located preferably on one of the larger Keys near the center of the system. Load requirements are expected to be well distributed throughout the system.

Of the land area suitable for development on the Upper Keys, it is estimated that less than 20 percent is actually developed at the present time, so that considerable land area is available for area growth.

III. FORECAST OF WATER AND POWER REQUIREMENTS

A. Population Growth Patterns

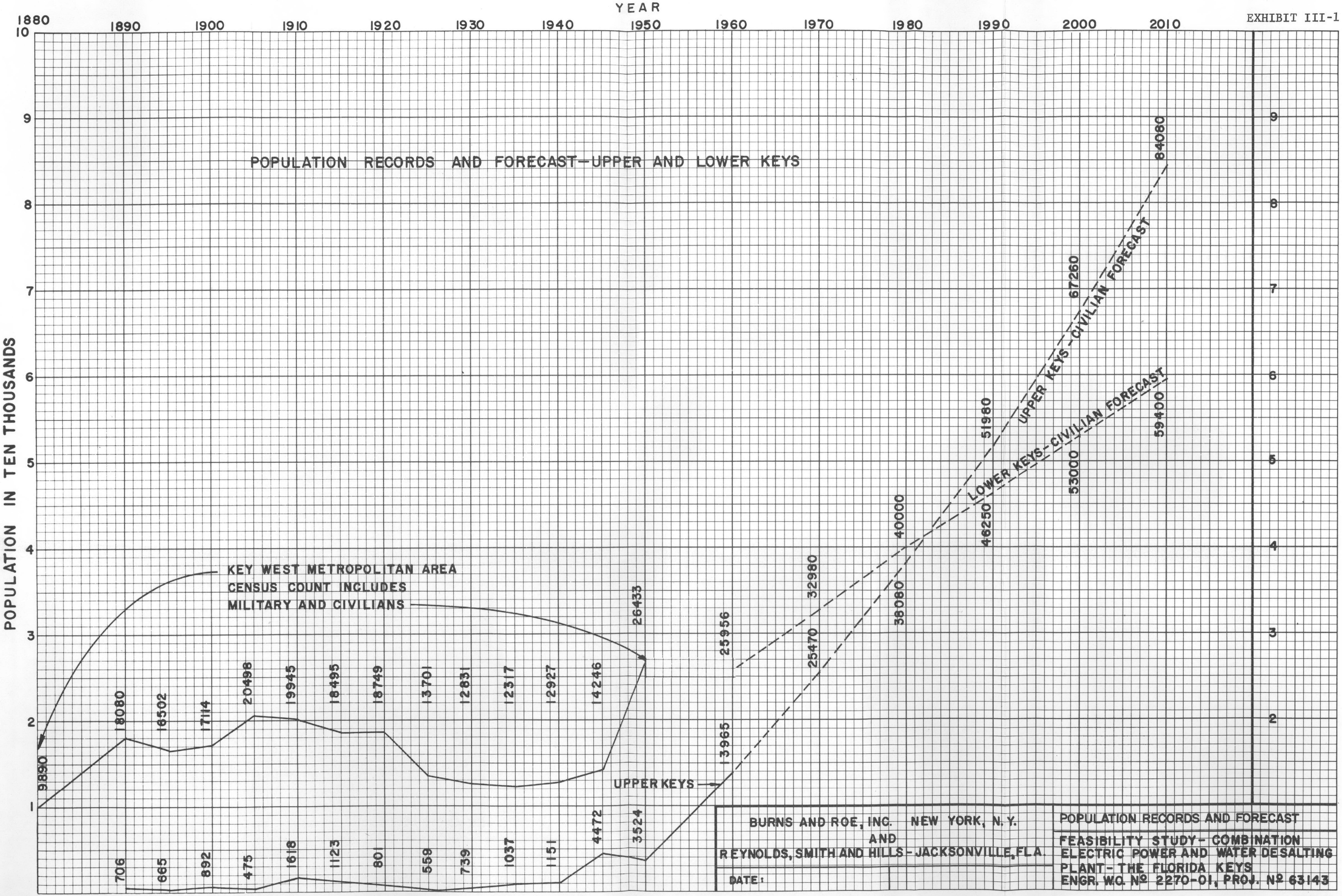
1. General

Normally, in making population studies of georgraphic areas and political subdivisions, it is possible, and the usual practice, to compare one area to another, under somewhat similar influences. It is usually possible for a municipality or political subdivision to have a rather unlimited land area upon which to expand and develop. Highways and railroads usually make the area accessible from multiple directions, with a resulting ease of ingress and egress both for public convenience and for trade. These normal circumstances, however, do not prevail in the area under study. The geographic location of the Florida Keys is so unusual that it was not considered completely fair and proper to make comparisons in population growth with other areas for the simple reason that there are few, if any, similar areas. This population study was made by dividing the area up into two sections: (1) the Lower Keys, which includes the area south of Seven Mile Bridge (to and including Key West), and (2) the Upper Keys, the area north of Seven Mile Bridge to the Dade-Monroe county line.

2. Lower Keys

The urban area known as Key West has existed for many years and is much older than Miami. Key West, a modern city, located at the southern tip of the Keys, is the county seat of Monroe County, Florida. Census records go back as far as 1860, and these records are shown graphically on Exhibit III-1, page III-2, of this section. The unique geographic location of Key West is such that for many years it was more readily accessible from Cuba than from the mainland of the United States, and for that reason a strong Spanish or Cuban influence has prevailed through the years. Except for certain towns, which have passed into oblivion due to the depletion of minerals upon which the economy of the town depended, few cities and towns in the United States have experienced the population trends which have prevailed in Key West. Strangely enough, a population of 20,498 is recorded for Key West in 1905 and this figure is only slightly below the

EXHIBIT III-1



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DATE:

POPULATION RECORDS AND FORECAST

FEASIBILITY STUDY - COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS
ENGR. W.O. Nº 2270-01, PROJ. Nº 63143

present population. In the interim, the population declined to a low of 12,317, recorded in 1935. The construction of the Florida East Coast Railroad from Miami to Key West was commenced shortly after the turn of the century, and the first train ran into Key West on January 22, 1912. The population of Key West continued to decline even after the coming of the railroad.

The principal industries of Key West, at the turn of the century, were handmade cigars, sponge fishing and commercial fishing; however, the cigar industry soon started migrating to Tampa, Florida, and by 1930 this migration was complete. On September 2, 1935, a severe hurricane so devastated the Florida East Coast Railroad on the Upper Keys that the railroad was abandoned. The decision to abandon the railroad was no doubt influenced by the fact that the economy and the population of Key West had been gradually declining from the 1905 high. Shortly after 1935 the Overseas Road and Toll Bridge District, which was created by Florida legislative enactment of 1933, purchased the abandoned railroad right-of-way, including bridge structures, for the construction of the toll highway. The construction of the toll highway, including the conversion of the railroad bridge structures, was virtually completed in 1940, and Key West and the Lower Keys were again made readily accessible from the Florida mainland. While hampered by wartime restrictions which prevailed from 1941 through 1945, the growth and development of Key West and the Florida Keys has been steady since the construction of the toll highway. A portion of the increase in population in the Key West area is closely associated with the reactivation of the Key West Naval Base in 1941 and its subsequent growth.

Examination of the census records for Key West and Monroe County shows that the population record for Key West goes back much farther than that for Monroe County. This is due to the fact that Monroe County was established by the Florida State Legislature in 1887. Prior to 1887, Key West and all the Keys were in Dade County, Florida. There is a land area on the mainland which is included in

Monroe County, but this land area is so low in elevation that it is not deemed worthy of consideration for future development.

The past population for the Upper Keys was determined by subtracting the population of Key West metropolitan area (as same is set out in the U.S. Census publications) from the population of Monroe County. The actual area comprising the Lower Keys (Key West to Seven Mile Bridge) is greater than the Key West metropolitan area, but the portion between Seven Mile Bridge and Key West having been very sparsely populated, the error based on past records is very small. In projecting future growth and future population of both the Upper and Lower Keys, adjustments were made to compensate for the minor error involved in differentiating between "the Lower Keys" and "Key West metropolitan area."

From 1940 to 1945 (Florida State Census) a 10 percent growth in population was recorded in Key West, from 1945 to 1950 a population growth of 85.5, and from 1950 to 1960 (Federal Census) a growth of 28.5 percent was experienced. Records of electric connections, water connections and telephone connections as given on Exhibits III-2, 3, 4 and 5, pages III-5, 6, 7 and 8, show the area growth between 1950 and 1963 to be somewhat erratic; but with the damage caused by Hurricane Donna in 1960 it is understandable why a drop in growth occurred in 1960 and 1961. The City of Key West Electric System showed an increase of 109 percent in residential connections during the period of 1950 to 1963. The Florida Keys Electric Cooperative Association showed a 403 percent increase during the same period. The Florida Keys Aqueduct Commission residential water connections records show the Lower Keys had the same percent of growth increase as shown by the City of Key West Electric System, namely 109 percent.

The present and foreseeable economy in the Lower Keys, with the exception of the U.S. Navy and other defense installations, is and will be based upon commercial fishing and tourists. The U.S. Navy is the principal economic factor of the area, and there is every indication that defense activities will continue to grow. The fishing industry of the year 1962 grossed approximately $6,800,000, which is an increase of approximately 50

EXHIBIT III-2

CITY OF KEY WEST ELECTRIC SYSTEM - ELECTRICAL CONNECTIONS

(MARCH OF EACH YEAR)

	RESIDENTIAL			COMMERCIAL			INDUSTRIAL		
YEAR	METERS	NUMERICAL INCREASE	PERCENT INCREASE	METERS	NUMERICAL INCREASE	PERCENT INCREASE	METERS	NUMERICAL INCREASE	PERCENT INCREASE
1950	4,592			770			19		
1951	4,908	316	6.9	811	41	5.3	19	0	0
1952	5,307	399	8.1	867	56	6.9	19	0	0
1953	6,517	1,209	22.8	898	31	3.6	19	0	0
1954	6,903	386	5.9	1,002	104	11.6	19	0	0
1955	7,414	511	7.4	1,062	60	6.0	21	2	10.5
1956	8,023	609	8.2	1,206	144	13.5	21	0	0
1957	8,526	503	6.3	1,313	107	8.4	20	(-1)	-
1958	8,570	44	0.5	1,350	37	2.8	21	1	5.0
1959	8,938	368	4.3	1,458	108	8.0	21	0	0
1960	8,906	(-32)	-	1,554	96	6.6	20	(-1)	-
1961	8,978	72	0.8	1,340	(-214)	-	14	(-6)	-
1962	9,599	621	6.9	1,449	109	8.1	14	0	0
1963	9,619	20	0.2	1,551	102	8.9	14	0	0

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CITY OF KEY WEST ELECTRIC SYSTEM
ELECTRICAL CONNECTIONS

FEASIBILITY STUDY - COMBINATION
ELECTRIC POWER AND WATER DESALTING
PLANT - THE FLORIDA KEYS
ENGR. W.O.Nº 2270-01, PROJ. Nº 63143

EXHIBIT III-3

ELECTRICAL CONNECTIONS
FLORIDA KEYS ELECTRIC COOPERATIVE ASSOCIATION, INC.

	RESIDENTIAL			COMMERCIAL		
YEAR	METERS	NUMERCIAL INCREASE	PERCENTAGE INCREASE	METERS	NUMERCIAL INCREASE	PERCENTAGE INCREASE
1950	536			370		
1951	654	118	22.0	422	52	14.1
1952	854	200	30.6	574	152	36.0
1953	1,021	167	19.6	701	127	22.1
1954	1,230	209	20.5	793	92	13.1
1955	1,483	253	20.6	864	71	9.0
1956	1,723	240	16.2	997	133	15.4
1957	2,002	279	16.2	1,052	55	5.5
1958	2,240	238	11.9	1,129	77	7.3
1959	2,527	287	12.8	1,219	90	7.9
1960	2,823	296	11.7	1,315	96	7.9
1961	2,752	-71	—	1,202	-113	—

ELECTRICAL CONNECTIONS FLA. KEYS ELECTRIC COOPERATIVE ASSO.,INC.	BURNS AND ROE, INC. — NEW YORK, N.Y. AND REYNOLDS, SMITH AND HILLS - JACKSONVILLE, FLA.
FEASIBILITY STUDY - COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS ENGR. W.O. Nº 2270-01, PROJ. Nº 63143	DATE:

EXHIBIT III-4

WATER CONNECTIONS
FLORIDA KEYS AQUEDUCT COMMISSION
(MONTHLY AVERAGE)

	UPPER KEYS						LOWER KEYS					
	RESIDENTIAL			COMMERCIAL			RESIDENTIAL			COMMERCIAL		
YEAR	TOTAL	NUMBER INCREASE	INCREASE	TOTAL	NUMBER INCREASE	INCREASE	TOTAL	NUMBER INCREASE	INCREASE	TOTAL	NUMBER INCREASE	INCREASE
1950	473			216			2,909			513		
1951	632	159	33.6	257	41	19.0	3,182	273	9.5	576	63	12.3
1952	780	148	23.4	353	- 4		3,388	206	6.7	668	92	15.9
1953	1,004	824	105.5	412	59	16.7	3,600	212	5.9	710	42	6.3
1954	1,281	277	27.6	462	50	12.2	3,869	269	7.5	775	65	9.1
1955	1,540	259	20.2	503	41	8.9	4,742	873	22.6	803	28	3.6
1956	1,977	437	28.4	531	28	5.6	5,018	276	5.8	787	-16	
1957	2,335	358	18.2	568	37	7.0	5,225	227	4.5	789	2	0.3
1958	2,781	446	19.2	598	30	5.3	5,478	223	4.2	787	- 2	
1959	3,438	657	23.6	617	19	3.1	5,666	188	3.4	801	14	1.8
1960	3,981	543	15.8	648	31	5.0	5,728	62	1.1	782	-19	
1961	4,154	173	4.3	666	18	2.8	5,833	105	1.8	786	4	0.5
1962	4,582	428	10.3	692	26	3.9	6,022	189	3.2	777	- 9	
1963	4,862[1]	280	—	726[1]	34	—	6,086[1]	64	—	753[1]	24	—

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[1] Average for Jan. thru Aug.

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FLORIDA KEYS AQUEDUCT COMMISSION
WATER CONNECTIONS
FEASIBILITY STUDY — COMBINATION
ELECTRIC POWER AND WATER DESALTING
PLANT — THE FLORIDA KEYS
ENGR. W.O. Nº 2270-01, PROJ. Nº 63143

EXHIBIT III-5

TELEPHONE CONNECTIONS
(JANUARY 1 - EACH YEAR)

	UPPER KEYS			LOWER KEYS		
	TELEPHONE	NUMBER INCREASE	PERCENT INCREASE	TELEPHONE	NUMBER INCREASE	PERCENT INCREASE
1950				4,277		
1951	120			4,636	359	8.4
1952	464	344	28.7	5,376	740	16.0
1953	807	340	73.4	5,914	538	10.0
1954	875	67	8.4	6,659	745	12.6
1955	1,081	206	23.6	7,722	1,063	16.0
1956	1,344	263	24.4	8,359	637	8.3
1957	1,656	312	23.2	8,962	603	7.2
1958	2,321	665	40.1	9,619	657	7.3
1959	2,938	617	26.6	10,364	745	7.7
1960	3,287	349	11.9	10,669	305	3.0
1961	3,482	195	5.9	11,855	1,186	11.1
1962	4,194	712	20.4	12,371	516	4.3
1963	4,677	483	11.5	13,888	1,517	12.3

OBTAINED FROM SOUTHERN BELL TELEPHONE CO. - KEY WEST

TELEPHONE CONNECTIONS	BURNS AND ROE, INC. – NEW YORK, N.Y. AND REYNOLDS, SMITH AND HILLS - JACKSONVILLE, FLA.
FEASIBILITY STUDY – COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT – THE FLORIDA KEYS ENGR. W.O. Nº 2270-01, PROJ. Nº 63143	DATE:

percent since 1955. Exhibit III-6, page III-10, indicates the Key West economic status has continued to improve since 1950. The increase in population in the Key West area from 1945 to 1960 shows a population growth approaching 138 percent. From 1950 to 1960 the percentage of increase was 28 percent. The Lower Keys has approximately 118,000 lots available for future development. Sugarloaf Key, with approximately 39,700 ultimate lots, is an area of potentially large growth. It is the opinion of the engineers, in the projection of population, that the growth pattern for the Lower Keys will continue at a uniform annual growth rate as experienced from 1950 to 1960, shown on Exhibit III-1, page III-2.

3. Upper Keys

The construction and operation of the Florida East Coast Railroad (1906-1912) resulted in a peak population in the Upper Keys, in 1910, as demonstrated by the Monroe County (Florida) census tabulation previously set out in this section. The record for several decades prior to 1910 indicates the population of the Upper Keys to have varied, but never exceeded 1000. However, in 1910, a population of 1618 is recorded which diminished to 529 in 1925. Since the 1925 census the population trend of the Upper Keys has been constantly upward, reaching 13,965 in 1960. The Upper Keys population figures were derived by subtracting the Key West metropolitan area census figure from the total Monroe County census count. This is not entirely a true count of the Upper Keys since it includes a small part of the Lower Keys, but for comparative purposes it shows a general growth pattern.

There are four post offices located along the Upper Keys highway. The gross postal receipts of these post offices indicate an increase of postal earnings from 1950 to 1960 of 418 percent. The area from the Florida mainland to Jewfish Creek is very sparsely inhabited, and the Florida Keys, for all practical purposes, commence south of Jewfish Creek. The entire Upper Keys area (Dade-Monroe county line to Marathon, Florida) is served with electrical power by the Florida Keys Electrical Cooperative Association, whose diesel-driven power plant is located at Marathon, Florida. The main Coop office is located at Tavernier. This utility reports 906 consumer

EXHIBIT III-6

KEY WEST ECONOMIC STATISTICS

YEAR	BUILDING PERMITS KEY WEST	TOTAL ASSETS THE FLORIDA NATIONAL BANK AT KEY WEST	TOTAL ASSETS KEY WEST STATE BANK	TOTAL ASSETS FIRST FEDERAL SAVINGS AND LOAN ASSOCIATION
1950	$ 960,685	$ 8,808,646.38		
1951	10,656,809	10,669,235.48		
1952	2,552,708	12,722,283.01		$ 353,800
1953	2,790,264	13,892,186.65		919,400
1954	2,622,131	13,446,488.16		1,483,200
1955	4,645,203	16,482,109.72	$ 2,095,942.03	1,863,500
1956	4,832,477	13,136,429.31	6,614,414.23	2,401,400
1957	2,130,428	11,840,779.73	7,373,544.78	2,710,300
1958	3,595,402	12,429,938.70	6,885,126.58	3,166,600
1959	2,479,583	12,989,933.27	8,414,894.02	3,979,000
1960	2,045,766	12,144,611.30	8,379,350.85	4,836,000
1961	2,671,268	13,343,241.88	8,670,073.58	5,570,000
1962	1,747,955	14,400,352.44	8,422,123.86	6,517,000
1963	2,434,577[1]	13,078,766.92[2]	—	—

[1] January thru August

[2] Last day of June

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KEY WEST ECONOMIC STATISTICS

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connections in 1950 and 4138 consumer connections in 1960, an indicated increase of 346 percent in the 10-year period. The records of the Florida Keys Aqueduct Commission show the Upper Keys had 473 residential and 216 commercial connections in 1950 and 3981 residential and 648 commercial connections in 1960, or an increase of 742 percent and 200 percent respectively. Recently AeroJet General Corporation and Seadade Corporation have made large purchases of land just north of the Dade-Monroe county line and have indicated large industrial developments are to materialize within the next five years.

With the continued construction of residences and commercial facilities on the Keys and the impetus given to the general area from either AeroJet General or Seadade proceeding with their planned construction, there seems to be substantial evidence that the Upper Keys population figure will continue to increase at a high rate.

The economic factors which affect the population growth of the Upper Keys are tourism, pleasure and commercial fishing, and residential overflow from any nearby industrial area. The population growth will also be influenced by retirees. The percentage of population growth in the Upper Keys from 1945 to 1950 was 72 percent, and from 1950 to 1960 was 296 percent. It is doubtful that this population growth percentage can continue throughout the 50-year period of forecast covered by this study. A forecast of increase in population of the Upper Keys, as shown on Exhibit III-1, page III-2, indicates that the population in 2010 will be approximately 84,080. Due to the tremendous amount of land area available and suitable for development (approximately 54,800 acres), such a population will result in an overall density of approximately 1.54 persons per acre, an estimate which is believed to be on the conservative side.

The geographic location of the Florida Keys is such that the entire area is subject to hurricanes in the late summer and early fall each year, and two devastating storms have had a deterring influence, for a temporary period, on population growth. The storm of September, 1935, was the most devastating with a heavy loss of lives. It will be noted that the population increase in the Upper Keys during the ensuing five-year period to 1940 was only 114, or slightly more than 10 percent of the entire Monroe County population increase for the same five-year period. The latest severe storm of 1960, referred to as Hurricane Donna, resulted in heavy losses in the Upper Keys, especially Marathon and Islamorada. The memory of these hurricanes has influenced much of the new construction methods in the Keys. Since the 1935 storm the Hurricane Warning Service was established in the Keys and is operated by the U.S. Weather Bureau.

Due to the single major highway traversing the Keys the population will be distributed along the entire highway length. Population centers have developed within reasonable proximity to the four post offices along the Keys. Judging from previous patterns the land area available for development contiguous to the Upper Keys post offices does not and will not have a deciding influence on population growth, and, oddly enough, the larger and higher islands (Keys) are not necessarily preferred as building sites. The location of new construction during the past decade, and particularly since 1945, has been influenced by the proximity of and views afforded by the Atlantic Ocean and Gulf of Mexico. A review of the post office earnings for the four post offices along the Keys indicated that Key Largo, a large island near the mainland, reported 504 percent increase in total receipts from 1950 to 1960. Marathon, Tavernier and Islamorada are next in order in the magnitude of the percentage of total earnings for the same period. It is the opinion of the Engineers that the population distribution as indicated by the percentages of growth of post office receipts as determined in 1960 has established a pattern that should prevail for future years, and this pattern has accordingly been used for the distribution of future population growth.

Much of the new construction along the Upper Keys within recent years has been directed toward providing commercial housing accommodations, such as motels and motor courts for tourists. Records for the Upper Keys indicate twice the water consumption during the winter and spring months than during the summer and fall months. Considering these circumstances it would seem that the population of the Upper Keys during the tourist season (winter and spring months) is approximately twice the normal or year-round population. As long as the business and economic conditions of the country continue on the so-called peacetime basis, it is expected that this seasonal influx of population on the Upper Keys will continue.

4. Naval Personnel

The Navy Department maintains service personnel at each of its installations in the Key West area. The Key West Naval Base is located at the southwest extremity of the island. The Naval Hospital is located on the northeast extremity of the island, and the Boca Chica Air Station is located on Boca Chica Key which is immediately north and east of Key West along U.S. No. 1 and the route of the Navy Aqueduct. There are other small installations which are considered satellites to these three. The combined service personnel strength of these installations, in 1960, was approximately 16,200 including "on board" servicemen plus dependents. During the recent Cuban crisis there was a buildup to 19,800 service personnel and their dependents in the Key West area which was an indication of the maximum increase in service personnel strength under emergency or mobilized conditions.

B. WATER USAGE

1. General

The principal factors that affect the quantity of water used per capita are the following: the living standards of the inhabitants; the size of the community; the quality and cost of water; the water pressure; the amount used by industries and manufacturing plants; the quantity used for public purposes; the amount of waste and leakage; the percentage of supply that is metered; and the quantity needed for watering lawns and gardens.

The total water pumped may be divided into four categories: (1) domestic, (2) commercial and industrial, (3) public, and (4) leakage and waste. Domestic consumption includes only water that is used in residences for household purposes and for lawns. Commercial and industrial consumption includes water used in offices and manufacturing plants.

Water used for public purposes is for fire fighting, public buildings, flushing sewers and ornamental displays. Leakage and waste may occur in connection with any or all three of the above categories of water consumption.

The standard of living in the Florida Keys is similar to that in other Florida resort areas. The income varies from the low-bracket to the multimillionaire class, but the medium income is comparable with other nonagricultural areas of Florida. The present aqueduct water has no objectionable taste or odor and is considered a soft water. The cost to the civilian consumer of water in the Keys is higher than any other city or community in the state. The cost of water in the Keys probably is the greatest contributor to the low per capita water consumption now being experienced. The water pressure varies from 300 psig (maximum) in the vicinity of the booster pumping stations along the aqueduct to almost no pressure at the extremity of the FKAC various distribution points. The operating personnel of the Navy Aqueduct and the FKAC are cognizant of the waste and leakage occurring in both systems and have made every effort to eliminate any waste or leakage.

The water demands of the military and civilian population for both Upper and Lower Keys have constantly increased since the aqueduct was constructed and put in operation. This is demonstrated by the consumption record which appears on Exhibit III-7, page III-15, and on a graphical record of water consumption which appears on Exhibit III-8, page III-16.

2. Lower Keys

In and about Key West the older residents make up a large percentage of the population and are accustomed by habit to use water sparingly, while the residents in the northern Keys are mostly newcomers to the area and conversely are accustomed by habit to using water abundantly.

Under present operating procedure, the Florida Keys Aqueduct Commission receives in its Stock Island and Key West reservoirs that surplus of the total aqueduct flow which is available daily after the Navy reservoirs have been filled. This procedure is based upon normal operation of the aqueduct facilities without failure or interruptions.

EXHIBIT III-7

WATER USAGE ON FLORIDA KEYS

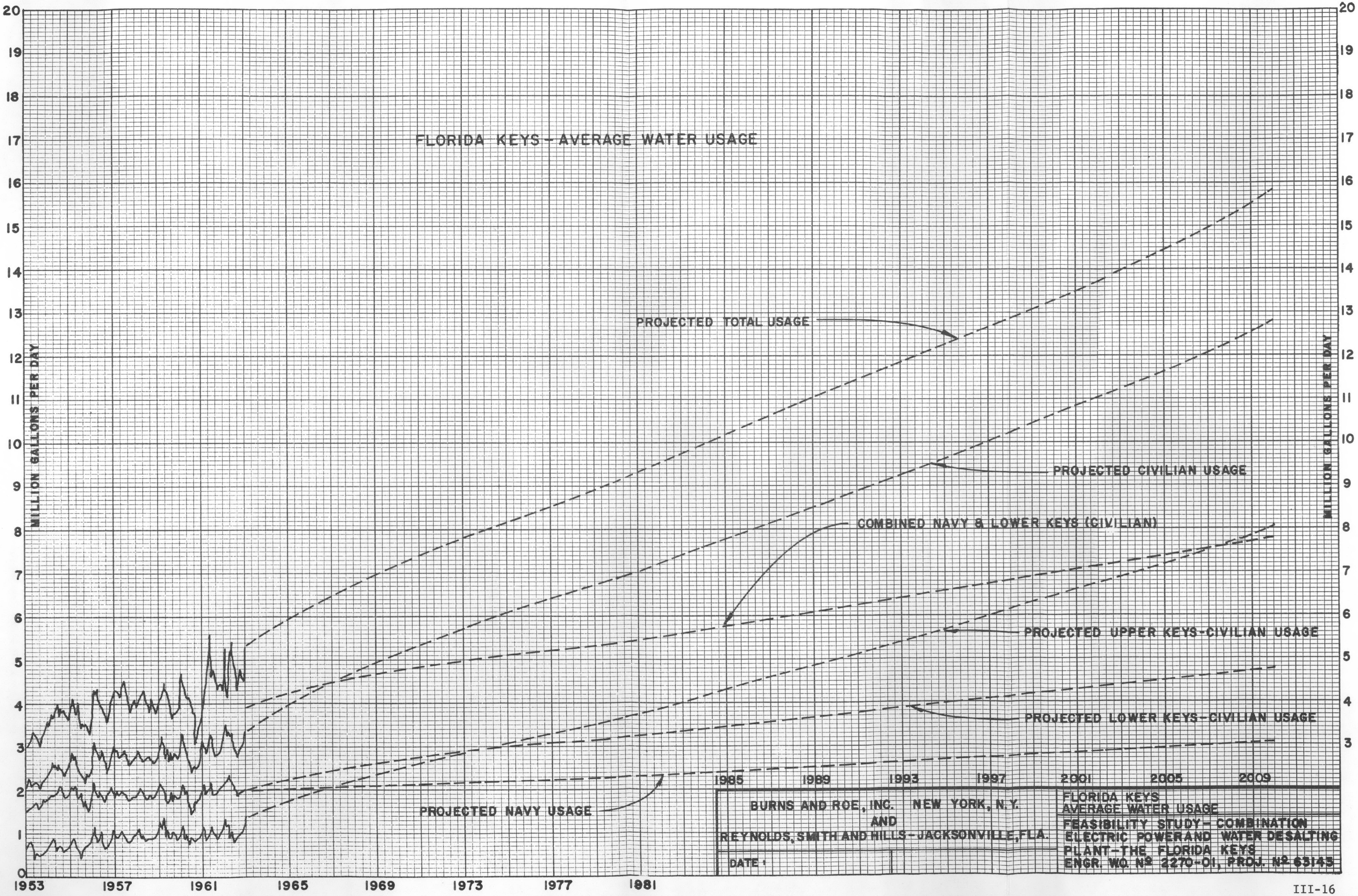
AVERAGE DAILY USAGE IN MILLION GALLONS PER DAY

(INCLUDES DEFENSE AGENCIES AND CIVILIAN USAGE)

YEAR	TOTAL USAGE	MILITARY USAGE	LOWER KEYS AND MILITARY	CIVILIAN USAGE	UPPER KEYS - CIVILIAN USAGE			LOWER KEYS - CIVILIAN USAGE		
					TOTAL	DOMESTIC	COMMERCIAL	TOTAL	DOMESTIC	COMMERCIAL
	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.	M.G.D.
1953	3.18	1.15	2.68	2.03	0.50	0.38	0.12	1.53	1.01	0.52
1954	3.73	1.27	3.13	2.46	0.60	0.45	0.15	1.86	1.12	0.74
1955	3.69	1.17	3.03	2.53	0.66	0.50	0.19	1.86	1.36	0.50
1956	4.04	1.29	3.16	2.75	0.88	0.63	0.25	1.87	1.41	0.46
1957	4.14	1.40	3.25	2.74	0.89	0.64	0.25	1.85	1.40	0.45
1958	4.04	1.32	3.15	2.72	0.89	0.63	0.27	1.83	1.42	0.41
1959	4.04	1.14	2.98	2.86	1.02	0.73	0.29	1.84	1.47	0.37
1960	3.95	1.21	3.04	2.74	0.91	0.72	0.19	1.83	1.37	0.46
1961	4.58	1.76	3.63	2.82	0.95	0.79	0.16	1.87	1.40	0.47
1962	4.93	1.87	3.94	3.06	0.99	0.82	0.17	2.07	1.51	0.56
1963	5.35	2.01	3.99	3.34	1.36	1.11	0.25	1.98	1.45	0.53
1970(1)	7.19	2.10	4.84	5.09	2.45	1.98	0.47	2.64	1.89	0.81
1980(1)	9.08	2.22	5.44	6.86	3.66	2.96	0.70	3.20	2.24	0.96
1990(1)	11.23	2.54	6.24	8.69	4.99	4.04	0.95	3.70	2.60	1.10
2000(1)	13.31	2.71	6.95	10.60	6.46	5.24	1.22	4.24	2.98	1.27
2010(1)	15.83	3.01	7.76	12.82	8.07	6.53	1.54	4.75	3.33	1.42

REMARKS: (1)Projected Years

BURNS AND ROE, INC —NEW YORK, N.Y. AND REYNOLDS SMITH AND HILLS - JACKSONVILLE, FLA.	**TOTAL WATER USAGE ON FLORIDA KEYS AND PROJECTIONS**
DATE:	FEASIBILITY STUDY - COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS ENGR. W.O. Nº 2270-01, PROJ. Nº 63143



BURNS AND ROE, INC. NEW YORK, N.Y.
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DATE:

FLORIDA KEYS
AVERAGE WATER USAGE

FEASIBILITY STUDY - COMBINATION
ELECTRIC POWER AND WATER DESALTING
PLANT - THE FLORIDA KEYS
ENGR. WO. Nº 2270-01, PROJ. Nº 63145

The FKAC repumps the water delivered into its reservoirs into the water distribution system serving the population of Key West proper. If during each day the demand for water in Key West is such that the water level in the FKAC reservoirs is falling too rapidly, the line pressure is reduced in the distribution system to reduce the water consumption. The reduction of pressure in the distribution system is accomplished by diminishing the pumping rate. This procedure was put in force during April and May of 1963. During this period the reservoirs in the Key West area, which have a capacity of 12,000,000 gallons, dropped to a low of 4,000,000 gallons. The last year the existing Florida Keys' water supply facilities were adequate to meet all demands during peak periods of consumption was 1962. The totals and unit figures presented and discussed in this report do not reflect the days of maximum demand and in most instances are monthly averages and yearly totals. In 1960, based on an estimated civilian population in the Lower Keys of 25,956, the per capita consumption was 70 gallons per day. Using the current monthly averages a figure of 80 gallons per capita per day, which includes 10 percent allowance for line losses, was arrived at and used for the estimation of civilian water consumption in the Keys in future years. This per capita consumption is below that prevailing in other Florida cities of comparable size but is regarded as being adequate for the reasons given hereinafter. In other Florida towns with residential areas of comparable or larger size, rather generous landscaped areas are maintained. These landscaped areas require large amounts of water for irrigation, particularly during the dry months. By comparison, large landscaped areas have not been provided in the residential sections of Key West, due to the confined land area available for expansion and growth, and the characteristics of the soil. It is not considered likely that such landscaped areas will be provided in the future. Therefore, the amount of water used by the householders in the Key West area for irrigation is fractional when compared with that used in other Florida cities.

3. Upper Keys

Water consumption in the Upper Keys has steadily increased through the years as shown on Exhibit III-9, page III-18. In 1945 the per capital con-

EXHIBIT III-9

CIVILIAN DAILY USAGE

BASED ON HISTORICAL NAVY BILLING AND PROJECTIONS

(MILLION GALLONS PER DAY)

YEAR	COMBINED			UPPER KEYS			LOWER KEYS		
	MAXIMUM (3)	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE	MINIMUM
1953	2.30	2.03	1.92	0.53	0.50	0.44	1.77	1.53	1.48
1954	2.65	2.46	2.29	0.64	0.60	0.54	2.01	1.86	1.75
1955	2.87	2.52	2.18	0.83	0.66	0.58	2.04	1.86	1.60
1956	3.18	2.75	2.27	1.08	0.88	0.77	2.10	1.87	1.40
1957	3.01	2.74	2.54	0.99	0.89	0.78	2.02	1.89	1.76
1958	2.95	2.72	2.58	0.95	0.89	0.81	2.00	1.83	1.77
1959	3.32	2.86	2.61	1.21	1.02	0.88	2.11	1.84	1.73
1960	3.36	2.74	2.37	1.19	0.91	0.75	2.17	1.83	1.62
1961	3.30	2.82	2.51	1.14	0.95	0.88	2.16	1.87	1.63
1962	3.56	3.06	2.61	1.34	0.99	0.77	2.22	2.07	1.84
1963 (1)	3.61	3.34	3.09	1.44	1.36	1.33	2.17	1.93	1.76
1970 (2)	6.13	5.09	4.22	2.95	2.45	2.03	3.18	2.64	2.19
1980 (2)	8.27	6.86	5.69	4.41	3.66	3.03	3.86	3.20	2.66
1990 (2)	10.47	8.69	7.21	6.01	4.99	4.14	4.46	3.70	3.07
2000 (2)	12.89	10.60	8.88	7.78	6.46	5.36	5.11	4.24	3.52
2010 (2)	15.44	12.82	10.64	9.72	8.07	6.70	5.72	4.75	3.94
REMARKS	(1) January thru August			(2) Projected Years			(3) Daily Rate for Peak Month		

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DATE:

CIVILIAN WATER USAGE AND PROJECTIONS

FEASIBILITY STUDY – COMBINATION ELECTRIC POWER AND WATER DESALTING PLANT – THE FLORIDA KEYS
ENGR. W.O. Nº 2270-01, PROJ. Nº 63143

sumption based on the Florida State census was 14 gallons per day. Based on the 1950 Federal census the per capita consumption was 67 gallons per day. Using the 1963 estimated population of 17,100 civilians the per capita consumption figure rose to 80 gallons per day. Such per capita consumption figures as those in 1945, for nonmigratory civilian population, are unusually low and are worthy of some attempt of expansion.

It must be remembered that over the wide expanse of the Upper Keys very little growth and development (by comparison with more recent years) resulted after the construction of the toll highway. This was so even after building restrictions were lifted during the 1954 period. The records of the Navy Aqueduct Office indicate that water was delivered to only 105 taps on the aqueduct between Florida City and Key West in 1948. The number of taps along the aqueduct in 1945 is not known, but it is estimated that the number did not exceed 40 to 50. It is quite likely that many of those who received fresh water from the aqueduct in the Upper Keys in 1945 secured it by hauling it in tanks and containers from the nearest tap to the point of consumption, and under such circumstances the per capita consumption would obviously be very low. During the intervening years when additional taps have been permitted, the percentage of the total population receiving water directly from the aqueduct and consuming said water through modern plumbing facilities has steadily increased with a resulting increase in per capita consumption. This increase in per capita consumption is expected to continue and level off at approximately 96 gallons per day, including line losses, assuming no great changes in the retail price of water.

Many housing units (principally motels and tourist courts) have been provided for tourists along the Upper Keys, and this construction is expected to continue barring any unfavorable and deteriorating influences. Tourist trade is one of the principal items, if not the primary item, influencing the Upper Keys economy. As previously mentioned in this report, the population of the Upper Keys at the height of the tourist season is approximately twice the normal or year-round population.

4. Naval Personnel

During the first eight months of 1963 the Navy used an average of 2,010,000 gallons per day. It is anticipated that the Navy use of water will increase to a demand of approximately 3,010,000 gallons per day by the year 2010.

5. Future Demand

The average rate of daily water consumption for the defense agencies and all civilian usage in the Florida Keys has been calculated by multiplying the estimated population by the estimated per capita consumption. The future quantities so determined appear on Exhibits III-7 and 8, pages III-15 and 16. The line loss on the aqueduct has in past years exceeded 10 percent during more than one year. The line loss for 1962 was 11.9 percent. It has varied from a maximum of 15.8 percent in 1945 to a minimum of 5.7 percent in 1956. By giving careful consideration to all possible means of reducing the line loss in the existing or in future supply lines it is entirely possible and conceivable that line loss during future years will be less than 10 percent. Total water to be pumped or total annual water requirements for future years have been calculated by multiplying the estimated average daily requirements by 365. The existing Navy Aqueduct facilities were operating at peak output during the months of April and May of this year, but this peak delivery was insufficient to supply both the Navy and and civilian demand. Therefore, until additional water supply facilities are installed and operating, a shortage of water will exist. It is estimated that funding, design and construction of a new facility would require a minimum of three years.

Estimates of average daily civilian and defense total water requirements, determined by procedures previously described, indicate that the average daily demands will be as shown in Exhibit III-9, page III-18.

By comparison with the phenomenal growth and development in south Florida, if and when an adequate supply of water is made available in the Keys, the resulting increase in consumption may ultimately exceed present estimates. It must be remembered that the making of additional consumer taps on the aqueduct along the Upper Keys has been restricted for some time and that the water pressure is dropped in Key West to conserve water -- both circumstances being due directly to the inadequacy of the existing facilities.

C. Selection of Water Desalination Plant Size

1. Desalination Plants with Power Generation

The construction of sea water desalination facilities is one of the possible methods of alleviating potable water shortages in the Florida Keys. The fact that additional power as well as additional water is required led to investigation of combined desalination and power plants, particularly since such combinations offer economic advantages to both water and power production. One advantage is that low-cost extraction steam from the turbine is available as a heat source for the desalination plant. Certain facilities such as roads, compressed air equipment and cooling water piping are shared by both plants, thus reducing total capital investment and operating costs.

The optimum size of the desalination plant depends on cost factors which, in turn, are dependent on the supply scheme selected and on the criteria used for comparison. Supply schemes which were judged worthy of investigation are described and evaluated in Section III-C of this report. Criteria and assumptions used for economic comparisons are as follows:

a. Type of Plant

Previous reports, e.g., "Saline Water Conversion Report for 1962," issued by the Office of Saline Water have shown the flash evaporation process to be the most economical method of water conversion for capacities required by the Florida Keys. The demonstration plant at San Diego has shown the desirability and practicability of operation with a 250° F brine temperature to the first stage. Accordingly, desalination cost studies in this report are based on a flash evaporation process with a 250° F maximum brine temperature.

b. Size Range

A review of the water usage forecast indicates the average civilian demand of the Keys in the year 2010 to be about 12,800,000 gallons per day. This is the largest requirement from a single desalination plant unless the plant is also assumed to supply the military requirements at Key West. The Navy well field at Florida City and the existing aqueduct is assumed to remain available indefinitely for military use. Therefore, the maximum size plant considered was one capable of an average daily output of 12,800,000 gallons. A plant capacity factor of 0.8 was applied to all plants studied to allow for meeting of peak demands and for the filling of storage facilities prior to maintenance shutdowns. Thus, the largest plant must have a design capacity of 12,800,000/0.8 = 16,000,000 gallons per day.

The required output, of course, can be provided by two smaller plants, installed one at a time as required. This would allow each smaller plant to operate at a higher average capacity factor through its lifetime. On the other hand, the capital investment required for two smaller plants is greater than that needed for one full-size plant. The optimum size was determined by a present worth cost analysis over the range of 4,000,000 to 16,000,000 gallons per day. This cost analysis and its results are described in Section V-D following.

c. Fixed Charge Rate

Fixed charges include cost of money, depreciation, interim replacements, insurance and taxes. Annual rates for each of these items were determined as follows:

(1) Cost of Money

Municipal financing was assumed. An analysis of the City of Key West Electric System finances as of March 31, 1963, showed an average interest rate of 3.81 percent. This rate, however, applies to bonds issued in 1955 and 1960. It is believed that future bonds would bear higher interest charges. Accordingly, the economic analysis for this study is based on a 4 percent cost of money.

(2) Depreciation

A 30-year amortization period is assumed for both desalination and power plants. The annual contribution to a sinking fund to recover the original investment after 30 years with the sinking fund reinvested at 4 percent is 1.78 percent of the plant investment.

(3) Interim Replacements

In accordance with the AEC Ground Rules for Evaluating Nuclear Power Plants as stated in TID-7025, "Guide to Nuclear Power Cost Evaluation," a yearly allowance of 0.35 percent of the initial investment has been made to replace items of equipment having a life-span less than the estimated life of the plants. The 0.35 percent figure is also applied, in this study, to fossil-fired power plants and to desalination plants.

(4) Insurance and Taxes

The analysis of the City of Key West Electrical System finances as of March 31, 1963, shows annual expenditures of 0.35 percent and 0.67 percent respectively for insurance and taxes. These same figures are used in the present study except for increasing the insurance allotment of nuclear plants by 0.15 percent. This increased rate is based on the AEC Ground Rules which assumes nuclear insurance to cost 0.15 percent more than conventional plant insurance. Where a desalination plant is associated with a fossil-fired plant, the conventional plant insurance rate is applied to both power and desalination plants. Where a desalination plant is associated with a nuclear plant, the nuclear insurance rate is applied to the desalination plant as well as the nuclear plant.

(5) Recapitulation

The above fixed charge items for conventional plants are summarized below:

	Depreciating Capital	Nondepreciating Capital
Cost of Money	4.00%	4.00%
Depreciation	1.78	-
Interim Replacements	0.35	-
Insurance	0.35	0.35
Taxes	0.67	0.67
	7.15%	5.02%

The same figures hold for nuclear plants (including desalination plants associated with nuclear plants) except for insurance, which is increased to 0.50 percent. Thus, the total annual fixed charge rate for depreciating nuclear items is 7.30 percent.

d. Steam Consumption

The performance ratio, that is, the ratio of product water to steam consumption, was selected by computer optimization. A design limit of 14, however, was placed on the performance ratio based on advice from Westinghouse engineers who believe 14 is the maximum attainable with equipment presently obtainable. The annual cost of steam is dependent on the type and size of power plant producing the steam. Power plant descriptions and production costs are given in Sections VII and VIII.

e. Electricity Costs

Electricity costs to the desalination plant are also discussed in Sections VII and VIII. The electrical requirements for various-size desalination plants were initially assumed equal to 275 kilowatts per million gallons of product based on data from a Bechtel study and the OSW "1962 Saline Water Conversion Report." The plant designs considered for the present worth analysis, however, were based on a power requirement of 300 kilowatts per million gallons of product as a result of advice from OSW personnel that the 275 figure was somewhat low. For the final computer optimization discussed below the power requirements increased to 400 kilowatts per million gallons.

f. Chemical Costs

A chemical cost of 2.6 ¢/1000 gallons of product water is assumed. This is based on data from the San Diego Multistage Flash Evaporation Desalination Demonstration Plant.

g. Labor Costs

All desalination plant labor cost estimates assume the desalination plant to be located close enough to a power plant to permit sharing of certain maintenance and labor personnel such as welders, laborers and watchmen. In each case, the power plant is assumed to be fully staffed for independent operation, and the desalination plant is provided with enough additional personnel to permit both plants to operate as a single unit.

The same-size staff is assumed appropriate for all desalination plants studied. A breakdown of the labor costs is given below:

Supervision and Clerical	No. Required	Annual Pay Scale	Total Annual Salary
Assistant Superintendent	1	$12,000	$12,000
Chemical Engineer	1	9,000	9,000
Clerk-Typist	1	3,200	3,200
			$24,200
Operation			
Operators	10	$ 6,500	$65,000
Assistant Chemists	4	4,800	19,200
			$84,200
Maintenance			
Instrument Mechanic	1	6,400	6,400
Mechanic - First Class	2	6,400	12,800
Mechanic - Second Class	1	5,000	5,000
Welder	1	5,900	5,900
Foreman	1	7,000	7,000
Janitor	1	2,500	2,500
Electrician - First Class	1	6,400	6,400
Electrician - Second Class	1	6,000	6,000
Total Men =	26		$ 52,000
Total Operation and Maintenance Labor			160,400
Payroll Extras 20%			32,100
			$192,500
Administrative and General Overhead 14%			27,000
		TOTAL	$219,500

The 20 percent allowance for payroll extras and the 14 percent allowance for administrative and general overhead are in accordance with our own experience and with TID 7025, "Guide to Nuclear Power Cost Evaluation."

h. Interest on Working Capital

Working capital requirements, as suggested by the OSW Standard Procedure, are estimated as 60 days' production at the total operating cost.

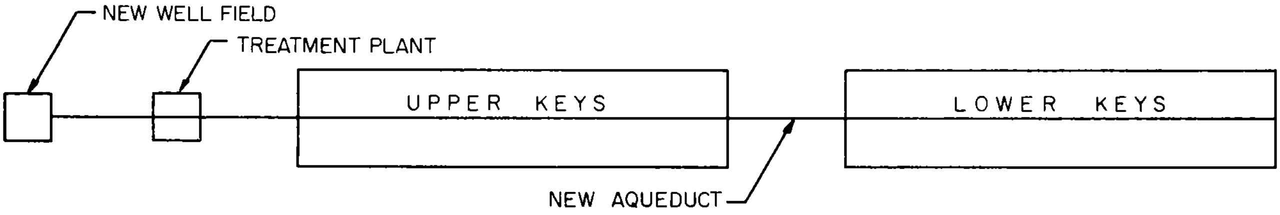
An annual interest charge of 4 percent of the working capital is included as part of the yearly operating expense.

2. Description of Water Supply Schemes

Several alternative methods are available for supplying potable water to the Florida Keys: the existing Navy Aqueduct could continue in use; total or partial new aqueducts could be constructed; or single or multiple desalination plants could be installed and operated in conjunction with the selected aqueduct alternate. Although many permutations and combinations of the above methods may be conceived, essentially only six different schemes need be postulated to include all possibilities deemed worthy of analysis. These six schemes may be described as follows:

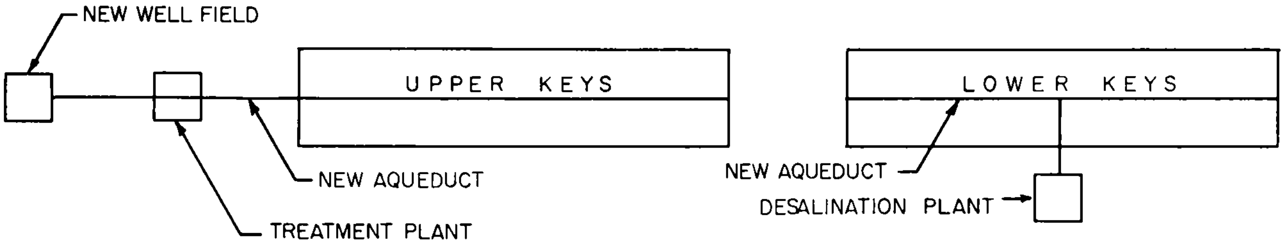
Scheme 1

An obvious way of increasing capacity of existing water supply facilities is to add similar additional facilities. Therefore, the first scheme to be investigated consists of a new well field at Florida City supplying water to the civilian population of both the Upper and Lower Keys through a new aqueduct. The scheme may be diagrammatically illustrated as follows:



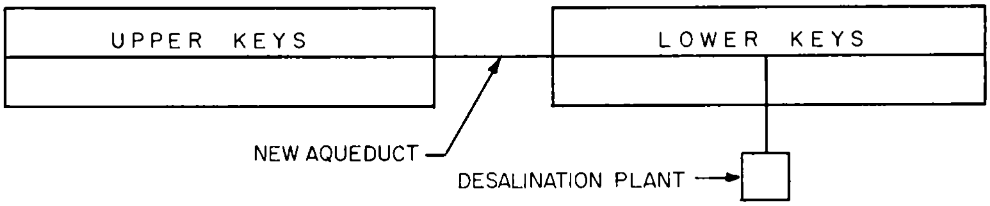
Scheme 2

Scheme 1 can be varied by using the new well field for supplying only the Upper Keys. A desalination plant would then be installed at Sugarloaf Key for supplying water to the Lower Keys. New aqueducts would be used for distribution in both the Upper and Lower Keys. Diagrammatically the arrangement would appear as follows:



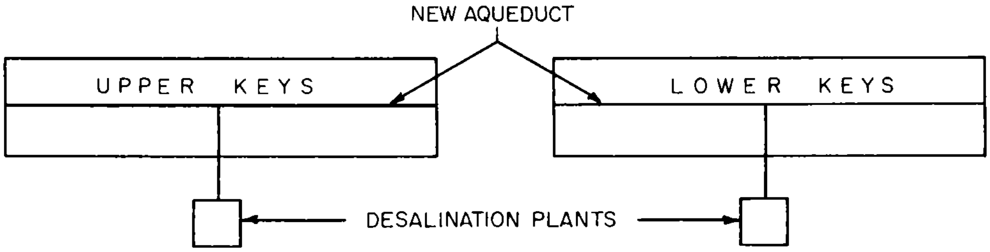
Scheme 3

Scheme 3 eliminates the new well field entirely. A desalination plant at Sugarloaf Key would furnish potable water through a new aqueduct to the civilian population of both the Upper and Lower Keys.



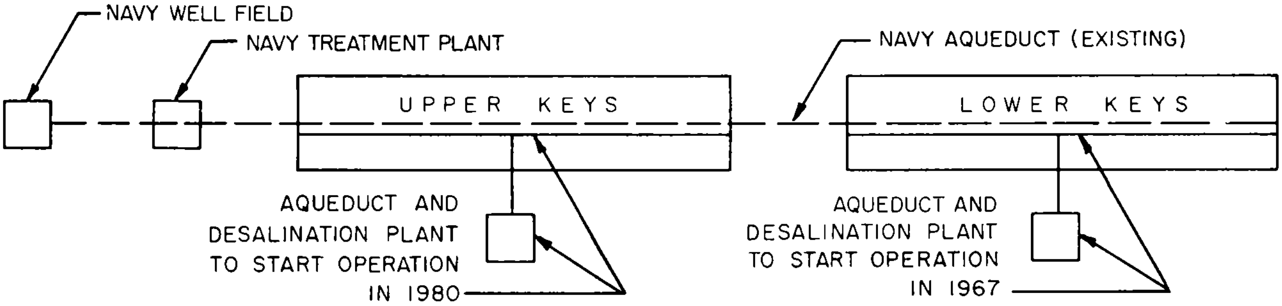
Scheme 4

Scheme 4 is similar to Scheme 3 except that separate desalination plants would be used for the Upper and for the Lower Keys. The Upper Keys desalination plant would be located at Marathon Key and the Lower Keys plant at Sugarloaf Key. New aqueducts would be used for distribution in both the Upper and Lower Keys.



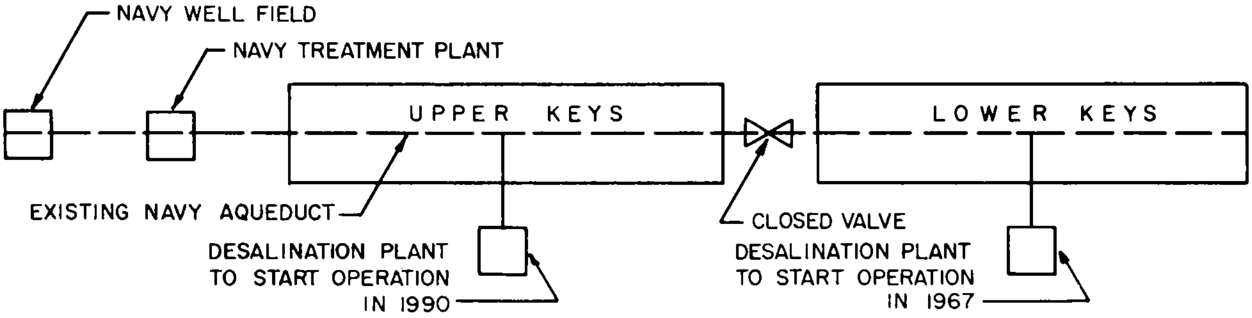
Scheme 5

Scheme 5 is predicated upon obtaining Navy cooperation until 1980. Initially a desalination plant and new aqueduct would be constructed to serve the civilian population in the Lower Keys. The Navy would continue to furnish water from the well field at Florida City through the existing aqueduct to the Upper Keys and to the Navy installations at Key West. A desalination plant and new aqueduct would be put into operation in 1980 for the Upper Keys. Thereafter the Navy would supply water to only military personnel in the Lower Keys.



Scheme 6

Scheme 6 is also dependent on Navy cooperation. In this case no new aqueduct would be constructed and water from the Navy well field would be used nearer its source, i.e., in the Upper Keys. The Lower Keys population, both civilian and military, would be supplied by a water desalination plant as soon as practical, probably about 1967. The Upper Keys would be supplied solely by the Navy from existing well fields until 1990 when a new desalination plant at Marathon Key would be put into operation to supplement the Navy supply. The presently existing aqueduct would be valved closed between the Upper and Lower Keys so that it would function as two separate aqueducts.



Priority

Schemes 5 and 6 described above require continued use of the Navy Aqueduct for civilian purposes. Undoubtedly, such an arrangement would be more attractive to the Navy if it were assured that its water needs would be given priority at all times. Inasmuch as the maximum duty of the Navy Aqueduct and well fields under either Scheme 5 or 6 would be much less than the present duty, even if the military demands were to increase above those anticipated in this study, it is unlikely that the Navy would have to exercise its priority rights. Nevertheless under Scheme 6, which is the most attractive one economically, the assurance can be given that, in the event of reduced water production from the desalination plant(s), the valve dividing the Upper and Lower Keys sections of the aqueduct can be opened and potable water obtained from the well field to meet the Navy's requirements.

3. Selection of Most Economical Supply Pattern

Schemes 2 through 6 described in Section III-C-2 above are subject to further variations. Instead of using a single desalination plant to serve the Upper Keys, Lower Keys or all the Keys as the case may be, two or more smaller plants could be installed one at a time as demand increases. Further, the capacities of the two or more smaller plants for each particular scheme need not be necessarily equal. The selection of the proper size and number of desalination plants for any particular scheme and the selection of the most advantageous scheme is best made by a present worth cost analysis. This type of analysis accounts for the significant effects of plant capacity factor variations. The development of the present worth cost analysis is outlined in the next section.

The mathematical principles of the present worth technique are well known, and it finds frequent application in the solution of numerous problems in the operational economics of electric utilities, especially as an aid to judgment in establishing an economic basis for decision on the choice between two or more alternative courses of action, as in this engineering study. In this instance the alternatives involve differences as to the time when expenditures are made, and this involves moving the costs, for each alternative, through time to the desired date to permit selection of the least expensive alternative in terms of the current worth of money.

To limit the scope of work in this study to practical proportions, no more than two desalination plants were considered for either the Upper or Lower Keys in Schemes 2, 4, 5 or 6 and no more than two desalination plants were considered to serve all the Florida Keys for Scheme 3. Present worth analyses covering the years 1967 through 2010 were prepared for several different size combinations of desalination plants for each of Schemes 2 through 6. It should be noted that the costs are based on desalination plants sized to meet average demands since storage capacity would be added to meet peak requirements.

The projections were made to the year 2010 to cover the requirements given in the scope of work and also to maintain compatibility with the power plant studies and the life of the aqueducts postulated. While this may appear inconsistent with the 30-year amortization period taken for the desalination plants, it should be noted that process plants frequently exceed their amortized life by considerable lengths of time. Moreover, replacement allowances (or expenditures) should vary equally with plant capacity for all schemes considered and, therefore, if they were predictable, and were factored in the analyses, would only increase all the present worth totals proportionately and not affect the final conclusions.

The results of the present worth analysis are plotted on Exhibit III-10, page III-32. The minimum present worth from each of the curves was then added to the present worth of the aqueduct and other associated equipment included in each scheme to determine which of the various schemes shows the lowest present worth over the period of interest.

The results of adding the present worth figures are given in Table III-1, page III-33. In considering the various alternates, those cost items which are identical for all schemes were not included since partial totals without these equal costs separately determine the minimum cost scheme. Examples of equal costs would be overhead and administrative charges such as for billing and collecting. Applying the same principle, no entry is made in Table III-1 for the Navy Aqueduct (which is appraised at $6,000,000) in the column headed -- Plant Investment Required in 1967, Dollars, since it is assessed for all schemes that ownership of this facility is retained by the Navy. Likewise, capital investments for refinancing FKAC bonds are omitted since these are comparable for all schemes. Navy aqueduct operating costs are included because the charges will vary depending on the amount of water pumped, which is not constant for all schemes.

The procedure for developing present worth figures is quite lengthy. Therefore, complete calculations leading to all the figures in Table III-1 are not shown herein. Instead, Section III-C-4 gives a detailed explanation of the present worth estimate for the New Lower Keys Desalination Plant for Scheme 6. Present worth calculations for the new aqueduct of Scheme 1 and the additional desalination plants and aqueduct of the other schemes were performed in a similar manner. The figures for the components of each scheme were then added as shown on Table III-1 to enable selection of the most economic scheme. The earliest time at which any new aqueduct or desalination plant could start

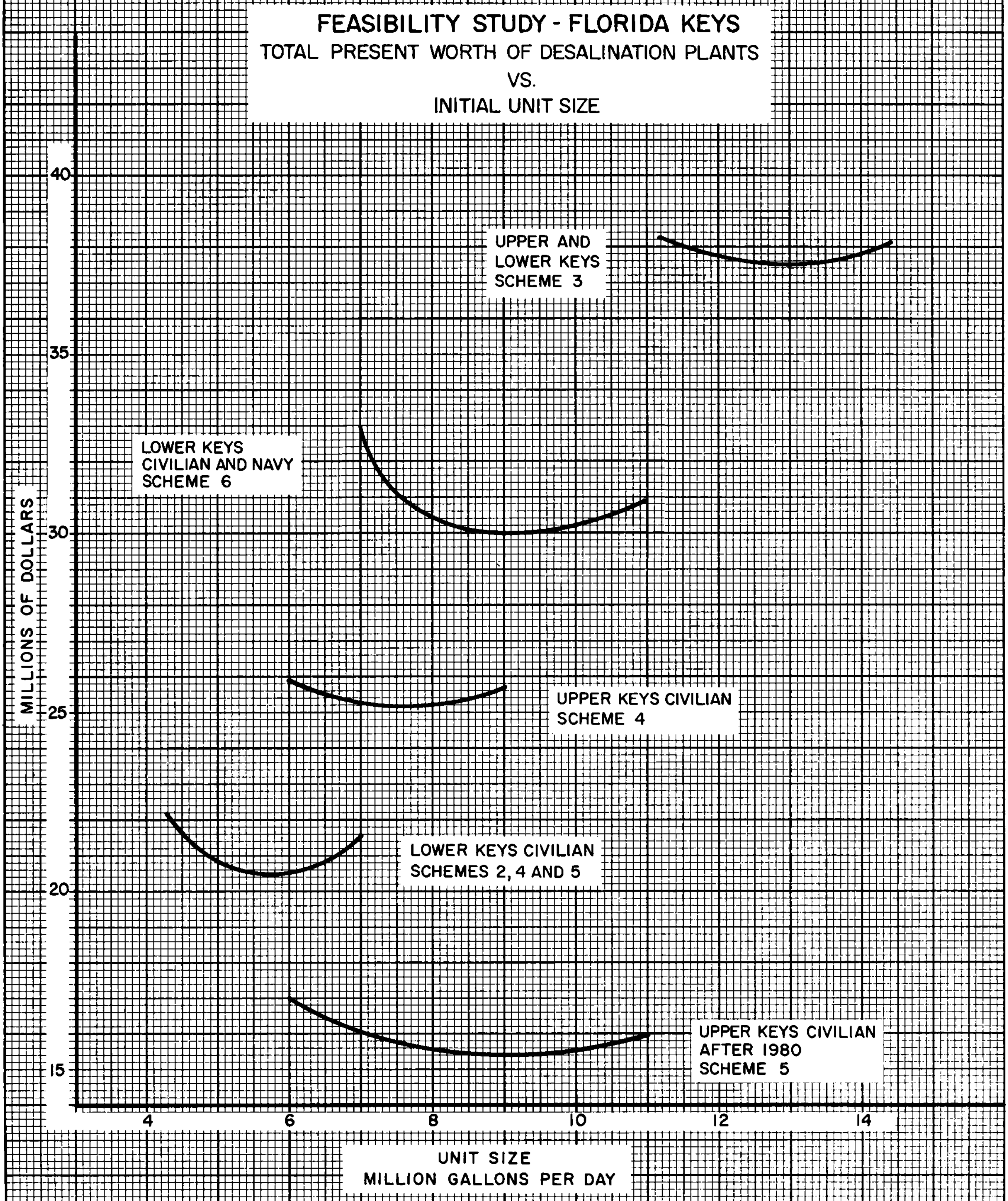

FEASIBILITY STUDY - FLORIDA KEYS
TOTAL PRESENT WORTH OF DESALINATION PLANTS
VS.
INITIAL UNIT SIZE
MILLIONS OF DOLLARS
40
35
30
25
20
15
UPPER AND
LOWER KEYS
SCHEME 3
LOWER KEYS
CIVILIAN AND NAVY
SCHEME 6
UPPER KEYS CIVILIAN
SCHEME 4
LOWER KEYS CIVILIAN
SCHEMES 2, 4 AND 5
UPPER KEYS CIVILIAN
AFTER 1980
SCHEME 5
4
6
8
10
12
14
UNIT SIZE
MILLION GALLONS PER DAY

TABLE III-1

FLORIDA KEYS - FEASIBILITY STUDY

COST COMPARISON OF ECONOMICS OF WATER SUPPLY SCHEMES

Description	Design Capacities of Desalination Plants - Millions of Gallons/Day	Plant Startup Year	Plant Investment Required in 1967, Dollars (1)	Sum of Present Worth of Annual Costs Through 2010, Dollars
Scheme 1				
Navy Aqueduct			-	11,362,000*
New Aqueduct		1967	33,074,000	52,685,000
Total			33,074,000	64,047,000
Scheme 2				
Navy Aqueduct			-	11,362,000*
New Upper Keys Aqueduct		1967	18,200,000	31,600,000
New Lower Keys Aqueduct		1967	5,560,000	10,600,000
Lower Keys Desalination Plant	6.0	1967	6,250,000	20,471,000
Total			30,010,000	74,033,000
Scheme 3				
Navy Aqueduct			-	11,362,000*
New Upper and Lower Keys Aqueduct		1967	23,700,000	36,302,000
Upper and Lower Keys Desalination Plants	13.0	1967	11,300,000	37,487,000
Total			35,000,000	85,151,000
Scheme 4				
Navy Aqueduct			-	11,362,000*
New Upper Keys Aqueduct		1967	10,800,000	16,900,000
New Lower Keys Aqueduct		1967	5,560,000	10,600,000
Upper Keys Desalination Plants	7.65	1967	7,550,000	25,100,000
Lower Keys Desalination Plant	6.0	1967	6,250,000	20,471,000
Total			30,160,000	84,433,000
Scheme 5				
Navy Aqueduct			-	17,400,000*
New Upper Keys Aqueduct		1980	-	10,800,000
New Lower Keys Aqueduct		1967	5,560,000	10,600,000
Upper Keys Desalination Plant	9.0	1980	-	15,438,000
Lower Keys Desalination Plant	6.0	1967	6,250,000	20,471,000
Total			11,810,000	74,709,000
Scheme 6				
Navy Aqueduct (Upper and Lower Keys Portions)			-	18,500,000
Upper Keys Desalination Plant	3.75	1990	-	4,701,000
Lower Keys Desalination Plant	10.0	1967	9,240,000	30,215,000
Total			9,240,000	53,416,000

Notes:

(1) The desalination plant investments are based on purchase of steam from a power plant.

* Navy Aqueduct includes operation, maintenance and replacement costs only. These were estimated from charges to the Florida Keys Aqueduct Commission.

operation is estimated to be 1967. Table III-1, in addition to showing present worth totals, also shows the capital investment required for the portion of each scheme which would be scheduled to start operation in 1967.

As can be seen from Table III-1, Scheme 6 shows the minimum present worth, $53,416,000, as compared to $64,047,000 for Scheme 1, which is the next in line. Thus, Scheme 6 would entail the least total expenditures over the study period considered for this report and is, therefore, the optimum selection. Based on the distinct economic advantage of Scheme 6 we recommend that this alternative be followed as a means of meeting potable water requirements in the Florida Keys. While Scheme 6 assumes continuing use of the existing Navy Aqueduct it should be emphasized that by dividing the pipeline into two sections, one for the Lower Keys and one for the Upper Keys, water flow can be returned to less than design capacity initially and to no greater than design capacity eventually. Further, an advantage is afforded to the Navy for its bases, in and around Key West, by having a water desalination plant close by at Sugarloaf Key. This will assure a second, independent source of potable water supply in the event of damage to the aqueduct by hurricanes.

For comparison purposes present worth calculations were also made for sea transportation. Typical present worth costs for supplying potable water by barging up to the year 2010 are as follows:

(a) Delivery of water to Stock Island for supply to entire Keys area--

Navy Aqueduct	$11,362,000
Barging	76,193,000
Total	$87,555,000

(b) Delivery of water to: (1) Stock Island - Lower Keys, (2) Marathon Key - Upper Keys --

Navy Aqueduct	$11,362,000
Barging	69,693,000
Total	$80,955,000

While the above costs are of the same order-of-magnitude as those for Schemes 3 and 4, they are far greater than those for Scheme 6, the recommended alternative.

An additional possibility that was examined was that of expanding the water storage facilities to the point where the size of the desalination plant could be reduced. Assuming that the peak water requirements occur for three months of the year, the initial (1967) water desalination plant design capacity under Scheme 6 could be reduced from 10,000,000 to 7,000,000 gallons per day if 300,000,000 gallons of storage facilities were installed.

Storage facilities for the above concept may consist of several aboveground tanks or a single artificial lake. A brief description of the optimum arrangement of each system and the estimated costs, excluding piping, pumps, gate valves, etc., follows:

a. Aboveground tanks:

(1) Steel tanks consisting of 20 units, 60 ft high by 210 ft diameter, with roof.

Plate, erection and painting	$9,000,000
Grading	110,000
Concrete ring, 1,250 cy @ $80	100,000
Subgrade 25,000 cy crushed stone @ $3.50	88,000
Total	$9,288,000

(2) Prestressed concrete tanks, 10 units, 60 ft high by 300 ft diameter, complete with grading and foundations:

Tanks with roofs	$8,000,000
Tanks without roofs	6,000,000

b. Artificial Lake

Formed with local materials, approximately 1600 ft. diameter by 28 ft deep, 6 ft freeboard, bottom at sea level. Bottom and top of dam paved with asphalt; inside face of dam grouted with concrete.

Excavate, crush, place & roll 300,000 cy @ $9.00	$2,700,000
3-inch asphalt paving - 250,000 sy @ $3.50	875,000
Concrete grout, seals & other miscellaneous work	425,000
	$4,000,000

To compare the increased storage possibility with Scheme 6 present worth calculations were completed based on the artificial lake, the lowest-cost water storage arrangement. The results are as follows:

	Initial Desalination Plant Capacity, Millions of Gal/Day	Plant Startup Year	Plant Investment in 1967, Dollars	Sum of Present Worth of Annual Costs Through 2010, Dollars
Navy Aqueduct	--	--	--	18,500,000
Upper Keys Desalination Plant	3.75	1990	--	4,701,000
Lower Keys Desalination Plant	7.0	1967	6,950,000	25,400,000
Storage Facilities (300,000,000 gallons)	--	1967	4,000,000	5,180,000
			10,950,000	53,781,000

As can be seen, the present worth of the storage arrangement is somewhat higher than that for Scheme 6 ($53,781,000 as compared to $53,416,000) and its initial investment is higher by $1,710,000. Moreover, while the use of an artificial lake is feasible in most locations, it cannot be recommended without reservations until considerable detailed study is made of an installation in the Florida Keys. The cavernous limestone formation upon which it may be located might introduce costly preparation work and require extraordinary construction to ensure against salt water intrusion. Also, the assumed freeboard was taken as 6 feet, but this height may prove insufficient by a large margin in view of the hurricane intensity and frequency experienced in the area. The estimated cost does not include these considerations.

4. Typical Present Worth Calculation

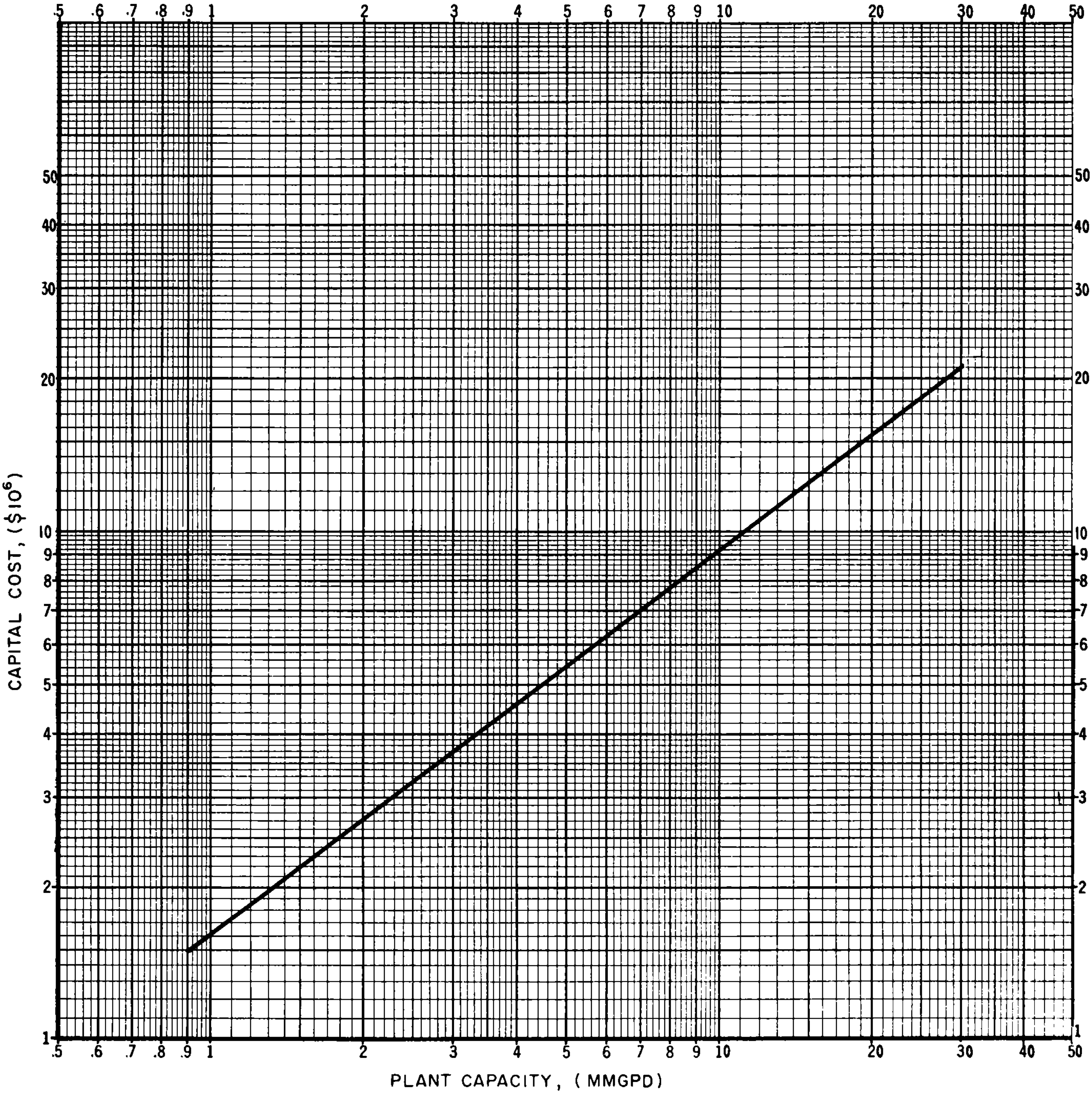
The present worth calculations for the Lower Keys Desalination Plant of Scheme 6 illustrate the development of a typical present worth estimate. Since calculations must be made for several different-sized plants, data showing the variation of capital investment versus plant capacity are necessary. For purposes of water supply scheme selection only, multistage flash evaporation desalination plant costs were taken from OSW "Progress Report No. 72." These costs are plotted on Exhibit III-11, page III-37.

For ease of calculation it is convenient to separate annual costs,

FEASIBILITY STUDY - FLORIDA KEYS

CAPITAL COST VS. PLANT CAPACITY FOR MULTISTAGE FLASH EVAPORATION WATER DESALINATION PLANTS

(ADAPTED FROM TABLE XVIII - XX OF RESEARCH AND DEVELOPMENT PROGRESS REPORT NO. 72 - OFFICE OF SALINE WATER)



which are a function only of plant size, from those which are a function of plant output. Costs which depend only on plant size are called invariant costs in this report; those which depend on plant output are called variable costs. Invariant and variable costs will be discussed separately below:

a. Invariant costs

These consist of: (1) annual fixed charges on plant investment, (2) supplies and maintenance materials costs which are assumed here to be a function only of plant investment, and (3) operating and maintenance labor and overhead which are assumed constant for all desalination plants covered by this study.

Fixed charges are taken as 7.15 percent per year based on the above for conventional fossil-fueled plants.

Supplies and maintenance material costs are estimated at 0.5 percent per annum of the total plant investment in accordance with the OSW "Standardized Procedure for Estimating Costs of Saline Water Conversion."

Labor, administration and overhead are assumed to total $219,500 per year as previously explained.

Invariant costs thus total $219,500 + (0.0715 + 0.005) x (Total Plant Investment) = $219,500 + 0.0765 x (Total Plant Investment)

The so-called "Invariant Costs" do vary somewhat. After 30 years the interest and amortization payments are assumed complete and the fixed charge rate is thus reduced by 5.78 percent. On the other hand, when demand increases beyond the capacity of a single plant, the "Invariant Costs" of the second plant must be added each year.

b. Variable Costs

These consist of steam, electricity and chemical costs. Interest on working capital which theoretically should also be included is very small and was ignored to expedite calculations. Based on preliminary estimates of a performance ratio of 13.5 pounds of product water per pound of steam and a cost of 35 cents per thousand pounds of steam, the steam cost equals 21.6 cents per thousand gallons of product water.

Electricity costs were based on a preliminary estimate of 7.21 mills per kilowatt-hour and a requirement of 275 kilowatts per million gallons per day of plant capacity. This amounts to 4.76 cents per thousand gallons of product water.

Chemical costs are assumed to equal 2.6 cents per thousand gallons of product water based on operating experience at the San Diego Demonstration Plant.

The variable yearly costs thus total 29 cents per thousand gallons of product as follows:

	¢/1000 Gallons of Product
Steam	21.6
Electricity	4.8
Chemicals	2.6
	29.0

c. Total Yearly Costs

These costs for each year from 1967 through 2010 are shown on Exhibit III-12, page III-40, for a Lower Keys Desalination Plant for Scheme 6 based on a unit with a 10,000,000-gallon-per-day design capacity. A single unit would be suitable at this design capacity since at a maximum capacity factor of 0.8 it can more than adequately meet the forecasted ultimate demand of 7,760,000 gallons per day in 2010. These costs were determined by calculating invariant and variable costs for each year as described above. The daily production figure used for developing the variable costs were taken from Exhibit III-8, page III-16. Present worth factors for each year are also listed in Exhibit III-12. The present worth factors as based on the beginning of 1967 as a datum and 4 percent per year interest on money. The last column on the table, "Present Worth of Annual Total Costs," is obtained by multiplying each annual total cost by the present worth factor. The sums of all the present worth figures are given on Exhibit III-12 for study periods ending in 1990 and in 2010. The total up to the year 1990 is shown for comparison purposes only. The total up to the year 2010, i.e., $30,215,000, is the number which is plotted on Exhibit III-10, page III-32. The entire procedure described above including preparation of an exhibit similar to Exhibit III-12 is repeated for each of several initial plant sizes for each scheme to enable plotting the curves on Exhibit III-10. The minimum point on each

FEASIBILITY STUDY - FLORIDA KEYS

PRESENT WORTH CALCULATIONS OF DESALINATION PLANTS (IN $)

LOWER KEYS - NAVY AND CIVILIAN WATER SUPPLY UNDER SCHEME 6

Initial Unit Size: 10 MMGPD

Year	Capital Investment	Annual ① Fixed Charges, Supplies and Maintenance Materials	Annual Labor Costs	Annual Invariant Costs	Average Lower Keys Water Usage Civilian + Navy - MMGPD	Annual Variable Costs (@ 29¢ per 1000 gal H_2O)	Annual Total Costs	Present Worth Factor (@ 4% Interest)	Present Worth of Annual Total Costs
1967	9,240,000	706,860	219,500	926,360	4.72	499,610	1,425,970	0.9615	1,370,000
1968					4.84	512,310	1,438,670	0.9246	1,330,000
1969					4.94	522,900	1,449,260	0.8890	1,290,000
1970					5.02	532,430	1,458,790	0.8548	1,250,000
1971					5.13	543,010	1,469,370	0.8219	1,210,000
1972					5.22	552,540	1,478,900	0.7903	1,170,000
1973					5.30	561,010	1,487,370	0.7599	1,130,000
1974					5.38	569,470	1,495,830	0.7307	1,090,000
1975					5.44	575,820	1,502,180	0.7026	1,055,000
1976					5.52	584,290	1,510,650	0.6756	1,020,000
1977					5.58	590,640	1,517,000	0.6496	985,000
1978					5.64	596,990	1,523,350	0.6246	950,000
1979					5.70	603,350	1,529,710	0.6006	920,000
1980					5.74	608,640	1,535,000	0.5775	895,000
1981					5.81	614,990	1,541,350	0.5553	855,000
1982					5.86	620,280	1,546,640	0.5339	825,000
1983					5.93	627,290	1,553,650	0.5134	800,000
1984					5.99	634,030	1,560,390	0.4936	770,000
1985					6.06	641,450	1,567,810	0.4746	745,000
1986					6.13	648,860	1,575,220	0.4564	720,000
1987					6.21	657,330	1,583,690	0.4388	695,000
1988					6.29	665,800	1,592,160	0.4220	670,000
1989					6.38	675,320	1,601,680	0.4057	650,000
1990					6.46	683,790	1,610,150	0.3901	630,000
1991					6.54	692,260	1,618,620	0.3751	605,000
1992					6.63	701,790	1,628,150	0.3607	585,000
1993					6.71	710,250	1,636,610	0.3468	565,000
1994					6.79	718,720	1,645,080	0.3335	550,000
1995					6.88	728,250	1,654,610	0.3207	530,000
1996		↓		↓	6.96	736,720	1,663,080	0.3083	515,000
1997		172,790		392,290	7.03	744,130	1,136,420	0.2965	337,000
1998					7.11	752,590	1,144,880	0.2851	327,000
1999					7.18	760,000	1,152,290	0.2741	316,000
2000					7.23	768,470	1,160,760	0.2636	306,000
2001					7.32	774,820	1,167,110	0.2534	296,000
2002					7.39	782,230	1,174,520	0.2437	286,000
2003					7.46	789,640	1,181,930	0.2343	277,000
2004					7.52	795,990	1,188,280	0.2253	267,000
2005					7.59	803,400	1,195,690	0.2166	258,000
2006					7.64	808,690	1,200,980	0.2083	250,000
2007					7.70	815,050	1,207,340	0.2003	242,000
2008					7.76	821,400	1,213,690	0.1926	234,000
2009					7.80	825,630	1,217,920	0.1852	226,000
2010		↓	↓	↓	7.85	830,920	1,223,210	0.1780	218,000

Total Present Worths 1967-1990 = $23,025,000
1967-2010 = $30,215,000

Notes: (1) As discussed on page V-42, supplies and maintenance materials are taken as 0.5 percent of the capital investment. Fixed charges amount to 7.15 percent.

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EXHIBIT III-12

curve was selected to obtain the desalination plant present worth costs shown on Table III-1, page III-33, except where the initial plant size for minimum cost has a capacity close to the total required in the year 2010. In these cases it was assumed that a single plant large enough for the 2010 demand would be installed in 1967. For this reason the initial size of the Lower Keys Desalination Plant in Schemes 2, 4 and 5 was increased from the indicated minimum cost size of 5,750,000 gallons per day to 6,000,000 gallons per day and the Lower Keys Desalination Plant for Scheme 6 was established at 10,000,000 gallons per day.

Another exception was made in the choice of a desalination plant for the Upper Keys in Scheme 6. In this case, it was decided for this study that the plant, which would be constructed to start operation in 1990, should be sized for the ultimate output required in 2010. This is because the plant size, 3,750,000 gallons per day, is small compared to those required in other schemes and because the initial capacity factor, 54 percent, is fairly high. As a practical matter, reassessment of water requirements in about 1985 should determine the actual design capacity selected, the most suitable location, and the most efficient separation process for the Upper Keys desalination plant.

5. Computer Optimization

Optimization of the water desalination plant design was performed on an IBM 7094 at the AEC computing center at New York University. A program designed to calculate heat and material balances on each stage of the multistage flash evaporators was used for the computer runs. This program was initially developed by Bechtel Corporation.* Several changes were made in the program to adapt it to analysis of the plants contemplated for the Florida Keys Feasibility Study. The major changes were as follows:

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* "Cost studies pertaining to various sizes of large scale saline water conversion plants for the Office of Saline Water," Bechtel Corporation, San Francisco, Calif., July, 1963. A description of the program and applicable nomenclature is given in the Bechtel Report.

(1) The program was generalized to accept as input a fixed charge factor to be used in computing the capital cost amortized over the life of the plant. Suitably adjusting this factor allows one to represent any plant life and amortization rate. The original version was limited to 20- and 30-year plant life.

(2) The calculations in the heat and material balance section of the program were modified to give a design in which each heat rejection stage had improved heat transfer characteristics (higher sea water velocity, and larger terminal temperature differences).

(3) An additional input quantity was provided to allow specifying the pump horsepower required for pumping the cooling sea water through the heat rejection section. Moreover, the horsepower calculation procedure was corrected to include total pressure drops for both the recycle brine pump and the sea water pump.

(4) The output was revised to emphasize that the condenser surface cost includes the cost of furnishing and installing the evaporators and auxiliaries. Portions of the original program which allowed for listing of concrete or steel structures costs were eliminated.

After completing initial trial runs, program modifications and debugging, production runs were made for water desalination plant capacities of 6,000,000 and 10,000,000 gallons per day. For all the production runs the input quantities which were held constant at the values shown are given in Table III-2, page III-43. The input quantities which varied from run to run are given in Table III-3, page III-44. Cost data for the brine heater and the evaporator-condensers are shown on Exhibit III-13, page III-45. In the case of the brine heater these costs include the heater proper plus the steam condensate pumps, all installed. For the evaporator-condensers, the costs allow for the purchase and installation of condenser surface, vessels, auxiliary systems and product and brine blowdown pumps.

TABLE III-2

FLORIDA KEYS FEASIBILITY STUDY
DESALINATION PLANT COMPUTER OPTIMIZATIONS

Constant Computer Input Data For 6 and 10 MMGPD Plants

Brine Heater Temperature	250° F
Sea Water Temperature	78° F
Concentration Ratio	1.7
Condenser Tube Thickness	0.049 inches
Brine Heater Tube Thickness	0.049 inches
Recycle Brine Velocity	8 ft/sec
Cold Fouling Factor	.0005 hr-sq ft °F/Btu
Hot Fouling Factor	.001 hr-sq ft °F/Btu
Δ P Headers	4.0 ft of brine
Pump Cost	$85.00/brake hp
Plant Life	30 years

A summary of the cost output for the optimum desalination plants is given in Table III-4, page III-46. The complete output for the final run (Computer Case No. 14) for the proposed 10,000,000-gallon-per-day water desalination plant is given on Exhibit III-14, page III-47. Out of the subcases considered in Computer Case No. 14, Subcase No. 14-3 was chosen as the reference design since it had an even number of stages, 40, and it showed the lowest total capital cost. The power and steam costs used as input for Computer Cǎse No. 14 were based on initial calculations for the recommended dual-purpose 50 MWe nuclear power plant and 10,000,000-gallon-per-day water plant. Thus, a steam cost of 15¢/1000 lb, and a power cost of $0.00775/kw-hr were used for the computer input rather than the final costs of 15.5¢/1000 lb and $0.00793/kw-hr for steam and power respectively. These slight differences in costs would not materially affect the results of Computer Case No. 14.

It should be stressed that the results from the computer calculations are not intended to be final designs of water desalination plants. Rather, they are used primarily to furnish preliminary design criteria and to establish sufficient information to develop cost estimates for the water desalination plant of sufficient completeness and accuracy for a feasibility study of this nature.

TABLE III-3

FEASIBILITY STUDY - FLORIDA KEYS

DESALINATION PLANT COMPUTER OPTIMIZATIONS

VARIABLE COMPUTER INPUT DATA

Computer Case No.*	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Water Production Rate, MMGPD	6	→	→	→	→	→	→	→	→	10	→	→	→	→
MMlb/hr	2.074	→	→	→	→	→	→	→	→	3.457	→	→	→	→
Steam Pressure, psia	37.9	49.0	67.0	37.9	49.0	67.0	37.9	49.0	67.0	37.9	37.9	33.0	37.9	37.9
Condenser Tube, O.D. inches	.750	→	→	→	→	→	→	→	→	.625	.750	→	→	→
Condenser Tube Length, ft	20	→	→	→	→	→	→	→	→	16	20	20	24	24
Brine Heater Tube, O.D. inches	.750	→	→	→	→	→	→	→	→	.625	.750	→	→	→
Tubes per Bundle Vertically	64	→	→	→	→	→	→	→	→	16	64	→	→	→
Steam Cost, $/M lb	0.35	0.35	0.35	0.20	0.20	0.20	0.44	0.44	0.44	0.35	0.35	0.35	0.35	0.15
Power Cost, $/kwhr	0.007	→	→	→	→	→	→	→	→	→	→	→	→	0.00775
Condenser Surface Cost**,$/sq ft	5.40	→	→	→	→	→	→	→	→	3.60	4.80	→	→	→
Brine Heater Surface Cost,$/sq ft	7.80	→	→	→	→	→	→	→	→	6.80	→	→	→	→
Fixed Charge Rate for 30 Year Plant	3.603	→	→	→	→	→	→	→	→	3.180	→	→	→	→

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* Cases have been renumbered to provide a more convenient grouping for these tables

** The variance of the evaporator-condenser and brine heater costs with water production is shown on Exhibit VII-16.

FEASIBILITY STUDY - FLORIDA KEYS

COSTS OF EVAPORATOR-CONDENSERS AND BRINE HEATERS
FOR
MULTISTAGE FLASH EVAPORATION WATER DESALINATION PLANTS

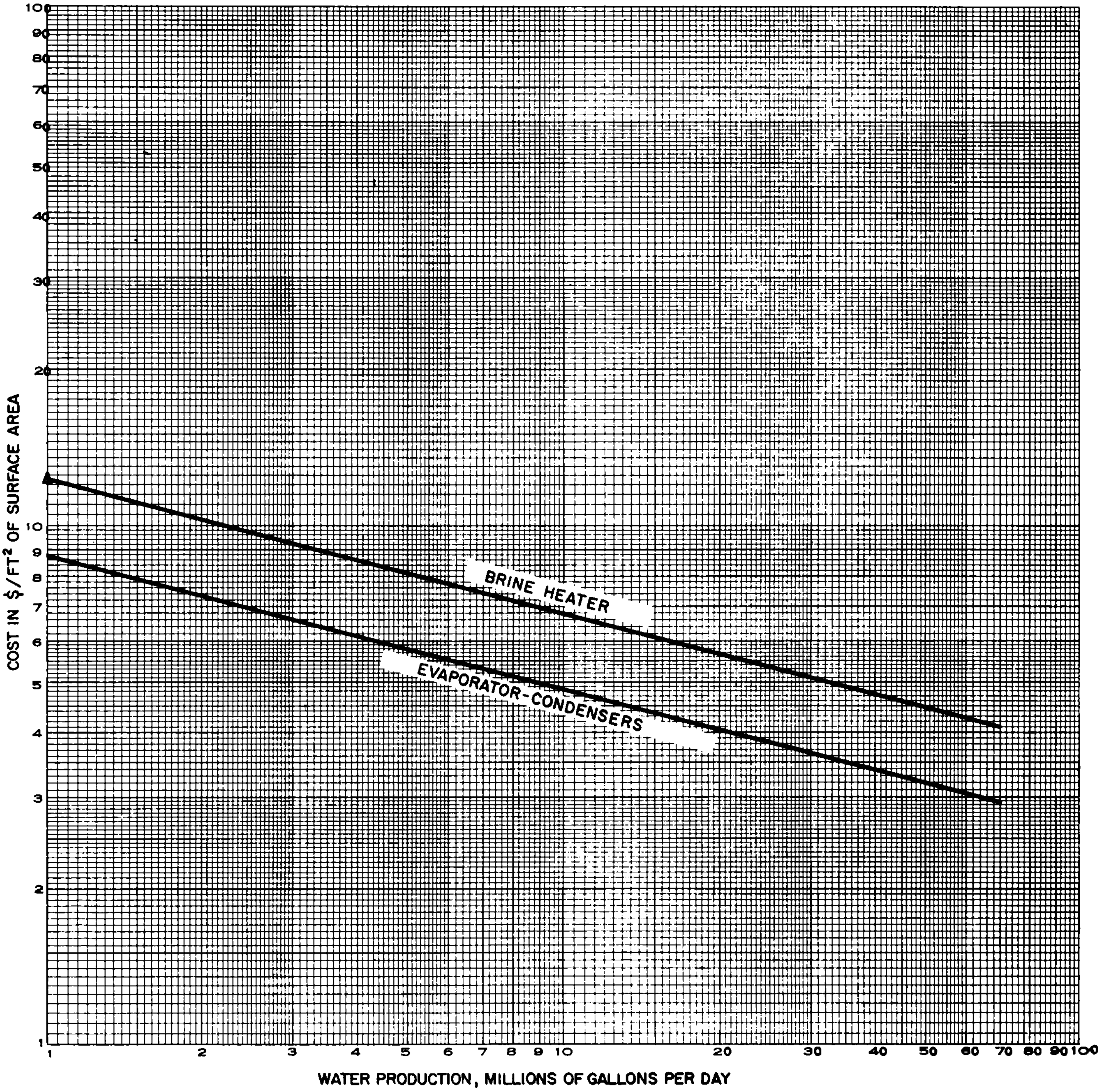

TABLE III-4

FEASIBILITY STUDY - FLORIDA KEYS

DESALINATION PLANT COMPUTER OPTIMIZATIONS

SUMMARY OF COSTS FOR OPTIMUM PLANTS

Computer Case No.*	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Water Production Rate, MMGPD	6								→	10				→
Number of Stages	36	36	36	35	35	35	38	38	38	34	40	40	39	40
TTD, °F	5.0	5.0	5.0	6.0	6.0	6.0	4.5	4.5	4.5	3.0	4.5	4.5	4.0	4.0
Condenser Area, MM sq ft	.643	.643	.643	.549	.549	.549	.708	.708	.708	1.316	1.186	1.186	1.250	1.209
Cost of Furnishing and Installing Evaporators and Auxiliaries MM$	3.47	3.47	3.47	2.97	2.97	2.97	3.82	3.82	3.82	4.73	5.69	5.69	6.00	5.80
Total Brine Recycle and Sea Water Pump HP, M HP	1.818	1.791	1.779	2.170	2.141	2.128	1.770	1.744	1.732	2.172	3.395	3.324	4.101	5.375
Total Pump Cost, MM $	.155	.152	.151	.184	.182	.181	.150	.148	.147	.185	.289	.283	.349	.457
Brine Heater Area, M sq ft	15.7	8.6	5.4	16.8	9.3	5.9	14.9	8.1	5.1	19.8	24.4	44.8	23.7	24.0
Brine Heater Cost, MM $	.122	.067	.042	.131	.072	.046	.116	.063	.040	.135	.165	.305	.161	.163
Total Capital Cost, MM $	3.75	3.69	3.67	3.28	3.22	3.19	4.09	4.03	4.01	5.05	6.17	6.28	6.51	6.42
Steam Cost, MM $	14.9	15.1	15.4	9.4	9.5	9.6	17.6	17.8	18.1	21.3	22.8	22.4	21.9	9.4
Power Cost, MM $	2.49	2.46	2.44	2.98	2.94	2.92	2.43	2.39	2.38	3.62	4.45	4.56	5.62	8.16
Capital Cost, MM $	13.5	13.3	13.2	11.8	11.6	11.5	14.7	14.5	14.4	16.1	19.5	20.0	20.7	20.4
Total Cost, MM $	30.94	30.88	31.01	24.18	24.03	24.07	34.72	34.70	34.88	41.02	46.78	47.21	48.23	39.97

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* Computer cases have been regrouped and renumbered to provide a more convenient grouping for these tables.

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                       ECØNØMIC SELECTIØN ØF FLASH EVAPØRATIØN
                              WATER DESALINATIØN PLANTS
                       FLØRIDA KEYS FEASIBILITY STUDY.                10 MMGPD          CASE 14

               CØST BASES FØR STUDY

               CØST ØF STEAM IS $0.150/MLBS

               CØST ØF PØWER IS $0.00775/KWH

               CØST ØF    EVAPØRATØRS    IS $4.800/SQFT

               CØST ØF  BRINE HEATERS IS $6.800/SQFT

               CØST ØF PUMPS (RECYCLE AND SEA WATER) IS $ 85.00/HP


          1     1 CØND.1    CØST ØF      1 TØTAL  1 TØTAL  1 BRINE HEATER  1 TØTAL  1 STEAM1 PØWER1CAPITAL11 TØTAL  11
 CASE NØ. 1 TTD 1 AREA 1FURNISHING AND 1 PUMP   1 PUMP   1---------------1CAPITAL1 CØST 1 CØST 1 CØST   11 CØST   11
      STA-1     1      1INSTALLING EVAP1 H.P.   1 CØST   1 AREA 1  CØST  1 CØST   1 MM $ 1 MM $ 1 MM $   11 MM $   11
  NØ. GES 1DEG F1MMSQFT1AND AUX.   MM $ 1 M HP   1 MM $   1M SQFT1  MM $ 1 MM $   1      1      1        11        11
1-----+-----+------+------+---------------+--------+--------+------+--------+--------+------+------+--------++--------++
14, 1   45 1 4.0 1 1.27 1      6.08       1 6.028 1 0.512 1 22.7 1 0.154 1   6.75 1   8.9 1 9.15 1   21.5 11 39.52 11
14, 2   45 1 4.0 1 1.27 1      6.11       1 5.984 1 0.509 1 22.6 1 0.154 1   6.78 1   8.9 1 9.09 1   21.6 11 39.51 11
14, 3   40 1 4.0 1 1.21 1      5.80       1 5.375 1 0.457 1 24.0 1 0.163 1   6.42 1   9.4 1 8.16 1   20.4 11 37.97 11
14, 4   41 1 4.0 1 1.26 1      6.04       1 4.983 1 0.424 1 23.3 1 0.158 1   6.62 1   9.2 1 7.57 1   21.1 11 37.83 11
```

EXHIBIT III-14
Sheet 2 of 4

```
                                        ECONOMIC SELECTION OF FLASH EVAPORATION
                                              WATER DESALINATION PLANTS
                                         FLORIDA KEYS FEASIBILITY STUDY.                    10 MMGPD          CASE 14

                          PRODUCTION=  3457000. LBS/HR.  RECYCLE RATIO= 6.73 LBS/LB PRODUCT

                          CONCENTRATION RATIO= 1.70, TOTAL NUMBER OF STAGES IS  40

                          TEMPERATURE OF FLASHING BRINE FROM BRINE HEATER IS 250.00 DEG F.

                          SEA WATER TEMPERATURE IS  78.00 DEG F.   APPROXIMATE TTD=  4.00 DEG F.

STAGE   FLASHING      DISTILLATE     RECYCLE      CONCENTRATION  PRODUCTION      PRESSURE    VAPOR FLOW     BOILING POINT
 NO.  BRINE,MLB/HR   PROD,MLB/HR  BRINE,MLB/HR     WT. PERCENT   M LB/HR           PSIA    M CU FT/SEC    ELEV. DEG F.
  1         23190.          89.        23279.          5.9728            89.     26.7848        387.00          2.2879
  2         23102.         178.        23279.          5.9958            89.     25.0203        411.55          2.2776
  3         23013.         267.        23279.          6.0189            89.     23.3483        438.06          2.2671
  4         22924.         355.        23279.          6.0422            89.     21.7654        466.71          2.2565
  5         22836.         444.        23279.          6.0657            89.     20.2686        497.72          2.2458
  6         22747.         532.        23279.          6.0892            88.     18.8545        531.30          2.2349
  7         22659.         621.        23279.          6.1130            88.     17.5200        567.71          2.2239
  8         22571.         709.        23279.          6.1368            88.     16.2620        607.21          2.2128
  9         22483.         797.        23279.          6.1608            88.     15.0775        650.12          2.2016
 10         22395.         885.        23279.          6.1850            88.     13.9634        696.77          2.1902
 11         22307.         972.        23279.          6.2093            88.     12.9168        747.54          2.1787
 12         22220.        1060.        23279.          6.2338            88.     11.9347        802.84          2.1671
 13         22132.        1147.        23279.          6.2584            87.     11.0138        863.17          2.1553
 14         22045.        1234.        23279.          6.2831            87.     10.1521        928.98          2.1435
 15         21958.        1321.        23279.          6.3080            87.      9.3465       1000.89          2.1316
 16         21871.        1408.        23279.          6.3330            87.      8.5943       1079.51          2.1195
 17         21785.        1495.        23279.          6.3582            87.      7.8928       1165.58          2.1073
 18         21698.        1581.        23279.          6.3835            86.      7.2396       1259.88          2.0951
 19         21612.        1667.        23279.          6.4089            86.      6.6320       1363.29          2.0827
 20         21526.        1753.        23279.          6.4345            86.      6.0677       1476.82          2.0703
 21         21441.        1839.        23279.          6.4602            86.      5.5443       1601.55          2.0578
 22         21355.        1924.        23279.          6.4860            85.      5.0594       1738.74          2.0452
 23         21270.        2009.        23279.          6.5120            85.      4.6110       1889.75          2.0325
 24         21186.        2094.        23279.          6.5381            85.      4.1969       2056.14          2.0197
 25         21101.        2178.        23279.          6.5643            85.      3.8149       2239.63          2.0069
 26         21017.        2263.        23279.          6.5906            84.      3.4631       2442.17          1.9940
 27         20933.        2346.        23279.          6.6170            84.      3.1397       2665.90          1.9811
 28         20849.        2430.        23279.          6.6435            84.      2.8426       2913.26          1.9681
 29         20766.        2513.        23279.          6.6701            83.      2.5703       3186.96          1.9551
 30         20684.        2596.        23279.          6.6967            83.      2.3211       3490.02          1.9420
 31         20601.        2678.        23279.          6.7235            82.      2.0933       3825.85          1.9289
 32         20519.        2760.        23279.          6.7504            82.      1.8854       4198.25          1.9158
 33         20438.        2842.        23279.          6.7773            81.      1.6959       4611.44          1.9027
 34         20357.        2923.        23279.          6.8042            81.      1.5236       5070.18          1.8895
 35         20276.        3003.        23279.          6.8313            81.      1.3670       5579.76          1.8764
 36         20196.        3083.        23279.          6.8583            80.      1.2250       6146.05          1.8632
 37         20117.        3163.        23279.          6.8854            79.      1.0965       6775.64          1.8501
 38         20038.        3242.        23279.          6.9126            79.      0.9803       7475.82          1.8370
                                               HEAT REJECTION SECTION
                                  RAW SEA WATER
 39         19930.        3349.        19230.          6.9312           108.      0.8167      12130.34          1.8118
 40         19822.        3457.        19230.          6.9688           108.      0.6766      14435.16          1.7895
```

EXHIBIT III-14
Sheet 3 of 4

STAGE NO.	TEMP FLASHING BRINE, DEG F	TEMP DIST PROD, DEG F	TEMP RECYCLE BRINE, DEG F	TERMINAL TEMP DIFFERENCE, F	LOG MEAN TEMP DIFFERENCE, F	HEAT TRANSFER MBTU/STAGE	OVERALL U BTU/FT2/F/HR	AREA SQ FT/STAGE
1	246.20	243.92	239.92	4.0000	5.6893	84515.	496.16	29940.
2	242.40	240.12	236.12	4.0013	5.6950	84636.	496.39	29939.
3	238.58	236.31	232.31	4.0039	5.7015	84749.	496.56	29934.
4	234.75	232.50	228.49	4.0070	5.7084	84857.	496.68	29930.
5	230.92	228.67	224.66	4.0105	5.7156	84960.	496.73	29925.
6	227.08	224.84	220.83	4.0145	5.7231	85057.	496.72	29920.
7	223.23	221.00	216.98	4.0190	5.7310	85147.	496.65	29915.
8	219.37	217.15	213.13	4.0239	5.7393	85231.	496.51	29910.
9	215.50	213.30	209.27	4.0294	5.7479	85308.	496.29	29905.
10	211.63	209.44	205.40	4.0354	5.7570	85377.	496.00	29900.
11	207.75	205.57	201.53	4.0419	5.7664	85438.	495.63	29895.
12	203.86	201.70	197.65	4.0490	5.7762	85491.	495.17	29889.
13	199.97	197.82	193.76	4.0567	5.7865	85534.	494.63	29884.
14	196.07	193.93	189.87	4.0651	5.7972	85568.	494.01	29879.
15	192.17	190.04	185.97	4.0741	5.8084	85592.	493.29	29873.
16	188.27	186.15	182.07	4.0837	5.8200	85606.	492.47	29867.
17	184.36	182.25	178.16	4.0941	5.8321	85608.	491.56	29862.
18	180.45	178.36	174.25	4.1051	5.8447	85599.	490.54	29856.
19	176.54	174.45	170.34	4.1169	5.8578	85577.	489.42	29850.
20	172.62	170.55	166.42	4.1295	5.8714	85543.	488.19	29843.
21	168.71	166.65	162.51	4.1429	5.8856	85494.	486.84	29837.
22	164.79	162.75	158.59	4.1571	5.9003	85431.	485.38	29831.
23	160.88	158.85	154.67	4.1722	5.9156	85354.	483.79	29824.
24	156.97	154.95	150.76	4.1881	5.9315	85260.	482.08	29817.
25	153.06	151.05	146.84	4.2050	5.9480	85150.	480.23	29810.
26	149.15	147.16	142.93	4.2229	5.9651	85023.	478.26	29803.
27	145.25	143.27	139.02	4.2417	5.9828	84877.	476.15	29795.
28	141.35	139.38	135.12	4.2615	6.0012	84713.	473.89	29787.
29	137.46	135.50	131.22	4.2824	6.0203	84529.	471.49	29779.
30	133.58	131.63	127.33	4.3044	6.0400	84324.	468.94	29771.
31	129.70	127.77	123.44	4.3275	6.0605	84098.	466.24	29762.
32	125.84	123.92	119.57	4.3517	6.0817	83849.	463.38	29753.
33	121.98	120.08	115.70	4.3772	6.1036	83577.	460.36	29744.
34	118.14	116.25	111.84	4.4039	6.1263	83281.	457.18	29735.
35	114.31	112.43	108.00	4.4319	6.1498	82959.	453.83	29725.
36	110.49	108.63	104.17	4.4612	6.1740	82611.	450.30	29714.
37	106.70	104.85	100.35	4.4918	6.1991	82235.	446.60	29704.
38	102.91	101.08	96.55	4.5239	6.2250	81830.	442.72	29692.
							TOTAL AREA=	1133798.
				HEAT REJECTION SECTION				
39	96.87	95.06	90.06	5.0000	7.6313	112200.	392.21	37487.
40	90.79	89.01	84.01	5.0000	7.6313	112200.	385.04	38185.
							TOTAL AREA=	75672.
							GRAND TOTAL AREA=	1209470.

EXHIBIT III-14
Sheet 4 of 4

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                              DESIGN DATA
                              ------ ----

                          HEAT RECØVERY SECTIØN

NUMBER ØF TUBES PER STAGE IS  6332.
VELØCITY ØF RECYCLE BRINE IN TUBES IS   7.06 FT/SEC
PRESSURE DRØP THRØUGH THIS SECTIØN IS 116.65 PSI
LENGTH ØF TUBES IS 24.00 FEET
ØUTSIDE DIAMETER ØF TUBES IS 0.7500 INCHES
WALL THICKNESS ØF TUBES IS 0.0490 INCHES
TØTAL WEIGHT ØF TUBES IN EACH STAGE IS   60825. PØUNDS


                          HEAT REJECTIØN SECTIØN

NUMBER ØF TUBES PER STAGE IS  8029.
VELØCITY ØF RAW SEA WATER IN TUBES IS 4.598 FT/SEC
PRESSURE DRØP THRØUGH THIS SECTIØN IS  3.29 PSI
LENGTH ØF TUBES IS 24.00 FEET
ØUTSIDE DIAMETER ØF TUBES IS 0.7500 INCHES
WALL THICKNESS ØF TUBES IS 0.0490 INCHES
TØTAL WEIGHT ØF TUBES IN EACH STAGE IS   77132. PØUNDS


                          BRINE HEATER

TØTAL NUMBER ØF TUBES IN HEATER IS  5587.
VELØCITY ØF RECYCLE BRINE IN TUBES IS 8.000 FT/SEC
PRESSURE DRØP THRØUGH THIS SECTIØN IS  4.78 PSI
LENGTH ØF TUBES IS 21.82 FEET
ØUTSIDE DIAMETER ØF TUBES IS 0.7500 INCHES
WALL THICKNESS ØF TUBES IS 0.0490 INCHES
TØTAL WEIGHT ØF TUBES IN BRINE HEATER IS   48794. PØUNDS
TØTAL RECYCLE BRINE PUMP HEAD IS   147.53 PSI
STEAM PRESSURE=  37.9 PSIA. STEAM TEMPERATURE= 264.0 DEG F.
TEMPERATURE RISE ØF BRINE THRØUGH HEATER= 10.085 DEG F.  LØG MEAN TEMPERATURE DIFFERENCE= 18.594
ØVERALL HEAT TRANSFER CØEFFICIENT =  504.22 BTU/FT2/F/HR
HEAT REQUIREMENT ØF HEATER IS     224.401 MMBTU/HR. AREA REQUIREMENT ØF HEATER IS   23935. SQ.FT.
STEAM REQUIREMENT=   239762. LB/HR
STEAM ECØNØMY RATIØ IS  14.42 LBS PRØDUCT/LB STEAM
```

A schematic flow chart of the water desalination plant arrangement used as the basis for the computer runs is shown on Exhibit III-15, page III-52.

D. Power Requirements

1. General

The electrical load forecast for the Upper Keys through 1975 was obtained from the Load Growth and Power Requirements Study prepared by the E. P. McLean Engineering Co. and dated January, 1962. This forecast was accepted as reasonable.

The forecast for the Lower Keys through 1975 has been obtained from the R. W. Beck and Associates supplementary letter and report dated August 6, 1963. The forecast in this supplementary report was based on historical data given in a previous R. W. Beck report dated July, 1963. For the years after 1975 it was felt that the predictions in the R. W. Beck report could be reduced. A plot of the population of the Upper and Lower Keys shown in Exhibit III-1, page III-2, illustrates that in 1996 the population for the Upper Keys will equal that of the Lower Keys. Beyond 1996, the population of the Upper Keys will exceed that of the Lower Keys. The original R. W. Beck electrical load forecasts for these latter years indicate that the electrical load for the Upper Keys would be far less than that for the Lower Keys even though the population for the Upper Keys would be greater. Since electrical loads vary with population, the R. W. Beck forecast for the years beyond 1975 was adjusted to reflect more likely trends in area growth rate.

The load forecasts as outlined above and used in the study of power plant unit size and location are summarized below.

2. Lower Keys

a. Projected Loads

The projected system loading for the City of Key West Electric System territories is shown on Table III-5, page III-53. To provide an orderly method of estimating the required transmission and distribution costs, the present system was analyzed to ascertain the characteristics and

FEASIBILITY STUDY – FLORIDA KEYS
DESALINATION PLANT COMPUTER OPTIMIZATIONS
SCHEMATIC FLOW CHART

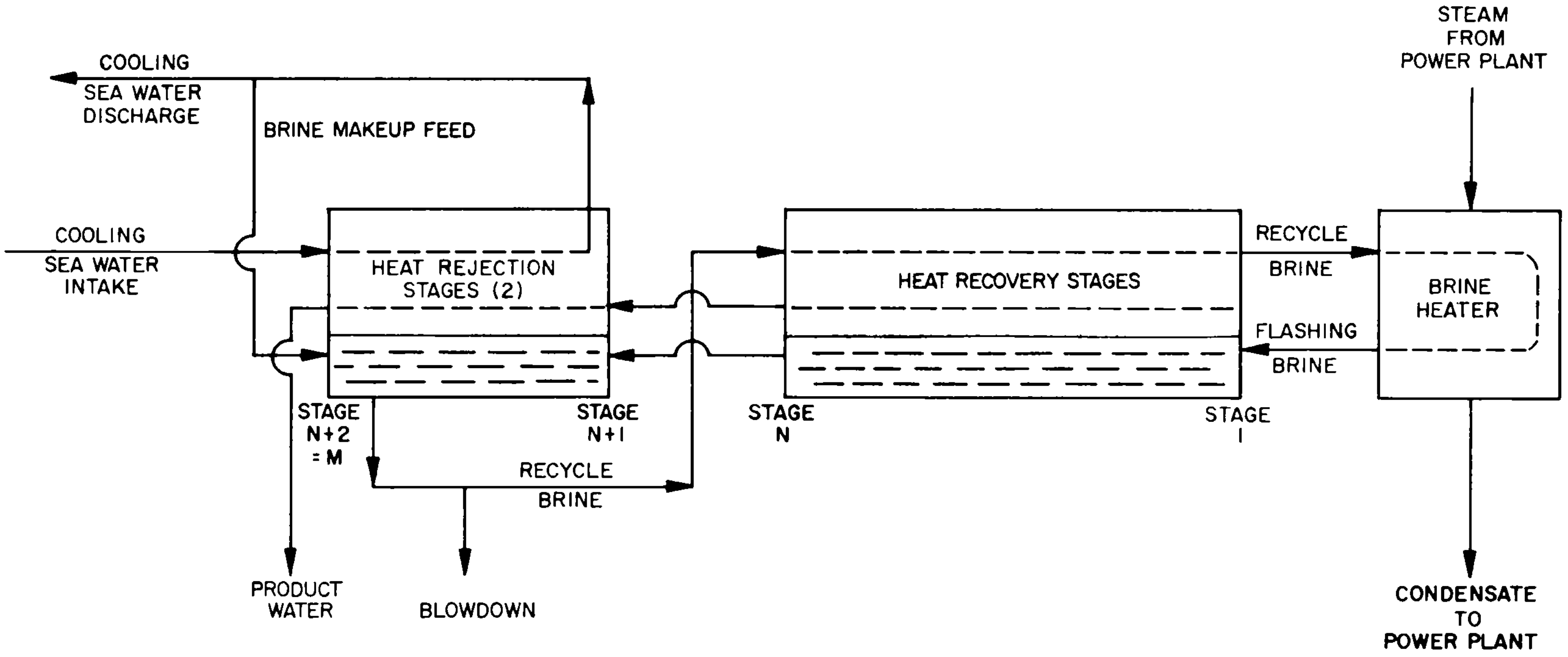


EXHIBIT III-15

TABLE III-5

PROJECTED SYSTEM LOADING FOR THE CITY OF KEY WEST POWER SYSTEM

Year	System Peak* - MW	Year	System Peak* - MW
1963	28.5	1991	230
1964	33.0	1992	240
1965	38.4	1993	250
1966	42.2	1994	262
1967	47.0	1995	276
1968	52.5	1996	290
1969	58.0	1997	300
1970	63.3	1998	320
1971	70.0	1999	330
1972	77.0	2000	350
1973	84.0	2001	360
1974	92.0	2002	380
1975	100	2003	400
1976	105	2004	420
1977	112	2005	440
1978	120	2006	460
1979	126	2007	480
1980	132	2008	500
1981	140	2009	520
1982	148	2010	550
1983	155		
1984	161		
1985	170		
1986	180		
1987	190		
1988	200		
1989	210		
1990	220		

---

* Net loads at generating station bus.

loading of individual 13.8-kv and 69-kv lines and transformers. Circuit load mva ratings were determined from the known characteristics such as wire types and sizes, operating voltage, transformer ratings, etc. The present system loadings were analyzed by a computer load flow study which developed system operating conditions and circuit loadings as of the present year. By comparison of the loads now carried with the ratings of the circuits developed, as described above, the margin available in the present system for accommodation of future loads was established. This then served as a base for future load projections. Using this base for the years 1964 and '65, individual circuit loads were developed to increase in proportion to a growing yearly system peak.

For the years 1966 to 1971 individual circuit loads were adjusted to reflect the addition of new generation at Sugarloaf Key and extension of the 69-kv transmission system to the Sugarloaf plant. In each case, it was assumed, for purposes of establishing the maximum circuit loading, that all of the system requirements would be met by base loading the new generation as rapidly as available.

In 1968, with the connection of step-down transformers at Big Coppitt Key, the important load increases envisioned in this area can be supplied from the new substation. This reduces to normal the heavy loading which would otherwise occur on the 13.8-kv Keys line.

By 1972, loads north of Sugarloaf Key are expected to increase sufficiently to warrant extension of the 69-kv transmission line to Big Pine Key and establishment of a step-down substation there. Except as a backup for emergency transfer of power and the possible benefit of having common reserve capacity available, no significant advantage is seen for extension of the 69-kv line to the Upper Keys for the case of separate system operation in as much as peak requirements for the two systems are expected to be substantially coincidental. This excess capacity in the early years of a new unit installation can be significant and, of course, is frequently the basis for mutually advantageous operation of interconnected systems. However, for the purposes of clear separation of study cases the cost of all tie-line construction between Upper and Lower Keys (i.e., the portion between Big Pine Key and Marathon Substation) is included only in the combined case study.

In the years from 1972 to 2010 it is anticipated that the load growth along the Keys line will accelerate faster than at the City of Key West due to development of many of the desirable larger vacant lot areas and because of the present land use saturation in the city area.

It is assumed that the load along this Keys line will be in the order of 40 percent of the total in 2010, inclusive of Boca Chica. The remaining 60 percent is assumed to be required for the City of Key West proper inclusive of Stock Island and Racoon Key.

This 60-40 division is based on the anticipated relative population of the Keys and represents occupancy of about 8500 lots exclusive of Boca Chica. This represents improvement of about one half of the presently developed lots, or about 4-1/2 percent of the maximum possible development. The present occupancy is 1363 lots.

The growth envisioned above appears within the realm of practical possibility.

b. Location of New Generating Facilities

The ideal location for generation from the standpoint of economy of transmission is, of course, at or near the major electrical load center. For various reasons such as availability of land, geological considerations, access for fueling, cooling water requirements, and, in the case of nuclear plants, also compliance with present AEC siting criteria, the final choice is a compromise between all factors.

Consideration of all of these points and others for location of a new generating plant for the City of Key West system (the lower keys) pointed to a location on Sugarloaf Key. Other details of this site and selection are given in Section VII-D.

Whether or not the new plant is nuclear or fossil-fuel-fired, location at Sugarloaf Key will materially assist in providing adequate service voltage to consumers from Big Coppitt to Big Pine Keys due to its central location in this area.

c. Distribution and Transmission System Expansion

The portion of the distribution system studied is that operating at intermediate system voltages and used to transmit power to step-down substations and distribution transformers throughout the system. The City of Key West system uses a voltage of 13.8 kv for this purpose.

This voltage level for distribution is continued for purposes of this study. However, at the higher load levels in future years the requirement for paralleling a multiplicity of circuits to provide sufficient capacity to carry the load suggests the desirability of eventually going to higher distribution voltages. For the Keys line, due to the relatively long distances involved, a higher operating voltage in the future is imperative to maintain feasibility and for economy. Study shows that a 25-kv distribution system here with supply points from the 69-kv step-down substations will provide a workable system of practical physical proportions.

For study comparison purposes, costs of distribution were developed for the portion of the distribution plant operating at 13.8 and 25 kv. The step-down substations and distribution transformers operating to reduce these distribution voltages to 4.17, 2.4 kv and lower voltages are a part of the next lower tier distribution system intimately associated with consumer use and common to all systems. The costs for the lower tier distribution are not included or required for purposes of this report. The high-voltage side of these distribution transformers has been taken as the distribution system dividing point.

The expansion of the transmission system envisions the extension of the existing 69-kv system from the 13th Street Substation eastward along the keys to step-down substations at the Big Coppitt, Sugarloaf and Big Pine Keys. Location of generating plants and substations and general routing of transmission lines is shown on Exhibit III-16, page III-57.

Details of construction for the transmission system are properly the subject of detailed design studies for a specific installation. However, the characteristics of the system must be developed in order to provide a practical basis for development of costs.

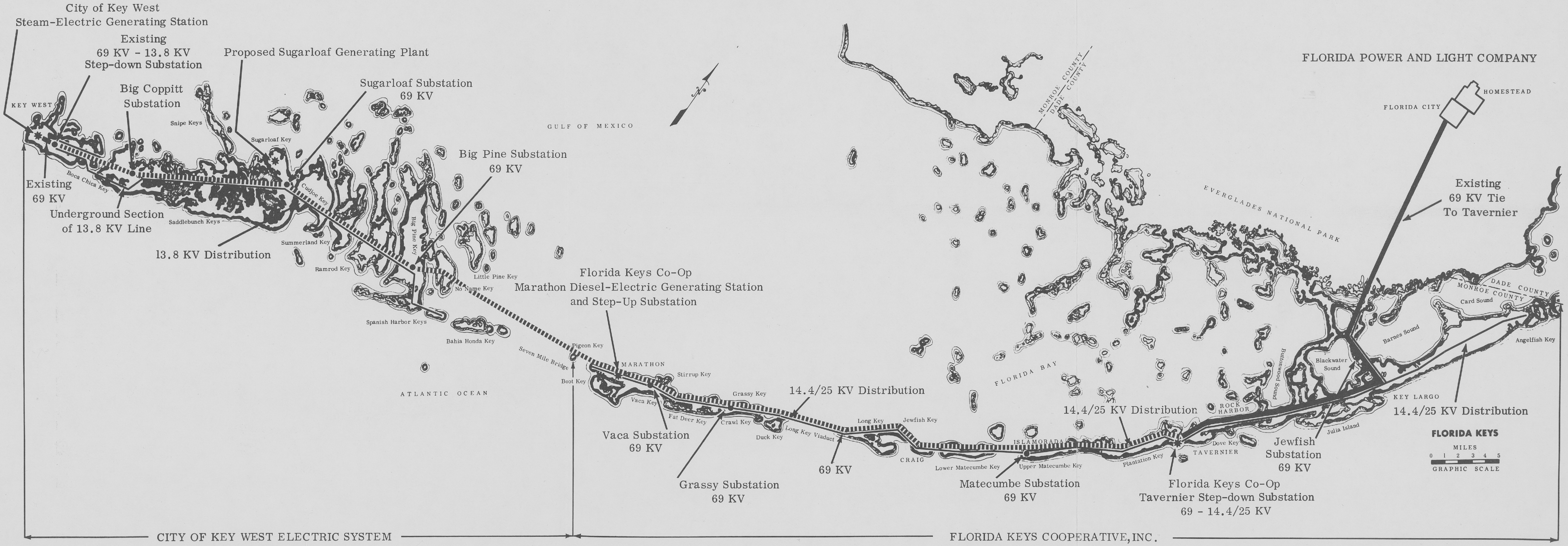
EXHIBIT III-16

▬ EXISTING 69 KV

▪▪▪▪ PROPOSED 69 KV

NOTE:

1. All transmission lines operating at 69KV are constructed with 138 KV insulation.
2. Florida Keys Cooperative plans to extend their 69KV tie line from Tavernier to Marathon by approximately 1965.



Proposed 69 KV Transmission Line
Connecting Upper and Lower Keys

The foremost considerations in selection of a bulk power transmission system is the development of such essential factors as quantity of power to be transmitted, over what distances, and subject to what environmental and operating conditions.

The City of Key West has found the use of 69-kv transmission mounted on 138-kv insulators, for increased creepage path to minimize effects of salt deposit, and prestressed concrete poles, a satisfactory system for bulk power transmission. There is no reason, therefore, why this system should not be continued if otherwise suitable for accommodating the projected loads under study.

An initial single-circuit line between 13th Street and the proposed new plant will suffice to about 1980 if the wire size initially installed is large enough (954 MCM ACSR or equivalent) to permit a transfer rating of about 120 mw. Cost studies indicate a very high cost for replacement of wires once installed so that it is of maximum benefit to install initially the largest wire size expected to be needed for future loads.

To accommodate loads beyond 1980, additional 69-kv circuits are needed to operate in parallel with the initial circuit.

Consideration has been given to use of transmission voltages higher than 69 kv. However, there is a special problem along the Keys with salt deposits on insulators increasing the possibility of flashovers. Trouble from this source as mentioned above is minimized on the present system by installation of higher-rated insulators.

This procedure may, of course, be followed at the higher voltages but requires progressively larger insulators and supporting towers. Use of voltages higher than 69 kv on the present system does not appear to be warranted. Also, for comparative study purposes, using 69-kv transmission for the early years is realistic, and for the later years feasible. It provides, also, a study unit and a common basis.

In the future, however, when it becomes necessary to install additional parallel transmission circuits it is recommended that a reappraisal of the transmission voltage level be made in the light of deviation from predicted load growth, advances in the art which may be available by that time, and further experience with the 69-kv system. A decision can then properly be made based on these and economic considerations whether to continue with expansion of the 69-kv system or to install the additional circuits for operation at a higher voltage level.

d. Estimates of Installed Costs

Using the projection of loads developed in Table III-5, page III-53, the loads were examined for each year and compared with the respective circuit ratings. When ratings were exceeded or about to be exceeded additional construction was indicated. A selection of an appropriate expansion change was made and recorded as an item of construction for that year. The new circuit rating was then carried forward for comparison with loads in succeeding years.

The estimated costs presented herein represent minimum investment to accommodate future loads. For actual installation it may be desirable to advance construction in some cases to provide a margin for contingency operation. Also, prior to any actual construction decision each significant change should be computer analyzed (or the equivalent) in detail to ascertain load flow conditions such as reactive transfer, voltage levels, transformer tap settings, system power factor, etc., to assess the need for voltage regulators, capacitors (switched or fixed) or advance in installation of parallel wire circuits to reduce transmission and distribution losses.

The above factors along with short-circuit and stability considerations are properly the subject of detailed design studies and were not developed or required for this report.

A tabulation of the cost of expansion to accommodate the future loads is given in Table III-6, page III-60. These costs are also used in the total cost figures developed for system expansion under the combined power plant transmission system tabulations.

Transmission and distribution costs as given in Table III-6 were adjusted in accordance with the formulas:

i. Direct Cost (Material and Labor)
ii. Contractors, 10% + 10%
iii. Contractors Total = i + ii

iv. Contingency, 10%

v. Construction Inspection and Supervision = 5% (iii + iv)

vi. Sales Tax = 3% Material (60% (i))

vii. Engineering = 5% (iii + iv)

Estimated Total = iii + iv + v + vi + vii

3. Upper Keys

a. Projected Loads

The projected system loading for the Florida Keys Electric Cooperative is shown on Table III-7, page III-61. To establish a basis for estimating required construction, a projection of load by circuits was made similar to that described for the Lower Keys system. Advantage was taken, however, of the availability of an analyzer study recently completed for the years through 1975. The distribution of loads therein developed were useful in making feasible projections for later years.

TABLE III-6

CITY OF KEY WEST POWER SYSTEM

ESTIMATED COST OF TRANSMISSION AND DISTRIBUTION EXPANSION

(1963 - 2010)

Year		Total Cost*
1966		$1,739,395
1968		209,570
1972		1,192,050
1974		277,820
1975		392,905
1977		58,690
1979		336,795
1980		947,650
1983		88,930
1986		1,089,650
1989		388,690
1991		182,820
1995		1,114,090
1998		784,615
2002		1,436,970
2005		1,097,940
2007		388,530
	Total	$11,727,110

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* 1963 prices without escalation

TABLE III-7

PROJECTED SYSTEM LOADING FOR THE FLORIDA KEYS ELECTRIC COOPERATIVE POWER SYSTEM

Year	System Peak* - MW
1963	17.5
1964	20.4
1965	23.4
1966	26.4
1967	30.2
1968	34.0
1969	38.4
1970	42.8
1971	48.4
1972	53.9
1973	60.0
1974	66.7
1975	74.5
1976	82.0
1977	89.0
1978	98.0
1979	106.0
1980	119.1
1981	125.0
1982	135.0
1983	148.0
1984	161.0
1985	174.1
1986	189.0
1987	201.0
1988	213.0
1989	228.0
1990	242.4
1991	252.0
1992	272.0
1993	288.0
1994	305.0
1995	323.4
1996	340.0
1997	358.0
2000	422.0
2001	440.0
2002	463.0
2003	488.0
2004	510.0
2005	536.2
2006	552.0
2007	581.0
2008	607.0
2009	636.0
2010	665.9

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* Net loads at generating station bus.

Actual loading between points along the Keys as reported in the Bi-Annual Work Plan of 1963-64 was used to develop the portion of the total Keys load assignable to individual circuits.

The detailed loading conditions developed by the network studies on a different assumption of system yearly peak (through 1975) were adjusted proportionately so as to arrive at the detailed loading conditions for the system yearly peaks.

Aside from completion of the Matecumbe step-down substation and connection to the distribution circuits at Upper Matecumbe Key, planned for 1964, no additional construction is indicated to accommodate the loads projected through 1965.

In 1966 the establishment of new generating facilities at Marathon along with completion of the 69-kv transmission tie to Matecumbe will provide the facilities needed to effectively distribute all power, available from Marathon, throughout the system. The initial installation of the largest conductor required to accommodate future loads on the transmission system is recommended and construction projections herein presented were made on this basis.

Establishment of 69-kv step-down substations, at Grassy Key in 1969, Jewfish in 1970 and Vaca in 1974, along with further sectionalizing of the Keys line at Long Key in 1969 and at Key Largo in 1970, completes the basic pattern for the transmission-distribution system envisioned for satisfactory accommodation of future loads. Reinforcements by means of parallel or higher-rated facilities can be added as projected loads require them.

b. Location of New Generating Facilities

In view of the present load density in the Marathon area and the expectation that this will increase and will continue to be a major part of the future system load, it appears advantageous to provide for addition of steam-electric generation at Marathon.

Extension of the 69-kv transmission line from Matecumbe to Marathon will enable transmission of sizable blocks of power to the Matecumbe-Tavernier area. Under Case II discussed in Section IV of this report new generation has been selected on the basis of complete eventual self-sufficiency for the Cooperative System. This provides a clear-cut basis for comparison.

About 1980, when it will become necessary to consider installation of additional parallel transmission facilities, the economics of providing a second power plant in the Matecumbe-Tavernier area should be reviewed. Advances in the art of generation and transmission which may be then achieved should be compared with the availability and comparative cost of purchased power from the Florida Power and Light System.

In view of the above and the probability that some power will continue to be purchased from the Florida Power and Light System, further detailed study of this case is not pertinent at this time. Therefore, for the separate systems study, all new generation is considered to be added at Marathon.

c. Distribution and Transmission System Expansion

Continuation of the present distribution system voltage level of 25 kv is indicated for future loads. With sectionalization possible with installation of the 69-kv bulk power substations the physical requirements to assure sufficient line capacities for the 25-kv circuits are within practical proportions.

The expansion of the transmission system envisions the extension of the 69-kv system from Tavernier to Matecumbe (now under construction) and on to Marathon. Step-down substations at Matecumbe, Grassy, Jewfish and Vaca Keys will enable sectionalizing of the 25-kv distribution line to keep physical requirements within practical limits. Expansion of transmission at the 69-kv voltage level appears logical for the projected load requirements.

d. Estimates of Installed Costs

The same procedure for estimating required construction and costs, as described previously for the Lower Keys, was also used in developing similar information for the Upper Keys.

The projected loads given in Table III-7,page III-61,were compared with ratings of circuits starting with existing facilities. New construction was assigned in the years when the projected loads were about to exceed circuit ratings. This construction timetable was then used as a basis for developing the cost estimates for the future transmission and distribution system expansion. A summary of these estimated costs using 1963 prices without escalation is given in Table III-8, page III-65.

4. Combined Systems

a. Projected Loads

The projected system loading for combined operation (Case I in Section IV) of both the Upper and Lower Keys systems is given in Table III-9, page III-66. The values given are a summation of the loads of the separate systems. No diversity between systems has been figured as it is estimated that peak requirements will be essentially coincidental due to the similar nature and character of the Keys' geography and loading characteristics.

b. Transmission Facilities and Distribution System

The transmission system required for combined operation of the Keys is shown in schematic form on Exhibit III-17, page III-67 (Drawing No. 2270E3) and in general geographic location on Exhibit III-16, page III-57. Most of the transmission system shown is also required for separate operation of the two systems. To operate with common generation facilities at the Sugarloaf site it is necessary to reinforce the transmission line between this plant and Marathon.

An initial interconnection operating in 1966 at 69 kv and using 954 MCM, ASCR or equivalent will suffice for all loads to about 1977, at which time the load will exceed the rating of the single line and additional parallel facilities will be required. This 954 MCM line with a capacity of about 120 mw is used as the transmission unit for study purposes. Operation at 69 kv appears to be a logical first step in keeping with transmission voltages used throughout both Upper and Lower Keys systems. A continuation of this voltage for the second circuit appears to be a logical expansion step requiring no transformer capacity, for transfer of power between different transmission voltages.

TABLE III-8

FLORIDA KEYS ELECTRIC COOPERATIVE SYSTEM
ESTIMATED COST OF TRANSMISSION AND DISTRIBUTION EXPANSION

(1963-2010)

Year		Total Cost*
1966		$ 2,654,430
1967		120,650
1969		293,605
1970		172,960
1974		474,995
1977		1,977,715
1981		385,490
1983		483,830
1986		1,843,890
1988		441,675
1992		2,479,260
1994		1,597,485
1996		759,285
2000		565,345
2001		3,364,815
2007		927,225
	Total	$18,542,655

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* 1963 prices without escalation

TABLE III-9

PROJECTED SYSTEM LOADING
COMBINED UPPER AND LOWER KEYS SYSTEMS

Year	System Peak* - MW	Year	System Peak* - MW
1963	46.0	1987	391.0
1964	53.4	1988	413.0
1965	61.8	1989	348.0
1966	68.6	1990	462.4
1967	77.2	1991	482.0
1968	86.5	1992	512.0
1969	96.4	1993	538.0
1970	106.1	1994	567.0
1971	118.4	1995	599.4
1972	130.9	1996	630.0
1973	144.0	1997	658.0
1974	158.7	1998	687.0
1975	174.5	1999	724.0
1976	187.0	2000	772.0
1977	210.0	2001	800.0
1978	218.0	2002	843.0
1979	232.0	2003	888.0
1980	251.1	2004	930.0
1981	265.0	2005	976.2
1982	283.0	2006	1012.0
1983	303.0	2007	1061.0
1984	322.0	2008	1107.0
1985	344.1	2009	1156.0
1986	369.0	2010	1215.9

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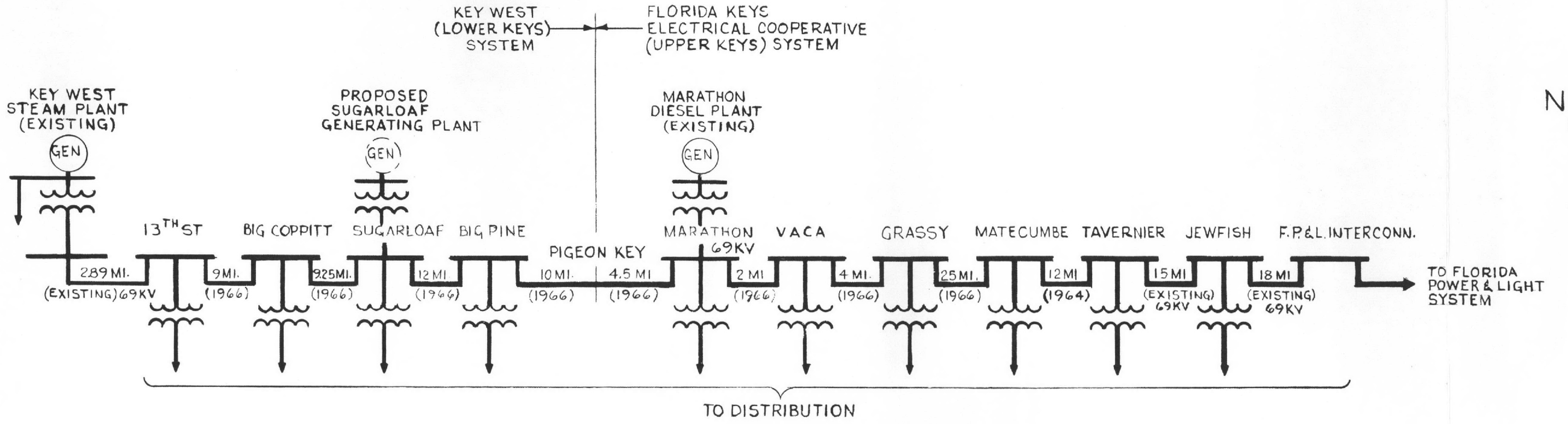
[*] Net loads at generating station bus.



NOTE:
1. YEAR IN BRACKET IS DATE OF INITIAL OPERATION.

FEASIBILITY REPORT EXHIBIT

BURNS AND ROE INC.	NEW YORK, N.Y.
REYNOLDS, SMITH AND HILLS	JACKSONVILLE, FLA.

ELECTRIC POWER TRANSMISSION SYSTEM
FOR COMBINED OPERATION OF KEY WEST AND
FLORIDA KEYS COOPERATIVE SYSTEMS

DRAWN R. M^c K TRACED CHECKED	SQUAD LEADER	DATE	SCALE
	V. SOCCI	11-28-63	NONE

APPROVED LAK DATE Dec 12, 1963
B&R CHIEF ELECTRICAL ENG'R

W. O. 2270
PROJ. 63143
DWG. 2270E3

TITLE	CHECKED	DATE	TITLE	CLEARED	DATE
ELECTRICAL SUPERVISOR			ELECTRICAL ENGINEER		
MECHANICAL "			MECHANICAL "		
STRUCTURAL "			STRUCTURAL "		
CHIEF DRAFTSMAN					

REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE

About 1987 the peak load requirements will exceed the rating of the above two circuits and additional parallel facilities will be required. At this time a review should be made of the economics of going to a higher transmission voltage for the additional circuits. Advances in the art and availability of suitable materials may warrant operation at higher voltages. Additional parallel facilities will be required in succeeding years until the equivalent of six circuits is operable by about 2004.

Interconnection of the two Keys systems and operation from a common generating source will have no significant effect on requirements or operation of the distribution system which in any case will be supplied by step-down substations fed from the 69-kv system. Hence, for the combined case there is no difference in the estimated cost of distribution over the separate systems case.

c. Estimates of Installed Costs

Table III-10, page III-69, gives the differential costs and Table III-11, page III-70, gives the total transmission and distribution cost by year of expenditure for the combined systems case. Estimated costs of distribution expansion up to the high side of the distribution transformers are included.

These costs reflect the savings possible from installation of larger main unit step-up transformers by virtue of the larger sizes feasible when the systems are combined. The cost of the required additional transmission is included.

Although it is recommended that serious consideration be given for establishment of a central load dispatching center to assist in efficient combined system operation, the cost of such a center is not included in this study.

d. Differential Losses

The transfer of large blocks of power from the Sugarloaf plant to Marathon will entail losses in transmission not present for the separate systems case. The magnitude of these losses was calculated from the projected circuit loading and line characteristics. Annual kilowatt-hours of losses were calculated using a loss factor developed from a differential loss duration curve in turn calculated from line losses and system load duration characteristics. The above procedure was used to arrive at a loss penalty for the combined case. These costs of losses are included in the final comparative summaries.

TABLE III-10

DIFFERENTIAL CONSTRUCTION COSTS FOR COMBINED SYSTEM RELATIVE TO SEPARATE SYSTEM OPERATION

Year	Estimated Cost*	Year	Estimated Cost*
1966	$ + 1,877,230	1980	$ + 286,490
1967	+ 64,470	1984	+ 286,490
1968	- 120,645	1986	- 471,160
		1988	+ 2,390,850
1971	+ 189,560	1994	+ 2,436,425
1972	- 1,001,900	1996	- 346,665
		1998	- 258,480
1974	- 185,115	2000	+ 2,460,435
1975	+ 4,445	2001	- 346,665
1977	- 185,115	2002	- 258,480
1978	+ 1,933,400	2004	+ 1,933,400
1979	- 157,100	2006	+ 527,040
		2007	- 605,140
		Total	$ +10,333,124

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* 1963 prices without escalation

TABLE III-11

ESTIMATED TOTAL TRANSMISSION AND DISTRIBUTION* COST FOR COMBINED SYSTEMS

OPERATION - CASE I

Year	Estimated Cost**	Year	Estimated Cost**
1966	$ 6,271,055	1986	$ 2,462,380
1967	185,120	1988	2,832,525
1968	88,925	1989	388,690
1969	172,960	1991	182,820
1970	172,960	1992	2,479,260
1971	189,560	1994	4,033,910
1972	190,150	1995	1,114,090
1974	567,700	1996	412,620
1975	397,350	1998	526,135
1977	1,851,290	2000	3,025,780
1978	1,933,400	2001	3,018,150
1979	179,695	2002	1,178,490
1980	1,234,140	2004	1,933,400
1981	385,490	2005	1,097,940
1983	572,760	2006	527,040
1984	286,490	2007	710,615
		Total	$ 40,602,890

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* To high side of 14.4-25-kv transformers

** 1963 prices without escalation

IV. POWER PLANT SIZE(S) AND LOCATION(S)

A. Basis for Selection of Study Cases

Two basic plans for installation of fossil-fuel-fired power plants were developed to meet the future power requirements of the Florida Keys area. The first of these plans, Case I, is based on one central power station to be located on Sugarloaf Key. This station will supply power to both the Upper and Lower Keys through additions to the transmission system as required.

The second plan, designated as Case II, is based on two central power stations: one located on Sugarloaf Key and supplying power to the Lower Keys only, and the other located on Marathon Key and supplying power to the Upper Keys only. The size of the initial unit for Case I was 50 mw as compared to two 25-mw initial units for Case II. For the study of unit size and location, only fossil-fuel-fired plants were considered.

The patterns of plant installation for the above cases are shown on Exhibit IV-1, page IV-2. The basis for the selection of the units was that the firm capacity (defined as the capacity of the system with the largest unit out of service) must be equal to or greater than the expected system peak load. It may be observed from Exhibit IV-1 that this basis for selection was not applied in the early years of this study because of the time lag required to get the first units into operation.

B. Generating Plant and Transmission System Investment Costs

Power plant and transmission system investment costs for the period between the years 1966 and 2010 are summarized on Exhibit IV-2, Sheet 1 for Case I (page IV-3), and Exhibit IV-2, Sheet 2 for Case II (page IV-4). The breakdowns for the power plant capital investments are further shown on Exhibit IV-3, Sheets 1 to 3 inclusive (pages IV-5-7). A discussion of transmission system investment costs is given in Section III. Escalation for both the power plant and transmission system investments are not included in this report since escalation is highly uncertain, and it was felt that a

FEASIBILITY STUDY - FLORIDA KEYS
STUDY OF UNIT SIZE AND LOCATION
DEVELOPMENT OF PATTERNS FOR POWER PLANT INSTALLATIONS

CASE I

COMBINED SYSTEM — UPPER AND LOWER KEYS					
Year	Load-MWe	New Units-MWe	Total Capacity MWe	Firm Capacity MWe	Deficiency MWe
1963	46.0	--	61.0	44.4	1.6
1964	53.4	--	61.0	44.4	9.0
1965	61.8	--	61.0	44.4	17.4
1966	68.6	1-- 50	111.0	61.0	7.6
1967	77.2	1-- 50	161.0	111.0	0
1968	86.5	--	161.0	111.0	0
1969	96.4	--	161.0	111.0	0
1970	106.1	--	161.0	111.0	0
1971	118.4	1-- 75	236.0	161.0	0
1972	130.9	--	236.0	161.0	0
1973	144.0	--	236.0	161.0	0
1974	158.7	--	236.0	161.0	0
1975	174.5	1-- 75	311.0	236.0	0
1976	187.0	--	311.0	236.0	0
1977	201.0	--	311.0	236.0	0
1978	218.0	--	311.0	236.0	0
1979	232.0	--	311.0	236.0	0
1980	251.1	1--100	411.0	311.0	0
1981	265.0	--	411.0	311.0	0
1982	283.0	--	411.0	311.0	0
1983	303.0	--	411.0	311.0	0
1984	322.0	1--150	561.0	411.0	0
1985	344.1	--	561.0	411.0	0
1986	369.0	--	561.0	411.0	0
1987	391.0	--	561.0	411.0	0
1988	413.0	1--200	761.0	561.0	0
1989	438.0	--	761.0	561.0	0
1990	462.4	--	761.0	561.0	0
1991	482.0	--	761.0	561.0	0
1992	512.0	--	761.0	561.0	0
1993	538.0	--	761.0	561.0	0
1994	567.0	1--225	986.0	761.0	0
1995	599.4	--	986.0	761.0	0
1996	630.0	--	986.0	761.0	0
1997	658.0	--	986.0	761.0	0
1998	687.0	--	986.0	761.0	0
1999	724.0	--	986.0	761.0	0
2000	772.0	1--250	1236.0	986.0	0
2001	800.0	--	1236.0	986.0	0
2002	843.0	--	1236.0	986.0	0
2003	888.0	--	1236.0	986.0	0
2004	930.0	--	1236.0	986.0	0
2005	976.2	--	1236.0	986.0	0
2006	1012.0	1--250	1486.0	1236.0	0
2007	1061.0	--	1486.0	1236.0	0
2008	1107.0	--	1486.0	1236.0	0
2009	1156.0	--	1486.0	1236.0	0
2010	1215.9	--	1486.0	1236.0	0

CASE II

SEPARATE SYSTEMS — UPPER AND LOWER KEYS									
Upper Keys					Lower Keys				
Load-MWe	New Units-MWe	Total Capacity MWe	Firm Capacity MWe	Deficiency MWe	Load-MWe	New Units-MWe	Total Capacity MWe	Firm Capacity MWe	Deficiency MWe
17.5	--	11.0	8.0	9.5	28.5	--	50.0	33.4	0
20.4	--	11.0	8.0	12.4	33.0	--	50.0	33.4	0
23.4	--	11.0	8.0	15.4	38.4	--	50.0	33.4	5
26.4	1-- 25	36.0	11.0	15.4	42.2	1-- 25	75.0	50.0	0
30.2	1-- 25	61.0	36.0	0	47.0	--	75.0	50.0	0
34.0	--	61.0	36.0	0	52.5	1-- 25	100.0	75.0	0
38.4	1-- 25	86.0	61.0	0	58.0	--	100.0	75.0	0
42.8	--	86.0	61.0	0	63.3	--	100.0	75.0	0
48.4	--	86.0	61.0	0	70.0	--	100.0	75.0	0
53.9	--	86.0	61.0	0	77.0	1-- 25	125.0	100.0	0
60.0	--	86.0	61.0	0	84.0	--	125.0	100.0	0
66.7	1-- 50	136.0	86.0	0	92.0	--	125.0	100.0	0
74.5	--	136.0	86.0	0	100.0	1-- 50	175.0	125.0	0
82.0	--	136.0	86.0	0	105.0	--	175.0	125.0	0
89.0	1-- 50	186.0	136.0	0	112.0	--	175.0	125.0	0
98.0	--	186.0	136.0	0	120.0	--	175.0	125.0	0
106.0	--	186.0	136.0	0	126.0	1-- 50	225.0	175.0	0
119.1	--	186.0	136.0	0	132.0	--	225.0	175.0	0
125.0	--	186.0	136.0	0	140.0	--	225.0	175.0	0
135.0	--	186.0	136.0	0	148.0	--	225.0	175.0	0
148.0	1-- 75	261.0	186.0	0	155.0	--	225.0	175.0	0
161.0	--	261.0	186.0	0	161.0	--	225.0	175.0	0
174.1	--	261.0	186.0	0	170.0	--	225.0	175.0	0
189.0	1-- 75	336.0	261.0	0	180.0	1-- 75	300.0	225.0	0
201.0	--	336.0	261.0	0	190.0	--	300.0	225.0	0
213.0	--	336.0	261.0	0	200.0	--	300.0	225.0	0
228.0	--	336.0	261.0	0	210.0	--	300.0	225.0	0
242.4	--	336.0	261.0	0	220.0	--	300.0	225.0	0
252.0	--	336.0	261.0	0	230.0	1-- 75	375.0	300.0	0
272.0	1--100	436.0	336.0	0	240.0	--	375.0	300.0	0
288.0	--	436.0	336.0	0	250.0	--	375.0	300.0	0
305.0	--	436.0	336.0	0	262.0	--	375.0	300.0	0
323.4	--	436.0	336.0	0	276.0	--	375.0	300.0	0
340.0	1--125	561.0	436.0	0	290.0	--	375.0	300.0	0
358.0	--	561.0	436.0	0	300.0	--	375.0	300.0	0
367.0	--	561.0	436.0	0	320.0	1--100	475.0	375.0	0
394.0	--	561.0	436.0	0	330.0	--	475.0	375.0	0
422.0	--	561.0	436.0	0	350.0	--	475.0	375.0	0
440.0	1--125	686.0	561.0	0	360.0	--	475.0	375.0	0
463.0	--	686.0	561.0	0	380.0	1--100	575.0	475.0	0
488.0	--	686.0	561.0	0	400.0	--	575.0	475.0	0
510.0	--	686.0	561.0	0	420.0	--	575.0	475.0	0
536.2	--	686.0	561.0	0	440.0	--	575.0	475.0	0
552.0	--	686.0	561.0	0	460.0	--	575.0	475.0	0
581.0	1--125	811.0	686.0	0	480.0	1--100	675.0	575.0	0
607.0	--	811.0	686.0	0	500.0	--	675.0	575.0	0
636.0	--	811.0	686.0	0	520.0	--	675.0	575.0	0
665.9	--	811.0	686.0	0	550.0	--	675.0	575.0	0

EXHIBIT IV-2
Sheet 1 of 2

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION CASE I - COMBINED SYSTEM (UPPER AND LOWER KEYS COMBINED)

ANNUAL COSTS - $1,000

Year	Capital Investments - $1,000		Fixed Charges		Fuel	Loss Penalty	Operation and Maintenance		Totals	Present Worth Factor @ 4%	Present Worth of Annual Cost $1,000
	Generation	Transmission	Generation	Transmission			Generating Plant	Transmission Plant			
1966	10,203	6,271	730	403	1,484	9	507	94	3,227	.9615	3,103
1967	7,968	185	1,299	414	1,664	12	626	97	4,112	.9246	3,802
1968	-	89	1,299	420	1,865	15	640	98	4,337	.8890	3,856
1969	-	173	1,299	431	2,078	19	655	101	4,583	.8548	3,918
1970	-	173	1,299	442	2,288	24	670	103	4,826	.8219	3,966
1971	11,988	190	2,156	455	2,412	31	893	106	6,053	.7903	4,784
1972	-	190	2,156	467	2,672	45	912	109	6,361	.7599	4,834
1973	-	-	2,156	467	2,949	53	932	109	6,666	.7307	4,871
1974	-	568	2,156	503	3,261	65	955	118	7,058	.7026	4,959
1975	11,523	397	2,980	529	3,548	83	1,084	124	8,348	.6756	5,640
1976	-	-	2,980	529	3,802	99	1,103	124	8,605	.6496	5,590
1977	-	1,851	2,980	648	4,088	117	1,125	151	9,109	.6246	5,689
1978	-	1,933	2,980	772	4,437	70	1,151	180	9,590	.6006	5,760
1979	-	180	2,980	783	4,724	82	1,172	183	9,924	.5775	5,731
1980	15,700	1,234	4,103	862	4,915	102	1,584	202	11,768	.5553	6,535
1981	-	385	4,103	887	5,206	113	1,609	207	12,125	.5339	6,474
1982	-	-	4,103	887	5,572	132	1,637	207	12,538	.5134	6,437
1983	-	573	4,103	924	5,972	157	1,665	216	13,037	.4936	6,435
1984	23,099	286	5,754	942	5,964	186	1,733	220	14,799	.4746	7,024
1985	-	-	5,754	942	6,390	216	1,759	220	15,281	.4564	6,974
1986	-	2,462	5,754	1,100	6,870	255	1,790	257	16,026	.4388	7,032
1987	-	-	5,754	1,100	7,298	287	1,818	257	16,514	.4220	6,969
1988	30,686	2,833	7,948	1,282	7,528	208	2,057	300	19,323	.4057	7,839
1989	-	389	7,948	1,307	7,987	247	2,086	305	19,880	.3901	7,755
1990	-	-	7,948	1,307	8,435	277	2,114	305	20,386	.3751	7,647
1991	-	183	7,948	1,319	8,795	301	2,137	308	20,808	.3607	7,505
1992	-	2,479	7,948	1,478	9,349	350	2,172	345	21,642	.3468	7,505
1993	-	-	7,948	1,478	9,841	391	2,203	345	22,206	.3335	7,406
1994	34,118	4,034	10,388	1,737	10,317	326	2,594	406	25,768	.3207	8,264
1995	-	1,114	10,388	1,809	10,908	369	2,634	423	26,531	.3083	8,180
1996	-	413	9,798	1,835	11,465	409	2,667	429	26,603	.2965	7,888
1997	-	-	9,338	1,835	11,976	351	2,701	429	26,630	.2851	7,592
1998	-	526	9,338	1,869	12,506	475	2,734	437	27,359	.2741	7,499
1999	-	-	9,338	1,869	13,184	546	2,776	437	28,150	.2636	7,420
2000	36,963	3,026	11,981	2,063	14,040	501	2,845	482	31,912	.2534	8,087
2001	-	3,018	11,287	2,257	14,550	544	2,874	527	32,039	.2437	7,808
2002	-	1,178	11,287	2,333	15,333	600	2,918	545	33,016	.2343	7,736
2003	-	-	11,287	2,333	16,153	668	2,968	545	33,954	.2253	7,650
2004	-	1,933	11,287	2,457	16,933	588	3,012	424	34,701	.2166	7,516
2005	-	1,098	10,662	2,527	17,760	647	3,063	590	35,249	.2083	7,342
2006	35,799	527	13,222	2,244	18,402	683	3,280	598	38,429	.2003	7,697
2007	-	711	13,222	2,280	19,293	757	3,328	609	39,489	.1926	7,606
2008	-	-	13,222	2,276	20,078	828	3,373	609	40,386	.1852	7,479
2009	-	-	13,222	2,267	21,022	908	3,422	609	41,450	.1781	7,382
2010	-	-	12,274	2,258	22,113	996	3,484	609	41,734	.1712	7,145
										Total	$296,331

EXHIBIT IV-2
Sheet 2 of 2

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION CASE II - SEPARATE SYSTEMS (UPPER AND LOWER KEYS SEPARATE)

ANNUAL COSTS - $1,000 (SINGLE INTEREST RATE @ 4%)

Year	Capital Investments - $1,000		Fixed Charges		Fuel	Loss Penalty	Operation and Maintenance		Totals	Present Worth Factor @ 4%	Present Worth of Annual Cost $1,000
	Generation	Transmission	Generation	Transmission			Generating Plant	Transmission Plant			
1966	12,270	4,393	877	282	1,586	Base	727	66	3,538	.9615	3,402
1967	4,350	121	1,188	290	1,799		781	68	4,126	.9246	3,815
1968	4,350	210	1,499	303	1,982		837	71	4,692	.8890	4,171
1969	4,350	294	1,810	322	2,210		986	75	5,403	.8548	4,618
1970	-	173	1,810	333	2,432		1,007	78	5,660	.8219	4,652
1971	-	-	1,810	333	2,718		1,032	78	5,971	.7903	4,719
1972	4,350	1,192	2,121	410	3,001		1,186	96	6,814	.7599	5,178
1973	-	-	2,121	410	3,302		1,214	96	7,143	.7307	5,219
1974	8,403	753	2,722	458	3,550		1,609	107	8,446	.7026	5,934
1975	8,403	393	3,323	483	3,783		1,990	113	9,692	.6756	6,548
1976	-	-	3,323	483	4,062		2,013	113	9,994	.6496	6,492
1977	7,968	2,037	3,893	614	4,366		2,142	143	11,158	.6246	6,969
1978	-	-	3,893	614	4,757		2,179	143	11,586	.6006	6,959
1979	7,968	337	4,462	636	5,003		2,283	149	12,533	.5775	7,238
1980	-	948	4,462	697	5,415		2,312	163	13,049	.5553	7,246
1981	-	385	4,462	721	5,715		2,334	169	13,401	.5339	7,155
1982	-	-	4,462	721	6,106		2,363	169	13,821	.5134	7,096
1983	11,988	1,373	5,320	809	6,381		2,609	189	15,308	.4936	7,556
1984	-	-	5,320	809	6,788		2,628	189	15,734	.4746	7,467
1985	-	-	5,320	809	7,268		2,868	189	16,454	.4564	7,510
1986	23,451	2,934	7,001	998	7,554		3,006	233	18,792	.4388	8,246
1987	-	-	7,001	998	8,018		3,040	233	19,290	.4220	8,140
1988	-	442	7,001	1,026	8,476		3,073	240	19,816	.4057	8,039
1989	-	389	7,001	1,051	9,002		3,112	246	20,412	.3901	7,963
1990	15,700	-	8,123	1,051	9,518		3,150	246	22,088	.3751	8,285
1991	11,523	183	8,947	1,063	9,822		3,284	248	23,364	.3607	8,427
1992	-	2,479	8,947	1,222	10,236		3,717	286	24,408	.3468	8,465
1993	-	-	8,947	1,222	10,771		3,756	286	24,982	.3335	8,331
1994	-	1,597	8,947	1,325	11,368		3,801	309	25,750	.3207	8,258
1995	-	1,114	8,947	1,396	12,041		3,852	326	26,562	.3083	8,189
1996	19,375	759	9,623	1,444	12,350		3,931	338	27,686	.2965	8,209
1997	-	-	9,372	1,444	12,926		3,970	338	28,050	.2851	7,997
1998	15,700	785	10,243	1,495	13,267		4,395	349	29,749	.2741	8,154
1999	-	-	9,992	1,495	14,005		4,447	349	30,288	.2636	7,984
2000	-	565	9,992	1,532	14,967		4,464	358	31,313	.2534	7,935
2001	18,618	3,365	11,323	1,748	15,356		4,756	408	33,591	.2437	8,186
2002	14,904	1,437	12,136	1,840	16,042		4,844	430	35,292	.2343	8,269
2003	-	-	12,136	1,840	16,919		4,902	430	36,227	.2253	8,162
2004	-	-	11,652	1,840	17,745		4,958	430	36,625	.2166	7,933
2005	-	1,098	11,166	1,910	18,661		5,020	446	37,203	.2083	7,749
2006	-	-	11,166	1,688	19,371		5,071	446	37,742	.2003	7,560
2007	33,522	1,316	13,102	1,767	20,118		5,399	466	40,852	.1926	7,868
2008	-	-	13,102	1,757	21,005		5,456	466	41,786	.1852	7,739
2009	-	-	12,641	1,742	21,948		5,516	466	42,313	.1781	7,536
2010	-	-	12,641	1,733	23,123		5,595	466	43,558	.1712	7,457
										Total	$321,025

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION - CASE I, COMBINED SYSTEM

CAPITAL COST ESTIMATES FOR FOSSIL FUEL STEAM-ELECTRIC GENERATING PLANTS

(All Costs in Thousands of Dollars)

Year Unit Installed	1966	1967	1971	1975	1980	1984	1988	1994	2000	2006
Number and MWe Rating of New Unit	1- 50	1- 50	1- 75	1- 75	1-100	1-150	1-200	1-225	1-250	1-250
Land and Land Rights	279①	-	-	-	-	-	-	-	-	-
Structures and Improvements	1,167②	386	505	505	662	852	1,082	1,182	1,288	1,288
Boiler Plant Equipment	3,495	3,495	4,647	4,647	6,217	9,858	14,086	15,851	17,675	17,675
Turbogenerator Equipment	2,083	2,083	3,016	3,016	3,914	5,507	6,765	7,485	7,923	7,923
Accessory Electric Equipment	631	631	850	850	1,125	1,575	1,950	2,160	2,250	2,250
Miscellaneous Power Plant Equipment	100	100	125	125	150	150	175	200	225	225
Other Expenses	125	125	150	150	150	175	200	200	225	225
Subtotal	7,880	6,820	9,293	9,293	12,218	18,117	24,258	27,078	29,586	29,586
Engineering, Field Supervision, Construction Management, Contingency, Interest during Construction, etc.	2,323	1,148	2,695	2,230	3,482	4,982	6,428	7,040	7,377	6,213
Total Estimated Plant Cost	10,203	7,968	11,988	11,523	15,700	23,099	30,686	34,118	36,963	35,799

Notes:

1. Initial unit includes required land for roads and all future additions.
2. Initial unit includes dock and channel facilities for fuel oil handling, plus special provisions for hurricane resistance.

EXHIBIT IV-3
Sheet 1 of 3

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION - CASE II, SEPARATE SYSTEMS (LOWER KEYS)①

CAPITAL COST ESTIMATES FOR FOSSIL FUEL STEAM-ELECTRIC GENERATING PLANTS

(All Costs in Thousands of Dollars)

Year Unit Installed	1966	1968	1972	1975	1979	1986	1991	1998	2002	2007
Number and MWe Rating of New Unit	1-25	1-25	1-25	1-50	1-50	1-75	1-75	1-100	1-100	1-100
Land and Land Rights	258②	-	-	-	-	-	-	-	-	-
Structures and Improvements	1,240③	285	285	386	386	505	505	662	662	662
Boiler Plant Equipment	1,625	1,625	1,625	3,037	3,037	4,647	4,647	6,217	6,217	6,217
Turbogenerator Equipment	1,181	1,121	1,121	2,243	2,143	3,016	3,016	3,914	3,814	3,814
Accessory Electric Equipment	310	300	300	598	583	850	850	1,125	1,100	1,100
Miscellaneous Power Plant Equipment	100	60	60	100	100	125	125	150	125	125
Other Expenses	90	90	90	125	125	150	150	150	150	150
Subtotal	4,804	3,481	3,481	6,489	6,374	9,293	9,293	12,218	12,068	12,068
Engineering, Field Supervision, Construction Management, Contingency, Interest during Construction, etc.	1,442	869	869	1,914	1,594	2,695	2,230	3,482	2,836	2,836
Total Estimated Plant Cost	6,246	4,350	4,350	8,403	7,968	11,988	11,523	15,700	14,904	14,904

Notes:

1. All plants located on Sugar Loaf Key.
2. Initial unit includes required land for roads and all future additions.
3. Initial unit includes dock and channel facilities for fuel oil handling.

EXHIBIT IV-3
Sheet 2 of 3

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION - CASE II, SEPARATE SYSTEMS (UPPER KEYS)

CAPITAL COST ESTIMATES FOR FOSSIL FUEL STEAM-ELECTRIC GENERATING PLANTS

(All Costs in Thousands of Dollars)

Year Unit Installed	1966	1967	1969	1974	1977	1983	1986	1990	1996	2001	2007
Number and MWe Rating of New Unit	1-25	1-25	1-25	1-50	1-50	1-75	1-75	1-100	1-125	1-125	1-125
Land and Land Rights	578①	-	-	-	-	-	-	-	-	-	-
Structures and Improvements	750②	285	285	386	386	505	505	662	788	788	788
Boiler Plant Equipment	1,625	1,625	1,625	3,037	3,037	4,647	4,647	6,217	8,070	8,070	8,070
Turbogenerator Equipment	1,181	1,121	1,121	2,243	2,143	3,016	3,016	3,914	4,660	4,660	4,660
Accessory Electric Equipment	310	300	300	598	583	850	850	1,125	1,344	1,344	1,344
Miscellaneous Power Plant Equipment	100	60	60	100	100	125	125	150	125	125	125
Other Expenses	90	90	90	125	125	150	150	150	150	150	150
Subtotal	4,634	3,481	3,481	6,489	6,374	9,293	9,293	12,218	15,137	15,137	15,137
Engineering, Field Supervision, Construction Management, Contingency, Interest during Construction, etc.	1,390	869	869	1,914	1,594	2,695	2,230	3,482	4,238	3,481	3,481
Total Estimated Plant Cost	6,024	4,350	4,350	8,403	7,968	11,988	11,523	15,700	19,375	18,618	18,618

Notes:

1. Initial unit includes required land for roads and all future additions.
2. Initial unit includes dock and channel facilities for fuel oil handling.

EXHIBIT IV-3
Sheet 3 of 3

projection of escalation out to the year 2010 would be meaningless. Therefore, all equipment costs are as of the date of this report. Descriptions of the fossil-fuel plants and associated equipment are given in Section VIII. For the cases considered in the study of unit size and location, the first unit installed in the respective cases includes the purchase and preparation of the land and docking facilities for fuel oil delivery for all of the subsequent units.

The steam conditions listed below were used in the study of unit size and location. These conditions were the basis for generating station investment costs and also for the heat rates used in calculating expected annual fuel costs.

Size of Unit, Net Electrical Output kw	Steam Conditions, Main Pressure/ Throttle Temp/Reheat Temp
25,000	850 psig/900° F
50,000	1450 psig/1000° F
75,000	1450 psig/1000° F
100,000	1450 psig/1000° F/1000° F
125,000	1800 psig/1000° F/1000° F
150,000	2400 psig/1000° F/1000° F
200,000	2400 psig/1000° F/1000° F
225,000	2400 psig/1000° F/1000° F
250,000	2400 psig/1000° F/1000° F

The above steam conditions were selected as representative for the sizes considered. Any particular plant would require optimization as part of the detailed design of the individual plant.

C. Fixed Charge Rates

The fixed charge rates applied in the study of the power plant's unit size and location are based on a 30-year life for power plant equipment and a 40-year life for transmission equipment. Certain equipment installed early in the study will be completely amortized before the year 2010, and when this situation occurs, the equipment is assumed to continue operating with the fixed charges consisting only of interim replacements, insurance and taxes. Each of the contributions to the fixed charge rate was reviewed in Section III; for convenience they are summarized again below:

Generation Equipment (30-Year Life)	Municipal	REA
Cost of Money	4.00%	2.00%
Depreciation	1.78	2.47
Interim Replacements	0.35	0.35
Insurance	0.35	0.35
Taxes	0.67	0.67
Total	7.15%	5.84%
Total less Depreciation and Interest	1.37%	1.37%

Transmission Equipment	Municipal	REA
Cost of Money	4.00%	2.00%
Depreciation	1.05	1.66
Interim Replacements	0.35	0.35
Insurance	0.35	0.35
Taxes	0.67	0.67
Total	6.42%	5.03%
Total less Depreciation and Interest	1.37%	1.37%

There is some question as to whether municipal or REA financing will apply to the cases considered in the study of unit size and location. In general, it may be assumed that municipal rates will apply to expenditures made by the Lower Keys, and REA rates will apply to expenditures made by the Upper Keys. However, even here the line of demarcation is not definite, for in Case I, where a combined system is considered, transmission equipment must be installed in the Lower Keys for wheeling power to the Upper Keys. The basic study of unit size and location shown on Exhibit VI-2, page VI-3, was, therefore, made with municipal financing. The results would not have been appreciably different if REA financing were assumed. For illustrative purposes, Case II, where separate systems for the Upper and Lower Keys were considered, was recalculated on

Exhibit IV-8, page IV-20, using municipal rates of financing for the Lower Keys and REA financing for the Upper Keys. It should be pointed out that while the annual costs are not affected too much by the method of financing, the present worth values are affected considerably.

D. Production and Transmission Costs

1. General

Power production and transmission costs were computed for the two cases under consideration. These costs included fuel, transmission system losses, and operating labor and maintenance expenses of generating plants and transmission systems. All production costs for the cases considered are summarized on Exhibit IV-2, pages IV-3 and 4.

2. Fuel

The total cost of fuel for each year for the cases under consideration in this study are tabulated in Exhibit IV-2. The cost of fuel oil was taken at $0.42 per million Btu which is approximately the present-day price of fuel oil delivered to either the Upper or Lower Keys. The methods used for calculating the annual fuel costs are outlined as follows:

a. The typical load duration curve, included as Exhibit IV-4, page IV-11, was set up for each of the years from 1966 to 2010. This was accomplished by multiplying the ordinate on the typical load duration curve, expressed in percentage of annual peak load, by the expected system net peak loads shown on the Development of Patterns for Power Plant Installations, Exhibit IV-1, page IV-2.

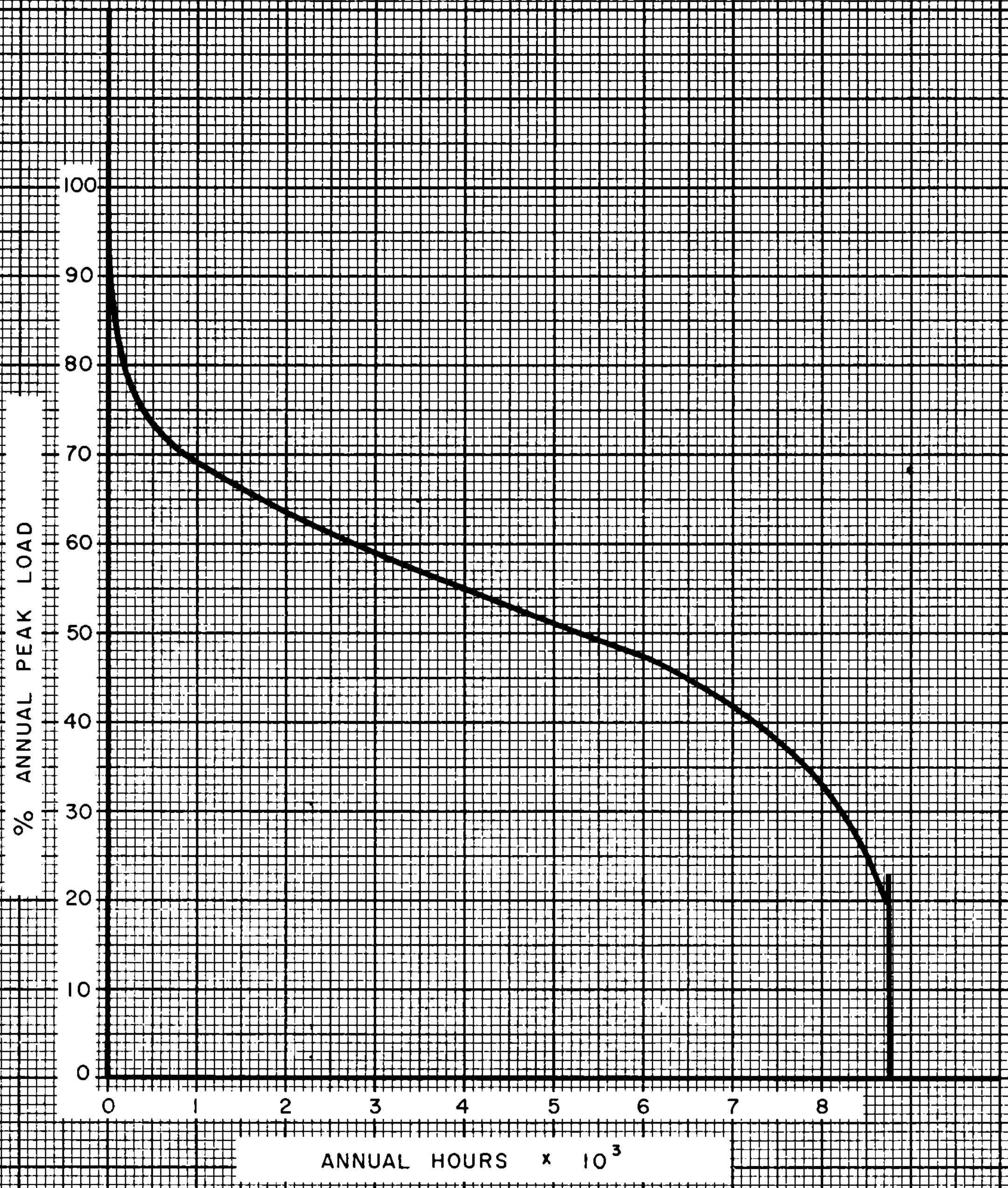
b. Generating capacity was then entered on the system load duration curves and the energy generated by each unit was then determined by measuring the areas for each respective unit with a planimeter. The newer, more efficient units were placed at the bottom of the load duration curve and in time would relegate the older, less efficient units to peaking and/or reserve status.

c. The net plant heat rates for the plants under consideration were then calculated. The following tabulation represents a summary of the results of these calculations at the capacity shown.

EXHIBIT IV-4

FEASIBILITY STUDY - FLORIDA KEYS

TYPICAL ANNUAL LOAD DURATION CURVE



Summary of Net Plant Heat Rates at 2.0 Inches Hga

Net Output KWe	Main Steam Pressure, psig	Main Steam Temp, °F	Reheat Steam Temp, °F	Net Plant Heat Rate, Btu/kwhr
25,000	850	900	-	11,165
50,000	1450	1000	-	10,500
75,000	1450	1000	-	9,900
100,000	1450	1000	1000	9,420
125,000	1800	1000	1000	9,055
150,000	2400	1000	1000	8,938
200,000	2400	1000	1000	8,865
225,000	2400	1000	1000	8,860
250,000	2400	1000	1000	8,855

While the above tabulation shows net plant heat rates corresponding to the plant investment costs used in this study, it should be noted that the net plant heat rate for any particular unit could vary considerably from that shown above depending on individual cycle characteristics such as turbine exhaust end selection, cycle arrangement, number of heaters, etc.

d. The fuel costs for each year were then calculated for each case using the appropriate energy, net plant heat rates and fuel cost. When more than one unit of the same size was installed, the energy associated with these units was assumed to be divided equally among them.

e. A factor of 5 percent was added to the total fuel costs calculated as outlined above to allow for part load operation and operating contingencies. The net plant heat rates shown in Paragraph c, above, are those which could be obtained with optimum operating conditions with the units at guaranteed efficiency. Some slight deviation from these operating conditions usually occurs during normal operation and this allowance is included in the 5 percent figure.

3. Transmission Losses

System losses for Case II where separate systems are considered will be less than for Case I which has a single generating plant for both the Upper and Lower Keys. These differential losses were applied as a penalty to Case I and were evaluated at $7 per kw per year for power and 4 mills per kwhr for energy. The differential losses were calculated to be the following:

Year	kw	10^6 kwhr	Year	kw	10^6 kwhr
1966	490	1.310	1989	13,930	37.300
1967	680	1.815	1990	15,690	41.900
1968	860	2.300	1991	17,030	45.500
1969	1,100	2.930	1992	19,760	52.800
1970	1,370	3.660	1993	22,100	59.000
1971	1,760	4.770	1994	18,460	49.300
1972	2,520	6.720	1995	20,850	55.700
1973	3,020	8.070	1996	23,140	61.800
1974	3,650	9.750	1997	25,520	68.100
1975	4,670	12.460	1998	26,880	71.800
1976	5,590	14.930	1999	30,860	82.400
1977	6,590	17.600	2000	28,300	75.600
1978	3,970	10.600	2001	30,780	82.200
1979	4,660	12.430	2002	33,940	90.500
1980	5,770	15.400	2003	37,790	100.900
1981	6,400	17.100	2004	33,240	88.800
1982	7,440	19.850	2005	36,590	97.700
1983	8,880	23.700	2006	38,640	103.100
1984	10,530	28.100	2007	42,860	114.300
1985	12,220	32.600	2008	46,900	125.000
1986	14,410	38.500	2009	51,440	137.000
1987	16,240	43.400	2010	56,440	150.300
1988	11,760	31.400			

From the above table, it can be seen that for certain years the differential losses decrease rather than increase. These decreases correspond to transmission system additions.

4. Operation and Maintenance

a. Fixed Operating and Maintenance Labor

Estimated cost of operating and maintenance labor is based on the tables of plant manpower which are shown on Exhibit IV-5, page IV-14. The annual rates shown for the various classifications are estimated rates for the Florida Keys area. These annual rates do not include fringe benefits such as provision for retirement and life insurance, nor provision for administrative and general costs. In plant operation, however, manpower must be available to take care of ordinary sickness and vacations, and this

EXHIBIT IV-5

FEASIBILITY STUDY - FLORIDA KEYS
FOSSIL FUEL ELECTRIC GENERATING PLANTS
OPERATING AND MAINTENANCE LABOR, MATERIALS AND SUPPLIES COST (IN DOLLARS)

PLANT DATA														
Number of Units	1	2	3	1	2	3	4	1	2	3	4	1	2	3
Unit Size Range - MWe	25			50 - 75				100 - 200				225 - 250		
Supervision and Clerical														
Plant Superintendent	1 @ 10,400	→	→	1 @ 10,400	→	→	→	1 @ 10,400	→	→	→	1 @ 10,400	→	→
Assistant Superintendent	--	1 @ 8,000	→	1 @ 8,000	→	→	→	1 @ 8,000	→	→	→	1 @ 8,000	→	→
Chief Clerk	--	--	--	--	1 @ 5,500	→	→	1 @ 5,500	→	→	→	1 @ 5,500	→	→
Stenographer	--	--	1 @ 3,500	1 @ 3,500	→	→	2 @ 3,500	1 @ 3,500	→	→	2 @ 3,500	1 @ 3,500	→	→
Clerk-Typist	1 @ 3,200	→	→	1 @ 3,200	→	2 @ 3,200	→	1 @ 3,200	→	2 @ 3,200	→	1 @ 3,200	→	2 @ 3,200
Storekeeper	1 @ 4,000	→	→	1 @ 4,000	→	→	→	1 @ 4,000	→	→	→	1 @ 4,000	→	→
	3 - 17,600	4 - 25,600	5 - 29,100	5 - 29,100	6 - 34,600	7 - 37,800	8 - 41,300	6 - 34,600	6 - 34,600	7 - 37,800	8 - 41,300	6 - 34,600	6 - 34,600	7 - 37,800
Operation														
Operations Supervisor	--	--	1 @ 7,500	1 @ 7,500	→	→	→	1 @ 7,500	→	→	→	1 @ 7,500	→	→
Shift Supervisor	5 @ 7,000	→	→	5 @ 7,000	→	→	→	5 @ 7,000	→	→	→	5 @ 7,000	→	→
Control Operator	4 @ 5,800	→	→	4 @ 5,800	→	8 @ 5,800	→	4 @ 5,800	→	8 @ 5,800	→	4 @ 5,800	→	8 @ 5,800
Assistant Control Operator	--	--	4 @ 5,300	4 @ 5,300	→	8 @ 5,300	→	4 @ 5,300	→	8 @ 5,300	→	4 @ 5,300	→	8 @ 5,300
Boiler Operator	4 @ 5,200	→	8 @ 5,200	4 @ 5,200	8 @ 5,200	12 @ 5,200	16 @ 5,200	4 @ 5,200	8 @ 5,200	12 @ 5,200	16 @ 5,200	4 @ 5,200	8 @ 5,200	12 @ 5,200
Turbine Operator	2 @ 5,200	→	4 @ 5,200	2 @ 5,200	4 @ 5,200	6 @ 5,200	8 @ 5,200	2 @ 5,200	4 @ 5,200	6 @ 5,200	8 @ 5,200	2 @ 5,200	4 @ 5,200	6 @ 5,200
Auxiliary Equipment Operator	1 @ 5,000	→	2 @ 5,000	2 @ 5,000	4 @ 5,000	6 @ 5,000	8 @ 5,000	3 @ 5,000	5 @ 5,000	7 @ 5,000	9 @ 5,000	3 @ 5,000	5 @ 5,000	7 @ 5,000
Engineer-in-Training	--	--	--	1 @ 5,500	→	2 @ 5,500	→	1 @ 5,500	→	2 @ 5,500	→	1 @ 5,500	→	2 @ 5,500
Relief Operator	2 @ 5,200	→	→	2 @ 5,200	→	4 @ 5,200	→	2 @ 5,200	→	4 @ 5,200	→	2 @ 5,200	→	4 @ 5,200
	18 – 104,800	18 – 104,800	30 – 169,700	25 – 144,000	33 – 185,200	52 – 286,700	60 – 327,900	26 – 149,000	34 – 190,200	53 – 291,700	61 – 332,900	26 – 149,000	34 – 190,200	53 – 291,700
Results Engineer	1 @ 9,000	→	→	1 @ 9,000	→	→	→	1 @ 9,000	→	→	→	1 @ 9,000	→	→
Laboratory Technician 1st Class	--	--	--	--	1 @ 5,200	→	2 @ 5,200	1 @ 5,200	→	2 @ 5,200	→	1 @ 5,200	→	2 @ 5,200
Laboratory Technician 2nd Class	--	--	1 @ 4,800	1 @ 4,800	→	2 @ 4,800	→	1 @ 4,800	→	2 @ 4,800	→	1 @ 4,800	→	2 @ 4,800
Chemist	1 @ 7,000	→	→	1 @ 7,000	→	→	→	1 @ 7,000	→	→	→	1 @ 7,000	→	→
	2 - 16,000	2 - 16,000	2 - 20,800	3 - 20,800	4 - 26,000	5 - 30,800	6 - 36,000	4 - 26,000	4 - 26,000	6 - 36,000	6 - 36,000	4 - 26,000	4 - 26,000	6 - 36,000
Maintenance														
Maintenance Supervisor	1 - 8,000	→	→	1 @ 8,000	→	→	→	1 @ 8,000	→	→	→	1 @ 8,000	→	→
Mechanical Maintenance Foreman	--	1 @ 7,000	→	1 @ 7,000	→	→	→	1 @ 7,000	→	→	→	1 @ 7,000	→	→
Mechanic 1st Class	2 @ 6,400	→	→	2 @ 6,400	→	3 @ 6,400	→	3 @ 6,400	→	4 @ 6,400	→	3 @ 6,400	→	4 @ 6,400
Mechanic 2nd Class	1 @ 5,000	2 @ 5,000	3 @ 5,000	3 @ 5,000	5 @ 5,000	7 @ 5,000	8 @ 5,000	3 @ 5,000	5 @ 5,000	7 @ 5,000	8 @ 5,000	3 @ 5,000	5 @ 5,000	7 @ 5,000
Electrical Maintenance Foreman	--	--	1 @ 7,000	1 @ 7,000	→	→	→	1 @ 7,000	→	→	→	1 @ 7,000	→	→
Electrician 1st Class	2 @ 6,400	→	→	2 @ 6,400	→	3 @ 6,400	4 @ 6,400	3 @ 6,400	→	4 @ 6,400	5 @ 6,400	3 @ 6,400	→	4 @ 6,400
Electrician 2nd Class	1 @ 6,000	2 @ 6,000	3 @ 6,000	1 @ 6,000	2 @ 6,000	3 @ 6,000	4 @ 6,000	2 @ 6,000	3 @ 6,000	4 @ 6,000	5 @ 6,000	2 @ 6,000	3 @ 6,000	4 @ 6,000
Certified Welder	1 @ 5,900	→	→	1 @ 5,900	→	2 @ 5,900	→	1 @ 5,900	→	2 @ 5,900	→	1 @ 5,900	→	2 @ 5,900
Welder	--	--	--	--	1 @ 4,400	→	2 @ 4,400	1 @ 4,400	→	2 @ 4,400	→	1 @ 4,400	→	2 @ 4,400
Labor Foreman	1 @ 6,000	→	→	1 @ 6,000	→	→	→	1 @ 6,000	→	→	→	1 @ 6,000	→	→
Laborer	2 @ 2,500	→	3 @ 2,500	2 @ 2,500	3 @ 2,500	4 @ 2,500	5 @ 2,500	2 @ 2,500	4 @ 2,500	5 @ 2,500	6 @ 2,500	2 @ 2,500	4 @ 2,500	5 @ 2,500
Janitor	1 @ 2,500	→	→	1 @ 2,500	2 @ 2,500	3 @ 2,500	4 @ 2,500	1 @ 2,500	2 @ 2,500	3 @ 2,500	4 @ 2,500	1 @ 2,500	2 @ 2,500	3 @ 2,500
Watchman	4 @ 2,800	→	→	4 @ 2,800	→	→	→	4 @ 2,800	→	→	→	4 @ 2,800	→	→
	16 - 75,200	19 - 93,200	23- 113,700	20 - 99,200	26 – 124,600	34 – 164,300	40 – 191,100	24 – 122,400	30 – 145,900	39 – 190,000	44 – 212,400	24 – 122,400	30 – 145,900	39 – 190,000
Total Employees and Annual Salaries	39 - 213,600	43 - 239,600	60—333,300	53 - 293,100	69 – 370,400	98 – 519,600	114 – 596,300	60 – 332,000	74 – 396,700	105 – 555,500	119 – 622,600	60 – 332,000	74 – 396,700	105 – 555,500
Cost of Maintenance Materials and Operating Supplies - Mill/kwhr	0.45	0.45	0.45	0.33	0.33	0.33	0.33	0.25	0.25	0.25	0.25	0.20	0.20	0.20
Fringe Benefits @ 20% of Annual Salaries	42,700	47,900	66,700	58,600	74,100	103,900	119,300	66,400	79,300	111,100	124,500	66,400	79,300	111,100
Total Annual Fixed Operating and Maintenance Costs (Annual Salaries Plus Fringe Benefits)	256,300	287,500	400,000	351,700	444,500	623,500	715,600	398,400	476,000	666,600	747,100	398,400	476,000	666,600
Annual Administrative and General Costs @ 14% of Total Fixed Operating and Maintenance Costs	35,900	40,300	56,000	49,200	62,200	87,300	100,200	55,800	66,600	93,300	104,600	55,800	66,600	93,300
Total Annual Fixed Operating and Maintenance Plus Administrative and General Costs	292,200	327,800	456,000	400,900	506,700	710,800	815,800	454,200	542,600	759,900	851,700	454,200	542,600	759,900

manpower has been included in the tables. Since sickness and vacations have been provided for, an allowance of 20 percent of direct labor cost is estimated to be sufficient to take care of other fringe benefits. In addition, 14 percent of total operating and maintenance labor costs has been added to allow for administrative and general expenses.

The basic plant organization reflects the fact that steam plant operation is on a seven-day-week, 52-week-a-year basis. The basic plant utilizes central mechanical control rooms which are expandable to control three to four units each. Steam generator, fan, water, pump and turbine controls are concentrated in this room. In the smaller plants, the switchgear and all electrical controls are also handled here.

b. Variable Costs - Maintenance, Materials and Operating Supplies

In addition to the above fixed labor and associated costs, there is a variable cost of maintenance material and operating supplies which is a direct function of the energy generated by the units considered. This cost was estimated to be the following:

Size of Units, mw	Variable Cost, Mills/kwhr
25	0.45
50-75	0.33
100-200	0.25
225-250	0.20

Exhibit IV-6, page IV-16, entitled "Operation and Maintenance Cost Totals by Years (Including Maintenance Materials and Operating Supplies)," shows how the fixed and variable operation and maintenance costs are combined to get the total annual costs. The final figures from Exhibit IV-6 are entered on Exhibit IV-2, pages IV-3-4, in order that the present worth calculations can be made.

c. Transmission

The annual costs for operation and maintenance of transmission plant were estimated at 1-1/2 percent of the cumulative transmission system investment in each case. The figure of 1-1/2 percent mentioned above

EXHIBIT IV-6

FEASIBILITY STUDY - FLORIDA KEYS
OPERATION AND MAINTENANCE COST TOTALS BY YEARS
(INCLUDING MAINTENANCE MATERIALS AND SUPPLIES)

YEAR	CASE I - COMBINED SYSTEM								
	TOTAL ENERGY 10^6 KWHR	NEW UNITS MWe	LABOR* $1,000	MAINTENANCE MATERIALS AND OPERATING SUPPLIES					TOTAL-LABOR MATERIALS AND SUPPLIES $1,000
				10^6 KWHR AT .45 MILLS/KWHR	10^6 KWHR AT .33 MILLS/KWHR	10^6 KWHR AT .25 MILLS/KWHR	10^6 KWHR AT .20 MILLS/KWHR	TOTAL $1,000	
1966	319.4	50	400.9	3.8	315.6			106	506.9
1967	359.4	50	506.7		359.4			119	625.7
1968	402.7	-	506.7		402.7			133	639.7
1969	448.8	-	506.7		448.8			148	654.7
1970	494.0	-	506.7		494.0			163	669.7
1971	551.3	75	710.8		551.3			182	892.8
1972	609.5	-	710.8		609.5			201	911.8
1973	670.5	-	710.8		670.5			221	931.8
1974	738.9	-	710.8		738.9			244	954.8
1975	812.5	75	815.8		812.5			268	1,083.8
1976	870.7	-	815.8		870.7			287	1,102.8
1977	935.8	-	815.8		935.8			309	1,124.8
1978	1,015.0	-	815.8		1,015.0			335	1,150.8
1979	1,080.2	-	815.8		1,080.2			356	1,171.8
1980	1,169.1	100	1,270.0		274.8	894.3		314	1,584.0
1981	1,233.8	-	1,270.0		381.6	852.2		339	1,609.0
1982	1,317.6	-	1,270.0		466.4	851.2		367	1,637.0
1983	1,410.8	-	1,270.0		523.6	887.2		395	1,665.0
1984	1,499.2	150	1,358.4		.2	1,499.0		375	1,733.4
1985	1,602.1	-	1,358.4		5.5	1,596.6		401	1,759.4
1986	1,718.0	-	1,358.4		26.5	1,691.5		432	1,790.4
1987	1,820.5	-	1,358.4		59.4	1,761.1		460	1,818.4
1988	1,922.9	200	1,575.7		-	1,922.9		481	2,056.7
1989	2,039.3	-	1,575.7		-	2,039.3		510	2,085.7
1990	2,152.9	-	1,575.7		.1	2,152.8		538	2,113.7
1991	2,244.2	-	1,575.7		.2	2,244.0		561	2,136.7
1992	2,383.8	-	1,575.7		.3	2,383.5		596	2,171.7
1993	2,504.9	-	1,575.7		10.8	2,494.1		627	2,202.7
1994	2,639.9	225	2,029.9			725.7	1,914.2	564	2,593.9
1995	2,790.8	-	2,029.9			911.2	1,879.6	604	2,633.9
1996	2,933.2	-	2,029.9			1,005.6	1,927.6	637	2,666.9
1997	3,063.6	-	2,029.9			1,158.5	1,905.1	671	2,700.9
1998	3,198.6	-	2,029.9			1,288.8	1,909.8	704	2,733.9
1999	3,370.9	-	2,029.9			1,442.4	1,928.5	746	2,775.9
2000	3,594.3	250	2,118.3			161.0	3,433.3	727	2,845.3
2001	3,724.8	-	2,118.3			217.6	3,507.2	756	2,874.3
2002	3,925.0	-	2,118.3			290.1	3,634.9	800	2,918.3
2003	4,134.5	-	2,118.3			458.4	3,676.1	850	2,968.3
2004	4,330.0	-	2,118.3			550.6	3,779.4	894	3,012.3
2005	4,545.1	-	2,118.3			722.6	3,822.5	945	3,063.3
2006	4,711.8	250	2,335.6			40.6	4,671.2	944	3,279.6
2007	4,940.0	-	2,335.6			76.7	4,863.3	992	3,327.6
2008	5,154.1	-	2,335.6			115.0	5,039.1	1,037	3,372.6
2009	5,382.3	-	2,335.6			181.6	5,200.7	1,086	3,421.6
2010	5,661.2	-	2,335.6			316.3	5,344.9	1,148	3,483.6

YEAR	CASE II - SEPARATE SYSTEM (LOWER KEYS)								
	TOTAL ENERGY 10^6 KWHR	NEW UNITS MWe	LABOR* $1,000	MAINTENANCE MATERIALS AND OPERATING SUPPLIES					TOTAL-LABOR MATERIALS AND SUPPLIES $1,000
				10^6 KWHR AT .45 MILLS/KWHR	10^6 KWHR AT .33 MILLS/KWHR	10^6 KWHR AT .25 MILLS/KWHR	10^6 KWHR AT .20 MILLS/KWHR	TOTAL $1,000	
1966	196.5	25	292.2	196.5				88	380.2
1967	218.8	-	292.2	218.8				98	390.2
1968	244.4	25	327.8	244.4				110	437.8
1969	270.0	-	327.8	270.0				122	449.8
1970	294.7	-	327.8	294.7				133	460.8
1971	325.9	-	327.8	325.9				147	474.8
1972	358.5	25	456.0	358.5				161	617.0
1973	391.1	-	456.0	391.1				176	632.0
1974	428.3	-	456.0	428.3				193	649.0
1975	465.6	50	856.9	62.4	403.2			161	1,017.9
1976	488.9	-	856.9	81.1	407.8			171	1,027.9
1977	521.4	-	856.9	109.7	411.7			185	1,041.9
1978	558.7	-	856.9	194.4	364.3			208	1,064.9
1979	586.7	50	962.7	3.5	583.2			194	1,156.7
1980	614.6	-	962.7	5.3	609.3			203	1,165.7
1981	651.8	-	962.7	6.7	645.1			216	1,178.7
1982	689.1	-	962.7	13.6	675.5			229	1,191.7
1983	721.7	-	962.7	21.7	700.0			241	1,203.7
1984	749.6	-	962.7	32.2	717.4			251	1,213.7
1985	791.5	-	962.7	47.6	743.9			267	1,433.8
1986	838.1	75	1,166.8	0.1	838.0			277	1,443.8
1987	884.6	-	1,166.8	0.1	884.5			292	1,458.8
1988	931.2	-	1,166.8	0.8	930.4			307	1,473.8
1989	977.7	-	1,166.8	5.0	972.7			323	1,489.8
1990	1,024.3	-	1,166.8	7.0	1,017.3			339	1,505.8
1991	1,070.9	75	1,271.8	-	1,070.9			353	1,624.8
1992	1,117.4	-	1,271.8	-	1,117.4			369	1,640.8
1993	1,164.0	-	1,271.8	-	1,164.0			384	1,655.8
1994	1,219.8	-	1,271.8	0.1	1,219.7			403	1,674.8
1995	1,285.1	-	1,271.8	0.2	1,284.9			424	1,695.8
1996	1,350.2	-	1,271.8	3.5	1,346.7			446	1,717.8
1997	1,396.8	-	1,271.8	6.0	1,390.8			462	1,733.8
1998	1,489.9	100	1,726.0	-	609.3	880.6		421	2,147.0
1999	1,536.5	-	1,726.0	-	673.2	863.3		438	2,164.0
2000	1,629.5	-	1,726.0	-	770.0	859.5		469	2,195.0
2001	1,676.2	-	1,726.0	0.1	820.8	855.3		485	2,211.0
2002	1,769.3	100	1,814.4	-	196.3	1,573.0		458	2,272.4
2003	1,862.4	-	1,814.4	-	256.0	1,606.4		486	2,300.4
2004	1,955.5	-	1,814.4	-	342.7	1,612.8		516	2,330.4
2005	2,048.6	-	1,814.4	-	403.1	1,645.5		544	2,358.4
2006	2,141.7	-	1,814.4	0.1	502.3	1,639.3		576	2,390.4
2007	2,234.9	100	2,031.7	-	88.5	2,146.4		566	2,597.7
2008	2,327.9	-	2,031.7	-	128.3	2,199.6		592	2,623.7
2009	2,421.1	-	2,031.7	-	160.2	2,260.9		618	2,649.7
2010	2,560.8	-	2,031.7	-	255.2	2,305.6		661	2,692.7

YEAR	CASE II - SEPARATE SYSTEM (UPPER KEYS)								
	TOTAL ENERGY 10^6 KWHR	NEW UNITS	LABOR* $1,000	MAINTENANCE MATERIALS AND OPERATING SUPPLIES					TOTAL-LABOR MATERIALS AND SUPPLIES $1,000
				10^6 KWHR AT .45 MILLS/KWHR	10^6 KWHR AT .33 MILLS/KWHR	10^6 KWHR AT .25 MILLS/KWHR	10^6 KWHR AT .20 MILLS/KWHR	TOTAL $1,000	
1966	122.9	25	292.2	122.9				55	347.2
1967	140.6	25	327.8	140.6				63	390.8
1968	158.3	-	327.8	158.3				71	398.8
1969	178.8	25	456.0	178.8				80	536.0
1970	199.3	-	456.0	199.3				90	546.0
1971	225.4	-	456.0	225.4				101	557.0
1972	251.0	-	456.0	251.0				113	569.0
1973	279.4	-	456.0	279.4				126	582.0
1974	310.6	50	856.9	1.9	308.7			103	959.9
1975	346.9	-	856.9	8.3	338.6			115	971.9
1976	381.8	-	856.9	19.7	362.1			128	984.9
1977	414.4	50	962.7	-	414.4			137	1,099.7
1978	456.3	-	962.7	-	456.3			151	1,113.7
1979	493.5	-	962.7	0.1	493.4			163	1,125.7
1980	554.5	-	962.7	0.5	554.0			183	1,145.7
1981	582.0	-	962.7	1.0	581.0			192	1,154.7
1982	628.5	-	962.7	3.8	624.7			208	1,170.7
1983	689.1	75	1,166.8	91.8	597.3			238	1,404.8
1984	749.6	-	1,166.8	-	749.6			247	1,413.8
1985	810.6	-	1,166.8	-	810.6			267	1,433.8
1986	879.9	75	1,271.8	-	879.9			290	1,561.8
1987	935.9	-	1,271.8	-	935.9			309	1,580.8
1988	991.7	-	1,271.8	-	991.7			327	1,598.8
1989	1,061.6	-	1,271.8	-	1,061.6			350	1,621.8
1990	1,128.6	-	1,271.8	-	1,128.6			372	1,643.8
1991	1,173.3	-	1,271.8	0.1	1,173.2			387	1,658.8
1992	1,266.4	100	1,726.0		415.7	850.7		350	2,076.0
1993	1,340.9	-	1,726.0		482.7	858.2		374	2,100.0
1994	1,420.1	-	1,726.0		557.6	862.5		400	2,126.0
1995	1,505.7	-	1,726.0		670.1	835.6		430	2,156.0
1996	1,583.0	125	1,814.4		35.4	1,547.6		399	2,213.4
1997	1,666.8	-	1,814.4		70.2	1,596.6		422	2,236.4
1998	1,708.7	-	1,814.4		82.2	1,626.5		434	2,248.4
1999	1,834.4	-	1,814.4		129.3	1,705.1		469	2,283.4
2000	1,964.8	-	1,814.4		177.4	1,787.4		505	2,319.4
2001	2,048.6	125	2,031.7		8.8	2,039.8		513	2,544.7
2002	2,155.7	-	2,031.7		18.5	2,137.2		540	2,571.7
2003	2,272.1	-	2,031.7		25.4	2,246.7		570	2,601.7
2004	2,374.5	-	2,031.7		32.7	2,341.8		596	2,627.7
2005	2,496.5	-	2,031.7		75.3	2,421.2		630	2,661.7
2006	2,570.1	-	2,031.7		75.6	2,494.5		649	2,680.7
2007	2,705.1	125	2,123.5		4.6	2,700.5		677	2,800.5
2008	2,826.2	-	2,123.5		12.1	2,814.1		708	2,831.5
2009	2,961.2	-	2,123.5		17.9	2,943.3		742	2,865.5
2010	3,100.4	-	2,123.5		34.9	3,065.5		778	2,901.5

* Includes Fringe Benefits and Administrative and General Expenses

BURNS AND ROE, INC./REYNOLDS, SMITH AND HILLS was arrived at after due consideration of the operating and maintenance costs in the area. Allowances were made for the high incidence of salt-water corrosion, wind and storm damage, etc.

E. Economic Comparisons

The economic comparisons for the study of power plant size and location are summarized on Exhibit IV-2, pages IV-3-4. On these exhibits the present worth of the total annual costs for the years from 1966 to 2010 are shown and, of course, the case having the lowest present worth is the most desirable and recommended. In a study of this sort, the primary interest is in the units to be installed in the early part of the study period. The purpose of considering a relatively long-range period rather than just the first few years is that only under a long-range program can the effects of different unit sizes be properly evaluated. For example, in comparing the installation of the large unit with the installation of a smaller unit, the large unit will have higher fixed charges in the early years. As the years go by, another small unit will be needed to supply the increasing load. This will usually raise the fixed charges in the small unit alternate since the investment costs for small units will be greater than those for large units. Production costs for the large and small units will also vary. Only by extending the alternate growth patterns for a number of years can the effects be properly evaluated.

As mentioned previously, escalation was entirely eliminated due to uncertainties of the future. The effect of adding escalation in this study would probably not have been significant since all cases would be affected and the overall difference caused by escalation would be small.

The results of the study of power plant size and location are as follows:

Case	Description	Financing Agency	Interest Rate	Total Present Worth of Annual Costs
I	Combined System	Municipal	4%	$296,331,000
II	Separate Systems	Municipal	4%	$321,025,000

These results indicate that the most economically favorable course of action for the future supply of electricity in the Florida Keys is to locate a single expandable installation on Sugarloaf Key to supply power to both the Upper and Lower Keys; a comparison of Case I is more favorable by $24,694,000 throughout the study period.

It should be noted that the results shown above are for comparison purposes only. If another method of financing is applied, as, for example, apportioning the power plant costs to both municipal and REA financing, the results would lead to similar conclusions. Exhibits IV-7, page IV-19, and IV-8, page IV-20, were developed for the purpose of separating items such as fuel cost, operation and maintenance, etc., into Lower Keys and Upper Keys components and to enable calculation of present worths for Cases IA and IIA. Case IA is for the combined power system but with financing based on the 4 percent municipal interest rate for the Lower Keys and a 2 percent REA interest rate for the Upper Keys. Capital investments and all production costs have been assigned between the two Keys areas in proportion to their electric loads. Case IIA is for the separate power systems with the respective municipal and REA interest rates applied.

The results of the divided financing study are as follows:

Case	Description	Financing Agency	Interest Rate	Total Present Worth of Annual Costs
IA	Combined System	Lower Keys - Municipal	4%	$153,569,000
		Upper Keys - REA	2%	$227,935,000
			Total	$381,504,000
IIA	Separate Systems	Lower Keys - Municipal	4%	$151,714,000
		Upper Keys - REA	2%	$264,063,000
			Total	$415,777,000

As can be seen from the above tabulation the results again indicate that the combined system for power expansion, with a present worth advantage of $34,273,000, is the most favorable course of action. Finally, if

EXHIBIT IV-7

FEASIBILITY STUDY - FLORIDA KEYS
STUDY OF UNIT SIZE AND LOCATION CASE IA - COMBINED SYSTEMS (UPPER AND LOWER KEYS SEPARATE)
ANNUAL COSTS - $1000. (INTEREST RATES @ 2% AND 4%)

Year	Capital Investments - $1,000				Fixed Charges				Fuel		Loss Penalty		Operation and Maintenance				Totals			Present Worth Factors		Present Worth of Annual Costs - $1,000		
	Generation		Transmission		Generation		Transmission						Generating Plant		Transmission Plant									
	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper and Lower Keys	Upper Keys @ 2%	Lower Keys @ 4%	Upper Keys	Lower Keys	Upper and Lower Keys
1966	3,950	6,253	2,413	3,858	231	446	121	248	571	913	3.5	5.5	195	312	36	58	1,157.5	1,982.5	3,140	.9804	.9615	1,135	1,906	3,041
1967	3,117	4,851	72	113	413	794	125	255	651	1,013	4.7	7.3	245	381	38	59	1,476.7	2,509.3	3,986	.9612	.9246	1,419	2,320	3,739
1968	-	-	35	54	413	794	127	258	733	1,132	5.9	9.1	252	388	39	59	1,569.9	2,640.1	4,210	.9423	.8890	1,479	2,347	3,826
1969	-	-	69	104	413	794	130	265	828	1,250	7.6	11.4	261	394	40	61	1,679.6	2,775.4	4,455	.9238	.8548	1,552	2,372	3,924
1970	-	-	70	103	413	794	134	272	923	1,365	9.7	14.3	270	400	42	61	1,791.7	2,906.3	4,698	.9057	.8219	1,623	2,389	4,012
1971	4,901	7,087	78	112	699	1,301	138	279	986	1,426	13	18	365	528	43	63	2,244	3,615	5,859	.8880	.7903	1,993	2,857	4,850
1972	-	-	78	112	699	1,301	142	286	1,100	1,572	19	26	376	536	45	64	2,381	3,785	6,166	.8706	.7599	2,073	2,876	4,949
1973	-	-	-	-	699	1,301	142	286	1,229	1,720	22	31	388	544	45	64	2,525	3,946	6,471	.8535	.7307	2,155	2,883	5,038
1974	-	-	239	329	699	1,301	154	307	1,371	1,890	27	38	401	554	50	68	2,702	4,158	6,860	.8368	.7026	2,261	2,921	5,182
1975	4,920	6,603	169	228	986	1,844	162	322	1,515	2,033	35	48	463	621	53	71	3,214	4,939	8,153	.8203	.6756	2,636	3,337	5,973
1976	-	-	-	-	986	1,844	162	322	1,667	2,135	43	56	483	620	54	70	3,395	5,047	8,442	.8043	.6496	2,731	3,279	6,010
1977	-	-	820	1,031	986	1,844	203	388	1,810	2,278	52	65	498	626	67	84	3,616	5,285	8,901	.7885	.6246	2,851	3,301	6,152
1978	-	-	869	1,064	986	1,844	247	456	1,995	2,442	31	39	518	633	81	99	3,858	5,513	9,371	.7730	.6006	2,982	3,311	6,293
1979	-	-	82	98	986	1,844	251	463	2,158	2,566	37	45	535	636	84	99	4,051	5,653	9,704	.7579	.5775	3,070	3,265	6,335
1980	7,445	8,255	585	649	1,421	2,435	281	504	2,331	2,584	48	54	751	833	95	106	4,927	6,516	11,443	.7430	.5553	3,661	3,618	7,279
1981	-	-	182	203	1,421	2,435	290	517	2,456	2,750	53	60	759	850	98	109	5,077	6,721	11,798	.7284	.5339	3,698	3,588	7,286
1982	-	-	-	-	1,421	2,435	290	517	2,658	2,914	63	69	781	856	99	108	5,312	6,899	12,211	.7142	.5134	3,794	3,542	7,336
1983	-	-	280	293	1,421	2,435	304	536	2,917	3,055	77	80	813	852	106	110	5,638	7,068	12,706	.7002	.4936	3,948	3,489	7,437
1984	11,550	11,550	143	143	2,096	3,260	311	545	2,982	2,982	93	93	867	867	110	110	6,459	7,857	14,316	.6864	.4746	4,433	3,729	8,162
1985	-	-	-	-	2,096	3,260	311	545	3,233	3,157	109	107	890	869	111	109	6,750	8,047	14,797	.6730	.4564	4,543	3,673	8,216
1986	-	-	1,261	1,201	2,096	3,260	374	622	3,519	3,351	131	125	917	873	132	125	7,169	8,356	15,525	.6598	.4388	4,730	3,667	8,397
1987	-	-	-	-	2,096	3,260	374	622	3,752	3,546	147	140	935	883	132	125	7,436	8,576	16,012	.6468	.4220	4,810	3,619	8,429
1988	15,826	14,860	1,461	1,372	3,020	4,323	448	711	3,882	3,646	107	101	1,060	997	155	145	8,672	9,923	18,595	.6342	.4057	5,500	4,026	9,526
1989	-	-	203	186	3,020	4,323	458	722	4,158	3,829	129	118	1,086	1,000	159	146	9,010	10,138	19,148	.6217	.3901	5,602	3,955	9,557
1990	-	-	-	-	3,020	4,323	458	722	4,418	4,017	145	132	1,108	1,006	160	145	9,309	10,345	19,654	.6095	.3751	5,674	3,880	9,554
1991	-	-	96	87	3,020	4,323	463	728	4,598	4,197	157	144	1,117	1,020	161	147	9,516	10,559	20,075	.5976	.3607	5,688	3,809	9,497
1992	-	-	1,317	1,162	3,020	4,323	529	803	4,967	4,382	186	164	1,154	1,018	183	162	10,039	10,852	20,891	.5859	.3468	5,882	3,763	9,645
1993	-	-	-	-	3,020	4,323	529	803	5,268	4,573	209	182	1,179	1,024	185	160	10,390	11,065	21,455	.5744	.3335	5,968	3,690	9,658
1994	15,531	18,587	2,170	1,864	3,927	5,652	638	922	5,550	4,767	175	151	1,395	1,199	218	188	11,903	12,879	24,782	.5631	.3207	6,703	4,130	10,833
1995	-	-	601	513	3,927	5,652	669	955	5,885	5,023	199	170	1,421	1,213	228	195	12,329	13,208	25,537	.5521	.3083	6,807	4,072	10,879
1996	-	-	223	190	3,761	5,219	680	967	6,187	5,278	221	188	1,439	1,228	232	197	12,520	13,077	25,597	.5412	.2965	6,776	3,877	10,653
1997	-	-	-	-	3,611	4,938	680	967	6,516	5,460	191	160	1,470	1,231	233	196	12,701	12,952	25,653	.5306	.2851	6,739	3,693	10,432
1998	-	-	281	245	3,611	4,938	694	983	6,681	5,825	254	221	1,460	1,274	233	204	12,933	13,445	26,378	.5202	.2741	6,728	3,685	10,413
1999	-	-	-	-	3,611	4,938	694	983	7,175	6,009	297	249	1,511	1,265	238	199	13,526	13,643	27,169	.5100	.2636	6,898	3,596	10,494
2000	20,205	16,758	1,654	1,372	4,791	6,137	777	1,071	7,675	6,365	274	227	1,555	1,290	263	219	15,335	15,309	30,644	.5000	.2534	7,668	3,879	11,547
2001	-	-	1,660	1,358	4,572	5,727	861	1,158	8,003	6,547	299	245	1,580	1,294	290	237	15,605	15,208	30,813	.4902	.2437	7,650	3,706	11,356
2002	-	-	647	531	4,572	5,727	893	1,193	8,421	6,912	330	270	1,603	1,315	299	246	16,118	15,663	31,781	.4806	.2343	7,746	3,670	11,416
2003	-	-	-	-	4,572	5,727	893	1,193	8,877	7,276	367	301	1,631	1,337	300	245	16,640	16,079	32,719	.4712	.2253	7,841	3,623	11,464
2004	-	-	1,060	873	4,572	5,727	947	1,249	9,286	7,647	322	266	1,651	1,361	232	192	17,010	16,442	33,452	.4620	.2166	7,859	3,561	11,420
2005	-	-	603	495	4,352	5,346	977	1,280	9,753	8,007	355	292	1,682	1,381	324	266	17,443	16,572	34,015	.4529	.2083	7,900	3,452	11,352
2006	19,527	16,272	287	240	5,492	6,509	903	874	10,037	8,365	373	310	1,789	1,491	326	272	18,920	17,821	36,741	.4440	.2003	8,400	3,570	11,970
2007	-	-	389	322	5,492	6,509	920	886	10,565	8,728	415	342	1,822	1,506	333	276	19,547	18,247	37,794	.4353	.1926	8,509	3,514	12,023
2008	-	-	-	-	5,492	6,509	919	884	11,009	9,069	454	374	1,850	1,523	334	275	20,058	18,634	38,692	.4268	.1852	8,561	3,451	12,012
2009	-	-	-	-	5,492	6,509	916	862	11,566	9,456	500	408	1,883	1,539	335	274	20,692	19,048	39,740	.4184	.1781	8,658	3,392	12,050
2010	-	-	-	-	5,159	6,032	913	858	12,110	10,003	545	451	1,908	1,576	334	275	20,969	19,195	40,164	.4102	.1712	8,601	3,286	11,887
																					Totals	227,935	153,569	381,504

FEASIBILITY STUDY - FLORIDA KEYS

STUDY OF UNIT SIZE AND LOCATION CASE IIA -SEPARATE SYSTEMS (UPPER AND LOWER KEYS SEPARATE)

ANNUAL COSTS - $1,000 (INTEREST RATES @ 2% AND 4%)

EXHIBIT IV-8

Year	Capital Investments - $1,000				Fixed Charges				Fuel		Loss Penalty		Operation and Maintenance		Operation and Maintenance		Totals			Present Worth Factors		Present Worth of Annual Costs - $1,000		
	Generation		Transmission		Generation		Transmission						Generating Plant		Transmission Plant									
	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper Keys	Lower Keys	Upper and Lower Keys	Upper Keys @ 2%	Lower Keys @ 4%	Upper Keys	Lower Keys	Upper and Lower Keys
1966	6,024	6,246	2,654	1,739	352	447	133	112	605	981	Base	Base	347	380	40	26	1,477	1,946	3,423	.9804	.9615	1,448	1,871	3,319
1967	4,350	-	121	-	606	447	140	112	692	1,107			391	390	42	26	1,871	2,082	3,953	.9612	.9246	1,798	1,925	3,723
1968	-	4,350	-	210	606	758	140	125	779	1,203			399	438	42	29	1,966	2,553	4,519	.9423	.8890	1,853	2,270	4,123
1969	4,350	-	294	-	860	758	154	125	880	1,330			536	450	46	29	2,476	2,692	5,168	.9238	.8548	2,287	2,301	4,588
1970	-	-	173	-	860	758	163	125	981	1,451			546	461	49	29	2,599	2,824	5,423	.9057	.8219	2,354	2,321	4,675
1971	-	-	-	-	860	758	163	125	1,110	1,608			557	475	49	29	2,739	2,995	5,734	.8880	.7903	2,432	2,367	4,799
1972	-	4,350	-	1,192	860	1,069	163	202	1,236	1,765			569	617	49	47	2,877	3,700	6,577	.8706	.7599	2,505	2,812	5,317
1973	-	-	-	-	860	1,069	163	202	1,376	1,926			582	632	49	47	3,030	3,876	6,906	.8535	.7307	2,586	2,832	5,418
1974	8,403	-	475	278	1,351	1,069	187	219	1,439	2,111			960	649	56	51	3,993	4,099	8,092	.8368	.7026	3,341	2,880	6,221
1975	-	8,403	-	393	1,351	1,669	187	245	1,609	2,174			972	1,018	56	57	4,175	5,163	9,338	.8203	.6756	3,425	3,488	6,913
1976	-	-	-	-	1,351	1,669	187	245	1,774	2,288			985	1,028	56	57	4,353	5,287	9,640	.8043	.6496	3,501	3,434	6,935
1977	7,968	-	1,978	59	1,816	1,669	286	249	1,919	2,447			1,100	1,042	85	58	5,206	5,465	10,671	.7885	.6246	4,105	3,413	7,518
1978	-	-	-	-	1,816	1,669	286	249	2,113	2,644			1,114	1,065	85	58	5,414	5,685	11,099	.7730	.6006	4,185	3,414	7,599
1979	-	7,968	-	337	1,816	2,239	286	270	2,285	2,718			1,126	1,157	85	63	5,598	6,447	12,045	.7579	.5775	4,243	3,723	7,966
1980	-	-	-	948	1,816	2,239	286	331	2,568	2,847			1,146	1,166	85	77	5,901	6,660	12,561	.7430	.5553	4,384	3,698	8,082
1981	-	-	385	-	1,816	2,239	306	331	2,695	3,020			1,155	1,179	91	77	6,063	6,846	12,909	.7284	.5339	4,416	3,655	8,071
1982	-	-	-	-	1,816	2,239	306	331	2,911	3,195			1,171	1,192	91	77	6,295	7,034	13,329	.7142	.5134	4,496	3,611	8,107
1983	11,988	-	484	889	2,516	2,239	330	388	3,033	3,348			1,405	1,204	98	91	7,382	7,270	14,652	.7002	.4936	5,169	3,588	8,757
1984	-	-	-	-	2,516	2,239	330	388	3,308	3,480			1,414	1,214	98	91	7,666	7,412	15,078	.6864	.4746	5,262	3,518	8,780
1985	-	-	-	-	2,516	2,239	330	388	3,589	3,679			1,434	1,434	98	91	7,967	7,831	15,798	.6730	.4564	5,362	3,574	8,936
1986	11,523	11,988	1,844	1,090	3,189	3,096	423	458	3,842	3,712			1,562	1,444	126	107	9,142	8,817	17,959	.6598	.4388	6,032	3,869	9,901
1987	-	-	-	-	3,189	3,096	423	458	4,088	3,930			1,581	1,459	126	107	9,407	9,050	18,457	.6468	.4220	6,084	3,819	9,903
1988	-	-	442	-	3,189	3,096	445	458	4,332	4,144			1,599	1,474	133	107	9,698	9,279	18,977	.6342	.4057	6,150	3,764	9,914
1989	-	-	-	389	3,189	3,096	445	483	4,641	4,361			1,622	1,490	133	113	10,030	9,543	19,573	.6217	.3901	6,236	3,723	9,959
1990	15,700	-	-	-	4,106	3,096	445	483	4,940	4,578			1,644	1,506	133	113	11,268	9,776	21,044	.6095	.3751	6,868	3,667	10,535
1991	-	11,523	-	183	4,106	3,920	445	495	5,140	4,682			1,659	1,625	133	116	11,483	10,838	22,321	.5976	.3607	6,862	3,909	10,771
1992	-	-	2,479	-	4,106	3,920	570	495	5,349	4,887			2,076	1,641	170	116	12,271	11,059	23,330	.5859	.3468	7,190	3,835	11,025
1993	-	-	-	-	4,106	3,920	570	495	5,673	5,098			2,100	1,656	170	116	12,619	11,285	23,904	.5744	.3335	7,248	3,764	11,012
1994	-	-	1,597	-	4,106	3,920	650	495	6,019	5,349			2,126	1,675	194	116	13,095	11,555	24,650	.5631	.3207	7,374	3,706	11,080
1995	-	-	-	1,114	4,106	3,920	650	566	6,399	5,642			2,156	1,696	194	132	13,505	11,956	25,461	.5521	.3083	7,456	3,686	11,142
1996	19,375	-	759	-	4,969	3,560	688	566	6,411	5,939			2,213	1,718	205	132	14,486	11,915	26,401	.5412	.2965	7,840	3,533	11,373
1997	-	-	-	-	4,773	3,560	688	566	6,772	6,154			2,236	1,734	205	132	14,674	12,146	26,820	.5306	.2851	7,786	3,463	11,249
1998	-	15,700	-	785	4,773	4,430	688	617	6,947	6,320			2,248	2,147	205	144	14,861	13,658	28,519	.5202	.2741	7,731	3,744	11,475
1999	-	-	-	-	4,579	4,430	688	617	7,477	6,528			2,283	2,164	205	144	15,232	13,883	29,115	.5100	.2636	7,768	3,660	11,428
2000	-	-	565	-	4,579	4,430	717	617	8,031	6,936			2,319	2,195	214	144	15,860	14,322	30,182	.5000	.2534	7,930	3,629	11,559
2001	18,618	-	3,365	-	5,667	4,430	886	617	8,211	7,145			2,545	2,211	264	144	17,573	14,547	32,120	.4902	.2437	8,614	3,545	12,159
2002	-	14,904	-	1,437	5,667	5,245	886	709	8,650	7,392			2,572	2,272	264	166	18,039	15,784	33,823	.4806	.2343	8,670	3,698	12,368
2003	-	-	-	-	5,067	5,245	886	709	9,127	7,792			2,602	2,300	264	166	18,546	16,212	34,758	.4712	.2253	8,739	3,653	12,392
2004	-	-	-	-	5,291	5,245	886	709	9,547	8,198			2,628	2,330	264	166	18,616	16,648	35,264	.4620	.2166	8,601	3,606	12,207
2005	-	-	-	1,098	5,291	4,759	886	779	10,063	8,598			2,662	2,358	264	182	19,166	16,676	35,842	.4529	.2083	8,680	3,474	12,154
2006	-	-	-	-	5,291	4,759	789	692	10,363	9,008			2,681	2,390	264	182	19,388	17,031	36,419	.4440	.2003	8,608	3,411	12,019
2007	18,618	14,904	927	389	6,016	5,825	831	717	10,815	9,303			2,801	2,598	278	188	20,741	18,631	39,372	.4353	.1926	9,029	3,588	12,617
2008	-	-	-	-	6,016	5,825	831	706	11,307	9,698			2,832	2,624	278	188	21,264	19,041	40,305	.4268	.1852	9,075	3,526	12,601
2009	-	-	-	-	6,016	5,364	820	706	11,855	10,093			2,866	2,650	278	188	21,835	19,001	40,836	.4184	.1781	9,136	3,384	12,520
2010	-	-	-	-	6,016	5,364	814	706	12,428	10,695			2,902	2,693	278	188	22,438	19,646	42,084	.4102	.1712	9,204	3,363	12,567
																					Total	264,063	151,714	415,777

BURNS AND ROE, INC./REYNOLDS, SMITH AND HILLS entirely different interest rates were applied, the magnitudes of the present worth values would be different but the study conclusions would remain the same.

The first unit to be built at the recommended expandable plant should have a net capacity of 50 MWe.

Although the above results show a decided economic advantage in meeting future power requirements in the Florida Keys with a single-expanding power plant installation, designed to supply power to both the Upper and Lower Keys, it is recognized that the two utilities involved may not deem it desirable to commit themselves to combined operations up to the year 2010. Irrespective of this possibility the installation of a first 50-MWe unit for combined needs without further commitments, rather than two 25-MWe separate units, still retains the lowest cost and has greater economic merit. An examination of Exhibit VI-2, page VI-3, yields the following cost information demonstrating this conclusion.

Description	Capital Investments, $1,000	Total Annual Costs*, $1,000
A. Initial installation of one 50-MWe plant plus transmission systems (including intertie) designed to meet combined Upper and Lower Keys power requirements in 1966.	Generation......10,203	
	Transmission.... 6,271	
	Total.....16,474	3,227
B. Initial installation of two 25-MWe plants plus transmission systems (no intertie) designed to meet separate power requirements in Upper and Lower Keys in 1966.	1. Upper	
	Generation...... 6,024	
	Transmission.... 2,654	
	Total..... 8,678	1,477
	2. Lower	
	Generation...... 6,246	
	Transmission.... 1,739	1,946
	Total..... 7,985	
	Grand Total.....16,663	Total..3,423

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* Including fixed charges based on 4 percent interest, fuel and operation and maintenance costs.

As can be seen from the above tabulation an initial unit for the combined systems is more favorable than single units by \$189,000 in first costs and \$196,000 in annual costs. Doubtless many details would require resolution before a combined system is acceptable to all agencies concerned. One possible arrangement would be for the City of Key West Electric System to own and operate the 50-MWe power plant with the Florida Keys Electric Cooperative Association agreeing to buy a block of 25-MWe at a cost which would assure no loss or gain to either utility.

V. EVALUATION OF NUCLEAR REACTOR PROPOSALS

A. Costs

1. Equipment

The contract with the United States Atomic Energy Commission required that Burns and Roe, Inc. "obtain information on boiling- and pressurized-water reactor systems in approximate size range needed to meet the requirements. While systems may be either direct or indirect cycle with respect to the turbine, they must be indirect with respect to the brine heater, i.e., primary reactor coolant must not come into contact with the brine heater."

To this end, inquiries were sent to companies with experience in the design and construction of pressurized- and boiling-water reactors. Replies containing data on design features, equipment costs, fuel costs and operation and maintenance costs were received from five reactor manufacturers. These data covered the range of power levels between 120 and 260 thermal megawatts. Design features of the submittals are described in Section V-B.

It was requested that manufacturers' quotations on the nuclear island or nuclear package be equivalent to costs which the manufacturer would guarantee to a purchaser for a complete reactor facility. The analysis made in Exhibit V-1, page V-2, shows that all submittals except these made by Vendor E, and Vendor A were substantially complete with respect to coverage. To put the Vendor E prices on a basis equivalent to those of the other vendors would require an additional $5,978,000. Similarly, the Vendor A prices required an increase of $625,000. The Vendor C price was increased by $78,000 and the Vendor D price increase was $50,000. The increase in the Vendor B price was $75,000.

To meet criteria included in the contract, and already noted, the cost of process steam generators must be added to the boiling-water reactor costs proposed by Vendor C and Vendor E. This offsets to some extent the advantage that comes from a direct cycle. These added costs are included in the increases noted above.

EXHIBIT V-1

NUCLEAR ISLAND INVESTMENT COST

PROPOSAL COMPLETENESS

	Item	C	A	B	E	D
	Vendor					
1.	Major Equipment	x	x	x	x	x
2.	Minor Equipment	x	x	x	N.I.C.	x
3.	Equipment Installation	x	x	x	N.I.C.	x
4.	Nuclear Island Buildings	x	x	x	N.I.C.	x
5.	Containment	x	x	x	N.I.C.	x
6.	Spent Fuel	x	x	x	N.I.C.	x
7.	Auxiliary	x	x	x	N.I.C.	x
8.	Foundations	x	x	x	N.I.C.	x
9.	Stack	x	N.I.C.	N.I.C.	N.I.C.	x
10.	Core Procurement Specifications	N.I.C.	x	x	-	x
11.	Control Rods	x	x	x	x	x
12.	Design of Facility	x	N.I.C.	x	N.I.C.	x
13.	Design Coordination for Electricity and Desalination	x	x	x	x	x
14.	Design Assistance - Hazards Report	N.I.C.	x	x	x	x
15.	Assistance in Training	N.I.C.	x	x	x	N.I.C.
16.	Field Representatives during Installation and Startup	x	x	x	x	x
17.	Equipment Installation and Operating Manuals	x	x	x	x	x
18.	Appearing at Licensing Meetings	N.I.C.	x	x	N.I.C.	x
19.	Steam Piping inside Containment	x	x	x	N.I.C.	x
20.	Intermediate HX for Desalination	N.I.C.	N.A.	N.A.	N.I.C.	N.A.

---

x = In investment cost

N.I.C. = Not in investment cost

N.A. = Not applicable

Inclusion of these factors resulted in the normalized quotations plotted in Exhibit V-2, page V-4. This shows the Vendor A investment cost as the lowest over the range of power levels applicable to this study.

2. Fuel

Fuel costs fall into two categories: first-core costs and equilibrium fuel cycle costs. First-core costs are a major item in calculating the interest on the working capital, an item which is a small portion of the total power cost. The first-core costs submitted by the various reactor manufacturers are plotted in Exhibit V-3, page V-5. Only the Vendor A first-core cost was checked since this vendor had the lowest investment costs. Vendor A quoted a cost of $148.50/kgU as compared to a calculated fabrication cost of $151.71/kgU given in Exhibit V-5, page V-7. Considering the good agreement shown by this comparison and the small effect of first-core cost variations on power costs, no further checks were made and the vendors' prices were taken at face value.

Equilibrium fuel cycle costs obtained from the reactor manufacturers making submittals for this project are plotted in Exhibit V-4, page V-6, Examination of the exhibit shows that Vendor A, B and E submitted costs which were close together, indicating that they are reasonable. As further verification of the validity of these costs the lowest fuel cost, which was the one submitted by Vendor A, was checked for the design producing 412 psia steam. The procedure used was identical to that given in TID-7025, "Guide to Nuclear Power Evaluation, Volume 4." Parameters used there were the same as those in TID-7025 except that the plutonium credit was changed to $10 per fissile gram and that processing plant cost was set at $24,000 per day. The latter was based on estimated charges for processing fuel in 1968 in the Nuclear Fuel Services plant now under construction. The required physics data are in the Vendor A submittal. This shows the core to be a three-region shuffle core. Since Region 1 consists of only one element, while each of the other regions consists of 18 elements, it was considered as a two-region core to simplify the cost analysis. The complete calculation is shown on Exhibit V-5. It shows a unit cost of 24.3 cents/million Btu as compared

EXHIBIT V-2

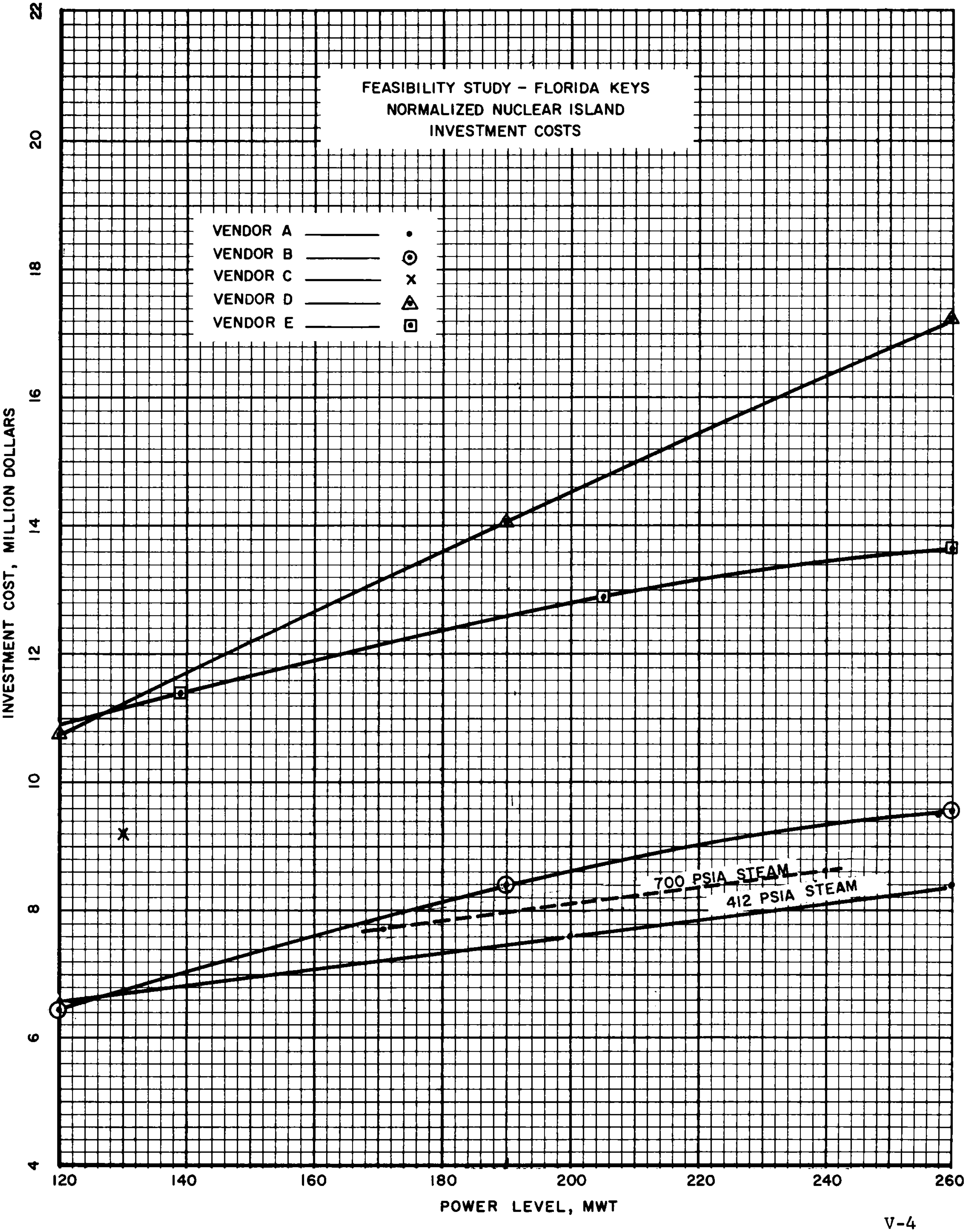
FEASIBILITY STUDY - FLORIDA KEYS
NORMALIZED NUCLEAR ISLAND
INVESTMENT COSTS
VENDOR A •
VENDOR B ⊙
VENDOR C ×
VENDOR D △
VENDOR E ⊡
700 PSIA STEAM
412 PSIA STEAM
INVESTMENT COST, MILLION DOLLARS
4
6
8
10
12
14
16
18
20
22
120
140
160
180
200
220
240
260
POWER LEVEL, MWT

EXHIBIT V-3

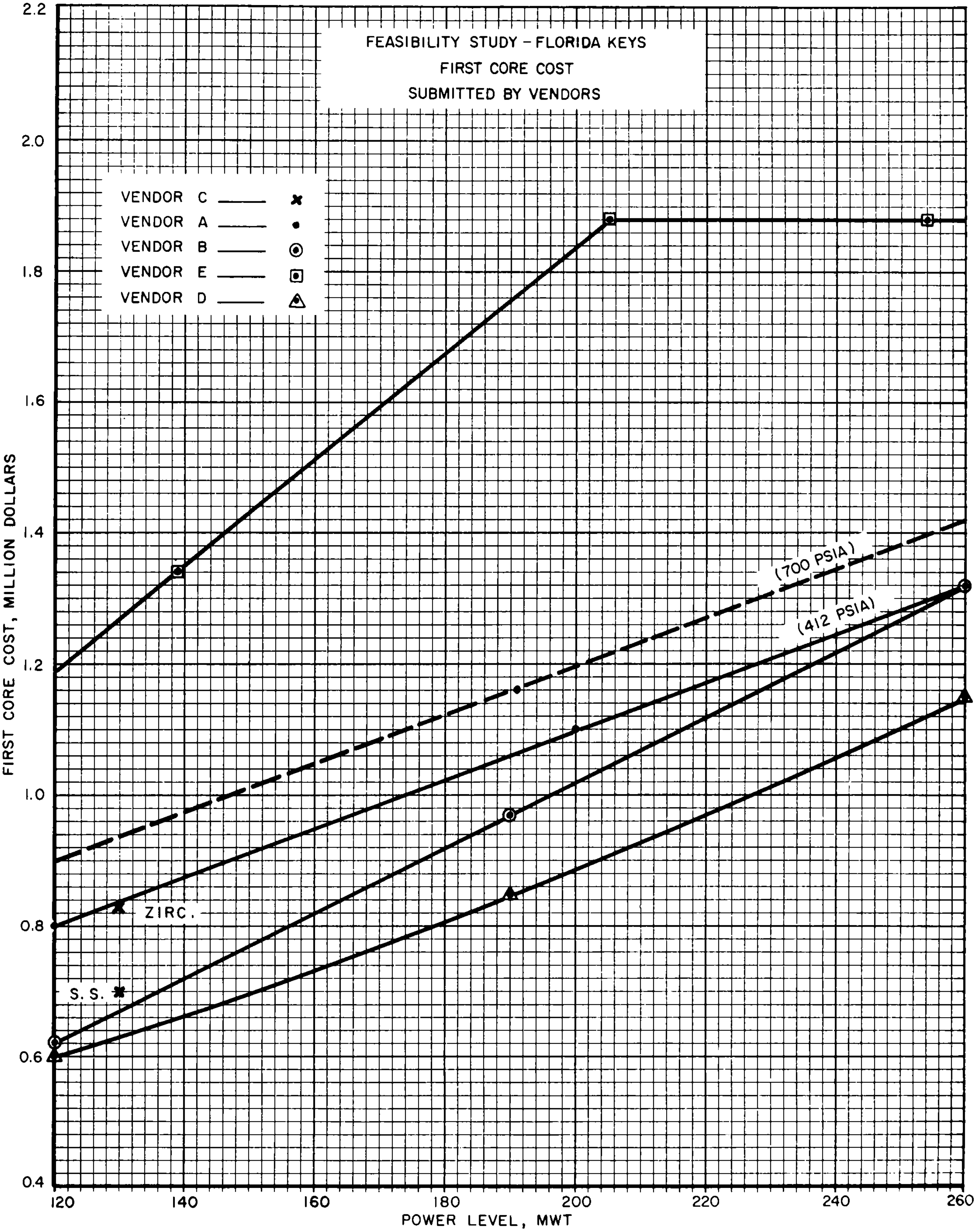
FEASIBILITY STUDY - FLORIDA KEYS
FIRST CORE COST
SUBMITTED BY VENDORS
VENDOR C
VENDOR A
VENDOR B
VENDOR E
VENDOR D
(700 PSIA)
(412 PSIA)
ZIRC.
S. S.
FIRST CORE COST, MILLION DOLLARS
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
120
140
160
180
200
220
240
260
POWER LEVEL, MWT

EXHIBIT V-4

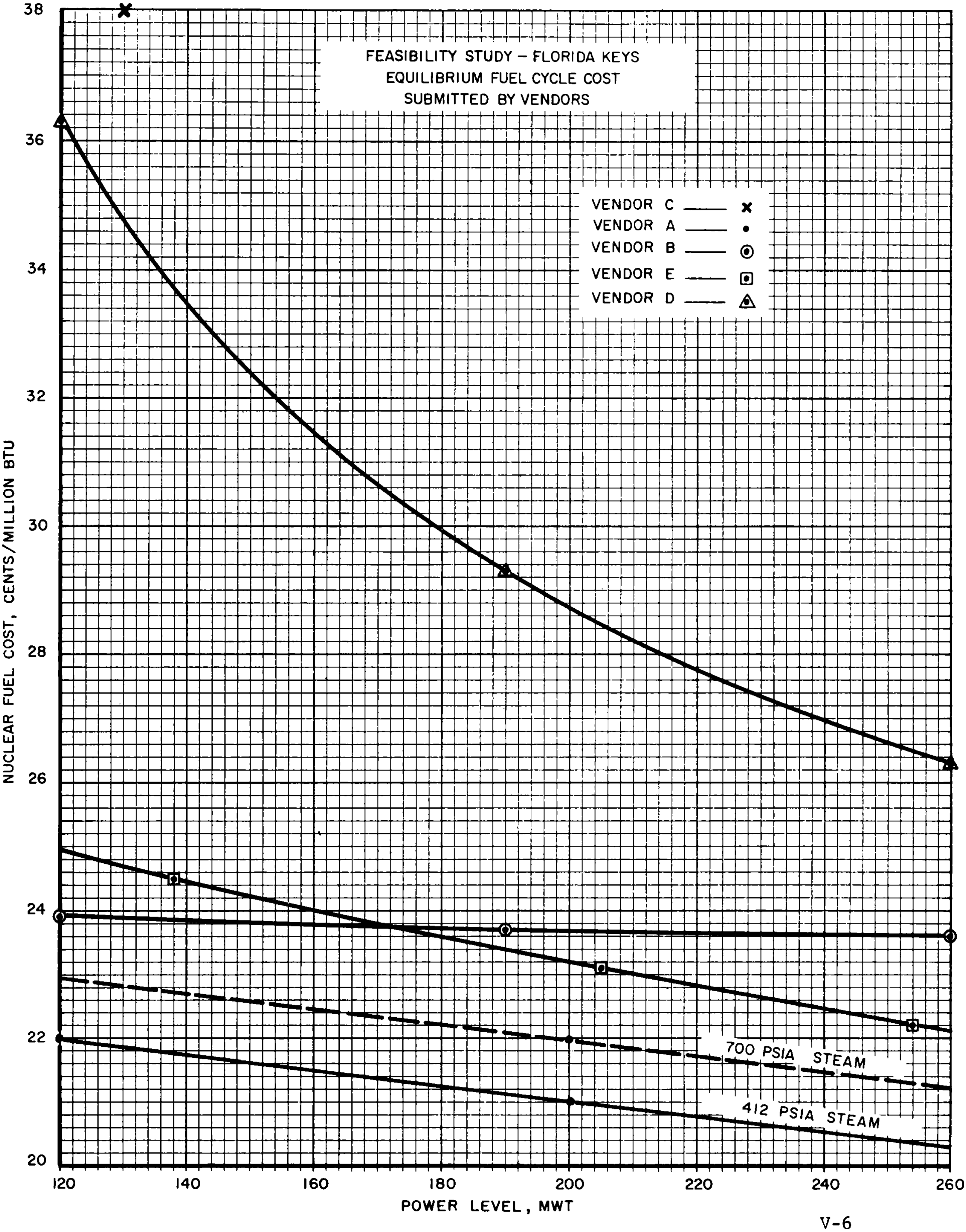
FEASIBILITY STUDY - FLORIDA KEYS
EQUILIBRIUM FUEL CYCLE COST
SUBMITTED BY VENDORS
VENDOR C ✕
VENDOR A ●
VENDOR B ◎
VENDOR E ▣
VENDOR D △
700 PSIA STEAM
412 PSIA STEAM
NUCLEAR FUEL COST, CENTS/MILLION BTU
38
36
34
32
30
28
26
24
22
20
120
140
160
180
200
220
240
260
POWER LEVEL, MWT

EXHIBIT V-5
Sheet 1 of 7

FEASIBILITY STUDY - FLORIDA KEYS

NUCLEAR FUEL COST - VENDOR A EQUILIBRIUM CYCLE

FUEL COST DATA

I. Design Parameters

1. Fuel composition	UO_2, 0.420" pins
2. Cladding material	Zircalloy
3. Fuel enrichment when charged to reactor	3.97%
4. Fuel enrichment when discharged from reactor	1.65%
5. Average fuel exposure	24,000 MWD/MTUO$_2$
6. Plutonium in discharged fuel (fissile content)	5.76 g/kgU (1)
7. Rated gross power level	200 MWt
8. Rated net power level	50 MWe
9. Reactor fuel loading, initial	7.7118 MTU
10. Total fuel discharged per initial fuel loading	7.4330 MTU
11. Description of fuel management program	Two zone, out -in

II. Operating Parameters, Set by Industry

1. Predicted plant operating factor	80%
2. Shipping time, AEC to fabricator	20 days
3. Shipping time, fabricator to reactor	20 days
4. Shipping time, recycle scrap to AEC	20 days
5. Shipping time, reactor to chemical processing site	20 days
6. Conversion and fabrication plant throughput rate	4.0 MTU/month
7. Time interval between delivery of fuel batch to reactor site and charging to reactor	30 days
8. Spare fuel maintained on hand at all times, exclusive of discrete charging batches (10% annual throughput)	0.24 MTU
9. Batch size charged to reactor per refueling	3855.9 kg U
10. Batch size discharged from reactor per refueling	3716.5 kg U
11. Number of discharge batches accumulated for chemical processing campaign	One
12. Irrecoverable losses during conversion of UF_6 to UO_2	1.0% (2)
13. Irrecoverable losses during fabrication	1.0% (2)
14. Conversion and fabrication, recycle to AEC	10.0% (2)

EXHIBIT V-5
Sheet 2 of 7

15. Minimum decay period for irradiated fuel	120 days	
16. Irrecoverable loss during chemical separation, U.	1.0%	(3)
17. Irrecoverable loss during chemical separation, Pu.	1.0%	(3)
18. Irrecoverable loss during conversion, U.	0.3%	(4)
19. Chemical separation plant processing rate	0.88 MTU/day	

III. Economic Parameters, Set by Industry

1. Conversion and fabrication processing cost (exclude shipping, use charges and losses)	137.50 $/kgU	
2. Shipping charge, AEC to fabricator	1.50 $/kgU	(5)
3. Shipping charge, fabricator to reactor	1.50 $/kgU	(5)
4. Shipping charge, reactor to chemical processing site	16.00 $/kgU	(5)
5. Separations plant daily charge	24,000 $	(6)

IV. Economic Parameters Set by AEC

1. Use charge rate	4.75% /yr	
2. Uranium price at enrichment prior to irradiation (as UF_6)	362.42 $/kgU	
3. Uranium price at discharge enrichment (as UF_6)	110.40 $/kgU	
4. Conversion charge, UNH to UF_6	5.60 $/kgU	(7)
5. Pu price (credit)	10.00 $/g	(8)
6. Shipping charge, chemical process site to AEC receiving plants (U and Pu)	1.00 $/kgU	(9)

Footnotes

(1) Per kg U discharged

(2) Percentage of finished product from fabrication

(3) Percentage of weight fed to separation

(4) Percentage of weight fed to conversion

(5) Cost per kg U shipped

(6) Estimated NFS charges for 1968

(7) Cost per kg U fed to conversion

(8) Delivered to AEC as aqueous nitrate solution. Fissile content of plutonium is Pu-239 + Pu-241

(9) Cost per kg U shipped, includes charge for shipping Pu

EXHIBIT V-5
Sheet 3 of 7

1. FABRICATION

a. Processing

(1) Conversion and Fabrication

Quantity: 1.00 kgU/kgU charged

Unit Charges:

Conversion: Figure 450-1

$$7 \frac{\$}{\text{lb } UO_2} \times \frac{270 \text{ lb } UO_2}{238 \text{ lb U}} \times \frac{1 \text{ lb U}}{0.4536} = 17.50 \ \$/\text{kgU}$$

Fabrication: Figure 450-6

120 $/kgU

Conversion and Fabrication $137.50/kgU charged

b. Shipping

(1) Transit to Conversion Site and to Fabricator

Quantity: 1.00 (1 + .01 + 0.01 + 0.10) = 1.12 kgU/kgU charged

Unit Charge: $1.50/kgU

$$\text{Shipping: } 1.12 \frac{\text{kgU}}{\text{kgU charged}} \times 1.50 \frac{\$}{\text{kgU}} = \$1.68 \ \$/\text{kgU charged}$$

(2) Transit to Reactor and Recycle Scrap to AEC

Quantity: 1.10 kgU/kgU charged

Unit Charge: $1.50/kgU

Shipping: 1.10 x 1.50 = 1.65 $/kgU charged

c. Use Charges

(1) Transit to Conversion Site and to Fabricator

Quantity: 1.12 kgU/kgU charged

Time: 20 days

Unit Price: 362.42 $/kgU

$$\text{Use Charge: } 1.12 \times 0.0475 \times 362.42 \times \frac{20}{365} = 1.06 \ \$/\text{kgU charged}$$

(2) In Conversion and Fabrication

Quantity (Average) = 1.12 kg/kgU charged

Time:3.86 MTU x 30 days/4.0 MTU = 29.0 days

$$\text{Use Charge: } 1.12 \times 0.0475 \times 362.42 \times \frac{29.0}{365} = 1.53 \ \$/\text{kgU charged}$$

(3) Transit to Reactor and Recycle Scrap Transit

Quantity: 1.10 kgU/kgU charged

Time: 20 days

Unit Price: 362.42 \$/kgU

Use Charge: $1.10 \times 0.0475 \times 362.42 \times \frac{20}{365} = 1.04$ \$/kgU charged

d. Uranium Losses

(1) Conversion and Fabrication

Quantity Lost: 0.02 kgU/kgU charged

Unit Price: 362.42 \$/kgU

Loss: $.02 \times 362.42 = 7.25$ \$/kgU charged

2. CHARGES INCURRED AT REACTOR

a. Processing Charges: none

b. Shipping Charges: none

c. Use Charges

(1) Delivery of Charging Batch Prior to Charging

Quantity: 1 kgU/kgU charged

Time: 30 days

Unit Price: 362.42 \$/kgU

Use Charge: $1 \times .0475 \times 362.42 \times \frac{30}{365} = 1.42$ \$/kgU charged

(2) Spare Fuel Inventory

Quantity: $\frac{0.24 \text{ kgU}}{7.71 \text{ kgU charged}}$

Time: $\frac{24{,}000 \text{ MWD/MTU}}{0.80 \times 200 \text{ MWt}/ 7.71 \text{ MTU}} = 1156$ days (Vendor A quoted 1080 days)

Unit Price: 362.42 \$/kgU

Use Charge: $\frac{0.24}{7.71} \times 0.0475 \times 362.42 \times \frac{1156}{365} = 1.70$ \$/kgU charged

Total Use Charge = 3.12 \$/kgU charged

(3) Irradiation Inventory

Quantity 1 kgU/kgU charged

Time: 1156 days

Unit Price: $1/2\ (362.42 + \frac{7.43}{7.71} \times 110.40) = 234.40$ \$/kgU

Use Charge: $1 \times 0.0475 \times 234.40 \times \frac{1156}{365} = 35.26$ \$/kgU charged

EXHIBIT V-5
Sheet 5 of 7

(4) Decay Storage

Quantity: $\frac{7.43}{7.71} = 0.964$ kgU/kgU charged

Time: 120 days

Unit Price: 110.40 $/kgU

Use Charge: $0.964 \times 0.0475 \times 110.40 \times \frac{120}{365} = 1.66$ $/kgU charged

d. <u>U 235 Consumption</u>

(1) Uranium Consumed

Initial Quantity: 1 kgU/kgU charged

Unit Value: 362.42 $/kgU charged

Discharged Quantity: 0.964 kgU/kgU charged

Unit Value: 0.964 x 110.40= 106.43 $/kgU charged

Depletion Charge: 362.42 - 106.43 = 255.99 $/kgu charged

e. <u>Pu Consumption or Production</u>

Quantity: 5.76 g Pu/kgU x 0.964 kgU/kgU charged =
5.55 g Pu/kgU charged

Unit Price: 10.00 $/g Pu

Credit: 5.55 x 10 = 55.50 $/kgU charged

3. <u>Charges Incurred in Chemical Processing</u>

a. <u>Separation</u>

Quantity: 0.964 kgU/kgU charged

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 24{,}000 \frac{\$}{\text{day}} \times \frac{2 \times \dfrac{3.767 \text{ MTU}}{0.88 \text{ MTU/day}}}{3.767 \times 10^3 \text{ kg}} = 52.58 \text{ \$/kgU charged}$$

b. <u>Conversion</u>

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times .99 \times 5.60 \text{ \$/kgU} = \$5.34/\text{kgU}$$

c. <u>Conversion Pu</u>

$$0.964 \times .99 \frac{\text{kgU}}{\text{kgU charged}} \times 5.76 \text{ g Pu/kgU} \times 1.50 \text{ \$/g Pu} =$$

$8.24/kgU charged

d. <u>Shipping Charges</u>

(1) Transit to Processing Site

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 16.00 \text{ \$/kgU} = 15.42 \text{ \$/kgU charged}$$

EXHIBIT V-5
Sheet 6 of 7

(2) Transit U and Pu to AEC

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times .99 \times .997 \times 1.00 \ \$/\text{kgU} =$$

$$\$0.95/\text{kgU charged}$$

e. Use Charges

(1) Transit to Processing Site

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 110.47 \frac{\$}{\text{kgU}} \times 0.0475 \times \frac{20}{365} =$$

$$\$0.28/\text{kgU charged}$$

(2) Chemical Separation

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 110.47 \frac{\$}{\text{kgU}} \times \frac{0.0475}{365 \text{ day}} \times \left(\frac{3.72 \text{ MTU}}{0.88 \text{ MTU/day}} + 30\right) =$$

$$\$0.47/\text{kgU charged}$$

(3) Conversion

$$0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 110.47 \frac{\$}{\text{kgU}} \times \frac{0.0475}{365 \text{ day}} \times \left(\frac{.99 \times 3.72}{1} + 5\right) =$$

$$\$.12/\text{kgU charged}$$

(4) Transit to AEC Included in Separation and Conversion

f. Uranium

(1) Separations

$$0.01 \times 0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 110.40 \ \$/\text{kgU} = \$1.06/\text{kgU charged}$$

(2) Conversion

$$.003 \times 0.99 \times 0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 110.40\$/\text{kgU} = \$0.32/\text{kgU charged}$$

g. Plutonium Losses

Separation

$$.01 \times 0.964 \frac{\text{kgU}}{\text{kgU charged}} \times 5.55 \text{ g Pu/kgU} \times 10.00\$/\text{gm Pu} =$$

$$\$0.54/\text{kgU charged}$$

Unit Fuel Cost

$$24{,}000 \frac{\text{MWD}}{\text{MTU}} \times \frac{1 \text{ MTU}}{10^3 \text{ kgU}} = 24 \frac{\text{MWD}}{\text{kgU}}$$

$$\frac{24 \text{ hr}}{\text{day}} \times \frac{10^3 \text{ kw}}{\text{mw}} \times \frac{3.413 \times 10^3 \text{ Btu}}{\text{kwhr}} = 81.8 \times 10^6 \frac{\text{Btu}}{\text{MWD}}$$

$$\frac{477.56 \frac{\$}{\text{kgU}} \times 10^2 \ ¢/\$}{24 \frac{\text{MWD}}{\text{kgU}} \times 81.8 \times 10^6 \frac{\text{Btu}}{\text{MWD}}} = 24.33 \frac{¢}{10^6 \text{ Btu}}$$

EXHIBIT V-5
Sheet 7 of 7

UNIT NUCLEAR FUEL COST - VENDOR A EQUILIBRIUM CYCLE SUMMARY

	Vendor A - 200 MWt					
	(a) Pro-cessing	(b) Ship-ping	(c) Use Charge	(d) U Loss or Con-sumption	(e) Pu Loss or Prod-tion	Totals
1.0 FABRICATION						
Transit to Conversion Site (and Fabricator)	-	1.68	1.06	-	-	2.74
Conversion and Fabrication	137.50	-	1.53	7.25	-	146.28
Transit to Reactor and Recycle	-	1.65	1.04	-	-	2.69
Subtotal	137.50	3.33	3.63	7.25	-	151.71
2.0 REACTOR						
Preirradiation Inventory	-	-	3.12	-	-	3.12
Irradiation	-	-	35.26	255.99	(55.50)	235.75
Decay	-	-	1.66	-	-	1.66
Subtotal	-	-	40.04	255.99	(55.50)	240.53
3.0 CHEMICAL PROCESSING						
Transit to Process Site	-	15.42	0.28	-	-	15.70
Separation	52.58	-	0.47	1.06	0.54	54.65
Uranium Conversion	5.34	-	0.12	0.32	-	5.78
Plutonium Conversion	8.24	-	-	-	-	8.24
Transit to Receiving Point	-	0.95	-	-	-	.95
Subtotal	66.16	16.37	0.87	1.38	0.54	85.32
Totals; \$/kgU	203.66	19.70	44.54	264.62	(54.96)	477.56
¢/million Btu					→	24.3

Notes: Costs in $kgU are based on U charged into reactor.
Conversion to ¢/million Btu based on the liberation of 1963 x 10^6 Btu/kgU charged to the reactor.
Values shown in parentheses ( ) are credits for net plutonium production.

to 21.0 cents/million Btu given in the proposal. This is fair agreement considering the preliminary nature of the submittal.

Since physics data were not available for the Vendor A 700 psia case, a detailed check was not possible. Slightly higher costs would be expected, because poorer neutron economy results from a higher proportion of cladding in the core. For a study of this nature, it is difficult to justify designing similar cores in sufficient detail to place a high degree of reliance on the cost differential between them. As a result, the Vendor A fuel cost was set at the calculated value of 24.3 cents/million Btu which is greater than any of the fuel costs quoted by either Vendor A or Vendor B. Fuel costs for other vendors were taken as submitted.

3. Operation, Maintenance and Insurance

Operation and maintenance costs submitted by the reactor manufacturers are tabulated on Exhibit V-6, page V-15. These costs should be chargeable to the reactor portion only. However, they show considerable variation, most likely depending on the manufacturer's interpretation of what is chargeable to the nuclear plant.

To compensate for the variations, operation and maintenance costs were estimated for the combined reactor-power generating plants. The salary and wage portion was obtained by modifying the personnel requirements for the fossil-fuel plant to meet the nuclear plant requirements, and applying a salary schedule with an allowance of 20 percent for fringe benefits. Administrative and general expenses were taken as 14 percent of the salaries and wages portion. An allowance of 0.25 mills per kilowatt-hour was made for maintenance materials and operating supplies. The adjusted operation and maintenance costs are shown on Exhibit V-7, page V-16.

Nuclear insurance requirements for each of the cases studies are shown in Exhibit V-8, page V-17. They were determined on the basis of 10 CFR 140 which requires a coverage of $150 per thermal kilowatt carried privately for third party liability and an additional premium of $30 per thermal megawatt payable to the government for indemnity protection. The

EXHIBIT V-6

FEASIBILITY STUDY - FLORIDA KEYS

NUCLEAR PLANT OPERATION AND MAINTENANCE COSTS SUBMITTED BY VENDORS

Vendor	Power MWt	Annual Cost, Dollars
A	120	300,000
	200	300,000
B	120	310,000
	190	418,000
	260	528,000
C	130	330,000
D	120	155,300
	190	150,200
	260	155,400
E	139	331,000
	205	331,000
	254	331,000

EXHIBIT V-7

FEASIBILITY STUDY - FLORIDA KEYS
COMBINATION ELECTRIC POWER AND WATER DESALINATION PLANT
OPERATING AND MAINTENANCE COST DETERMINATION

SINGLE-UNIT 50-MW PRESSURIZED-WATER NUCLEAR PLANT*

Supervision and Clerical		
Plant Superintendent	1 -	$15,000
Assistant Superintendent	1 -	12,000
Stenographer	1 -	3,500
Clerk-Typist	1 -	3,200
Storekeeper	1 -	4,200
	5 -	$37,700
Operation		
Operations Supervisor (L)	1 -	$11,300
Shift Supervisor (L)	5 @	10,800
Control Operator (L)	4 @	7,600
Assistant Control Operator (L)	4 @	7,300
Turbine Operator	2 @	5,200
Auxiliary Equipment Operator	2 @	5,000
Engineer-in-Training	1 @	5,500
Relief Operator	2 @	5,200
	21 -	$161,200
Nuclear Engineer	1 -	10,800
Health Physicist	1 -	8,400
Results Engineer	1 -	9,000
Laboratory Technician	1 -	4,800
Chemist	1 -	7,000
	5 -	$40,000
Maintenance		
Maintenance Supervisor	1 -	8,000
Mechanical Maintenance Foreman	1 -	7,000
Mechanic - 1st Class	2 @	6,400
Mechanic - 2nd Class	3 @	5,000
Welder	1 -	5,900
Labor Foreman	1 -	6,000
Laborer	2 @	2,500
Janitor	1 -	2,500
Electrical Maintenance Foreman	1 -	7,000
Electrician - 1st Class	2 @	6,400
Electrician - 2nd Class	1 -	6,000
	16 -	$88,000
TOTAL	47 -	$326,900

(L) Licensed reactor operator.

Annual fixed operating and maintenance cost = 1.20 (salaries and wages) = $392,300 = $7.85/net kw

Administrative and general costs = 0.14 (annual fixed operating and maintenance cost) = $54,900/yr = $1.10/net kw

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* To above total labor costs add 0.25 mill/kwhr for maintenance materials and operating supplies, which is the variable part of the operating and maintenance cost.

EXHIBIT V-8

FEASIBILITY STUDY - FLORIDA KEYS

NUCLEAR LIABILITY AND INDEMNITY INSURANCE COSTS

Case	MWt	Required Liability Coverage Million $	Liability Premium $/yr	Indemnity Premium $/yr	Total Premium $/yr	Premium Unit Cost $/yr - net kw
F	185.1	27.8	134,800	5,600	140,400	2.81
G	212.9	31.9	139,900	6,400	146,300	2.93
H	170.6	25.6	132,000	5,100	137,100	2.74
J	198.4	29.8	137,200	6,000	143,200	2.86
K	201.9	30.3	137,900	6,100	144,000	2.88
L	204.0	30.6	138,200	6,100	144,300	2.89
M	221.8	33.3	141,600	6,700	148,300	2.97

Basis for Calculations

1. Required Liability Coverage = 150 $/KWt x No. of KWt output
2. Liability Premium Scale:

Liability Coverage, $		Premium, $/$$10^6$
To	1×10^6	25,000
Next	4×10^6	12,500
Next	5×10^6	5,000
Next	10×10^6	2,500
Next	20×10^6	1,250
Next	20×10^6	625

3. Indemnity Premium = 30 $/MWt x No. of MWt output
4. Total Premium = Liability Premium + Indemnity Premium
5. Premium Unit Cost = $\frac{\text{Total Premium, \$/yr}}{\text{Net Electric Output, Net kw}}$

required liability coverage is based on a population factor of one, which appears reasonable in view of the lightly populated nature of the Lower Keys. A base premium of $25,000 was applied to the first million dollars of coverage. This is lower than that given in TID-7025, but is based on present premium rates. The premium rate decreases with increasing coverage and is proportional to the decrease in TID-7025.

B. Design Features of Each System

1. Vendor A

The Vendor A proposal is based on a design developed for possible maritime applications. It is a pressurized-water reactor which has been modified to provide compactness to make it attractive for use in ship propulsion. This compactness appears to offer advantages for use in smaller land-based station. In addition to its compact configuration, the design is distinguished by a once-through steam generator and hydrogen gas overpressure for pressurization, rather than an electrically heated separate pressurizer. The gas mixture which gives the overpressure is composed of 4/5 water vapor and 1/5 hydrogen by volume. In principle the reactor selected is similar to other pressurized-water systems presently in military and civilian use throughout the United States, and full advantage may be taken of the existing highly developed technology.

The entire reactor primary system is contained within a single pressure vessel. Three primary coolant pumps mounted on vessel nozzles direct flow downward through the steam generator and then upward, in a single pass, through the core. All primary components are contained in a pressure suppression containment system.

The once-through steam generating system is located concentric to the pressure vessel wall in the space between a core support cylinder and the vessel wall. Four separate steam outlets and feedwater inlets are provided. These are spaced equally around the vessel for even steam removal and feedwater flow to the once-through steam generator. In one of the designs submitted by Vendor A, superheated steam is discharged from the steam generator at 412 psia and 523° F. In the other design the feedwater temperature given by Vendor A was increased from 340° to 375° F. To avoid the necessity for changing the nuclear island cost, it was necessary to maintain the same steam generator surface by adjusting the steam generator temperature to keep the same log mean temperature difference. This resulted in the temperature of the 700 psia steam being lowered from 580° to 572° F.

2. Vendor B

Vendor B submitted a proposal based on a pressurized-water reactor. The proposal contained data on three reactor sizes, 120 MWt, 190 MWt and 260 MWt in order to facilitate economic studies. The design submitted is, in most respects, typical of pressurized-water reactors. It differs in that it uses a once-through steam generator to produce superheated steam at 700 psia and 560° F. Operating conditions are a 2000 psig operating pressure and a 585° F reactor outlet temperature. The shell side of this steam generator is supplied with primary water from two loops. Centrifugal pumps with controlled leakage seals circulate the primary water around the two loops.

The primary system is installed in the familiar spherical containment shell.

3. Vendor C

Cost data submitted in this proposal are for a power level of 130 MWt. It is based on a direct-cycle boiling-water reactor. The proposed core is similar to other core designs where boiling occurs, in that it features a reasonably high power density with some flux flattening. The saturated steam generated in the reactor is at a pressure of 850 psig. Feedwater is returned to the reactor at 337° F.

4. Vendor D

Vendor D submitted a proposal based on a pressurized-water design. The proposal contained data for three power levels, 120 MWt, 190 MWt and 260 MWt.

The design submitted is typical of pressurized-water reactors. It is based on a reactor operating pressure of 2150 psia. The single primary coolant loop has a vertical U-tube steam generator. Steam is generated on the shell side of the steam generator at a pressure of 600 psia. After passing through integral moisture separators the steam leaves the steam generators with a moisture content of less than 0.25 percent.

5. Vendor E

Vendor E submittals for this study are based on plants rated at 139 MWt, 205 MWt and 254 MWt. All three designs are direct-cycle, natural circulation boiling-water reactors. Saturated steam is generated at a pressure of 1015 psia. Feedwater is returned to the reactor at 260° or 275° F depending on plant capacity.

In these designs containment is of the pressure-suppression type.

VI. ECONOMIC COMPARISON OF REACTOR SYSTEMS

A. Nuclear-Fueled Cases Considered

Cost studies were based on the submittals of Vendor A and Vendor B, since these proposals showed the most favorable economics. In the case of Vendor A, studies included the design producing 412 psia steam as well as the one producing 700 psia steam. In all the studies, the net electrical power output is 50 megawatts. Preliminary calculations for each submittal were based on an unassociated plant producing power only and a dual-purpose plant producing power plus 6,000,000 gallons per day of fresh water. Based on a performance ratio of 14.0 these studies showed Vendor A to have an edge with the design producing 700 psia steam. Hence, the additional dual-purpose cases studied were limited to this design. Three of these cases were analyzed to determine the effect of extraction pressure on the price of steam to the brine heater. They were made for the base case production rate of 6,000,000 gallons per day with steam pressures of 37.9, 49 and 67 psia at the brine heater.

The case which gives 37.9 psia steam at the brine heater corresponds to the pressure used for the nuclear-fueled dual-purpose plant heat balance. Based on the economic selection studies discussed in Section III-C the final nuclear-fueled case considered was for a water desalination plant capable of producing 10,000,000 gallons per day of fresh water. The designations and major parameters for these cases are summarized in Exhibit VI-1, page VI-2.

B. Power Cost Factors

Power cost estimates appear in Exhibit VI-1. The first 13 items of this exhibit list various parameters for each of the cases. The fourteenth item is the estimated plant investment. Items entering into the determination of plant investment cost are shown on Exhibit VI-2, page VI-3, along with estimates of their cost and the total plant cost. The investment cost per unit of net power generated is obtained for convenience in calculating unit power costs.

The remainder of Exhibit VI-1 shows the power cost calculation using a format similar to that given in Federal Power Commission Memorandum

EXHIBIT VI-1

FEASIBILITY STUDY - FLORIDA KEYS

SUMMARY OF POWER PLANT DATA, POWER COSTS AND ENERGY COSTS TO DESALINATION PLANT

CASE	Fossil	Nuclear	Units	A	B	C	F	G	H	J	K	L	M
Nuclear Island Vendor			Units	Fossil-Fuel			Vendor A - Nuclear-Fueled						
Steam Temperature/Pressure			°F/psia	1000/1465	1000/1465	1000/1465	523/412	523/412	572/700	572/700	572/700	572/700	572/700
Type of Plant				Power Only	Dual Purpose Power and Desalination		Power Only	Dual Purpose	Power Only	Dual Purpose Power and Desalination			
Desalination Plant Design Capacity			10^6 gal/day	-	6.0	10.0	-	6.0	-	6.0	6.0	6.0	10.0
Steam Pressure at Brine Heater			psia	-	37.9	37.9	-	37.9	-	37.9	49.0	67.0	37.9
Steam Flow at Brine Heater			10^3 lb/hr	-	148.8	246.9	-	148.8	-	148.8	150.6	153.0	246.9
Steam Flow at Steam Generator			10^3 lb/hr	425	498	564.5	667	767	639	743	756.1	763.9	830.5
Circulating Water Flow (Assume 10° F Rise)			gpm	54,580	41,100	33,100	89,840	79,940	79,490	69,620	72,100	73,660	63,840
Reactor Power Level or Boiler Output (Boiler Eff = 0.87)			MWt or Btu/hr	4.55×10^8	5.33×10^8	6.05×10^8	185.1	212.9	170.6	198.4	201.9	204.	221.8
Gross Capability			kw	52,630	54,370	56,840	52,360	54,080	53,190	54,950	54,950	54,950	57,450
Auxiliary Power, Desalination Plant			kw	-	1,650	4,000	-	1,650	-	1,650	1,650	1,650	4,000
Auxiliary Power, Reactor Plant			kw	2,630	2,720	2,840	2,360	2,430	3,190	3,300	3,300	3,300	3,450
Net Electric Power Capability			kw	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Average Annual Net Plant Heat Rate (1)			Btu/kwhr	10,570	12,390	14,040	12,760	14,680	11,760	13,680	13,900	14,100	15,290
Estimated Plant Investment Cost Excluding Step-Up Substation													
a. Nuclear Island			10^3 \$	-	-	-	7,439	7,786	7,723	8,070	8,114	8,140	8,362
b. Total Plant			10^3 \$	9,948	11,011	11,686	14,007	15,419	14,514	15,888	15,967	16,022	16,938
A. Net Investment Cost, Plant Excluding Step-Up Substation (15b) ÷ (13)			\$/net kw	198.96	220.22	233.72	280.14	308.38	290.28	317.76	319.0	320.0	338.76
B. Annual Capacity Cost													
1. Fixed Charges, Municipal Financing	Fossil	Nuclear											
a. Cost of Money	4.00%	4.00%	\$/net kw	7.96	8.81	9.35	11.21	12.34	11.61	12.71	12.76	12.80	13.55
b. Depreciation (4%, 30-Year Sinking Fund)	1.78	1.78		3.54	3.92	4.16	4.99	5.49	5.17	5.66	5.68	5.69	6.03
c. Interim Replacements	0.35	0.35		0.70	0.77	0.82	0.98	1.08	1.02	1.11	1.12	1.12	1.19
d. Insurance	0.35	0.50		0.70	0.77	0.82	1.40	1.54	1.45	1.59	1.60	1.60	1.69
e. Taxes	0.67	0.67		1.33	1.48	1.57	1.88	2.07	1.94	2.13	2.14	2.14	2.27
Total Fixed Charges	7.15%	7.30%		14.23	15.75	16.71	20.46	22.52	21.19	23.20	23.30	23.35	24.73
2. Interest on Working Capital (2)			\$/net kw	0.37	0.44	0.50	0.71	0.78	0.74	0.81	0.82	0.83	0.87
3. Fixed Operating Costs													
a. Nuclear Insurance or Fixed Fossil Fuel (3)			\$/net kw	2.80	3.28	3.71	2.81	2.93	2.74	2.86	2.88	2.89	2.97
b. Operating and Maintenance (4)			\$/net kw	7.03	7.03	7.03	7.85	7.85	7.85	7.85	7.85	7.85	7.85
c. Administrative and General 14% of Item 3b			\$/net kw	0.98	0.98	0.98	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Total Fixed Operating Cost			\$/net kw	10.81	11.29	11.72	11.76	11.88	11.69	11.81	11.83	11.84	11.92
Total Annual Fixed Costs = B(1) + B(2) + B(3)			\$/net kw	25.41	27.48	28.93	32.93	35.18	33.62	35.82	35.95	36.02	37.52
Total Fixed Costs (Capacity Cost) (5)			Mills/kwhr	3.63	3.93	4.13	4.70	5.03	4.80	5.12	5.14	5.15	5.36
C. Energy Cost, Variable Operating Costs													
1. Energy Fuel (6)			Mills/kwhr	4.04	4.74	5.37	3.10	3.57	2.86	3.33	3.38	3.43	3.72
2. Operating and Maintenance (7)			Mills/kwhr	0.32	0.33	0.34	0.26	0.27	0.27	0.27	0.27	0.27	0.29
Total Variable Operating Costs (Energy Cost)			Mills/kwhr	4.36	5.07	5.71	3.36	3.84	3.13	3.60	3.65	3.70	4.01
D. Total Unit Cost (Capacity and Energy Costs) = B + C			Mills/kwhr	7.99	9.00	9.84	8.06	8.87	7.93	8.72	8.79	8.85	9.37
E. Difference in Cost Dual Purpose - Corresponding Power Only			Mills/kwhr	-	1.01	1.85	-	0.81	-	0.79	0.86	0.92	1.44
F. Cost to Water Plant													
1. Steam Cost at Brine Heater (8)			¢/1000 lb stm	-	24.6	23.9	-	17.9	-	17.2	19.3	20.9	15.5

Notes:

(1) Design net plant heat rate increased one percent and rounded to nearest 10 Btu/kwhr

(2) For nuclear plants see Exhibit VII-12; for fossil fuel plants this is annual cost on fuel stock investment @ 42¢/million Btu for 110 days @ average operation

$$=(\text{net plant heat rate})\ (7008)\left(\frac{110}{365}\right)\left(\frac{0.42}{10^6}\right)(0.04) = (\text{net plant heat rate})\ (35.5 \times 10^{-6})$$

(3) Nuclear insurance - see Exhibit V-8, fixed fossil fuel - 9 percent for oil

$$= (\text{net plant heat rate})\ (7008)\ (0.09)\ \frac{0.42}{10^6} = (\text{net plant heat rate})\ (264.9 \times 10^{-6})$$

(4) Annual salary + 20 percent fringe benefits, for nuclear plants see Exhibit V-7 for fossil plants see Exhibit IV-5

(5) Based on 80 percent plant factor (7008 hr/yr)

(6) Nuclear fuel - based on 24.3¢/million Btu, fossil fuel - 91 percent for oil

$$= (\text{net plant heat rate})\ (0.91)\ \frac{0.42}{10^6} \times 10^3 = (\text{net plant heat rate})\ (0.3822 \times 10^{-3})$$

(7) Nuclear: 0.25 mills/kwhr x gross generation factor = 0.25 (gross kw capacity ÷ 50,000)
Fossil: 0.3 mills/kwhr x gross generation factor = 0.3 (gross kw capacity ÷ 50,000)

(8) Steam cost = energy cost - power cost:

$$\text{energy cost} = \frac{(\text{difference})\ \frac{¢}{\text{kwhr}} \times 50{,}000\ \frac{\text{kwhr}}{\text{hr}},}{(\text{steam flow})\quad 1000\ \text{lb/hr}}\ \frac{¢}{1000\ \text{lb stm}}$$

$$\text{power cost} = \frac{(\text{power cost})\ \frac{¢}{\text{kwhr}} \times (\text{difference in gross power generation})\ \frac{\text{kwhr}}{\text{hr},}}{(\text{steam flow})\quad 1000\ \text{lb/hr}}\ \frac{¢}{1000\ \text{lb stm}}$$

EXHIBIT VI-2

FEASIBILITY STUDY - FLORIDA KEYS

PROPOSED STEAM AND ELECTRIC GENERATING PLANTS

CAPITAL COST ESTIMATES
(All Costs In Thousands Of Dollars)

Acct. No.	Description	A	B	C	F	G	H	J	K	L	M
	Type of Plant	FOSSIL FUEL			NUCLEAR FUEL						
	Reactor Vendor	-	-	-	VENDOR A						
	Steam Conditions, °F/psia	1000/1465	1000/1465	1000/1465	523/412	523/412	572/700	572/700	572/700	572/700	572/700
	Desalination Plant Design Cap.	-	6.0	10.0	-	6.0	-	6.0	6.0	6.0	10.0
	Net Electric Power, kw	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
	Steam Press.at Brine Htr,psia	-	37.9	37.9	-	37.9	-	37.9	49	67	37.9
	Boiler Output, Btu/hr	4.55×10^8	5.33×10^8	5.645×10^8	-	-	-	-	-	-	-
	Reactor Power, MWt	-	-	-	185.1	212.9	170.6	198.4	201.9	204.0	221.8
310	Land and Land Rights	24.0	24.0	24.0	129.0	129.0	129.0	129.0	129.0	129.0	129.0
311	Structures and Improvements (4)	1,167.0	1,167.0	1,167.0	533.0	533.0	533.0	533.0	533.0	533.0	533.0
312	Boiler										
	a. Boiler or Nuclear Island (5)	2,007.0	2,353.5	2,668.5	7,439.0	7,786.0	7,723.0	8,070.0	8,114.0	8,140.0	8,362.0
	b. Other Items (1)	1,487.7	1,690.0	1,811.8	563.6	1,472.0	635.7	1,546.6	1,558.2	1,572.5	2,161.2
	c. Total	3,494.7	4,043.5	4,480.3	8,002.6	9,258.0	8,358.7	9,616.6	9,672.2	9,712.5	10,523.2
314	Turbogenerator	2,083.0	2,357.8	2,411.0	2,541.1	2,562.7	2,624.4	2,614.5	2,629.3	2,638.3	2,670.8
315	Accessory Electrical Equipment	631.6	652.4	682.1	628.3	649.0	638.3	659.4	659.4	659.4	689.4
316	Misc. Power Plant Equipment	100.0	100.0	100.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
	Other Expenses (2)	125.0	125.0	125.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Total Direct Cost	7,625.3	8,469.7	8,989.4	12,004.0	13,301.7	12,453.4	13,722.5	13,792.9	13,842.2	14,715.4
	Indirect Costs (3)	2,322.5	2,540.9	2,696.7	2,003.4	2,117.3	2,060.2	2,165.3	2,174.2	2,180.1	2,222.6
	Total Estimated Plant Cost	9,947.8	11,010.6	11,686.1	14,007.4	15,419.0	14,513.6	15,887.8	15,967.1	16,022.3	16,938.0

(1) Piping and heaters, makeup water, feedwater pumps, fuel oil storage, standby boiler for nuclear facilities, environmental radiation monitoring, spent fuel cask

(2) Includes surveying costs, temporary construction buildings, and temporary utilities at site

(3) On power: contingency, inspection and construction supervision, purchasing and accounting, engineering
On nuclear reactor: hazards and site report
On total: interest during construction, Florida sales tax, and startup costs

(4) Includes docking and channel facilities plus special provision for hurricane resistance

(5) Standby boiler added to nuclear facilities to permit operation of water desalination plant during reactor or turbine plant shutdowns

No. 1. In each case, whether single or dual purpose, the entire cost of the nuclear plant is charged against power. The incremental cost for the dual-purpose plant is a measure of the energy cost to the water plant and is discussed in greater detail later.

1. Fixed Costs

The fixed costs are those annual costs which remain the same during the life of the plant regardless of the load factor. They include fixed charges on the investment, interest on working capital, liability and indemnity insurance and portions of the operating and maintenance cost. The factors included and their magnitude are covered in Section III-C.

a. Fixed Charges

In determining power costs, the fixed charge rates are applied to the investment costs of the plant. As developed in Section III-C, these are 7.30 percent for depreciating capital and 5.17 percent for nondepreciating capital.

The same figures hold for conventional plants except for insurance, which is reduced to 0.35 percent. Thus the total annual fixed charge rate for depreciating conventional plant items is 7.15 percent.

b. Interest on Working Capital

Working capital is money kept on hand to meet current expenses and to maintain a stockpile of material and supplies. Since it cannot be invested, the interest which it could earn is charged against the power cost. The interest is charged at a rate of 5.17 percent since it is considered as nondepreciating capital. The calculation of the working capital is based on the format of TID-7025 (Volume 5), "Guide to Nuclear Power Cost Evaluation," Section 510, "Annual Fixed Charges." The results of the calculations appear as Exhibit VI-3, page VI-5, in this report.

c. Fixed Operating Costs

Fixed operating costs include nuclear liability insurance, and the salaries, fringe benefits and administrative portion of maintenance costs. The methods of calculating these costs have been discussed in Section V-A.

EXHIBIT VI-3

FEASIBILITY STUDY - FLORIDA KEYS
INTEREST ON WORKING CAPITAL
FOR NUCLEAR PLANTS

Case	Units	F	G	H	J	K	L	M
1. Annual Fuel Cost (Based on 24.3 cents/million Btu)	10^3 $	1087	1251	1001	1164	1191	1212	1302
2. Maintenance Materials and Operating Supplies Cost @ 0.25 mills/kwhr Gross	10^3 $	92	95	93	96	96	96	101
3. Annual Working Capital								
A.								
a. Annual Fuel Cost (Based on 24.3 cents/million Btu)	10^3 $	1087	1251	1001	1164	1191	1212	1302
b. Total Annual Operating and Maintenance ($447,000 + Item 2)	10^3 $	539	542	540	543	543	543	548
Subtotal (a + b)	10^3 $	1626	1793	1541	1635	1744	1679	1850
2.7% of Subtotal (Applied to Working Capital)	10^3 $	44	48	42	46	47	47	50
B. Core Fabrication Inventory @ 60% of Core Cost	10^3 $	626	689	651	713	724	731	766
C. Other Materials and Supplies @ 25% of Item 2	10^3 $	23	24	23	24	24	24	25
Total Annual Working Capital	10^3 $	693	761	716	783	795	802	841
Annual Cost	$/net kw	13.86	15.22	14.32	15.66	15.90	16.04	16.82
Interest on Working Capital @ 5.17%	$/net kw	0.71	0.78	0.74	0.81	0.82	0.83	0.87

$$\text{Annual Fuel Cost} = \text{KWt} \times 7008\ \frac{\text{hr}}{\text{yr}} \times 3413\ \frac{\text{Btu}}{\text{KWHRt}} \times \frac{0.243\ \$}{10^6\ \text{Btu}} \times 1.01 = 5.87\ \text{KWt}$$

where 1.01 is a correction factor to heat rate to account for startups and shutdowns

$$\text{Maintenance Materials and Operating Supplies Cost} = \text{Gross kw} \times 7008\ \frac{\text{hr}}{\text{yr}} \times \frac{0.25\ \text{mills/kwhr}}{1000\ \text{mills/\$}}$$

$$= 1.75\ (\text{gross kw}),\ \$/\text{yr}$$

d. Annual Capacity Cost

Together, the above items add up to the annual capacity cost, which represents the annual cost incurred regardless of the amount of power generated. In Exhibit VI-1, page VI-2, it was assumed, in order to obtain the total fixed cost, that the power and water plants operate at 100 percent capacity for 80 percent of the time.

2. Variable Costs

Variable costs are those annual costs which depend on the amount of power generated. They are the fuel cost and the cost of maintenance materials and operating supplies. The fuel cost of 24.3 cents/million Btu calculated in Exhibit V-5, page V-7-13, and the net plant heat rate were used to obtain the fuel cost per unit of net power output. Maintenance materials and operating supplies were charged at a unit cost of 0.25 mills per kilowatt-hour of gross generation. The unit cost per kilowatt-hour of net generation was slightly higher.

3. Total Costs

The total power costs are the sum of the annual capacity cost and the variable cost.

a. Unassociated Nuclear-Fueled Power Plant

These figures show a power cost of 7.93 mills/kwhr for the Vendor A design producing 700 psia steam as compared to 8.06 mills/kwhr for their design producing 412 psia steam.

b. Dual-Purpose Nuclear-Fueled Power and Desalination Plant

For a desalination plant performance ratio of 14.0 pounds of water per pound of steam and a water production rate of 6,000,000 gallons per day, the total power cost, including energy chargeable to the water plant, is 8.72 mills per net kilowatt-hour for the Vendor A 700 psia design. Under the same conditions, the 412-psia design produces power at a total cost of 8.87 mills per net kilowatt-hour. Finally, for the reference proposed dual-purpose 50-MWe nuclear power plant (700 psia steam) and 10,000,000-gallon-per-day-capacity water desalination plant (Case M), the total power cost, including energy chargeable to the water plant, is 9.37 mills/kwhr. The cost of steam to the brine heater is 15.5 ¢/1000 lb.

C. Recommended Reactor System

1. Discussion of Reference System

Since the lowest power costs for both the unassociated power plant and the power plant combined with a 6,000,000-gallon-per-day desalination plant were obtained with the Vendor A reactor system design producing 700 psia steam, and with all other design requisites satisfied, this submittal was selected as the reference system.

The pressurized-water reactor plant selected for the reference design is distinguished by its compact configuration, once-through steam generator and gas overpressure for pressurization, rather than an electrically heated separate pressurizer. The gas mixture which gives the overpressure is composed of 4/5 water vapor and 1/5 hydrogen by volume. In principle the reactor selected is similar to other pressurized-water systems presently in military and civilian use throughout the United States, and full advantage may be taken of the existing highly developed technology.

In the once-through generator, the steam is formed in the tubes rather than on the shell side as in most nuclear plants. This follows current practice in modern conventional fossil-fuel plant design. Although steam generators of this type have not been used with pressurized-water reactors they have been used for the Sodium Reactor Experiment and the Enrico Fermi Reactor.

The entire reactor primary system is contained with a single pressure vessel. Three primary coolant pumps are mounted on vessel nozzles and direct flow downward through the steam generator, and then upward, in a single pass, through the core. Primary piping is thus eliminated. The once-through steam generating system is located concentric to the pressure vessel wall in the space between a core support cylinder and the vessel wall. Four separate steam outlets and feedwater inlets are provided. These are spaced equally around the vessel for even steam removal and feedwater flow to the once-through steam generator.

Superheated steam is discharged at 700 psia and 572° F from the steam generator. The 572° F is an adjustment from the 580° F submitted by Vendor A. This adjustment was made to increase the feedwater temperature from 340° F to 375° F, a value which is more compatible with the turbine cycle, while holding the log mean temperature difference in the steam generator constant.

2. Unit Cost of Steam to Water Desalination Plant

a. Determination of Steam Costs

In each dual-purpose plant, the power cost increment above the corresponding unassociated case is a measure of the total energy cost to the desalination plant. This increment includes the cost of the additional auxiliary power needed to operate the desalination plant as well as the cost of extraction steam to the desalination plant. The two components involved in the difference are reflected in the details of the steam cost calculation outlined in the footnotes of Exhibit VI-1, page VI-2.

b. Variation of Steam Costs with Pressure

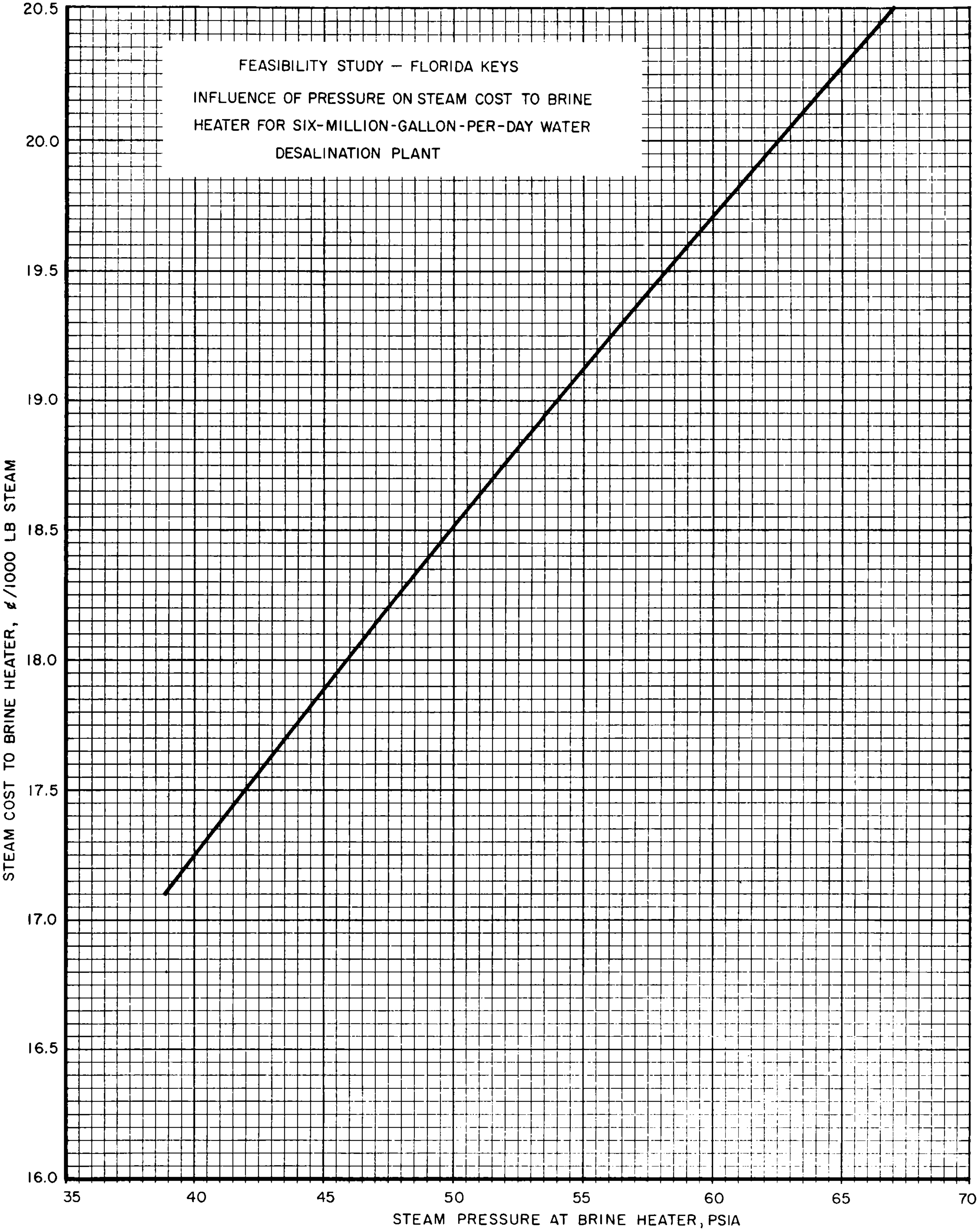
Cases J, K and L were investigated to provide a basis for estimating the effect of extraction pressure on steam cost at the brine heater. The results of this study were plotted in Exhibit VI-4, page VI-9. This exhibit shows the steam cost to increase with increasing extraction pressure. At the lower pressures the increase is more rapid than at the higher pressures. This reflects the fact that the high-pressure steam is worth more because less energy has been extracted from it by the turbine. If steam were extracted at the turbine throttle instead of one of the stages, the steam cost to the brine heater would be the same as the steam cost to the turbine throttle. Thus, the maximum steam cost would be at a pressure slightly lower than 700 psia and steam costs decrease as the pressure decreases from this point.

Of course, the pressure of the steam to the brine heater has a lower bound as determined by the brine exit temperature of 250° F and the brine heater heat transfer characteristics.

c. Selection of Optimum Steam Pressure

If saturated steam is supplied to the brine heater at 250° F and 29.8 psia, the brine heater would require an infinite surface to raise the brine temperature to 250° F. Obviously, the desalination plant cost would then be infinite also, even though the steam would be supplied at the lowest possible cost. At the other extreme, if steam were supplied to the brine heater at a high pressure, the high steam cost would obviate any reductions in plant cost thereby yielding a high water cost. At some intermediate pressure the water will be produced at the lowest possible cost.

EXHIBIT VI-4



FEASIBILITY STUDY — FLORIDA KEYS

INFLUENCE OF PRESSURE ON STEAM COST TO BRINE HEATER FOR SIX-MILLION-GALLON-PER-DAY WATER DESALINATION PLANT

For the three pressures considered, the plant investment costs were nearly identical, with the plant cost decreasing slightly with decreasing steam pressure. This made the steam cost the overriding factor in optimizing the water cost in the range of pressures investigated. Thus, the optimum water cost is obtained at a pressure of 37.9 psia.

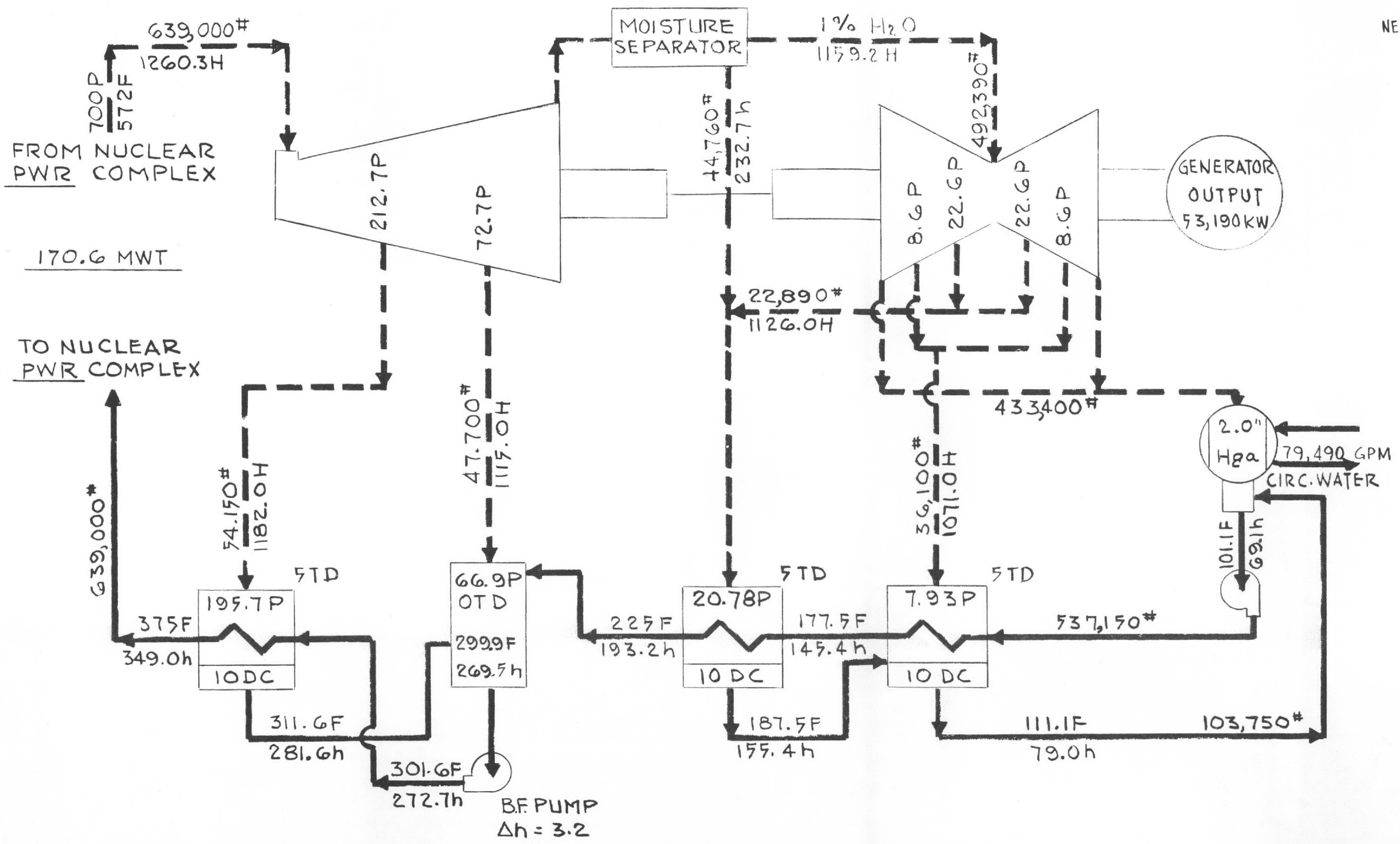
Because of both the lower unit power costs and lower steam costs, as compared to a fossil-fueled power plant, the nuclear reactor dual-purpose plant, with a reactor rated at 221.8 mw thermal, a net generation of 50 MWe and a water desalination plant with a design capacity of 10,000,000 gallons per day, is recommended as the most economical system for meeting future power and water needs in the Florida Keys.

The heat balances for the nuclear plants are given in Exhibit VI-5, page VI-11, for the unassociated nuclear power plant (Case H) and in Exhibit VI-6, page VI-12, for the reference proposed dual-purpose 50-MWe nuclear power plant and 10,000,000-gallon-per-day water desalination plant (Case M).

In addition to Cases F, G, H, J, K and M given on Exhibit VI-1, page VI-2, calculations were worked out for variations of Case M with water plant capacity to determine how steam costs would vary with water production. A plot of steam cost versus net water plant output for the nuclear-fired 50,000-kw electrical and 10,000,000-gallon-per-day water plant is shown on Exhibit VI-7, page VI-13.

GROSS TURBINE HEAT RATE = $\frac{639{,}000(1260.3-349.0+3.2)}{53.190} = 10.986\ \frac{\text{BTU}}{\text{KWHR}}$

NET PLANT HEAT RATE = $\frac{639{,}000\ (1260.3-349.0)}{50{,}000} = 11{,}646\ \frac{\text{BTU}}{\text{KWHR}}$



AUXILIARY POWER

REACTOR & TURBINE PLANT = 3,190 KW
NET PLANT OUTPUT = 50,000 KW

CASE H

UNASSOCIATED PLANT

LEGEND

— —	STEAM
——	LIQUID
P	PRESSURE, PSI ABSOLUTE
h	LIQUID ENTHALPY, BTU/LB.
H	VAPOR ENTHALPY, BTU/LB.
#	FLOW, LB/HR
F	TEMPERATURE, °F

Reynolds, Smith and Hills, Jacksonville, Fla.
BURNS AND ROE, INC. **NEW YORK, N. Y.**

HEAT BALANCE FOR STUDY PURPOSES

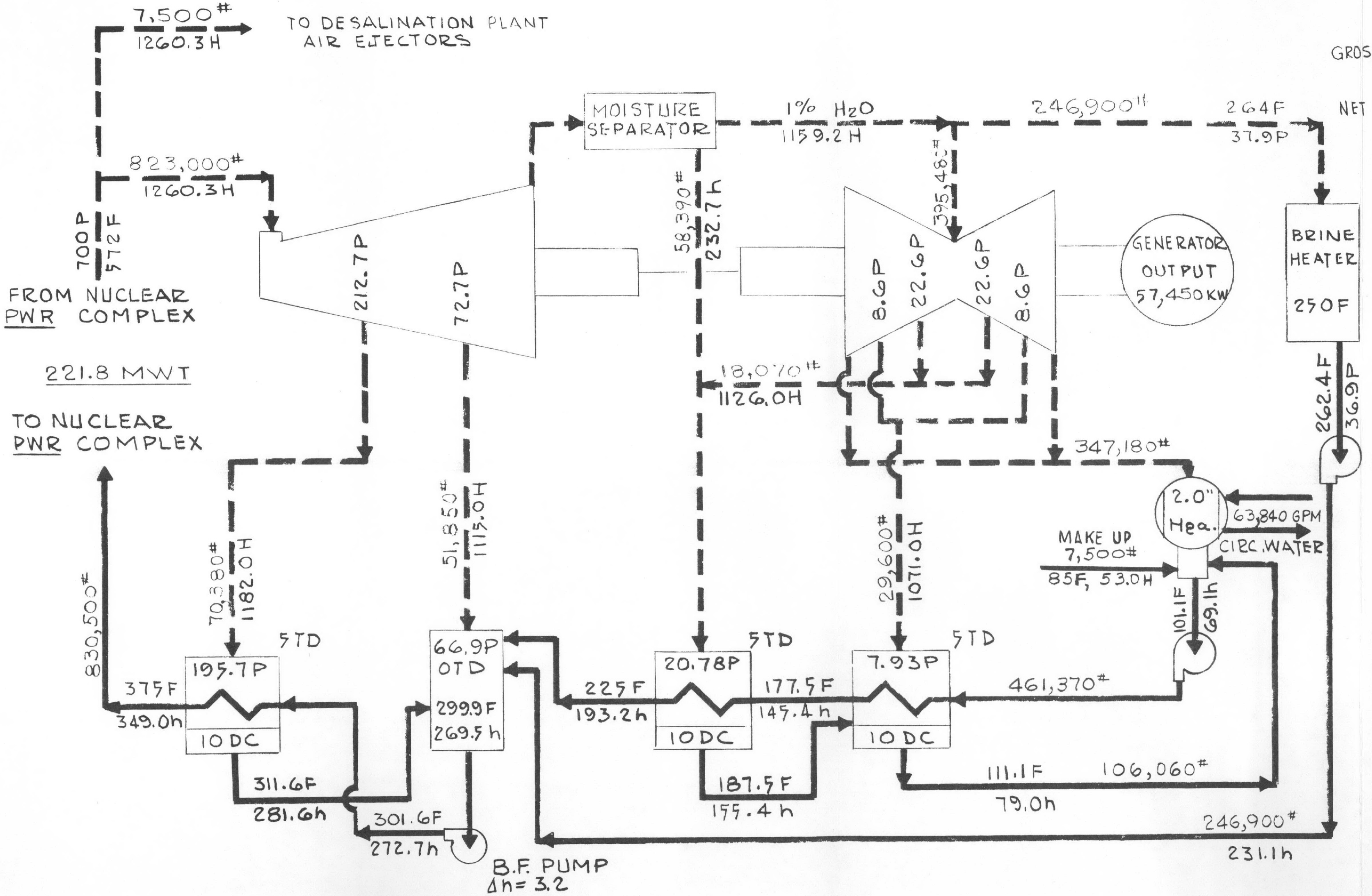
FEASIBILITY STUDY-COMB. ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS

DRAWN FAM TRACED CHECKED	SQUAD LEADER AMF	DATE 12-63	SCALE ∞
APPROVED	DATE 12-27-63 Henry D Schwerdtfeger Supt. Mech Engr.		W. O. 2271-01 DWG.

TITLE	CHECKED	DATE
ELECTRICAL SUPERVISOR		
MECHANICAL "		
STRUCTURAL "		
CHIEF DRAFTSMAN		

TITLE	CLEARED	DATE
ELECTRICAL ENGINEER		
MECHANICAL "		
STRUCTURAL "		

REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE



$$\text{GROSS TURBINE HEAT RATE} = \frac{830{,}500(1260.3-349+3.2)}{57{,}450} = 13{,}220\ \frac{\text{BTU}}{\text{KWHR}}$$

$$\text{NET PLANT HEAT RATE} = \frac{830{,}500(1260.3-349)}{50{,}000} = 15{,}137\ \frac{\text{BTU}}{\text{KWHR}}$$

AUXILIARY POWER

DESALINATION PLANT = 4,000 KW
REACTOR & TURBINE PLANT = 3,450 KW
7,450 KW

NET PLANT OUTPUT = 50,000 KW

WATER PRODUCTION RATE = $10 \times 10^6\ \frac{\text{GAL}}{\text{DAY}}$

PERFORMANCE RATIO = 14.0 $\frac{\text{LB. WATER}}{\text{LB. STEAM}}$

CASE M

LEGEND

— — STEAM
—— LIQUID
P PRESSURE, PSI ABSOLUTE
h LIQUID ENTHALPY, BTU/LB.
H VAPOR ENTHALPY, BTU/LB.
\# FLOW, LB/HR
F TEMPERATURE, °F

Reynolds, Smith and Hills, Jacksonville, Fla.
BURNS AND ROE, INC. NEW YORK, N. Y.

HEAT BALANCE FOR STUDY PURPOSES

FEASIBILITY STUDY - COMB. ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS

DRAWN FMM TRACED CHECKED	SQUAD LEADER	DATE	SCALE
	AMF	12-63	

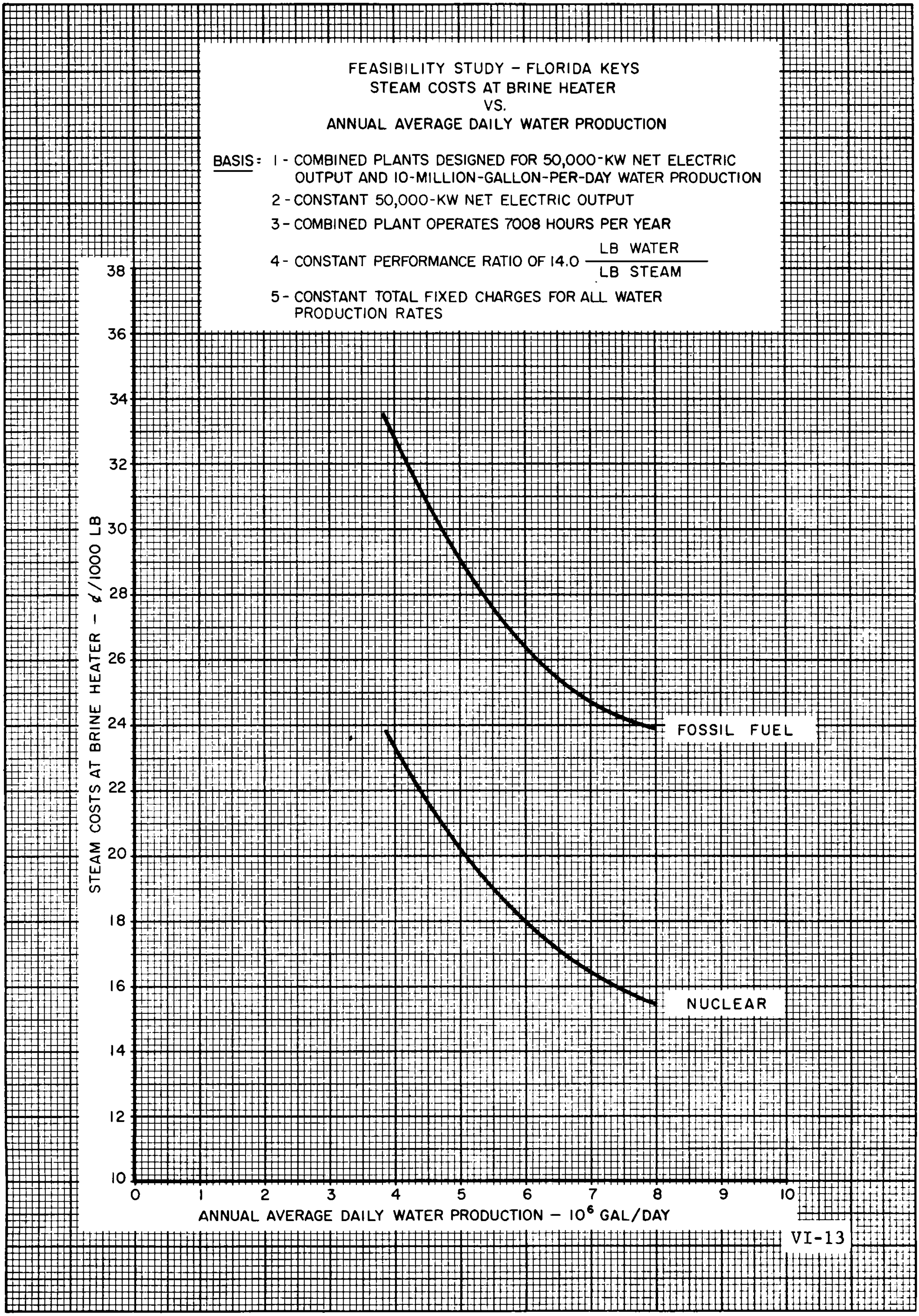
APPROVED	DATE 12-20-63	W. O. 2271-01
Henry D Schwanntter Supv Mech Engr		DWG.

TITLE	CHECKED	DATE
ELECTRICAL SUPERVISOR		
MECHANICAL "		
STRUCTURAL "		
CHIEF DRAFTSMAN		

TITLE	CLEARED	DATE
ELECTRICAL ENGINEER		
MECHANICAL "		
STRUCTURAL "		

REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE

EXHIBIT VI-7



FEASIBILITY STUDY – FLORIDA KEYS
STEAM COSTS AT BRINE HEATER
VS.
ANNUAL AVERAGE DAILY WATER PRODUCTION

BASIS: 1 - COMBINED PLANTS DESIGNED FOR 50,000-KW NET ELECTRIC OUTPUT AND 10-MILLION-GALLON-PER-DAY WATER PRODUCTION
2 - CONSTANT 50,000-KW NET ELECTRIC OUTPUT
3 - COMBINED PLANT OPERATES 7008 HOURS PER YEAR
4 - CONSTANT PERFORMANCE RATIO OF 14.0 $\frac{\text{LB WATER}}{\text{LB STEAM}}$
5 - CONSTANT TOTAL FIXED CHARGES FOR ALL WATER PRODUCTION RATES

VII. NUCLEAR POWER PLANT DESIGN

A. Reactor Power Level, Combined Plant Layout and Construction Schedule

1. Reactor Power Level

As indicated previously, the desalination plant studies reported in Section III-C led to the selection of a design water production rate of 10,000,000 gallons per day. Further, the results of the power plant investigations show a unit selected to meet the combined power needs of the Upper and Lower Keys, and rated at 50 MWe net, gave the most economical case for future expansion. To meet these dual-purpose requirements the recommended pressurized-water nuclear reactor system (Vendor A's 700 psia steam proposal) would need a power level of 221.8 MWt.

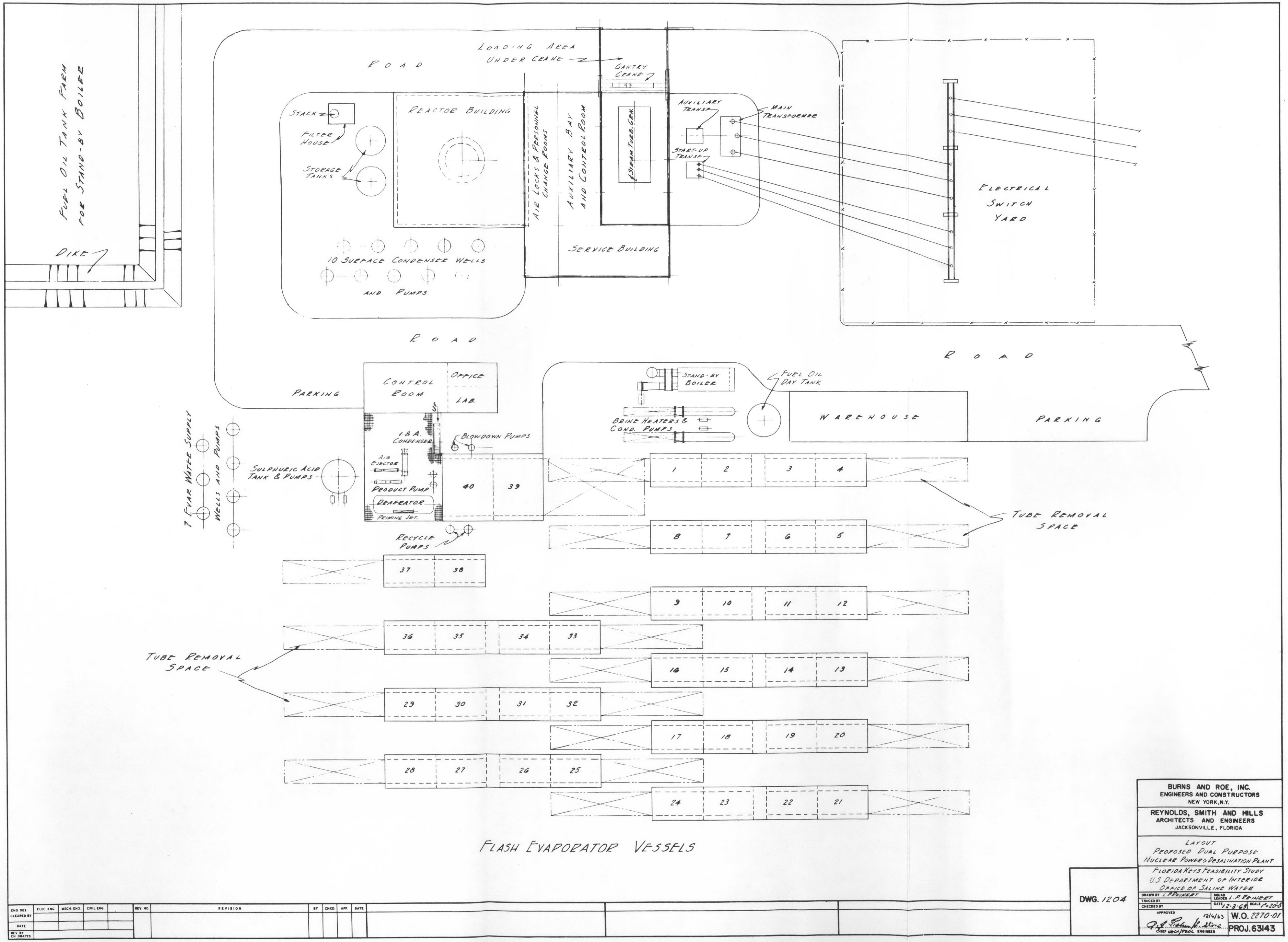
2. Plant Layouts

The layout of the combined 10,000,000-gallon-per-day water desalination plant and the 50-mw nuclear reactor electric plant is shown on Exhibit VII-1 (Drawing No. 1204), page VII-2. The access road to the plant site parallels the edge of Sugarloaf Key. Just outside the plant site a parking lot borders the access road. This road divides the plant in two sections as shown in Exhibit VII-1. One one side is the desalination plant. On the other side are the reactor and power plants. An overall plot plan of the combined facilities, including the water storage tank farm, is shown on Exhibit VII-2, page VII-3.

The combined plant layout is governed by the required process flow of the water plant and the water plant's compatibility with the electric generating plant.

The layout of the multistage flash evaporation water desalination plant with a parallel, staggered, U-shaped grouping of the two banks of evaporator vessels requires a minimum of ground area and allows utilization of the space between the staggered vessels for tube replacement. Additionally, the layout suits required countercurrent-series flow of the process fluids and results in free area at each vessel and for tube inspection, repair and replacement. Each vessel consists of four stages with a water box between the second and third stages and a water box at each end. Furthermore, this type of layout requires minimum piping runs between vessels and between the vessels and the wells and turbine.

EXHIBIT VII-1



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NEW YORK, N.Y.

REYNOLDS, SMITH AND HILLS
ARCHITECTS AND ENGINEERS
JACKSONVILLE, FLORIDA

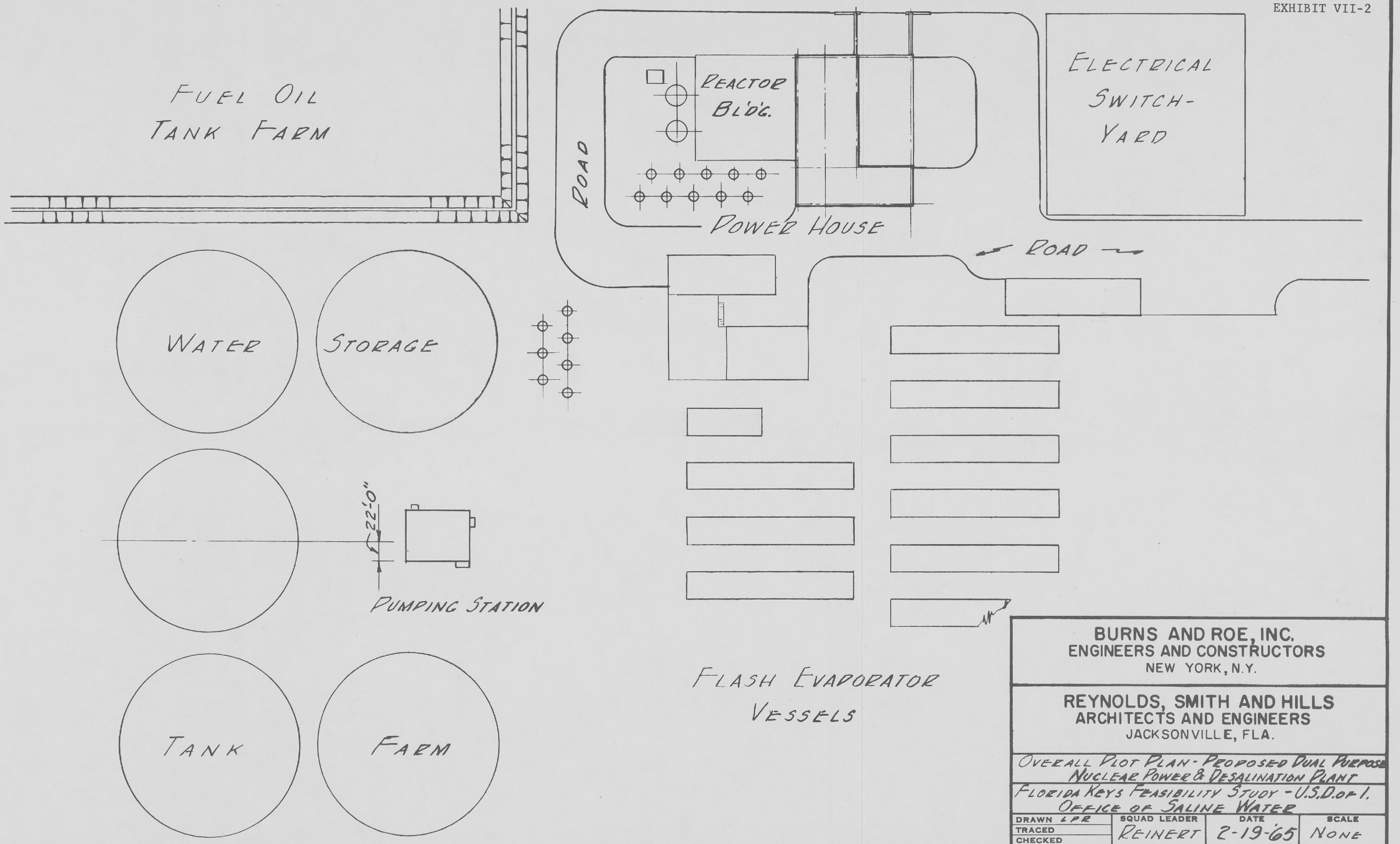
LAYOUT
PROPOSED DUAL PURPOSE
NUCLEAR POWER & DESALINATION PLANT

FLORIDA KEYS FEASIBILITY STUDY
U.S. DEPARTMENT OF INTERIOR
OFFICE OF SALINE WATER

DWG. 1204

DRAWN BY L.P. REINERT
TRACED BY
CHECKED BY
SQUAD LEADER L.P. REINERT
DATE 12-3-63
SCALE 1"=20'-0"
APPROVED 12/4/63
CHIEF MECH/PROC. ENGINEER
W.O. 2270-01
PROJ. 63143

EXHIBIT VII-2



BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
NEW YORK, N.Y.

REYNOLDS, SMITH AND HILLS
ARCHITECTS AND ENGINEERS
JACKSONVILLE, FLA.

OVERALL PLOT PLAN - PROPOSED DUAL PURPOSE NUCLEAR POWER & DESALINATION PLANT

FLORIDA KEYS FEASIBILITY STUDY - U.S.D. of I. OFFICE OF SALINE WATER

DRAWN LPR TRACED CHECKED	SQUAD LEADER REINERT	DATE 2-19-65	SCALE NONE

APPROVED DATE 2/21/64

CHIEF MECH ENGINEER

W. O. 2270-01

PROJ. 63143

TITLE	CHECKED	DATE
ELECTRICAL SUPERVISOR		
MECHANICAL "		
STRUCTURAL "		
CHIEF DRAFTSMAN		

TITLE	CLEARED	DATE
ELECTRICAL ENGINEER		
MECHANICAL "		
STRUCTURAL "		

REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE

In the flash evaporation process flashing brine in the bottom of each stage produces vapor which condenses on tubes carrying recycle brine. The condensate drips into a trough and leaves the evaporator as product. Pressure in each stage is decreased progressively from the hotter to the colder stages. The hot brine flows from stage to stage through interstage orifices, flashing and becoming cooler in each stage while the countercurrent stream of recycle brine in the condenser tubes becomes warmer as it passes from stage to stage. The warmest recycle brine leaving the first stage enters the brine heater where it receives additional heat from extraction steam. It is then returned to the first stage as flashing brine.

Cooling for most of the stages is provided by recycle brine as described above. However, the coldest two stages, called heat rejection stages, are cooled by well water which has been deaerated to remove hydrogen sulfide. The well water leaving the heat rejection stages is divided into two main streams, one of which is discharged to waste; the other enters the brine recycle stream as makeup.

Part of the recycle stream is continually discharged as blowdown to prevent buildup of solids and eventual fouling of the flash evaporator. Scale buildup on heat transfer surfaces is prevented by injection of sulfuric acid into the brine recycle system.

Noncondensible gases are removed and proper vacuum conditions in the flash evaporator are maintained by a steam jet ejector.

The use of wells for surface condenser cooling water and for feed to the water plant permits well locations in areas close to the equipment being served thereby requiring minimum piping runs. The wells are located so that they are readily accessible for maintenance and access by plant personnel. The water obtained from these wells is salt water. However, it is free of seaweed and sand, which eliminates the necessity for a screened intake structure. Since it contains hydrogen sulfide, that portion which is used as desalination plant feed is deaerated before desalination. The desalination takes place in flash evaporators which have a design similar to those used at Point Loma. After desalination, the water is cooled and pumped into the distribution system.

The brine heaters, consisting of two half-capacity parallel units for reliability, are located adjacent to the evaporator first stage which places the units at the point closest to the heating steam source whether this be the turbine or steam generator.

The auxiliary equipment, including pumps, steam jet air ejector, deaerator and chemical feed units are located close to the evaporator vessels served and are generally arranged to minimize piping requirements and to be readily accessible to plant personnel for servicing.

The U-shaped arrangement also results in all of the equipment, other than the evaporator vessels themselves, being centrally located at the top of the U, and readily accessible from the control building conveniently located at this point.

The layout of the turbine-generator plant with associated switchyard and fuel oil storage areas conforms to a conventional, accepted arrangement for this size and type of plant.

The nuclear reactor on Exhibit VII-1, page VII-2, is the compact, pressurized-water system which serves as a source of heat for the desalination plant as well as steam for the electric generating plant. A standby boiler is located adjacent to the brine heaters so that the water plant may be operated when the reactor is taken out of operation for refueling at intervals of approximately 18 months. The reactor plant is somewhat smaller than would be expected, because of the compact nature of the reference design. The reactor and primary system are in a tank. Around this tank is a water-filled annulus which provides pressure suppression. The building over the reactor proper provides shielding, houses auxiliaries and encloses the steam line to the turbine. The generator is located toward the plant entrance so that power can be transmitted to the distribution system via the switchyard with a minimum expenditure for overhead cables.

All areas of the combined total plant are accessible by service roads with the maintenance area and warehouse convenient to both plants.

B. Overall Construction Schedule for Recommended Combined Plants

A proposed overall construction schedule for the combined nuclear power and water desalination plants under Scheme 6 was prepared and is included as Exhibit VII-3, page VII-7. The construction schedule is separated into four major components: the reactor plant, the turbine plant, the water plant, and the associated transmission system.

It may be observed on Exhibit VII-3 that the total construction time is 42 months which is governed by the nuclear reactor. It is felt that this total construction time is conservative and could possibly be shortened. However, detailed investigations of construction time are beyond the scope of this report.

Although engineering and design work will probably last close to the entire job length, major work is estimated to be completed as shown. Design work as shown on Exhibit VII-3 is assumed to include engineering and purchasing and expediting.

C. Functional Specifications

Functional specifications have been prepared for the major equipment in the nuclear power plant complex. These specifications are not intended to be definitive; their main purpose is to sufficiently delineate the performance of the major equipments so as to form a basis for inviting manufacturers' proposals. The operating conditions given in the functional specifications are those developed for the recommended proposed dual-purpose system designed to meet the potable water and power needs in the Florida Keys. This system is a 10,000,000-gallon-per-day multistage flash evaporation-water desalination plant and a coupled 50-MWe net power plant using a nuclear reactor as the prime energy source.

1. Nuclear Reactor System

a. Reactor Core

(1) Function

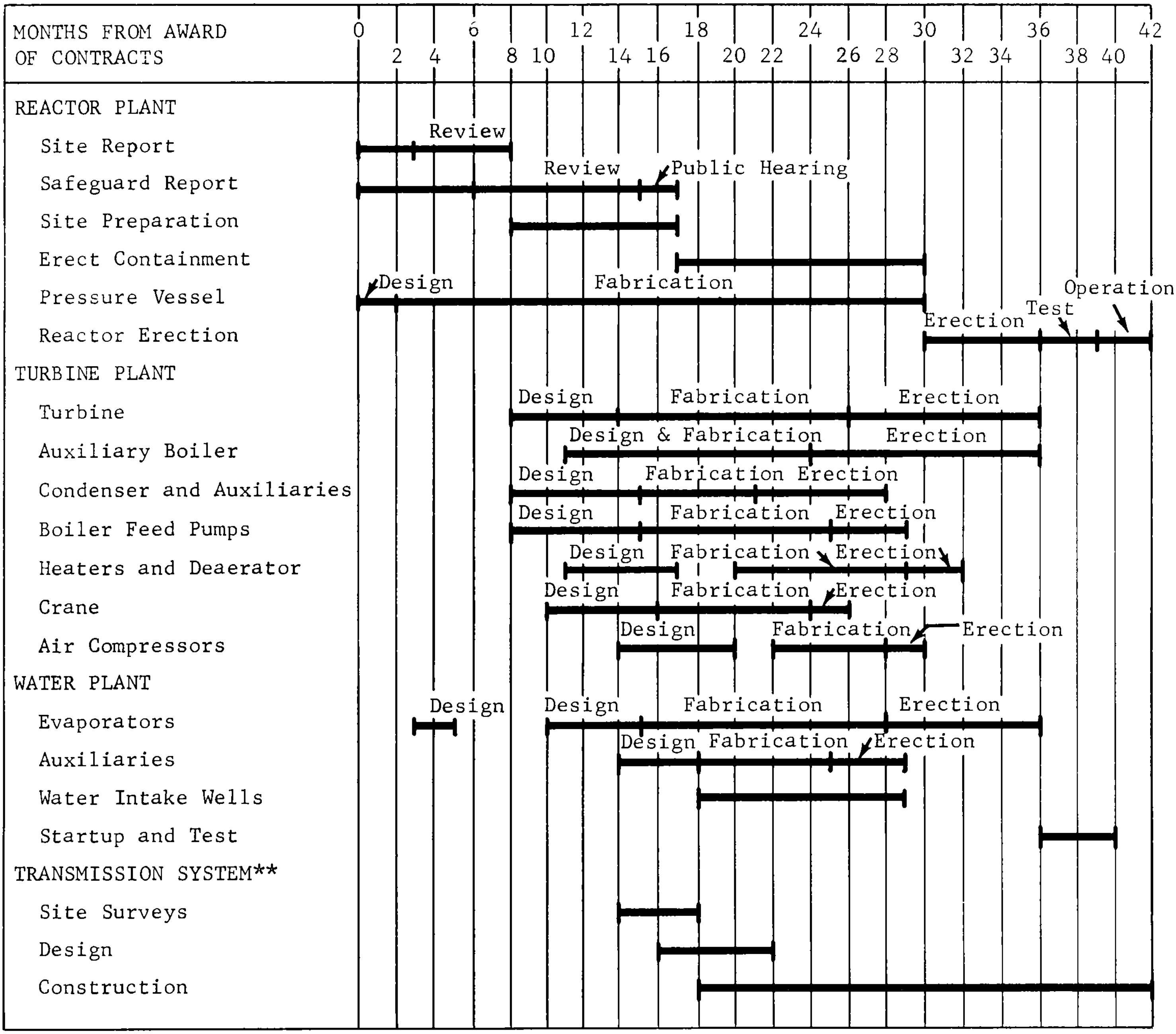
The core shall produce heat for subsequent use in desalination of salt water and for conversion to electric power.

(2) Description

The core shall consist of fuel elements and control rods immersed in pressurized light-water coolant and moderator.

EXHIBIT VII-3

FEASIBILITY STUDY - FLORIDA KEYS
CONSTRUCTION SCHEDULE *
PROPOSED COMBINED PLANTS UNDER SCHEME 6



* Some condensation of this schedule could be obtained by reduction of time allotments for site and safeguard report reviews and by reducing pressure vessel fabrication time.

** Transmission system could be installed sooner to facilitate electric power distribution with intertie between Upper and Lower Keys.

(3) Operating Conditions

Power Level, MWt	221.8
Operating pressure, reactor outlet, psia	1650
Operating temperatures: reactor outlet, °F	601
reactor inlet, °F	578
Average equilibrium burnup, MWD/MTU	24,000
Reference initial enrichment, W/O U 235	3.97
Reactor primary coolant flow, 10^6 lb/hr	23.9

(4) Design and Construction

The core shall be divided into two shuffle zones. Core physics shall be based on removing spent fuel from the inner region, shuffling fuel from the outer to the inner region and putting fresh fuel in the outer region.

Each fuel element shall consist of fuel rods held in a lattice by spacer grids. The pitch of the lattice shall be sufficient to allow proper coolant flow between the rods. Fuel rods shall be of uranium dioxide pellets in Zircalloy-2 or stainless-steel tubing with welded end caps. Provision shall be made to accommodate pressure buildup due to fission product gas release.

Control rods of neutron-absorbing material shall be provided to control the reaction rate. They shall provide a safe shutdown margin for the cold core in its most reactive condition. Supplemental reactivity shim control during the core life may be obtained by means of boric acid dissolved in the moderator. Control rod drives shall operate satisfactorily in the reactor environment and shall be designed to fail safe.

(5) Accessories

Fuel elements shall be held in place between upper and lower support plates. These plates shall have passages to direct the flow of coolant to the fuel elements. The support plates shall serve as guides for the control rods and permit their passage between the fuel elements. Provision shall be made for attaching the support plates to the reactor vessel.

Baffles and other devices shall be provided, as necssary, to direct the coolant flow and prevent short-circuiting of the desired coolant flow paths.

b. Reactor Pressure Vessel and Pressurizer

(1) Function

The reactor pressure vessel contains the core, steam generator and pressurizer. It supports the primary pump on a short section of primary piping.

(2) Description

The reactor pressure vessel is a vertical right cylindrical vessel with a hemispherical bottom head and a removable top head.

The pressurizer is an integral part of the reactor pressure vessel. Pressurization is obtained in the vapor space resulting from the primary coolant having a free surface below the top head of the pressure vessel.

(3) Design Conditions

Design pressure, psia	1900
Design temperature, °F	629

(4) Design and Construction

The reactor pressure vessel shall meet the requirements of Section VIII of the ASME Boiler and Pressure Vessel Code. Stress analysis due to discontinuities, and thermal transients shall be made in accordance with the provisions of "Tentative Structural Design Basis for Reactor Pressure Vessels and Directly Associated Components," U.S. Department of Commerce, Office of Technical Services, PB 151987.

The reactor pressure vessel shall be fabricated from carbon steel meeting the requirements of ASTM A-302 grade B where plate is required, and ASTM A-336 where forged material is required. Surfaces in contact with primary coolant shall be clad with stainless steel meeting the requirements of ASTM A-240 type 304.

The top head shall have a heavy bolting flange which shall rest on a mating flange, with removable studs for bolting, on the pressure vessel. A double "O" ring-type seal shall be provided between the vessel and the top head with provisions for seal welding the closure.

(5) Accessories

Nozzles shall be provided for the primary coolant inlet and outlet, feedwater inlets, steam outlets, poison injection, primary water injection, primary steam bleed, control rod drives, level detectors, pressure detectors and temperature detectors.

Adequate supports shall be provided for mounting the reactor vessel.

c. Primary Coolant Pumps

(1) Function

The primary coolant pumps circulate primary coolant through the primary system so that heat removed from the reactor core may be used to produce steam in the steam generator.

(2) Description

The primary coolant pumps shall be axial-flow canned motor pumps mounted integrally with and around the reactor pressure vessel.

(3) Operating Conditions

Number	3
Operating pressure, psia	1650
Total primary system pressure drop, psi	~20
Operating temperature, °F	601
Flow, gpm per pump	~ 17,700
Brake horsepower per pump	~ 250

(4) Design and Construction

Pump suction shall be through the annular region between two concentric pipes and the discharge shall be through the central pipe.

The design pressure shall be 1900 psia and the design temperature 629° F.

Material contacting the primary fluid shall meet the requirements of the following ASTM specifications:

Forgings	Stainless Steel A-182 F304
Castings	Stainless Steel A-351 CF8

Electric motors cooled by the contained fluid shall be used as the pump drives.

(5) Accessories

Check valves shall be provided on the pump discharge to prevent a shutdown pump from windmilling and to prevent flow bypassing through the core.

d. Primary Coolant Piping

(1) Function

The primary coolant piping provides a circuit to transport heated primary coolant to the steam generator and return it to the reactor after it has given up energy to produce steam.

(2) Description

The primary coolant piping system consists of three circuits, one for each pump. Each circuit consists of two concentric pipes. The annulus between the pipes carries the flow to the pump while the central pipe carries the flow to the reactor. Each circuit is mounted on the reactor vessel and serves as a mounting for its respective pump.

(3) Design Conditions

Design pressure, psia	1900
Design temperature, °F	629

(4) Design and Construction

The piping shall meet the requirements of ASTM A-376 type 304.

(5) Accessories

None.

e. Steam Generators

(1) Function

The steam generators transfer heat from the primary to the secondary coolant to produce steam.

(2) Description

The steam generators shall be located in the reactor vessel in the annulus between the chimney riser and the reactor vessel. Primary coolant shall flow around the outside of the tubes and superheated steam shall be generated on the inside.

(3) Operating Conditions

Duty, 10^6 Btu/hr	757.5
Primary flow, 10^6 Btu/hr	23.9
Primary inlet temperature, °F	601
Primary outlet temperature, °F	578
Feedwater pressure, psia	725
Feedwater temperature, °F	375
Steam pressure, psia	700
Steam temperature, °F	572
Steam flow, 10^3 lb/hr	830.5

(4) Design and Construction

The steam generator shall consist of four sections, each with its own feedwater inlet and steam outlet. These connections shall be spaced equally around the circumference of the reactor vessel. Provision shall be made for isolating each section so the remaining sections may be operated independently.

The steam generators shall be designed to meet the requirements of the ASME Boiler and Pressure Vessel Code and MIL-S-21204 entitled "Steam Generators, Pressurized Water, Nuclear Naval Ship Propulsion," insofar as they apply to stationary systems. Stress analysis due to discontinuities and thermal transients shall be made in accordance with the provisions of "Tentative Structural Design Basis for Reactor Pressure Vessels and Directly Associated Components," U.S. Department of Commerce, Office of Technical Services, PB 151987.

Plate materials shall be stainless steel meeting the requirements of ASTM A-167, grade 3. Tubing shall be stainless steel meeting the requirements of ASTM-A-213, type 304.

The design pressure shall be 1900 psia, external to the tubes. The design temperature shall be 629° F.

(5) Accessories

Provision shall be made to adequately support the steam generator inside the reactor vessel.

f. Secondary System Piping

(1) Function

The secondary system piping carries steam from the steam generator to the power and water desalination plants and returns feedwater to the steam generator.

(2) Description

Within the scope of this specification the secondary system piping consists of that portion of the steam piping between the steam generator outlet and a point five feet outside of the containment building, and that portion of the feedwater piping between a point five feet outside of the containment building and the steam generator inlet.

(3) Design Conditions

Design pressure, psia	850
Design temperature, °F	629

(4) Design and Construction

The secondary system shall meet the requirements of the latest edition of ASA B-31.1, "American Standard Code for Pressure Piping." Piping shall be carbon steel meeting the requirements of ASTM A-106.

(5) Accessories

Pipe hangers and supports shall be provided as indicated by stress analysis.

2. Auxiliary Systems

a. Chemical Control and Sampling Systems

(1) Function

The chemical control systems shall control and provide means for checking the water chemistry of the primary system.

(2) Description

Chemical control shall be provided by the chemical addition systems and the primary coolant purification system. The chemical addition systems shall inject chemicals, dissolved in primary makeup water, for shim control, pH control and oxygen scavenging. They, the necessary chemicals, shall be injected as required, into the return of the primary purification system with the primary makeup pump boosting the pressure to that of the primary system.

The primary purification system shall be operated intermittently to remove soluble poison for shim control, and to prevent the buildup of excessive crud concentrations. Primary water shall be circulated in this system by the purification pump. It shall be cooled before being demineralized and returned to the reactor.

Sample bombs shall be provided as part of the primary purification system. They shall take water, which has been cooled by the purification cooler, from two sample points, one before and one after the demineralizer. Valving shall permit samples to be taken before the demineralizer when it is not in use. Both sample lines shall have pressure reducing devices before the bombs, double valving on both sides of the bombs and valves to regulate the flow rate. The sampling system shall permit continuous flow through the bombs to avoid stagnant samples. After water has flowed through the bombs it shall go to the suction of the primary makeup pump which shall boost the pressure so the sample streams may be returned to the primary system.

b. Volume Control System

(1) Function

The volume control system shall maintain the proper primary coolant volume and water level in the reactor vessel.

(2) Description

The primary makeup pump shall take demineralized water from storage for the initial filling of the primary system.

Excess volume resulting from heating the cold system or from long-term chemical injection shall be demineralized to remove potential contamination and then let down to storage tanks. Water shall be pumped from the primary makeup storage tanks, to replace losses from the primary system.

Small volume changes and those associated with transients shall be accommodated by fluctuations of the water level in the reactor vessel.

Hydrogen overpressure in the space above the primary cooling shall be provided by gaseous hydrogen from cylinders added to the return line of the primary purification system.

c. Primary Relief System

(1) Function

The primary relief system shall prevent damage to primary system components by relieving excessive overpressures.

(2) Description

The primary relief system shall consist of valves having the relieving capacity required by Section VIII of the ASME Boiler and Pressure Vessel Code. These valves shall be located so that they vent steam from the pressurization space in the reactor vessel to the containment. Vented steam will condense either in the dry well or in the vapor suppression compartment.

d. Off-Gas System

(1) Function

The off-gas system shall be used to vent accumulated gases in the pressurization space prior to removal of the top head of the reactor vessel.

(2) Description

Accumulated gases from the pressurizer space in the reactor vessel shall be vented to a hydrogen recombiner. The resulting vapors shall be cooled and the condensed portion drained to the vapor suppression compartment. The remaining gaseous portion shall be handled as gaseous radioactive waste.

e. Radioactive Waste Disposal System

(1) Function

The radioactive waste disposal system shall provide for the collection, storage and disposal of contaminated solids and radioactive liquids and gases.

(2) Description

Solid radioactive wastes shall be packaged in concrete at a drumming station for off-site disposal.

Two wastes holdup tanks shall be provided for collection of liquid radioactive wastes. Those liquid wastes containing boric acid shall be neutralized before being stored in the waste holdup tanks. The liquid waste holdup tanks shall be vented to the gaseous waste disposal system. An evaporative system shall be provided for the periodic concentration of these wastes. The concentrated waste shall be packaged in concrete at a drumming station for off-site disposal.

Gaseous radioactive waste shall be diluted and vented to the stack if activity levels are sufficiently low. Otherwise it shall be compressed and bottled for decay, eventual release to the stack or off-site disposal.

f. Intermediate Cooling System

(1) Function

The intermediate cooling system shall provide cooling for components to prevent contamination of the circulating water.

(2) Description

The intermediate cooling system shall consist of parallel loops providing cooling for the purification cooler, the spent fuel storage pool, the vapor suppression compartment and the containment dry well. Coolant from all loops shall be pumped through the intermediate cooler, where it shall be cooled by salt water from wells which shall be wasted after being used.

g. Decay Heat Removal System

(1) Function

The decay heat removal system shall remove heat from the reactor when it is shut down.

(2) Description

The decay heat removal system shall consist of a decay heat cooler in a loop parallel to the secondary system. This cooler shall remove heat from the secondary system by natural convection of air.

h. Fuel Handling Equipment

(1) Function

The fuel handling equipment shall place fresh fuel in the reactor, shuffle partially burned fuel and transfer spent fuel from the reactor to the spent fuel storage pool.

(2) Description

Tools shall be provided to meet the functional requirements stated in the previous section.

i. Instrumentation and Controls

(1) Function

Instrumentation shall measure and record those parameters required for safe and efficient operation of the plant. Controls shall be provided for adjustment of the operating parameters.

(2) Description

The instruments shall be classed as nuclear, process and radiation monitoring instrumentation. Nuclear instruments shall be provided to measure flux levels and reactor period. Process instruments shall be provided to obtain data on pressure, temperature, flow, level and conductivity in all systems associated with the nuclear island. Radiation monitoring equipment shall be provided to measure radiation levels in those portions of the nuclear island which are occupied by personnel continuously or intermittently. It shall include instruments required for normal health physics operations, but not instruments for site monitoring.

Controls shall be of the automatic or manual type as dictated by the requirements of each system. Automatic controls shall include all interlocks necessary for safety and protection of components. Control panels are not required.

j. Containment and Shielding

(1) Function

The containment shall minimize the release of activity if an accident occurs. Shielding shall provide radiation protection for operating personnel.

(2) Description

The containment shall be of the pressure suppression type. It shall consist of a cylindrical dry well tank surrounded by an annular vapor suppression compartment which is partially filled with water. Large pipes shall penetrate the wall between the dry well and vapor suppression chamber and discharge to smaller pipes with outlets below the water level.

Shielding shall be designed to provide radiation levels meeting the requirements of 10 CFR 20.

k. Heating and Ventilation

(1) Function

Heating and ventilation shall be provided for the health and comfort of operating and maintenance personnel in the nuclear plant.

(2) Description

The type of heating system used shall be optional. The design shall be based on winter conditions at Key West, Florida.

The ventilation system shall be capable of circulating 100 percent fresh air in all areas occupied by operating and maintenance personnel at any time. It shall exhaust to the stack through filters. Design shall be based on summertime conditions at Key West, Florida.

3. Turbine Generator Plant

a. Turbine Generator

(1) Function

The steam turbine generator unit will serve the dual function of electric power conversion and furnishing process steam for the salt water distillation plant when supplied with superheated steam by the reactor steam generator.

(2) Description

(a) Turbine

The turbine installed indoors and direct connected to the generator shall be a tandem-compound, double-flow, nonreheat, multistage, extraction, condensing-type unit. It shall include a speed control (including overspeed) system, pressure regulator, gland sealing system, complete lubricating oil system, moisture extraction devices where required, vacuum breaker and motor-operated turning gear.

(b) Generator

The generator shall be a totally enclosed, self-ventilated synchronous, three-phase, 60-cycle, hydrogen-cooled unit. It shall include a shaft-driven main exciter, motor-driven spare exciter, switchgear, gas cooling and purge system, gland seal oil system and voltage regulator.

(3) Operating Conditions

(a) Turbine

Rated capacity (nameplate)	50,000 kw
Throttle conditions	685 psig 572 ° F
Exhaust pressure	2.0 in. Hg Abs
Controlled extraction pressure	37.9 psia
Controlled extraction flow	246,900 lb/hr
Number of uncontrolled extraction openings	4
Speed	3,600 rpm

(b) Generator

Rated capacity	66,400 kva
Power factor	0.85
Short circuit ratio	0.64
Voltage	13,800 volts
Speed	3,600 rpm
Hydrogen pressure	30 psig max

(c) Exciter

Voltage	250 volts

(4) Design and Construction

The design and construction shall comply with the applicable minimum requirements of the latest revisions of the following: ASA, ASME, ASTM, AIEE, NEMA and NBFU.

(a) Turbine

Stop, throttle and control valves shall be hydraulically operated with the stop and throttle valves including limit switches, steam strainers and solenoid trip.

Speed governors shall be oil-relay type with manual load limit control and with overspeed governors tripping at 110 percent speed and reset above 101 percent.

Additional features shall include a motor-operated speed changer, oil-operated speed changer, oil-operated pilot dump valve and thrust, low oil pressure and low vacuum trips including alarm switches.

The lubricating oil system shall include a reservoir with level switches and gage, shaft-driven main oil pump, twin oil coolers, auxiliary oil pumps with automatic starting and all interconnecting piping.

The unit shall be capable of operation up to 120 percent over rated speed without excessive vibration or signs of stress or instability.

The control system shall be designed so that steam is not admitted until there is sufficient oil pressure for lubrication.

In addition to design for pressure and temperature conditions, materials selected for areas where protection from wet steam is required shall be highly corrosion and erosion resistant. Special materials such as chrome stainless steel for blading and buckets and stellite for valve seats shall be used.

All piping required to connect equipment furnished by the manufacturer that is mounted on or immediately adjacent to the turbine generator shall be furnished.

(b) Generator

The hydrogen control system shall include pressure regulators, and devices for maintaining the degree of purity required; a system for safe filling and scavenging the generator; equipment for the removal of gases and water from the gland seal oil and instruments and alarms for auxiliary apparatus and the pressure of water in the generator.

Additional features shall include a field discharge resistor, bushing current transformers and temperature detectors for both the generator and exciter.

The excitation system shall include the excitation cubicles with voltage regulator, field air circuit breaker, motor-operated main exciter field rheostat and enclosure, and illumination.

The spare exciter shall be of the high-inertia motor-generator type with performance equal to that of the shaft-driven exciter.

Insulation of the generators and exciters shall be Class B.

Generator windings, connections and terminal leads shall withstand, without damage, any three-phase fault current at the generator terminals.

Standard insulation and steel appearance lagging for an enclosed turbine room installation shall be provided. Reusable blankets and maintenance joints are required.

(5) Accessories

(a) Turbine

A complete set of turbine supervisory instruments, panel mounted to record the following: rotor eccentricity and vibration, casing and differential expansion, rotor position and speed, control and stop valve position and metal temperatures.

Pressure transmitters and receivers, pressure gages, thermocouples and thermometers shall be supplied as required for a complete installation.

(b) Generator

All alarms and instruments required to safeguard the generator, exciters and hydrogen equipment shall be provided, assembled on a floor-mounted panel.

b. Feedwater Heaters

(1) Function

The feedwater heaters heat regeneratively the feedwater from the temperature at the surface condenser hot well to the temperature required at the inlet of the reactor steam generator. Bleed steam from the turbine is the heating medium.

(2) Description

The one high-pressure and two low-pressure feedwater heaters shall be of the closed, shell-and-tube type with the steam on the shell side and the feedwater in the tubes. Condensate drains shall be cascaded with high-pressure heater drains cascaded to the deaerating feedwater heater and low-pressure heater drains to the surface condenser hot well.

(3) Operating Conditions

(a) Tube Side

	Htr No. 1	Htr No. 2	Htr No. 4
Feedwater flow, lb/hr	461,370	461,370	830,500
Feedwater temp in, ° F	101.1	177.5	301.6
Feedwater temp out, ° F	177.5	225.0	375.0
Maximum pressure drop, psi	10	10	10
Design temp, ° F	300	300	450
Design pressure, psig	250	250	1,100

(b) Shell Side

	Htr No. 1	Htr No. 2	Htr No. 4
Steam pressure, psia	7.93	20.78	195.7
Steam inlet enthalpy, Btu/lb	1071.0	1126.0	1182.0
Steam flow, lb/hr	29,600	18,070	70,380
Drains outlet temp, ° F	111.1	187.5	311.6
Drains inlet flow lb/hr	76,460	58,390*	-
Drains inlet flow enthalpy, Btu/lb	155.4	232.7*	-
Design temperature, ° F	250	300	450
Design pressure, psig	50	50	300

* From Moisture Separator

(4) Design and Construction

The design and construction of the heaters shall comply with the minimum requirements of the latest revision of the ASME and FHMA.

All shell side joints welded and the side joints shall employ the conventional bolted closures. All nozzles shall be weld-ends.

(5) Accessories

All necessary instruments, controls and connections for level control and alarm, gage glass, pressure and temperature gages, safety and relief valves shall be furnished.

c. Condensate Pumps

(1) Function

The condensate pumps take suction from the surface condenser hot well and discharge through various heat exchangers and the low-pressure feedwater heaters to the deaerating feedwater heater.

(2) Description

The 100 percent capacity pumps installed indoors shall be horizontal centrifugal, volute-type units connected through a flexible coupling to electric motor drives.

(3) Operating Conditions

Capacity	1125 gpm
Total head	200 psi
Condensate temperature	101.1 ° F

(4) Design and Construction

The design of the pumps and motors shall comply with the applicable minimum requirements of the latest revision of the following standards: H.I.S., ASME, ASTM, AIEE and NEMA.

Pump materials shall be standard, bronze fitted. The casing shall be horizontally split permitting dismantling without disturbing the suction and discharge nozzles. Bearings shall be the ball type with grease or oil lubrication.

The electric motors designed to operate at 440 volts, 3 phase, 60 cycles shall be drip-proof, squirrel-cage induction with ball bearings and designed to operate in a maximum ambient temperature of 50° C.

d. Boiler Feed Pumps

(1) Function

The boiler feed pumps take suction from the elevated deaerating feedwater heater storage tank and discharge the feedwater through the high-pressure feedwater heaters to the reactor steam generator.

(2) Description

The two 50 percent capacity pumps operating in parallel and installed indoors shall be horizontal centrifugal, multistage-type units directly connected through a flexible coupling to electric motor drives with provision for minimum flow recirculation back to the deaerator.

(3) Operating Conditions

Discharge flow	900,000 lb/hr
Deaerator pressure	66.9 psia
Static suction head (minimum)	30 ft
Suction temperature	300 °F
TDH	900 psi
Shutoff head (maximum)	120% of rated head

(4) Design and Construction

The design and construction of the pumps and motors shall comply with the applicable minimum requirements of the latest revision of the following standards: ASME, H.I.S., ASTM, AIEE and NEMA.

The pump casing shall be horizontally split and shall permit pump dismantling without disturbing the suction and discharge nozzles.

Stuffing boxes under suction pressure shall be water cooled with packing material suitable for the service conditions.

Radial and thrust bearings shall be the ball type with oil lubrication and water cooled. Pump materials shall be standard, bronze fitted.

Recirculation control equipment shall be complete and shall include, but is not limited to, a stainless-steel breakdown orifice, control valve, three-way solenoid valve, flowmeter, relays, and limit switches suitable for 125-volt d-c operation.

The electric motors designed to operate at 4,000 volts, 3 phase, 60 cycles shall be drip-proof, squirrel-cage induction with sleeve bearings and designed to operate in a maximum ambient temperature of 50° C.

e. Deaerating Feedwater Heater

(1) Function

The deaerating feedwater heater heats and deaerates the feed and makeup water to the steam generator and is located in the feedwater stream between the low- and high-pressure feedwater heaters. Bleed steam from the turbine is the heating medium.

(2) Description

The deaerating heater shall be the spray or tray type with vent condenser and shall be mounted on a horizontal storage tank. The unit shall deaerate and heat both the brine heater drains and feedwater in addition to handling the condensate drains from the high-pressure feedwater heaters.

(3) Operating Conditions

Outlet capacity	830,500	lb/hr
Outlet feedwater temperature	299.9	° F
Steam pressure	66.9	psia
Steam flow	51,850	lb/hr
Steam enthalpy	1115.0	Btu/lb
Feedwater flow	449,390	lb/hr
Feedwater temperature	225.0	° F
H.P. heater drains flow	70,380	lb/hr
H.P. heater drains temperature	311.6	° F
Brine heater return flow	246,900	lb/hr
Brine heater return temperature	262.4	° F
Maximum oxygen content	0.005	cc/liter

(4) Design and Construction

The storage tank shall be horizontal with a capacity of 8500 gallons. The deaerating unit shall be mounted either horizontally or vertically on the storage tank.

Trays, spray nozzles, impingement plates and vent condenser shall be fabricated of stainless steel with the remainder of the unit fabricated of rolled and welded carbon steel. Design shall be to ASME code for unfired pressure vessels.

Design shall be such that deaerated feedwater is sent directly to the suction of the boiler feed pump.

(5) Accessories

All necessary instruments, controls and connections, i.e., level controls and alarms, gage glasses, pressure and temperature gages, safety valve and vacuum breaker, shall be furnished.

f. Steam Generator

(1) Function

The steam generator's function is to produce steam required by the desalination plant when either the turbine or reactor is out of service.

(2) Description

One steam generator with normal design margins shall be utilized. The steam generator shall be fuel-oil-fired, natural circulation units with pressurized or balanced draft, and designed for installation outdoors.

The unit shall be furnished where required, with economizer, forced-draft fans, and accessories. Dust collectors are not required.

(3) Operating Conditions

Maximum continuous capacity	300,000 lb/hr
Steam pressure at outlet	125 psig
Steam temperature at outlet	saturated (353° F)
Inlet feedwater temperature	250 ° F
Ambient air temperature	110 ° F

(4) Design and Construction

Design and construction shall comply with the applicable requirements of the latest revisions of the following: ASME Boiler Construction Code, ASTM and all other state and local codes that may apply.

The furnace shall be of pressure-fired tangent tube construction, completely water cooled and preferably designed for forced-draft operation without induced-draft fans. The ignition system shall be permanently installed with remote automatic operation and complete with burners and auxiliaries for use with gas or light oil.

Fuel oil burned shall be that with a high sulfur and vanadium content, and final air outlet temperatures shall be such that the metal temperatures shall be maintained above flue gas dew points. Furnace design and boiler convection surfaces shall be arranged to prevent distress due to high vanadium oils.

An economizer, if required, shall have bare inline tubes with a nonsteaming design preferred.

Steam retractable soot blowers automatic and sequentially operated complete with piping and valves to a common terminal shall be of a sufficient number and properly placed in the furnace and convection pass(es).

The steam separators or purifiers shall guarantee not more than 1.0 ppm solids at all loads.

All ducts and breechings shall be leaktight and fully insulated for personnel protection with a maximum surface temperature of 160° F.

Forced-draft fans shall be sized for the design quantity and pressure to which shall be added standard test block tolerances and shall have backward curved blades, control dampers, self-aligning pressure-lubricated bearings and shall be driven through flexible couplings by electric motors.

(5) Accessories

All accessories necessary to comprise a complete installation shall include, but not be limited to, the following: steam temperature controls with control range 65 percent to 100 percent of gross generating capacity, safety valves, orifices, thermocouples, bearing monitoring system, ultra-violet safety flame detection devices, water level gages and columns, vent and drain valves, valved sampling connections, dampers, thermometers and pressure gages, feedwater stop check valve, blowoff valves and feedwater regulator controls.

(6) Electric Motors

The electric motors shall be designed for outdoor service and to operate at 440 volts, 3 phase, 60 cycles, shall be weather-protected NEMA Type II, squirrel-cage induction with sleeve bearings and designed to operate in a maximum ambient temperature of 50° C.

g. Surface Condenser

(1) Function

The surface condenser shall serve to condense all of the turbine exhaust steam utilizing well water as the cooling medium. The condensate is pumped from the condenser hot well to the deaerating heater by the condensate pump via the low-pressure feedwater heaters.

(2) Description

The surface condenser shall be a 2-pass divided water-box type with a nondeaerating hot well, internal air cooling section and designed for indoor installation. The condenser shall be rigidly supported on foundations with an expansion joint between the turbine exhaust and the condenser steam inlet. Auxiliaries for a complete installation shall include, but not be limited to, the following: steam jet air ejector with surface-type inter-after-condenser, hogging ejector, loop seal trap or traps and integral steam piping to a common connection. Condensate from the condenser shall be used as the cooling medium for the air ejector condenser.

(3) Operating Conditions

Steam condenser	335,000 950	lb/hr @ Btu/lb
Absolute pressure @ condenser inlet	2.0	inches, Hga
Inlet temperature of cooling water	85	° F
Cleanliness factor	85	%
Maximum water velocity through tubes	7.0	ft/sec
Quantity of cooling water	64,500	gpm
Quality and source of cooling water	Saline well water that also contains 3 ppm of dissolved H_2S	

(4) Design and Construction

The design shall be in accordance with the standards of the HEI.

Water box design pressure	25	psig
Tube material	70-30	Cu Ni
Gage of tubes	1"-18	BWG
Maximum tube length	24	ft

Tubes furnished by the contractor shall be rolled into both tube sheets with the inlet end belled, and expansion taken care of by an expansion joint. Hot well shall be sized for 10 minutes' storage.

(5) Accessories

Accessories for a complete installation shall include, but are not limited to, the following: atmosphere relief valve, air leakage meter, vacuum gage, thermometers, liquid level controllers and gage glass.

h. Circulating Water Pumps

(1) Function

The circulating water pumps pump cooling water from deep wells to the steam surface condenser.

(2) Description

The pumps shall be vertical, single stage, mixed flow, wet-pit type installed outdoors in a well casing with the pump discharge above grade. The pumps shall support and be driven by vertical electric motors connected through a rigid coupling.

(3) Pump Operating Conditions

Number of pumps	2	1/2 capacity
Design capacity of each	32,250	gpm
Total dynamic head	35	ft

(4) Design and Construction

The design of the pumps and motors shall comply with the applicable minimum requirements of the latest revision of the following standards: H.I.S., ASME, ASTM, AIEE and NEMA.

The pump casing of cast iron and column of carbon steel shall be epoxy lined inside and out. The impeller shall be zincless bronze with stainless-steel shaft. The column shaft shall be carbon steel with water-lubricated bearings. The pump shall be fitted with a bottom screen.

The electric motors, designed to operate at 440 volts, 3 phase, 60 cycles, shall be the vertical type suitable for outdoor installation. The motors shall be weather protected NEMA Type II, squirrel-cage induction with ball bearings and designed to operate in a maximum ambient temperature of 50° C.

i. Air Compressors

(1) Function

Two air compressors, driven by electric motors, will furnish the supply of compressed air required by the instruments and plant services. One unit will supply the instrument air and one unit will supply the plant service air.

(2) Description

The instrument air compressor, installed indoors, shall be a reciprocating, single-stage, double-acting, water-cooled, cross-head-type unit with oilless piston action and aftercooler.

The plant service air compressor, installed indoors, shall be a reciprocating, two-stage, double-acting, water-cooled, cross-head type, with interstage cooler and aftercooler.

Each unit shall be furnished with a moisture separator, inlet-air filter silencer and air receiver.

The instrument air unit shall, in addition, be furnished with an automatic air drier complete with piping, control valves, dessicant, control panel, pre- and afterfilters and all necessary accessories for a complete unit.

The plant service air unit will serve as the backup for the instrument air unit and, therefore, an oil separator adsorber shall be furnished.

The electric motors shall be squirrel-cage, induction-type units suitable for indoor installation.

(3) Operating Conditions

(a) Compressors

	Instrument	Service
Capacity; cfm net	120	120
Altitude	Sea level	Sea level
Discharge pressure, psig	100	100
Ambient temperature ° F	105	105
Cooling water temperature ° F	85	85
Cooling water pressure psig	50	50

(b) Motors

	Instrument	Service
Volts	440	440
Phase	3	3
Frequency - cycles/second	60	60

(4) Design and Construction

The design of the compressors and motors shall comply with the applicable minimum requirements of the latest revision of the ASME, ASTM, AIEE and NEMA.

All equipment shall be classified as heavy-duty and built for 24-hour continuous service.

The instrument air compressor shall be V-belt driven and design shall include pulleys, V-belts and guards. The service air compressors shall be direct connected through a flexible coupling.

Inter- and aftercoolers shall have nonferrous tube bundles with proper provision for expansion and moisture separation. Maximum tube side pressure drop shall be 10 psi.

Air receivers shall be vertical with a volume of 34 cu ft each.

The air drier shall dry continuously, the rated capacity of the instrument air compressor, to a dew point of -40° F. If heat reactivated, the cycle shall be 4 hours.

The oil separator-adsorber shall be sized for the rated flow of the instrument air compressor with a maximum pressure drop of 5 psi with a maximum oil contamination of 1.5 ppm. Accessories for a complete unit are required.

The instrument air compressor control shall be constant speed with automatic unloading with control permitting automatic unloading during startup. The service air compressor control shall be dual-control permitting constant speed automatic unloading or automatic start-and-stop regulation.

(5) Accessories

Accessories for a complete system including but not limited to the following shall be provided: relief valves, safety valves, thermostatic shutdown control, thermometers, pressure gages, drain traps, oil pressure failure device, pressure switches, automatic water valve, solenoid valves.

D. Preliminary Hazards Review of Plant Site

1. Selection and Description

To obtain better economics for water distribution, the site review concentrated on the centrally located Keys in the Lower Keys area. In addition it was felt that a fair degree of isolation would be desirable for a nuclear plant. The northern tip of Sugarloaf Key, Exhibit VII-3, meets these requirements.

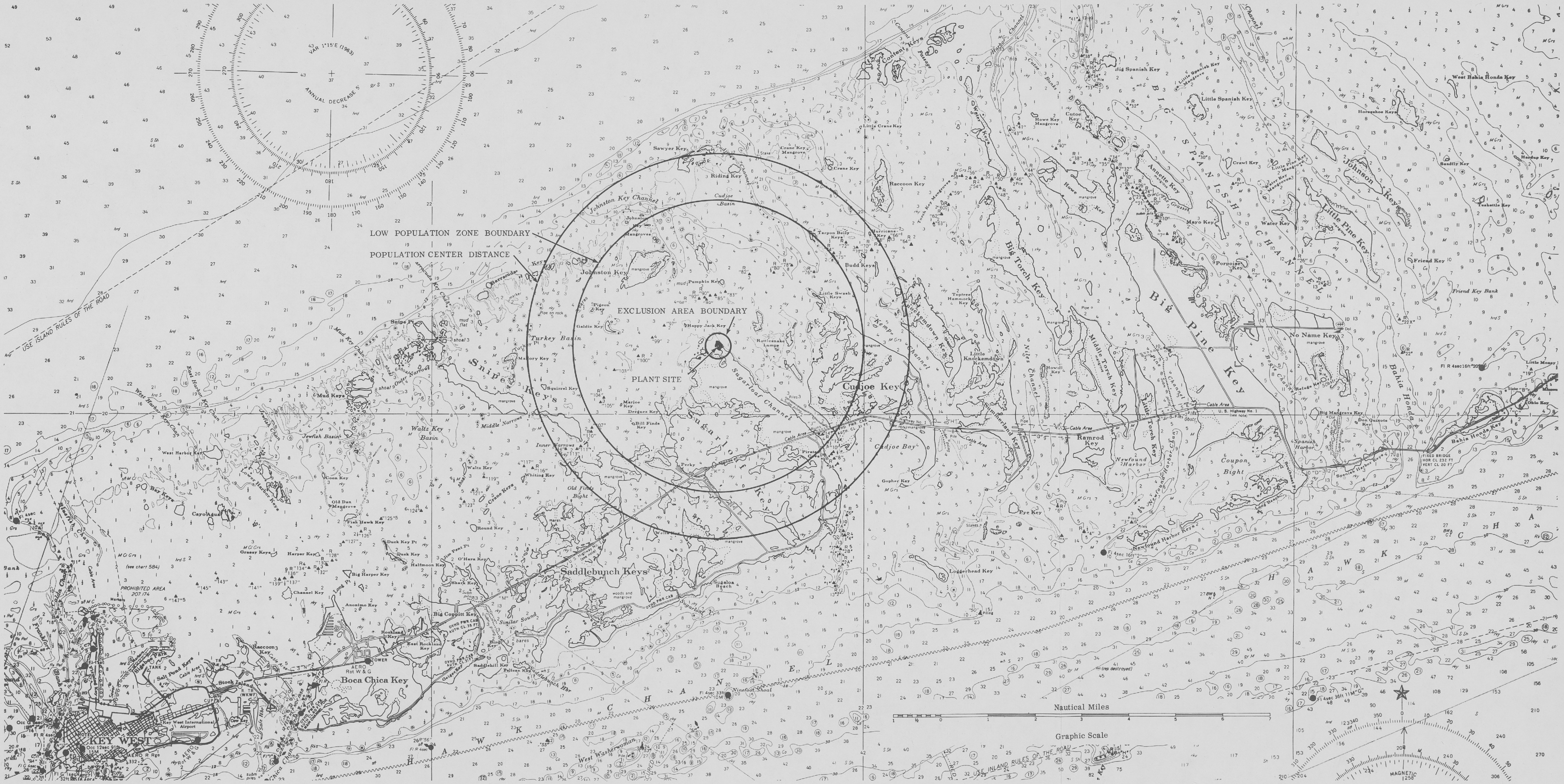
In addition such a site provides the highest degree of protection against hurricanes that can be expected of a site in the Florida Keys. On the Florida Straits side, protection is afforded by Sugarloaf Key itself. On the Gulf side protection is offered by the Keys and the shallow water to the north.

Exhibit VII-4, page VII-34, shows the boundaries of the exclusion area and the low population zone. It should be noted that a substantial portion of both includes water area instead of habitable land area. Location of the plant site at the extremity of the Key is also helpful in that it will still have a fair degree of isolation even if population grows on Sugarloaf Key. From the exhibit, it is seen that Key West, the nearest population center, is a substantial distance beyond the population center distance. The radii of the various zones were obtained from TID-14844 which gives this data for water-cooled reactors. Since site conditions are so favorable and the project is only in a feasibility stage, no attempt has been made to reduce these distances by more sophisticated engineering.

2. Meteorology

Summer temperatures average about 84° F. During the winter the temperatures average about 70° F. The annual mean temperature

FEASIBILITY STUDY - FLORIDA KEYS



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for the period of record, which dates back to 1906, is about 77° F. Temperature extremes of 97° F in August, 1906, and 41° F in January, 1886, were observed at other nearby stations.

During the six months from November through April only about 30 percent of the annual rainfall occurs, with most of it in an average of two heavy and three or four light showers in a month. The remaining 70 percent falls in numerous showers and thunderstorms a few days apart in the period from May through October. Heavy rains are also associated with hurricanes which occasionally pass through this area. The average annual precipitation is about 37.5 inches, with the maximum annual precipitation since 1906 being the 58.01 inches which fell in 1958. The maximum monthly precipitation of 23.56 inches fell in October, 1933. The maximum daily precipitation was 19.88 inches in November, 1954. Due to the moderate temperatures none of the precipitation has occurred as snow. Fog of short duration occurs infrequently and adds up to a total of one day of fog per year.

Surface winds are mainly from the northeast at speeds slightly over 10 mph during the winter. In the summer they are from the southeast at slightly lower speeds.

The Florida Keys area is subject to hurricanes which usually occur in the period between June and October. However, they have occurred as early as March and as late as December. Discounting the period prior to 1900, because the records do not give a true indication of frequency, the total number of tropical storms affecting the state of Florida through the end of 1960 was 117. Of this total, 43 had winds, while in the Florida coastal area, of 74 mph or greater to qualify them as hurricanes. Based on this period of record the average hurricane frequency in the Upper Keys is one in 3.4 years, while in the Lower Keys it is one in 5.1 years. Although the frequency is relatively low, hurricanes in the Keys are particularly destructive, because there is open water on both sides.

Aside from the heavy rainfall (already discussed) associated with hurricanes, their manifestations are low barometric pressure, high winds, high tides and wave action. The low barometric pressure is not damaging in itself. However, it contributes to the tidal effect and is a partial index of wind intensity. As a result of studies made by the U.S. Weather Bureau, a standard project hurricane has been designed. The magnitude of this hurricane is that of one which could be expected once every 100 years. For the Florida Keys this hurricane has a minimum central pressure of 26.8 inches and maximum ten-minute average winds of 118 mph. The resulting tide would range from 7.5 feet in the Lower Keys to 12.0 feet in the Upper Keys. Tides could be even higher if the hurricane tides coincided with normal high tides. This would correspond to taking a storm of lower frequency as the design storm.

In the "Labor Day Hurricane" of 1935 the barometric pressure dropped to 26.35 inches of mercury, the lowest ever recorded at Craig, Florida. Though there were no instruments to record wind velocities, special Weather Bureau studies indicate that sustained velocities ranged from 114 to 126 mph with peak winds, in gusts, reaching 190 to 210 mph. This is comparable to the maximum recorded wind velocity of 122 mph at Key West. During the "Labor Day Hurricane," which struck between Lower Matecumbe Key and Long Key, the water level rose from ten to twelve feet exclusive of wave runup. Wave runup on sloping beaches could increase this by four or five feet, locally. All of this data on maximum storms of record serves to establish the reliability of the design parameters of the U.S. Weather Bureau standard project hurricane.

The terrain has no significant effect on meteorology since the Florida Keys are small, low-lying islands in an enormously larger mass of open water. For this reason, allowance need not be made for local meteorological effects in applying offsite data to the proposed site.

The preceding discussion of meteorological conditions is based on:

1. Local Climatological Data with Comparative Data, 1961, Key West, Florida, U.S. Department of Commerce, Weather Bureau.

2. Survey Report, Analysis of Hurricane Problems in Coastal Areas of Florida, Corps of Engineers, U.S. Army Engineer District, Jacksonville, Florida, September 29, 1961.

3. Geology

The Upper Keys are of coral-reef origin and are elongated in a direction parallel to the coastline along which the reef grew during the Pleistocene epoch. The Lower Keys are an extension of the oolitic limestone reef or bar on which Miami and other mainland cities of southeastern Florida are built. Their northwest-southeast elongation results from the combined effects of tidal scour and the original shape of the oolitic bar from which they were formed. The overburden varies from a sand to an organic muck. It is thin, and outcrops of rock can be seen along the highway.

It is expected that proper foundation treatment will enable the underlying limestone to support the structures necessary for this facility. Such foundation treatment would consist of filling and grouting any potholes or solution channels that might be found in the limestone. This procedure has been used where large dams, such as those of the TVA, have been built on limestone formations. In such cases foundation treatment is even more important, because the high head of water behind the dam causes excessive seepage under the dam, and possible enlargement of the channels with resultant weakening of the foundation.

Since the soil is thin, it would have negligible effect on the retention, by ion exchange or filtration, of material from a spillage of radioactive liquid.

The basis for the preceding discussion of geological characteristics of the Florida Keys is:

1. U.S. Department of the Interior, Geological Survey Water Supply Paper 1255, Water Resources of Southeastern Florida.

4. Seismology

All of Florida, including the Keys, is seismically quiet. The Keys can be considered as part of the Gulf of Mexico area which is a minor stable mass. The nearest earthquake on record occurred on

January 12, 1879, in northern Florida, west of Saint Augustine. Its intensity was such that the damage at Saint Augustine was limited to articles being thrown from shelves and plaster being shaken down. This earthquake was felt from Savannah, Georgia, to Daytona, Florida.

In terms of the zones defined by the International Conference of Building Officials, this area is in Zone zero. In this zone earthquake damage is not anticipated and need not be considered in design of structures.

References used in evaluating seismic conditions were:

1. Seismicity of the Earth, Gutenberg and Richter, Princeton University Press, 1954.
2. Earthquake Damage and Earthquake Insurance, John R. Freeman, McGraw-Hill, 1932.
3. Uniform Building Code, Volume 1, International Conference of Building Officials, 1961.

5. Hydrology

The small size of the islands making up the Keys, together with the limited thickness of overburden results in rapid runoff of rainfall that does not find its way to solution channels in the underlying limestone. Because of the above considerations and the low relief, the runoff goes directly to the Gulf of Mexico or the Straits of Florida instead of being carried away by streams. The Gulf of Mexico is a large body of water, while the Florida Straits are the channel for the Gulf Stream, which has a velocity of four to five miles per hour in this vicinity.

Both bodies have a considerable amount of aquatic life and the good fishing undoubtedly is a factor in attracting tourist trade.

Potholes or natural wells, resulting from solution of the limestone, are common. Sometimes these potholes coalesce to form ponds reaching near the water table, which then become centers of extremely lush vegetation.

Potable water in the Florida Keys is supplied by an aqueduct from the mainland instead of water from local wells. The latter have a high salinity and mineral content. An analysis of the circulating water wells of the City of Key West power plant is shown below. The water in these wells is at depths ranging from 106 to 180 feet during pumping. It has a temperature of 78° F all year.

City of Key West Electric Plant
Water Analysis - April 1961
Salt Water Wells

	ppm
H_2S	2.82
Total hardness as $CaCO_3$	7000.
Magnesium hardness as $CaCO_3$	5840.
Calcium hardness as $CaCO_3$	1160.
P Alk as $CaCO_3$	0.0
MO Alk as $CaCO_3$	132.
Free CO_2	12
Chlorides as NaCl	36200
Sulphate as Mg_2SO_4	4360
Phosphate as PO_4	0.4
SiO_2	2.5
Iron as Fe	0.2
pH	7.45

Information on hydrology was obtained from:

1. U.S. Department of the Interior, Geological Survey Water Supply Paper 1255, Water Resources of Southeastern Florida.
2. Records of wells of the City of Key West Power Plant.

6. Background Radiation

The gross alpha and beta activity of water in Key West cistern samples and in the treated supply is as follows:

Florida State Board of Health

Analysis of Water for Gross Radioactivity

I. Key West Cistern Samples

Date Sampled	Gross Alpha (pc/l)	Gross Beta (pc/l)
11/4/60	0.14	N.D.
12/5/60	0.38	N.D.
1/4/61	N.D.*	0.7
2/3/61	0.12	0.6
3/2/61	0.11	6.7
4/3/61	0.24	4.0
5/1/61	N.D.	N.D.
6/5/61	0.17	4.9
8/2/61	0.04	3.2
8/2/61 (duplicate)	0.10	10.3
8/2/61 (duplicate)	0.18	5.5
8/2/61 (duplicate)	N.D.	10.9
9/5/61	0.05	4.1
11/15/61	0.38	27.3
12/4/61	N.D.	29.5
1/2/62	N.D.	73.2
2/5/62	---	71.5
3/5/62	---	61.5
4/3/62	---	29.3
5/3/62	---	39.6
6/7/62	0.05	35.2
7/2/62	---	26.3
8/1/62	0.03	31.7
9/5/62	0.17	30.9
10/4/62	0.12	28.3
3/4/63	---	231
4/1/63	---	168
5/2/63	0.25	164
5/22/63	0.19	360
6/10/63	0.08	149
7/1/63	0.14	284

*Not Detectable

II. Key West Treated Water Supply Sample

Date Sampled	Gross Alpha (pc/l)	Gross Beta (pc/l)
5/17/62	N.D.	6.4

VIII. COMPARATIVE FOSSIL-FUELED POWER PLANT

A. Plant Size, Heat Balance and Turbine Plant Design

1. Plant Description

General. The fossil-fuel-fired steam electric generating plants considered in this report are residual-oil-fired units complete in all respects, and include all equipment up to the low-voltage side of the main power transformer. The main power transformers are not included since these are considered as part of the transmission system. All of the fossil-fired steam electric plants are designed to produce power at the low-voltage side of the main power transformer. Heat balances as follows are included.

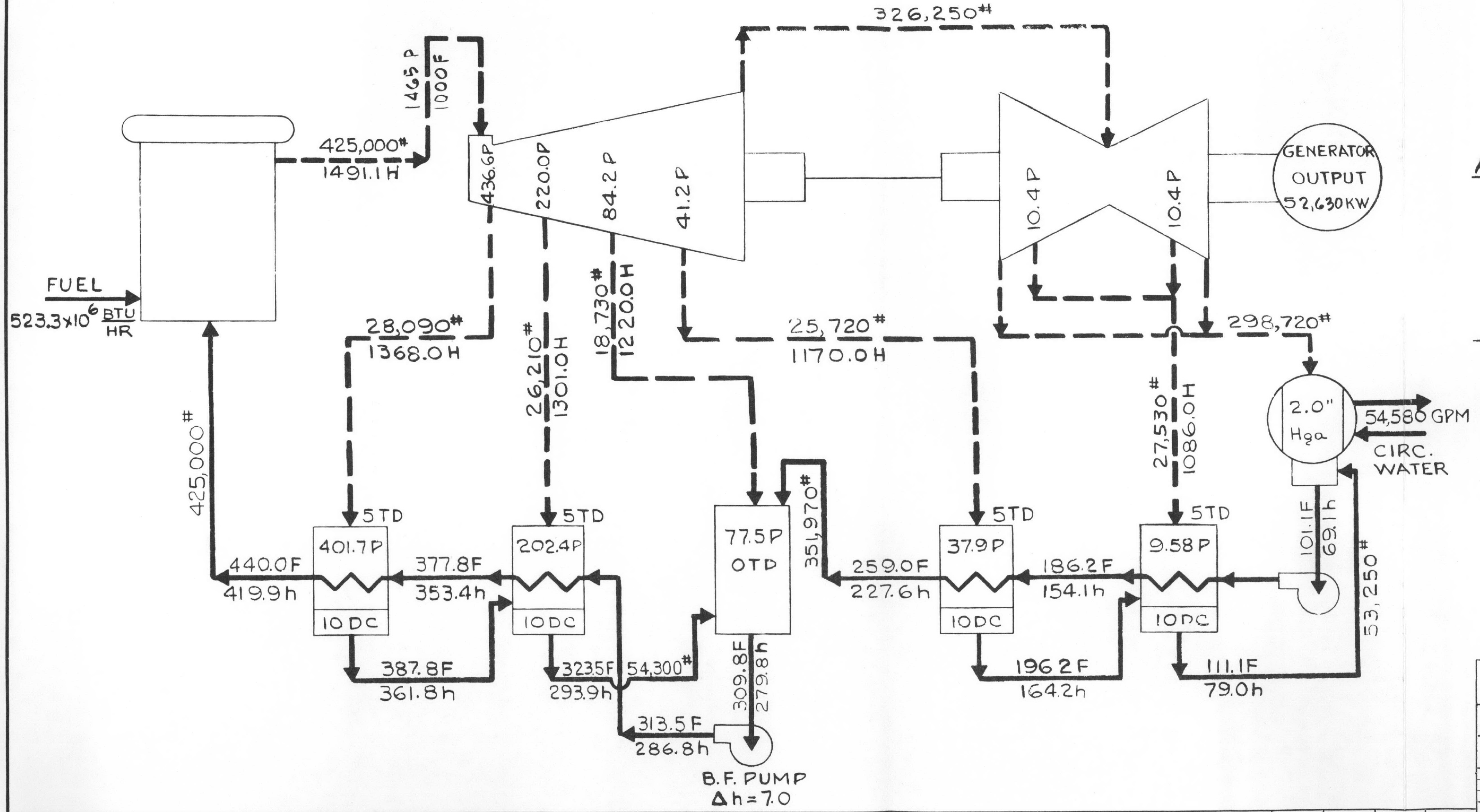
Exhibit VIII-1- (page VIII-2)	50,000-KW Net Electrical Output - Unassociated with Water Plant
Exhibit VIII-2- (page VIII-3)	50,000-KW Net Electrical Output - Associated with Water Plant of 10,000,000-Gallon-per-Day Capacity

The overall design of the fossil-fired steam electric generating plants is consistent with the high plant factors predicted for the operating life of the plant. The plants are of semioutdoor design with the turbine bay and control room enclosed and the boiler outside and provided with the necessary weatherproofing. The turbine room will be provided with a crane designed to lift the generator rotor and turbine casing sections.

Steam Generators. Steam generators are of proven conventional design and are equipped with boiler and superheater sections, air preheater, forced-draft fans, heavy oil burners and burner lighters, steam soot blowers, ductwork, breeching and stack. Boiler instrumentation, steam temperature, combustion and burner lighter controls, as well as secondary accessories are also included. For the cases where water plants are considered, two steam generators, each of 50 percent capacity, will be supplied in order to ensure continuous operation of the water desalination plant.

GROSS TURBINE HEAT RATE $= \frac{425{,}000(1491.1-419.9+7.0)}{52{,}630} = 8{,}707 \frac{\text{BTU}}{\text{KWHR}}$

NET PLANT HEAT RATE $= \frac{425{,}000(1491.1-419.9)}{50{,}000(.87)} = 10{,}466 \frac{\text{BTU}}{\text{KWHR}}$



AUXILIARY POWER
BLR. & TURBINE PLANT = 2,630 KW

NET PLANT OUTPUT = 50,000 KW

UNASSOCIATED PLANT

CASE A

LEGEND
- ▬ ▬ ▬ STEAM
- ▬▬▬ LIQUID
- P PRESSURE, PSI ABSOLUTE
- h LIQUID ENTHALPY, BTU/LB
- H VAPOR ENTHALPY, BTU/LB
- # FLOW, LB/HR
- F TEMPERATURE, °F

Reynolds, Smith and Hills, Jacksonville, Fla.
BURNS AND ROE, INC. NEW YORK, N. Y.

HEAT BALANCE FOR STUDY PURPOSES

FEASIBILITY STUDY - COMB. ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS

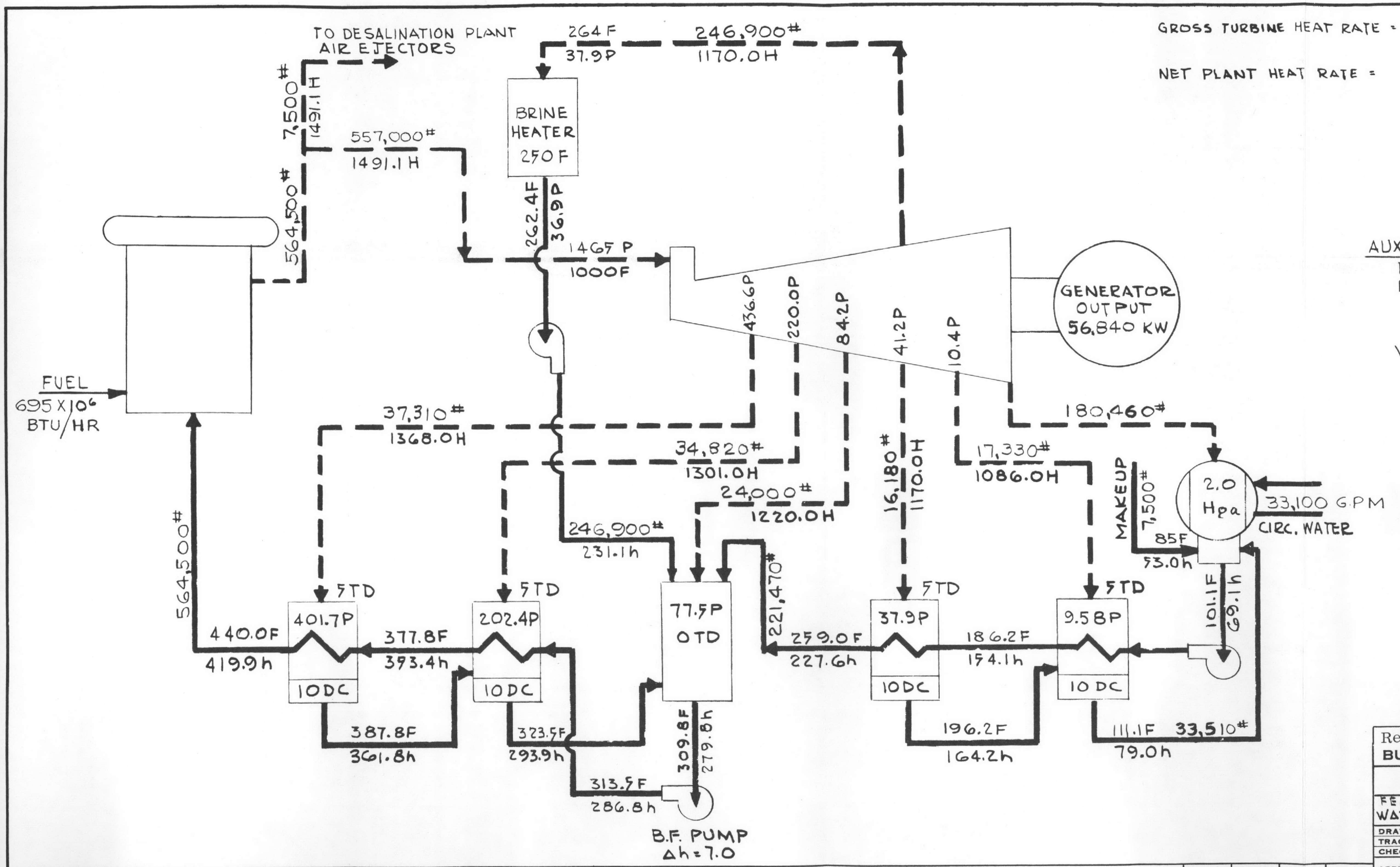
DRAWN G.V.
TRACED
CHECKED
SQUAD LEADER AMF
DATE 12/6.3
SCALE NONE
APPROVED DATE 12-20-63
Henry D Schoenwetter Supv Mech Engr
W. O. 2271-01
DWG.

TITLE	CHECKED	DATE	TITLE	CLEARED	DATE	REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE
ELECTRICAL SUPERVISOR			ELECTRICAL ENGINEER								
MECHANICAL "			MECHANICAL "								
STRUCTURAL "			STRUCTURAL "								
CHIEF DRAFTSMAN											

EXHIBIT VIII-2

GROSS TURBINE HEAT RATE = $\frac{564{,}500(1491.1-419.9+7)}{56840} = 10{,}708 \ \frac{BTU}{KW\,HR}$

NET PLANT HEAT RATE = $\frac{564{,}500(1491.1-419.9)}{50{,}000\ (0.87)} = 13{,}901 \ \frac{BTU}{KW\,HR}$



AUXILIARY POWER

DESALINATION PLANT = 4,000 KW
BLR. & TURBINE PLANT = 2840 KW
TOTAL AUXILIARY POWER = 6,840 KW
NET PLANT OUTPUT = 50,000 KW

WATER PRODUCTION RATE = 10 X 10⁶ $\frac{GAL}{DAY}$

PERFORMANCE RATIO = 14.0 $\frac{LB.\ WATER}{LB.\ STEAM}$

CASE C

LEGEND

▬ ▬ ▬ STEAM
━━━ LIQUID
P PRESSURE, PSI ABSOLUTE
h LIQUID ENTHALPY, BTU/LB
H VAPOR ENTHALPY, BTU/LB
\# FLOW, LB/HR.
F TEMPERATURE, °F

Reynolds, Smith and Hills, Jacksonville, Fla.
BURNS AND ROE, INC. NEW YORK, N. Y.

HEAT BALANCE FOR STUDY PURPOSES

FEASIBILITY STUDY - COMB. ELECTRIC POWER AND WATER DESALTING PLANT - THE FLORIDA KEYS

DRAWN FAM TRACED CHECKED	SQUAD LEADER	DATE	SCALE
	AMF	12 - 63	

APPROVED DATE 12-20-63
Henry D Schoenwitter Supy Mech Engr

W. O. 2271-01
DWG.

TITLE	CHECKED	DATE
ELECTRICAL SUPERVISOR		
MECHANICAL "		
STRUCTURAL "		
CHIEF DRAFTSMAN		

TITLE	CLEARED	DATE
ELECTRICAL ENGINEER		
MECHANICAL "		
STRUCTURAL "		

REV. NO.	REVISIONS	BY	CHKD.	APP.	DATE

Site Improvements. Site improvements at the power plant will include clearing, dredging for fuel oil delivery by barge, diking and filling as required, and the construction of salt water wells for cooling water supply to the condenser. The economical maximum size for a drilled well is approximately 36 inches in diameter. Each well of this size is expected to yield approximately 6000 gpm. Thus, the condenser for the 50,000-net-kw fossil-fired steam electric generating plant considered herein will require eight wells. The advantages of using wells rather than a pump and screen house for the supply of the condenser circulating water are that the wells are more economical, the water is cleaner and the temperature is lower.

Turbine Generating Plant. Turbine generators shall be single-shaft machines designed for continuous operation and shall be furnished complete with necessary surface condenser, auxiliaries, instrumentation and controls. The turbines furnished for the cases where export steam is produced for the water plant will be supplied with a single automatic extraction control to maintain the desalination plant brine heater water temperature at 250° F.

Boiler Feed Pumps. Two half-capacity boiler feed pumps will be provided for each turbine generator unit. At least 65 percent of full turbine generator capacity may be carried on either boiler feed pump.

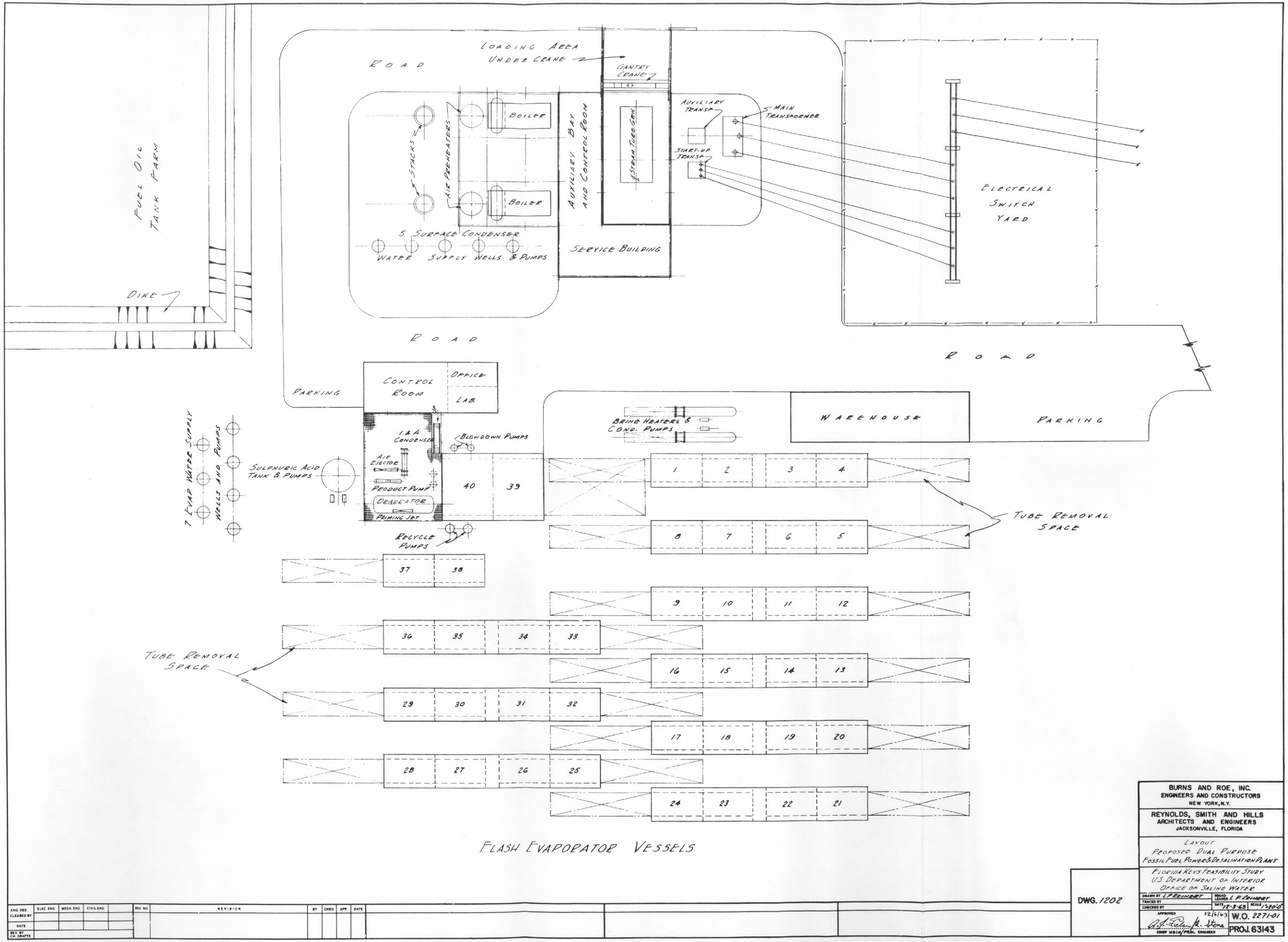
2. Plant Layout

The layout of the combined 10,000,000-gallon-per-day water desalination plant and the 50-mw electric plant is shown on Exhibit VIII-3 (Drawing No. 1202), page VIII-5, for the fossil fuel steam generator. Except for the heat source, it is similar to the layout shown on Exhibit VII-1, page VII-2, for the nuclear reactor system. In this case, heat is supplied by two half-capacity fossil-fuel steam generators. They offer the flexibility of operating with only one unit when steam is required by the water plant only.

B. Costs

(1) Capital Investment. The estimated fossil-fuel-fired 50,000-kw steam electric generating plant investment costs used in this

EXHIBIT VIII-3



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NEW YORK, N.Y.

REYNOLDS, SMITH AND HILLS
ARCHITECTS AND ENGINEERS
JACKSONVILLE, FLORIDA

LAYOUT
PROPOSED DUAL PURPOSE
FOSSIL FUEL POWER & DESALINATION PLANT

FLORIDA KEYS FEASIBILITY STUDY
U.S. DEPARTMENT OF INTERIOR
OFFICE OF SALINE WATER

DWG. 1202

DRAWN BY L P REINERT
TRACED BY
CHECKED BY
SQUAD LEADER L. P. REINERT
DATE 12-3-63
SCALE 1"=20'-0"
APPROVED 12/6/63
A. J. Fielen R. Stone
CHIEF MECH./PROC. ENGINEER
W.O. 2271-01
PROJ. 63143

report, and shown on Exhibit VI-2, page VI-3, as Cases A, B and C for an unassociated power plant, a combined 6,000,000-gallon-per-day water plant and power plant and the recommended combined 10,000,000-gallon-per-day water plant and power plant respectively, are based on current cost information for the plants as described in the preceding section. These investment costs include all the basic equipment and erection costs for engineering, design, field supervision, interest during construction and contingency.

(2) Fuel. The costs of fuel oil storage for Cases A, B and C are shown on Exhibit VI-1, page VI-2. This cost is based on storing fuel for 110 days of average operation at a fuel cost of $.42 per million Btu, the present-day fuel cost in the Florida Keys area. The actual annual investment in the fuel oil stockpile is based on the interest only and this, for the municipal financing considered in this report, is taken at 4 percent per annum.

Exhibit VI-1 also shows the annual fuel costs for each of Cases A, B and C. These costs are divided into fixed and variable portions. The fixed portion was assumed to be 9 percent based on oil-fired plants and is in accordance with the Federal Power Commission's Instructions for Estimating Electric Power Costs and Values. It may be observed that one percent was added to the design net plant heat rates for the purpose of calculating fuel costs. This one percent figure will allow for part load operation and for slight deterioration in the turbine with aging. Even though this one percent figure may at first glance seem low, it must be remembered that the plants considered herein will essentially operate at full load.

Since 9 percent of the fuel cost was assumed to be fixed, it is obvious that the variable portion of the fuel cost will be 91 percent.

(3) Operation and Maintenance. The operation and maintenance costs shown on Exhibit VI-1 are also subdivided into fixed and variable portions. Exhibit IV-5, page IV-14, shows the expected manning and salary requirements upon which the fixed portion of operation and maintenance costs for the fossil-fuel-fired plants are based. From Exhibit IV-5 it may be observed that fixed maintenance labor is rather high. This may be explained by the fact that the Florida Keys are rather remotely located, and that experi-

enced maintenance labor would be readily available only if employed directly by the power station on a permanent basis.

(4) Fixed Costs. The fixed costs are those annual costs which remain the same during the life of the plant regardless of load factor. They include fixed charges on the investment, interest on fuel storage, insurance, and portions of the operating and maintenance costs.

In determining power costs, the fixed charge rate was applied to the unit investment cost of the plant. The fixed charge rate included the cost of money, depreciation, interim replacements, insurance and taxes. The annual rates for each of these items were discussed previously. For a fossil-fueled plant the total annual fixed charge rates are 7.15 percent for depreciating capital and 5.02 percent for nondepreciating capital.

C. Unit Power and Steam Costs

The power costs estimates for the fossil-fuel-fired cases considered in this report are entered in Exhibit VI-1, page VI-2, for Cases A, B and C. From these costs the unit power and steam costs were calculated. These calculations were made using a formula similar to that given in Federal Power Commission Memorandum No. 1. In each case, the base power-only plant is used to obtain the power cost. The incremental cost for the combined power and water plant is a measure of the energy cost to the water plant.

In addition to Cases A, B and C on Exhibit VI-1 mentioned above, calculations were completed for variations in Case C with water plant capacity factors, i.e., Case C was based on 10,000,000 gallons per day; for the additional cases water outputs of 8,000,000 gallons per day and 4,800,000 gallons per day were selected. Heat balances were then calculated which led to corrections to the power plant base heat rate and resulted in a plot of steam cost versus the desalination plant capacity for the fossil-fired 50,000-kw electrical and 10,000,000-gallons-per-day water plant. This plot was shown on Exhibit VI-7, page VI-13.

As can be seen from Exhibit VI-1, the unit power cost for the unassociated 50-MWe fossil-fueled power plant is 7.99 mills/kwhr; for the dual-purpose plant (Case C) the cost of steam to the brine heater is 23.9¢/1000 lb.