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Bureau for Science and Technology
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TECHNICAL FEASIBILITY OF
REHABILITATION OF SELECTED IREE FACILITIES

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I INTRODUCTION AND OBJECTIVE</td>
<td>1-1</td>
</tr>
<tr>
<td>II REPORT SUMMARY</td>
<td>2-1</td>
</tr>
<tr>
<td>III SUMMARY OF INVESTIGATIONS</td>
<td>3-1</td>
</tr>
<tr>
<td>IV EVALUATION OF REHABILITATION TECHNICAL FEASIBILITY, COST &amp; SCHEDULE</td>
<td>4-1</td>
</tr>
<tr>
<td>V RECOMMENDATIONS BASED UPON INVESTIGATIONS TO DATE</td>
<td>5-1</td>
</tr>
</tbody>
</table>

APPENDIX A  PHOTOGRAPHIC RECORD OF LAS MINAS FACILITY

APPENDIX B  PHOTOGRAPHS OF SAN FRANCISCO FACILITY
SECTION I

BACKGROUND AND OBJECTIVE

The Instituto de Recursos Hidroelectricas y Electrificacion (IRHE) is the sole utility in the country of Panama. IRHE's generation capabilities include both hydro electric and thermal power plants. The installed hydro electric capacity provides for most of the country's base load capacity needs. The thermal capacity is comprised of both conventional steam plants and combustion turbines. The ages of the thermal power plants vary from over thirty years old for some of the steam plants to only three to five years for the newest combustion turbines.

Financial constraints experienced by the utility and the government over the past ten years have severely restricted the needed maintenance and operations activities, and have resulted in significant degradation in availability and reliability of the installed capacity. In many cases, operating units or facilities have been decommissioned or abandoned to concentrate remaining resources and equipment on operating units.

In parallel with the eroding generation capabilities, the country has experienced a healthy growth in electrical demand. In 1990, a total of 2737 Giga-Watt Hours of electrical power was purchased from the utility. This represents a 5% increase from 1989. The utility forecasts similar near term growth in demand for electricity.

The Office of Energy in the Agency for International Development's Bureau for Science and Technology was requested by USAID/Panama, IRHE, and the Panamanian government to assess the feasibility of rehabilitating a portion of the existing equipment through private participation as a first means of meeting the growing needs of the country. Private participation under consideration consists of leasing IRHE facilities, refurbishment of equipment, operation and maintenance of the facility and sale of the power to IRHE. Two particular sites were suggested for consideration - the Unit 2 steam plant at Las Minas, and the four diesel engine generators and steam plant at the San Francisco Station.
The objective of this report is to:

- document the findings of the technical investigations performed to date
- present the evaluation of the refurbishment required
- present the options available to achieve IRHE's goals
- provide recommendations for follow-on activities
Meetings and site inspections were held with IRHE and Office of Energy personnel the week of January 14-18, 1991. Both the San Francisco and Las Minas facilities were visited and considered in the initial assessments. The information gathered during this period is presented in Section III and evaluated in Section IV. Recommendations are provided in Section V of this report. Several significant points summarize this initial effort:

- Certain IRHE plants have degraded to the point where they are no longer operable units. The Unit 2 at Las Minas and the San Francisco units are two such facilities.

- IRHE personnel believe that as early as 1992, the current capacity of the operable generating equipment may be insufficient to meet the expected growth in load demand.

- Refurbishment of existing facilities currently out of service is a viable option available to IRHE to meet this expected near term demand.

- Results of the initial site inspections, discussions with IRHE staff, and review of records indicate that both facilities could be refurbished and returned to service by the private sector. The San Francisco plant could be refurbished within a reasonably short period of time after project mobilization (3 to 5 months). Initial cost estimates for refurbishment are $5,500,000 to $6,500,000, and include both the steam plant and the diesel plants.

- The Las Minas Unit 2 facility requires significantly more refurbishment. First estimates indicate a construction schedule up to 18 months. The estimated cost of the repairs is $9,000,000 to $10,000,000.

- Given that IRHE decides to pursue refurbishment of the facility through private sector participation, technical specifications should be prepared that detail IRHE's expectations of the refurbishment, operation and maintenance of the facility, and expected generation performance criteria. This work could be done within 2 to 3 months. If the San Francisco facility were selected...
for this project, initial repairs and refurbishment could be completed by early 1992, provided this project is initiated by March, 1991.
SECTION III

EVALUATION OF REHABILITATION TECHNICAL FEASIBILITY.

COST & SCHEDULE

A general discussion of both facilities under consideration is provided below. In addition to a brief presentation of each facility design, a review of the current condition of the facility, as observed during the site visits the week of January 14, 1991, is also provided.

SAN FRANCISCO

General

The San Francisco facility consists of a steam plant and four diesel engine driven generators. The facility was built in the 1940's, and additions have been made during the 1950's, 60's and early 70's. The first two steam units have been abandoned, and are not considered salvageable. Unit 3 of the steam plant and the four diesel engine generators are considered for possible refurbishment. A general description of the equipment is provided below, along with the results of the visual inspection performed. In addition, limited amounts of documentation were available on the original design and performance of these units. A summary of this information is also provided.

The station consists of two adjoining facilities, one each for the diesel plants and steam plant with adjacent outdoor facilities. The boiler is an outdoor design with enclosed firing aisles. The steam turbine and auxiliary equipment, as well as the diesel generator units, are located in a turbine building. The available drawings do not show the diesel generator units; these are located in a building extension next to Unit 3.

The steam plant was last operated in the early 1980's. The last of the diesel generators was also operated in the same time period. Preservation procedures have been in effect as discussed below. With the cautions/exceptions noted, both plants are considered capable of being refurbished and returned to operation.
STEAM PLANT - UNIT 3

Plant Description

The unit was commissioned in 1958. It is nominally rated at 12.65 MW, and consists of the major equipment listed below. All major equipment is made in the U.S.A. to American codes and standards.

Boiler & Auxiliaries

The boiler is a balanced draft design. Maximum continuous rating (MCR) is 150,000 lb/hr at 625 psig, 830°F with 374°F feedwater and firing Bunker "C" fuel oil having 18,000 Btu/lb heating value. The boiler is manufactured by Babcock & Wilcox (B&W).

The boiler arrangement is a standard front-fired unit. Fuel is fired in four steam-atomized burners arranged in two levels. The furnace is water cooled. The drums and the evaporator and superheater tubes are located at the end of the furnace, opposite the burners.

The draft system is single-train. A Ljungstrom regenerative air heater and a steam coil air preheater preheat combustion air while maintaining the required exit gas temperature. Ductwork is #10 gage carbon steel. Forced draft (FD) and induced draft (ID) fans, one each, are of outdoor design. The fans are sized for 10% excess air, and were manufactured by Green Fuel Economizer Company. The FD fan has an inlet damper control and the ID fan is controlled by its discharge damper. Sootblowers were supplied by Diamond Power Specialty Co., and are designed to use main steam.

Boiler controls are pneumatic, boiler-following type, manufactured by Bailey Controls. Steam temperature is controlled by attemperation between the high temperature and low temperature superheater sections.

The boiler is started on #2 diesel oil, and is switched to Bunker "C" residual oil as soon as possible. The oil is filtered and heated in shell and tube heat exchangers. All fuel oil is brought to the plant site by tanker trucks.

Residual oil data was provided by IRHE. Due to the high vanadium and sulfur content, Calgon "Combustrol 542" additive has been used to limit fireside corrosion when available funding permitted. IRHE staff stated that the choice of additive was based on extensive experimentation with several suppliers' products. It was further
reported that the air preheater would typically last about three months without the "Combustrol" treatment, and about one year with the treatment.

The feedwater and water treatment and makeup systems are described in a separate section below.

**Turbine - Generator Unit**

The turbine is a single-casing, single flow unit, manufactured by Elliott. The ratings are consistent with those of the boiler. Rated exhaust pressure is 2.5 in. Hg absolute. Additional design data used in the evaluation included turbine arrangement cross-sections, and the 100% load heat balance.

Steam flow is controlled by seven governing valves which are cam-operated by a low-pressure oil relay governing system. The valves operate sequentially to control turbine power output at constant main steam pressure. Steam chest is integral with the turbine casing. Shaft packings are steam sealed labyrinth type. Three uncontrolled extractions supply steam to three feedwater heaters, makeup evaporator and the steam air heater.

The generator is rated 13,529 kVA, 13.8 kV, 60 Hz, and is a totally enclosed, air/water cooled (TEWAC) design, with a self-ventilated exciter.

**Condensate and Feedwater System**

The condenser is a two-pass, non-divided water box design, manufactured by Worthington Corporation. Total surface is 14,000 sq.ft.; tube material is (not available), and design cooling water velocity is 6.46 fps. Non-condensible gases are removed by a Worthington twin-element, two-stage steam jet air ejector.

Two 100% capacity condensate pumps are provided. The pumps are horizontal, centrifugal single suction pumps, and are motor driven. The pumps were manufactured by Worthington Corporation.

The low pressure feedwater heater is a vertical U-tube closed heater arranged with the channel up. The heater accepts steam air heater drains in addition to extraction steam; drains are pumped forward. Tubes are 3/4"-18 BWG Admiralty metal with a carbon steel tube sheet; design water velocity is 5.9 fps. The heater was supplied by Whitlock Manufacturing Company.
The deaerating heater is a spray-tray unit with a carbon steel shell and storage tank, Type 304 stainless steel trays, and a spray type vent condenser. The heater accepts evaporator heater drains and evaporated steam in addition to extraction steam. The deaerator was supplied by Graham Manufacturing Company.

Two 100% capacity boiler feed pumps (BFP) are provided. The pumps are 8-stage, horizontal centrifugal pumps of opposed impeller single suction design, with horizontally split casings. Ingersoll-Rand was the supplier. The BFPs are motor driven at constant speed.

Circulating Water System

The circulating water system is a closed (recirculating) system using treated city water (contrary to System Description, which states that sea water is used). Heat is dissipated in a cooling tower.

The cooling tower is rated to cool 18,000 gpm of circulating water from 107°F to 95°F at 83°F wet bulb temperature (12°F range and 12°F approach). Design evaporation and drift losses are 1.2% and 0.2%, respectively. The tower is a two-cell, cross flow, induced draft unit, constructed of redwood with silicon bronze fasteners. Water distribution piping is constructed of redwood staves. Corrosion resistant materials or epoxy coated carbon steel and epoxy coated cast iron are used for structural fittings and motor and gear supports. Fans are single-speed, with 12 adjustable pitch fiberglass blades per fan. The cooling tower was supplied by the Marley Company.

A single circulating water circuit is provided, with a single circulating water pump. The circulating water pump is of dry pit, double suction, horizontal centrifugal type with a horizontally split casing, driven at constant speed. The circulating water pump was manufactured by Worthington Corporation.

Water Treatment

As reported by IRHE staff, the water treatment philosophy is the same for both San Francisco and Las Minas steam plants. Some of the information contradicts system descriptions found in plant records, presumably because the descriptions had never been updated. Discussed below are the makeup, condensate/feedwater, boiler water and closed cooling system treatment approaches as
given by the IRHE Chemical Engineering staff. Grab samples are used for all water analyses except conductivity measurements.

Plant makeup - Potable (City) water is used as plant makeup. The actual makeup water analysis varies with the plant site, but the treatment procedure is the same in all cases.

Potable water is first treated with sodium sulfate to reduce chlorine content. Next, the water goes to a cation/anion demineralizer (no filtering); the deionized water is discharged to the condensate storage tank. Makeup to the cycle is introduced into the condenser hotwell. The condenser is designed to deaerate all condensate to 0.03 cc/l maximum dissolved oxygen.

Condensate treatment follows typical U.S. practice for systems containing copper alloys, in that hotwell effluent is treated with cyclohexylamine to maintain pH in the range from 8.5-8.8. The deaerator is designed to reduce dissolved oxygen content to 0.005 cc/l maximum. Hydrazine is used to scavenge any oxygen remaining in the system after the deaerator.

Boiler water receives coordinated phosphate treatment using mono-sodium and trisodium phosphates to maintain boiler pH in the range from 10-10.2; the resulting steam pH is reported to be 8.5-8.8. Blowdown is used to control dissolved solids in the boiler water. IRHE staff reports that the treatment has been effective in that minimal deposits are typically found in the boilers after periods as long as ten years without chemical cleaning.

Condenser leaks are typically a problem in plants with sea water cooling or cooling towers when an inline demineralizer is not provided. IRHE staff stated that strict instructions are in place to shut down the plant if a conductivity increase, due to a condenser leak, cannot be dealt with by dumping contaminated condensate. Reportedly, these instructions are actually followed due to a past experience with "significant" turbine damage on Las Minas Unit 3 after operating for some time with a condenser leak.

Closed cooling water systems are typically dosed with calgon "Phreegard 2200."

Layup of idle plant: Boiler water side is filled with condensate containing 200 ppm hydrazine and 300 ppm ammonia, without circulation or nitrogen blanketing. System is periodically checked and refilled. Piping is sealed but empty. Feedwater heaters are
filled with condensate containing nitrite borax, without circulation or nitrogen blanketing. IRHE staff stated that N₂ blanketing had been tried, but had been unsuccessful due to leaks in the system. For the same reason, it is periodically necessary to add treated water to the systems.

**Electrical Systems and Major Equipment**

Unit 3 generates electric power at 13.8 kV, 60 Hz. Power is exported from the plant at generation voltage. All auxiliary power in the plant is distributed at 440 V. 440 V Unit Auxiliary Switchgear No. 3 distributes power to large motors (75-300 hp) and to Unit Motor Control Center No. 3 which in turn supplies small process related motors. 440 V Station Service Switchgear No. 3-4, fed from (not available), supplies a Station Service Motor Control Center No. 3-4 which in turn supplies loads such as building services, battery charger, air compressors, turbine turning gear, lift pumps and other similar services.

All main switchgear, control board, generator cubicle, unit auxiliary substation and motor control centers are supplied by Westinghouse Electric International Company. Additional system design and electrical equipment descriptions were used in the evaluation.

**CONDITION OF PLANT EQUIPMENT - UNIT 3**

**Boiler and Auxiliaries**

Boiler waterwalls, economizer, superheater, and drums were observed externally. They appeared to be intact, and serviceable (see photo). Minimal amount of slag was observed on the tubes visible through the furnace observation ports. The boiler exterior, covered by insulation and lagging, appears to be well maintained. During the inspection, it was noted that the boiler furnace was being electrically heated in an effort to minimize condensation and corrosion. Only minimal corrosion was visible.

IRHE plant staff indicated that the unit was "laid up" on the tube side; the layup practice has been discussed under Water Treatment. The layup procedure should prevent significant corrosion from moisture and salt air, however, some corrosion is to be expected due to local depletion of the protective chemicals and occasional oxygen ingress due to lack of a nitrogen blanket and periodic partial draining due to leakage.
Due to the high vanadium and sulfur content, some fireside corrosion is to be expected, particularly if oil additive has not been available. Tube failures were noted by the staff as periodic. The staff also indicated that routine (every one to five years) hydrostatic testing and tube wall thickness sampling was performed on this unit to confirm it's continued fitness for service.

The air preheater was examined externally; the internals were not accessible for inspection. The external casing housing the air heater appeared to be well maintained with no signs of significant damage. The air heater, however, is subject to corrosion and fouling. Basket life has in general been short (about one year) even with the use of additives. IRHE plant staff indicated that the air heater has been damaged from the loading of baskets, and in general believed that the air heater as it currently exists is not serviceable.

Draft Fans and Drives were primarily viewed externally; only a limited internal inspection of these fans was possible. The fans appear to be intact and operable. The FD fan hub was available for inspection, and both fans turned freely in their bearings. Plant staff indicated that they had a good operating history with the fans, and the fans should be serviceable in their present condition.

Ductwork and Stack - The ductwork was covered by insulation and lagging, and was not accessible for inspection. The insulation appeared well maintained, thereby protecting the ductwork from the outside environment. The extent of gas side corrosion could not be determined. The concrete stack appeared to be in sound and operable condition. A 40-50 ft. steel extension on top of the concrete stack appeared to have been recently replaced. IRHE plant staff indicated that the replacement was recent (last 5 years), and was a "replacement in kind" based on the original design. The stack breeching appears to be in excellent condition (see photo).

Fuel oil system equipment and burners appeared to be intact and in good condition. There was little evidence of leaks, indicating that the equipment had been well maintained while operating (see photo).

Main steam and feedwater piping appeared to be in good condition, as no obvious hanger damage was observed, and insulation was in generally good condition. Given the relatively low operating temperature and pressure conditions, the piping should be in good condition.
Turbine Generator

The internals of the turbine, including the rotor, blading and casing, were not available for inspection. Externally the turbine appeared to be well maintained (see photo). Coating over metal surfaces appears to be routinely maintained, and provide excellent protection of the base metals. It is reported to be IRHE's practice to periodically turn over turbine rotors when idle to prevent a set and to equalize environmental exposure on the rotor.

The plant staff from IRHE noted that the turbine has had a good operating history with no known operating incidents which could result in long term damage. The staff noted that the manufacturer has been supervising all routine (every five years) overhauls and inspections of the equipment. In general, IRHE staff believes that the turbine has a lot of remaining life.

Detailed operating records were not found. The reported general operating history and inspection results to date have been very encouraging. Further, the unit operates at relatively low main steam temperature, which is beneficial in minimizing thermal fatigue of the hot sections of the turbine. However, it is clear that this unit had to be subjected to considerable variations in load due to its small size and relatively high heat rate. It would therefore appear to be prudent to perform a thorough nondestructive examination of the hot turbine parts and generator rotor at the next scheduled inspection. This inspection would provide a more accurate indication of the remaining life expectancy of the turbine.

Exhaust moisture content expected under design conditions is 10%, and would decrease as turbine efficiency deteriorated with age. Consequently, last row blading would be expected to be in good condition.

Condensate and Feedwater System Equipment

Condenser and feedwater heaters could only be inspected externally. The condenser can be expected to have some surface corrosion of the carbon steel shell and tube support plates which primarily would extend feedwater cleanup upon unit restart. The copper alloy tubes should be unaffected. Feedwater heaters are laid up, therefore only minimal corrosion of carbon steel parts is expected due to local depletion of the protective chemicals and occasional oxygen
ingress due to lack of a nitrogen blanket and periodic partial draining due to leakage.

Pumps and piping can be expected to have some superficial corrosion which would primarily extend feedwater cleanup upon unit re-start. Should some repairs be required, they would not become a major cost item. The foregoing assumes that lubrication will be maintained, and the pumps will be turned periodically.

Electrical equipment is typically equipped with space heaters, all of which appeared to be in service to prevent condensation. Areas where electrical equipment is located were found to be dry and well ventilated. No missing components were noted, other than a few instruments in control panels. Electrical connections throughout the plant appeared to be undisturbed.

The pneumatic controls are subject to obsolescence. While the controls may still be functional, spare parts will be difficult to obtain; replacement with electronic controls should be considered if plant service life is to be extended for maintainability as well as enhanced control of the plant.

**DIESEL GENERATOR PLANT - UNITS 1-4**

**Plant Description**

The diesel generator plant consists of four identical units, which are nominally rated at 7.5 MW each. The four units are arranged in parallel; all equipment, with the exception of exhaust stacks and fuel oil tanks, is housed indoors in a building extension next to Unit 3 of the steam plant. A partition wall and loading dock separate the steam plant from the diesel generator units. A 5-ton overhead traveling crane, which spans the length of the diesel generator units, is provided for servicing. Switchgear and motor control centers for the diesel generator plant are located in separate electrical equipment rooms.

The engines are manufactured by S.E.M.T. Pielstick, and the generators by Jeumont-Schneider, both of France. Design and construction standards used for this equipment are not known at this time. The engines and generators are briefly described below.

**Engines and Auxiliaries**

The engines are Pielstick Model PC2.5V400, turbocharged, V-16, four-stroke, single-acting, 514 rpm units rated at 10,400 hp.
The engines are permitted to operate at 10 percent overload for periods not exceeding one hour at a time.

Fuel system is of the direct mechanical injection type, operating at nominal 240 bar (3500 psi) pressure. The engines are operated on load with Bunker "C" residual oil fuel of the same composition as used in the steam plant boilers, i.e., containing up to 4% sulfur and approximately 200 ppm vanadium. The residual fuel is centrifuged and filtered to remove water and solids. Marine diesel oil is used during startup and shutdown to reduce the amount of corrosive combustion products remaining in the engine during shutdown.

The engines are cooled with treated water, with heat rejected to the atmosphere by cooling towers. Engine exhausts are silenced to minimize noise offsite.

The diesel engine is a standard 16 cylinder machine. Layout of the diesel generator equipment can be seen in Appendix B, plant photographs.

Generator & Auxiliaries

The generators are Jeumont-Schneider Type SAT-230-45-14, directly connected to the engine drivers. Each generator is rated 9,300 kVA, 13.8 kV, 60 Hz, 0.8 power factor, and is a totally enclosed, air/water cooled (TEWAC) design.

Electrical Systems and Major Equipment

Electric power is exported from the plant at generation voltage. All auxiliary power in the plant is distributed at 440 V. Station single line diagrams were not obtained.

All main switchgear, control board, generator cubicle, unit auxiliary substation and motor control centers are supplied by (not available). More detailed description of the electrical equipment is presently unavailable.

Switchgear and motor control centers for the diesel generator plant are located in separate electrical equipment rooms. Photos in Appendix B show the general arrangement of the electrical equipment rooms.
CONDITION OF PLANT EQUIPMENT - DIESEL GENERATOR UNITS

Engines, Generators and Auxiliaries

The four diesel units were commissioned in 1976. At the present time, all four units are shut down due to lack of spare parts. The last unit operating was Unit 4, which was shut down in 1988. The total reported operating hours are as follows:

Unit #1 - 29,526 hrs  
Unit #2 - 23,831 hrs  
Unit #3 - 26,322 hrs  
Unit #4 - 36,268 hrs

Three of the diesel generator units, 1, 3 and 4, are believed to be in relatively good condition. The units require only selected spare parts, valves and piston rings in particular, for return to service. Initial assessments were made for spare parts and installation supervision by TRHE. Further insight into the condition of the engines was obtained from a representative of Coltec Industries who personally made a detailed field inspection and reviewed all operating and maintenance logs. Coltec's findings support the conclusion that the engines require only "off-the-shelf" parts for return to service. However, review of the engine history indicated that the engines had operated part-time with straight Bunker "C" fuel due to the failure of oil conditioning equipment. Fuel metering to individual cylinders had also been out of adjustment for a large part of the operating time as indicated by combustion pressure and exhaust temperature logs. Given these conditions, more rapid deterioration may have occurred than might otherwise be anticipated.

Preservation procedures for these units include heating and circulating the lubricating oil, periodic turn over, and energized generator space heaters. Exterior surfaces of all units were found to be clean with paint intact. Internal condition of the engines is believed to be good. The effects of operating with dirty fuel and incorrect cylinder balance as discussed above, primarily affect the pistons, rings and valves.

Unit 2 has been used as a source of spare parts for the other three units, and requires pistons and connecting rods, valves, most of the cylinder heads, turbocharger and various exhaust parts, as well as numerous smaller components and instruments. An exact inventory
of the required parts was not taken. The block, crankcase and
generator are believed to be in good condition; the crankshaft was
found stored outside the engine, and appeared to be reusable.

Fuel and lubricating oil conditioning systems require a thorough
overhaul, according to Coltec's inspection findings.

The generators are believed to be in good condition, with the
possible exception of the #4 generator. According to IRHE staff,
the #4 generator may have sustained fire damage. The generator
casings were noticeably warm to the touch, indicating that their
space heaters are effective.

The electrical equipment rooms housing switchgear and motor control
centers for the diesel generator plant were found to be clean and
dry. Space heaters were energized to limit condensation.

There was no obvious damage to equipment foundations.

In summary, all four diesel generator units are believed to be
capable of being returned to service after a thorough overhaul and
replacement of missing components on Unit 2.

LAS MINAS STATION DATA

General

The plant comprises a total of six units, as follows:

Units 1 through 4 are steam turbine plants. Nameplate ratings and
commissioning dates are as follows:

- Unit 1: 22 MW, commissioned in 1963
- Unit 2: 40 MW, commissioned in 1969
- Unit 3: 40 MW, commissioned in 1971
- Unit 4: 40 MW, commissioned in 1974

Units 5 and 6 are nominally 30 MW combustion turbines, commissioned
in 1988, and presently operate in an open cycle. These turbines
can be converted to combined cycle.

All units have been derated due to aging. Unit 2 has not been
operational since 1984, and has been used as a source of spare
parts for Units 3 and 4. Major equipment of Unit 2 is still in
place, but requires refurbishing as discussed below.
Unit 1 is located at one end of the site, Units 5 and 6 are located side by side near the center of the site, and Units 2-4 are located indoors in a common building at the opposite end of the site from Unit 1.

Power from Unit 1 is fed into Switchyard #1, and power from Units 2-4 is fed into common Switchyard 2-4 located next to the Units 2-4 plant building.

Once-through cooling by sea water taken from Las Minas Bay is used as condenser circulating water. Closed-loop cooling water systems with cooling towers are used to cool plant auxiliary equipment. Combustion turbine auxiliaries are air cooled by finned fan coolers.

The steam plants are started on diesel oil, and use Bunker C residual oil in normal operation. The residual oil supply and storage is centrally located, and is shared by all steam Units. Diesel oil facilities are located in Units 1 and 2 only, the latter being shared by Units 2-4. The combustion turbines use treated marine diesel fuel; the supply and storage facility is located next to the residual oil storage.

Unit 2, which is typical of all units 2-4 with minor exceptions, was investigated in some detail as described below. Units 1, 5 and 6 received only a cursory review, and are not discussed further.

Unit 2 is being considered by IRHE for possible refurbishment. A general description of the equipment is provided below, along with the results of the visual inspection performed. In addition, extensive design and performance documentation was available from an IRHE specification issued for refurbishing of Unit 3 which is virtually a duplicate of Unit 2.

UNIT 2

Boiler and Auxiliaries

The boiler is manufactured by Franco Tosi under license from Combustion Engineering. It is designated as Type VU-50-BPW, rated at 343,100 lb/h (155,430 kg/h) of superheated steam at 1250 psig (89 at), 955°F (513°C) with 426°F (219°C) feedwater. The boiler is permitted to be overloaded to a 165,330 kg/h steaming capacity for a four-hour maximum period.
The boiler setting is a pressurized design. The furnace is water cooled, and is arranged horizontally, with the drums and pendant superheaters located at the end opposite the burners. Six steam atomizing wall burners are used, arranged in two levels. Normal operating fuel is Bunker "C" residual oil.

The boiler and all auxiliaries other than the forced draft (FD) fan and air heaters are located indoors in a building shared by all three units. The draft system is single-train. A Ljungstrom regenerative air heater rotating in a vertical plane and a steam coil air preheater heat combustion air while maintaining the required exit gas temperature. Ductwork is carbon steel. The FD fan is of outdoor design, manufactured by Franco Tosi to Westinghouse design. The FD fan is rated 101,800 scfm (173,000 Nm³/h) at 27.2 "H₂O (690 mm H₂O), operating at 1775 rpm. Steam sootblowers are provided.

Boiler controls are pneumatic, presumably boiler-following type. Steam temperature is controlled by attemperation between the high temperature and low temperature superheater sections.

The boiler is started on #2 diesel oil, and is switched to Bunker "C" residual oil as soon as possible. The oil is filtered and heated in shell and tube heat exchangers. Fuel oil is brought to the plant site by pipeline.

Residual oil data was provided by IRHE. Due to the high vanadium and sulfur content, Calgon "Combustrol 542" additive has been used to limit fireside corrosion when available funding permitted. IRHE staff stated that the choice of additive was based on extensive experimentation with several suppliers' products. It was further reported that the air preheater would typically last about three months without the "Combustrol" treatment, and about one year with the treatment.

The feedwater system, water treatment and makeup system are described in a separate section below.

**Turbine - Generator Unit**

The turbine is a single-casing, impulse-reaction, single flow unit, manufactured by Franco Tosi. The ratings are consistent with those of the boiler. Rated exhaust pressure is 2.0" Hg absolute (0.0691 ata).
Steam flow is controlled by six governing valves which are actuated by a bar lift mechanism operated by a low-pressure oil relay governing system. The valves operate sequentially to control turbine power output at constant main steam pressure. Steam chest is integral with the turbine casing. Shaft packings are steam sealed labyrinth type. Five uncontrolled extractions supply steam to four closed feedwater heaters, a deaerator and the steam air preheater.

The generator is hydrogen cooled, rated 47,000 kVA @ 14.2 psig (1 ate) hydrogen pressure, 13.8 kV, 60 Hz, or 52,000 kVA @ 28.4 psig.

**Condensate and Feedwater System**

The condenser is a single-pass, divided water box design, manufactured by Franco Tosi to Westinghouse design. Total surface is 37,350 ft² (3,470 m²); tube material is aluminum brass and 70/30 CuNi. Design cooling water velocity is 7.2 fps. Non-condensible gases are removed by a twin-element, two-stage steam jet air ejector.

Two 100% capacity condensate pumps are provided. The pumps are vertical centrifugal single suction pumps with integral suction cans, motor driven at 1750 rpm.

The low pressure feedwater heaters are horizontal U-tube closed heaters with drain coolers. Tubes are 5/8"-18 BWG Admiralty metal, expanded into carbon steel tube sheets; design water velocity is not available. The heaters were supplied by Franco Tosi. Heater drains are cascaded to the condenser.

The deaerating heater is a spray-tray unit with a carbon steel shell and storage tank, stainless steel trays, and a spray type vent condenser. The heater accepts cascaded high pressure heater drains in addition to extraction steam. The deaerator was supplied by Franco Tosi.

Two 100% capacity boiler feed pumps (BFP) are provided. Pump design details were not available, other than that they are multi-stage, horizontal centrifugal pumps with vertically split casings and mechanical seals. The pumps are believed to be supplied by KSB. Casings and impellers appear to be made of 13% Cr steel. The BFPs are motor driven at constant speed.

The high pressure feedwater heaters are horizontal U-tube closed heaters with desuperheating sections and drain coolers. Tubes are
5/8" by (approx) 14 BWG (2 mm) 70/30 CuNi, expanded and welded into carbon steel tube sheets; design water velocity is not available. The heaters were supplied by Franco Tosi. Heater drains are cascaded to the deaerator or dumped to the condenser.

**Circulating Water System**

The circulating water system is a once-through system using salt water from Las Minas Bay. A single circulating water circuit is provided per unit, with a single circulating water pump. The circulating water pump is of vertical wet pit, mixed-flow type, pullout construction, driven at constant speed. The casing is made of nickel cast iron and the impeller and shaft are stainless steel (type unknown). The pump was manufactured by Franco Tosi.

A total of three circulating pumps are provided for Units 2 and 3, one per unit plus a third, identical, pump which is a shared back-up for either unit. Piping is made of fiberglass.

A reinforced concrete intake structure is shared by Units 2 and 3, with a separate two-circuit intake for Unit 4 added on to the Unit 3 end of the intake structure. The intake structure includes stop logs at the inlet and discharge, coarse screens, traveling fine screens, and removable bag filters.

**Water Treatment**

As reported by IRHE staff, the water treatment philosophy is the same for both San Francisco and Las Minas steam plants. Discussed below are the makeup, condensate/feedwater, boiler water and closed cooling system treatment approaches as given by the IRHE Chemical Engineering staff. Grab samples are used for all water analyses except conductivity measurements.

Plant makeup - Potable (City) water is used as plant makeup. The actual makeup water analysis varies with the plant site, but the treatment procedure is the same in all cases.

Potable water is first treated with sodium sulfite to reduce chlorine content. Next, the water goes to a cation/anion demineralizer (no filtering); the deionized water is discharged to the condensate storage tank. Makeup to the cycle is introduced into the condenser hotwell. The condenser is designed to deaerate all condensate to 0.03 cc/l maximum dissolved oxygen.
Condensate treatment follows typical U.S. practice for systems containing copper alloys, in that hotwell effluent is treated with cyclohexylamine to maintain pH in the range from 8.5-8.8. The deaerator is designed to reduce dissolved oxygen content to 0.005 cc/l maximum. Hydrazine is used to scavenge any oxygen remaining in the system after the deaerator.

Boiler water receives coordinated phosphate treatment using monosodium and trisodium phosphates to maintain boiler pH in the range from 10-10.2; the resulting steam pH is reported to be 8.5-8.8. Blowdown is used to control dissolved solids in the boiler water. IRHE staff reports that the treatment has been effective in that minimal deposits are typically found in the boilers after periods as long as ten years without chemical cleaning.

Condenser leaks are typically a problem in plants with sea water cooling or cooling towers when an inline demineralizer is not provided. IRHE staff stated that strict instructions are in place to shut down the plant if conductivity increase, due to a condenser leak, cannot be dealt with by dumping contaminated condensate. Reportedly, these instructions are actually followed due to a past experience with "significant" turbine damage on Las Minas Unit 3 after operating for some time with a condenser leak.

Closed cooling water systems are dosed with calgon "Phreegard 2200".

Once-through sea water circulating water systems are chlorinated with liquid chlorine to limit infestation by marine organisms. Chlorination has been only partially effective. IRHE voluntarily limits residual chlorine in circulating water to 0.5-1.0 ppm, same as required in the U.S.A. Calgon H900 chlorobromide tablets and Calgon "Chlorine helper 361" have been used, but are expensive.

Layup of idle plant: Boiler water side is filled with condensate containing 200 ppm hydrazine and 300 ppm ammonia, without circulation or nitrogen blanketing. System is periodically checked and refilled. Piping is sealed but empty. Feedwater heaters are filled with condensate containing nitrite borax, without circulation or nitrogen blanketing. IRHE staff stated that N₂ blanketing had been tried, but had been unsuccessful due to leaks in the system. For the same reason, it is periodically necessary to add treated water to the systems.
Electrical Systems and Major Equipment

Unit 2 generates electric power at 13.8 kV, 60 Hz. A 52 mVA step-up transformer raises export power voltage to 115 kV. Auxiliary power for plant use is supplied either through the unit auxiliary transformer or the startup transformer which is shared by Units 2 and 3. Auxiliary power in the plant is distributed at 4.16 kV to large motors, i.e., FD fan, boiler feed pumps and the circulating water pump, and at 440 V to all other smaller services. Design data for the major equipment can be found on the Single Line Diagrams; data for the smaller components was not available.

CONDITION OF PLANT EQUIPMENT - UNIT 2

General

The unit was last operated about six years ago. Preservation procedures have been partially implemented, and parts have been removed for use in the other two units. As a result, some major repairs are known to be necessary, and others may be needed, as discussed below.

The general level of maintenance appeared to be significantly lower than in Unit 1, with the same maintenance crew. Discussing this apparent anomaly with the maintenance personnel, it was established that Units 2-4 are considered difficult to work on. This explanation is considered valid since Units 2-4 have compact layouts and enclosed pressurized boilers. Unit 1, on the other hand, has a more open layout and balanced draft outdoor boiler. It is also suspected that boiler casing leaks may have contributed to the reluctance of operating and maintenance personnel to spend time in the plant. At this stage, little can be done about the layout. It may be prudent, however, to give serious consideration to improved ventilation and lighting. These improvements would encourage operators and maintenance personnel to spend more time in Units 2-4 performing routine walkdowns and preventive maintenance.

Boiler and Auxiliaries

Boiler waterwalls, superheater, and drums were observed externally. Corrosion and slag was noted on the waterwalls; this is not surprising, considering the high vanadium and sulfur content of the fuel. TRHE staff noted the furnace has experienced one or more explosions. It is expected that major repairs will be required as
a minimum. The boiler does not have an economizer. Fire side corrosion was noted on the superheater, indicating probable need for replacement. The drums appeared to be serviceable externally, but internal condition could not be determined. Based on the age of the unit, relatively modest operating pressure and temperature, and Chemistry staff's belief in the effectiveness of boiler water treatment, it is expected that the drum is still serviceable. However, NDE should be performed to confirm fitness for further service, particularly in view of the stress corrosion incident discussed in the turbine section, which was reportedly caused by feedwater chemistry. The boiler exterior is covered by insulation and lagging; these appear to be serviceable. IRHE plant staff indicated that the unit was "laid up" on the tube side; the layup practice has been discussed under Water Treatment. The layup procedure should prevent significant corrosion from moisture and salt air, however, some corrosion is to be expected due to local depletion of the protective chemicals and occasional oxygen ingress due to lack of a nitrogen blanket and periodic partial draining due to leakage.

The air preheater was examined externally. The internals were not accessible for inspection, except for one damaged sector and this was found to be in poor condition. The external casing of the Ljungstrom air heater appeared to be serviceable. However, IRHE staff reported that the drive is damaged and baskets are generally in poor condition. It is expected that the air heater will require major repairs. According to IRHE Chemical staff, basket life has in general been short. Baskets can be expected to last about one year when additives are used, and about three months if additives are not used.

The FD fan and driver were viewed externally, as only very limited access for internal inspection was possible. The fan appears to be serviceable as is.

Ductwork and stack - The ductwork was covered by insulation and lagging, and was not accessible for inspection. The insulation appeared generally well maintained; the extent of ductwork and stack gas side corrosion could not be determined. The steel stack showed signs of corrosion on the outside; internal condition could not be determined in the time available.

Fuel oil system equipment appeared to be serviceable. The burners had been removed (see photos), and will probably require replacement. Fuel piping and control wiring at the burner front appears to have been disconnected and left loose.
Main steam and feedwater piping appeared to be in good condition, as no obvious hanger damage was observed, and insulation was in generally good condition. Given the relatively low operating temperature and pressure conditions, the piping should be in good condition.

Turbine Generator

The main turbine was open, with an older, damaged, rotor installed for periodically turning the generator (see photo); a reconditioned rotor was on hand in protective crating. Internals of the turbine appeared to be in serviceable condition, but should be thoroughly cleaned and inspected before returning to service. The used rotor presently installed showed a relatively small degree of erosion of the last blade row. Control wiring, and oil and hydraulic piping appeared partially disassembled. The generator was closed, and according to IRHE personnel, was filled with hydrogen - apparently at very low pressure.

It is reported to be IRHE's practice to periodically turn over turbine rotors when idle to prevent a set and to equalize environmental exposure on the rotor. This appeared to be in effect for Unit 2 as well. However, the turbine internals and the condenser were open to the atmosphere in this case.

IRHE plant staff noted that the turbine rotor had broken near the generator coupling due to stress corrosion, with corrosive believed to have come from the feedwater used to attemperate seal steam. Since seal steam pressure is relatively low, the attemperator water source has been switched from feedwater to condensate. This was the only operating incident reported by IRHE staff; operating logs were not examined due to time constraints. The staff noted that IRHE normally contracts with the manufacturer to supervise all routine (every five years) overhauls and inspections of the equipment.

The unit operates at relatively moderate main steam temperature, which is beneficial in minimizing thermal fatigue of the hot sections of the turbine. The stress corrosion incident should be a closed issue once the new rotor is installed. However, it is clear that this unit had to be subjected to some load cycling, since its load factor is only about 60%. It would therefore appear to be prudent to perform a thorough nondestructive examination of the hot stationary parts and generator rotor. This inspection would provide a more accurate indication of the remaining life expectancy of the turbine and generator. The reconditioned turbine
Rotor should have a life expectancy at least equal to the rest of the major pieces of equipment.

Condensate and Feedwater System Equipment

The feedwater heaters could only be inspected externally. They are reportedly laid up in accordance with the procedures outlined above. Only minimal corrosion of carbon steel parts is expected due to local depletion of the protective chemicals and occasional oxygen ingress due to lack of a nitrogen blanket and periodic partial draining due to leakage.

Pumps and piping can be expected to have some superficial corrosion which would primarily extend feedwater cleanup upon unit restart. Should some repairs be required, they would not become a major cost item. The foregoing assumes that lubrication will be maintained, and the pumps will be turned periodically.

The deaerator was found stripped of insulation and repainted with protective coating. The internals were reported by IRHE staff to be in good condition. Reinsulation will be required before return to service.

Condenser and Circulating Water System

The condenser could only be inspected externally. The condenser can be expected to have some surface corrosion of the carbon steel shell and tube support plates which primarily would extend feedwater cleanup upon unit restart. The copper alloy tubes should be unaffected, assuming they were drained when the unit was shut down. Interior of the water boxes was not inspected. Given the severe mussel infestation observed on the circulating water pumps, cleaning may be necessary. Tube damage is also possible if the tubes had not been cleaned when the plant was shut down.

Circulating water intake structure shows damage to surface concrete, with salt water having reached at least the outer layers of reinforcing bars. A repair was in progress (see photo) chipping the surface concrete to expose the outer layer of rebar, replace the rebar, and restore the concrete cover. Corrosion was also noted on the screen housing (see photo) and guide channels for the stop logs. Screen structure and sprockets had surface corrosion, but were serviceable according to IRHE staff; screen cloth and baskets appeared to be still intact.
The circulating water pump was found disassembled. The attachment flange for the suction bell was severely corroded; in addition, there was severe surface corrosion and a layer of mussel shells attached to the pullout column (see photo). The pump appears to require a major rebuild.

Circulating water piping is made of fiberglass. According to IRHE staff, this piping has required numerous repairs. The prevalent repair method was reported to be by encasing the failed sections in concrete.

IRHE staff reports that the chlorination system has been destroyed by corrosion, and has been unusable in recent years.

**Electrical Equipment and Controls**

Electrical equipment is typically equipped with space heaters which appeared to be in service to prevent condensation. Part of the switchgear was located on the turbine deck, near the generator. Areas where electrical equipment is located were found to be dry and ventilated. Some missing components were noted, which were presumably used as replacements in the other units.

The pneumatic controls are subject to obsolescence. While the controls may still be functional, spare parts will be difficult to obtain. Replacement with electronic controls should be considered if plant service life is to be extended - for maintainability as well as enhanced control of the plant.

Some difficulty may also be encountered in replacing the missing instruments in the various control panels. Again, use of more modern replacement instruments should be considered.
SECTION IV

EVALUATION OF REHABILITATION TECHNICAL FEASIBILITY AND COST

Using the insights gained from the site visits along with the design information collected, and the interviews with the IRHE plant operating and maintenance staff, a first assessment for rehabilitation of the facility can be made. In making these assessments, the reviewers relied upon experience with completed life extension projects of similar size and configuration. By doing this, the results of extensive studies could be applied to this project and bounding limits on expected pricing could be established. Both the Las Minas Unit 2 facility and the San Francisco facilities are discussed below.

It should be emphasized that detailed evaluations, tests, and inspections are required before decisions for repair, or replacement of major equipment are made. These tests and inspections provide the needed additional information as to the current condition of the structure or component under review. The results of this evaluation would enable decisions to be made regarding the return of the structure or component to service.

For each facility a summary level discussion of the types of repairs and refurbishments required will be presented. In addition, the development of order-of-magnitude costs for the project will be given.

LAS MINAS UNIT 2 FACILITY

Major repairs and replacements are required to the Unit 2 Las Minas facility and have been grouped into four categories. Each category is discussed separately - Boiler Plant, Turbine System, Electrical and Control systems equipment, and balance of plant equipment.

Boiler Plant (tubes, headers, drums, firing equipment, draft fans air and gas ductwork, and Air Preheater)

Major replacements are required to this system. The tubes walls have been subjected to boiler internal explosions and gas side corrosion, and should be replaced. Noted problems with the superheater tubes and corresponding tube failures indicate the need for replacement of the superheater section. In addition, the air preheater will also require replacement. The firing equipment, including the burners, heaters, pumps and piping system, although not optimum for emissions, could be kept. The unit should be retrofitted with a fuel additive system, similar to that installed in Unit 1. The draft fans and air and gas ductwork appear to be serviceable as is.
Turbine Plant

A major overhaul is required on the turbine and generator systems. This system has not been stored in accordance with normal storage practice. During the overhaul, the repaired rotor and blades could be installed and used.

Electrical and Control Systems Equipment

The main electrical system has a combination of design and operating problems. These problems need to be addressed prior to returning the system to reliable and maintainable service. Major replacement of the boiler controls and electrical system is also needed prior to returning this unit to service. Longer term considerations for this system would include replacing the outdated pneumatic controls with a distributive control system, as parts for the pneumatics in many cases are no longer manufactured.

Balance of Plant Equipment (piping, pumps, structures, etc)

This equipment has similar problems to those described above. The piping systems appear to be highly subject to corrosion from the salt air and high humidity. Major degradation has taken place where piping is exposed to seawater. Portions of the circulating water systems and other related systems require replacement.

Corrosion damage was also evident in the Circulating water pump house which necessitates major repairs. The boiler and turbine structures although less affected by corrosion damage will also require repairs.

Other Considerations

IRHE is giving consideration to private sector participation of Unit 2 at Las Minas. This unit shares common facilities with Units 3 and 4, which are currently operable plants. While Unit 2 could be potentially split off as an independent unit, the resulting inefficiencies with independent operating and maintenance staffs should be considered.

Summary

Unit 2 is a potential candidate for rehabilitation. The repairs and replacements needed to return the unit to an operable condition can be performed and should result in considerable remaining life. As previously indicated, stand alone operation of this unit is hampered by the common facilities it shares with units 3 and 4.
SAN FRANCISCO FACILITY

From the discussion in Section III, significant repairs and replacement parts are required to both the steam plant as well as the diesel generators. IRHE has given some consideration to the rehabilitation of the existing diesel generators and has developed specifications for the needed spare parts. This information, coupled with proposal information, is relied upon for condition assessment and cost purposes. No similar information is available on the boiler plant. An overall evaluation of each of these facilities is provided below.

Steam Plant

As discussed in Section III, this plant appears to be in fairly serviceable condition. Adequate precautions appear to have been taken by IRHE to maintain critical components. No major replacement to return the unit to initial service is anticipated. A major overhaul and inspection should be performed on all major equipment prior to commissioning; however, this process may result in identification of repairs and replacements.

The air preheater will require replacement prior to commissioning. In addition, the electrical and controls systems are candidates for potential replacement/upgrade as part of a life extension program.

Diesel Generators

As indicated, the diesel generators have been the subject of more detailed investigation and review by both IRHE and the original manufacturer. More consideration has been given to the tasks required to return these units to service by the manufacturer. Units 1, 3, and 4 require an overhaul, basic replacement parts and upgrades. Coltec Industries has given this project significant consideration, and believes that a basic rebuild of the equipment can be performed. Pricing for this has been developed and is presented below. Unit number 2 is currently in need of additional parts that were removed for parts for the other units, but also appears to be an excellent candidate for refurbishment. Estimates for the cost for this unit, along with estimates on construction schedule durations, are provided below.

Summary

The current condition of the unit 3 steam plant, coupled with the low operating temperature of the critical components, makes it an ideal candidate for refurbishment. The only factors that counter this recommendation relate to the operating efficiencies of the plant, once refurbished. The design and actual heat rates are significantly higher than those of state of the art new plant.

4-3
designs, which might result in overall higher operating costs. Nevertheless, the operating cost of this unit may still be consistent with those of other thermal units in the IRHE System. This should be considered in the final decision to return this unit to service.

The diesel generator units also appear to be excellent candidates for refurbishment and return to service. Initial repairs appear to be limited and, if properly operated and maintained, considerable life remains (>10 years).

**ORDER OF MAGNITUDE COST ESTIMATE AND SCHEDULE**

As noted previously, definitive cost estimates were not possible within this initial survey period; however, order of magnitude engineering estimates for refurbishment can be established. Listed below are several founding assumptions used in developing these estimates:

- The expected operating life of the plant after refurbishment is 10 to 20 years
- The unit will not be used for only peaking which requires heavy cycling service
- Materials and labor pricing are consistent with those of the United States
- The required accuracy for this costing effort is ± 40%.

**Las Minas**

The costs and schedule associated with refurbishment of Unit 2 are in two basic categories - those repairs required to return the unit to service, and those required for future reliable operation for a minimum ten year planning horizon. Each category is discussed separately.
REPAIRS
Costs (Installed)

- Waterwalls, superheaters and headers $1,000,000
- Turbine and Auxiliaries Overhaul $1,000,000
- Electrical and Control Systems $500,000
- Balance of Plant Structures/Equip. $1,000,000

Total $3,500,000

Life Extension Considerations

Bechtel recently completed a detailed life extension evaluation assessment on a similarly sized unit in the Los Angeles Basin area. Some general conclusions from this effort are applicable to Las Minas Unit 2. The plant is a 40 MW Oil/Gas fired boiler (C-E) built in the mid 1950's. Many of the plant design features and technology are similar to those at Las Minas. The results of the detailed evaluation on this other unit indicated that, even though the plant has been well maintained over the years, an additional $6,000,000 was recommended to maintain the plant as a reliable source of generation for the next ten to twenty years.

Life Extension
Costs (Installed)

- Control Systems Upgrade $2,500,000
- Feedwater Heaters-Retube 1,000,000
- Pipe and Valve Replacements 1,500,000
  (Extraction Steam, Feedwater, Other)
- Other 1,000,000

Total $6,000,000

These are the types of life extension items that would be considered and are likely to be implemented at Las Minas.

Accordingly, total installed costs for the Las Minas facility would be in the range of $9,000,000 to $10,000,000.
Schedule

Most of the equipment is readily available in the international market today, and does not appear to constrain the return to service of the unit. First estimates of the outage durations to make each of the individual repairs would be on the order of 12 to 15 months of construction, with an additional 2 to 3 month commissioning period. We would recommend allowing on the order of eighteen months for the refurbishment activities. As indicated above, these activities should only be pursued after the proper investigations were completed.

San Francisco

Steam Plant

Only limited damage was noted by the IRHE staff, or identified during the site investigation. The costs associated with initial repairs for return to service are estimated to be $500,000. Life extension considerations likely would identify additional items that are necessary for longer term reliable operation, as was noted for the Las Minas facility. Approximately $1,000,000 in these areas could be expected.

Accordingly, total installed costs for the San Francisco facility would be in the range of $1,000,000 to $1,500,000.

Diesel Generators

Formal specifications have been developed and proposals have been received for 3 of the diesels. Parts pricing for the needed replacement equipment for the 3 units is approximately $2,300,000. Additional parts required for the fourth diesel generator have not yet been detailed, but are more extensive than the other 3 units. Engineering estimates for refurbishment of this unit is $1,500,000. Labor costs for refurbishment of all of the units would be on the order of $1,000,000.

Accordingly, total installed costs for the San Francisco diesel generators would be in the range of $4,500,000 to $5,000,000.

Schedule

The steam unit appears capable of being readily refurbished and returned to service. A 3 to 5 month commissioning period is anticipated. The diesel generators, while needing more extensive repairs, could still be recommissioned in the same time period. As indicated above, these activities should only be pursued after the proper investigations were completed.
SECTION V
RECOMMENDATIONS BASED UPON INVESTIGATIONS TO DATE

General observations and conclusions are made on the basis of the investigations performed to date and are presented below. Recommendations are also provided where follow-on work is needed to confirm these findings, or where additional outside consultants could help in facilitating this work.

Feasibility of Facility Rehabilitation

In general, both the Las Minas Unit 2 and San Francisco facility are currently in degraded conditions and in need of refurbishment prior to recommissioning. Both facilities appear capable of rehabilitation. Comparing the two facilities, Las Minas unit 2 has additional requirements and considerations that make it less desirable than San Francisco. The San Francisco facility is in better physical condition than Las Minas Unit 2, requires less capital to initially refurbish, and is easier to isolate for private sector use.

It is our opinion that given a reasonable return for power sales, private participation in leasing the San Francisco property from IRHE and refurbishment of the operating diesels and steam plant should be of interest to selected organizations in the private sector.

As an alternate to strict rehabilitation of these facilities, IRHE may want the private sector to consider repowering or replacement of selected portions of the facility. The decision to repower or replace would be the result of life cycle planning that considers both the present and future cost of fuel, plant efficiency, and expected plant demand over the planning horizon. For example, the Unit 3 Steam plant at San Francisco could be repowered with a combustion turbine. Repowering would provide approximately three times the power output at about one-half of the existing steam plant heat rate.

SUGGESTED FOLLOW-ON ACTIVITIES

Once basic decisions have been reached regarding the acceptability of private power participation and the site is selected, more detailed specifications need to be developed.

The technical portion of the specifications should include items such as:

- Minimum levels of availability and reliability of the units
- Minimum acceptable levels of maintenance
• Expected electrical demand on the facility over the contract life

• Fuel supply considerations, limitations and commitments

• IRHE's requirements for specific modifications or upgrades to the facility

Future system demand studies need to be reviewed to support the development of the specifications. This information can provide guidance on the timing and the extent of the expected shortfall in IRHE's generation. Additional load studies may also be beneficial in determining optimistic, pessimistic, and most probable future electrical demand.

These additional activities can be done within two to three months. The technical specifications, along with the contract requirements could then be issued to bid. When these follow-on activities are initiated, evaluation and award of contracts could be effected within seven to eight months. If the San Francisco units are pursued for refurbishment, IRHE could potentially expect power generation from these units within three to five months after project mobilization.
APPENDIX A

PHOTOGRAPHIC RECORDS OF LAS MINAS FACILITY
VIEW OF UNITS 2, 3, & 4 FROM UNIT 1

UNITS 2, 3, 4 OIL STORAGE TANKS
UNIT 2 INTAKE STRUCTURE ONGOING REPAIR TO STRUCTURE

INTAKE STRUCTURES TRAVELING SCREENS (DAMAGED)

UNIT 2 CIRCULATING WATER PUMP (DISASSEMBLED)
UNIT 2 ID FAN, BREACHING, AND STACK
SECTION OF APH IN FOREGROUND

UNIT 2 BURNER FRONT

UNIT 2 STACK
UNIT 2 PORTION OF 2/3 CONTROL ROOM

UNIT 2 TURBINE (WITH OLD ROTOR)
APPENDIX B

PHOTOGRAPHS OF THE SAN FRANCISCO FACILITY
UNIT 3 BOILER PLANT

UNIT 3 STACK (FOREGROUND)
UNIT 2 STACK (BEHIND)

ID FAN DISCHARGE DUCTWORK TO STACK
UNIT 3 BOILER FEEDPUMP

UNIT 3 TURBINE GENERATOR & TURBINE ROOM CRANE
UNIT 3 CIRCULATING WATER PUMP & PIPING
UNIT 3 COOLING TOWER UNDER RECONSTRUCTION

UNIT 3 COOLING TOWER DISTRIBUTION HEADER
UNIT 3 COOLING TOWER & OIL STORAGE TANKS

OIL STORAGE TANKS & LOADING FACILITY
MCC'S FOR DIESEL GENERATORS

SWITCHGEAR ROOM FOR DIESEL GENERATORS
FUEL OIL TANKS FOR DIESEL GENERATORS

DIESEL EXHAUST SILENCERS
DIESELS #3 & 4 AUXILIARY EQUIPMENT

DIESEL GENERATORS (UNIT 1, FOREGROUND)

SIDE VIEW OF #4 DIESEL & EXHAUST