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Implementation of a Wood-Fueled Steam-Electric Generation Plant for Rural Application

The MITRE Corporation

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REPORT

IMPLEMENTATION OF THE WOOD-FUELED STEAM-ELECTRIC GENERATION PROJECT AT YAVIZA

TO

INSTITUTO DE RECURSOS HIDRAULICOS Y ELECTRIFICACION (IRHE)

AND

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT (AID)

BY

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PANAMA, R.P. 24 JULY 1980.

ABSTRACT

This document records the result of MITRE participation in a team effort to establish the technical basis for the preparation of an invitation to bid for a 200 KW wood-fueled steam-electric generation plant at Yaviza, Panama. The document produced by the Panamanian Agency, Instituto de Recursos Hidraulicos y Electrificacion (IRHE) is incorporated. It includes the plant description, fuel wood supply, and major equipment specifications. Drawings show the schematic flow diagram and the plot plan. Other team members were from IRHE and an independent consultant.

ACKNOWLEDGMENT

The authors are grateful for valuable assistance received from Abu Talib of the MITRE CORPORATION by developing through telephone conversations critical information concerned with the selection of the steam turbine and steam generator, and for supplementing the list of potential suppliers. Also, María Isabel Reyes, Ruth E. Rodríguez and Magally Brower of IRHE performed the monumental secretarial and typing tasks needed to complete the finished report within a tight schedule.

PREFACE

The MITRE Corporation participated in an effort, during July 1980, in which the Panamanian government agency responsible for the country's electricity supply defined the design of a 200 KW wood-fueled steam electric station. The station is to be located in a forested rural area to replace an aging diesel-electric generator. The design and construction project is to be funded jointly by the Government of Panama through its agency, the Instituto de Recursos Hidraulicos y Electrification (IRHE) and by the Government of the United States through its Agency for International Development (AID).

The basic concept emerged from a study of Panamanian alternative energy sources; this report concerns the documentation required to enable the equipment procurement process to start. The documentation is titled, "Implementation of the Wood-Fueled Steam-Electric Generation Project at Yaviza," jointly authored by Snrs. Benavides, Mayta and Miller of IRHE, Consultant Robert Rollins and Charles Bliss of The MITRE Corporation.

The following features in the documentation are significant:

- Alternative Systems. Two alternative systems are specified, from which a choice is to be made. The first is a cycle based on the use of lower pressure saturated steam as produced by a fire-tube steam generator. The second is a higher pressure superheated steam as produced by a water-tube

steam generator. The choice will be influenced by a comparison of capital cost and cycle efficiency differences. It is likely that a third system will also be evaluated, namely that involving the use of a steam engine rather than a steam turbine as the prime mover for the generator. Greater maintenance requirements for the steam engine may be the influential factor here.

- Plant Location. An in-town location was arbitrarily specified; this will involve hauling the fuel logs about 5 km by water, maintaining a substantial stockpile of fuel at the plant location, and a significant consumption of petroleum distillate fuel. Hence, there may be reasons to reconsider the front-end plant design based on a relocation at the forest reserve which is to supply the wood fuel and the construction of a connecting transmission line.
- Boiler Feedwater. The quality of boiler feedwater is a significant, if not a critical, factor in assuring trouble-free operation. Boiler feedwater treatment technology is complex and likely to be impractical to apply in a small plant in a rural and remote location. Accordingly, a water distillation unit is specified using off-peak steam from the boiler as its energy supply. The only treatment required then will be control of pH as specified by the boiler manufacturer.

The report is reproduced on the following pages exactly as it exists. The two working drawings are reproduced in much reduced format basically for illustrative purposes. The readers who wish to obtain readible copies for their own specific purposes should apply directly to the Design Department of IRHE (Apartado 5285, Panama 5, R.P.). Material in Appendix D is reproduced exactly as generated except as noted on page D-1. The format is that of working information for use in the preparation of a formal Invitation to bid document.

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EXECUTIVE SUMMARY

The authors operated as a project team during the period 8-24 July 1980, and further defined the Yaviza wood-fueled steam electric project. This project is now ready for the process of equipment procurement to begin. The individual activities, required by IRHE and AID standard practices, are defined in a project schedule (Drawing number 1). The time requirement for these activities, together with current delivery periods for the major equipment components and those for the actual plant construction and commissioning, show a project completion schedule of two years. Accordingly, the earliest date for the first Yaviza plant operation is 1 August 1982.

Equipment procurement procedures for the Yaviza project differ from those usually followed by IRHE in their day-to-day activities. Normally, IRHE issues an invitation for bid based on a single system completely engineered beforehand. The small size of the plant, the high degree of sensitivity of the cycle efficiency to alternative major equipment components, and the very limited industrial experience background for the type of plant at its scale of capacity, all indicate that bids received should be evaluated by setting-up alternative systems for the plant design and evaluating the costs and performance of each system against those for the others. Equipment would then be specified and procured for the system selected.

The substitution of wood fuel for petroleum diesel oil as the

energy supply to the Yaviza electricity grid appears so far to reduce the cost of the energy supply, but, the number of plant operating staff will increase and the operating and maintenance efforts will be a higher order of magnitude. Providing for the maintenance and operational needs of the Yaviza steam-electric plant should be undertaken at the time equipment purchase begins as a special effort, and a high level of priority and resources should be assigned to this.

Attention should be given to eliminating all petroleum (i.e., gasoline) consumption in connection with the supply of wood fuel. Inspection of estimates of delivered wood fuel costs so far available, indicate that gasoline costs alone represent at least 15% of the total delivered cost of roundwood at the plant site. For example mule power seems to be practical for use in the tree harvesting operations in place of sophisticated petroleum fuel consuming machinery. Also, storage-battery power electric motor drives for river craft may also be practical.

The scope of work assigned to the authors (Appendix A) has been addressed as follows:

Preparation of IFB (Items 1, 2, 8)

The entire technical specifications section of the IFB has been prepared and appears in the Report as Appendix D. The standardized content, taken from a model IFB provided by IRHE, is abstracted and included in draft form in this Appendix. A remaining task, accordingly, is to rewrite and appropriately reorganize the content to produce the finished IFB document. The discussion in

this Report supports the content in Appendix D. Simplification of some of the content may be necessary because of the small size of equipment.

Non-technical IFB Aspects (Items 3 and 8).

Discussion on non-technical aspects is reflected in the Report in the formulation, organization, and explanation of the Project Schedule (Chapter III), and the guidelines for implementation (Chapter IV).

Potential US/Panamanian Bidders (Item 4)

The list is presented in Appendix E. A draft of a letter is available which, with the mailing list, permits securing cost estimates and technical information earlier than otherwise scheduled.

Maintenance Operational Training (Item 6)

Aside from the effort of procuring and constructing the plant, the efforts to establish and implement maintenance practices and to train operating personnel are vital and most important. These efforts should begin at the time equipment is finally specified, about May/June 1981.

Alternative types of wood fueled systems based on steam generation and turbo expansion are discussed in the Report (Chapter II). Types based on steam-engine drives are obsolete and inefficient (high wood consumption) because of inability to exhaust steam under vacuum conditions. Types based on wood gasification and engine drives apparently were originally ruled out in the formulation of the project.

Reference Materials (Item 7)

Some sources are the following:

- Requests for estimating data and brochures from the list of vendors in Appendix E.
- Contacts with local business concerns interested in energy recovery from waste material.
- Enter IRHE's name on the mailing list for: Morbark Industries Inc. (address in report) monthly news letter "What's New in Total Chip Harvesting".
- U.S. Embassy Commercial Section, in the library (e.g., the latest edition of Thomas Register) (Telephone 27-1777).

Knowledge Transfer (Item 5, 9)

The authors operated as a team in which full opportunity for discussion and resolution of issues and problems existed. Moreover, all sections of the Report were reviewed and agreed upon beforehand and changes were introduced in the drafting stage. This final Report, accordingly, represents the product of the joint effort among all the authors.

I. INTRODUCTION

The Government of Panama through its Hydraulic Resources and Electrification Institute (IRHE) operates an isolated electricity supply and distribution system at Yaviza in Darien Province. The system supplies three communities: Yaviza, El Real de Santa María and Pinogana; each distant from each other about five kilometers. The electricity is generated by aging diesel-electric sets, one rated at 135 kW and three others at 75 kW. Diesel-oil is supplied in 55-gallon drums which are manhandled and emptied by pumping into a 10,000 gallon storage tank. Sawmills in the area are not connected to the system. The only currently operating mill uses direct-drive diesel engines to provide power to the saws and planers. Although, a petroleum refinery exists within the Republic of Panama, all crude oil to supply it is imported.

The Government of Panama has adopted a policy of developing alternative energy sources, and has agreed with the Agency for International Development (AID) to cooperate in a number of alternative energy projects which have the objective of the installation of demonstration facilities employing renewable sources of energy. One such project is to install at Yaviza, a wood-fueled conventional steam-turbine electricity generation plant which can eventually replace the existing diesel-engine facility.

Toward this end AID commisioned a study by Robert Peck, a tropical forester, to evaluate the wood resources in the Yaviza area for the supply of the wood requirements of the projected plant.[1]

From Page 2 - Footnote

The forester's(1) report, dated 24 January 1980, concluded that:

- resources of fuel wood in the Yaviza area can meet a daily requirement of 6.4 tons of dry wood;
- two sources of wood to meet such a requirement are sawmill wastes and weed trees growing along the river banks; and
- for the longer term, an energy forest reserve should be created, and a program of tree farming should be established.

In addition, the forester suggested that a one-month minimum supply of fuel wood be located at the power plant, and that the plant be located on the Yaviza side of the river adjacent to the new agricultural produce storage warehouse recently constructed by an agency of the Ministry of Agricultural Development (IMA) This location is also adjacent to the town's drinking water treatment and supply plant.

The wood supply function remains the responsibility of IRHE, but the plan is to delegate the labor supply and management functions involved to another agency of the Ministry of Agricultural Development, the Dirección Nacional de Recursos Renovables (RENARE), who has long-established labor supply relationships with the local population.

IRHE has studied the past and current pattern of electricity consumption for the Yaviza system, and has projected a 1990 demand at 184 kW. Accordingly, the installed capacity of the wood-

(1) Subsequently, a broader scope study of the forest resources of Darien province by Per Christiansen, provided to RENARE by FAO, included corroborative findings relevant to wood supply to the Yaviza steam-electric project.

fired installation has been selected to be 200 kW.

The present purpose is to continue from the results so far achieved through to the next further step which is to assemble the information, evaluate the content, and specify the equipment and services so that IRHE can establish and publish the invitations to bid (IFB) for the supply of equipment and construction of the plant. The precise activities involved are specified in Appendix A. For this purpose, AID supplied the services of authors Bliss and Rollins and IRHE the services of authors Benavides, Mayta and Miller. The necessary work was undertaken as a team effort and was accomplished during the period 8-24 July 1980. Appendix B is a chronological account of the specific activities in which the team engaged during this period. The discussion in the report is organized by Chapters and the details are presented as appendices.

Chapter II addresses details in the project concept, and developes the basis for the schematic drawing and plant plot plan. Project implementation, which developes project schedule and the basis for the technical information in the IFB, is discussed in Chapter III. Implementation guidelines are presented in Chapter IV. These guidelines offer suggestions for carrying out the critical tasks specified in the construction schedule and for the ultimate operation of the project.

II. CONCEPT OF PROJECT

The objectives in this Chapter are:

- To record the features of the project as they existed at the time the work reported here began.
- To discuss changes that arose from the work, including the rationale that supports these changes.
- To present the technical plant design in schematic form both as a flow diagram and as preliminary plan arrangement of the equipment components and fuelwood handling facilities, and
- To discuss the environmental emissions.

The discussion in this Chapter is divided as to economic aspects, fuelwood supply, technical plant design, and environmental emissions.

A. ECONOMIC ASPECTS

The economic aspects of interest are the project size, its capital cost, and the savings between (1) the foreign exchange cost of the petroleum fuel driving the present diesel-electric units and (2) the domestic cost of collecting, transporting, handling, and preparing the wood fuel requirement of the plant. Converting a foreign exchange expense to a localized expense generates new local employment and corresponding economic growth. This benefit is obvious and is not further addressed here, since securing it is no doubt the rationale for adopting the project in the first place.

1. Project Size

The size of the project is stated in the AID Panama Project Paper on Alternative Energy Sources (page 22) as 120 kW. In early 1980, a brief study by IRHE of the future growth of demand, based on past demand experiences for the

Yaviza distribution network,produced a projected daily average demand in 1990 of 184 kW. Currently peak demand occurs about 7-8 P.M. and is about 140 kW. Average demand on May 10, 1980 reached a high of 97 kW.

IRHE projected demand by discounting 1970-1980 growth, which averaged annually about 27%, to an 1980-1990 averaged growth rate of 2.7% They attributed the high growth rate to non-recurring factors. It appears that this projection of average demand caused an increase in the project size from 120 kW to 200 kW, and this is the installed capacity upon which the designs and specifications resulting from current work are based. Since the project is conceived as a demonstration project and is adequately sized to meet current demand, we believe that the 200 kW is appropriate.

Nevertheless, certain potential developments in electricity demand are apparent, which could affect IRHE's statistical projection significantly and which should be at least noted. These are the following:

- One source of fuelwood is planned to be the waste produced in the Doncella sawmill. The power for this mill is now mechanically supplied by diesel engines. At the 10 ¢/kWh charge now made by IRHE in the Yaviza area, electricity would be significantly less costly to the sawmill operator. At a delivered cost of $1.25 per gallon, for diesel fuel and assuming that his diesel equipment is 17% efficient (which is the efficiency of the Ya-

viza diesel-electric plant), the equivalent power cost from the diesel fuel to the sawmill operator is about 16.7 ¢/kWh. Connection of the Doncella load to the Yaviza plant, as well as those of other sawmills in the area, if the necessary transmission line were built, could be a significant increase in the day-time load of the projected wood-fueled steam-electric plant.

- IRHE's Department of Isolated Power Plants has under consideration the linking of many communities in Darien Province, including La Palma, the provincial capital, into one transmission grid and the closing down of the very small isolated generating stations. The projected plant at Yaviza could serve such a network with a greater utilization of its installed capacity.
- According to RENARE, some consideration is being given to the construction of a plywood mill in the Yaviza area. Plywood manufacture could offer a large steady electrical load, if the factory were to be served from Yaviza. On the other hand, it could also offer an alternative market for Doncella's waste wood, and thereby place a price on this fuel source.

Because of this apparent potential for load growth which is not considered in a statistical projection of demand, the physical layout of the Yaviza plant provides space for future expansion of capacity by the installation of

a second unit.

2. Capital Cost

A recent estimate of the capital cost of the Yaviza plant appears on page 11 of Annex 1 to the Project Grant Agreement between the Republic of Panama and the United States, dated August 29, 1979, as a total of $450,000. This includes the costs of construction, technical assistance and training, and the first year of operation. The estimate is now one-year old in an inflationary era. Moreover, as will be apparent below, the details of the plant design have been modified.

At the small-scale of the equipment sizes which the project calls for, and with the high degree of sensitivity of required equipment sizes (particularly the steam generator and wood supply facilities) to turbo-generator efficiency, preparing a capital cost estimate at this time could be misleadingly high or low. The earliest date when a realistic cost estimate can be prepared appears, from the project schedule presented in Chapter IV, to be about January/February 1981, when the equipment selections will be better defined.

3. Projected Savings

In the AID Panama Project Paper - Alternative Energy Sources, Page 1 of Annex H-4, the cost of diesel fuel at Yaviza in 1978 per gallon is given as $0.5501. The current (July 1980) cost is $1.2286 per gallon. Using a heating value of 150,000 Btu/gallon and a cycle efficiency for the diesel-electric generator of 17%, the

cost of fuel per kWh generated is (125) (3413)/(150000) (0.17) = 16.73 ¢.

No definitive cost estimate of chipped fuel-wood at the steam-generator burner feed location has yet been made, but an idea can be obtained by assembling data extracted from reports by the FAO (Per Christiansen, March 1980) and by AID (Robert B. Peck, January 1980).

Christiansen, pages 39 and 40, gives a cost of B/.10.50 per cubic meter of roundwood delivered to Yaviza by road. Peck, pages 28 and 29, gives a cost of $27200 per year at an average 17.5 m^3/day production delivered to Yaviza by water and an annual cost of B/.14000 for the river craft, gasoline, and maintenance (1). The total is B/41,200, or (41,200)/(365) (17.5) = B/.6.45 per cubic meter. Using an average price of 0.5 (6.45 + 10.50) = B/.8.48, a density of 40 lbs/cubic foot, and heating value of 7250000 Btu/tonne, the cost of fuel-wood delivered at the plant dock is

$$\frac{(8.48)\ (2204)\ (1000000)}{(35.31)\ (40)\ (7250000)} = \text{B/. } 1.83/\text{million Btu.}$$

(1) In this figure, Peck amortizes the capital equipment (canoes and engines) in one year while allowwing $2000 for maintenance at the same time. This appears to be a highly conservative approach.

If the cycle thermal efficiency (determined below) is 7.97%, then the cost of wood is B/.1,83 (3413)/(0.0797) (1000 000) or B/. 0.0788 per kWh.

The difference between current diesel oil cost per kWh generated and the projected wood cost per kWh (remembering that the extra cost of wood handling and chipping is yet to be accomodated) is 16.73 - 7.88 or 8.85 ¢/kWh. Total savings, of course, will depend on the quantity of future generated electrical energy, after allowing for the fixed and variable costs of round-wood handling and chipping, and on whether definitive cost estimates made, when sufficient design data are available, support the estimate above.

B. FUELWOOD SUPPLY

The power plant has three sources of fuelwood available to it, two of which are immediate supplies, and one a future supply. The immediate supplies are the scrapwood generated by the sawmill at Donoella, about 5 km. downstream from Yaviza, and the harvesting of weed trees in a forest reserve of 800 hectares which RENARE has set aside for the future supply of the Yaviza power plant. It is possible that weed trees located outside the reserve may also be harvested.

The future supply will be assured by planting trees of the luecuena species, in the forest reserve, which, on the basis of a six-year rotation cycle, are expected to reach a size of 15 cm. in diameter and 10-12 meters in length.

The concern to be addressed here is the fuel wood supply in the first few years of plant operation. According to Peck, page 3, the boiler fuel wood requirement is taken at 6.4 tons

of dry wood per day, or in terms of the units used in this report, 12.8 tons of wet wood per day. As shown below, the projected consumption of fuelwood at full design capacity of the plant is 28.34 tonnes per day. At current average plant capacity, the wet wood requirement is about (90) (28.34)/(200) or 12.75 tons/day, about equal to Peck's estimate.

Peck's observed (page 9) that the Doncella sawmill burned about 300 cubic meters of scrap wood weekly when the mill fully operated. During our visit, the saw was not operating (there was no reserve of logs at the plant). Only the planer was operating on the rough planks from previous sawing operations, which had been stacked in the sun to dry. The pile of unburned waste was small.

At an average bulk density of 20 lbs/cubic foot, 300 cubic meters weekly is a production of (300) (35.31) (20)/(2204) (7) = 13.73 tonnes/day, adequate for the initial need of the plant. But, it is clear from observation during out visit, that the waste wood may not be available in the required quantity constantly throughout the year. The Yaviza plant should therefore have an alternative source of fuel-wood.

With respect to the harvesting of weed trees, we discussed with RENARE a requirement of 398 trees per day, assuming an average trunk diameter of 6 inches and length of 16 feet. This number is equivalent to the fuelwood tonnage (28.34) required to operate the plant at full capacity continuously. In RENARE's opinion, obtaining this number poses no problem during the initial six year period, while the energy plantation is being established in the forest reserve. Moreover, it is

unlikely that this quantity will actually be required.

One further, but minor, source of fuelwood is the numerous weathered logs floating in the rivers surrounding Yaviza. These logs represent a navigation hazard to small river craft, particularly, to the outboard engines. IRHE, in the public interest, could offer to purchase such logs at the plant gate to a price formula attractive to the local teen-age male population, who could earn an income while at the same time clearing the rivers. The number of logs purchased this way should be limited to avoid abuse by unauthorized cutting in the forests. Also, freshly cut logs from such a source should be readily identifiable and easily rejected.

C. TECHNICAL PLANT DESIGN

Appendix C contains a descriptions of the technical plant design and operation, a preliminary schematic diagram showing material flows and equipment components, and a preliminary plot plan of the equipment components to establish the approximate dimensions of the required site. The discussion in this section focusses on the technical factors which determined the information content of Appendix C.

1. Turbine Steam Rate

The single most important technical factor in the plant design is the steam rate required by the turbine, i.e., pounds of steam required per kWh of generated electricity. Selections from three small-turbine manufacturers using the previously established inlet steam pressure of 250 psig with zero superheat and an exhaust pressure of 4 inches of mercury absolute as stated in the AID Pana-

ma Project Paper on Alternative Energy Sources (page 3 of Annex 6), produced the selection of turbines shown in Table 1.

In addition, the turbine manufacturers individually suggested a turbine speed of 5000 RPM with about a three to one gear reduction to match the generator operating at 1800 RPM.

2. Steam Quality

An area of caution, fully supported by the turbine manufacturers concerned a rigid requirement that steam quality exceed a minimum of 97% (3% maximum water droplet content) to avoid excessive erosion of the turbine wheel.

3. Turbine Selection Basis

Turbodyne provided information for their unit 30052W which would operate at inlet conditions of 350 psig with 190°F of superheat and at an exhaust pressure of 4 inches Hg. The steam rate is 22.6 lbs/kWh. Erosion problems are obviously avoided when the steam is superheated. We chose the Turbodyne 30052W as a basis for the plant design, and accordingly, the inlet pressure of 350 psig at the turbine and a steam superheat of 190°F above saturation temperature. These conditions determine the steam generator design and the calculations in Table 2.

4. Fuel Wood Requirement

On the basis of the turbine selected, the fuelwood requirement at rated capacity, continuously operating, is 28.34 tonnes/day. The overall cycle efficiency from fuel-

TABLE 1

TURBINE STEAM RATES, LB/KWH

MANUFACTURER	TURBINE SPEED 3600 RPM	TURBINE SPEED 5400 RPM
Elliot		
Type CYR	33	26
Type DYR	28	24
Terry	30-35	26
Worthington (Turbodyne)		
Type 30051W	---	26.35 (at 5000 RPM)

Source: Turbine manufacturer's suggestions using 200 KW capacity, 250 psig inlet pressure dry saturated steam, and 4 inches Hg exhaust pressure.

(follows Page 12)

TABLE 2

CALCULATION OF WOOD REQUIREMENT BASED ON MANUFACTURER (TURBODYNE) SUPPLIED PERFORMANCE DATA

1. Inlet Steam Conditions — 350 psig, 190°F Superheat (626°F Total Temperature)

   Outlet Conditions (Steam) — 4" Hg. abs.

   Turbine Speed - 5000 RPM

   Turbine steam rate is 22.6 lbs/kWh

   200 x 22.6 = 4520 lbs/hr.

   4520 (1325 - 94) = 5,564,000 Btu/hr.

3. Wood Fuel Requirement

   Boiler Efficiency (50% moisture wood chips) = 65%

   Wood Heating Value = 7250 000 Btu/tonne (wet)

   $$\frac{(5564000)\ (24)}{(0.65)\ (7250000)} = 28.34 \text{ tonnes/day (wet)}$$

4. No. of trees harvested/day (rated capacity)

   Assume: (a) Wood density 50 lb/ft^3

   (b) Average dimensions 6" Ø x 16' long

   Weight of tree $\frac{\pi (0.5)^2}{4} \times 16 \times 50 = 157$ lbs/tree

   No. of trees (28.34) (2204)/157 = 398

5. Efficiency of Power Generation Cycle (Wood Fuel to Generator Terminal)

   $$\frac{5564000}{(0.65)\ 200} = 42800 \text{ Btu/kWh, or } \frac{3413}{42800} \times 100 = 7.97\%$$

(follows page 12 and Table 1)

wood to generator terminals) is accordingly 7.97%.

5. Comparison of Water and Fire Tube Boiler Design

Small, less than 10,000 lbs/hr, water-tube steam generators are available to suit the pressure and superheat conditions upon which the calculations in Table 2 are based. A list is included in Appendix E.

In summary, both water-tube and fire-tube boilers are available in the capacity desired. The water-tube design offers higher pressure steam than the fire-tube design and the supply of superheat in the steam. This is the type of boiler which can be built in larger sizes almost without limit, which is an advantage if the Yaviza plant should become a prototype from which larger capacity units would be built in future years. Moreover, because of the lower quantity of resident boiling water in the water-tube design, it is a "safer" unit to operate. Fire-tube boilers, on the other hand are likely to be less expensive, but with lower steam pressures and cycle efficiency, wood requirements will be higher. Also, more attention will have to be paid to limiting the wetness (water droplets) in the steam to the allowable level.

The specifications for the steam generation equipment in Appendix D are written to allow both the water-tube and fire-tube types to be offered.

6. Feed Water Quality

The quality, or purity, of boiler feed water is a critical factor. Dissolved impurities can cause tube corro-

sion by an acidic reaction, pH less than 7.0, and also can form deposits on tube surfaces which raise tube temperatures and promote mechanical failures. Boiler feed water treatment by chemical additives and/or ion exchange must be carefully done and water quality continuously monitored. Because of the remote location of the power plant and its small size, we decided to use distilled water and left it to the manufacturer to recommend an additive, if necessary in his opinion to maintain alkalinity in the feed water (pH above 7.0).

7. Drying Fuel Wood

The nominal moisture content of chips from green wood is expected to be about 50%, whether made from logs or from Doncella waste. The effect of this moisture content is to lower the thermal efficiency of steam generator. In the case of the water tube design at 5000 lbs/hr generating capacity, the thermal efficiency drops from about 77-82% net at 5-10% moisture content to 65-68% net for green wood. If fuelwood were to be dried, additional wood would have to be burned to supply the necessary heat, the heat in the stack gases being insufficient for this purpose. Moreover, the complexity of the plant would increase because of the operation of an additional piece of equipment. Accordingly, the plant design omits the drying operation as not justified by the benefits.

If, during the wet season, the water content of the fuelwood chips becomes excessive, the fire can become

unstable. Therefore, a steam coil is installed in the combustion air duct-work to preheat the combustion air to about 150°F. Air preheat then will stabilize the flames and prevent loss of combustion.

D. ENVIRONMENTAL EMISSIONS

The replacement of the present diesel-electric station by a wood-fired steam thermal station will change the type and extent of emissions presently experienced at Yaviza. The size of the steam generator in the station is considerably smaller than the minimum size of steam generators now regulated in the U.S. by the Environmental Protection Agency. The minimum size is a heat input of 250 million Btu/hr, about 25 times larger than the Yaviza unit.

1. Sulfur Dioxides

The sulfur content of diesel fuel depends on the sulfur content of the source of crude oil used in the refinery and the extent to which desulfurization of product fractions is practiced in the refinery processing. All sulfur in the diesel fuel consumed is discharged to the atmosphere as sulfur dioxide. A similar situation will exist for the thermal power plant. Any sulfur content in the fuelwood will be discharged to the atmosphere as sulfur dioxide. A quantitative comparison can readily be made once typical sulfur contents of fuelwood and diesel oil are known.

2. Nitrogen Oxides

The sources of this pollution are the nitrogen in the

fuel and the nitrogen in the combustion air. The fuel nitrogen is the first to react and will probably entirely appear as nitrogen oxide emissions. Prediction can be made by analysis of the nitrogen content of the fuelwood.

The extent to which the nitrogen in the air will react with oxygen depends on temperature distribution characteristics of the fuel combustion equipment and the kinetics of the chemical reaction between nitrogen and oxygen that can occur within the temperature distribution pattern. The nitrogen oxide content of the present diesel exhaust gases can certainly be readily measured. For the thermal plant, measurement can be made only after operation; although the boiler manufacturer can empirically design the fuelwood burning system to promise reduced nitrogen-oxide formation.

3. Particulates

Particulates appear in the diesel exhaust gases, particularly on load changes, as submicron particles of unburned carbon which may contain decomposition hydrocarbons of a complex nature. The EPA in the U.S. is currently concerned with potential harmful health effects, since the submicron particles readily reach the lungs in the breathing process and the hydrocarbon content is thought to be carcinogenic.

Current research work has not yet produced conclusions that justify regulation.

More fully burned particulates will discharged from

the thermal station stack to the extent they are not captured by the separator provided in the ductwork of the steam generator. The extent of emission unquestionably will be less than the particulate emissions from the open burning of waste wood now practiced at the Doncella sawmill, a practice which can disappear when the thermal station operates.

4. Othe Sources

A solid ash residue will be produced in the thermal station, a type of emission source which does not exist in the present diesel plant; coarse ash from the burner grate of the steam generator and fine ash from the dust separator in the flue to the stack.

The ash can be disposed of in an area selected for the purpose. The ash can be used as a soil conditioner, but only a relatively small quantity will be produced. By use of Doncella waste wood, the ash residues at the sawmill can be eliminated.

Noise levels at the thermal station should be considerably less than present noise levels at the diesel-electric station.

The ecological implications of weed wood harvesting and of the deliberate growth of trees as an energy resource in a dedicated plantation are assumed to have been evaluated with a positive conclusion at the time the decision to build a wood-fired steam-electric station at Yaviza was taken.

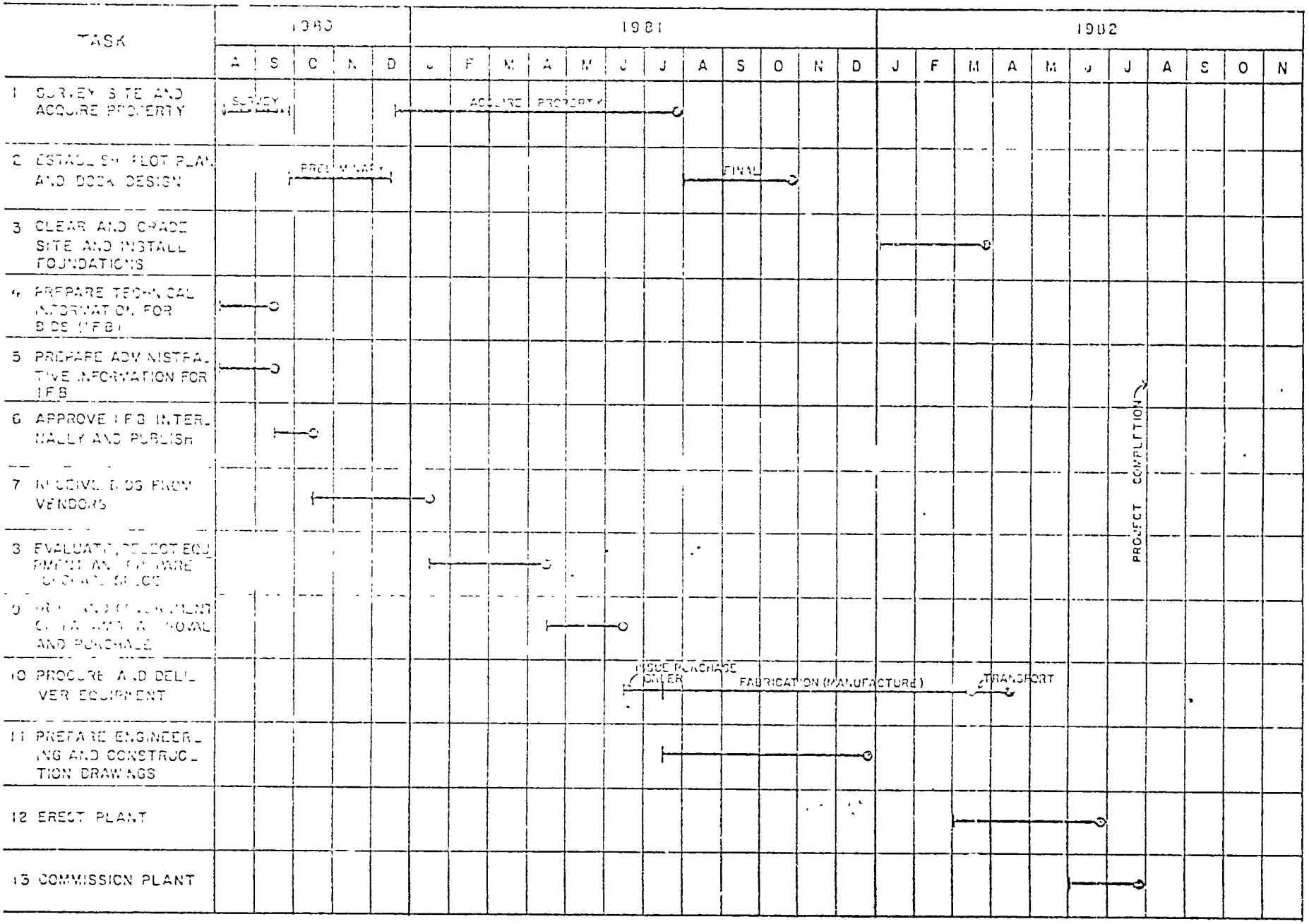
III PROJECT IMPLEMENTATION

Project implementation comprises thirteen scheduled tasks which are to be undertaken by IRHE personnel and two tasks, namely (a) the interim supply of roundwood from weed tree harvesting and (b) the ultimate supply of roundwood from an energy plantation, both of which are to be undertaken by RENARE on IRHE's behalf. The interrelationships among the thirteen IRHE tasks and the time required for their accomplishment are shown on Drawing No. 1. Based on the standarized practices of the IRHE organization and on current delivery schedules for manufactured equipment, the total time to bring the projected steam-electric power station at Yaviza into operation is 24 months. Accordingly, with a 1 August 1980 starting date, the plant should be ready for operation on 1 August 1982.

A. RENARE TASK

The details of the RENARE task are to to be covered by a written agreement between RENARE and IRHE, which is currently being negotiated. This agreement provides for the ultimate dedication of an area of 800 hectares as a forest reserve to supply the ultimate fuelwood needs of the Yaviza station. Of this reserve, 200 hectares will be worked immediately. The reserve is located upstream of Yaviza on the Río Chucunaque, just upstream of its junction with the Río Tupisa, on both shores extending perpendicularly to the river axis. The agreement provides for IRHE to pay stated costs and for RENARE to manage the efforts and labor involved to bring the roundwood supply to the power plant dock ready for unloading.

Accordingly, on the basis of estimates of wood requirement



TENTATIVE PROJECT SCHEDULE
DRAWING Nº 1

presented above, the maximum physical capacity to be planned for by RENARE is a continuous daily supply of 28 tons of roundwood, initially by the harvesting of weed trees and eventually by the harvesting of trees from an energy plantation. Actual consumption of the power plant in the early years will be considerably smaller.

Since the plan is to acquire a wood chipper capable of accepting a maximum log diameter of 6 inches (15 cm.), the harvesting diameter projected for a 6-year growth of the luecuena tree species selected for the plantation, a saw installation at the plant will be needed to reduce over-size logs along the longitudinal axis to an acceptable cross section, should the diameter of the weed trees require this.

RENARE's activities should be planned to establish a 30-day stockpile at the plant by 31 July 1982.

B. IRHE'S SCHEDULED TASKS

IRHE's tasks are two types, the administrative tasks which are required to enable the procurement of equipment and the construction tasks required to enable the erection of the plant.

1. Administrative Tasks

The administrative tasks are shown in the schedule (Drawing No. 1), as tasks 4 through 9 inclusive. Their accomplishment by the standarized IRHE procedures is estimated to require a total of 10-11 months. The earliest date for preparing a definitive capital cost estimate for the entire project, a definition of the operating cost, and an estimate of bus-bar electricity cost will occur during the evaluation of bids received (task 8), that is, during February/ March 1981. However, the preparation of a cost estimate will be

unofficially undertaken in parallel with the task to prepare the technical information for bids (task 4), during August/September 1980. For this purpose, the authors prepared a sample form letter.

2. Construction Tasks

The construction tasks are of two types: those pertaining to the acquisition and the improvement of the site (tasks 1, 2 and 3); and those pertaining to the procurement and erection of the equipment (tasks 10, 11, 12 and 13).

It is clear that the allocation of responsibility, and delegation of authority, to the project manager should consider either (a) encompassing both the administrative and the construction tasks in one person; or (b) ensuring a smooth and effective transition, about June 1981, from the person discharging the administrative responsibility and the person discharging the construction responsibility. In any event, the activities of RENARE under the RENARE/IRHE agreement should be monitored to assure that a reliable wood supply is available to the plant at the lowest practical cost upon its completion and during its operation.

C. TECHNICAL INFORMATION FOR PREPARATION OF INVITATION FOR BID

Technical information for preparation of the technical specifications section of the information for bid (IFB), which is the activity to be undertaken in Task 4, is contained in Appendix D of this Report.

The technical information incorporates the following:

- the technical specifications for the equipment comprising the Yaviza woodfueled steam-electric plant, and
- general information required by IRHE practices applicable to

the supply of the equipment.

The technical specifications are developed from the plant design factors discussed above and from the description of the plant contained in Appendix C. The general information is taken from a previous IRHE invitation for bid, which was adopted for use as a model. The model used was the technical specifications section of the Invitation for Bid, issued for the San Francisco de la Caleta, Panama-City - Extension of the Thermal Power Plant, dated June 1973.

Appendix D is presented in draft form. The reason is that the paragraphs to be extracted from the model IFB are referred to rather than copied, as time did not permit further effort. Instead, the relevant pages of the model IFB with the markings are duplicated and appear immediately following Appendix D. Accordingly, once Appendix D is modified by copying into it the paragraphs referred to, and the applicability confirmed, the complete technical specifications section of the IFB for the Yaviza project will exist.

IV IMPLEMENTATION GUIDELINES

The objective in this Chapter is to provide technical and administrative judgments and opinions on the topics headed below, for use at the appropriate time in the execution of the various tasks delineated in the Tentative Project Schedule (Drawing No. 1).

A. USE OF THE MODEL IFB

In the review of a copy of the Technical Specification for the San Francisco de la Caleta Panama City - Extension of the Thermal Power Plant (used as a model for the type of IFB to be prepared by the IRHE project manager in order to solicit bids for the equipment items comprising the Yaviza Woodfueled Steam-Electric Station) the authors found it to represent a completely engineered station design.

On the other hand, the present effort to prepare technical specifications for the Yaviza IFB represents only the conceptual design engineering portion of the work. The presently drafted IFB technical specifications in (Appendix D) may be issued to interested bidders who will submit prices and descriptions of the equipment they manufacture, which may be considered for the Yaviza plant. As discussed below in Section B, the Yaviza project team must study the bids received, and select a suitable combination of equipment meeting the basic requirements and having economic or technical advantages over the other equipment offered. From this selection, a technical specification for purchase may be prepared.

The functional difference between the Model IFB and the Yaviza IFB should be continuously kept in view during the course of the project activities. Moreover, when preparing the legal section of the IFB,

for Yaviza, the legal requirements specified in Chapter 3, Procurement of Equipment and Materials (AID Handbook 11 - Country Contracting) must be incorporated along with relevant legal requirements of IRHE.

B. BID EVALUATION ASPECTS

The discussion in this section is relevant to the activities in Task 8, which is scheduled to occur during January through April 1981.

The basis for the discussion is an assumption that the response to the publication of the Yaviza Invitation to Bid, which is the result of Task 6 in the schedule, is voluminous.

1. Section of Alternatives

Two alternatives are apparent at this time. Other may be identified during the evaluation of bids. One is the use of firetube boiler at the maximum practical generation pressure and zero superheat. The other is the use of a watertube boiler at higher levels of pressure and a specified level of steam superheat. Each of these alternatives support a different selection of steam turbine and will require more or less fuelwood with resulting differences in steam generation capacity. Accordingly, comparison of individual equipment items across systems will be illogical.

Each system must be studied individually, and the combined effect of the performance and cost of the equipment of that system compared to the alternative system.

2. Evaluation as a System

In system evaluation, the components and their performances which are specific to the system, are identified. Their costs are lis-

ted and summarized and the performance of the entire system estimated in terms of cycle efficiency, fuelwood requirement, operating and maintenance manpower, land requirement, and other factors which may appear useful. Two cost figures are then estimated for the system: (1) the capital cost of the plant ready to operate; and (2) the generation cost of electricity at the bus bar. These data are estimated for each system identified.

3. Comparisons of Intangibles

Certain aspects of each system evaluated will be intangible. Examples are: (1) the safety aspects of a lower-pressure firetube boiler versus a higher-pressure watertube boiler in the event of misoperation of the relief valves; (2) the greater attention that needs to be paid to feedwater quality in the case of watertube boilers; and (3) the greater probability with a firetube boiler of damage to the turbine should excessive water be present in the high-pressure steam.

Such intangible factors would have to be weighed qualitatively and subjectively in order to judge the attractiveness and acceptability of the least cost system.

4. Presentation of Selection

A selection of a system should be made and recommended to IRHE management, together with the evaluations of all systems considered, a statement of the intangible factors and their treatment, and the rationale for the recommendation.

C. SPECIFICATION OF AUXILIARY EQUIPMENT

The auxiliary equipment comprises the feedwater pump, miscellaneous transfer pumps, the feedwater deareator tank, various storage tanks,

power saw for reducing oversize logs longitudinally and other items shown, or not shown (such as maintenance tools), on the flow diagram in Appendix C, or which may be introduced by the bidders. The costs of these items will have been estimated approximately, but on a consistent basis, when the alternative systems were compared.

Once the recommended system has been selected, the detailed and formal specifications for the auxiliary equipment for this system have to be established to enable procurement when the system selection is officially approved.

A useful procedure for the task of identifying and specifying the auxiliary equipment is to involve the prospective plant manager and to solicit his views as the responsible person to assure reliable operation.

D. FINAL PLANT DESIGN

As soon as it appears that the recommended selection will be approved, the final plant design can begin. This is task 11 in the Tentative Project Schedule. The two parts to this task are the civil works and the equipment integration.

1. Civil Works

Because of the intense rainy season at Yaviza during the final months of the year, all areas should be sheltered beginning with the roundwood storage.

Except for the turbo-generator/condenser package, shelters may be open sided with sufficient roof overhang to protect reasonably against a driving rain. Construction may be of local materials (such as those observed during the visit to the Doncella sawmill); but, around the boiler and turbo-generator construction should be fireproof.

All working areas should have concrete or wood floors sufficiently elevated above grade to avoid flooding. Others should be graded and provided with adequately sized drains to avoid water accummulation in pools.

The design of the dock should provide for a rise and fall of level of the river which could exceed 15 feet at times, and the prospect that excessive erosion of the river bank can occur because of the rapid river current.

If it is determined that the plot width should be reduced (see note 1 on the plot plan drawing), the stacked height of logs may be increased to reduce width.

In this event, labor and equipment needs should be reviewed to assure efficient and effective log handling.

2. Equipment Integration

Equipment integration will show the piping and electrical wiring requirements, the control panel layout to permit centralized observation and correction of operating conditions, insulation of live steam lines, interconnection of control valves and sensing devices, painting for corrosion prevention, valves, vents and drains, and other such items to produce a finished plant. The final equipment locations will enable final foundation drawings to be prepared.

E. INTEGRATION OF NEW PLANT WITH EXISTING PLANT AND TRANSMISSION SYSTEM

We understand that IRHE operations now have plans to relocate the existing 135 kW diesel electric generator to the original power house on the Yaviza side of the river as a means of reducing the cost of delivering diesel fuel. At the same time the Yaviza steam

electric plant design also provides space in the plot plan for the relocation of the 135 kW unit as standby and for start up purposes. It would seem that any current relocation plan should be reconsidered to avoid unnecessary expense.

In any event, the electrical interconnection between the projected and existing plant with respect to the transmission line should be designed and should provide for control of load sharing between the two generating units to any extent from zero to 100% to 100% to zero.

F. PLANT MAINTENANCE ASPECTS

The Yaviza steam-electric plant will require paying serious attention to preventive maintenance, especially because of its remote location and sensitivity of equipment to new factors, such as water quality, that do not apply as seriously to diesel-electric installations. Maintenance in general in the Yaviza area can be a serious problem. For example, during the visit to Yaviza, the transfer pump for the drinking water system between the settling tank and the storage tank was disassembled, and apparently inoperable for a long period judging from the accummulation of cobwebs in the storage building for the treating chemicals.

As soon as the equipment specifications are known, at the time task 10 begins (June 1981), a maintenance practice for the Yaviza steam-electric plant, which assures reliable operation, should be formulated and officially adopted.

Inadequate maintenance could, without justification, mar the potential success of the Yaviza installation as a demonstration of petroleum fuel substitution by a renewable energy source.

G. OPERATIONAL ASPECTS

A larger operating force is required for a steam-electric plant, than for a diesel-electric plant. The shift supervisor would concern himself mostly with the operation of the turbo-generator-condenser package, while the second operator would concern himself primarly with the steam generator and fuel supply beginning with the operation of the Day Storage Silo.

The day shift would be concerned with log receipt, handling, chipping, and maintaining the supply of chips in the storage silo. The supply of logs to the plant pier is the responsibility of RENARE.

H. FUTURE LOAD-GROWTH STIMULATION

Given a successful demonstration of the Yaviza steam-electric plant and a favorable cost experience, IRHE could find it attractive to stimulate load-growth deliberately to utilize the full installed capacity of the plant. At such a time, the following suggestions may be appropriate.

1. Conversion of Domestic Appliances

A significant use of petroleum products occurs in the service area of the Yaviza plant as liquified petroleum gas for domestic cooking and as kerosene for fueling refrigerators. Conversion to electric cooking and to conventional electric refrigeration would seem to be in the national interest, at least, if not in IRHE's direct interest from an income and capital return point of view.

2. Servicing the Doncella Saw Mill

The need for power at the Doncella Sawmill appears about equal to present average demand on the existing Yaviza power plant. The new unit could readily handle this load. At the current tariff for electricity, the sawmill could realize a significant energy sa-

ving which they might be willing to use in part to help pay the cost of the transmission line. Also, receiving electricity from Yaviza would give the sawmill operator a vested interest in supplying his waste wood as fuel, and he might conceivably be willing to load waste aboard IRHE's or RENARE's river craft.

3. Interconnection of Isolated Networks

One objective of interconnecting the isolated networks of Darien province is to eliminate the very small isolated diesel electric generators.

Such interconnection would enable the Yaviza station to utilize surplus installed capacity to service a larger area.

APPENDIX A

Scope of Work

APPENDIX A

SCOPE OF WORK

Background

The Water Resources and Electrification Institute (IRHE) has selected Yaviza, Darien as the site to construct a wood-fired, steam boiler turbine electric system to provide approximately 200 kW to the communities of Yaviza, Pinogana and El Real. The goal of IRHE is to replace an existing, aging diesel system with one that helps alleviate Panama's dependence on imported petroleum.

The equipment of the proposed plant will consist of a boiler, turbine, alternator, and auxiliary equipment related to drying, storage, and chipping of the wood.

Tasks

1. Select equipment components necessary to result in a totally functioning system. Equipment will be of U.S. or Panamanian origin. Task will include the preparation of a detailed equipment schematic.
2. Prepare technical specifications and performance standards that will represent a section of the IFB for equipment and technical assistance.
3. Advise IRHE on non-technical aspects of the IFB.
4. Prepare a list of potential U.S. or Panamanian bidders to be considered by IRHE.
5. Transmit sufficient knowledge to IRHE engineers that they could prepare similar specifications at a later date.
6. Advise IRHE concerning maintenance standards, training local

personnel, and other types of wood-fueled systems available.

7. Suggest reference materials to IRHE that would prove useful for future work of this nature.

8. Assist IRHE as time allows with the other sections of the IFB.

9. Prior to departing from Panama, prepare a written report summarizing work performed and make additional recommendations.

APPENDIX B

Chronological Account of Activities

APPENDIX B

CHRONOLOGICAL ACCOUNT OF ACTIVITIES

(8 - 24 July 1980)

Arrival formalities and initial introduction of the authors were completed in the morning of the first day. By noon of the first day, active work was underway.

A flow chart of the wood-fueled electricity generation system was developed on the blackboard and drawn up in draft form, for refinement as the individual equipment specifications were developed. The selection of 200 kW size was discussed and reviewed briefly. Since this installation is to be considered a demonstration unit, the size was considered as adequately large for its intended service.

It was agreed the Scope of Work extended from supplying fuel and treatment of boiler feed water to the 480/240 volt generator terminal connections.

IRHE will arrange separately for the connection of the wood fueled electricity generation facilities to the existing 13.2 kV net.

For the output of 200 kW, steam rates for the generator turbine drive were estimated from curves and other data published by three potential turbine manufacturers (Terry, Worthington, and Elliot).

Previous development work for the Yaviza project was based upon a steam generation pressure level of 250 psig and no superheat, which had appeared logical since most experience with wood-fueled boilers has been with the fire tube type boiler, and 250 psig is considered to be a good safe upper pressure limit for this type of boiler.

The steam rates resulting from the estimates were twice as high as those previously estimated during the project development, and resulted naturally in a considerable increase in the fuel requirements, beyond those considered in the Peck report.

It was agreed at this point to seek clarification from the three major turbine manufacturers cited above before proceeding further with detailed specifications. Their published data in this range of steam pressure, and considering the lack of superheat, appeared to be unreliable.

Moreover, an increase in steam system pressure (to 400-600 psig), and designing the boiler to include superheating (100-150°F over saturated steam temperature at operating pressure), would greatly reduce the steam rate and fuel requirements and small water-tube equipment in the capacity range of interest could be available. It was decided to investigate the availability of a wood-fueled water tube type boiler design which would permit attaining these preferable conditions of operation. In the opinion of all concerned this appeared not appreciably to increase the complexity of the system, while reducing fuel requirement and providing additional operating flexibility.

The various components of the system from fuel gathering to power generation terminals were listed, and separated into logical groupings representing the scope of the individual technical specifications to be prepared for the invitation to bid document. The main groupings were:

- Fuel gathering and transport.
- Fuel handling and storage.
- Steam generation, including boiler feed water system.

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Turbo generator and condenser.

At this point in the progress of the work, an outline of the contents of the final report was developed in order to plan the work efficiently, and some time was given to discussing the field trip to Yaviza to assure as much as possible was covered in the limited time available for the trip.

Friday, 11 July, 1980, the AID coordinator and the project team flew to Yaviza where they were joined by the local RENARE representative. The towns of Yaviza and El Real were visited, the existing diesel power generation installation and the site chosen for the wood fueled electricity generation installation were inspected, the area designated by RENARE as a fuel plantation was seen from the river, and the sawmill operation at Doncella and its potential supply of waste-wood fuel were visited and inspected. Through general observation during the field trip, an appreciation of the local environment was obtained by the team, which will be reflected in the development of the final plant specifications.

The second week was begun by organizing meetings with the Director of the Isolated Systems Department of IRHE on Monday 14 July 1980, with RENARE representatives on Tuesday 15 July , and the Director of Energy and Tariffs of IRHE on Friday, 18 July 1980.

The meeting with the Director of the Isolated Systems Department provided an insight for the team of the particular problems of maintenance, source of supply, and lack of suitable, reliable, boiler feed water at the remote Yaviza location.

RENARE personnel were given the most recent estimate of fuel wood requirements for the Yaviza Project, and the means of sa-

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tisfying them developed by the team. RENARE personnel presented their views on the wood cutting, reforestation, and transport of fuelwood to the power generation site. It was suggested they consider another means, possibly the use of mules, to move the cut trees within the plantation instead of the diesel-powered minitractor presently under consideration, and thereby save diesel fuel consumption. RENARE and the team agreed the cut logs could be transported either by a multi-canoe fleet or by a catamaran type of special motor driven barge. General agreement was reached that the wood resources were adequate to supply plant needs.

The intervals between meetings were devoted to preparing a preliminary schedule, plot plan arrangement, and a more definitive flow diagram of the project. The technical descriptions and specifications for the equipment and facilities at the generation plant site were also developed. By Monday evening 14 July 1980, it was learned that the boiler could be a water tube type, since there are current manufacturers, and the turbine efficiency could be increased by using 350 psig steam with 190°F of superheat, levels of generation available from current boiler manufacturers. These two improvements were incorporated in the equipment specifications.

The third week was devoted to the preparation of the final report and submission to IRHE and AID. Briefings were given on the content.

APPENDIX C

Description of Plant

APPENDIX C

DESCRIPTION OF PLANT

The plant comprises all physical components between the production and harvesting of the fuelwood and the terminals of the generator. Included are the auxiliary components such as the supply and purification of the boiler feedwater and the transport of fuelwood to the plant. The schematic arrangement of the components is shown on the Invitation to Bid Flow Diagram (IRHE Drawing Number 3). The preliminary arrangement of the plant is shown on the Preliminary Plot Plan (IRHE Drawing Number 4). Both of these drawings are part of this Report.

Although IRHE retains responsibility for all components and their management and operation, RENARE, by agreement with IRHE, will take responsibility for the design, supply of labor, and management of the initial harvesting of weed wood, the delivery of fuelwood to the plant dock, the planning and establishment of the tree plantation, and the ultimate harvesting operations.

IRHE will provide the capital equipment for this purpose, and these capital costs are to be included in the definitive capital cost estimate for the Yaviza steam-electric plant.

IRHE retains the responsiblity for negotiating for supply, loading at the source and transporting the waste wood production of the Doncella (and other) sawmills to the plant dock. It appears likely that the river craft involved can manage both transport functions (waste sawmill wood and weed tree harvest).

1. FUELWOOD, RECEIPT, HANDLING, AND STORAGE

Upon arrival at the plant dock, the fuelwood is unloaded by derrick and lifted to a staging area adjacent to the fuelwood storage area. Bundling of fuelwood at the source should be investigated to simplify the unloading operation and minimize docking time for the river craft at the plant dock. In the staging area, waste wood is preferably fed to the chipper, and the roundwood preferably stored.

The roundwood storage pile is shown as five foot in height to facilitate manhandling the logs. Because of the requirement for a 15-day storage, the width of the storage pile is 240 feet, which may be excessive for the available property. The height of the pile can be increased to suit the property width, and this may require reconsideration of the handling technique by providing mechanical assistance. In any event, the pattern of reclamation of roundwood from the storage pile should be designed such that the maximum period of storage for any log does not exceed 15 days.

The chipper is located between the roundwood storage pile and the chipped fuelwood storage shed. Two options are available for its installation, one movable on a track, the other fixed at one end of the area with the installation of conveyors. Three options are available for the chipper drive: an engine, probably diesel; an electric motor; and an electric motor and fly wheel assembly to level load on the generator. The most practical choice of options will depend on manufacturer's recommendations, labor requirement, generator operation, and cost.

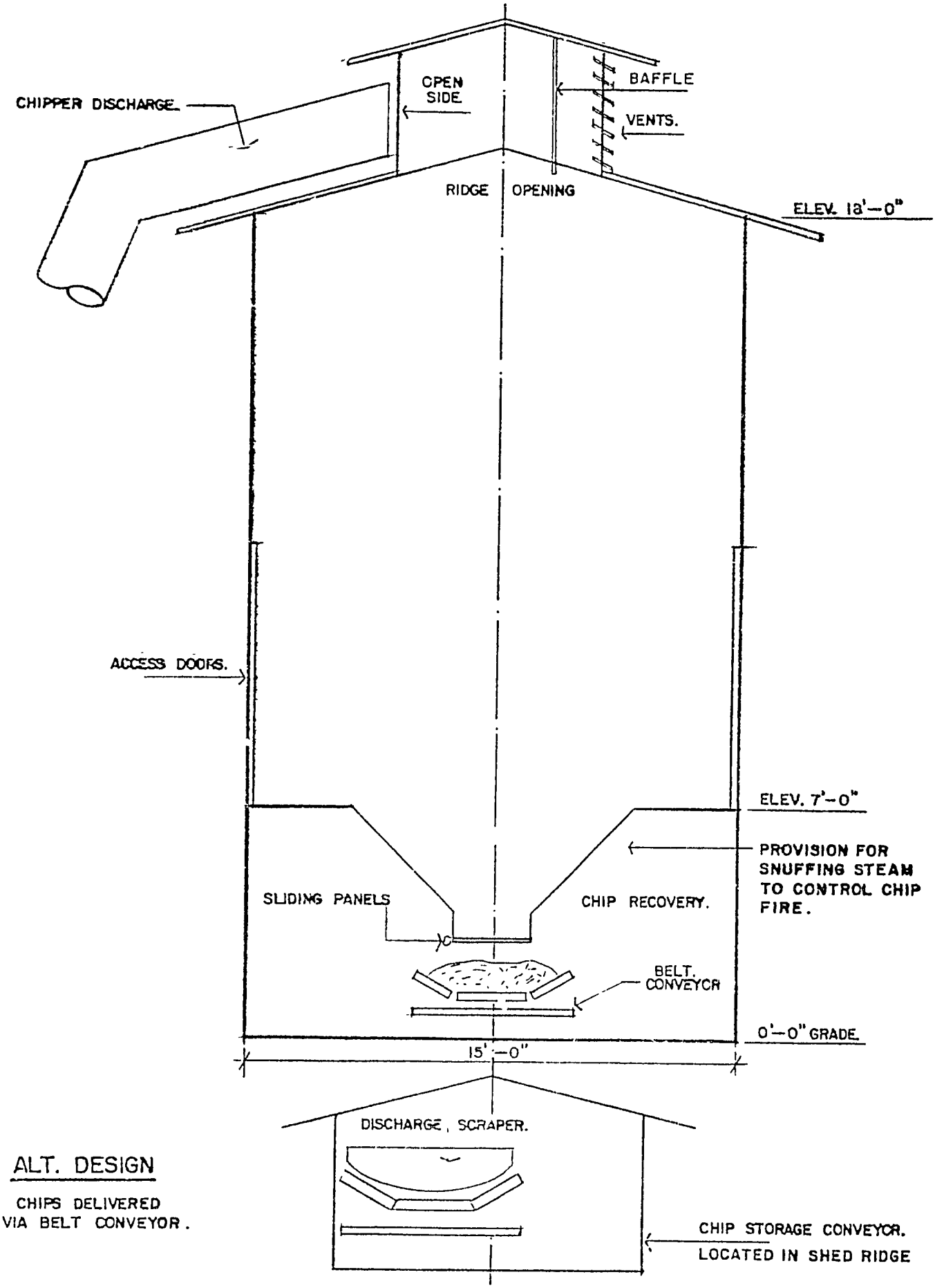
The choice should be made during the evaluation of the bids received.

Chipped fuelwood is fed to the chipped wood storage shed, whose proportions are similar to those for the roundwood storage pile. The storage shed crossection is shown on IRHE Drawing No. 2, located on the following page. This storage is likewise operated so that no chips are stored longer than 15 days. The shed is provided with connections for snuffing steam to fight fires caused by spontaneous combustion of the chips. Such fires will be detectable and located by noting smoke emissions at the top of the shed.

Chips retrieved from the storage shed are delivered by conveyor to the day silo from which the steam generator receives its fuel supply. Again a choice of conveying methods has been allowed. The capacity of this silo is shown as one-day, but when the labor requirements of the plant are estimated, it may be found that a 64-hour supply capacity should be provided to carry the operation through the weekend without further transfer from the chip storage shed.

The entire operating area is to be protected by a roofed structure with sufficient overhang to protect against the most intense rains. Construction may be of locally available materials. The floor of this area should be of concrete paving or wood, sufficiently elevated above grade, to protect the storage and operating area against flooding during heavy rainstorms. The installation of storm drains or covered trenches leading to the river could be useful in this respect.

CHIP STORAGE SHED.



ALT. DESIGN

CHIPS DELIVERED VIA BELT CONVEYOR.

C-3-A

DRAWING Nº 2
(NOT TO SCALE)

2. STEAM GENERATOR

There are two options in the selection of the steam generator; a fire-tube design, or a water tube design. The selection will be made during the evaluation of the bids received. In either case, the combustion air supply is provided with a steam coil, operated by steam from the boiler, to preheat the combustion air during the wet season, when the moisture content in the fuelwood chips could become excessive. The main criterion for selection of steam generator type appears to be the effect of the pressure/superheat conditions of the steam generated on the cycle efficiency for the entire plant.

The chip feeding and combustion equipment will be integral with the steam generator equipment, and its design will depend on the ultimate selection. In any event, because wet chips are to be burned, the furnace chamber should have areas of uncovered refractory walls or arches to insure the stability and completeness of combustion.

The required purity of the feedwater makeup depends on the generation pressure. This will be higher for the water-tube unit than for the fire-tube unit, and accordingly maintaining the required feedwater quality will be more critical for the water-tube design. In any event, specifications have been included for the feedwater makeup to come from a water distillation plant to reduce to a minimum the necessary attention to be paid to maintain water purity.

The size of the unit will depend on the blowdown recommended by the steam-generator manufacturer and the amount of steam vented to the atmosphere during periods when the steam

generator cannot respond sufficiently rapidly to sudden reductions of demand on the plant.

The capacity of the water distillation unit should be selected to provide for the water needs within one 8-hour shift in order to provide overcapacity by operating for a longer daily period.

Instrumentation provided with the steam generator will regulate the generated steam pressure at the rated level by controlling the fuel and air rates to the burner, provide for venting steam at times when the effect of reduction in firing rates cannot accommodate sudden reductions in demand, and separately relieve pressure when this becomes excessive for any reason.

Periodically, coarse wood ash is to be removed from the burner grate area and fine ash collected from the ash separator. This production can be transported to the disposal area. Equipment design can be arranged so that ash removal can occur during the day shift when labor is available from the roundwood handling operations.

The steam generator is protected by an open sided fireproof structure, with sufficient roof overhang to protect against intense rain fall.

3. TURBO-GENERATOR/CONDENSER

Although the selection of the steam turbine will determine the cycle efficiency of the plant and the selection of the steam generator, the physical size and arrangement will not vary significantly. Regardless of selection, the turbine is pro-

tected against water droplets in the steam by a steam separator mounted at the turbine inlet. The inlet steam connection between steam generator and turbine should be as short as practical with provision to accommodate pipe expansion with no forces exerted on the turbine nozzle. The connection between the turbine-exhaust and condenser should likewise be as short as practical to minimize pressure drop between these equipment items. This line should be designed with a minimum of flanges.

With respect to the condensation of exhaust steam, the turbo-generator supplier has the option of specifying either an air-cooled or water cooled design. If any a water-cooled design is chosen the water supply would come from a pump in the river, be screened, passed through the condenser, maintaining a minimum velocity of 7 feet per second, and discharged a maximum distance from the intake point. If a river source for the water distillation unit is used (instead of the local drinking water supply), the two intakes can be combined.

Turbine manufacturers appear to agree separately that the turbine speed should be 5000 RPM driving an 1800 RPM generator. It is likely that the final selection will be this speeds with an appropriate gear box intalled.

Turbine regulation to the demand on the generator will likely be the standard Woodward governor. The project terminates with the connection to the generator.

The turbo-generator/condenser equipment is to be installed in a totally enclosed fire-proof building.

4. MISCELLANEOUS EQUIPMENT

Pumps, tanks, and deaerator are shown on the schematic flow sheet. Sizing of the equipment will depend on the ultimate selection of the critical equipment components discussed above.

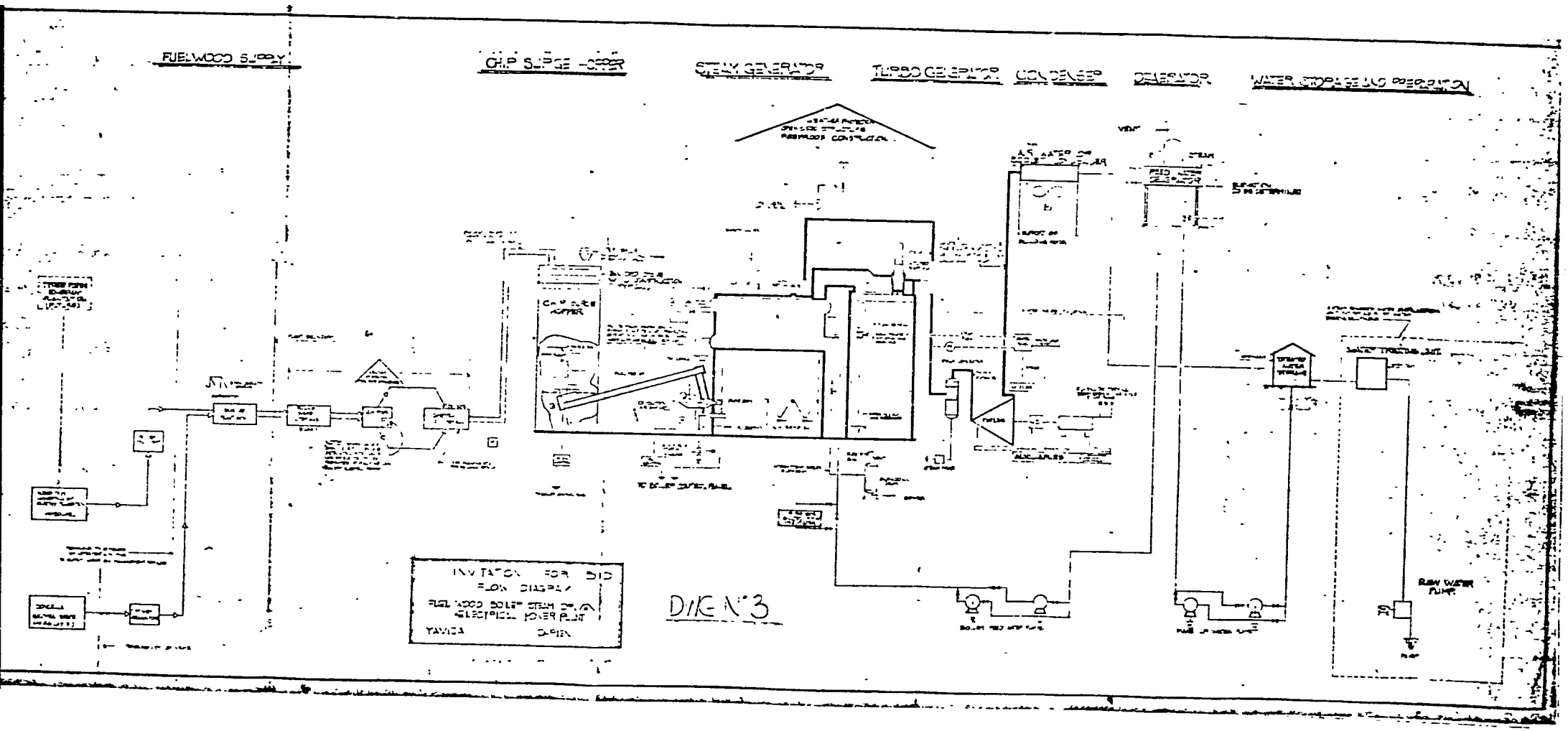
5. INTEGRATION WITH EXISTING PLANT.

The logical future for the existing diesel-electric plant is the transfer of the 135 kW unit to the site of the steam-electric plant for use as standby, and possible peaking when load growth justifies.

Depending on the decision in this respect, the responsibility remains with IRHE to redesign the present transformer installation, add additional equipment, and provide the controls for load sharing between the two generators to meet the demand of the transmission network.

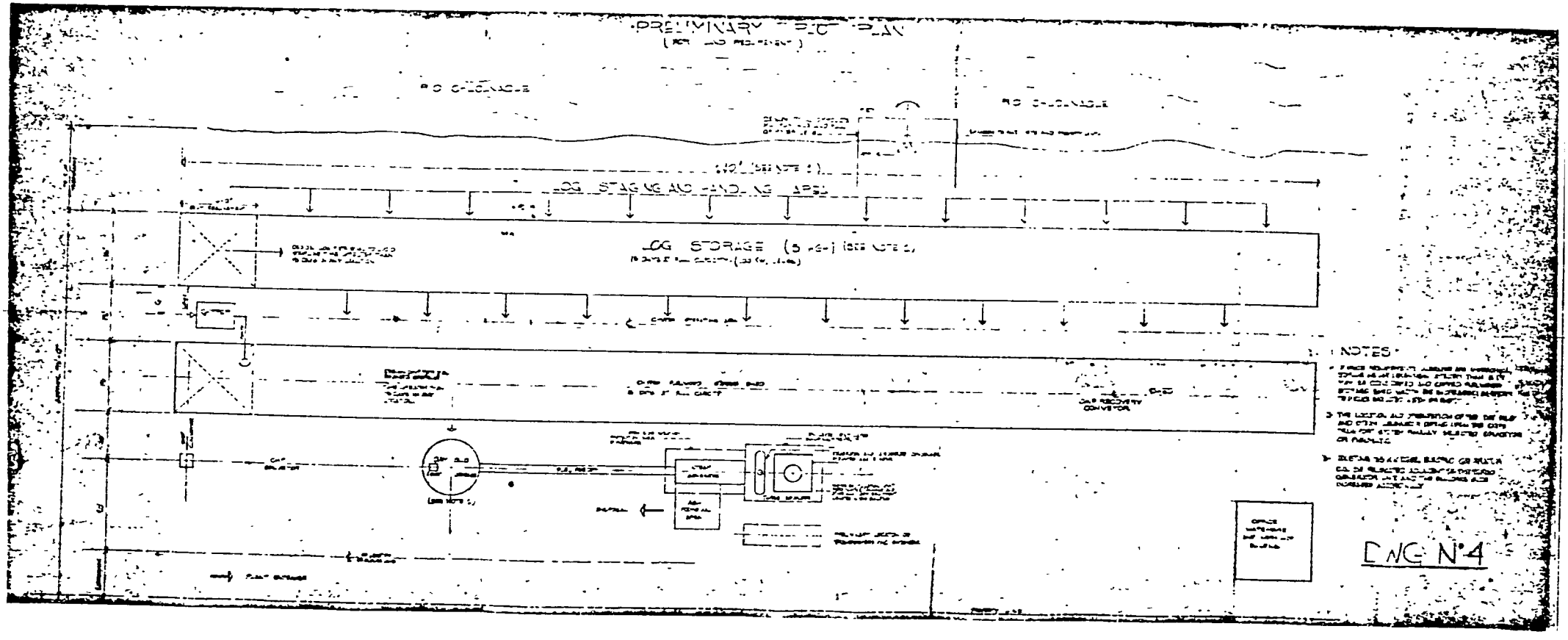
6. FUTURE EXPANSION

Because of the prospect that unforeseen events can increase the demand on the Yaviza station beyond that forecasted by the statistical projection, the preliminary plot plan provides space for a second installation. The fuelwood handling and storage area can support an additional plant by increasing its height. The chip storage area could operate for an additional shift to supply a second day silo.



DRAWING 3
SCHEMATIC FLOW DIAGRAM

Best Available Document



DRAWING 4
PRELIMINARY PLOT PLAN

Best Available Document

APPENDIX D

DRAFT

OF

TECHNICAL SPECIFICATION SECTION

FOR THE

WOODFUELED STEAM - ELECTRIC PLANT

NOTE:

Appendix D is complete as regards the technical specifications directly related to the Yaviza Fuelwood Electricity Generation Project equipment requirements.

The present document contains instruction to copy certain paragraphs from the Technical Specifications section* of the Invitation for Bid issued for the S. Francisco de la Caleta, Panama City- Extension of the Thermal Power Plant. These paragraphs represent general requirements which when incorporated in the present document will complete it for issue to interested bidders.

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*The relevant pages of this Technical Specifications section appeared in the original document following Page D-39. These pages have been omitted since the purpose of reproducing the original document as illustrative of the result is still retained.

D R A F T

YAVIZA, DARIEN, WOODFUELDED

ELECTRICITY GENERATION PROJECT

TECHNICAL SPECIFICATIONS

Note: The notations (copy) or (copy ✓ paragraphs) used in this draft refers to copying the identical numbered paragraph from the S. Francisco de la Caleta, Panama-City - Extension of the Thermal Power Plant - Technical Specifications.

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GENERAL INDEX

SECTION 1. General Prescriptions

2. Equipment Specifications

3. Testing

4. Guarantees

SV

Section 1 - General Prescriptions

1. Scope of the Technical Specifications

The Technical Specifications cover the design, manufacture, shop testing, preparation for export, and provision of construction and start up assistance for the machinery and equipment relevant to the present Invitation for Bid.

All bids received in accordance with the terms and conditions of the Invitation for Bid shall be studied and evaluated taking into consideration all facts such as price, efficiency, reliability, manpower requirements, etc., and the most appropriate equipment chosen for purchase.

3. Regulations and local conditions- Technical details

3.1.1 (copy)

3.1.2 (copy, except as marked X)

3.2 Local conditions

3.2.1 Site location Yaviza is located in the province of Darien, along the Chucunaque river, at about latitude 9° 05' and longitude 77°42'. Most of the year it is accessable only by air and boat.

3.2.2 Meteorology

(IRHE to fill in from records)

3.2.4 Service Water System. The only available water is river water, running along the south side of the site, which is affected by tidal waters and therefore contains contaminants.

The Analysis of River Water if found in Table D-1

The specifications for the plant also consider the production of distilled feed water from excess steam production.

3.2.5 Fuel The power plant will burn woodfuel from an Energy Plantation or any other available source.

At the Energy Plantation the selection of trees for fuel shall be made by a forester. Fallen, logged trees shall be bucked into 5-8 foot long lengths and transported by boat to the power plant landing during and 8 hour daylight shift.

At the power plant fifteen days of log storage and fifteen days of chip storage shall be maintained.

Chipping and chip storage activities shall be carried out during one 8 hour, daylight shift per day, seven days per week.

2. Plant Layout

The new 200 KW Woodfuel Electricity Generation Project at Yaviza, Darien, will operate in conjunction with the 135 KW Diesel Generation Unit presently supplying the electric power requirements of Yaviza, El Real, and Pinogana.

The Plant will consist of an Energy Plantation operated under the direction of RENARE, and a power generation site operated by IRHE where whole or split wood logs or sawmill scrap will be converted into chip fuelwood , stored as required, supplied to a steam generator which may produce a superheated intermediate pressure steam to drive a turbo generator set producing 200 KW of 240/480 volt-3 phase-60 cycle power with 0.8 power factor.

The plant will be completely integrated and will be operated and controlled from its own resources starting from fuel logs.

The preliminary plant layout may be found on drawings 3 and 4.

INSTITUTO DE RECURSOS HIDRAULICOS Y ELECTRIFICACION

DIRECCION DE INGENIERIA — DEPARTAMENTO DE HIDROMETEOROLOGIA

PARAMETROS DE CALIDAD DE LAS AGUAS NATURALES DE LA REPUBLICA DE PANAMA

LONGITUD _____ RIO CHUCUNAQUE — ESTACION _____

LATITUD _____ Yaviza, DARIEN

ELEVACION 10 MSNMM — LUGAR VARIOS

FECHA	HORA	CAUDAL m³/seg	PROF m	CALIDAD QUIMICA														CALIDAD FISICA					CALIDAD BIOLOGICA		
				PH	ALC. TOTAL	OH^-	$CO_3^=$	HCO_3^-	Cl^-	Ca	Mg	DUREZA TOTAL	NO_3	NO_2	PO_4	SiO_2	SO_4	t °C	TURBIDEZ (1)	CONDUCTIVIDAD ESPECIFICA (2)	SOL. TOTALES	SOL. EN SUSP.	CD (3)	DQO (4)	DBO (5)
					MILIGRAMOS POR LITROS = PARTES POR MILLON																mg/l		mg/l		
✓	24			6.40	62	N.D	N.D	62	5.50	12	4.86	54.9	N.D	N.D	.06	10.54	12.0			155.4	593	57.50		7.75	
✓	30			6.50	73	N.D	N.D	73	12.50	20	[illegible]	75.3	.50	N.D	.07	2.45	7.6			126.4	372	15.20		4.55	
✓	33			7.60	77	N.D	N.D	73	17.00	22	[illegible]	[illegible]	.09	.015	.03	[illegible]	11.0			195.4	[illegible]	[illegible]		4.50	
✓	34			7.10	60	N.D	N.D	60	7.00	16	6.07	61.9	.50	N.D	.34	10.05	8.0			146.9	460	23.51		6.45	
✓	35			7.40	77	N.D	N.D	77	12.50	22	7.29	79.9	.50	N.D	.15	12.23	7.6			153.3	908	[illegible]		3.97	
✓	36			6.20	42	N.D	N.D	42	10.00	12	4.86	43.9	.50	N.D	N.D	12.05	13.6			114.0	660	19.00		11.69	
✓	[illegible]			6.40	39	N.D	N.D	39	11.25	10	3.64	39.9	.50	N.D	.20	5.58	14.0			107.4	246	5.45		12.20	
✓	41			7.10	64	N.D	N.D	64	[illegible]	16	7.29	69.9	.05	N.D	.03	11.22	9.4			143.7	312	[illegible]		5.55	
✓	37			[illegible]	69	N.D	N.D	69	4.00	20	4.86	69.9	.04	N.D	.04	27.06	14.5			160.5	[illegible]	[illegible]		3.95	
✓	40			6.50	56.4	N.D	N.D	56.4	6.00	16	6.07	64.9	.04	N.D	.02	13.34	11.7			136.9	496	32.40		5.37	
✓	41			7.10	88	N.D	N.D	88	5.25	22	6.07	79.9	.14	N.D	.07	31.65	15.1			112.1	692	13.24		1.54	
✓	42			6.70	62	N.D	N.D	62	9.00	18	4.57	61.9	.07	N.D	.04	20.53	9.9			146.9	576	32.00		4.95	
✓	43			6.70	72	N.D	N.D	72	12.00	22	6.07	79.9	.06	N.D	.05	32.50	11.9			180.8	302	25.00		4.28	
	44			6.70	50	N.D	N.D	50	6.20	14	6.07	59.9	N.D	N.D	.08	31.12	12.9			135.6	548	13.00		3.29	
✓	45			6.70	54	N.D	N.D	54	9.00	16	4.86	59.9	N.D	N.D	.08	19.25	10.2			141.3	684	76.00		5.05	

ND NO DETECTABLE

(1) UNIDADES JACKSON

(3) OXIGENO DISUELTO

(4) DEMANDA QUIMICA DE OXIGENO

TABLE D-1

(Following D-6)

22 Rio Tuira Pinogama 10:50 River Clearer

23 Rio Tuira Cuacua 12:10

23 Union Choco R. Tuira 12:30 p.m.

25 La Hoya R. Tuira 3:05 p.m. 1 Hr. from union Choco

26 Pinogama R. Tuira 6 p.m.

27 R. Pirre 8-3 11:39

29 El Real High Tide 8-3 11:45 R. Pirre

30 R. Chucunaque 8-3 12:30 p.m. Donocep

31 Yaviza R. Chucunaque 3-8-76 2:00 p.m.

32 8-4 R. Chucunaque Reverso Ignacia

33 R. Chucunaque Baja de Boca de Uragantí (8' deep)

34 8-4 R. Uragantí Boca (4 feet)

35 R. Chucunaque arriba de Río Uragantí: 8-4

36 R. Chucunaque Near Rev. Ignacio with Prec.

37 Small addition to tributary R. Chucunaque near Reversa Ignacia.

38 Río Chucunaque abajo de la boca de río chico 2-8-76

39 Río Chico a 100 mts. de la boca (crecito) 3-8-76

40 Río Chucunaque abajo de la boca de Río Chico 3-8-76

41 Río Chico a 100 mts. de la boca 2-8-76

42 Río Chucunaque arriba de la boca de Río Chico 2-8-76

43 Río Chucunaque arriba de la boca del Río Tuquesa 3-8-76

44 Río Chucunaque arriba de la boca del Río Chico 3-8-76

3.2.6 Transportation The preferred port of entry is Port Balboa, Panama. If material is received in Port of Cristobal, Colon, Panama, it must be transhipped overland to Balboa and then on small river craft to Yaviza, Darien.

Commercial air facilities for passenger and freight are available at Tocumen Airport, Panama City.

There is an air strip at Yaviza, but any freight would have to be manhandled from the strip, across the river, to the site of the power plant.

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4. Materials and Workmanship

4.1 General

4.2 (copy)

4.3 Testing

Testing shall be conducted in accordance with ASTM or ASME standards. The test on equipment shall be manufacturers standard unless mentioned otherwise in the equipment specifications.

All testing cost shall be borne by the supplier of equipment.

4.4 Workmanship

4.4.1 (copy)

4.4.2 (copy)

4.4.3 (copy)

4.4.4 (copy)

4.4.5 (copy)

4.5 Tropicalization
(copy)

5.1 General

(copy ✓ paragraphs only)

The electric power for internal plant use shall be 240 V ± 10% at 60 cycles/sec. ± 5%.

5.2 Electric Motors

5.2.1 Design Requirements

All equipment motor drivers shall be fan cooled totally enclosed type in accordance with NEMA standards.

(copy paragraph only)

5.2.2 Local Control Station A NEMA class D stop-start pushbutton station shall be provided for each motor and located on a stanchion

near by the motor, except when a common control panel is provided located within sight of the motor.

5.3 Low Voltage and Control Cables

(copy ✓ paragraphsonly)

5.4 Accessories

(copy ✓ paragraphs only)

Relays or other control devices shall be located in NEMA standard enclosures Class D explosion proof wherever possible, or, of equivalent construction suited to the remote tropical conditions of the environment.

5.5 Earthing

Earthing contacts shall be provided for all individual items of equipment, and when equipment is packaged and skid mounted all equipment shall be grounded to the skid.

5.6 Test on Electrical Equipment

5.6.1 (copy ✓ paragraphs only)

6. <u>Treatment of Surface</u>

6.1 Treatment for shipping.

(copy ✓ paragraphs only)

6.2 Standards for Preparation of Surfaces for Painting

(copy ✓ paragraphs only)

6.3 Application of Paint - General Standards

The supplier of equipment shall be responsible to apply sufficient shop coats of quality paint so as to guarantee three years life to painted surfaces when subject to the climatic conditions stated above (Section 3.2.2.).

Section 2

EQUIPMENT SPECIFICATIONS

1. General

1.1 Scope

The present Section 2 covers the Technical Specification for the following listed pieces of equipment which constitute all the major equipment requirements for the Fuelwood Steam Turbo Generation Plant.

Item No.	Description
C-1	Wood Chipper, with alternate chip storage handling schemes and alternate drivers.
C-2	Chip fuelwood recovery conveyor with alternate schemes for delivery of the chips to the top of the fuelwood day-storage silo.
S-1	Day Storage Silo.
SG-1	Steam Generator, complete with all accessories.
TG-1	Turbo Generator Set, complete with condenser and all accessories.
BFW-1	Boiler Feed Water preparation equipment.

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1.2 Limits of Supply

All items covered in the present Section 2 shall be furnished complete with all accessories required for an integrated operating plant whether specified or not. It shall be the responsability of the equipment supplier, or suppliers, to assure the completeness of their supply to meet the requirements of the specifications.

The equipment duties specified herein have been selected based upon published equipment efficiency data available to the plant designers. Bidders may quote more efficient equipment as an alternate, modifying the design to suit, and supporting the reliability of the more efficient equipment in their bid documents.

SPECIFICATION FOR WOOD CHIPPER, Item C-1

Capacity Rating: 4.5 metric tonnes per hour, greenwood, 50% moistire, 50 #/cu. ft.

Feed: 6" max. diameter logs.

Chip size: 2" to 3" maximum.

Mounting: Narrow gage railway car flat bed, or fixed.

Drive: Engine or electric motor. With an electric motor consideration shall be given to the installation of a flywheel in order to reduce the torque requirement and the effect on the turbogenerator.

Description of Operation: Logs, or split sections, shall arrive from an Energy Plantation, as well as scrap slabs from a sawmill, and be stored in piles along one side of a narrow gage track. The chipper shall travel along the track, parallel to the log storage pile, and be hand fed from the pile. It shall deliver by pneumatic conveyor the chip product to the ridge of a chip storage shed, running parallel to the tracks, requiring a 12 foot horizontal movement and a 20 foot vertical lift of the chip product by pneumatic conveyor.

Reference Notes:

a. The specifications of 6" max. diameter logs is based upon logs recoverable from the reforestation program which will require 6-7 years to realize.

b. Mounting the chipper on a flat car is one alternative. The chipper could be mounted on a fixed foundation, and deliver chips to an elevator bin where a bucket conveyor would transfer the chips to a belt conveyor running along the ridge of the chip storage shed. See chip storage shed Drawing No.2 Bidder may quote this alternative separately considering a 12 foot

only pneumatic horizontal movement, an elevator with 20 feet vertical lift (screw or bucketype), and ridge supported belt conveyor with a travelling discharge mechanism to distribute chips along 240 feet of chip storage shed

b. Bidder shall quote the flat car separately.

c. Bidder may quote equipment with smaller log diameter feed restructions. The cost of the additional log splitting operation will be considered when evaluating proposals received.

Information to be supplied with bid

1. Complete description, sketch, and pictorial description of the equipment being offered.
2. Diameter and length of feed rolls.
3. Feed rate and size of chips.
4. Power unit type, size, fuel consumption, fuel tank (if any) capacity.
5. Chipper opening size and number of knives.
6. Weight and overall dimensions.
7. List and cost of spare parts for two years operation
8. Quoted price shall include supply of six (6) sets of drawings and Installation, Operating and Maintenence instructions.

SPECIFICATION FOR CHIP RECOVERY CONVEYOR - Item C-2

The fuelwood is recovered from the chip storage shed by a belt conveyor travelling lengthwise under the center of the storage shed. Feed to the conveyor is controlled by sliding panels operated from one side of the shed. A walk path is provided on either side of the shed to allow an operator to sweep residual chips on to the conveyer.

The fuelwood is then carried laterally to the base of the fuelwood day-storage silo where it is elevated to the top of the silo. Either mechanical (bucket elevator, inclined conveyor, or helical screws) or pneumatic means may be quoted by Bidder for this movement.

Capacity:	8 tons/hr 800 cuft/hr	4 hours operating/day

Main Recovery Conveyor:	240 feet long.
Lateral conveyor:	12 " "
Vertical Lift Conveyor:	30 feet lift

Conveyors are to be powered by 220V-3 phase-60 cycle electric TEFC motors.

Information to be supplied with bid

1. Price and description of Main Recovery Conveyor.
   Price and description of alternate means of performing the lateral and vertical lift movement of the chips.
2. Materials of construction for all equipment.
3. Capacity and speed of conveyors
4. Horsepower of drivers.
5. A clear definition of limits of supply.

6. List and cost of spare parts for two years operation .
7. Weight and overall dimensions.
8. Quoted price shall include supply of six (6) sets of drawings and Installation, Operating, and Maintenance instructions.

SPECIFICATION FOR DAY STORAGE SILO - Item S-1

The volume of chipped fuelwood required for one day (24 hours) firing at 200 KW plant output is 3200 cubic feet. A 12-foot diameter by 30 ft. straight side silo would provide this volume. The actual dimensions may vary to meet the Manufacturer's standard equipment, provided the desired volume is maintained. Materials of construction, such as wood, concrete, or corrugated steel, are commonly used with steel band reinforcement.

The base of the silo shall be designed to accomodate a rotating vertical pipe stand assembly (with chains of sufficient length attached at two foot intervals) driven by the motor of the boiler fuel feed system. The assembly agitates the fuel chips to assure free flowing conditions to the inlet of the boiler fuel feed system.

This item shall be field assembled from locally available materials.

This item may be purchased locally in its entirety.

The need for supporting pneumatic dust separator equipment on the roof will be determined after selection of the appropriate conveying system for the recovered chips.

Bidder may quote supply of design and engineering drawings sufficiently detailed to permit purchase of materials and erection by others. In this case, Bidder shall quote the supply of any special parts.

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SPECIFICATIONS FOR THE STEAM GENERATOR - Item SG-1

The steam generator comprises all components between agitating and transporting the fuelwood chips from the day storage bin, through the combustion of the fuelwood, and the stack for discharging the combustion gases. Also included are all pressure parts between receipt of feed water and discharge of the generated superheated steam. A fly-ash separator is to be installed before the stack or the induced draft fan. Include provision for steam heating the combustion air when required by excess water content in the fuel wood, and preheating the boiler feed water while colling the furnace grates, if practical.

Steam Requirements

Capacity: 4600 Lbs/hr required for 200 KW Electrical Generator output 24 hours per day. Stable operation at 50% capacity must be guaranteed.

Minimum Overdesign: 15%

Superheater outlet pressure: 365 psig.

Superheater outlet temperature: 190° F superheat.

A dry steam production at no superheat, but at higher pressure to allow superheating by throttling will be considered.

Feed water

Source: Turbine condensate plus distilled water make up, deaerated and chemically treated per boiler manufacturer's recommendations.

Blowdown: Manufacturer's recommendation.

Chemical Additives: Manufacturer's recommendation.

Fuelwood

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Quality: Green chips.

Size: 2" to 3" largest side.

Dryness: 50% moisture (variable)

Heating Value: approximately 3300 Btu/pound, as fired.

Other Information: Chips, approximately 15 days aged. Chip density, 50 pounds per cubic foot. Bulk density, 20 pounds per cubic foot.

Ambient Air Temperature: 85°F (use 85% humidity)

Control System

Vendor shall propose an appropriate system to control fuel firing rate and combustion air in response to steam header pressure variations.

The boiler control system will also activate a control valve to relieve excess pressure in the turbine supply header (365 psig operating pressure) should the firing control not react in time to limit the turbine supply header pressure.

The steam turbine, generator will be the basis of a single source of electricity to an isolated system. The unit shall be responsive to the largest practical extent to load changes, without discharge of steam to atmosphere, by proper selection of steam drum size and design pressure, fire box configuration, and design capacity.

Control shall be by mechanical or electrical means.

Minimum accessories to be provided by vendor :

1) Boiler feed water level controller and control valve:

2) Safety Relief Valves.

3) Steam header pressure controlled vent valve and exhaust head.

4) Boiler drum level indicator.

5) Try cocks

6) Non-return valve.

7) The fuel feed system and drive, including the rotating vertical pipe stand (located in the feed silo) which agitates the fuel chips to assure flow t the feeder.

8) Blowdown valves and blowdown drum.

9) Start up auxiliary burner, capable of burning waste lube oil.

10) Steam header pressure gauge and temperature indicator.

11) Draft gauges

12) Deaerator vessel, complete with all accessories, sized to satisfy boiler requirements..

13) Boiler feed water supply pumps, two required, sized to satisfy the boiler requirements and ASME code regulation.

14) Chemical additive system.

15) Vendor to list other recommended instrumentation or accessories provided with the package.

Design Codes: ASME Power Boiler Code, ASTM Standards, NEMA

Vendor Information Required:

Boiler design capacity:

Boiler capacity range:

Boiler design pressure:

Boiler Design Temperatures:

Steam drum steam volume:

Heating surface, steam coil:

Heating surface, superheater:

Furnace Volume:

Calculated firing rate at design capacity:

Overall thermal efficiency:

Stack temperature:

Stack height:

Fly ash separator type:

Fly ash separator material of construction:

Maximum content of particulates in stack gas:

Minimum boiler feed water quality:

Boiler feed water pumps data sheet:

Deaerator drawing, including list and description of accessories:

Maximum blowdown rate:

Tube material for steam heat transfer surface

Tube material for superheater heat transfer surface

Refractory type and Specification:

Physical dimensions:

Weight:

Vendor shall furnish all special tools, and data describing boiler response to changes in load and fuel moisture content.

Instructors to bidder:

1. Include list and cost of recommended spare parts for two years operation.
2. Quoted price shall include supply of six (6) sets of drawings and Installation, Operating and Maintenance instructions.

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3. The pressure, temperature, quality, production capabilities and operating controls of the steam generator must be compatible with the turbine selected for item TG-1, Turbo Generator set.

SPECIFICATION FOR THE TURBO GENERATOR SET- Item TG-1

Scope of Equipment

The turbo generator set comprises all components between the main, pressure controlled, steam header through the steam turbine, gear reducer and synchronous generator to the 3 phase, 240/480 volt, 60 cycle generator termianls. Controls and accessories are to be provided as specified below, and all equipment mounted on a suitable base plate.

Steam Conditions:

Pressure: 365 psig with 190°F superheat

Exhaust Conditions:

The turbine vendor shall select a back pressure and specify and supply an air-cooled or water-cooled condenser to meet this specification representing the most efficient combination of turbine and condenser. Present plant design is based on a back pressure of 4 inches Hg. Ambient air condition are 85°F and 85% humidity. A water cooled condenser should be considered using river water at minimum velocity of 7 feet per second.

Power Requirements:

200 KW (250 KVA) at 240/480 V - 3 phase - 60 cycle - 0.8 pf.

Generator Rating

Continuous service, overload capacity 110% for 2 hours, temperature rise 105°C, stator and rotor.

Reducting Gear Rating

The American Gear Manufacturers Association (AGMA) recommendations shall apply Vendor shall state AGMA service factor in his proposal. If service factor is less than 2, vendor must

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support his selection.

Turbine Rating

Continuous service, overdesigned to meet generator overload conditions, and constructed to meet API, or equal, general purpose standards and NEMA SM-23 1979.

Equipment Specifications

Steam Inlet Control Valve

The control valve shall meet ASA pressure temperature regulations, and be selected to provide rapid, smooth, response to the governor's signals.

Vendor to include a complete description in his proposal including manufacturer and type.

Steam Separator

A steam separator of the highest practical efficiency shall be provided to protect the turbine in the event steam quality reduces to wet steam. A continuous duty steam trap, sized for these conditions, shall be provided.

Vendor to provide operating specifications for this equipment in his proposal, selected manufacturer, and type.

Separator to be designed per the ASME Code, Section VIII.

Turbine

The turbine shall be selected for its record of ruggedness and reliability during continuous service in areas innaccesible to the maintenance of heavy equipment pieces.

A horizontally split casing with inlet and exhaust connections in the lower half is preferred.

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The rotor shall be a solid steel forging dynamically balanced, and the shaft minimum SAE-4140 material with chrome plating or better, in the gland areas. Vendor shall describe rotor, shaft, bearing, and glands to the fullest extent in his proposal.

Lubrication protection during start up and shutdown shall be described in vendor's proposal.

Provide overspeed trip independent from the governor.

Turbine Governor

The turbine governor shall be a Woodward NEMA "D" class or equal.

Reducing Gear

A suitable ratio reducing gear shall be supplied in accordance with AGMA standards and API 613 recommendations.

The casing shall be heavy duty cast iron construction, horizontally split.

Gear and pinion are to be dynamically balanced, vendor to advise tolerances in his proposal. A double-helical design is preferred to balance axial thrust. Vendor to describe fully design and materials of construction in his proposal.

Vendor to advise extent of testing included in his proposal.

Generator and Accessories

The base load characteristics of the existing 135 KW diesel system producing power for the area today are:

Maximum load over two hour peak period: approx. 150 KW.

Minimum load over two hour period: approx. 63 KW .

Average daily load: 85 KW.

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Generator Design and Construction

Editorial Note: The content in the following discussion is taken from specifications prepared for a 24MW urban installation. It should be modified as further consideration of the conditions at Yaviza and the small size of the generator.

1. The generator of air cooling type shall be manufactured using the best available materials for the required conditions of operation and according to the most up-to-date engineering practice and technique.

The generator shall be designed for the following local conditions: ambient temperature not exceeding 40°C, elevations 10 m above sea leval, presence of sawdust and salinity in the air.

The alternator shall withstand without harm the overspeed of 20% as well as three phase short circuit at its terminals, according to applicable Standards. It shall run quietly and with acceptable vibrations under load condition, with rated voltage ± 10%.

Design characteristics shall be as follows:

a. Three-phase, multipoles according the speed, 60 cycles synchronous generator;

b. Rated voltage (phase-to-phase) 240/480 volts

c. Rated continuous output 250KVA 0.80 lagging power factor.

Said output shall be kept within limits stated by the Standards for rated voltage ± 5% and within the safety limits of the unit, even if not in compliance with the Standards, for rated voltage ± 10%.

d. Peak output (2 hours per day): this value shall be 110% of rated continuous output at the rated power factor; the temperatures may exceed the limits stated by ANSI Standards but shall be within the safety limits

of the unit.

e. Short circuit ratio (referred to 250 kVA and 440 V): not less than 0.65.

f. Deviation of the wave shape (with no load voltage at the terminals) not exceeding 5%.

g. Permissible continuous load asymmetry: the value of the negative-phase-sequence current shall not exceed 0.2% of the rated current.

h. Rotor short-time requirements for unbalanced faults: in accordance with ANSI Standards.

i. Telephone influence factor with generator at no-load and rated voltage:

balanced TIF not exceeding 70

residual TIF not exceeding 50

k. Max vibration amplitude on bearings: 20 micron (peak to peak).

2. Stator

2.1 Stator Frame The stator frame shall consist of a strong housing of suitable thickness, in order to obtain a protective structure capable to guarantee:

elimination of any possible vibration during operation;

sturdiness to withstand handling during transport and erection.

Inspection holes shall be provided wherever necessary for the purpose of inspection and maintenance.

The stator frame shall be mounted on a bed-plate, common to the turbine, foreseen in such a manner, that the weight

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of the equipment shall be uniformly distributed over the foundation.

The supply shall include, besides the bed-plate for alternator, the foundation bolts and all the other necessary steel parts.

2.2 Stator Core

The stator core shall be made up of low loss, nor aging type silicon steel laminations. Special attention shall be paid to the insulation of the laminations and to the finishing of the edges after punching.

The stator core laminations shall form several packets, separated by ventilating ducts; each packet shall be perfectly compact so as to avoid vibrations.

Particular provisions will be taken to avoid the effect of the double frequency vibration; after core flexible mounting shall be adopted.

2.3 Stator Winding

The stator windings shall be made up of coils insulated in class B.

Each coil shall be composed by insulated straps of electrolytic copper, having reduced thickness and internally transposed.

Each coil shall be insulated with the thermosetting resin base insulation, in order to prevent the mica migration phenomenon.

During the manufacturing, the coils shall be submitted to special treatment to prevent air inclusion between single

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conductors and insulating materials

The part of the coil to be embedded in the slots shall be varnished with semi-conducting varnish, in order to distribute in a uniform way the potential gradient and to avoid potential difference between the slot wall and the coil surface.

The stator coils shall be adequately clamped with external rings to prevent any deformation or damage in the case of short circuit at the stator terminals.

The stator windings shall be star connected and the ends shall be brought out the casing by means of nine bushing insulators (6 on the generation side and 3 on the star centre side).

The bushings shall b so dimensioned as to allow the placement on each one of them a single conductor, according to the capacity of the generator.

The coils ends, clamps devices and covers shall be designed so as to minimize additional losses and to avoid vibrations.

3. Rotor

3.1 Rotor Core The rotor core shall be of forged steel with high mechanical strength characteristics.

The forging shall be checked by ultrasonic inspection.

The whole rotor shall be seasoned and balanced both from the mechanical and the thermal point of view.

Suitable grooves shall be provided on the rotor surface to reduce losses and improve ventilation.

3.2 Rotor Winding Axial ducts in the interal body of the rotor shall allow an efficient ventilation below the conductors. Slots closed by means of non-magnetic wedges shall be provided in the rotor for housing the windings. The rotor winding, made of proper silver alloy bars with high mechanical resistance, shall be insulated according to class B and pressed into the slots so as to form a compact whole with the rotor intself, taking into account the effects of maximum overspeed. In addition suitable locking caps shall be fixed on to the rotor coil ends to withstand the effects of centrifugal forces.

The insulation and the construction of the rotor details shall be such as to avoid ground faults in the winding during operation and deformation under any condition of operation.

An overspeed test shall be provided for the rotor and a carefull check of the rotor shall be achieved, before assembling into the stator.

4. Air Cooling System

The alternator air cooling system shall be of open circuit type.

Cooling air taken up from the surrounding ambient passes through one set of filters and is conveyed to the generator heads.

The cooling air circuilation is obtained by means of fans mounted on the shaft outside the blindage rings. The outlet air returning to the ambient air.

The material employed for the manufacture of the ventilators and filters

. shall be selected with particular care taking into account the aggressivity of the ambient air. Stainless steel or aluminium alloys shall be preferred.

5. Bearings

The alternator shall be insulated with reference to leakage currents in order to avoid damage to the bearings. The alternator shall be equipped with two journal bearings lined with white metal for which oil forced lubrication is provided. The bearings lubrication system shall be in common with the turbine.

6. Excitation System

6.1 General The generator shall be provided with brushless excitation system able to guarantee all conditions of alternator loading.

6.2 Exciter Main Components The excitation system shall comprise (but not necessarily limited to) the following main components:

a. Alternating current main exciter, directly connected to the generator shaft.

b. Pilot exciter, consisting of a permanent magnet high frequency a.c. generator, providing power to the voltage regulator and coupled to the above mentioned main exciter;

c. Rotary diode rectifier, supplying excitation to the generator field. The rectifier assembly shall be dimensioned in such a way that rated operation shall be allowed even with 25% of the diodes out of service.

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Series -fused diode protection shall be provided with blown-fuse signalling device (visible in operation by means of a stroboscope lamp through a suitable transparent window).

d. Regulating equipment which shall consist mainly of the following components;

voltage regulator with adjusting rheostat for the control of the voltage of the generator from 0 up to 110% of the rated voltage;
current regulator;
transistor operational amplifier;
under excitation and overexcitation limit devices;
pulse generator;
meters, rectifier blowers, space breaker, controls switches, signalling lamp and accessories.

All regulating equipment shall be mounted in a switchgear assembly which shall be placed near the generator unit. The assembly of the components shall be such as to assure very easy maintenance and replacement. Particularly the thyristors and diodes power units shall be mounted in withdrawable cases and all the regulating components in standard modules.

Electronic components used in the system circuit shall be operated well below their electrical and thermal limits to ensure reliability and long life. No oompoment shall operate at more than 50% of its nominal current and voltage ratings, and all the static units shall be designed to

operate at a maximum ambient temperature of 50°C without the use of auxiliary cooling equipment.

Ambient temperature shall be considered as the air temperature surrounding the cabined housings. Provisions shall be made for a spare amount of diode-thyristor power supply units (25%) so that it is possible to allow the maintenance of an out of service modular part of the regulating system while the generator is operating at nominal rating.

Automatic and manual controls shall be provided and automatic change-over from one to another control system shall intervene in case of failure without a change in generator output voltage. The voltage regulating system shall be so designed as to satisfy the following special characteristicas:

ceiling voltage rating		1.6
regulator accuracy	±	0.5%

6.3 Alternative Excitation System In case the brushless system be not a Bidder's standard, an equivalent excitation static system may be accepted.

All excitation system component parts shall be preferably assembled on one panel. All interconnecting cabling and wiring are in the scope of the supply. The features and the layout of the system shall be submitted to the Engineer's approval.

7. Service and Accessories of Alternator

7.1 Bushing Terminal Box The nine bushings terminals

of the alternator shall be contained in a sheet steel terminal box.

The terminal box shall be suitable for connection of cables.

7.2 Heaters Alternating current resistors shall be suitably placed inside the casing of the alternator in order to keep the windings dry in the event of prolonged interruption of operation.

7.3 Name Plate The alternator name plate shall be made of stainless steel and signed in accordance with Standards.

Instructions to Bidder

1. Include list and cost of recommended spare parts for two years operation.
2. Quoted price shall include suppy of six (6) sets of drawings and Installation, Operating, and Maintanance instructions.
3. Data sheets for the turbine, gear, generator and lubrication system to be provided in bids.
4. Quoted price shall include complete control system integrated with the boiler control and supplier shall furnish a detailed description with the bid. Electric means of control is preferred.

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SPECIFICATION FOR THE BOILER FEED WATER PREPARATION EQUIPMENT - ITEM BFW-1

Scope of Equipment

Two alternate supply sources of boiler feed water make up are to be considered.

River water, influenced by 12-18 foot tides, of quality as reported in Section 1 of the Invitation to Bid, is available running along the south side of the site. It requires filtration and treatment to make it suitable for boiler feed.

The steam and electric power produced within the plant system would be available during most of the day in sufficient quantities to supply a Water Distillation unit sized to meet the selected boiler requirements. Condensation could be by air or water, as is economically most convenient.

Instructions to Bidders

1. Bidder may elect to bid on one or both of the above described alternates.
2. A complete description of the equipment selected and the utilities and chemicals required to operate the unit at the required capacity are to be included in the bid.
3. Include list and cost of recommended spare parts for two years operation.
4. Quoted price shall include supply of six (6) sets of drawings and Installation, Operating and Maintenance instructions.

Section 3 Testing

The supplier shall carry out all neccessary tests to assure the satisfactory design and manufacture of his equipment in accordance with the various standards and the present Specification at his expense; included in the bid price of equipment and services.

The supplier shall make all preparation for test and provide the test apparatus and personnel and shall inform the Engineer in adequate time of the imminence of the tests to be withnessed, counters maintain written records of the tests and their results comtersigned by all present, and shall inform any local authorities necessary to be present at the tests.

Bidder shall specify tests included in his bid price and where they will be performed.

Section 4 - Guarantees

Bidder shall clearly state the extent of his guarantees as regards equipment , materials, and performance, and to what extent he will make good any failure to meet guaranteed conditions.

The completeness of guarantees shall be a consideration in the bid evaluation and selection of a supplier.

Bidders should consider the remoteness of the location of the plant and the need for guaranteed serviceable equipment requiring a minimum of maintenance.

APPENDIX E

List of Available Suppliers of Equipment and Services

APPENDIX E

LIST OF AVAILABLE SUPPLIERS OF EQUIPMENT AND SERVICES

Wood Chipper

Morbark Industries
Box 1000
Winn, Michigan 48896

Attn: Gerry Morey
Telex 227443
Phone (517) 866-2381

Bush Hog Div. (Allied Products Corp.)
P.O. Box 1039, Selma, Ala. 36701

Fulghum Ind., Inc.
S. Main Street, Wadley, GA 30477 Phone (912) 252-5223

Nicholson Mfg, Co.
3670 E. Marginal Way South
Seattle, Wash. 98134

Telex 032-204
Phone (206) 682-2752

Passavant Corp.
P.O. Box 2503
Brimingham, Ala.

Vermeer Mfg. Co.
3804 New Sharon Rd.
Pella, Iowa 50219 Phone (515) 628-3141

Lindig Mfg. Corp.
1881 W. Country Rd. C
St. Paul, Minn. 55113 Phone (612) 633-3072

Universal Saw and Tool Co.
Tylertown, Miss. 39667 Phone (601) 876-3442

HMC Corp.
23 Maple St.
Contoocook, N.H. 03229 Phone (603) 746-4691

Superior Machine Co., Inc.
492 Cashua Road
P.O. Box. 3258
Florence, S.C. 29502 Phone (803) 662-1042

Murray Machinery, Inc.
104 Murray Blvd.
Wausau, Wis. 54401

Attn: D. Demopoulos
Phone (715) 845-3151

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Silo and Feeder

Sprout Waldron Div. (Koppers Inc) 802 Logan St. Muncy, Pa. 17756	Telex 841411 Phone (717) 546-8211
National Bulk Equipment Inc. 12729 Riley St. Holland, Mich. 49423	Phone (616) 399-2220
Godfrey Conveyn Co. P.O. Box 1088 Elkhart, Ind. 46514	Phone (219) 293-9535
Roger Dunbar, Inc. P.O. Box 149-T New Paris, Ind. 46553	Phone (219) 831-2960
Marietta Techtonics, Inc. Box 323 T Marietta, Ohio 45750	Phone (614) 373-9445

Steam Generator

ABCO Ind., Inc. 2675 East Hwy. 80 Abilene, Texas, 79604	Attn: Don Briston Phone(915) 677-2011
York Shipley E.N. Poyet Assoc. Inc. P.O. Box 349 York, Penn. 17405	Attn: Larry Kreischer Phone (305) 666-1938
American FYR-FEEDER Eng. P.O. Box 285 1265 Rand Rd. Des Plaines, Ill. 60016	Attn: Victor A. Ganger Phone (312) 298-0044
Wellons Inc. P.O. Box 381 Sherwood, Oregon 97140	Attn: Martin Nye Phone (503) 625-6131
Ray Burner Co. 1303 San Jose Ave. San Francisco, Ca. 94112	Phone (415) 333-5800
Industrial Boiler P.O. Box 936 Thomasville, GA 31792	Phone (912) 226-3024

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Zurn Industries Inc.
Energy Division
One Zurn Place
Erie, PA 16512 — Phone (814) 452-2111

Deltak Corp.
P.O. Box 9496 T
Minn., Minn. 55440 — Telex 290812
Phone (612) 544-3371

Lasker Boiler & Eng. Corp.
3203 S. Walcott Ave.
Chicago, Ill. 60608 — Phone (312) 523-3700

Turbine Generator Set

Terry Corporation
Ralph Healey & Assoc. Inc.
P.O. Box 93643
Atlanta, Ga. 30318 — Phone (404) 351-1861

Elliott Overseas Company
1570 Madruga Ave.
Coral Gables, Fla. 33146 — Telex 518703
Phone (305) 661-6081

Worthington Turbodyne Corp.
5915 Ponce de Lyon Blvd.-Suite 11
Coral Gables, Fla. 33146 — Attn: Hector Mayorga
Telex 519590
Phone (305) 661-1087

Trane Murray Div. (Trane Co.)
1106 Washington St.
P.O. Box 967
Burlington, Iowa 52601 — Phone (319) 753-5431

Skinner Eng. Co.
P.O. Box 1149
Erie, PA 16512 — Phone (814) 454-7103

The O'Brien Machine Co.
Green St. and Powerhouse Place
Downingtown, PA. 19335 — Telex 835319
Phone (215) 269-6600

All Power Supply Co.
130 E. Washington St.
P.O. Box 1189
Norristown, PA 19404 — Phone (215) 279-2880

Energistics, Inc.
1917 Lynn Blvd.
Birmingham Ala.

Therms Electron Corp.
101 First Ave.
Waltham, Mass. 02154 — Phone (617) 890-8700

Coppus Eng. Corp.
341 Park Ave.
Worcester, Mass.

Condensers

G.E.A. Power Cooling System
P.O. Box 81608
John T. Hopkins Dr.
San Diego, Ca. 92138 — Phone (714) 455-4270

Graham Mfg Co. Dept G.
170 Great Neck Road.
Great Neck, N.Y. 11021 — Phone (516) 482-5200

Ecodyne Corp.
MRM Div. Dept. TR
608 First St. S.W.
Massillon, Ohio 44646 — Phone (216) 832-5091

Boiler Feed Water Preparation Unit

Southeastern Control Corp. — Attn: Dave N. Bauer
P.O. Box 1420
8333 S.E. Pine Circle
Hobe Sound, Fla. 33455 — Phone (305) 546-3884

Riley Beaird
P.O. Box 31115
Shireive Port, LA. 71130 — Phone (318) 865-6351

Agua - Chem
P.O. Box 421
Milwaukee, Wisc. 43201 — Telex 26679, Phone (414) 962-0100

Small Architect - Engineering Services

U.S. Sources

José Rivero Associates Inc.
P.O. Box 4825
San Juan, Puerto Rico, 00936 — Phone (809) 782-6084

Mater Engineering
P.O. Box 0
Corvallis, Oregon 97330 — Phone (503) 753-7335

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DSS Engineers, Inc.
7483 Northwest 4th. St.
Ft. Lauderdale, Fla. 33317

Phone (305) 792-6660

Panamanian Sources

In addition to sources that may already be known to IRHE, additional sources might be developed by consultation with:

Camara de Comercio
Ave. Ecuador y Ave. Cuba
Apdo. 74
Panamá 1, R.P.

Lic. Aurelio Barría
Telephone 25-4615 and 25-4245

Sindicato de Industriales de Panamá
Edificio Maheli
Ave. Bolivar
Apdo. 952
Panamá 1, R.P.

Lic. Daniel Vega P., Execucive Director
Ing. Vincente Pascual, President
Telephone 61-1066 and 61-1130

Department Approval: Richard J. Trulsgaard

MITRE Project Approval: Charles Bliss