Los Alamos National Laboratory

Steam Plant Project

Report

Bechtel National Inc.
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LANL STEAM PLANT PROJECT REPORT

1. Background

1.1 General

The Los Alamos National Laboratory (LANL) has been able to meet its electric power needs in the recent past without being required to operate its own on-site generating equipment. This is due in large part to the unique power pooling arrangement between the Department of Energy (DOE), acting for LANL, and Los Alamos County and their combined ability to purchase fossil fueled and hydroelectric generation capacity at very competitive prices. The County, as a member the Power Pool, owns the 14 MW Abiquiu and the 8 MW El Vado hydroelectric plants and has equity in 36 MW from San Juan Unit 4. In addition, the County included in the Power Pool a life-of-the-plant entitlement to 10 MW from the Laramie River Station in Wheatland, Wyoming and a small, approximately 1MW, allocation from the Western Area Power Administration ("Western"). DOE initially contributed its 20 MW on-site generating capacity from steam turbine generators, and a 34 MW Western allocation that is currently limited to approximately 18 MW. DOE also contributed its Eastern Technical Area (ETA) substation, including transformers, capacitor banks, static VAR compensator and related facilities, as well as its portion of the ETA to Norton line.

In early 2008, DOE issued an order (O 430.2B) requiring all of its sites to install on-site renewable energy projects. In November of 2008, LANL and Los Alamos County jointly published the "Renewable Energy Feasibility Study" (the "RE Study"). The RE Study looked at several potential demand growth scenarios to assist LANL and the County in planning for their future power needs. The assumptions for each growth scenario are well documented in the RE Study, and considered both County and LANL potential demands. A Minimum Growth scenario, a Moderate-Low Growth scenario, a Moderate-High Growth scenario, and a Maximum Growth scenario were all developed in the RE Study. LANL is positioned to attract significant growth in high performance computing that is expected to increase demand for both electric power and equipment cooling.

1.2 Existing Power Plant

The on-site power plant consists of three natural gas fired boilers that are also capable of operation on #2 fuel oil, three steam turbine generators (STGs) and associated auxiliaries, including deaerators, feedwater heaters, condensers, and a three cell cooling tower. STGs # 1&2 are rated at 5 MW each; STG #3 is rated at 10 MW. All three STGs have been tested and are capable of producing more than the rated output. No. 1 STG is currently operational. No. 2 STG is under going repair at the time this Report was being developed, and No. 3 STG required major repairs to its condenser at the same time. As stated above, the STGs are not needed because all of the LANL loads are currently met by importing power from the grid. LANL considers the cost of the imported power to be lower than the cost of self generation with the existing Power Plant. The three boilers are operational following repair, and one or more of these boilers operates continuously to provide district heating.

The plant and its district steam distribution system, located in Technical Area 3 (TA-3), are approximately 60 years old and are not in good condition despite substantial efforts of a dedicated cadre of people. This is demonstrated by the fact that only about 30% of the steam that is generated is returned as condensate. This Technical Area houses the bulk of the administrative staff as well as significant portions of the programmatic activity, including essentially all of the high performance computing program facilities, and is by far the largest TA from an electric load perspective. The district heating steam is used for various purposes in the buildings in TA-3, including space and hot water heating.

There is also a new Combustion Gas Turbine Generator (CGTG) located in the same general area as the Power Plant described above. The CGTG is a Rolls Royce RB-211, model 6761 DLE, rated at approximately 24 MW at site conditions, and was installed as an emergency generation source. It is operational, but is not operated under normal conditions.

1.3 Existing Electrical Transmission System

The Power Pool's transmission infrastructure includes two redundant 115 kV transmission lines that connect to the Public Service of New Mexico (PNM) system at different locations. Each line can support a load of approximately 110 MW. LANL's current operating philosophy is to have 100% backup capability so they can continue to operate in the event of the loss of one of the transmission lines. See Attachment 7 for a single line diagram.

The 115 kV system for on-site transmission of electrical power runs from one substation to another and forms a transmission loop configuration for the substations. This loop ties the substation in the Eastern Technical Area (ETA) to the one in the Southern Technical Area (STA) by a line designated the SA line. STA is connected to a substation in the Western Technical Area (WTA) by a line designated the SW line. WTA is connected to a substation in TA-3 by a line designated the WT Line. TA-3 is connected to a substation servicing the Los Alamos Neutron Science Center (LANSCE) by a line designated the MP Line. The loop is closed as the substation at LANSCE is connected to ETA by a line designated the LA Line. There is one 115 kV crosstie from Substation ETA to WTA (designated the TE Line) to give more flexibility for the transmission system and its electrical service. See Attachment 7 for a single line representation of the 115 kV transmission loop.

At Substation ETA there is a 115 kV connection to the Public Service Company of New Mexico (PNM) grid from the PNM Norton Substation using the "NL" line. The NL line is rated at 115 MVA, and is owned partially by DOE and partially by PNM, with the dividing line at dead end towers at the Rio Grande River crossing. In addition to the LANL loads, the NL line carries the electrical loads for two Substations in White Rock and for the Buckman Substation. At substation STA there is a 115 kV connection to the PNM grid from the PNM "BA Substation" using the "RL" line. The RL line is rated at 130 MVA, and is owned by PNM. Therefore, all of LANL's imported power comes from either the PNM Norton Substation or the PNM BA Substation, and to maintain 100% redundancy, the import capability of the Power Pool is limited to approximately 110 MW.

Each substation on the115 kV transmission loop steps the voltage down to 13.8 kV and a separate distribution loop among these same substations exists at the 13.8 kV level as distribution connections.

1.4 Charter for This Report

Bechtel National, Inc. (BNI) has been asked, through the Request for Offsite Services (ROS) process, to assist LANL in studying alternatives and developing a report ("this Report") summarizing specific options for meeting the potential demand growth designated as the "Moderate-High" in the RE Study. BNI has sought cooperation from Bechtel Power Corp. (BPC) to provide technical expertise where required. (Together, BNI & BPC are referred to as Bechtel in this Report.)

The selected growth scenario envisions completion and operation of many new projects that will take the peak demand above the 110 MW capability of each of the current 115 kV feeder systems. The Statement of Work (SOW) associated with the ROS document recognize that the skill and/or knowledge required to develop conceptual designs and estimates for some of the options to service the projected demand are not available within LANL resources. Therefore, such skills have been requested from one of the parents of Los Alamos National Security, LLC (LANS). LANS is a team composed of Bechtel National Inc., the University of California, the Babcock & Wilcox Company, and the Washington Division of URS that operates LANL.

LANL has established a three dimensional decision matrix to assist to selecting the most advantageous options. The primary axis is a set of criteria derived from design considerations, such as the limits of the electrical transmission system, environmental discharge limits, and making a positive contribution to the local economy. The secondary axis is the set of power system design options, such as biomass-fired boilers, photovoltaic solar arrays, operation of the installed combustion gas turbine generator (CGTG) in simple or combined cycle modes, etc. The tertiary axis is the set of physical configurations options, such as central plant or distributed resources, locations for new equipment, etc.

With the projected increase in electrical consumption outlined in the High-Moderate Growth scenario, there are differing ways of meeting that electrical need. LANL could import more electrical power or use on-site electrical generation to make up the needed increase in electrical capacity. Each of these solutions is significantly different in approach to meeting the electrical needs of LANL; and each comes with its own inherent pros & cons. Bechtel has been asked to provide layouts and estimates for one reasonably achievable solution that can be incorporated without the need for additional power import capability. In addition, Bechtel was asked to provide estimating input for options that will increase the power import capability of the Laboratory. Resource limitations have restricted the scope to the alternatives developed in this Report. Other alternatives could be developed further if so authorized and directed.

2. Options for Meeting Power Growth Needs and Sustainability Goals

An initial visit was made by Bechtel team leadership under the approved ROS to meet with the LANL team members and walk down the site to more completely understand the Bechtel scope for the study. Bechtel and LANL team members then participated in workshops with LANL environmental compliance staff, infrastructure planning staff and others to formulate the set of possible solutions. The following were among the options discussed.

- Installing new renewable energy systems including:
    - Photovoltaic (PV) solar generation since LANL is located in a region with high average solar radiation
    - Concentrating solar systems
    - Fuel cells
    - Biomass fueled boilers
    - Wind power systems
    - Dry hot rock geothermal systems
    - Traditional geothermal systems
    - Hydroelectric generation
    - Renewable Power Purchase Agreements
- Refurbishing the existing 3 natural gas / fuel oil boilers, the existing steam turbine generators, and associated auxiliaries
- In conjunction with the above equipment refurbishment, refurbishing the existing steam and condensate return systems
- Abandoning the existing power house and its auxiliaries together with the steam and condensate distribution systems and installing new small natural gas fired boilers in each building currently served by the steam distribution system
- Installing a new hot water heating system to replace the existing steam and condensate systems
- Operating the existing combustion gas turbine generator (CGTG) in a simple cycle base load condition
- Modifying the CGTG to provide black start, isochronous (Independent or island) operation, and remote operational control capabilities
- Adding a heat recovery steam generator (HRSG) to the CGTG for additional steam and/or power generation
- Options for use of steam from the HRSG included:

    - Connecting to the existing high pressure steam header and refurbishing the existing #3 STG and relevant auxiliaries for power generation
    - Installing a new more efficient STG for power generation
    - Connecting directly to the existing lower pressure steam distribution system. This would require refurbishing the existing steam and condensate systems
    - In addition to high pressure superheated steam for power generation, provide a lower pressure steam outlet for use either for power generation or as a heat source for the district heating system
    - As a heat source for potential new absorption chillers
- Installing a central chilled water system to service increased demand for computer system cooling
- Installing new central centrifugal and/or absorption chillers to produce the chilled water
- Installing peak shaving systems to reduce peak electrical and peak chilled water demand
- Transmission Line Upgrades
    - Installing the third transmission line as envisioned in earlier studies, i.e., routed from the Norton Station to LANL only on Federal lands
    - Installing the transmission line being proposed by Tecumseh Energy
    - Reconductoring the existing incoming 115 kV transmission lines
- Some combination of the above options working in synergy with each other

One of the conclusions that the LANL/Bechtel team working on this Report (the “Team”) agrees on is that the annual forecasts for Power Pool capacity and energy requirements need to be done on a timely basis and as accurately as possible. PNM and the Power Pool can only make plans for how to address any increased loads that are projected if the forecasts are completed accurately and in a timely fashion. The fact that the Power Purchase Agreement (PPA) between PNM and the Power Pool for the years 2015 through 2020 is due to be renewed in 2010 puts pressure on LANL to ensure that its forecasts reflect the increases that LANL wants to be served by imported power in those years.

3. Option Evaluation

3.1. Renewable Energy Options

Revitalizing the power plant and heating system presents LANL with an opportunity to meet environmental sustainability goals established in O 430.2B. The RE Study presents a comprehensive review of available renewable technologies, and makes recommendations with respect to each one. The RE Study was reviewed by the Team, and a brief review of it as well as the Team’s comments on it are summarized below.

3.1.1 **Solar Photovoltaic (PV) Generation**

Solar electric power provides the most power at peak sunlight, which is normally coincident with the peak electric load at the Laboratory. The RE Study recommended installation of 8.5 MW of photovoltaic generation at TA-36 and TA-61. The Team supports this recommendation, as it will help to meet the DOE goal for renewable energy projects and will also help reduce the need to purchase bulk power at peak rates. Bechtel was requested not to include PV in this Report, since LANL has the skill and knowledge to develop the concepts, estimates and other documents required to realize such a project.

3.1.2 **Concentrating Solar**

The RE Study recommended against consideration of concentrating solar at the Laboratory principally because commercially proven systems require more land with a less than1% slope than LANL has available. In addition, the estimated cost of energy from such a system was estimated to be in excess of that available from other renewable sources. The Team supports this recommendation, but thought that additional consideration might be given to roof-top solar systems on a case-by-case basis. For

example, refurbishing the rooftop system on the OTAWI building should be considered as a means of demonstrating LANL's commitment to renewable energy. Bechtel was requested not to include concentrating solar or roof-top solar systems in this Report.

3.1.3 **Fuel Cells**

The RE Study recommended against fuel cell technology because there are no fuel cells on the market today that can deliver power at a cost that is competitive with energy as currently delivered to the Laboratory, considering the available incentives. Fuel cell technology is only as "renewable" as the fuel source, and there are insufficient local sources of renewable fuels that can be used to power the fuel cells. It is noted that fuel cell installations are eligible for carbon credits, if there are such credits technically available for the particular installation. LANL scientists may pursue large fuel cell research, in which case installation might come as part of such research. The fuel cell research currently conducted by LANL is not in the fuel cell technology used in large units, and therefore, there is no synergy between that technology and the power needs to meet the Medium-High growth Scenario. Bechtel was requested not to include fuel cell layouts or estimates in this Report.

3.1.4 **Biomass Fueled Boilers**

Biomass energy is a renewable because the plant matter it consumes can be continuously grown. When biomass fuel burns, it releases the carbon dioxide and solar energy absorbed during the growth stage, functioning as a natural solar energy storage system. Biomass combustion is regarded as "carbon neutral" because the amount of carbon dioxide emitted during combustion is equal to the carbon it absorbed during growth.

There are several developing technologies that convert biomass into energy without combustion; however, none are commercially available or described in this Report.

Biomass combustion could be used at the Laboratory as a source of heat to generate either (1) steam or hot water for district heating, or (2) steam for cogeneration of electricity and district heat, or (3) some combination of both. Forest Energy Systems (Forest) completed a feasibility study for a thermal (steam) and combined electric and thermal power plant fueled by chipped wood and wood pellets.

LANL has performed sufficient due diligence to determine that there is adequate biomass available within a 50 mile radius of the Laboratory from local wood wastes, forest thinning, and downfall to support a biomass boiler, at least during the warmer weather months. The Team has agreed that Bechtel should include a layout and cost estimate for a wood chip fired boiler rated at approximately 20 MMBTU/hr, i.e., twenty million British Thermal Units per hour. (This is equivalent to approximately 7,850 horsepower.) Please see Attachment 3 for a conceptual design and configuration for a biomass fired boiler.

3.1.5 **Wind Power**

The RE Study concluded that local wind resources at LANL, or anywhere in Los Alamos county, are insufficient to support a wind power generation project. Therefore, no further consideration is given to wind power in this Report.

3.1.6 **Dry Hot Rock (DHR) Geothermal**

The RE Study, as well as LANL Subject Matter experts, believe that additional development of DHR is in the interest of the United States goal of energy independence. If Enhanced Geothermal System (EGS) technology that uses artificial stimulation to convert any geothermal resource to useful power proves to be commercially successful, it may be added to the LANL generation in the future. For the purposes of this Report, DHR using EGS technology was not recommended for immediate consideration because the technology is immature, but the team supports further study of this

technology outside the scope of this Report. Dr. D. Brown, LANL's subject matter expert on DHR geothermal, recommended against it for TA-3 due seismic concerns and unfavorable geological conditions, because injecting fluids into unfavorable geology may provide the impetus for an earthquake.

3.1.7 Traditional Geothermal Systems

The RE Study considered traditional geothermal systems because geothermal energy is a statute-recognized renewable energy resource. The US Geological Survey identified the Valles Caldera as a high-temperature geothermal resource. A 50 MW geothermal power station was proposed in 1977, after confirmatory drilling took place. Drilling continued for several years, but the project was terminated in 1982 because there were too many technical and financial complications. For the purpose of this Report, traditional geothermal systems were not considered, except as a possible source for a renewable power purchase agreement, as discussed below.

3.1.8 Hydroelectric Generation

Los Alamos County has recently considered several new hydroelectric opportunities. A third unit of 3 MW at the existing Abiquiu dam has the best economics of the projects considered and is included in the Fiscal Year 2009 budget. The RE Study, and the Team agree that the third unit at Abiquiu Dam should be completed. This can be considered as adding to the renewable generation capability of the Laboratory. Bechtel was requested not to include layouts and estimates for the third unit at Abiquiu in this Report, since LANL has the skill and knowledge to develop the concepts, estimates and other documents required to realize this project.

3.1.9 Renewable Power Purchase Agreements (PPA)

The RE Study recommended that the Power Pool consider renewable PPAs as an element in its purchased power options. Additional research and study were further recommended from both the economic perspective and the perspective of facilitating local pueblos' participation in generation projects. The Team supports the RE Study recommendation. It is noted that LANL has the resources to undertake such research, and no further consideration is given to renewable PPAs in this Report.

3.2 Non-Renewable Power Generation and Heating/Cooling Options

There are a large number of options and possible solutions to the issue of providing thermal and electrical energy to meet the requirements of the Moderate-High Growth scenario without increasing the Power Pool's capability to import power. Many factors that affect the final decisions, such as detailed condition assessments, detailed trade-off studies, and detailed technical specification development are beyond the scope of this Report. Many other factors, including environmental compliance regulations, emissions from new boilers, LANL research projects in the energy field, and the effects on the local economy and on the Pueblos in the vicinity of LANL will have to be considered when making the final decisions. For the purposes of this Report, Bechtel has been asked to provide layout and estimate information for specific options as outlined below.

3.2.1 District Heating versus Distributed Boilers

This was one of the subjects that received significant attention from the Team. Either system is capable of meeting the design parameters for space temperature control. Both systems have historically high reliability, although the service life of the central boiler may be longer. A centralized system can accommodate standby equipment of equal size, providing a back-up in case of a planned or unplanned outage. While redundant boilers can be installed in distributed locations, this will require more local space and may not be economically competitive. The central boilers can also be configured to burn No. 2 Fuel Oil in the event of a natural gas shortage or interruption. The decentralized boilers would probably not have this capability. Adding distributed boilers at each building would require

additional space to be allocated within the congested campus area. Adding centralized heating boilers at the existing cogeneration facility would require demolition of some existing unused equipment and structures.

In terms of maintenance, the centralized boilers can be operated and serviced by the existing utilities plant staff. Furthermore, this system would provide the benefit of having the equipment located well away from the occupants of the various LANL buildings in an appropriate work service environment. Because of their larger capacity, there would be substantially fewer boilers to service. The centralized boiler system would require a separate underground steam or hot water supply and return system which would be an additional maintenance item. Decentralized boilers can be efficient to maintain if they are conveniently located and if spare parts are standardized. Around-the-clock on scene operators are required for the centralized boilers, but would not be mandated for the distributed boilers.

For the purposes of this Report, Bechtel has been asked to layout and estimate the cost of adding two new ~68 MMBTU natural gas fired boilers capable of burning #2 fuel oil in an emergency. These boilers would most likely be located in the general area of the existing Power Plant. Installation would require demolition of two existing, but unused cooling towers. Other equipment in the Power Plant area may need to be relocated to accommodate the new boilers. Please see Attachment 4 for the conceptual design and configuration for new ~68 MMBTU boilers. As noted above, Bechtel is also including a layout and estimate for a new biomass boiler in this Report. The new biomass boiler would operate in parallel with the new dual fueled boilers at the same outlet temperature and pressure conditions. The new biomass boiler may be located in the same general area as the new dual fueled boilers, or in a location to be determined later. If the TA-3 substation adjacent to the power plant is relocated, the space left open by that move may be suitable for a biomass boiler and its auxiliaries.

3.2.2 District Steam versus District Hot Water Heating System

Refurbishing the existing system must start with a detailed condition assessment of the piping, joints, fittings, expansion joints, manholes, etc. Such an assessment is beyond the scope of this Report. However, some general statements can be made about the pros and cons of steam versus water for district heating.

Either system is capable of meeting the design parameters for space temperature control. Both systems have been historically used to the benefit of the using entity. Heat transfer in a steam generator can be accomplished with less tube area than that in a hot water generating system. There is significantly more energy, i.e., BTU content, in steam than in water at the same temperature. Any steam system needs to have an efficient way of collecting condensate that inevitably forms during the heat transfer process, whether in a designated heat exchanger, or in the actual piping runs. This requires steam traps, and they require regular maintenance. It has been demonstrated that regular maintenance of steam traps within the various buildings is a difficult undertaking at LANL and DOE for a number of reasons endemic to the Laboratory organizational structure. (This is intended as a statement and not a criticism of any kind.)

A hot water system can be installed as a single piping system with supply and return headers, rather than requiring separate steam and condensate systems, and does not require steam traps. A hot water piping system at ~230F can be designed with less consideration for expansion and contraction than a 100 psig steam system. Water chemistry can be better controlled with a closed hot water district heating system.

For the purposes of this Report, Bechtel has been asked to layout and estimate the cost of adding a new hot water district heating system. This new system, as conceived for this Report, would serve only selected buildings within TA-3. A northern loop would serve buildings 1498, 207, 1400, 261, 2327, 2322, 510, 28, 1405, 422, and 216 sequentially. A southeastern loop is also contemplated to serve buildings 223, 66, 169, and 141. It is contemplated that all other existing buildings in TA-3 will have their own indigenous heating system, i.e., natural gas fired packaged boilers. Please see Attachment 1

for the conceptual design and configuration of a conceptual hot water district heating system, and Attachments 3 & 4 for conceptual descriptions of hot water boiler equipment.

Some of the new buildings being considered for installation in TA-3 will potentially be sited along the proposed route for the hot water system outlined in this Report. This is one of the reasons for proposing the route shown in Figure 1-2. When detailed design is undertaken, consideration could be given to spare capacity to service development of new facilities that may be installed on the land made available by demolition of existing facilities near the proposed route.

Assuming projects to install the new boilers referenced in paragraph 3.2.2 above and the new hot water district heating system referenced in this paragraph are approved and implemented, the old power plant and the district steam heating and condensate systems could be demolished or abandoned in place when the new systems become operational. Until that time, the old system will have to be operated and maintained to satisfy the TA-3 building requirements.

3.2.3 Combustion Gas Turbine Generator Operation

The peak generation capacity and energy requirements of the Moderate-High Growth scenario discussed above will exceed the capabilities of each of the existing 115 kV transmission lines coming into the Laboratory. Without building the third transmission line or otherwise upgrading the Power Pool's capability to import power, LANL will have to self generate electricity in order to meet such peak demand. The existing Rolls Royce RB-211 CGTG can assist in meeting the increased capacity needs.

At the present time the CGTG is not equipped to run unless it is operating in parallel with some other power source or the power grid. Additional control electronics and software can be added to its present control system to provide the capability to operate independent of other sources, i.e., to support LANL in an "island" condition. This mode of operation is known as isochronous operation, and will allow the generator to provide proper control of the turbine to maintain frequency and voltage level as loads are added or removed from the electrical system, without the requirement of being connected to the grid. Isochronous operational electronics would be provided such that it could be turned on and off as required based on the conditions of the electrical system and the load scenarios that are encountered. The Team recommends adding isochronous capability to the CGTG.

The Team also recommends providing the CGTG with the capability to be controlled remotely. This would allow the control of the CGTG to be turned over to the power pool operations group with certain stipulations and allow them to alter the generators operation based on the existing power grid conditions and the load scenarios at any given time.

Providing a black start capability would also provide LANL with additional flexibility in the event of a total loss of off-site power during off peak hours when the CGTG was not operating. If the existing diesel generators do not have the capacity to start the natural gas compressors required to operate the CGTG, then black start capability will require either additional diesels, the addition of a new high pressure natural gas pipeline from the gas main into the power plant area, or the installation of a low voltage motor starter ("soft" starter) for the gas compressor. The Team supports provision of a soft starter for the gas compressor as the easiest and least expensive way to provide assurance of being able to start the compressors in a black start condition. Since LANL has the expertise and resources to procure this type of equipment, no further consideration is given to the CGTG black start issue in this Report, and the cost for such equipment is not included in the ROM estimates shown in Attachment 9.

3.2.4 Heat Recovery Steam Generator (HRSG)

Adding an HRSG to the exhaust gas flow path of the CGTG would provide LANL with an additional source for power generation and/or hot water or steam for district heating without increasing the net fuel consumption at the Laboratory. For any organization interested in reducing its carbon footprint, raising the generation capacity without raising fuel consumption must be considered a significant

advantage. LANL has requested that Bechtel provide a layout and estimate for adding an HRSG to the existing CGTG.

3.2.5 Usage of HRSG Steam

As indicated above, many options were considered for using the energy captured in the HRSG. Since one of the key elements in the development of this Report was to have Bechtel include layouts and estimates for a new hot water district heating system and two new dual fueled boilers, as well as well a new biomass fueled boiler, the synergistic option for the HRSG is to provide steam outlets at two pressures. One pressure would be as high as the exhaust gas temperature will allow with some degree of superheat. That would be used as the inlet to a new high efficiency steam turbine generator. The other steam off-take would be a low pressure steam that can be an additional admission to the STG or that can supply steam to a header that can be used as the heat source for a heat exchanger to heat water returning from the district heating system back up to the appropriate HW supply temperature. This low pressure header could be used for other purposes, including as a heat source for new absorption chillers. Please see Attachment 2 for the conceptual design and configuration for utilizing the CGTG in combined cycle mode, and Attachment 5 for a conceptual description of HRSG and STG equipment.

3.2.6 Central versus Distributed Chilled Water System

Much of the new load assumed in the Moderate-High Growth scenario is from the addition of supercomputing facilities at LANL. The supercomputers contemplated consume not only large quantities of reliable power, but also require large quantities of chilled water to keep the sophisticated equipment cool enough to operate reliably. Depending on the locations of the new equipment, a central chilled water system might prove to be the best way to meet the cooling requirements. Since LANL is assuming that buildings 2327, 1400, 207, and 1495 in the northern area of TA-3 may become the sites for new computing installations or other installations that will require significant chilled water in the future, Bechtel has included a layout and estimate for adding central chilled water systems to service those buildings. In addition, the proposed route would be able to serve the Otowi Building (#3-261), which may need an air conditioning system upgrade to serve all of the facilities in use in that building. LANL can also consider providing a water-side economizer in the cooling tower for later incorporation into the central system to provide chilled water without having to operate the chillers themselves. This is possible because the dry bulb temperature at night for much of the year at Los Alamos is low enough to provide chilled water without a refrigeration system. Such a system would lower the overall O&M cost of a central chilled water system. Please see Attachment 6 for the conceptual design and configuration for a new central chilled water system.

3.2.7 Centrifugal versus Absorption Chillers

It is assumed that centrifugal chillers would be used to supply the new central chilled water systems. This is because the coefficient of performance for centrifugal chillers is far superior to that for absorption chillers. Therefore, steam generated in the HRSG is best utilized to generate electricity that can be used to drive centrifugal chillers. Bechtel was only requested to allow for steam and hot water in the northern and southeastern areas as sources of heat for possible absorption chillers, in the event LANL decides in the future to use such equipment. Since hot water is assumed to be available in those areas (see paragraph 3.2.2 above), and since steam is assumed to be available from the low pressure inlet/outlet in the new STG, (see paragraph 3.2.5 above), no further layout or estimating information related to chillers has been requested from Bechtel for inclusion in this Report.

3.3 Environmental Considerations

The Environmental Protection Agency's (EPA) New Source Review (NSR) requires stationary sources of air pollution to get permits before they start construction. Permits are legal documents that the source must follow. They specify what construction is allowed, what emission limits must be met, and often how the source must be operated. They may contain conditions to make sure that the source is built to match parameters in the application that the permit agency relied on in their analysis. For example, the permit may specify stack heights that the permit agency used in their analysis of the source. Some limits in a permit may be there at the request of the source to keep them out of other requirements. For example, the source may take limits in a minor NSR permit to keep the source out of the Prevention of Significant Deterioration (PSD) category. To assure that sources follow the permit requirements, permits also contain monitoring, recordkeeping, and reporting requirements. NSR permits in Los Alamos County New Mexico are issued by the Air Quality Bureau of the New Mexico Environment Department.

There are three types of NSR permitting requirements, as follows:

1. Prevention of Significant Deterioration (PSD) permits which are required for new major sources or a major source making a major modification in an attainment area;
2. Nonattainment NSR permits which are required for new major sources or major sources making a major modification in a nonattainment area; and
3. Minor source permits.

PSD requires the following:

1. installation of the "Best Available Control Technology (BACT)";
2. an air quality analysis;
3. an additional impacts analysis; and
4. public involvement.

Please note that those terms in the text above that are underlined and/or that show in a color other than black, are directly linked to websites that provide amplification of the meaning of the terms.

For the purposes of the EPA regulations (Federal Regulation 40 CFR 52.21), a Major stationary source means one of a large number of types of sources of air pollutants which emit, or has the potential to emit, 100 tons per year or more of any regulated NSR pollutant. Among other sources that meet the EPA definition of Major source is a fossil fuel fired steam electric plant of more than 250 million BTU/hr heat input. The existing CGTG at full load and ISO conditions would consume approximately 280 million BTU/hr. However, it is equipped with Dry Low Emissions burners that maintain Nitrogen Oxides (NOX) to less than 25 ppm. On this basis, the Team's calculations demonstrate that it would have to operate at greater than 95% capacity factor for a full year before it emitted 100 tons of NOX. It has been assumed that the CGTG would be shut down for more than 5% of the year, for example, it would likely be shut down on weekends, when the peak load would be below the capability of the transmission lines. Therefore, it has been concluded for the sake of this Report, that the CTG, operating in combined cycle, i.e., as a fossil fuel fired steam electric plant, can be permitted as a Minor Source.

Another definition of a Major Source under 40 CFR 52.21 is "fossil-fuel boilers (or combinations thereof) totaling more than 250 million British thermal units per hour heat input." Since the combination of the two new fossil fueled hot water boilers is substantially less than 250 million BTU/hr, they would be separately permitted as Minor Sources.

The Team has assumed that all water and other liquid wastes to be discharged from the new facilities will be directed to the waste water treatment facilities that are to be built at LANL.

3.4 Electrical Power Supply Options

With the projected increase in electrical capacity needed by LANL under the Moderate-High Growth scenario, there are differing ways of meeting the requirements when considering only increasing LANL's capability to import power. Any of the import of power scenarios will entail the alteration of the existing electrical system configuration in order to handle the additional electrical capacity. In the paragraphs below, this Report outlines a few of the options that appear to be among the most practical and accomplishable that Bechtel has been specifically requested to include.

3.4.1 Reconductoring Existing Power Lines

The Norton Line (NL) from the PNM Norton Substation to the LANL ETA Substation is about 14 miles in length. The PNM Norton Substation has some spare capacity at the present time. One of the less expensive methods of obtaining additional capacity for the Power Pool is to install new conductors on the NL Line. The wooden H style transmission structures have all been maintained and/or replaced as needed over the years. As they have been replaced or worked on, their structures have been upgraded to be able to properly support parallel bundled 477 thousand Circular Mills (kcmil) Aluminum Conductor Steel Reinforced (ACSR) conductors or single 954 kcmil ACSR conductors. Single 954 kcmil ACSR conductors would have the same conductor weight and approximately the same conductor material costs as bundled 477kcmil ACSR. The single 954 kcmil ACSR conductors would be easier to string, hang and sag. The need for double rigging, identical sagging and somewhat specialized hardware would result in added installation costs with the bundled 477 kcmil ACSR conductor option. The new single 954 kcmil ACSR ("Cardinal") conductors would improve the import capability of the Power Pool by approximately 83 MVA. The additional labor and trouble related to the bundled 477 kcmil ACSR ("Flicker") would increase the available power carrying capability by approximately 145 MVA above the existing capability. It should be noted that there are several different ACSR conductors for each circular size with differing ampacities, and that the code names in parentheses above have ampacities that yield the indicated results. It should also be noted that there are conductors other than ACSR, such as Aluminum Conductor Composite Reinforced (ACCR) and Aluminum Conductor Steel Supported / Trapezoidal Wire (ACSS/TW) with mischmetal coasted core, that are now available that have higher ampacities than similarly sized ACSR conductors, and may be easier to install.

The potential pitfalls involved in obtaining all required permissions, licenses and permits to execute this reconductoring, as well as any increases in fees to use Pueblo lands for this purpose, are beyond the scope of this Report. Please see Attachment 7 for additional details regarding the layout and ROM estimate to reconductor the Norton Line.

The reconductoring of the RL line from PNM's BA Substation to the LANL STA switching station would be another project that would be required if LANL were to maintain its current philosophy of 100% redundancy. However, this line is approximately 40 miles long and has not had its structures upgraded as part of its normal maintenance. To reconductor this line, most of the structures would have to be replaced and upgraded to handle the additional conductor weight and sag & tension forces. About the only thing that would be reusable would be the route itself and even that may need to have the right of way renegotiated because of the need for different structures and conductors. Therefore it would basically be new Transmission line construction for the entire distance of the line. It may be appropriate to consider a change in voltage level to 345 kV or 500 kV to make it viable with the increase in capacity being very significant with the voltage level change. Because the cost of this project is considered prohibitive, Bechtel was not asked to include a layout & estimate for reconductoring the RL line in this Report.

3.4.2 Tecumseh Ojo to Norton Transmission Line

Tecumseh Professional Associates, Inc. ("Tecumseh") is a Graduate 8A Company, meaning that it was granted 8A status as a Native American Owned Small Business Enterprise more than 9 years

ago. Today they are still a Native American enterprise that has become, according to their website, “a multi-disciplined leader in the environmental, energy, facility operations, and real estate industries providing clients with high-quality technical, management, contracting, and planning services.”

Tecumseh, as a merchant developer, has been pursuing a project to bring a 345 kV transmission line from the Ojo substation in far northern New Mexico to the Norton Substation. This is feasible if the developer of the line can obtain the Right of Way (ROW) from the property owners along the proposed route. Tecumseh has been in discussions over a period of time with the private, state, federal, and Native American owners of the land along its proposed route. Their discussions with one of the land owning Native American tribes has some open issues, that if resolved in an economically reasonable manner, could result in Tecumseh’s advancing the project to the Environmental Assessment (EA) phase. The other land owners along the proposed route appear to be favorably disposed toward supporting the project.

Tecumseh believes that the EA phase can be initiated and completed within approximately twelve months. After all EA approvals are received, they are prepared to move into the engineering and construction phase, which they believe can be accomplished in approximately eighteen months. For this project to be of benefit to LANL, the Norton to ETA line must be upgraded somehow, or the “third transmission line”, discussed below, must be built.

Tecumseh has also looked at a more extensive (and more expensive) way to bring power into the Los Alamos / Santa Fe region. That would be a line from the Ojo substation to the STA switching station on LANL property. For this route to be feasible, Tecumseh considers that the “third transmission line” must be completed. They are not averse to participating in making the “third transmission line” a reality, but it would require an innovative commercial deal to make it attractive. Their primary interest, the Ojo to Norton line, can be profitable to them through their plan of leasing the line to PNM, and having PNM include the lease payments in their regular FERC (Federal Energy Regulatory Commission) tariff.

3.4.3 Third Transmission Line

This new line has been under study and consideration for a number of years. The proposed route would be from the Norton substation, through all federally owned land for a distance of approximately 7 miles, and then follow the Reeves ROW on LANL land for a distance of approximately five miles into the LANL’s STA substation. The line would be designed and built as a 345 kV line, though it might originally have to operate at 115 kV. In addition, the project would require a new 345 / 115 kV transformer, and related switchgear at the STA substation. There have been unresolved issues with the US Forest Service regarding land usage for this project. At this time, LANL cannot afford the luxury of planning on this line, so self generation as discussed above would be necessary if the Moderate-High Growth scenario is to be achieved.

3.4.4 City of Santa Fe Water Diversion Project

The City of Santa Fe is implementing a large water diversion project for commercial operation in the 2011 time frame. If this project goes forward, the current plan is to feed it from the Norton Station. Estimates of the peak power required to support this project are in the neighborhood of 20 MW. The Team recommends that DOE stay in close touch with PNM to ensure that their infrastructure continues to support the 110 MW import capability to STA.

3.5 Summary Analysis of Meeting Peak Generation Requirements

Under the Moderate-High Growth scenario, the Power Pool’s peak demand in 2014 is estimated to be approximately 154 MW. Growth may continue under the scenario and possibly reach up to 167 MW by 2018. The projects included in this Report would essentially meet the 2014 demand, when the ambient temperature is approximately 50F. As the ambient temperature goes up, the output from the CGTG

goes down, and conversely, as the temperature goes down, the output goes up. . This situation is considered adequate for the purpose of this Report, since it is considered that a few kilowatts of peak load could be shed without impairing Laboratory operations during a peak demand occurrence in the hot weather, or the transmission cables could be operated in a slightly overloaded condition for brief periods, as is generally acceptable for a limited accumulated time period by cable manufacturers. Alternatively, the transmission lines supplying power to LANL normally operate in parallel, and having them both on line would easily provide sufficient capacity prior to shedding any loads. A summary of the capacity of the sources included in this Report follows:

Project / Source	Capacity (MW)
Existing Transmission Lines	110.0
New Photovoltaic installation	8.5
Rolls Royce RB 211*	23.6
New Combined Cycle STG*	9.3
LANL Diesel Generators	2.5
Total	153.9

*See Heat Balance in Attachment 2 for site conditions (50F ambient) associated with this output, as well as Heat Balances for other site conditions.

4.0 Layout and ROM Cost Estimate

Bechtel has made a conceptual layout that shows two new 68 MMBTU/hr natural gas fired hot water boilers, one 20 MMBTU/hr biomass hot water boiler, and a new STG in a new building in the area behind Building 22. Some small equipment would need to be relocated if this arrangement is considered for further detailed study. In addition, this location requires demolition of two abandoned cooling towers and their respective auxiliaries. The layout also shows the potential location for two new centrifugal chillers that would service a central chilled water system. Please see Attachment 8 for this conceptual layout.

Bechtel has also prepared a ROM estimate for the building, equipment, piping, etc. included in the layout. Please see Attachment 9 for a summary of the ROM estimate.

Attachment 1 Concept for New District Heating Hot Water System
Attachment 2 Concept for Utilizing the Existing CGTG in Combined Cycle Mode
Attachment 3 Concept for New Biomass Hot Water Generating System Equipment
Attachment 4 Concept for New Dual-Fuel Hot Water Generating System Equipment
Attachment 5 Concept for New HRSG and STG Equipment
Attachment 6 Concept for New District Chilled Water System and Equipment
Attachment 7 Concept for High Voltage Electrical System Upgrades and ROM Estimate for Reconductoring the Norton Line
Attachment 8 Conceptual Layout for New Hot Water, Chilled Water and Power Generating Systems
Attachment 9 ROM Estimate Summary for New Hot Water, Chilled Water and Power Generating Systems

LANL STEAM PLANT PROJECT REPORT ATTACHMENT 1

Concept for New District Heating Hot Water System

The Team has developed a concept for the installation of two new dual-fuel (natural gas and No. 2 fuel oil) boilers and a biomass (wood) fired boiler designed to produce hot water to be used for a new district heating system. The total heat duty for the buildings considered in this Report is approximately 68 MMBTU/hr. This information was provided by LANL from available data gathered at the Laboratory. To provide the basic thermal energy requirements and considering a satisfactory level of redundancy, the Team has suggested two 100% dual-fuel fired hot water boilers, each with 68 MMBTU/hr capacity, as the thermal energy source under normal operating conditions. To add flexibility to the system, hot water for district heating has also been conceptualized to be supplied from a heat exchanger that takes energy from the low pressure HRSG steam in the power generation system.

The Team has assessed that a 20 MMBTU/hr biomass fired boiler operating at a 25% capacity factor will meet the DOE goal for renewable thermal energy consumption (7.5%) at LANL. LANL has performed sufficient due diligence to determine that it would not be difficult for the local population to develop an infrastructure to supply chipped wood from local wood wastes, forest thinning, and downfall, at least during the fair weather months. A wood fired hot water boiler of 20,000 BTU/hr has been included in the conceptual configuration to meet the renewable energy goal established by DOE.

As conceptualized in this Report, the hot water would be circulated through a closed loop system. The hot water system would start as a larger diameter piping header at the confluence of the boiler outlets and get progressively smaller as the hot water flows in sequence through the high temperature side of the building heat exchangers along the loop. The return loop would start as a smaller diameter system and get progressively larger as the cooler water is collected in sequence from each building in the loop. Some of the buildings to be serviced by the new system do not have heat exchangers at the service entrances. For those buildings (including 1498, 207, 261, 28, 223, 66 & 169), the existing internal systems could be with control systems upgrades to maintain the 50 degree temperature differential, or alternatively, heat exchangers might be installed at the entrance to those buildings. If the existing internal systems are retained in the buildings in question, a proper water treatment system is needed to ensure the water quality is maintained at a suitable level for the boilers. The costs for modifications to the internal systems in these buildings are not included, since that level of detail is beyond the scope of this Report.

Air removal is necessary and has been included in the conceptual design of the hot water system for two main reasons. First, air contains oxygen, which can cause corrosion of metal surfaces; and second, air acts as an insulator and can affect heat transfer as well as the operation of temperature controls.

Please see Figure 1-1 for the conceptual process flow diagram. Figure 1-2 shows the concept of the HW system in Technical Area 3, and Figure 1-3 lists the buildings included in the conceptualized hot water system together with their heat duties, as indicated in data by LANL.

Figure 1-1 Proposed Hot Water System Process Flow Diagram
Figure 1-2 Conceptual New Hot Water System in TA-3
Figure 1-3 Current Steam Loads / New Hot Water System Loads

Figure 1-1: Proposed Hot Water System Process Flow Diagram

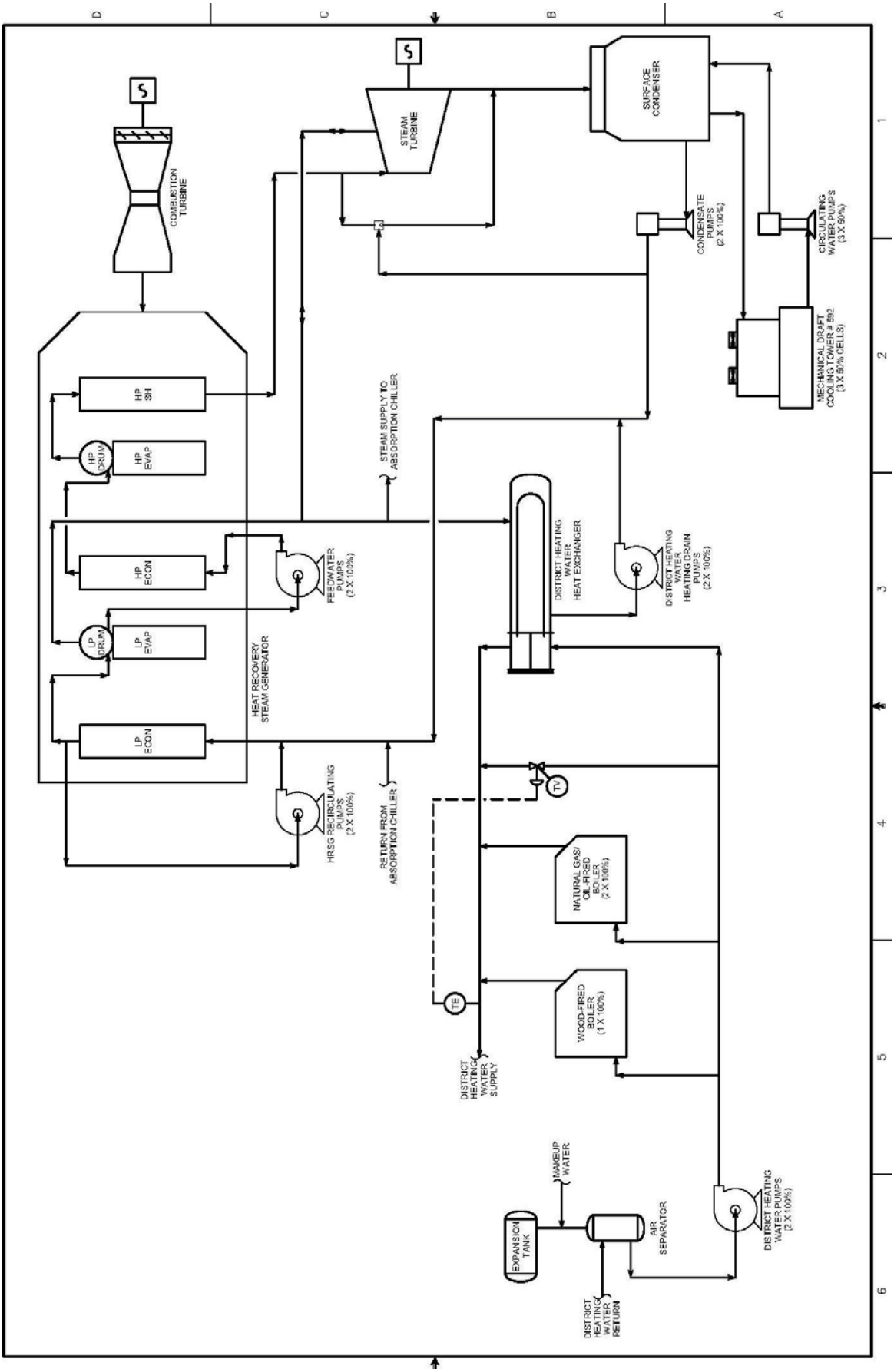


Figure 1-2: Conceptual New Hot Water System in TA-3

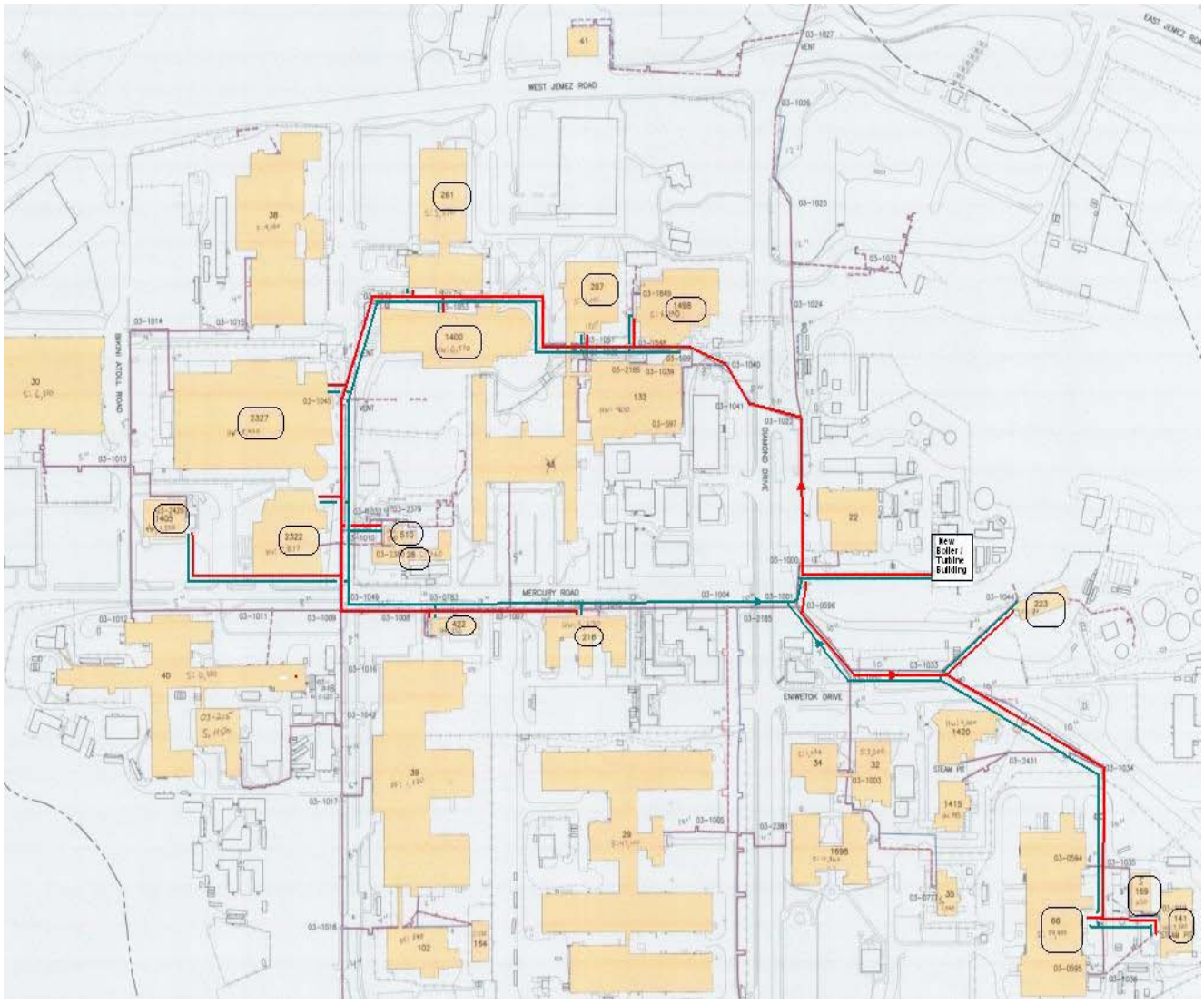


Figure 1-3
Current Steam Loads / New Hot Water System Loads

Building (TA – Bldg))	Load kBtu/HR)	Building Flow, gpm	Downstream Available, gpm	Supply size
		Northern Loop		
Common			2,000	10
3-1498	6,390	256	1,744	10
3-207	3,000	120	1,624	10
3-1400	6,870	275	1,350	8
3-261	3,575	143	1,207	8
3-2327	8,920	357	850	8
3-2322	8,817	353	497	6
3-510	340	14	484	6
3-28	760	30	453	6
3-1405	1,800	72	381	6
3-422	250	10	371	6
3-216	3,670	147	224	6
Sub Total	44,392	1,776	NA	
		Southeastern Loop		
Common			1,000	8
3-223	1,180	47	953	8
3-66	17,450	698	255	8
3-169	650	26	229	6
3-141	3,500	140	89	6
Sub Total	22,780	911	NA	
Total	67,172			
Supply			3000	12
Return			3000	12

Notes for Figure 1-3

1. LANL indicated that Buildings 30, 40, 43-01, 43, 132 and the unnumbered building south of Building 132 will be phased out near term and were, therefore, not considered for the district hot water heating system.
2. Steam users in buildings not listed in Figure 1-3 would generally be converted to distributed boilers.
3. For buildings that are slated for eventual demolition, e.g. CMR building #29, a leased boiler would be considered for the interim period after activation of the hot water system, and deactivation of the building.
4. Only one supply to the Sigma building (#66) was considered for inclusion in the hot water system, providing half of the original design demand. It is assumed that Sigma would require a significant HVAC upgrade that would reduce the amount the amount of heat required by approximately one half.

LANL STEAM PLANT PROJECT REPORT ATTACHMENT 2

Concept for Utilizing the Existing CGTG in Combined Cycle Mode

With the addition of a Heat Recovery Steam Generator (HRSG) and a Steam Turbine Generator (STG) to work in conjunction with the existing Rolls Royce RB-211 Combustion Gas Turbine Generator (CGTG), a combined cycle power plant can be created which will recover waste energy from the flue gas of the CGTG and produce steam for the purpose of generating electricity. The system can also be arranged such that an additional level of redundancy can be provided for the district heating system by utilizing a stream of low pressure steam from the HRSG as the heating medium in a water-to-water district heating system heat exchanger.

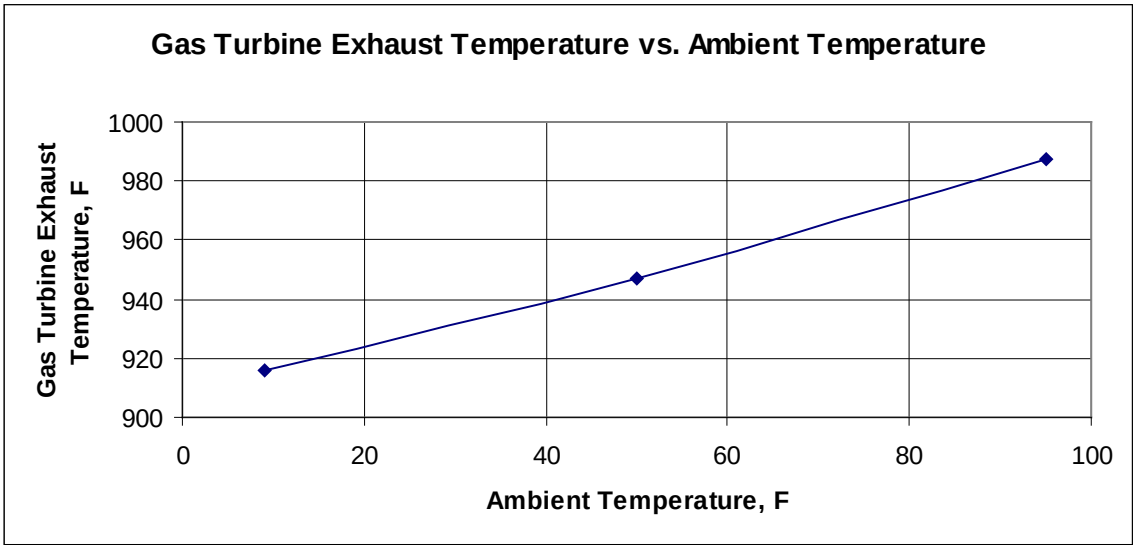
Steam Cycle Selection and Plant Performance

For the plant conceptualized in this Report, selection of HRSG and overall steam cycle design parameters are influenced by the already existing equipment that would be reused. The two major components influencing cycle selection and performance are the combustion gas turbine and the cooling tower. Steam cycle performance was developed based on the use of the GTPro (GTP) and GTMaster (GTM) heat balance programs.

Combustion Gas Turbine

The existing CGTG is a Rolls Royce RB211 6761 model with a dry low emissions (DLE) combustion system. Gas turbine performance characteristics utilized in developing steam cycle performance were based on the performance characteristics generated by the GTP/GTM programs for this model.

The gas turbine exhaust temperature obviously has a large impact on the temperature of steam that can be generated in the HRSG. Over the range of ambient temperatures expected for this site, the gas turbine exhaust temperature is shown in the graph below.



Cooling Tower

Currently at the site there is a 3-cell Marley mechanical draft counterflow cooling tower. The GTP/GTM model was developed to simulate the actual performance of the existing cooling tower. The tower is designed for a circulating water flow of 14,400 gallons per minute (gpm) and for a much higher duty than would result from operation of the proposed plant. In addition, operation at the full circulating water flow would result in a very low rise across the condenser. For purposes of this Report, it was assumed that only 2 of the 3 cooling tower cells would operate, and that only 2/3rds of the water would be pumped through the system.

Cycle Selection

Based on the gas turbine exhaust temperature characteristics given above, a nominal steam turbine throttle temperature of 900°F was selected. Based on this temperature and on experience with turbines of this size, a throttle pressure of 915 pounds per square inch absolute (psia) was selected. For a steam turbine of this size and with this gas turbine exhaust temperature, a non-reheat cycle is the only practical option. Note that the 900°F throttle temperature can only be maintained down to about 50°F ambient temperature, and at low ambients (9°F) would fall to ~870°F.

The remaining major cycle selection considerations are the HRSG configuration and the source of the building heating energy supply. The following options were considered:

1. single pressure HRSG, LP steam from ST extraction
2. single pressure HRSG, separate hot water coil in HRSG
3. dual pressure HRSG with 2nd pressure generating LP steam

Option 1 is a very inefficient design, as it results in a stack temperature of ~380°F. This indicates that there is a fair amount of energy still available for use in the HRSG, and this energy should be used to help satisfy the building heating demands. Options 2 and 3 examined ways to utilize this available energy.

Option 2 considered putting some of the water used for building heating directly through water heating coils in the HRSG to provide some of the energy needed for building heating. A disadvantage of Option 2 is that when building heating demand drops much of the gas turbine exhaust energy is wasted, much like the single pressure design. Sub-options were considered to try to alleviate this concern. These required more integration of the building heating system with the steam cycle, which resulted in more system complexity.

Option 3 considered generating saturated LP steam at 50 psia in a 2nd pressure level in the HRSG which would supply steam to a heat exchanger to be used to heat the building heating return water. When building heating demand is high, additional LP steam can be provided from a steam turbine extraction. When building heating demand is low, LP steam generated in the HRSG can be admitted to the steam turbine to produce more power. This offers a distinct advantage over the base Option 2 design, and Option 3 was selected for the conceptual layout and equipment selection.

In summary, the HRSG would generate HP steam at conditions that result in 915 psia / 900°F steam at the steam turbine throttle. In addition, the HRSG would generate saturated LP steam at 50 psia. HRSG LP steam would either be supplied for use in generating hot water for building heating, or excess LP steam would be admitted into the steam turbine. In the event that the required LP steam is more than can be supplied by the HRSG LP section, then additional LP steam would be provided by the steam turbine. Please see Figure 2-1 for the HRSG steam and electric power generation process flow diagram, and note that it is identical to Figure 1-1. It is shown in Attachment 1 to emphasize the concept of the district hot water heating system, and in Attachment 2 to emphasize the concept of the steam and electric power generation system.

For the purpose of considering an air permit for the revised combined cycle power plant, the Team considered the installation to be a steam electric station. To avoid the requirement of obtaining a PSD permit, the Team considered that a permit limiting NOX emissions to 100 tons per year was adequate technically, since the capacity factor required to achieve 100tpy was unachievable in the operational mode under consideration.

Plant Performance

Based on the above design, a heat balance model was created in GTP/GTM and various performance cases were run to understand how plant performance would vary over the year. The results of nine representative cases are shown in the enclosed Heat Balance runs, Figures 2-2 thru 2-10. Estimated net plant performance at various ambient temperatures and process steam flows is shown in the graph below.

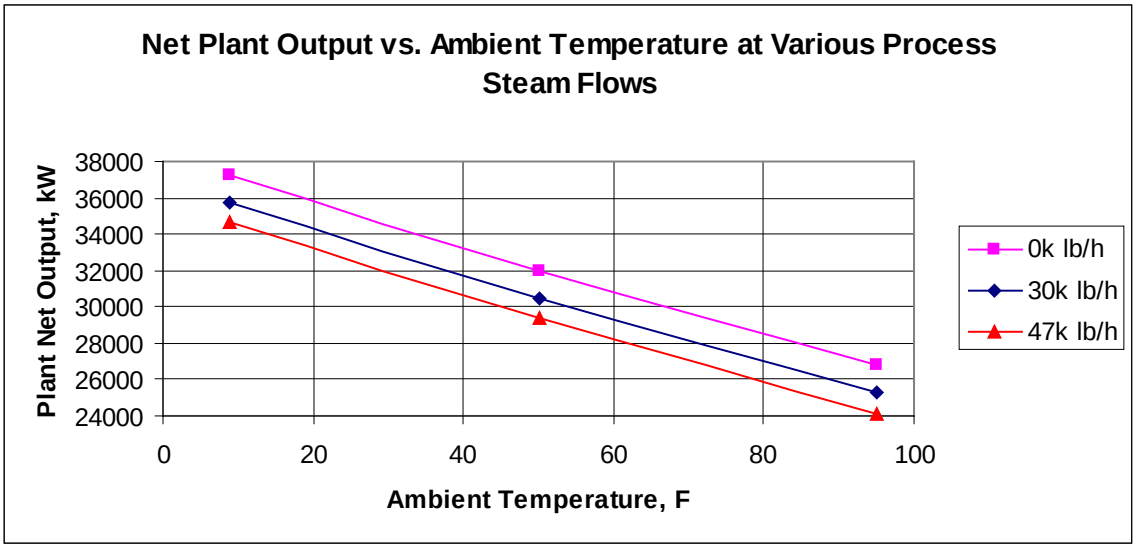


Figure 2-1 HRSG Steam and Electric Power Generation Process Flow Diagram
Figure 2-2 Heat Balance; 95F/11% RH & Moderate Steam Flow to HW Heat Exchanger
Figure 2-3 Heat Balance; 95F/11% RH & No Steam Flow to HW Heat Exchanger (Max Power)
Figure 2-4 Heat Balance; 95F/11% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)
Figure 2-5 Heat Balance; 50F/5% RH & Moderate Steam Flow to HW Heat Exchanger
Figure 2-6 Heat Balance; 50F/5% RH & No Steam Flow to HW Heat Exchanger (Max Power)
Figure 2-7 Heat Balance; 50F/5% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)
Figure 2-8 Heat Balance; 9F/20% RH & Moderate Steam Flow to HW Heat Exchanger
Figure 2-9 Heat Balance; 9F/20% RH & No Steam Flow to HW Heat Exchanger (Max Power)
Figure 2-10 Heat Balance; 9F/20% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)

Figure 2-1: HRSG Steam and Electric Power Generation Process Flow Diagram

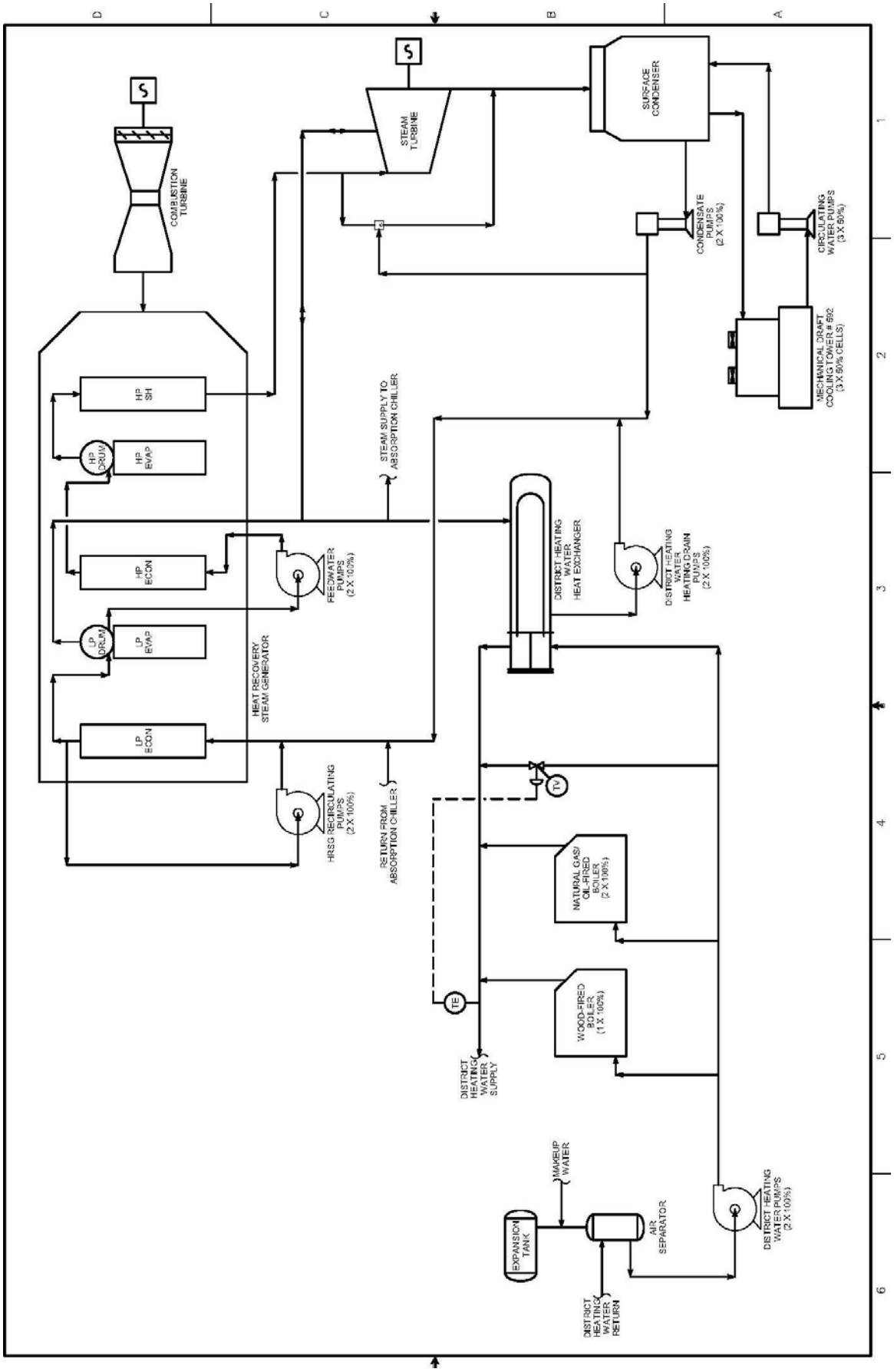


Figure 2-2
Heat Balance; 95F/11% RH & Moderate Steam Flow to HW Heat Exchanger

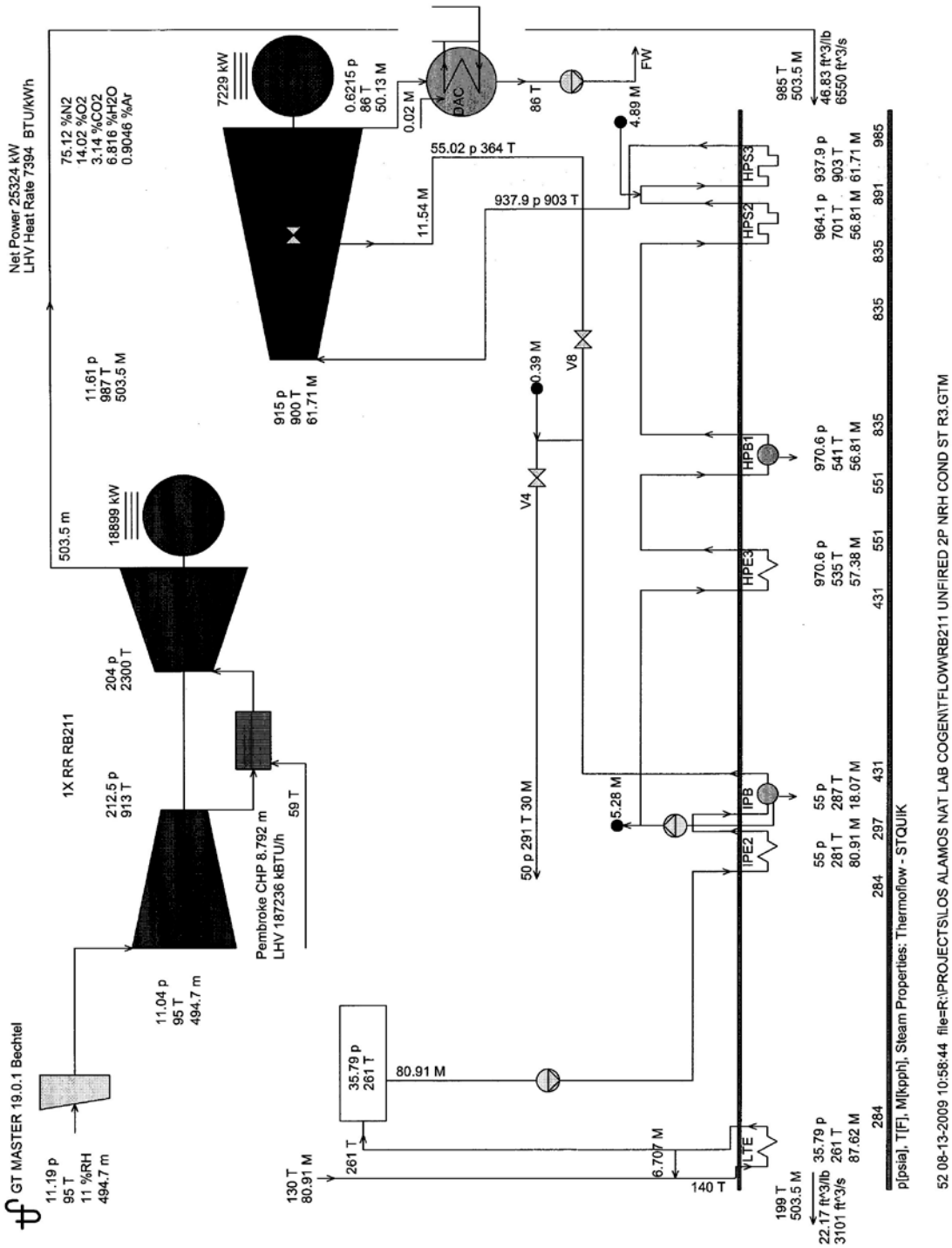


Figure 2-3
Heat Balance; 95F/11% RH & No Steam Flow to HW Heat Exchanger (Max Power)

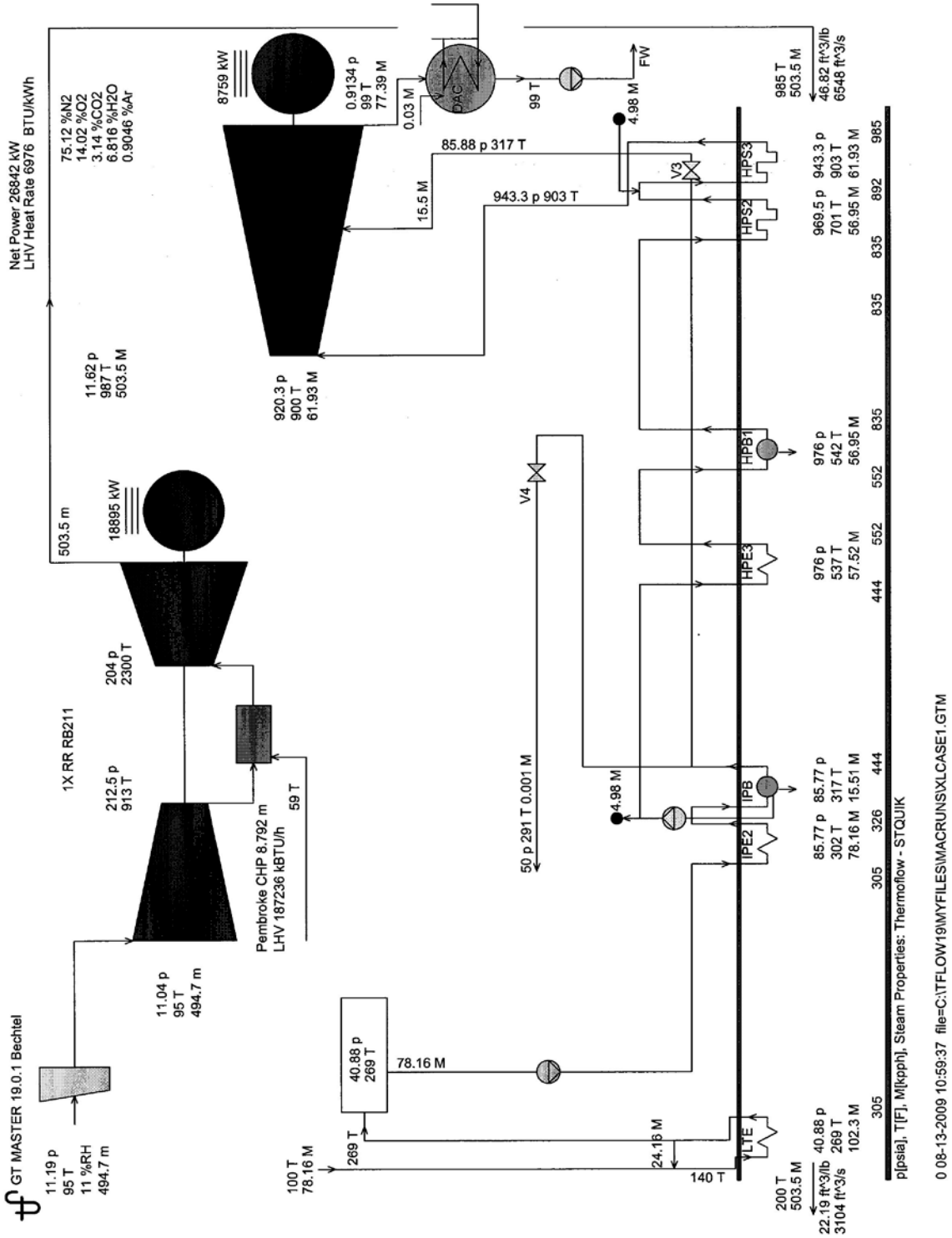


Figure 2-4
Heat Balance; 95F/11% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)

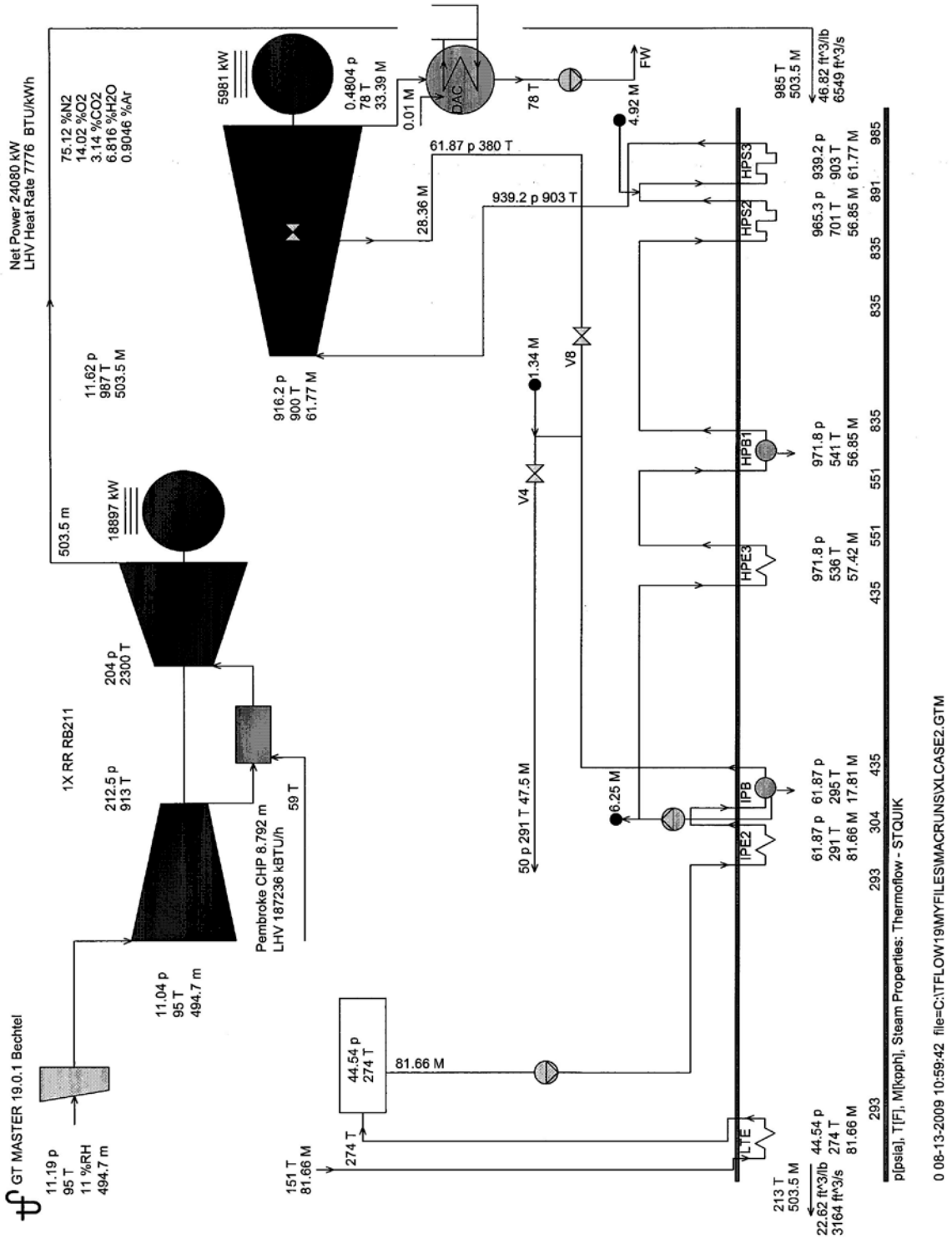


Figure 2-5
Heat Balance; 50F/5% RH & Moderate Steam Flow to HW Heat Exchanger

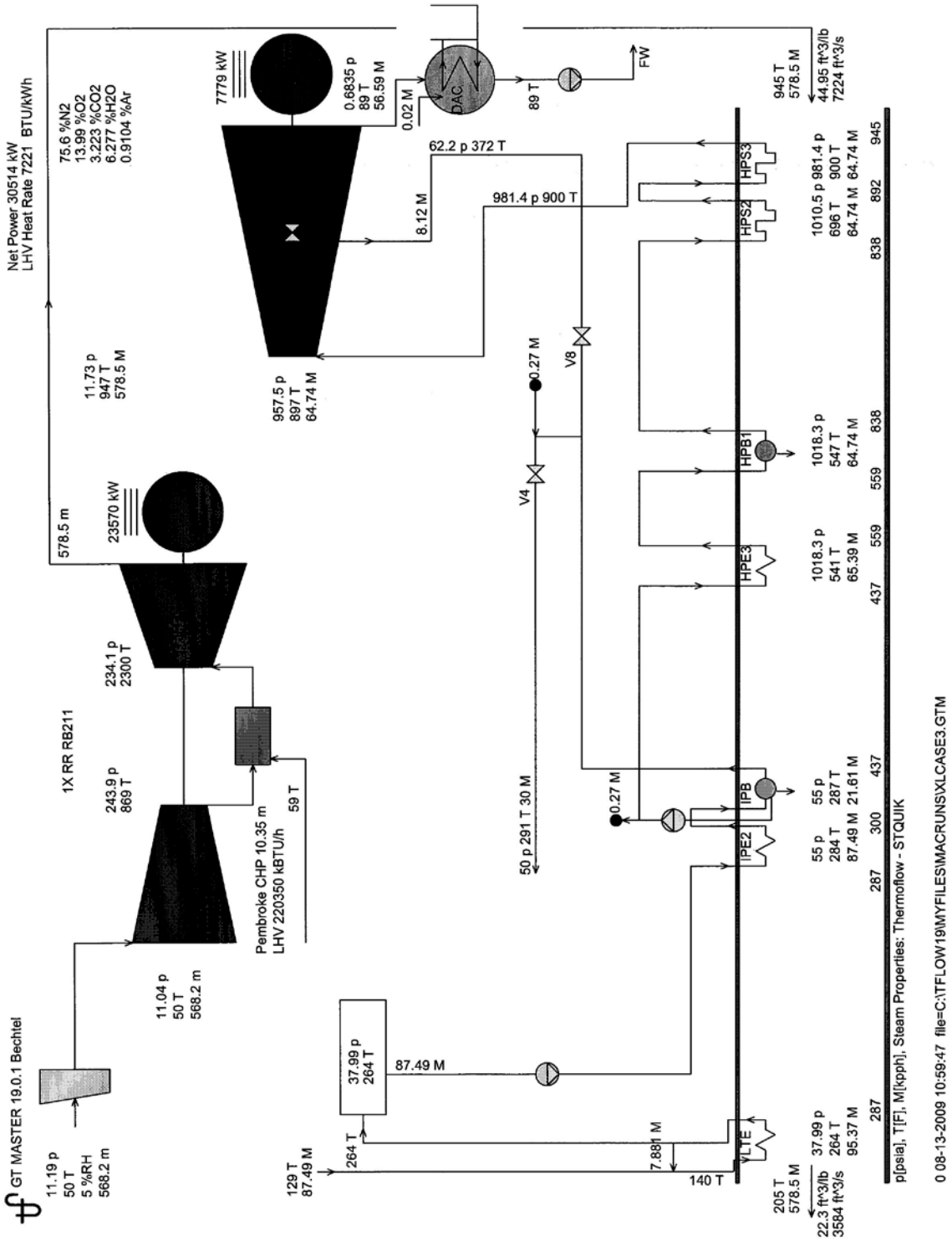


Figure 2-6
Heat Balance; 50F/5% RH & No Steam Flow to HW Heat Exchanger (Max Power)

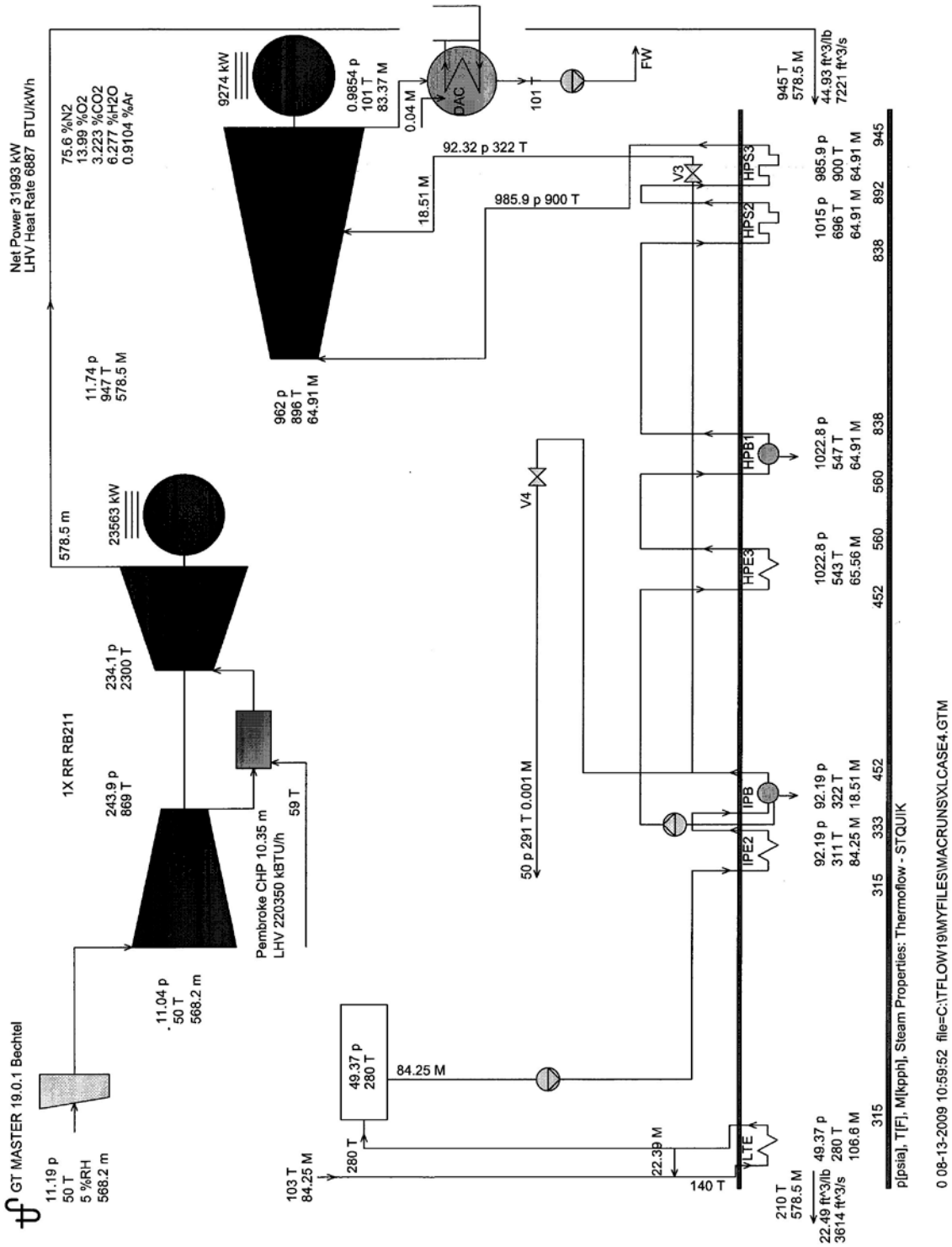


Figure 2-7
Heat Balance; 50F/5% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)

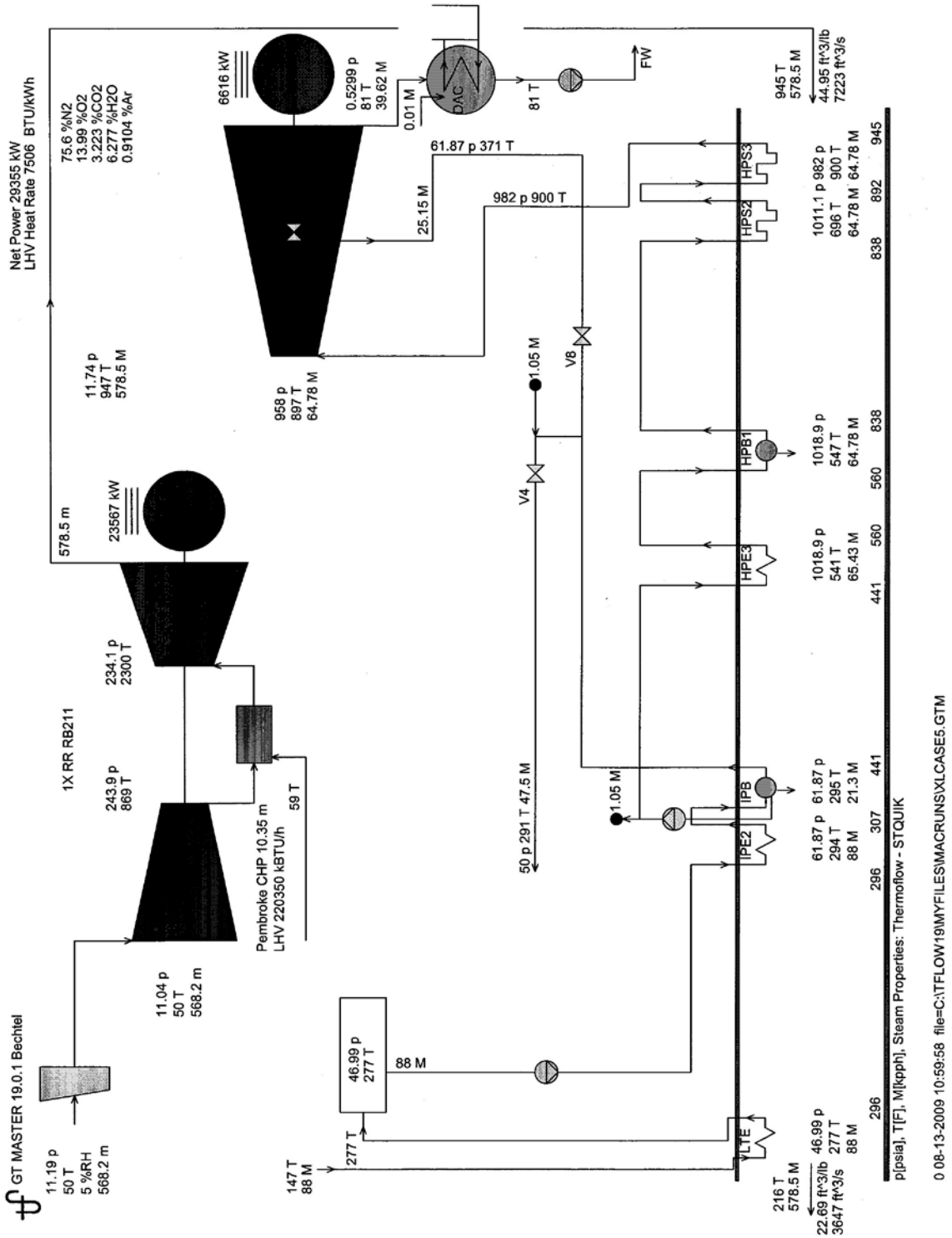


Figure 2-8
Heat Balance; 9F/20% RH & Moderate Steam Flow to HW Heat Exchanger

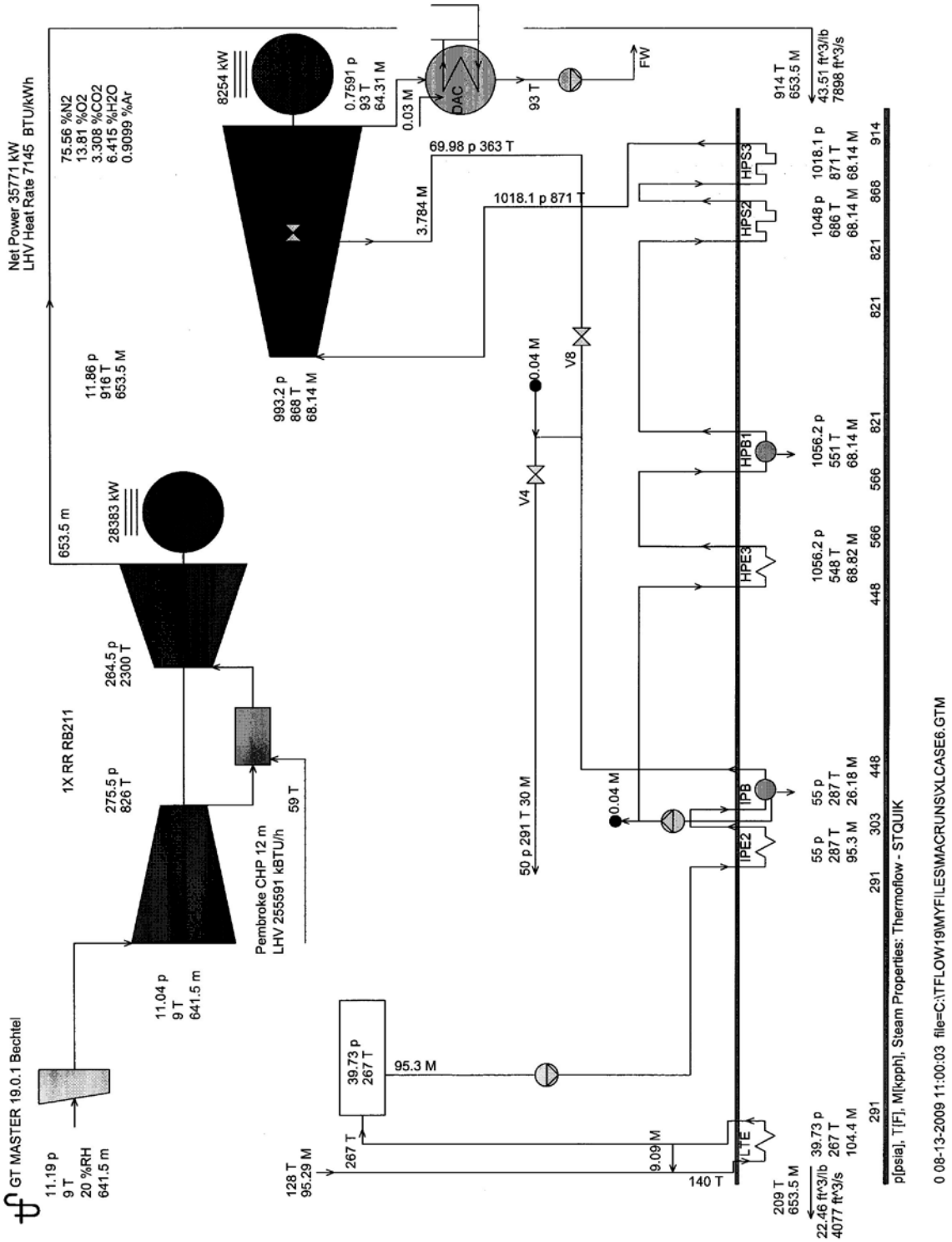


Figure 2-9
Heat Balance; 9F/20% RH & No Steam Flow to HW Heat Exchanger (Max Power)

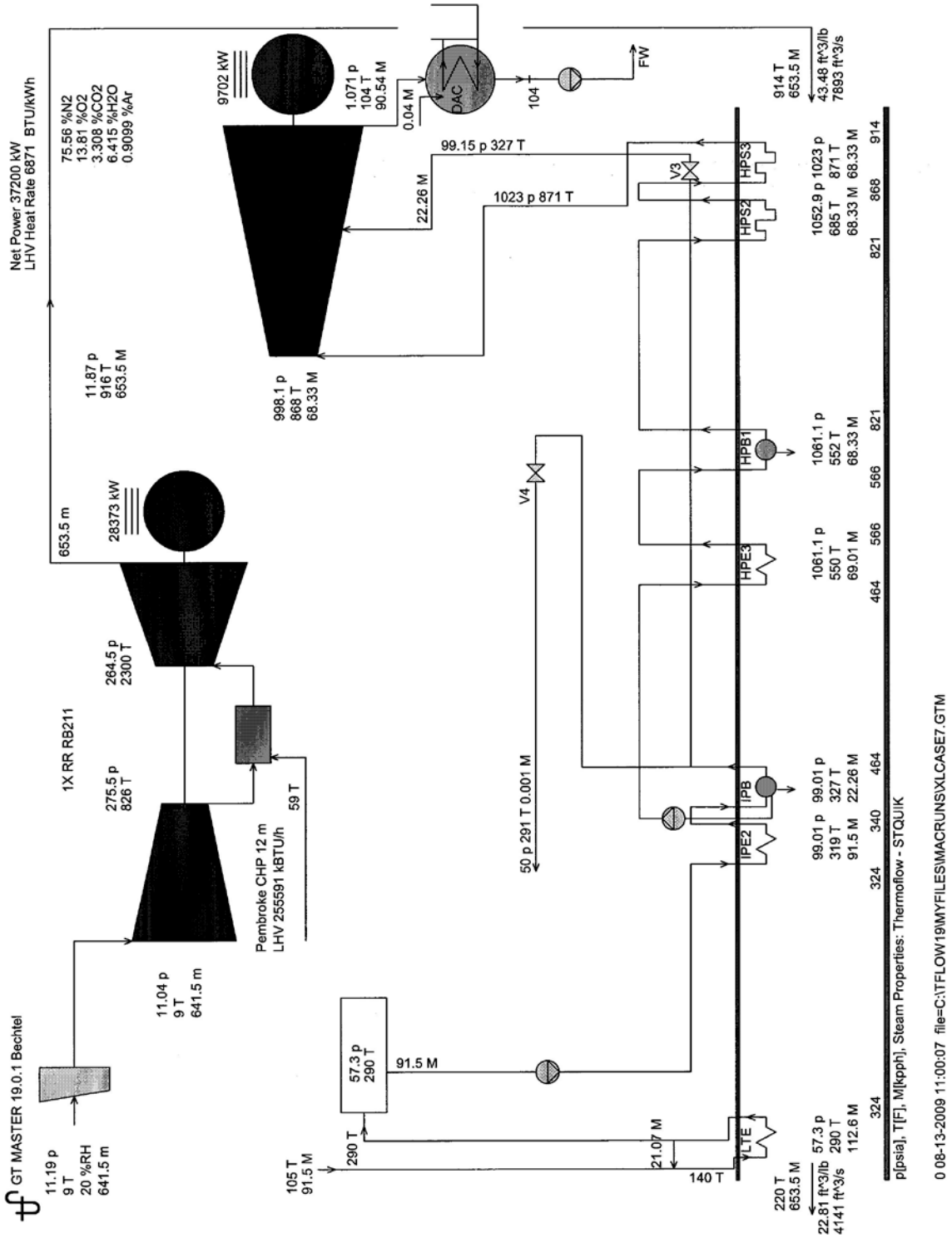
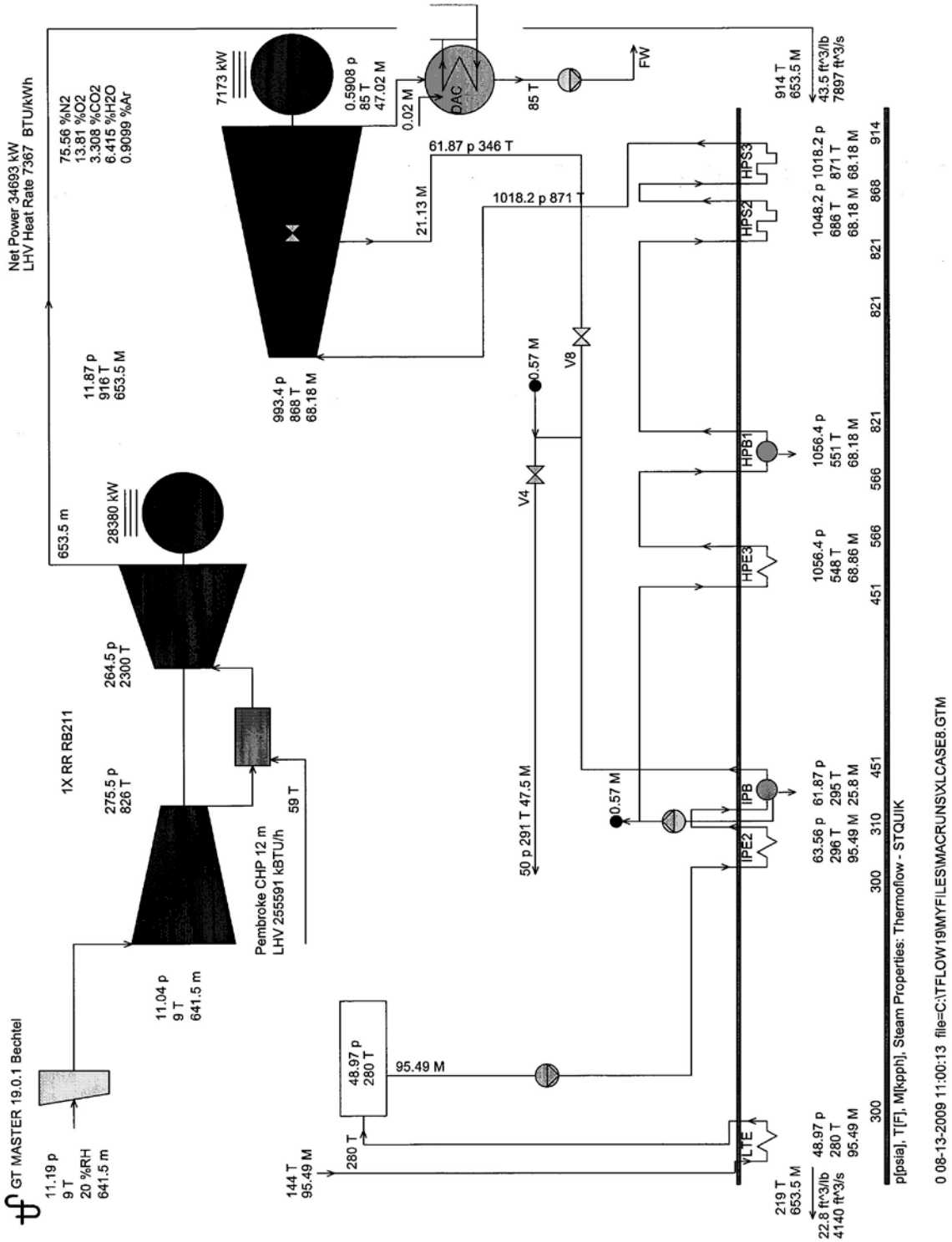


Figure 2-10
Heat Balance; 9F/20% RH & Maximum Steam Flow to HW Heat Exchanger (Min Power)



LANL STEAM PLANT PROJECT REPORT ATTACHMENT 3

Concept for New Biomass Hot Water Generating System Equipment

The Team requested conceptual proposals for a wood-fired boiler complete with traveling floor type material handling system and necessary appurtenances and auxiliary equipment. The potential suppliers were told that the fuel would be wood chips, not pellets; that the moisture content was to be considered as 50%; and that the available wood included ponderosa pine, pinon, juniper, white fir and douglas fir in descending order of availability. Proposals were received from Chiptec, Moss, and Hurst Boiler & Welding Co., Inc.

- The proposal from Chiptec includes a Chiptec Gasifier, Model B-600, which produces synthetic gas from wood chips to be burned in a packaged scotch marine type fire-tube ASME hot water boiler. The system includes Chiptec's moving wedge unloading system that is configured to be installed at grade and that accepts delivery of fuel from tractor trailers equipped with a self unloading system. The proposed receiving station has an overall foot print of approximately of 45 ft long x 12ft wide and fuel storage would consist of loaded trailers that would need to be kept on site. The boiler output is 20 MMBTU/HR with a discharge temperature of 230 °F. Estimated gasifier fuel feed rate is 6,700 lbs/hr. The budgetary quote for the gasifier and the boiler package is $ 1,750,000 and for the material handling system is an additional $ 350,000.

- The bid from Moss includes a gasifier combustion system designed to gasify wood chips, with the gas then being burned in a fire-tube boiler to produce 20 MMBTU/HR output of 230 °F hot water with a 180 °F return. The Moss gasifier system is an inclined cast iron grate assembly with internal ram transfer and steam injection for promoting syngas production, controlling fuel pile temperature and grate cooling. A thermal reactor ignition system is then used for combusting gases formed in the gasifier chamber. The system includes a walking floor fuel receiving system that is designed to receive fuel from dump trailer and is used to store the fuel until fed to the boiler metering bin. The floor system is sized to store approximately 50 tons of wood chips. The budgetary quote for this system is $ 1,709,152.

- Hurst Boiler & Welding Co., Inc. proposed the N 65 Firebox HPD UF package, which is a biomass fired hot water boiler. Their system consists of a substoichiometric wood fuel gasifier, which includes the metering bin, underfeed stoker, substoichiometric combustion air system, gasification chamber casing, and other related auxiliaries. For the combustion of fuel gas, Hurst furnishes a burner unit which includes a combustion air system and combustion chamber casing complete with their necessary auxiliaries. The Hurst hybrid boiler consists of a water-tube (radiant) section and a fire-tube (generator) section. Their offered material handling system includes a 6 section walking floor assembly with an estimated 100 ton capacity for fuel storage and transfer screw conveyors. The budgetary quote for the gasifier and the boiler package is $ 1,035,000 and for the material handling system is $ 232,000.

Each of the vendors was also asked if a 100 °F temperature rise across the boiler was achievable, this information being requested to be used in the potential future study to determine if a greater temperature rise (and corresponding lower water flow rate) would be of any benefit in the overall district heating system.

- Chiptec's response was that the maximum temperature rise they can generate is 90 °F.

- Moss indicated that a 50 °F is their maximum temperature rise in their fire-tube boilers and to achieve larger temperature differentials a water-tube boiler would be required. Based on the input from Moss, a water–tube boiler would be considerably more expensive.

- Hurst Boiler & Welding Co., Inc. suggested the use of a shunt pump to double the flow at the boiler while the system flow remains smaller; however they noted that it is best to have higher flows and smaller differential temperatures for the sake of thermal stress.

This matter must be studied in detail in the future if a change to higher temperature differential in the district heating system is pursued.

Each of the responses provided is technically acceptable for the conceptual conditions specified and includes the major equipment and accessories requested. However, there is additional equipment required to complete the installation of a workable biomass fired boiler. These additional items include a high pressure compressed air system (compressor, dryer and receiver) for soot blowing, compressed air feed for instrumentation, building ventilation and heating, boiler feed pumps (in this case, the district heating system pumps would serve this purpose), and fire protection systems. Although an allowance was made in the ROM estimate, these items must be considered and addressed in more detail in the final design and cost estimate for the project.

For information, Figure 3-1 shows the composition of fuel from ponderosa pine as gathered from the Phyllis data base. Figure 3-2 shows the composition of fuel from white fir & pine from the same data base. Phyllis is a database available to everyone on the Internet that contains information on the composition of biomass and waste. Phyllis presents data that enables analysis of individual biomass or waste materials available and offers the possibility of obtaining the average composition of any combination of groups and/or subgroups. From a review of the data in these Figures, the Team has assessed that a hot water boiler similar to that shown in Figure 3-3 would perform adequately at LANL.

For convenience, Figure 3-3 shows the Hurst Catalog #W25 N65 wood fired hot water boiler. This is also the boiler that was used in Conceptual Plant Arrangement shown in Attachment 8. Figure 3-4 provides information on the specified overall performance characteristics of the wood fired hot water boiler.

Figure 3-1 Ponderosa Pine Composition Data Table
Figure 3-2 Fir and Pine Composition Data Table
Figure 3-3 W-25 Firebox with Floor
Figure 3-4 Biomass Boiler Overall Performance

Figure 3-1

Ponderosa Pine Composition Data Table

PHYLLIS

the composition of biomass and waste

General information

Sample information	
Group	untreated wood
Subgroup	fir/pine/spruce
Material	wood, ponderosa pine
ID-number	1339
Reference:	O. Kitani and C. W. Hall: Biomass Handbook, Gordon and Breach science publishers, New York (1989).
Remarks:	

Material composition

Proximate analysis (wt. %)	dry	daf	ar	Ultimate analysis (wt. %)	dry	daf	ar
Ash	0.3		-	C	49.3	49.4	- Msr
Water			-	H	5.99	6	- Msr
Volatiles	82.5	82.8	-	O	44.4	44.5	- Msr
				N	0.06	0.06	- Msr
Calorific value (kJ/kg)				S	0.03	0.03	- Msr
	dry	daf	ar	Cl	0.01	0.01	- Msr
HHV	20020	20078	-	F	-	-	- ND
LHV	18713	18767	-	Br	-	-	- ND
HHV_{Milne}	19380	19437	-	Total:	100	100	0

Elemental analysis (mg/kg sample (dry))					
Al	- ND	Fe	- ND	Pb	- ND
As	- ND	Hg	- ND	Sb	- ND
B	- ND	K	- ND	Se	- ND
Ba	- ND	Mg	- ND	Si	- ND
Ca	- ND	Mn	- ND	Sn	- ND
Cd	- ND	Mo	- ND	Sr	- ND
Co	- ND	Na	- ND	Te	- ND
Cr	- ND	Ni	- ND	Ti	- ND
Cu	- ND	P	- ND	V	- ND
				Zn	- ND

Biochemical composition (wt.% dry)	
Method of analysis	Not Determined
Total Ash + Biochemical	*0.3*
Cellulose	- ND
Hemicellulose	- ND
Lignin	- ND

Lignin acid insoluble (AIL)	- ND
Lignin acid soluble (ASL)	- ND
Lipids	- ND
Protein	- ND
Extractives EtOH/toluene	- ND
Extractives 95% EtOH	- ND
Extractives hot water	- ND
Starch	- ND
Pectin	- ND
SUM C5	*0*
Arabinan	-
Xylan	-
SUM C6	*0*
Mannan	-
Galactan	-
Glucan	-
Rhamnan	-
Total non-structural carbo-hydrates (TNC)	- ND

Glossary	
daf	dry ash free
ar	as received
Msr	Measured
Lim	detection Limit
Cal	Calculated
ND	Not Determined
Unk	Unknown
Avg	Average
Sst	van Soest
Sgr	Sugar Analysis

Ash composition

Ash production method
-

Bulk density (kg ar/m3)
-

Ash composition (wt.% (ash))							
CO_2	-	P_2O_5	-	Al_2O_3	-	Na_2O	-
SO_3	-	SiO_2	-	CaO	-	K_2O	-
Cl	-	Fe_2O_3	-	MgO	-	TiO_2	-

Ash composition (mg/kg (ash))			
Pb	-	Hg	-
Cd	-	Mn	-
Cu	-	Cr	-

Remarks:

Database Version: Wed Apr 29 16:05:02 UTC+0200 2009

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Energy research Centre of the Netherlands (ECN) P.O. Box 1, 1755 ZG Petten, tel. +31 224 56 49 49
Webdesign and implementation by ECN-E&S

Figure 3-2

Fir and Pine Composition Data Table

PHYLLIS

the composition of biomass and waste

General information

Sample information	
Group	untreated wood
Subgroup	fir/pine/spruce
Material	white fir and ponderosa pine
ID-number	2801
Reference:	P. Thy, B.M. Jenkins, C.E. Lesher, S.Grundvig: Compositional constraints on slag formation and potassium volatilization from rice straw blended wood fuel. Fuel Processing Technology 87 (2006) 383-408
Remarks:	525°C ash contains 6.24% CO2, 0.69% SO2 and less than 0.065% Cl. 950°C ash ash contains 2.64% MnO too.

Material composition

Proximate analysis (wt. %)	dry	daf	ar
Ash	1.2		1.1
Water			10.4
Volatiles	-	-	-
Calorific value (kJ/kg)	**dry**	**daf**	**ar**
HHV	-	-	-
LHV	-	-	-
HHV_{Milne}	21254	21512	19044

Ultimate analysis (wt. %)	dry	daf	ar	
C	54.2	54.8	48.5	Msr
H	5.83	5.9	5.2	Msr
O	40.8	41.3	36.5	Msr
N	0.08	0.08	0.07	Msr
S	0.02	0.02	0.02	Msr
Cl	0.033	0.034	0.03	Msr
F	-	-	-	ND
Br	-	-	-	ND
Total:	102.1	102.2	101.9	

Elemental analysis (mg/kg sample (dry))					
Al	- ND	Fe	- ND	Pb	- ND
As	- ND	Hg	- ND	Sb	- ND
B	- ND	K	- ND	Se	- ND
Ba	- ND	Mg	- ND	Si	- ND
Ca	- ND	Mn	- ND	Sn	- ND
Cd	- ND	Mo	- ND	Sr	- ND
Co	- ND	Na	- ND	Te	- ND
Cr	- ND	Ni	- ND	Ti	- ND
Cu	- ND	P	- ND	V	- ND
				Zn	- ND

Biochemical composition (wt.% dry)	
Method of analysis	Not Determined
Total Ash + Biochemical	*1.2*
Cellulose	- ND

Hemicellulose	- ND
Lignin	- ND
Lignin acid insoluble (AIL)	- ND
Lignin acid soluble (ASL)	- ND
Lipids	- ND
Protein	- ND
Extractives EtOH/toluene	- ND
Extractives 95% EtOH	- ND
Extractives hot water	- ND
Starch	- ND
Pectin	- ND
SUM C5	*0*
Arabinan	-
Xylan	-
SUM C6	*0*
Mannan	-
Galactan	-
Glucan	-
Rhamnan	-
Total non-structural carbo-hydrates (TNC)	- ND

Glossary	
daf	dry ash free
ar	as received
Msr	Measured
Lim	detection Limit
Cal	Calculated
ND	Not Determined
Unk	Unknown
Avg	Average
Sst	van Soest
Sgr	Sugar Analysis

Ash composition

Ash production method

Ash content determined at 525°C, ash composition after heating to 950°C (resulting in 27.59% loss)

Bulk density (kg ar/m3)

-

Ash composition (wt.% (ash))							
CO_2	-	P_2O_5	4.7	Al_2O_3	4.7	Na_2O	0.6
SO_3	-	SiO_2	14	CaO	48	K_2O	16.1
Cl	-	Fe_2O_3	1.7	MgO	7.4	TiO_2	0.2

Ash composition (mg/kg (ash))			
Pb	-	Hg	-
Cd	-	Mn	-
Cu	-	Cr	-

Remarks:

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Webdesign and implementation by ECN-E&S

Figure 3-3
W-25 Firebox with Floor

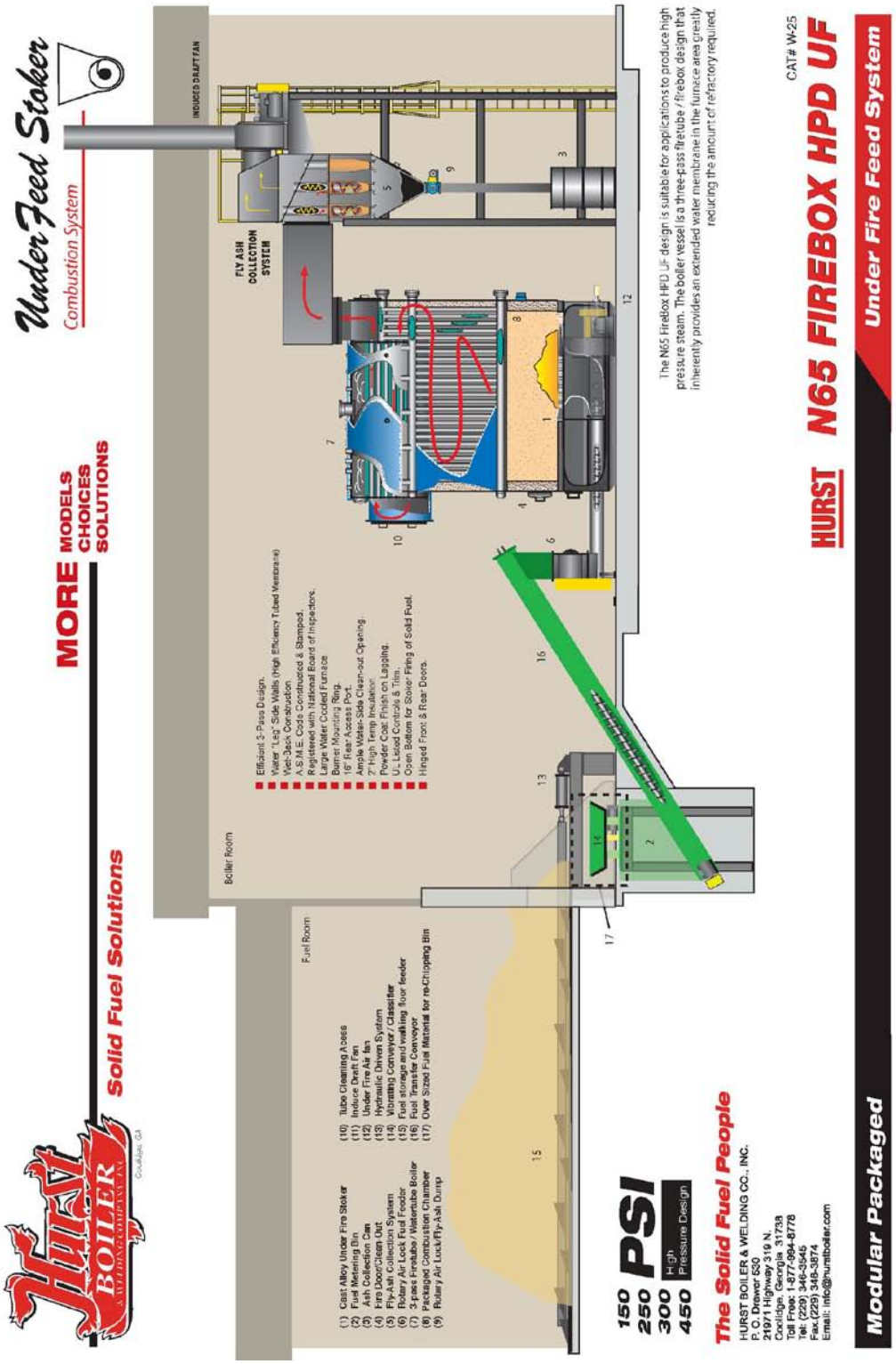


Figure 3-4

Biomass Boiler Overall Performance

Biomass Boiler	
Boiler horsepower	600
Boiler heat output, Btu/hr	20,100,000
Boiler efficiency based on HHV, %	70%
Boiler heat input, Btu/hr	28,700,000
Steam flow, lb/hr	9,150
Operating Pressure, psia	315
Saturation Temp,°F	422
Saturation Enthalpy, Btu/lb	1203.3
Feedwater temperature, °F	180
Feedwater enthalpy, Btu/lb	148.0
Fuel HHV, Btu/lb	7000
Fuel Moisture	50%
Fuel LHV, Btu/lb	
Fuel lb/hr	4,099
Fuel demand, US tons/day	49
Truck Size, tons	22
Deliveries, trucks/ week	15.7
Pressure reducing station	
Upstream enthalpy loss, Btu/lb	0
Outlet steam Pressure, psia	115
Outlet Steam Temperature, °F	350.2
Outlet Steam enthalpy, Btu/lb	1196.8
Superheat, °F	20
Dusuperheating flow %	0.62%
Dusuperheating flow, lb/hr	118.34
Outlet steam flow, lb/hr	19,269
Emissions	
CO, lb/MMBtu	0.033
NOX, lb/MMBtu	0.177
Particulates, lb/MMBtu	0.024
CO, lb/hr	0.947
NOX, lb/hr	5.079
Particulates, lb/hr	0.689
Operating Hours/year	2190
CO, tons/year	1.04
Nox, Tons/year	5.56
Particulate, tons/year	0.75

LANL STEAM PLANT PROJECT REPORT ATTACHMENT 4

Concept for New Dual-Fuel Hot Water Generating System Equipment

The Team requested conceptual proposals for two dual fuel natural gas/oil-fired boilers each with an output capacity of 68 MMBTU/HR complete with all necessary appurtenances and auxiliary equipment. Bidders were asked to provide two proposals; one for a 50 °F rise across the boiler (180 °F inlet and 230 °F outlet), and one for a 100 °F rise (180 °F inlet and 280 °F outlet). Bids were received from Cleaver-Brooks and Indeck Power Equipment Company.

- Cleaver-Brooks provided only one of the two requested options; a 68 MMBTU/HR boiler with 100 °F rise across the boiler (180 °F inlet and 280 °F outlet). Their offer is for an indoor installation and includes the pressure vessel, trim, NATCOM burner, burner management system, and combustion controls, which operates at 77 psig with a design pressure of 260 psig. The water flow at outlet temperature is 1446 gpm. The budgetary quote for this offer is $ 950,000 per generator. A natural gas/oil-fired boiler with 68 MMBTU/HR and 50 °F rise does not fit any of the boilers in their line of production and they therefore did not provide a proposal for the 50 F temperature rise option.

- Indeck Power Equipment Company provided two proposals as requested. The first option utilizes their Indeck/IBW International-Lamont® High Temperature Hot Water Generator, Model TJW-C-90. The units are designed to produce 68 MMBTU/hr capacity of high temperature hot water with an outlet temperature of 230°F and return temperature of 180°F. The equipment proposed would be designed, built and stamped in accordance with the latest edition of ASME Power Boiler Code for a design pressure of 100 PSIG and would fire natural gas or No. 2 fuel oil. The Generator would include the manufacturer's standard trim and controls. The second option is the Indeck/IBW International-Lamont® High Temperature Hot Water Generator, Model TJW-C-62.5. That proposed unit would be designed to produce 68 MMBTU/hr capacity of high temperature hot water with an outlet temperature of 280°F and return temperature of 180°F; and would be designed, built and stamped in accordance with the latest edition of ASME Power Boiler Code for a design pressure of 150 PSIG, and would be designed to fire natural gas and No. 2 oil. The Generator also includes the manufacturer's standard trim and controls.

  The budgetary quote for model TJW-C-90 is $ 1,100,219 per generator and the budgetary quote for model TJW-C-62.5 is $ 990,977 per generator.

Attachment 1 to this Report shows a conceptual process flow diagram that includes two new hot water boilers. Attachment 8 shows a conceptual layout of the equipment.

STEAM PLANT REPORT
DRAFT
ATTACHMENT 5

Concept for New Heat Recovery Steam Generator and Steam Turbine Generator Equipment

To support the conceptual design and estimate, the Team requested conceptual proposals for a two pressure, non-reheat, natural circulation HRSG with no duct firing including the necessary appurtenances and auxiliary equipment. Proposals were received from Rentech Boiler Systems, Nooter/Eriksen, and Innovative Steam Technologies. In addition, bids were solicited for a dual admission steam turbine generator package which would include the necessary lubricating oil, control oil, stator cooling, and gland steam systems. A summary of the conceptual proposals received for each piece of equipment is included below:

HRSG

- The proposal from Rentech is a drum type HRSG and includes HP economizer, evaporator, drum, and superheater; and LP evaporator, drum, and feedwater heater. It also includes the main stack, feedwater recirculating pump and motor, field mounted instrumentation, and the interconnecting piping between heat transfer sections. The performance of this HRSG satisfies the majority of the requested parameters, with the HP and LP flows being marginally less than requested. Overall, the proposal from Rentech is considered technically adequate and the budgetary price for this unit is $3,600,000.

- The bid from Nooter/Eriksen is also a drum type HRSG and includes HP economizer, evaporator, drum, and superheater; and LP evaporator, drum, and feedwater preheater. The performance of this HRSG meets the requested parameters and is considered technically adequate. The budgetary price for this HRSG is $ 5,500,000.

- The bid from Innovative Steam Technologies is a once through HRSG, which means there are no steam drums. In this HRSG feedwater travels through the tubes of different sections gaining heat until steam is ultimately generated at the outlet. The proposed HRSG has two pressure levels as requested and the overall performance of the unit is marginally below the requested parameters, but within the range that would still be technically adequate. The budgetary price for this HRSG is $ 3,178,000.

The design considered in this report is based upon the drum type HRSG offered by Rentech and Nooter/Eriksen. However, it is suggested that a future study should consider the potential benefits of the once through design offered by Innovative Steam Technologies. The once through design offers the benefit of having no blowdown systems, a smaller overall footprint, and no bypass system is required to operate the CGTG in simple cycle mode.

STG

While several potential suppliers were contacted, only one proposal was received for the STG. This proposal was submitted Mann-Turbo and consists of a geared, dual admission multistage turbine, generator, lubricating oil skid, control oil skid, stator cooling system, gland steam system and electrical and control cabinets. The nominal output of the proposed STG is 8 MW based on the winter operating conditions and 10 MW based on the summer conditions. The budgetary pricing for the STG package is $5,500,000.

While the HRSG and STG are the main pieces of equipment that must be purchased to utilize the existing CGTG in combined cycle mode, there are a considerable number of additional pieces of

equipment that would be required. These include a condenser, feedwater pumps, condensate pumps, instrument air system (compressors, dryers, and receiver), and component cooling water system (pumps and heat exchangers). While allowances were made for such equipment in the layout and ROM estimate, these items must be considered and addressed in more detail in the final design and cost estimate for the project.

Attachment 2 to this Report shows a conceptual process flow diagram that includes new HRSG and STG equipment. Attachment 8 shows a conceptual layout of the equipment

LANL STEAM PLANT PROJECT REPORT ATTACHMENT 6

Concept for New District Chilled Water System and Equipment

The Team has developed a concept for the installation of a 5,000 Ton (refrigeration) (TR) chilled water system, including a 1 million gallon chilled water storage tank, to produce chilled water for use in the district cooling system. The system is intended to provide chilled water to buildings 1498, 207, 1400, 261, 2327, 2322 and 1406. Please refer to Figure 6-1 for concept of the new chilled water system in Technical Area 3.

Similar to the district heating system described in Attachment 1, the chilled water would be circulated through a closed loop system, which starts as a larger diameter piping header at the chiller plant outlet and get progressively smaller as the chilled water flows in sequence through the cold side of the existing building heat exchangers along the loop. The return loop would start as a smaller diameter system and get progressively larger as the warmer water is collected in sequence from each building in the loop.

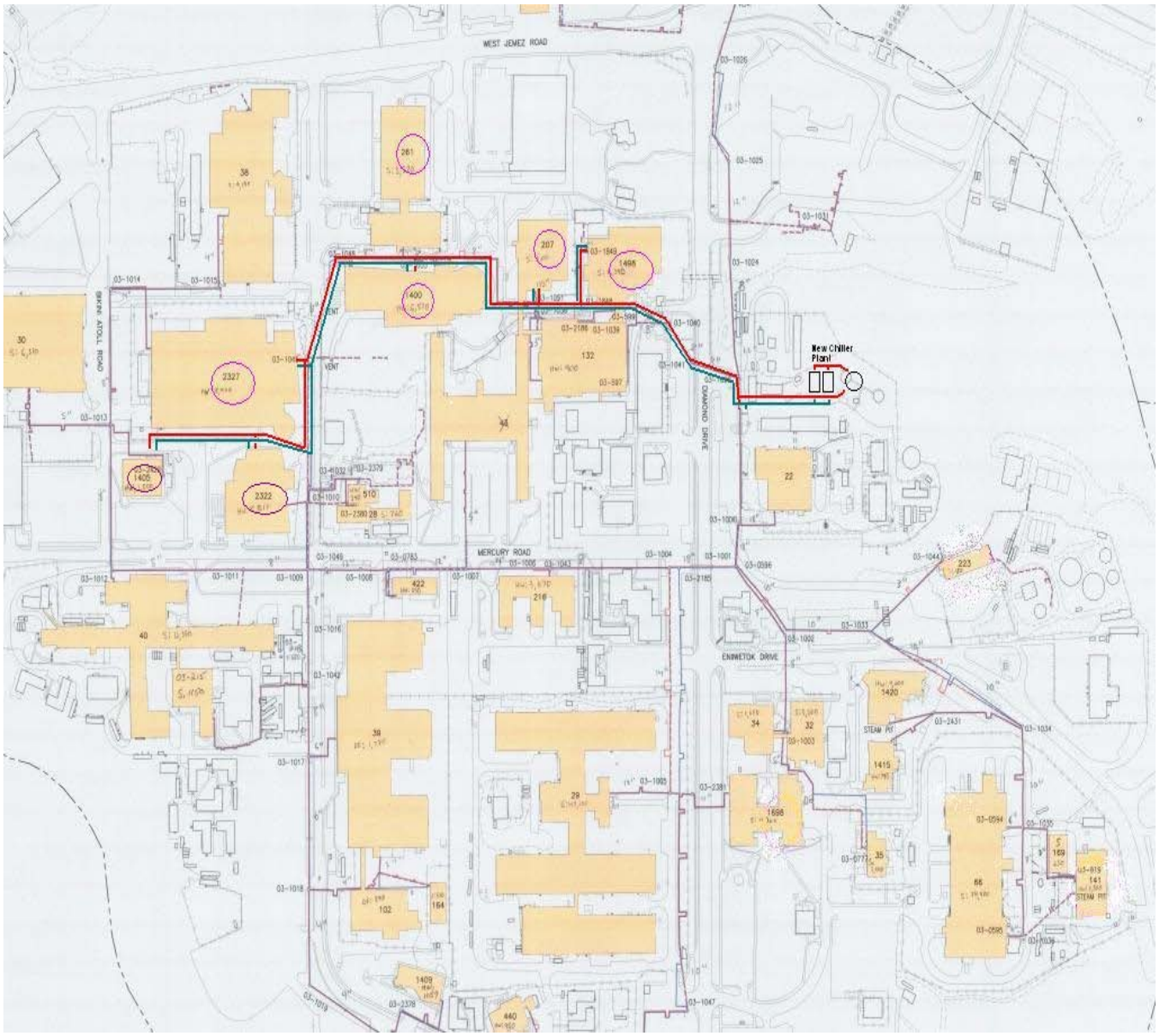
A chilled water storage tank is included in the concept for the new district chilled water system. This concept would contribute to the effort to avoid upgrading LANL's electric power import capabilities. Operationally, this would normally mean running the chillers during the evening hours when bulk electricity rates are at the lowest under existing power purchase agreements. The stored chilled water can then be used during peak demand periods without expending additional electric energy on chiller operation. Another consideration for later incorporation into the storage system is to provide a water-side economizer, i.e., a cooling tower to heat exchanger configuration. This type of system could provide chilled water to the storage tank (or even for direct use in the chilled water system under appropriate conditions) without having to operate the chillers themselves because of the dry bulb temperature at night for much of the year at Los Alamos.

The Team requested conceptual proposals for a chilled water system and necessary appurtenances and auxiliary equipment from several known suppliers. Only one proposal was received, that from Stellar.

Stellar's proposed a budget pricing for the design, supply, and commissioning of the chiller modules, cooling tower, and a thermal storage pumping skid. The proposal includes two (2) 2,500TR chiller modules including evaporator, condenser, ASME vessels, and Neoprene isolation pads. The package has two (2) 100% variable speed vertical primary chilled water pumps, two (2) 50% constant speed vertical condenser water pumps, four (4) cell induced-draft cooling tower with stainless steel basin, chemical pot feeder, condenser water treatment system, expansion tank, Allen-Bradley PLC based control system, structural steel base, and factory package enclosure. All required valves and piping associated with the chiller modules are included in the proposal. A tank pumping skid is also provided with (3) 50% variable speed pumps for the thermal storage tank. The budgetary quote for the proposed chilled water plant system and TES tank pump skid is $3,490,000. The thermal storage tank pricing is quoted as $850,000 for a total equipment price of $4,340,000.

Figure 6-1 Conceptual New Chilled Water System in TA-3

Figure 6-1
Conceptual New Chilled Water System in TA-3



LANL STEAM PLANT PROJECT REPORT ATTACHMENT 7

Concept for High Voltage Electrical System Upgrades and ROM Estimate for Reconductoring the Norton Line

The high voltage system servicing LANL is shown in the form of a single line diagram in Figure7-1. This diagram is a reprint of the Utilities and Infrastructure FOD's (Facility Operations Division) drawing dated January 1, 2009 and will assist all persons reading this Report to understand the system.

As discussed in Section 3.3.1 of this Report, It is possible to put new conductors on the existing poles on the Norton Line. Bechtel's estimating data base uses as a thumb rule that new transmission lines similar in configuration and voltage to the Norton Line cost approximately one million dollars per mile ($1,000,000/mi) to install. This thumb was independently confirmed with an operating utility specifically for this Report, and is a generally accepted industry standard for ROM estimating purposes. If all of the structures that comprise the Norton Line and their respective foundations are determined by inspection to be in excellent or very good condition; and if nothing needs to be replaced structurally in the field, then the only field work to be done would be to install the new conductors themselves and the attachment means from the conductor to the insulator. Under these conditions, the actual cost should come down to be between 50% and 75% of that new installation ROM cost. For the sake of this Report, we have chosen to use a ROM estimate for reconductoring the Norton Line with single 954 kcmil ACSR conductors as eight million four hundred thousand dollars ($8,400,000). We have also chosen to use a ROM estimate for reconductoring the Norton Line with bundled 477 kcmil ACSR conductors as eleven million dollars ($11,000,000). Please see Figures 7-2 and 7-3 to better understand the concept and conceptual layout for reconductoring the Norton Line.

As discussed in Section 3.3.2, Tecumseh Professional Associates, Inc. ("Tecumseh"), is a merchant developer pursuing a project to bring a 345 kV transmission line from the Ojo substation in far northern New Mexico to the Norton Substation near Los Alamos. Please see Figures 7-4 and 7-5 to better understand the concept and conceptual layout for the preferred method of achieving their goal and the route for this line. Tecumseh believes they can advance the project to the next phase if they can reach a financially reasonable agreement with one more Pueblo, since the other property owners along the proposed line appear to be favorably disposed to supporting the project. Please further see Figures 7-6 and 7-7 to better understand the concept and conceptual layout for the alternative method of achieving their goal and the route for such a line.

As discussed in Section 3.3.3, a project called the third transmission line has been under study and consideration for a number of years. Please see Figures 7-8 and 7-9 to better understand the concept and conceptual layout for the third transmission line.

Figure 7-1 Los Alamos Service Area (LASO) Single Line
Figure 7-2 Reconductor ETA to Norton Substation; Single Line Diagram
Figure 7-3 Reconductor ETA to Norton Substation; Conceptual Layout Diagram
Figure 7-4 New OJO to Norton 345 kV Line; Line Single Line Diagram
Figure 7-5 New OJO to Norton 345 kV Line; Conceptual Layout Diagram
Figure 7-6 New OJO to STA 345 kV Line Second Choice Option; Single Line Diagram
Figure 7-7 New OJO to STA 345 kV Line Second Choice Option; Conceptual Layout Diagram
Figure 7-8 New STA to Norton Substation HV Line; Single Line Diagram
Figure 7-9 New STA to Norton Substation HV Line; Conceptual Layout Diagram

Figure 7-1

Los Alamos Service Area (LASO) Single Line

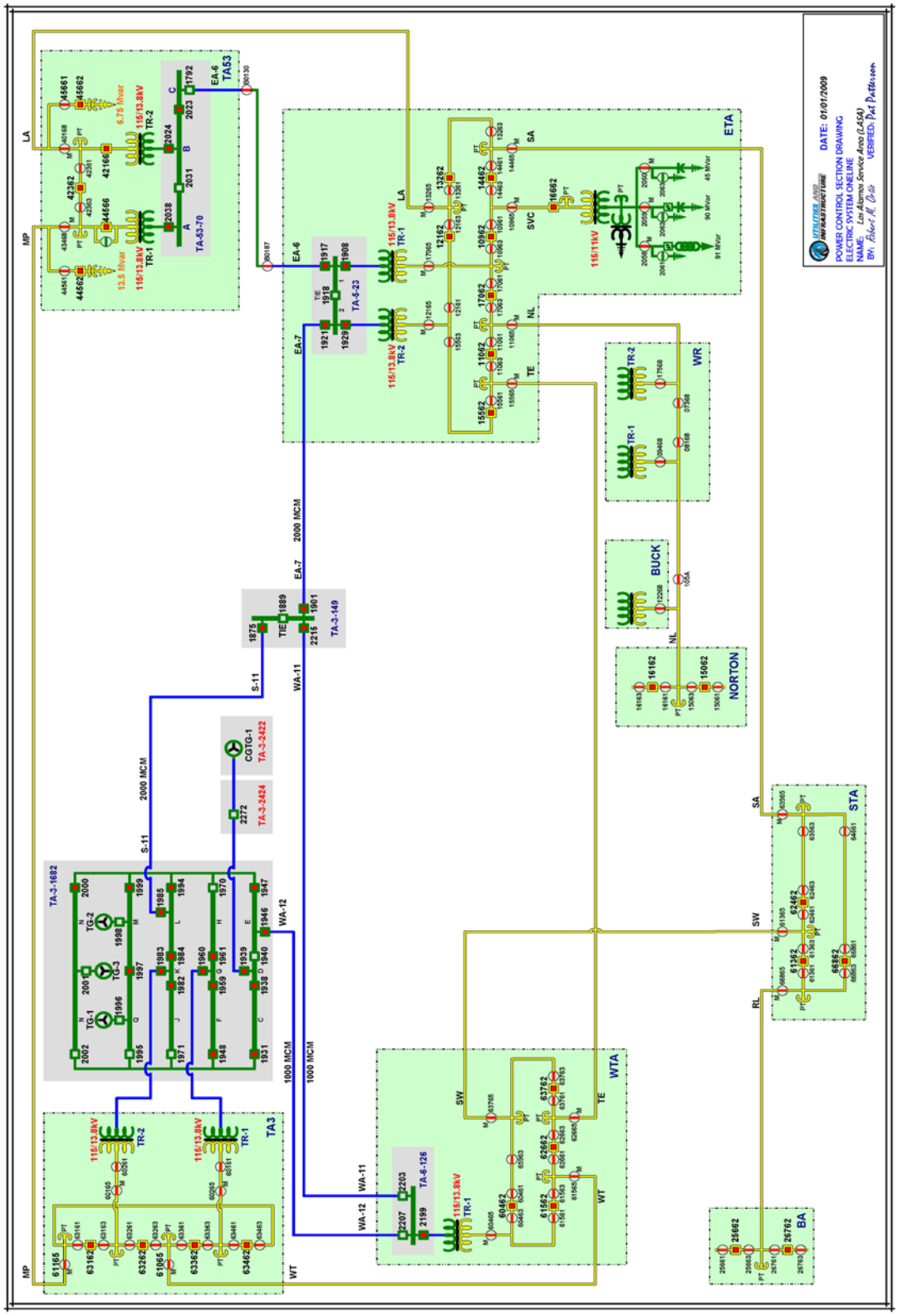


Figure 7-2

Los Alamos Area Transmission System
Reconductor ETA to Norton Substation Line
Single Line Diagram

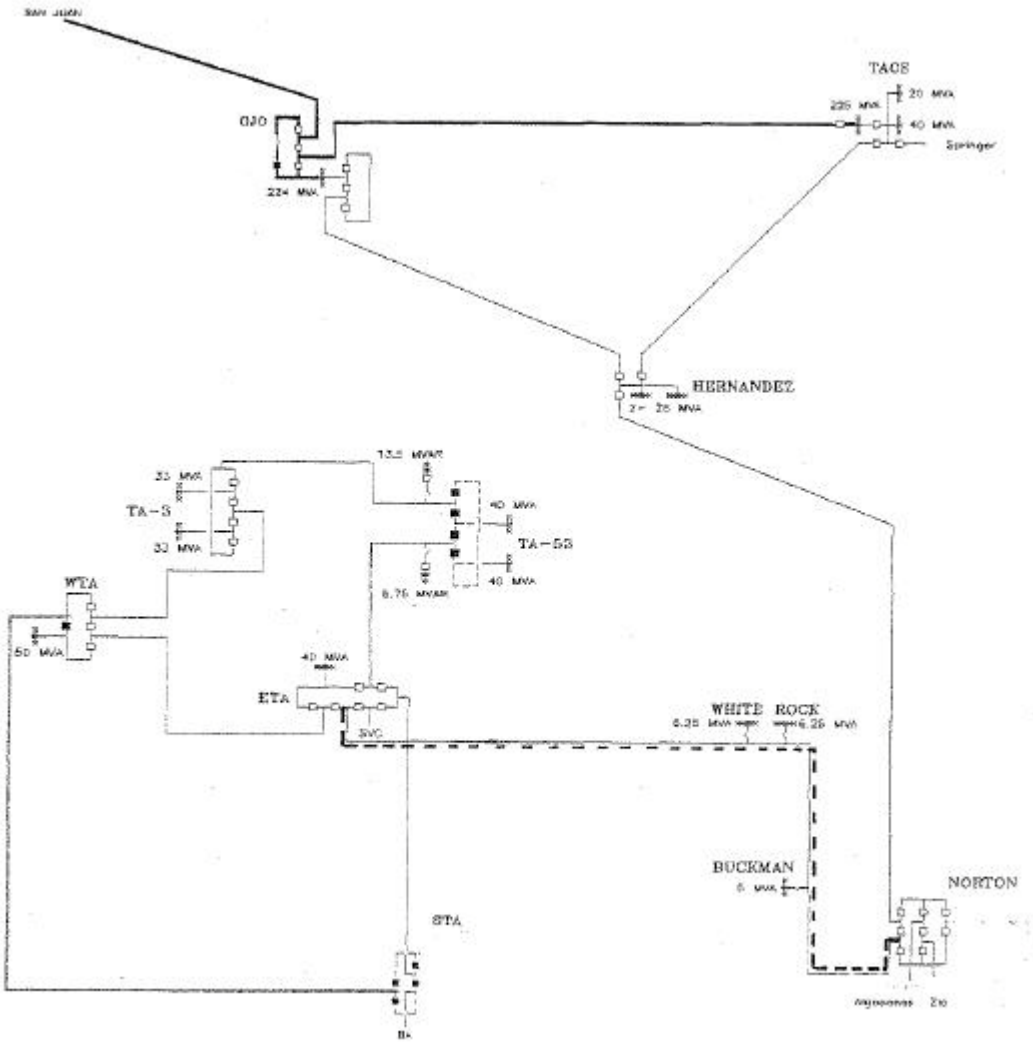


Figure 7-3

Los Alamos Area Transmission System
Reconductor ETA to Norton Substation
Conceptual Layout Diagram

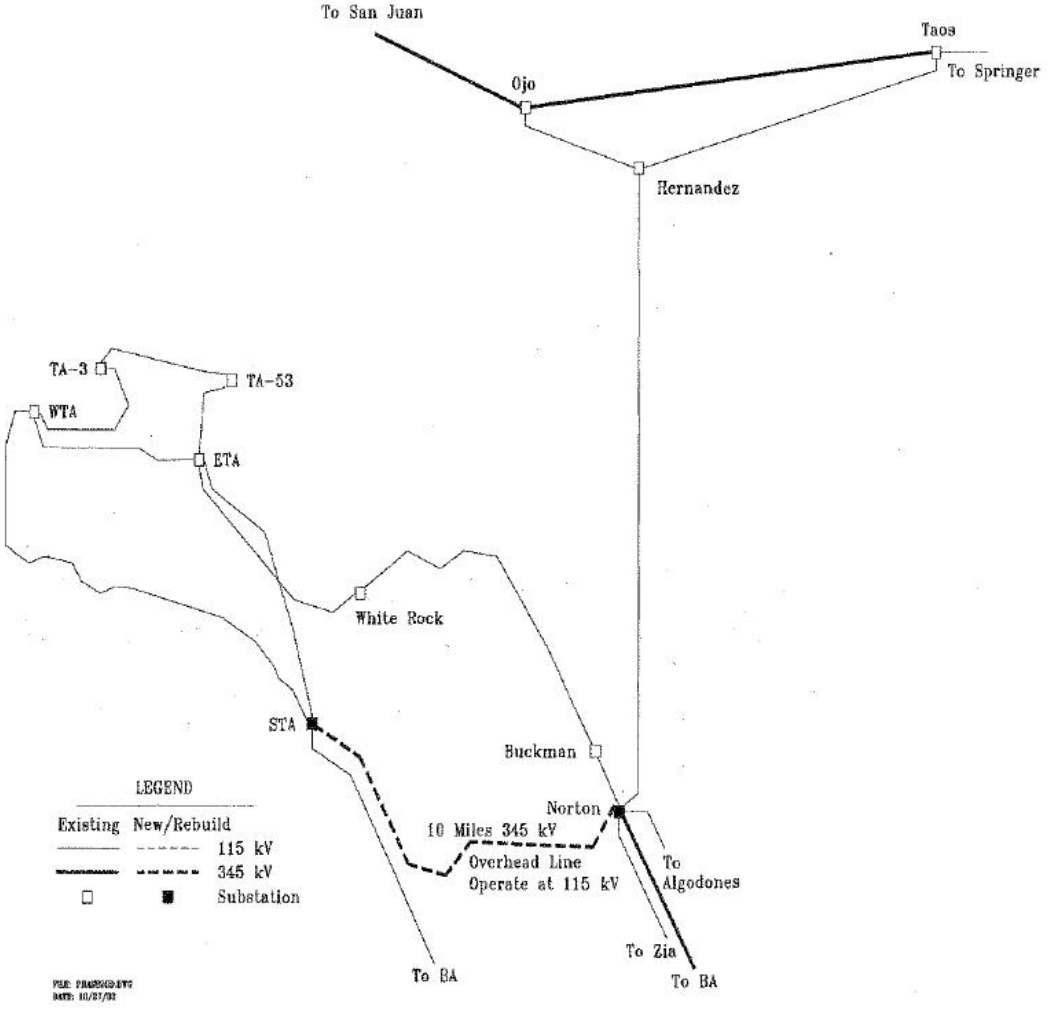


Figure 7-4

Los Alamos Area Transmission System
New OJO to Norton 345 kV Line
Single Line Diagram

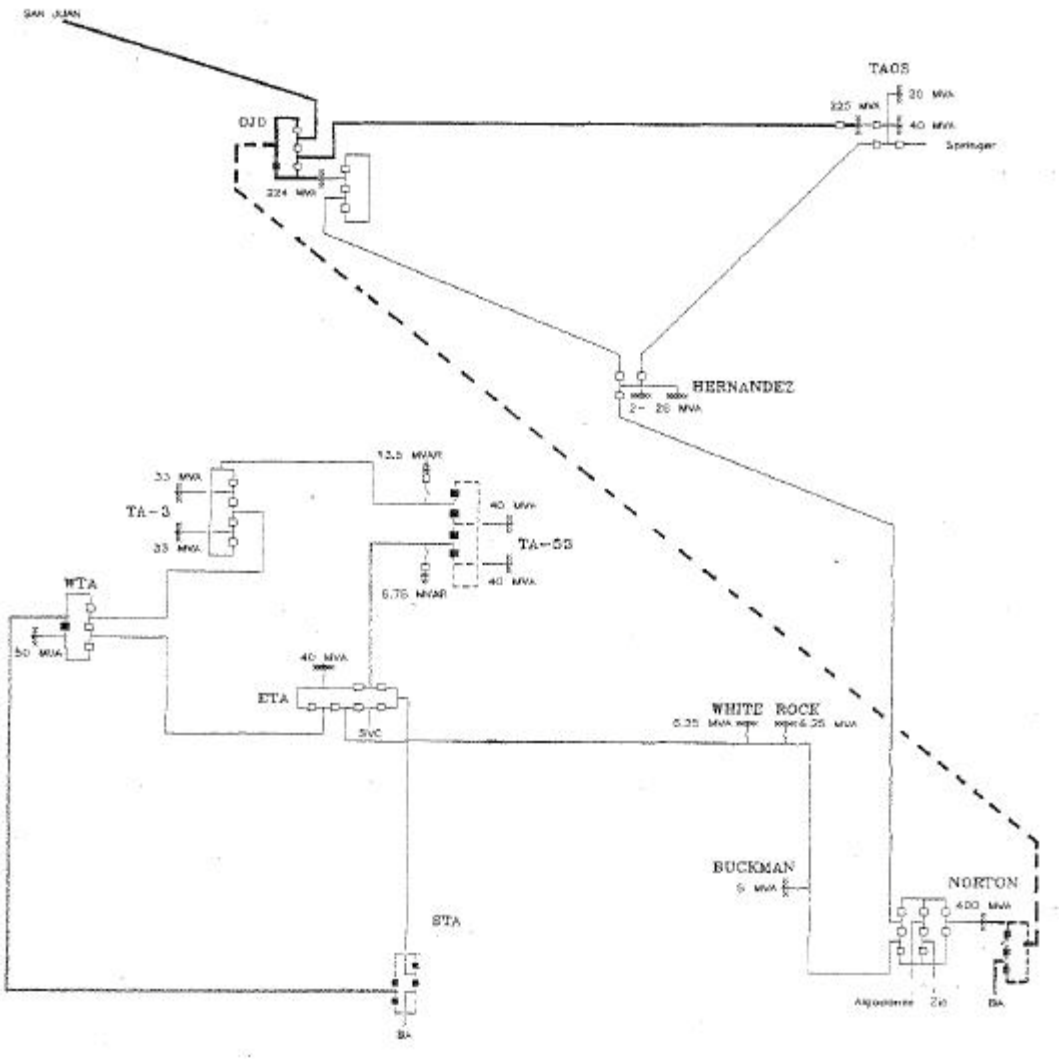


Figure 7-5

Los Alamos Area Transmission System
New OJO to Norton 345 kV Line
Conceptual Layout Diagram

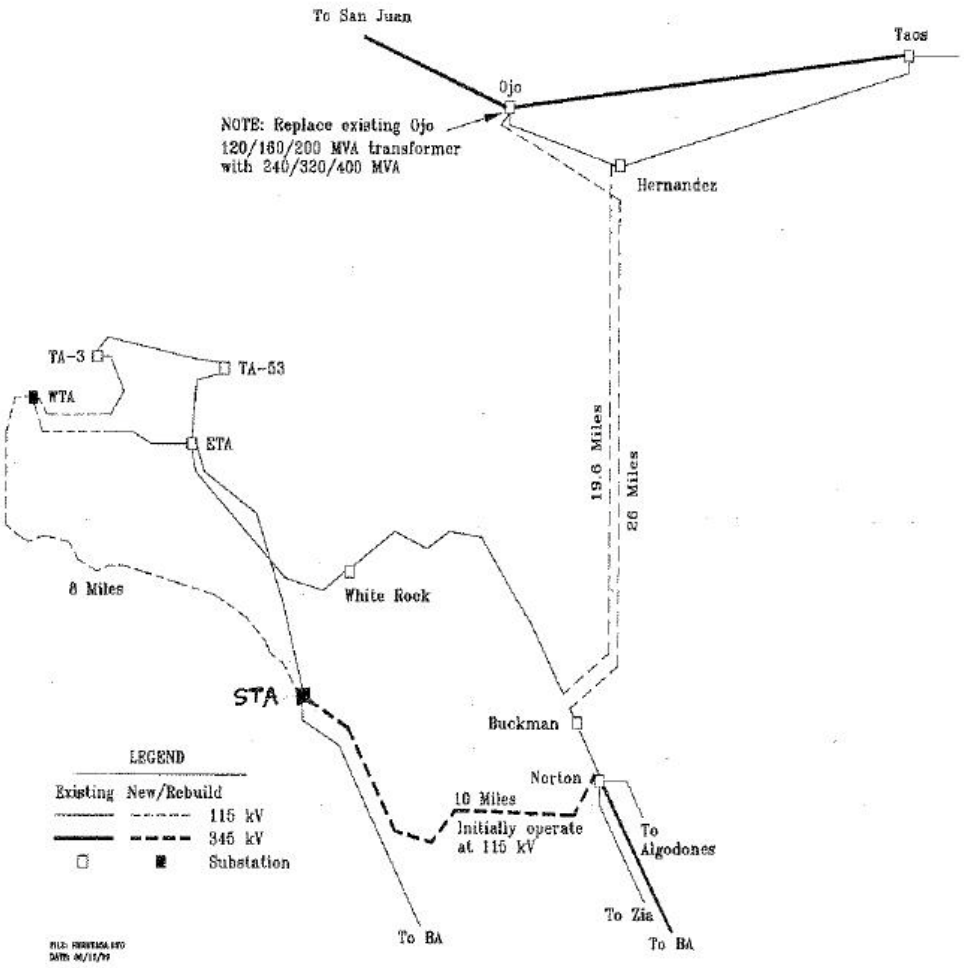


Figure 7-6

Los Alamos Area Transmission System
New OJO to STA 345 kV Line
Second Choice Option
Single Line Diagram

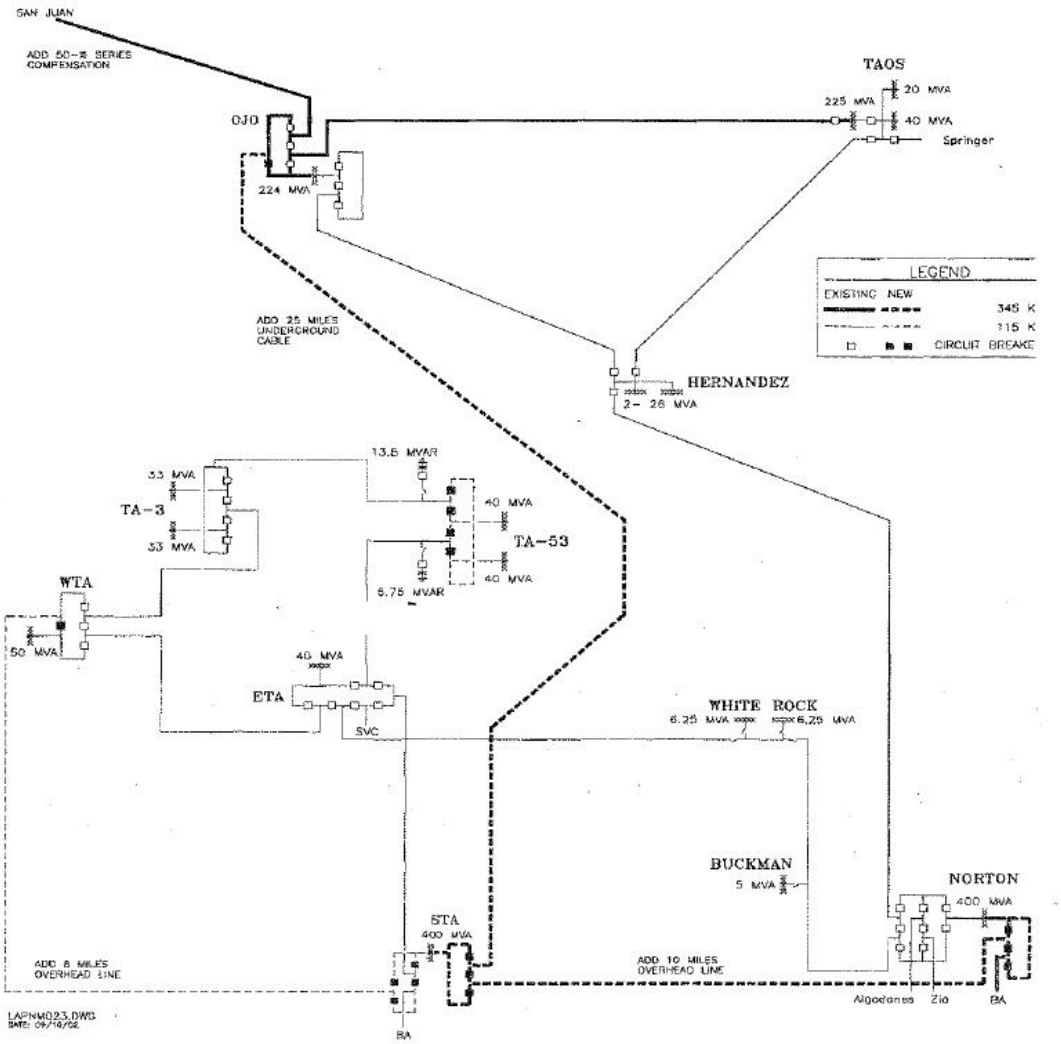


Figure 7-7

Los Alamos Area Transmission System
New OJO to STA 345 kV Line
Second Choice Option
Conceptual Layout Diagram

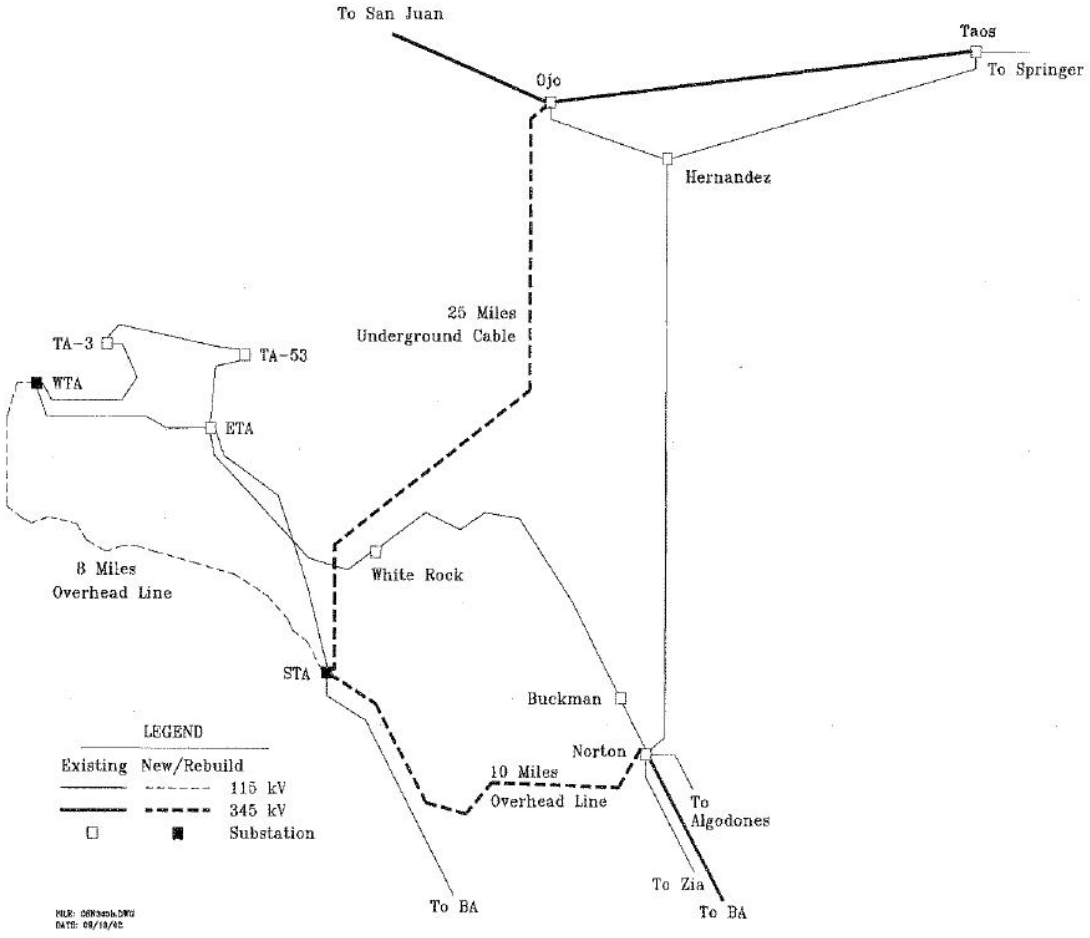


Figure 7-8

Los Alamos Area Transmission System
New STA to Norton Substation HV Line
345 kV Line Initially Operated at 115 kV
Single Line Diagram

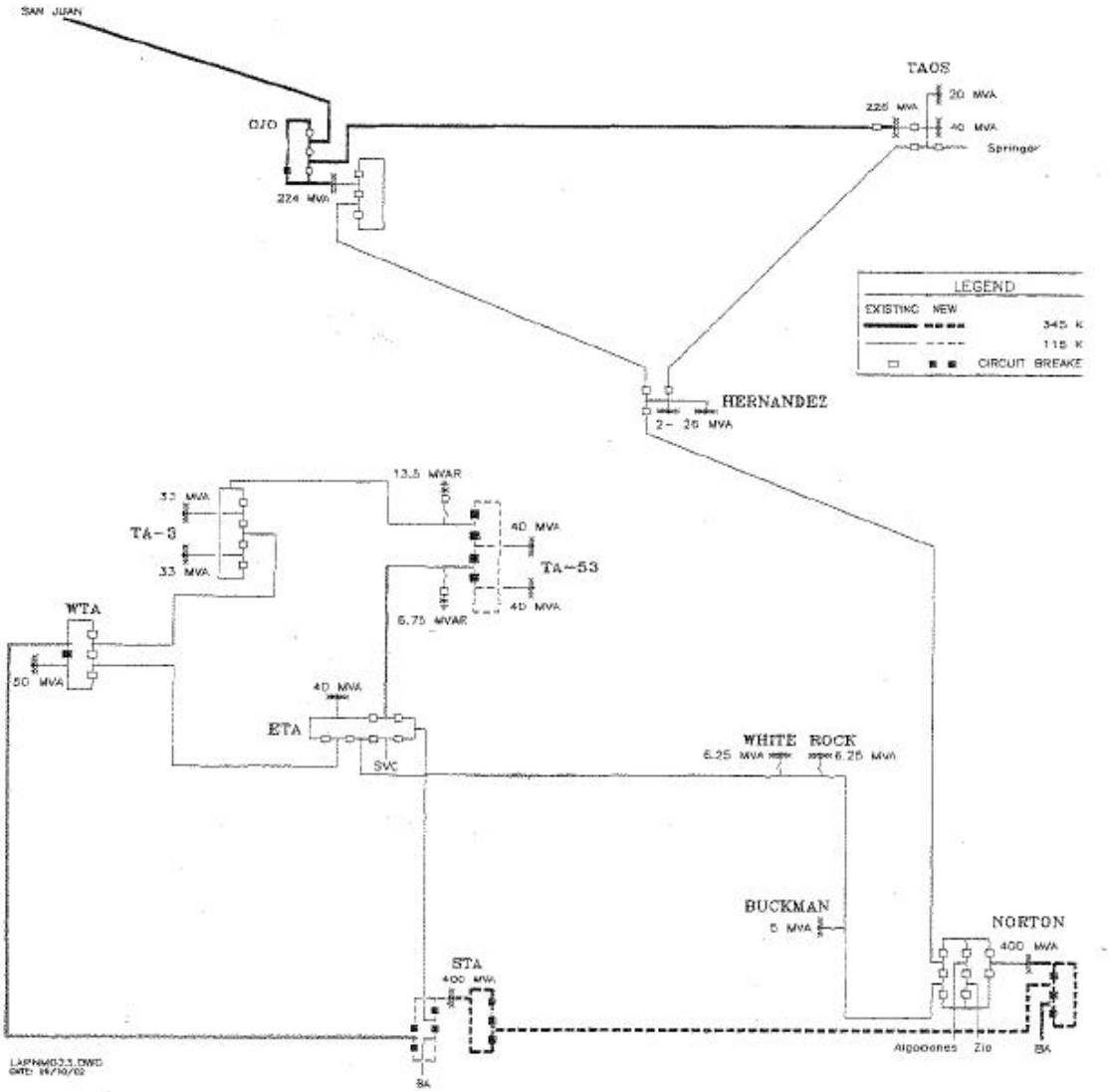
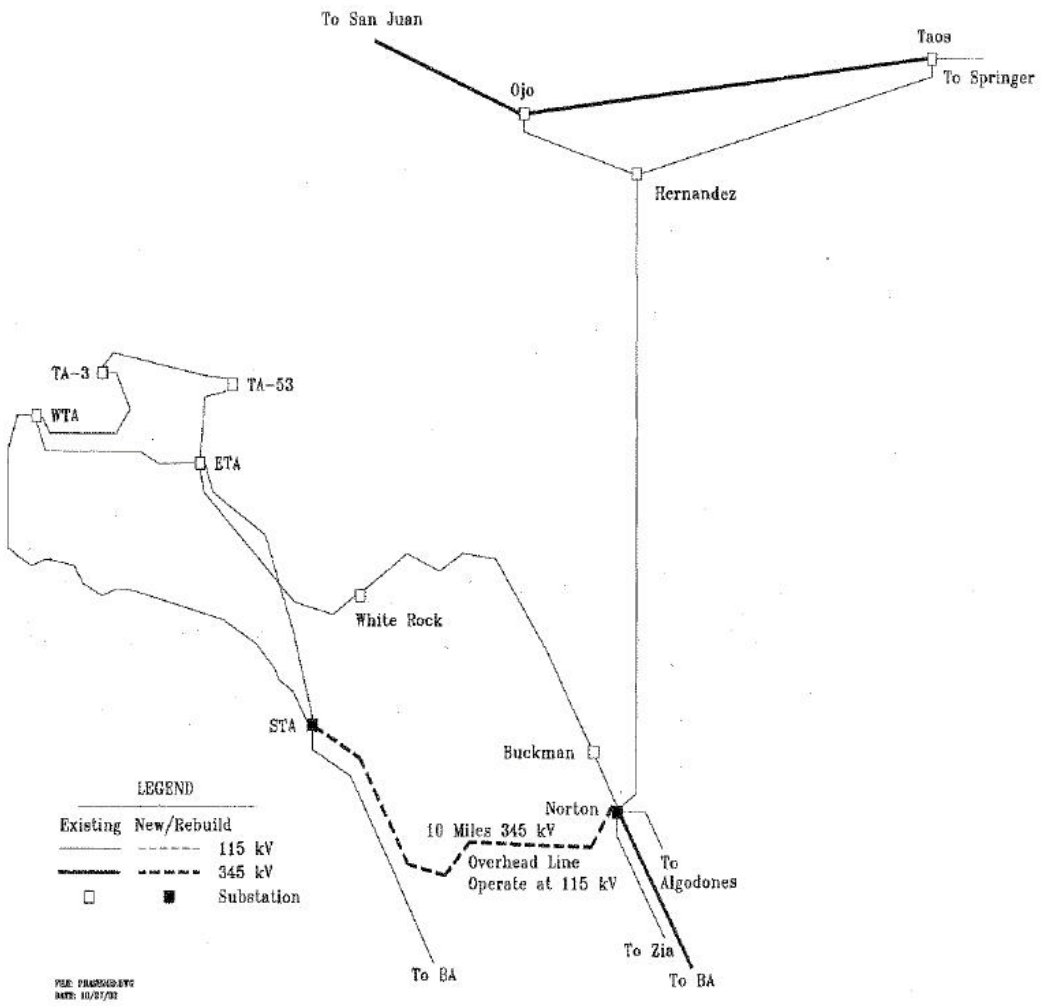


Figure 7-9

Los Alamos Area Transmission System
New STA to Norton Substation HV Line
345 kV Line Initially Operated at 115 kV
Conceptual Layout Diagram



LANL STEAM PLANT PROJECT REPORT ATTACHMENT 8

Conceptual Layout for New Hot Water, Chilled Water and Power Generating Systems

Based on the concepts outlined in Attachments 1 thru 6, Bechtel prepared a conceptual layout for new hot water, chilled water, and power generating systems. The layout is shown in Figures 8-1 and 8-2 and is based on the configurations indicated in budgetary proposals for the new biomass hot water boiler, new natural gas/oil fired hot water boilers, new HRSG, new STG, and new chillers. The concept is that the major new hot water boiler equipment and steam turbine generator will fit in a building approximately 130 feet wide by 118 feet long in the area behind Building 22. Some of the existing auxiliaries for the CGTG would have to be relocated in order to make room for such a building. In addition, the two abandoned cooling towers and their respective auxiliaries would have to be demolished if this space is to be utilized in the future. The HRSG shown is an outdoor design with two drums, and is approximately 70 feet long and 10 feet wide. Figure 8-1 also shows a conceptual location for new centrifugal chiller equipment and chilled water storage tank. Underground utilities were not considered when the location was conceptualized, and detailed consideration will have to given to such before this location is considered further. For the sake of preparing the ROM estimate shown in Attachment 9, the location shown in Figure 8-1 is considered adequate.

There would be a paved road to the south of the building providing access for maintenance and operation. The existing fence in the south would have to be moved further south, but not into the ravine, to accommodate such a road. Access to Diamond Drive could be provided by a new gate at the end of the southern access road, by the existing gate, and/or by a new gate at the end of the northern access road. Fuel for the natural gas/oil fired hot water boilers would be delivered by underground pipelines. Wood chips would be truck delivered along the northern access. A truck is shown for convenience on Figure 8-2.

In elevation, the building would have two stories in the steam turbine area. The boiler area would have only a single story. Space was allocated for a Control Room on the ground floor in the boiler area. Rotor pull space was allocated on the upper floor on the STG area. Main steam piping would have to be run from the HRSG high pressure superheater outlet into the STG area of the new building. Feedwater pumps are too large to fit in the building as conceptualized, so they would have to be located outdoors as shown in Figure 8-1. Circulating water piping would need to be run from the existing pumps at the operating cooling tower into the STG area of the new building. Figure 8-3 shows a list of the mechanical equipment that was considered when preparing the conceptual layout and ROM estimate.

Figure 8-1 Site Plan
Figure 8-2 Building General Arrangement
Figure 8-3 Mechanical Equipment List

Figure 8-1 – Site Plant

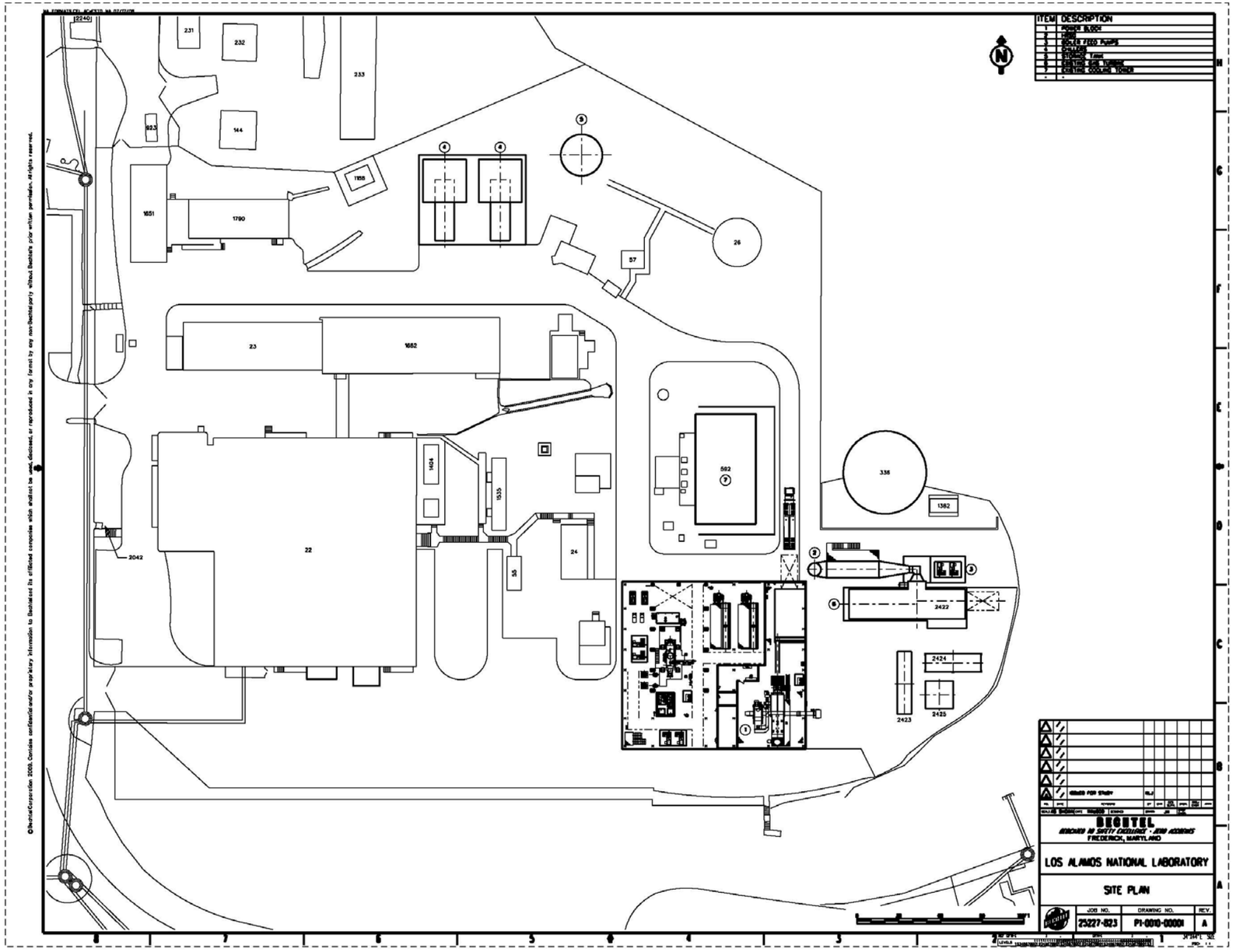


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Figure 8-2 – Building General Arrangement

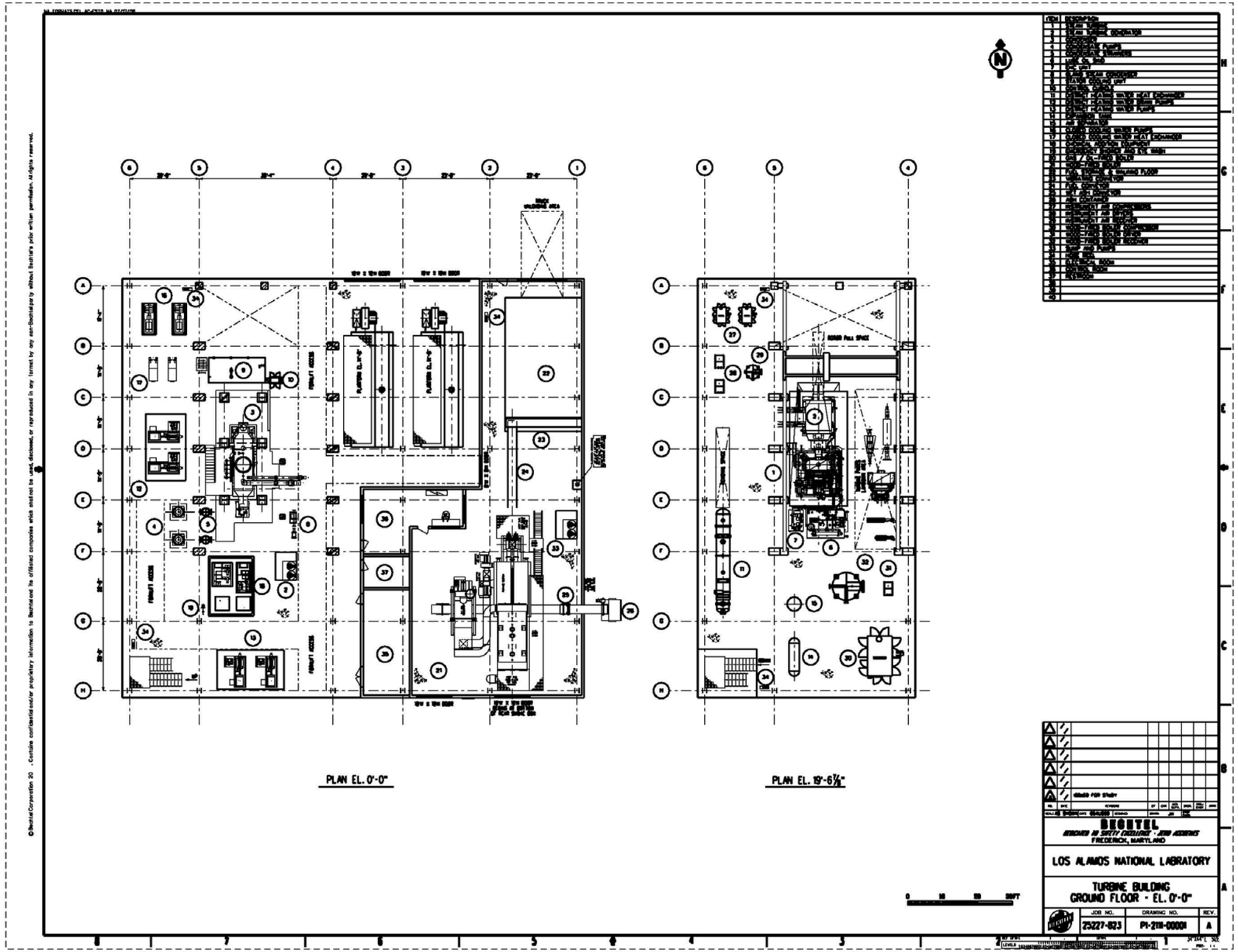

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Figure 8-3

Mechanical Equipment List

QTY	Description	Size or Capacity	Unit x Capacity (%)	Driver Horse-power (HP)	Remarks
1	Wood-Fired Hot Water Boiler	20 MMBtu/hr heat duty, 398,000 lb/hr flow	1 x 100%		600 HP, 28 MMBtu/hr fuel input
2	Natural Gas/Oil-Fired Hot Water Boiler	68 MMBtu/hr heat duty, 1,351,000 lb/hr flow	2 x 100%		2030 HP, 85 MMBtu/hr fuel input
2	District Heating Water Pumps	Centrifugal, 3,000 gpm, 335ft TDH	2 x 100%	350	
1	District Heating Water Heat Exchanger	48 MMBtu/hr heating duty HRSG stream: 47,500 lb/hr, 50 psia, 291 °F inlet, 200 °F outlet District heating water Stream: 955,100 lb/hr,150 psia, 180 °F inlet, 230 °F outlet	1 x 100%		
2	District Heating Water Heating Drain Pumps	Centrifugal, 105 gpm, 160 ft TDH	2 x 100%	6	
1	Air Separator		1 x 100%		Included in the boiler package
1	Expansion Tank		1 x 100%		Included in the boiler package
1	Heat Recovery Steam Generator	Two pressure, non-reheat, natural circulation, drum type units, horizontal gas flow, unfired. HP steam flow: 74160 lb/hr, 990 psia, 859 °F. IP steam flow: 27440 lb/hr, 61.6 psia, 294 °F.	1 x 100%		
2	HRSG Recirculation Pumps		2 x 100%		Included in HRSG
2	Feed Water Pumps	Centrifugal, ring section, 160 gpm, 3000 ft TDH	2 x 100%	150	
1	Combustion Turbine Generator	Rolls Royce RB-211 (Model 6567)	1 x 100%		Existing equipment
1	Steam Turbine Generator	HP/LP, non reheat, 9392 kW HP: 919.4 psia, 900 °F, 67260 lb/hr LP: 82.68 psia, 314 °F, 16470 lb/hr	1 x 100%		Complete STG package including lube oil, EHC, Stator cooling, and control module.
1	Surface Condenser	Single shell, waterbox, 78.16 MMBtu/hr, 1.094 psia	1 x 100%		
2	Condensate Pumps	Vertical canned, 316 SS impeller, 180 gpm, 290 ft TDH	2 x 100%	20	
1	Mechanical Draft Cooling Twr	3 Cells			Existing equipment

3	Circulating Water Pumps	Vertical wet pit, 5390 gpm, 110 ft TDH	3 x 50%	200	Existing equipment
2	Closed Cooling Water Heat Exchanger	Plate and Frame Type, 3.9 MMBtu/hr, 560 gpm, 15 °F rise	2 x 100%		
2	Closed Cooling Water Pumps	Horizontal Centrifugal, 560 gpm, 75 ft	2 x 100%	15	
1	District Heating Oxygen Scavenger Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	District Heating Amine Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	District Heating Dispersant Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	Steam Turbine Cycle Oxygen Scavenger Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	Steam Turbine Cycle Amine Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	HP Drum Phosphate Feed Skid	2 x 100% capacity diaphragm metering pumps and skid mounted mixing tank	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	Cooling Tower Sulfuric Acid Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	Cooling Tower Scale Inhibitor Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
1	Cooling Tower Sodium Hypochlorite Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	1	
1	Cooling Tower Sodium Hypochlorite Tank	6,000 gallon FRP	1 x 100%		
1	Cooling Tower Dispersant Feed Skid	2 x 100% capacity diaphragm metering pumps	1 x 100%	0.33	Chemicals provided by Owner in Tote Bins
2	Cation / Anion Exchangers	Flow =10 gpm, Strong Acid Cation / Strong Base Anion, Non-regenerable	2 x 100%		Sized for steam cycle and district heating make-up
1	Softened Water Storage Tank	7500 gallons - HDPE	1 x 100%		Provides approximately 1 day of storage
2	Air Compressor	125 psig, 100 CFM - air cooled	2 x 100%	25	
2	Air Dryer	Dual Tower - desiccant type - 100 SCFM, -40 °F Dewpoint	2 x 100%		
1	Air Receiver	1000 gallon capacity, 150 psig design pressure	1 x 100%		
1	Soot Blowing Air Compressor	500 SCFM, 350 psig	1 x 100%		
1	Soot Blowing Air Receiver	7500 gallons, 375 psi	1 x 100%		

1	Soot Blowing Air Dryer	High Pressure Refrigerated Type, 500 SCFM	1 x 100%		
1	Chemical Feed System		1 x 100%		
1	Turbine Area Bridge Crane	15 Ton Main Hook with 3 Ton Auxiliary Hook	1 x 100%		
6	Building Ventilation Fans - Turbine Area	10,000 cfm		2	
6	Building Ventilation Fans - Boiler Area	7,500 cfm		1.5	
1	Control Room HVAC Unit	1.5 Ton - Packaged Unit	1 x 100%		
1	Fire Suppression System for Turbine Bearings and lube Oil System	Dry pipe - preaction type	1 x 100%		
1	Fire Suppression System for Biomass Unloading Area	Dry pipe - preaction type	1 x 100%		
2	Water Cooled Chiller Plant	2500 Ton	2 x 50%		Complete system including centrifugal compressor chiller, chilled water pumps, condenser water pumps, control system, storage tank booster pumps, piping and valves
1	Chilled Water Storage Tank	1,000,000 gallons - Epoxy coated Carbon Steel - 67 ft diameter x 40 ft tall	1 x 100%		TANK MUST BE INSULATED
1	Turbine Area Duplex Sump Pump	50 gpm, 40 ft	2 x 100%	1	
1	Wood-Fired Boiler Area Duplex Sump Pump	50 gpm, 40 ft	2 x 100%	1	

LANL STEAM PLANT PROJECT REPORT ATTACHMENT 9

ROM Estimate Summaries for New Hot Water, Chilled Water and Power Generating Systems

Based on the concepts outlined in Attachments 1 thru 6 and Attachment 8, Bechtel prepared an overall Rough Order of magnitude (ROM) estimate for new hot water, chilled water, and power generating systems. The estimate is shown in Figure 9-1 and is based on budgetary proposals for the new biomass hot water boiler, new natural gas/oil fired hot water boilers, new HRSG, new STG, and new chillers. The Bechtel data base was used to estimate pricing for concrete, structural steel, boiler & turbine building, bridge crane, surface condenser, water treatment facilities, heat exchangers, pumps (including circulating water, feedwater, closed cooling water, & condensate pumps) piping and valves (including the district hot water heating, district chilled water, main steam, extraction steam, feedwater, condensate, fuel gas, closed cooling water, and fire protection piping systems). Other estimate categories were factored based on typical ratios for similar installations. The hours estimated for Project Management, Engineering, Procurement and related Services, as well as field non-manual and manual labor hours were estimated from Bechtel's experience base. The site was assumed to be level and required no piling or other earthworks to establish satisfactory foundations. Excluded from the attached ROM estimate are local costs, including costs associated with obtaining permits, any and all taxes that might become due, demolition other than selective demolition in the area where the new building was sited, utility relocations, and spare parts, as details associated with such items are beyond the scope of this Report. Also excluded from the estimates are Owner's costs, including LANL's "loads" on projects to support other LANL programs, LANL's in-house project management, engineering reviews, and other related support services.

At LANL's request, Bechtel has also divided the estimate into three distinct categories as follows:

- HRSG, STG, associated combined cycle equipment, gas-fired hot water boilers and biomass boiler
- Central chiller plant
- Chilled water and hot water piping systems for distribution around TA-3

Where known, the quotes and major pieces of equipment were separated into these categories. For line items in the estimate that could not be conveniently divided into the categories, allocations were made on the basis of Bechtel's judgment. Please see Figures 9-2, 9-3 & 9-4 for the ROM estimates for each of the three categories.

Figure 9-1 ROM Estimate Summary
Figure 9-2 ROM Estimate HRSG, STG, Associated Combined Cycle Equipment, Hot Water Boilers, and Biomass Boiler
Figure 9-3 ROM Estimate for Central Chiller Plant
Figure 9-4 ROM Estimate for Chilled Water and Hot Water Piping Systems

Figure 9-1
ROM Estimate for
New Hot Water District Heating, Chilled Water Distribution and Combined Cycle Power Generating Systems

COA	Description	Material Cost	Labor Cost	S/C Cost	Total Cost	Total Hours
12	Concrete Related	$696,000	$2,427,000	$0	$3,123,000	40,500
13	Steel Work & Other Structural	$1,400,000	$748,000	$0	$2,148,000	12,500
14	Architectural	$0	$0	$996,000	$996,000	0
40	Steam Generator	$7,510,000	$2,636,000	$800,000	$10,946,000	43,900
31	Gas Turbine Generator	$22,000	$78,000	$0	$100,000	1,300
32	Steam Turbine Generator	$3,685,000	$195,000	$0	$3,880,000	3,300
21	Rotating Equipment	$668,000	$95,000	$0	$763,000	1,600
23	Condenser / Chillers	$4,066,000	$569,000	$0	$4,635,000	9,500
26	Water Treatment & Chiller Tank	$536,000	$144,000	$1,200,000	$1,880,000	2,400
27	Other Mechanical Equipment	$173,000	$41,000	$856,000	$1,070,000	700
15.1	Chrome Piping	$651,000	$251,000	$11,000	$913,000	4,200
15	Other Piping Bulks	$4,766,000	$5,708,000	$0	$10,474,000	95,100
18	Insulation & Painting	$0	$0	$1,531,000	$1,531,000	0
17	Instrumentation	$1,194,000	$367,000	$101,000	$1,662,000	4,800
28	Electrical Equipment	$2,479,000	$383,000	$29,000	$2,891,000	6,000
16	Electrical Bulks	$1,128,000	$3,586,000	$0	$4,714,000	49,200
85	Traffic & Logistics	$1,500,000	$0	$0	$1,500,000	0
X	**Total Direct Costs**	**$30,474,000**	**$17,228,000**	**$5,524,000**	**$53,226,000**	**275,000**
52	Misc. Construction Services	$4,950,000	$2,856,000	$0	$7,806,000	47,600
56	Startup Manual Labor & Material	$914,000	$828,000	$0	$1,742,000	13,800
	Total Field Indirect Cost	**$5,864,000**	**$3,684,000**	**$0**	**$9,548,000**	**61,400**
54a	Field Non-Manual, Construction	$994,000	$6,348,000	$0	$7,342,000	55,200
56a	Startup Non-Manual	$234,000	$1,495,000	$0	$1,729,000	13,000
	Total Field Services	**$1,228,000**	**$7,843,000**	**$0**	**$9,071,000**	**68,200**
71a & c	Project Managm't, Engineering, Procurem't, & Related Services	$2,700,000	$17,250,000	$0	$19,950,000	150,000
	Total Home Office Services	**$2,700,000**	**$17,250,000**	**$0**	**$19,950,000**	**150,000**
	TOTAL CONSTRUCTED COST	**$40,266,000**	**$46,005,000**	**$5,524,000**	**$91,795,000**	
						-
ESC	To-Go Escalation				$2,689,000	
SEC	Securities				$462,000	-
PE	Project Insurances				$1,875,000	
	TOTAL PROJECT COST				**$96,821,000**	
Cont	Contingency @ 18%				$17,428,000	
	Total with Contingency				$114,249,000	
	Round off to				$114,000,000	

Figure 9-2
ROM Estimate for
HRSG, STG, Associated Combined Cycle Equipment, Hot water Boilers, & Biomass Boiler

COA	Description	Material Cost	Labor Cost	S/C Cost	Total Cost	Total Hours
12	Concrete Related	$452,400	$1,577,550	$0	$2,029,950	26,325
13	Steel Work & Other Structural	$910,000	$486,200	$0	$1,396,200	8,125
14	Architectural	$0	$0	$747,000	$747,000	0
40	Steam Generator	$7,510,000	$2,636,000	$800,000	$10,946,000	43,900
31	Gas Turbine Generator	$22,000	$78,000	$0	$100,000	1,300
32	Steam Turbine Generator	$3,685,000	$195,000	$0	$3,880,000	3,300
21	Rotating Equipment	$534,400	$76,000	$0	$610,400	1,280
23	Condenser / Chillers	$609,900	$85,350	$0	$695,250	1,425
26	Water Treatment & Chiller Tank	$53,600	$14,400	$0	$68,000	240
27	Other Mechanical Equipment	$129,750	$30,750	$642,000	$802,500	525
15.1	Chrome Piping	$651,000	$251,000	$11,000	$913,000	4,200
15	Other Piping Bulks	$476,600	$570,800	$0	$1,047,400	9,510
18	Insulation & Painting	$0	$0	$382,750	$382,750	0
17	Instrumentation	$955,200	$293,600	$80,800	$1,329,600	3,840
28	Electrical Equipment	$1,983,200	$306,400	$23,200	$2,312,800	4,800
16	Electrical Bulks	$902,400	$2,868,800	$0	$3,771,200	39,360
85	Traffic & Logistics	$1,050,000	$0	$0	$1,050,000	0
X	**Total Direct Costs**	$19,925,450	$9,469,850	$2,686,750	$32,082,050	$148,130
52	Misc. Construction Services	$2,970,000	$1,713,600	$0	$4,683,600	28,560
56	Startup Manual Labor & Material	$548,400	$496,800	$0	$1,045,200	8,280
	Total Field Indirect Cost	$3,518,400	$2,210,400	$0	$5,728,800	$36,840
54a	Field Non-Manual, Construction	$596,400	$3,808,800	$0	$4,405,200	33,120
56a	Startup Non-Manual	$140,400	$897,000	$0	$1,037,400	7,800
	Total Field Services	$736,800	$4,705,800	$0	$5,442,600	$40,920
71a & c	Project Managm't, Engineering, Procurem't, & Related Services	$1,620,000	$10,350,000	$0	$11,970,000	90,000
	Total Home Office Services	$1,620,000	$10,350,000	$0	$11,970,000	$90,000
	TOTAL CONSTRUCTED COST	$25,800,650	$26,736,050	$2,686,750	$55,223,450	
ESC	To-Go Escalation				$1,613,400	
SEC	Securities				$277,200	
PE	Project Insurances				$1,125,000	
	TOTAL PROJECT COST				$58,239,050	
Cont	Contingency @ 18%				$10,483,029	
	Total with Contingency				$68,722,079	
	Round off to				$68,700,000	

Figure 9-3
ROM Estimate for
Chiller Plant

COA	Description	Material Cost	Labor Cost	S/C Cost	Total Cost	Total Hours
12	Concrete Related	$104,400	$364,050	$0	$468,450	6,075
13	Steel Work & Other Structural	$210,000	$112,200	$0	$322,200	1,875
14	Architectural	$0	$0	$249,000	$249,000	0
40	Steam Generator	$0	$0	$0	$0	0
31	Gas Turbine Generator	$0	$0	$0	$0	0
32	Steam Turbine Generator	$0	$0	$0	$0	0
21	Rotating Equipment	$100,200	$14,250	$0	$114,450	240
23	Condenser / Chillers	$3,456,100	$483,650	$0	$3,939,750	8,075
26	Water Treatment & Chiller Tank	$482,400	$129,600	$1,200,000	$1,812,000	2,160
27	Other Mechanical Equipment	$34,600	$8,200	$171,200	$214,000	140
15.1	Chrome Piping	$0	$0	$0	$0	0
15	Other Piping Bulks	$238,300	$285,400	$0	$523,700	4,755
18	Insulation & Painting	$0	$0	$229,650	$229,650	0
17	Instrumentation	$179,100	$55,050	$15,150	$249,300	720
28	Electrical Equipment	$495,800	$76,600	$5,800	$578,200	1,200
16	Electrical Bulks	$225,600	$717,200	$0	$942,800	9,840
85	Traffic & Logistics	$300,000	$0	$0	$300,000	0
X	**Total Direct Costs**	$5,826,500	$2,246,200	$1,870,800	$9,943,500	$35,080
52	Misc. Construction Services	$891,000	$514,080	$0	$1,405,080	8,568
56	Startup Manual Labor & Material	$164,520	$149,040	$0	$313,560	2,484
	Total Field Indirect Cost	$1,055,520	$663,120	$0	$1,718,640	$11,052
54a	Field Non-Manual, Construction	$178,920	$1,142,640	$0	$1,321,560	9,936
56a	Startup Non-Manual	$42,120	$269,100	$0	$311,220	2,340
	Total Field Services	$221,040	$1,411,740	$0	$1,632,780	$12,276
71a & c	Project Managm't, Engineering, Procurem't, & Related Services	$486,000	$3,105,000	$0	$3,591,000	27,000
	Total Home Office Services	$486,000	$3,105,000	$0	$3,591,000	$27,000
	TOTAL CONSTRUCTED COST	$7,589,060	$7,426,060	$1,870,800	$16,885,920	
ESC	To-Go Escalation				$484,020	
SEC	Securities				$83,160	
PE	Project Insurances				$337,500	
	TOTAL PROJECT COST				$17,790,600	
Cont	Contingency @ 18% Total with Contingency Round off to				$3,202,308 $20,992,908 $21,000,000	

Figure 9-4
ROM Estimate for
Chilled Water and Hot Water Piping Systems

COA	Description	Material Cost	Labor Cost	S/C Cost	Total Cost	Total Hours
12	Concrete Related	$139,200	$485,400	$0	$624,600	8,100
13	Steel Work & Other Structural	$280,000	$149,600	$0	$429,600	2,500
14	Architectural	$0	$0	$0	$0	0
40	Steam Generator	$0	$0	$0	$0	0
31	Gas Turbine Generator	$0	$0	$0	$0	0
32	Steam Turbine Generator	$0	$0	$0	$0	0
21	Rotating Equipment	$33,400	$4,750	$0	$38,150	80
23	Condenser / Chillers	$0	$0	$0	$0	0
26	Water Treatment & Chiller Tank	$0	$0	$0	$0	0
27	Other Mechanical Equipment	$8,650	$2,050	$42,800	$53,500	35
15.1	Chrome Piping	$0	$0	$0	$0	0
15	Other Piping Bulks	$4,051,100	$4,851,800	$0	$8,902,900	80,835
18	Insulation & Painting	$0	$0	$918,600	$918,600	0
17	Instrumentation	$59,700	$18,350	$5,050	$83,100	240
28	Electrical Equipment	$0	$0	$0	$0	0
16	Electrical Bulks	$0	$0	$0	$0	0
85	Traffic & Logistics	$150,000	$0	$0	$150,000	0
X	**Total Direct Costs**	$4,722,050	$5,511,950	$966,450	$11,200,450	$91,790
52	Misc. Construction Services	$1,089,000	$628,320	$0	$1,717,320	10,472
56	Startup Manual Labor & Material	$201,080	$182,160	$0	$383,240	3,036
	Total Field Indirect Cost	$1,290,080	$810,480	$0	$2,100,560	$13,508
54a	Field Non-Manual, Construction	$218,680	$1,396,560	$0	$1,615,240	12,144
56a	Startup Non-Manual	$51,480	$328,900	$0	$380,380	2,860
	Total Field Services	$270,160	$1,725,460	$0	$1,995,620	$15,004
71a & c	Project Managm't, Engineering, Procurem't, & Related Services	$594,000	$3,795,000	$0	$4,389,000	33,000
	Total Home Office Services	$594,000	$3,795,000	$0	$4,389,000	$33,000
	TOTAL CONSTRUCTED COST	$6,876,290	$11,842,890	$966,450	$19,685,630	
ESC	To-Go Escalation				$591,580	
SEC	Securities				$101,640	
PE	Project Insurances				$412,500	
	TOTAL PROJECT COST				$20,791,350	
	Contingency @ 18%				$3,742,443	
Cont	Total with Contingency				$24,533,793	
	Round off to				$24,500,000	