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ENERGY CONSERVATION

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COO/4210-3/8
Distribution Category UC-95d

GRID-CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM

Phase II: Final Stage 2 Report

Preliminary Design Pyrolysis Facility

March 22, 1978

Work Performed Under Contract No. EC-77-C-02-4210

University of Minnesota Physical Plant
Minneapolis, Minnesota

U. S. DEPARTMENT OF ENERGY

Division of Buildings and Community Systems

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GRID-CONNECTED INTEGRATED COMMUNITY ENERGY SYSTEM

PHASE II

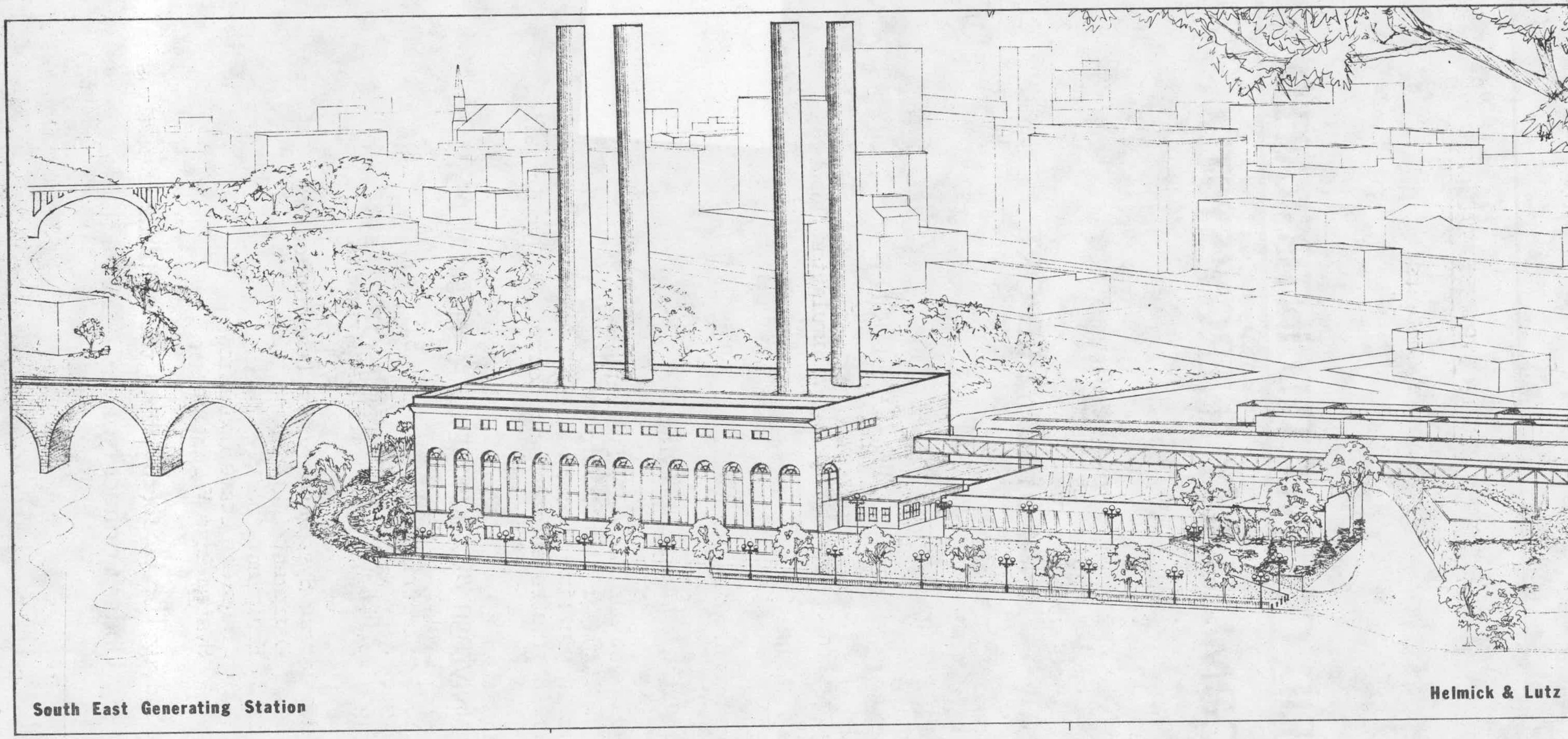
FINAL STAGE 2 REPORT

PRELIMINARY DESIGN
PYROLYSIS FACILITY

March 22, 1978

UNIVERSITY OF MINNESOTA PHYSICAL PLANT
319 15th AVE. S.E.
MINNEAPOLIS, MINNESOTA 55455
612-373-4521

Prepared For
The U.S. Department of Energy
Under Contract No. EC-77-C-02-4210


South East Generating Station
Helmick & Lutz

VOLUME 8

PRELIMINARY DESIGN PYROLYSIS FACILITY

Table of Contents

*Detailed Indexes can be found within the Sections themselves.

Table of Contents (Continued)

AN EQUAL OPPORTUNITY EMPLOYER AFFIRMATIVE ACTION PROGRAM

ANDCO INCORPORATED

1. POLICY STATEMENT

Andco Incorporated under the leadership of its president and chief executive officer A. E. Anderson, III, pursues an active philosophy of promoting the full realization of equal employment for all its employees and applicants for employment. The following constitutes the attitude of A. E. Anderson, III, and accordingly the policy of Andco Incorporated.

The Company shall do all that is in its power to provide for actual progress in the area of equal employment opportunity. This policy extends to all matters concerning the employment relationship including recruiting, hiring, apprenticeship programming, promotion, compensation, benefits, and all the terms and conditions of employment. Moreover, everyone in the employ of Andco Incorporated shall be encouraged to do all in their power to actively foster the Company's policy of equal employment opportunity and more specifically to fulfill and see implemented in a constructive way this affirmative action program. Specifically, this program includes but is not limited to:

A. The recruitment and hire of employees in all job classifications without regard to race, color, religion, sex, national origin, handicap, a veteran's disability or being a veteran of the Vietnam Era, except where sex, handicap or disability is a true and bonafide occupational qualification or limitation.

B. All decisions on employment are to be based upon the principle of furthering equal employment opportunity and more specifically, this Affirmative Action Program.

C. Any promotions made are to be based upon valid requirements consistent with principles of equal employment opportunity and with the view of implementing this Affirmative Action Program.

D. All other personnel programs and actions are to be administered without regard to race, color, religion, sex, national origin, handicap, a veteran's disability or being a veteran of the Vietnam Era except where sex, handicap or disability is a bonafide occupational qualification or limitation and this is to include actions such as transfers, layoffs, compensation, benefits, return from layoff, and Company sponsored or financed training or education, and any social recreration programs in which the Company plays a role.

It is further the desire of the Company that our subcontractors and suppliers and those doing business with the Company adhere to the principles necessary for the active promotion of equal employment opportunity for all regardless of race, color, religion, sex, national origin, handicap, a veteran's disability or being a veteran of the Vietnam Era.

HELMICK & LUTZ COMPANY

EQUAL OPPORTUNITY STATEMENT

Helmick & Lutz Company is committed to the policy that it will not discriminate against any employee or applicant for employment because or race, color, religion, sex, national origin, or handicap in regard to any position for which the employee or applicant for employment is qualified.

8.1

INTRODUCTION

The Andco-Torrax system is a new high temperature refuse conversion process known technically as slagging pyrolysis. Although the pyrolysis of solid waste is a relatively new innovation, pyrolysis processes have been used for years by industry. Typical examples are found in the production of char and methanol from wood and coal gasification. Pyrolysis, commonly referred to as destructive distillation, is defined as an irreversible chemical change brought about by the action of heat in an oxygen deficient atmosphere. The pyrolysis of organic material causes the volatile fraction to distill, forming combustible liquids and vapors. The vapors are composed primarily of methane, hydrogen, carbon monoixde, carbon dioxoide, water and the more complex hydrocarbons such as ethane, propane, oils and tars.

The exact components in percent composition of these gases formed by pyrolysis of municipal waste cannot accurately be predicted in that, in a real system, the complex multi-component fractions would be converted to more stable gases such as ethylene through a continuing pyrolysis action and are a result of complex time/temperature kinetic reactions. The material remaining from the pyrolyzed material is burned to carbon monoxide and carbon dioxide using high temperature air, thus releasing sufficient heat energy to convert all non-combustibles contained in the solid waste to molten slag and to further pyrolyze incoming waste material.

8.2 DEMONSTRATION PLANT

The development of the Andco-Torrax process began in early 1969 with the formation of a company called Torrax Systems, Inc., which was jointly owned by Andco Incorporated and the Carborundum Company. The purpose of Torrax Systems, Inc., was to acquire and develop all necessary technology for a new type of high temperature slagging pyrolysis process for disposal of municipal solid waste and then to make the necessary arrangements to build a prototype plant and to operate it successfully to prove out the technology. On July 1, 1969, Torrax Systems, Inc. entered into a contract with the County of Erie, a municipal corporation of the State of New York, to build and operate a 75 ton-per-day demonstration plant in Orchard Park, a suburb of Buffalo. This new plant program was made possible through the support of the U. S. Environmental Protection Agency, New York State, Erie County, the American Gas Association, the Carborundum Company and Andco Incorporated. Groundbreaking ceremonies for the demonstration plant were held in July of 1970 and operation commenced in the second quarter of 1971. Between 1971 and 1973, the plant operated as an engineering development facility to evaluate and prove system design features. During that period of time, the plant operated for 2,316 hours and processed 7,664 tons of municipal solid waste. The longest period of continuous operations was 120 hours. Although the plant capacity was 3.1 tons per hour, the equipment operated at throughput rates as low as 1.3 tons per hour and as high as 4.7 tons per hour.

In addition to normal municipal refuse, the Andco-Torrax demonstration plant handled other wastes, particulatrly those from industry. These wastes were mixed with municipal refuse and minor changes were made to the equipment and the operating procedures.

Some of the tests at the demonstration facility included the following:

Sewage Sludge. Undigested sewage sludge with 78 percent water content was charged with the municipal refuse in quantities averaging 28.5 percent of the total 3.8 TPH charge.

Waste Oil. Waste automotive lubricating oil was charged with municipal refuse in average quantities of 6.1 percent of the 4.4 TPH charge.

Combined Sludge and Oil. A test combining sewage sludge with waste oil and municipal refuse was accomplished. The total refuse rate was 3.4 TPH of which 30.1 percent was sludge and 3.0 percent was oil.

Tires. Unshredded automative tires were charged by bucket with the normal refuse. The average addition was 30 tires per hour or about 10 percent of the total 3.3 TPH consumption.

Polyvinylchloride (PVC). Bags filled with PVC plastic waste were charged with municipal refuse in quantities averaging 7 percent of the 3.2 TPH charge.

In these tests, changes in the process parameters (flows, temperatures, gas composition) were evident and were related to the changes in the input refuse heating value and composition.

In Orchard Park plant employed equipment which for the main part was similar to that used in commercial Andco-Torrax plants. However, the demonstration plant used a natural gas fired heat exchanger, rather than regenerative towers, to supply the high temperature primary combustion air. Other differences between the demonstration plant and commercial plants include the following:

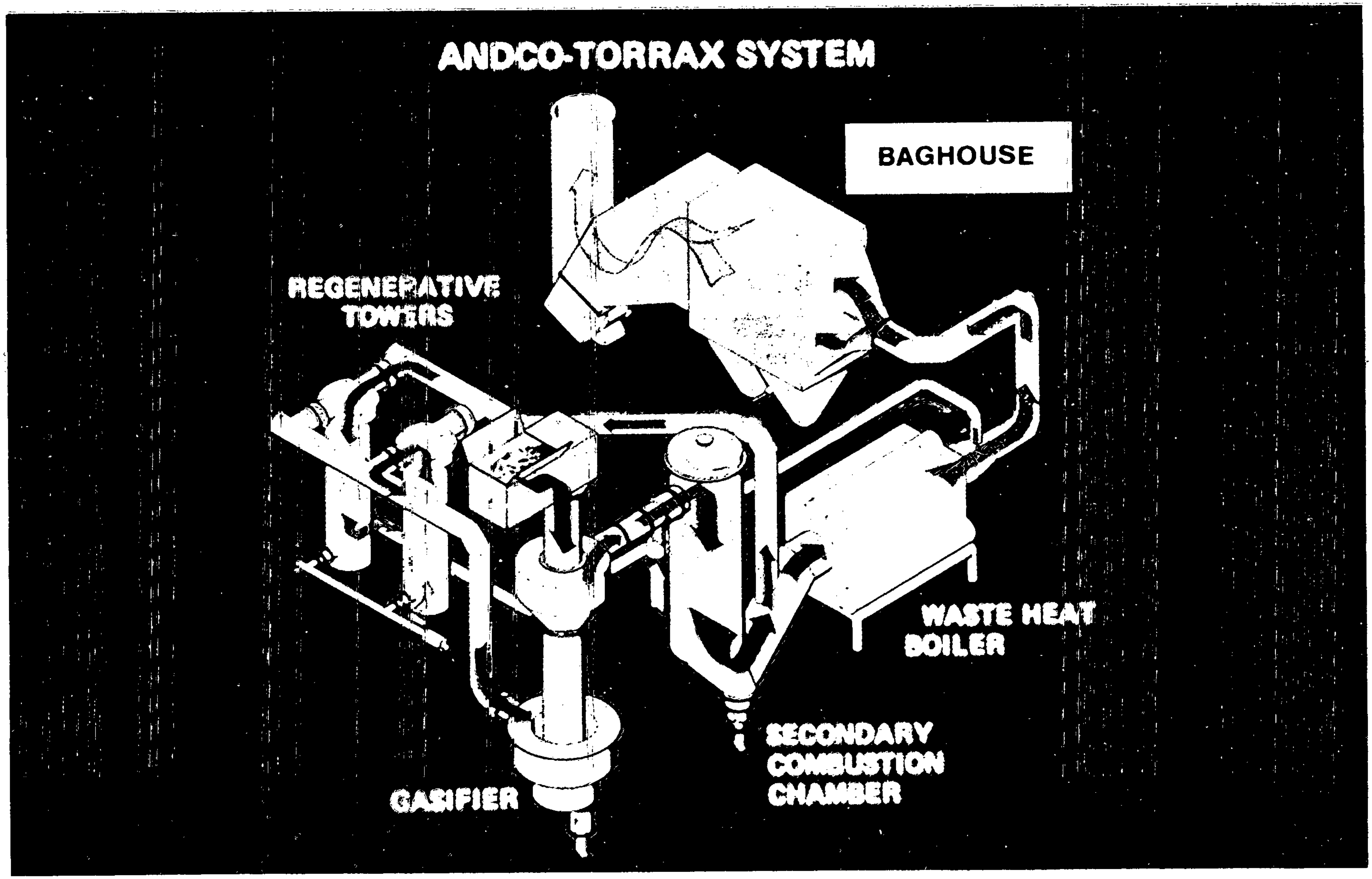
- Refuse was charged into the top of the gasifier through an open cone without any type of hopper feed.
- The residue was removed from the slag quench area with a front end loader rather than automatically as is the case in commercial plants.
- A wet scrubber was used rather than other gas cleaning equipment.

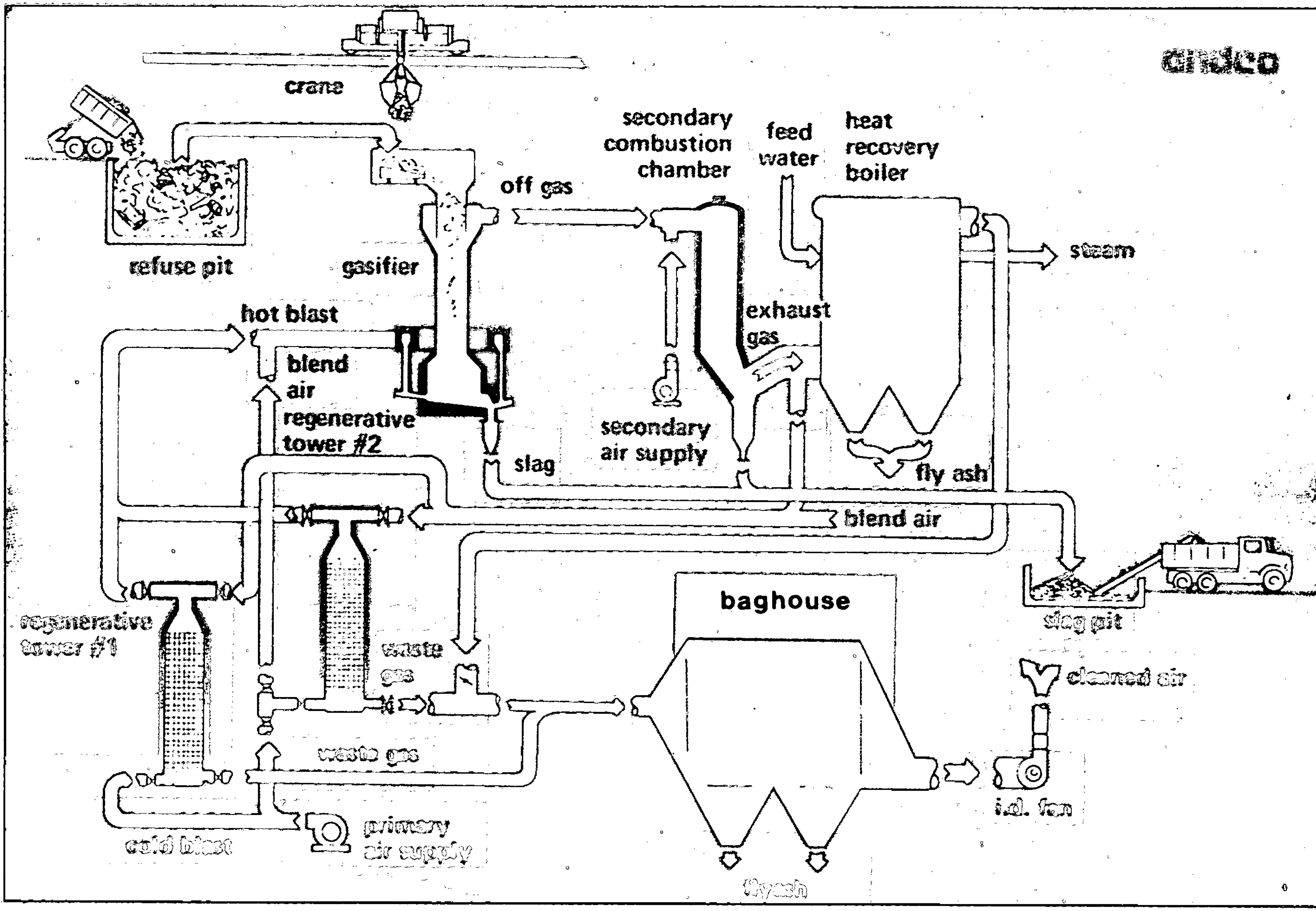
8.3 MARKET DEVELOPMENT

It was decided by Carborundum and Andco in early 1973 that the original objectives of Torrax Systems, Inc. had been successfully concluded. Since then the demonstration plant has only operated for sales demonstration purposes. In 1973, agreements were executed between Carborundum and Andco giving Andco commercial rights to the process in Canada, Australia and Europe. A further agreement was executed in 1976 which expanded Andco's commercial rights to the process to include the United States, the USSR, Japan, New Zealand, Indonesia, and counties in Polynesia, Latin America, Africa, and the Middle East.

8.4 PROCESS DESCRIPTION

The principal components of the Andco-Torrax system are the gasifier, secondary combustion chamber, primary air preheating equipment, waste heat boilers, and gas cleaning system. These components are shown in Figures 1 and 2. These figures illustrate the primary air preheating system as a regenerative tower system, although other alternatives may be used which could include a heat recuperator or a fossil fuel fired air preheater. The gasifier and secondary combustion chamber comprise the main process components and are shown in Figure 3.


ANDCO-TORRAX SYSTEM
BAGHOUSE
REGENERATIVE TOWERS
WASTE HEAT BOILER
SECONDARY COMBUSTION CHAMBER
GASIFIER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regenerative
tower #2
exhaust
gas
secondary
air supply
slag
fly ash
blend air
slag pit
baghouse
regenerative
tower #1
waste
gas
waste gas
cleaned air
i.d. fan
cold blast
primary
air supply
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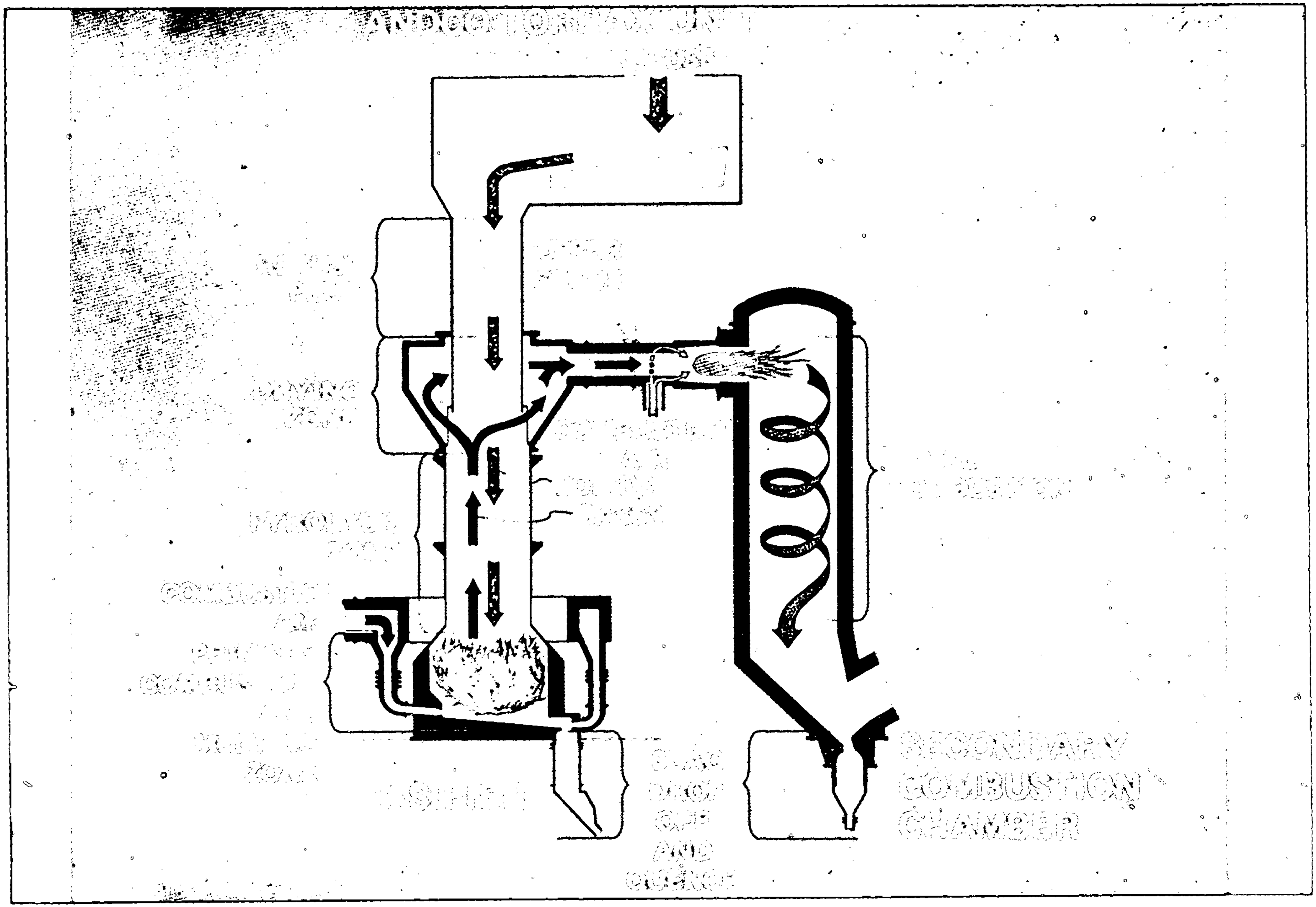

SECONDARY
COMBUSTION
CHAMBER

8.4.1 GASIFIER

A crane with grapple bucket removes refuse from the refuse pit without pretreatment other than the shearing of oversize items to approximately one meter dimensions. The refuse is directed into a hopper from which it is fed into the top of the gasifier by either a reciprocating ram or a vibrating feeder. The gasifier is a vertical shaft furnace so designed that the descending refuse burden and the ascending high temperatrue gases become an effective countercurrent heat exchanger. The gasifier shaft is normally 12-15 meters (40'-50') in overall height, 1.8-2.7 meters (6'-9') in diameter, and is fabricated from mild steel with refractory lining in the lantern and hearth areas only. The main stack between the lantern and hearth is externally cooled over its length by a jacketed water cascade. The hopper has a loose sealing mechanism to decrease the infiltration of air into the top of the gasifier. As the refuse descends in the gasifier, three distinct zones are encountered - drying, pyrolysis, and primary combustion. The function of the drying zone is to evaporate the moisture in the refuse and to act as a plug to further restrict the in-flow of air during charging. Refuse entering the top of the gasifier moves downward past the gas offtake plenum (lantern). From this point down, the refuse dries and then, in the pyrolysis zone, is heated from 260° to 1093° C (500- 2000° F) in a reducing atmosphere where the rate of decomposition to pyrolysis products increases with temperature. Various oils formed in the low temperature region of pyrolysis continue to pass down and are cracked into gases and char at the higher temperatures. These particles of char and oil that are entrained in the hot gases are to a large extent scrubbed out by the descending refuse and are recycled down into the higher temperature zone.

The heat for drying and pyrolyzing the refuse is supplied by the combustion of the carbon char with preheated air in the primary combustion zone. The preheated air at 1037° C (1900° F) is directed from the regenerative towers through a hot blast main into a circular bustle pipe. The air then passes through several downcomer-tuyere assemblies radially into the gasifier hearth where it is used to combust the char. The heat generated by this combustion process (up to 1650° C or 3000° F) also transforms the non-combustible materials to a molten slag. The temperature profile through the refractories results in the formation of a coating of solidified slag over the refractories in the hearth area. This coating assists in protecting the refractories from the high temperatures and corrosive action of the molten slag. The molten slag is drained continuously through a sealed slag tap into a water quenched tank to produce a black, glassy, sterile aggregate. The sealed slag tap arrangement allows removal of the frit while maintaining pressures in the hearth slightly above atmospheric. The slag formed in the hearth of the gasifier and in the secondary combustion chamber accumulate in a common slag agitation/holding tank, and several methods are available for transporting it from the tank. At the demonstration plant in Orchard Park, the material flowed into a slag pit and a front-end loader was used to manually carry it to a stockpile for later removal by truck. One automatic method uses drag and belt conveying equipment, with drag conveyors removing slag from the main slag pit and depositing it at a continuous rate on horizontal or inclined belt conveyors feeding a vertical bucket elevator. The bucket elevator directs the material to external storage bins or stockpiles for removal by transportation vehicles. Another method used is slurry pumping of slag from the main slag pit to dewatering tanks. The suspended solids quickly settle out in the dewatering tank for removal by grapple bucket or drag conveyor system. The conveying liquid may be pumped back through the system from the dewatering tanks for reuse in the quench tanks.

Volume reduction from the raw refuse to the slag residue is approximately 95-97 percent and the weight reduction is 80-85 percent, depending on the enert fraction in the refuse. Table 24 presents the physical and chemical properties of the slag residue produced at the Orchard Park demonstration plant.

At least 90% of the energy content of municipal refuse is contained in the gas stream which leaves the gasifier. This energy is in the form of combustible gases, vapors, and entrained particles and as sensible and latent heat. The temperature of this gas is approximately 400° C - 500° C (752° F - 932° F). The complete combustion of this gas stream produced about the same volume of products of combustion per unit of heat released as would be the case with other gaseous fuels. The composition and properties of the combustible gas stream are dependent, of course, on the refuse mix. The heating value of the gas will normally be in the range of 937 - 1,593 kcal/nm^3 (100 - 170 BTU/scf).

Although this combustible gas stream, with or without cleaning to remove entrained material, has potential application as an energy source where close coupling of the gasifier with the recipient combustion device (such as kilns, boilers, etc.) is possible, current commercial Andco-Torrax plants employ a secondary combustion chamber to burn this gas to completion.

TABLE 1.-SLAG RESIDUE CHARACTERISTICS

Constituent	Average % (by weight)	Range %
SiO_2	45	32.00 - 58.00
Al_2O_3	10	5.50 - 11.00
TiO_2	0.8	0.48 - 1.30
Fe_2O_3	10	0.50 - 22.00
FeO	15	11.00 - 21.00
MgO	2	1.80 - 3.30
CaO	8	4.80 - 12.10
MnO	0.6	0.20 - 1.00
Na_2O	6	4.00 - 8.60
K_2O	0.7	0.36 - 1.10
Cr_2O_3	0.5	0.11 - 1.70
CuO	0.2	0.11 - 0.28
ZnO	0.1	0.02 - 0.26
Trace Oxides	1.1	--
	100.0	

Dry Bulk Density..........1.40 gm/cc
True Residue Density...... 2.80 gm/cc

8.4.2 SECONDARY COMBUSTION CHAMBER

The offgas exits from the gasifier via the lantern, and is drawn into the secondary combustion chamber through a refractory lined cross-over duct by the system's induced draft fan. At the inlet to the secondary combustion chamber, the offgas is mixed with air in a high energy burner and is admitted to the chamber in a tangential fashion for a high turbulence, spiral flame. Excess air is normally used to maintain the exit temperatrue from the secondary combustion chamber between 1150^{o} F and 1250^{o} C (2100-2280^{o} F). The secondary combustion chamber is a vertical, refractory lined vessel in which temperatures up to 1400^{o} C (2550^{o} F) are realized, and where sufficient residence time, up to 1.7 seconds, is maintained to assure complete combustion. The particulate matter entrained in the offgas from the gasifier is burned and the inert portion is fused, melted and slagged out of the stream. This slag is also water quenched and is approximately 10% of the total residue produced in the process.

8.4.3 AIR PREHEATING SYSTEM

As mentioned previously, there are a number of possible methods for the preheating of primary combustion air by utilizing the energy from the hot combustion products which exit from the secondary combustion chamber or by burning fossil fuel. One such equipment system which has been built at both the SIDOR (Luxembourg) plant and the Frankfurt plant is represented in Figures 1 and 2. This system employs two regenerative towers, equipment successfully used for many years in the steel and glass industries for preheating air. Regenerative towers are refractory filled steel vessels containing a high heat capacity refractory with a multiplicity of vertical aligned flues which readily absorbs the heat from the hot products of combustion passing through them. During the heating cycle, approximately 10% of the total products of combustion from the secondary combustion chamber are introduced into the top of the regenerative towers. The heat from these gases is transferred to the refractories, bringing them up to temperature levels of approximately 1150^{o} C (2100^{o} F) at the top and 260^{o} C (500^{o} F) at the base. The waste gas exiting the regenerative tower sub-system is returned to a duct at the inlet of the gas cleaning system. A modulating damper valve in the boiler exit duct controls the amount of gas used in heating the regenerative tower refractory. During the "blast" cycle, the combustion products from the secondary combustion chamber are diverted to the second regenerative tower to heat its refractory. Ambient process air is introducted at the base of the fully heated regenerative tower and passes up through the refractory absorbing the stored heat. The exit temperature of the air from the tower ranges from 1037^{o} C (1900^{o} F) to 1110^{o} C (2030^{o} F). A constant primary air, or blast, temperature is maintained by blending the heated air with ambient air before introduction into the gasifier. Regenerative towers have been employed in the Grid ICES Andco-Torrax system.

A second method for preheating the primary combustion air employs a heat recuperator as used in the Grasse and Creteil plants. The metallic recuperator recovers heat from a portion of the products of combustion from the SCC exit and produces preheated air at a temperature of 600^{o} C. The additional 400^{o} C temperature differential is achieved through the use of a supplementary oil or gas fired burner.

A third method for preheating the primary combustion air employs a fossil fuel fired silicon carbide cross flow shell-and-tube heat exchanger similar to that used in the demonstration plant in Orchard Park, New York. While this unit proved reliable during operation, the cost and availability of liquid or gaseous fossil fuels makes such a unit unattractive for commercial plants. Using a regenerative or recuperative type of heat exchanger results in both energy and cost savings.

8.4.4 WASTE HEAT BOILER

With regenerative towers as the method of air preheating, approximately 90% of the gas flow exiting the secondary combustion chamber is directed to the energy recovery system, a waste heat boiler. Typically, the waste heat boiler is of the combination radiation-convection type and is designed with certain Andco-Torrax process characteristics in mind. These characteristics are high temperature inlet gases and absence of unburned material, low volumetric gas flow, and low particulate loading. Gases leave the boiler at approximately 238^{o} C (460^{o} F).

8.4.5 GAS CLEANING EQUIPMENT

At the exit of the waste heat boiler, the cooled waste gases from the regenerative towers (or alternative preheating systems) are combined with the exiting flow from the waste heat boiler and are ducted to the gas cleaning system.

8.5 COMMERCIAL PLANTS

Orders for four commercial Andco-Torrax systems have been received to January 1978. One order was placed in 1975 with Antox Wurth, Andco's West German licensee, by the City of Frankfurt. The unit capacity is 200 metric tons per day (220 TPD) and the system is located within an existing conventional incineration facility. Another order was placed in 1975 with Caliqua S. A. by the municipality of Grasse, France. The construction of the new 168 metric ton-per-day (185 TPD) plant is under the authority of Caliqua for use by the "Syndicat Intercommunal pour le Traitement et l'enlevement des Ordures Menageres et des Dechets Urbains de la Region de Grasse." The Grasse plant is currently undergoing its initial start-up phase and the Frankfurt plant construction will be complete in the first quarter of 1978. A third plant, with a capacity of 400 metric tons per day (440 TPD), is being built in Creteil, France, and will be completed in 1979.

The first order for a commercial Andco-Torrax system was awarded to S. A. Paul Wurth, Andco's Benelux licensee, in January 1974. This system has a 192 metric-ton-day (211 TPD) capacity, and is owned and operated by the Syndicat Intercommunal pour la Destruction des Ordures des Cantons de Luxembourg, Esch, et Cappellen, (SIDOR), a group of 35 municipalies in Luxembourg. Process design and sizing of the hardware components for this system were based largely on prior demonstration plant experience gathered at the Orchard Park facility, correlation with specific refuse analysis data for Luxembourg, and utilization of Andco's process simulation computer program. The design plant refuse composition, expressed in weight percent, for the SIDOR Andco Torrax system is:

Refuse Composition		Proximate Analysis		Ultimate Analysis	
Combustibles	51.4	Fixed Carbon	9.0	Carbon	29.3
Water	23.7	Volatiles	42.4	Hydrogen	3.6
Ash Inerts	24.9			Oxygen	18.5

This refuse analysis corresponds to a lower heating value of 2,500 kcal/kg (4,500 BTU/lb). Although the plant was designed for 2,500 kcal/kg refuse, actual refuse quality as received is closer to 1,600 kcal/kg (2,880 BTU/lb).

The over-all SIDOR plant consists of two conventional grate-type incinerators built by CNIM (Constructions Navales et Industrielles de la Mediteranee) and one 192 ton-per-day Andco-Torrax unit built by S. A. Paul Wurth. The Andco-Torrax equipment includes the refuse feeder, gasifier, secondary combustion chamber, regenerative towers, waste heat boiler, steam condensation units, electrostatic precipitator, induced draft fan, chimney, water cooling plant, controls system, and all secondary equipment for compressed air, auxiliary fuel and waste oil sub-systems.

The greater portion of the hot gases exiting from the SIDOR Andco-Torrax secondary combustion chamber is fed to a waste heat boiler, where the sensible heat content is used to generate steam. The boiler has been designed for a maximum gas throughput of 36,800 nm^3/h (21,600 scf/min), a maximum gas inlet temperature of 1370^O C (2500^O F) and a nominal gas inlet temperature of 1250^O C (2280^O F). The boiler is a 3-pass, vertical, combination radiation/convection boiler, with the first of the three passes comprising the radiation section. The boiler has a superheater at the end of the radiation section and an economizer in the third pass. With a feed-water temperature of 140° C (284° F), the boiler is designed to produce a maximum of 60,000 lb/hr of steam at a pressure of 35 kg/cm^2 (498 psi) and a temperature of 385° C (725° F).

The steam produced by all three refuse conversion units is directed to a 7 MW turbine generator producing electricity at 10 kV. The turbine generator is designed for a throughput lower than the plant's corresponding refuse capacity of 600 metric tons per day, in that the amount of waste currently generated and available to the plant is lower than the total design capacity. A second turbine generator will be installed as refuse production increases.

Theoretically, 1 kg (2.2 lb) of 2.000 kcal/kg (3,600 BTU/lb) refuse can be converted to 122 KWh of electricity. However, due to practical turbine efficiencies, line losses, and flue gas losses, the final conversion factor of refuse to electrical power is approximately 0.48 KWh per kg of refuse.

The waste gases from the boiler are combined with the exhaust gases from the regenerative towers and enter the electrostatic precipitator. The two-field precipitator is designed to produce particulate emissions no greater than 100 mg/nm^3, corrected to 7% CO_2. The cleaned gases then pass through an induced draft fan to a triple flue stack, 80 meters in overall height.

8.6 PRELIMINARY DESIGN CRITERIA

The pyrolysis unit has been sized for a refuse feed rate of 132 tons per day plus or minus 15 percent. This refuse feed rate is based on the following distribution:

57 TPD	=	Hospital and other Health Care Refuse (HHC)
23 TPD	=	University of Minnesota General Refuse (U of M)
52 TPD	=	Municipal Refuse
132 TPD	=	Total Nominal System Input

Corresponding to the 132 tons per day system are the following heating value estimates:

HHC:	Approximately 6,346 BTU per pound as fired
U of M:	Approximately 5,909 BTU per pound as fired
Municipal:	Approximately 5,383 BTU per pound as fired

The weighed average of the heating values is 5,890 BTU per pound as fired as this value has been used as the nominal design point.

Heat recovery in the form of a waste heat boiler will be designed to operate in parallel with existing boilers that operate at a steam header pressure of 400 psig, 750° F.

The exit gas stream from the waste heat boiler and the regenerative air heaters will be cleaned in a fabric filter baghouse before release to the atmosphere. Particulate emission will satisfy MPCA limits.

Slag from the gasifier and the secondary combustion chamber will be collected in a silo for storage. Slag will be trucked to an approved sanitary landfill until an economic market can be found.

8.7 SCOPE OF WORK

The University of Minnesota has purchased the so called Southeast Generating Station from the Northern States Power Company. This plant contains two coal fired boilers that will be retrofitted to burn low sulphur Montana coal. An area east of the existing boilers to the east wall of the building will be developed for the refuse storage pit and the Andco-Torrax Pyrolysis unit with auxiliaries. The roof will be raised approximately 10 feet.

An enclosed truck dock will be constructed so that refuse trucks can be unloaded. University of Minnesota general waste and municipal waste will be unloaded into a pit that will hold approximately 264 tons of refuse. A bridge crane with a grapple to hold 3 cubic yards of refuse will transport the refuse from the pit to the feeder on the gasifier. The crane will be controlled from a fixed control room. A weighing system will be provided so that performance of the pyrolysis system can be monitored. "Red bag" refuse will be transported from the hospitals and health care facilities in 2' x 2' x 2' box containers that will be unloaded on a horizontal conveyor adjacent to the gasifier. An elevator and feeder conveyor will deliver the boxes to the feeder on the gasifier. The operation of the "red bag" conveying system will be under the control fo the refuse crane operator. A weighing system will be provided. A "mix" of general refuse and "red bag" refuse will be made to maintain a reasonably uniform flow of material to the gasifier.

Building modifications and additions will be made to support the components of the Andco-Torrax system and integrate the system with the rest of the plant. Complete access in the form of platforms and stairs will be provided for inspection and maintenance.

A heat recovery boiler will be installed to lower the gas temperature at the exit of the secondary combustion chamber from 2300° F to approximately 460° F. A complete system of instrumentation and control will be provided. This boiler will operate in parallel with two coal fired boilers which supply steam to the 400 psig, 750° F header.

8.8

OPERATING CRITERIA

COMPUTER SIMULATION SUMMARIES

Nine computer runs were made, to identify the operating envelope shown on the Andco-Torrax system diagram. The refuse rate varies from 102 metric tons per day (112 TPD) to 138 metric tons per day (152 TPD). The refuse quality is expected to vary from 2,350 Kcal/kg (4,230 BTU/lb) to 3,200 Kcal/kg (5,760 BTU/lb). The average design conditions are for a refuse throughput rate of 120 metric tons per day (132 TPD) and a refuse lower heating value of 2,950 Kcal/kg (5,310 BTU/lb).

The following is a list of input variables for the computer runs for the variable system parameters other than refuse rate and quality:

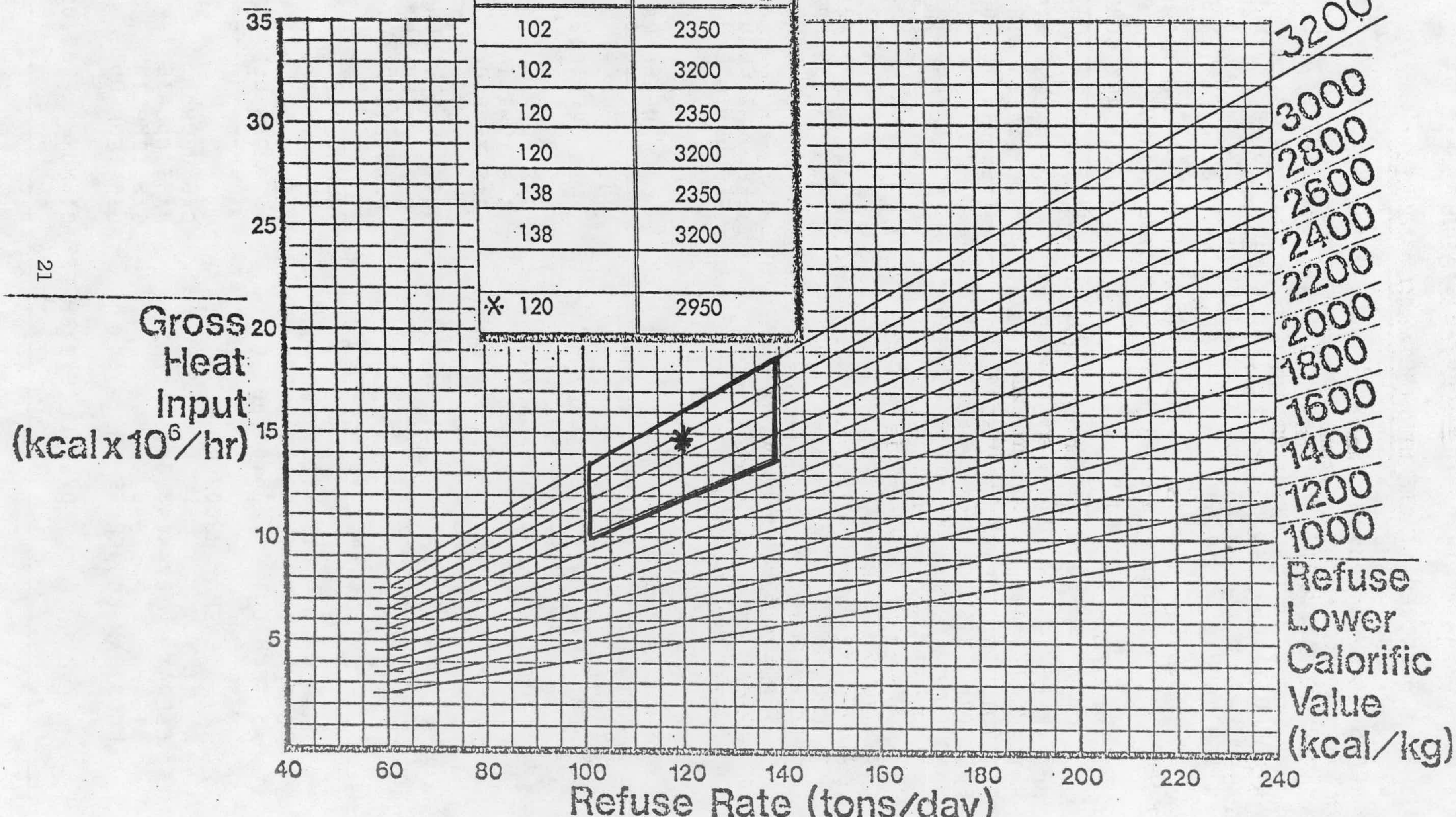
1. Auxiliary
2. Fuel Oil - Composition 87.2% carbon, 12% hyrdrogen, 0.3% ash, 0% water, specific gravity 0.865%, LHV 10,196 Kcal/kg
3. Boiler Data - Steam Pressure: 30.6 atmos.
   Steam Temperature: 385^{O} C
   Steam Enthalpy: 763.8 Kcal/kg
   Feedwater Enthalpy: 121.1 Kcal/kg
4. Ambient Temperature: 15.56^{O} C
5. Atmospheric Pressure is 1 atmos. (760 millimeters hg)
6. Gas Solids have 0 enthalpy at 15.56^{O} C
7. All supplemental fuel is combusted to CO_2 and water vapor with 100% heat release
8. Overall system efficiency is determined as follows: efficiency equals steam heat out minus water heat in all divided by refuse heat in plus total fuel heat in where refuse and fuel heats are determined from their lower heating values.

andco-torrax system operating diagram

LICENSEE:
PROJECT NAME: UNIVERSITY OF MINNESOTA
PROJECT NO: 961-001-00
DATE: FEBRUARY 3, 1978

Operating Points

M TPD	kcal/kg
102	2350
102	3200
120	2350
120	3200
138	2350
138	3200
* 120	2950



*DESIGN POINT

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	47.83	% FIXED CARBON	8.48	% CARBON	27.26
% WATER	32.63	% VOLATILES	39.35	% HYDROGEN	3.35
% ASH-INERTS	19.54	% WATER	32.63	% OXYGEN	17.22
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	2464.28 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	6.67 L/T
SLAG OUTPUT	830.61 KG/H

OFFGAS

FLOW	6424.87 NM3/H
TEMPERATURE	427.93 DEG C

HEATING VALUE

SENSIBLE	160.45 KCAL/NM3
LATENT	118.76 KCAL/NM3
CHEM + PART	1403.88 KCAL/NM3
TOTAL	1683.10 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	19379.31 NM3/H
GAS TEMP IN	1259.13 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	8744143.38 KCAL/H
STEAM	11448.21 KG/H
KG STEAM/KG REFUSE	2.69

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	15806.47 NM3/H
SCC EXCESS AIR	62. %
FUEL OIL TO SCC	8.00 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	5.9
% N2	68.0
% CO2	10.4
% H2O	15.7

EFFLUENT FLOW	21611.91 NM3/H
EFFLUENT TEMP	1259.13 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	2232.60 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	235.51 DEG C
HOT BLAST FLOW	2464.28 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	271.54 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	21883.46 NM3/H
PARTICULATE	69.68 KG/H
GAS TEMP IN	237.71 DEG C
GAS TEMP OUT	233.27 DEG C

OVERALL SYSTEM EFFICIENCY 69.82 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

HEAT AND MASS BALANCE

IN			OUT		
	KG/H	KCAL/H		KG/H	KCAL/H
GASIFIER					
REFUSE	4250.	9987500.	OFFGAS	6713.	10050630.
HOT BLAST	3186.	855839.	SLAG	747.	246429.
FUEL OIL	25.	250000.	HEAT LOSS		796280.
TOTAL	7461.	11093339.	TOTAL	7461.	11093339.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	6713.	10050630.	WASTE GAS	27519.	10150210.
TOTAL AIR	20859.	0.	SLAG	83.	27407.
FUEL OIL	29.	300000.	HEAT LOSS		173012.
TOTAL	27602.	10350630.	TOTAL	27602.	10350630.
WASTE HEAT BOILER					
WASTE GAS	24676.	9101652.	WASTE GAS	24676.	1561853.
FEED WATER	11448.	1386378.	STEAM	11448.	8744143.
			HEAT LOSS		182033.
TOTAL	36125.	10488030.	TOTAL	36125.	10488030.
REGENERATIVE TOWERS					
WASTE GAS	2843.	1048559.	WASTE GAS	3194.	178255.
COLD BLAST	3186.	16992.	HOT BLAST	3186.	855839.
BLEND AIR	351.		HEAT LOSS		31457.
TOTAL	6380.	1065551.	TOTAL	6380.	1065551.
GAS CLEANING SYSTEM					
WASTE GAS	27870.	1740108.	WASTE GAS	27801.	1705306.
			PARTICULATE	70.	
			HEAT LOSS		34802.
TOTAL	27870.	1740108.	TOTAL	27870.	1740108.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

ASSUMPTIONS :
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION :	87.20	% CARBON
(BY WEIGHT)	12.50	% HYDROGEN
	0.30	% ASH
	0.	% WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :
STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{\text{(STEAM HEAT OUT - FEEDWATER HEAT IN)}}{\text{(REFUSE HEAT IN + TOTAL FUEL HEAT IN)}}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N   DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	47.83	% FIXED CARBON	8.48	% CARBON	27.26
% WATER	32.63	% VOLATILES	39.35	% HYDROGEN	3.35
% ASH-INERTS	19.54	% WATER	32.63	% OXYGEN	17.22
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	2851.19 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	5.67 L/T
SLAG OUTPUT	977.16 KG/H

OFFGAS

FLOW	7507.66 NM3/H
TEMPERATURE	434.41 DEG C

HEATING VALUE

SENSIBLE	163.19 KCAL/NM3
LATENT	119.22 KCAL/NM3
CHEM + PART	1413.42 KCAL/NM3
TOTAL	1695.83 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	22781.57 NM3/H
GAS TEMP IN	1259.71 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	10284340.00 KCAL/H
STEAM	13464.70 KG/H
KG STEAM/KG REFUSE	2.69

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	18646.01 NM3/H
SCC EXCESS AIR	62. %
FUEL OIL TO SCC	6.80 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	5.9
% N2	68.0
% CO2	10.4
% H2O	15.7

EFFLUENT FLOW	25363.74 NM3/H
EFFLUENT TEMP	1259.71 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	2582.17 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	235.63 DEG C
HOT BLAST FLOW	2851.19 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	315.66 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	25679.40 NM3/H
PARTICULATE	81.76 KG/H
GAS TEMP IN	237.73 DEG C
GAS TEMP OUT	233.29 DEG C

OVERALL SYSTEM EFFICIENCY 70.36 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG. HHV = 2716. KCAL/KG

HEAT AND MASS BALANCE

	IN KG/H	IN KCAL/H		OUT KG/H	OUT KCAL/H
GASIFIER					
REFUSE	5000.	11750000.	OFFGAS	7832.	11836612.
HOT BLAST	3687.	990211.	SLAG	879.	289912.
FUEL OIL	25.	250000.	HEAT LOSS		863687.
TOTAL	8711.	12990211.	TOTAL	8711.	12990211.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	7832.	11836612.	WASTE GAS	32294.	11916715.
TOTAL AIR	24531.	0.	SLAG	98.	32239.
FUEL OIL	29.	300000.	HEAT LOSS		187658.
TOTAL	32392.	12136612.	TOTAL	32392.	12136612.
WASTE HEAT BOILER					
WASTE GAS	29007.	10703526.	WASTE GAS	29007.	1835691.
FEED WATER	13465.	1630576.	STEAM	13465.	10284340.
			HEAT LOSS		214071.
TOTAL	42471.	12334101.	TOTAL	42471.	12334101.
REGENERATIVE TOWERS					
WASTE GAS	3288.	1213189.	WASTE GAS	3696.	206242.
COLD BLAST	3687.	19660.	HOT BLAST	3687.	990211.
BLEND AIR	408.		HEAT LOSS		36396.
TOTAL	7382.	1232849.	TOTAL	7382.	1232849.
GAS CLEANING SYSTEM					
WASTE GAS	32703.	2041933.	WASTE GAS	32621.	2001094.
			PARTICULATE	82.	
			HEAT LOSS		40839.
TOTAL	32703.	2041933.	TOTAL	32703.	2041933.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

ASSUMPTIONS :
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION :	87.20 %	CARBON
(BY WEIGHT)	12.50 %	HYDROGEN
	0.30 %	ASH
	0. %	WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :
STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{\text{(STEAM HEAT OUT - FEEDWATER HEAT IN)}}{\text{(REFUSE HEAT IN + TOTAL FUEL HEAT IN)}}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	47.83	% FIXED CARBON	8.48	% CARBON	27.26
% WATER	32.63	% VOLATILES	39.35	% HYDROGEN	3.35
% ASH-INERTS	19.54	% WATER	32.63	% OXYGEN	17.22
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	3238.10 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	4.93 L/T
SLAG OUTPUT	1123.71 KG/H

OFFGAS

FLOW	8590.46 NM3/H
TEMPERATURE	440.65 DEG C

HEATING VALUE

SENSIBLE	165.80 KCAL/NM3
LATENT	119.56 KCAL/NM3
CHEM + PART	1420.55 KCAL/NM3
TOTAL	1705.92 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	26192.02 NM3/H
GAS TEMP IN	1260.40 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	11830762.50 KCAL/H
STEAM	15489.35 KG/H
KG STEAM/KG REFUSE	2.69

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	21493.27 NM3/H
SCC EXCESS AIR	62. %
FUEL OIL TO SCC	5.92 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	6.0
% N2	68.0
% CO2	10.4
% H2O	15.7

EFFLUENT FLOW	29123.29 NM3/H
EFFLUENT TEMP	1260.40 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	2931.27 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	235.77 DEG C
HOT BLAST FLOW	3238.10 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	360.51 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	29483.80 NM3/H
PARTICULATE	93.86 KG/H
GAS TEMP IN	237.75 DEG C
GAS TEMP OUT	233.31 DEG C

OVERALL SYSTEM EFFICIENCY 70.79 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

HEAT AND MASS BALANCE

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
GASIFIER					
REFUSE	5750.	13512500.	OFFGAS	8950.	13627487.
HOT BLAST	4187.	1124583.	SLAG	1011.	333395.
FUEL OIL	25.	250000.	HEAT LOSS		926201.
TOTAL	9961.	14887083.	TOTAL	9961.	14887083.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	8950.	13627487.	WASTE GAS	37080.	13689176.
TOTAL AIR	28213.	0.	SLAG	112.	37070.
FUEL OIL	29.	300000.	HEAT LOSS		201241.
TOTAL	37192.	13927487.	TOTAL	37192.	13927487.
WASTE HEAT BOILER					
WASTE GAS	33348.	12311356.	WASTE GAS	33348.	2110126.
FEED WATER	15489.	1875760.	STEAM	15489.	11830763.
			HEAT LOSS		246227.
TOTAL	48837.	14187116.	TOTAL	48837.	14187116.
REGENERATIVE TOWERS					
WASTE GAS	3732.	1377819.	WASTE GAS	4198.	234229.
COLD BLAST	4187.	22328.	HOT BLAST	4187.	1124583.
BLEND AIR	466.		HEAT LOSS		41335.
TOTAL	8385.	1400147.	TOTAL	8385.	1400147.
GAS CLEANING SYSTEM					
WASTE GAS	37546.	2344356.	WASTE GAS	37452.	2297468.
			PARTICULATE	94.	
			HEAT LOSS		46887.
TOTAL	37546.	2344356.	TOTAL	37546.	2344356.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N   DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2350. KCAL/KG, HHV = 2716. KCAL/KG

ASSUMPTIONS :
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION : 87.20 % CARBON
(BY WEIGHT) 12.50 % HYDROGEN
0.30 % ASH
0. % WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :

STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{STEAM HEAT OUT} - \text{FEEDWATER HEAT IN})}{(\text{REFUSE HEAT IN} + \text{TOTAL FUEL HEAT IN})}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	58.41	% FIXED CARBON	9.72	% CARBON	33.29
% WATER	22.05	% VOLATILES	48.69	% HYDROGEN	4.09
% ASH-INERTS	19.54	% WATER	22.05	% OXYGEN	21.03
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	2740.55 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	6.67 L/T
SLAG OUTPUT	830.61 KG/H

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	21734.18 NM3/H
SCC EXCESS AIR	80. %
FUEL OIL TO SCC	8.00 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	7.4
% N2	71.1
% CO2	9.9
% H2O	11.6

EFFLUENT FLOW	27546.78 NM3/H
EFFLUENT TEMP	1259.70 DEG C

OFFGAS

FLOW	6675.32 NM3/H
TEMPERATURE	595.88 DEG C

HEATING VALUE

SENSIBLE	230.77 KCAL/NM3
LATENT	77.97 KCAL/NM3
CHEM + PART	1671.25 KCAL/NM3
TOTAL	1979.99 KCAL/NM3

REGENERATIVE TOWER

EFFICIENCY 60%

GAS FLOW	2510.33 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	237.41 DEG C
HOT BLAST FLOW	2740.55 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	298.74 NM3/H

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	25036.45 NM3/H
GAS TEMP IN	1259.70 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	11193518.00 KCAL/H
STEAM	14655.04 KG/H
KG STEAM/KG REFUSE	3.45

GAS CLEANING EQUIPMENT

GAS FLOW	27845.52 NM3/H
PARTICULATE	89.82 KG/H
GAS TEMP IN	237.94 DEG C
GAS TEMP OUT	233.49 DEG C

OVERALL SYSTEM EFFICIENCY 71.97 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N   DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

HEAT AND MASS BALANCE

GASIFIER

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
REFUSE	4250.	12537500.	OFFGAS	7071.	12696576.
HOT BLAST	3544.	951785.	SLAG	747.	246429.
FUEL OIL	25.	250000.	HEAT LOSS		796280.
TOTAL	7818.	13739285.	TOTAL	7818.	13739285.

SECONDARY COMBUSTION CHAMBER

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
OFFGAS	7071.	12696576.	WASTE GAS	35541.	12796156.
TOTAL AIR	28524.	0.	SLAG	83.	27407.
FUEL OIL	29.	300000.	HEAT LOSS		173012.
TOTAL	35624.	12996576.	TOTAL	35624.	12996576.

WASTE HEAT BOILER

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
WASTE GAS	32302.	11630046.	WASTE GAS	32302.	1978652.
FEED WATER	14655.	1774725.	STEAM	14655.	11193518.
			HEAT LOSS		232601.
TOTAL	46957.	13404771.	TOTAL	46957.	13404771.

REGENERATIVE TOWERS

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
WASTE GAS	3239.	1166110.	WASTE GAS	3625.	198239.
COLD BLAST	3544.	18897.	HOT BLAST	3544.	951785.
BLEND AIR	386.		HEAT LOSS		34983.
TOTAL	7169.	1185007.	TOTAL	7169.	1185007.

GAS CLEANING SYSTEM

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
WASTE GAS	35927.	2176891.	WASTE GAS	35837.	2133353.
			PARTICULATE	90.	
			HEAT LOSS		43538.
TOTAL	35927.	2176891.	TOTAL	35927.	2176891.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

ASSUMPTIONS :

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION : 87.20 % CARBON
(BY WEIGHT) 12.50 % HYDROGEN
0.30 % ASH
0. % WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :

STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{STEAM HEAT OUT} - \text{FEEDWATER HEAT IN})}{(\text{REFUSE HEAT IN} + \text{TOTAL FUEL HEAT IN})}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	58.41	% FIXED CARBON	9.72	% CARBON	33.29
% WATER	22.05	% VOLATILES	48.69	% HYDROGEN	4.09
% ASH-INERTS	19.54	% WATER	22.05	% OXYGEN	21.03
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	3176.21 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	5.67 L/T
SLAG OUTPUT	977.16 KG/H

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	25631.46 NM3/H
SCC EXCESS AIR	80. %
FUEL OIL TO SCC	6.80 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	7.4
% N2	71.1
% CO2	9.9
% H2O	11.6

EFFLUENT FLOW	32357.61 NM3/H
EFFLUENT TEMP	1259.83 DEG C

OFFGAS

FLOW	7802.31 NM3/H
TEMPERATURE	602.92 DEG C

HEATING VALUE

SENSIBLE	233.86 KCAL/NM3
LATENT	78.14 KCAL/NM3
CHEM + PART	1682.17 KCAL/NM3
TOTAL	1994.17 KCAL/NM3

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	2909.65 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	237.45 DEG C
HOT BLAST FLOW	3176.21 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	346.58 NM3/H

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	29447.97 NM3/H
GAS TEMP IN	1259.83 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	13165104.00 KCAL/H
STEAM	17236.32 KG/H
KG STEAM/KG REFUSE	3.45

GAS CLEANING EQUIPMENT

GAS FLOW	32704.20 NM3/H
PARTICULATE	105.49 KG/H
GAS TEMP IN	237.94 DEG C
GAS TEMP OUT	233.50 DEG C

OVERALL SYSTEM EFFICIENCY 72.40 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

HEAT AND MASS BALANCE

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
GASIFIER					
REFUSE	5000.	14750000.	OFFGAS	8252.	14949489.
HOT BLAST	4107.	1103088.	SLAG	879.	289912.
FUEL OIL	25.	250000.	HEAT LOSS		863687.
TOTAL	9131.	16103088.	TOTAL	9131.	16103088.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	8252.	14949489.	WASTE GAS	41747.	15029592.
TOTAL AIR	33563.	0.	SLAG	98.	32239.
FUEL OIL	29.	300000.	HEAT LOSS		187658.
TOTAL	41845.	15249489.	TOTAL	41845.	15249489.
WASTE HEAT BOILER					
WASTE GAS	37993.	13678108.	WASTE GAS	37993.	2326761.
FEED WATER	17236.	2087319.	STEAM	17236.	13165104.
			HEAT LOSS		273562.
TOTAL	55229.	15765427.	TOTAL	55229.	15765427.
REGENERATIVE TOWERS					
WASTE GAS	3754.	1351484.	WASTE GAS	4202.	229752.
COLD BLAST	4107.	21901.	HOT BLAST	4107.	1103088.
BLEND AIR	448.		HEAT LOSS		40545.
TOTAL	8309.	1373385.	TOTAL	8309.	1373385.
GAS CLEANING SYSTEM					
WASTE GAS	42195.	2556513.	WASTE GAS	42089.	2505383.
			PARTICULATE	105.	
			HEAT LOSS		51130.
TOTAL	42195.	2556513.	TOTAL	42195.	2556513.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

ASSUMPTIONS :
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION : 87.20 % CARBON
(BY WEIGHT) 12.50 % HYDROGEN
0.30 % ASH
0. % WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :

STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{STEAM HEAT OUT} - \text{FEEDWATER HEAT IN})}{(\text{REFUSE HEAT IN} + \text{TOTAL FUEL HEAT IN})}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	58.41	% FIXED CARBON	9.72	% CARBON	33.29
% WATER	22.05	% VOLATILES	48.69	% HYDROGEN	4.09
% ASH-INERTS	19.54	% WATER	22.05	% OXYGEN	21.03
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	3611.87 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	4.93 L/T
SLAG OUTPUT	1123.71 KG/H

OFFGAS

FLOW	8929.30 NM3/H
TEMPERATURE	609.50 DEG C

HEATING VALUE

SENSIBLE	236.72 KCAL/NM3
LATENT	78.27 KCAL/NM3
CHEM + PART	1690.34 KCAL/NM3
TOTAL	2005.33 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	33868.13 NM3/H
GAS TEMP IN	1260.09 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	15142882.13 KCAL/H
STEAM	19825.72 KG/H
KG STEAM/KG REFUSE	3.45

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	29536.97 NM3/H
SCC EXCESS AIR	81. %
FUEL OIL TO SCC	5.92 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	7.5
% N2	71.1
% CO2	9.9
% H2O	11.5

EFFLUENT FLOW	37176.68 NM3/H
EFFLUENT TEMP	1260.09 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	3308.55 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	237.50 DEG C
HOT BLAST FLOW	3611.87 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	394.92 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	37571.61 NM3/H
PARTICULATE	121.19 KG/H
GAS TEMP IN	237.95 DEG C
GAS TEMP OUT	233.50 DEG C

OVERALL SYSTEM EFFICIENCY 72.76 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

HEAT AND MASS BALANCE

	IN KG/H	IN KCAL/H		OUT KG/H	OUT KCAL/H
GASIFIER					
REFUSE	5750.	16962500.	OFFGAS	9433.	17207296.
HOT BLAST	4670.	1254392.	SLAG	1011.	333395.
FUEL OIL	25.	250000.	HEAT LOSS		926201.
TOTAL	10445.	18466892.	TOTAL	10445.	18466892.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	9433.	17207296.	WASTE GAS	47963.	17268984.
TOTAL AIR	38613.	0.	SLAG	112.	37070.
FUEL OIL	29.	300000.	HEAT LOSS		201241.
TOTAL	48076.	17507296.	TOTAL	48076.	17507296.
WASTE HEAT BOILER					
WASTE GAS	43695.	15732126.	WASTE GAS	43695.	2675495.
FEED WATER	19826.	2400894.	STEAM	19826.	15142882.
			HEAT LOSS		314643.
TOTAL	63521.	18133020.	TOTAL	63521.	18133020.
REGENERATIVE TOWERS					
WASTE GAS	4269.	1536859.	WASTE GAS	4779.	261266.
COLD BLAST	4670.	24905.	HOT BLAST	4670.	1254392.
BLEND AIR	511.		HEAT LOSS		46106.
TOTAL	9449.	1561764.	TOTAL	9449.	1561764.
GAS CLEANING SYSTEM					
WASTE GAS	48474.	2936761.	WASTE GAS	48353.	2878026.
			PARTICULATE	121.	
			HEAT LOSS		58735.
TOTAL	48474.	2936761.	TOTAL	48474.	2936761.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 2950. KCAL/KG, HHV = 3293. KCAL/KG

ASSUMPTIONS :
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION :	87.20	% CARBON
(BY WEIGHT)	12.50	% HYDROGEN
	0.30	% ASH
	0.	% WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :
STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{STEAM HEAT OUT} - \text{FEEDWATER HEAT IN})}{(\text{REFUSE HEAT IN} + \text{TOTAL FUEL HEAT IN})}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	62.84	% FIXED CARBON	10.22	% CARBON	35.82
% WATER	17.62	% VOLATILES	52.62	% HYDROGEN	4.40
% ASH-INERTS	19.54	% WATER	17.62	% OXYGEN	22.62
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP 1037.00 DEG C
HOT BLAST AIR FLOW 2851.95 NM3/H
FUEL OIL TO TUYERES 0. L/T
FUEL OIL TO SLAG TAP 6.67 L/T
SLAG OUTPUT 830.61 KG/H

OFFGAS

FLOW 6777.06 NM3/H

TEMPERATURE 660.07 DEG C

HEATING VALUE

SENSIBLE 258.18 KCAL/NM3
LATENT 61.81 KCAL/NM3
CHEM + PART 1777.77 KCAL/NM3

TOTAL 2097.76 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW 27405.61 NM3/H
GAS TEMP IN 1259.50 DEG C
GAS TEMP OUT 238.00 DEG C

ENERGY RECOVERY

ENERGY 12214029.88 KCAL/H
STEAM 15991.14 KG/H
KG STEAM/KG REFUSE 3.76

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR 24216.41 NM3/H
SCC EXCESS AIR 85. %
FUEL OIL TO SCC 8.00 L/T

EFFLUENT CONSTITUENTS
BY VOLUME

% O2 7.8
% N2 72.1
% CO2 9.8
% H2O 10.3

EFFLUENT FLOW 30027.61 NM3/H
EFFLUENT TEMP 1259.50 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW 2622.00 NM3/H
GAS TEMP IN 1150.00 DEG C
GAS TEMP OUT 237.96 DEG C

HOT BLAST FLOW 2851.95 NM3/H
BLAST TEMP IN 37.00 DEG C
BLAST TEMP OUT 1038.00 DEG C

BLEND AIR 308.85 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW 30336.46 NM3/H
PARTICULATE 98.23 KG/H
GAS TEMP IN 238.00 DEG C
GAS TEMP OUT 233.55 DEG C

OVERALL SYSTEM EFFICIENCY 72.63 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

HEAT AND MASS BALANCE

	IN KG/H	IN KCAL/H		OUT KG/H	OUT KCAL/H
GASIFIER					
REFUSE	4250.	13600000.	OFFGAS	7215.	13797764.
HOT BLAST	3688.	990472.	SLAG	747.	246429.
FUEL OIL	25.	250000.	HEAT LOSS		796280.
TOTAL	7962.	14840473.	TOTAL	7962.	14840473.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	7215.	13797764.	WASTE GAS	38894.	13897344.
TOTAL AIR	31734.	0.	SLAG	83.	27407.
FUEL OIL	29.	300000.	HEAT LOSS		173012.
TOTAL	38978.	14097764.	TOTAL	38978.	14097764.
WASTE HEAT BOILER					
WASTE GAS	35498.	12683835.	WASTE GAS	35498.	2152655.
FEED WATER	15991.	1936527.	STEAM	15991.	12214030.
			HEAT LOSS		253677.
TOTAL	51489.	14620361.	TOTAL	51489.	14620361.
REGENERATIVE TOWERS					
WASTE GAS	3396.	1213509.	WASTE GAS	3796.	206297.
COLD BLAST	3688.	19665.	HOT BLAST	3688.	990472.
BLEND AIR	399.		HEAT LOSS		36405.
TOTAL	7483.	1233174.	TOTAL	7483.	1233174.
GAS CLEANING SYSTEM					
WASTE GAS	39294.	2358951.	WASTE GAS	39196.	2311772.
			PARTICULATE	98.	
			HEAT LOSS		47179.
TOTAL	39294.	2358951.	TOTAL	39294.	2358951.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N   DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 102. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

ASSUMPTIONS ;
----

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

   COMPOSITION : 87.20 % CARBON
   (BY WEIGHT) 12.50 % HYDROGEN
   0.30 % ASH
   0. % WATER
   SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
   LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :

   STEAM PRESSURE : 30.6 ATMOSPHERES
   STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
   STEAM ENTHALPY : 763.8 KCAL/KG
   FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :
----

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

   LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
   WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{ STEAM HEAT OUT - FEEDWATER HEAT IN })}{(\text{ REFUSE HEAT IN + TOTAL FUEL HEAT IN })}$$

   WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	62.84	% FIXED CARBON	10.22	% CARBON	35.82
% WATER	17.62	% VOLATILES	52.62	% HYDROGEN	4.40
% ASH-INERTS	19.54	% WATER	17.62	% OXYGEN	22.62
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	3307.26 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	5.67 L/T
SLAG OUTPUT	977.16 KG/H

OFFGAS

FLOW	7922.00 NM3/H
TEMPERATURE	667.33 DEG C

HEATING VALUE

SENSIBLE	261.40 KCAL/NM3
LATENT	61.88 KCAL/NM3
CHEM + PART	1789.22 KCAL/NM3
TOTAL	2112.49 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	32239.27 NM3/H
GAS TEMP IN	1259.50 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	14365387.25 KCAL/H
STEAM	18807.79 KG/H
KG STEAM/KG REFUSE	3.76

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	28556.00 NM3/H
SCC EXCESS AIR	86. %
FUEL OIL TO SCC	6.80 L/T

EFFLUENT CONSTITUENTS
BY VOLUME

% O2	7.9
% N2	72.1
% CO2	9.7
% H2O	10.3

EFFLUENT FLOW	35280.50 NM3/H
EFFLUENT TEMP	1259.50 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	3041.23 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	237.97 DEG C
HOT BLAST FLOW	3307.26 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	358.11 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	35638.61 NM3/H
PARTICULATE	115.40 KG/H
GAS TEMP IN	238.00 DEG C
GAS TEMP OUT	233.55 DEG C

OVERALL SYSTEM EFFICIENCY 73.04 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

HEAT AND MASS BALANCE

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
GASIFIER					
REFUSE	5000.	16000000.	OFFGAS	8421.	16245004.
HOT BLAST	4276.	1148603.	SLAG	879.	289912.
FUEL OIL	25.	250000.	HEAT LOSS		863687.
TOTAL	9301.	17398603.	TOTAL	9301.	17398603.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	8421.	16245004.	WASTE GAS	45698.	16325107.
TOTAL AIR	37345.	0.	SLAG	98.	32239.
FUEL OIL	29.	300000.	HEAT LOSS		187658.
TOTAL	45795.	16545004.	TOTAL	45795.	16545004.
WASTE HEAT BOILER					
WASTE GAS	41759.	14917859.	WASTE GAS	41759.	2531737.
FEED WATER	18808.	2277623.	STEAM	18808.	14365387.
			HEAT LOSS		298357.
TOTAL	60566.	17195482.	TOTAL	60566.	17195482.
REGENERATIVE TOWERS					
WASTE GAS	3939.	1407248.	WASTE GAS	4402.	239232.
COLD BLAST	4276.	22805.	HOT BLAST	4276.	1148603.
BLEND AIR	463.		HEAT LOSS		42217.
TOTAL	8679.	1430053.	TOTAL	8679.	1430053.
GAS CLEANING SYSTEM					
WASTE GAS	46161.	2770969.	WASTE GAS	46045.	2715550.
			PARTICULATE	115.	
			HEAT LOSS		55419.
TOTAL	46161.	2770969.	TOTAL	46161.	2770969.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 120. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

ASSUMPTIONS :

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION :	87.20 %	CARBON
(BY WEIGHT)	12.50 %	HYDROGEN
	0.30 %	ASH
	0. %	WATER

SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :
STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{\text{(STEAM HEAT OUT - FEEDWATER HEAT IN)}}{\text{(REFUSE HEAT IN + TOTAL FUEL HEAT IN)}}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

REFUSE ANALYSIS		PROXIMATE ANALYSIS		ULTIMATE ANALYSIS	
% COMBUSTIBLES	62.84	% FIXED CARBON	10.22	% CARBON	35.82
% WATER	17.62	% VOLATILES	52.62	% HYDROGEN	4.40
% ASH-INERTS	19.54	% WATER	17.62	% OXYGEN	22.62
		% INERTS	19.54		

GASIFIER

HOT BLAST TEMP	1037.00 DEG C
HOT BLAST AIR FLOW	3762.58 NM3/H
FUEL OIL TO TUYERES	0. L/T
FUEL OIL TO SLAG TAP	4.93 L/T
SLAG OUTPUT	1123.71 KG/H

OFFGAS

FLOW	9066.95 NM3/H
TEMPERATURE	674.04 DEG C

HEATING VALUE

SENSIBLE	264.35 KCAL/NM3
LATENT	61.93 KCAL/NM3
CHEM + PART	1797.77 KCAL/NM3
TOTAL	2124.05 KCAL/NM3

WASTE HEAT BOILER

EFFICIENCY 98 %

GAS FLOW	37081.74 NM3/H
GAS TEMP IN	1259.63 DEG C
GAS TEMP OUT	238.00 DEG C

ENERGY RECOVERY

ENERGY	16522924.38 KCAL/H
STEAM	21632.53 KG/H
KG STEAM/KG REFUSE	3.76

SECONDARY COMBUSTION CHAMBER

SCC PROCESS AIR	32904.00 NM3/H
SCC EXCESS AIR	86. %
FUEL OIL TO SCC	5.92 L/T

EFFLUENT CONSTITUENTS BY VOLUME

% O2	7.9
% N2	72.1
% CO2	9.7
% H2O	10.3

EFFLUENT FLOW	40541.82 NM3/H
EFFLUENT TEMP	1259.63 DEG C

REGENERATIVE TOWER

EFFICIENCY 80%

GAS FLOW	3460.00 NM3/H
GAS TEMP IN	1150.00 DEG C
GAS TEMP OUT	238.00 DEG C
HOT BLAST FLOW	3762.58 NM3/H
BLAST TEMP IN	37.00 DEG C
BLAST TEMP OUT	1038.00 DEG C
BLEND AIR	407.84 NM3/H

GAS CLEANING EQUIPMENT

GAS FLOW	40949.66 NM3/H
PARTICULATE	132.60 KG/H
GAS TEMP IN	238.00 DEG C
GAS TEMP OUT	233.55 DEG C

OVERALL SYSTEM EFFICIENCY 73.37 %

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

HEAT AND MASS BALANCE

IN	KG/H	KCAL/H	OUT	KG/H	KCAL/H
GASIFIER					
REFUSE	5750.	18400000.	OFFGAS	9628.	18697138.
HOT BLAST	4865.	1306734.	SLAG	1011.	333395.
FUEL OIL	25.	250000.	HEAT LOSS		926201.
TOTAL	10640.	19956734.	TOTAL	10640.	19956734.
SECONDARY COMBUSTION CHAMBER					
OFFGAS	9628.	18697138.	WASTE GAS	52512.	18758827.
TOTAL AIR	42967.	0.	SLAG	112.	37070.
FUEL OIL	29.	300000.	HEAT LOSS		201241.
TOTAL	52624.	18997138.	TOTAL	52624.	18997138.
WASTE HEAT BOILER					
WASTE GAS	48030.	17157839.	WASTE GAS	48030.	2911457.
FEED WATER	21633.	2619699.	STEAM	21633.	16522924.
			HEAT LOSS		343157.
TOTAL	69663.	19777538.	TOTAL	69663.	19777538.
REGENERATIVE TOWERS					
WASTE GAS	4482.	1600988.	WASTE GAS	5009.	272168.
COLD BLAST	4865.	25944.	HOT BLAST	4865.	1306734.
BLEND AIR	527.		HEAT LOSS		48030.
TOTAL	9874.	1626932.	TOTAL	9874.	1626932.
GAS CLEANING SYSTEM					
WASTE GAS	53039.	3183625.	WASTE GAS	52907.	3119952.
			PARTICULATE	133.	
			HEAT LOSS		63672.
TOTAL	53039.	3183625.	TOTAL	53039.	3183625.

ANDCO-TORRAX SOLID WASTE DISPOSAL SYSTEM -V 9.9 N DATE 02/20/78

CLIENT : UNIVERSITY OF MINNESOTA
RATE : 138. TONS/DAY
REFUSE : LHV = 3200. KCAL/KG, HHV = 3534. KCAL/KG

ASSUMPTIONS :

1) SUPPLEMENTAL FUEL TYPE IS FUEL OIL.

2) SUPPLEMENTAL FUEL DATA :

COMPOSITION : 87.20 % CARBON
(BY WEIGHT) 12.50 % HYDROGEN
0.30 % ASH
0. % WATER
SPECIFIC GRAVITY : 0.865 (WATER = 1.0)
LOWER HEATING VALUE : 10196. KCAL/KG

3) BOILER DATA :

STEAM PRESSURE : 30.6 ATMOSPHERES
STEAM TEMPERATURE : 385.0 DEGREES CELCIUS
STEAM ENTHALPY : 763.8 KCAL/KG
FEEDWATER ENTHALPY : 121.1 KCAL/KG

NOTES :

1) AMBIENT TEMPERATURE IS 15.56 DEGREES CELCIUS.

2) AMBIENT PRESSURE IS 1.0 ATMOSPHERE (760 MM HG).

3) GASES AND SOLIDS HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

4) WATER AND WATER VAPOR HAVE ZERO ENTHALPY AT 15.56 DEGREES CELCIUS.

5) PROCESS AND COMBUSTION AIR IS DRY.

6) ONE NORMAL CUBIC METER OF GAS IS AT 0.0 DEGREES CELCIUS AND 1.0 ATMOSPHERE.

7) ALL SUPPLEMENTAL FUEL IS COMBUSTED TO CARBON DIOXIDE AND WATER VAPOR WITH 100 % HEAT RELEASE.

8) ANCILLARY EQUIPMENT HEAT LOSSES ARE DETERMINED AS FOLLOWS :

LOSS = (1 - N) * HOT FLUID SENSIBLE HEAT IN
WHERE -N- IS THE EQUIPMENT ASSUMED EFFICIENCY.

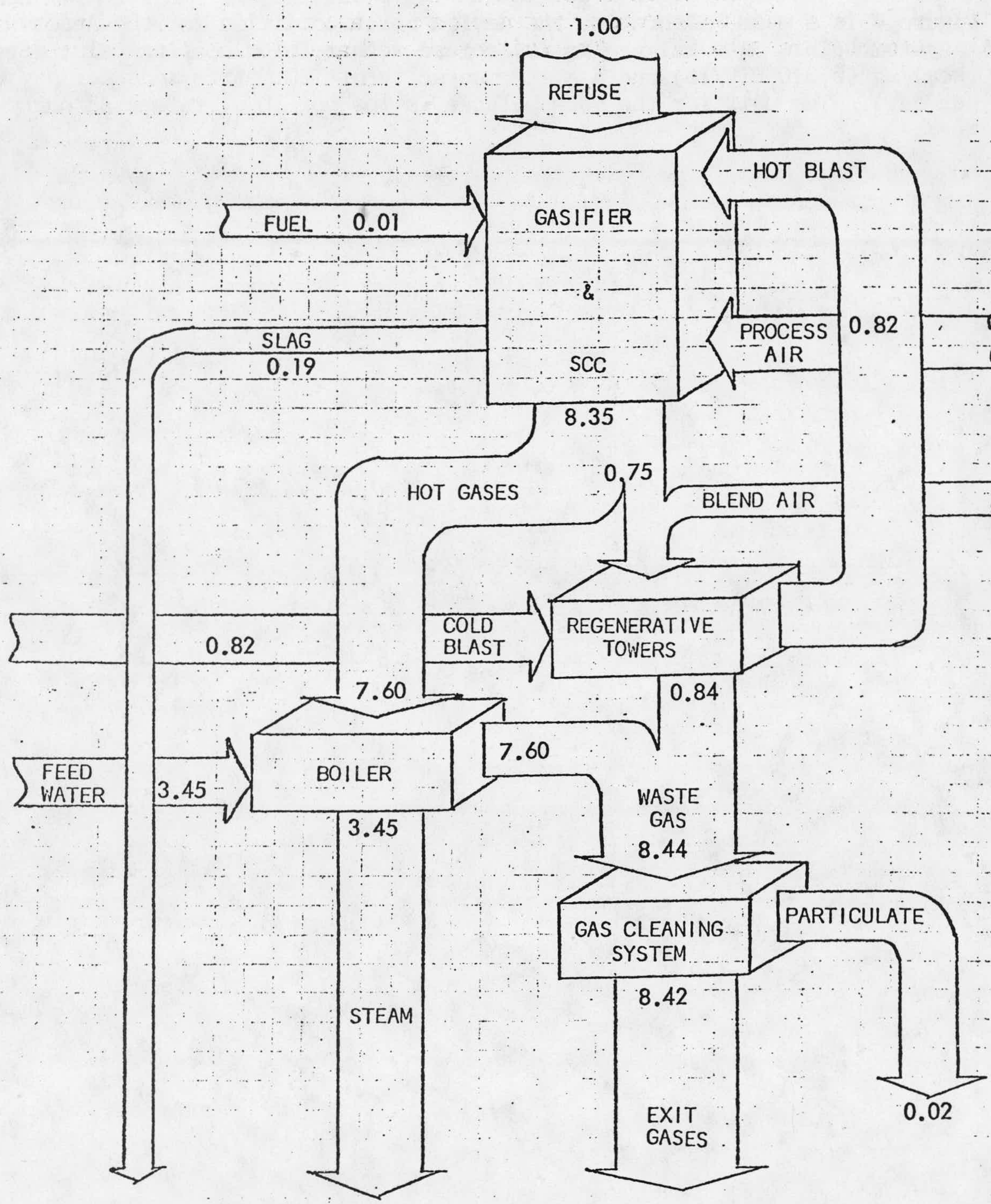
9) OVERALL SYSTEM EFFICIENCY IS DETERMINED AS FOLLOWS :

$$\text{EFFICIENCY} = \frac{(\text{STEAM HEAT OUT} - \text{FEEDWATER HEAT IN})}{(\text{REFUSE HEAT IN} + \text{TOTAL FUEL HEAT IN})}$$

WHERE REFUSE AND FUEL HEATS ARE DETERMINED FROM THEIR LOWER HEATING VALUES.

8.9 PROCESS MASS BALANCE

Figure 4 is a mass balance for the design point condition for the Andco-Torrax system. This mass balance is for refuse with a lower heating value of 2,950 kcal/kg (5,310 BTU/lb) and a system capacity of 120 metric tons per day (132 tons per day). The unit for the mass balance is lbs per lb of refuse throughput.



andco

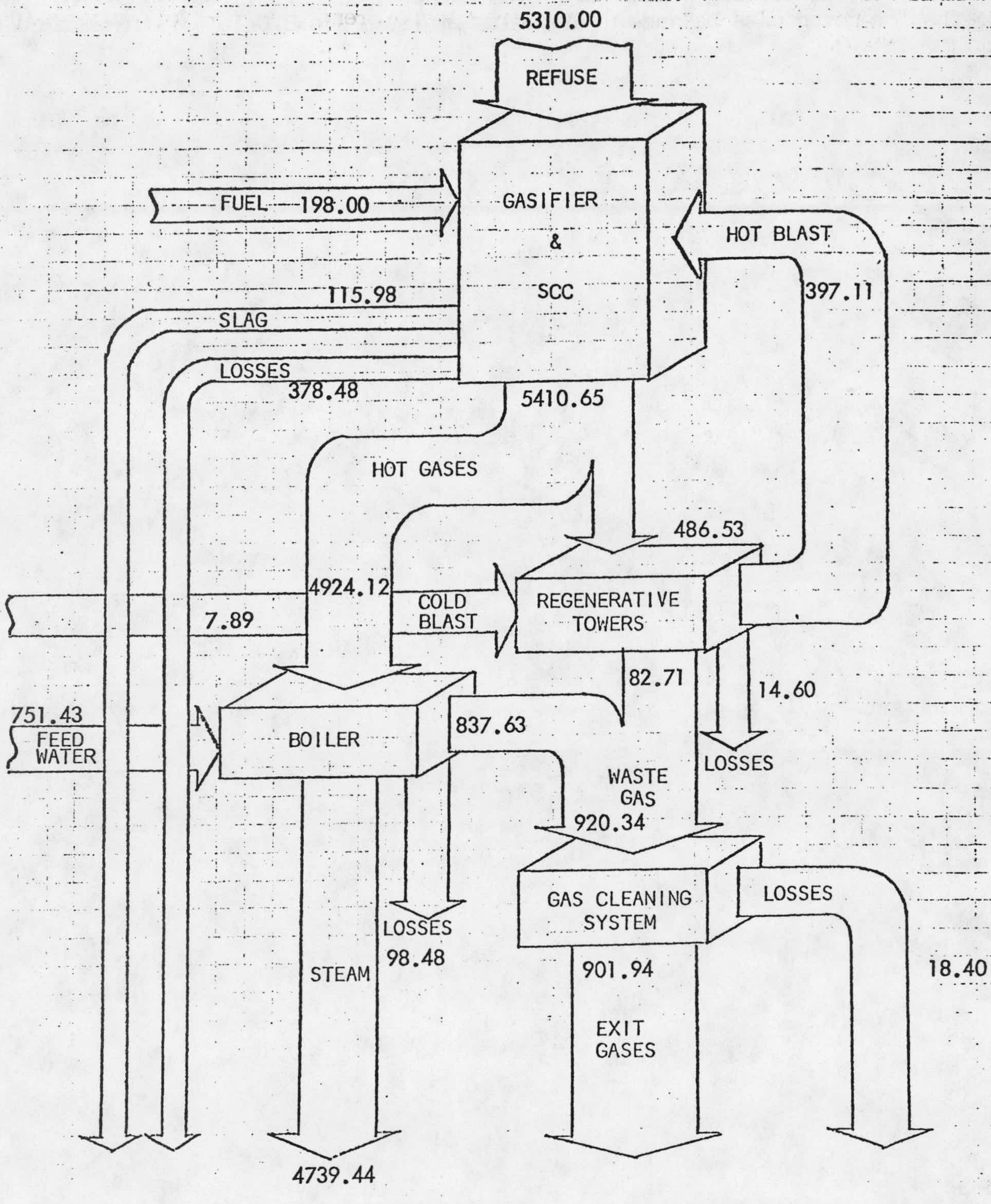
132 TPD ANDCO-TORRAX MASS BALANCE IN LB/LB OF REFUSE

5310 BTU/LB (LHV) FIGURE 4

by	date	checked		calculation	sheet of
			50		

8.10 PROCESS HEAT BALANCE

Figure 5 is the heat balance for the design point for the Andco-Torrax system. The refuse lower heating value and system capacity are similar to those provided for the foregoing mass balance. The units employed are BTU/lb of refuse throughput.



132 TPD ANDCO-TORRAX HEAT BALANCE. UNITS IN BTU/LB of REFUSE

5310 BTU/LB (LHV) FIGURE 5

andco

8.11 PRELIMINARY DESIGN DRAWINGS

The following pages outline the drawings submitted by Andco Incorporated to Helmick and Lutz Company for government contract No. EC-77-C-02-4210, Phase II, Stage 2. Many of these drawings are directly referenced in the following sections of this report.

Helmick and Lutz Company Drawings

625AA	Proposed Site Plan
625MM	Proposed Basement Floor Plan
625NN	Proposed Operating Floor Plan
625PP	Proposed Upper Levels Floor Plan
625TT	Proposed Building Sections Waste Heat Boiler
625UU	Proposed Building Sections Pyrolysis
	Equipment Flow Sheet - Southeast Plant Pyrolysis System
625FS2	Flow Sheet - Southeast Plant Pyrolysis System
625E4	Secondary Distribution Line Diagram - Option II
62513A	Existing Incinerator Plant

University of Minnesota

No. 11960	General Arrangement - 50 Ton Incinerator

Andco, Inc. Drawings

61001-D-00-600-01	Proposed Operating Floor Plan
61001-D-00-000-01A	General Arrangement Plan
61001-D-00-000-02A	General Arrangement Elevation
61001-D-10-300-01	Gasifier
61001-D-17-300-01	Refuse Feed Hopper Arrangement
61001-D-21-300-01	Secondary Combustion Chamber
61001-D-30-300-01	Regenerative Towers
61001-D-60-500-01	Cooling Water System Flow Diagram
61001-D-60-500-02	Cooling Water System Flow Diagram
61001-D-67-530-01	Auxiliary Fuel Diagram
61001-D-70-680-01	Instrument Symbols and Identifications
61001-D-70-681-01	Gasifier Process Instrument Flow Diagrams
61001-D-70-681-02	Gasifier Fuel Process Instrument Flow Diagram
61001-D-70-681-03	Secondary Combustion Chamber Process Instrument Flow Diagram
61001-D-70-681-04	Secondary Combustion Chamber Fuel Process Instrument Flow Diagram
61001-D-70-681-05	Primary Air Process Instrument Flow Diagram
61001-D-70-681-06	Waste Gas Process Instrument Flow Diagram
61001-D-70-681-07	Cooling Water System Instrument Flow Diagram
61001-D-70-681-08	Regenerative Tower Fuel Process Instrument Flow Diagram
61001-D-70-600-01	Motor Control Center A
61001-D-80-600-02	Motor Control Center B
61001-D-90-510-01	Main Cooling Water
61001-D-90-530-01	Fuel Oil Routing
61001-D-90-510-02	Main Water Cooling Basement Plan
61001-D-90-510-03	Fuel Gas Routing
61001-D-90-600-01	Carbon Monoxide Monitoring + Community Jack Location
61001-D-99-000-01	Energy and Mass Balance
61001-D-99-000-02	Energy and Mass Balance
61001-D-99-000-03	Energy and Mass Balance
61001-C-63-500-01	Water Treatment System Flow Diagram
61001-C-90-670-01	500 kva Turbine Generator

8.12 EQUIPMENT AND HARDWARE DESCRIPTION

8.12.1

MAJOR ELEMENT LIST

Table of Contents

MAJOR ELEMENT LIST

Major Element or System

Gasifier System consisting of gasifier, bustle pipe, penstock, downcomer, tuyeres and slag tap, waste heat boiler, induced draft fan and drive.

Function and Performance

132 ton per day nominal capacity. Fabricated steel vessel. Upper section acts as a drying zone for the refuse and is unlined. The lower section encloses the pyrolysis process and is water cooled over the entire length. The hearth is located at the base of the gasifier and is the area where primary combustion of the char and melting of the inert material occurs. The hearth is refractory lined.

Service

High temperature, heavy duty, steel mill type construction with water cooling. Refractory service range to 3000^{o} F.

Basis of Selection

Size of element based upon customer specified operation range. Normal element in system.

Commercial Availability

Fabricated item - delivery in five to six months.
Refractory items - delivery in six months

Fabricated Item	Refractory Suppliers
Sen-Weld Ind.	Harbison Walker
Oehler Ind.	A. P. Green
Fuel Economy	J. H. France
Michigan Boiler	Carborundum
Marine Iron	

REFERENCE DRAWING NO.: 61001-D-10-300-01

Major Element or System

Vibrating Feeder

Function and Performance

To move the refuse from the hopper into the gasifier for processing

Service

Operating rate of 5 tons per hour. Heavy duty design, low temperature, in a dirty and dusty atmosphere.

Basis of Selection

Based upon proven reliability from conventional incinerator system operation and Andco-Torrax system operation.

Commercial Availability

Manufactured item delivered in 16 to 18 weeks.

Jerffey
F.M.C.
(Bin-Master) NAVCO
Rexnord

REFERENCE DRAWING NO.: 61001-D-17-300-01

Major Element or System

Secondary Combustion Chamber consisting of start-up burner, offgas burner, slag taps and main burning chamber.

Function and Performance

The Secondary Combustion Chamber is a refractory lined steel cyclinder where the combustion of the pyrolysis gas occurs, releasing usable heat and energy.

Service

High temperature, heavy duty, steel mill type construction. Refractory service temperature range is to 3000° F.

Basis of Selection

Size of element based upon customer specified operation range. Normal element in system.

Commercial Availability

Fabricated item - delivery in four to five months
Refractory items - delivery in six months.

Burners

North American
Peabody
Cohen

REFERENCE DRAWING NO.: 61001-D-21-300-01

Major Element or System

Slag removal system - consisting of slurry tank, slag handling crane, vibrating separator, slag receiving hopper and a bucket elevator.

Function and Performance

To transport the slag which is removed from the gasifier and secondary combustion chamber in a sealed water tank to an outside storage area. The slag is removed by bucket crane from the main slag pit and deposited at a continuous rate onto a vibrating screen which will reject large clinkers and other large pieces of materials. The slag then falls into a storage hopper feeding a vertical bucket elevator. The bucket elevator moves the material to a storage bin outside of the building.

Service

Design rate of 2 tons per hour. Slag size is 1" or smaller. Heavy duty, maintenance free items have been selected.

Basis of Selection

Slag handling crane - durable and reliable based on performance at present Andco-Torrax plant location. All other major items were selected on a heavy duty, maintenance free type basis.

Commercial Availability

Manufactured items delivered in three to four months. Fabricated items delivered in two to three months.

NAVCO
F.M.C.
Jeffey
Hahl Ind.
(Fabricator as listed)

REFERENCE DRAWING NO.: 61001-D-00-000-01A
61001-D-00-000-02A

Major Element or System

Instrumentation consisting of control panel, instrument air compressor, air dryer and instruments.

Function and Performance

All instruments will be of the elctronic type and will record pressure, temperature, flows, etc. Instrumentation will be of the closed loop type. Graphic type panel will be provided to house all recorder and indicators.

Service

In an air conditioned control room and in a dirty and dusty atmosphere.

Basis of Selection

All of the instruments will be electronic or solid state type for reliability and accuracy, based on performance of Andco-Torrax plants.

Commercial Availability

Manufactured items delivered in six to eight months.
Honeywell
Taylor
Foxboro
Johnston Controls

Major Element or System

Miscellaneous Items
1. Steam Preheater
2. Maintenance Crane

Function and Performance

1. To preheat ambient air to 400^{o} F prior to entry into the SCC.
2. To service Andco-Torrax equipment.

Service

1. Temperature range to 400^{o} F, air volume 25,000 SCFM
2. Heavy duty, slow moving steel mill type maintenance crane.

Basis of Selection

1. Maximum efficiency, uses minimum amount of steam to obtain required temperature.
2. To minimize down time on the Andco-Torrax system.

Commercial Availability

1. Manufactured items delivered in six to eight months.
2. Manufactured items delivered in one to three months.
Trane and Voss - Steam Preheater
Hohl Industries
Shepard Niles

REFERENCE DRAWING NO.: 61001-D-00-000-01A
61001-D-00-000-02A

Major Element or System

Air Moving equipment consisting of primary air blower, secondary air blower.

Function or Performance

Primary air blower will be low pressure rotary compressor. Its function is to deliver process air at the required volume and pressure to the gasifier. Secondary air fan's function is to supply combustion air to the secondary combustion chamber burner.

Service

Primary air blower - 3000 SCFM capacity with a pressure rating of 7 psi.
Secondary air blower - 25,000 SCFM capacity with a pressure rating of 2 psi.
Minimum requirement on power factor.

Basis of Selection

Low noise level, long service life and minimum maintenance.

Commercial Availability

Manufactured item delivered in three to four months.
Buffalo Forge Co.
Spencer Turbine Co.
J. T. Sacma Co.

REFERENCE DRAWING NO.: 61001-D-00-000-01A
61001-D-00-000-02A

Major Element or System

Regenerative Towers System consisting of hot blast isolation valves, cold blast isolation valves, waste gas valve and refractory, checkers for transferring heat.

Function and Performance

To provide sufficient hot blast and temperature to the gasifier for processing.

Service

High temperature, heavy duty refractory lined vessels. Steel mill type construction. Refractory maximum service temperature is 2800^{O} F.

Basis of Selection

Deliver required hot bast temperature to gasifier.

Commercial Availability

Major items - Fabricated items delivered five to six months
Refractory items delivered in 8 months
Fabricators Item Refractory - See Gasifier List

Valves - Zimmerman & Jansen - Supports
T. M. Jansen
Bailey Valve Co.

Expansion Joints - Solar
New thermo transfer

REFERENCE DRAWING NO: 61001-D-00-000-01A
61001-D-00-000-02A
61001-D-30-300-01

Major Element or System

Water Cooling System consisting of pumps, water treatment unit and reservoir.

Function and Performance

To maintain the cooling water at the design temperature for the gasifier, the hot blast valves and the slag quench systems.

Service

Design pressure 150 psig - design temperature 200^{O} F.
Operating pressure 40-50 psig, operating temperature 130^{O}-110^{O} F

Basis of Selection

To minimize water usage in system

Commercial Availability

Major items - pumps - four to three months delivery
Pump - Bell & Gossett
Worthington Pump
Buffalo Forge Co.

REFERENCE DRAWING NO.: 61001-C-63-500-01
61001-D-60-500-01
61001-D-60-500-02
61001-D-90-510-01
61001-D-90-510-02

Major Element or System

Electrical Equipment

Function and Performance

A complete electrical power system including motor control centers and all necessary equipment to operate pyrolysis system will be provided in accordance with code requirements. A 500 kva emergency power system also will be provided. This will be a gas start, oil-fueled turbine generator with associated control equipment.

Service

Three phase, 60 cycle, 480 volts. Heavy duty type material has been selected. The 500 kva, 800 amps high speed generator is capable of returning power to primary air fan in less than 10 seconds.

Basis of Selection

Turbine generator - extremely fast and reliable starting. Light weight, small size - can be mounted anywhere within the plant - no special building is required to house.

Commercial Availability

Manufactured
Turbine Generator - Onan, International Harvester

Instruments and Supplies
General Electric
Reliance
Westinghouse

REFERENCE DRAWING NO.: 61001-D-80-600-01
61001-D-80-600-02

Major Element or System

Waste Heat Boiler and Auxiliaries. Heat Recovery boiler consisting of boiler, superheater, and economizer. Trim items such as soot blowers, blow down valves, superheat control.

Function or Performance

To generate steam at 400 psig, 725^{o} F with feedwater at 250^{o} F with gas from the secondary combustion chamber. Gas temperature to be reduced from 2300^{o} F to 460^{o} F.

Service

Continuous duty with gas stream having ash with a fusion temperature of 2100^{o} F. First heat transfer section will have a tendency to bridge and slag.

Basis of Selection

Open design, bare tube construction, heat transfer surface area, type of soot blowers.

Commercial Availability

Deltak
Zurn Industries
Keeler
Babcock & Wilcox Co.
Combustion Engineering Co.
Riley Co.

Major Element or System

Waste Heat Boiler induced draft fan and drive

Function or Performance

To transfer gas stream from waste heat boiler exit and low temperature gas from the air preheater system to the inlet of the fabric filter baghouse. Drive shall be motor with variable speed hydraulic type coupling.

Service

50,000 ACFM at a temperature of 460^{o} F against a static pressure differential of 28 iwg.

Basis of Selection

Construction, long service life and minimum maintenance

Commercial Availability

Fan - Buffalo Forge
Clarage
Westinghouse

Motor - Allis Chalmers
General Electric
Westinghouse

Hydraulic Coupling -
American Standard
Nelson

8.12.2

OUTLINE SPECIFICATIONS

I. GENERAL CODES

In addition to the requirements of the regulatory agencies listed, the design and construction shall conform to the latest edition of the following standards where applicable:

Minnesota State Building Code
American Concrete Institute
American Conference of Governmental Industrial Hygienists
American Institute of Steel Construction
Institute of Electrical and Electronic Engineers
American Society of Mechanical Engineers
American Society for Testing Materials
American National Standards Institute
American Welding Society
National Fire Protection Association
National Bureau of Standards
National Electric Code
American Water Works Association
Associated Air Balance Council
American Society of Heating, Refrigeration and Air Conditioning Engineers
National Safety Code for Mechancial Refrigeration
National Association of Sheet Metal and Air Conditioning Contractors

II. GENERAL SPECIFICATIONS

1. Welding & Brazing - All welding shall be done by certified welders and licensed fitters who are thoroughly trained in electric arc and/or gas welding and experienced in the welding positions and materials required. Certification shall be for type of work being performed by the welder and shall be accomplished in accordance with A.S.M.E. "Qualification Standard for Welding Procedures, Welders and Welding Operations."

   Mechanics engage in silver brazing will be required to pass certifying tests. This test shall include fabrication using fittings of the sizes and types to be used on the work and approximate job conditions. Test samples shall consist of two nippled (minimum length 3") and one coupling of the largest size to be used in the work. (Minimum size of pipe for tests to be 2" diameter.) Execute one sample joint in horizontal position six feet above floor. Execute one sample joint in vertical position five feet above floor, brazing upward. Test samples shall be sent by the Contractor to an independent testing laboratory for testing. The Contractor shall pay all expenses incurred in connection with this ceritifcation.

2. Testing - Contractors shall perform all tests required and shall assume responsibility for all charges and expense therefor. Certification of tests shall be submitted in multiple copies to the Director of Engineering and Construction through the University Construction Superintendent.

3. Water Piping Test - All water piping shall be tested hydrostatically by the Contractor in the presence of the Engineer and/or Inspector in strict accordance with Minnesota State Plumbing Code (but not less than 100 psi) prior to covering of piping and connection to fixtures and equipment. Stand pipe and sprinkler system piping shall be tested at 200 psi water pressure for a period of two (2) hours.

4. Sweat & Welded Joint Test - Sweat and welded joints to be tested shall be selected by the University Construction Superintendent. Number selected shall be 2% of joints made, but not less than two (2).

   Selected joints shall be radiographed by an independent testing laboratory and evaluated on the basis of appropriate codes and construction standards covering services installed.

5. Piping and Valve Identification - All piping in unfinished, accessible areas shall be identified every 20 feet and at every change of direction as to type of service and direction of flow by stenciling black letters on a yellow background. Direction of flow shall be indicated by a black arrow on the yellow background. Letters shall be a minimum height of 1". In lieu of stenciling, Seton "Setmark" pipemarkers may be specified.

   All manually operated service valves and automatic control valves not immediately in sight of the fixture or equipment it serves shall be provided with approved brass "S" hooks or chain on which shall be stamped the identifying description of the valves and equipment or piping controlled in terms of final (not Architect's) room numbers. The final room numbers may be secured from the office of the Director of Engineering and Construction.

6. Painting - All exposed piping, ducts, radiation, grilles, diffusers, etc. in finished spaces shall be painted under the General Contract.

   Painting of exposed piping, ducts, equipment, etc. in equipment spaces and accessible tunnels, crawl spaces, shaft and other unfinished spaces, shall be included in Mechanical Work specifications.

   All paint materials shall be of the best institutional grade manufactured by Pratt and Lamber, Martin-Senour, Benjamin Moore, Devoe, Glidden, Pittsburgh, or equal.

   All paint products shall be of the specific type recommended by the paint manufacturer for the particular material and conditions of exposure.

   All paint colors shall be selected by the Architect from University of Minnesota Standard Color Palette.

7. Materials, Manufacturers and Suppliers - Equipment specified and furnished shall be of a type and manufacture that has a local representative and a local replacement and service outlet to give complete coverage on parts and service at all times.

   All factory assembled equipment shall incorporate materials and fabrication methods consistent with these standards.

8. Serviceability - All equipment, valves and etc., should be located for ease of maintenance. All components should be serviceable with a minimum of process shutdown as possible.

9. Piping Hanger and Supports - Piping shall be supported by suitable trapeze hangers, Clevis hangers, Grinnell No. 260 supported from Grinnell No. 282CB universal concrete inserts, or by the use of approved Phillips shields.

   Piping, except plastic piping, shall be supported as above specified, or on heavy line hangers and distances between supports shall not exceed the following.

Pipe Size - Inches	Spacing of Hangers
3/8"	4' - 0" centers
1/2"	6' - 0" centers
3/4" to 1"	8' - 0" centers
1 1/4" to 2"	10' - 0" centers
2 1/2" to 5"	12' - 0" centers
8" to 12"	14' - 0" centers

   Hanger rods for piping supports shall comply with the following schedule:

Pipe Size - Inches	Hanger Rod Diameter - Inch
Up to 2"	3/8"
2 1/2" to 3 1/2"	1/2"
4" to 5"	5/8"
6"	3/4"
8" to 12"	7/8"

Hangers for insulated piping shall be large enough to encompass the insulation and the metal saddle for same. Procide Hydrous-Calcium Silicate at hanger points in sections 2" longer than saddle. Insulation to have same finish as adjacent covering. See also 15180.4.

Provide rise clamps for support of vertical rises at every floor.

Support members in trapeze hangers shall not be torch cut.

Saddles for 6" and larger pipes shall be fabricated of 16 gauge galvanized iron and for all smaller piping shall be fabricated of 18 gauge galvanized iron. Saddles shall be semi-circular and shall encompass the lower one-third of the covering. Saddles shall be secured to the pipe with approved metal straps. Lengths of saddles shall be as follows:

Pipe Size	Saddle Length
6" and less	9"
6" to 12"	12"

10. Pipe Sleeves - All pipe sleeves through slabs, walls and partitions shall be 1/2" greater in side diameter than the external diameter of pipe and insulation passing through. All sleeves shall be fabricated of new material, cut square and removed.

Sleeves Through Walls

a. Sleeves through interior partition walls shall be Schedule #40 steel pipe extending through the full thickness of the wall, and shall be flush with the finished surface. Seal space between piping and sleeve with plastic caulking.

b. Sleeves through exterior building walls above and below grade shall be Schedule #40 steel pipe install flush with finished surfaces and caulked between sleeves and piping with oakum and lead to provide a watertight joint.

Sleeves Through Slabs

a. Generally, no sleeves will be required through slabs on ground.

b. Sleeves through roof slabs shall be constructed of No. 22 gauge galvanized steel.

c. Sleeves through floor slabs in exposed areas (such as classrooms, offices, auditoria, and corridors, etc.) shall be Schedule #40 steel pipe and they shall extend 1/2" above the finished floor surface. Space between pipe and sleeve shall be packed with an approved plastic material flush with the top of sleeve to make a watertight joint.

d. Sleeves through floor slabs for concealed piping (concealed piping shall be considered piping in chases and within walls and partitions) shall be constructed of No. 22 gauge galvanized iron. Sleeves for water closets may be of No. 22 gauge galvanized iron.

e. Sleeves through floor slabs in kitchen areas, or damp areas, or concealed under cabinets or laboratory equipment, etc., shall be Schedule #40 steel pipe extending two (2) inches above the finished floor. Space between pipe and sleeve shall be packed with an approved plastic material flush with the top of the sleeve to make a watertight joint.

f. Sleeves for heating piping shall be anchored midway of sleeve with three (3) anchors 120^{o} apart.

g. Where exposed covered piping passes through floor slabs in kitchen areas, hospital areas, etc., the covering of floor shall be encased with an 18 gauge stainless steel cylindrical sleeve 6 inches in height, with lap joint fastened with two (2) stainless steel metal screws. In other exposed areas, 18 gauge galvanized iron sleeve may be used.

GASIFIER SYSTEM

Scope

This specification covers the design, fabrication and installation of a gasifier.

Function

To process the refuse

Major Items

a. Virbrating Feed Hopper
b. Fabricated Steel Vessel, Water Cooled and Refractory Lined
c. Refuse Level Indectors
d. Tuyeres

Design Data

132 U. S. Tons/day
±15%
Low Heating Values of 5,310 BTU/lb

REFERENCE DRAWING NO.: 61001-D-10-300-01

Vibrating Feed Hopper

Scope

To design, furnish and install one vibrating feed hopper for the gasifier system.

Functions

To move the refuse into the gasifier for processing

Major Items

Pan, Hopper, Motor

Design Data

6.3 tons/hour

Construction Specifications

Mild Steel A36, General Hopper dimensions shall be 12' x 3' deep x 5' wide, Hopper door will be 5' x 6'

Controls

Variable Flow Rate, Electrical (remote control)

Special Features

Motor below deck TEFC

Requirements

Service Availability - Intermittent, Maintainability - To be serviceable during operation

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Codes

See General Codes

REFERENCE DRAWING NO.: 61001-D-17-300-01

Fabricated Steel Vessel

Scope

To design, fabricate and install one gasifier with all associated items shown in the drawings.

Function

To process refuse as described in Major Equipment List

Major Items

Upper Stack, Middle Stack, Lantern, Bustle Pipe, Penstock

Design Data

All in accordance with American Institute Steel Construction

Construction Specifications

All mild steel A36 or better from a U. S. Manufacturer, See General Specifications

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Codes

See General Codes

Tuyeres

Scope

To design, fabricate and install all copper tuyeres for installation into the gasifier

Function

To deliver hot blast from the penstocks to hearth for process use.

Major Items

Single compartment tuyeres

Construction Specifications

No. 20-B High Conductivity Pure Copper

Requirements

Service availability - continuous; Maintenance availability

Drawings

Submittals prior to any fabrication for approval

Paint

None

Test

Steam and hydrostatically pressure tested

REGENERATIVE TOWERS

Scope

This specification covers the design, fabrication and installation of two units for the regenerative tower consisting of fabricated refractory lined vessels, hot blast valves, and controls

Function

To provide sufficient hot blast and temperature to the gasifier for processing

Major Items

Fabricated Vessel, Platform, Valves and Controls which will be specified under Instrumentation Specifications

Design Data

2300^{o} F at dome

REFERENCE DRAWING NO.: 61001-D-30-300-01

Fabricated Steel Vessel and Platforms

Scope

To design, fabricate and install steel shells and platform and associated items as shown on drawings

Function

To provide sufficient hot blast for system processing

Major Items

Shell, Refractory Checks, Platform

Design Data

A.I.S.C.

Construction Specifications

All mild steel, A36 or better, from a U. S. manufacturer. See General Specifications

Requirements

Service availability - continuous operation; Maintenance availability - All or any major parts must be serviceable during operation

Drawings

Submittal prior to fabrication for approval

Paint

See General Specifications

Codes

See General Codes

Valves

Scope

To design and install valves for Regenerative Tower System

Function

To control flow from the stoves to the gasifier

Major Items

Body, Seat, Bonnet Disc, Cylinder

Design Data

Temperature range - 2300° F

Construction Specifications

Refractory capable of 2300° F, Mild Steel, water cooled to maintain temperature

Controls

Manual and automatic with local and remote controls. Limit switches with DPDT controls for operations

Requirements

Service availability - Continuous operation; Maintenance availability - Service during downtime.

Drawings

Submittals prior to fabrication for approval

Paint

As specified by the manufacturer

SECONDARY COMBUSTION CHAMBER

Scope

This specification covers the design, fabrication and installation of the Secondary Combustion Chamber

Function

The Secondary Combustion Chamber is a refractory lined steel cylinder where the combustion gases are burned to completion releasing usable heat and energy

Major Items

Fabricated Shell, Refractory Lining, Slag Quench Tank and Burners

REFERENCE DRAWING NO.: 61001-D-21-300-01

Fabricated Steel Vessel

Scope

To design, fabricate and install one S. C. C. with all associated equipment as shown on the drawings

Function

Vessel where the pyrolysis gas is burned to completion

Major Items

Vessel, Slag Quench Tank, Burners

Design Data

A. I. S. C. Specifications

Construction Specifications

Mild Steel, A36 or better, all from a U. S. manufacturer. See General Specifications

Requirements

Service availability - Continuous operation; Maintenance availability - All or any major parts must be serviceable during operation

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Burner Specifications for the S.C.C.

Scope

To design, furnish and install the following burners for the S.C.C.:
a. Start-up
b. Slag
c. Pilot Burner and Off Gas Burner

Function

To provide heat for a chamber during operation and during start-up

Major Items

Burners, Burner Block, Control Pressure Indicators

Design Data

Slag Tap Burner	- 500,000 BTU/hr each
Start-Up	- 10 to 15 MM BTU/hr
Pilot	- 500,000 BTU/hr

Construction Specifications

Standard Oil Burner Contruction for industrial service

Controls

Automatic and manual controls with flame safe guards, local and remote operators

Requirements

Service availability - Continuous; Maintenance availability - As recommended by vendor.

Drawings

Submittals required prior to manufacturing

DRAWING REFERENCE NO: 61001-D-00-000-01A
61001-D-00-000-02A

AIR MOVING EQUIPMENT

Scope

The specification covers the design, fabrication and installation of the two major air blowers

Function

Primary Air Blower - to deliver process air at required volume and pressure to the gasifier

Secondary - To supply combustion air to the S. C. C. pilot burner

Major Items

Fans, Motor, Base, Housing, Wheel and Shaft

Design Data

Primary - 3,000 S. C. F. M @ 7 lbs pressure
Secondary - 25,000 S. C. F. M @ 2 lbs pressure

Construction Specifications

Housing, Mild Steel, Cork Ventilation Pad under each unit

Controls

Automatic and manual with local and remote controls

Special Features

All fans will be equipped with a variable speed motor

Requirements

Service availability - Continuous; Maintenance availability - As recommended by vender

Drawings

Submittals prior to manufacturing for approval

Paint

See General Specifications

Codes

Noise level requirements will be in compliance with Federal, State and local agencies

DRAWING REFERENCE NO.: 61001-D-00-000-01A
61001-D-00-000-02A

SLAG REMOVAL SYSTEM

Scope

This specification covers the design, fabrication and installation of the Slag Removal System as shown on the drawings.

Function

To transport slag ("Urban Ore") from slag hopper under gasifier to storage silo outside of building

Major Items

1. Slag tank under gasifier
2. Bucket crane (with runway)
3. Virbrating separator
4. Slag Receiving Hopper
5. Bucket Elevator
6. Storage Silo - by University of Minnesota

Design Data

Size of Slag	=	1 (one) inch or smaller
Design Rate	=	Two tons/hour
Operating Rate	=	One ton/hour
Weight of Slag	=	90 lbs/Ft^3

REFERENCE DRAWING NO.: 61001-D-00-000-01A
61001-D-00-000-02A

Slag Tank

Scope

To design, fabricate and install slag tank as shown on drawings

Function

Retain slag as it enters hopper from gasifier and S.C.C.

Construction Specifications

Mild Steel A-36; Weld type construction A.I.S.C. specifications will apply.

Requirements

Service availability - Continuous

Paint

See General Specifications

Drawings

Submittals prior to fabrication for approval

Vibrating Separator

Scope

To design and install one vibrating separator for the slag removal system

Function

To remove klinkers from slag before entering receiving hopper

Major Items

Grizzly, Hopper, Supports and Motor

Design Data

Capacity - 2 tons/hr or 27 CF/hr

Construction Specifications

Mild Steel, welded construction to take impact loads of 2,500 lbs

Controls

Manual and automatic with local and remote controls

Special Features

Silent type vibrating drive, isolating springs, support stand and removable gate

Requirements

Service availability - Continuous operation; Maintenance availability - As recommended by Vendor

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Bucket Crane

Scope

To design, fabricate and install Bucket Crane for the Slag Removal System

Function

Remove slag from slag tank and transport to slag receiving hopper

Major Items

Hoist, Bucket, Monorail

Design Data

27 CF/hr; Bucket Size - 1CY

Construction Specifications

Heavy duty type crane designed to work in a damp environment

Special Features

A standby crane and bucket will be provided for emergency use

Requirements

Service availability - Continuous; Maintenance availability - as recommended by Vendor

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Code

See General Specifications

Slag Receiving Hopper

Scope

To design, fabricate and install a slag receiving hopper for the Slag Removal System, as shown on drawing

Function

To receive and store slag from bucket crane

Major Items

Hoppers and supports

Construction Specifications

Mild Steel A-36, Welded type construction in accordance with A.I.S.C.

Design Data

27 CF/hr or 2 tons

Requirements

Service availability - Continuous operation

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Code

See General Codes

Bucket Elevator

Scope

To design and install Bucket Elevator for the Slag Removal System

Function

Transport slag vertically to an outside storage silo

Major Items

Housing, Chains, Buckets and Motor

Construction Specifications

Mild Steel, Sections bolted for maintenance and ease of erection

Controls

Automatic and manual; local and remote operators

Requirements

Service availability - Continuous; Maintenance availability - as recommended by vendor

Drawings

Submittals prior to fabrication for approval

Paint

See General Specifications

Code

See General Codes

COOLING WATER SYSTEM

Scope

To design, furnish and install water cooling system for the pyrolysis unit

Function

To supply sufficient water to various components of all systems to accomplish design functions

Major Items

1. Heat Exchanger
2. Reservior Cooling Pumps
3. Circuit Reservoir Return Pumps
4. Fabricated Reservior
5. Valves and Fittings
6. Butterfly Control Valves

REFERENCE DRAWING NOS.: 61001-C-63-500-01
61001-D-60-500-01
61001-D-60-500-02
61001-D-90-510-01
61001-D-90-510-02

Heat Exchanger for Open System

Function

Open circuit cooling and quenching water

Parameters

Tube Side
Flow - 200 GPM (Water)
Temperature In - 130° F
Temperature Out - 110° F
Inlet Pressure - 80 - 100 PSIG
S.G. - 1.0

Air Side
Temperature In - 95° F
Forced Draft

Construction Materials
Section - Carbon Steel
Header - Carbon Steel
Tube - Carbon Steel
Fin - Aluminum

Driver
Electric Motors - One motor @ 40 H.P.
Safety Factor - 1.15 Mill/Chemical
Enclosure - TEFC
Voltage -
Phase - 3
Cycle - 60

Other Considerations
All necessary supporting structures ladder, walkways, fan guards, etc.

Open Circuit Reservoir Cooling Pumps

Function

To supply sufficient amounts of water to the air cooled heat exchanger; hence distributed to the slag quench tanks and slag runner.

Requirements

Each pump shall be bronze fitted. The casing shall be of close-grained cast iron. The shaft sleeve shall be of stainless steel with a carbon steel shaft.

The motor shall be non-overloading to 125% of the rated capacity. Under no circumstance shall the motor service factor be used.

Pump Type

The pumps shall be of single stage, double suction, base mounted vertical split case design. The casing shall be a vertical split case design to facilitate servicing the pump bearing, packing, impeller, shaft and shaft sleeves without distrubing the pump volute or motor. The impeller shall be of the enclosed, double suction type in bronze construction and shall be dynamically balanced for quiet operation.

The stuffing box shall consist of four rings of impregnated asbestos packing with a lantern ring suitable for an external flush of clear water. To faciliate service, a flexible non-lubricated coupling of the center drop-out shall be furnished. The pump and motor shall be mounted on a common fabricated steel baseplate having sufficient grout volume with adequately sized grout holes. Grout the base after piping and after completing the preliminary pump alignment. After the system has been filled and the motor wired, check the alignment of the pump and motor, in accordance with the manufacturer's recommendations. Provide a coupler guard.

Design Data

Flow:	200 GPM
T.D.H.:	100
R.P.M.:	1,750
Horsepower	30
Specific Gravity:	1.0

Open Reservoir Return Pumps

Function

To return water form the clear water sump to the water reservoir

Requirement

Each pump shall be bronze fitted. The casing shall be of close-grained cast iron. The shaft sleeve shall be of stainless steel with a carbon steel shaft.

The motor shall be non-overloading to 125% of the rated capacity. Under no circumstance shall the motor service factor be used.

Pump Type

The pumps shall be of single stage, double suction, base mounted vertical split case design. The casing shall be vertical split case design to facilitate servicing the pump bearing, packing, impeller, shaft and shaft sleeves without disturbing the pump volute or motor. The impeller shall be of the enclosed double suction type in bronze construction and shall be dynamically balanced for quiet operation.

The stuffing box shall consist of four rings of impregnated asbestos packing with a lantern ring suitable for an external flush of clear water. To faciliate service, a flexible non-lubricated coupling of the center drop-out shall be furnished. The pump and motor shall be mounted on a common fabricated steel baseplate having sufficient grout volume with adequately sized grout holes. Grout the base after piping and after completing the preliminary pump alignment. After the system has been filled and the motor wired, check the alignment of the pump and motor, in accordance with the manufacturer's recommendations. Provide a coupler guard.

Design Data

Flow:	200 GPM
T.D.H.:	100
R.P.M.:	1,750
Horsepower:	30
Specific Gravity	1.0

Open Circuit Reservoir

Function

To retain cooling water for:

a. Air cooled heat exchanger
b. Closed circuit heat exchanger
c. Cascade cooling
d. Slag quench

Design Data

Working Volume	=	2,500 Gallons
Time Retention	=	12.5 Minutes
Construction	=	Carbon Steel: A.I.S.C.

Features

Covered, tank drain, suction nozzle emergency overflow drain, stilling area for make-up and other effluents, reservoir internal access ladder, sloped floor to drain at approximately 8 degrees for pump suction nozzle.

Drawings

Submittals prior to fabrication for approval

Open Cooling Water

Pipe

ASTM Spec. A-53 Gr. A or B (or A-106 Gr. A or B) Seamless Carbon Steel Pipe. All sizes shall be of standard weight unless noted otherwise.

Fittings

2½" size and larger: Steamless but welding ASTM Spec. A-234 Gr. WPA or WPB Carbon Steel to ANSI B16.9 and same schedule as pipe.

2" size and smaller: extra heavy cast iron ASTM spec. A126 screwed ends.

Flanges

150# ANSI B16.5 forged carbon steel to ASTM Spec. A-181-68 raised or flat face as required by equipment and valve flanges

Unions

2" size and smaller: 300# screwed unions - ASTM A47

Bolts and Nuts

Studs to ASTM Spec. A-193 Gr. B7 and Nuts to ASTM Spec. A-194 Class 3 or 2H.

Gaskets

Asbestos gaskets

Valves - Gate, Glove, Check (except automatic butterfly valves)

2½" and larger: 125# ASTM B16-1 cast iron flanged valves

2" and smaller: 200# screwed bronze to ASTM B-61

Insulation

On all lines with ambient temperature

Hangers

See General Specifications

Closed Cooling System

Major Items

1. Heat Exchanger - 1
2. Water Treatment Unit - 1
3. Circuit Cooling Pumps - 2
4. Reservoir - 1
5. Valves and Fittings
6. Control Valves
7. Tuyere Cocks

Design Data

Pressure:	150 PSIG
Temperature:	200° F Maximum
Operating Pressure:	40# - 45#
Operating Temperature:	130° - 110° F

Heat Exchanger for Closed System

Function

Cooling closed circuit cooling and quenching water

Parameters

Tube Side

Flow:	1,260 GPM (Water
Temperature In:	130° F
Temperature Out:	110° F
Inlet Pressure:	90-100 PSIG
SG:	1.0

Air Side

Temperature In:	950° F
Forced Draft	

Construction Materials

Section:	Carbon Steel
Header:	Carbon Steel
Tube:	Carbon Steel
Fin:	Aluminum

Driver

Electric Motors:	1 Motor @ 40 HP
Safety Factor:	1.15 Mill/Chemical
Enclosure:	TEFC
Voltage:	
Phase:	3
Cycle:	60

Other Considerations

All necessary supporting structures, ladders, walkways, fan guards, etc.

Make-Up Water Chemical Injection Unit

Function

To provide proper chemicals to the make-up water to the closed circuit cooling systems. Balancing the PH and introduction of stabilizing agents so as to prevent the deteriorating effects of solids plating out etc. in the cooling elements

Type

Constant Rate Feed

Design Parameters

Tanks
Unit to have a partitioned stainless steel tank of 50 ga. (24 hr) capacities each. Each compartment to have a mount for an electric motor agitator. Tank to have all necessary accoutrements such as drains, sight glasses, basket strains, etc.

Pump
Duplex, step valve controlled volume hydraulically activated diaphragm pump. Features to include pneumatic capacity adjustment, positive displacement, repetitive accuracy, adequate lubrication, etc.

Control
Pneumatic proportioning control is to be effected by pneumatic signals to the stroke adjusting unit on the pump. The adjustable stroke is linked to a PH controller - recorder. Both variables are transmitted to a ratio controller which then sends an air signal, adjusting the stroke in relation to both flow and PH. Signals are also monitored on flow.

Closed Circuit Cooling Pumps

Function

To supply sufficient amounts of water through the closed circuit cooling system.

Requirements

Each pump shall be bronze fitted. The casing shall be of close-grained cast iron. The shaft sleeve shall be of stainless steel with a carbon steel shaft.

The motor shall be non-overloading to 125% of the rated capacity. Under no circumstance shall the motor service factor be used.

Pump Type

The pumps shall be of single stage, double suction, base mounted vertical split case design. The casing shall be a vertical split case design to faciliate servicing the pump bearing, packing, impeller, shaft and shaft sleeves without disturbing the pump volute or motor. The impeller shall be of the enclosed, double suction type in bronze construction and shall be dynamically balanced for quiet operation.

Pump Types (Continued)

The stuffing box shall consist of four rings of impregnated asbestos packing with a lantern ring suitable for an external flush of clear water. To facilitate service, a flexible non-lubricating coupling of the center drop-out shall be furnished. The pump and motor shall be mounted on a common fabricated steel base plate having sufficient grout volume with adequately sized grout holes. Grout the base after piping and after completing the preliminary pump alignment. After the system has been filled and the motor wired, check the alignment of the pump and motor, in accordance with the manufacturer's recommendations. Provide a coupler guard.

Design Data

Flow:	1,260 GPM
T.D.H.:	200
Horsepower:	100
Specific Gravity:	1.0
RPM:	1,750

Closed Circuit Cooling Water Reservoir Tank

Function

To retain closed circuit cooling water for the tuyeres offtake valve, spill valve, regenerative isolation valves and gasifier shell

Design Data

Working Volume:	4,500
Time Retention:	3.5 Minutes
Construction:	Carbon Steel, Welded type construction

Features

Top cover, tank drain, suction nozzle, level control, make-up nozzle, emergency overflow drain, stilling area for make-up or other effluents, internal ladder.

Shop Drawings

Submittals prior to fabrication for approval

Paint

See Painting Specifications

Closed Cooling Water

Pipe

ASTM Spec. A-53 Gr. A or B (or A-106 Gr. A or B) Seamless Carbon Steel Pipe. All sizes shall be of standard weight unless noted otherwise.

Fittings

$2\frac{1}{2}$" size and larger: Seamless butt welding ASTM Spec. A-234 Gr. WPA or WPB Carbon Steel to ANSI B16.9 and same schedule number as pipe.

2" size and smaller extra heavy cast iron ASTM Spec. A-126 screwed ends.

Flanges

150# ANSI B16.5 forged carbon steel to ASTM Spec. A-181-68 raised or flat face as required by equipment and valve flanges.

Unions

2" size and smaller 300# Screw End ASTM A47

Bolts and Nuts

Studs to ASTM Spec. A-193 Gr. B7 and Nuts to ASTM Spec. A-194 Class 3 or 2H

Gaskets

Asbestos Gaskets

Valves, Gate, Globe, Check, except Automatic Butterfly Valves

$2\frac{1}{2}$" and larger: 125# ANSI B16.1 cast iron flanged valves

2" and smaller: 200# screwed bronze to ASTM B-61 and 150# carbon steel butt weld end for check valve only

Insulation

On all lines with ambient temperature or less

Hangers

See General Specifications

INSTRUMENTATION SYSTEM

Scope

To design and install a complete instrumentation package for the pyrolysis system

Function

To maintain, control, measure and record all pressure, temperatures, flows, etc. for the system

Major Items

Control Panel, Recorders, Gages, Air Compressor and Dryer

Design Data

Per attached design criteria

Special Features

Instruments will be electrical with graphic type panel

Requirements

Service availability - Continuous; Maintenance availability - All or any of the items must be serviceable during operation

Drawings

Submittals prior to manufacture for approval

Paint

As recommended by the vendor

Code

See General Specifications

REFERENCE DRAWING NO.: 61001-D-7-680-01
61001-D70-681-01 Thru -08

ELECTRICAL SYSTEM

Scope

This specification covers the design and installation of electrical systems and the general materials used in these systems.

Function

To provide a complete electrical power system that will operate the pyrolysis system.

Major Items

1. Motor Control Center A
2. Motor Control Center B
3. Transfer Switch Gear
4. Conduit and Fittings
5. Pull Boxes, Junction Boxes and Outlet Boxes
6. Wire and Cable
7. Grounding
8. Motor Starters
9. Motors

REFERENCE DRAWING NO.: 61001-D-80-600-01
61001-D-80-600-02

Motor Control Centers A & B

Applicable Standards and Requirements

1. The equipment covered by these specifications shall be designed and assembled in accordance with the applicable standards of A.S.A., I.E.E.E., and N.E.M.A.

2. All applicable equipment shall have Underwriters Laboratory approval for motor control centers.

3. The control center and all components shall meet all requirements of the latest National Electrical Code and Occupational Safety and Health Act.

4. The control center shall be assembled, wired, and tested by the manufacturer.

Ratings

1. Incoming Voltage
   a. Frequency: 60 Hz
   b. Phases: 3
   c. Operating Voltage: 240 or 480 as specified on drawings

2. Buses
   a. Horizontal: Amperes as called for in drawings
   b. Vertical: Sized for 100% load with allowance for spaces, 400 ampere minimum.
   c. Ground: 600 Ampere (1/4" x 2").

Construction

General

Each control center shall consist of vertical sections, joined together to form a rigid, free-standing, dead front, NEMA 12 control assembly. Lifting angles, and channel iron sills shall be furnished with the control centers.

Vertical Sections

Each vertical section shall be constructed as follows:

1. Fabricated of sheet metal in accordance with Underwriters Standards. Each section shall be nominally 20" deep, 20" wide and 90" high.

2. To accept "plug-in" or "bolt-on" type components as outlined herein.

3. With top horizontal wiring trough and bus compartment having removable covers, and bottom wiring space with removable access plates.

4. Full height vertical wiring trough, except where large starters or other equipment require the full width for mounting.

5. Doors held closed by means of quick captive screw fasteners.

6. Doors to be part of the structure such that they may be closed after the removal of a controller.

7. Doors to be interlocked with disconnect device that the device must be in the "OFF" position before the door may be opened. A defeater mechanism shall be provided on the door to allow authorized personnel to open the door without the disconnecting device being in the "OFF" position.

8. All components in units that are specified for mounting against a building wall shall be front access, front connected.

9. Unit specified for back to back mounting must not stab over the full vertical bus to insure proper mounting without regard to configuration of units within a section.

Painting

1. The entire control center shall be cleaned and coated with a rust inhibiting bonderizer. Baked enamel finished coats shall be applied over the bonderizer as follows:

   Exerior Surfaces & Trim: Light Gray
   Interior Surfaces: White

2. All unpainted metallic parts shall be coated with cadmium or zinc chromate to provide corrosion resistance.

Bus Work

1. All bus shall be copper and shall be silver plated at connections

Control Unit Assemblies

1. All units shall be furnished complete with components of one manufacturer, wired, and assembled as described herein.

2. The removable element shall have upper and lower barrier plates to provide isolation between units mounted above and below.

3. Each unit shall be held in place by a mechanical latch or quick disconnect device. This device shall also prevent closing the door until the assembly is properly engaged.

4. All units of the same physical size shall be interchangeable.

Wiring

1. The motor control centers shall be wired to conform to NEMA Standard construction as follows:

   Where motors or controls supplied from the motor control center are interlocked: NEMA Class II, Type B.

Motor Starters

1. All individual starters shall comply and be equipped with the following:
   a. Minimum Size: NEMA 1
   b. Combination magnetic type
   c. Underwriters Standard fuse clips for Bussman 600 volt dual element "Low Peak" fuses.

Wire and Cables

Applicable Standards

1. All cables specified herein shall conform to the latest requirements of the IPCEA and ASTM covering:
   a. Conducter stranding
   b. Insulation thickness
   c. Color coding
   d. Jacket thickness

2. All cables of the class inspected by the Underwriters Laboratory shall bear the inspection label.

600 Volt Control Cable

1. Control Cable in Conduit or Trays
   Shall conform to the following:
   a. #13 AWG consisting of seven or 19 tinned copper conductors stranded per ASTM Class B or C construction.

Motors

1. General
   a. All electrical motors must meet these standard specifications unless modified by the "Information Sheets" for a particular project.

2. A. C. Motors
   a. A. C. motors shall be squirrel cage induction, designed for full voltage starting, rate at 230/460 volts, 3 phase, 60 Hertz, NEMA Design B, totally enclosed fan cooled, having a 1.15 service factor, continuous duty, Class B insulation, 55^{o} C ambient and sealed or or shielded anti-friction bearings. Where application dictates deviation from these specification, written approval from the Owner is required.

Conduit, Conduit Fittings

Conduit

1. All conduit shall be rigid steel of a high ductile quality, sheardized or hot dipped galvanized inside and out and lacquer finished.

2. Minimum size of conduit for exposed work shall be 3/4"; for embedded runs encased in concrete, the minimum size shall be 1".

3. The use of thin wall steel conduit shall be limited to office buildings or similar installations after specific approval from the owner.

4. Standard 90^{o} conduit elbows may be used in conduit runs of $1\frac{1}{4}$" and larger for 600 volt cables. These elbows shall conform to the requirements of Paragraph 1. Field bends shall not be of a smaller radius than that of manufactured elbows of the same size, shall show no flattening of the conduit, and shall be made without the use of heat.

5. Field fabricated elbows, with a radius relative to the bending radius of the cable, shall be used for all conduits with cables supplying circuits rated over 600 volts. Standard factor elbows will not be acceptable.

Conduit Fittings

1. Fittings shall be cast ferrous alloy, cadmium plated, with threaded hubs, case ferrous alloy covers, and solid oil-resistant synthetic rubber gaskets.

2. Conduit connections to sheet metal boxes or enclosures in damp or wet locations shall be made with Myers "Scru-tite" hubs.

Grounding

1. Grounding circuits shall employ a copper-stranded conductor or copper bus.

2. At each building column, a copper plate shall be brazed to the column, 500 MCM copper wire mechanically lugged to the plate, extended and brazed to the building counter poise.

Grounding (Continued)

3. All equipment or building grounds must be extended from the counterpoise in one continuous size cable. Various taps smaller in size shall be brazed (if buried) or cad welded to the parent conductor.

4. Grounding systems shall be protected from mechanical injury by encasing in concrete, by rigid metallic conduit, or by installation in locations not subject to physical hazard.

Pull Boxes, Junction Boxes and Outlet Boxes

1. Pull boxes shall be proivded on all conduit runs exceeding 200 feet and at a maximum of 200-foot intervals.

2. Pull boxes and junction boxes shall be made of at least 10 gauge galvanized steel bent and welded and provided with gasketed screw covers of the same gauge thickness. The covers shall be held in place with brass hexagon head bolts.

Auxiliary Power System

Scope

To design, furnish and install on auxiliary power system for the pyrolysis system.

Function

The auxiliary power unit will be capable of returning Motor Control Center B to full operation at the various time intervals with the primary air fan instrumentation and lights within 10 seconds.

Major Items

Turbine Generator, Oil Cooler, Free Standing Control Package, Silencer, Outlet and Inlet, Fuel Tank, Transfer Switch.

Design Data

To re-energize to full power in the following sequences:

1.	Primary Air Fan, Lighting, Instrument Panel	10 seconds
2.	Open circuit cooling water pump	20 seconds
3.	Closed circuit cooling water pump	25 seconds
4.	Slag quench water pump	30 seconds
5.	Heat exchanger fan	30 seconds
6.	Slag grapple bucket hoist	40 seconds
7.	Slag screen shaker motor	45 seconds
8.	Slag bucket elevator	50 seconds
9.	Refuse crane operator compartment air conditioner	60 seconds

Requirements

Service availability - Emergency use only; Maintenance availability - Serviceable during operation.

Drawings

Submittals prior to manufacturing for approval only.

Paint

As advised by manufacturer

Code

See General Codes

REFERENCE DRAWING NO.: 61001-D-90-670-01

IV. WASTE HEAT RECOVERY BOILER

PART 1 - General

A. Work Under This Section

1. Provice one (1) complete steam generating unit with specified auxiliary equipment.

2. Erect the equipment furnished under this contract.

3. Boil out, adjust and test the unit.

B. Related Work by Others

1. Foundation

2. I. D. Fan, Drive and Gas Ducts

3. Dust collector

4. Fuel Supply Systems

5. Ash Removal Systems

6. Feedwater System

7. Combstuion Control System

8. General, Mechanical and Electrical Work to complete the project

C. General Description

1. Boiler shall generate steam at 450 psig, 725^{O} FTT, with feedwater temperature at 250^{O} F.

2. Built in accordance with Section I of the ASME Boiler and Pressure Vessel Code, 1977, and the laws of the State of Minnesota.

3. Boilers will be fired with gas from the secondary combustion chamber of a pyrolysis solid waste conversion system.

D. Performance

1. Guarantee the following items of boiler performance at rated boiler load:
   a. Capacity
   b. Pressure
   c. Steam temperature (See paragraph 2 below)
   d. Steam purity leaving the drum
   e. Exit gas temperature from the economizer
   f. Efficiency
   g. Gas pressure drops through the system

2. Steam temperature - Steam temperature shall be guaranteed to be controllable at 725^{O} F with operating conditions as specified, throughout the control range, and shall be guaranteed not to deviate more than ± 10^{O} F from the 725^{O} F set point for any load change up to 3% per minute.

3. Steam purity from the drum shall contain not more than 1 ppm solids.

E. Submittals

1. With proposal.
   a. General arrangement drawing showing overall dimensions of boiler and location of terminal connections.
   b. Estimated weights on the foundations.
   c. List of all motors giving the horsepower rating of each, the power requirements of the driven load at boiler rating, and the maximum power requirements for any operating condition.
   d. Description of accessory equipment.
   e. Performance data per paragraph E. above at rated load, 3/4 rating, 1/2 rating and 1/4 rating.
   f. Additional data as called for in Part 2 of the Specifications

2. For approval - Four (4) prints of outline and arrangement drawings.

3. Final drawings - Four (4) prints and one (1) reproducible of all drawings.

4. Manuals - Four (4) complete operation and maintenance manuals for the unit and all auxilaries including.
   a. Operating instructions
   b. Lubrication data and schedules
   c. Maintenance, repair, and adjustment data including manufacturer's instructions.
   d. Parts list, recommended stock, nearest parts depot and service organization.
   e. Assembly drawings, wiring diagrams and mechanical diagrams.

5. Acceptance Test Report - Three (3) copies of all data.

<u>PART 2 - Products</u>

A. Design Data

1. Fuel - Fuel will be waste gas from the secondary combustion chamber of a pyrolysis solid waste conversion system. The system will be designed to gasify hospital waste and general waste at the rate of 130 tons per day ± 15%.

   For purposes of design, the inlet gas conditions will be as follows:

Gas Flow	108,000 pounds per hour
Inlet Gas Temperature	2301° F
Inlet Gas Pressure	-18 iwg

   There will be particulate in the gas stream that may have slagging tendencies.

2. Feedwater System
   a. Feedwater will be approximately 75% returned condensate and 25% makeup water.
   b. Condensate will be treated in a condensate polishing system.
   c. Makeup water will be treated in a hot process softener.
   d. Feedwater will be deaerated and heated to 250° F.

B. Steam Generating Unit

1. Boiler - Describe the conponents in the proposal including such data as:
   a. Drum sizes
   b. Drum manhole sizes
   c. Tube diameter and material
   d. Steam purifier type and performance
   e. Maximum gas temperatures
   f. Gas velocities

2. Superheater
   a. Include superheat curves with the proposal.
   b. Provide complete superheater temperature system as required.
   c. List any limiations or restrictions on steam temperature and load relations.

3. Economizer - The economizer shall be designed to lower the exit gas temperature at 460^{o} F.

4. Soot Blowers - Provide a complete soot blower system with controls.

5. Trim
   a. Water columns, one at each end of drum.
      1. Column with high and lower water alarm contacts, illuminated glass.
      2. Column with illuminated glass and mirror for direct viewing from the operating floor.
      3. Include blowdown pipe and valve to approximately 4'-0" above the firing floor.
   b. All required safety valves.
   c. Drum and header blowdown valves and piping to approximately 4'-0" above firing floor.
   d. Chemical feed distributed, stainless steel.
   e. Connections for Owner's combustion control instrumentation such as:
      1. Draft gauges
      2. Temperature sensors
      3. Drum level transmitter
      4. Remote drum level gauge (Yarway)
      5. Drum pressure gauge
      6. Drum pressure switches

C. Casing Design - The casing shall be designed for a negative pressure of 24 iwg and a positive pressure of 15 iwg.

D. Outlet Gas Control Damper - A control damper shall be provided at the outlet of the unit with extended operating shafts for connection to an automatic control drive. Damper shall be multiple blade construction with lubricated bearings.

E. Insulation, Lagging and Finish.

1. Insulate the boiler and economizer so that the skin temperature will not exceed 140^{o} F.

2. Describe in detail the insulation materials and methods to be used.

3. Preferred outside covering would be 4" ribbed aluminum, 0.040" thick, of a manufacturer's standard color.

PART 3 - Execution

A. Erection

1. Furnish all labor and materials to unload, store, handle and erect the equipment furnished under this contract including auxiliaries and trim.

2. Grouting under baseplates and soleplates will be done by others but this Contractor shall furnish supervision for grouting his equipment.

3. Concrete foundations will be provided by others for the boiler. This Contractor shall check all foundations and anchor bolts before concrete is poured and again before erection is started to assure himself that they are correct for his equipment.

B. Inspection and Check-Out

1. After erection is complete, inspect each component and sub-system for proper installation and operation.

2. Boil out the boiler and inspect it for cleanliness in the presence of the Owner's representative. The Owner will provide chemicals for boil out.

3. Pre-test the unit for capacity and performance prior to scheduling the Acceptance Test.

C. Acceptance Test

1. Notify the Engineer when the unit has been checked out, pre-tested and is ready for the Acceptance Test.

2. Test the boiler for compliance with the Guaranteed Performance in co-operation with the Engineer and the Owner. The Test procedure will be mutually agreed upon prior to the test.

3. Submit an ASME test form report together with calculations and laboratory analysis reports in three (3) copies.

D. Operation Prior to Acceptance

1. The Owner will provide fuel, feedwater, chemicals, etc. for operation during check-out, boil-out, pre-testing and Acceptance Test.

2. Operating personnel will be provided to assist the Contractor.

3. The Contractor will retain supervision responsibility for the safe and proper operation of the equipment until it is accepted by the Owner.

4. In the event that the Owner puts the unit into service prior to acceptance, he will assume responsibility.

E. Instruction - Instruct the plant personnel in all phases of operation, adjustment, lubrication and maintenance of the equipment so the Plant Superintendent is satisfied that they are qualified to assume the responsibility of the equipment.

TABLE 2

GASEOUS AND PARTICULATE POLLUTANTS

AT THE SCC OUTLET, DEC. 75

(Pounds/Hour)

CONSTITUENT	GASEOUS	PARTICULATE
Va	0.019	0.028
HCl	4.01	5.04
HCN	0.01	0.0
Hg	0.0	0.0
Pb	0.0	0.83
Cd	0.0	0.12
Ni	0.0	0.81
Cu	0.0	0.075
Se	0.0	0.0
Zn	0.01	1.15
HF		0.02
C		45.2
Other		23.03
		76.3

TABLE 3

GENERAL DATA

BETWEEN SCC AND BOILER

PARAMETER	DEC. 75
SCFM	8,274
Particulate (Pounds/Hour)	76.3
% Carbon of Particulate Catch	63.0
SO_x(PPM)	1.2
NO_x(PPM)	192.0
$COCl_2$ (PPM)	70.1
Grain Loading (Grains/SCF)	1.01

TABLE 4

PARTICULATE SIZE DISTRIBUTION

(DEC. 75)

SIZE RANGE (microns)	SCC TO BOILER
.25 - .5	0.012
.5 - 1	0.117
1 - 2	0.914
2 - 4	9.82
4 - 8	29.0
8 - 16	32.87
16 - 32	27.6
32 - 64	0.0
Over 64	0.0

V. INDUCED DRAFT FAN AND DRIVE

GENERAL PROVISIONS

A. Provide a complete induced draft fan system to transfer gas from the combined gas stream downstream of the waste heat boiler to the inlet of the gas cleaning system. This will include the fan, fluid coupling and motor drive.

B. Include in the proposal all equipment necessary for a complete system.

OPERATING DATA

The system shall transfer gas at the rate of 55,000 ACFM at temperature of 460° F against a static pressure differential of 28 iwg.

INDUCED DRAFT FAN

Fan shall be heavy duty type designed for mechanical draft service.

Fan housing shall be constructed of ¼" carbon steel plate, adequately braced. Housing shall be base angle supported and split for wheel removal. Drains shall be provided in the bottom of scroll. Inlet and outlet connections shall be flanged. Raised cleanout doors, bolt-up type, shall be provided in the inlet sections and fan wheel section. Doors shall be raised to accommodate external insulation. Cleanout doors shall have inserts which will provide a continuous internal scroll surface.

Rotating assembly shall be stacially and dynamically balanced. Unit shall be designed to operate at overspeed conditions of 15%. Maximum speed shall be 1200 RPM. Shaft shall be extra heavy to keep deflection to a minimum. Shaft shall be double extended with flexible coupling on one end and coupling guard.

Wheels shall have blades formed from carbon steel plate, radial tip and a forward curved heel. Hub shall be heavy high grade cast iron or steel. To prevent erosion, blade liners, cut-away center plate, and side plate liners shall be used.

Independent bearing pedestals with a machined surface top and bottom shall be used. Machined sole leveling plates shall be provided. Bearing shall be sleeve oil-bath type, split, water cooled with all metal flexible connectors for supply and return water. Oil sight gauge with filler cup shall be provided.

Inlet dampers shall be of the heavy structural steel channel frame design with welded louvers supported by cold roll steel shafting. Louvers shall be balanced in the direction of opening. Inlet dampers for use with inlet boxes shall be arranged to spin the air in the direction of rotation of the fan. Bearings shall be prelubricated anti-friction or oil tight type mounted on steel plates attached to the exterior flange of the damper frame. Louver shafts shall be interconnected with heavy duty levers and linkages external to the duct.

All exterior surfaces shall be surfaced with Nelson NHP upset weld studs with speed clips at 9" horizontal and 12" vertical centers. Stud lengths shall be such that studs will not protrude from the insulation surface.

VARIABLE SPEED COUPLING

A variable speed type coupling shall be installed between the motor and the induced draft fan. The coupling shall be a fluid drive designed to transmit the power requirements at test block conditions. Unit shall be center supported and designed so as to give minimum vertical displacement between cold and hot conditions. Motor, variable speed coupling and bearing pedestals shall be supported on a common structural steel bed plate designed to maintain alignment. All control componenets required for adjusting fan speed in accordance with requirements of the control shall be furnished and installed. Sufficient space shall be provided on the output shaft of the coupling for a tachometer driver to indicate output shaft speed.

Coupling shall be American Blower, Nelson or approved equal.

MOTOR DRIVE

Motor shall be dripproof construction, induction type with Class B moisture and contamination resistant insulation. Electrical power supply is 3 phase, 60 cycle, 2300 volts. Acceptable manufacturers are Allis Chalmers, Electric Machinery, General Electric, Westinghouse or approved equal. Starters shall not be included. Drives shall have capacity to satisfy maximum fan requirements.

Fan Motors shall be furnished with 1" machined sole plates.

COUPLINGS

Flexible couplings complete with guards, between motors, variable speed drive and fan shall be Dodge Para-flex of the proper size to transmit load from the drive.

8.12.3 INSTRUMENTATION AND CONTROL DESIGN CRITERIA

Table of Contents

I. INTRODUCTION

The purpose of this document is to present the basic recommended control and instrumentation design criteria for use in the design of an Andco-Torrax system. The criteria consists of general written guidelines, system write-ups for each of the major subsystems, and drawings dealing with the specifics of the process system.

The various write-ups and drawings contained in this document do not represent a completed design basis, but rather the suggested or required minimum functions needed to control the systems safely and efficiently. These write-ups are intended to serve as the initial direction for the system designer.

Codes and Standards

It is recommended that the system design and the actual equipment be specified/ built in accordance with existing codes and standards. This recommendation applies particularly to those systems which could cause human injury or property damage should they malfunction.

The codes and standards will vary depending on the governmental jursidiction in which the equipment is located, the terms of the contract for the plant, the standards of technical societies, and prevailing design customers.

Centralized Control and Level of Automation

The level of automation desired for a particular application is usually determined on the basis of the number and qualification of the plant operating personnel.

In general, it is desirable to limit the number of operating personnel to a reasonable minimum. This approach dictates the use of a centralized control room. With a properly designed control room console including status monitoring equipment, a single operator can control several Andco-Torrax process trains.

It is essential that operating personnel be well qualified and properly instructed in the operation of the Andco-Torrax process equipment.

The central control console and other optional control room panels should give the operator:

1. Start/stop control and operating status indication of the process and auxiliary system equipment.

2. Process control analog signal display and adjustable set point capability.

3. Status monitoring and warning annunciators for equipment or system malfunction.

It is recognized that there are limits to the amount of data which a single operator can assimilate and act upon. The centralized control and level of automation concept should be limited to key information and control functions--with non-essential data functions relegated to auxiliary or local control panel status.

The central panel should be designed considering the following features:

1. A slanted face sit down console is preferred to a vertical panel.

2. A process "Mimic" display, showing the equipment in symbolic form.

3. Miniaturized control switches and process controllers.

4. Color coding for level of urgency of annunciator messages.

Central Control Room

Centralized control is accomplished within the central control room environment. Given the high degree of responsibility placed on the operator, it is essential that the control room environment enhance the operator's work functions. Consideration should be given to the design of the operating console, the method on voice communications with other areas of the plant, the control room lighting level, the control room heating, ventilation and air conditioning, and the control room background sound level.

The location of the operating console with respect to enhancing overview is important. A relatively dust free environment should also be considered due to the nature of the process.

Analog Control Signals

Certain drawings and descriptions related to the control of the process subsystem are presented in this document. These drawings depict the analog control signals as electronic in nature. This is not a requirement. It is left to the system designer to determine whether electronic or pneumatic conrol equipment best suits the particular application.

If pneumatic control equipment is selected, proper attention should be given to the drying, filtration and pressure regulation of the instrument air. It is suggested that a central control panel alarm should be provided which would actuate in the event of a low instrument air condition. This would alert the operator to disregard certain display data and to take action to ensure that process control is manually overridden.

Reliability and Redundancy

It is recommended that the system designer consider control equipment which is highly reliable and easily serviced. This will serve to minimize the number of process upsets due to equipment malfunction.

In any case where the malfunction of a control element should adversely affect the safety of plant personnel or equipment, due consideration must be given not only to equipment reliability but also to redundancy of function. In these cases, duplicate control systems should be considered.

II. CONTROL SYSTEMS DESCRIPTION

The total plant process control system is divided here for descriptive purposes into twelve major control sub-systems. The control sub-systems are identified as follows:

1. Gasifier
2. Secondary Combustion Chamber
3. Process Cooling Water Flow
4. Regenerative Towers
5. Waste Heat Boiler
6. Gas Cleaning Equipment
7. Compressed Air Supplies
8. Process Cooling Water Equipment
9. Supplemental Fuel Equipment
10. Refuse Feeding Equipment
11. Slag and Fly Ash Handling Equipment
12. Auxiliary Power Supply

The gasifier, secondary combustion chamber and process cooling water flow sub-systems will be discussed together and referred to as the process system. The process system is developed in sufficient detail in this document to give the system designer the minimum required functions which are recommended for control of the process system. Additional features and functions may be incorporated so long as they do not interfere with the minimum required functions.

The remaining nine sub-systems will be discussed individually with the control system considerations presented as general requirements. No attempt has been made here to detail these sub-systems in the same way as the process system.

PROCESS SYSTEM

The process system consists of the gasifier, secondary combustion chamber and process cooling water flow sub-system.

The process system is divided into 26 areas of control called loops. Each loop contains the equipment required to control or monitor a particular parameter of the Andco-Torrax process.

The following comments pertain to all burner control loops:

1. All burners utilize a distillate heating oil, which is hydraulically atomized, as their fuel.

2. All burners are provided with a fuel flow switch to obtain a positive indication of fuel flow to each burner.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

The following comments pertain to all process control loops:

1. All controllers should be provided with automatic and manual modes of of operation. The transition from one mode to the other should be bumpless.

2. All cylinder operated valves should be provided with locally mounted, easily accessible, manual control station.

3. An alarm or indicating light should be provided in the control room to inform the operator when the operation of any valve is being manually controlled.

Loop 1 - Primary Air Flow Control

The primary air flow rate is recorded as the air passes through a pressure compensated venturi flow measuring device.

The primary air flow controller operates to maintain the required flow rate of primary air entering the gasifier by varying the speed of the primary air blower.

The check valve located in the primary air blower discharge line is provided to prevent back-flow of primary air in the event the primary air blower enters into a surge condition or if a primary air blower failure occurs during process operation.

If tuyere fuel is required, the primary air flow rate is automatically increased to provide additional primary air for the stoichiometric combustion of the fuel. When the fuel is no longer required, the air flow rate is automatically reduced to its nominal flow rate.

Loop 2 - Cold Air Blend Control

The hot blast temperature is measured as the blast enters the bustle pipe.

The cold air blend temperature controller operates to maintain the required hot blast temperature by modulating the cold air blend valve.

The cold air blend modulating and shut-off valves are both automatically closed if a primary air blower failure occurs.

When the hot blast temperature decreases to the lower limit of regenerative tower operation, a command signal is sent to the regenerative towers control equipment to initiate tower cycling. If the hot blast temperature continues to decrease to the minimum process operating temperature, an audible annunciator is sounded.

The cold air blend modulating valve is automatically positioned partly open while the regenerative towers are cycling to minimize temperature variation in the hot blast flow.

Loop 4 - Panel Mounted Pressure Gauges

The pressure gauges are mounted on the Andco-Torrax control panel in the main control room.

The gauge scale ranges are selected to provide mid-scale indication during process operation.

The pressures indicated are:

1. Gasifier Lantern

2. Gasifier Hearth (slag tap region)

Loop 5 - Tuyere Burners Controls

The tuyere burners control is designed to allow manual or automatic control of the initiation and termination of fuel flow to the gasifier tuyere burners.

The gasifier slag tap process temperature is displayed on the Andco-Torrax control panel in the main control room.

Low temperature and high temperature switches are provided for process temperature monitoring. The switches annunciate alarms in either the manual or automatic mode of control and are utilized for automatic control of tuyere fuel flow.

All bunrer control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 6 - High Temperature Multi-Point Recorder

The temperatures being recorded are:

1. Secondary Combustion Chamber Dome (Process)

2. Gasifier at top of transition (Process)

3. Gasifier at top of transition (Process)

4. Secondary Combustion Chamber Discharge (Process)

5. Gasifier Lantern (Process)

6. Gasifier Lantern (Process)

7. Gasifier Lantern Outlet (Process)

High temperature switches are provided to annunciate alarms for the secondary combustion chamber dome and the secondary combustion chamber discharge temperatures.

Loop 7 - Intermediate Temperature Multi-Point Recorder

The temperatures being recorded are:

1. Gasifier Offtake (Process)
2. Gasifier Hearth (Refractory)
3. Gasifier Hearth (Refractory)
4. Gasifier Hearth (Refractory)
5. Gasifier Penstock (Process)
6. Gasifier Penstock (Process)
7. Gasifier Penstock (Process)
8. Gasifier Penstock (Process)
9. Gasifier Bustle Pipe (Process)
10. Gasifier Bustle Pipe (Process)

Loop 8 - Low Temperature Indicators

The temperatures being indicated, at the locations noted, are:

1. Gasifier Tuyere Cooling Water (one per tuyere, panel and local)
2. Gasifier Slag Tap Cooling Water (panel and local)
3. Gasifier Stack Cooling Water (panel and local)
4. Offtake Isolation Valve Body Cooling Water (panel and local)
5. Offtake Isolation Valve Disk Cooling Water (panel and local)
6. Closed Loop Supply Cooling Water (local)
7. Open Loop Supply Cooling Water (local)
8. Oxygen Analyzer Sample Cooler Outlet Cooling Water (local)
9. Open Loop Return Cooling Water (local)
10. Closed Loop Return Cooling Water (local)

Items one through five inclusive are all provided with high and high/high temperature switches to annunciate alarms.

Loop 9 - Gasifier Slag Tap Burners Control

There is one burner provided in the slag tap region of the gasifier. The starting is manually initiated. The stopping is manually or automatically initiated.

The burner "A" is designed to operate during all phases of process operation by utilizing one independent source of combustion air. The burner will stop operating automatically if an over-temperature condition exists in the runner refractories. A burner experiencing a loss of flame will be automatically stopped.

An annunciator alarm is activated whenever a burner is not operating.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 10 - Gasifier Slag Tap Runner Temperature

The gasifier slag tap runner temperature is displayed on the Andco-Torrax control panel in the main control room.

A high temperature switch is provided to annunciate an alarm and stop operation of the gasifier slag tap burners.

Loop 11 - Locally Mounted Pressure Gauges

The pressure gauges are positioned to be easily observed by operating personnel.

The gauge scale ranges are selected to provide mid-scale indication during process operation.

The pressures indicated are:

1. Bustle Pipe

2. Gasifier Lantern

3. Gasifier at Top of Transition

4. Gasifier at Top of Transition

5. Gasifier Hearth (slag tap region)

Loop 12 - Induced Draft Valve Control

The offgas pressure is indicated as the offgas leaves the gasifier. The control point is inside the gasifier lantern. The induced draft valve pressure controller operates to maintain the required offgas static pressure by modulating the induced draft control valve.

Loop 13 - Gasifier Refuse Water Spray Control

The gasifier top chamber temperature is indicated on the Andco-Torrax control panel in the main control room.

A high temperature switch is provided to initiate water flow to the refuse spray and actuate an indicating light when the spray is operating. Water flow is stopped manually or automatically.

Loop 14 - Secondary Air Flow Recorder

The secondary air flow rate is recorded as the air passes through a pressure compensated venturi flow measuring device.

The secondary air flow recorder is located on the Andco-Torrax control panel in the main control room.

Loop 15 - Secondary Air Flow Control

The oxygen content and temperature of the secondary combustion chamber effluent flow are monitored.

The oxygen recording controller operates to maintain the required oxygen content in the effluent flow by modulating the inlet valve to the secondary air fan.

The temperature controller operates to prevent the effluent flow temperatures from exceeding the required maximum limit by modulating the inlet valve to the secondary air fan.

The oxygen recording controller modulates the fan inlet valve when the effluent temperature is below the maximum limit. The temperature controller takes over and modulates the fan inlet valve when the effluent temperature exceeds the maximum limit.

The offgas burner air supply valve is closed during heating and cooling phases of operation and is open during the refuse processing phase.

Loop 16 - Seconary Combustion Chamber Pilot Burner Control

The starting of the burner is manually initiated. The topping is manually or automatically initiated.

The pilot burner can be operated during off phases of process operation.

The burner is automatically stopped upon loss of flame.

An annunciator is activated whenever the burner is not operating.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 17 - Secondary Combustion Chamber Heat-Up Burner Control

The heat-up burner is used to heat the secondary combustion chamber (prior to system operation) and to maintain the minimum secondary combustion chamber effluent flow temperature during refuse processing.

The burner control is designed to allow manual and automatic control of the initiation and termination of burner operation.

The burner will operate in the automatic mode after it has been manually started. If the burner is manually stopped, it will cease to operate automatically.

The automatic operation of the burner is controlled by the secondary combustion chamber effluent flow temperature.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 19 - Secondary Combustion Chamber Slag Tap Burners Control

There are three burners provided in the slag tap region of the secondary combustion chamber. The burners are all individually controlled. The starting is manually initiated. The stopping is manually or automatically initiated.

All three burners are designed to operate during all phases of process operation.

All three buners will stop operating automatically if an over-temeperature condition exists in the runner refractories. A burner experiencing a loss of flame will be automatically stopped.

An annunciator is activated whenever a burner is not operating.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 20 - Offtake Isolation and Spill Stack Valves Control

The offtake isolation and spill stack valves are provided to prevent the flow of offgas to the secondary combustion chamber during abnormal process operation.

The isolation valve is open and the spill stack valve is closed during all normal phases of process operation. The spill stack valve opens and the isolation valves closes automatically, when an abnormal state occurs during any phase of process operation.

Loop 21 - Regenerative Towers Waste Gas Flow Control

The regenerative towers waste gas flow rate is indicated as the gas passes through a temperature compensated venturi flow measuring device.

The towers waste gas flow controller operates to maintain the required flow rate of regenerative gas through the towers by modulating the boiler waste gas discharge valve.

If both tower waste gas discharge valves are closed during any phase of process operation, the boiler waste gas discharge valve is automatically opened fully. When at least one tower waste gas discharge valve is open, the control of the boiler waste gas discharge valve is maintained by the tower's waste gas flow controller.

Loop 22 - Supplemental Fuel Flow Monitor

The instantaneous and totalized supplemental fuel flow rates to the process are indicated as the fuel passes through a positive displacement flow measuring device.

Loop 23 - Master Controls and Interlocks

The master control and interlocks are designed to simplify process operation by automatically performing the necessary control actions to satisfy an operator or interlock initiated command.

The operator manually initiates the process operational modes. The master controls will automatically initiate the required responses for the interlock commands.

The operator is provided with three operational modes. Each mode requires particular process operating parameters to exist before the mode can be initiated. The operational modes available are: Process Start, Process Run and Process Stop.

The Process Start mode allows the operator to bring the process equipment from a non-operating state to completion of heat-up. The Process Run mode initiates refuse feeding and establishes operational interlocks. The Process Stop mode terminates refuse feeding, maintains operational interlocks until the gasifier burn-down is complete, allows equipment cool-down to proceed and allows the process to be put into a non-operating state.

There are two types of interlock utilized in the operation of the master controls. The types of interlocks are: Operational Interlocks and Failure Interlocks.

Operational interlocks are automatically initiated control functions that do not change the mode of process operation. Refuse feeder operation, gasifier refuse water spray operation, waste heat boiler discharge valve operation and burners operation are examples of operational interlocks.

Failure interlocks are automatically initiated control functions that result in an immediate change in the mode of process operation. Primary air blower failure, secondary air fan failure and induced draft fan failure all cause failure interlocks to occur. A failure interlock can occur during any mode of process operation. The end result of a failure interlock is to place the process in a non-operating state.

Loop 23 - Master Controls and Interlocks (Continued)

Initiation of a failure interlock will initiate some operational interlocks also. When a failure interlock occurs, the process must be placed in a completely non-operating state and the cause of the failure must be corrected before the process can be restarted by the operator.

Loop 24 - Refuse Level Control

The refuse level in the gasifier is monitored as the refuse descends within the gasifier upper stack region.

The level controller operates to maintain the required refuse level by automatically initiating and terminating the operation of the refuse feeding equipment.

Loop 36 - Regenerative Tower Burner

The regenerative tower burner is used to heat the two tower during initial plant start-up. The temperature of the towers is raised from ambient to 1150° C.

The starting of the burner is manually initiated. The stopping is manual. If the burner experiences a loss of flame, it will be automatically stopped.

An annunciator is activated whenever the burner is not operating.

All burner control hardward utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not includes these safety features. All the functional features designed into this burner control must be included in the final design.

Loop 37 - Hot Blast Main Burner

The burner is used to heat the hot blast main and bustle pipe during initial plant start-up.

The burner will operate in the automatic mode after it has been manually started. If the burner is manually stopped, it will cease to operate automatically.

The burner is stopped upon loss of flame. An annunciator is activated whenever the burner is not operating.

The burner will stop operating automatically if an over-temperature condition exists in the hot blast main.

All burner control hardware utilized was selected to provide the desired functional operations with a minimum amount of hardware. Particular safety features will be required to meet local safety codes. Where no safety codes apply, sound engineering design providing sufficient safety features must be utilized. The control shown does not include these safety features. All the functional features designed into thie burner control must be included in the final design.

Loop 38 - Boiler Exit Waste Gas Temperature

The boiler exit waste gas temperature is measured at the entrance to the I.D. fan.

A modulating cold air blend valve operates to maintain the required temperature to the baghouse.

When the boiler exit temperature increased above the set point, a signal activates the positive shut-off valve to allow the modulating valve to reduce the temperature back to the set point.

REGENERATIVE TOWERS SUB-SYSTEM

The regenerative tower sub-system consists of the following major equipment:

Regenerative towers
Hot blast valves*
Cold blast valves*
Regenerative gas valves*
Waste gas valves*
Dome mixing air shutoff valve*

*NOTE: All regenerative tower system isolation valves must be gate valves which are capable of 100% mechanically ensured positive shutoff. Only the dome mixing air control valve may have a butterfly type construction.

Control of the regenerative tower sub-system consists of analog control for dome temperature control, stove sequence control, and stove system monitoring. These control systems are described in the following sections.

In order to prevent damage to the regenerative tower dome refractory, it is essential that the refractory temperature be prevented from becoming excessive. To accomplish this result, a dome mixing air temperature control loop should be included with the regenerative gas supply line. This control loop should function as follows: When a regenerative tower is on its heat up cycle, the refractory temperature in the tower dome may begin to rise above a pre-determined set point. At this time the dome mixing air shutoff valve should be opened fully and the dome mixing air control valve should begin to modulate open admitting ambient air to the regenerative gas stream. The dome mixing air control valve should continue to modulate open until the refractory temperature is returned to and held at the present control point temperature.

REGENERATIVE TOWERS SUB-SYSTEM OPERATION

The following is a description of recommended methods of sequence control for the cyclic operation of the regenerative towers. If desired, Andco Incorporated will provide design aid for utilization of these methods of control to suit the needs of any particular application.

Cyclic Operation of the Regenerative Towers

The regenerative tower cycling control system should provide the following methods for complete control of all the regenerative tower equipment as dictated by the position of a mode select switch.

Fully Automatic Mode

This mode of the control system will cause the tower cycling to proceed automatically when required to change from the "blast" mode to the "gas" mode of operation. The control will be properly sequenced and interlocked to assure that when the primary air temperature indicates that a tower that is on blast has expended it usable heat content, a fully heated tower will be placed on blast. With the fresh tower on blast, the expended tower will be placed on gas.

Semi-Automatic Mode

In this mode, a three position selector switch will provide means for a semi-automatic interlocked operation of all the valves on a single tower without affecting the operations of the other tower. Tower cycling sequence is manually initiated.

Manual Mode

In this mode, all the valves may be operated independently, either from control switches on the operating panel or from local pushbutton stations at each valve. Safety interlocks will prevent the operator from putting the tower into an unsafe condition.

Function Description on Fully Automatic Mode

The following will describe the fully automatic mode of operation for a complete tower change cycle starting with Tower No. 1 on gas and Tower No. 2 on blast.

The Model Select Switch is in the Full Automatic Position. We will assume that Tower No. 2 presently on Blast, has exhausted its usable heat and the cold Air Blend Regulating Valve is now in the closed postiion, and that Tower No. 1 is fully heated. As Tower No. 1 is still on gas, a bottom temperature recording controller indicates that the tower is at set temperature and a permissive control circuit allows the "off gas" sequence of Tower No. 1 to be initiated.

The "off gas" sequence, fully interlocked, follows:

1. The regenerative gas valve closes.
2. The dome mixing air and shutoff valves close.
3. The waste gas valve closes.

NOTE: During this transient period, the entire flow from the secondary combustion chamber is drawn through the waste heat boiler. The boiler feedwater rate must be adjusted accordingly.

Closure of the waste gas valve will now allow a permissive control circuit to initiate the "on blast" sequence for Tower No. 1. The following automatic actions will proceed:

1. The cold blast valve is opened.
2. The cold air blend regulating valve is opened to a preset position.
3. The cold air blend shutoff valve is opened.
4. The hot blast valve is opened.

With the completion of the above sequenced and interlocked operation of the valves, a permissive control circuit now allows No. 2 Tower, presently on blast, to be taken off blast and put on gas as follows:

1. The hot blast valve will close.

2. The cold blast valve will close.

Closure of the above valves will cause initiation of the "on gas" sequence of operations, described below:

1. The waste gas valve will open.

2. The regenerative gas valve will open.

3. A temperature control circuit on the dome mixing air control valves to operate to maintain a present maximum dome temperature.

4. The dome mixing air shutoff valve will open.

5. The boiler waste gas flow control valve will be driven to a partially closed position as determined by a manually set flow control point to maintain proper regenerative gas flow.

Tower No. 2 is now on gas under the control of its dome and bottom temperature controllers, and will remain on bottom temperature control until it is selected for blast operation.

If a tower is on gas and the bottom temperature control indicates that it is fully heated, and it is not yet required for blast service, it will be automatically put in a "bottled" condition as follows:

1. The regenerative gas valve closes.

2. The dome mixing air butterfly and shutoff valves close.

3. The waste gas valve closes.

The tower will be held in this state until the primary air temperature controller indicates that the "on blast" tower's heat is depleted. Then the heated tower will automatically be transferred from the bottled condition to blast. During the bottled condition, the waste heat boiler must take full waste gas flow.

<u>Functional Description of Semi-Automatic Mode</u>

With the mode select switch turned to the semi-automatic position, the semi-automatic control sequence selector switch for each tower becomes the controlling mechanism for further tower sequence changes.

An example of operation of the semi-automatic control system follows: Should the operator desire to remove Tower No. 1 from blast and place Tower No. 2 on blast, he must select Tower No. 2 "on blast" position and depress the initiate pushbutton. This action will:

1. Close the regenerative gas valve.

2. Close the dome mixing air regulating and shutoff valves.

3. Close the waste gas valve.

4. Open the cold blast valve.

5. Open the cold air blend regulating valve to maintain the preset hot blast temperature.

6. Open the hot blast valve.

With Tower No. 2 now on blast, Tower No. 1 can be removed from the blast mode by the operator selecting the Tower No. 1 "on gas" position and depressing the initiate pushbutton. The tower control system will then cause the following interlocked operations to take place.

1. Hot blast valve will close.

2. Cold blast valve will close.

3. The waste gas valve will open.

4. The heating gas valve will open.

5. The waste gas proportioning valve control and the dome mixing air valve control will be activated.

6. The tower heating cycle will begin under the control of the dome temperature controller and buttom temperature controller.

To isolate a hot tower that is not yet needed on blast, the operator selects the "bottled" position, which will close the regenerative gas valve, dome mixing air butterfly and shutoff valves, and the waste gas valve. The tower will remain in its heated condition until it is needed for blast service.

Functional Description of Manual Mode

Any of the valves on either of the towers can be operated by using the control switches on the operating panel or the local pushbutton stations that are mounted adjacent to each valve's drive unit. The model select switch must be placed in the manual position to obtain this control.

In addition to the tower dome temperature control, and tower cycle sequence control, the operator should have ready access to the following information and control:

1. Tower valve position indication - feedback from the actual valve position.

2. Indication of the status of each tower operating state (i.e., on blast, on gas, or bottled.)

3. Indication of tower differential pressure.

4. Indication and recording of tower dome temperature, regenerative gas temperature, hot blast temperature out of the towers, tower bottom temperature, waste gas temperature.

5. Alarms and indications to alert the operator of various associated equipment or system malfunction.

WASTE HEAT RECOVERY BOILER

1. Feedwater control will be 3 element type based on:
   a. Feedwater Flow
   b. Steam Flow
   c. Drum Level

2. Steam Temperature Control will be variable orifice type desuperheater with condensate as the desuperheating media.

3. Continuous Blowdown Control

4. Instrumentation
   a. Draft gauges at each section
   b. Recording temperature at each section
   c. Recording steam flow, steam pressure, steam temperature
   d. Inlet gas flow, gas pressure

GAS CLEANING SUB-SYSTEM

Particulate removal will be done in a fabric filter baghouse that will also service Boiler No. 3 and Boiler No. 4. This baghouse will have a complete instrumentation and control system.

COMPRESSED AIR SUPPLIES SUB-SYSTEM

Compressed air has several potential applications in the equipment control systems. These are: control valve motive power, air cylinder positioner motive power, and instrument air supply (if any pneumatic instrumentation is used).

It is recommended that the compressor system be equipped with sensors to monitor the equipment status--such as sufficient lubricating oil pressure, sufficient cooling water flow, etc. These compressor status monitors should be tied into a common annunciator point in the central control room. In addition, it is recommended that the air system pressure be monitored with an additional annunciator point to alarm on a low pressure condition. These alarms would give the operator a warning of impending loss of control thus providing an opportunity to react to the circumstances.

PROCESS COOLING WATER EQUIPMENT SUB-SYSTEM

It is essential that certain areas of the process equipment be supplied with cooling water on a continuous basis. These include the water cooled gas valves, gasifier stack, tuyeres, gasifier and secondary combustion chamber slag tap coolers, and slag quench tanks.

The cooling water must be supplied to the equipment at adequate pressure, flow and temperature to be effective as a cooling medium. It must also not cause fouling or deterioration of the heat exchange surfaces. The control system designer must keep all of these considerations in mind while formulating the cooling water system control and protective monitoring scheme.

The following is a list of the criteria which the designer should consider:

Cooling Water Pumping

System reliability must be very high in order to prevent damage to the equipment which requires continuous cooling. The designer should consider the use of backup pumps with automatic startup in the event of failure of the on line pumps. Alternate methods of pump motive power may also be considered.

In order to prevent damage to the pumps for cavitation, the designer should protect the upstream side of the pumping system with pressure switches or isolation valve limit switches to prevent the inadvertent starvation of the pump fluid supply.

Reservoirs which feed the cooling water pumps should be equipped with low level detecting devices to warn the operator of the condition, to automatically engage an emergency water supply, or stop the pump operation.

In the event the discharge system of the pump is shut off, damage to the pump may occur--the likelihood of damage depends on the pump and system design. The designer should consider the use of shutoff valve limit switches to detect the situation or automatic recirculation control to avoid the situation.

The formulation of the design for system control and monitoring should consider that use of all of the following types of devices: water pressure, temperature, and differential pressure switches, water flow meters, and vessel level switches.

Cooling Water Heat Exchange

Heat pick-up or drop-out across the various pieces of equipment should be monitored in order to determine equipment cooling system malfunction in a timely fashion. This is most usually accomplished by monitoring the cooling water flow to and differential temperature across each piece of equipment--thus enabling operating personnel to monitor total system performance.

Cooling Water Chemical Treatment

In most applications of cooling water systems, the economics of water supply dictate the use of a recirculated cooling water system. With a recirculated cooling water system, chemical treatment is necessary to protect the equipment from malfunction and costly maintenance.

In this type of system, the influent should be properly filtered to remove any suspended solids.

The influent and recirculated water should be chemically treated to control pH, reduce corrosive properties of the water, reduce biological fouling and control scale build-up.

In order to comply with governmental regulations regarding environmental pollution, it may be necessary to control the heat level of the system effluent (blowdown, overflow, etc.), the total dissolved solids, acidity, and possible heavy metal contamination of the effluent.

Suitable controls and monitoring equipment should be chosen to alert operating personnel when there is an off normal water quality problem which requires attention.

SUPPLEMENTAL FUEL SUB-SYSTEM

This section is concerned with the storage and distribution of supplemental fuel to the various burners in the process system and the waste heat boiler. Regulation of the fuel supply to individual burners based upon process conditions (combustion control, burner control, flame detection and safety shutoff) is covered in the individual process equipment section of this document.

Fuel Storage

Liquid fuel is stored in tanks which must be constructed, located and vented per governing codes.

Gaseous fuel, if not provided by connection to a pipeline distribution network, is stored in a liquified state in gas cylinders. These cylinders must be located, installed and vented per governing codes.

Storage systems should be equipped with level sensing instrumentation to monitor the available fuel reserves.

Fuel Supply Systems

Liquid fuel pumping and distribution systems and gaseous fuel distribution systems should ensure that the fuel supply is available at the burners in sufficient quantity at an adequate pressure level. The system designer should consider the application of pressure, temperature and flow sensors to monitor the state of the equipment and fuel supply and also to conform to governing safety codes. Excess liquid fuel supply available at the burner due to pressure control considerations, fluid heating considerations, or a fuel shutoff event should be recirculated back to the fuel storage tank. Excess gaseous fuel supply present in the system at a fuel shutoff event should be vented in accordance with governing safety codes.

REFUSE CHARGING SUB-SYSTEM

Based on the number of successful applications throughout the world, a bucket or grapple crane is recommended to lift the refuse from the storage pit to the gasifier feeder hopper.

Since the process system relies on a continuous source of refuse from the gasifier charging equipment, the system must be highly reliable. It is recommended that a vibrating table feeder or a ram type feeder be considered for this application. The feeder rate should be sufficient to provide the initial charge to the gasifier quickly enough to provide for stable process system start-up and operation.

In order to provide a back-up level of feed reliability, the designer should consider a plant layout which would allow the pit bucket crane to charge directly into the gasifier top, bypassing the refuse feeder.

The gasifier stack should be equipped with level monitoring and control equipment. When the stack refuse level falls below a certain desired point, either the feeder should operate automatically to refill the stack, or a status indication should be sent to the control room to allow the operator to actuate the feeder mechanism. The stack level monitoring equipment can consist of a mechanical depth probe or a non-contracting level measurement device such as a gamma-ray nuclear gauge.

It is considered worthwhile if the level detection system selected could provide the operator with an indication of the time rate of change of the stack level--which is indicative of the process system operation rate.

The design of the gasifier refuse feed system should provide for sealing to prevent the ingrest of air to the gasifier stack which will be operating at a slight negative pressure.

SLAG AND FLYASH HANDLING EQUIPMENT SUB-SYSTEM

Slag System

The gasifier and SCC slag tank must discharge frequently to avoid overfill or plugging. The discharge of the tanks will be directed to a transport means which will convey the slag to a storage area. If a slurry transport is used, the slag can be dewatered at the storage area.

Since even a moderate term outage in the slag handling equipment can force a cutback in the process system production rate, it is necessary that the slag handling equipment be highly reliable. The designer should consider the application of redundant prime movers or even redundant complete system.

In order to prevent a back-up of material in the system or a material spill, the prime movers of the various elements in the system should be interlocked (i.e. the trip of any element will cause the automatic trip of all upstream equipment).

The control system designer should consider the application of sensors to detect plugging or back-up of material in the system, conveyor malfunction and malfunction of the slag tank water level control. The occurrence of any of these equipment malfunctions should cause an annunciated alarm in the central control room to advise the operating personnel of the vent so that quick remedial action can be taken.

Flayash System

Flyash will be collected in hoppers at the bottom of each heat transfer section of the waste heat recovery boiler. This ash will be removed as required through automatically controlled rotary valves and transported to an ash storage silo with a pneumatic type ash handling system.

AUXILIARY POWER SUPPLY SUB-SYSTEM

It is essential that certain areas of the process equipment be supplied with cooling water on a continuous basis. These include the water cooled gas valves, gasifier stack, tuyeres, gasifier and secondary combustion chamber slag tap coolers, slag quench tank as well as the feedwater for the waste heat boiler.

In the event of an electrical power failure, damage could occur to the equipment which relies on the motor driven pumps for their water supply.

Since electrical power failures will occur, it is necessary to have alternative means of assuring a continuous supply of cooling water. This could take the form of automatic steam trubine driven auxiliary pumps (if a reliable source of steam is available) or the use of an auxiliary electric power supply--an engine driven electric generator. If the generator is chosen, it should be designed to provide emergency lighting near the equipment and in the control room power to the control panel and motor control circuitry, as well as motive power for the essential prime movers themselves.

It is not essential to keep the auxiliary generator running at all times with automatic instananeous throwover capability providing an uninterrupted power supply. However, the generator should have automatic quick start capability so that the equipment is not without power for longer than about 15 seconds.

The generator should have a fuel supply sufficient for operation for a 24 hour period--this period is considered to be sufficient to allow for a safe shutdown and cooldown of the equipment.

CONTROL DRAWINGS

The drawings provided are for the process sub-system.

All drawing numbers have a five digit numeric prefix, 61001. The drawing number is further modified by an alphabetic suffix that corresponds to the latest revision of that drawing.

CONTROL DRAWING LIST

The following is a preliminary control drawing list:

- D-70-680-01 - Instrument Symbols and Identification
- D-70-681-01 - Gasifier Process Instrumentation Flow Diagram
- D-70-681-02 - Gasifier Fuel Process Instrumentation Flow Diagram
- D-70-681-03 - Secondary Combustion Chamber Process Instrumentation Flow Diagram
- D-70-681-04 - Secondary Combustion Chamber Fuel Process Instrumentation Flow Diagram
- D-70-681-05 - Primary Air Process Instrumentation Flow Diagram
- D-70-681-06 - Waste Gas Process Instrumentation Flow Diagram
- D-70-681-07 - Cooling Water System Instrumentation Flow Diagram
- D-70-681-08 - Regenerative Tower Fuel Process Instrumentation Flow Diagram

8.13 UTILITIES

8.13.1 FUEL OIL

No. 2 fuel oil is used as an auxiliary fuel for start-up to preheat the gasifier, the secondary combustion chamber, the cowpers, and the hot blast main.

During normal operations, fuel oil is used at the gasifier and the Secondary Combustion Chamber slag taps.

Fuel oil requirements are as follows:

Start-Up

Item	Start-Up Time Hours	Rate of Flow GPH	Total Flow Gallons
Cowper Burner	72	39.63	2,853.4
Secondary Combustion Chamber Start-Up Burner	18	105.70	1,902.6
Secondary Combustion Chamber Slag Burner	18	10.57	190.2
Secondary Combustion Chamber Pilot Burner	96	2.906	279.0
Gasifier Slag Burner	18	6.605	118.9
Hot Blast Main Burner	96	7.926	760.9
			6,105.0

Normal Operation

Item	Daily Requirements - Gallons
Gasifier	190
Secondary Combustion Chamber	253
	443

REFERENCE DRAWING NOS.: D-67-530-01
D-90-510-03

8.13.2 NATURAL GAS

Natural gas is used as an auxiliary fuel in the gasifier tuyeres for start-up purposes or if the refuse heating value is abnormally low.

Natural gas requirements for start-up are as follows:

Item	Start-Up Time Hours	Rate of Flow SCFH	Total Flow SCF
Gasifier Tuyeres	18	6,000	108,000

REFERENCE DRAWING NOS.: D-67-530-01
D-90-510-03

8.13.3 ELECTRIC POWER

The following table is the power (3 phase, 60 Hertz) requirements for the Andco-Torrax system:

Item	Motor Size HP	Power Demand KW	KWh/Ton Refuse
Primary Air Fan	100	74.6	13.56
Secondary Air Fan	75	55.9	10.16
Induced Draft Fan	500	375.0	43.50
Vibrating Feeder	20	14.9	2.70
Slag Bucket Elevator	7.5	5.6	1.02
Slag Grapple - Bucket Hoist	2	1.5	0.27
Open Circuit Cooling Pump	30	23.37	4.25
Close Circuit Cooling Pump	100	74.6	13.56
Slag Quench Reservoir Pump	30	23.37	4.25
Instrument Air Compressor	15	11.2	1.02
Control Panel (120 Volt)		7.5	1.36
Burner Fans (Total)	15	11.2	2.03
Slag Screen Shaker	3	2.2	0.40
Chemical Feed Pump	1	0.745	0.13
Total			98.21

NOTE: The heat exchanger Fans, No. 1 and No. 2, operate only if the auxiliary power system is actuated.

REFERENCE DRAWING NOS.: D-80-600-01
D-80-600-02

8.13.4 CITY WATER AND SEWER

Two closed cooling water circuits are employed. The two loops recirculate water at a total rate of 1,435 gpm. Water make-up requirements for normal operation are estimated to be 50 gpm for both circuits. The daily water make-up is estimated at 72,000 gallons.

REFERENCE DRAWING NOS.: D-60-500-01
D-60-500-02
D-70-681-07
D-90-510-01
D-63-500-01

8.13.5 EMERGENCY PLANT AIR REQUIREMENTS

In the event of plant power failure, the Andco-Torrax emergency power unit will supply the necessary power to maintain system operation (Reference Drawing No. C-90-670-01). Fuel atomization air required for the regenerative tower and gasifier slag tap burners will be supplied at a continuous rate by an auxiliary compressor. At 80 SCF of air per gallon of fuel oil, a volumetric flow rate of 62 SCFM is required. This air will be available at a maximum pressure of 25 psig and will require an estimated 10 HP motor.

Air for valve actuation will be supplied from a receiver which is charged by a second compressor also powered by the Andco/Torrax emergency power unit. The air required for the periodic actuation of each valve is tabulated below:

	Valve	Total Air
(2)	Regenerative Tower Inlet Air	12 SCFH Each
(2)	Regenerative Tower Discharge	12 SCFH Each
(2)	Waste Gas Isolation	12 SCFH Each
(2)	Hot Blast Isolation	12 SCFH Each
(1)	Gasifier/SCC Isolation	12 SCFH
(1)	SCC Flapper	8 SCFH
(1)	Spill Stack	8 SCFH
(2)	Blend Air	8 SCFH Each
	Total	140 SCFH

Since valve actuation occurs at approximately 1/2 hour increments, the receiver was sized for 1/2 the above total or 70 SCF plus a 30 SCF margin. For a charge pressure of 200 psig and a minimum blowdown pressure of 100 psig, the receiver volume is approximately 15 ft^3 charged by an estimated 3 HP compressor motor.

Separation of atomization (continuous) air from actuation (intermittent) air not only minimizes compressor and storage vessel requirements, it also removes the time limit during which burndown can occur.

8.14 ANDCO-TORRAX SYSTEM OPERATION DESCRIPTION

ITEM

System Operation

Equipment Location

Equipment Check

Transient State Operation

Cold Start

Warm-up Cycle

Plant Operation

Shut-Downs

Failure Analysis

General Description

Operational Failures-Andco-Torrax Equipment

Gasifier

Water System

Refuse Feeder

Secondary Combustion Champer Failures

Auxiliary System Failure

System Rate Variation

Parameter Description

8.14.1 EQUIPMENT LOCATION

The location of each sub-system in the Andco-Torrax system has been chosen for both ease of maintenance and accessibility. The gasifier, SCC, boiler and stoves are located on the operating floor of the plant. The primary blower is located in the basement to aid in reducing noise level on the operating floor. Platforms and walkways are interconnected throughout the plant at various elevations.

The water cooling heat exchangers have been placed on the roof to reduce heat loads inside of the building.

The slag removal equipment for both the gasifier and SCC and the cooling water equipment are located in the basement of the plant.

There are two bridge cranes located at various places throughout the plant. The first is the refuse crane and bucket located over the refuse bunker. The second is the maintenance crane located directly above the SCC and stoves.

The control equipment is located on the operating floor.

8.14.2 EQUIPMENT CHECK

Control Room and Plant Instrumentation.

Each piece of equipment must be checked for proper operation prior to any system start-up.

The first total equipment check-out occurs upon completion of construction.

The equipment check-out starts with both the control room and plant instrumentation. Each item on the control panel and those located throughout the plant must be checked for proper installation. Individual transmitting elements such as thermocouples, pressure transmitters, etc. will have signals generated for checking the correct operation of instruments located in the control room.

Blower, Fan and Pump Motors

The various motors located throughout the plant must have their electrical circuitry checked. The motor starters and start/stop switches must be actuated to determine proper directional rotation.

The air moving motors to be tested are those for the primary and SCC blower and I.D. fan. Other motors to be checked include those for the cooling water system, slag systems, boiler feed water system and stove-valve cooling system and heat exchanger fans.

Valves

The various controlled valves throughout the plant must be checked for proper electrical and/or pneumatic hook-up.

All thermocouples must be checked using a potentiometer. Each lead wire, as well as the T/C element is to be checked with the potentiometer for line continutiy.

Required Equipment

Appropriate meters are used to check main line amperage and voltage.

The pneumatic lines and pressure gauges must be checked for leaks. A portable compressor will be utilized to check the valves and lines for proper action.

The fuel system will be pneumatically checked for leaks before operation.

8.14.3 TRANSIENT STATE OPERATION

Cold Start

Cold Starts require that all equipment be operating without heat in the system. The system must always be started cold under any circumstances. Avoid attempting to start any burners without having a draft in the system since there is danger of collecting and exploding combustible gases.

The plant must undergo cold-start and cold operation when the equipment check-out phase has been completed. This phase allows for checking the equipment during running operation. Malfunctioning must be corrected during this period.

The procedure for cold start-up and operation is as follows:

Close all manual fuel valves to all burners.

Power Sequencing for Motors and Instrumentation

1. Close system start-up switch. This switch actuates a series of relays that locks out all fan and blower failure modes. The switch will also close the spill stack valve and open the isolation valve.

2. Close feeder system stop buttton (This action prevents refuse from being fed into the gasifier during cold start and warm up period).

3. Set all controls on panel to zero.

4. Close starter for plant air system.

5. Close starter for instrument air system.

6. Start Plant air system.

7. Start instrument air system.

8. Electrically powered control panel. The plant and instrument air system must be brought to full capacity before any other action occurs. This insures pressurized air for both control panel instrument and the various pneumatic valves through the plant.

9. Close Starter for I.D. fan.

10. Close starter for primary blower.

11. Close starter for Secondary Combustion Chamber blower.

12. Close starter for heat exchanger fans.

13. Close starters for slag cooling system.

14. Close starter for vibrator separator.

15. Close starter closed loop cooling system--gasifier, isolation valve, re-generative tower valves.

16. Set cold air blend controller to full open.

17. Set oxygen analyzer to close position.

18. Bottle regenerative towers (consult Vendor procedure) then

19. Open regenerative waste gas inlet and outlet valves.

20. Start induced draft fan.

21. Start Secondary Combustion Chamber air fan.

22. Start primary blower.

    Plant water systems are to put on line at this time, as water seals for both the gasifier and Secondary Combustion Chamber are required.

23. Close emergency water system valves.

24. Start heat exchanger fans.

25. Start slag cooling water pumps.

26. Start vibrator separator motor.

27. Start closed loop cooling pump.

28. Start O_2 analyzer cooling water.

29. The system is now ready for the purge cycle. With all blowers operating, air passes through the gasifier, Secondary Combustion Chamber, and stoves for a predetermined period to remove any combustible gases that may have collected in the system.

30. The plant is now operating. Each piece of equipment is checked over its full range of operation. If any malfunctioning occurs, corrective action is taken during this period.

Checking Equipment Operation

The procedure to follow for checking equipment operation is:

1. All controllers are set to zero.

2. Each controller must be actuated through its operating range to check the simultaneous action for valve operation.

3. The temperature controllers and temperature indicators are checked by generating various potentials at their transmitter elements. Use a potentiometer to check the continuity of all electrical and temperature transmitting lines.

4. When the operation check-out period is completed for all the equipment items, the system is shut down.

Warm-Up Cycle

Introduction

There are two distinct types of warm-up cycles for the gasifier, secondary combustion chamber and stoves. The first type takes into account drying of the refractory. The procedure for drying the materials in the various vessels is standard, accepted practice and the vendor supplying the refractory is to be consulted for determining the time and temperature cycles to employ during this dry-out period. The refractory has one dry-out period and must be done at the beginning of the first warming period for the plant.

The second type of warm-up cycle for the system is the standard warming procedure prior to processing of refuse. The warming cycles is also the second phase of the above procedure. Both are described below.

The items 1 through 30 above describing the system Cold Start, are used to ready the plant in cold running condition before the fuel burners are started.

The controllers are set to zero and readjusted to provide combustion air for fuel being combusted at the regenerative tower burner.

The drying-warming cycle for the initial heating of the processing equipment is begun after the completion of the cold operation cycle.

During the drying period mositure is removed slowly to prevent damage to the refractory. The main start-up burner is ignited to dry the secondary combustion chamber. The tuyeres are ignited to dry both the tuyere inserts and hearth-burning zone refractories in the gasifier.

Warming Schedule

The regenerative towers are the first to be started; the towers will take several days to reach operating temperature (1100^{o} C). When fifty percent of the heating cycle has been completed, the secondary combustion chamber is heated and at the same time the gasifier tuyere fuel is turned on so that all main hardware items will reach operating temperature at the same time. At the end of the heat-up period, all the system equipment will be ready for processing refuse. The boiler, however, will not be producing maximum steam output. The boiler will be on line.

Plant Operation

When the plant has reached the end of its warm-up cycle, hot condition, it is ready for processing refuse. The following are basic steps done prior to charging the gasifier with refuse:

Prior to Charging

a. Check all instruments for operating temperatures:
   1. Bustle pipe
   2. Gasifier slag seal
   3. Secondary combustion chamber chamber
   4. Hot blast at stoves

b. Turn off tuyere fuel.

c. Reduce primary air flow to set to minimum.

d. Increase I.D. pull to maintain a negative draw sufficient to keep offgas contained within gasifier, one-two inches of water pressure.

e. All slag burners on full fire.

f. Check slag drain runners for blockage.

g. Both regenerative towers must be at minimum hot blast temperature.

h. Boiler must be on line.

i. All water systems are functioning.
   1. Tuyere water system
   2. Slag tap cooling water system
   3. Slag quench water system
   4. Gasifier cooling water system

j. Gasifier ready to charge.

Charging Procedure

a. Before an operator starts charging, he must satisfy himself that all systems are in working order, all personnel are at their respective work stations.

b. Notify crane operator to start charging main hopper. After hopper is full, start feeder, actuate auto run button. Feeder will continue operations until refuse level reaches the detector. As the refuse level increases in the gasifier, process air is slowly added and by the time the level reaches the detector, the process air is to be at the proper value. During the charging procedure, all instruments must be monitored to maintain proper negative pressure at lantern.

c. Once a full stack condition is achieved, the operator checks all systems conditions. The secondary combustion chamber discharge temperature and boiler temperature must be checked frequently for the first hour.

d. Tuyere fuel is added only if necessary.

e. Both gasifier and secondary combustion chamber slag taps must be checked until a stable drain condition is reached, 1 to 2 hours after full stack.

   The hearth and burning-zone will drop in temperature during the gasifier filling operation. It will take approximately 4 hours to completely stabilize the system. Fuel may be needed during the transient condition in order that the slag can drain during this period. The shift operator must monitor the control panel instrument to detect any malfunctions. It will be noted during the transient state the temperatures being recorded or indicated with vary until steady state occurs.

Operation

Make periodic checks on condition of tuyere, gasifier slag tap, secondary combustion chamber slag tap, boiler, baghouse and water cooling system.

a. Tuyeres:
   During normal operations, tuyeres should remain hot and active. Carbon dropping into the hearth should readily mix and dissipate into the individual tuyere

puddles, tuyere levels should be in the low medium range, but more importantly should remain stable (indicating good drainage).

If it becomes necessary to control individual tuyere levels or "eyebrows", etc. during operations, then this is accomplished by slightly increasing fuel flow.

b. Gasifier Slag Tap:
Slag flow should remain steady, hot and uniform during typical operations. The tap should be clean and open.

C. Secondary Combustion Chamber Slag Tap
During slagging periods, slag should flow freely and not accumulate on refractory sidewalls. Regulate burner to maintain desired temperature in this area.

d. Periodically check O_2 analyzer readout to insure optimal burning conditions in the secondary combustion chamber.

e. Periodically check hot blast temperature to see if the regenerative tower is maintaining blast temperature.

f. The operator should be aware of the stack conditions at all times during operation. For example:
   1. A sharp increase in bustle pressure with a corresponding increase in hearth pressure and resulting drop in offtake temperature indicates a stack drop and a temporary tight stack condition. The process air system will automatically compensate for this condition.
   2. A lingering low hearth pressure (less than .1 psi) with an increasing offtake temperature indicates that the stack is burning through and possibly bridged above the lantern section.

g. Also, during operations, checks are made on the following operating equipment to insure a smooth running facility.
   1. Check cooling tower pump pressure at blow down intake screen trap.
   2. Slag pump pressure.
   3. Cooling water temperatures; add water if required.
   4. Tap runner circulating water pressure and temperature within limits.
   5. Check I.D. fan for vibration, bearing oil levels and pressure drops.
   6. Check out boiler, condenser, deaerator.

The refuse rate will vary slightly from hour to hour, depending upon the heating value and moisture content. The total daily average will be at the required rate.

Shutdowns

There are two ways in which the system operation can be terminated. The first initiated by the operator, is a normal shutdown for plant maintenance. The second way in which the system can be shut down is because of emergency failures. Emergency failures are divided into two classes: total plant power failure and blower failure.

Weekend Shutdown

When the plant is in steady-state operation and shutdown has been scheduled for maintenance work, the following procedure is used:

1. The feeder system is the first to terminate operation. When the hopper is empty, the stop button is pressed.

2. The air flow will be controlled manually as the refuse level in the stack begins to drop.

3. Fuel may be needed at the gasifier tuyeres so that slag continues to flow from the hearth. During routine burndown, there is normally ample carbon to supply the necessary heat for removal of the slag.

4. When the burndown has been completed, a portion of the inert material remains in the hearth zone. This mass is referred to as the "dead man." To facilitate removal of this mass in a small period of time, fuel is burned at the tuyeres to maintain a temperature high enough for slagging. Some portion of this mass is typically left in the hearth, unless a long shutdown is anticipated, to retain heat for faster reheat of the system. When the burndown has been completed. the fuel is turned off at the tuyeres and slag tap.

5. The tuyere water and slag tap runner cooling water must continue to operate to prevent structural, and/or refractory damage.

6. The stoves' normal cycling operation is discontinued during shutdown. The hot stove is bottled, and the cool stove is used to supply "hot" blast air for burn-out of the gasifier. Upon completing the burn-out, which should take about two hours, the second stove is also bottled.

7. The secondary combustion chamber slowly enters an idle condition at the same time as the gasifier burn-out. The offgas combustion air is reduced to help maintain ignition temperature in the chamber because the offgas production rate slowly reduces. If necessary, fuel may be needed to maintain proper secondary combustion chamber temperature for complete combustion of the gas. The secondary combustion chamber arrives at the idle condition upon completion of the gasifier burn-out and, at the same time, power to the induced draft fan is cut.

8. The boiler has been cooling since the refuse feed to the gasifier was stopped. Cool-down must be slow so no structural damage will occur to the boiler. The boiler water level is maintained to prevent damage.

9. The spill stack valve is opened and the offgas isolation valve is closed.

The system will take approximately three days to cool to a safe level for workmen to enter the secondary combustion chamber or the gasifier. Once the system is ready for re-start, the same start-up procedure is used.

Failure Analysis

General Description

Andco-Torrax hardware failures are divided into two classes. The first is an emergency failure and is caused by a complete power failure in the plant or failure of the primary gas mover, secondary air blower, or induced draft fan. This type of failure would immediately and automatically shut down the plant.

The second class of failures are operational and could also cause plant shutdown. The failures are secondary combustion chamber low temperature, secondary combustion chamber flameout, and slag tap and quench tank cooling water system failures.

Emergency Failures (EF)

The first class of failures are handled in the following manner: Fuel to both the gasifier and secondary combustion chamber is automatically turned off. The offtake spill stack will open and the cross-over isolation valve will close. Three valves on each of the stoves will close; the top two valves and the cold blast air valve. The purging of the equipment downstream of the cross-over isolation valve will be aided by the main stack draft.

Total Power Failures (TPF)

System in steady state:

If the total power should fail to all items in the Andco-Torrax System the following events occur:

1. All external fuel will automatically be turned off.

2. Offtake spill stack will open.

3. Cross-over isolation valve will close.

4. Three valves on each tower will close; first, the two top valves and second, the cold blast bottom air valve.

The above sequence of event will allow the gasifier to vent and prevent any build-up of CO in the gasifier stack. The secondary combustion chamber chamber is then effectively plugged by the natural draft of the main stack and the stove is protected from any CO flow. Both the gasifier and the secondary combustion chamber will be purged by natural draft which will allow continuous removal of any combustible gases.

The gasifier will proceed through a very slow burn-out of the remaining material in the stack. Slag flow will gradually come to a stop as the process temperature drops to below 2000^{o} F. The offgas produced from the remaining refuse in the gasifier stack will be consumed by an optional aspirated burner located at the top of the spill stack and external to the building. The hearth temperature will drop slowly so as not to cause structural damage to the metal hardware in this area. Cooling water for the gasifier must now be supplied by the municipal water system.

A similar but separate cooling system is also needed for the tuyere water during a complete power failure.

Primary Air Blower Failure

Several control commands will be initiated simultaneously when this device fails. All fuel to the gasifier is turned off. The offtake spill valve stack is opened and the cross-over isolation valve is closed. Three valves on both stoves will close.

The equipment downstream of the cross-over isolation valve will function as normal except for the addition of fuel to the secondary combustion chamber to maintain a reduced boiler steam output.

The gasifier will follow the same slow burnout as described in Item TPF, p. 141.
The secondary combustion chamber will continue to function as normal but with the addition of enough fuel for maintaining the desired secondary combustion chamber temperature and a reduced boiler steam output.

The cooling water will continue to flow to the slag tap area, the hearth shell, stack shell, and tuyeres.

Secondary Air Blower Failure

All fuel to the secondary combustion chamber will be turned off.

The spill stack will open, the offtake isolation valve will close, air to purge the secondary combustion chamber is drawn in by the I.D. fan.

Hot blast air will be used to complete burndown in the gasifier.

Induced Draft Fan Failure

All fuel to the secondary combustion chamber will be turned off. The secondary combustion chamber main blower will be allowed to purge the secondary combustion chamber.

The spill stack will be opened and the cross-over isolation valve will close to aid the purging process.

Hot blast air will be used to complete burndown in the gasifier.

Operational Failures - Andco-Torrax Equipment

Gasifier

The gasifier has four areas that could have operational failures. The items are classified in four categories: refractory, water, feeder, fuel failures.

Hearth Refractory

A refractory failure in the hearth need not be detrimental to the operation of the gasifier. If a portion drops into the process, the high process temperatures will consume it. Its residue will flow from the gasifier as part of the slag.

Slag will naturally coat the now exposed metal wall section so that no damage will be caused to the metal shell.

Slag Tap Refractory

The slag tap refractory erodes very slowly during operation. However, if a sizable piece should fall and block the flow of slag, oxygen lancing must be initiated in order to rapidly melt away the blockage. If the above should occur, the slag tap pressure is reduced to zero and the slag tap burner to off. Since slag will continue to flow until hearth temperatures drops below 2000° F, lancing must be done as quickly as possible. The lancing operation will open a path for the slag to flow through and once a hole is made, flowing hot slag will enlarge the hole very rapidly.

When done, the slag tap area is resealed. The slag tap burner's fuel is increased to help enlarge the hole in a short time.

Downcomer & Penstock Refractory

The refractory protecting the downcomer and penstock should not fail. However, if failure should occur due to tuyere fuel burning damage, it can be detected so that a repair can be made.

Bustle Pipe Refractory

Bustle pipe refractory failures rarely occur, but if they do, water can be sprayed on the hot spot until a more convenient shutdown can take place.

Water System

The most common failures in water systems are pump failures. Two pumps are normally placed in parallel so that when one fails, the other can be manually or automatically operated to resume normal operations.

Slag Tap Cooling Pipes

The prime reason for slag runner cooling pipe failure is damage by inaccurate lancing in the tap area. The high temperature lancing rods burn through the pipes and the water must be turned off. Some damage will occur to the refractory because of wear by the slag, however, the gasifier can continue to operate normally until a scheduled shutdown.

Gasifier Stack Cooling System

The cooling system failures can be of varying magnitude and complexity. If a small leak should occur during the operation, the water can simply be collected and routed back to the cooler and the repair scheduled for a later date. If the cooling system should develop a large uncontrollable leak, the gasifier must be placed in the burndown condition. The gasifier must be completely cooled and repairs made because significant damage to both the metal structure and refractory is possible. Once the repairs have been made, the gasifier must be reheated as in initial start-up.

Tuyere Cooling System

A tuyere cooling system failure, other than pump failure, must follow the same shutdown procedure as a major cooling system failure. The damaged tuyere must be completely removed from the gasifier, hence exposing the process to its ambient surroundings.

Refuse Feeder

Several areas of failure are possible in the refuse feeding system. These are the vibrating pan, the level detector, and refuse blockage.

Vibrating Pan

The gasifier can be fed directly from the top while repairs are being made. Operation can continue as normal.

Refuse Level Detector

Failure of the level detector will not upset the normal operation of the gasifier. The level can be determined by visual inspection.

Refuse Blockage

If a blockage were to occur in the feeder system, the gasifier can be put into a slow burndown by reducing the hot blast, thereby maintaining a hot hearth until the blockage is suitably removed.

Secondary Combustion Chamber Failures

The failures that may occur in the secondary combustion chamber are classified similar to those in the gasifier--refractory, water and flame-out condition.

Flame Failures due to Low BTU Offgas

Flame failure due to secondary combustion chamber blower failure is classed as an emergency condition. If flame failures is due to low BTU, fuel will be automatically added to maintain slagging conditions and steam output. The system can operate as normal under low BTU gas input to the secondary combustion chamber.

Refractory

If a refractory failure occurs to the dome or walls, the system will be put into a shutdown procedure. All external fuel is turned off and the offtake spill stack valve will open and the isolation valve will close to separate the secondary combustion chamber from the gasifier. The gasifier is placed in a normal burndown condition. The stove that was being heated when failure occured will be bottled, all valves closed to maintain present temperatures. The system must be completely shut down for repairs to the secondary combustion chamber.

Slag Tap Failures

The slag tap operation is the same as the gasifier slag tap. Damage to its refractory or blockage should rarely occur. If such a failure occurs, the system will be operated in the same manner as with gasifier slag tap failure; a scheduled shutdown can be planned if severe damage occurs.

Quench Tank Valve

The system will be put into the reduced operation mode until the valve is fixed or replaced. On any shutdown, the stoves are bottled for maintaining the heat capacity and will remain at operating conditions because very little heat is lost during shutdowns.

External Fuel System

Under normal operating conditions, external fuel is necessary only for the slag tap and pilot burner. If failure occurs to the fuel system, the normal mode of operation can be maintained for a small period until repairs are made. If repairs cannot be made, operation may need to be terminated.

Pilot Burner

The pilot burner will very rarely fail. Failure of this burner is a result of ultra-violet sensor burn-out, or an actual fuel stoppage. Repairs are to be made as quickly as possible.

Auxiliary System Failure

Failures of the auxiliary systems, such as boiler, gas cleaning equipment, water treatment, heat exchanger or feeding crane will cause complete shutdown of the total system. The shutdown must be started by the system operators and once started, it is completely automatic. All the external fuel will be terminated; the offtake spill stack valve will open and the isolation valve will close. The burden in the stack will slowly descend and the combustible gas generated can be burned with the spill stack's aspirating burner. A normal burndown will take place in the gasifier.

Once repairs have been completed, the system can be brought back to operating temperature. The hot blast will be started at a reduced flow and fuel added to the tuyere for heating the slag to a flowing condition. Once this has been completed, refuse feeding can be resumed.

Failures that may occur to items such as slag pit crane, thermocouples on pressure gauges will not cause shutdown of the system. These type of failures can be repaired while the system is operating in its normal mode.

Stove Failure

There are four basic areas where failures may occur; Refractory, water cooled-valves, flue blockage and steel shell. These failures will cause complete shutdown of the system. If they occur, the system will be put into shutdown procedure.

Water Cooled Valves

The water cooled valve failure will cause the shortest repair down time. It will take approximately eight hours to replace a valve. Any other type of failure will cause a longer down time. Historically, major stove failures do not occur until they reach many years of operating service.

Flue Blockage

Flue blockage is related to dust build-up on the surface of the flue. This build-up can be monitored by pressure drop valve and a scheduled downtime can be planned. These expected stove cleaning cycle is once a year for the Andco-Torrax System.

8.14.4 SYSTEM RATE VARIATION

Parameter Description

The Andco-Torrax System is designed to operate over a range of refuse rates. The terms that are used to describe the change is turn-up and turn-down from the point of operation.

The term turn-up means that the total system will process more refuse in a given time period. The means by which this is accomplished is to increase the oxygen content (wind rate) to the hearth of the gasifier. This increase is done over a finite period of time so as not to shock the hearth and cause temperature transients to occur. The time referred to above is approximately 30 minutes.

The term turn-down is just the opposite of turn-up; the refuse destruction rate is decreased, and the means in which it is accomplished is to decrease the wind rate to the hearth and the refuse consumed will reduce per unit time.

The two conditions described above will have transient periods before the required operation point is reached.

The transient time period for an increased refuse rate is the time that it takes the hearth to reach a new stable temperature profile. The hearth temperature will increase slightly because more carbon material is being consumed in a fixed volume therefore there will also be slightly more heat loss from this region.

The offgas temperature will remain about in the same range because the increased refuse rate will absorb the added heat load through the stack.

The transient time period for a turn-down condition is similar to the turn-up. With a decrease in wind to the hearth zone, less material is consumed, therefore lower heat release takes place. The heat losses are reduced because a slight change in temperature takes place. However, before the temperature decreases, slightly more inerts are removed from the hearth causing the refuse rate to drop off a little slower than expected.

There is one parameter that must be changed to make the Andco-Torrax System have a change in processing rate. The parameter is primary air; however there are other parameters that are affected by this independent variable. When the wind rate has been increased to cause an increase in processing rate, more combustion air is necessary at the secondary combustion chamber to completely consume the increase in offgas flow.

The secondary combustion chamber will have a temperature change if the processing rates are changed at the gasifier.

The remaining downstream equipment such as boiler, and gas cleaning equipment will be sized to handle changes to the processing rate at the gasifier.

8.15 COST ANALYSIS OF PRYOLYSIS AND BACK-UP FACILITY

OPERATING COST ANALYSIS FOR PYROLYSIS SYSTEM

Operating Costs:

The pyrolysis unit has been sized for a refuse feed rate of 132 tons per day plus or minus 15 percent. This refuse feed rate is based on the following percentage split:

57 TPD Hospital and Other Health Care Refuse (HHC)
23 TPD University of MInnesota General Refuse (U of M)
52 TPD Municipal Refuse
132 TPD Total System Input

Operating costs are based on the pyrolysis unit operating at a refuse feed rate of 132 tons per day for 350 days per year with 15 days per year being allocated for downtime and maintenance. The annual refuse handled by this system will be:

132 x 350 = 46,200 Tons

Operating costs include the following:

Labor
Fuel Oil
Natural Gas
Electric Power
City Water
Maintenance and Repair
Insurance and Miscellaneous Services
Slag Disposal

Labor Cost

The following personnel schedule assumes a three shift operation per day with a swing shift for vacations, holidays, 40 hour week, etc. Overall staffing of the Southeast Plant has been assessed to determine the personnel chargeable to the pyrolysis system. Proposed shift charges appear below:

	Shift			
	1	2	3	Swing
Principal Operator	1	1	1	1.3
Junior Operator	1.5	1.5	1.5	0.65
Crane Operator	1	1	1	1.3

Operating labor costs have been based on the following wage rate schedule, effective in 1978.

Designation	Type	Base Rate	Fringe Benefits	Vacation Sick Leave & Holiday	Total	Annual
Principal Operator	Civil Service	$8.16	$1.56	$1.16	$10.88	$22,630
Junior Operator	Civil Service	7.20	1.37	1.02	9.59	19,947
Crane Operator	Civil Service	7.62	1.51	1.12	10.25	21,320

The total labor will be:

22,630 x 4.3 + 19,947 x 5.15 + 21,320 x 4.3

97,309 + 102,727 + 91,676 = $291,712

The labor cost per ton will be:

$$\frac{291,712}{46,200} = \$6.31 \text{ per ton}$$

Fuel Oil

Fuel Oil (No. 2) and natural gas requirements have been estimated by Andco and appear below. Four cold start-ups per year and 350 days of normal operation has been budgeted.

Fuel Oil Requirements for Start-Up

Items	Start-Up Time Hours	Rate of Flow GPH	Total Flow Gallons
Cowper Burner	72	39.63	2,853.4
SCC Start-Up Burner	18	105.70	1,902.6
SCC Slag Burner	18	10.57	190.2
SCC Pilot Burner	96	2.906	279.0
Gasifier Slag Burner	18	6.605	118.9
Hot Blast Main Burner	96	7.926	760.9
Total			6,105.0

Fuel Oil Requirements Normal Operation

Item	Daily Requirement Gallons
Gasifier	190
SCC	253
Total	443

Fuel Gas Requirement for Start-Up

Item	Fuel	Rate of Flow SCFH	Total Flow SCF
Gasifier Tuyeres	Natural Gas	6,000	108,000

Annual fuel oil requirements will be:

6,105 x 4 + 443 x 350 = 179,470 gallons

At a price of $.365 per gallon, the annual cost of fuel oil will be $65,507 and the cost per ton of refuse will be:

$$\frac{65,507}{46,200} = \$1.42$$

Natural Gas

Annual natural gas requirements will be:

108 x 4 = 432 MCF

At a price of $2.60 per MCF, the annual cost of natural gas will be:

432 x 2.60 = $1,123

and the cost per ton of refuse will be:

$$\frac{1,123}{46,200} = \$.02$$

Electric Power

Electric power requirements have been estimated for a refuse rate of 132 tons per day. The induced draft fans include the induced draft fan for the waste heat boiler and the portion of the power of the baghouse induced draft fan which is allocated to the pyrolysis system.

Item	Motor Size HP	Power Demand KW	Power Required KWh/ton of refuse
Primary air fan	100	74.60	13.56
Secondary air fan	75	55.90	10.16
Induced draft fans	31	375.00	43.50
Vibrating Feeder	20	14.90	2.70
Slag Bucket elevator	7.5	5.60	1.02
Slag grapple - Bucket hoist	2	1.50	0.27
Open circuit cooling pump	30	23.37	4.25
Close circuit cooling pump	100	74.60	13.56
Slag quench reservoir pump	30	23.37	4.25
Instrument air compressor	15	11.20	1.02
Control panel (120 volt)	-	7.50	1.36
Burner fans (total)	15	11.20	2.03
Slag screen shaker	3	2.20	0.40
Chemical feed pump	1	0.745	0.13
Total			98.21

With an electric energy rate of $.0262 per KWh, the electric power cost per ton of refuse will be:

98.21 x .0262 = $2.57

City Water and Sewer

Water make-up requirements for normal operations have been estimated by Andco to be 25 gpm for the open water loop and 25 gpm for the closed loop or a total of 50 gpm for the system. Daily water make-up will be:

50 x 60 x 24 = 72,000 gallons

At a refuse rate of 132 tons per day and a water and sewer cost of $.535 per 1,000 gallons, the cost of make-up water will be:

$$\frac{72,000}{132} \times \frac{.535}{1,000} = \$0.29 \text{ per ton of refuse}$$

Maintenance and Repair

Andco has estimted the annual cost of maintenance and repair to be $106,000 for the frame size of 132 T/day. At a refuse rate of 46,200 tons per year, the cost of maintenance and repair will be:

$$\frac{106,000}{46,200} = \$2.30 \text{ per ton}$$

Insurance and Miscellaneous Services

The following annual charges have been prorated to the pyrolysis unit:

Insurance, boiler, fire, etc.	=	$10,000
Administration	=	5,000
Buildings and Grounds	=	4,000
Misc. Service Contracts	=	6,000
		$25,000

At a refuse rate of 46,200 tons per year, these charges will be:

$$\frac{25,000}{46,200} = \$0.54 \text{ per ton of refuse}$$

Slag Disposal

Slag will be collected at the bottom of the gasifier and the bottom of the secondary combustion chamber at the following rates:

Gasifier	=	1,938 pounds per hour
Secondary Combustion Chamber	=	216 pounds per hour
Total		2,154 pounds per hour

or

$$\frac{2,154 \times 24}{2,000} = 25.8 \text{ tons per day}$$

The hauling charge to landfill is estimated to be $1.43 per ton which results in a charge of:

$$\frac{25.8 \times 1.43}{132} = \$0.28 \text{ per ton of refuse.}$$

There may be a market for the slag, but neither the market nor the product value is available at this time. Further study has not been considered within the scope of this report.

Summary

Total operating costs for year 1978 are summarized below:

Item	Estimated Cost $/Ton Refuse (1978)
Labor	$ 6.31
Fuel Oil	1.42
Natural Gas	.02
Electric Power	2.57
City and Water Sewer	.29
Maintenance and Repair	2.30
Insurance and Miscellaneous Charges	.54
Slag Disposal	.28
Total	$13.73

Energy Recovery

A waste heat boiler has been included with the pyrolysis system to recover energy in the form of steam that will be supplied to the 450 psig header. Gas from the secondary combustion chamber at a temperature of 2300° F will be admitted to the waste heat boiler, superheater, and economizer where the temperature will be reduced to 460° F and feedwater at 250° F, steam will be produced at a rate of 38,770 pounds per hour at a refuse rate of 132 tons per day. The refuse is assumed to have a HHV of 5,925 BTU per pound. Daily steam production will be:

$$\frac{38,770 \times 24}{1,000} = 930.5 \text{ pounds per day}$$

of:

$$\frac{930.5}{132} = 7.05 \times 1,000 \text{ pounds of steam per ton of refuse}$$

The average cost of steam generated by Boiler No. 3 and Boiler No. 4 is estimated to be $1.66 per 1,000 pounds.

8.15.1 CAPITAL COST OF PYROLYSIS UNIT

The following budget estimate is based on the Andco unit rate 132 ± 15 percent tons of refuse per day. The unit will be located in the area of the Southeast Plant east of Boiler No. 4. A refuse pit has been sized to contain 264 tons. A bridge crane with grapple will handle normal waste from the pit and a separate conveying system will convey "red bag" hospital waste to the feeder over the gasifier. The gas clean-up will be done in the baghouse that will also clean the gas for Boiler No. 3 and Boiler No. 4. The proportionate cost burden has been allocated for the pyrolysis unit. Estimated costs are "order of magnitude" based on 1977 prices. The general arrangement of equipment has been shown on Helmick and Lutz Company drawings 625-PP.

PHASE II - STAGE 2 - CAPITAL COST BUDGET (1978 COSTS)
UNIVERSITY OF MINNESOTA - GRID ICES
OPTION II - PYROLYSIS

TABLE 4

	Equipment	General	Construction Mechanical	Construction Electrical	Total
1. Andco System Delivered & Erected (excluding Engineering)					
a. Gasifier	241,000	162,537	16,673	4,000	424,210
b. Secondary Combustion Chamber	234,000	179,400	6,170		419,570
c. Regenerative Towers	530,000	150,000	11,480		691,480
d. Duct Work	218,000	130,000	32,380	23,300	403,680
e. Slag Handling System	60,000	50,000	4,000	2,000	116,000
f. Electrical	215,400	75,000	2,000	76,770	369,170
g. Instrumentation	158,900	55,000	3,000	18,000	234,900
h. Air Moving Equipment	55,460	18,500	12,000	8,000	93,960
i. Piping & Cooling Water Systems	95,000	172,500	12,640		280,140
j. Refuse Feed System	24,000	19,200	2,270		45,470
k. Auxiliary Fuel Systems	54,120	30,000	8,000	3,000	95,120
l. Secondary Air Preheat	25,000	16,000	5,000	3,000	49,000
m. Slag Silo	20,000	10,000	6,000	800	36,800
n. Stairs & Platforms	85,000	57,500			142,500
o. Grout	1,800	4,500			6,300
p. Paint	12,000	26,450			38,450
q. Communication System	8,000	4,600			12,600
r. CO Monitor	12,150	4,000			16,150
Sub-Total	2,049,830	1,165,187	121,613	138,870	3,475,500
Field Management		171,100			171,100
Field Office	12,700		1,000	2,000	15,700
Storage Building	58,000	60,200	2,800	4,000	125,000
Construction Support		57,500			57,500
Spare Parts	140,000				140,000
Contingencies	175,000	175,000	10,000	15,000	375,000
Sub-Total	385,700	463,800	13,800	21,000	884,300
ANDCO TOTAL	2,435,530	1,628,987	135,413	159,875	4,359,800

TABLE 4 Cont.

	Equipment	Construction			Total
		General	Mechanical	Electrical	
2. Auxiliary Equipment & Andco Connections					
a. Waste Heat Boiler	351,000	9,000	90,000	20,000	470,000
b. I.D. Fan and V.S. Drive	67,000	4,000	8,500	12,500	92,000
c. Instruments & Controls	30,000		25,000		55,000
d. Pollution Control Addition	561,000	90,000	20,000	32,500	703,500
e. Refuse Crane	120,000	13,000		1,500	134,500
f. Contaminated Material Conveyor	50,000			1,500	51,500
g. Ash System Addition	15,000	8,000	3,500		26,500
h. Equipment Erection	233,000				233,000
i. Andco Connections			45,000	57,000	102,000
3. Related Construction					
a. General Construction					
(1) Stack Removal		47,000			47,000
(2) Building Construction		820,000			820,000
b. Mechanical Construction			40,000		40,000
c. Electrical Construction				45,000	45,000
4. Up-Grade Incinerators	88,000	35,000	35,000	5,000	163,000
Sub-Total	1,515,000	1,026,000	267,000	175.000	2,983,000
Engineering & Contingencies (12%)					358,000
Total, Option II (1978 Costs)					7,700,800

8.15.2 COST ANALYSIS OF BACK-UP FACILITY

General

The existing incinerator plant is located west of the Minneapolis heating plant and is shown in location on Helmick and Lutz Company Drawing No. 625-Task 13A and in detail on University of Minnesota Drawing No. 11960. Each of the two incinerators is rated 50 tons per day and consists of a reciprocating grate for burning normal refuse and a separate hearth for burning animals. Forced draft air is admitted under the grate and over fire air is admitted above the grate. Exit gas is transported via breeching to a concrete-masonry stack. Refuse is moved on the tipping floor to the area of the incinerator inlets with a 4 wheel vehicle fitted with a front end blade. Refuse is transferred manually to the incinerator inlets. Ashes from under the grates are pulled manually and transported to a truck. Ashes from the discharge of the grates drop into a container outside the building and are transported via truck to landfill.

A series of tests were conducted on September 19, 1977 and September 22, 1977 burning general campus waste and hospital waste. Results of the tests include the following:

Test No.	Burning Rate Tons/Hour	Heat Content of Refuse BTU/lb HHV
1	2.78	5,594
2	2.60	5,427
3	2.66	5,176
4	2.66	4,970
5	2.92	5,526
6	2.80	5,271
7	3.14	4,586
8	2.81	5,691
Average		5,280

A review of the test results lead to the following conclusions:

1. Excess air is abnormally high

2. Exit gas temperature is abnormally low

3. Ash collected appears high

It appears that immediate consideration should be given to improve the combustion process within the incinerator by reducing air infiltration and raising the temperature of combustion, which will improve the destruction of the refuse. Visual observation of the stack discharge on an intermittent basis indicates that under some conditions the incinerators are operated poorly.

As a back-up facility for the pyrolysis unit, the existing incinerator plant would operate only during a scheduled outage of 15 days per year for maintenance and repair or for relatively short periods during an unscheduled outage. During these periods the incinerator would burn the waste collected by the hospitals and health care centers and general waste from the University of Minnesota. This waste load is estimated to be 80 tons per day which is within the capabilities of the existing plant.

Since the existing plant will be required to operate on a standby basis, a minimum investment should be made to bring the operation of the incinerator to meet code compliance. The following recommendations are made:

1. Inspect the complete system and repair as necessary to reduce air infiltration and increase the combustion temperature which will result in improved combustion efficiency and lower particulate emission from the stack.

2. Replace the gas burners rated 1,800 C.F.H. at the animal hearths with larger burners fired with No. 2 oil. Install additional burners fired with No. 2 oil located downstream of the vertical baffle in the furnace. These burners would operate only as required to improve the combustion process and lower the particulate emission to the stack.

3. Install smoke density recorders to monitor the exit gas streams and assist the operators to maintain a "clean stack".

4. Improve the method of handling ashes.

The estimated cost for these improvements follows:

Item	Estimated Cost
Inspection and repair of existing incinerators	Under Contract
Oil Burners, flame safeguards, burner control, installed	$ 83,000
Instrumentation and smoke density recorders	13,000
Oil piping from heating plant	10,000
Improved ash handling	35,000
Electrical	5,000
Contingencies (20 percent)	27,000
Total Estimated Project Cost	$173,000

Operating Costs

The following study has been made to extrapolate the operating costs of the existing incinerator plant as presently operated to an operation that will handle 100 tons per day for 350 days per year.

Records for 1977 indicate that the present incinerator plant operated at an average rate of 120 tons per week for 52 weeks or at an annual rate of:

$$120 \times 52 = 6,240 \text{ tons}$$

The comparison will be made with an operating rate of 100 tons per day for 350 days per year or an annual rate of 35,000 tons.

Labor Costs

The present incinerator plant operates one 8 hour shift per day with an annual labor cost of $88,258 or:

$$\frac{88,258}{6,240} = \$14.14 \text{ per ton of refuse}$$

If the operating rate is increased to 100 tons per day, the plant will operate 3 shifts per day. If the labor per shift is assumed to remain the same, the annual labor cost will be:

$$\$88,258 \times 3 = \$264,774$$

and the cost per ton of refuse will be:

$$\frac{264,774}{35,000} = \$7.56$$

Fuel Cost

The fuel cost for present operation is $9,963 per year or:

$$\frac{9,963}{6,240} = \$1.60 \text{ per ton of refuse}$$

This fuel is used predominantly for start-up and when the incinerator is up to operating temperature, the burning process is self-sustaining. At a refuse rate of 120 tons per week, one incinerator is normally used. At a refuse rate of 100 tons per day two incinerators will be required and it has been assumed that the total fuel will be:

$$2 \times 9,963 = \$19,926 \text{ per year}$$

The cost per ton of refuse will be:

$$\frac{19,926}{35,000} = \$.57$$

Electric Power

Each incinerator is equipped with a forced draft fan, over fire air fan and grate drive which requires electric power. Furnace draft is maintained with a 200 foot high concrete stack. Total power for incinerator is approximately 12.5 horsepower or 9.325 KW. Miscellaneous plant power is assumed to 2.5 KW. Power rate for 1978 is $.0262 per KW hour.

Power consumption for a refuse rate of 120 tons per week will be:

$$(9.325 + 2.5) \times 8 \times 7 = 662.2 \text{ KWh per week}$$

Power cost per ton of refuse will be:

$$\frac{662.2 \times .0262}{120} = \$.14$$

Power consumption for a refuse rate of 100 tons per day will be:

$$(2 \times 9.325 + 2.5) \times 24 = 507.6 \text{ KWh per day}$$

Power cost per ton of refuse will be:

$$\frac{507.6 \times .0262}{100} = \$.13$$

City Water and Sewer

The use of city water in the plant is considered negligible.

Maintenance and Repair

The annual cost of maintenance and repair has been estimated to be $28,000 per year for one incinerator with a refuse rate of 6,240 tons per year or:

$$\frac{28,000}{6,240} = \$4.49 \text{ per ton of refuse}$$

The annual cost of maintenance and repair has been estimated to be:

$$\$28,000 \times 1.5 \times 2$$

or $84,000 with a refuse rate of 35,000 tons per year or:

$$\frac{84,000}{35,000} = \$2.40 \text{ per ton of refuse}$$

Insurance and Miscellaenous Services

An annual charge for this item has been assumed at $6,000 per year. At a refuse rate of 6,240 tons per year, the cost will be:

$$\frac{6,000}{6,240} = \$.96 \text{ per ton of refuse.}$$

At a refuse rate of 35,000 tons per year, the cost will be:

$$\frac{6,000}{35,000} = \$.17 \text{ per ton of refuse}$$

Ash Disposal

The ash produced when operating at a refuse rate of 120 tons per week was 54 cubic yards per week. At an assumed ash density of 25 pounds per cubic foot, the weight was:

$$\frac{54 \times 27 \times 25}{2,000} = 18.2 \text{ tons per week.}$$

The hauling cost to landfill is $5.72 per ton which results in an ash disposal cost of:

$$\frac{18.2 \times 5.72}{120} = \$.87 \text{ per ton of refuse}$$

Energy Recovery

The existing incinerator plant is not fitted with heat recovery equipment. It is not considered economic to install such equipment when the plant is being considered as a stand-by facility.

Comparative Costs

A cost comparison has been for refuse rates of 6,240 tons per year and 35,000 tons per year.

TABLE 30

Back-Up Facility
Operating Cost Summary

Item	6,240 Tons/Year	35,000 Tons/Year
Labor, $/Ton	14.14	7.56
Fuel	1.60	.57
Electric Power	.14	.13
City Water and Sewer	Negligible	Negligible
Maintenance and Repair	4.49	2.40
Insurance and Miscellaneous Services	.96	.17
Ash Disposal	.87	.87
Total, $/Ton	22.20	11.70
Credit for Steam Generation, $/Ton	0	0

8.15.3 COMPARATIVE OPERATING COST SUMMARY

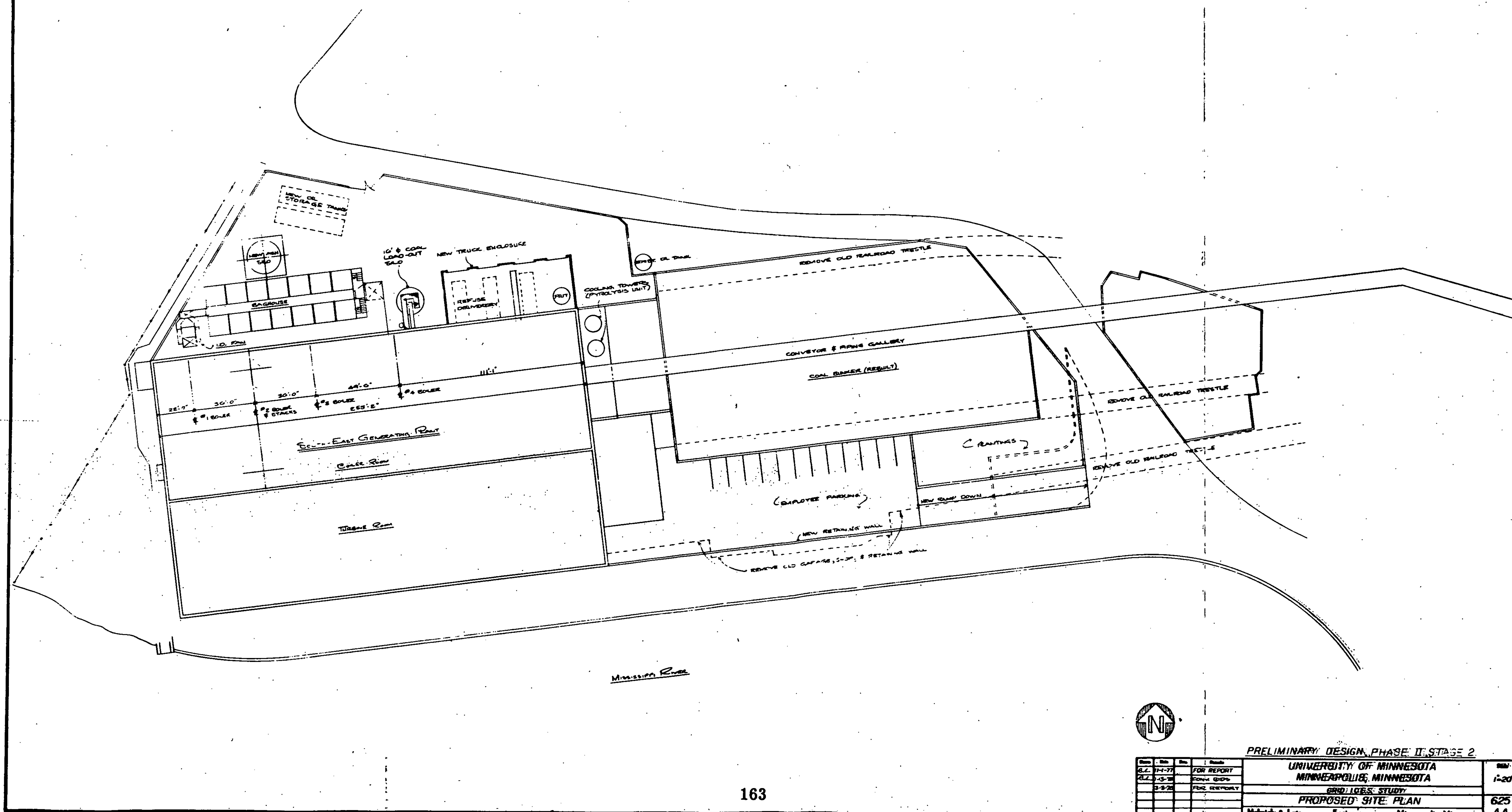
The following summary compares the operating costs of the pyrolysis system operating at 100 tons per day and the existing incinerator plant operating at a refuse rate of 100 tons per day.

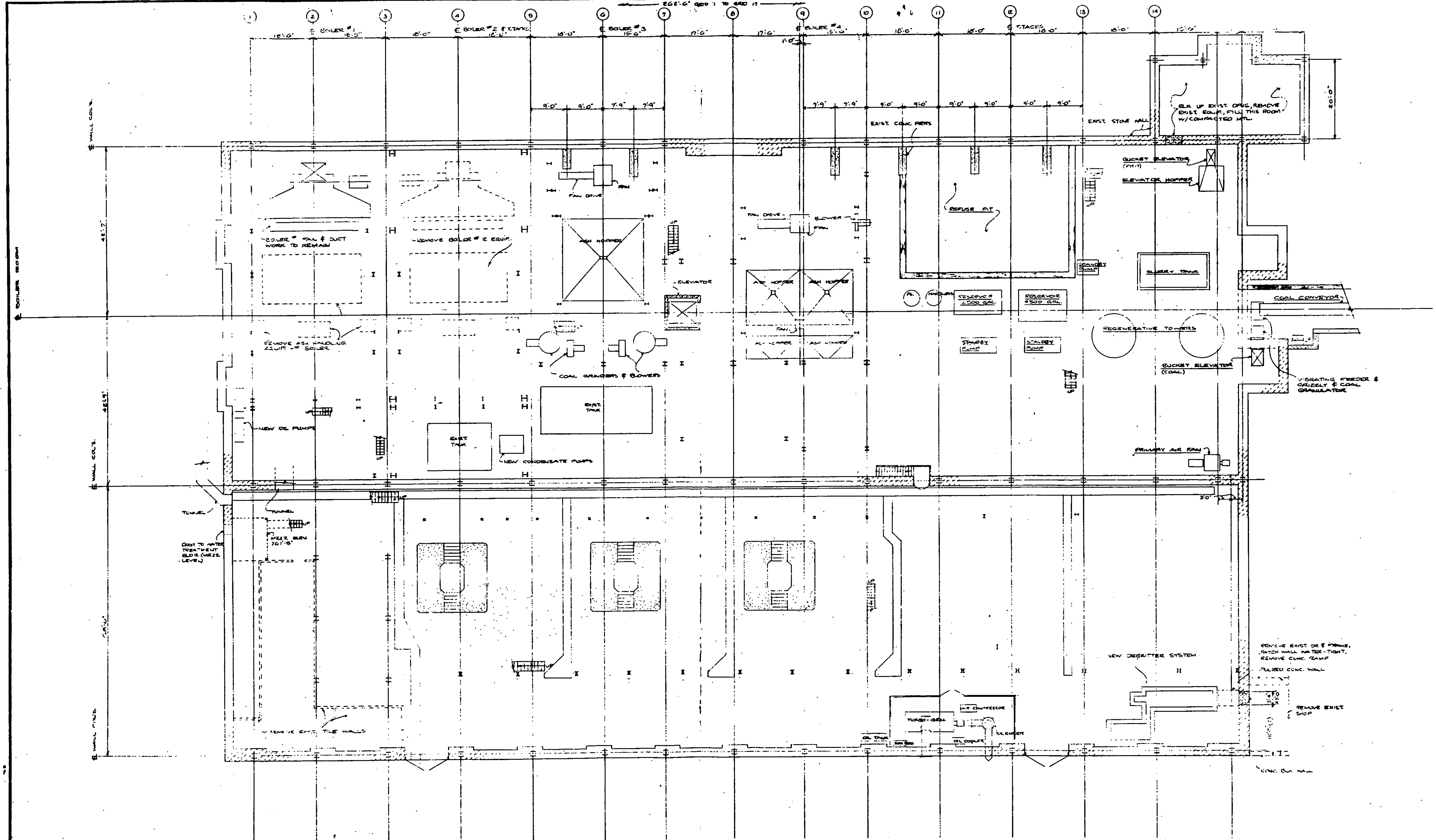
TABLE 31

Operating Cost Summary

Type of System	Existing Incinerators	Pyrolysis
Refuse Rate, Tons per day	100	100
Operating Days per Year	350	350
Labor, $/Ton	7.56	8.33
Auxiliary Fuel	.57	1.90
Electric Power	.13	2.57
City Water and Sewer	Negligible	.38
Maintenance and Repair	2.40	3.04
Insurance and Miscellaneous Services	.17	.71
Ash or Slag Disposal	.87	.28
Total, $/Ton	11.70	17.21
Credit for Steam Generation, $/Ton	0	11.70

INDEX


NEW OIL STORAGE TANKS
NEW TRUCK ENCLOSURE
REFUSE DELIVERY
BAGHOUSE
I.D. FAN
COOLING TOWERS (PYROLYSIS UNIT)
REMOVE OLD RAILROAD TRESTLE
CONVEYOR & PIPING GALLERY
COAL BUNKER (REBUILT)
BOILER ROOM
TURBINE ROOM
EMPLOYEE PARKING
NEW RETAINING WALL
NEW RAMP DOWN
MISSISSIPPI RIVER
N
PRELIMINARY DESIGN, PHASE II, STAGE 2
FOR REPORT
FOR REPORT
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA
PROPOSED SITE PLAN
625
AA

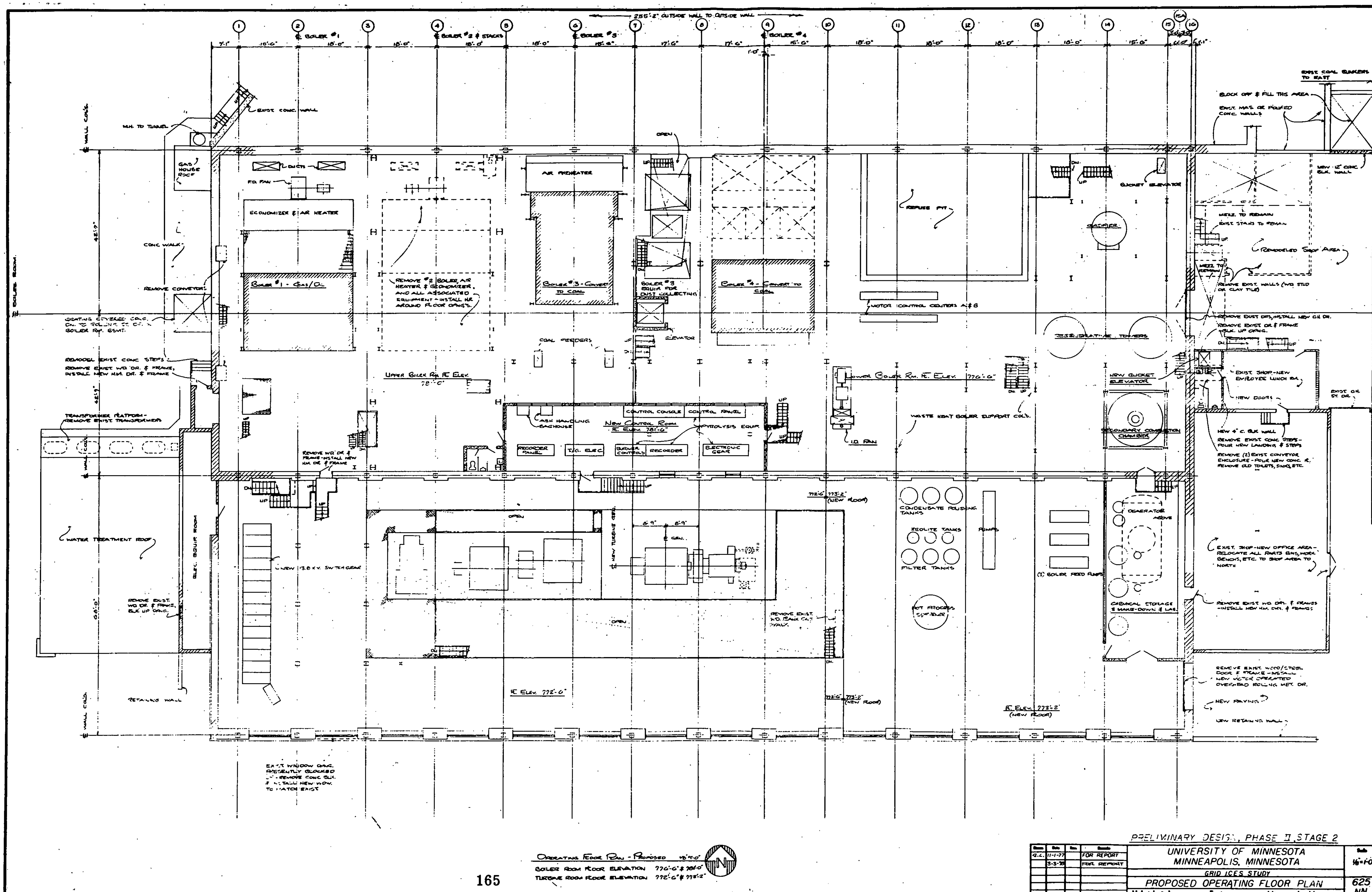


Basement Plan - Proposed 1/8"=1'-0"
Boiler Room Floor Elevation 762'-6"
Turbine Room Floor Elevation 752'-6"

PRELIMINARY DESIGN, PHASE II, STAGE 2

S.L.	11-1-77		FOR REPORT
	5-3-78		FOR REPORT

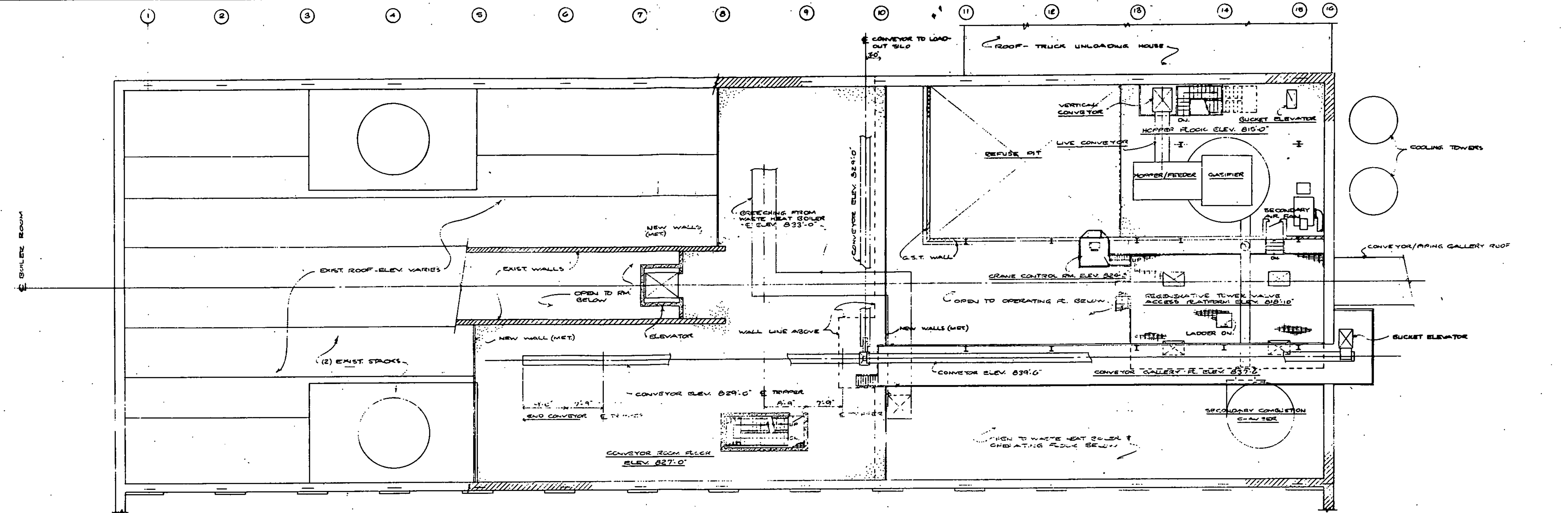
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA
GRID ICES STUDY
PROPOSED BASEMENT FLOOR PLAN
Helmick & Lutz Engineers Minneapolis, Minnesota
1/8"=1'-0"
625



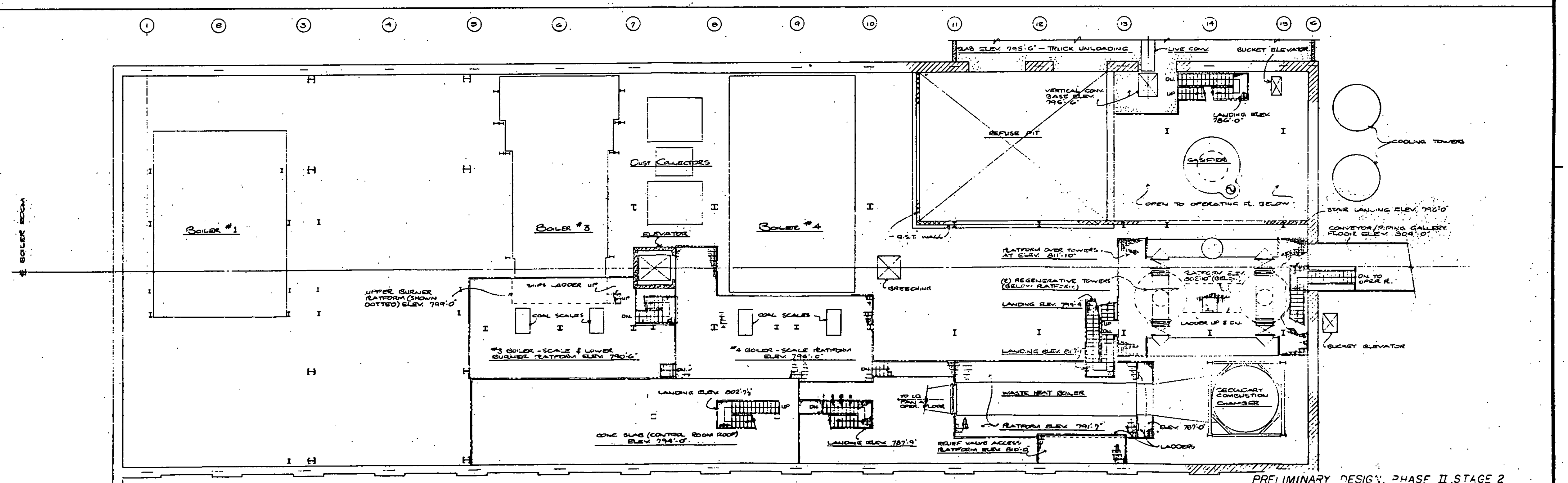
PRELIMINARY DESIGN, PHASE II, STAGE 2

Date	Remarks
11-1-77	FOR REPORT
3-3-78	FOR REPORT

UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA
GRID ICES STUDY
PROPOSED OPERATING FLOOR PLAN
Scale 1/16"=1'-0"
625 NN
Helmick & Lutz Engineers Minneapolis, Minnesota



PLAN - CONVEYOR FLOOR, GASIFIER HOPPER FLOOR, ACCESS PLATFORM - ELEVATIONS VARY



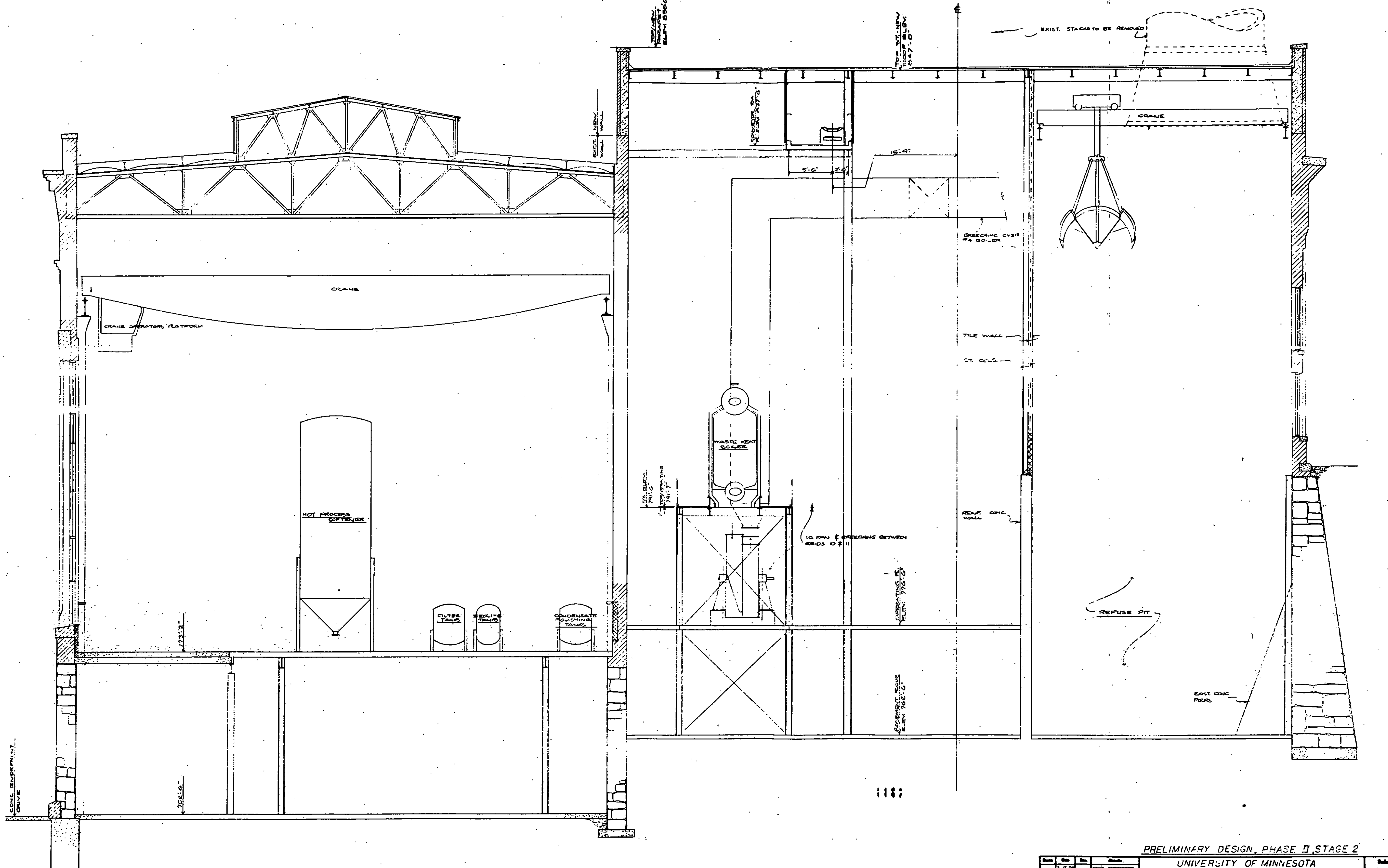
PLAN - ACCESS PLATFORMS - ELEVATIONS VARY

NOTE: NEW PLATFORMS ONLY - NO EXIST. PLATFORMS SHOWN

PRELIMINARY DESIGN, PHASE II, STAGE 2

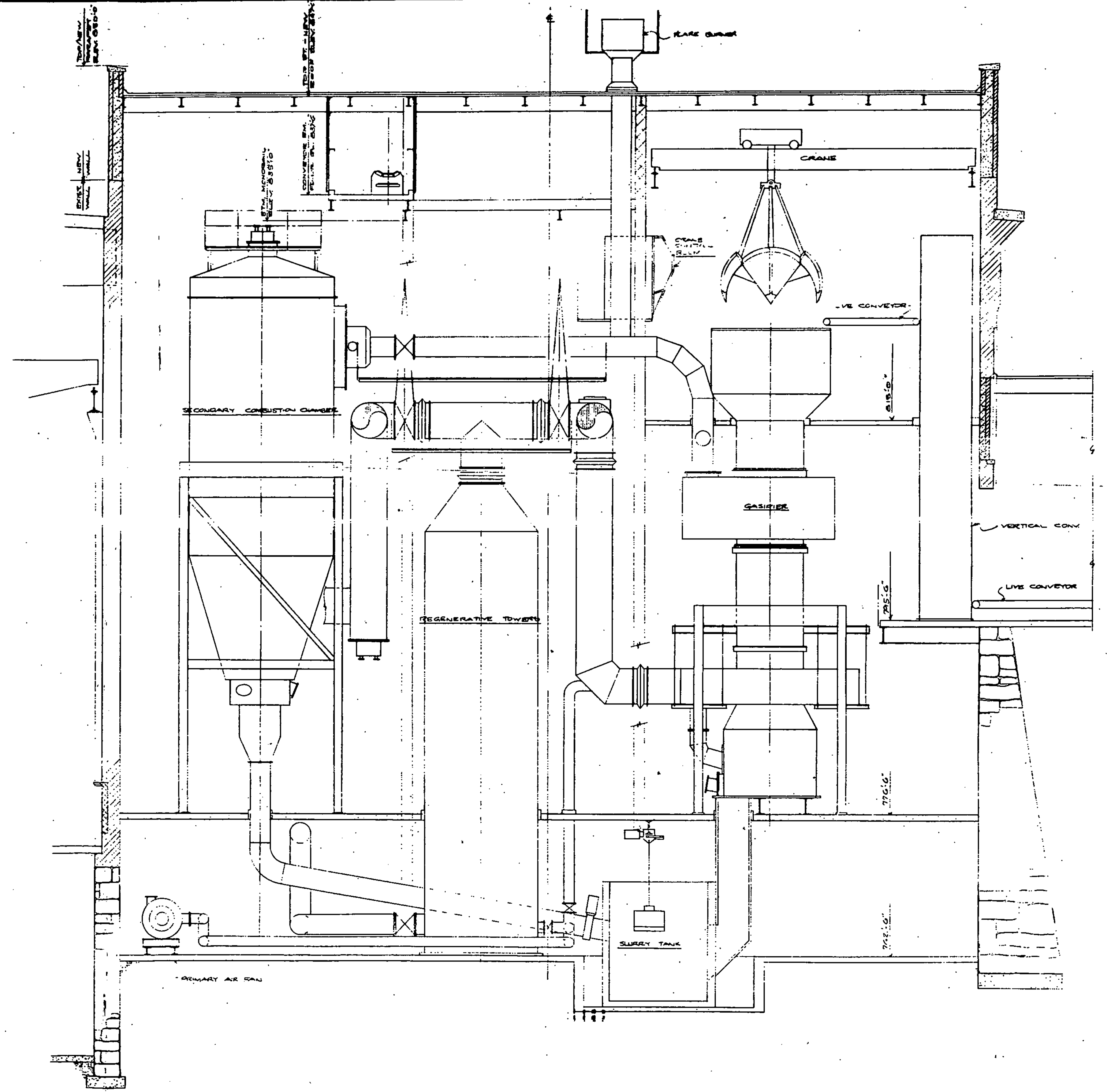
Drawn	Date	Rev.	Remarks
G.L.	3-3-78		FOR REPORT

UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA
GRID LOES. STUDY
PROPOSED UPPER LEVELS FLOOR PLAN
Helmick & Lutz Engineers Minneapolis, Minnesota
Scale 1/8" = 1'-0"
625 PP



PRELIMINARY DESIGN, PHASE II, STAGE 2

	3-3-?		FOR REPORT	UNIVERSITY OF MINNESOTA MINNEAPOLIS, MINNESOTA	1/4" = 1'-0"
				GRID ICES STUDY	
				PROPOSED BLDG. SECT. - WASTE HEAT BOILER	625 TT
				Helmick & Lutz Engineers Minneapolis, Minnesota	



PRELIMINARY DESIGN, PHASE II, STAGE 2

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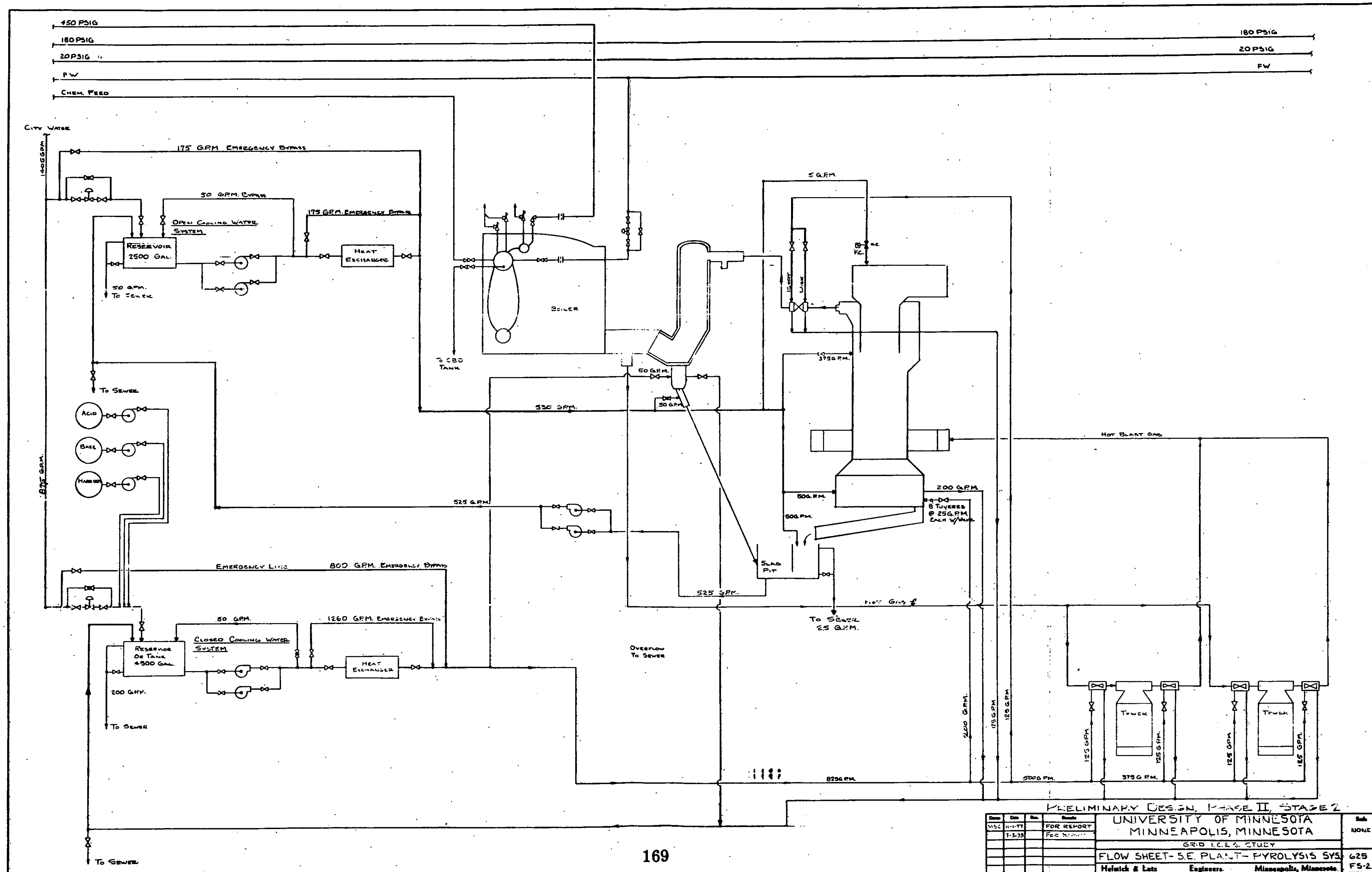
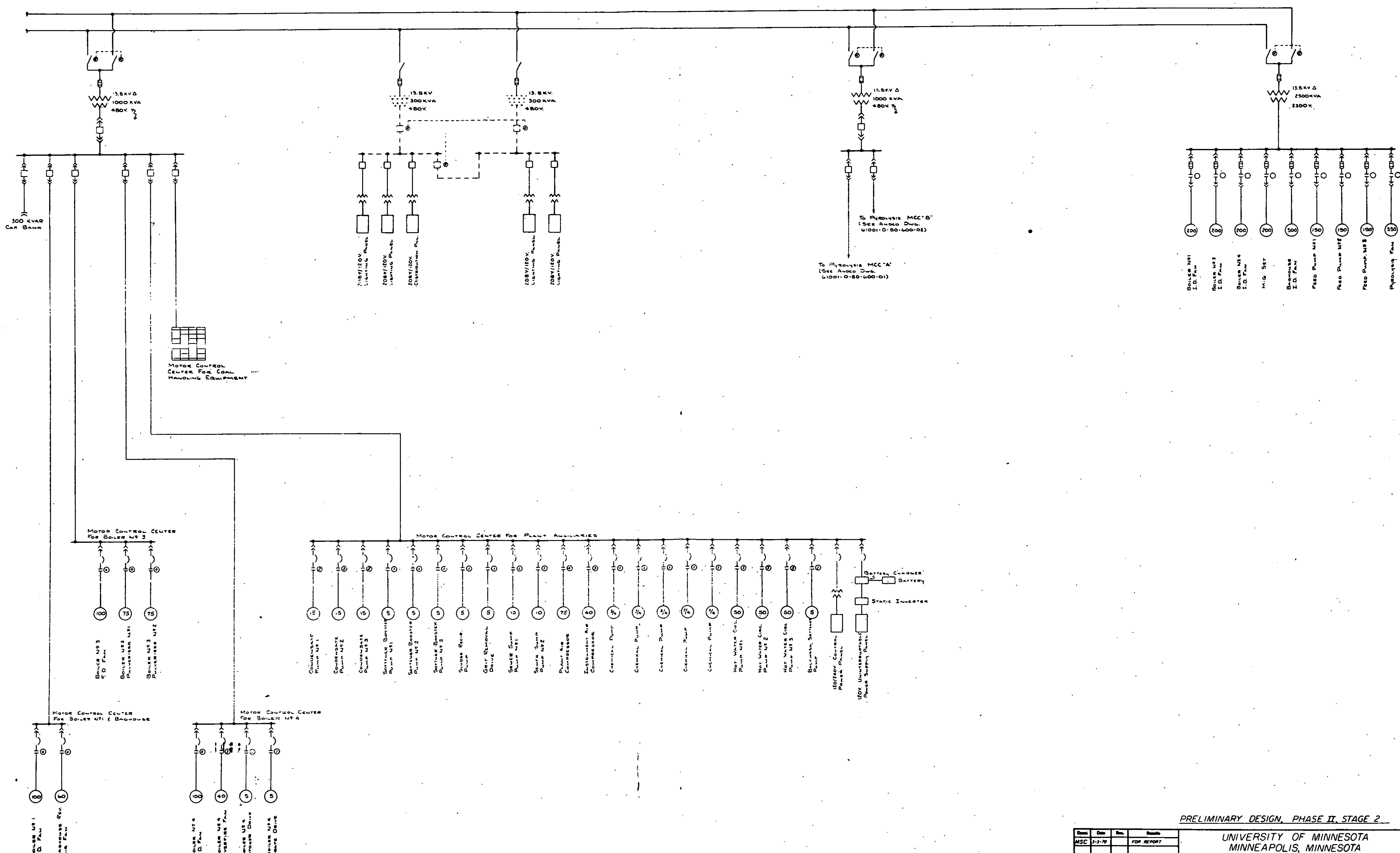
				GRIC I.C.E.S. STUDY	
				PROPOSED BLDG. SECT.-PYROLSIS EQUIP.	625 UU
				Helmick & Lutz Engineers Minneapolis, Minnesota	



450 PSIG
180 PSIG
20 PSIG
FW
CHEM. FEED
CITY WATER
175 GPM EMERGENCY BYPASS
50 GPM BYPASS
OPEN COOLING WATER SYSTEM
175 GPM EMERGENCY BYPASS
RESERVOIR 2500 GAL.
HEAT EXCHANGER
50 GPM. TO SEWER
BOILER
TO CBD TANK
TO SEWER
ACID
BASE
530 GPM.
525 GPM.
5 GPM.
375 GPM.
50 GPM.
500 GPM.
200 GPM.
8 TUYERES @ 25 GPM EACH W/VALVE
HOT BLAST GAS
SLAG PIT
525 GPM.
HOT GAS
TO SEWER 25 GPM.
EMERGENCY LINE
800 GPM. EMERGENCY BYPASS
50 GPM.
1260 GPM. EMERGENCY BYPASS
RESERVIOR OR TANK 4500 GAL.
CLOSED COOLING WATER SYSTEM
HEAT EXCHANGER
200 GPM.
TO SEWER
OVERFLOW TO SEWER
825 GPM.
500 GPM.
375 GPM.
125 GPM
TOWER
TOWER
TO SEWER
PRELIMINARY DESIGN, PHASE II, STAGE 2
11-1-77 FOR REPORT
3-3-78
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA
NONE
GRID I.C.E.S. STUDY
FLOW SHEET - S.E. PLANT - PYROLYSIS SYS.
625 FS-2
Helmick & Lutz Engineers Minneapolis, Minnesota



170

PRELIMINARY DESIGN, PHASE II, STAGE 2

Drawn	Date	Rev.	Remarks
MSC	3-3-70		FOR REPORT

UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA

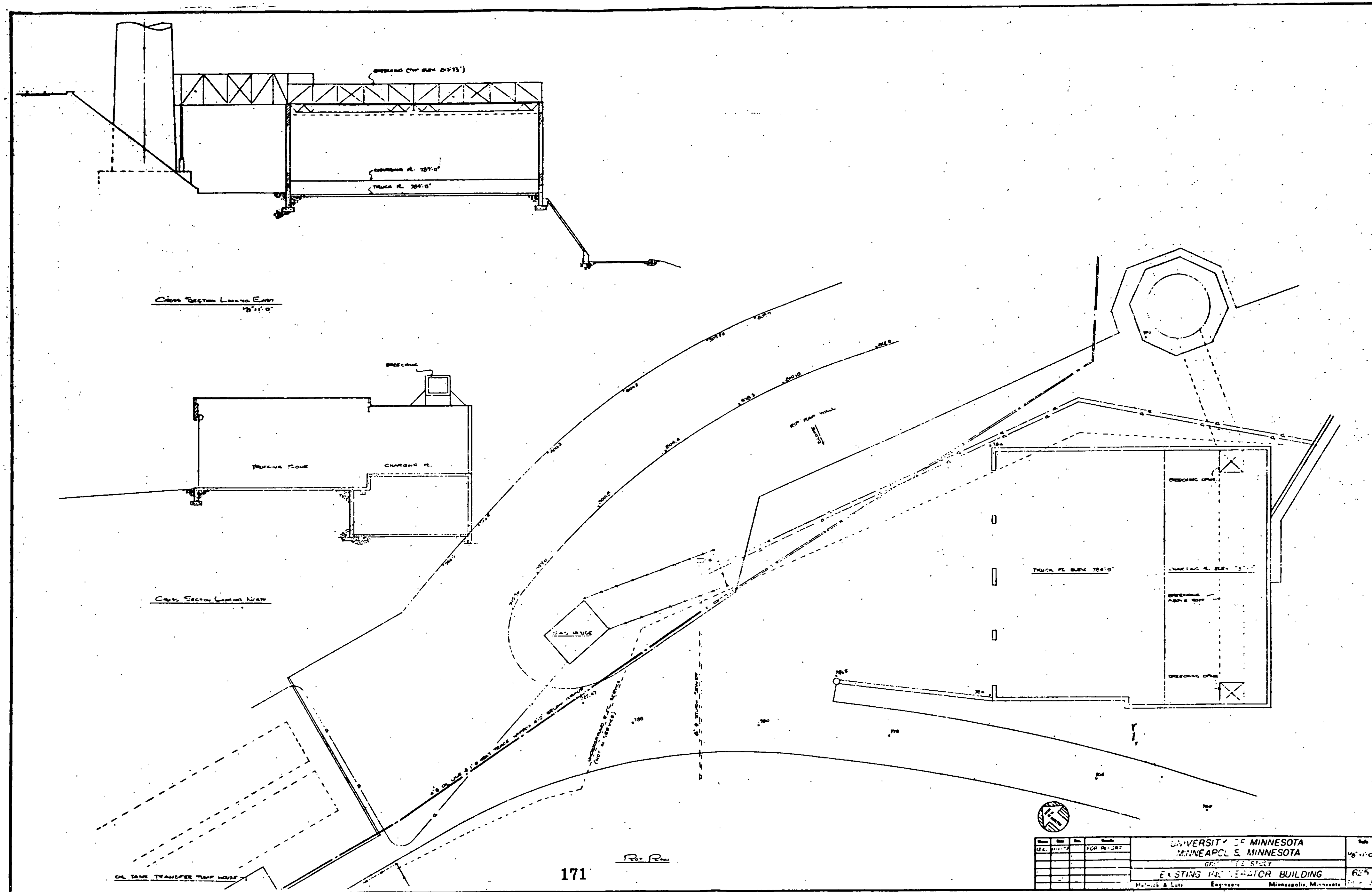
GRID ICES STUDY

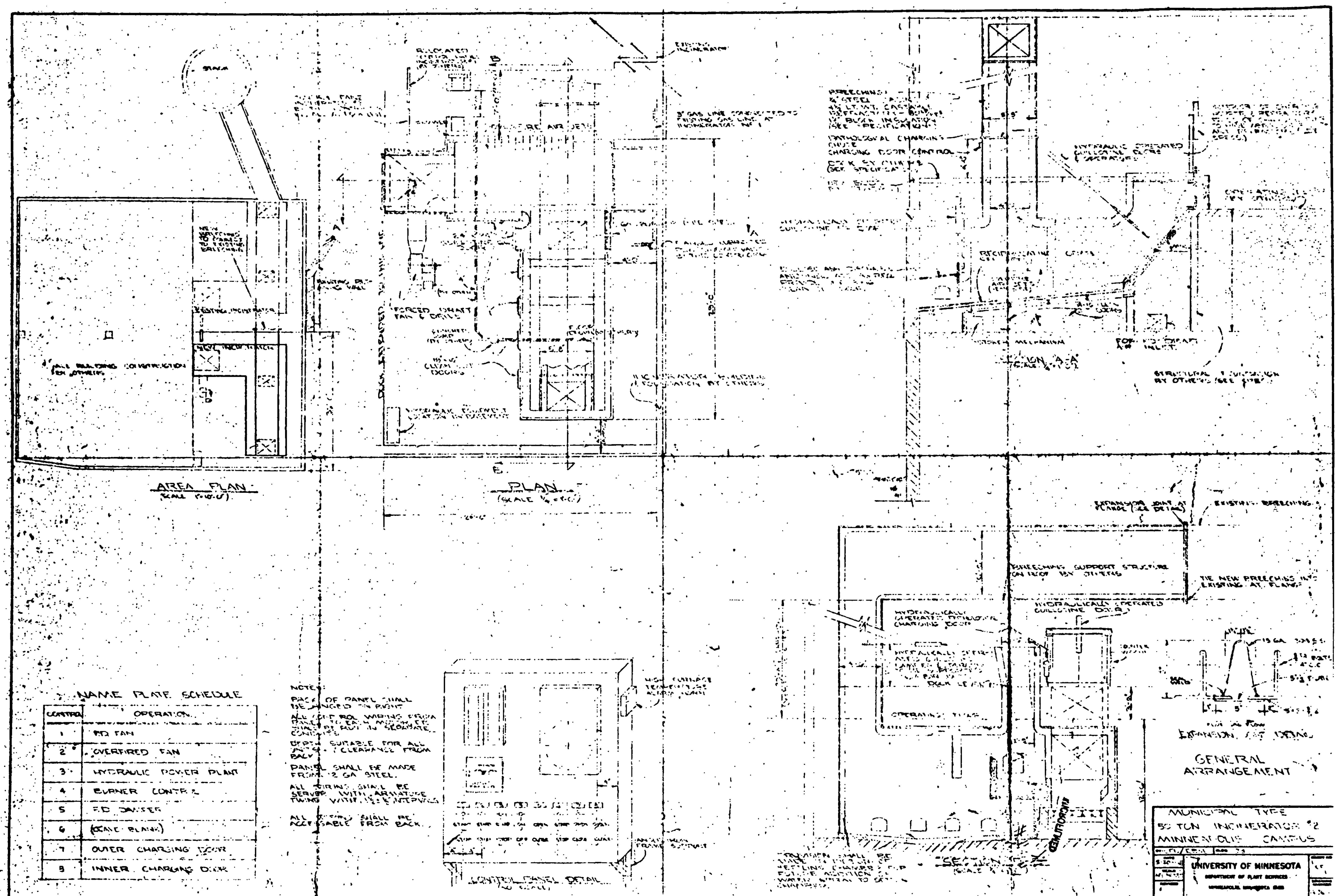
SECONDARY DISTRIBUTION LINE DIAGRAM — OPTION II

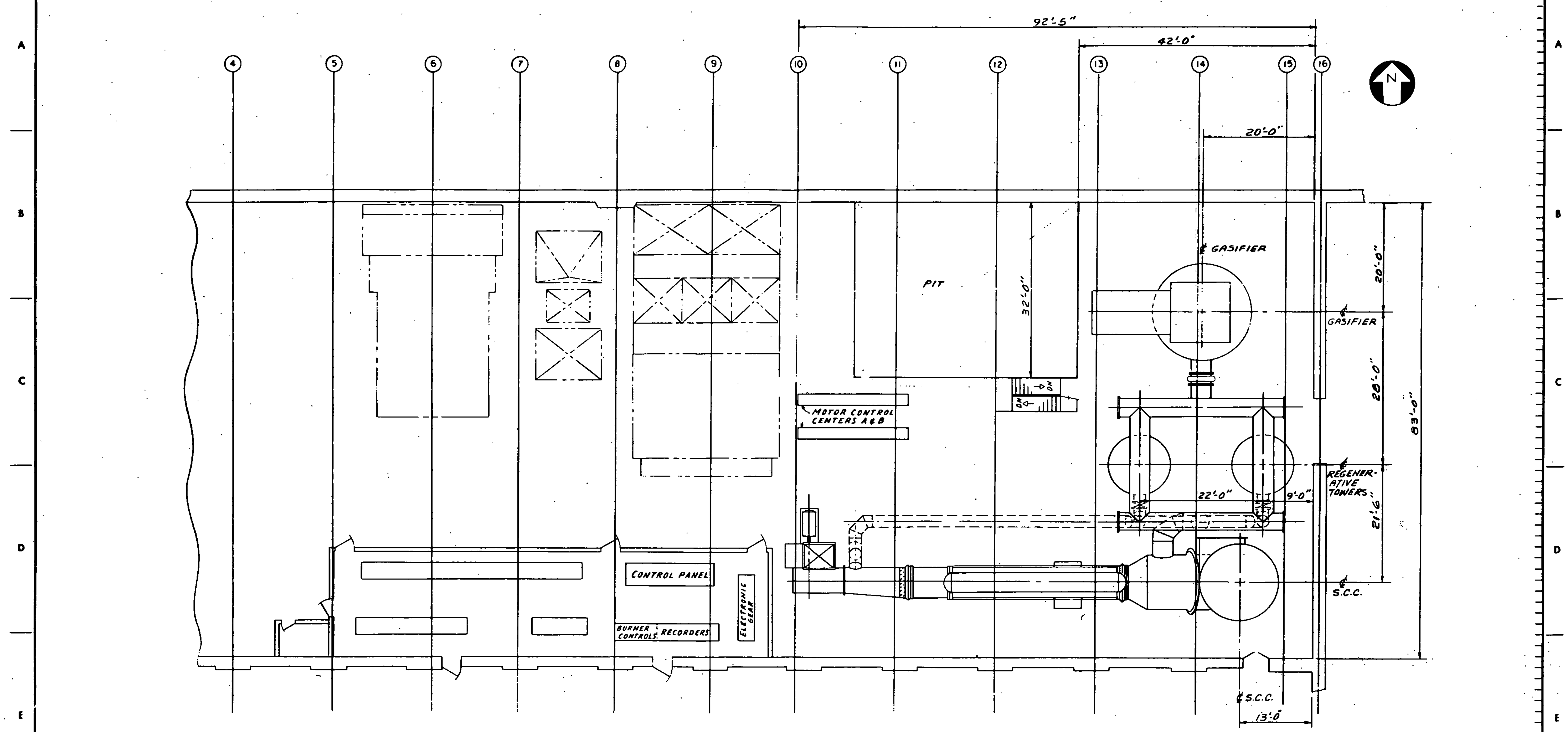
Helmick & Lutz Engineers Minneapolis, Minnesota

Scale: NONE

625
E4


MINNESOTA
MINNESOTA
BUILDING
Minneapolis, Minnesota
625


AREA PLAN
PLAN
SECTION "A-A"
NAME PLATE SCHEDULE
CONTROL
OPERATION
1 FD FAN
2 OVERFIRED FAN
3 HYDRAULIC POWER PLANT
4 BURNER CONTROL
5 FD DAMPER
6 (LEAVE BLANK)
7 OUTER CHARGING DOOR
8 INNER CHARGING DOOR
CONTROL PANEL DETAIL
GENERAL ARRANGEMENT
MUNICIPAL TYPE
50 TON INCINERATOR #2
MINNEAPOLIS CAMPUS
UNIVERSITY OF MINNESOTA



rev.	date	by	description

revisions

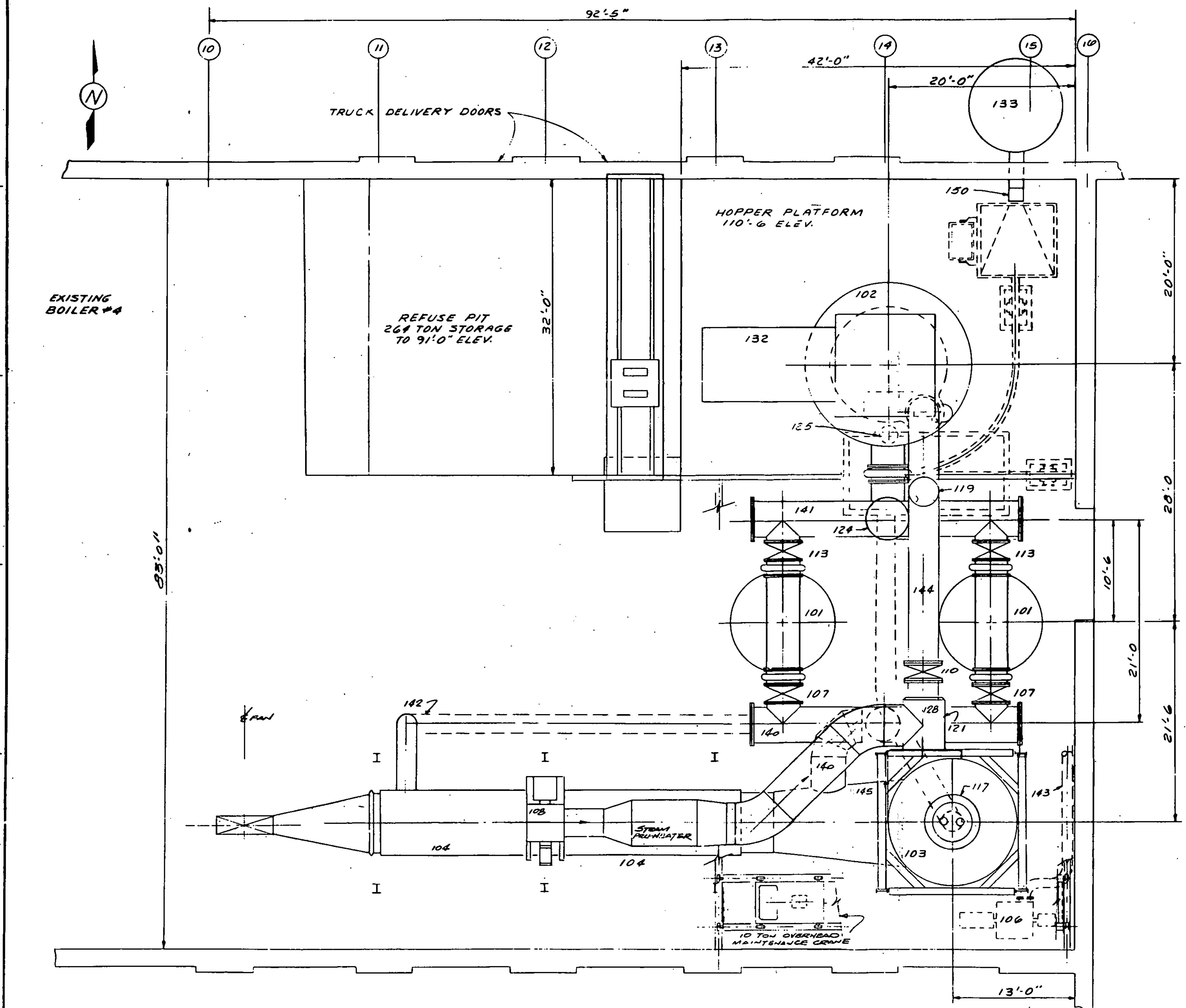
Dimensional tolerances unless otherwise noted are to be machining ± 0.010" — fractional dimensions over lengths ± 1/16 on others ± 1/32 non-accumulative
Machined surface finish unless otherwise noted 125√

andco incorporated

PRELIMINARY DESIGN
PHASE II STAGE 2

UNIVERSITY OF MINNESOTA
ANDCO/TORRAX 132 TON UNIT
PROPOSED OPERATING FLOOR PLAN

drawn J.L.V.	date 1-19-78	scale 1/8" = 1'-0"	proj. 961-001-00
checked	date	drawing number	6100/-0-00-600-01
approved	date		



PLAN VIEW

bill of material						
item	mark	quan.	description	mat'l.	wgt.	remarks

EQUIPMENT LEGEND

- 101 REGENERATIVE TOWER
- 102 GASIFIER
- 103 SECONDARY COMBUSTION CHAMBER
- 104 WASTE HEAT BOILER AND FLOW CONTROL VALVE
- 106 PRIMARY AIR FAN
- 107 TOWER WASTE GAS INLET ISOLATION VALVE
- 108 SECONDARY AIR FAN
- 110 ISOLATION VALVE (GASIFIER/SCC)
- 113 TOWER HOT BLAST ISOLATION VALVE
- 119 SPILL STACK WITH BURNER
- 120 SPILL VALVE (GASIFIER OFFTAKE)
- 132 REFUSE HOPPER/VIBRATION FEEDER
- 133 SLAG SILO
- 136 SLAG HANDLING BUCKET
- 140 GAS LINE-SCC OUTLET TO REGENERATIVE TOWER
- 141 HOT BLAST LINE-REGENERATIVE TOWER TO BUSTLEPIPE
- 142 WASTE GAS LINE-REGENERATIVE TOWER TO BOILER OUTLET
- 143 PRIMARY AIR LINE-BLOWER TO TOWERS
- 144 GAS LINE-GASIFIER TO SCC
- 145 GAS LINE-SCC TO BOILER
- 150 BUCKET ELEVATOR
- 151 COLD BLEND LINE

BURNER LEGEND

- 117 START-UP BURNER, SCC
- 121 OFF GAS BURNER
- 122 REGENERATIVE TOWER BURNER
- 124 HOT BLAST MAIN BURNER
- 125 GASIFIER SLAG TAP BURNER
- 126 SCC SLAG TAP BURNERS (3)
- 128 PILOT BURNER

WORK WITH DWGS:

G1001-D-00-000-02A GENERAL ARRANGEMENT ELEV.
D-67-530-01 AUXILIARY FUEL DIAGRAM
D-90-510-03 FUEL GAS ROUTING
D-90-530-01 FUEL OIL ROUTING

rev.	date	by	description
A	1-13-78		WAS G1001-D-00-900-15

revisions

Dimensional tolerances unless otherwise noted are to be machining ± 0.010" — fractional dimensions overall lengths ± 1/16, all others ± 1/32 non-accumulative.
Machined surface finish unless otherwise noted 125

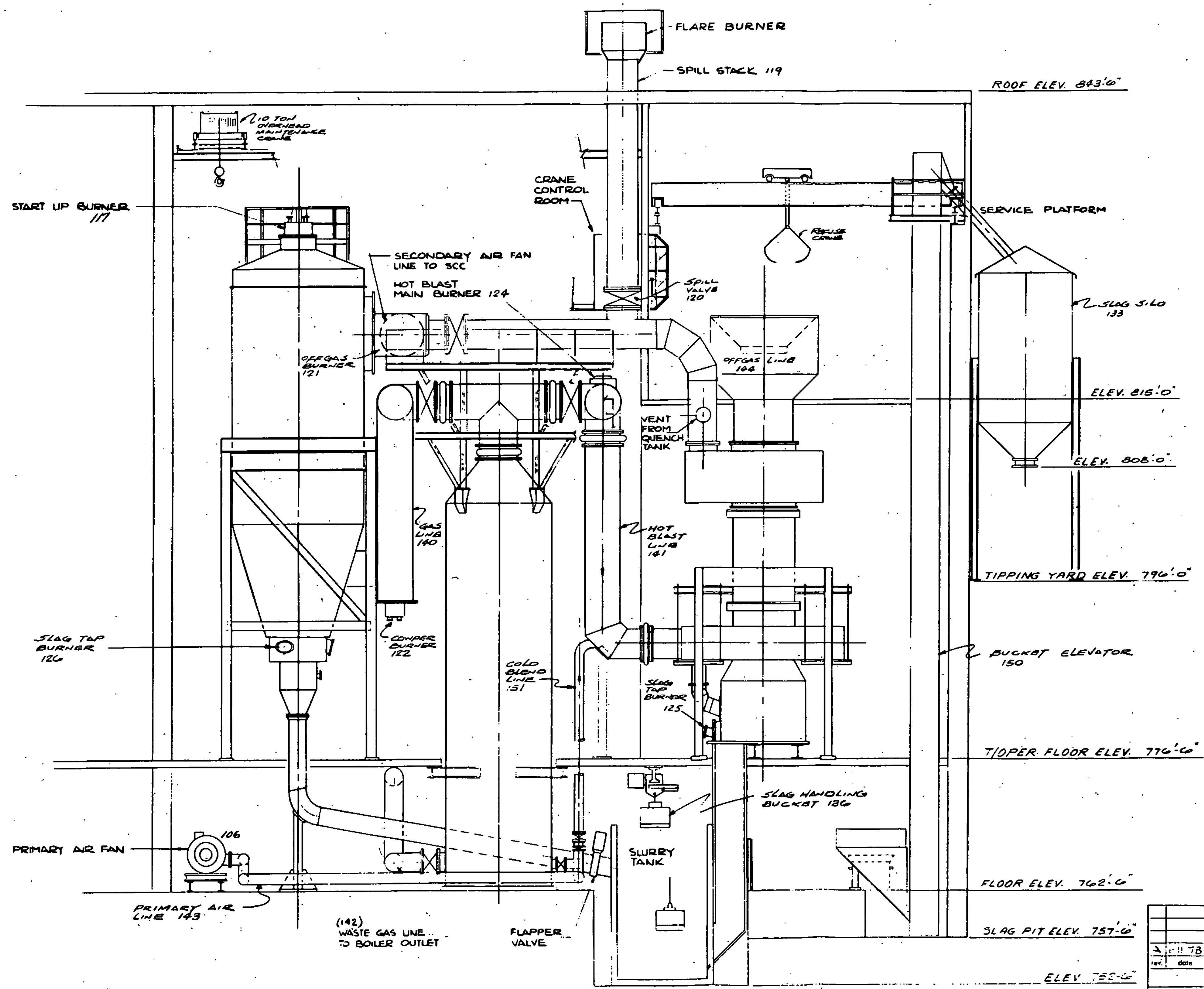
andco incorporated

PRELIMINARY DESIGN
PHASE II STAGE 2

UNIVERSITY OF MINNESOTA
PHASE II

ANDCO/TORRAX 132 TON UNIT
GENERAL ARRANGEMENT-PLAN

drawn J.L.V.	date 1-13-78	scale 3/16" = 1'-0"	proj. 961-001-00
checked	date	drawing number	
approved	date	G1001-D-00-000-01A	



WORK THIS DWG. WITH DWG. 61001-D-00-000-01A

rev.	date	by	description
A	11-11-78		DWG No WAS 61001-D-00-900-110

revisions

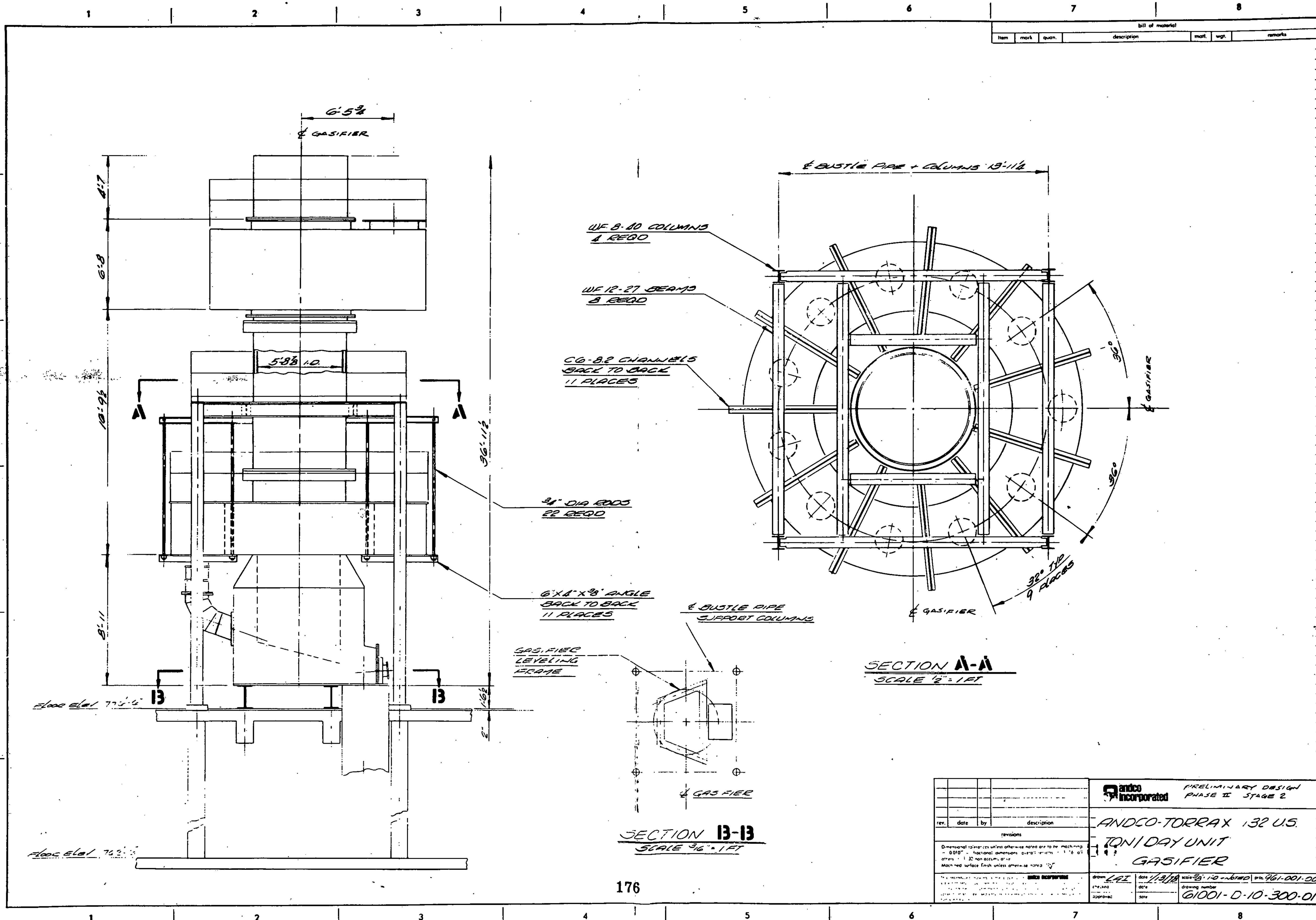
Dimensions and tolerances unless otherwise noted are to be machining ± 0.010" — fractional dimensions overall lengths ± 1/16 all others ± 1/32 non-accumulative.
Machined surface finish unless otherwise noted 125

andco incorporated

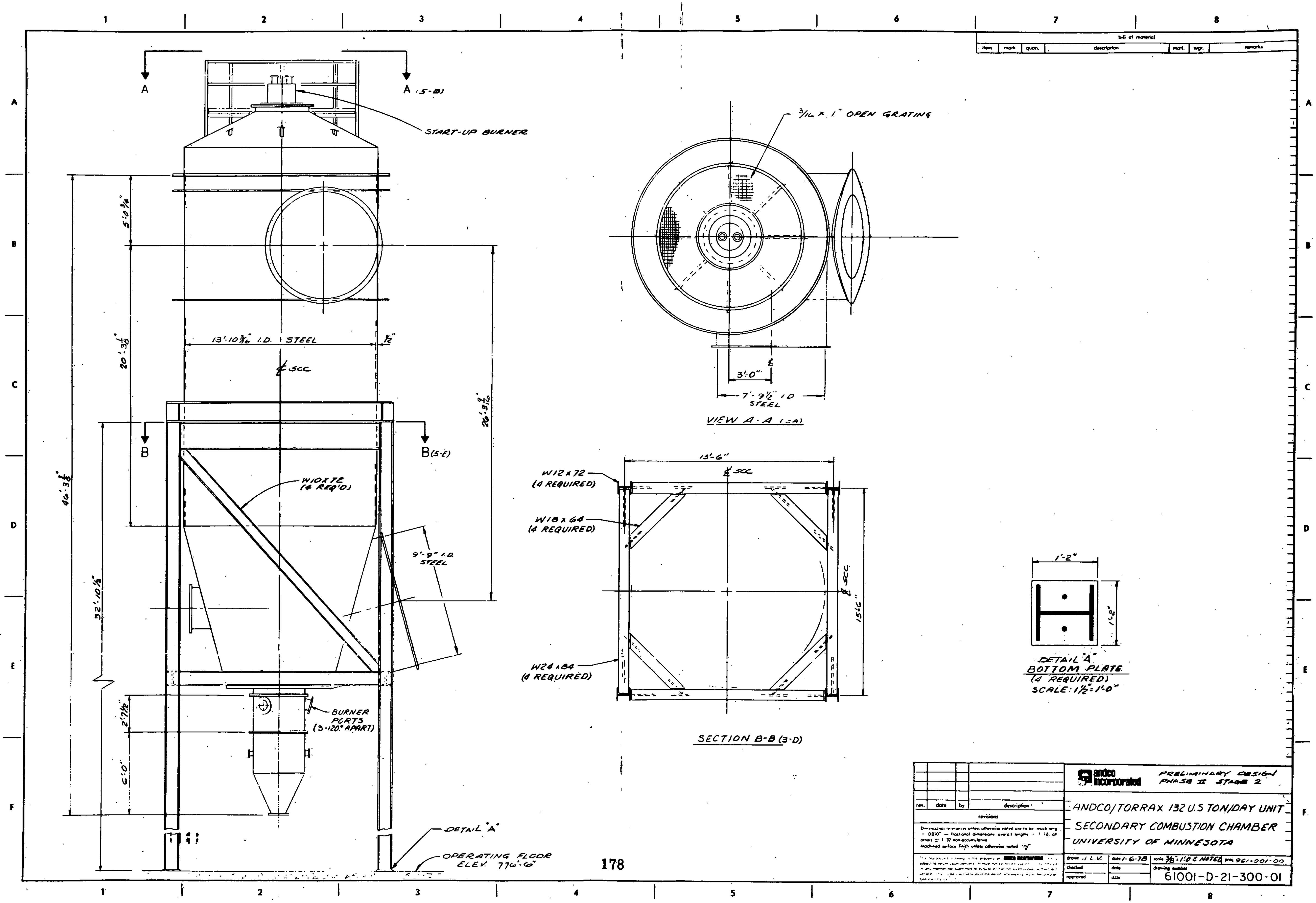
PRELIMINARY DESIGN PHASE II STAGE 2

ANDCO/TORRAX 132 U.S. TON/DAY UNIT
GENERAL ARRANGEMENT - ELEV.
UNIVERSITY OF MINNESOTA

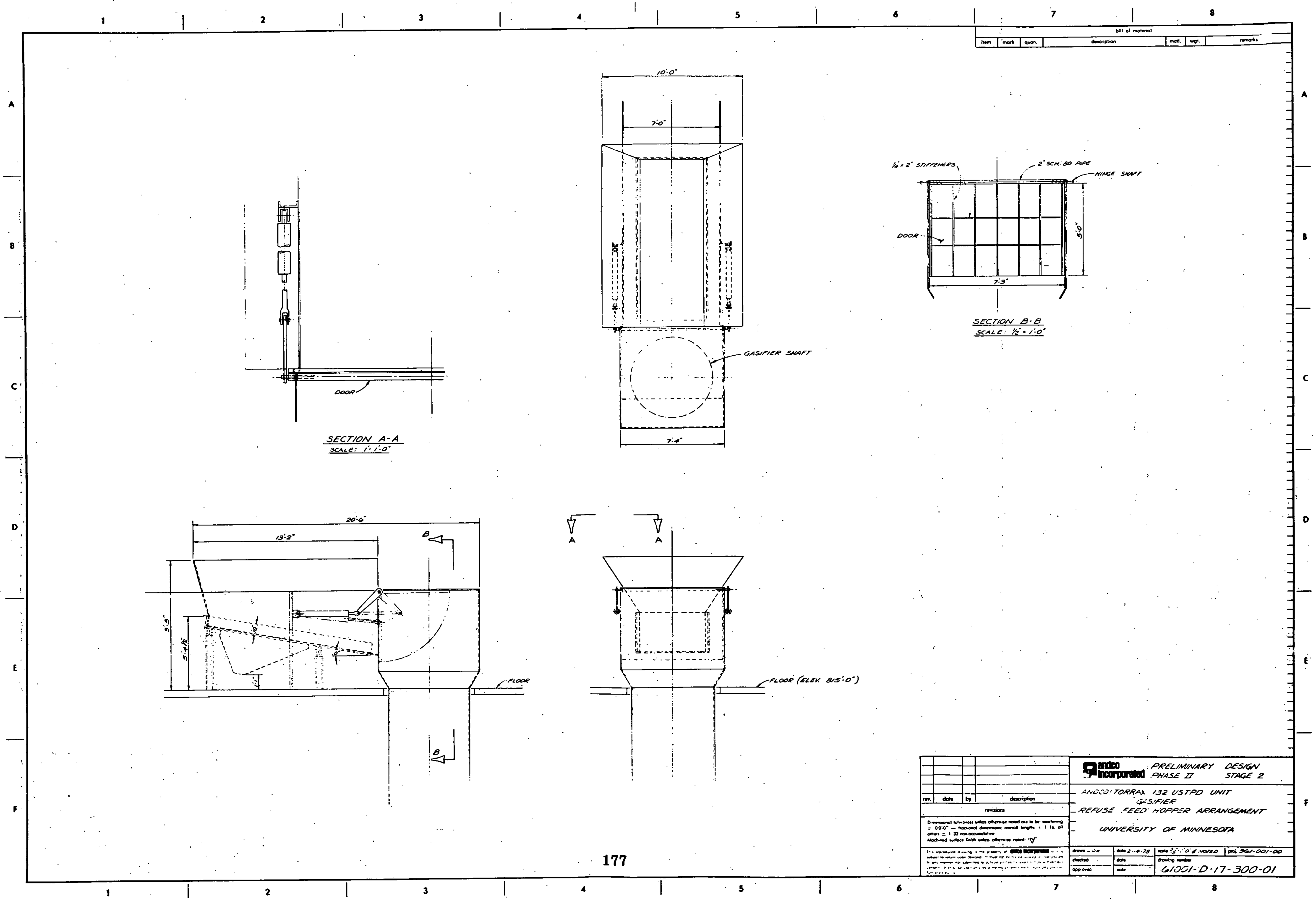
drawn J.L.V. | date 1-13-78 | scale 3/16" = 1'-0 | proj. 96-001-00
checked | date | drawing number 61-001-D-00-000-02A
approved | date

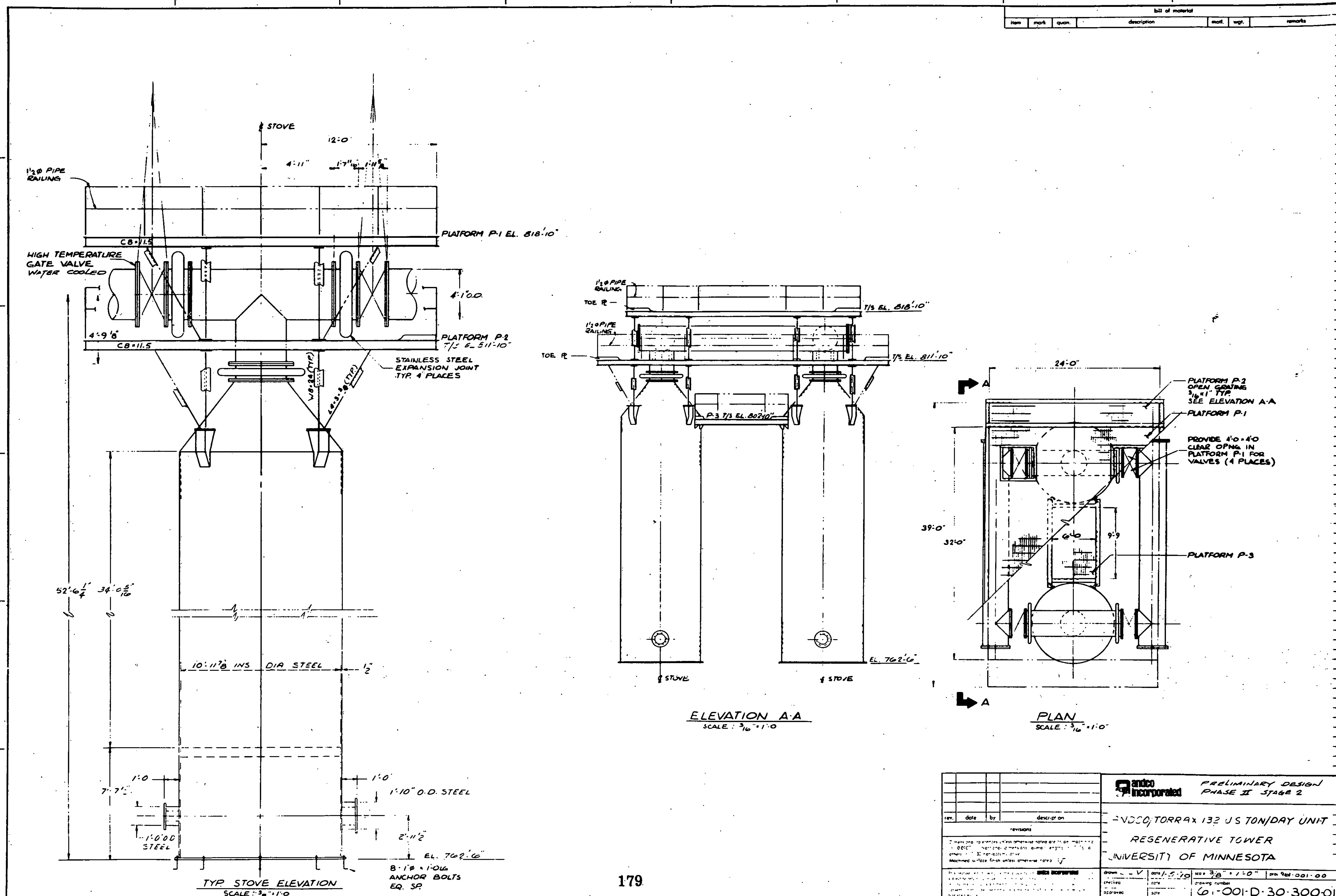


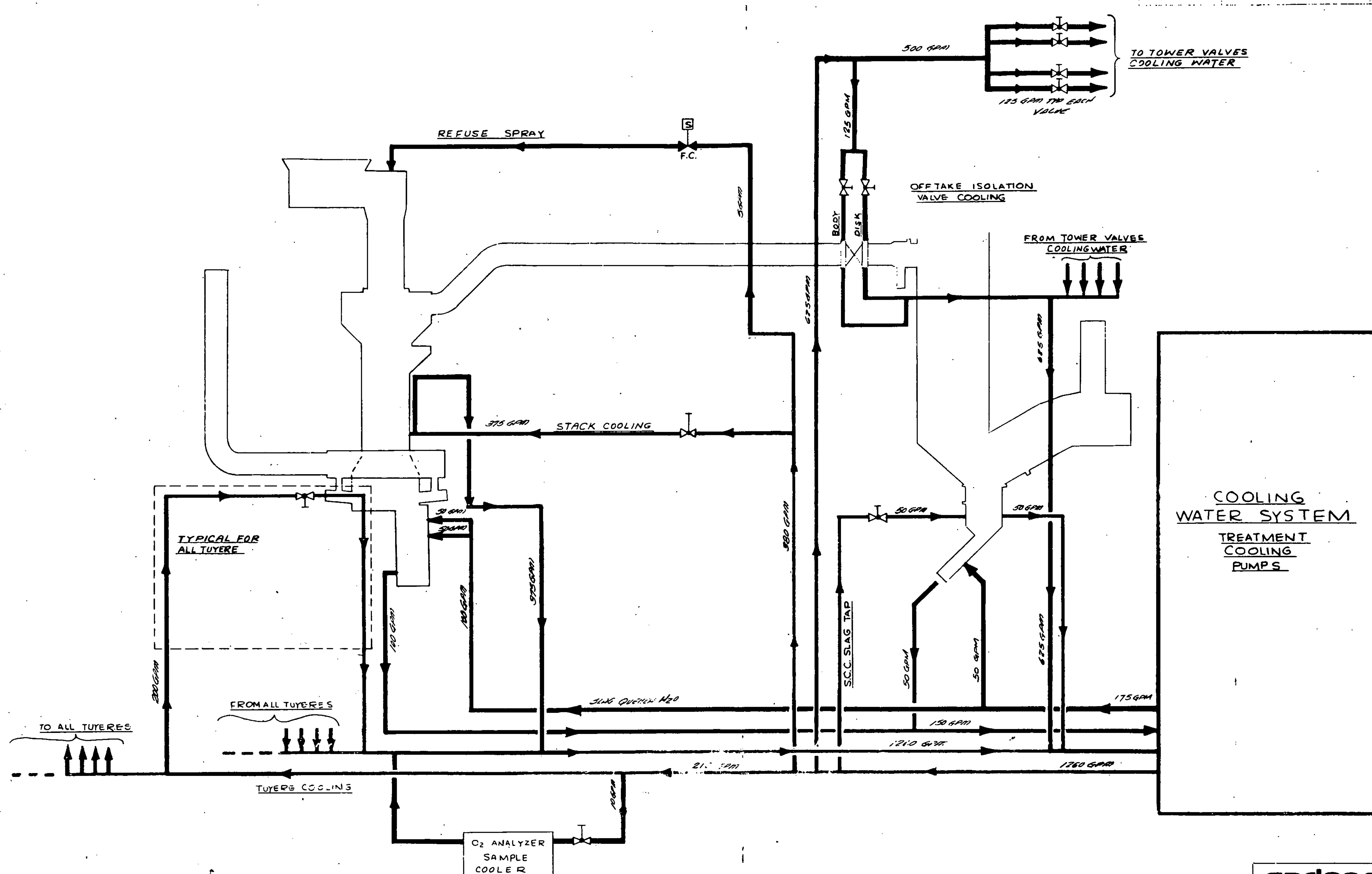
bill of material
item | mark | quan. | description | matl. | wgt. | remarks
6'-5¾"
℄ GASIFIER
4'-7"
6'-8"
5'-8⅞" I.D.
10'-9½"
96'-1½"
8'-11"
1'-6½"
2"
A
A
B
B
FLOOR ELEV 773'-6"
FLOOR ELEV 763'-6"
⅜" DIA RODS
22 REQD
6"x4"x⅜" ANGLE
BACK TO BACK
11 PLACES
WF 8-10 COLUMNS
4 REQD
WF 12-27 BEAMS
8 REQD
C6-8.2 CHANNELS
BACK TO BACK
11 PLACES
℄ BUSTLE PIPE + COLUMNS 19'-11¼"
36°
36°
℄ GASIFIER
32° TYP
9 PLACES
℄ GASIFIER
SECTION A-A
SCALE ½" = 1 FT
℄ BUSTLE PIPE
SUPPORT COLUMNS
GASIFIER
LEVELING
FRAME
℄ GASIFIER
SECTION B-B
SCALE 3/16" = 1 FT
rev. | date | by | description
revisions
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO-TORRAX 132 U.S.
TON/DAY UNIT
GASIFIER
drawn LAI
date 7/13/78
ref. 961-001-00
drawing number
61001-D-10-300-01



A
A (5-B)
START-UP BURNER
5'-0 3/8"
20'-3 1/8"
13'-10 3/16" I.D. STEEL
1/2"
℄ SCC
26'-3 9/16"
46'-3 3/8"
B
B (5-E)
W10 x 72
(4 REQ'D)
9'-9" I.D.
STEEL
32'-10 1/2"
2'-7 1/2"
6'-0"
BURNER
PORTS
(3-120° APART)
DETAIL "A"
OPERATING FLOOR
ELEV. 776'-6"
3/16 x 1" OPEN GRATING
3'-0"
7'-9 1/2" I.D.
STEEL
VIEW A-A (5-A)
13'-6"
℄ SCC
W12 x 72
(4 REQUIRED)
W18 x 64
(4 REQUIRED)
W24 x 84
(4 REQUIRED)
15'-6"
SECTION B-B (3-D)
1'-2"
1'-2"
DETAIL "A"
BOTTOM PLATE
(4 REQUIRED)
SCALE: 1 1/2" = 1'-0"
bill of material
item
mark
quan.
description
matl.
wgt.
remarks
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
rev.
date
by
description
revisions
Dimensional tolerances unless otherwise noted are to be machining ± 0.010" — fractional dimensions: overall lengths ± 1/16, all others ± 1/32 non-accumulative
Machined surface finish unless otherwise noted
ANDCO/TORRAX 132 U.S TON/DAY UNIT
SECONDARY COMBUSTION CHAMBER
UNIVERSITY OF MINNESOTA
drawn J.L.V.
date 1-6-78
scale 3/8" = 1'-0" & NOTED
proj. 961-001-00
checked
date
approved
date
drawing number
61001-D-21-300-01


bill of material
item
mark
quan.
description
matl.
wgt.
remarks
10'-0"
7'-0"
GASIFIER SHAFT
7'-4"
½ x 2" STIFFENERS
2" SCH. 80 PIPE
HINGE SHAFT
DOOR
5'-0"
7'-9"
SECTION B-B
SCALE: ½" = 1'-0"
DOOR
SECTION A-A
SCALE: 1"=1'-0"
20'-6"
13'-2"
B
B
9'-5"
5'-4½"
FLOOR
A
A
FLOOR (ELEV. 815'-0")
rev.
date
by
description
revisions
Dimensional tolerances unless otherwise noted are to be: machining ± 0.010" — fractional dimensions: overall lengths ± 1/16, all others ± 1/32 non-accumulative
Machined surface finish unless otherwise noted: 125
andco incorporated
PRELIMINARY DESIGN
PHASE II
STAGE 2
ANDCO-TORRAX 132 USTPD UNIT
GASIFIER
REFUSE FEED HOPPER ARRANGEMENT
UNIVERSITY OF MINNESOTA
date 2-4-78
scale AS NOTED
proj. 961-001-00
checked
date
approved
date
drawing number
61001-D-17-300-01


bill of material
item | mark | quan. | description | matl. | wgt. | remarks
℄ STOVE
12'-0"
4'-11"
1'-7½" 1'-11⅝"
1½φ PIPE RAILING
PLATFORM P-1 EL. 818'-10"
C8×11.5
HIGH TEMPERATURE GATE VALVE WATER COOLED
4'-1" O.D.
4'-9⅛"
PLATFORM P-2 T/S EL. 811'-10"
STAINLESS STEEL EXPANSION JOINT TYP. 4 PLACES
W8×24 (TYP)
52'-6¼"
34'-0 5/16"
10'-11⅞ INS DIA STEEL
½"
1'-0"
7'-7½"
1'-10" O.D. STEEL
1'-0" O.D. STEEL
2'-11½"
EL. 762'-6"
8-1"φ × 1'-0½ ANCHOR BOLTS EQ. SP.
TYP. STOVE ELEVATION
SCALE: ⅜"=1'-0
1½φ PIPE RAILING
TOE ℞
T/S EL. 818'-10"
T/S EL. 811'-10"
P-3 T/S EL. 802'-10"
EL. 762'-6"
℄ STOVE
℄ STOVE
ELEVATION A-A
SCALE: 3/16"=1'-0
24'-0"
A
PLATFORM P-2 OPEN GRATING 3/16×1" TYP. SEE ELEVATION A-A
PLATFORM P-1
PROVIDE 4'-0×4'-0 CLEAR OPNG IN PLATFORM P-1 FOR VALVES (4 PLACES)
39'-0"
32'-0"
6'-0
9'-9
PLATFORM P-3
A
PLAN
SCALE: 3/16"=1'-0"
rev. | date | by | description
revisions
Machined surface finish unless otherwise noted
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 US TON/DAY UNIT
REGENERATIVE TOWER
UNIVERSITY OF MINNESOTA
drawn | date 1-5-70 | scale ⅜"=1'-0" | proj. 9bl-001-00
checked | date | drawing number
approved | date | 61-001-D-30-300-01



WORK WITH DWGS:

61001-C-63-500-01 FLOW DIAGRAM
D-60-500-02 FLOW DIAGRAM
D-90-510-01 PLAN & SECTS
D-90-510-02 BASEMENT PLAN

andco PRELIMINARY DESIGN PHASE II STAGE 2

UNIVERSITY OF MINNESOTA
ANDCO-TORAX 132 US TON/DAY UNIT

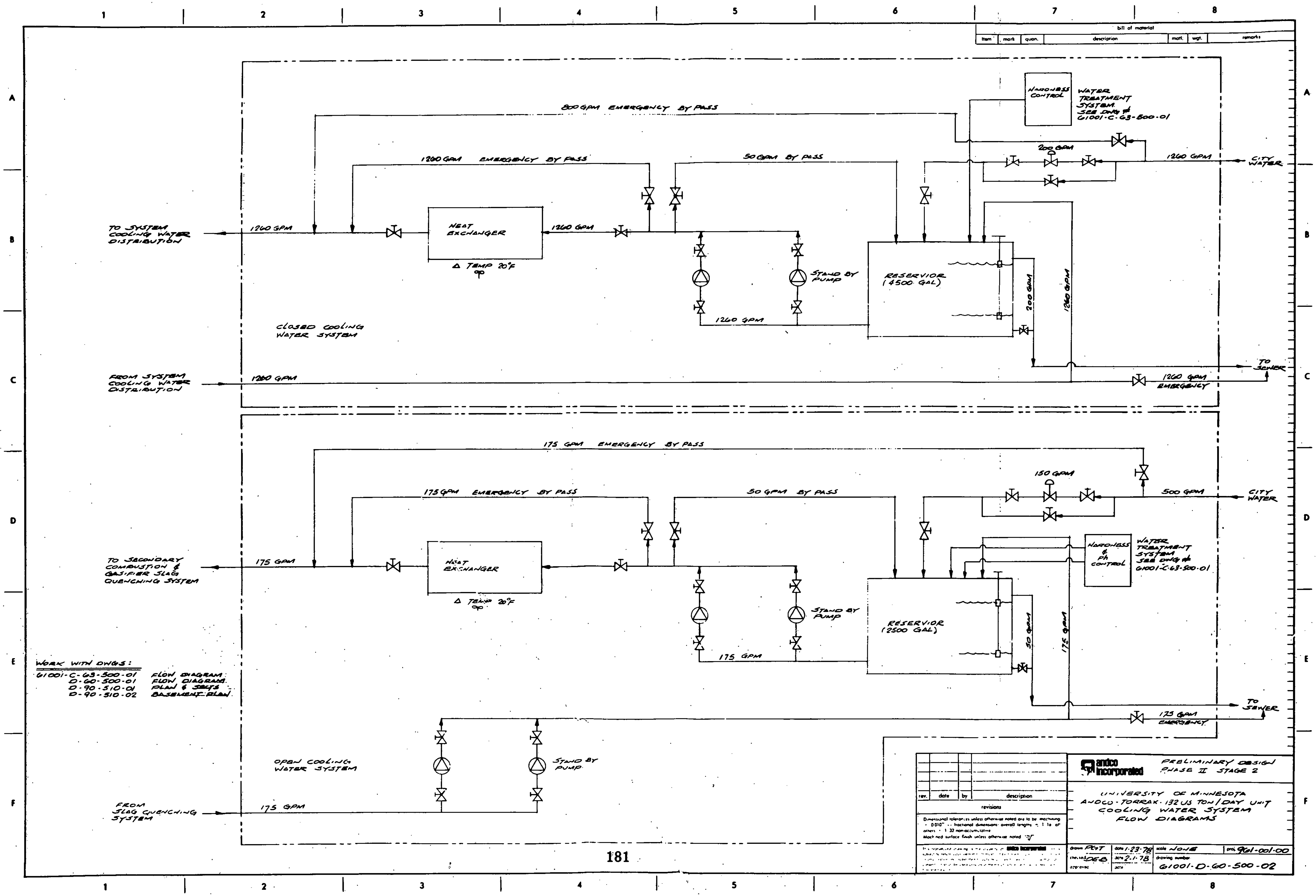
COOLING WATER SYSTEM

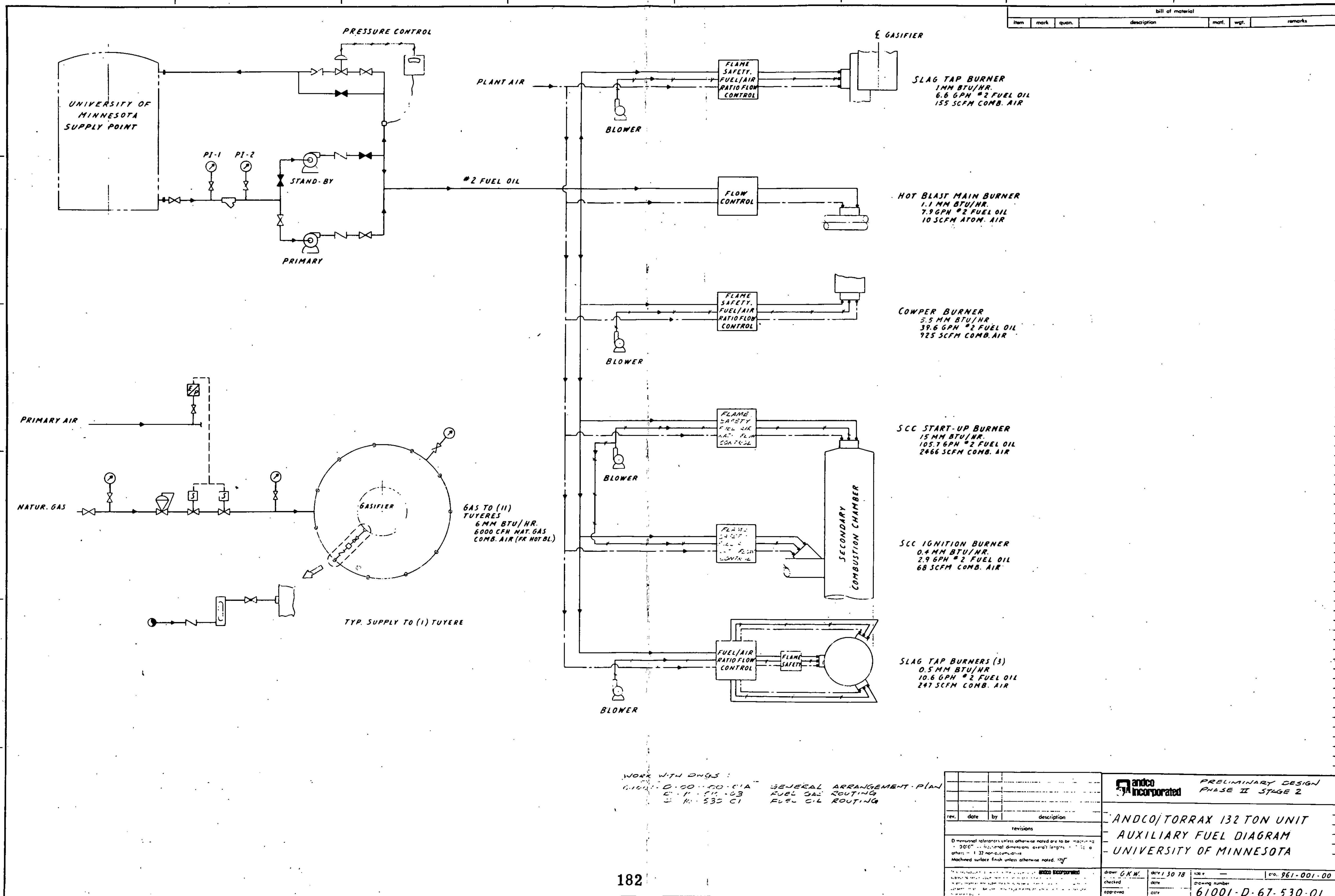
FLOW DIAGRAM

N.T.S.

961-001-00

61001-D-60-500-01


800 GPM EMERGENCY BY PASS
HARDNESS CONTROL
WATER TREATMENT SYSTEM SEE DWG # G1001-C-63-500-01
200 GPM
1260 GPM
CITY WATER
1260 GPM EMERGENCY BY PASS
50 GPM BY PASS
TO SYSTEM COOLING WATER DISTRIBUTION
1260 GPM
HEAT EXCHANGER
Δ TEMP 20°F
STAND BY PUMP
RESERVIOR (4500 GAL)
200 GPM
1260 GPM
CLOSED COOLING WATER SYSTEM
TO SEWER
FROM SYSTEM COOLING WATER DISTRIBUTION
1260 GPM EMERGENCY
175 GPM EMERGENCY BY PASS
150 GPM
500 GPM
175 GPM EMERGENCY BY PASS
50 GPM BY PASS
HARDNESS & ph CONTROL
WATER TREATMENT SYSTEM SEE DWG # G1001-C-63-500-01
TO SECONDARY COMBUSTION & GASIFIER SLAG QUENCHING SYSTEM
175 GPM
HEAT EXCHANGER
Δ TEMP 20°F
STAND BY PUMP
RESERVIOR (2500 GAL)
50 GPM
175 GPM
WORK WITH DWGS:
G1001-C-63-500-01 FLOW DIAGRAM
D-60-500-01 FLOW DIAGRAM
D-90-510-01 PLAN & SECTS
D-90-510-02 BASEMENT PLAN
175 GPM EMERGENCY
OPEN COOLING WATER SYSTEM
FROM SLAG QUENCHING SYSTEM
175 GPM
bill of material
item | mark | quan. | description | matl. | wgt. | remarks
rev. | date | by | description
revisions
Dimensional tolerances unless otherwise noted are to be machining ± 0.010" – fractional dimensions: overall lengths ± 1/16 all others ± 1/32 non-accumulative
Machined surface finish unless otherwise noted
andco incorporated
PRELIMINARY DESIGN PHASE II STAGE 2
UNIVERSITY OF MINNESOTA
ANDCO-TORRAX 132 US TON/DAY UNIT
COOLING WATER SYSTEM
FLOW DIAGRAMS
drawn PGT
date 1-23-78
checked DEB
date 2-1-78
approved
scale NONE
proj. 961-001-00
drawing number G1001-D-60-500-02



PRESSURE CONTROL
UNIVERSITY OF MINNESOTA SUPPLY POINT
PI-1
PI-2
STAND-BY
PRIMARY
#2 FUEL OIL
PLANT AIR
BLOWER
FLAME SAFETY, FUEL/AIR RATIO FLOW CONTROL
℄ GASIFIER
SLAG TAP BURNER
1MM BTU/HR.
6.6 GPH #2 FUEL OIL
155 SCFM COMB. AIR
FLOW CONTROL
HOT BLAST MAIN BURNER
1.1 MM BTU/HR.
7.9 GPH #2 FUEL OIL
10 SCFM ATOM. AIR
COWPER BURNER
5.5 MM BTU/HR
39.6 GPH #2 FUEL OIL
925 SCFM COMB. AIR
SCC START-UP BURNER
15 MM BTU/HR.
105.7 GPH #2 FUEL OIL
2466 SCFM COMB. AIR
SECONDARY COMBUSTION CHAMBER
SCC IGNITION BURNER
0.4 MM BTU/HR.
2.9 GPH #2 FUEL OIL
68 SCFM COMB. AIR
FUEL/AIR RATIO FLOW CONTROL
FLAME SAFETY
SLAG TAP BURNERS (3)
0.5 MM BTU/HR
10.6 GPH #2 FUEL OIL
247 SCFM COMB. AIR
PRIMARY AIR
NATUR. GAS
GASIFIER
GAS TO (11) TUYERES
6MM BTU/HR.
6000 CFH NAT. GAS
COMB. AIR (FR HOT BL.)
TYP. SUPPLY TO (1) TUYERE
WORK WITH DWGS:
GENERAL ARRANGEMENT PLAN
FUEL GAS ROUTING
FUEL OIL ROUTING
rev. date by description
revisions
Machined surface finish unless otherwise noted.
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 TON UNIT
AUXILIARY FUEL DIAGRAM
UNIVERSITY OF MINNESOTA
drawn G.K.W.
date 1 30 78
checked
approved
c.o. 961-001-00
drawing number
61001-D-67-530-01

MEANINGS OF FUNCTIONAL IDENTIFICATION LETTERS

THIS TABLE APPLIES ONLY TO THE FUNCTIONAL IDENTIFICATION OF INSTRUMENTS.
NOTE: NUMBERS IN PARENTHESES REFER TO SPECIFIC EXPLANATORY NOTES.

	FIRST LETTER		SUCCEEDING LETTERS (1)		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS (2)	ABSOLUTE	ALARM		OPEN (6)
B	BURNER FLAME				CLOSED (6)
C	CONDUCTIVITY (ELECTRICAL)			CONTROL	INTERMEDIATE (6)
D	DENSITY (MASS) OR SPECIFIC GRAVITY	DIFFERENTIAL			
E	VOLTAGE (EMF)		PRIMARY SENSING ELE.		
F	FLOW RATE	RATIO (FRACTION)			
G			GLASS (3)		
H	HAND (MANUALLY INITIATED)				HIGH
I	CURRENT (ELECTRICAL)		INDICATE		
J	POWER	SCAN			
K				CONTROL STATION	
L	LEVEL				LOW
M	MOISTURE OR HUMIDITY				
N					
O					
P	PRESSURE OR VACUUM		TEST CONNECTION		
Q		INTEGRATE OR TOTALIZE			
R	RADIATION (5)		RECORD OR PRINT		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U					
V	VISCOSITY			VALVE, DAMPER OR LOUVER	
W	WEIGHT OR FORCE				
X					
Y	(4)			RELAY OR COMPUTE	
Z	POSITION			DRIVE ACTUATE OR UNCLASSIFIED FINAL CONT. ELEMENT	

NOTES

(1) THE GRAMMATICAL FORM OF THE SUCCEEDING-LETTER MEANINGS MAY BE MODIFIED AS REQUIRED. FOR EXAMPLE: "INDICATE" MAY BE APPLIED AS "INDICATOR" OR "INDICATING", "TRANSMIT" AS "TRANSMITTER" OR "TRANSMITTING", ETC.

(2) THE FIRST-LETTER "A" FOR "ANALYSIS" COVERS ALL ANALYSES NOT LISTED IN THE TABLE. THE TYPE OF ANALYSIS IS DEFINED OUTSIDE THE TAGGING BALLOON ON THE FLOOR DIAGRAM.

(3) PASSIVE FUNCTION "GLASS" APPLIES TO INSTRUMENTS THAT PROVIDE AN UNCALIBRATED DIRECT VIEW OF THE PROCESS.

(4) THE FIRST LETTER "Y" IS USED FOR HARDWARE ITEMS REQUIRED FOR CONTROL OF PROCESS CONTROL OR MONITORING DEVICES.

(5) THE FIRST LETTER "R" FOR "RADIATION" COVERS ALL TYPES OF RADIATION. FOR EXAMPLE: GAMMA, ULTRAVIOLET, INFRARED, ETC.

(6) MODIFIERS "OPEN" "CLOSED" AND "INTERMEDIATE" ARE USED TO DESIGNATE THE LOCATION OF POSITION SWITCHES USED ON PROCESS CONTROL VALVES.

EXAMPLE-INSTRUMENTATION IDENTIFICATION

PIC 31-6A

FIRST LETTER ①	SUCCEEDING LETTERS ②	LOOP NUMBER	ELEMENT NUMBER	ELEMENT SUFFIX ③
FUNCTIONAL IDENTIFICATION		LOOP AND ELEMENT IDENTIFICATION		
INSTRUMENTATION IDENTIFICATION OR TAG NUMBER				

① FIRST LETTER MAY INCLUDE MODIFIER.
② SUCCEEDING LETTERS MAY INCLUDE MODIFIER.
③ ELEMENT SUFFIX IS USED WHEN MULTIPLE IDENTICAL ELEMENTS APPEAR IN THE SAME LOOP.

INSTRUMENT BALLOON SYM. AND EXAMPLES

- LOCALLY MOUNTED INSTRUMENT.
- CONTROL PANEL FRONT MOUNTED INSTRUMENT.
- INSTRUMENT MOUNTED INSIDE A CONTROL PANEL.
- PC 31-6A * FOR RELAYS OR CONTROLLERS ONLY, FUNCTION DESIGNATION IS PLACED HERE. (SEE TABLE)

FUNCTION DESIGNATIONS FOR RELAYS

SYMBOLS	FUNCTION
Σ + Δ	BIAS-USED FOR SINGLE INPUT RELAY.
X	MULTIPLY
÷	DIVIDE
√ OR SQ. RT.	EXTRACT SQUARE ROOT
> OR HIGHEST (MEASURED VARIABLE)	HIGH-SELECT. SELECT HIGHEST (HIGHER) MEASURED VARIABLE (NOT SIGNAL UNLESS SO NOTED)
< OR LOWEST (MEASURED VARIABLE)	LOW-SELECT. SELECT LOWEST (LOWER) MEASURED VARIABLE (NOT SIGNAL UNLESS SO NOTED)
REV.	REVERSE
1:1	BOOSTER RELAY (VOL. BOOSTER OR ISOLATION RELAY)
1/D	INVERSE DERIVATIVE
INPUT/OUTPUT	DESIGNATION: E, H, I, P — SIGNAL: VOLTAGE, HYDRAULIC, CURRENT, PNEUMATIC. FOR EXAMPLE: E/P = VOLTAGE TO PNEUMATIC CONVERSION

FUNCTION DESIGNATIONS FOR CONTROLLERS

SYMBOLS	FUNCTION
DIR	DIRECT ACTING
REV.	REVERSE ACTING
%	PROPORTIONAL ACTION
∫	RESET (INTEGRAL) ACTION
D	RATE (DERIVATIVE) ACTION
S.P.	SET POINT

FLOW LINES

- SYSTEM PROCESS FLOW
- CONNECTION TO PROCESS-INSTR. INPUT
- INSTR. PNEUMATIC CONTROL SIGNAL LINES.
- INSTR. ELECTRICAL CONTROL SIGNAL LINES
- SUB-SYSTEM PROCESS FLOW
- ELECTROMAGNETIC OR SONIC (WITHOUT WIRING OR TUBING)

CONTROL VALVES

- (NO)* (NC)* FO** FC** — GATE VALVE
- * NORMALLY OPEN OR NORMALLY CLOSED REFERS TO STATE OF VALVE DURING NORMAL RUNNING PROCESS CONDITION
- ** FO = FAIL OPEN, FC = FAIL CLOSED
- (NO) (NC) — GLOBE VALVE
- BUTTERFLY, DAMPER, OR LOUVER
- CHECK VALVE

ACTUATORS

- PNEUMATIC ACTUATOR
  - * Ao = AIR TO OPEN
  - Ac = AIR TO CLOSE
- M — MOTOR OPERATED
- HAND OPERATED
- DOUBLE ACTING CYLINDER

item	mark	quan.	description	matl	wgt.	remarks

bill of material

SOLENOID VALVES

- S — 2-WAY
- S — 3-WAY
- VENTS THIS WAY ON DE-ENERGIZATION
- S — 4-WAY

FLOW

- FE — ORIFICE PLATE METER
- VENTURI OR NOZZLE METER
- POSITIVE DISPLACEMENT LIQUID FLOW METER.

PRESSURE

- PCV — PRESSURE REDUCING REGULATOR
- PCV — TO PROCESS — PRESSURE REDUCING REGULATOR (EXT. COMPENSATED)

MISCELLANEOUS

- I — ELECTRICAL INTERLOCK
- IA1 — INSTRUMENT AIR SUPPLY OF SUFFICIENT PRESSURE LEVEL TO ACTUATE PROCESS VALVE FULLY.

NOTE:
THIS INSTRUMENT IDENTIFICATION SYSTEM IS BASED UPON ISA STANDARD S5.1-1973.

rev.	date	by	description

revisions

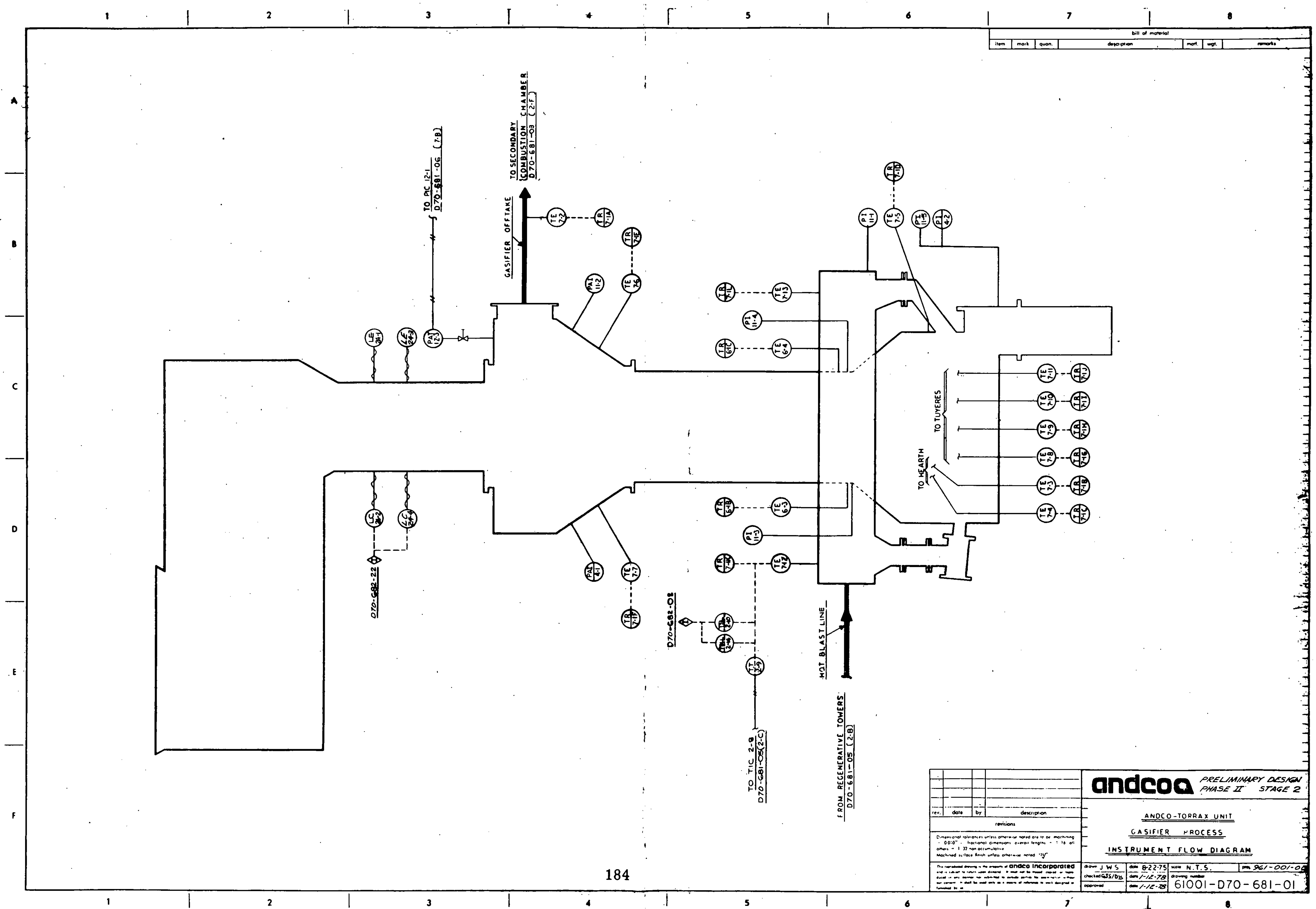
Dimensional tolerances unless otherwise noted are to be machined ± 0.010" – fractional dimensions overall lengths ± 1/16 all others ± 1/32 non-cumulative. Machined surface finish unless otherwise noted 125√

andco — PRELIMINARY DESIGN PHASE II STAGE 2

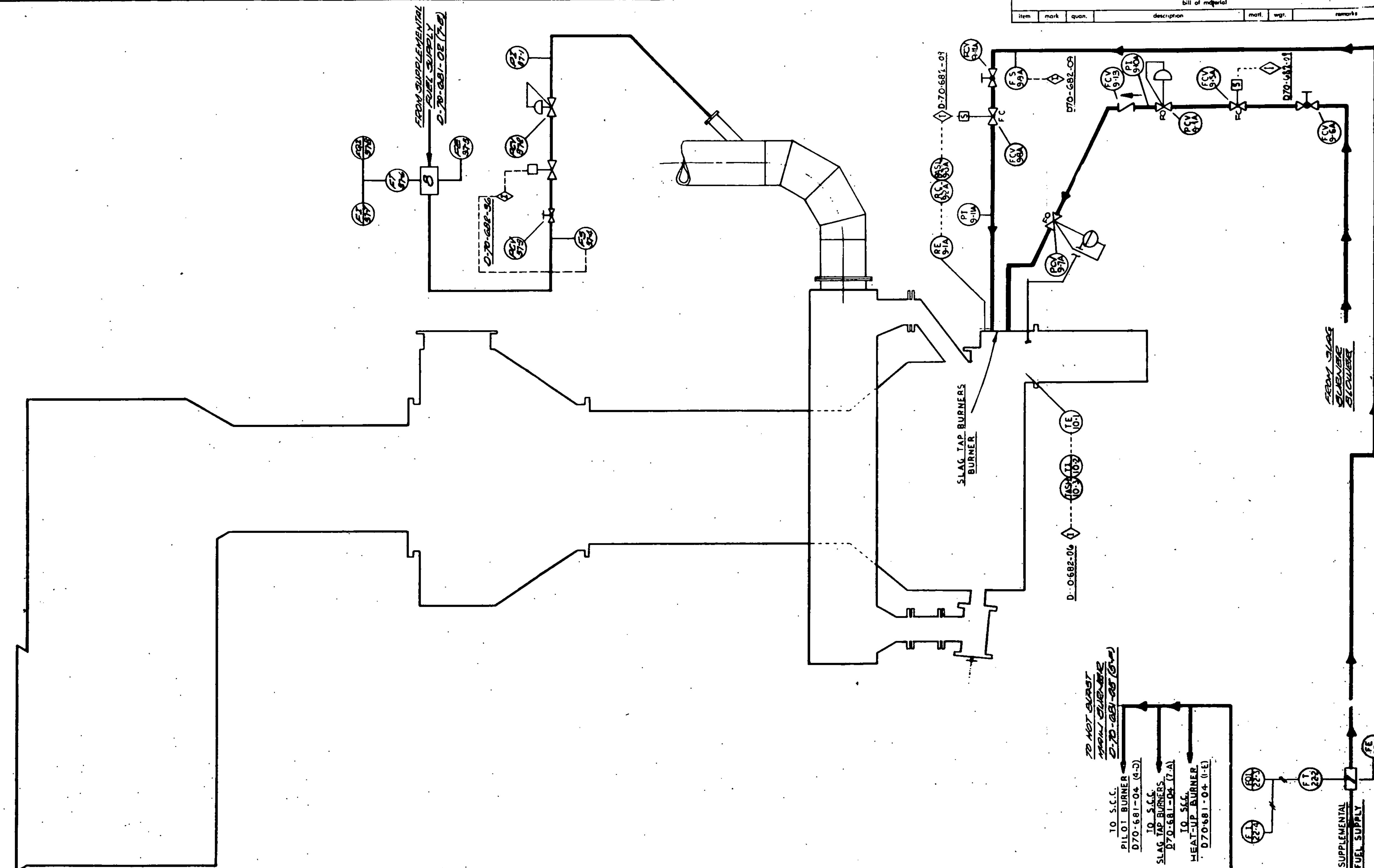
ANDCO-TORRAX UNIT

INSTRUMENT IDENTIFICATION & SYMBOLS

drawn RRR. date 9-16-75 scale N.T.S. 961-001-00
checked date 1-12-78
approved date 1-12-78
drawing number 61001-D70-680-01



bill of material
TO SECONDARY COMBUSTION CHAMBER D70-681-03 (2-F)
GASIFIER OFFTAKE
TO PIC 12-1 D70-681-06 (7-B)
D70-682-22
D70-682-08
TO TIC 2-9 D70-681-05 (2-C)
HOT BLAST LINE
FROM REGENERATIVE TOWERS D70-681-05 (2-B)
TO TUYERES
TO HEARTH
andco
PRELIMINARY DESIGN PHASE II STAGE 2
ANDCO-TORRAX UNIT
GASIFIER PROCESS
INSTRUMENT FLOW DIAGRAM
N.T.S.
61001-D70-681-01



NOTE:

ALL BURNER CONTROL HARDWARE UTILIZED WAS SELECTED TO PROVIDE THE DESIRED FUNCTIONAL OPERATIONS WITH A MINIMUM AMOUNT OF HARDWARE. PARTICULAR SAFETY FEATURES WILL BE REQUIRED TO MEET LOCAL SAFETY CODES. WHERE NO SAFETY APPLY, SOUND ENGINEERING DESIGN PROVIDING SUFFICIENT SAFETY FEATURES MUST BE UTILIZED. THE CONTROL LOOPS SHOWN DO NOT INCLUDE THESE SAFETY FEATURES. ALL THE FUNCTIONAL FEATURES DESIGNED INTO THESE BURNER CONTROL LOOPS MUST BE INCLUDED IN THE FINAL DESIGN.

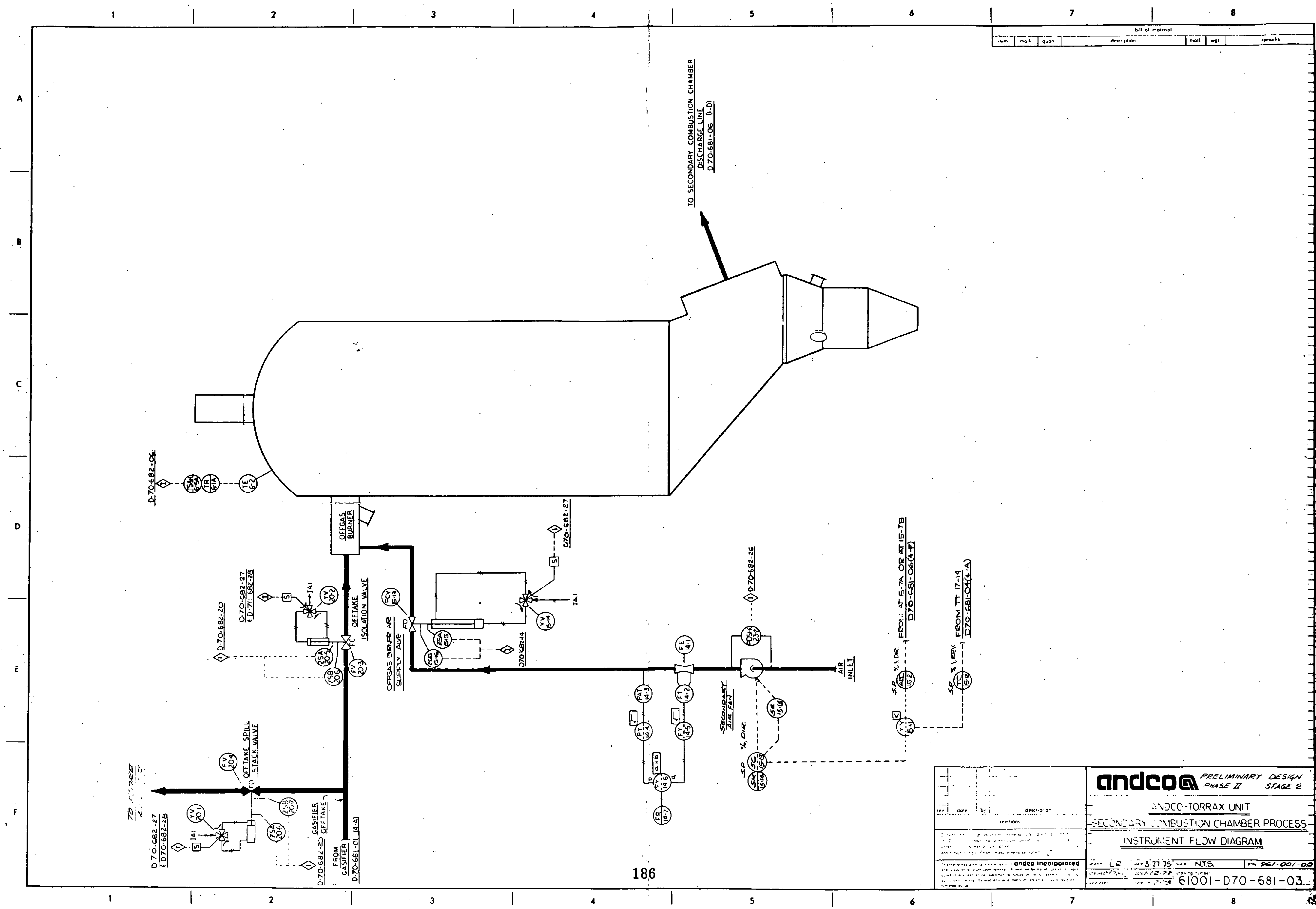
andco PRELIMINARY DESIGN. PHASE II STAGE 2

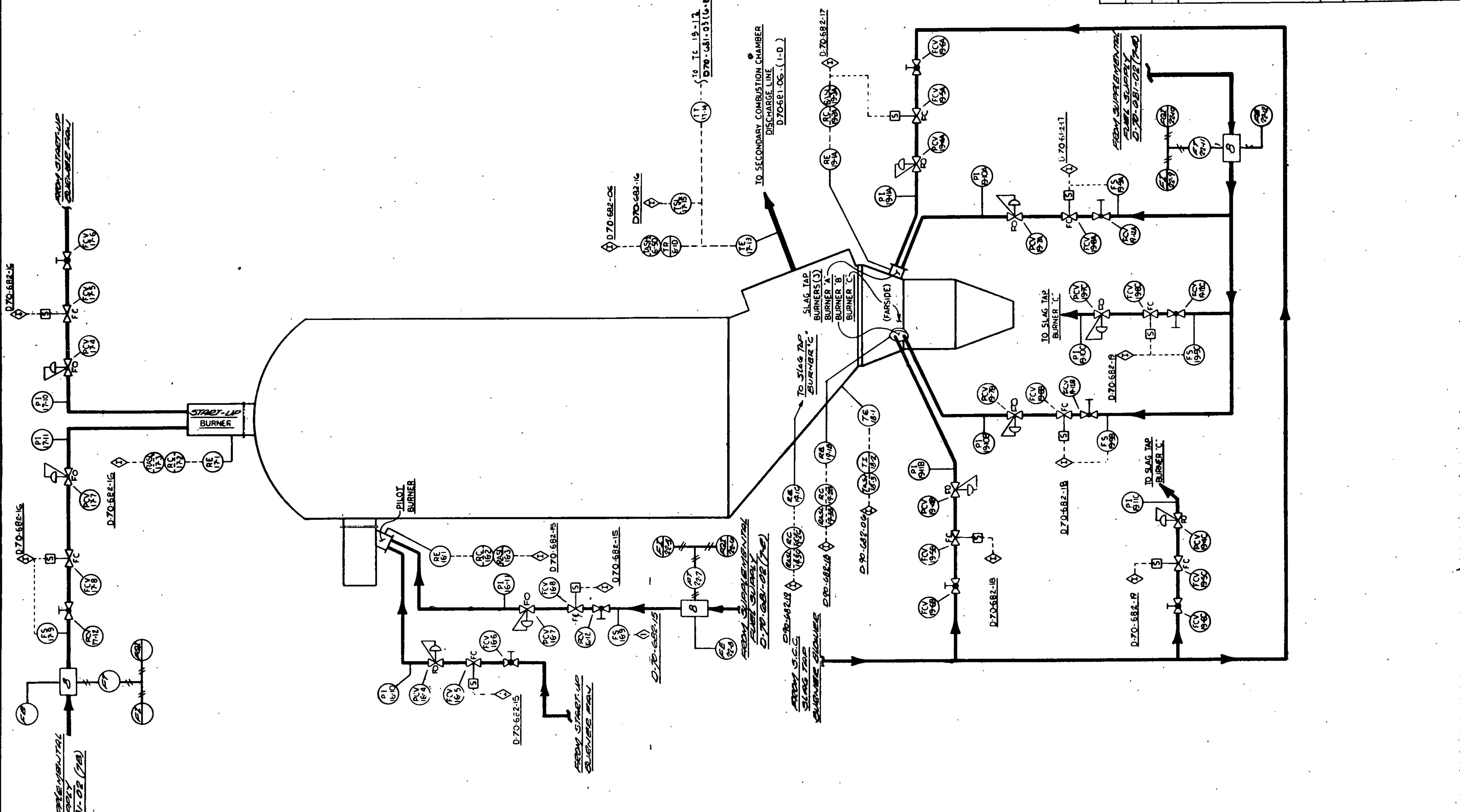
ANDCO-TOPRAX UNIT

GASIFIER FUEL PROCESS

INSTRUMENT FLOW DIAGRAM

drawn J.W.S.	date 8/21/75	scale N.T.S.	proj. 961-001-00
checked GJS/DJS	date 1-12-78	drawing number	
approved	date 1-12-78	61001-D70-681-02	


andco PRELIMINARY DESIGN PHASE II STAGE 2
ANDCO-TORRAX UNIT
SECONDARY COMBUSTION CHAMBER PROCESS
INSTRUMENT FLOW DIAGRAM
andco incorporated
LR
8-27-75
N.T.S.
961-001-00
61001-D70-681-03
TO SECONDARY COMBUSTION CHAMBER DISCHARGE LINE D70-681-06 (1-D)
OFFGAS BURNER
OFFTAKE ISOLATION VALVE
OFFGAS BURNER AIR SUPPLY VALVE
OFFTAKE SPILL STACK VALVE
GASIFIER OFFTAKE
FROM GASIFIER D70-681-01 (4-A)
SECONDARY AIR FAN
AIR INLET
FROM TT 17-14 D70-681-04 (4-A)
D70-682-27
D70-682-26
D70-682-20
D70-682-14
D70-682-06



NOTE:

ALL BURNER CONTROL HARDWARE UTILIZED WAS SELECTED TO PROVIDE THE DESIRED FUNCTIONAL OPERATIONS WITH A MINIMUM AMOUNT OF HARDWARE. PARTICULAR SAFETY FEATURES WILL BE REQUIRED TO MEET LOCAL SAFETY CODES. WHERE NO SAFETY CODES APPLY, SOUND ENGINEERING DESIGN PROVIDING SUFFICIENT SAFETY FEATURES MUST BE UTILIZED. THE CONTROL LOOPS SHOWN DO NOT INCLUDE THESE SAFETY FEATURES. ALL THE FUNCTIONAL FEATURES DESIGNED INTO THESE BURNER CONTROL LOOPS MUST BE INCLUDED IN THE FINAL DESIGN.

andco	PRELIMINARY DESIGN PHASE II STAGE 2
	ANDCO-TORRAX UNIT
	SEC. COMBUSTION CHMBR. FUEL PROCESS
	INSTRUMENT FLOW DIAGRAM
drawn LR	date 8-22-75
checked	date 1-12-78
approved	date 1-12-78
scale N.T.S.	961-001-00
drawing number	61001-D70-681-04

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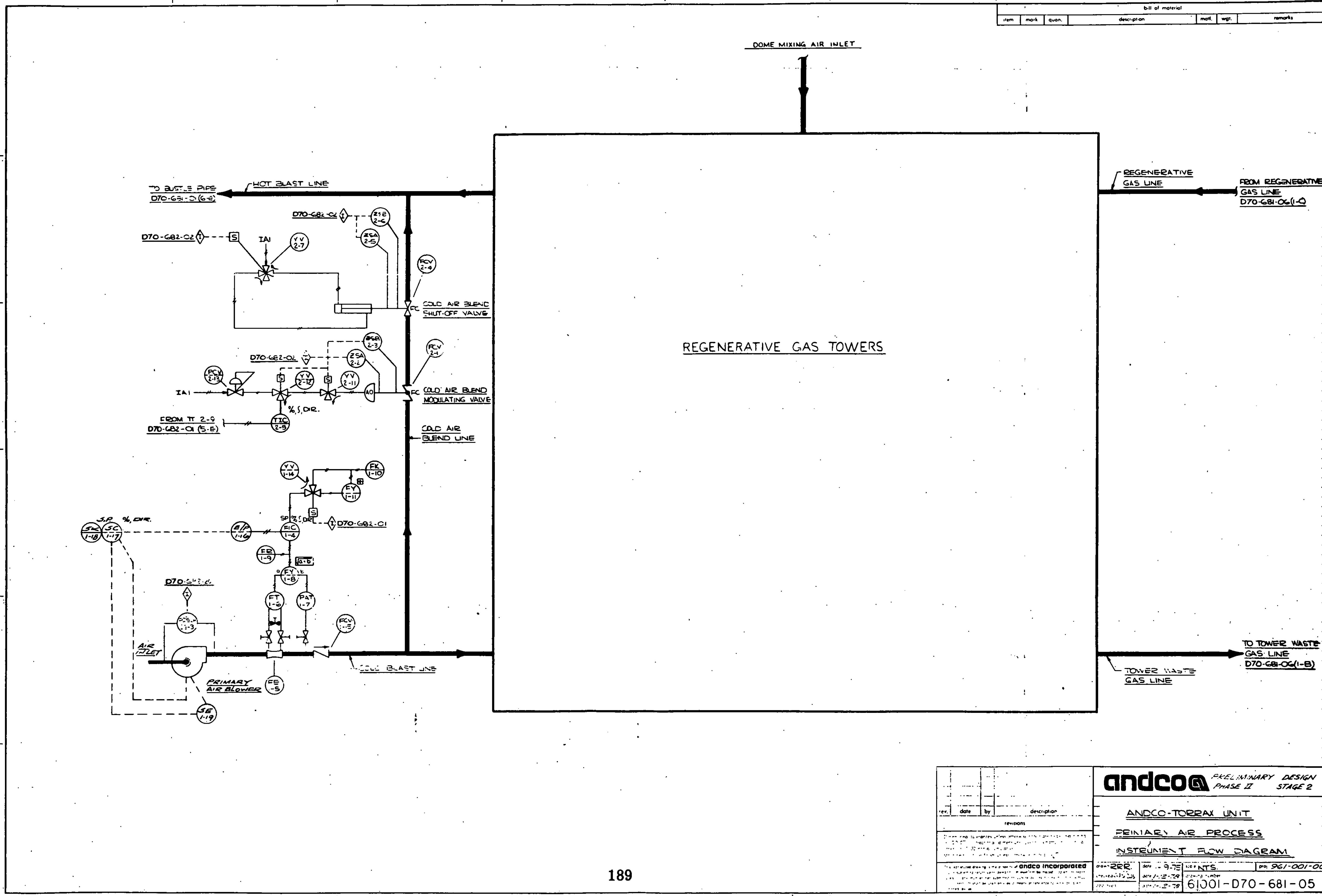
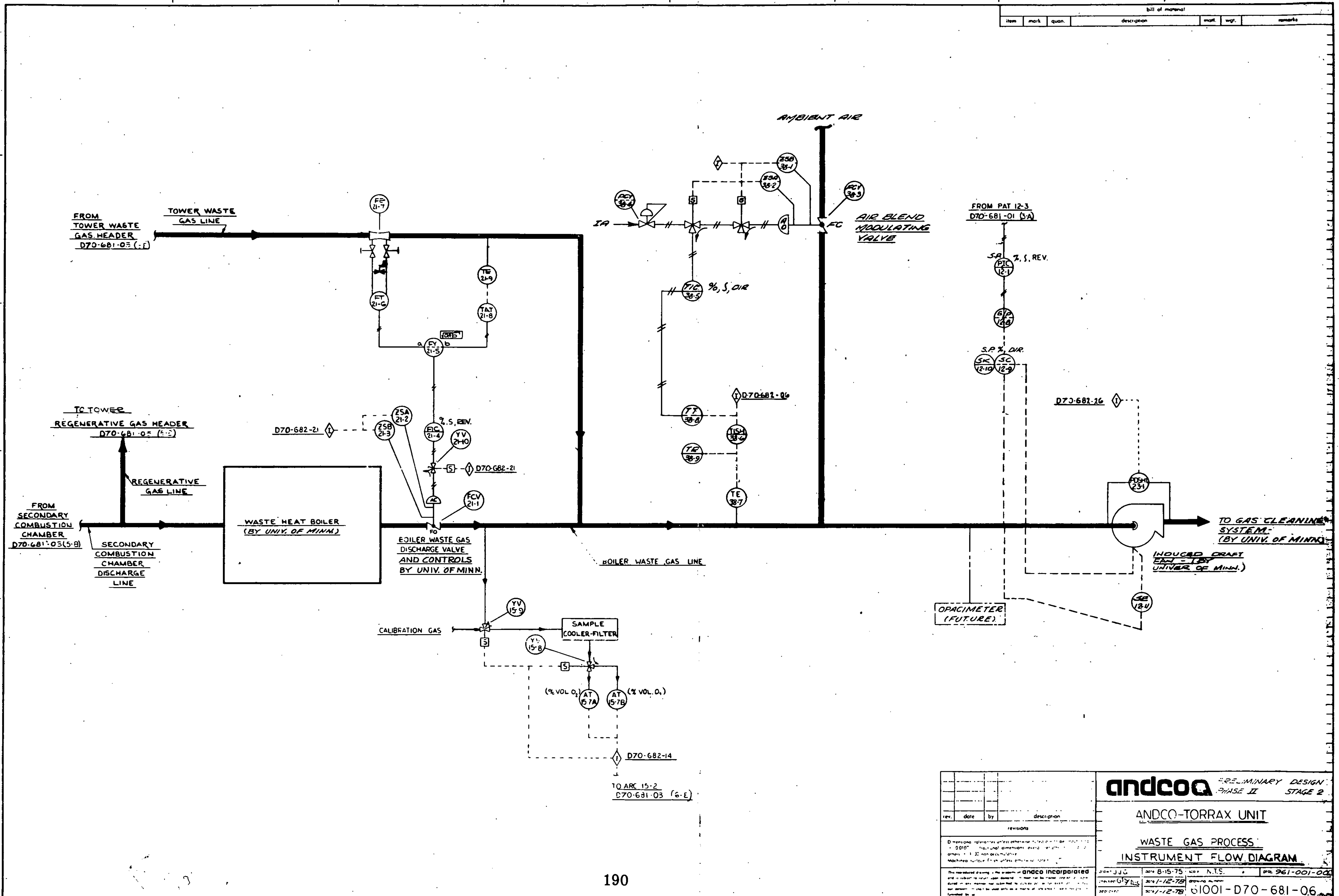


DOME MIXING AIR INLET
REGENERATIVE GAS TOWERS
HOT BLAST LINE
TO BUSTLE PIPE D70-681-01(6-E)
REGENERATIVE GAS LINE
FROM REGENERATIVE GAS LINE D70-681-06(1-C)
COLD AIR BLEND SHUT-OFF VALVE
COLD AIR BLEND MODULATING VALVE
COLD AIR BLEND LINE
FROM TT 2-9 D70-682-01 (5-E)
COLD BLAST LINE
AIR INLET
PRIMARY AIR BLOWER
TO TOWER WASTE GAS LINE D70-681-06(1-B)
TOWER WASTE GAS LINE
D70-682-01
D70-682-02
IAI
andco PRELIMINARY DESIGN PHASE II STAGE 2
ANDCO-TORRAX UNIT
PRIMARY AIR PROCESS
INSTRUMENT FLOW DIAGRAM
NTS.
961-001-00
61001-D70-681-05



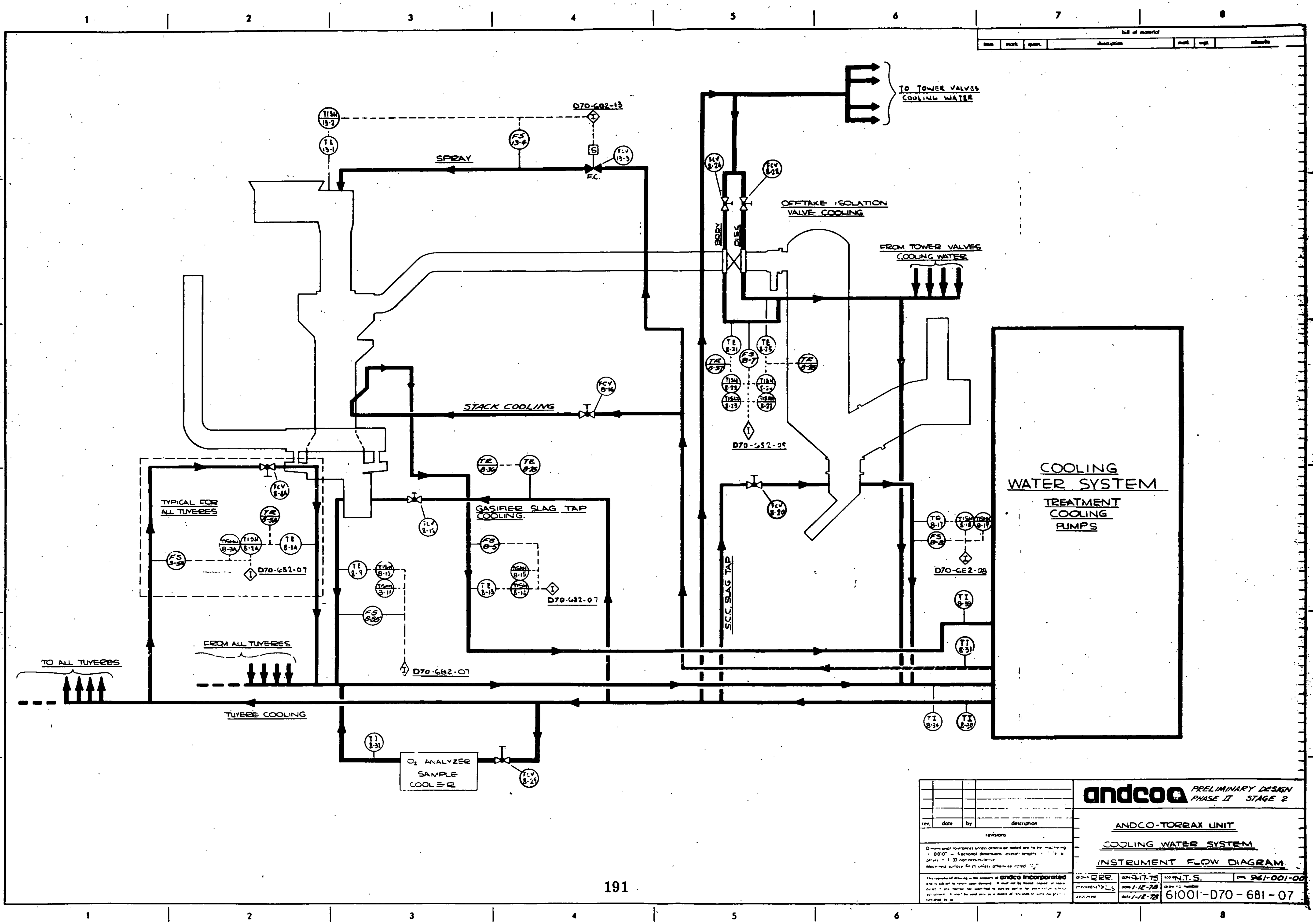
andco PRELIMINARY DESIGN PHASE II STAGE 2

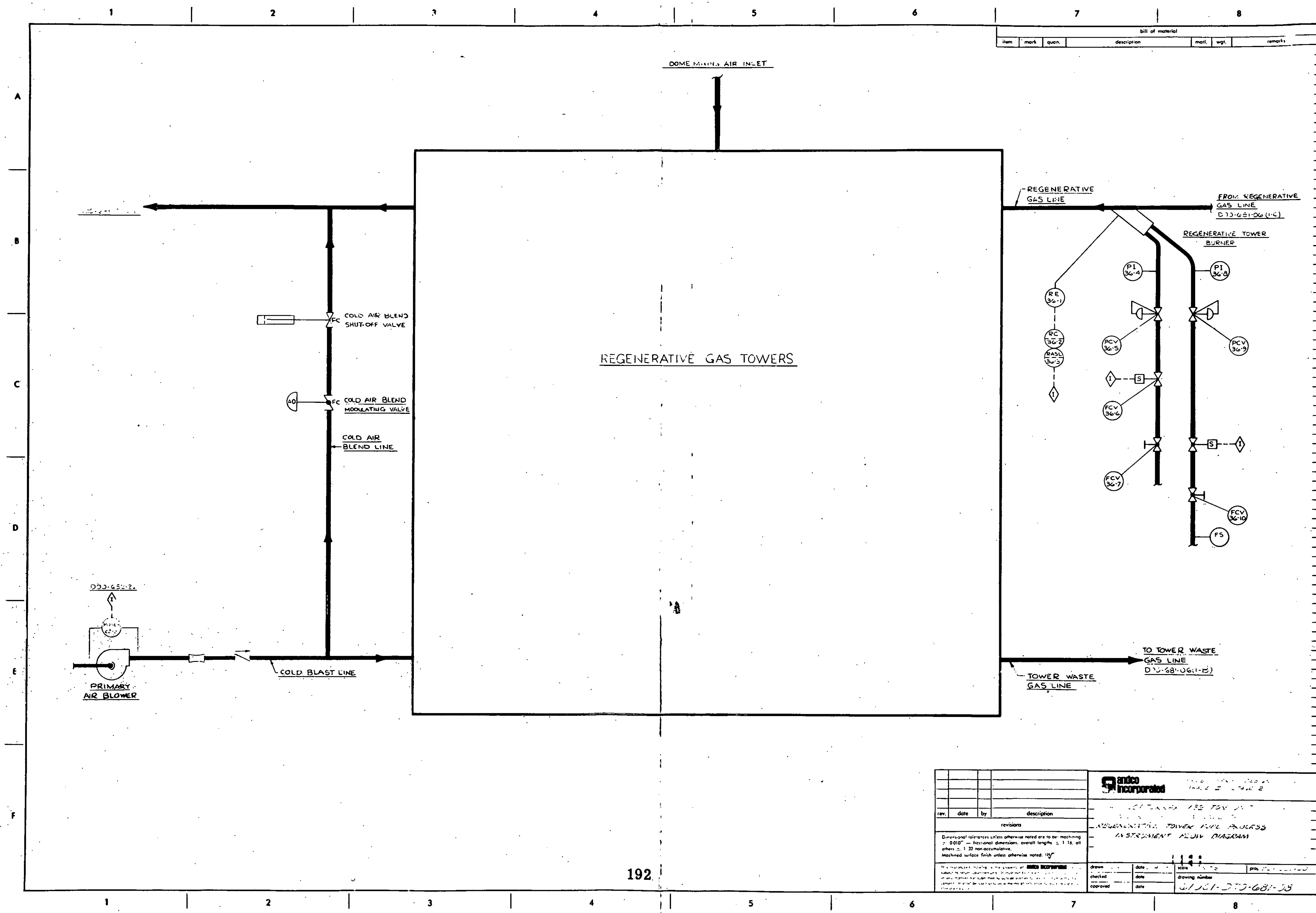
ANDCO-TORRAX UNIT

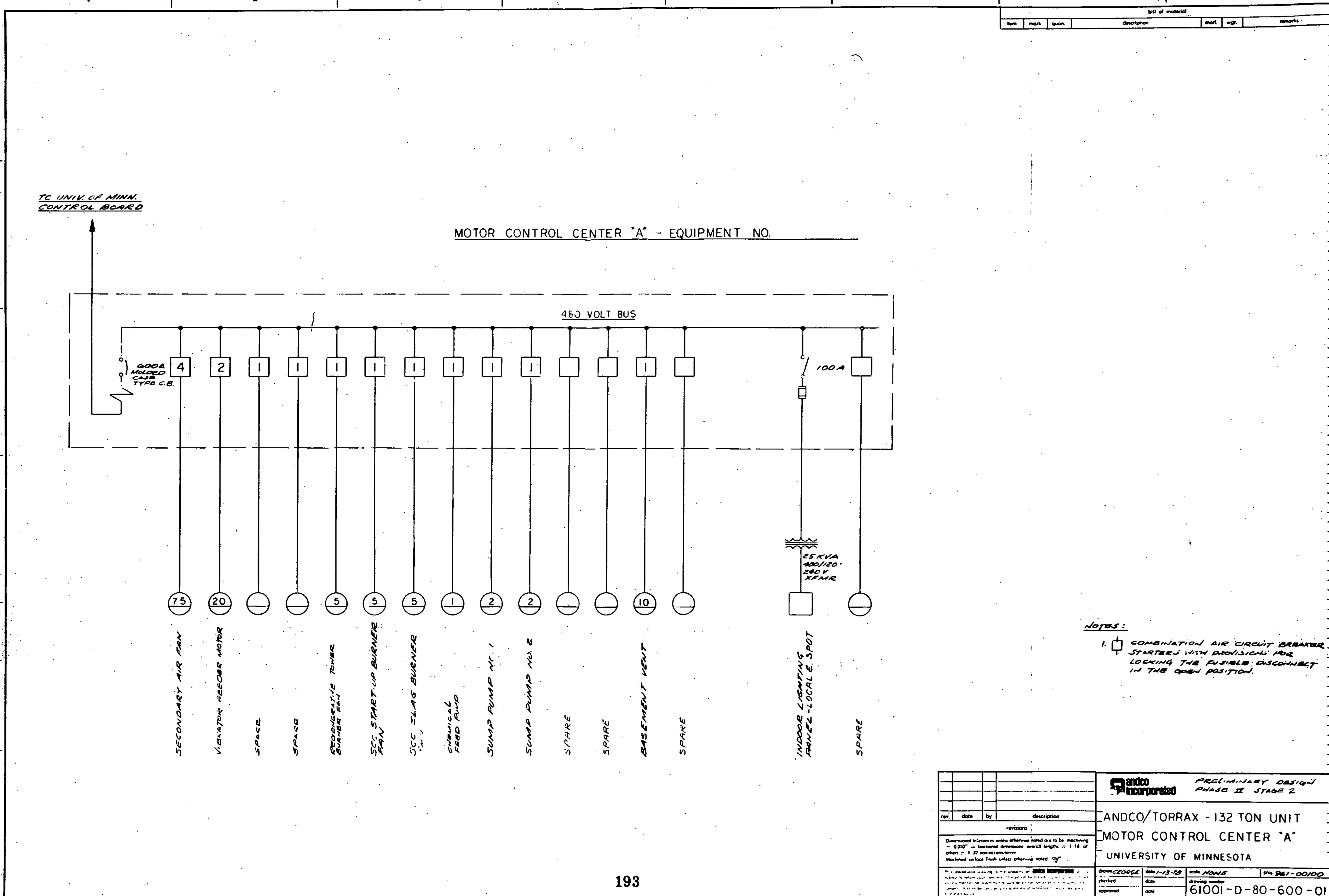
WASTE GAS PROCESS

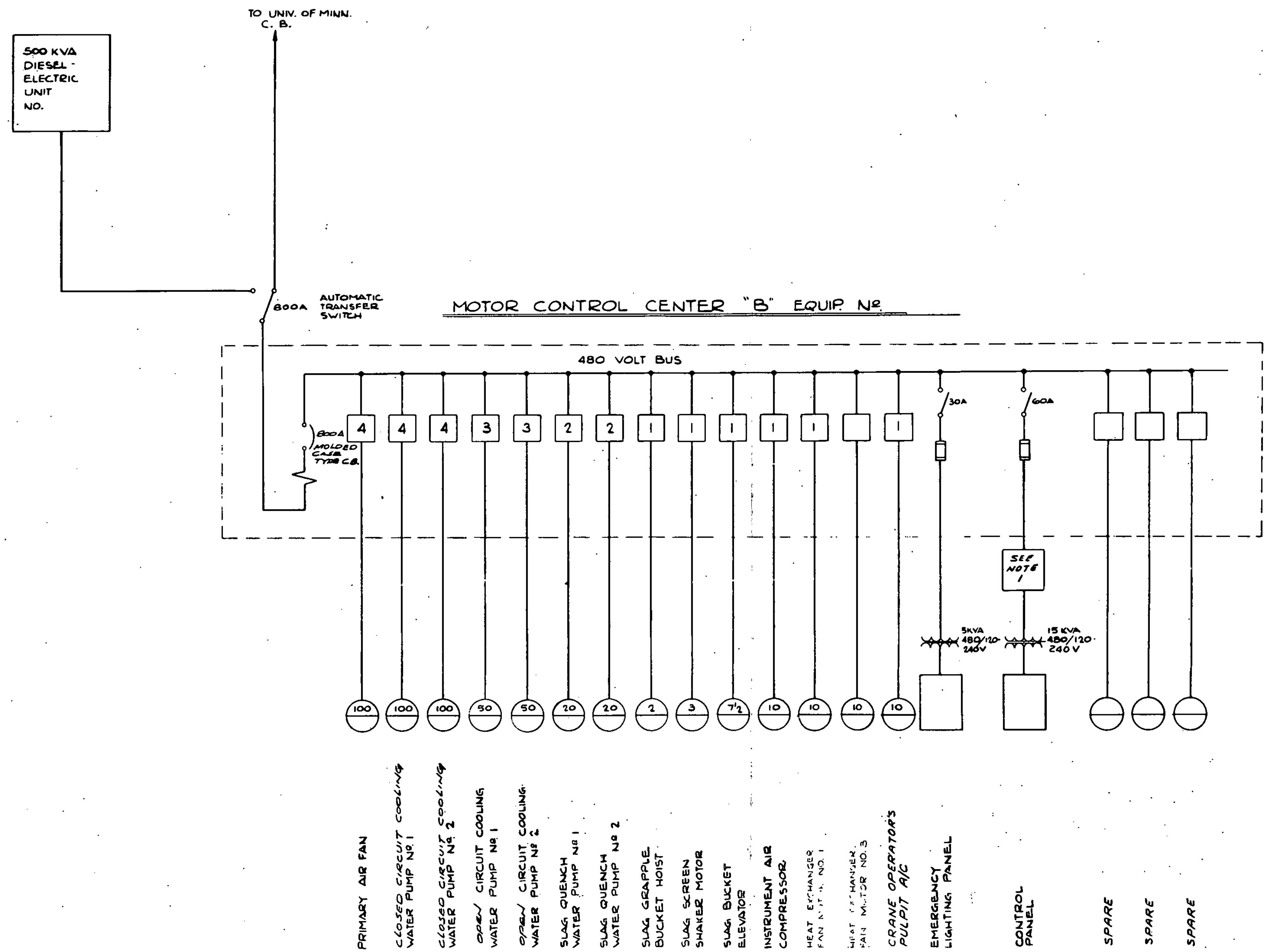
INSTRUMENT FLOW DIAGRAM

61001-D70-681-06


TO TOWER VALVES COOLING WATER
D70-682-13
SPRAY
F.C.
OFFTAKE ISOLATION VALVE COOLING
BODY
DISC
FROM TOWER VALVES COOLING WATER
STACK COOLING
D70-682-08
COOLING WATER SYSTEM
TREATMENT
COOLING
PUMPS
TYPICAL FOR ALL TUYERES
D70-682-07
GASIFIER SLAG TAP COOLING
S.C.C. SLAG TAP
D70-682-07
D70-682-08
FROM ALL TUYERES
TO ALL TUYERES
D70-682-07
TUYERE COOLING
O_2 ANALYZER SAMPLE COOLER
andco
PRELIMINARY DESIGN PHASE II STAGE 2
ANDCO-TORRAX UNIT
COOLING WATER SYSTEM
INSTRUMENT FLOW DIAGRAM
N.T.S.
961-001-00
61001-D70-681-07

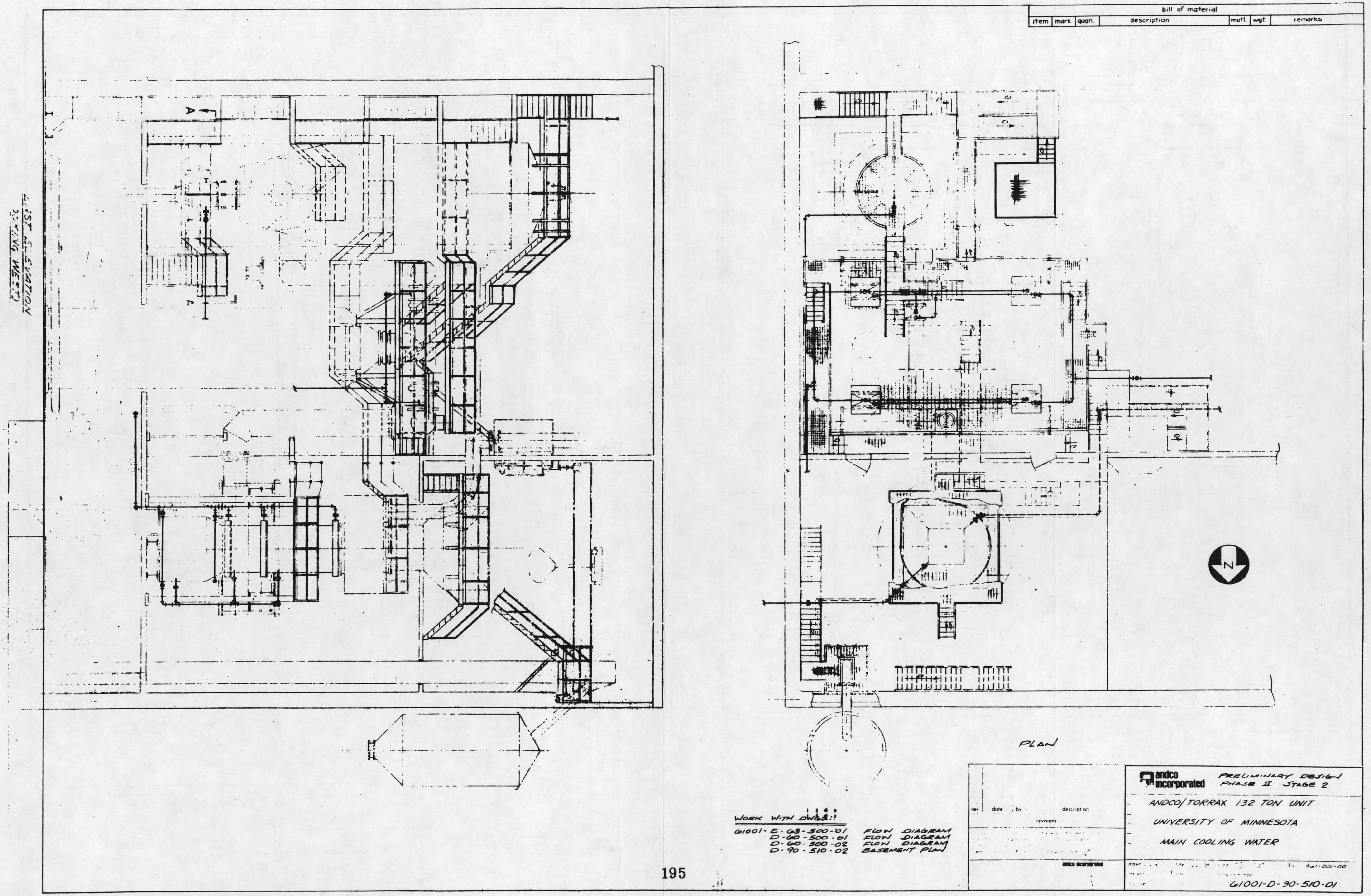

bill of material
item
mark
quan.
description
matl.
wgt.
remarks
DOME MIXING AIR INLET
REGENERATIVE GAS TOWERS
REGENERATIVE GAS LINE
FROM REGENERATIVE GAS LINE
REGENERATIVE TOWER BURNER
PI 36-4
PI 36-8
RE 36-1
RC 36-2
PCV 36-5
PCV 36-9
FCV 36-6
FCV 36-7
FCV 36-10
FS
COLD AIR BLEND SHUT-OFF VALVE
FC
COLD AIR BLEND MODULATING VALVE
AO
COLD AIR BLEND LINE
COLD BLAST LINE
PRIMARY AIR BLOWER
TO TOWER WASTE GAS LINE
TOWER WASTE GAS LINE
rev.
date
by
description
revisions
Dimensional tolerances unless otherwise noted are to be: machining ± 0.010" — fractional dimensions, overall lengths ± 1/16, all others ± 1/32 non-accumulative.
Machined surface finish unless otherwise noted: 125
andco incorporated
REGENERATIVE TOWER FUEL PROCESS
INSTRUMENT FLOW DIAGRAM
drawn
date
checked
date
approved
date
scale
proj.
drawing number

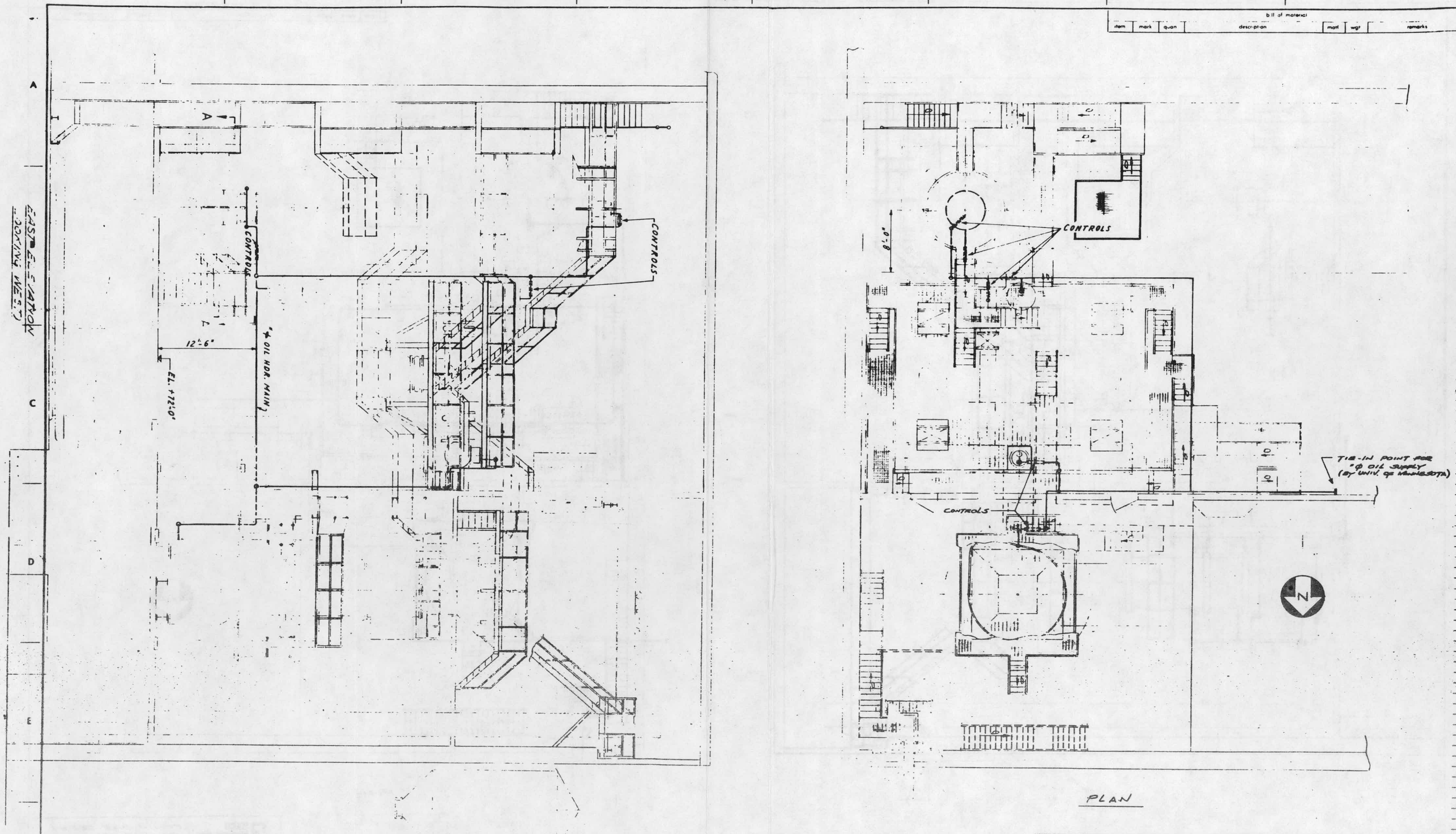

TO UNIV. OF MINN. CONTROL BOARD
MOTOR CONTROL CENTER "A" - EQUIPMENT NO.
460 VOLT BUS
600A MOLDED CASE TYPE C.B.
100A
25 KVA 480/120-240 V XFMR
75
20
5
5
5
1
2
2
10
SECONDARY AIR FAN
VIBRATOR FEEDER MOTOR
SPARE
SPARE
REGENERATIVE TOWER BURNER FAN
SCC START-UP BURNER FAN
SCC SLAG BURNER
CHEMICAL FEED PUMP
SUMP PUMP NO. 1
SUMP PUMP NO. 2
SPARE
SPARE
BASEMENT VENT
SPARE
INDOOR LIGHTING PANEL-LOCAL & SPOT
SPARE
NOTES:
1. COMBINATION AIR CIRCUIT BREAKER STARTERS WITH PROVISIONS FOR LOCKING THE FUSIBLE DISCONNECT IN THE OPEN POSITION.
bill of material
item
mark
quan.
description
matl.
wgt.
remarks
rev.
date
by
description
revisions
Dimensional tolerances unless otherwise noted are to be machining ± 0.010" — fractional dimensions: overall lengths ± 1/16, all others ± 1/32 non-accumulative
Machined surface finish unless otherwise noted 125
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX - 132 TON UNIT
MOTOR CONTROL CENTER "A"
UNIVERSITY OF MINNESOTA
drawn GEORGE
date 1-13-78
scale NONE
proj. 961-00100
checked
date
approved
date
drawing number
61001-D-80-600-01



NOTES
1. UNINTERUPTABLE POWER UNIT BATTERIES INVERTER FILTER
2. COMBINATION AIR CIRCUIT BREAKER STARTERS WITH PROVISIONS FOR LOCKING THE FUSIBLE DISCONNECT IN THE OPEN POSITION.

andco Incorporated	PRELIMINARY DESIGN PHASE II STAGE 2
ANDCO/TORRAX 132 TON UNIT	
MOTOR CONTROL CENTER "B"	
UNIVERSITY OF MINNESOTA	
drawn D.J.M. date 1-13-78	scale N.T.S. proj. 961-00100
drawing number	61001-D80-600-02


bill of material
item | mark | quan. | description | matl. | wgt. | remarks
EAST ELEVATION
(LOOKING WEST)
A
A
N
PLAN
WORK WITH DWGS.:
G1001-E-63-500-01 FLOW DIAGRAM
D-60-500-01 FLOW DIAGRAM
D-60-500-02 FLOW DIAGRAM
D-90-510-02 BASEMENT PLAN
rev | date | by | description
revisions
andco incorporated
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 TON UNIT
UNIVERSITY OF MINNESOTA
MAIN COOLING WATER
G1001-D-90-510-01



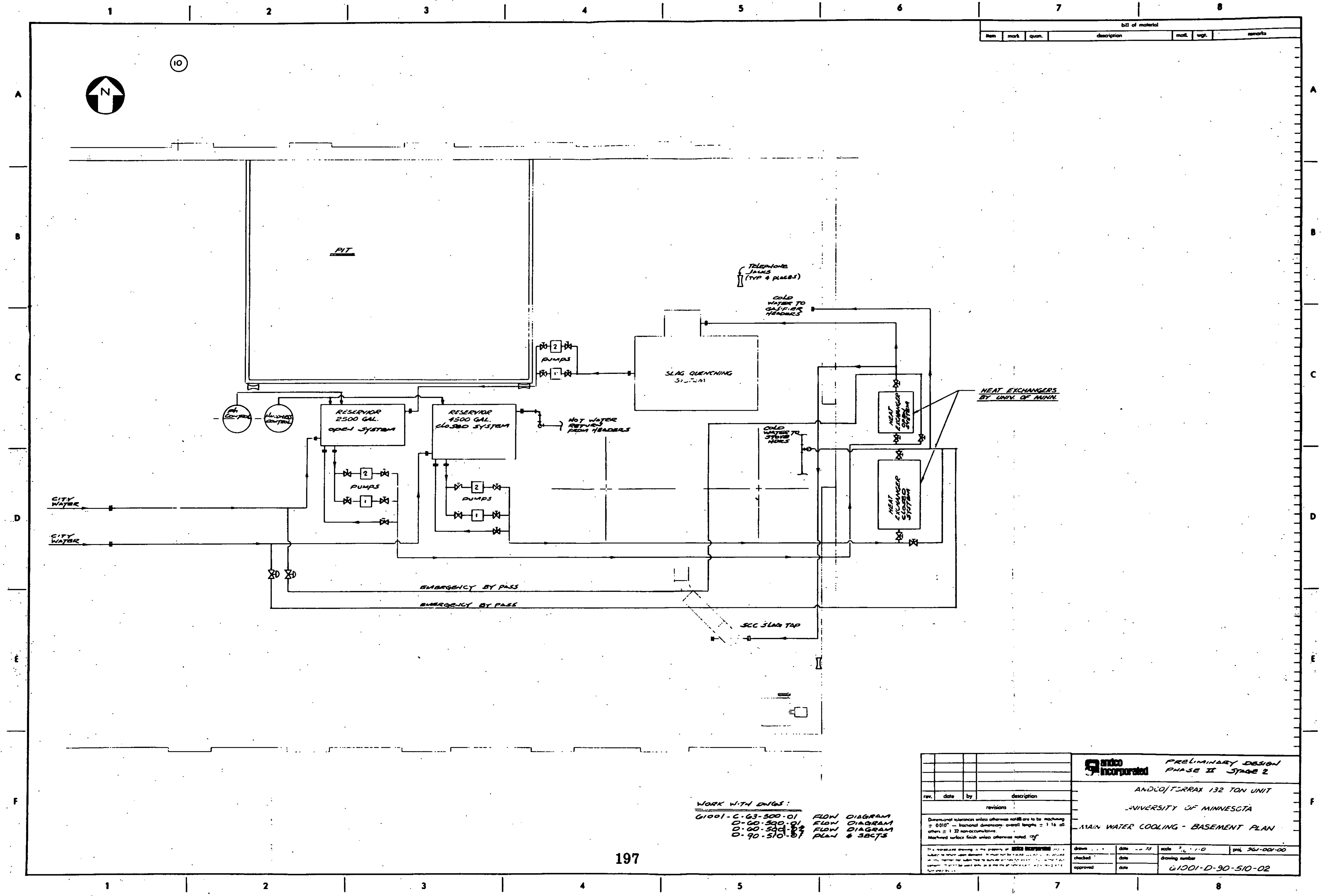
WORK WITH DWGS.:
61001-D-00-000-01A GENERAL ARRANGEMENT-PLAN
D-97-530-01 AUXILIARY FUEL DIAGRAM
D-90-510-03 FUEL GAS ROUTING

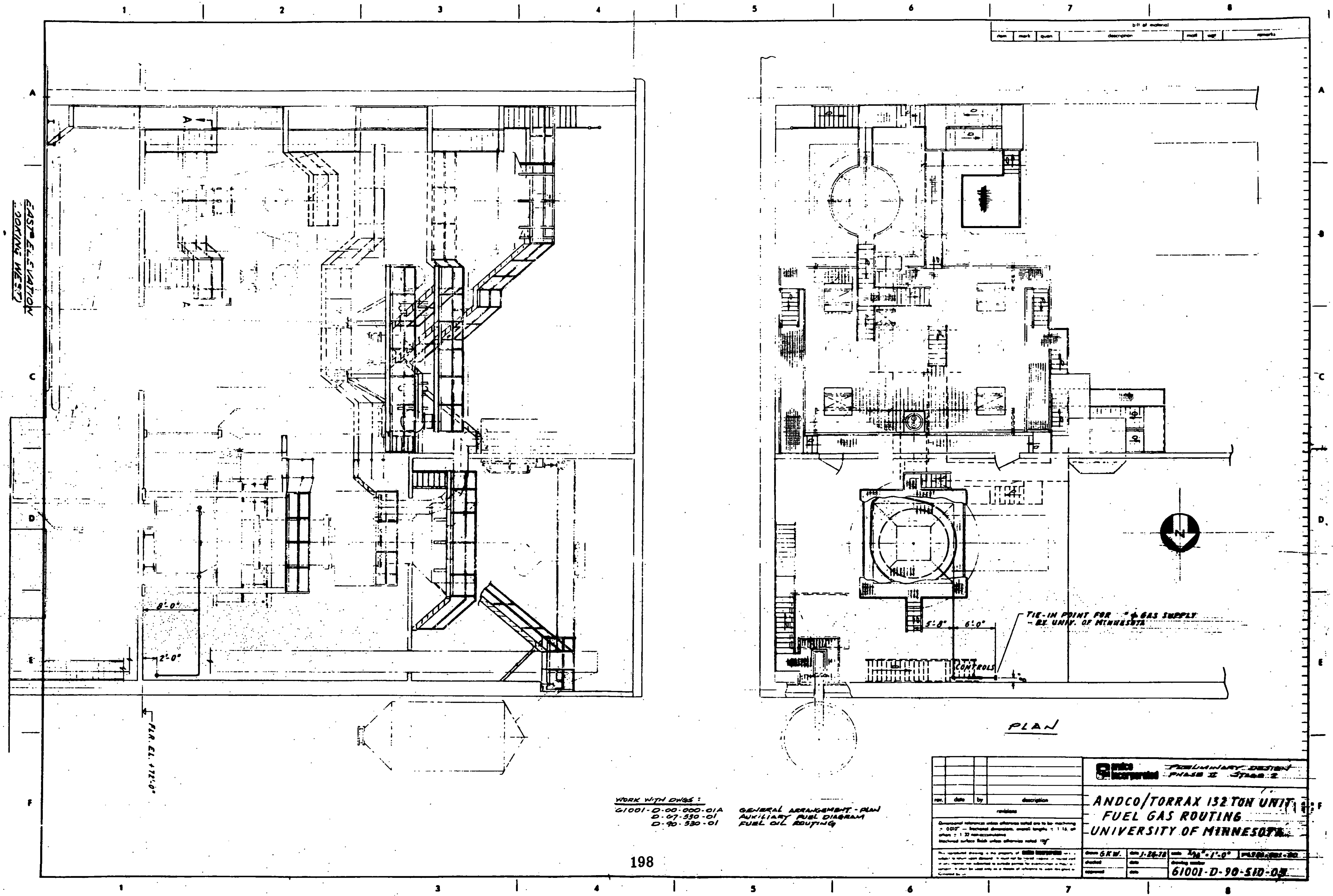
andco incorporated

PRELIMINARY DESIGN
PHASE II STAGE 2

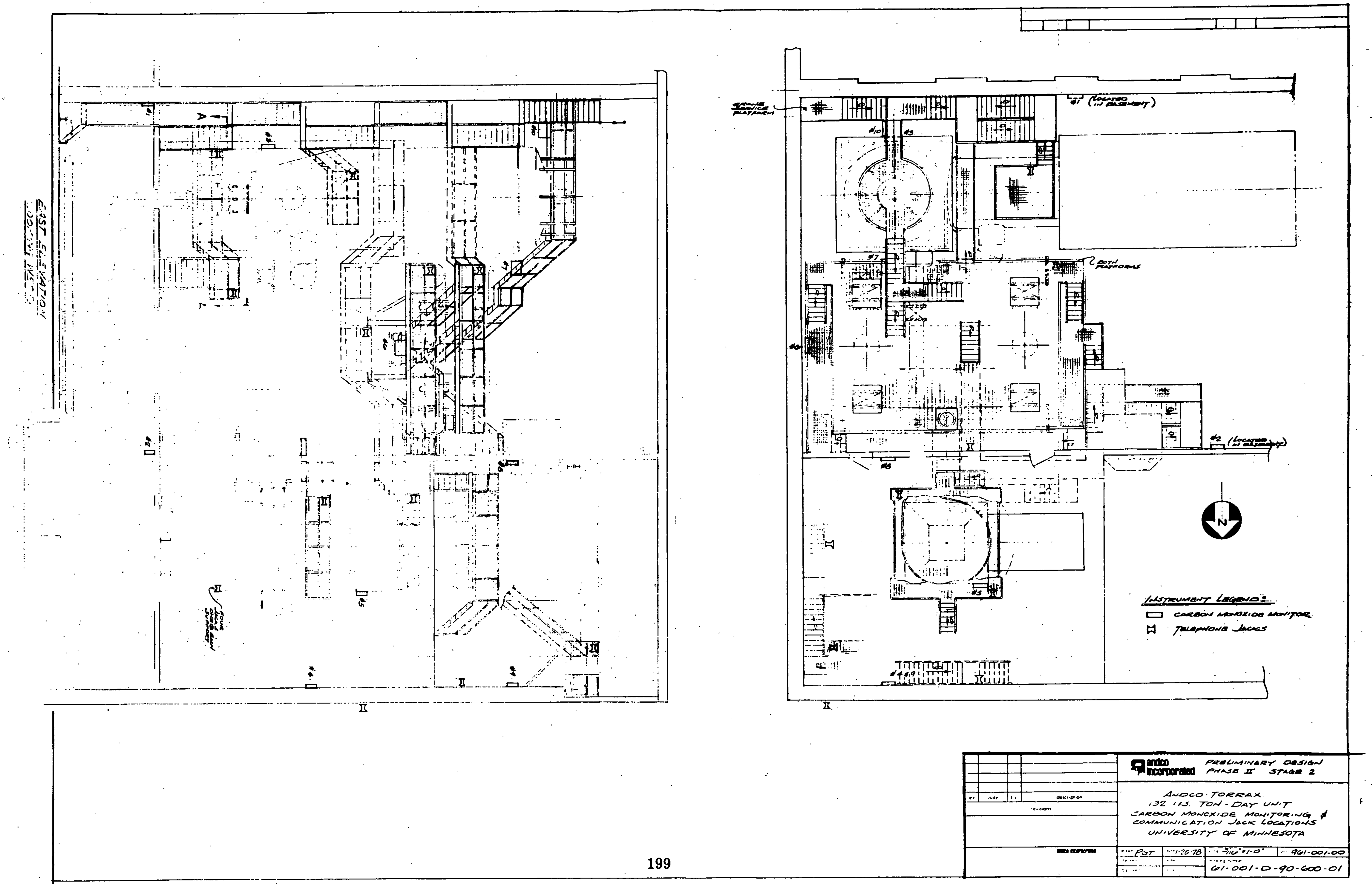
ANDCO/TORRAX 132 TON UNIT
FUEL OIL ROUTING
UNIVERSITY OF MINNESOTA

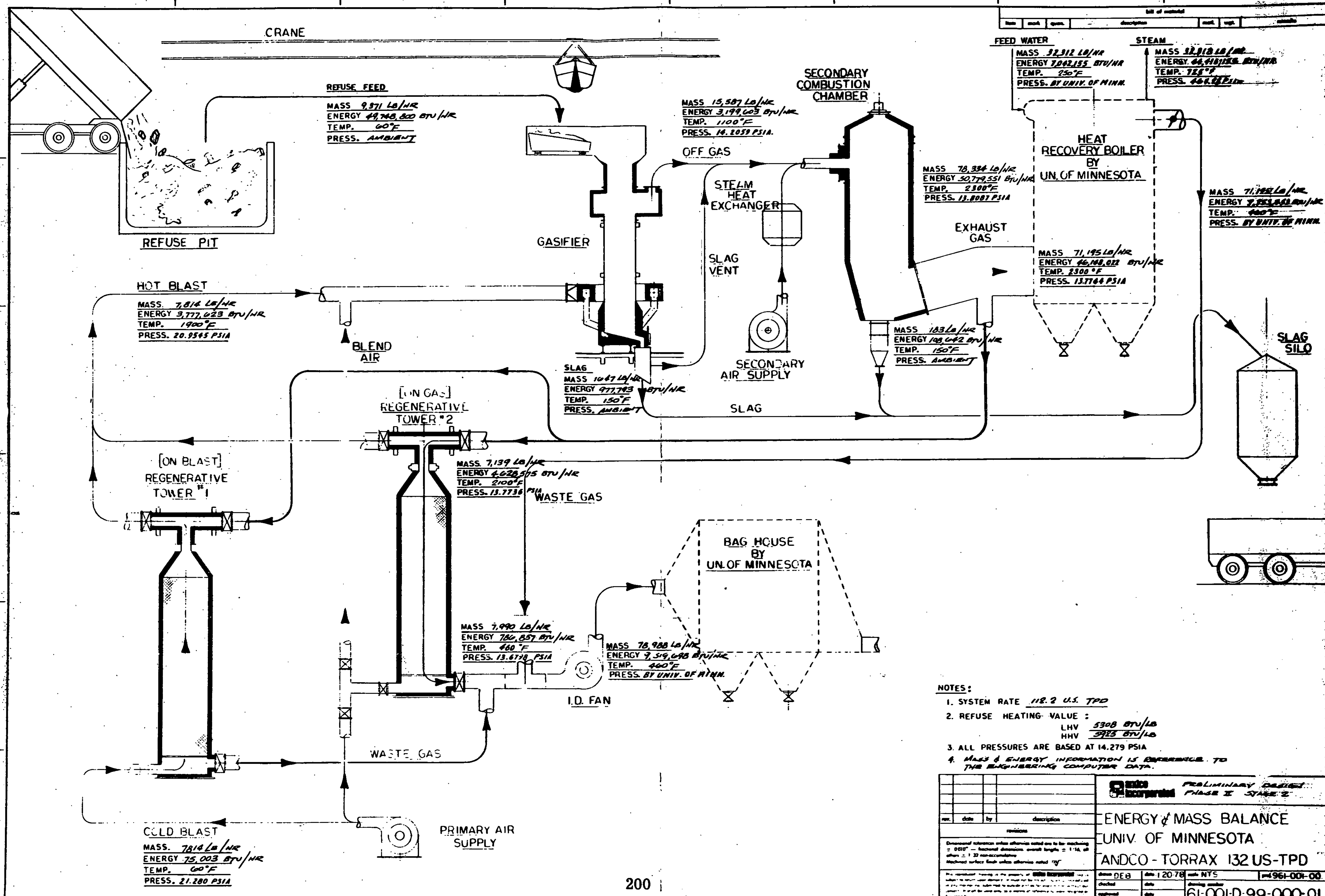
drawn G.K.W. date 1-25-78 scale 3/16" = 1'-0"
checked
approved
drawing number 61001-D-90-530-01

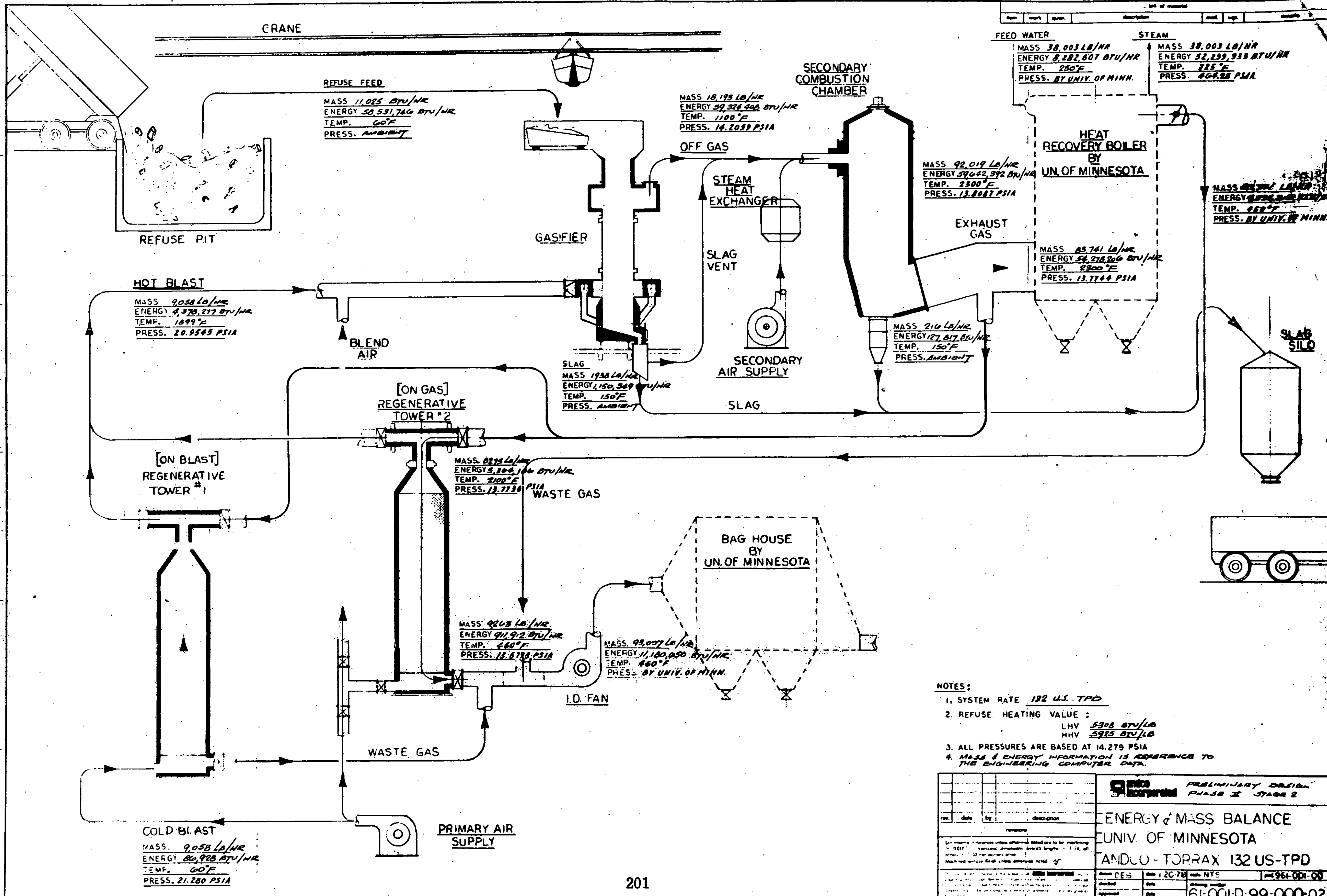

PIT
RESERVOIR 2500 GAL. OPEN SYSTEM
RESERVOIR 4500 GAL. CLOSED SYSTEM
PUMPS
SLAG QUENCHING SYSTEM
HOT WATER RETURN FROM HEADERS
COLD WATER TO GASIFIER HEADERS
HEAT EXCHANGERS BY UNIV. OF MINN.
CITY WATER
CITY WATER
EMERGENCY BY PASS
EMERGENCY BY PASS
SCC SLAG TAP
WORK WITH DWGS:
G1001-C-63-500-01 FLOW DIAGRAM
D-60-500-01 FLOW DIAGRAM
D-60-500-02 FLOW DIAGRAM
D-90-510-01 PLAN & SECTS
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 TON UNIT
UNIVERSITY OF MINNESOTA
MAIN WATER COOLING - BASEMENT PLAN
rev. date by description
revisions
drawn
checked
approved
date
proj. 961-001-00
drawing number
G1001-D-90-510-02



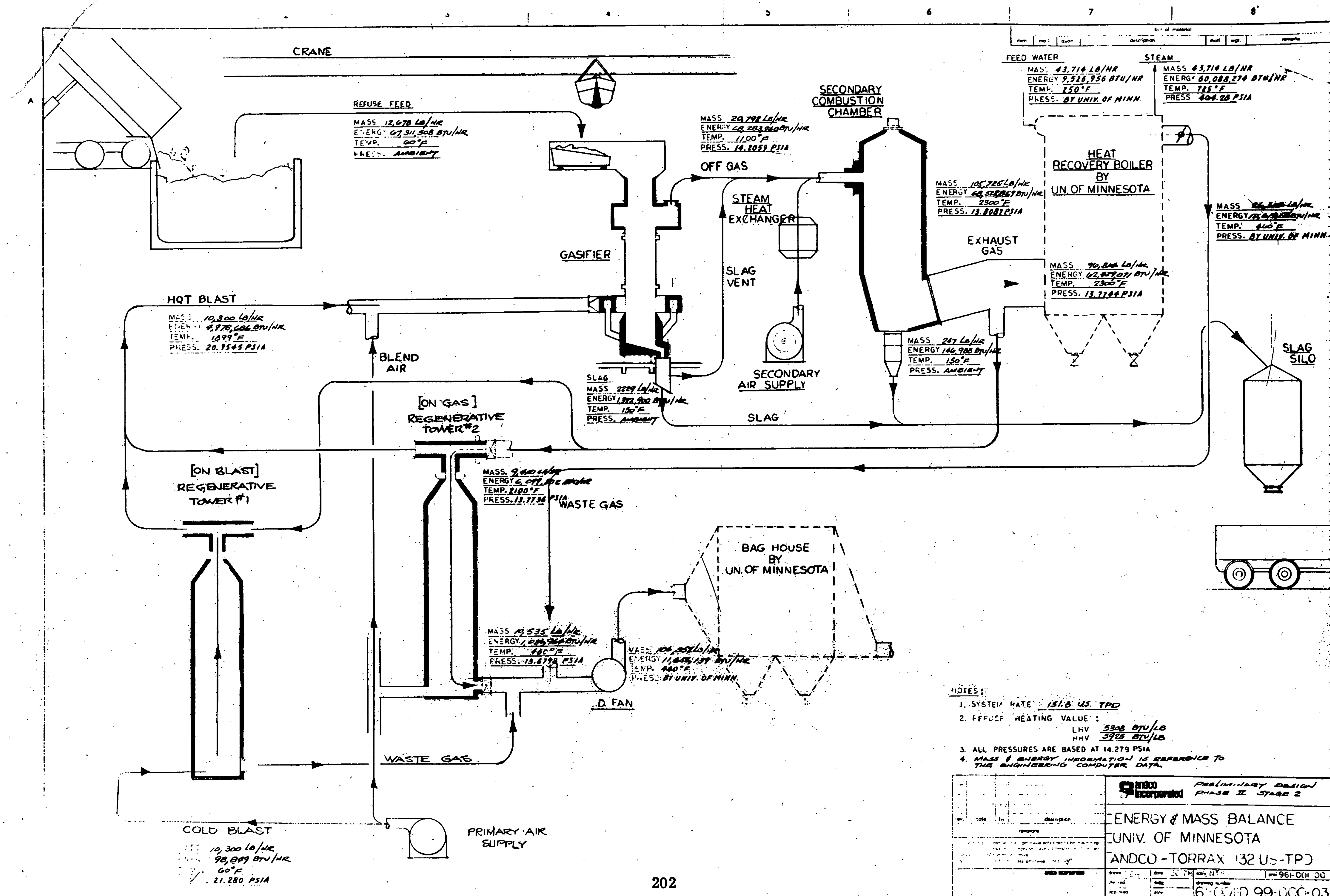
EAST ELEVATION
LOOKING WEST
8'-0"
2'-0"
FLR. EL. 172'-0"
TIE-IN POINT FOR " GAS SUPPLY
- BY UNIV. OF MINNESOTA
5'-8"
6'-0"
CONTROLS
PLAN
WORK WITH DWGS :
61001-D-00-000-01A GENERAL ARRANGEMENT - PLAN
D-07-530-01 AUXILIARY FUEL DIAGRAM
D-90-530-01 FUEL OIL ROUTING
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 TON UNIT
FUEL GAS ROUTING
UNIVERSITY OF MINNESOTA
GKW.
1-26-78
61001-D-90-510-01

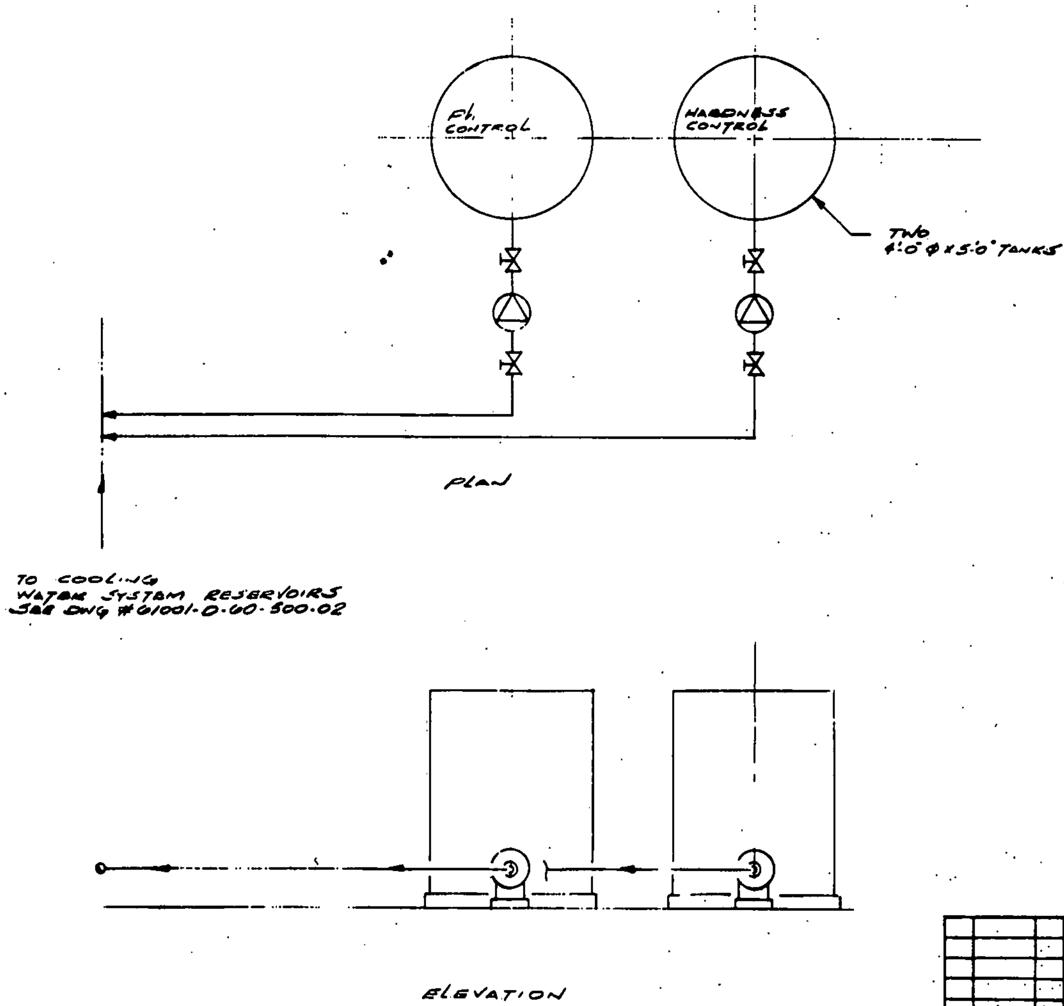

EAST ELEVATION
A
GRANE SERVICE PLATFORM
#1 (LOCATED IN BASEMENT)
#2 (LOCATED IN BASEMENT)
BOTH PLATFORMS
N
INSTRUMENT LEGEND:
CARBON MONOXIDE MONITOR
TELEPHONE JACKS
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO-TORRAX
132 U.S. TON-DAY UNIT
CARBON MONOXIDE MONITORING &
COMMUNICATION JACK LOCATIONS
UNIVERSITY OF MINNESOTA
PGT
1-25-78
3/16"=1'-0"
961-001-00
61-001-D-90-600-01
description
revisions


CRANE
REFUSE FEED
MASS 9,371 LB/HR
ENERGY 49,748,800 BTU/HR
TEMP. 60°F
PRESS. AMBIENT
REFUSE PIT
GASIFIER
MASS 15,587 LB/HR
ENERGY 3,199,603 BTU/HR
TEMP. 1100°F
PRESS. 14.2059 PSIA.
OFF GAS
SECONDARY COMBUSTION CHAMBER
STEAM HEAT EXCHANGER
SLAG VENT
SECONDARY AIR SUPPLY
MASS 78,334 LB/HR
ENERGY 50,779,551 BTU/HR
TEMP. 2300°F
PRESS. 13.8087 PSIA
EXHAUST GAS
FEED WATER
MASS 32,312 LB/HR
ENERGY 7,042,155 BTU/HR
TEMP. 250°F
PRESS. BY UNIV. OF MINN.
STEAM
HEAT RECOVERY BOILER BY UN. OF MINNESOTA
MASS 71,195 LB/HR
ENERGY 46,148,022 BTU/HR
TEMP. 2300 °F
PRESS. 13.7764 PSIA
HOT BLAST
MASS 7,814 LB/HR
ENERGY 3,777,623 BTU/HR
TEMP. 1900°F
PRESS. 20.9545 PSIA
BLEND AIR
SLAG
MASS 1047 LB/HR
ENERGY 977,793 BTU/HR
TEMP. 150°F
PRESS. AMBIENT
MASS 183 LB/HR
ENERGY 108,042 BTU/HR
TEMP. 150°F
PRESS. AMBIENT
SLAG
SLAG SILO
[ON GAS] REGENERATIVE TOWER #2
[ON BLAST] REGENERATIVE TOWER #1
MASS 7,139 LB/HR
ENERGY 4,628,575 BTU/HR
TEMP. 2100°F
PRESS. 13.7736 PSIA
WASTE GAS
BAG HOUSE BY UN. OF MINNESOTA
MASS 7,990 LB/HR
ENERGY 780,857 BTU/HR
TEMP. 460°F
PRESS. 13.6798 PSIA
MASS 78,988 LB/HR
ENERGY 9,319,698 BTU/HR
TEMP. 460°F
PRESS. BY UNIV. OF MINN.
I.D. FAN
WASTE GAS
COLD BLAST
MASS 7814 LB/HR
ENERGY 75,003 BTU/HR
TEMP. 60°F
PRESS. 21.280 PSIA
PRIMARY AIR SUPPLY
NOTES:
1. SYSTEM RATE 118.2 U.S. TPD
2. REFUSE HEATING VALUE:
LHV 5308 BTU/LB
HHV 5925 BTU/LB
3. ALL PRESSURES ARE BASED AT 14.279 PSIA
4. MASS & ENERGY INFORMATION IS REFERENCE TO THE ENGINEERING COMPUTER DATA.
PRELIMINARY DESIGN PHASE II STAGE 2
ENERGY & MASS BALANCE
UNIV. OF MINNESOTA
ANDCO - TORRAX 132 US-TPD
DEB
1 20 78
NTS
961-001-00
61-001-D-99-000-01



CRANE
REFUSE FEED
MASS 11,025 BTU/HR
ENERGY 58,531,766 BTU/HR
TEMP. 60°F
PRESS. AMBIENT
REFUSE PIT
GASIFIER
OFF GAS
MASS 18,193 LB/HR
ENERGY 59,326,605 BTU/HR
TEMP. 1100°F
PRESS. 14.2059 PSIA
SECONDARY COMBUSTION CHAMBER
STEAM HEAT EXCHANGER
SLAG VENT
SECONDARY AIR SUPPLY
MASS 92,019 LB/HR
ENERGY 59,662,392 BTU/HR
TEMP. 2300°F
PRESS. 13.8087 PSIA
EXHAUST GAS
FEED WATER
MASS 38,003 LB/HR
ENERGY 8,282,607 BTU/HR
TEMP. 250°F
PRESS. BY UNIV. OF MINN.
STEAM
MASS 38,003 LB/HR
ENERGY 52,239,933 BTU/HR
TEMP. 825°F
PRESS. 464.98 PSIA
HEAT RECOVERY BOILER BY UN. OF MINNESOTA
MASS 83,741 LB/HR
ENERGY 54,278,206 BTU/HR
TEMP. 2300°F
PRESS. 13.7744 PSIA
PRESS. BY UNIV. OF MINN.
MASS 216 LB/HR
ENERGY 127,817 BTU/HR
TEMP. 150°F
PRESS. AMBIENT
SLAG SILO
HOT BLAST
MASS 9,058 LB/HR
ENERGY 4,378,277 BTU/HR
TEMP. 1899°F
PRESS. 20.9545 PSIA
BLEND AIR
SLAG
MASS 1938 LB/HR
ENERGY 1,150,369 BTU/HR
TEMP. 150°F
PRESS. AMBIENT
SLAG
[ON GAS] REGENERATIVE TOWER #2
[ON BLAST] REGENERATIVE TOWER #1
MASS 8896 LB/HR
ENERGY 5,806,166 BTU/HR
TEMP. 2100°F
PRESS. 13.7736 PSIA
WASTE GAS
BAG HOUSE BY UN. OF MINNESOTA
MASS 9268 LB/HR
ENERGY 911,912 BTU/HR
TEMP. 460°F
PRESS. 13.6798 PSIA
MASS 93,007 LB/HR
ENERGY 11,180,050 BTU/HR
TEMP. 460°F
PRESS. BY UNIV. OF MINN.
I.D. FAN
WASTE GAS
COLD BLAST
MASS 9,058 LB/HR
ENERGY 86,928 BTU/HR
TEMP. 60°F
PRESS. 21.280 PSIA
PRIMARY AIR SUPPLY
NOTES:
1. SYSTEM RATE 132 U.S. TPD
2. REFUSE HEATING VALUE : LHV 5308 BTU/LB HHV 5925 BTU/LB
3. ALL PRESSURES ARE BASED AT 14.279 PSIA
4. MASS & ENERGY INFORMATION IS REFERENCE TO THE ENGINEERING COMPUTER DATA.
unico incorporated
PRELIMINARY DESIGN PHASE II STAGE 2
ENERGY & MASS BALANCE
UNIV. OF MINNESOTA
ANDCO - TORRAX 132 US-TPD
CEB 1-20-78 NTS
61-001-D-99-000-02


CRANE
REFUSE FEED
MASS 12,678 LB/HR
ENERGY 67,311,508 BTU/HR
TEMP. 60°F
PRESS. AMBIENT
GASIFIER
OFF GAS
MASS 20,798 LB/HR
TEMP. 1100°F
PRESS. 14.2059 PSIA
SECONDARY COMBUSTION CHAMBER
STEAM HEAT EXCHANGER
SLAG VENT
SECONDARY AIR SUPPLY
FEED WATER
MASS 43,714 LB/HR
ENERGY 9,526,956 BTU/HR
TEMP. 250°F
PRESS. BY UNIV. OF MINN.
STEAM
MASS 43,714 LB/HR
ENERGY 60,088,274 BTU/HR
TEMP. 725°F
HEAT RECOVERY BOILER BY UN. OF MINNESOTA
MASS 105,725 LB/HR
TEMP. 2300°F
PRESS. 13.8087 PSIA
EXHAUST GAS
TEMP. 2300°F
PRESS. 13.7744 PSIA
TEMP. 460°F
PRESS. BY UNIV. OF MINN.
MASS 267 LB/HR
ENERGY 164,988 BTU/HR
TEMP. 150°F
PRESS. AMBIENT
SLAG
MASS 2229 LB/HR
TEMP. 150°F
PRESS. AMBIENT
SLAG SILO
HOT BLAST
MASS 10,300 LB/HR
ENERGY 9,978,686 BTU/HR
TEMP. 1899°F
PRESS. 20.9545 PSIA
BLEND AIR
[ON GAS] REGENERATIVE TOWER #2
[ON BLAST] REGENERATIVE TOWER #1
TEMP. 2100°F
PRESS. 13.7738 PSIA
WASTE GAS
BAG HOUSE BY UN. OF MINNESOTA
TEMP. 460°F
PRESS. 13.6798 PSIA
TEMP. 460°F
PRESS. BY UNIV. OF MINN.
I.D. FAN
WASTE GAS
COLD BLAST
10,300 LB/HR
98,849 BTU/HR
60°F
21.280 PSIA
PRIMARY AIR SUPPLY
NOTES:
1. SYSTEM RATE 151.8 U.S. TPD
2. REFUSE HEATING VALUE:
LHV 5308 BTU/LB
HHV 3925 BTU/LB
3. ALL PRESSURES ARE BASED AT 14.279 PSIA
4. MASS & ENERGY INFORMATION IS REFERENCE TO THE ENGINEERING COMPUTER DATA.
andco incorporated
PRELIMINARY DESIGN PHASE II STAGE 2
ENERGY & MASS BALANCE
UNIV. OF MINNESOTA
ANDCO-TORRAX 132 US-TPD



WORK WITH DWGS :

61001-D-60-500-01	FLOW DIAGRAM
D-60-500-02	FLOW DIAGRAM
D-90-510-01	PLAN & SECTS
D-90-510-02	BASEMENT PLAN

rev.	date	by	description

revisions

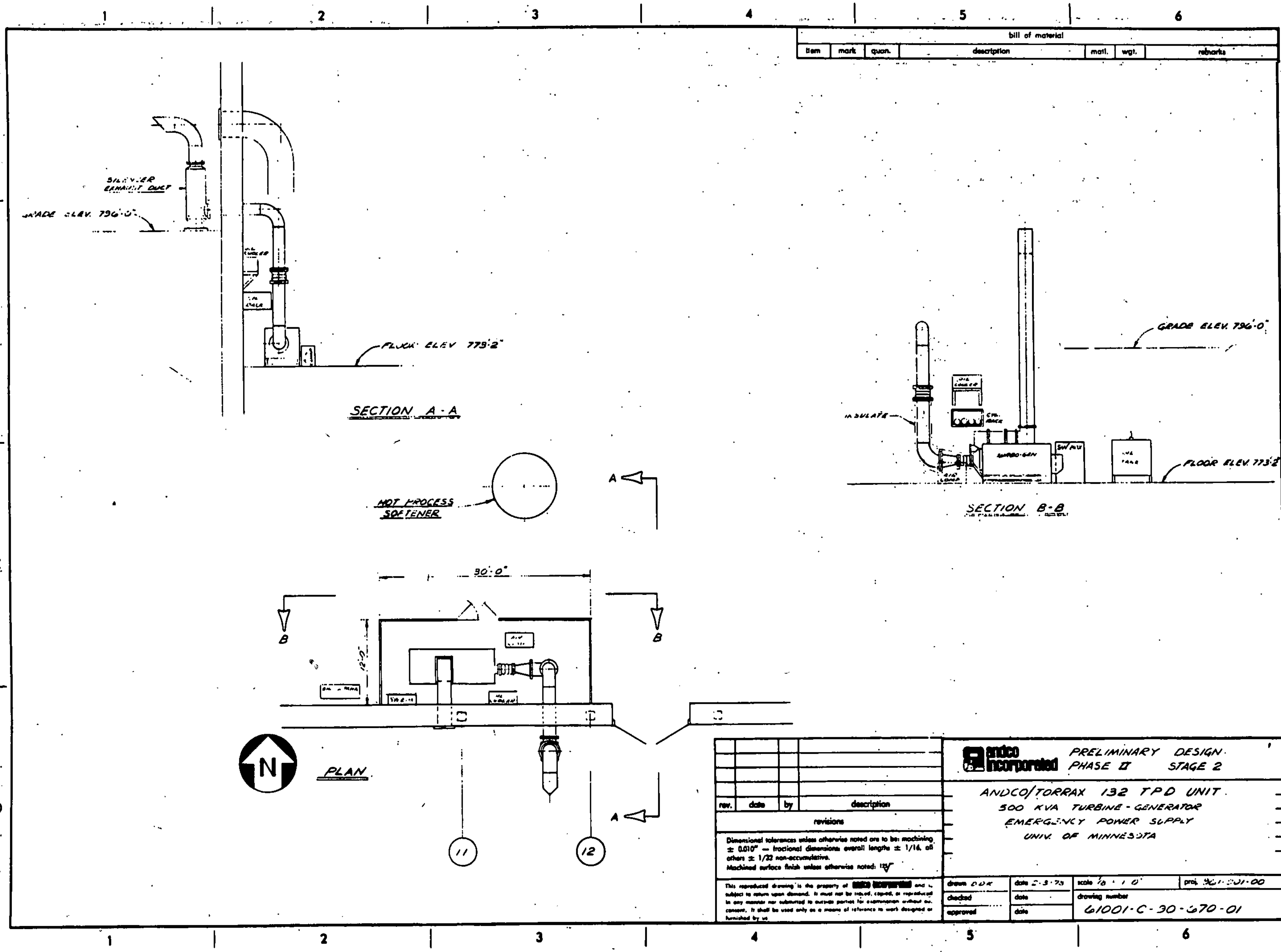
Dimensional tolerances unless otherwise noted are to be: machining ± 0.010" — fractional dimensions: overall lengths ± 1/16, all others ± 1/32 non-accumulative.
Machined surface finish unless otherwise noted: 125

andco incorporated

PRELIMINARY DESIGN
PHASE II STAGE 2

UNIVERSITY OF MINNESOTA
ANDCO · TORRAX · 132 US TON/DAY UNIT
WATER TREATMENT SYSTEM
FLOW DIAGRAM

drawn RGT	date 1-28-78	scale NONE	proj. 901-001-00
checked	date	drawing number	61001-C-63-500-01
approved	date		


bill of material
item | mark | quan. | description | matl. | wgt. | remarks
SILENCER
EXHAUST DUCT
GRADE ELEV. 796'-0"
FLOOR ELEV. 773'-2"
SECTION A-A
GRADE ELEV. 796'-0"
INSULATE
TURBO-GEN
FLOOR ELEV. 773'-2"
SECTION B-B
HOT PROCESS SOFTENER
A
A
B
B
90'-0"
12'-0"
N
PLAN
11
12
rev. | date | by | description
revisions
Dimensional tolerances unless otherwise noted are to be: machining ± 0.010" — fractional dimensions overall lengths ± 1/16, all others ± 1/32 non-accumulative.
Machined surface finish unless otherwise noted: 125
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and is subject to return upon demand. It must not be traced, copied, or reproduced in any manner nor submitted to outside parties for examination without our consent. It shall be used only as a means of reference to work designed or furnished by us
andco incorporated
PRELIMINARY DESIGN
PHASE II STAGE 2
ANDCO/TORRAX 132 TPD UNIT
500 KVA TURBINE-GENERATOR
EMERGENCY POWER SUPPLY
UNIV. OF MINNESOTA
drawn DDK
date 2-3-75
scale 1/8" = 1'-0"
checked
date
approved
date
drawing number
61001-C-30-670-01