COAL TO METHANOL FEASIBILITY STUDY BELUGA METHANOL PROJECT

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FINAL REPORT

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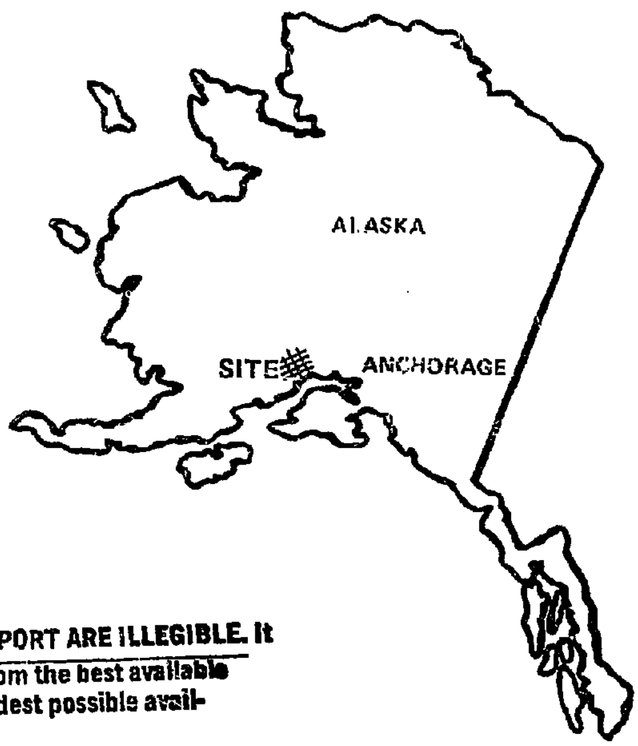
VOLUME II
TECHNICAL



COOK INLET REGION, INC.
AND
PLACER AMEX INC.

SEPTEMBER 1981

VOLUME II

COAL-TO-METHANOL PLANT

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TASK CROSS REFERENCE

The organization of this report does not follow the sequence of Tasks 1.00 through 9.00 in the Statement of Work and Study Schedule stipulated in the CIRI/Placer Proposal of 25 April, 1980. It has been found more convenient and orderly to arrange the subject matter as now presented in Volumes I through V.

To enable those concerned to review the study findings with respect to the associated assigned tasks, the following cross referenced tabulation is provided.

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9.03	Reports	Quarterly reports issued during Phase I. Progress reports will be issued as required in future phases.	

SECTION 1.0

INTRODUCTION

1.1 GENERAL

This Volume II contains the rationale for and conceptual design of the coal to methanol plant, and describes the feedstock, the selected processes, facilities, auxiliaries, utilities, buildings, equipment, plant operations and products.

For orientation and reference convenience the text which follows provides a general review of data on the methanol product, its utilization and production; the selection of processes, descriptions of the plant facilities, and an assessment of the technical viability of the Beluga Coal to Methanol Project as outlined in this Phase I Feasibility Study.

1.2 METHANOL PRODUCT

Utilization

Methanol has received great attention in recent years as a synthetic fuel which could substitute for conventional fuels currently used, or as a feedstock for chemicals. Examples of the new uses considered are:

1. Power generation in the electric utility industry, with particular interest in its use in existing combined cycle facilities which run at high efficiency and at reasonable load factors.

2. Use in gasoline blends at levels of 3 to 6%.

3. Use of neat methanol as a motor fuel in converted engines or engines factory-built to use methanol.

4. Production of gasoline additives, such as Methyl Tertiary Butyl Ether (MTBE).

5. Conversion to high octane gasoline.

Methanol is a clear liquid of low vapor pressure and is readily handled in fuel uses. When used as a fuel, it has no sulfur or particulate emissions and has less nitrogen oxides and carbon monoxide in the flue gases than those produced by natural gas, fuel oil or coal combustion. As a feedstock in its chemical grade form, it provides an easy to handle form of carbon and hydrogen suitable for use in producing a wide range of chemicals. It has the potential to replace petroleum as a source of ethylene and aromatics. Widespread success in the development of various engine types, internal combustion and turbine, and direct combustion systems indicate a rapidly expanding fuel-based market is available for methanol or methanol-derived products.

Methanol Feedstocks

In large commercial plants methanol is produced from synthesis gas, which is a controlled mixture of hydrogen, carbon monoxide, carbon dioxide and small amounts of inerts, usually nitrogen and methane. In theory, the required synthesis gas can be produced from any feedstock which contains carbon. Thus, potential feedstocks for methanol production include natural gas, naptha, LPG, low octane petroleum fractions, petroleum residues and all ranks of coal and biomass.

Plant complexity and the cost of producing synthesis gas increases as the hydrogen content of the feedstock decreases. Therefore, with respect to both capital and feedstock costs, large natural gas-based plants generally have been less costly. However, bottom line production costs, as well as feedstock availability, location, and desirability of use, will dictate which feedstocks will be used for very large scale methanol production.

Addressing specifically coal as a feedstock, there are particular methanol production and marketing situations in which the coal-based methanol is a viable economic candidate. This is particularly true when proven technologies are utilized and start-up delays and production interruptions are minimized.

1.3 PROCESS SELECTION FOR THE BELUGA PLANT

The production of methanol from coal requires multiple processing steps. Maximum utilization of energy in each process stage is of critical importance in achieving the highest overall plant thermal efficiency, which in turn enhances the technical and economic feasibility of the project.

The coal to methanol plant for this study has been designed utilizing commercially available and demonstrated technology. All major units have been selected to provide an integrated process plant with maximum reliability. The design incorporates multiple trains, the sparing of critical items and the incorporation of equipment of commercially available size. Particular attention has been given to the optimal integration of all utilities and heat recovery systems and controlling environmental impact to regulated levels.

Only developed technology, which has proven high reliability and thus economy of operation, has been utilized and each individual process stage has been carefully examined for the highest energy yield. As a result, an efficient, proven configuration for the 7500 STPD fuel grade methanol plant complex has been developed.

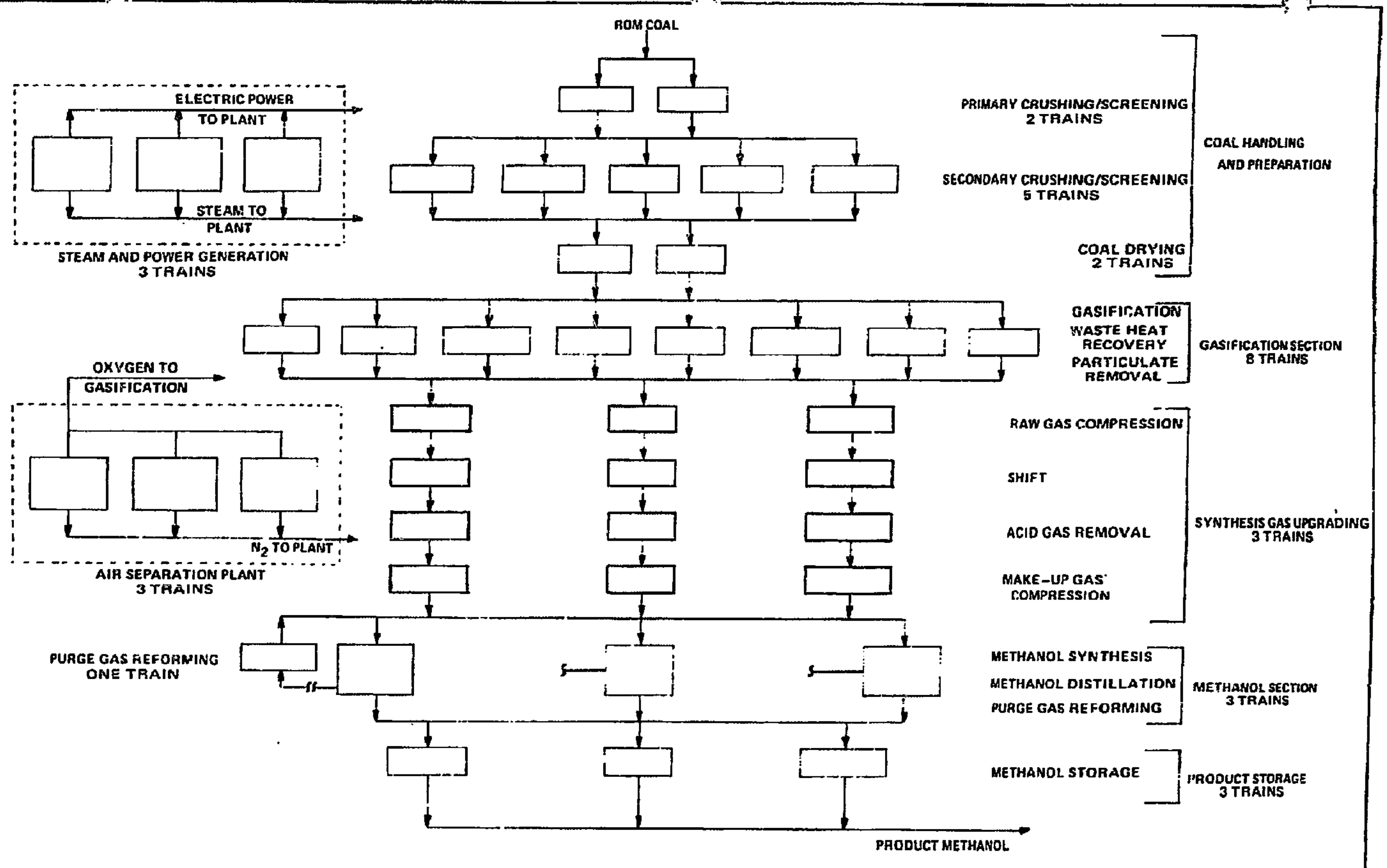
A graphic block diagram (Figure 1-1) illustrates the multiple train concept, which provides plant reliability necessary to meet the overall project production criteria.

The following is a discussion of process selections by major plant section. Gasification is discussed first, as this selection establishes various critical design parameters for the other major process and auxiliary sections.

1.3.1 Selection of the Gasification Process

The gasification section provides the mixture of H_2, CO and CO_2 for the methanol synthesis. The selection of the gasification process is critical to any coal-based, chemical synthesis process, and this selection has been made using the following major criteria:

- Feedstock characteristics
- Product desired/product gas
- Environmental impact
- Competitive capital investment and operating/maintenance economy
- Commercial status of the process



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FEASIBILITY STUDY
FOR
ALTERNATIVE FUELS PRODUCTION

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PROCESSING TRAINS
FIGURE 1-1

There are three commercially proven, large scale coal gasification processes capable of producing the synthesis gas in the required quantities from the available coal. In general, none of the three is the "best" process in all circumstances, but by addressing criteria particular to this project, the selected process does offer the best combination of features.

There are also a number of advanced coal conversion processes at various stages of development. Many advanced gasification systems exhibit great promise, and the progress of these will be closely monitored. A brief discussion of the most promising pioneer processes is included in the Technical Viability section of the Executive Review.

The type and size of the Beluga plant requires that risks be minimized. Start-up risks and risks of low plant production availability are much less with commercially proven processes than with the unproven advanced technologies, particularly if applied to this scale. Therefore, the commercial status of the gasification system is a very critical criteria for the large coal-based chemical complexes.

1.3.2 <u>Comparison of Gasification Systems</u>

There are three basic methods utilized for gasification of coal. They are:

- Fixed bed gasification
- Fluidized bed gasification
- Entrained flow gasification

Table 1-1 presents the various process and hardware parameters for these three classifications. The hardware parameters in general refer to the most common features of the commercially available systems.

TABLE 1-1

GASIFIER COMPARISON TABLE

COMPARISON PARAMETER	FIXED BED GASIFICATION	FLUID BED GASIFICATION	ENTRAINED GASIFICATION
FEEDSTOCK REQUIREMENTS:			
A. Size	Lump coal; no fines 1¼" x ¼"	Crushed coal 3/8" x 0	Pulverized coal; 95% 200 mesh
B. Ash %	Not critical	Not critical; up to 50%	Low ash required for economy
Fusion temp.	Moderately high	Moderately High	Low ash fusion preferable
C. Moisture content	Up to 30% acceptable	8–12%	2%
D. Reactivity	Moderate to high	Moderate to high	All ranges
E. Caking characteristics	Low to moderate	Low to moderate	Accepts caking coal
OPERATING CHARACTERISTICS:			
A. Gasification temp.	Varies through bed 900–2200°F	Homogeneous bed temp. 1850–2100°F	2500–3400°F
B. Coal residence time	Hours	Minutes	Seconds
C. Throughput/gasifier	Low	High	High
D. Steam requirements	Very High	Moderate	Low
E. Oxygen requirements	Low	Moderate	High
RAW PRODUCT GAS:			
A. H_2/CO Ratio	2/1 to 1.5/1	1.2/1 to .9/1	.5/1 to .4/1
total % in gas	55–60% (Liquids Free Basis)	75–80%	78–85%
B. CH_4	10–18%	1.5–6%	Trace
C. Other components	Naphtha, phenols, ammonia, tars, oils	Trace	Trace
D. Solids content	Minimal char	Some char	Fused ash
E. Product gas temp.	450–1200°F	1850–2100°F	2500–3400°F
F. Recoverable sensible heat lb. stm/lb. coal	Only low grade available	1.2/1 high pressure, superheated	Direct quench (to 1800°F) 1/1 high pressure, superheated
HARDWARE DESIGN*			
A. Gasifier	A.	A.	A.
1. Shell	1. Carbon steel, water jacketed	1. Carbon steel, single wall	1. Carbon steel, water/steam jacket
2. Refractory	2. None in gasification zones	2. Standard refractory materials, 2 component system	2. Special refractories
3. Internals	3. Mechanically driven distributors and ash grates	3. No internals	3. Slag spray at gas outlet
B. Ash handling	B. Dry	B. Dry	B. Molten slag discharge
C. Pressure operation	C. 20–25 ATA	C. 1–1.5 ATA	C. 1 ATA
Commercial	Lurgi	Winkler	Koppers–Totzek
Advanced/Pilot	BGC Slagging Lurgi	HTW Westinghouse IGT U-Gas	Shell–Koppers Texaco

Beluga Gasification Criteria

Using the major criteria presented above, the following is a list of parameters specific to the Beluga project:

o Feedstock Characteristics

When considering the processing and, in particular, gasification for chemical synthesis, the Beluga coals can be generally characterized as follows:

(1) Highly reactive
(2) High ash
(3) High moisture
(4) High grindability index
(5) Non-caking
(6) Relatively high ash deformation temperature
(7) Very low in sulfur
(8) Ash widely varies in relative percentage and composition

o Product Desired/Product Gas

The maximum amount of product methanol from the processed coal with the minimization of any by-products is an important criteria for the Beluga plant. A maximum overall in-plant carbon utilization as feed and fuel with an optimum production of $CO + H_2$ is also critical. Due to plant location, certain coal processing by-products such as coal fines, char, tars and oils are not locally marketable items, and export costs would be prohibitive.

- o **Environmental Impact**

  Any coal conversion plant must be designed and built to provide an environmentally acceptable complex. This is particularly true in the state of Alaska. Proper handling, processing and disposal of all plant effluents is critical.

- o **Competitive Capital Investment and Operating/Maintenance Economy**

  This guideline for selection is especially critical in the Alaskan location where the costs of labor and delivery of materials for construction, plant operation and maintenance will be very high. A combination of initial capital cost and reliable low maintenance operation are a key to an economically feasible plant.

- o **Commercial Status**

  There are three gasification processes which are widely recognized as large scale commercially demonstrated processes. They are:

  - Lurgi (dry ash/fixed bed)
  - Winkler (fluid bed)
  - Koppers-Totzek (entrained)

  Each of these processes has a long history of commercial utilziation, and they are the logical choices to consider for a project scheduled to proceed into detail design in the near future.

1.3.3 Selection of Type of Gasifier

Upon a quantitative evaluation of the available methods of gasification (fixed bed, fluid bed and entrained) and applying the specific Beluga gasification criteria, the selected gasification system is the fluid bed process. The advantages as applied to the Beluga plant include:

- Excellent Feedstock Suitability and Utilization

  In particular, the Beluga coals are highly reactive, and high reactivity has been demonstrated to be most suitable for high throughput, fluid bed systems. The relatively high and variable ash percentage is not detrimental to the fluid bed operation relative to energy consumption or materials of construction as ash is not processed or handled in a molten state. The ash fusion temperature is high enough to allow relatively high temperature (2100°F) operation in a gasifier without slagging. The rapid mixing and bed turbulence occurring in a fluid bed can also prevent any localized problems which could be created by fusion of any lower melting ash components. The high moisture content of the run-of-mine coal will be moderately lowered by external drying to 2-10%. This ensures flowability and optimization of oxygen consumption in the gasifier. This is in contrast with the requirement for less than 2% moisture for the entrained gasifier.

  Since crushed coal with fines is acceptable to a fluid bed, the overall utilization of feedstock is optimum. It is not necessary to reject the -1/4" coal as with the fixed bed, or to expend energy for coal pulverizing, as with the entrained system.

- o **Product Desired/Product Gas**

  The overall carbon utilization in the production of H_2, CO, CO_2 and CH_4 in a fluid bed system is optimum for the Beluga plant. Probably the most important raw gas characteristic is the lack of any significant tar, oils, phenols, ammonia or other by-products not directly utilized for methanol synthesis. This is in great contrast to the Lurgi System, which makes large amounts of tars, oils and aqueous liquor.

  The CO/H_2 ratio requires less shifting than the gas produced from an entrained unit. This characteristic offers savings in capital and operating expense. The amount of methane produced is at a level which does not significantly increase the syngas upgrading costs.

- o **Environmental Impact**

  The overall process design and operating conditions of a fluid bed gasifier provide effluent streams which can be easily handled and safely disposed of with conventional technology. The lack of significant quantities of higher hydrocarbons and other by-products, as produced in fixed bed systems, is an important advantage in the construction of the complex in the Beluga area.

- o **Capital Investment and Operating/Maintenance**

  The basic fluid bed gasifier is by far the least complex to construct and operate of the three major types of gasifiers. The high throughput and large raw gas production per gasification unit in combination with relatively low consumptions of steam and oxygen make fluid bed operation the most cost effective system for the Beluga complex.

1.3.4 Selection of the Gasifier

With the significant advantages displayed by the fluid bed gasification system for the Beluga project, the final step in this selection process is to identify the specific fluid bed gasifier to be used. The Winkler process has been selected. This process, developed in Europe, has been operating commercially since 1926. Since that time, more than 60 commercial Winkler gasifiers have been built and operated in Europe and Asia. The majority of these Winkler gasifiers were designed to produce synthesis gas for methanol, ammonia and hydrogen.

The following information, of both a technical and operational nature, details the process advantages and the particular suitability of the Winkler process for the Beluga complex:

- The demonstrated production of synthesis gas which has been used commercially for the production of methanol, ammonia, and hydrogen for a longer period than any other existing process.

- Commercially demonstrated reliability, safety and flexibility of operation.

- Coal utilization is high and preparation cost is low. Only minor crushing is required to prepare the coal size required for the gasifier. All coal 3/8" x 0 can be fed to the gasifier.

- The suitability of the Beluga feedstock from the standpoint of reactivity can be seen in the Grout Apfelbeck Diagram (Figure 1-2). This diagram is a method of ranking gasifier feedstocks and indicating relative reactivity by carbon, hydrogen and oxygen composition. It can be seen that the Beluga coal is well within the range of Winkler experience and is nearly identical in rank to the coal used in the Kutahya plant in Turkey.

- Gasifier operation at high enough temperatures to prevent the formation of tars, oils and higher hydrocarbons.

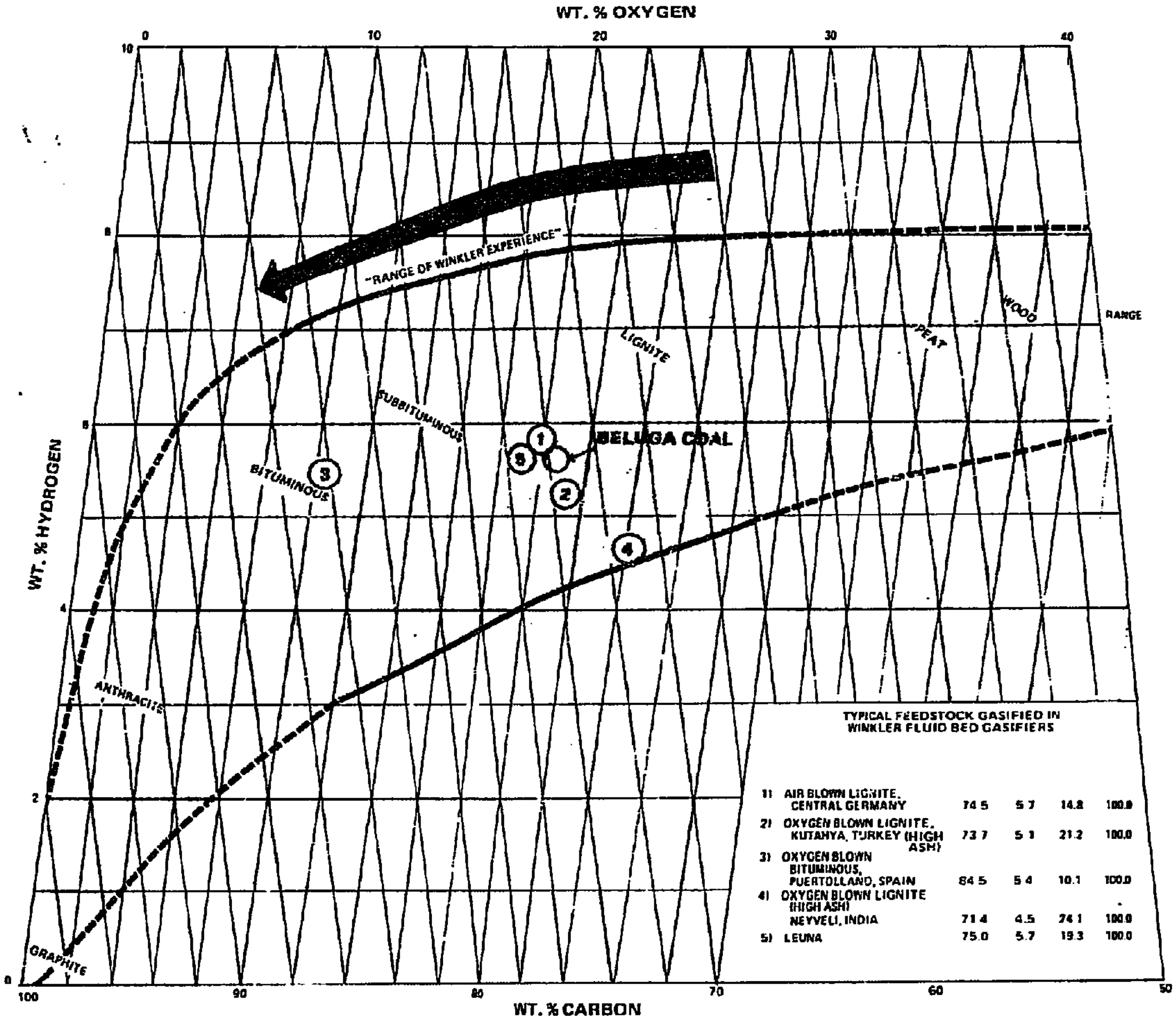
  The trace compounds in the raw gas are predicted to fall into the following ranges:

NH_3	3 to 10 ppm (vol)
HCN	10 to 20 ppm (vol)
C_2H_2	50 to 150 ppm (vol)
C_6H_6	10 to 30 ppm (vol)
H_2S	700 ppm (vol)
COS	100 ppm (vol)

- The dry char material recovered after the gasifier is a suitable fuel and can be burned in an offsite boiler to increase total carbon utilization.

- The operating campaigns on existing gasifiers average nine months between maintenance shutdowns. This is far longer than experienced on any other process.

- The inventory of carbon in the fluid bed greatly reduces the possibility of oxygen breakthrough, thus providing safe operation.



RANGE OF WINKLER GASIFIER EXPERIENCE
GROUT APFELBECK TRIAXIAL DIAGRAM

FIGURE 1–2

- The inventory of ash in the fluid bed is such that variations in the ash content of the incoming coal can be tolerated.

- The Winkler gasifier has great flexibility between maximum and minimum flows and can be "banked" at time of zero gas requirement (e.g., when downstream equipment is undergoing maintenance).

1.4 COAL HANDLING AND COAL PREPARATION

All of the equipment selected for coal handling and preparation is of standard industrial design. All railcar unloading, blending, sampling, conveying, stacking, reclaiming, screening, crushing and drying units are sized to allow procurement of standard equipment widely used in the coal industry. Design for all units includes dust control and fire protection systems.

As large scale crushing and drying tests were not completed during this study, the available coal data was used in a conservative manner to specify the crushing and drying units. Due to the relatively large amount of fuel coal required for this complex, an initial screening of as received -3/8" material is designed to be conveyed directly to the boiler house. Although this fines screening is not required for gasification, it will significantly reduce boiler coal pulverizing power requirements of this relatively high Hardgrove index coal.

The fluid bed coal dryers are designed to be coal fired. Dried coal and carryover to cyclones from the drying bed are pulverized and used for direct coal firing to supply heat for drying. All storage for dried coal is blanketed with nitrogen to prevent explosions and fires.

1.5 SYNTHESIS GAS UPGRADING

A number of major processing steps are included in this section of the plant. Various processes and equipment configurations are available to accomplish these steps. Trade-off studies were completed to arrive at the system selected. The major criteria used in the system selection were:

- Commercial availability of the process or equipment and proven operation at specific design conditions.
- Environmental acceptability of effluent streams.
- Capital, operating and maintenance costs.
- Process efficiency.
- Flexibility for large plant operation.

The trade-off studies and evaluations included the review of the available systems which meet the above criteria.

Synthesis gas upgrading includes three major processing steps:

- Compression of the gas from the gasifier raw gas pressure to methanol synthesis pressure;
- Adjustment of the relative compositions of H_2, CO and CO_2 to the desired percentages required for methanol synthesis; and
- Removal of all sulfur compounds and other catalyst poisons.

As certain key processing steps to be evaluated have not been demonstrated above 65 ATA, the initial raw gas compression ratio was limited to about 20:1 for the trade-off study. This limitation dictated an additional stage of compression prior to methanol synthesis. A total compression ratio of about 35:1 is required.

The result of this trade-off study is presented in Volume V (Task 3.10).

Three parallel trains are used for synthesis gas upgrading to provide operating flexibility and permit use of proven equipment.

It is also important to note that raw gas saturation, which is required prior to the sulfur resistant CO shift section, has been integrated within the methanol distillation column. This integration results in a significant steam savings.

Absorptive acid gas removal has been selected. The trade-off study indicates some capital and operating expense advantages for Selexol. The final selection will be made prior to start of final design when coal and gas properties and costs are sufficiently detailed.

1.6 SELECTION OF THE METHANOL SYNTHESIS PROCESS

The selected process (ICI Low Pressure) will synthesize methanol from a mixture of H_2, CO and CO_2, regardless of whether this mixture is derived from steam reforming of methane or naphtha, or alternatively, from the partial oxidation of oil or gasification of coal. However, all process and operating histories of methanol synthesis have been considered for this project.

There are two types of processes for the synthesis of methanol:

- "High Pressure" using zinc/chrome catalyst.
- "Low Pressure" using a copper catalyst.

The synthesis of methanol from mixtures of H_2, CO and CO_2 is reversible, and the degree of conversion in the two reactions is favored by low temperature and high pressure.

$$2H_2 + CO \rightleftharpoons CH_3OH$$

$$3H_2 + CO_2 \rightleftharpoons CH_3OH + H_2O$$

The rate of reaction is, however, retarded by low temperature. The initial catalyst developed for the reaction (zinc/chrome) was so unreactive at the low temperatures favoring the equilibrium that it was necessary to raise the temperature to obtain adequate synthesis. To counter the adverse effect on the equilibrium caused by the high temperature, it was necessary to operate the process at very high pressures (typically 4500 psi) to obtain an economic level of product of methanol at the outlet of the converter.

The very high pressure used in the so-called "High Pressure Process" had the disadvantage that the compressors were invariably reciprocating machines with high capital cost, high maintenance cost, low availability, and high operating cost characteristics.

Prior to World War II, ICI in England, Commercial Solvents in the USA, and IG Farben in Germany experimented with a very active copper catalyst for the synthesis of methanol. However, with the gas purification techniques then available, it was not possible to remove trace impurities of sulfur and chlorides, preventing commercial development of the catalyst. As a result, ICI and others continued for many years to use the far less active zinc/chrome catalysts for methanol synthesis.

This situation changed dramatically in the 1960's when ICI, using the same techniques developed to remove sulfur from upstream of its Naphtha Reforming Catalyst, developed a practical methanol synthesis process based on a copper catalyst.

The new catalyst is so active at low temperature (400°F to 550°F) and the yield of methanol at the converter outlet so high that operation with pressures as low as 750 psi are possible. The pressures now used range from 750 to 1500 psi, depending upon plant size and various design optimizations. This low pressure allows centrifugal compressors to be used down to very low capacity (approximately 150 tons/day).

The process selected for his project, the ICI Low Pressure Process, is the most widely used methanol synthesis process in the world. Nearly 80% of th world capacity built during the past decade uses this process.

The ICI process is used for:

- The largest single stream methanol plant in current operation.
- The largest plants currently being built or on order.
- The only modern methanol plant based on coal in current operation (A.E. & C.I., Modderfontein, South Africa).

The catalyst (ICI 51-2) is the most successful catalyst used in any methanol process and has:

- The longest commercial experience of any copper catalyst.
- Longest economic operating life.
- Very high activity.
- There has never been an unscheduled loss of catalyst on a commercial plant.

For the reason stated above the proposed plant is not a pioneer plant in size, capacity, operating pressure, temperature, nor any other parameter.

1.7 OVERALL PLANT DESCRIPTION

The Beluga coal-to-methanol plant design is a grass roots facility. It has been designed to be self-sufficient, importing only coal for feedstock and utility fuel, raw water, and small amounts of gas and water treatment chemicals. The product is 7,500 tons per day of fuel grade methanol, with the capability for production of chemical grade methanol. The only by-product is a minor amount of sulfur.

The processing and major ancillary systems include the following sections:

- Coal Handling and Preparation
- Gasification
- Synthesis Gas Upgrading
- Methanol Synthesis, Distillation and Purge Gas Reforming
- Major Support Facilities
- Air Separation
- Steam and Power Generation

The plant being designed for self-sufficiency, all necessary ancillary systems are included in the design and are detailed in Sections 7 to 12 of this Volume.

The major processes are briefly described as follows:

1.7.1 Coal Handling and Preparation

A blend of 70% Capps and 30% Chuitna run-of-mine coals, 6" x 0, is received by rail, unloaded, stacked, and stored in 15-day capacity storage piles.

The coal is retrieved from active storage and transferred to either the process plant or utility boilers. Coal for the boilers is crushed to 1-1/2" x 0 in this area and transferred to the boiler area for pulverizing.

Coal to be used in gasification is crushed to 3/8" x 0; dried to 8% moisture; and sent to active, closed storage ready to be transferred to the gasification section.

1.7.2 Gasification

The gasification section consists of the gasifiers, waste heat recovery systems, and particulate removal systems. Eight fluid bed gasifiers are required. They operate at 4ATA and 2100°F. The coal is fed into the gasifiers by means of a lock hopper system. The coal feed rate is controlled by variable speed screw conveyors.

During gasification, the carbon in the coal reacts with oxygen and steam to form carbon oxides, methane, and hydrogen. Oxygen is supplied by three (3) large-tonnage air separation plants. These plants also supply nitrogen for process and utility use. The hot raw gas exits the top of the gasifiers. Larger residue solids are removed from the bottom of the gasifier, and finer particles exit with the gas. The ash exiting from the bottom is lock hoppered to atmospheric pressure and pneumatically conveyed to storage for eventual disposal to the mine.

The hot gases leaving the top of the gasifier enter the waste heat recovery system (one unit for each gasifier train). These units use the heat in the gas to generate high pressure, superheated steam which is used throughout the plant. The solids, entrained in the raw gas, are a combustible char (approximately 30% carbon, 70% ash) which is used as fuel in the utility boilers. A portion of the char is collected at the bottom of the waste heat recovery unit, but the majority is removed in a dry cyclone immediately following the waste heat recovery system. The dry char collected from the waste heat sections and cyclones is conveyed to the boiler for blending with raw coal for use as fuel.

Fine particles that may still be entrained in the gas are removed via a direct quench Venturi-type scrubber (one scrubber per gasifier train). The particle-laden water is sent to settling ponds where the particulate is concentrated and filtered. The water purge is sent to wastewater treatment for water recovery.

The raw gas is now cooled and clean of particulate. It is delivered to the synthesis gas upgrading section for production of a gas suitable for methanol synthesis.

1.7.3 Synthesis Gas Upgrading

Four (4) major gas processing steps are included in the synthesis gas upgrading section:

- Compression from 40 psia to 1390 psia (methanol loop pressure).
- Adjustment of H_2 to CO ratio.
- Removal of all sulfur compounds and other catalyst poisons.
- Reduction of CO_2 content.

The synthesis gas preparation area consists of three (3) parallel trains.

The first step in this section is raw gas compression which increases the pressure of the gas from 40 psia to 770 psia. Centrifugal, multi-body turbine driven compressors are used.

From compression, the gas is then saturated, preheated, and sent through a CO shift reactor, where the ratio of hydrogen to carbon monoxide is adjusted with sulfur-resistant catalyst to the required level for methanol synthesis. The reactor is a packed bed of catalyst.

From COS hydrolysis, the raw gas goes to the Selexol acid gas removal unit. The purpose of this unit is to remove the sulfur components in the gas and to adjust the CO_2 level in the gas to the required percentage for methanol synthesis. This process is selective in that it removes H_2S from the raw gas in the first absorber, and CO_2 removal is done with a second absorber. Since the solvent is recirculated, it must be continually regenerated by flashing. The absorbers are packed columns in which the gas streams are contacted with the liquid solvent. The purge gas stream leaving the H_2S flash system is sent to the sulfur recovery unit.

The gas leaving the CO_2 vent is 99%+ CO_2 and, hence, is simply vented. Since large amounts of CO_2 are released, consideration has been given to collection and possible sale for secondary oil recovery. The synthesis gas leaving the Selexol unit contains only trace levels of H_2S and COS and has the proper ratios of CO, CO_2 and H_2 for methanol synthesis. Guard beds are provided for removal of any trace sulfur compounds and other catalyst poisons.

The final stage in this preparation area is make-up gas compression. The synthesis gas is compressed to the level required for methanol synthesis, which is 1390 psia. Turbine driven, centrifugal type compressors are used.

1.7.4 Methanol Synthesis Distillation and Purge Gas Reforming

The ICI low pressure methanol process is used in this section of the plant. In order to produce 7500 STPD of product methanol, three (3) synthesis and distillation trains are required. Each train consists of one converter, one circulator, a distillation column and a set of heat recovery units. The circulator is a steam-driven, single-stage, centrifugal compressor.

The methanol converter is a pressure vessel of single-wall design constructed of low-alloy steel holding a single continuous bed of catalyst. Temperature control is achieved by injecting feed gas at appropriate levels directly into the bed, using specially developed distributors.

The converter exit gas is split for optimum heat recovery; one part heats the feed gas to the top of the converter, and the second heats the CO shift saturator water and reboils the distillation column. The streams are combined to heat all of the circulating gas and then cooled. The crude methanol is separated and let down from loop pressure to 60 psia.

The non-reactive components (mainly, CH_4, and N_2) in the make-up gas are purged from the synthesis loop between the separator and the point of make-up gas addition. This purge gas and the flash gas from the letdown vessels are used as feed to a steam reformer. Seventy-five (75%) percent of this gas is used as process feedstock, and 25% is utilized as fuel for the reformer furnace. The reformed gas is recompressed and blended with the main synthesis gas stream.

A one-column distillation system is provided to produce the required product purity. The crude methanol from the letdown vessels flows to the preheater and then to the column. The reboiler heat is provided by part of the converter exit gas. The purpose of the distillation column is to remove water (and the light ends) from the crude methanol. The column overhead is completely condensed and returned to the column as reflux. Product methanol is withdrawn three trays below the reflux tray and is cooled prior to passing to the methanol product storage tank. The distillation column bottoms, which is essentially water, is cooled and pumped to the wastewater treatment area.

Product storage facilities have also been provided in this section. Storage tanks for crude methanol and methanol product are provided.

1.7.5 Major Support Facilities

- Air Separation

  This section produces all the oxygen required for gasification. The normal production is 7500 STPD at 99.5% purity and 90 psia. Three (3) units are required for this capacity. Air and oxygen compressors are steam turbine-driven.

- Steam and Power Generation The remaining import coal not used in the gasification process is used in the boiler house for steam and power generation. Coal is blended with gasification char and is used as fuel for the three boilers to generate 1200 psig steam. This steam is used both for process requirements and power generation from turbo-generators.

1.8 TECHNICAL VIABILITY

The following text presents a review of key selected processes and critical hardware from a technical preparedness standpoint. As previously discussed, the coal-to-methanol route is more complex than the currently dominant natural gas-based methanol production. The overall design concept developed for the Beluga complex is similar to well established coal-based chemical plants, but varies with refinements justified by demonstrated innovations now available for use. A minor variation from commercial technology involves raising the pressure of the Winkler gasifier about 2.5 ATA. Numerous avenues of process and hardware design have been explored; and the resultant detail design minimizes risk, but assures state-of-the-art commercial operability, efficiency, and safety.

1.8.1 COAL HANDLING AND PREPARATION

All coal handling and preparation equipment is standard coal industry hardware. Final specification of crushing and drying equipment will be based upon large-scale testing of the Beluga coals.

1.8.2 GASIFICATION

o Fluid Bed Gasification

Earlier in this section the reasons for the selection of fluid bed gasification using Winkler technology are discussed in detail. In summary, this technology is the best system for the Beluga project for the following reasons:

- Excellent suitability to feedstock.
- Optimum raw gas for methanol production.
- Contaminants in effluent streams can be economically treated to environmentally acceptable levels with conventional technology.
- Best combination of capital, operating, and maintenance economy.
- Longest history of successful commercial operation for production of synthesis gas for chemicals.

The gasification system designed for use in the Beluga plant is the third generation Winkler system, which incorporates nearly 60 years of development including: laboratory and pilot plant testing (1922-1926), and commercial operating experience with continuing technical improvement from 1926 to the present.

Winkler gasification has been demonstrated in 22 plants since 1926. A list of these facilities with details of operation is included in Table 1-2.

The first generation Winkler gasifier was the first major industrial application of fluid bed technology. The system was based on the 1922 patent (No. 437970) awarded to Dr. Winkler for the gasification of coal fines. The gasifier was initially designed with a mechanically swept, water-cooled grid below the fluid bed area.

TABLE 1-2

WINKLER COAL AND COKE, FLUID BED GASIFICATION PLANTS

Plant Number	Plant	Product	Capacity Per Gasifier 1000 scfh	Number Gasifiers	Operating Dates
1	BASF, Ludwigshaven, West Germany	Pilot Plant	75	1	1925-58
2	Leuna-Werke, Merseburg, East Germany	LBTU Fuel Gas & Synthesis Gas for MeOH & NH_3	3,730 2,240	5	1926-70
3	BRABAG, Bohlen, East Germany	Hydrogen	1,120	3	1938-Present
4	BRABAG, Magdeburg, East Germany	Hydrogen	1,230	3	1938-45
5	Yahagi, Japan	Ammonia	330	1	1937-60
6	Dai-Nihonyinzo-Hiryo, Japan	Ammonia	520	2	1937-59
7	Nippon Tar, Japan	Ammonia	520	2	1937-60
8	Toyo Koatsu, Japan	Ammonia	750	2	1938-69
9	Fushun, Mandschukuo, Japan	Syn. Gas for F. T. Fuel	750	4	1939-?
10	BRABAG, Zeitz, East Germany	Hydrogen	850	3	1941-Present
11	Treibstoffwerke, Brux (now Most), Czechoslovakia	Hydrogen	1,120 1,200	5 2	1943-72 1954-73
12	Salawad, USSR	Medium BTU Gas	860	7	?-Present
13	Baschkirien, USSR	Medium BTU Gas	860	4	?-Present
14	Dimitroffgrad, Bulgaria	Medium BTU Gas	670	4	1951-Present

TABLE 1-2 - WINKLER COAL AND COKE, FLUID BED GASIFICATION PLANTS (Continued)

Plant Number	Plant	Product	Capacity Per Gasifier 1000 scfh	Number Gasifiers	Operating Dates
15	Stara Zagora, Bulgaria	Medium BTU Gas	1,120	5	1962-Present
16	Fabrika Azotnih, Jendinjenja, Gorazde Yugoslavia	Ammonia	260	1	1952-Present
17	Calvo Sotelo I, Puertollano, Spain	Ammonia	350	1	1956-70
18	Calvo Sotelo II	Ammonia	350	1	1959-70
19	UKW, Wesseling I, West Germany	Synthesis Gas for MeOH and NH_3	630	1	1958-67
20	UKW, Wesseling II, West Germany	Synthesis Gas for MeOH and NH_3	630	1	1962-67
21	Azot Sanayii TAS, Kutahya, Turkey	Ammonia	450	2	1959-Present
22	Neyveli Lignite Corp., India	Ammonia	785	3	1965-79
22	(Including Pilot Plant)			63 (Including Pilot Plant)	
	IN OPERATION AT PRESENT			29	

September, 1981

This configuration was replaced with a simple refractory cone with fluidizing gases injected through circumferential nozzles at various levels in the cone. This simplified gasifier produced up to 3.73 MM SCFH of raw gas in the air-blown mode at the Leuna-Werke plant.

The second generation provided higher CO and H_2 in the raw gas, greater once-through carbon conversion, and the ability to gasify less reactive coals economically. The injection of additional gasifying media above the fluid bed was later introduced to further react unconverted carbon in any entrained solids. A radiant boiler (German Patent No. 1 421 655) was introduced in the upper portion of the gasifier to prevent any fused ash particles from leaving with the raw gas.

A significant step in the evolution of the Winkler process is included in the third generation system. This system (described in 1978 U. S. Patent 4017272) added pressurized gasification to the previous developments. A 4-ATA unit is currently offered.

o Pressurized Fluid Bed Design

The use of fluid beds at elevated pressure has been widely demonstrated. Catalytic cracking systems have successfully employed pressurized fluid beds for a number of years. The Institute of Gas Technology (IGT) has developed an extensive data base for pressurized fluid bed design. IGT has operated large gasification pilot units as high as 1,650 psig and the reliability and safety of fluid bed operation at elevated pressure.

Numerous studies, detail designs, and equipment test work have been completed in order to verify the advantages and technical viability of moderate pressurization of the fluid bed Winkler for synthesis gas production. The current commercial operating experience does not exceed 1.5 ATA for Winkler systems. Moderate pressurization (4 ATA) offers substantial reduction of capital cost by a reduction of the number of gasification trains required. This moderate pressurization also eliminates one stage of raw gas compression which reduces the overall compression ratio, raw gas to methanol synthesis pressure, from 70:1 to 35:1.

o Gasifier

The gasifier is designed in accordanc with the ASME Unfired Pressure Vessel Code, Section VIII, Division 1. The carbon steel shell and nozzles are designed for 75 psig and a design temperature of 650°F. The refractory lining prevents all parts of the shell from reaching temperatures greater than 300°F during operation.

The overall dimensions of the gasifier are the same as those used in a number of commercial units: 18' I.D. by approximately 72' high. The refractory lining scheme is identical to that used in the Kutahya gasifiers; brick construction with an inner abrasion-resistant brick and an outer insulating brick. The linings in the Kutahya gasifiers, which are still operating, have not been replaced or required major repairs since the plant was commissioned in 1959. The actual lining materials selected are somewhat different to take advantage of advances in materials technology and more recent refractory installation techniques.

The radiant boiler section included in the top of the gasifier is to be constructed of low-alloy, superheater-quality boiler tubing. This same tubing material has been used with great success in operating gasifiers.

o Pressurized Solids Feed and Discharge Systems

In the development of a dry solids pressurized system, the most critical parameters are reliability and safety. The design of the Beluga coal feeding, char discharge, and ash discharge systems is based on extensive design, testing, and operating experience.

- Valve Design

  The most critical single component in a lock hopper system is the lock hopper valve, which must be capable of reliable, continuous operation with positive pressure sealing. The valves and associated actuating systems have been tested and operated under conditions more severe than any that will be encountered by this gasification process.

  The coal feed valves are very similar in configuration to the valves successfully operated in the FIOR (fluidized iron ore reduction) plant. The valves in the FIOR plant operate with a 10-ATA differential pressure and are used to feed 75 STPH of iron ore into a fluid bed. Similar valves have also been used for pressurized blast furnace feed systems.

  The feed valve in the Beluga plant design is a full-opening, "bell"-type valve. Each valve has a redundant pneumatic actuator system. Heat resistant (up to 250°F) elastomer seals, which are protected from direct exposure to the solids flow, are contacted with the metal bell and provide a positive pressure seal.

The large, full-open dimension is designed to provide rapid, reliable coal flow (42 STPH/hopper system) from surge bins to the lock hopper. The valve will operate only once every hour, assuring long valve life.

The valves to be used for the char and ash services are of a different design. They will be smaller in size as they will handle less material, and will be temperature-resistant. Both the char and ash will normally be cooled below 350°F prior to exposure to the valves, but provision is made to handle solids with temperatures as high as 900°F in case of a temporary process upset. All valve components are designed for the abrasive ash expected with the Beluga coal.

- Gasifier Screw Feeder

Although not directly a part of the lock hopper system, the gasifier screw feeder is a critical component used in the pressurized coal feed to the gasifier. The internals of this feeder are identical to the components developed in existing Winkler units. The low-speed, variable drive ensures a continuous, controlled feed to the gasifier. The outer pressure sealing shell is a coded, pressure pipe (ANSI B31.3) with abrasion-resistant linings. A standard double-seal arrangement is used for sealing the conveyor shaft.

- Redundancy and Maintenance

  Each gasifier is provided with two complete coal feeding systems. The systems are designed for nominal gasifier capacity when both systems are operating. Should a system require maintenance, isolation valving is provided. Additionally, the single operating system can be adjusted, by programming shorter lock hopper cycles and increased speed on the screw conveyors, to provide adequate coal for full raw gas production.

o Waste Heat Recovery System

As discussed in the gasifier selection section, the Winkler fluid bed offers a distinct advantage over the other available systems in the area of waste heat recovery. The amount of the heat recovered before any direct quenching will be significant. The Beluga plant will recover in this section about one pound of superheated steam (870 psia, 840°F) for each pound of coal gasified. This steam will be utilized throughout the plant.

The pressure and temperature selected will allow the use of standard boiler construction materials. The overall design of this unit is particularly critical due in part to the solids loading. The special "know-how" for this recovery system has been developed over years of operating experien· ·.

- Dry Solids Removal

  A large portion of the char particles contained in the raw gas is removed in a dry cyclone. As the removal takes place at gasification pressure, special care must be taken to ensure the prevention of solids erosion on the pressure shell. A highly efficient design has been developed, which exposes only internal, non-pressure sealing components to erosion.

  It should also be noted that the char cyclone is downstream of the waste heat recovery section. This allows much more efficient solids separation and at the same time utilizes commercially demonstrated materials in construction of the cyclone.

- 10 ATA Gasification

  One train in the gasification section is designed for 10-ATA operation. This unit will have the capability to demonstrate a further advance in the Winkler system. A 60% increase in gasifier throughput, when compared to the 4-ATA unit, is predicted with a slight increase in production of CH_4. This increase in methane (3.02 to 5.57 MOL %) in the particulate-free raw gas will not adversely affect the downstream syngas upgrading economics. Demonstration of the process and mechanical viability of this 10-ATA unit will provide any future plant expansion with the advantage of a reduced number of gasification trains for syngas production.

  All of the components included in the design of the 10-ATA train also have the capability of 4-ATA operation.

- Advanced Gasification Technology

There have been extensive efforts in the research and development sector to improve coal conversion technologies. Many advanced pilot systems exhibit great promise. Certain members of the Beluga Project have been closely monitoring and were often directly involved with these developments. The area of fluid bed gasification development has been particularly active with U. S. organizations such as the Institute of Gas Technology (Hygas and U-Gas), Battelle Memorial Laboratories (Agglomerating Char Gasifier), the Westinghouse Corporation (The Westinghouse Gasifier), and the United States Department of Energy (Synthane, CO_2 Acceptor, and H-Coal). The Institute of Gas Technology has developed a vast data base on the kinetics and dynamics of high pressure (up to 1650 psig) fluid bed operation. Since 1975 in Europe, Rheinische Braunkohlenwerke AG, and Uhde GmbH have been cooperating in the development of the fluid bed HTW (High Temperature Winkler) process.

It is to be noted that the status of the more successful efforts will be followed. As the Beluga project develops through detail design and procurement, certain demonstration plants incorporating the more successful pilot designs could be operating. The final selection of the gasification system will take into consideration demonstrated advanced technologies from these pioneer units.

- The IGT U-Gas Gasifier

The IGT U-Gas gasifier is a pressurized fluid bed, ash-agglomerating unit. Successful pilot tests in the 4-foot diameter unit in Chicago have led to the following planned projects:

1) Memphis Power and Light: A medium BTU Fuel Gas Plant to operate at 6-ATA and produce 50 billion BTU/day of 300 BTU/SCF fuel gas.

2) Veg-Gasinstituut, Netherlands: A pilot unit for 20-ATA operation producing fuel gas.

o The Westinghouse Gasifier

Westinghouse and Sasol have recently announced a joint effort to demonstrate the technical viability of the Westinghouse gasifier in the Sasolburg facility. In an effort to utilize the fines not acceptable for use in the existing Lurgi fixed-bed units, and to avoid unwanted liquid and gaseous by-products, Sasol has selected fluid bed technology. This 1,200 STPD, ash-agglomerating gasifier will be totally supplied by Westinghouse for operation by Sasol. It is scheduled to start up in 1983.

o HTW Process

The HTW (High Temperature Winkler) process is an attempt to improve Winkler fluid bed technology by increasing the operating temperature and the operating pressure.

A pilot facility with a 24-inch diameter gasifier has been operated in West Germany by Rheinische Braunkohlwerke and Uhde. The technology is a pressurized (10-ATA) fluid bed process operating below the ash fusion temperature of the coal to be gasified. Their original processing scheme included an apparently unsuccessful limestone addition to the gasifier to allow operation above the normal ash fusion temperature.

With the support of the West German government, a facility will be constructed near Koln, Germany, to demonstrate a single HTW gasifier for production of synthesis gas from brown coal. This unit is scheduled to go onstream in 1984.

- The Beluga Gasification System

The 4-ATA fluid bed gasifier to be used in this project is a moderate extension of many years of commercial experience and technological development in the production of synthesis gas from carbon-containing solids. The inclusion of a 10-ATA demonstration unit, which can also operate at 4-ATA for normal plant production, will permit test runs and allow future expansion of the Beluga complex to include developed improvements.

With the current status of advanced coal gasification technologies, there is little probability that significant technical improvements can be commercially applied in plants to be designed in the next two or three years.

It should also be noted that the capital cost of the gasification portion of the Beluga plant is less than 15% of the total plant cost. An absolute minimium of risk must be maintained in the development of large-scale, coal-based methanol plants, such as the Beluga complex. The Winkler process meets this criteria.

1.8.3 METHANOL PRODUCTION

All process design and components designed for use in the methanol synthesis, distillation, and purge gas reforming units are fully demonstrated technology. The basic ICI catalyst has been in use since 1967. The ICI low-pressure process for high-capacity methanol production has been demonstrated in the plants listed in Table 1-3.

A single distillation column for each train will be used to produce the fuel quality methanol. The steam reformer is of a standard design, with the furnace containing 312 reformer tubes. Reformer furnaces have been designed and constructed with 600 reformer tubes. The Mobil, New Zealand reformer will contain 680 tubes.

TABLE 1–3
PLANTS USING THE ICI LOW PRESSURE METHANOL PROCESS TECHNOLOGY

LICENSED PLANTS	LOCATION	CAPACITY STPD	ICI LICENSEE	STATUS/ START-UP
Taesung Lumber Company	Korea	165	Davy McKee	Onstream
Georgia Pacific Corpn.	USA	1200	Davy McKee	Onstream
Chang Chun Petrochemical	Taiwan	165	Davy McKee	Onstream
Monsanto Company	USA	1000	Chemico	Onstream
Nishi Nihon	Japan	1100	Kellogg	Onstream
Dor Chemicals	Middle East	165	Humphreys & Glasgow	Onstream
Elf Oil, Speyer	W. Germany	900	Humphreys & Glasgow	Onstream
Celanese Corporation	USA	2100	Davy McKee	Onstream (Expansion 1976)
Methanol Chemie Nederland	Holland	1100	Davy McKee	Onstream
PCUK (Ugine Kuhlmann)	France	660	Davy McKee	Onstream
Metanor SA	Brazil	200	Davy McKee	Onstream
Indiquimica, Algeciras	Spain	660	Davy McKee	Onstream
Taesung Methanol Company	Korea	1100	Davy McKee	Onstream
Rumanian Ministry	Rumania	660	Davy McKee	Onstream
China National Technical	China	330	Humphreys & Glasgow	Onstream
National Methanol Company	Libya	1100	Uhde	Onstream
Techmashimport, Gubaha	USSR	2750	Davy McKee	1982
Techmashimport	USSR	2750	Davy McKee	1982
SCT	Saudi Arabia	2300	Davy McKee	1983
Borden	USA	2000	Davy McKee	1980 (Revamp)
Almar Arzew	Algeria	330	Humphreys & Glasgow	Onstream
AE & CI Modderfontein	South Africa	60	Uhde	Onstream
Gujarat SFC	India	70	Linde	1982
MSK Kidinda	Yugoslavia	330	Technip	1983
CPDC	Taiwan	140	Lummus	1983
Ocelot	Canada	1340	Davy McKee	1983
ARCO Chemical	USA	2000	Davy McKee	1983
Air Products	USA	500	Davy McKee	1982 (Revamp)
Mobil R & D Corporation	New Zealand.	4850	Davy McKee	1984
ICI PLANTS				
Billingham	England	300		Onstream
Billingham	England	1200		Onstream

1.8.4 AIR SEPARATION PLANT

The type and size of air separation units selected for the Beluga complex are identical to operating units located in the Sasol facility in South Africa. The individual module has a capacity of 2500 STPD for production of 99.5% O_2. A recent survey of large air separation plants involving several hundred plant years of operation, indicates that the average plant on-stream factor is 98%.

There is considerable optimism in the air separation industry that a single train capacity of 5000 to 6000 STPD of O_2 is within the range of extension to existing technology. This would offer savings in the cost of oxygen production.

1.8.5 STEAM AND POWER GENERATION

The primary steam and power production facility for the Beluga plant will be a pulverized coal/char fired system with a steam turbine generation system. The aspect of char utilization when blended with raw coal has been demonstrated in the Winkler facilities in Mershberg, Wesseling, Neyveli and Kutahya. The ratio of raw coal to char for the Beluga project does not exceed the demonstrated successful combustion experience.

The possible application of fluidized bed combustion (FBC) is a consideration which will be explored prior to the final selection of boilers for this section. Proven FBC as applied to the Beluga complex could offer significant thermal efficiency and economic advantages.

SECTION 2.0

CONCEPTUAL DESIGN BASIS FOR PROCESS PLANT

2.1 GENERAL DESIGN CONSIDERATIONS

2.1.1 The coal-to-methanol process plant will be a grass roots facility including all required process and utility units. The overall plant area plan is shown on Drawing 5530-001-P-001, and mass and utility block flow diagrams are shown on drawings 5530-Y-001 and 5530-Y-002. (These drawings are inserted at the end of this Section 2.0).

2.1.2 The design capacity of the plant will be 2,550,000 tons per year (7500 tons per day and 340 days per year) of fuel grade methanol.

2.1.3 The Winkler gasification process and the ICI low pressure methanol synthesis process will be used.

2.1.4 The gasification units of the plant will operate at a pressure of four (4) atmospheres. One of these units will be so designed that it can be operated at either 4 or 10 atmospheres.

2.1.5 All gaseous and particulate emissions will be held within acceptable regulatory levels. Wastewater effluent will be minimized and treated to meet regulatory quality requirements.

2.1.5 Use of air coolers will be considered in process areas.

2.1.7 Use of cooling tower water will be the design basis for condensing turbine cooling water requirements. "Once-through" cooling water will be considered as an alternative.

2.2 SITE AND CLIMATIC DATA

- Site Elevation: 225 ft.
- Design Dry Bulb Temperature:
  Summer, 62°F; Winter, -35°F extreme low
  For Cooling Tower Design (5%, Summer):
  Dry Bulb, 67°F
  Wet Bulb, 59°F
- Dew Point: Summer, 48°F; Winter, 5°F
- Winds: Velocity, 110 mph max., 7 mph min.
  Direction: Summer, S-SW; Winter, N-NE
- Earthquake Code: 4
- Ice and snow accumulation will be considered in design criteria.

2.3 RAW MATERIALS AND UTILITIES

2.3.1 "As Received" Coal

Will be delivered by rail, unloaded, blended (70% from Capps area and 30% from Chuitna area), and stored for process and boiler fuel.

		Wt.%
o Size analysis:	+6"	0
	-6" to +3/8"	85
	-3/8"	15
		100

2.3.2 Blended Coal

o Proximate Analysis

Proximate Analysis	Wt.%
Moisture	23.90
Ash	20.73
Volatile	30.98
Fixed Carbon	24.24
Sulfur	0.15
	100.00

Higher Heating Value, Btu/lb. 12,409
(Dry, ash-free basis)

o Ultimate Analysis

Ultimate Analysis	Wt.% Dry Basis
Ash	27.24
Carbon	53.23
Hydrogen	3.92
Nitrogen	0.70
Oxygen	14.67
Sulfur	0.20
Chlorine	0.04
	100.00

2.3.3 Utility Coal

Coal for utility use will be supplied from primary crushers and screening operations. No drying will be required. Size: -1 1/2" x 0.

2.3.4 Process Coal

Will be supplied from crushing and screening operations and dried to 8% moisture.

o Analysis	Wt.%
Carbon	48.97
Hydrogen	3.61
Sulfur	0.18
Oxygen	13.50
Nitrogen	0.64
Moisture	8.00
Ash	25.06
Chlorine	0.04
	100.00

2.3.5 Water

Available from fresh water wells or surface water supplies.

2.3.6 Boiler Feed Water

Raw water will be treated to the quality specified by standard boiler codes for particular steam levels.

2.3.7 Oxygen

Supplied from the air separation plants.

- Purity: 99.5% vol.
- Temperature: 257°F
- Pressure: 90 psia

2.3.8 Nitrogen

Available from the air separation plants.

- Purity: 100% (10 ppm oxygen max.)

- Temperature: Ambient
- Pressure: 15 psia min.

2.3.9 Sulfuric Acid

2.3.10 Caustic (50% solution)

2.3.11 Lime

2.3.12 Start-up and Emergency Fuel

Fuel oil and natural gas will be used as required.

2.3.13 Start-up Steam

Will be available at two conditions:

o Temperature:	338°F	950°F
o Pressure:	115 psia	1270 psia

2.3.14 Steam Levels

High Pressure Superheated (Power generation)

- Pressure: 1270 psia
- Temperature: 950°F

High Pressure Superheated (Process)

- Pressure: 870 psia
- Temperature: 840°F

Medium Pressure

- o Pressure: 115 psia
- o Temperature: 338°F

Low Pressure

- o Pressure: 50 psia
- o Temperature: 298°F

2.3.15 Electric Power

Plant will be designed for utilization of gasification char in the boilers to generate steam for process steam turbines and electric power for the plant and supporting facilities.

169,000 Volts - 3 Phase - 60 Hz	Transmission
69,000 Volts - 3 Phase - 60 Hz	Subtransmission
13,800 Volts - 3 Phase - 60 Hz	Generation/Distribution for Plant
4,160 Volts - 3 Phase - 60 Hz	Plant Utilization
480 Volts - 3 Phase - 60 Hz	Plant Utilization

2.3.16 Vacuum Condensate

- o Pressure: 2 Hg" Absolute
- o Temperature: 100°F

Typical Analysis Parameter	Concentration (MG/L) #1 - Well Pad
Bicarbonate	390.0
Calcium	89.0
Chloride	2.4
Copper	0.001
Fluoride	0.2
Iron	6.2
Lead	0.0
Magnesium	16.0
Manganese	1.1
Potassium	7.6
Silica	39.0
Sodium	13.0
Sulfate	2.2
Total Hardness (as $CaCO_3$)	290.0

Corrosion Index 0.02

Me/L ($Cl^- = SO_4^{2-}$)
Me/L (Alkalinity as $CaCO_3$)

2.4 PRODUCT SPECIFICATIONS

2.4.1 Fuel Grade Methanol

	Wt.%
o Methanol and other alcohols	99.5 min.
o Water Content	0.5 max.
o Sodium Content	1 ppm max.

2.4.2 Federal Grade A Methanol (For Reference Only)

Characteristics	Grade A Requirements
o Acetone and Aldehydes, % max.	0.003
o Acetone, % max.	-----
o Ethanol, % max.	-----
o Acidity (as Acetic Acid) % max.	0.003
Appearance and hydrocarbons	Free of opalescence, suspended matter and sediment
Carbonisable substances, color	Not darker than color standard No. 30 of ASTM D1209, Platinum-Cobalt scale.
Color	Not darker than color standard No. 5 of ASTM D1209, Platinum-Cobalt scale.
Distillation Range	Not more than 1°C and shall include 64.6°C $\pm$ 0.10°C at 760 mm.
Specific Gravity, max.	0.7928 @ 20°/20°C
Percent methanol by wt. min.	99.85
Nonvolatile content, gm/100 ml, max.	0.0010
Odor	Characteristics, non-residual
Permanganate	No discharge of color in 30 minutes
Water, percent max.	0.15

2.4.3 Sulfur

Sulfur will be available from the Sulfur Recovery unit as a flaked solid for sale or disposal.

Temperature: Ambient

2.4.4 Carbon Dioxide

CO_2 will be available for sale from the Selexol unit. The expected flow will be as follows:

	% Vol.
CO	0.08
CO_2	99.45
H_2	0.05
CH_4	0.42
H_2S	1 ppm Vol
COS	58 ppm Vol
N_2	13 ppm Vol
TOTAL	100.0

Total Lb Mols/Hr: 20,110.8
Pressure: 5 psig
Temperature: 50°F

2.5 Drawings

The following drawings will be found following Page 2/10:

5530-001-P-001	Process Overall Plant Area Plan
5530-Y-001	Mass Block Flow Diagram
5530-Y-002	Utility Block Flow Diagram

2.6 Overall Plant Area Plan

The numerical designations assigned to plant areas are as follows:

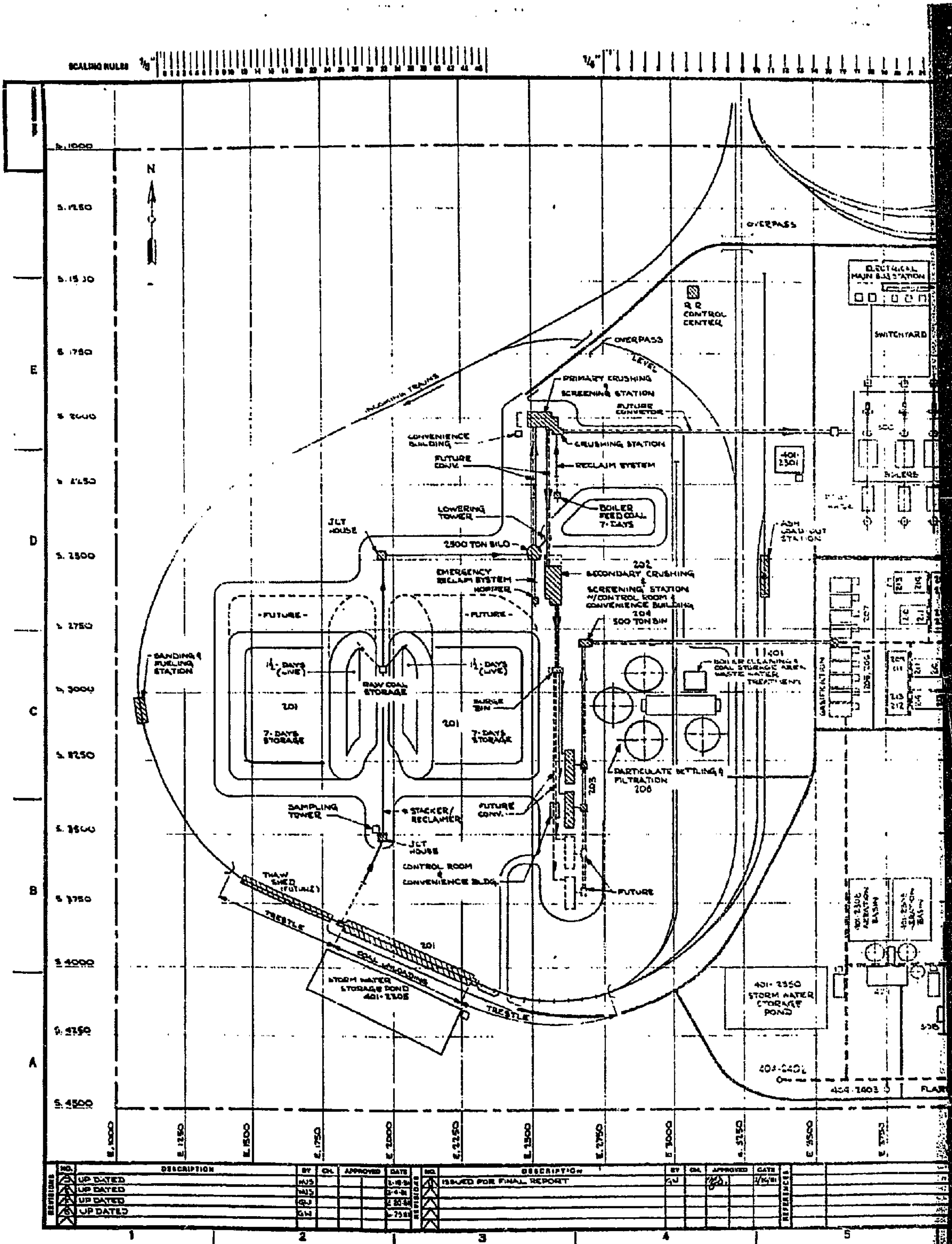
100 Areas
101 - Air Separation Plant
102 - Nitrogen/Plant Air System
103 - Cooling Water System and Distribution
104 - Railroad
105 - Chemical Storage
106 - Fuel Storage
107 - Dock

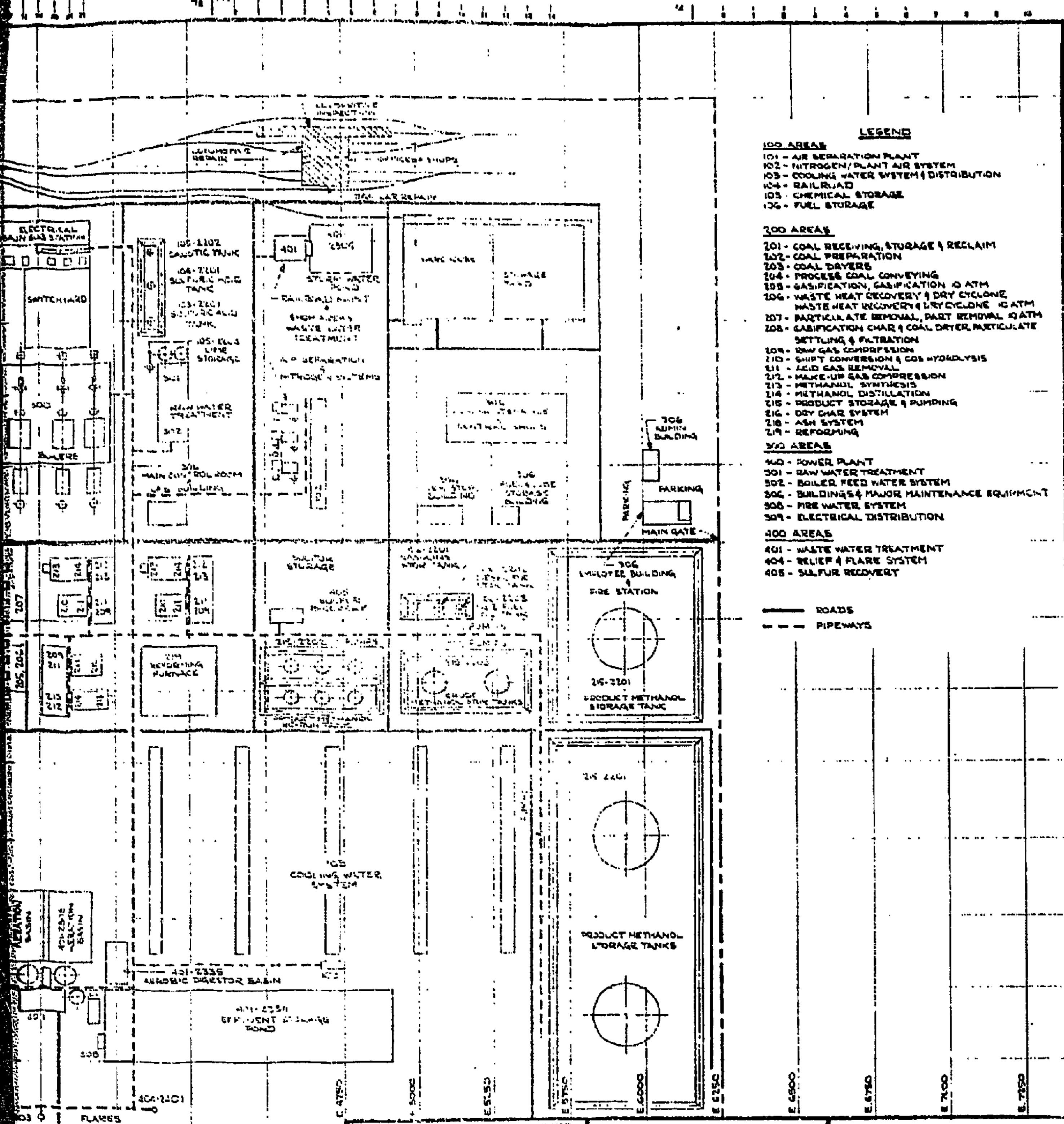
200 Areas
201 - Coal Receiving, Storage and Reclaim
202 - Coal Preparation
203 - Coal Dryers
204 - Process Coal Conveying
205 - Gasification, Gasification 10 ATM
206 - Waste Heat Recovery and Dry Cyclone
Waste Heat Recovery and Dry Cyclone 10 ATM
207 - Particulate Removal, Particulate Removal 10 ATM
208 - Gasification Char and Coal Dryer Particulate Settling and Filtration
209 - Raw Gas Compression
210 - Shift Conversion and COS Hydrolysis
211 - Acid Gas Removal
212 - Make-up Gas Compression
213 - Methanol Synthesis
214 - Methanol Distillation
215 - Product Storage and Pumping
216 - Dry Char System
218 - Ash System
219 - Reforming

300 Areas
300 - Power Plant
301 - Raw Water Treatment
302 - Boiler Feed Water System
305 - Plant Steam System
306 - Buildings and Major Maintenance Equipment
308 - Fire Water System
309 - Electrical Distribution

400 Areas
401 - Waste Water Treatment
404 - Relief and Flare System
405 - Sulfur Recovery

600 Areas
601 - Coal Facilities Capps Mine
602 - Coal Facilities Chuitna Mine


SCALING RULES
N
OVERPASS
ELECTRICAL MAIN SUBSTATION
R R CONTROL CENTER
SWITCHYARD
OVERPASS
LEVEL
INCOMING TRAINS
PRIMARY CRUSHING & SCREENING STATION
FUTURE CONVEYOR
CONVENIENCE BUILDING
CRUSHING STATION
FUTURE CONV.
RECLAIM SYSTEM
401-2301
BOILERS
BOILER FEED COAL 7-DAYS
LOWERING TOWER
JCT HOUSE
2500 TON SILO
ASH LOAD-OUT STATION
202
EMERGENCY RECLAIM SYSTEM
SECONDARY CRUSHING & SCREENING STATION W/CONTROL ROOM & CONVENIENCE BUILDING
HOPPER
- FUTURE -
204
500 TON BIN
401
BOILER CLEANING & COAL STORAGE AREA WASTE WATER TREATMENT
SANDING & FUELING STATION
1½ - DAYS (LIVE)
RAW COAL STORAGE
201
SURGE BIN
7-DAYS STORAGE
GASIFICATION
PARTICULATE SETTLING & FILTRATION
206
203
SAMPLING TOWER
STACKER/ RECLAIMER
FUTURE CONV.
JCT HOUSE
CONTROL ROOM & CONVENIENCE BLDG.
FUTURE
THAW SHED (FUTURE)
TRESTLE
COAL UNLOADING
STORM WATER STORAGE POND 401-2305
401-2350 STORM WATER STORAGE POND
TRESTLE
401-2302 AERATION BASIN
404-2402
404-2403
FLAR
S. 1000
S. 1250
S. 1500
S. 1750
S. 2000
S. 2250
S. 2500
S. 2750
S. 3000
S. 3250
S. 3500
S. 3750
S. 4000
S. 4250
S. 4500
E. 1000
E. 1250
E. 1500
E. 1750
E. 2000
E. 2250
E. 2500
E. 2750
E. 3000
E. 3250
E. 3500
E. 3750
A B C D E
1 2 3 4 5
REVISIONS
NO. DESCRIPTION BY CH. APPROVED DATE
UP DATED
UP DATED
UP DATED
UP DATED
ISSUED FOR FINAL REPORT
REFERENCES



LEGEND

100 AREAS
101 - AIR SEPARATION PLANT
102 - NITROGEN/PLANT AIR SYSTEM
103 - COOLING WATER SYSTEM & DISTRIBUTION
104 - RAILROAD
105 - CHEMICAL STORAGE
106 - FUEL STORAGE

200 AREAS
201 - COAL RECEIVING, STORAGE & RECLAIM
202 - COAL PREPARATION
203 - COAL DRYERS
204 - PROCESS COAL CONVEYING
205 - GASIFICATION, GASIFICATION 10 ATM
206 - WASTE HEAT RECOVERY & DRY CYCLONE
WASTE HEAT RECOVERY & DRY CYCLONE 10 ATM
207 - PARTICULATE REMOVAL, PART REMOVAL 10 ATM
208 - GASIFICATION CHAR & COAL DRYER PARTICULATE SETTLING & FILTRATION
209 - RAW GAS COMPRESSION
210 - SHIFT CONVERSION & COS HYDROLYSIS
211 - ACID GAS REMOVAL
212 - MAKE-UP GAS COMPRESSION
213 - METHANOL SYNTHESIS
214 - METHANOL DISTILLATION
215 - PRODUCT STORAGE & PUMPING
216 - DRY CHAR SYSTEM
218 - ASH SYSTEM
219 - REFORMING

300 AREAS
300 - POWER PLANT
301 - RAW WATER TREATMENT
302 - BOILER FEED WATER SYSTEM
306 - BUILDINGS & MAJOR MAINTENANCE EQUIPMENT
308 - FIRE WATER SYSTEM
309 - ELECTRICAL DISTRIBUTION

400 AREAS
401 - WASTE WATER TREATMENT
404 - RELIEF & FLARE SYSTEM
405 - SULFUR RECOVERY

ROADS
PIPEWAYS

CLIENT
CIRI/PLACER
BELUGA METHANOL PROJECT
COOK INLET, ALASKA

Davy McKee
ENGINEERS AND CONSTRUCTORS

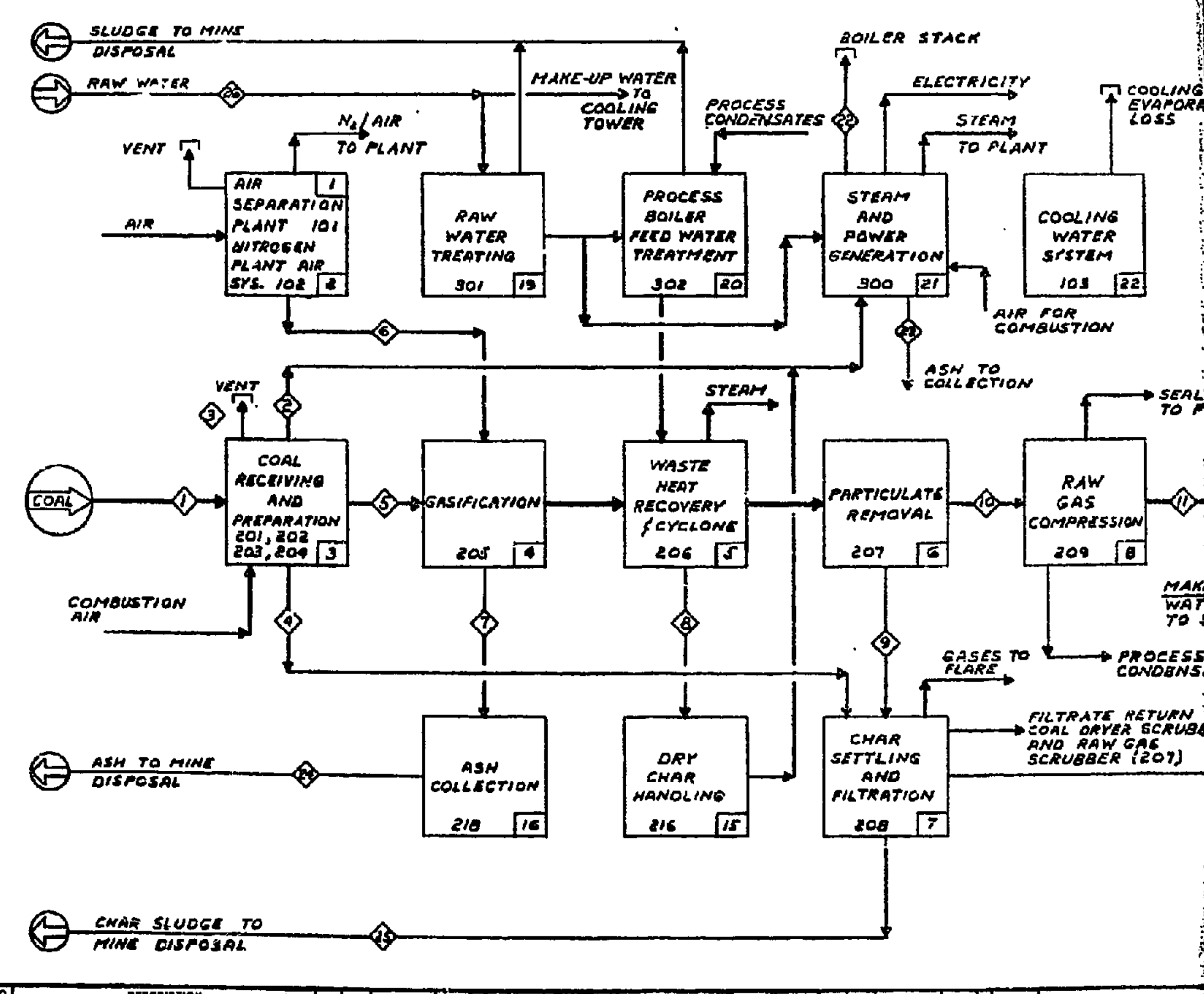
TITLE
OVERALL PLANT
AREA PLAN

SCALE 1" = 200'

5530-00?-P-001

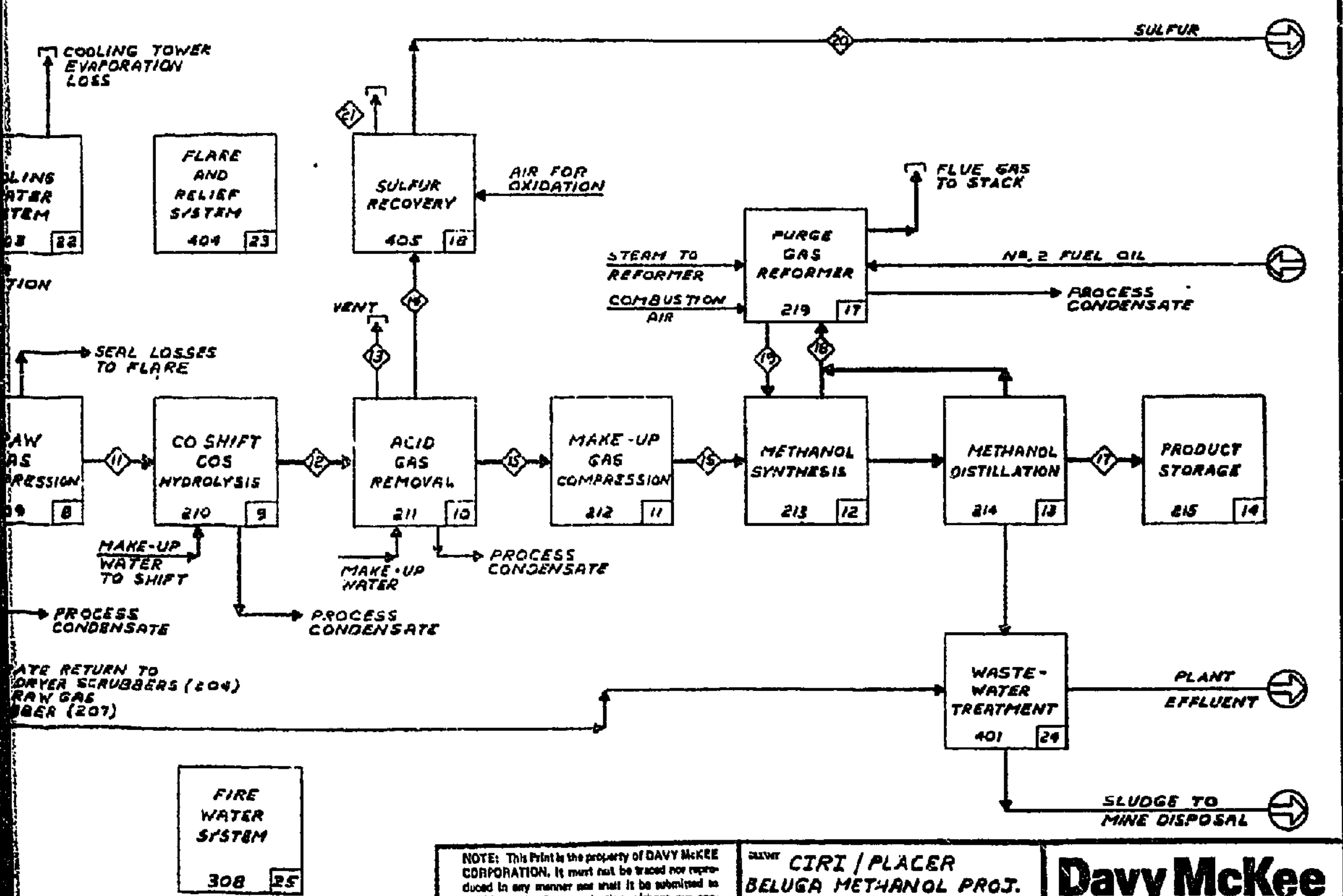
REVISION 0

STREAM No.		1	2	3	4	5	6	7	8	9	10	11	12
STREAM DESCRIPTION		AS REC'D COAL	BOILER COAL	COAL DRY. VENT	DRY. SCRUB. SLURRY	PROCESS COAL	OXYGEN	GASIFIER BOTT. ASH	CHAR TO BOILER	CHAR SLURRY TO SETTLER	RAW GAS TO COMP.	COMP. GAS TO SHIFT	SYN. GAS TO A.G.R.
PHASE		S	S	G	L/S	S	G	S	S	S/L	G	G	G
COMPONENT	MOL. WT.	WT. %	WT. %	MOL. %	WT. %	WT. %	MOL. %	WT. %	WT. %	WT. %	MOL. %	MOL. %	MOL. %
CARBON	12.011	40.51	40.51			48.97		9.89	29.98	0.12			
HYDROGEN	2.016	2.98	2.98			3.61				6PPM WT.	36.18	35.97	47.84
NITROGEN	28.014	0.53	0.53	61.18		0.64	0.50			1PPM WT.	1.38	1.41	1.15
SULFUR	32.060	0.73	0.15			0.18			0.18	67PPM WT.			
OXYGEN	32.000	11.17	11.17	11.22		13.80	99.50						
CHLORINE	35.453	0.03	0.03			0.04				41PPM WT.			
ASH		20.75	20.75		9.90	25.06		90.11	69.89	0.27			
WATER	18.016	23.90	23.90	23.09	90.10	8.00				99.59	2.65	.41	0.14
CARBON MONOXIDE	28.011									42PPM WT.	39.36	40.24	14.48
CARBON DIOXIDE	44.011			4.51						0.02	18.33	18.80	33.81
METHANE	16.043									1PPM WT.	3.02	3.03	2.52
HYDROGEN SULFIDE	34.076										0.07	0.07	0.06
CARBONYL SULFIDE	60.071										28PPM VOL.	0.01	2PPM
SULFUR DIOXIDE	64.066			63 PPM VOL.									
METHANOL	32.043												
DIMETHYL ETHER	46.068												
HIGHER ALCOHOL	74.120												
TOTAL	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TOTAL (WET)	MOL/HR			80,200.00			19,405.64				74,379.79	72,110.31	68,197.82
FLOW (DRY)	SCFM			23,407,429			7,365,760				27,479,501	27,254,441	33,444,958
TOTAL FLOW	LB/HR	2,124,323	400,000	2,155,422	224,636	1,337,773	620,722	111,707	285,333	13,218,153	1,575,415	1,533,534	1,823,958
PRESSURE	PSIA			14.9	65		90			40	40	770	695
TEMPERATURE	°F	AMB.	AMB.	147	147	147	257	300	300	153	104	335	100
HHV	BTU/LB	6871	6871			8306			4220				



NO.	DESCRIPTION	BY	CK.	APPROVED	DATE
0	ISSUED FOR FINAL REPORT	I.D.			

⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕	㉖
GAS SHIFT	SYN. GAS TO A.G.R.	CO_2 VENT STREAM	H_2S TO SULF. RECOVERY	GAS TO MAKE UP GAS COMP.	MAKE-UP GAS TO METH. UNIT	PRODUCT METHANOL	GASES TO REFORMER	REFORMED GASES	MOLTEN SUL. BY PROD.	SULF. RECO. VENT GASES	BOILER STACK	BOILER ASH	DRY ASH TO DISPOSAL	WET ASH & CHAR	RAW WTR. TO PLANT
	G	G	G	G	G	L	G	G	L	G	G	S	S	S	L
.%	MOL.%	MOL.%	MOL.%	MOL.%	MOL.%	WT.%	MOL.%	MOL.%	WT.%	MOL.%	MOL.%	WT.%	WT.%	WT.%	%
													2.80	6.19	
.97	47.84	2.06	0.03	66.09	66.04		46.41	40.07		0.03					
.41	1.15	13 PPM VOL.	9 PPM VOL.	1.69	1.59		23.16	17.18		14.59	73.98				
									100.00					0.03	
										4.71	3.91				
												0.04	0.03	0.22	
												99.96	97.17	23.56	
.41	0.14		5.74			0.28	0.04	0.07		5.35	7.91			70.00	100.00
.29	14.48	0.08	0.06	19.96	19.96		4.67	14.23		0.04					
.80	33.81	99.45	92.57	9.08	9.08		9.08	5.37		70.07	14.63				
.09	2.52	0.42	0.28	3.33	3.33		15.32	3.14		0.21					
.07	0.06	1 PPM VOL.	1.32	1 PPM VOL.						8 PPM VOL.					
.01	2 PPM	5 PPM VOL.	16 PPM VOL.	1 PPM VOL.						12 PPM VOL.					
											0.02				
						99.42	1.19								
							0.19								
						0.30									
.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
10.81	88,197.82	20,110.80	4343.59	63,872.46	63,872.41	19541.99	13,327.08	18,058.85		5738.05	141,841.82				
4,441	31,444,959	7,631,848	1,553,651	24,238,941	24,238,941		5,088,388	5,918,132		2061,115	53,851,180				
,534	1,823,358	882,075	183,628	759,939	759,935	625,960	209,458	232,335	1833	226,889	4,814,448	282,443	394,150	849,758	7,372,806
10	695	20	20	670	1420	25	365	409	50	17	15				
15	100	50	100	75	100	100	100	100	260-270	100	350-400			100	55
						9750			3483						



CLIENT: CIRI / PLACER
BELUGA METHANOL PROJ.
COOK INLET, ALASKA

Davy McKee
ENGINEERS AND CONSTRUCTORS

TITLE: MASS BLOCK FLOW DIAGRAM

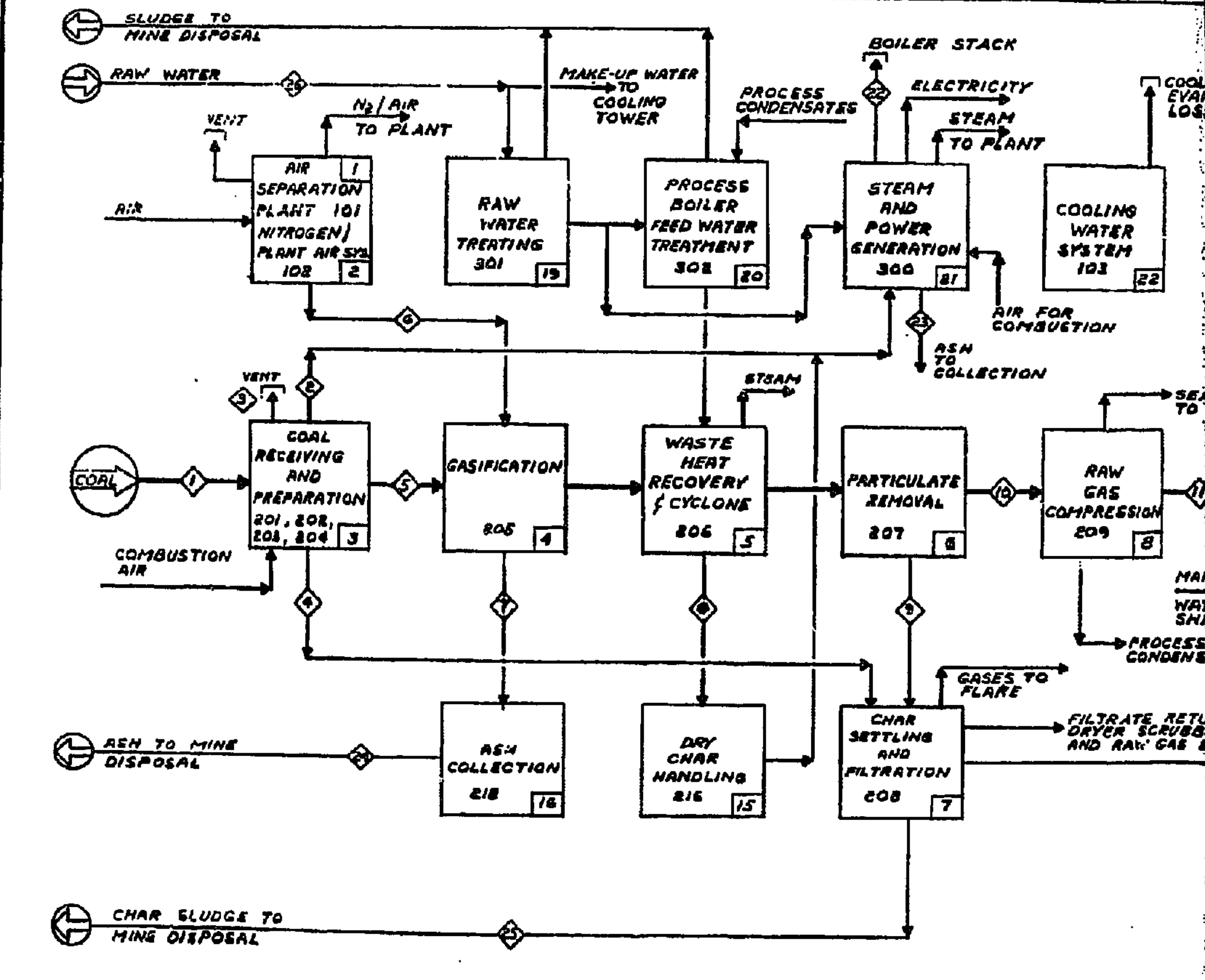
SCALE: NONE

5530-Y-001

	BY	DATE
DESIGNED		
DRAWN	K.F.	6/81
CHECKED	C.G.	7/81
APPROVED 1	TKS	7/81
APPROVED 2		
APPROVED 3		

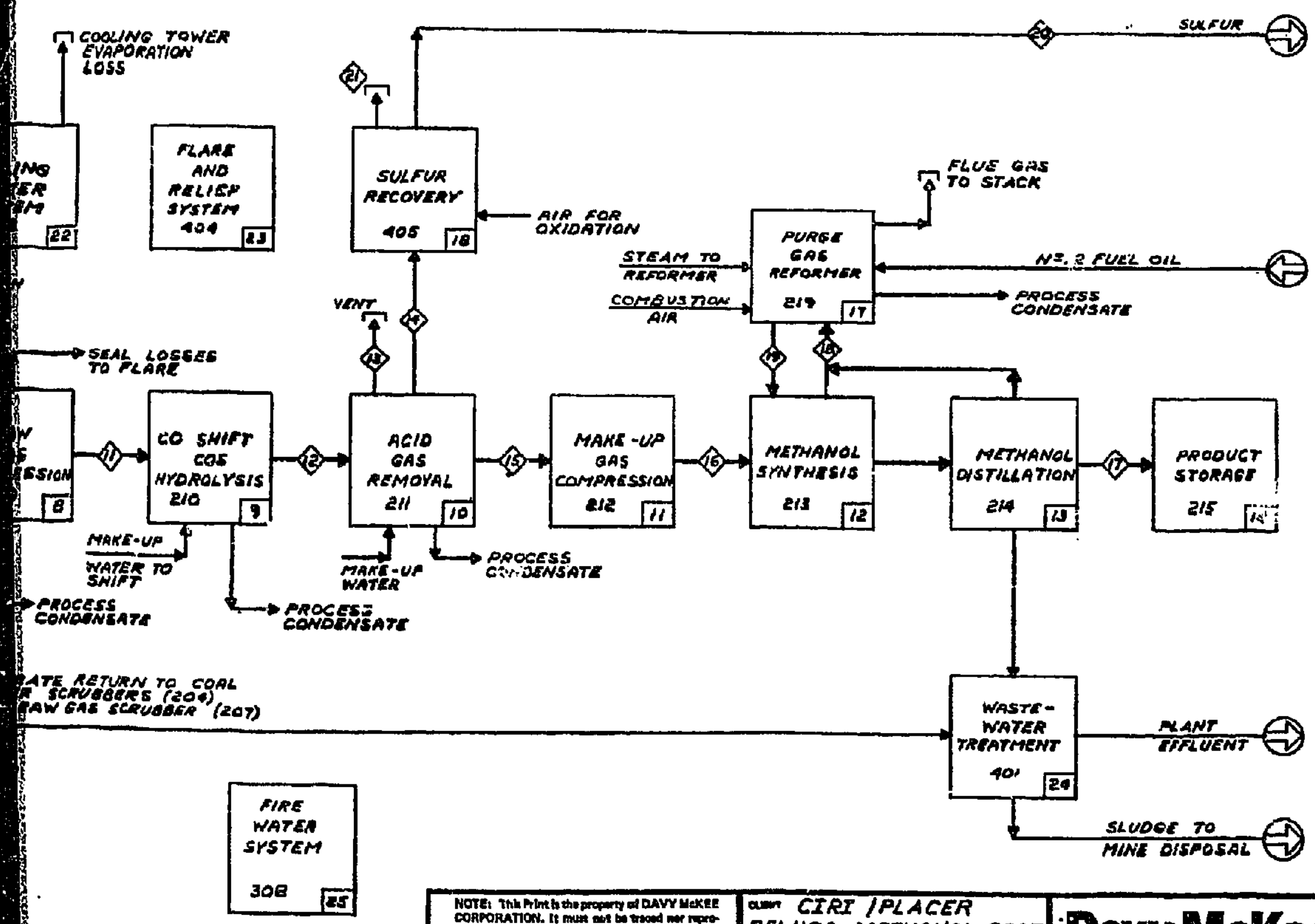
PLANT UTILITY TABLE

UTILITY CODE		1	2	3	4	5	6	7	8	9	10	11	12
AREA		101	102	201, 202, 203, 204	205	206	207	208	209	210	211	212	2
COOLING WATER	GPM	80,060	850		920	300		62,310	82,980		16,370	12,370	73
ELECTRICITY	KW												
CONSUMED		22	5173	14,590	1910		155	2430	100	580	32,195	200	13
GENERATED													
STEAM USER	LB/HR												
1515 PSIA, 900°F													
1270 PSIA, 950°F		810,665											
870 PSIA, 840°F									929,779			184,320	117,
115 PSIA, SAT.					535,006						57,820		
STEAM GENERATED	LB/HR												
1515 PSIA, 900°F													
1270 PSIA, 950°F													
870 PSIA, 840°F						1,222,512							
115 PSIA, SAT.						5937							
BFW REQUIRED	LB/HR					1,246,962				690,753			
AIR FOR COMBUSTION	SCFH			23,558,280									
NITROGEN	SCFH			27,000	447,911								
FUEL REQUIREMENTS													
NATURAL GAS	SCFH												
No. 2 FUEL OIL	BBL/DAY												



NO.	DESCRIPTION	BY	CH.	APPROVED	DATE	NO.	DESCRIPTION	BY	CH.	APPROVED	DATE
A	ISSUED FOR FINAL REPORT	J.D.									

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
212	213	214	215	216	218	219	405	301	302	300	103	404	401	308
12,370	7300	962				10,528	750			54,167	329,867			
200	1345	2995	4980	185	375	245	1570	520	2350	15,000	16,220		1089	410
										165,000				
						228,113								
184,320	117,000													
		64,314				492	155,523	114,350	38,411					
							(INCLUDES							
						236,700	TOTAL PLANT							
							STEAM							
							TRACING)			810,665				
										969,487				
						244,000				2,767,600				
						5,120,724				50,195 DIR				
					912,000									
												1000		
						128								



CLIENT CIRI / PLACER
BELUGA METHANOL PROJ.
COOK INLET, ALASKA

Davy McKee
ENGINEERS AND CONSTRUCTORS

TITLE UTILITY BLOCK FLOW DIAGRAM

SCALE NONE

5530-Y-002

REVISION 0

	BY	DATE
DESIGNED		
DRAWN	K.K.	6/81
CHECKED		7/81
APPROVED 1		7/81
APPROVED 2		
APPROVED 3		

6 7 8 9 10