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Scale-Up Of Mild Gasification To A Process Development Unit - Mildgas 24 Ton/Day PDU Design Report

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ABSTRACT

From November 1991 to April 1996, the Kerr-McGee Coal Corporation (K-M Coal) led a project to develop the Institute of Gas Technology (IGT) Mild Gasification (MILDGAS) process for near-term commercialization. The specific objectives of the program were to: design, construct, and operate a 24-tons/day adiabatic process development unit (PDU) to obtain process performance data suitable for further design scale-up; obtain large batches of coal-derived co-products for industrial evaluation; prepare a detailed design of a demonstration unit; and develop technical and economic plans for commercialization of the MILDGAS process. The project team for the PDU development program consisted of: K-M Coal, IGT, Bechtel Corporation, Southern Illinois University at Carbondale (SIUC), General Motors (GM), Pellet Technology Corporation (PTC), LTV Steel, Armco Steel, Reilly Industries, and Auto Research.

The MILDGAS process is capable of processing both eastern caking and western non-caking coals, and is designed to offer options in the product slate by varying the process conditions and by blending different feed coals. The solid product (char) can be briquetted to make form coke for steel-making blast furnaces, foundry cupola operations, or improved fuel for power generation. The mild gasification and briquetting processes are done entirely within closed vessels, which offers significant advantages over conventional coking practices for control of fugitive emissions. The co-product liquids can be processed into chemical feedstocks, pitch for electrode binders, and fuels. In a preceding program sponsored by DOE, the MILDGAS process was operated successfully by IGT at coal feed rates up to 100 lb/hr with several caking eastern coals and a non-caking western coal.

The project work began with the preparation and submission of documentation required by the National Environmental Policy Act (NEPA) in January 1992, and a Finding of No Significant Impact was issued in February 1994. After obtaining the Permit to Construct from the Illinois EPA in April 1994, the process engineering was finalized, detailed engineering was begun, and purchase orders for the major equipment units were placed. The project was terminated at the end of July 1995 as a result of rescission of FY95 funding by Congressional action. At that time, the site preparation was completed, most of the major pieces of equipment were built, and the structural steel was almost ready for erection.

The 1-ton/hr PDU facility would have consisted of a 2.5-ft-ID adiabatic gasifier for the production of gases, coal liquids, and char; a thermal oxidizer; a scrubber for environmentally acceptable disposal of all process-generated gases; and other auxiliary facilities. The product testing was devised to obtain a realistic assessment of the quality and economic value of both the coal liquids and solid chars produced. This information is required to confirm the market potential of the co-products and determine the slate of products and the economics of a commercial demonstration plant using the MILDGAS process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

In November 1991, the Kerr-McGee Coal Corporation (K-M Coal) was awarded Cooperative Agreement No. DE-FC21-92MC27391 from the U.S. Department of Energy based on a proposal submitted in response to PRDA No. DE-RA21-91MC27391 for the "Scaleup of Mild Gasification to a Process Development Unit." The overall objective of the Cooperative Agreement was to develop the Institute of Gas Technology (IGT) Mild Gasification (MILDGAS) process for near-term commercialization. Commercialization of the MILDGAS technology would have introduced a new industry into an economically depressed area, utilizing marginally marketable coal to make an environmentally safe form coke which is vitally needed in our metallurgical industry, produce coal liquids which address import problems, and also address the use of char for our electric utility industry. The specific objectives of the program were to: design, construct, and operate a 24-tons/day adiabatic process development unit (PDU) to obtain process performance data suitable for further design scale-up; obtain large batches of coal-derived co-products for industrial evaluation; prepare a detailed design of a demonstration unit; and develop technical and economic plans for commercialization of the MILDGAS process.

The project team for the PDU development program consists of: K-M Coal, IGT, Bechtel Corporation, Southern Illinois University at Carbondale (SIUC), General Motors (GM), Pellet Technology Corporation (PTC), LTV Steel, Armco Steel, Reilly Industries, and Auto Research. The State of Illinois is the major contributor of the cost sharing portion of this program, and their contributions are supplemented by K-M Coal, SIUC, and GM. Contributions of Reilly Industries and the steel companies are gratefully acknowledged but not considered toward the cost sharing.

The responsibilities of the project team members were as follows:

- K-M Coal was responsible for the overall management and technical direction of the program. Advising K-M Coal was an Industrial Project Advisory Group (IPAG) consisting of representatives of the steel industry, tar processing industry, foundry industry, turbine manufacturers, and consultants.

- IGT, as the originator of the MILDGAS technology, was responsible for technology development, product evaluation management, and overall technical supervision.

- Bechtel Corporation served as the A&E firm responsible for the design and construction of the PDU facility, development of a demonstration plant design, and were to contribute to the commercialization plan revision.

- SIUC operates the Illinois Coal Development Park at Carterville, Illinois, which was to be the location of the PDU. SIUC would have been responsible for operation of the PDU facility and for evaluation of the char product for relative reactivity and suitability as a boiler fuel in a fluidized-bed combustor.

- GM Research Laboratories was charged with testing and evaluating foundry coke made from the char. A large quantity of form coke was also to be tested for foundry use at PTC's 60-inch cupola.

- LTV and Armco were two of several steel companies enlisted to evaluate metallurgical form coke from the MILDGAS char. The major portion of the char from the PDU was to be used to produce form coke briquettes for blast furnaces and foundry cupolas.

- Reilly Industries had the responsibility to process and evaluate the PDU coal liquids, which were to be collected and evaluated as feedstock for high-value chemicals, industrial binders, and fuels. Reilly was also to conduct separate modification operations, such as thermal treatment with or without a Lewis acid catalyst, fractional distillation, and hydrotreating, to produce specification-grade products. Reilly would have taken all the coal liquids produced at the PDU facility.

- Auto Research, Incorporated was included in the project team to evaluate middle distillates from the co-product liquids as a source of motor fuels.

The project work began with the preparation of documentation required by the National Environmental Policy Act (NEPA). This documentation was prepared and submitted to DOE/METC in the first Quarter of the project. The final documentation was submitted by DOE/METC to DOE headquarters in January 1993. In September 1993, DOE submitted an Environmental Assessment of the PDU plans, and a Finding of No Significant Impact was issued in February 1994. After obtaining the Permit to Construct from the Illinois EPA in April 1994, the process engineering was finalized, detailed engineering was begun, and purchase orders for the major equipment units were placed. The project was terminated at the end of July 1995 as a result of rescission of FY95 funding by Congressional action. At that time, the site preparation was completed, most of the major pieces of equipment were built, and the structural steel was almost ready for erection.

The MILDGAS process is capable of processing both eastern caking and western non-caking coals. The MILDGAS reactor is a single-stage fluidized bed with no mechanical agitation that is capable of handling agglomerating coals without pretreatment. The MILDGAS process is designed to offer options in the product slate by varying the process conditions and by blending different feed coals. Depending on the feed coal characteristics and the operating conditions, the char can be briquetted to make form coke for steel-making blast furnaces, foundry cupola operations, or improved fuel for power generation. The briquetting process offers options for blending various chars, coals, and other additives, such as alloying agents, to tailor the properties of the form coke. The mild gasification and briquetting processes are done entirely within closed vessels, which offers significant advantages over conventional coking practices for control of fugitive emissions. The co-product liquids can be processed as feedstocks for chemicals (*e.g.*, BTX, phenol, cresols, xylenols, naphthalene, and indene), pitch for use as a binder for electrodes in the aluminum industry, and fuels.

In a preceding program sponsored by DOE, an 8-inch-ID isothermal process research unit (PRU) for the MILDGAS process was constructed and operated successfully by IGT for 26 steady-state tests, with closed material balances, at coal feed rates up to 100 lb/hr. In these tests, several caking eastern coals and a non-caking western coal were successfully tested. The continuous processing of caking coals in a single reactor was the major achievement of this program. The PRU produced char and liquids for bench-scale evaluation. The char was processed into form coke briquettes on a small scale, and these were tested for strength and density. The liquids were evaluated for fractionation into chemical feedstocks.

The 1-ton/hr PDU facility would have consisted of a 2.5-ft-ID adiabatic gasifier for the production of gases, coal liquids, and char; a thermal oxidizer; a scrubber for environmentally acceptable disposal of all process-generated gases; and other auxiliary facilities.

The product testing to be conducted in the proposed program was devised to obtain a realistic assessment of the quality and economic value of both the coal liquids and solid chars produced. This information is required to confirm the market potential of the co-products and determine the slate of products and the economics of a commercial demonstration plant using the MILDGAS process.

BACKGROUND

The use of coal as source of liquid fuels, principally kerosene, was first explored in the mid-1880's. Even though the first concerted effort to develop a coal-based synthetic fuels industry was initiated during the 1920-1923 oil shortage, the deployment of coal conversion technologies has been stopped, then and each time thereafter, by new supplies of conventional fuels. The past R&D efforts were directed toward the production of premium fuels -- diesel fuels, motor and aviation gasoline, and high-Btu gas -- with the hope that these high-end-use products would assure commercial success. The high-temperature, high-pressure processes required were capital-intensive, and it was repeatedly revealed that the resulting products could not compete with conventional fuels on the open market.

Mild gasification, an alternative approach to coal conversion as a continuous coal carbonization process to make marketable products, may be an affordable route to increase eastern coal utilization and open new jobs in the current economic climate. Because of its mild operating conditions and process simplicity, the technology is envisioned to be ready for commercialization within the short time period of approximately 5 to 10 years after obtaining the data needed for scale-up from the PDU testing. Systems analysis studies by Bajura and Ghate[1] and Klara and Hand,[2] as well as then-current DOE-sponsored projects, all supported this prospect.

Under DOE contract No. DE-AC21-87MC24266, Development of an Advanced Continuous Mild Gasification Process for the Production of Co-products, a literature and market survey was conducted,[3] which formed the basis for the selection of the IGT mild gasification reactor consisting of coaxial fluidized- and entrained-bed reaction stages. In that program a Process Research Unit (PRU) was also constructed and a series of tests were performed with both caking and non-caking coals.

The MILDGAS reactor operates with caking coals in a single fluidized bed, with a fluidization gas distributor designed to promote rapid mixing and dispersal of the incoming coal throughout the bed of char. The fines fraction of the coal feed (generally -60 mesh) is fed to the entrained section, with lower residence times sufficient for conversion of the smaller particles. Using this reactor configuration, IGT built the 100-lb/h-coal-capacity isothermal PRU at its Energy Development Center in Chicago, Illinois. In the course of PRU testing and data analysis, it was found that the relationship of incoming coal feed rate to the mass inventory of char in the fluidized bed was critical in controlling agglomeration with caking coals.

PRU Description

The PRU was designed with operational flexibility provided by multiple solids feed and char discharge nozzles, in addition to a nozzle for possible char recycle to the fluidized bed. Coal can be fed to the freeboard above the fluidized bed or directly into the fluidized bed. A char discharge screw controls the char removal rate from the fluidized bed via either a bottom discharge pipe or a bed char overflow pipe. The char discharge rate controls the fluidized-bed height and solids residence time. The bottom closure flange supports the fluidized-bed gas distributor, which has been constructed to test various gas distributor arrangements.

A char receiver/lockhopper system is provided for char removal, while two cyclones, heated to prevent tar condensation, collect the entrained char. A hot product gas sampling system collects a slipstream of about 5% of the total product gas stream for condensation and characterization. The remainder of the product gas is disposed of by combustion. An on-line gas chromatograph monitors the gas composition during the test operation, and 1-hour, steady-state samples of oils/tars are collected for detailed off-line laboratory analysis, along with char and additional gas samples.

Co-Product Selection, Evaluation, and Upgrading

The criteria for co-product selection were identified in the Task 1 Topical Report market survey.[3] Char is the major by-product, comprising about 60% to 70% of the total co-product stream, so its beneficial utilization is critical to commercialization of MILDGAS technology. Char upgrading studies were completed under a DOE-supported program, and the results were reported in the Task 3 Topical Report.[4]

An advisory group of volunteers from the coal mining industry, coal tar processors, the iron and steel industry, foundries, and government was formed to provide market direction. Consultation with this Industrial Project Advisory Group (IPAG) members in meetings held at IGT led to the conclusion that the use of mild gasification char to make form coke for blast furnaces and foundries should be given the highest priority. The total potential market for this end use is about 30 million tons/year. In order of decreasing priority, the other potential char markets are production of smokeless fuel as an alternative to firewood for domestic heating (50 to 100 million tons/year) and steam activation of char for industrial water treatment applications (1 to 2 million tons/year).

Mild gasification oils/tars can also be upgraded into value-added products. Different fractions of the condensable hydrocarbons can be used as binders for electrodes in the steel and aluminum industries (market size 0.7 million tons/year), in roofing and road paving industries (330,000 tons/year), as pitch coke for electrodes (1.7 million tons/year), as chemical feedstocks used for production of plastics, paints, adhesives, dye intermediates, insecticides, surfactants, etc. (at least 15 million tons/year), and as fuel for peaking turbines (0.9 million tons/year). The consensus of IPAG members is that pitch-based products -- binders and pitch coke -- should be the highest priority targeted products from the oils/tars, followed by chemical feedstocks and fuel uses.

Form Coke Co-Product

A form coke co-product from the MILDGAS char has two sub-markets. The larger of the two markets for form coke is in blast furnace production of iron, with a current annual consumption of about 25 million tons of coke per year. A smaller market of about 1.8 million tons per year of foundry coke is used in cupolas for re-melting and alloying iron to make special steels. The cost of coke from various suppliers is about $150 per ton (1996), so a suitable form coke from

MILDGAS would present an excellent value-added product. In addition, the MILDGAS process offers continuous form coke production with superior environmental control that is difficult and costly to achieve in present coke oven batteries.

The existing coking plants in the United States are reaching the limits of useful age, and environmentally acceptable methods to produce supplementary supplies of coke rapidly are urgently needed. The replacement coke could come from imports, although this source would not assure a long-term supply. An assured domestic supply of form coke from a continuous, environmentally safe process would have significant benefits for the steel and coal companies and the nation.

In the United States, the future of basic ironmaking -- which provides the only source of virgin iron units to the steelmaking process -- depends on one of two principal approaches: the blast furnace process, or a direct ironmaking approach for which the process has yet to be invented or developed. The continued operation of blast furnaces requires a supply of coke, which is traditionally produced only from coking-grade coals. The U.S. foundry industry is in a similar situation. The existing conventional by-product coking batteries are being decommissioned as they reach the stage where major repairs are required. These batteries can be replaced in three different ways:

I. Rebuild the original structures: The conventional coke-making process design leads to environmental problems for which the batteries are well-known. Coke ovens are also very expensive to build. At the present time, there are no known plans for building new conventional coking batteries in the United States.

II. Build new non-recovery coke batteries: The non-recovery coking process is a horizontal-chamber process based originally along the lines of the beehive oven concept. Environmentally, the process is definitely superior to the by-product process, but it also does not recover any by-products, gaseous or liquid. Volatile gases and oils/tars are burned above the coal bed in the horizontal chamber, partially to provide process heat. The coke quality is similar to that from the by-product coke oven, but coal blend selection and preparation is more strict.

III. Build new form coke plants: Form coking, the third choice for supplying metallurgical coke, is currently represented by three different approaches for binding devolatilized char into a carbon agglomerate:

   A. Briquetting with pitch binder followed by curing and calcining (FMC coke). 20,000 tons of FMC-produced form coke were tested in the No. 5 blast furnace of Inland Steel in 1973.

   B. Binderless briquetting with highly agglomerating coals (Bergbau-Forschung, Lurgi, and Ancit). 10,000 tons of Bergbau-Forschung form coke was tested on a Thyssen blast furnace, Duisburg, FRG, in 1976.

C. Briquetting with a mixture of coal and pitch-type material (Nippon Steel). 90,000 tons of this type of form coke was tested on the No. 4 Nippon Steel blast furnace in 1986-7.

The basic advantages of form coking are reduced environmental pollution and the ability to use a wide variety of coals, including non-coking grades.

One alternative to completely eliminate coke from the iron making process is direct reduction of iron oxide. This could be accomplished in one of three ways:

1) Reduction of finely sized iron oxide in a liquid bath of iron that is simultaneously reacting with injected coal and pure oxygen (HiSmelt plant, 300 ton/day, to be built in Australia).

2) Pre-reduction of iron oxide ore (finely or coarsely sized) in a separate shaft furnace with reducing gases from the smelting unit, which is fired with powdered coal (or other carbonaceous fuel) and oxygen (Klochner-CRA pilot plant, Germany, and Dios process, Japan).

3) Reduction of sized ore or pellets in a shaft by gases produced in a separate gasifier section of the process in which the selected coals are reacted with oxygen (Corex plant, 1000 ton/day, Pretoria, South Africa).

The common denominator of the above three basic process groups is that all of them use pure oxygen, usually in amounts of 0.85 to 1.0 ton per ton of iron. The direct iron-making approaches appear to be of potential value in small "greenfield" installations or in steel plants requiring the addition of small incremental volumes of liquid iron (electric furnace plants, foundries, etc.) The basic advantage of this kind of iron smelting installation is the elimination of the coking and, possibly, sintering sections of the iron smelting complex, though the need then arises to replace these with a large oxygen plant. Economics seem to indicate that the conventional blast furnace as it exists today will be difficult to challenge in the foreseeable future in the U.S.

Form coke made from MILDGAS char can meet the requirements for physical and chemical coke properties. In general, coke needs a strength sufficient to support the burden in the blast furnace, and also has to provide a certain bulk porosity for gas, liquid metal, and flux flows. In addition to these properties, the coke must also meet a reactivity criterion based on the reaction of carbon with carbon dioxide, and its sulfur and ash contents should be low. Blast furnace coke is usually produced in the coke oven by selectively blending several coking coals, usually a high-volatile and a low-volatile coal, to make a strong structure with a desired reactivity. MILDGAS chars can be produced and blended in a similar manner with better control of the process conditions and emissions than can be attained in coke ovens. Some key performance properties for blast furnace and foundry cokes are shown in Table 1, along with typical values for commercial U.S. cokes.[4]

Table 1. Typical Values for Coke Properties

Test Description	Blast Furnace Coke	Foundry Coke
Moisture, %	10.0	2.0
Volatile Matter, %	1.0	0.7
Ash, %	8.0	7.0
Total Sulfur, %	0.8	0.6
Sieve Analysis, in.	3/4×2	3×5 to 8×12
Specific Gravity	1.90 to 1.95	1.95 - 2.00
Porosity, %	50	45
Bulk Density, lb/ft^3	29 to 32	less than 25
Tumbler Stability	45 to 63	--[a]
Tumbler Hardness	62 to 73	--[a]
Drop-Shatter Test, 3 in.	--[a]	90
Drop-Shatter Test, 2 in.	--[a]	98
Reactivity Test, % wt loss @ 1800°F (Bethlehem)[5]	10 to 45	NA[b]

[a] Tumbler test is used for blast furnace coke, drop-shatter test for foundry coke
[b] Data not available

The properties of foundry coke differ from those of blast furnace coke, but the char from mild gasification could be processed to satisfy the required criteria. Porosity and reactivity are more important than strength in a cupola, because the foundry coke is a source of both heat and carbon for transfer into the iron melt to make various steels. A form coke for foundry applications could also incorporate metallic fines, such as silicon and manganese, that are normally added in the cupola for alloying with the steel. This would enhance the value of foundry form coke significantly by providing a secondary benefit in improving cupola operations.

Six form coke processes that have produced enough coke for actual blast furnace tests were reviewed in a DOE funded study.[3] Form coke can be made by blending char with a separate pitch binder, as has been done in the HPN, DKS, and FMC coke processes. However, if a highly caking coal is available, "binderless" briquetting can be done in which the non-caking char is blended with a fresh caking coal and the mixture raised to a temperature at which the coal softens and performs the function of a binder. This method was used in the Ancit, BFL, and Sapozhnikov processes, the latter two of which have reportedly been used in blast furnace tests with satisfactory results. The principal advantage of binderless briquetting lies in the fact that it does not consume co-product pitch, which may command an even higher market value than the form coke for specific applications

The suitability of the granular char from the MILDGAS PRU for production of sufficiently strong briquettes for metallurgical applications was investigated in two bench-scale briquetting studies, followed by a pilot-scale production of pillow-shaped briquettes. The investigation was limited to binderless briquetting. First, one-inch-diameter by 3/8-inch-thick briquettes were made with MILDGAS char and tested for strength and coke reactivity. Several 3-inch-diameter by one-inch-thick briquettes were then made in a larger mold, focusing on the best conditions to produce a strong briquette. Lastly, a large quantity of 1.00-inch × 1.75-inch pillow briquettes were made at a rate of 1 ton/hour with equipment at a test facility of a roll briquetting equipment manufacturer.

The strength of these initial briquettes approached that of commercial cokes, but more work is needed to optimize the briquetting process. In addition to physical strength, reactivity is an important coke property. A test briquette made with the West Virginia char yielded a reactivity value comparable to conventional coke of medium reactivity.

The major factors that affect both strength and reactivity of form coke are density, porosity, voidage, and the type of coal(s) used. Foundry coke, because it is a source of heat for melting iron and also a source of carbon for solution into the iron, does not depend as strongly on CO_2 reactivity as does blast furnace coke. The strength requirement is also not as stringent, because the height of the burden in a cupola is much less than in a blast furnace. However, the size of foundry coke is substantially larger than blast furnace coke. This potentially gives form coke an added advantage, because the size of the briquette can be tailored to the requirements of the process. Also, the blending of fine particles of alloying materials into the foundry coke would increase its value.

Other Char Co-Products

Other products which could be made from MILDGAS char have also been investigated. These included smokeless domestic fuel, activated char, and utility fuel. Since this project is focusing on form coke, the co-product identified as having the greatest near-term potential in terms of both market size and price, the other products will not be discussed in detail. Detailed data on the testing of MILDGAS char for these end uses can be found elsewhere.[4]

Binder Pitches

Pitch is a term used to describe the non-distillable residue from a fractional distillation of coal tar or petroleum. It is defined as material with an initial atmospheric boiling point anywhere from 600°F to 950°F. Pitch is generally used as a binder for a variety of applications, including continuous anodes for aluminum production, prebaked anodes for aluminum smelting and steel arc furnaces, membrane roofs, briquettes, driveways, pitch-fiber pipes, foundry cores, dry batteries, and clay pigeons. The aluminum industry accounts for the largest market share, followed by the roofing industry. A large potential market also exists for the use of coal-based pitch for road paving, but for historical reasons, this U.S. market is almost entirely captured by petroleum-based binders (bitumen). In other countries, however, coal tar pitch is still used to a significant extent for road surfaces, with good results.

Electrode binder pitch is traditionally obtained from coke-oven tars, and the industrial specifications for these products are written specifically to exclude other types of pitch. The pitch produced from coal tar, after it has been upgraded from "soft" pitch to "hard" pitch by distillation, is superior to petroleum residues because the latter generally have higher sulfur content and lower carbon contents. However, the supply of high-quality coal tar pitch has been declining in the U.S. because of the closing of coke oven operations due to aging and environmental concerns. A portion of the demand for this pitch is being met by imports from Canada, Mexico, Asia, West Germany, and Australia.

Electrodes are made from a blend of binder pitch and a solid filler, called "grist." Ideally, the binder should adequately wet the grist particles, flow to fill pores and voids, carbonize with maximum carbon yield, and exhibit optimum cementing properties when the electrode is baked. In addition, the pitch must have physical properties that allow for convenient transportation and storage. All pitches are a compromise, because these properties act to some extent at cross-purposes. Coking, or solid carbon formation and consequent mechanical strength, is favored by a high primary quinoline-insoluble (QI) content, but cementing capacity is favored by a high toluene-insoluble (TI) content.[6] Primary QI (α_1-resins) are soot- and coke-like particles in the 1-10 μm range which are formed in the slow coke-oven carbonization process; these substances are formed in the vapor phase. Secondary QI (α_2-resins) are high-molecular-weight sphericular particles formed by thermal polymerization of pitch in the liquid state and are also called "mesophase." Electrode binders are favored by a high primary QI and low secondary QI content, because of the inability of mesophase to wet and penetrate the pores of the grist.[6] Table 2 shows some typical industrial specifications for electrode binder pitches, where "prebaked" refers to anodes requiring about 18% pitch, and "continuous" refers to the Söderberg electrodes still in use by most older aluminum smelters, which require about 30% pitch. The table values refer to pitch after coal tar distillation.

Table 2. Typical Properties for Electrode Binder Pitches

	Prebaked	Continuous
Softening Point, °F	105 to 115	105 to 115
Specific Gravity (25°C)	1.28 to 1.31	1.25 to 1.29
Quinoline Insolubles, %	5 to 18	5 to 15
Toluene Insolubles, %	20 to 35	15 to 25
Ash, %	0.3	0.3
Moisture, % (Max.)	0.1	0.1
Sulfur, % (Max.)	0.5	0.5
Conradson Carbon (Min.)	57	50

For flat and low-slope roofing, coal-tar pitches are superior to asphalt in most characteristics, including water resistance and a "self-healing" property. Pitch specifications for roofing and waterproofing are covered by ASTM D450-71. Sulfur content is not a factor in this application. There has reportedly been an increase of interest in coal-tar built-up roofing in recent years.[7]

A possibility also exists that soft pitch could compete with petroleum-based bitumen for road binders. As with roofing tar, sulfur content is not an important property. Blends of coal- and petroleum-based binders have been shown to have improved adhesive properties, water resistance, and skid resistance of highway surfaces.

Pitch Coke

Pitch coke is used as an alternative to petroleum coke in electrode manufacture. Petroleum coke is used primarily because of price and availability, but pitch coke actually has superior properties in most respects. The lower sulfur content of coal-based pitch coke is a distinct advantage that will increase in importance in the future, because of pollution control regulations applying to aluminum smelters. Low sulfur content is also advantageous in avoiding corrosion in the electrolysis cells. Pitch coke has higher hardness and strength than petroleum coke. For pitch coke production, pitches with lower QI content are actually preferable to high-QI pitches used as electrode binders, because of superior graphitizing properties. Recent work has shown that tars with alkyl or heteroatomic substituents favor mesophase (secondary QI) production and lead ultimately to extensive graphitization. Mild gasification tars would require less thermal modification to produce a mesophase-producing pitch best suited for pitch coke production.

Chemical Feedstocks

Until the advent of abundant cheap petroleum, coal was the primary source of many chemicals for industry. Yields of BTX and phenols are higher from MILDGAS than from coke ovens. These chemical feedstocks are widely used as starting materials to ultimately make plastics, synthetic fibers, and building materials. Some of the major products include phenolic resins, nylons, polycarbonates, polyesters, and plasticizers for PVC. The markets for these chemicals are almost entirely dominated by petrochemicals, however. Some chemicals, like naphthalene, are still produced in significant amounts from coal tar. Naphthalene is an alternative to *o*-xylene in the manufacture of phthalic anhydride, which is a feedstock for polyester production. Other coal-based chemicals of interest are indane and indene, which are valuable feedstocks for manufacture of specialty polymers. Newly developed high-performance polymers also use higher PAH backbones, such as anthracene, which are only available from coal liquids.

Liquid Fuels

MILDGAS liquids, or some fraction thereof, have potential for being converted into transportation fuels. The middle to heavy distillates, covering the boiling range of 390 to 650°F, can be used as a diesel fuel blending stock, although upgrading is necessary to remove sulfur, nitrogen, and oxygen, both for reducing emissions and for stabilizing the fuel against undesirable degradation reactions during storage. Although the highly aromatic nature of the coal-derived liquids may have certain advantages such as a high octane number for spark-ignited engines, it adversely affects cetane number for diesel fuel operation and can result in excessive soot formation.

In spite of these limitations, coal-derived liquids have been exploited to a small extent for use as transportation fuels. Diesel-oil fractions from the Coalite process, for example, have been used to fuel city buses in Bolsover, England.[3] Another fuel application that has been studied recently is the conversion of coal-derived liquids to high-density jet fuels. These applications are either limited in scope or have not been developed beyond the laboratory stage.

A more suitable fuel application for MILDGAS liquids with minimal upgrading may be in combustion gas turbines, which have less stringent operating requirements than internal combustion engines. Turbines can essentially use any type of fuel that does not produce corrosive gases or erosive particulates upon combustion. Emissions can be predicted easily from the fuel properties. MILDGAS liquids, which are virtually free of ash, alkali, and chlorine, should meet these requirements for a gas turbine fuel.

Based on these factors, a potential market for middle- to heavy-oil fractions could be power-generation peaking turbines. Those installations which can tolerate a low-grade fuel such as the MILDGAS liquids, however, would not command a premium price, and would at best supply an outlet for liquid fractions that are not used for producing value-added products.

The conversion of MILDGAS condensibles into fuel fractions may not derive the maximum value-added benefits, so the economic impact of that option would depend on the successful use of MILDGAS char for value-added uses such as metallurgical form coke or smokeless domestic fuel and, to a lesser degree, on the simultaneous production of specification-grade binder pitch from the oils/tars. The economic benefits derived from the sale of these co-products would allow the upgrading of condensibles to fuel quality for utilization as transport fuels.

PROJECT ACTIVITIES TIMELINE SUMMARY

The project activities were begun in November 1991 to design, construct, and operate the 24-TPD process development unit at the SIUC Carterville site. The program activities are summarized in the following quarterly program segments that follow the normal progress reporting periods, which started with Quarter No. 1 from November 1991 to February 1992.

In Quarter No. 1, drafts of the PDU Work Plan, Environmental Plan, and information required for National Environmental Policy Act (NEPA) environmental assessment documentation were presented at a team kickoff meeting in January 1992. This meeting took place at the Morgantown Energy Technology Center. Team members from K-M Coal, IGT, Bechtel Engineers, SIUC, and the State of Illinois attended.

In this and the subsequent four Quarters, actions were taken to execute the modifications and directions agreed upon at the kickoff meeting concerning the Work Plan, Environmental Plan, and the NEPA information. Also in this and the following Quarters, issues that were raised about the PDU process design and its supporting equipment were addressed by K-M Coal, Bechtel, SIUC, and IGT. Various changes to the PDU system design and arrangement of the system components were made based on these discussions and submitted for final approval.

The design of the gasifier vessel, the operation of the PDU system, and the specification of the associated equipment were finalized and detailed design engineering activities began for development of a definitive cost estimate. Special conditions at the Carterville site were included in the PDU design from discussions with SIUC and various groups at the site, such as the Crab Orchard Wildlife Refuge water and sewage treatment operators, the local fire marshal, and the local electric and gas companies.

Continued progress was made in the first four Quarters as IGT and Bechtel engineers from various engineering disciplines developed the details of the PDU and its layout at the site. Equipment specifications were prepared and requests for vendor quotes were sent to about 35 vendors to obtain a definitive PDU cost estimate. However, a DOE stop-work order was put in place during the months of August through November 1992, and so none of the bids received were analyzed.

The program was reactivated as the stop-work order was rescinded by DOE on November 12, 1992. Meetings were held in December with the team members and with the new DOE technical monitor and the new DOE environmental representative to review the PDU design and NEPA documentation information. Hence, the work to collect information to prepare a definitive cost estimate for the PDU system and its construction was placed on hold until decisions on environmental issues at the site were made by DOE and a favorable NEPA assessment was received.

In the fifth through seventh Quarters, activities were conducted only to update the NEPA documentation, incorporating information about various questions raised by DOE and the Crab Orchard Wildlife Refuge's operators concerning water and sewer issues. An existing cooling water pond at the SIUC site had to be incorporated to reduce the impact on the Refuge's water and sewer facilities. In the sixth Quarter, DOE granted permission to pursue the documentation necessary to obtain the permit to construct the PDU from the Illinois EPA. The EPA review identified concerns with control of particulate air emissions from handling operations and the scrubber for the effluent from the thermal oxidizer of all the PDU gas streams. These were addressed and incorporated into the PDU equipment and operation.

In the eighth Quarter ending in November 1993, the Environmental Assessment (EA) prepared by DOE was submitted to the Crab Orchard Wildlife Refuge and to the State of Illinois for comments. Comments were received and considered in the revised EA.

A Finding of No Significant Impact (FONSI) was obtained on the NEPA submittal on February 10, 1994 which allowed the project to proceed. The revised application for the construction permit was submitted to the Illinois EPA. Detailed engineering design activities were restarted, but because the interruption and the delays had increased the project cost, an overall PDU system review had to be conducted to incorporate the various environmental and process modifications. The PDU equipment and operation were simplified while maintaining the objective of obtaining critical process data for scale-up commercial design. The PDU system simplifications involved providing heat to the gasifier vessel by boosting the temperature of the recycled gas stream using natural gas preheaters and burners. This approach avoided dilution of the product gas with combustion air, thus maintaining the heating value of the product gas. In a commercial plant, these preheaters and booster heaters could be fired with a portion of the product gas, or with pulverized coal if necessary.

In the tenth Quarter, a PDU construction permit was granted by the Illinois EPA, and in February 1994, meetings between IGT and Bechtel were held to restart the detailed engineering and obtain the definitive cost estimate. The PDU process flowsheet, the reactor heat supply design details, and the heat and material balances were revised. Bechtel began preparing the revised process flow diagrams, the piping and instrumentation diagrams, and the process equipment specifications and data sheets necessary for re-submittal to the bidders.

On April 23, 1994, a ground-breaking ceremony was held at the site with all of the members of the team, Illinois State legislators, Illinois members of the U.S. Congress, and representatives of various industries.

In the eleventh Quarter, bid quotes were received and analyzed. Discussions were held with various bidders in the twelfth Quarter, and Roberts & Schaefer Engineers (R&S) of Salt Lake City was selected to perform the detailed integrated facility design and construct the complete PDU system at the Carterville site. Site preparation work was awarded to a local contractor to clear and grade the site, install culverts, erect security fencing, prepare foundation footings, and lay down gravel for construction traffic.

In the thirteenth Quarter, detailed design meetings began in December 1994 at R&S facilities with Bechtel and IGT engineers. Progress was made over the following Quarters on the final design of the major equipment and sub-systems. Equipment layout, mechanical systems, structural steel, pipe sizing and insulation, controls and instrumentation, electrical loads, and detailed drawings and specifications for fabrication bids were completed. Subcontracts were awarded for the fabrication of the gasifier and cyclones, the coal feed and char handling system, the heating and cooling transfer screw conveyors, the emission control system, the process preheaters and booster heaters, and the liquids recovery equipment and associated transfer vessels and storage tanks. A hazards and operability review (HazOp) was conducted, and safety and operability design features were incorporated into the final design of the instrumentation and process control system. R&S began to develop the control logic, control loop drawings, and instrumentation list. Orders were placed for the control software, programmable logic controllers, digital input and output devices, electrical cabinets and racks, and CRT displays.

By the end of the fifteenth Quarter in August 1995, based on firm equipment dimensions, the layout and structural steel supports were finalized, structural steel was purchased, and fabrication began. Fabricator site visits were made to monitor the fabrication of the major vessels and auxiliary equipment. The second phase of the site civil construction subcontract was completed for the underground utility piping and conduits, the electrical grounding grid, a rainwater collection and treatment sump, and the remaining foundations..

Project activities were terminated at the end of July 1995 as a result of the recission of FY95 funding by Congressional action. Termination and close-out activities began with negotiations with vendors and suppliers for costs to restore the Carterville site to its original state and archive the design and construction information.

IGT MILDGAS TECHNOLOGY DESCRIPTION

General Process Description and Basis of PDU Design

MILDGAS is a method of continuous pyrolysis in which coal is heated in the absence of oxygen to give off volatile gases and liquids, leaving behind a solid char. MILDGAS uses relatively low-severity process conditions of 1100°-1300°F temperature and 25 psig pressure.

The MILDGAS reactor operates with caking coals in a single fluidized bed, with a fluidization gas distributor designed to promote rapid mixing and dispersal of the incoming coal throughout the large bed of char. The coarser feed fraction (-6+60 mesh) enters the lower bubbling-bed section. The bubbling bed section is further divided into a lower turbulent flow section and an upper bubbling-bed zone. The fines fraction of the coal feed (-60 mesh) is fed to the entrained section above the fluidized bed, with lower residence times sufficient for conversion of the smaller particles.

The PDU is an adiabatic reactor system with the heat supplied to the gasifier through the sensible heat of the fluidization gas. The fluidization gas for the gasifier is a combination of product recycle gas and a small portion of flue gas from a natural gas-fired booster burner. This combination allows flexibility in the amount of heat as well its distribution to the grid and central jet regions plus a simplification and shortening of the PDU test startup time. The combustion air and recycled product gas streams are preheated to reduce the booster burner size and product gas dilution. This method of supplying heat yields a product gas with a sufficiently high heating value to allow it to be used elsewhere for process heating. In a commercial plant, the preheaters may be fired with the product gas and the burners may be fired with pulverized coal.

Two char streams are produced by the process. The coarse char is removed from the reactor by a bed overflow and the fine char is removed from the second overhead gas cyclone. The fines from the first product gas cyclone are recycled to the bed to maintain the char dilution necessary to prevent caking of agglomerating coals. The temperatures of both char streams are lowered using water-cooled screws before the char is stored in inert-blanketed bins.

After removal of particulates with two cyclones in series, the reactor gas stream is cooled in three stages to remove three liquid products, heavy, medium, and light oils. Cooled product oils from each stage are used in each of the countercurrent spray condensation units.

For improving the reliability of scale-up, reactor operation should minimize wall effects and be conducted at adiabatic conditions so that the heat losses are negligible compared to the heat contents of reactants and products. The PDU design for the gasifier specifies a 2.5-foot inside diameter, with adequate insulation for achieving adiabatic operations. The design of the PDU operating conditions and geometry were based on testing conducted in the 100-lb/h isothermal PRU at IGT.

Feedstock Characteristics

The results of PRU testing were presented in two separate Topical Reports[8,9] encompassing data from 48 tests with four different coals. In Task 2, Bench-Scale Mild Gasification Study,[8] Illinois No. 6 coal from Peabody's Randolph Preparation Plant in Baldwin, Illinois, and a West Virginia coal from Peabody's Wells Complex in Wharton, West Virginia, were tested to determine basic system performance and design information for scale-up. In Task 4, System Integration Studies,[9] these same two coals and two additional coals -- a subbituminous coal from a Peabody mine in Rochelle, Wyoming, and a low-sulfur Illinois No. 6 coal from a Consol mine in Sesser, Illinois -- were also tested in the course of converting the PRU to integrated operation using a full-stream quench system for condensibles recovery. Properties of typical samples of the four test coals are shown in Table 3.

With the three caking coals, coke breeze was initially used as a non-caking diluent to prevent reactor fouling, simulating char recycle that would maintain an adequate bed char inventory to prevent agglomeration. All of the caking coals could be processed continuously when pre-blended at a 1:1 weight ratio with coke breeze. The volume of devolatilized char present in the fluidized bed is very important for the dilution and distribution of the incoming caking coal, as previous experience at IGT in operating the 3-foot-ID U-GAS coal gasification pilot plant showed that caking coals could be fed without blending if the incoming coal feed rate remained at or below a critical fraction of the inventory of the char in the fluidized bed. This volume of char serves to maintain a lean distribution of coal particles until the coal loses its caking tendency through devolatilization. Blending the feed coal with coke breeze assured that this relationship was maintained in the small PRU unit. This same criterion will be satisfied in the PDU by the large volume of char in the fluidized bed and rapid mixing of the incoming coal. With the non-caking subbituminous coal, there was no need to use a diluent, and throughput was about doubled compared to bituminous coals.

Co-Product Characteristics

Material balances for 26 successful PRU tests were reported in the Task 2 and Task 4 Topical Reports. Data analysis from the successful Task 2 PRU tests with Peabody's Illinois No. 6 and West Virginia coals showed that, in the temperature range of 1035 to 1390°F, coal conversion ranged from 33% to 46%, resulting in 54% to 76% char, 13% to 28% oils/tars, and 7% to 19% fuel gas. The co-product yield data from the Task 2 PRU tests are shown graphically in Figure 1. The test data with both bituminous coals showed that increasing reaction temperature increased coal conversion with decreasing char yield. The oils/tars yield appeared to maximize around 1100°F while the gas yield increased steadily with increasing temperature, primarily because of increasing secondary thermal cracking reactions. Task 4 tests made with sequentially recycled char as a diluent in place of coke breeze showed no significant change in yield distribution for either coal. The data for the subbituminous coal showed the expected lower oils/tars and higher gas yields, and Illinois Sesser coal performed similarly to the other Illinois No. 6 coal.

Table 3. Analyses of Coals Tested in IGT Mild Gasification PRU

	Illinois No. 6[a] Randolph P.P.	West Virginia[b] Wells Complex	Subituminous Rochelle Mine	Illinois No. 6 Sesser Seam
Proximate	Wt% as fed to reactor			
Moisture	5.3	1.4	16.2	6.6
Volatile Matter	34.7	30.6	35.9	31.6
Ash	15.0	6.4	4.6	4.2
Fixed Carbon	45.0	61.6	43.3	57.5
Ultimate	Wt% dry basis			
Ash	15.8	6.4	5.5	4.5
Carbon	64.3	80.2	68.3	78.2
Hydrogen	4.2	5.0	4.2	5.0
Nitrogen	1.4	1.7	1.1	2.0
Sulfur	3.9	1.3	0.14	1.1
Oxygen (by diff)	10.4	5.4	20.8	9.3
Free Swelling Index	1	5	0	2
HHV, Btu/lb (dry)	11,599	14,372	11,219	13,732

[a] Baldwin No. 1, Marissa, and River King No. 6 Mines
[b] 55% No. 2 Gas Seam/45% Campbell's Creek Seam

As shown in Figure 1, the gas yield increases with temperature, whereas the maximum oils/tars yield appears between 1100° and 1200°F. Char yield decreases, as expected, with increasing temperature, and the chemical water production appears fairly constant. The West Virginia and Illinois No. 6 coals gave generally similar yield distributions across the temperature range studied, whereas the Rochelle subbituminous coal gave the higher gas and lower oils/tars yields that are characteristic of lower rank coals. For the bituminous coal tests conducted around 1100°F, the oils/tars yields were consistently above 25%, and in some cases exceeded 30%.

Also shown for comparison on Figure 1 are pilot plant data from the COED[10] and Occidental Flash Pyrolysis[11] processes and laboratory data from CSIRO.[12] The COED data was obtained with Illinois No. 6 coal, the Occidental data with Kentucky No. 9 coal, and the CSIRO data with Australian Liddell B bituminous coal. Both of the latter coals are similar in ash and volatile matter content and in swelling/caking behavior to the Illinois No. 6 coal used in the PRU tests.

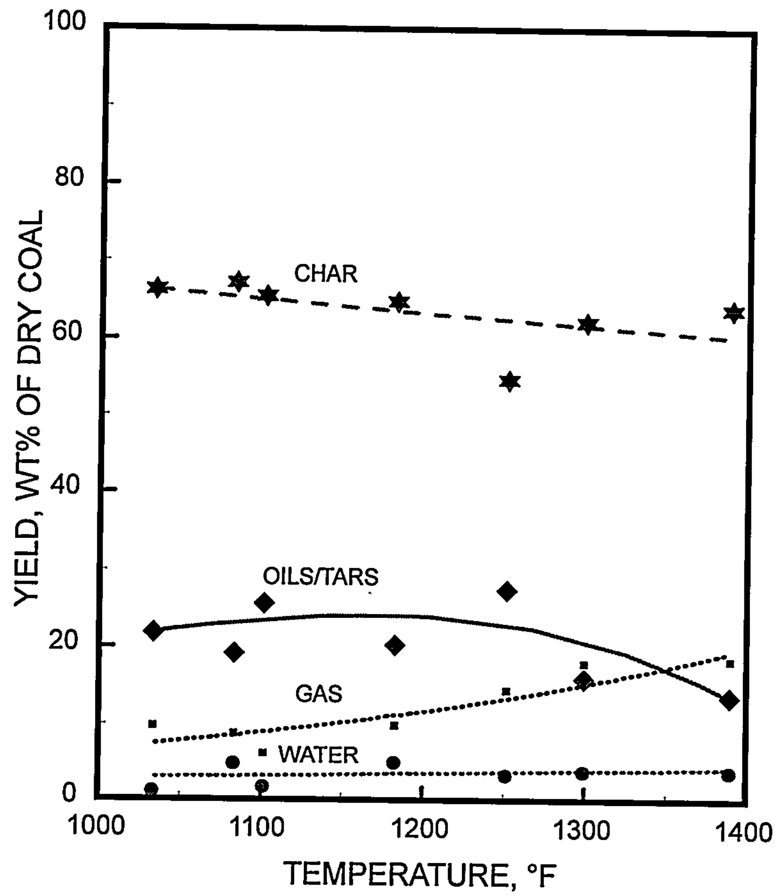


Figure 1. Co-Product Yields from IGT Mild Gasification PRU

Table 4 shows typical diluent-free char compositions from Illinois No. 6, West Virginia, and Rochelle coals subjected to mild gasification at 1062-1107°F and Illinois No. 6, West Virginia, and Sesser coals processed at 1252-1288°F.

The highly aromatic mild gasification oils/tars were characterized for elemental composition and by GC/MS to estimate the light oil (<350°F), middle oils (350 to 590°F), heavy oil (590 to 750°F), and pitch (>750°F) fractions. Selected chemical species of particular interest were also determined. The predominance of secondary reactions is evident in the effect of temperature on the amounts of various oils produced. It was determined that, with increasing mild gasification temperature, the pitch fraction decreased, with a corresponding increase in heavy oil and light oils. There did not appear to be any significant change in the yield of middle oils with increasing temperature. Figure 2 shows the changes in oils/tars boiling-range distribution with temperature for the Randolph Prep Plant Illinois No. 6 coal. Table 5 and Table 6 show some of the properties of the oils/tars from the four coals tested in two temperature ranges.

Table 4. Properties of Mild Gasification Chars

Coal tested	IL No. 6 Randolph Prep. Plant		West Virginia Wells		Rochelle Subbit	IL No. 6 Sesser
Test No.	IST-9	MG-12	IST-13	IST-14	IST-15	IST-17
Test Temperature, °F	1107	1252	1084	1275	1062	1288
	Wt% dry basis					
Volatile Matter	11.84	11.18	10.02	6.44	19.82	8.69
Ash	28.72	25.03	8.33	8.49	8.26	7.45
Carbon	61.58	69.14	82.59	85.14	79.64	87.59
Hydrogen	1.18	1.10	2.43	1.36	2.36	1.24
Nitrogen	0.83	1.66	1.78	2.40	1.50	2.11
Sulfur	3.19	3.07	1.07	1.87	0.21	0.95
Oxygen (by diff)	4.51	0.00	3.80	1.74	8.03	0.66
HHV, Btu/lb (calculated)	9,328	10,600	13,212	12,959	12,477	13,445
VM_{char}/VM_{coal}	0.36	0.31	0.34	0.24	0.55	0.27
Ash_{char}/Ash_{coal}	1.79	1.78	1.58	1.56	1.50	1.60
S_{char}/S_{coal}	0.91	0.81	0.96	0.76	1.50	0.83
Potential Sulfur Emissions, lb $SO_2/10^6$ Btu	6.80	5.74	1.61	2.87	0.34	1.41

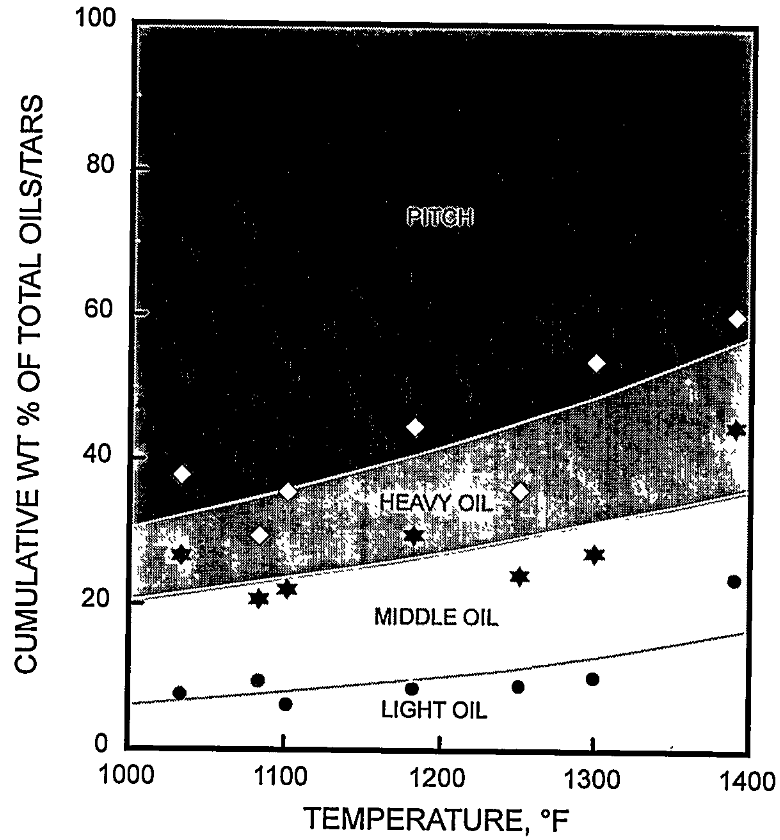


Figure 2. Boiling-Range Distribution of Mild Gasification Oils/Tars

Table 5. Bulk Properties of Mild Gasification Oils/Tars

Coal tested	IL No. 6 Randolph Prep. Plant		West Virginia Wells		Rochelle Subbit	IL No. 6 Sesser
Test No.	IST-9	MG-12	IST-13	IST-14	IST-15	IST-17
Test Temperature, °F	1107	1252	1084	1275	1062	1288
Elemental Analysis		---- Wt% dry basis ----				
Ash	0.22	0.36	0.04	0.00	0.20	0.00
Carbon	76.06	75.74	81.50	84.14	78.98	80.46
Hydrogen	7.53	6.21	7.34	6.58	8.04	6.87
Nitrogen	0.72	1.27	0.89	1.20	0.82	1.23
Sulfur	1.94	2.03	0.72	0.67	0.27	0.71
Oxygen (by diff.)	12.53	14.38	9.51	7.41	11.69	10.73
H/C Atomic Ratio	1.18	0.98	1.07	0.93	1.21	1.02
Simulate Distillation by Gas Chromatography						
Cumulative wt% Recovered		---- Boiling Point, °F ----				
5	334	353	354	323	329	288
10	393	433	451	388	364	314
15	453	506	558	458	402	342
20	515	573	673	535	440	372
30	646	705	902	706	523	437
40	792	844	--	890	618	511
50	971	1023	--	--	733	596
60	--	--	--	--	904	697
70	--	--	--	--	--	814
EP (end point)[d]	1040	1093	1040	1040	1040	1040
% Residue at EP	46.9	47.6	63.22	51.54	36.93	12.85

Table 6. Chemical Composition of Mild Gasification Oils/Tars

Coal tested	IL No. 6 Randolph Prep. Plant		West Virginia Wells		Rochelle Subbit	IL No. 6 Sesser
Test No.	IST-9	MG-12	IST-13	IST-14	IST-15	IST-17
Test Temperature, °F	1107	1252	1084	1275	1062	1288
Component		Wt% of total oils/tars				
Benzene	0.6	1.2	0.4	2.1	1.4	1.3
Toluene	0.4	1.3	0.4	1.3	1.4	1.1
Xylenes	0.4	0.8	0.5	0.8	0.9	0.7
Ethylbenzene	0.1	0.6	0.1	0.1	0.2	0.1
Indene	0.02	0.4	0.1	0.4	0.2	0.3
Styrene	0.1	0.3	0.1	0.2	0.1	0.2
Other Light Oils	9.9	4.3	7.9	15.6	14.4	19.2
Total Light Oil[a]	11.5	8.9	9.5	20.5	18.6	22.9
Phenol	0.6	1.0	0.3	0.5	2.1	1.4
Cresols	1.4	1.4	0.8	1.1	2.1	3.0
Xylenols	1.7	0.6	1.2	1.7	2.1	3.1
Naphthalene	0.1	0.5	0.1	0.3	0.3	0.3
Other Middle Oils	14.0	11.8	8.2	9.8	18.4	21.6
Total Middle Oil[b]	17.8	15.3	10.6	13.4	25.0	29.4
Heavy Oil[c]	10.9	11.7	6.6	7.8	12.6	14.5
Pitch[d]	59.9	64.1	73.3	58.3	43.7	33.2
Total Oils/Tars	100.0	100.0	100.0	100.0	100.0	100.0

a Atmospheric boiling point <360°F; estimated from simulated distillation data; gasoline -range liquids would be in this category.

b Atmospheric boiling point 360° to 590°F; diesel-fuel boiling-range liquids would be principally in this category.

c Atmospheric boiling point 590° to 750°F; no. 6 fuel oils would fall in this boiling range.

d Atmospheric boiling point > 750°F

Table 7. Mild Gasification Gas Compositions

Coal tested	IL No. 6 Randolph Prep. Plant		West Virginia Wells		Rochelle Subbituminous	IL No. 6 Sesser
Test No.	IST-9	MG-12	IST-13	IST-14	IST-15	IST-17
Test Temperature, °F	1107	1252	1084	1275	1062	1288
Component	------------ Mol % in gas, nitrogen-free ------------					
H_2	25.7	37.5	21.4	42.9	21.5	42.4
CO	12.6	16.1	3.1	7.1	17.1	12.3
CO_2	12.2	8.7	2.8	2.4	37.8	3.3
CH_4	27.4	23.3	52.4	34.5	16.7	31.4
C_2H_4	5.0	6.3	7.0	5.7	2.5	4.3
C_2H_6	6.3	2.5	6.6	3.4	2.1	3.3
C_3H_6	2.7	2.1	3.3	2.8	1.5	1.5
C_3H_8	0.7	0.2	2.0	0.6	0.5	0.4
H_2S	7.4	3.3	1.4	0.6	0.3	1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Molecular Weight	21.1	17.5	17.6	13.8	26.8	14.2
Higher Heating Value, Btu/scf	718	626	971	744	419	672

The fuel gas from mild gasification is rich in hydrogen and methane and also contains other light hydrocarbons, carbon oxides, and hydrogen sulfide. Increasing temperature reduces methane and increases hydrogen content, which are also attributable to the secondary cracking and reforming reactions and to gas-phase C/H/O equilibria. Table 7 shows some typical gas compositions from PRU tests. As expected, the gas compositions reflect the parent coal compositions, particularly in terms of CO_x content.

The fate of sulfur is, of course, of paramount importance in assessing process performance and selecting co-product upgrading methods for the targeted markets. Analysis of the fate of sulfur with increasing temperature showed that the sulfur content in char and gases decreased while the sulfur content of oils/tars remained the same or increased slightly. In general, for bituminous coals, the char contained 36% to 67% of the sulfur in the feed coal, which is similar to or slightly lower than the char yield. Oils and tars from the bituminous coals contained significantly lower levels of sulfur than the parent coal, yielding 8% to 13% of the total sulfur. The fuel gas accounted for 20% to 55% of the total sulfur.

In the PRU program at IGT, a preliminary evaluation by Reilly Industries, one of the IPAG members, was performed on four tar samples recovered via three different methods from tests with Illinois No. 6 and West Virginia coals. The samples, which were all black glassy solids at room temperature, were each subjected to some of the following key analyses:

- Distillation (ASTM D20)
- QI content (ASTM D2318)
- Coking value (ASTM D2416)
- Aliphaticity via IR index
- Fraction of aromatic H (f_a) by NMR
- GC/MS analyses for major components

The first two samples were scrubbed out of the full product gas stream with a xylene spray quench. The third sample constituted a THF extract of solids filtered from the xylene quench of a West Virginia coal test, and the last sample was the +360°F fraction from a THF wash of the slipstream sampling system following a later West Virginia coal test.

The results from all of these analyses are shown in Table 8, which also shows values for a typical coke-oven tar. The properties of the xylene quench samples are typical for low-temperature pitch that has not been upgraded by conventional (thermal) processing. The IR index, which is a ratio of peak areas for aliphatic C-H and aromatic C-H bands, showed a low aromatic C-H content (high index) compared to a specification-grade coke-oven tar pitch; and QI were low for all of the samples. It is important to note, however, the variations in the properties from samples recovered in different ways. The low QI in the xylene quench tars may be attributed to the insolubility of QI in the xylene. The slipstream oils/tars from Test IST-14 contained an order of magnitude more QI, indicating that the stronger THF solvent used to clean

Table 8. Evaluation of Tar Samples by Reilly Industries

	Xylene Quench Tar Test IST-9	Xylene Quench Tar Test IST-10	Quench Solids THF Extract Test IST-13	Slipstream Oils/Tars Test IST-14	Typical Coke Oven Tar
Distillation (ASTM D20)					
0-170°C	1.3	0.0	ND	ND	2.0
210	3.7	1.9	--	--	6.0
235	6.6	3.7	--	--	13.0
270	14.9	8.6	--	--	24.0
300	24.8	13.6	--	--	29.0
315	29.1	17.6	--	--	38.0
360	53.9	28.9	--	--	NA
400	ND	49.1	--	--	NA
Residue	46.1	50.9	--	--	62.0
QI (ASTM D2318)	ND	0.01	0.002	0.23	2.0
Coking Value (ASTM D2416)	28.61	34.87	ND	ND	30.0
IR Index (aliphaticity)	7.4	4.8	10.2	3.0	~0.5[1]
f_a by NMR (aromaticity)	ND	ND	0.71	0.79	~0.95[a]
GC Analysis					
Phenol	1.34	1.11	3.47	3.02	
C_1-phenols	2.73	1.50	4.92	5.49	2.0
C_2-phenols	3.68	2.65	7.28	7.59	
Naphthalene	0.61	0.96	1.63	2.81	8.0
C_1-naphthalenes	2.35	2.98	6.72	7.14	ND
C_2-Naphthalenes	0.59	ND	ND	ND	ND
Fluorene	0.59	1.08	ND	ND	ND
Phenanthrene	0.42	1.23	ND	ND	ND
Anthracene	1.06	1.31	ND	ND	ND
Pyrene	3.79	3.83	ND	ND	ND

ND = not determined

[a] Value shown is for binder pitches derived from coke-oven tar.

out the slipstream system can disperse more of the QI present in the MILDGAS liquids, and confirming the underestimation of QI based on the xylene quench liquids. This also suggests that additional QI may be recoverable in the neat (undiluted) tar.

The PRU equipment required a quench solvent, and thus did not allow for recovery of a neat tar. The conceptual design for the PDU, however, does include provisions for condensing the heavier fractions of the MILDGAS oils/tars without a quench solvent, thus allowing recovery of all of the QI present in the liquids. All of the PRU tars had virtually no ash. The sulfur content of the WV tar was 0.88 wt%, which is close to the 0.6 wt% typical level for an electrode binder pitch.

However, it is apparent from these data that the MILDGAS pitch would require post-treatment to increase aromaticity and remove heteroatoms in order to be acceptable for electrode binders. Reilly suggested that an on-stream thermal upgrading step prior to tar condensation has the potential to render MILDGAS liquids acceptable for binder pitch production. A liquids recovery system design that condenses the higher boiling fraction of the oils/tars neat would maximize the QI content of the pitch and thus may reduce the upgrading requirement for meeting electrode binder pitch specifications, which rule out mesophase pitch. This also suggests operation at somewhat higher PDU temperatures may be fruitful.

About 67% of the MILDGAS oils/tars are recoverable as soft pitch, which can be converted to hard pitch and pitch coke for electrode binders, with the remainder becoming fuel gas and light liquids. In addition to coking coals, mild gasification can also use noncoking Eastern bituminous coals to produce pitch, provided the sulfur content is low enough to generate a specification pitch. This may be possible even with high-sulfur coals, based on the results of a parallel study at IGT[13] that showed that sulfur in the oils/tars tends to be concentrated in the lower boiling fractions. Low-rank coals are not expected to produce a pitch of the same quality as bituminous coal, because of the inherent cross-linked structure of low-rank coal. However, a 1968 USBM study with low-temperature carbonization of a Texas lignite yielded a heat-treated pitch that was used to make electrodes.[14] In more recent studies sponsored by the Illinois Clean Coal Institute, a novel method of post-condensation heat-treating was shown to upgrade soft pitch from mild gasification of Illinois coal, producing about 30% electrode binder pitch and 20% pitch coke.[15]

MILDGAS Gasifier Design Basis

The technical basis for the MILDGAS process gasifier design and operating conditions is from the body of data obtained during IGT PRU testing. The key results of the PRU program were --

- The development and design of a mild gasification reactor system which can handle all types of coals, including caking coals, over a wide range of particle sizes. This was achieved at the PRU level by the use of a coaxial fluidized- and entrained-bed system with char recycle at a 1:1 ratio.

- The development and design of a system that maximizes the yields of the targeted value-added co-products (form coke, pitch, and chemical feedstocks), based on rapid heating obtainable in fluidized- and entrained-bed reactors.

- Tailoring of processing options to market conditions promises the greatest value-added benefits for mild gasification co-products, which has dictated, for example, the use of binderless briquetting for form coke production from char, staged condensation to recover condensable fractions already separated for different markets, and vapor-phase thermocracking to produce premium tars for electrode binder pitch production.

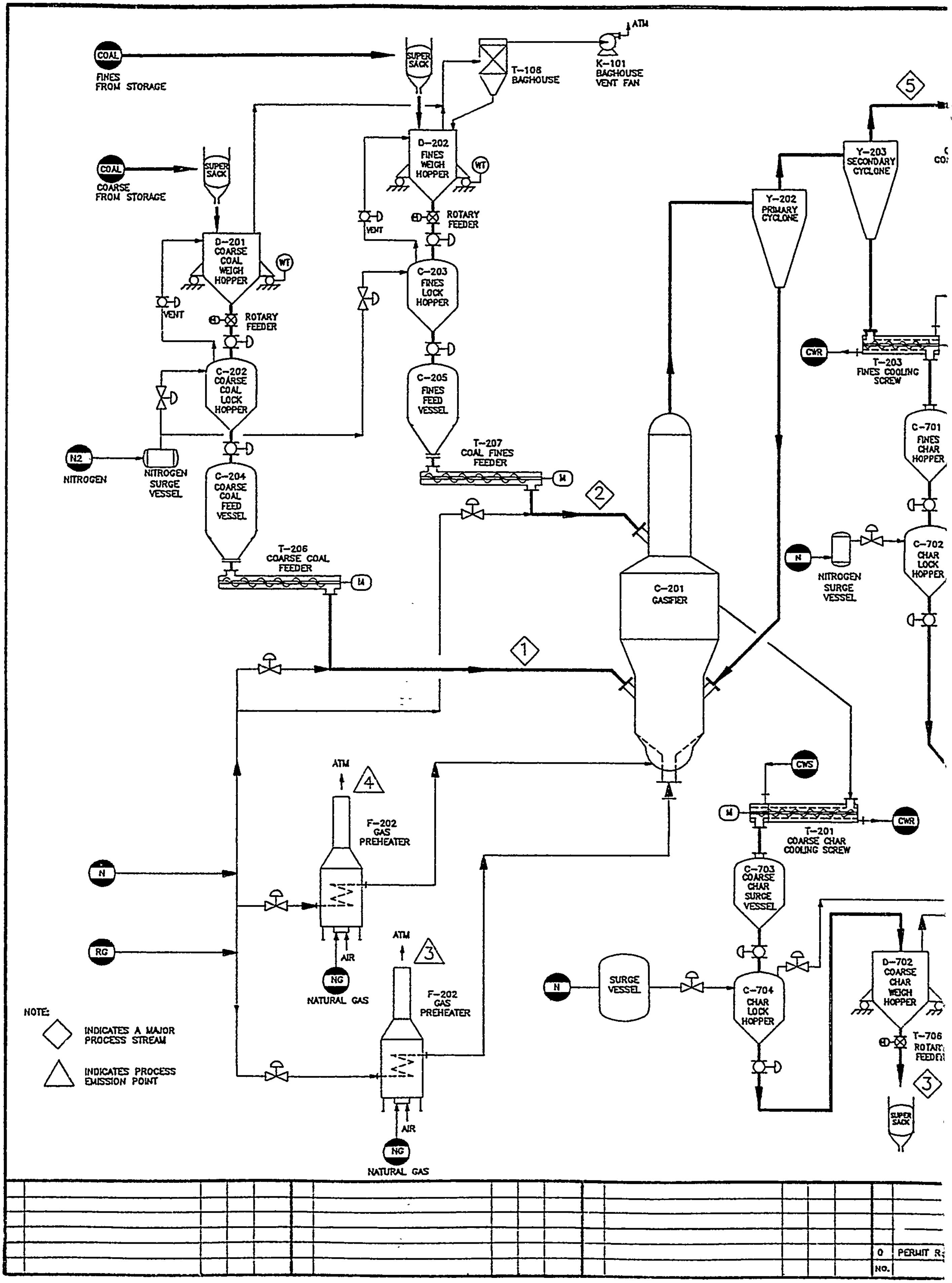
The data obtained in the 100-lb/h PRU test program and in bench-scale char upgrading tests support the selected approach and form a solid foundation for design of the PDU. The general process flow diagram (PFD) of the 24-ton/day MILDGAS Development Unit is illustrated in Figure 3. The facility consists of the MILDGAS reactor, coal handling, preheating, and feeding units, liquids condensation train, and char recovery and cooling units. In addition, there is a thermal oxidizer and gas effluent scrubber for environmentally acceptable disposal of all process-generated gases. These sections of the PDU system are described in detail in *Description of the 24-tpd Process Development Unit.*

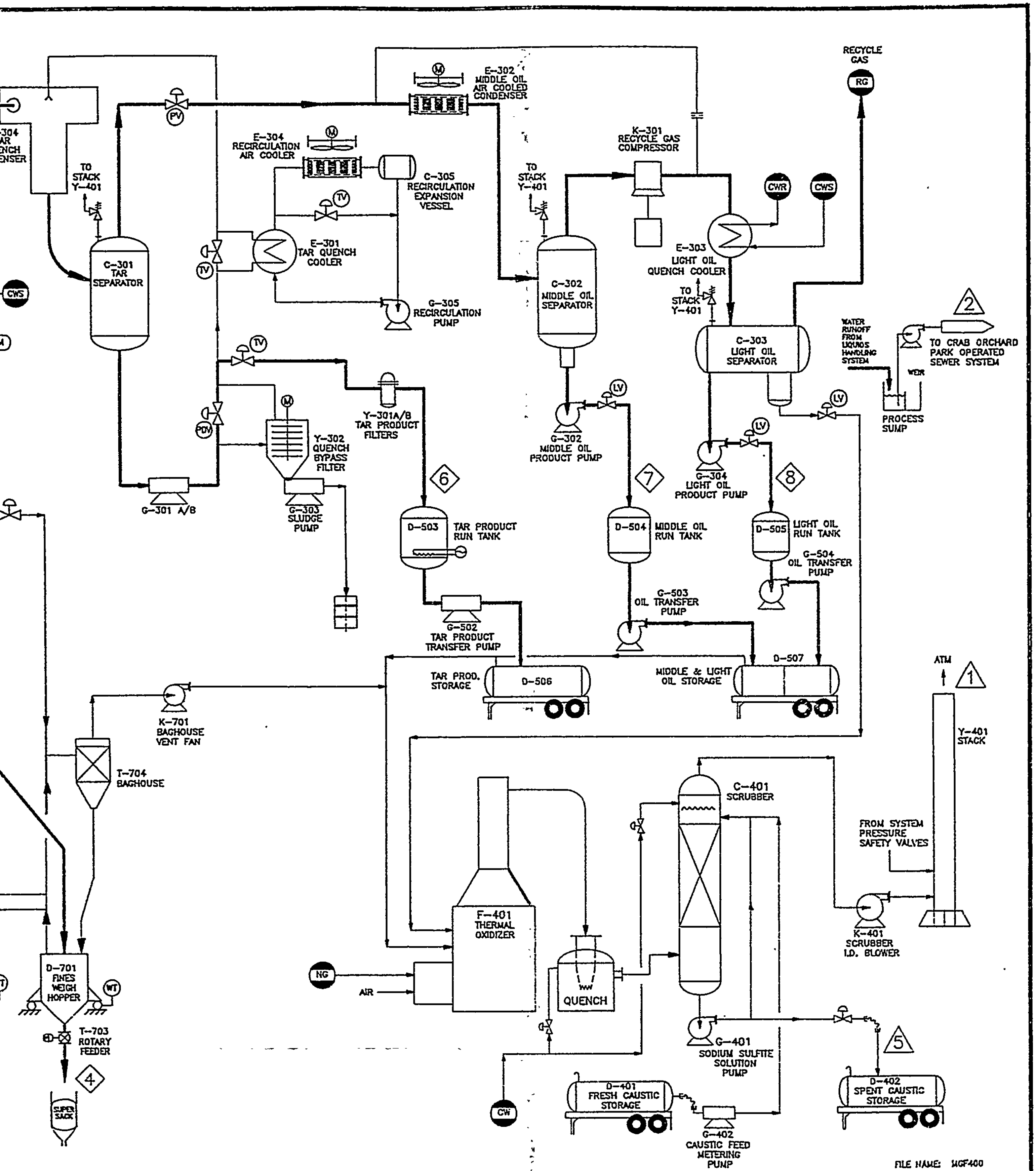
Mild Gasification Reactor Details

The mild gasification system employs the proprietary IGT fluidized-bed reactor concept specifically configured for processing both caking and non-caking coals. This configuration, which is illustrated in Figure 4, makes provision for separate feed of coal fines to the upper entrained-bed section. The coarser feed fraction enters the lower bubbling-bed section. The bubbling bed section is further divided into a lower turbulent flow section and an upper bubbling-bed zone.

The preheated coarse coal feed is introduced into the turbulent flow zone, where it is rapidly mixed with devolatilized char and hot fluidizing gas. The high degree of turbulence in this zone disperses the fresh feed and prevents agglomeration which would otherwise result during the initial heating of a caking coal. The upper expanded portion of the bed retains the char in a dense-phase fluidization for sufficient time to allow heat penetration into the larger coal particles.

The preheated coal fines are introduced into the bottom of the upper high-velocity entrained-flow zone. These fines require little time for heat penetration and pyrolyze rapidly in suspension flow. Their addition at this point also provides significant cooling of the hot vapors leaving the fluidized bed, thus reducing the overall heat input requirement for the mild gasification.


COAL
FINES FROM STORAGE
SUPER SACK
T-106 BAGHOUSE
ATM
K-101 BAGHOUSE VENT FAN
COAL
COARSE FROM STORAGE
D-202 FINES WEIGH HOPPER
WT
ROTARY FEEDER
VENT
D-201 COARSE COAL WEIGH HOPPER
C-203 FINES LOCK HOPPER
C-202 COARSE COAL LOCK HOPPER
C-205 FINES FEED VESSEL
N2
NITROGEN
NITROGEN SURGE VESSEL
C-204 COARSE COAL FEED VESSEL
T-207 COAL FINES FEEDER
M
T-206 COARSE COAL FEEDER
Y-203 SECONDARY CYCLONE
Y-202 PRIMARY CYCLONE
CWR
T-203 FINES COOLING SCREW
C-701 FINES CHAR HOPPER
N
NITROGEN SURGE VESSEL
C-702 CHAR LOCK HOPPER
C-201 GASIFIER
CWS
T-201 COARSE CHAR COOLING SCREW
C-703 COARSE CHAR SURGE VESSEL
SURGE VESSEL
C-704 CHAR LOCK HOPPER
D-702 COARSE CHAR WEIGH HOPPER
T-706 ROTARY FEEDER
F-202 GAS PREHEATER
AIR
NG
NATURAL GAS
RG
NOTE:
INDICATES A MAJOR PROCESS STREAM
INDICATES PROCESS EMISSION POINT
0
PERMIT
NO.



TOLERANCES (EXCEPT AS NOTED) REMOVE ALL BURRS	DES.	M. ONISCHAK	7/1/93	NOTE: THIS IS THE PROPERTY OF THE INSTITUTE OF GAS TECHNOLOGY, AND SHALL NOT BE TRACED, PHOTOGRAPHED, PHOTOSTATED OR REPRODUCED IN ANY MANNER, NOR USED FOR ANY PURPOSE WHATSOEVER EXCEPT BY WRITTEN PERMISSION OF THE INSTITUTE OF GAS TECHNOLOGY.	PROJECT NO. 65082	INSTITUTE OF GAS TECHNOLOGY ENERGY DEVELOPMENT CENTER CHICAGO, ILLINOIS
FRACTIONAL ±	DR.	S. J. WOHADLO	7/30/93			
DECIMAL ±	CK.	J. GISSY	7/1/93	TITLE: MILD GASIFICATION PROCESS FLOW DIAGRAM (PFD)		DRAWING NO. MG-F-400-D
ANGULAR ±	APP.	R. CARTY	7/30/93			REV. 0
	MATERIAL: N/A					
	SCALE: N/A					

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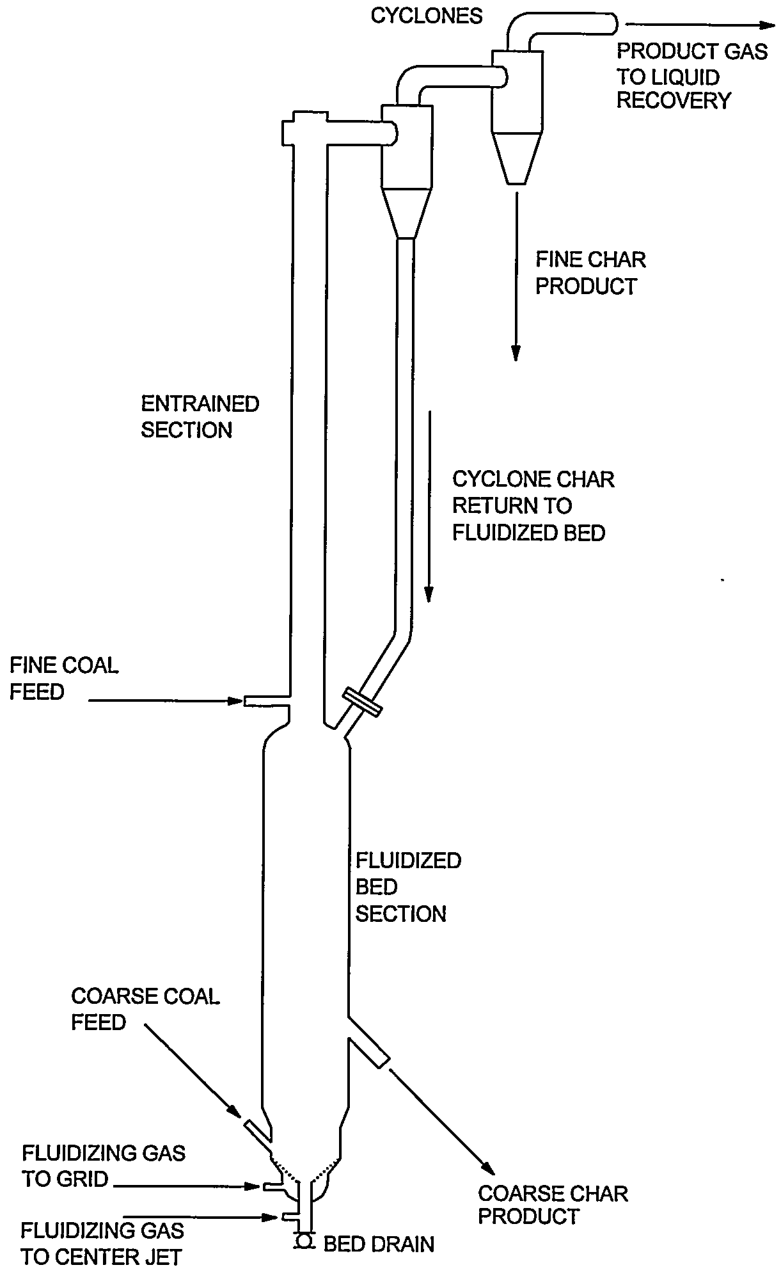


Figure 4. MILDGAS Reactor System

The heat required for raising the coal feed from preheat to pyrolysis temperature is provided by two natural gas-fired burners, one for the fluidization gas distribution grid and one for a higher temperature central jet that induces solids mixing. By using a lower temperature gas in to the fluidization grid, materials problems were avoided. For both streams, flue gas from the burner is mixed with recycle gas. Both the combustion air for the burners and the recycle gas are preheated with natural gas burners. This scheme provides maximum flexibility for temperature control of the two fluidization gas streams. The temperature of the central jet will be considerably higher than the temperature of the grid gases. This allows for the introduction of the necessary heat while minimizing the temperatures that the gas grid will be exposed to and it maximizes the heating value of the effluent product gas.

DESCRIPTION OF THE 24-TPD PROCESS DEVELOPMENT UNIT

An overall simplified process flow diagram (PFD) for the 24-TPD MILDGAS process development unit (PDU) was shown in Figure 3.3. The PDU is designed as a comprehensive, stand-alone test facility, able to test various coal types under various process conditions. It is well instrumented for detailed process stream measurement and control and to obtain process data for preparation of material and energy balances.

The MILDGAS PDU system is divided into six main processing sections:

1. Coal Preheating and Metering
2. Mild Gasification
3. Liquids Recovery
4. Emission Control
5. Liquids Storage and Handling
6. Char Storage and Handling

A description of each section of the PDU follows.

1. Coal Preheating and Metering Section

The selected PDU test coals will be dried and sized at an offsite location and delivered to the PDU in two size fractions: a 6×60-mesh coarse fraction and a minus-60 mesh fines fraction. The prepared test coal will be delivered to the PDU in large capacity polypropylene "supersack" containers able to hold one ton of prepared coal. These sacks will be reusable. Storage capacity for the sacks at the PDU site is sufficient for several PDU tests with each test coal. These sacks will be handled by a forklift truck and then hoisted to the top of the structure where an operator will position the sacks over an unloading station to empty into the PDU feed delivery vessels. The weight of the coal loaded is recorded by load cells on a weigh hopper. A lockhopper under the weigh hopper receives the weighed coal by gravity. Once the transfer is complete, the lockhopper is isolated and pressurized up to the system operating pressure. After pressurization is complete, the control logic allows the batch of coal to be released to the feed storage (surge) vessels.

The coal is transferred from the storage vessel and preheated (up to 500°F) with a heated metering-conveying screw immediately prior to introduction into the mild gasifier reactor. The gasifier coal feed rate is metered by utilizing a variable speed motor to drive the screw conveyor. Both the coarse feed coal fraction and the fine feed coal fraction are handled and metered in this manner. Feed rate calibrations with the metering screws will be obtained prior to tests with each coal. The conveying screws are heated with hot oil from a separate hot oil system.

2. Mild Gasification Section

The MILDGAS reactor vessel is divided into a fluidized bed where the coarse coal size fraction is fed, and an entrained bed directly atop the fluidized bed where the fine coal fraction is fed. In the fluidized bed, hot fluidizing gases and hot fluidized bed char contact and disperse the incoming coal and elevate its temperature to about 1000° to 1200°F. The coal particles are devolatilized, avoiding agglomeration and producing a coarse char particle. Fine coal is injected strategically at the entrance of the entrained bed section and is heated by the upflowing hot gases and hot entrained fine char particles from the fluidized bed.

The product gas leaving the MILDGAS reactor contains the devolatilization products of hydrocarbon gases and vaporized condensible liquids (the condensible liquids are described as heavy, middle, and light oils), plus entrained char from the fluidized bed as well as all of the devolatilized fine coal char. The gas stream passes through two cyclones. The fines collected by the first cyclone are directed back into the fluidized bed to increase their conversion and assure a stream of hot char fines to the entrained bed section. The fines collected by the second cyclone are collected as the fine char product. The coarse char product is withdrawn from near the top of the fluidized bed in the gasifier which controls the fluidized bed height. Both of these product char streams are cooled and delivered by a water-cooled conveying screw to a char lockhopper and then to a coarse and a fine char storage vessel. The char is unloaded from the storage vessels after the test into the large transport sacks. The char product will be sent various locations for evaluation tests or for disposal.

The heat to sustain the gasifier fluidized and entrained bed operation is furnished by a hot recycled product gas stream. The reactor fluidization gases consist of recycled product gases separated in the liquids recovery section. This gas is first preheated to about 1100°F and then split into two streams and directed to two booster heaters that raise the temperature to about 2000°F. A small amount of natural gas and air is combusted separately and mixed with the recycle gases in the booster heaters to raise the recycle gas temperature. The hot gas streams enter at the bottom of the fluidized bed of the gasifier through a conical fluidization grid and a central jet at the bottom of the conical grid. This arrangement of fluidization gas input promotes rapid mixing of the hot bed char with the incoming feed coal.

3. Liquids Recovery Section

The condensible liquids recovery system comprises three sequential cooling stages that condense and collect the three selected boiling ranges of the condensible liquids. Operation parameters of the MILDGAS reactor will be selected to maximize the yield of heavy oil and pitch. Cooling of the approximately 1000°F product gas stream will be accomplished in the first collection stage by spraying the gases with a recirculating stream of cooled heavy oil. Thus the heavy oil and pitch are condensed in the first stage of condensation at about 450°F. The recovered liquids are filtered and stored in a product run tank. Heating coils in the tank will aid the discharge of the heavy product for delivery.

Condensible liquids from the second stage of condensation will yield middle oils. An air heat exchanger-condenser will be operated at a temperature of about 170°F. The 170°F temperature is selected to collect dry middle oils to avoid formation of emulsions with water. The middle oils will be sent to a storage tank for collection. The final cooling in the condensation train recovers the light oil fraction and water. Separation of the oil and water is accomplished in a horizontal liquid phase separator. The light oil is pumped to a storage tank, and the sour water is sent to the thermal oxidizer and scrubber.

Product gases separated from the light oil section are compressed and recycled back to the gasifier section to supply the heat and fluidization requirements of the gasifier. Any excess product gas is directed to the thermal oxidizer.

4. Emission Control Section

The emission control section of the PDU consists of a thermal oxidizer and a wet gas scrubber to control emissions during the test operations of the PDU. The thermal oxidizer unit is designed to oxidize all of the process combustible gases, process sour water, and condensible liquids including their contained sulfur species. The oxidizer is intended to convert the sulfur compounds to sulfur dioxide and to oxidize the dissolved ammonia, phenols, and sulfur species in the sour water recovered in the liquids recovery section. The temperature of the thermal oxidizer combustion zone is 1800°F, and the exiting hot flue gases are directed to a fresh water quench section, where evaporative cooling reduces the gas bulk temperature before entering the wet gas scrubber.

The wet gas scrubber is a packed tower to enable intimate contact between an aqueous caustic solution of sodium hydroxide and the quenched flue gases from the thermal oxidizer. The caustic solution circulates through the tower in a countercurrent fashion absorbing any acid gas pollutants in the gas stream. Process gases are pulled up through the packing via an induced draft fan. The cleaned gases exit the tower from a stack. Treatment of the product gas emissions in this manner utilizes the best available control technology.

Spent caustic is generated (sodium sulfite) by the scrubber. The spent liquid will be collected and handled as an industrial waste stream and disposed of through a licensed disposal service. If a licensed waste disposal service is not available near the PDU site, then the option exists for neutralization of the spent caustic and permitted disposal into the water treatment works operated by the U.S. Fish and Wildlife Service of the Crab Orchard Refuge. Fresh caustic storage will be accomplished through the use of a tanker truck connected directly to the fresh caustic make-up pump.

No other process water is required by the PDU and no liquid wastewater discharge is generated. The rain water run-off around the liquids recovery and storage area is contained. Tanks and pumps rest in curbed concrete pads, and all run-off is collected in a central sump, and will be treated before being released into the permitted treatment works of the Refuge. The sump contains a weir for separation of gross accumulations of oils and solids, which are allowed to settle. The liquid in the sump is pumped to an intermediate tank that will be sampled for analytical verification of suspended solids, pH, and level of organics. Carbon filtration provisions for excessive organic removal will be available to meet the local discharge requirements. The spent activated carbon will be disposed through a certified waste disposal service.

Fugitive dust emissions arising from the handling of coal and char are controlled by the use of filter baghouses. Each of the two baghouses will be of the pulse jet type and sized for a maximum gas to cloth ratio of 3 to 1 at the designed capacity flow rates. Filter bag material will be according to the manufacturer's recommendation, and baghouse efficiencies are designed for 99.9% removal of particles larger than 1 micron. The recovered dusts will be disposed of in accordance with local regulations. Good housekeeping practices will be implemented to control airborne dust and process chemicals. Precautions will be implemented to prevent skin contact through the use of protective eyeglasses, face shields, respirators, boots, gloves, steel toe shoes, and long pants and long sleeve shirts. All chemicals will be stored in outdoor areas; no chemicals will be stored within enclosed buildings.

5. Liquids Storage and Handling Section

Each of the recovered coal liquid fractions (heavy oil and pitch, middle oils, and light oils) in each of the tests will be accumulated in the dedicated run tanks. Load cells mounted on each of the tanks will provide accumulation data and, along with a provision for sampling to analyze for composition. This information will be used for process performance. Long term storage, up to 6 months, is considered necessary to allow adequate time to conduct the PDU analytical work. Therefore, the run tanks will be emptied into semi-truck tank trailers with isolated compartments for the heavy and middle fractions. These tank trailers will be positioned on-site to accumulate these liquid products. Reilly Tar and Chemical has agreed to dispose of the liquids into their processing facility.

6. Char Storage and Handling Section

The coarse char product from the fluidized bed and the fine char collected by the second cyclone are each cooled in separate water-jacketed conveyor screws. The temperature is reduced from 1000°F to about 150°F. The coarse and fine solids are delivered to a separate surge vessels and then transferred by gravity into separate lockhopper vessels. The lockhoppers depressurize the coarse and fine solids in batch-wise steps to atmospheric pressure. Each batch of char is weighed and recorded. After the lockhoppers are depressurized, the solids are pneumatically transported into larger storage hoppers. These hoppers are sized to hold the entire quantity of char produced during one long-term test or three short-term tests, as explained in the following section. After each of the long-term tests is completed, the char will be unloaded from the storage hoppers into the large super sacks for delivery. The char will be sent either to be briquetted for further evaluation tests, or to a user of char for disposal.

PDU Operating Variable Range

The MILDGAS PDU reactor is mechanically designed to operate at fluidized bed temperatures up to 1200°F and operating pressure up to 50 psig. Normal operating pressure is expected to be about 25 psig and will not be varied, because pressure is not to be an operating parameter. Operating temperature will be a test parameter and is expected to be varied when testing different types of coal and in maximizing the yield of a co-product, such as pitch, for example.

The reactor is sized to convert 2000 dry lb/h of coal (24 tons per day), divided into the coarse and fine coal feeds to the fluidized bed and the entrained bed, respectively, as follows: 1600 lb/h coarse coal fraction to the fluidized bed, and 400 lb/h fine coal to the entrained bed. Three types of coals are intended to be tested in the reactor. The majority of tests will be conducted with the Illinois No.6 coal, followed by a metallurgical coal from West Virginia, and a few tests with a western sub-bituminous coal. All of the candidate coals will be obtained from Kerr-McGee Coal Company mines in Illinois, West Virginia, and Wyoming.

The durations of the tests with these coals range from several 24-hour steady-state periods with each coal type to determine co-product yields and optimize reactor temperatures. After this series of short tests, longer duration 72-hour steady state tests will be operated at optimum conditions to product sufficient quantities of co-products for post-test evaluations. The PDU is not intended to be a permanent operating facility. Provisions have been made for dismantling after the conclusion of the testing.

The lockhoppers for the feed coal and the product chars were sized to accommodate the solid volumes for four lockhopper pressurization and depressurization cycles per hour. The solids storage hoppers were sized to contain the entire production of char from a 72-hour steady state period, including the period of startup where the starter materials are run out.

PDU Instrumentation and Controls

The PDU includes instrumentation and a centralized control center to safely regulate and monitor process variables. CRT screens that will be located in the control room trailer will display real time process data such as system operating temperatures, pressures, differential pressures, flow rates, load cell weights, emission control data, and status of all motors, blowers, and pumps. State-of-the-art microprocessor-based hardware will be used in the PDU system, and programmable logic controllers will manage the system electrical interlock requirements of equipment operation. Stand-alone single loop digital controllers will be used to implement process PID regulatory control functions. Standard annunciator systems will alert the operator when a system variable exceeds its operating range. If the problem is not corrected and it is a key variable for the safe and proper operation of the PDU equipment, then the control system will automatically begin shutdown actions. The extensive hazards and operability review sessions (HazOp) were conducted for the entire system and identified the key variables in each section of the PDU. The HazOp review is included in Appendix A of this report.

A personal computer- (PC-) based data acquisition system will access, collect, and store the system parameters for archive purposes. System inputs are automatically logged to the PC hard drive, which can be downloaded to floppy disks or printed on demand for on-line review or for record retention. Status reports can be regularly printed and stored to help monitor the system performance.

PDU Material Balances

The input and output stream values used in the design of the PDU MILDGAS system are described in the single summary Table 4.1 below. Values are given for the input all of the raw materials in addition to the feed coal, the output products, and the generated waste products. All of these streams plus the measured flow and composition of the product gas will be used in the calculation of the heat and material balances for each PDU test.

Detailed material flows and stream conditions are presented in the series of Process Flow Diagrams, Figures 4.1 to 4.6, at the end of this section. Additional details and values for the streams and parameters are presented in the following series of figures presenting the Piping and Instrumentation Diagrams, Figures 5.1 to 5.11, presented in Section 5 which follows.

Table 9. MILDGAS PDU Material Streams

State	Material	Service	Nominal rate	Usage, ton/yr
Raw Input Material				
Solid	Feed coal	Gasifier feedstock	2000 lb/h	1092
Liquid	Xylene	Cleaning solvent	N/A 150 gal/test	11
Liquid	Caustic NaOH (25% soln)	Wet gas scrubber wash liquid	120 lb/h	66
Gas	Natural gas	Recycle gas preheater	2700 scfh	62
		Thermal oxidizer	240 scfh	13
Liquid	Water	Scrubber make up	400 lb/h	300
		Cooling water	125 gpm	
Products				
Solid	Raw coarse char	Granular gasifier char	870 lb/h	475
Solid	Raw fine char	Gasifier char from cyclones	412 lb/h	225
Liquid	Coal liquid	Recovered light oil	88 lb/h	48
Liquid	Coal liquid	Recovered medium oil	135 lb/h	74
Liquid	Coal liquid	Recovered heavy oil	264 lb/h	144
Liquid	Unsteady state Condensate	Coal liquids, spent xylene	N/A	50
Waste Products				
Gas	Flue gas	Scrubbed thermal oxidizer flue gas (MW=24.88)	4658 lb/h	7350
Liquid	Sodium sulfite	Spent caustic (25% soln.)	190 lb/h	104

PDU Startup and Shutdown Procedure

The practical startup and shutdown procedures of the PDU are interrelated with equipment design and combinations of sub-system equipment. The following procedures were developed during the detailed design of the components of the PDU system. The goals for the types of tests to be conducted are restated below for the PDU to focus on the special operations needed to bring all equipment on-line and to hold at selected test conditions while key process conversion data and stream sampling is conducted.

Goal of short-duration 24-hour steady-state tests: The purpose is to hold selected test conditions at steady conditions and collect operational data and product samples for off-line analysis for process evaluations from steady state material and energy balances.

Goal of long-duration 3-day steady state tests: The purpose is to operate PDU at near-optimum conditions identified from the series of short-duration tests to collect larger quantities of the co-products, namely coarse char, fine char, and the three liquid product fractions.

PDU startup steps from cold start:

1. Ready natural gas-fired heaters for recycle gas with nitrogen gas

2. Start flow of nitrogen gas and recycle through heaters, gasifier, and liquids recovery section, from recycle gas compressor; a portion is exhausted through thermal oxidizer and stack.

3. Ready natural gas-fired oil heater for feed coal screw heaters

4. Ready pilot flame on thermal oxidizer

5. Ready cooling water to cooling screws and liquids recovery sections

6. Ready liquids recovery sections with startup liquids: creosote or diesel for the heavy oil section, diesel for the middle weight oils section, and xylene for the light weight oil section. [Note that these liquids will be used in the first test of any one type of coal. When subsequent tests are made with the same coal, the collected liquid product fractions from the previous tests will be used as the startup liquids.]

7. Load coarse coke breeze to coal feed system and build up fluidized bed in gasifier.

8. Heat the fluidized bed of coke breeze, the gasifier, and downstream piping with hot nitrogen gas: operate at near test pressure. [Pressure will not be a test variable]

9. Start coarse coal feed when temperatures at test target at about 1/3 of target feed rate. [No fine coke or coal fed to entrained bed portion of gasifier] Stabilize gasifier conditions for about one hour before next feed increment.

10. Start collection of coarse fluidized bed char overflow and fine char carryover through cooling screw-lockhopper system

11. Start draining any collected liquids as necessary

12. Increase coal feed rate to about 2/3 of target feed rate and stabilize gasifier conditions for about one hour.

13. Start fine coal feed to entrained bed section at about 1/2 target feed rate and hold for about one hour.

14. Increase coarse coal feed to fluidized bed to target feed rate and fine coal feed to entrained bed to target feed rate. Stabilize and hold conditions until coke breeze is run out of fluidized bed in gasifier and startup liquids are run out of the three sections of the liquids recovery section. [Expect about 12 to 18 hours to run out coke breeze and up to 24 hours to run out starting liquids]

PDU shutdown steps (voluntary shutdown):

1. Stop the fine coal feed to the entrained bed section by running the heating screw empty, and shut down the oil heater for both coal heating screws.

2. Stop the coarse coal feed to the gasifier by running the heating screw empty.

3. Reduce the temperature of the recycle gas heaters in steps and begin substituting nitrogen in place of the recycled product gas.

4. Keep collecting coarse char from the gasifier until the fluidized bed level is below the coarse char discharge nozzle, but keep collecting fine coal char from cyclones until the gas flow is stopped. In all cases isolate char products collected during shutdown from the char products from the steady state test period.

5. Keep draining and collecting liquids from each condensing section until empty.

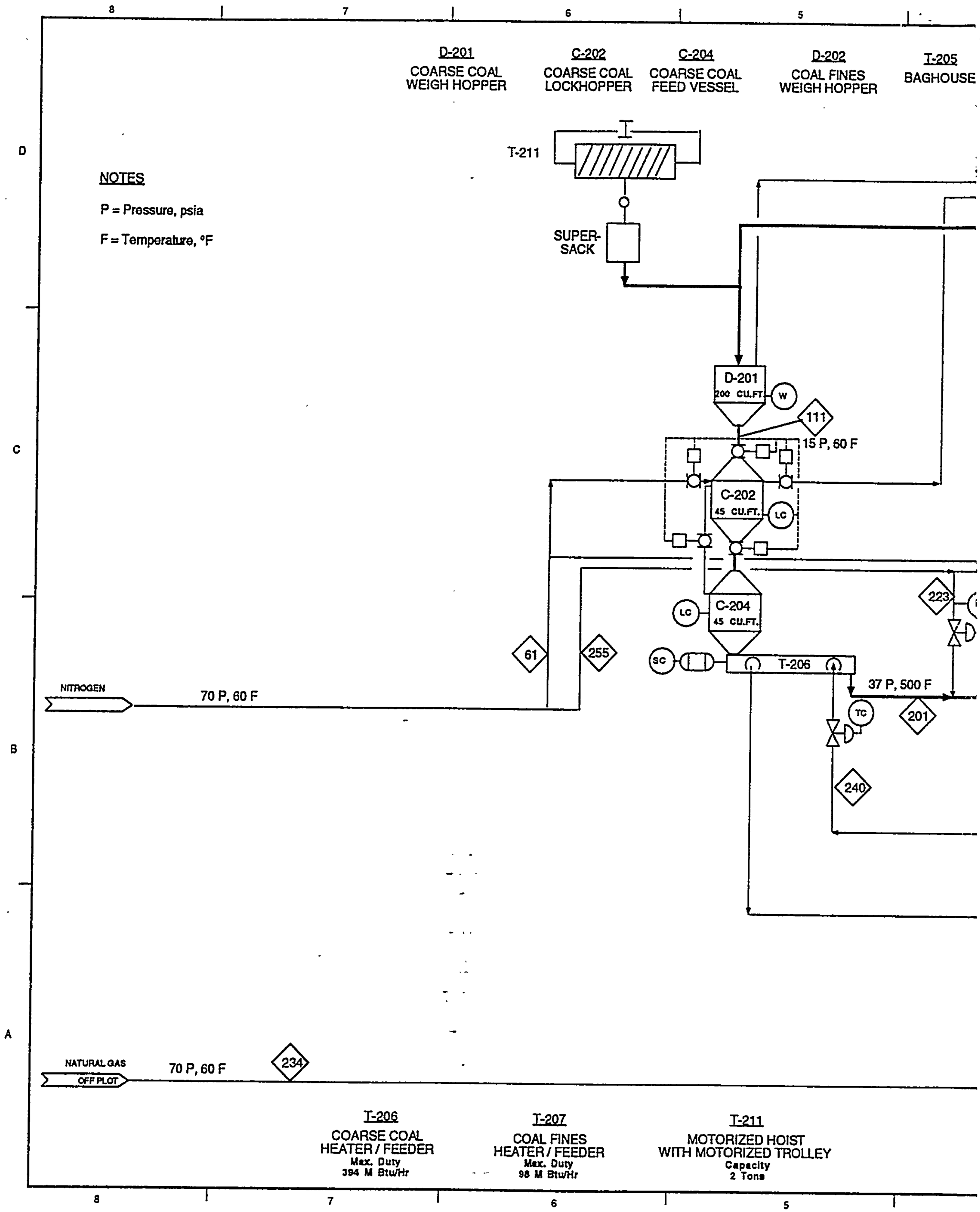
6. Wait for system temperatures to be below 500 °F, and when coarse char discharge and recirculating liquids are drained, then stop nitrogen gas flow through system.

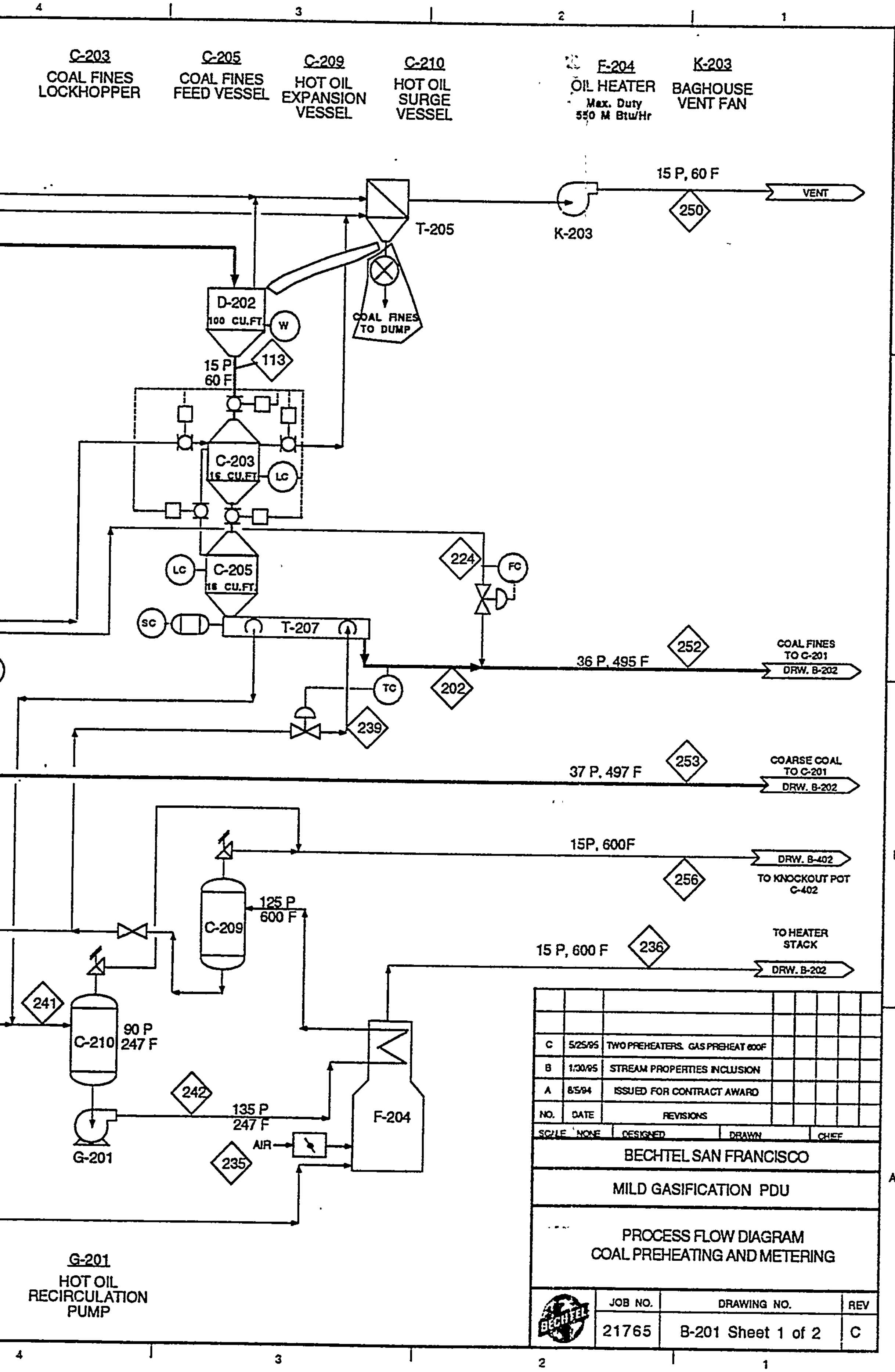
7. Shut down thermal oxidizer and scrubber.

8. Let system cool under small nitrogen purge.

9. Begin sample collection, labeling, and distribution for further analysis or disposal.

10. With cold system, begin system inspection and cleaning operations for next test.


D-201
COARSE COAL WEIGH HOPPER
C-202
COARSE COAL LOCKHOPPER
C-204
COARSE COAL FEED VESSEL
D-202
COAL FINES WEIGH HOPPER
T-205
BAGHOUSE
NOTES
P = Pressure, psia
F = Temperature, °F
T-211
SUPER-SACK
D-201
200 CU.FT.
W
111
15 P, 60 F
C-202
45 CU.FT.
LC
C-204
45 CU.FT.
LC
223
SC
T-206
37 P, 500 F
TC
201
240
61
255
NITROGEN
70 P, 60 F
NATURAL GAS
OFF PLOT
70 P, 60 F
234
T-206
COARSE COAL HEATER / FEEDER
Max. Duty
394 M Btu/Hr
T-207
COAL FINES HEATER / FEEDER
Max. Duty
98 M Btu/Hr
T-211
MOTORIZED HOIST WITH MOTORIZED TROLLEY
Capacity
2 Tons



C-203
COAL FINES LOCKHOPPER
C-205
COAL FINES FEED VESSEL
C-209
HOT OIL EXPANSION VESSEL
C-210
HOT OIL SURGE VESSEL
F-204
OIL HEATER
Max. Duty 550 M Btu/Hr
K-203
BAGHOUSE VENT FAN
15 P, 60 F
VENT
250
T-205
K-203
D-202
100 CU.FT.
W
COAL FINES TO DUMP
15 P
60 F
113
C-203
15 CU.FT.
LC
LC
C-205
15 CU.FT.
224
FC
SC
T-207
252
COAL FINES TO C-201
36 P, 495 F
DRW. B-202
TC
202
239
253
COARSE COAL TO C-201
37 P, 497 F
DRW. B-202
15P, 600F
DRW. B-402
256
TO KNOCKOUT POT C-402
125 P
600 F
C-209
TO HEATER STACK
15 P, 600 F
236
DRW. B-202
241
C-210
90 P
247 F
242
135 P
247 F
F-204
G-201
AIR
235
G-201
HOT OIL RECIRCULATION PUMP
C 5/25/95 TWO PREHEATERS. GAS PREHEAT 600F
B 1/30/95 STREAM PROPERTIES INCLUSION
A 8/5/94 ISSUED FOR CONTRACT AWARD
NO. DATE REVISIONS
SCALE NONE DESIGNED DRAWN CHECK
BECHTEL SAN FRANCISCO
MILD GASIFICATION PDU
PROCESS FLOW DIAGRAM
COAL PREHEATING AND METERING
JOB NO. 21765
DRAWING NO. B-201 Sheet 1 of 2
REV C

Stream Number		61	111	113	201	202	223	224	234	235	
Description		Nitrogen To Lockhoppers	Coarse Coal from D-201	Coal Fines from D-202	Preheated Coarse Coal	Preheated Coal Fines	Coarse Coal Injection Gas	Coal Fines Injection Gas	Nat'l Gas to Oil Heater	Air to Oil Heater	Oil H Stack
Nominal Operating Conditions											
Phase		Gas	Solid	Solid	Mixed	Mixed	Gas	Gas	Gas	Gas	G
Pressure	psia	70	15	15	37	36	70	70	75	15	1
Temperature	°F	60	60	60	500	500	60	60	60	60	6
Total Flow	lb/hr	21	1,684 (2)	421 (2)	1,684	421	16	7	25	500	52
Gas Flow	SCFH	280					211	94	555	6,571	
	ACFH	59					44	20	109	6,440	1
Solid Component Flow Rates											
Coal(MF)	lb/hr		1,600.0	400.0	1,600.0	400.0					
Char(MF)	lb/hr										
Moisture	lb/hr		84.2	21.1							
Gas/Liquid Component Flow Rates											
Nitrogen	lb/hr	20.7					15.6	6.9	0.2	374.8	
Argon	lb/hr									6.4	
Oxygen	lb/hr									114.9	
Carbon Monoxide	lb/hr										
Carbon Dioxide	lb/hr								0.5	0.2	
Water	lb/hr				84.2	21.1				3.3	
Hydrogen	lb/hr										
Methane	lb/hr								22.3		
Ethylene	lb/hr										
Ethane	lb/hr								1.1		
Propylene	lb/hr										
Propane	lb/hr								0.4		
Butane	lb/hr								0.3		
Light Oil	lb/hr										
Middle Oil	lb/hr										
Tar/Hvy Oil	lb/hr										
Sulfur Dioxide	lb/hr										
Hydrogen Sulfide	lb/hr										
Ammonia	lb/hr										
Hydrogen Chloride	lb/hr										
Recirculated Heating Oil	lb/hr										
Viscosity	cp	0.017					0.017	0.017	0.011	0.018	0
Thermal Conductivity	Btu/hr-ft-°F	0.014					0.014	0.014	0.018	0.014	0
Density	lb/ft^3	0.352					0.352	0.352	0.228	0.078	0
Heat Capacity	Btu/lb-°F	0.249					0.249	0.249	0.515	0.242	0
Maximum Operating Conditions											
Pressure	psia	70	15	15	37	36	70	70	75	15	
Temperature	°F	60	95	95	500	500	60	60	60	95	
Total Flow	lb/hr	21	1,684 (2)	421 (2)	1,684	421	16	7	31	608	

Notes

(1) Hot oil relief expressed as light oil equivalent of estimated heating value.
(2) Intermittent fill rate lasting 45 minutes each hour.
(3) Hourly average vent rate. Total hourly release within 15 minutes per hour.
(4) This temperature gives maximum heat load.
(5) These properties are of gas phase only.

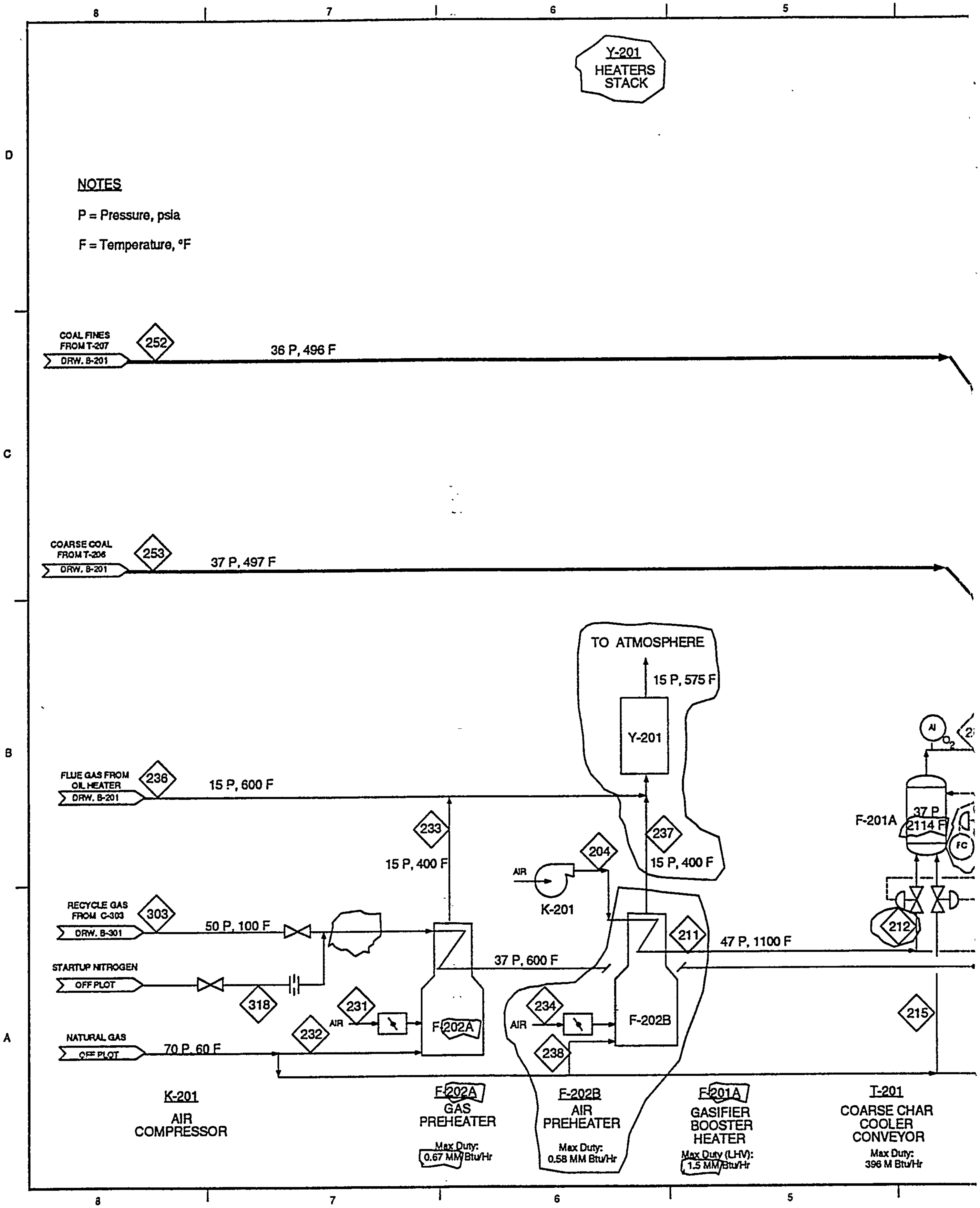
36	239	240	241	242	250	252	253	255	256
r nt	Hot Oil to Fines Preht	Hot Oil to Coarse Preht	Combined Oil Return	Hot Oil to Heater	Lockhopper Vents	Coal Fines to Gasifier	Coarse Coal to Gasifier	N2 Gas To Coal Transport	Hot Oil Relief
	Liquid	Liquid	Liquid	Liquid	Gas	Mixed	Mixed	Gas	Gas
	125	125	90	135	15	36	37	70	15
	600	600	250	247	60	496	497	60	600
	540	2,158	2,698	2,698	21	428	1,700	22	0
39					280	537	1,985	304	
62					275	403	1,452	64	
						400.0	1,600.0		
.1					20.7	6.9	15.6	22.5	
.4									
.2									
.3									
.5						21.1	84.2		
	539.6	2,158.4	2,698.0	2,698.0					
						Note 5	Note 5		
28	0.320	0.320	2.50	2.50	0.017	0.020	0.020	0.017	0.013
26	0.046	0.046	0.067	0.067	0.014	0.023	0.023	0.014	0.020
37	40.840	40.840	53.00	53.00	0.075	0.069	0.069	0.352	0.138
78	0.510	0.510	0.426	0.426	0.249	0.417	0.437	0.249	0.483
5	125	125	90	135	15	36	37	70	15
00	600	600	200 (4)	200 (4)	95	496	497	60	600
37	540	2,158	2,698	2,698	21	428	1,700	22	88 (1)

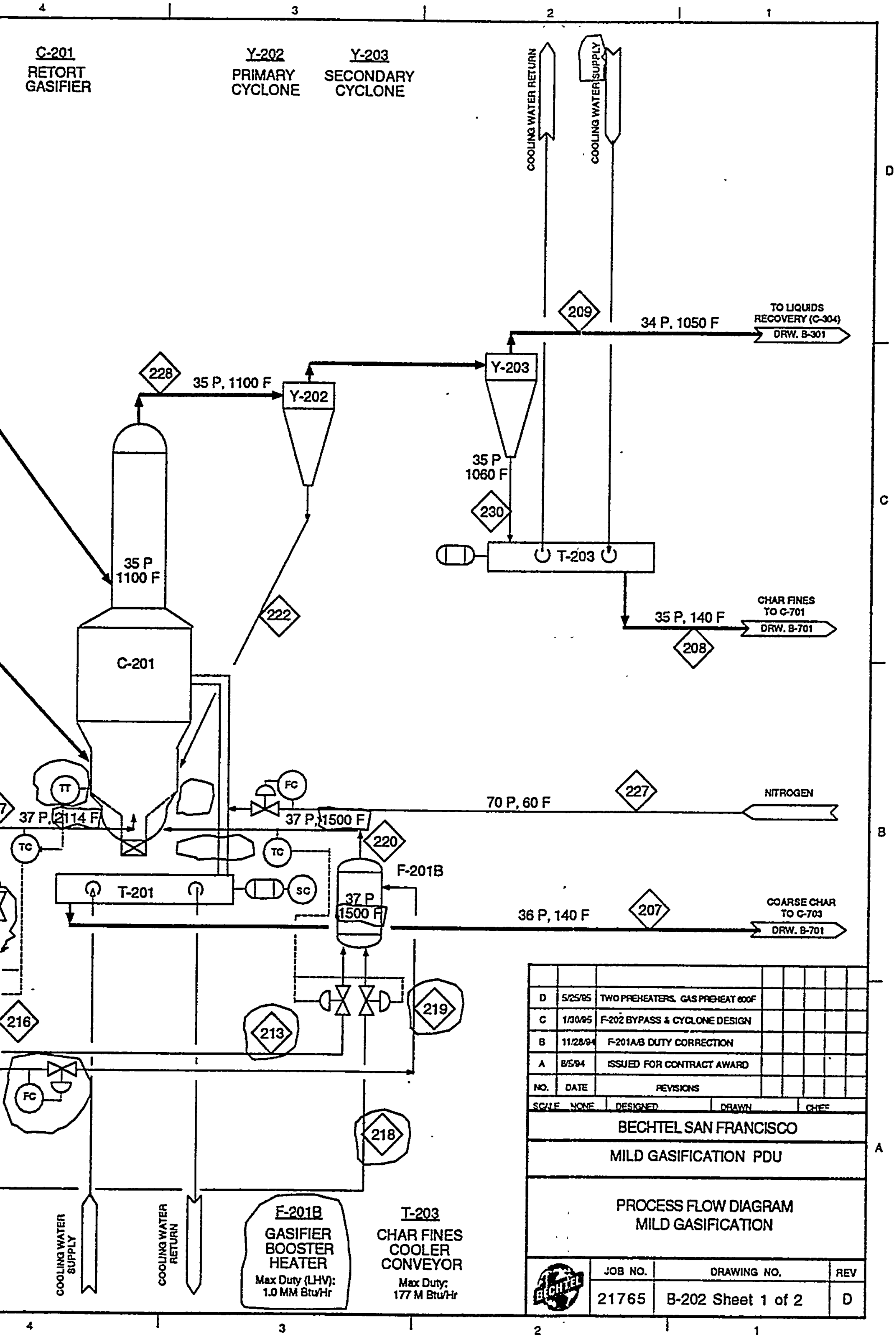
COAL PREHEATING & METERING

B-201 Sheet 2 of 2

Rev C: Two Preheaters and Recycle Gas Preheated to 600°F

Dated 5/25/95


Y-201
HEATERS STACK
NOTES
P = Pressure, psia
F = Temperature, °F
COAL FINES FROM T-207
DRW. B-201
252
36 P, 496 F
COARSE COAL FROM T-206
DRW. B-201
253
37 P, 497 F
TO ATMOSPHERE
15 P, 575 F
Y-201
FLUE GAS FROM OIL HEATER
DRW. B-201
236
15 P, 600 F
233
15 P, 400 F
237
15 P, 400 F
204
AIR
K-201
F-201A
37 P
2114 F
FC
AI
RECYCLE GAS FROM C-303
DRW. B-301
303
50 P, 100 F
STARTUP NITROGEN
OFF PLOT
318
37 P, 600 F
211
47 P, 1100 F
212
215
231
AIR
232
234
AIR
238
F-202A
F-202B
NATURAL GAS
OFF PLOT
70 P, 60 F
K-201
AIR COMPRESSOR
F-202A
GAS PREHEATER
Max Duty:
0.67 MM Btu/Hr
F-202B
AIR PREHEATER
Max Duty:
0.58 MM Btu/Hr
F-201A
GASIFIER BOOSTER HEATER
Max Duty (LHV):
1.5 MM Btu/Hr
T-201
COARSE CHAR COOLER CONVEYOR
Max Duty:
396 M Btu/Hr



NO.	DATE	REVISIONS
D	5/25/95	TWO PREHEATERS. GAS PREHEAT 600F
C	1/30/95	F-202 BYPASS & CYCLONE DESIGN
B	11/28/94	F-201A/B DUTY CORRECTION
A	8/5/94	ISSUED FOR CONTRACT AWARD

SCALE NONE | DESIGNED | DRAWN | CHECKED

BECHTEL SAN FRANCISCO

MILD GASIFICATION PDU

PROCESS FLOW DIAGRAM
MILD GASIFICATION

JOB NO.	DRAWING NO.	REV
21765	B-202 Sheet 1 of 2	D

Stream Number		204	207	208	209	211	212	213	215	216	217	218	21
:ription		Air from K-201A	Coarse Char Product	Char Fines Product	Gas to Liq Recovery	Preheated Air	Air to F-201A	Air to F-201B	Nat'l Gas to F-201A	Recycle Gas To F-201A	Hot Gas to Gasifier Centr	Nat'l Gas to F-201B	Recycle Ga: To F-201I
Nominal Operating Conditions													
Phase		Gas	Solids	Solids	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas
Pressure	psia	65	35	35	34	47	47	47	47	37	37	47	37
Temperature	°F	60 (1)	140	140	1,050	1,100	1,100	1,100	60	600	1,620	60	600
Total Flow	lb/hr	1,179	1,040	206	5,983	1,179	818	361	49	2,519	3,391	22	1,311
Gas Flow	SCFH	15,513			79,157	15,513	10,764	4,749	1,090	34,778	46,792	481	18,092
	ACFH	3,508			99,381	14,556	10,100	4,456	341	28,166	74,361	150	14,652
Solid Component Flow Rates													
Coal(MF)	lb/hr												
Char(MF)	lb/hr		1,040.0	206.0	34.0								
Moisture	lb/hr												
Gas/Liquid Component Flow Rates													
Nitrogen	lb/hr	884.8			3,589.0	884.8	613.9	270.9	0.5	1,749.9	2,365.8	0.2	910.
Argon	lb/hr	15.1			58.3	15.1	10.5	4.6		28.4	38.9		14.
Oxygen	lb/hr	271.1				271.1	188.1	83.0					
Carbon Monoxide	lb/hr				170.6					83.2	83.1		43.
Carbon Dioxide	lb/hr	0.6			881.2	0.6	0.4	0.2	0.9	429.7	562.2	0.4	223.
Water	lb/hr	7.7			375.7	7.7	5.3	2.4		28.7	141.7		14.
Hydrogen	lb/hr				28.6					13.9	14.0		7.
Methane	lb/hr				141.4				43.9	69.0	68.8	19.4	35.
Ethylene	lb/hr				66.9					32.6	32.4		17.
Ethane	lb/hr				28.4				2.2	13.9	13.8	0.9	7.
Propylene	lb/hr				33.4					16.3	16.2		8.
Propane	lb/hr				3.3				0.7	1.6	1.7	0.3	0.
Butane	lb/hr								0.7			0.3	
Light Oil	lb/hr				74.8					21.2	21.2		11.
Middle Oil	lb/hr				75.2					1.3	1.3		0.
Tar/Hvy Oil	lb/hr				375.9					8.8	8.8		4.
Sulfur Dioxide	lb/hr												
Hydrogen Sulfide	lb/hr				42.5					20.7	20.7		10.
Ammonia	lb/hr				0.4								
ogen Chloride	lb/hr				3.1								
irculated Heating Oil	lb/hr												
					Note 2								
Viscosity	cp	0.018			0.036	0.039	0.039	0.039	0.011	0.028	0.052	0.011	0.02
Thermal Conductivity	Btu/hr-ft-°F	0.014			0.044	0.036	0.036	0.036	0.018	0.031	0.063	0.018	0.03
Density	lb/ft^3	0.336			0.058	0.081	0.081	0.081	0.143	0.089	0.037	0.143	0.08
Heat Capacity	Btu/lb-°F	0.242			0.330	0.268	0.268	0.268	0.515	0.290	0.343	0.515	0.29
Maximum Operating Conditions													
Pressure	psia	65	35	35	34	47	47	47	47	37	37	47	3
Temperature	°F	95 (1)	140	140	1,100	1,100	1,100	1,100	60	600	2,114	60	60
Total Flow	lb/hr	1,580	1,300	310	6,052	1,580	1,096	484	65	2,285	3,303	29	1,18

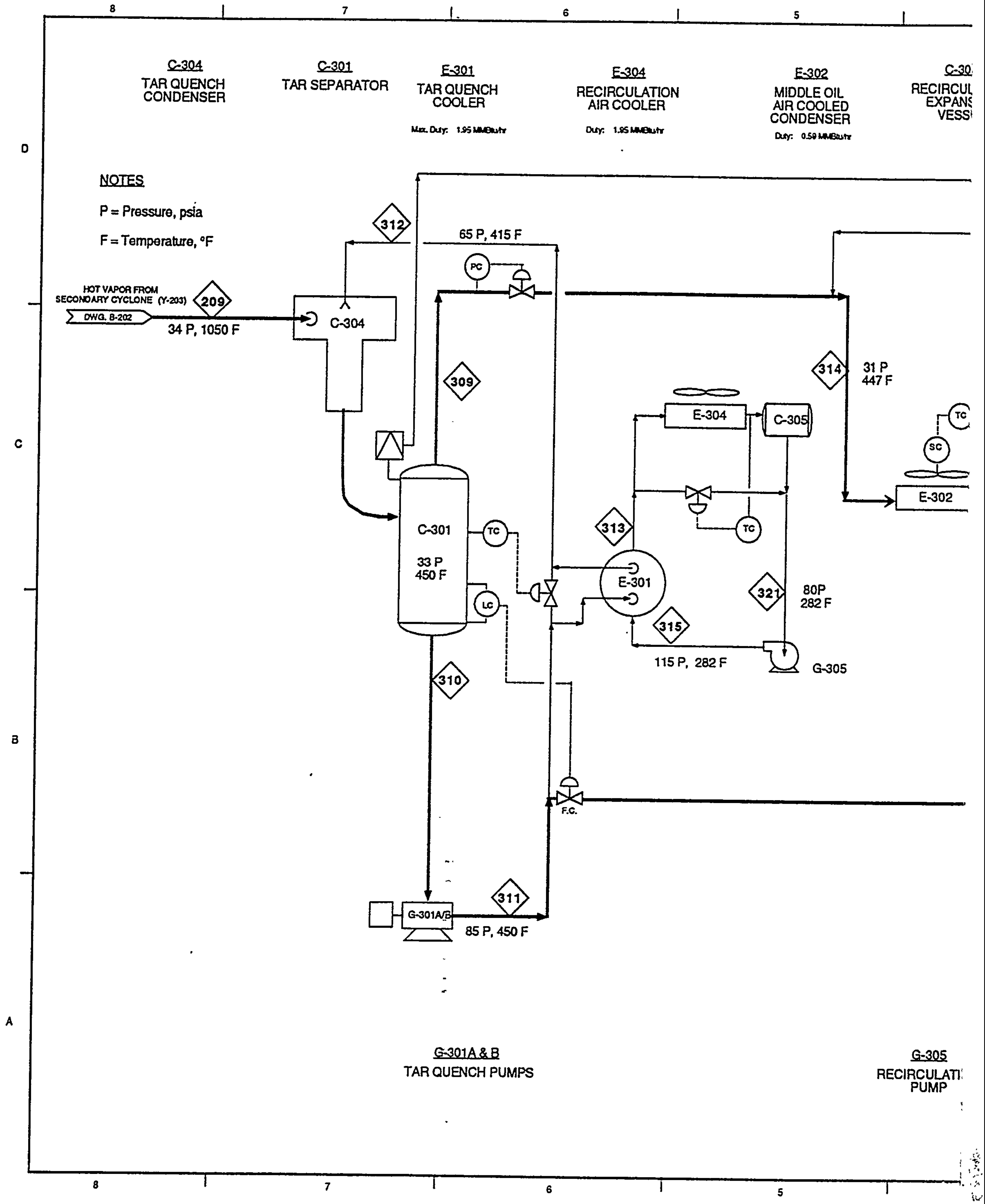
Notes

(1) This temperature is at the compressor inlet. The compressor outlet temperature will be higher than this.

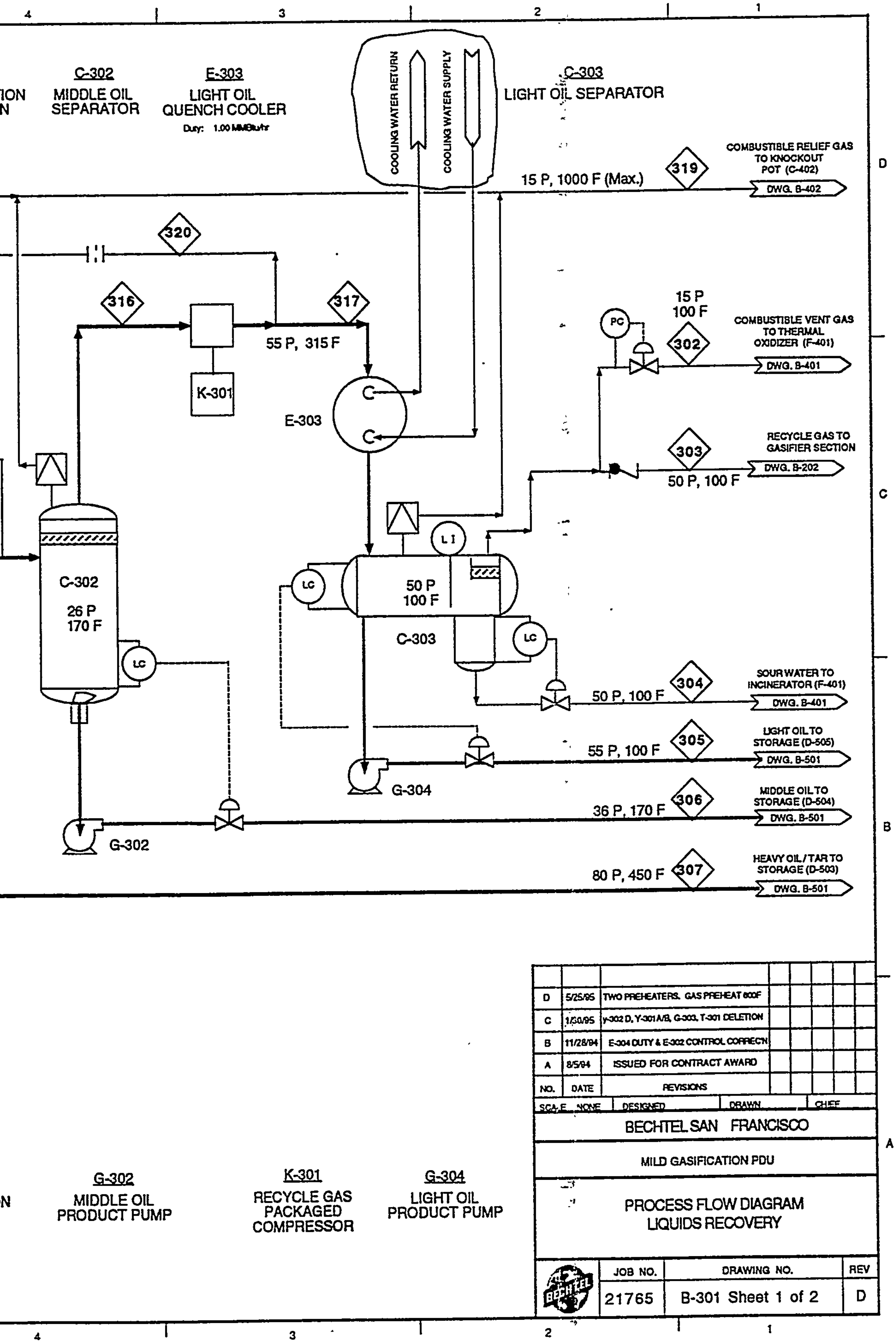
(2) These properties are of gas phase only. Particle density of solids is 75 lb/ft^3 and heat capacity of solids is 0.28 Btu/lb°F.

220	222	227	228	230	231	232	233	234	237	238	252	253	303
Hot Gas to Gasifier Grid	Char Injection	N2 Purge of Char Withdrawl	Gasifier Overhead	Secondary Cyclone Fines	Comb Air To F-202A	Natural Gas To F-202A	F-202A Stack Gas	Comb Air To F-202B	F-202B Stack Gas	Natural Gas To F-202B	Coal Fines to Gasifier	Coarse Coal to Gasifier	Recycle Gas To F-202A
Gas	Solids	Gas	Mixed	Solids	Gas	Gas	Gas	Gas	Gas	Gas	Mixed	Mixed	Gas
37	34	70	35	35	15.7	75	15	15.7	15	75	36	37	50
1,500	1,050	60	1,100	1,050	60	60	400	60	400	60	496	497	100
1,692	3,760	21	9,949	206	490	24	514	424	445	21	428	1,700	3,830
23,353		280	79,157		6,447	544	7,003	5,581	6,062	471	538	1,985	52,870
34,972		59	99,738		6,036	107	11,350	5,225	9,825	92	404	1,452	16,739
	3,760.0		4,000.0	206.0							400.0	1,600.0	
1,180.0		20.7	3,589.0		367.7	0.2	367.9	318.3	318.5	0.2	6.9	15.6	2,660.3
19.4			58.3		6.3		6.3	5.4	5.4				43.2
					112.7		18.8	97.5	16.3				
43.2			170.6										126.5
281.5			881.2		0.2	0.5	66.0	0.2	57.2	0.4			653.2
64.6			375.7		3.2		55.4	2.8	48.0		21.1	84.2	43.6
7.3			28.6										21.2
35.8			141.4			21.9				19.0			104.8
16.9			66.9										49.6
7.2			28.4			1.1				0.9			21.1
8.4			33.4										24.8
0.9			3.3			0.4				0.3			2.5
						0.3				0.3			
11.0			74.8										32.2
0.7			75.2										2.0
4.6			375.9										13.4
10.8			42.5										31.5
			0.4										
			3.1										
			Note 1								Note 1	Note 1	
0.043		0.017	0.036		0.018	0.011	0.024	0.018	0.024	0.011	0.020	0.020	0.017
0.051		0.014	0.044		0.014	0.018	0.021	0.014	0.021	0.018	0.023	0.023	0.017
0.048		0.352	0.058		0.076	0.228	0.045	0.076	0.045	0.228	0.069	0.069	0.229
0.330		0.249	0.330		0.242	0.515	0.270	0.242	0.270	0.515	0.417	0.437	0.267
37	34	70	35	35	16	75	15	16	15	75	36	37	50
1,500	1,300	60	1,100	1,100	95	60	400	95	400	60	496	497	100
1,707	3,760	21	10,018	310	513.2	25.5	538.7	444.3	466.4	22.1	428	1,700	3,830

MILD GASIFICATION
B-202 Sheet 2 of 2
Rev D: Two Preheaters and Recycle Gas Preheated to 600°F
Dated 5/25/95



C-304
TAR QUENCH CONDENSER
C-301
TAR SEPARATOR
E-301
TAR QUENCH COOLER
Max. Duty: 1.95 MMBtu/hr
E-304
RECIRCULATION AIR COOLER
Duty: 1.95 MMBtu/hr
E-302
MIDDLE OIL AIR COOLED CONDENSER
Duty: 0.59 MMBtu/hr
C-30
RECIRCUL
EXPANS
VESS
NOTES
P = Pressure, psia
F = Temperature, °F
HOT VAPOR FROM SECONDARY CYCLONE (Y-203)
DWG. B-202
209
34 P, 1050 F
C-304
312
65 P, 415 F
PC
309
314
31 P
447 F
E-304
C-305
TC
SC
E-302
C-301
33 P
450 F
TC
313
TC
E-301
LC
321
80P
282 F
315
115 P, 282 F
G-305
310
F.C.
311
G-301A/B
85 P, 450 F
G-301A & B
TAR QUENCH PUMPS
G-305
RECIRCULATI
PUMP



C-302
MIDDLE OIL SEPARATOR
E-303
LIGHT OIL QUENCH COOLER
Duty: 1.00 MMBtu/hr
COOLING WATER RETURN
COOLING WATER SUPPLY
C-303
LIGHT OIL SEPARATOR
15 P, 1000 F (Max.)
319
COMBUSTIBLE RELIEF GAS TO KNOCKOUT POT (C-402)
DWG. B-402
320
316
317
55 P, 315 F
K-301
PC
15 P
100 F
302
COMBUSTIBLE VENT GAS TO THERMAL OXIDIZER (F-401)
DWG. B-401
E-303
303
RECYCLE GAS TO GASIFIER SECTION
DWG. B-202
50 P, 100 F
L I
LC
50 P
100 F
C-302
26 P
170 F
LC
C-303
LC
304
SOUR WATER TO INCINERATOR (F-401)
50 P, 100 F
DWG. B-401
305
LIGHT OIL TO STORAGE (D-505)
55 P, 100 F
DWG. B-501
G-304
306
MIDDLE OIL TO STORAGE (D-504)
36 P, 170 F
DWG. B-501
G-302
307
HEAVY OIL / TAR TO STORAGE (D-503)
80 P, 450 F
DWG. B-501
G-302
MIDDLE OIL PRODUCT PUMP
K-301
RECYCLE GAS PACKAGED COMPRESSOR
G-304
LIGHT OIL PRODUCT PUMP
D 5/25/95 TWO PREHEATERS. GAS PREHEAT 800F
C 1/30/95 Y-302 D, Y-301A/B, G-303, T-301 DELETION
B 11/28/94 E-304 DUTY & E-302 CONTROL CORRECN
A 8/5/94 ISSUED FOR CONTRACT AWARD
NO. DATE REVISIONS
SCALE NONE DESIGNED DRAWN CHEF
BECHTEL SAN FRANCISCO
MILD GASIFICATION PDU
PROCESS FLOW DIAGRAM
LIQUIDS RECOVERY
JOB NO. 21765
DRAWING NO. B-301 Sheet 1 of 2
REV D

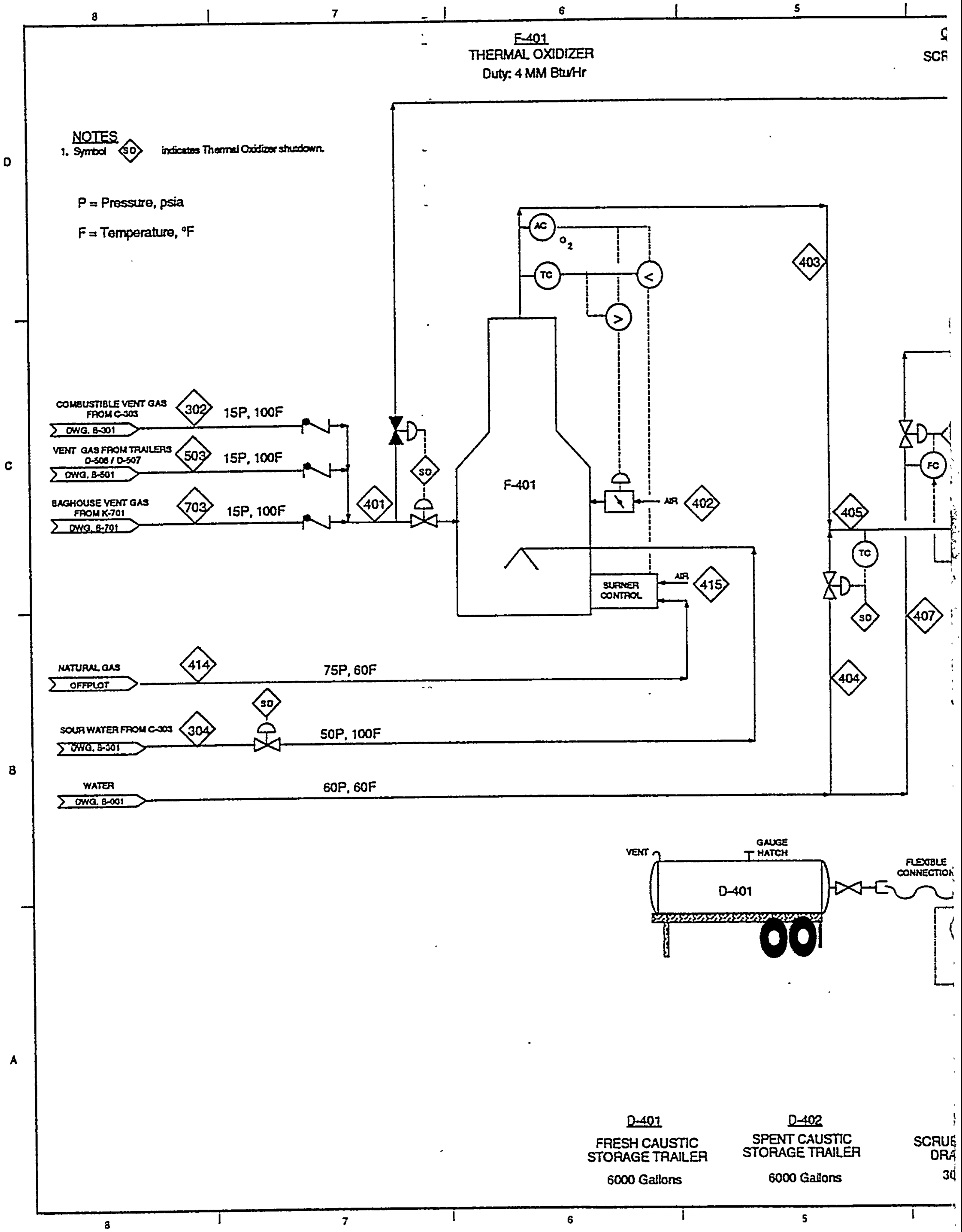
Stream Number		209	302	303	304	305	306	307	309	310	311	312	3
Description		Gas to Liq Recovery	Vent Gas to Incinerator	Recycle Gas to F-202A	Sour Water	Light Oil To Storage	Middle Oil To Storage	Tar to Storage	Gas to M.O Recovery	Tar From Separator	Tar Pump Discharge	Cool Tar Recycle	Glyco From
Nominal Operating Conditions													
Phase		Gas	Gas	Gas	Liquid	Liquid	Liquid	Liquid	Gas	Liquid	Liquid	Liquid	Li
Pressure	psia	34	15	50	50	55	36	80	33	33	85	65	1
Temperature	°F	1,050	100	100	100	100	170	450	450	450	450	415	3
Total Flow	lb/hr	5,983	1,314	3,830	320	88	134	285	5,710	66,084	66,084	65,810	64,
Gas Flow	SCFH	79,157	18,152	52,870					78,651				
	ACFH	99,381	19,157	16,739					61,312				
Char	lb/hr	34						34		8,200	8,200	8,166	
Component Flow Rates													
Nitrogen	lb/hr	3,589.0	906.2	2,660.3					3,589.0				
Argon	lb/hr	58.3	15.1	43.2					58.3				
Oxygen	lb/hr												
Carbon Monoxide	lb/hr	170.6	44.2	126.5					170.6				
Carbon Dioxide	lb/hr	881.2	227.9	653.2	0.1				881.2				
Water	lb/hr	375.7	15.2	43.6	316.9				375.7				32,3
Hydrogen	lb/hr	28.6	7.4	21.2					28.6				
Methane	lb/hr	141.4	36.6	104.8					141.4				
Ethylene	lb/hr	66.9	17.3	49.6					66.9				
Ethane	lb/hr	28.4	7.4	21.1					28.4				
Propylene	lb/hr	33.4	8.7	24.8					33.4				
Propane	lb/hr	3.3	0.9	2.5					3.3				
Butane	lb/hr												
Light Oil	lb/hr	74.8	11.2	32.2		23.9	7.2	0.2	74.5	58.7	58.7	58.5	
Middle Oil	lb/hr	75.2	0.7	2.0		19.8	50.6	2.2	73.1	509.4	509.4	507.3	
Tar/Hvy Oil	lb/hr	375.9	4.7	13.4		44.5	76.6	248.7	139.2	57,315.9	57,315.9	57,078.2	
Sulfur Dioxide	lb/hr												
Hydrogen Sulfide	lb/hr	42.5	11.0	31.5	0.0				42.5				
Ammonia	lb/hr	0.4			0.4				0.4				
Hydrogen Chloride	lb/hr	3.1	5.27E-04	2.56E-03	3.1				3.1				
Ethylene Glycol	lb/hr												32
Maximum Operating Conditions													
Pressure	psia	34	15	50	50	55	36	80	33	33	85	65	
Temperature	°F	1,100	100	100	100	100	170	450	450	450	450	400 (2)	
Total Flow	lb/hr	6,052	1,693	3,830	370	88	134	285	5,780	66,084	66,084	65,810	6
		Note 6						Note 5		Note 5	Note 5	Note 5	
Viscosity	cp	0.036	0.017	0.017	0.696	0.985	1.242	3.886	0.027	3.889	3.886	3.00 (4)	
Thermal Conductivity	Btu/hrft°F	0.044	0.017	0.017	0.363	0.077	0.071	0.057	0.031	0.057	0.057	0.064	
Density	lb/ft^3	0.058	0.069	0.229	62.381	59.562	61.542	62.370	0.093	62.370	62.370	62.370	6
Heat Capacity	Btu/lb°F	0.330	0.267	0.267	1.005	0.426	0.415	0.637	0.306	0.637	0.637	0.637	

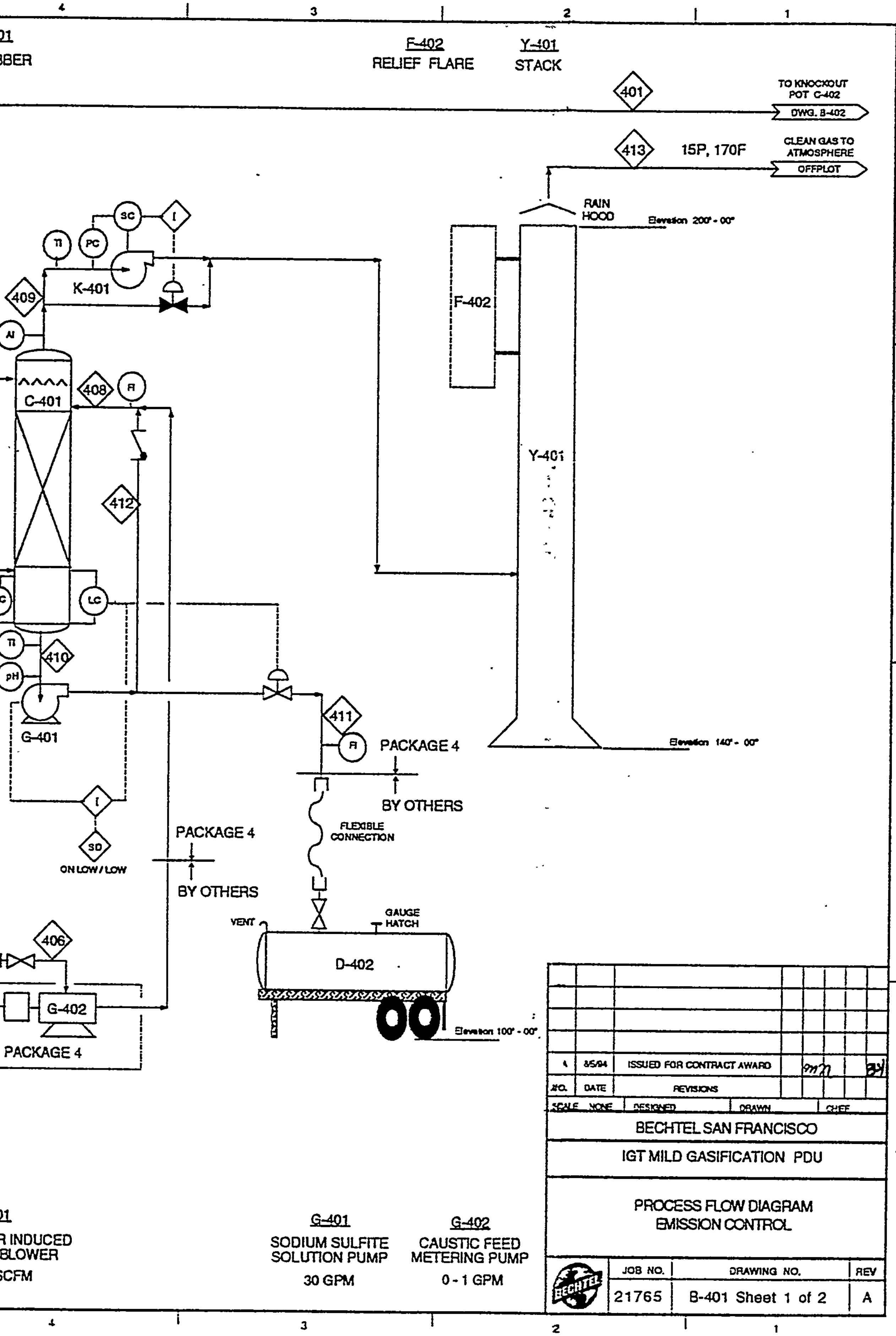
Notes

(1) Deleted.
(2) Minimum assumed temperature.
(3) Normally there is no flow in stream 319.
(4) At 300°F the viscosity of liquid in stream 312 is 52 cp.
(5) Properties are of liquid phase only. Particle density of solids is 75 lb/ft^3. Heat capacity of solids is 0.28 Btu/lb°F.
(6) Properties are of gas phase only. Particle density of solids is 75 lb/ft^3, and heat capacity of solids is 0.28 Btu/lb°F.

3	314	315	316	317	318	319	320	321
Vater -301	Combined Gas to M.O. Separator	Glycol/Water From G-305	Gas to Recycle Compressor	Gas to L.O. Recovery	Start-Up Nitrogen	Relief Gas To Incinerator	Compressor Recycle	Glycol/Water to E-301
d	Gas	Liquid	Gas	Gas	Gas	Gas	Gas	Liquid
	31	115	26	55	70	15	55	80
	447	282	170	315	60	1,050	315	282
0	5,810	64,600	5,675	5,575		6,174	100	64,600
						Note 3		
	80,055		79,680	78,276		81,687	1,404	
	66,214		54,580	31,181		232,463	559	
	3,653.3		3,653.3	3,589.0		3,724.8	64.4	
	59.4		59.4	58.3		60.5	1.1	
	173.7		173.7	170.6		177.1	3.1	
	897.1		897.1	881.2		914.6	15.8	
.0	382.5	32,300.0	382.5	375.7		390.0	6.7	32,300.0
	29.1		29.1	28.6		29.7	0.5	
	144.0		144.0	141.4		146.8	2.5	
	68.1		68.1	66.9		69.4	1.2	
	29.0		29.0	28.4		29.5	0.5	
	34.0		34.0	33.4		34.7	0.6	
	3.4		3.4	3.3		3.5	0.1	
	75.7		68.5	67.3		77.6	1.2	
	73.5		22.9	22.5		78.1	0.4	
	140.3		63.7	62.6		390.2	1.1	
	43.2		43.2	42.5		44.1	0.8	
	0.4		0.4	0.4		0.4	0.0	
	3.2		3.1	3.1		3.2	0.1	
0.0		32,300.0						32,300.0
05	31	115	26	55	70	15	55	80
00	447	282	170	315	60	1,050	315	282
00	5,880	64,600	5,746	5,646	165	6,174	100	64,600
63	0.023	0.263	0.018	0.022	0.017	0.036	0.022	0.305
51	0.035	0.251	0.019	0.023	0.014	0.044	0.023	0.251
87	0.088	65.787	0.104	0.179	0.352	0.027	0.179	65.787
16	0.367	1.016	0.282	0.289	0.249	0.330	0.289	0.990

LIQUIDS RECOVERY
B-301 Sheet 2 of 2
Rev D: Two Preheaters and Recycle Gas Preheated to 600°F
Dated 5/25/95


F-401
THERMAL OXIDIZER
Duty: 4 MM Btu/Hr
NOTES
1. Symbol SD indicates Thermal Oxidizer shutdown.
P = Pressure, psia
F = Temperature, °F
COMBUSTIBLE VENT GAS FROM C-303
DWG. B-301
302
15P, 100F
VENT GAS FROM TRAILERS D-506 / D-507
DWG. B-501
503
15P, 100F
BAGHOUSE VENT GAS FROM K-701
DWG. B-701
703
15P, 100F
401
F-401
AIR
402
403
AC
TC
BURNER CONTROL
AIR
415
NATURAL GAS
OFFPLOT
414
75P, 60F
SOUR WATER FROM C-303
DWG. B-301
304
50P, 100F
WATER
DWG. B-001
60P, 60F
405
TC
SD
407
404
FC
VENT
GAUGE HATCH
D-401
FLEXIBLE CONNECTION
D-401
FRESH CAUSTIC STORAGE TRAILER
6000 Gallons
D-402
SPENT CAUSTIC STORAGE TRAILER
6000 Gallons



01
BBER
F-402
RELIEF FLARE
Y-401
STACK
401
TO KNOCKOUT POT C-402
DWG. B-402
413
15P, 170F
CLEAN GAS TO ATMOSPHERE
OFFPLOT
RAIN HOOD
Elevation 200' - 00"
SC
TI
PC
K-401
409
AI
F-402
408
FI
C-401
412
Y-401
LC
TI
410
pH
G-401
411
FI
PACKAGE 4
BY OTHERS
FLEXIBLE CONNECTION
SD
ON LOW / LOW
PACKAGE 4
BY OTHERS
Elevation 140' - 00"
VENT
GAUGE HATCH
D-402
406
G-402
PACKAGE 4
Elevation 100' - 00"
4
8/5/94
ISSUED FOR CONTRACT AWARD
NO.
DATE
REVISIONS
SCALE NONE
DESIGNED
DRAWN
CHEF
BECHTEL SAN FRANCISCO
IGT MILD GASIFICATION PDU
PROCESS FLOW DIAGRAM
EMISSION CONTROL
01
R INDUCED
BLOWER
SCFM
G-401
SODIUM SULFITE SOLUTION PUMP
30 GPM
G-402
CAUSTIC FEED METERING PUMP
0 - 1 GPM
JOB NO.
21765
DRAWING NO.
B-401 Sheet 1 of 2
REV
A

Stream Number		256	302	304	319	401	402	403	404	405
Description		Hot Oil Relief	Excess Recycle Gas	Sour Water	Relief Gas To Incinerator	Combined Vent Gas	Dilution Air to Incin	Incinerator Effluent	Quench Water	Quenched Incin Effl
Nominal Operating Conditions										
Phase		Gas	Gas	Liquid	Gas	Gas	Gas	Gas	Liquid	Gas
Pressure	psia	15	15	50	15	15	15	14	60	14
Temperature	°F	600	100	100	1,050	100	60	1,800	60	200
Total flow	lb/h	0	834	257	6,174 See Note 4	959	3,192	4,841	2,037	6,878
Gas Flow	SCFH		12,084		85,096	13,788	41,993	66,142		109,049
	ACFH		12,754		242,163	14,551	41,153	301,838		145,328
Component Flow Rates										
Nitrogen	lb/hr		524.2	0.0	3,445.7	649.2	2,395.2	3,354.3	0.0	3,354.3
Argon	lb/hr		8.6	0.0	54.1	8.6	40.9	54.7	0.0	54.7
Oxygen	lb/hr		0.0	0.0		0.0	733.9	355.1	0.0	355.1
Carbon Monoxide	lb/hr		44.1	0.0	278.2	44.1	0.0	0.0	0.0	0.0
Carbon Dioxide	lb/hr		145.8	0.1	919.1	145.8	1.6	511.6	0.0	511.6
Water	lb/hr		10.2	253.5	336.9	10.2	20.8	541.2	2,036.8	2,578.0
Hydrogen	lb/hr		7.4	0.0	46.6	7.4	0.0	0.0	0.0	0.0
Methane	lb/hr		36.6	0.0	230.6	37.0	0.0	0.0	0.0	0.0
Ethylene	lb/hr		17.3	0.0	109.0	17.3	0.0	0.0	0.0	0.0
Ethane	lb/hr		7.4	0.0	46.4	7.4	0.0	0.0	0.0	0.0
Propylene	lb/hr		8.7	0.0	54.5	8.7	0.0	0.0	0.0	0.0
Propane	lb/hr		0.9	0.0	5.4	0.9	0.0	0.0	0.0	0.0
Butane	lb/hr		0.0	0.0		0.0	0.0	0.0	0.0	0.0
Light Oil	lb/hr		8.0	0.0	87.8	8.0	0.0	0.0	0.0	0.0
Middle Oil	lb/hr		0.5	0.0	81.1	0.5	0.0	0.0	0.0	0.0
Tar/Hvy Oil	lb/hr		3.0	0.0	405.5	3.0	0.0	0.0	0.0	0.0
Sulfur Dioxide	lb/hr		0.0	0.0		0.0	0.0	21.2	0.0	21.2
Hydrogen Sulfide	lb/hr		11.0	0.0	69.2	11.0	0.0	0.0	0.0	0.0
Ammonia	lb/hr		0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Hydrogen Chloride	lb/hr		0.0	3.1	3.3	0.0	0.0	3.1	0.0	3.1
Sodium Hydroxide	lb/hr		0.0	0.0		0.0	0.0	0.0	0.0	0.0
Sodium Sulfite	lb/hr		0.0	0.0		0.0	0.0	0.0	0.0	0.0
Sodium Chloride	lb/hr		0.0	0.0		0.0	0.0	0.0	0.0	0.0
Max. Operating Conditions										
Max. Hourly Flow	lb/hr	88 (3)	*939*	*271*	6,174	*1,064*	*3,323*	*5,344*	*2,244*	*7,587*
Max. Instantaneous Flow	lb/hr	88 (3)			6,174					
Particulates	lb/MM SCF									

Notes:

(1) Vent gas from storage trailers expressed as light oil equivalent based on estimated heating value.

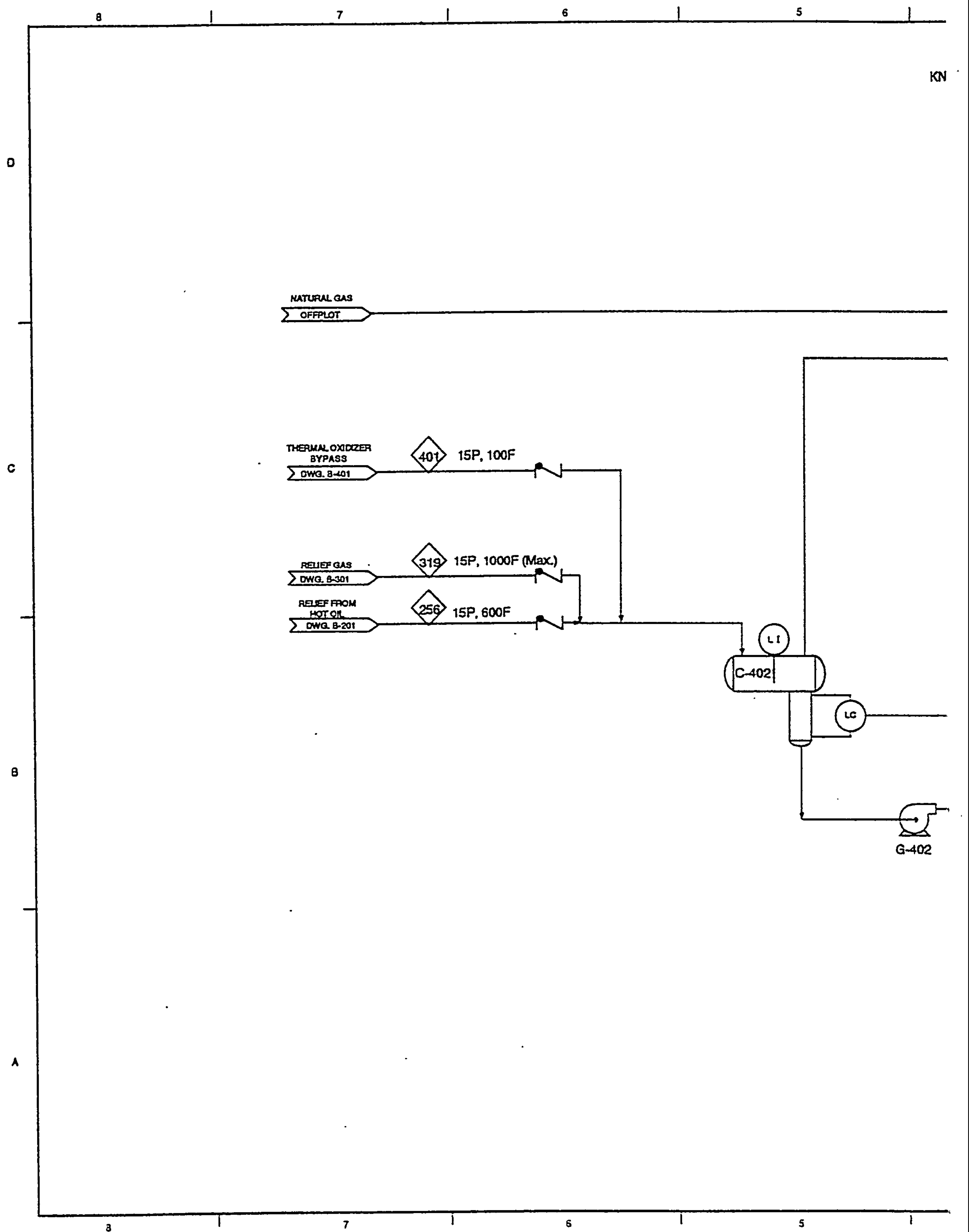
(2) Natural gas requirement will be dependent on the heating value of feeds to the thermal oxidizer. Maximum rate corresponds to estimated heat duty being supplied solely by natural gas.

(3) **Hot oil relief expressed as light oil equivalent based on estimated heating value. Normally there is no flow in stream 256.**

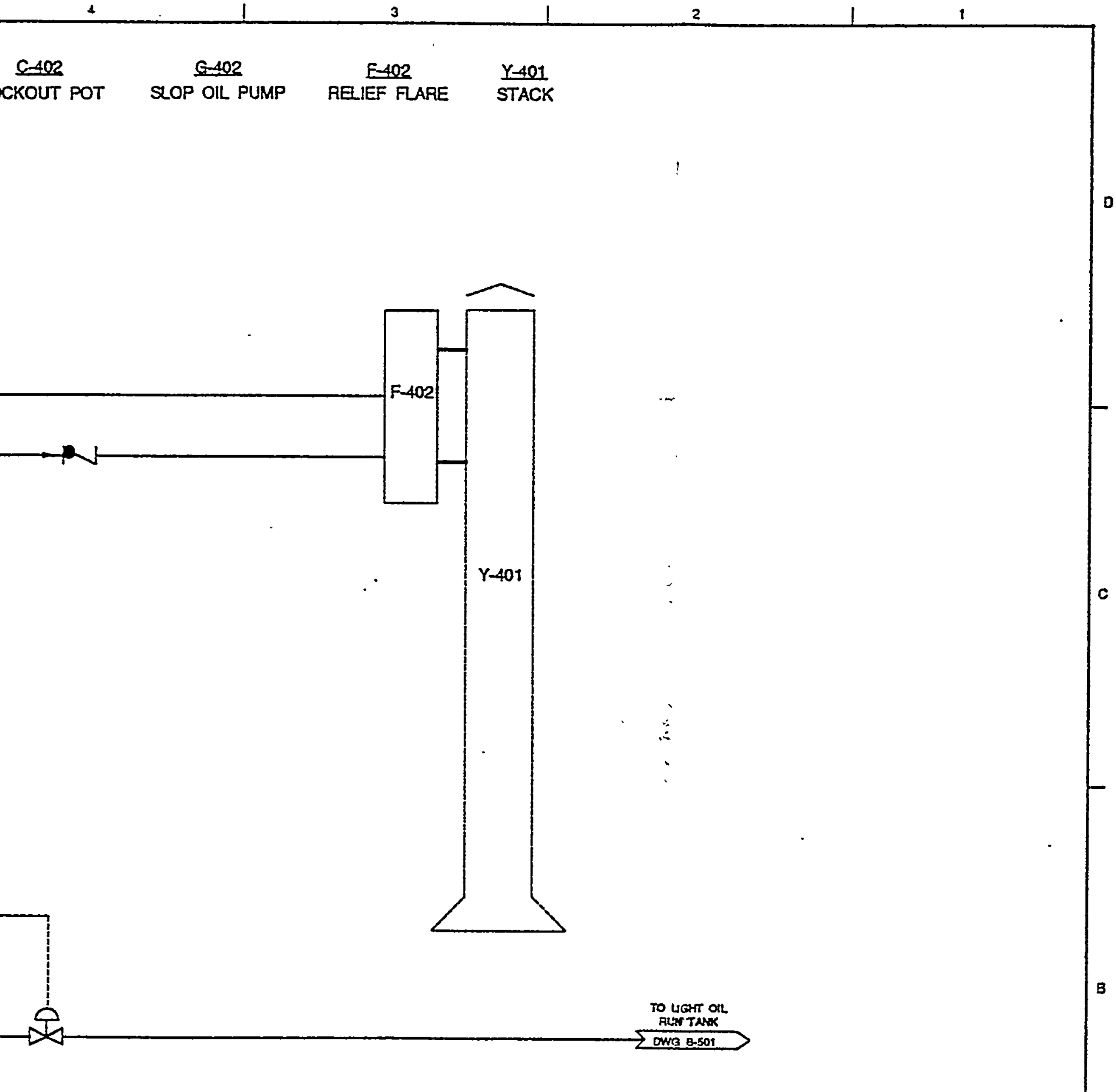
(4) **Normally there is no flow in stream 319.**

406	407	408	409	410	411	412	413	414	415	503	703
Fresh Caustic	Scrubbing Water	Liquid to Scrubber	Scrubber Effluent	Liquid from Scrubber	Spent Caustic	Recirculate Caustic	Vent to Atmosphere	Natural Gas	Air to Incin. Burner	Truck Vents	Char Trans Gas
Liquid	Liquid	Liquid	Gas	Liquid	Liquid	Liquid	Gas	Gas	Gas	Gas	Gas
15	60	15	12	14	15	15	15	75	15	15	15
60	60	169	170	170	170	170	170	60	60	100	100
118	123	11,011	6,919	11,094	201	10,893	6,919	20	412	0.4	125
			110,258				110,258	457	5,385		
			163,674				130,939	90	5,278		
0.0	0.0	0.0	3,354.3	0.0	0.0	0.0	3,354.3	0.2	309.2	0.0	125.0
0.0	0.0	0.0	54.7	0.0	0.0	0.0	54.7	0.0	5.3	0.0	0.0
0.0	0.0	0.0	355.1	0.0	0.0	0.0	355.1	0.0	94.7	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	511.6	0.0	0.0	0.0	511.6	0.4	0.2	0.0	0.0
88.6	123.4	8,476.9	2,642.9	8,542.9	154.6	8,388.3	2,642.9	0.0	2.7	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4	0.0	0.4	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29.5	0.0	29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	2,236.5	0.0	2,277.7	41.2	2,235.5	0.0	0.0	0.0	0.0	0.0
0.0	0.0	268.3	0.0	273.3	4.9	268.3	0.0	0.0	0.0	0.0	0.0
118	*130*	*12,138*	*7,635*	*12,221*	*201*	*12,020*	*7,635*	186 (2)	3,882. (2)	88 (1)	125
								186 (2)	3,882 (2)	270 (1)	905
											3.3

EMISSION CONTROL



KN
NATURAL GAS
OFFPLOT
THERMAL OXIDIZER BYPASS
DWG. B-401
401
15P, 100F
RELIEF GAS
DWG. B-301
319
15P, 1000F (Max.)
RELIEF FROM HOT OIL
DWG. B-201
256
15P, 600F
LI
C-402
LC
G-402



NO.	DATE	REVISIONS		
A	8/5/94	ISSUED FOR CONTRACT AWARD		

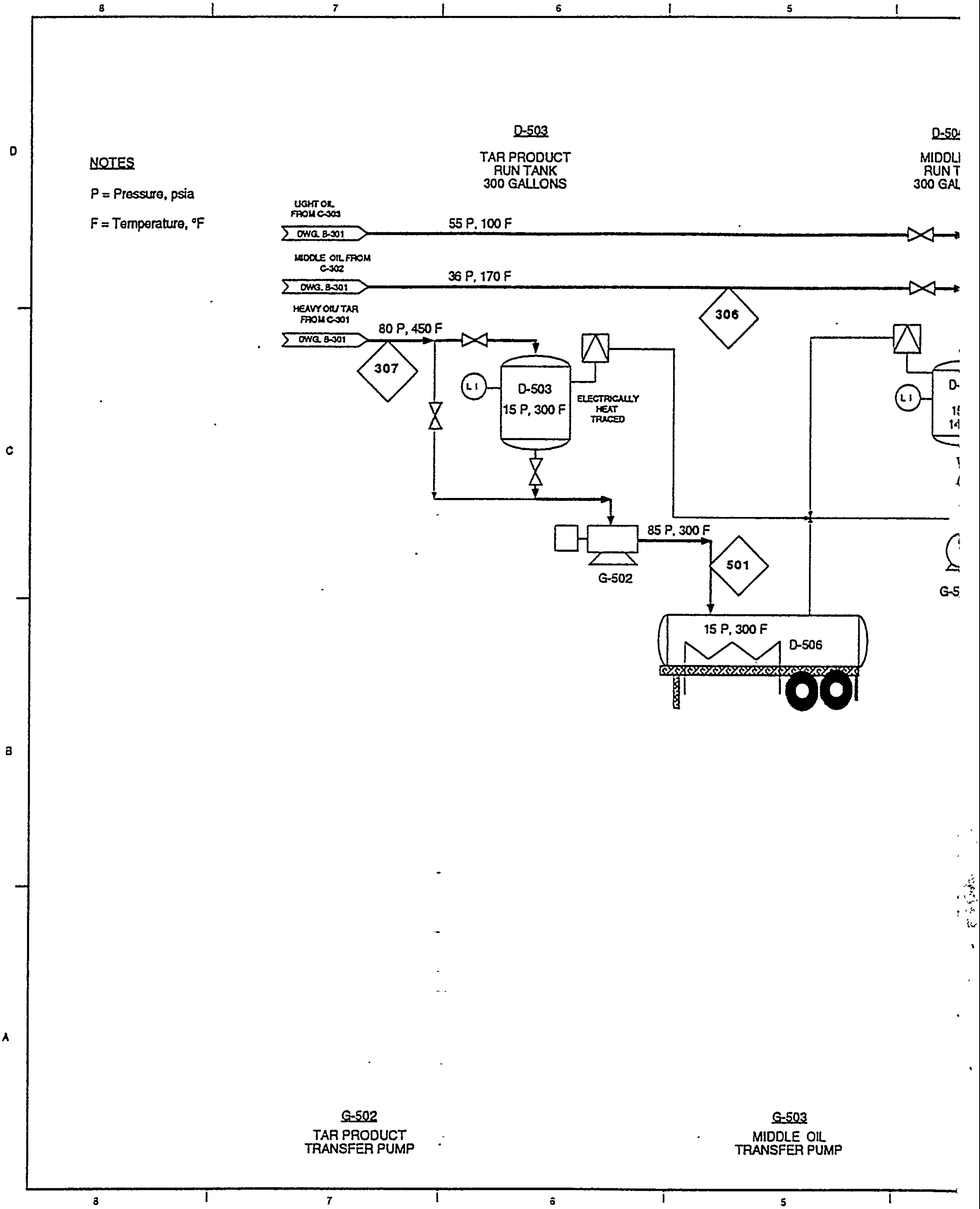
SCALE NONE | DESIGNED | DRAWN | CHEF

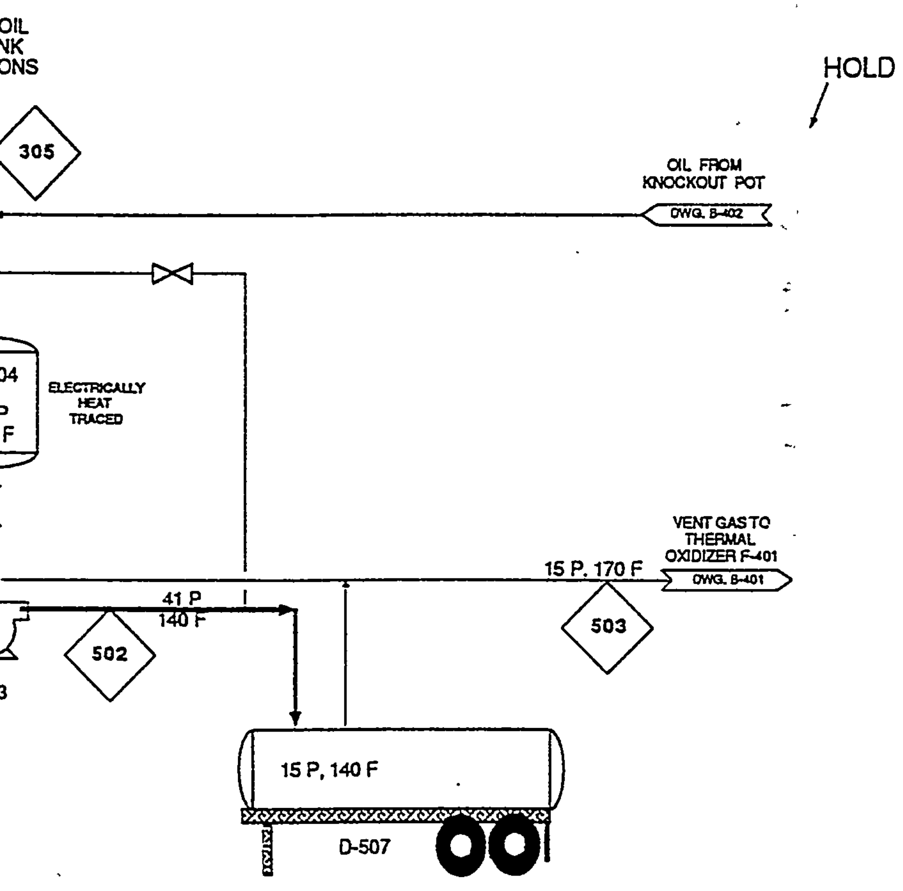
BECHTEL SAN FRANCISCO

IGT MILD GASIFICATION PDU

PROCESS FLOW DIAGRAM
EMISSION CONTROL

JOB NO.	DRAWING NO.	REV
21765	B-402 Sheet 1 of 1	A


NOTES
P = Pressure, psia
F = Temperature, °F
D-503
TAR PRODUCT
RUN TANK
300 GALLONS
LIGHT OIL
FROM C-303
DWG. B-301
55 P, 100 F
MIDDLE OIL FROM
C-302
DWG. B-301
36 P, 170 F
HEAVY OIL/ TAR
FROM C-301
DWG. B-301
80 P, 450 F
307
306
L I
D-503
15 P, 300 F
ELECTRICALLY
HEAT
TRACED
85 P, 300 F
501
G-502
15 P, 300 F
D-506
G-502
TAR PRODUCT
TRANSFER PUMP
G-503
MIDDLE OIL
TRANSFER PUMP



D-506
TAR PRODUCT STORAGE TRAILER

D-507
MIDDLE OIL STORAGE TRAILER

NO.	DATE	REVISIONS
C	5/25/95	TWO PREHEATERS, GAS PREHEAT 600F
B	1/30/95	L.O. & M. O. STORAGE MERGER
A	8/5/94	ISSUED FOR CONTRACT AWARD

SCALE NONE | DESIGNED | DRAWN | CHIEF

BECHTEL SAN FRANCISCO

MILD GASIFICATION PDU

PROCESS FLOW DIAGRAM
LIQUIDS STORAGE AND HANDLING

JOB NO.	DRAWING NO.	REV
21765	B-501 Sheet 1 of 2	C

Stream Number		305	306	307	501	502
Description		Light Oil To Storage	Middle Oil To Storage	Tar To Storage	Tar To Disposal	Middle & Light Oil Disposal
Nominal Operating Conditions						
Phase		Liquid	Liquid	Liquid	Liquid	Liquid
Pressure	psia	55	36	80	85	41
Temperature	°F	100	170	450	300	140
Total Flow	lb/hr	88	134	285	10927	9,930
Char	lb/h			34	1,356	
Component Flow Rates						
Light Oil	lb/hr	24	7	0	8	1,740
Middle Oil	lb/hr	20	51	2	84	2,941
Tar/Hvy Oil	lb/hr	45	77	249	9,479	5,249
C8+aromatics	lb/hr					
Maximum Operating Conditions						
Pressure	psia	55	36	80	125	41
Temperature	°F	100	170	450	288	140
Total Flow	lb/hr	88	134	285	10,927	9,930
				Note 1	Note 1	
Viscosity	cp	0.985	1.242	3.886	51.00	1.140
Thermal conductivity	Btu/hr-ft-°F	0.077	0.071	0.057	0.057	0.073
Density	lb/ft^3	59.56	61.54	62.37	62.37	60.75
Heat capacity	Btu/lb-°F	0.426	0.415	0.637	0.637	0.419

Notes
(1) Properties are of liquid phase only.
Particle density of solids is 75 lb/ft^3, and
Solids heat capacity is 0.28 Btu/lb°F

LIQUIDS STORAGE AN[D
B-501 S
Rev. C: Two Pr
Recycle Gas Preh
Da

503
Vent Gas To Incinerator
Gas
15
170
10
14.7
170
10
0.013
0.020
0.170
0.483

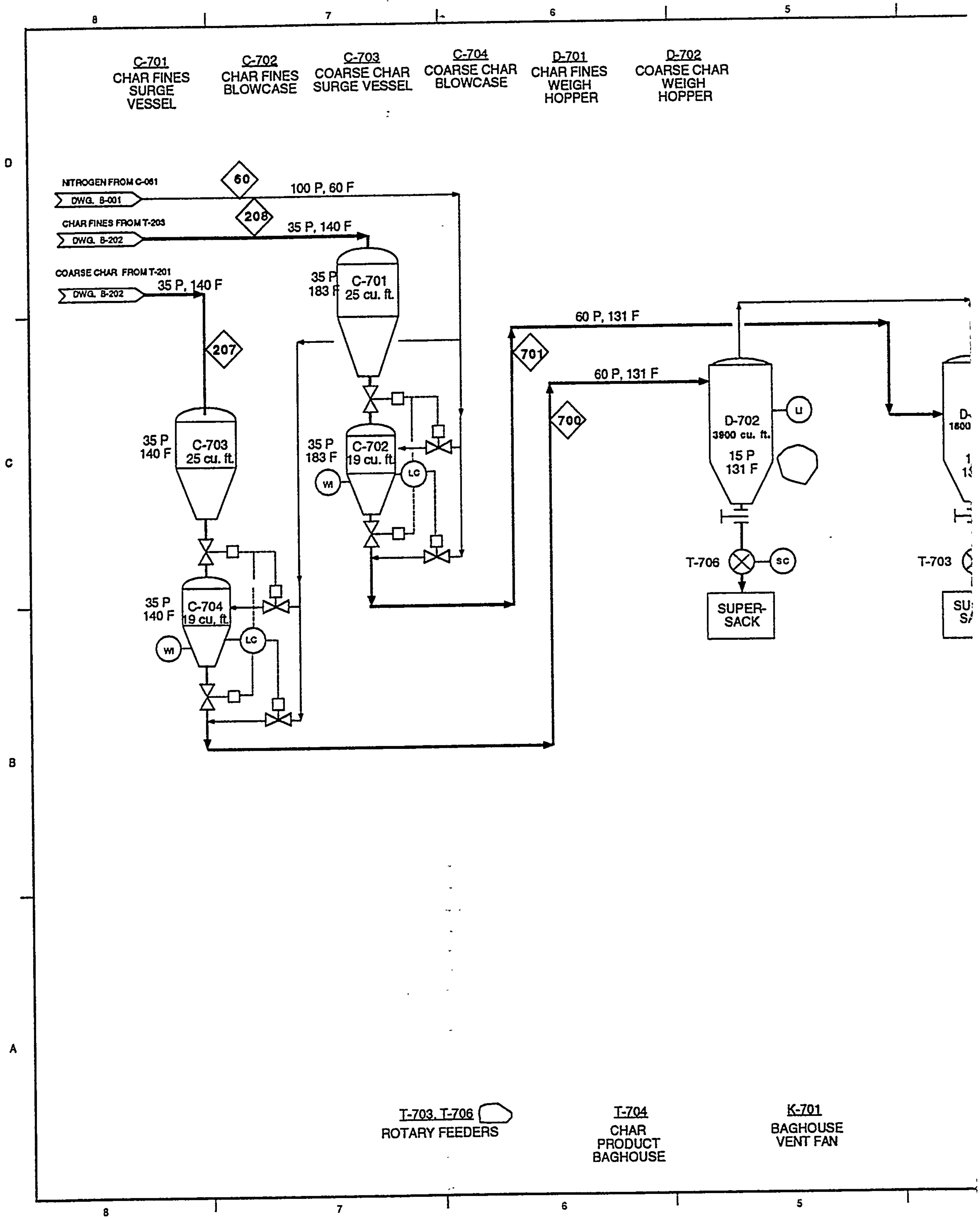
HANDLING

eet 2 of 2

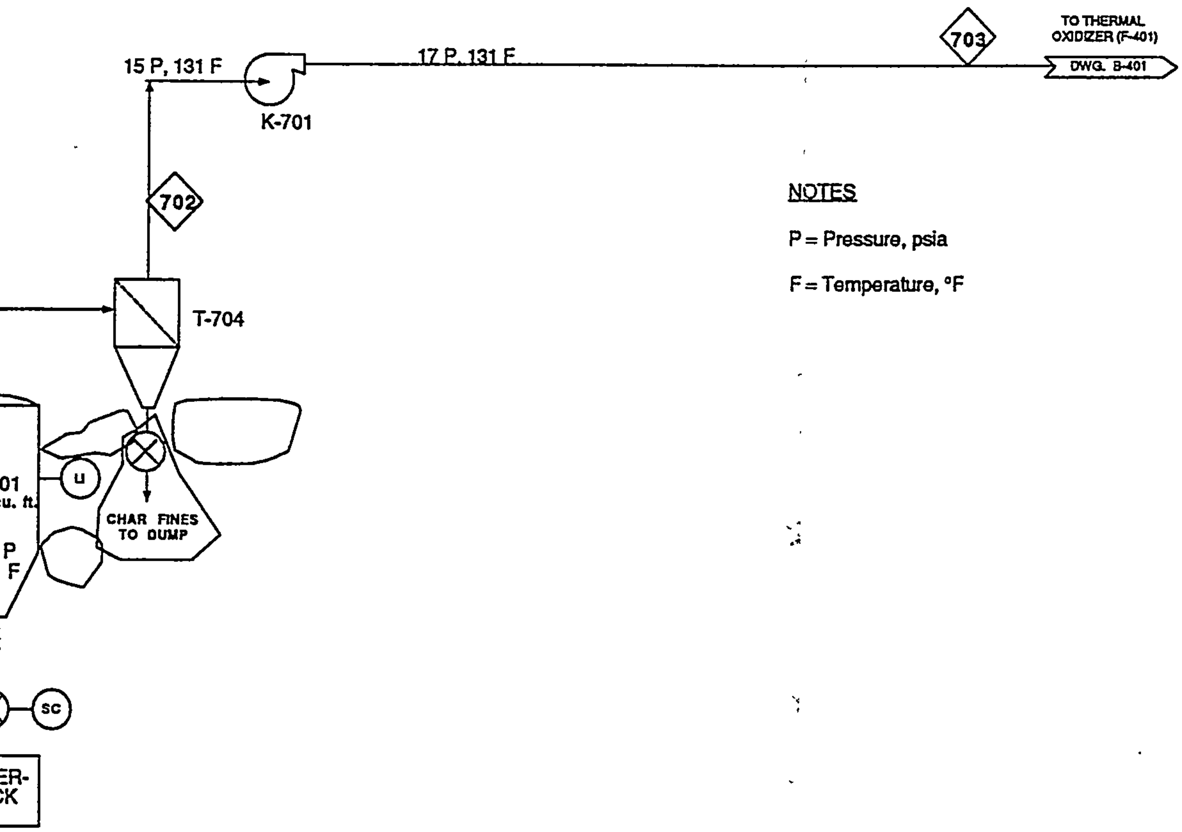
eaters and

ted to 600°F

d 5/25/95



C-701
CHAR FINES SURGE VESSEL
C-702
CHAR FINES BLOWCASE
C-703
COARSE CHAR SURGE VESSEL
C-704
COARSE CHAR BLOWCASE
D-701
CHAR FINES WEIGH HOPPER
D-702
COARSE CHAR WEIGH HOPPER
NITROGEN FROM C-061
DWG. B-001
60
100 P, 60 F
CHAR FINES FROM T-203
DWG. B-202
208
35 P, 140 F
COARSE CHAR FROM T-201
DWG. B-202
35 P, 140 F
207
35 P
183 F
C-701
25 cu. ft.
60 P, 131 F
701
60 P, 131 F
700
35 P
140 F
C-703
25 cu. ft.
35 P
183 F
C-702
19 cu. ft.
WI
LC
D-702
3800 cu. ft.
15 P
131 F
LI
T-706
SC
SUPER-SACK
T-703
35 P
140 F
C-704
19 cu. ft.
WI
LC
T-703, T-706
ROTARY FEEDERS
T-704
CHAR PRODUCT BAGHOUSE
K-701
BAGHOUSE VENT FAN



NOTES

P = Pressure, psia

F = Temperature, °F

NO.	DATE	REVISIONS
C	5/25/95	TWO PREHEATERS. GAS PREHEAT 600F
B	1/30/95	CYCLONES DESIGN CHANGES
A	6/5/94	ISSUED FOR CONTRACT AWARD

SCALE NONE | DESIGNED | DRAWN | CHEF

BECHTEL SAN FRANCISCO

MILD GASIFICATION PDU

PROCESS FLOW DIAGRAM
CHAR STORAGE AND HANDLING

JOB NO.	DRAWING NO.	REV
21765	B-701 Sheet 1 of 2	C

Stream Number	700	701	702	703	60	207
Stream Description	Fluidized Coarse Char from C-704 to D-702	Fluidized Char Fines from C-702 to D-701	Vent Gas from T-704 to K-701	Vent Gas from K-701 to F-401	Nitrogen from C-061 to C-701,2,3,&4	Coarse Cl from T-2 to C-70
Nominal Operating Conditions						
Total Flowrate (Avg.)	1153 lb/hr	209 lb/hr	125 lb/hr	125 lb/hr	125 lb/hr	1040
Solids Flowrate (Avg.)	1040 lb/hr	206 lb/hr				1040
Gas Flowrate (Avg.)	26 SCFM	1 SCFM	28 SCFM	28 SCFM	28 SCFM	
Temperature	132 °F	139 °F	132 °F	131 °F	60 °F	140
Pressure	45 psig	45 psig	5 "H2O g	53 "H2O g	85 psig	20
Density , lb/cu. ft.	22.59 (1)	24.68 (1)	0.07		0.50	25
Maximum Operating Conditions						
Total Flowrate (Avg.)	1442 lb/hr	314 lb/hr	155 lb/hr	155 lb/hr	164 lb/hr	1300
Solids Flowrate (Avg.)	1300 lb/hr	310 lb/hr				1300
Gas Flowrate (Avg.)	32 SCFM	1 SCFM	35 SCFM	35 SCFM	37 SCFM	
Temperature	132 °F	139 °F	131 °F	131 °F	60 °F	140
Pressure	85 psig	85 psig	6 "H2O g	53 "H2O g	85 psig	40
Minimum Operating Conditions						
Total Flowrate (Avg.)	481 lb/hr	105 lb/hr	1 lb/hr	1 lb/hr	55 lb/hr	433
Solids Flowrate (Avg.)	433 lb/hr	103 lb/hr				433
Gas Flowrate (Avg.)	11 SCFM	0.3 SCFM	0.3 SCFM	0.3 SCFM	12 SCFM	
Temperature					20 °F	100
Pressure	6 "H2O g	6 "H2O g	0 "H2O g	0 "H2O g	85 psig	10

Notes:

(1) Mix Mean Density
(2) Coarse coal and coal fines combined limit
(3) Sporadic rate averaging 15 min/hr.

CHAR STORAGE
B-70
Rev. C: Tw
Recycle Gas

	208
ar 01 3	Char Fines from T-203 to C-701
/hr	206 lb/hr
/hr	206 lb/hr
°F	140 °F
sig	20 psig
00	25.00
/hr	310 lb/hr
/hr	310 lb/hr
°F	140 °F
sig	40 psig
/hr	103 lb/hr
/hr	103 lb/hr
°F	100 °F
sig	10 psig

AND HANDLING

Sheet 2 of 2

Preheaters and

reheated to 600°F

Dated 5/25/95

24-TPD PDU DETAILED DESCRIPTION

The following sections present the detailed PDU system design in terms of the Piping & Instrumentation Diagrams (P&ID), Figure 18 to Figure 28. The P&ID's were developed in the system design stage which included and PDU process hazards and operability review. The HazOp review is included in Appendix A. The changes suggested by the HazOp review were being incorporated into the master system P&ID's. The vendor P&ID's for the thermal oxidizer and scrubber sections of the PDU system are incomplete and are not included in the master list because of the termination of the program.

The P&ID's are presented in the following Figure 18 to Figure 28.

TYPICAL LETTER COMBINATIONS

FIRST LETTERS	INITIATING OR MEASURED VARIABLE	CONTROLLERS RECORD	CONTROLLERS INDICATE	CONTROLLERS BLIND	SELF-ATUATED CONTROL VALVES	READOUT DEVICES RECORDING	READOUT DEVICES INDICATING			SWITCHES/ALARM DEVICES HI	SWITCHES/ALARM DEVICES LOW	SWITCHES/ALARM DEVICES COMB		TRANSMITTERS RECORDING	TRANSMITTERS INDICATING	TRANSMITTERS BLIND		SOLENOIDS RELAYS, COMPUTING DEVICE	PRIMARY ELEMENT		TE PC
A	ANALYSIS	ARC	AIC	AC		AR	AI			ASH	ASL	ASHL		ART	AIT	AT		AY	AE		AP
B	BURNER/COMBUST.	BRC	BIC	BC		BR	BI			BSH	BSL	BSHL		BRT	BIT	BT		BY	BE		
C	USER'S CHOICE																				
D	USER'S CHOICE																				
E	VOLTAGE	ERC	EIC	EC		ER	EI			ESH	ESL	ESHL		ERT	EIT	ET		EY	EE		
F	FLOW RATE	FRC	FIC	FC	FCV, FICV	FR	FI			FSH	FSL	FSHL		FRT	FIT	FT		FY	FE		FP
FQ	FLOW QUANTITY	FQRC	FQIC			FQR	FQI			FQSH	FQSL				FQIT	FQT		FQY	FQE		
FF	FLOW RATIO	FFRC	FFIC	FFC		FFR	FFI			FFSH	FFSL								FE		
G	USER'S CHOICE																				
H	HAND		HIC	HC								HS									
I	CURRENT	IRC	IIC			IR	II			ISH	ISL	ISHL		IRT	IIT	IT		IY	IE		
J	POWER	JRC	JIC			JR	JI			JSH	JSL	JSHL		JRT	JIT	JT		JY	JE		
K	TIME	KRC	KIC	KC	KCV	KR	KI			KSH	KSL	KSHL		KRT	KIT	KT		KY	KE		
L	LEVEL	LRC	LIC	LC	LCV	LR	LI			LSH	LSL	LSHL		LRT	LIT	LT		LY	LE		
M	STARTER/CONTACTOR			MC														MY			
N	USER'S CHOICE																				
O	USER'S CHOICE																				
P	PRESSURE/VAC.	PRC	PIC	PC	PCV	PR	PI			PSH	PSL	PSHL		PRT	PIT	PT		PY	PE		PP
PD	PRESSURE DIFFER.	PDRC	PDIC	PDC	PDCV	PDR	PDI			PDSH	PDSL			PDRT	PDIT	PDT		PDY	PE		PP
Q	QUANTITY	QRC	QIC			QR	QI			QSH	QSL	QSHL		QRT	QIT	QT		QY	QE		
R	RADIATION	RRC	RIC	RC		RR	RI			RSH	RSL	RSHL		RRT	RIT	RT		RY	RE		
S	SPEED/FREQ.	SRC	SIC	SC	SCV	SR	SI			SSH	SSL	SSHL		SRT	SIT	ST		SY	SE		
T	TEMPERATURE	TRC	TIC	TC	TCV	TR	TI			TSH	TSL	TSHL		TRT	TIT	TT		TY	TE		TP
TD	TEMP. DIFFER.	TDRC	TDIC	TDC	TDCV	TDR	TDI			TDSH	TDSL			TDRT	TDIT	TDT		TDY	TE		TP
U	MULTIVARIABLE					UR	UI											UY			
V	VIBRA/MACHINERY					VR	VI			VSH	VSL	VSHL		VRT	VIT	VT		VY	VE		
W	WEIGHT/FORCE	WRC	WIC	WC	WCV	WR	WI			WSH	WSL	WSHL		WRT	WIT	WT		WY	WE		
WD	WT./FORCE DIFF.	WDRC	WDIC	WDC	WDCV	WDR	WDI			WDSH	WDSL			WDRT	WDIT	WDT		WDY	WE		
X	UNCLASSIFIED																				
Y	EVENT/STATE		YIC	YC		YR	YI			YSH	YSL					YT		YY	YE		
Z	POSITION/DIM.	ZRC	ZIC	ZC	ZCV	ZR	ZI			ZSH	ZSL	ZSHL		ZRT	ZIT	ZT		ZY	ZE		
ZD	GAUGING/DEVIAT.	ZDRC	ZDIC	ZDC	ZDCV	ZDR	ZDI			ZDSH	ZDSL			ZDRT	ZDIT	ZDT		ZDY	ZDE		

FUNCTION DESIGNATIONS FOR RELAYS

SYMBOL	FUNCTION
1. 1-0 OR ON-OFF	AUTOMATICALLY CONNECT, DISCONNECT OR TRANSFER ONE OR MORE CIRCUITS PROVIDED THAT THIS IS NOT THE FIRST SUCH DEVICE IN A LOOP
2. Σ OR ADD	ADD OR TOTALIZE (ADD AND SUBTRACT)
3. ? OR DIFF	SUBTRACT OR DIFFERENTIAL
4. ? / + / ⊟	BIAS
5. AVG	AVERAGE
6. % OR 1:3 OR 1:2 (TYP)	GAIN OR ATTENUATE (INPUT:OUTPUT)
7. ⊠	MULTIPLY
8. ÷	DIVIDE
9. ☑	EXTRACT SQUARE ROOT
10. X^n OR $^1\!/\!X^n$	RAISE TO POWER
11. f(x)	CHARACTERIZE
12. 1:1	BOOST
13. ⊳	HIGH SELECT. SELECT HIGHEST MEASURED VARIABLE
14. ⊲	LOW SELECT. SELECT LOWEST MEASURED VARIABLE
15. REV	REVERSE
16. A. E/P OR P/I (TYP)	CONVERT FOR INPUT/OUTPUT SEQ OF THE FOLLOWING DESIGNATION — SIGNAL E — VOLTAGE H — HYDRAULIC I — CURRENT O — ELECTRO-MAGNETIC OR SONIC P — PNEUMATIC R — RESISTANCE
B. A/D OR D/A	FOR INPUT/OUTPUT SEQ OF THE FOLLOWING A — ANALOG D — DIGITAL
17. ∫	INTEGRATE (TIME INTEGRAL)
18. D OR d/dt	DERIVATIVE OR RATE
19. 1/D	INVERSE DERIVATIVE

SUMMARY OF SPECIAL ABBR

ABBREVIATION	MEANING
A	ANALOG SIGNAL
ADAPT	ADAPTIVE CONTROL MODE
AS	AIR SUPPLY
AVG	AVERAGE
C	PATCHBOARD OR MATRIX BOARD CONN
D	DERIVATIVE CONTROL MODE DIGITAL SIGNAL
DIFF	SUBTRACT
DIR	DIRECT ACTING
E	VOLTAGE SIGNAL
ES	ELECTRIC SUPPLY
(F)	FURNISHED
FC	FAIL CLOSED
FI	FAIL INDETERMINATE
FL	FAIL LOCKED
FO	FAIL OPEN
GS	GAS SUPPLY
H	HYDRAULIC SIGNAL
HS	HYDRAULIC SUPPLY
I	CURRENT (ELECTRICAL) SIGNAL INTERLOCK
M	MOTOR ACTUATOR

ABBREVIATIO
MAX
MIN
NS
O
OPT
P
R
REV
RTD
S
SP
SQ RT
SS
T
WS
X

REFERENCE DRAWING	REFERENCE DRAWING	REFERENCE DRAWING	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION	REV	DATE	BY	CHECK	DESCRIPTION OF REV

T	WELL OR PROBE	VIEWING DEVICE, GLASS	SAFETY DEVICE	FINAL ELEMENT
	AW			AV
	BW	BG		BZ
				EZ
		FG		FV
				FOV
				FFV
			HSS	HV
				IZ
				JV
				KV
	LW	LG		LV
			PSV, PSE	PV
				PDV
				QZ
	RW			RZ
				SV
	TW		TSE	TV
	TW			TDV
				UV
				VZ
				WZ
				WDZ
				YZ
			ZSS	ZV
				ZDV

VIATIONS

[illegible]	MEANING
	MAXIMIZING CONTROL MODE
	MINIMIZING CONTROL MODE
	NITROGEN SUPPLY
	ELECTROMAGNETIC OR SONIC SIGNAL
	OPTIMIZING CONTROL MODE
	PNEUMATIC SIGNAL / PROPORTIONAL CONTROL MODE / PURGE OR FLUSHING SERVICE
	AUTOMATIC RESET CONTROL MODE / RESET OF FAIL LOCKED DEVICE / RESISTANCE (SIGNAL)
	REVERSE ACTING
	RESISTANCE (TYPE) TEMP DETECTOR
	SOLENOID ACTUATOR
	SET-POINT
	SQUARE ROOT
	STEAM SUPPLY
	TRAP
	WATER SUPPLY
	MULTIPLY / UNCLASSIFIED ACTUATOR

INSTRUMENT SYMBOLS

- CHEMICAL SEAL
- RUPTURE DISC
- ORIFICE
- SIGHT GLASS
- FLOW NOZZLE
- VORTEX SENSOR
- POSITIVE DISPLACEMENT METER
- MAG (FE) — MAGNETIC FLOW ELEMENT
- MASS (FE) — MASS FLOW ELEMENT
- TURBINE FLOW ELEMENT
- ANNUBAR FLOW ELEMENT
- IN-LINE STATIC MIXER

PIPING SYMBOLS

- GATE VALVE
- GLOBE VALVE
- BALL VALVE
- CHECK VALVE
- BUTTERFLY VALVE
- NEEDLE VALVE
- DIAPHRAGM VALVE
- PLUG VALVE
- HAND CONTROLLED GATE VALVE
- EDUCTOR
- KNIFE GATE VALVE
- CUTTER SAMPLER
- PINCH VALVE
- LINE REDUCER
- BLIND FLANGE
- END CAP
- HOSE
- FLEXIBLE CONNECTOR
- HOSE CONNECTION
- IN-LINE SAMPLER
- FLOOR DRAIN
- STEAM OR LIQUID TRAP
- STRAINER "Y" TYPE
- DUAL BASKET STRAINER
- SPEC BREAK
- VENT
- HOODED VENT OR AIR INTAKE
- SPRAY NOZZLE
- SPRAY PIPE OR SPARGER
- INSULATED PIPE
- ELECTRICALLY TRACED LINE
- INSULATED EQUIPMENT
- LAUNDER (BY MECHANICAL)
- PROCESS OR UTILITY LINE
- FUTURE OR NEW LINE

4"PA-0245-SI-?-ET

- LINE SIZE
- PIPE SPEC
- SEQUENTIAL LINE NUMBER
- FLUID SYMBOL
- TRACING: ET = ELECTRIC
- INSULATION

CONTROL VALVE ACTUATORS

- AIR OPERATED CONTROL VALVE
- SINGLE-ACTING CYLINDER VALVE
- DOUBLE-ACTING CYLINDER VALVE
- MANUALLY OPERATED FOUR WAY VALVE
- TWO WAY SOLENOID VALVE
- MOTOR OPERATED CONTROL VALVE
- FOUR WAY SOLENOID VALVE
- THREE WAY SOLENOID VALVE
- | - VENT
- DE - INDICATES DE-ENERGIZED FLOW

PRESSURE SAFETY VALVES

- PRESSURE RELIEF OR SAFETY VALVE ANGLE PATTERN
- PRESSURE RELIEF OR SAFETY VALVE STRAIGHT-THROUGH PATTERN
- PRESSURE & VACUUM RELIEF MANHOLE COVER
- RUPTURE DISC OR SAFETY HEAD FOR PRESSURE RELIEF
- VACUUM RELIEF VALVE ANGLE PATTERN
- PRESSURE & VACUUM RELIEF VALVE
- RUPTURE DISC OR SAFETY HEAD FOR VACUUM RELIEF
- PRESSURE RELIEF OR SAFETY VALVE ANGLE PATTERN TRIPPED BY INTEGRAL SOLENOID

SYMBOLS FOR SELF-ACTUATED REGULATORS

- LCV — LEVEL REGULATOR WITH MECHANICAL LINKAGE
- TVC — TEMPERATURE REGULATOR FILLED SYSTEM TYPE
- PCV — SELF-CONTAINED PRESSURE REGULATOR
- FCV — AUTOMATIC FLOW REGULATOR

NOTES:

1. THE FOLLOWING ABBREVIATIONS SHALL DENOTE THE TYPE OF SUPPLY. THESE DESIGNATORS SHALL ALSO BE USED FOR PURGE FLUID SUPPLIES.
   - AS : AIR SUPPLY
   - ES : ELECTRIC SUPPLY
   - GS : GAS SUPPLY
   - HS : HYDRAULIC SUPPLY
   - NS : NITROGEN SUPPLY
   - SS : STEAM SUPPLY
   - WS : WATER SUPPLY
2. ALL LINES SHALL BE FINE IN RELATION TO PROCESS PIPING LINES.

ACADNOTE:

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CHICAGO – SALT LAKE CITY
9417

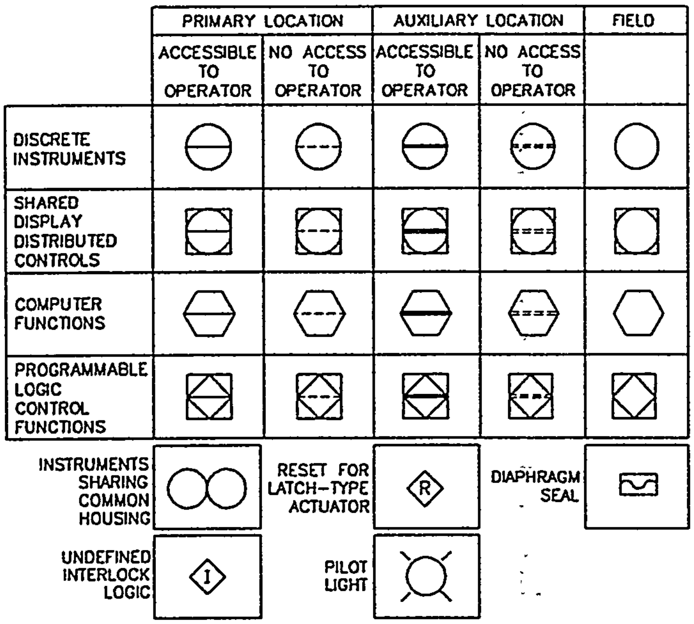
DRAWN BY J.R.HOYT

P&ID LEGEND
SHEET 1
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

SCALE NONE | DATE 01/10/95
DRAWING NO. 9417-I001 | REV. A

9417 K:\9417\RELEASED\9417I001 12/14/95 13:49 ALAND

INSTRUMENT FUNCTION SYMBOLS

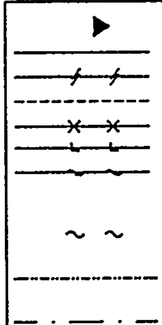


COMMONLY USED IDENTIFICATION LETTERS

ES - CONTROL POWER
HMS - MOMENTARY PUSHBUTTON OR SWITCH
HSS - EMERGENCY PULL CORD SWITCH
ISH - STARTER OVERLOAD CONTACT
MC - STARTER COIL & CONTACTOR COIL
MY - STARTER AUX. CONTACT
SSL - SPEED SWITCH LOW - ZERO SPEED
ZSS - BELT MISALIGNMENT

EQUIPMENT DESIGNATION EXAMPLE

INSTRUMENT LINE SYMBOLS



INSTRUMENT AIR CONNECTION
PROCESS CONNECTION
PNEUMATIC SIGNAL
ELECTRIC SIGNAL
CAPILLARY TUBING (FIELD SYSTEM)
HYDRAULIC SIGNAL
ELECTROMAGNETIC OR SONIC SIGNAL (HEAT, RADIO WAVES, NUCLEAR RADIATION AND LIGHT)
ELECTROMAGNETIC OR SONIC SIGNAL (NOT GUIDED)
INTERNAL SYSTEM LINK (SOFTWARE OR DATA LINK)
MECHANICAL LINK

REFERENCE DRAWING	REFERENCE DRAWING	REFERENCE DRAWING	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION	REV	DATE	BY	CHECK	DESCRIPTION OF REV

INSTRUMENTATION IDENTIFICATION LETTERS

	FIRST-LETTER (4)		SUCCEEDING-LETTERS (3)		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS(5,19)		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE(1)	USER'S CHOICE(1)	USER'S CHOICE(1)
C	USER'S CHOICE(1)	COMMAND		CONTROL(13)	
D	USER'S CHOICE(1)	DIFFERENTIAL(4)			
E	VOLTAGE		SENSOR (PRIMARY ELEMENT)		
F	FLOW RATE	RATIO (FRACTION)(4)			
G	USER'S CHOICE(1)		GLASS, VIEWING DEVICE(9)		
H	HAND				HIGH(7,15,16)
I	CURRENT (ELECTRICAL)		INDICATE(10)		
J	POWER	SCAN(7)			
K	TIME, TIME SCHEDULE	TIME RATE OF CHANGE(4,21)		CONTROL STATION(22)	
L	LEVEL		LIGHT(11)		LOW(7,15,16)
M	USER'S CHOICE(1) STARTER/CONTACTOR	MOMENTARY(4)			MIDDLE, INTERMEDIATE(7,15)
N	USER'S CHOICE(1)		USER'S CHOICE(1)	USER'S CHOICE(1)	USER'S CHOICE(1)
O	USER'S CHOICE(1)		ORIFICE, RESTRICTION		
P	PRESSURE, VACUUM		POINT (TEST) CONNECTION		
Q	QUANTITY	INTEGRATE/TOTALIZE(4)			
R	RADIATION		RECORD(17)		
S	SPEED, FREQUENCY	SAFETY(8)		SWITCH(13)	
T	TEMPERATURE			TRANSMIT(13)	
U	MULTIVARIABLE(6)		MULTIFUNCTION(12)	MULTIFUNCTION(12)	MULTIFUNCTION(12)
V	VIBRATION, MECHANICAL ANALYSIS(19)			VALVE, DAMPER, LOUVER(13)	
W	WEIGHT, FORCE		WELL		
X	UNCLASSIFIED(2)	X AXIS	UNCLASSIFIED(2)	UNCLASSIFIED(2)	UNCLASSIFIED(2)
Y	EVENT, STATE OR PRESENCE(20)	Y AXIS		RELAY, COMPUTE, CONVERT(13,14,18)	
Z	POSITION, DIMENSION	Z AXIS		DRIVER, ACTUATOR, UNCLASSIFIED FINAL CONTROL ELEMENT	

SEE ISA 5.1 FOR EXPLANATION OF NUMBERS IN PARENTHESIS

NOTE:

1. THE LETTER X IS USED TO COVER UNLISTED MEANINGS, EACH OF WHICH IS USED TO A LIMITED EXTENT. IF USED, EACH MEANING WILL BE DEFINED BY THE R&S INSTRUMENTATION AND CONTROL SYMBOLS TABLE.
2. THE TYPE OF ANALYSIS IN EACH INSTANCE WILL BE DEFINED.
3. FOR FURTHER CLARIFICATION OF INSTRUMENT NOMENCLATURE, REFER TO, INSTRUMENT SOCIETY OF AMERICA STANDARD, ANSI/ISA-S5.1-1984

ACADNOTE:

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9417

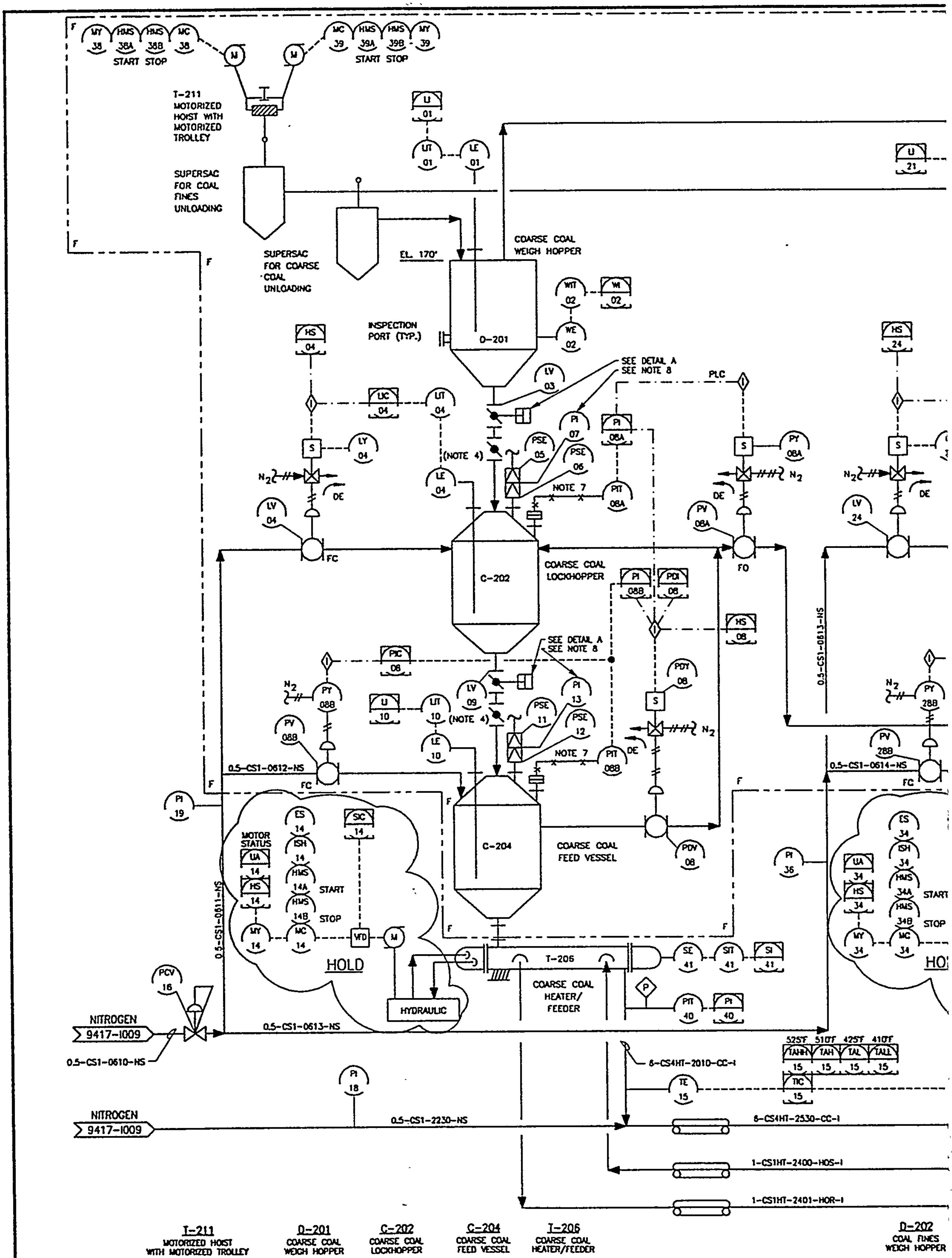
J.R.HOYT

P&ID LEGEND
SHEET 2
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

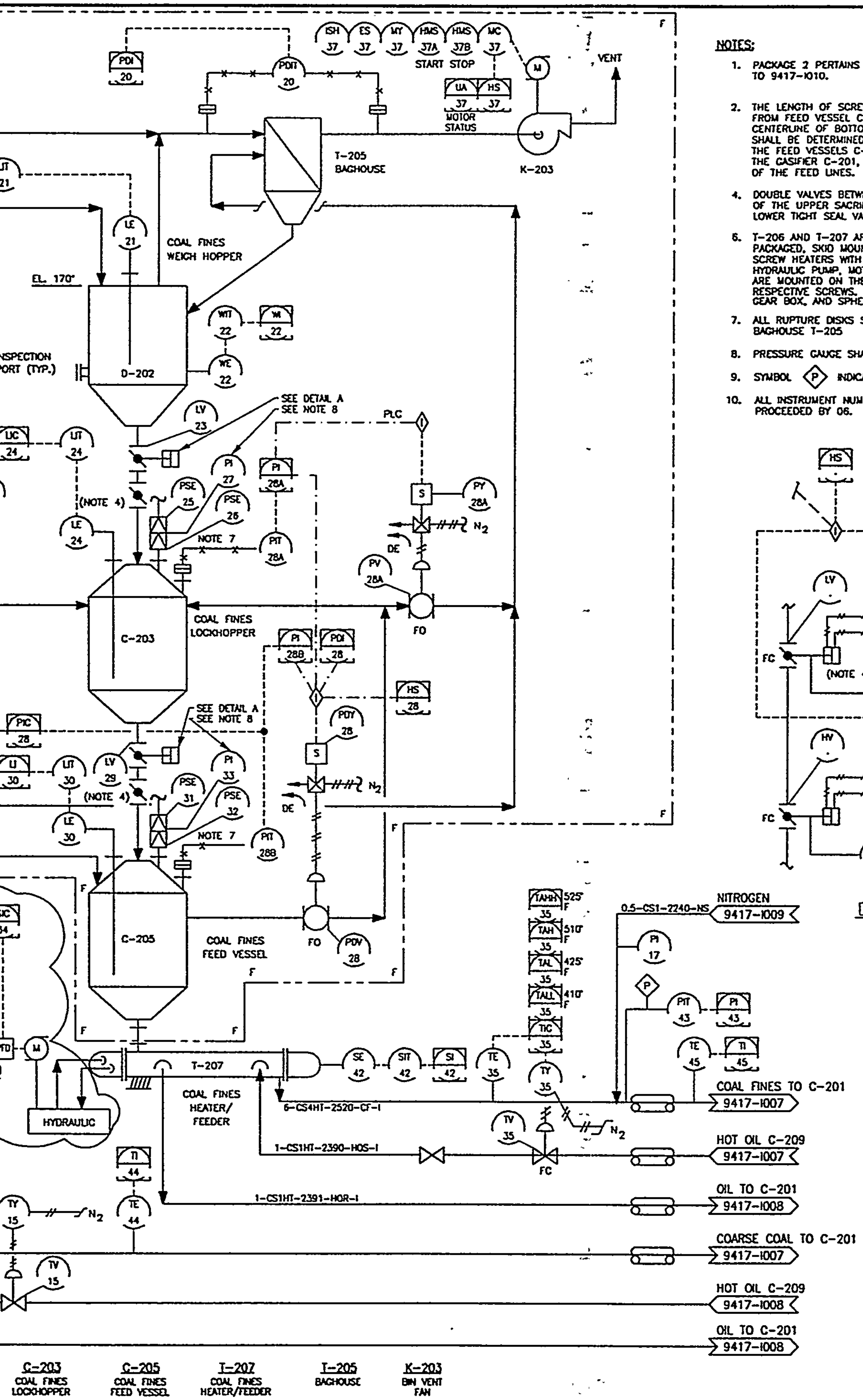
NONE | 01/10/95

9417-I002

9417 K:\9417\RELEASED\9417I002 12/14/95 13:50 ALAND

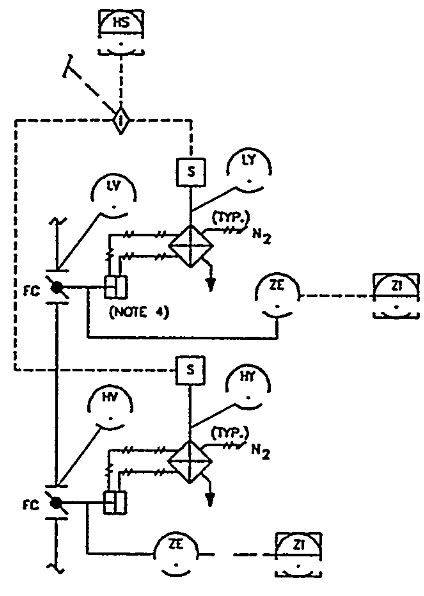


REFERENCE DRAWING	REFERENCE DRAWING	REFERENCE DRAWING	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION
BECHTEL, A-202								C	02/09/95	DAF		FOR REVIEW
								B	01/18/95	JRH	LAP	CUSTOMER COMMENT
								A	11/22/94	DAF		PRELIMINARY FOR COMMENT



NOTES:

1. PACKAGE 2 PERTAINS TO DRAWINGS 9417-1006 TO 9417-1010.
2. THE LENGTH OF SCREWS T-206 & T-207 FROM FEED VESSEL CENTERLINE TO CENTERLINE OF BOTTOM DISCHARGE NOZZLE SHALL BE DETERMINED BY THE LOCATION OF THE FEED VESSELS C-204 & C-205 AND THE GASIFIER C-201, & THE REQUIRED SLOPE OF THE FEED LINES.
4. DOUBLE VALVES BETWEEN VESSELS CONSIST OF THE UPPER SACRIFICIAL VALVE AND THE LOWER TIGHT SEAL VALVE. REFER TO DET. A
6. T-206 AND T-207 ARE INDIVIDUALLY PACKAGED, SKID MOUNTED PRESSURIZED SCREW HEATERS WITH HYDRAULIC DRIVE HYDRAULIC PUMP, MOTOR AND RESERVOIR ARE MOUNTED ON THE SAME SKID AS THEIR RESPECTIVE SCREWS. GEAR BOX, AND SPHERICAL BEARINGS.
7. ALL RUPTURE DISKS SHALL VENT TO BAGHOUSE T-205
8. PRESSURE GAUGE SHALL BE PEAK PICKING TYPE
9. SYMBOL ⟨P⟩ INDICATES NITROGEN PURGE.
10. ALL INSTRUMENT NUMBERS ON THIS DRAWING PROCEEDED BY 06.



DETAIL "A"

INSTRUMENT NUMBERS USED 01-45
INSTRUMENT NUMBERS NOT USED 0

C-203	C-205	T-207	T-205	K-203
COAL FINES LOCKHOPPER	COAL FINES FEED VESSEL	COAL FINES HEATER/FEEDER	BAGHOUSE	BIN VENT FAN

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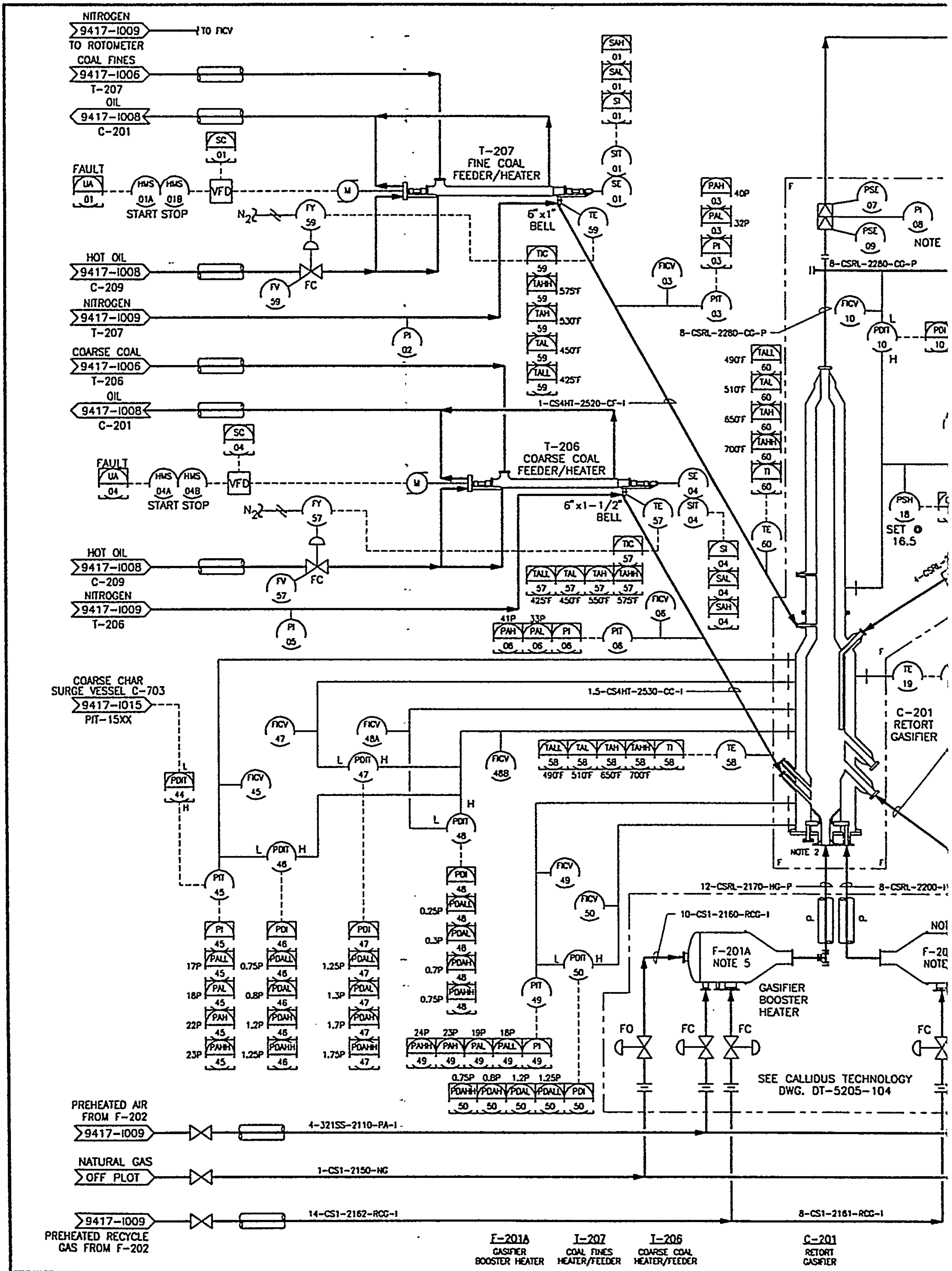
DAF — LAP

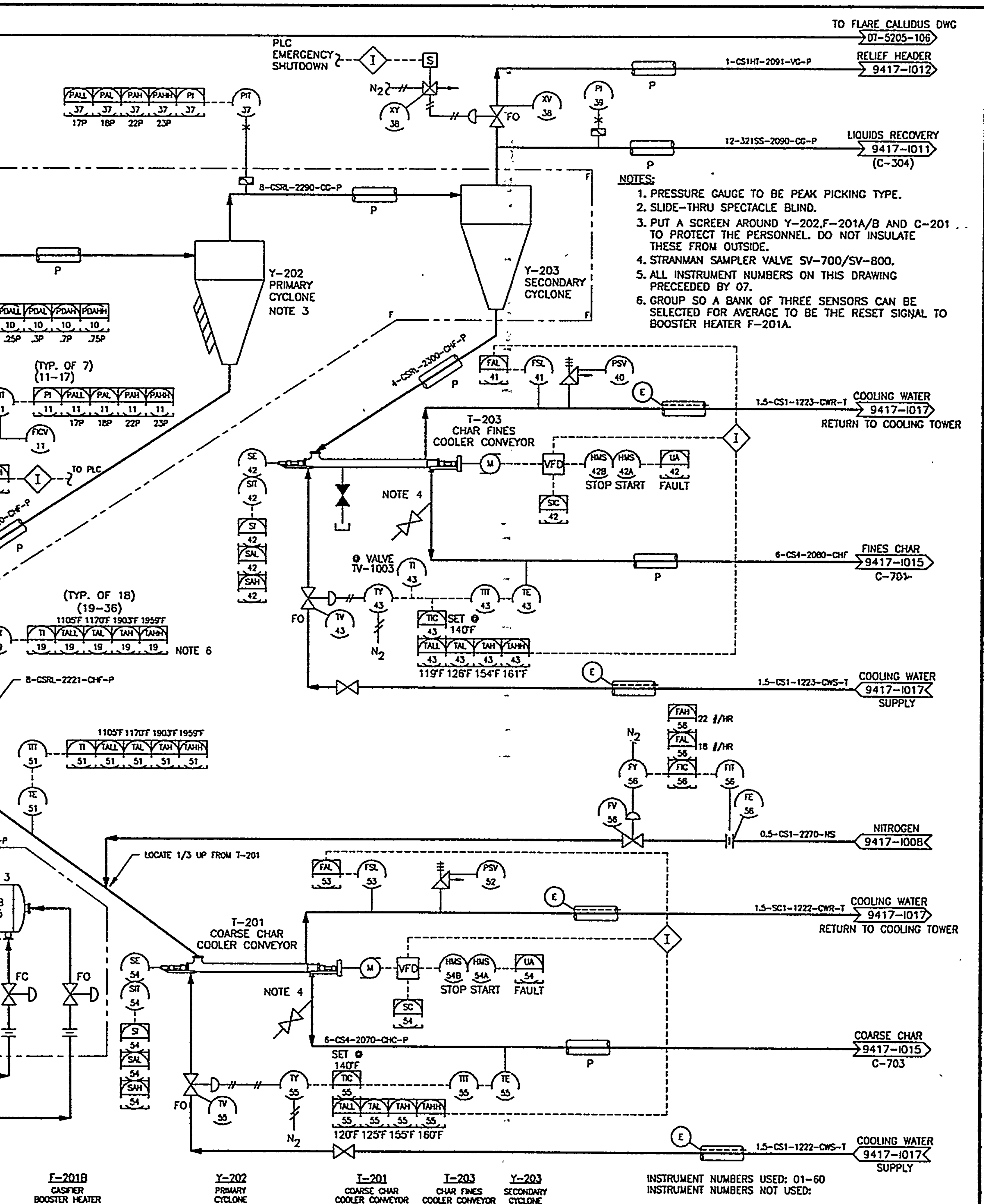
PIPING AND INSTRUMENT DIAGRAM
GASIFIER FEED PRESSURIZATION
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

SCALE: NONE
DATE: 11/22/94
9417-1006
REV. C

9417 K:\9417\RELEASED\9417I006 01/04/95 11:46 ALAND



REFERENCE DRAWING	REFERENCE DRAWING	REFERENCE DRAWING	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION	REV	DATE	BY	CHECK	DESCRIPTION OF REVISION
BECHTEL A-203								D	12/14/95	DAF	LAP	FOR CUSTOMER COMMENT
								C	02/10/95	DAF	GEO	FOR REVIEW
								B	01/18/95	JRH	LAP	CUSTOMER COMMENT
								A	11/22/94	DAF		PRELIMINARY FOR COMMENT



NOTES:

1. PRESSURE GAUGE TO BE PEAK PICKING TYPE.
2. SLIDE-THRU SPECTACLE BLIND.
3. PUT A SCREEN AROUND Y-202, F-201A/B AND C-201 TO PROTECT THE PERSONNEL. DO NOT INSULATE THESE FROM OUTSIDE.
4. STRANMAN SAMPLER VALVE SV-700/SV-800.
5. ALL INSTRUMENT NUMBERS ON THIS DRAWING PRECEEDED BY 07.
6. GROUP SO A BANK OF THREE SENSORS CAN BE SELECTED FOR AVERAGE TO BE THE RESET SIGNAL TO BOOSTER HEATER F-201A.

INSTRUMENT NUMBERS USED: 01-60
INSTRUMENT NUMBERS NOT USED:

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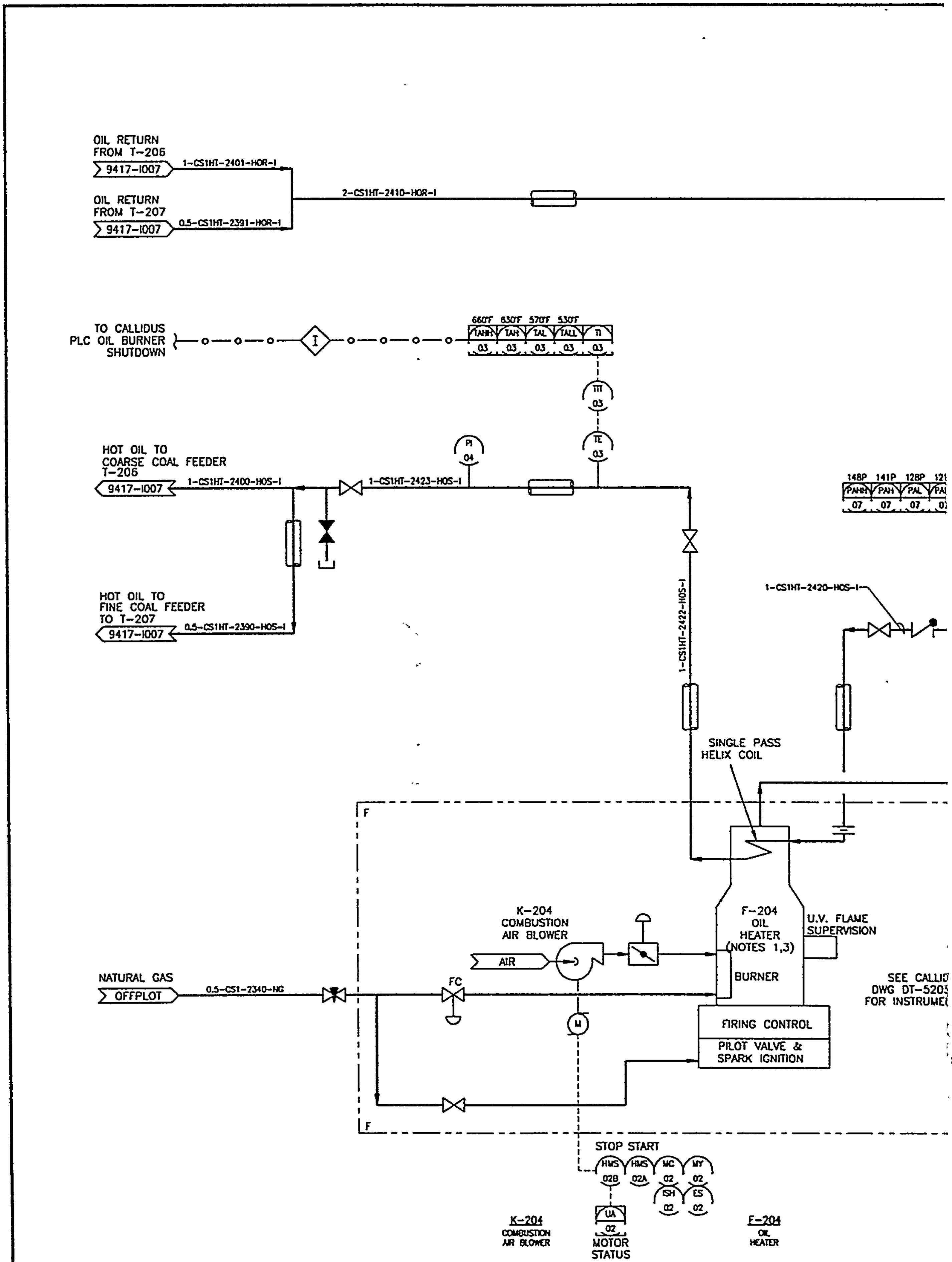
DAF | LAP

PIPING AND INSTRUMENT DIAGRAM
MILD GASIFIER & COARSE CHAR RECOVERY
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

NONE | 11/22/94
9417-1007 | D

9417 K:\9417\RELEASED\94171007 12/14/95 13:51 ALAND



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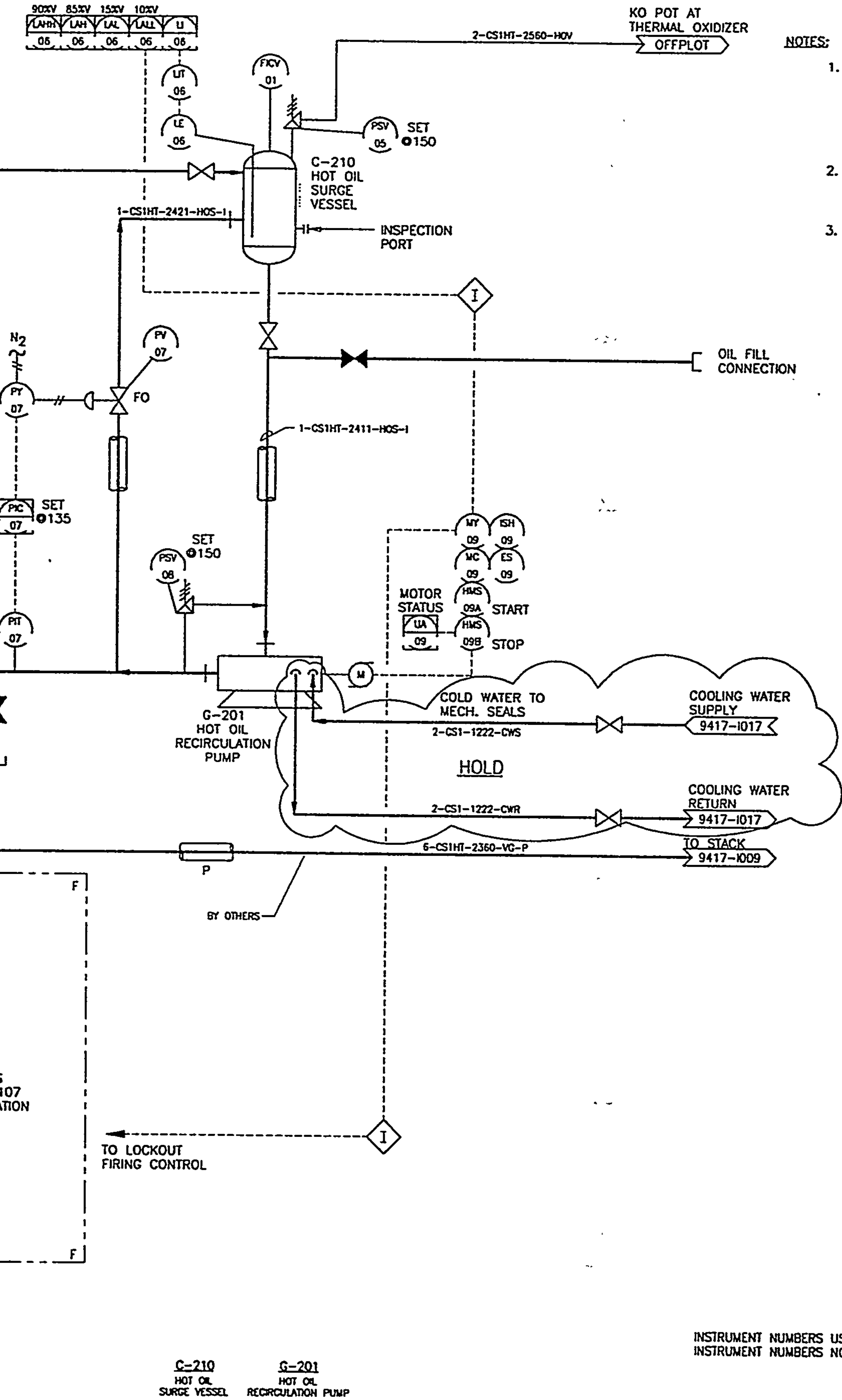
BECHTEL, A-204								D	12/14/95	DAF	LAP	FOR CUSTOMER COMMENT
								C	02/10/95	DAF	GEO	FOR REVIEW
								B	01/18/95	JRH	LAP	CUSTOMER COMMENT
								A	11/22/94	DAF		PRELIMINARY FOR COMMENT



NOTES:

1. F-204 SHALL BE FURNISHED COMPLETE WITH ALL FIRING CONTROL ACCESSORIES REQUIRED FOR UNATTENDED CYCLIC OPERATION. SOFTWALL INSULATION IS ACCEPTABLE IN LIEU OF CASTABLE REFRACTORY.

2. G-201 SHALL BE FURNISHED WITH BLOCK VALVES AND EXPANSION JOINTS ON THE SUCTION AND DISCHARGE.

3. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 08.

INSTRUMENT NUMBERS USED: 01-09
INSTRUMENT NUMBERS NOT USED: 0

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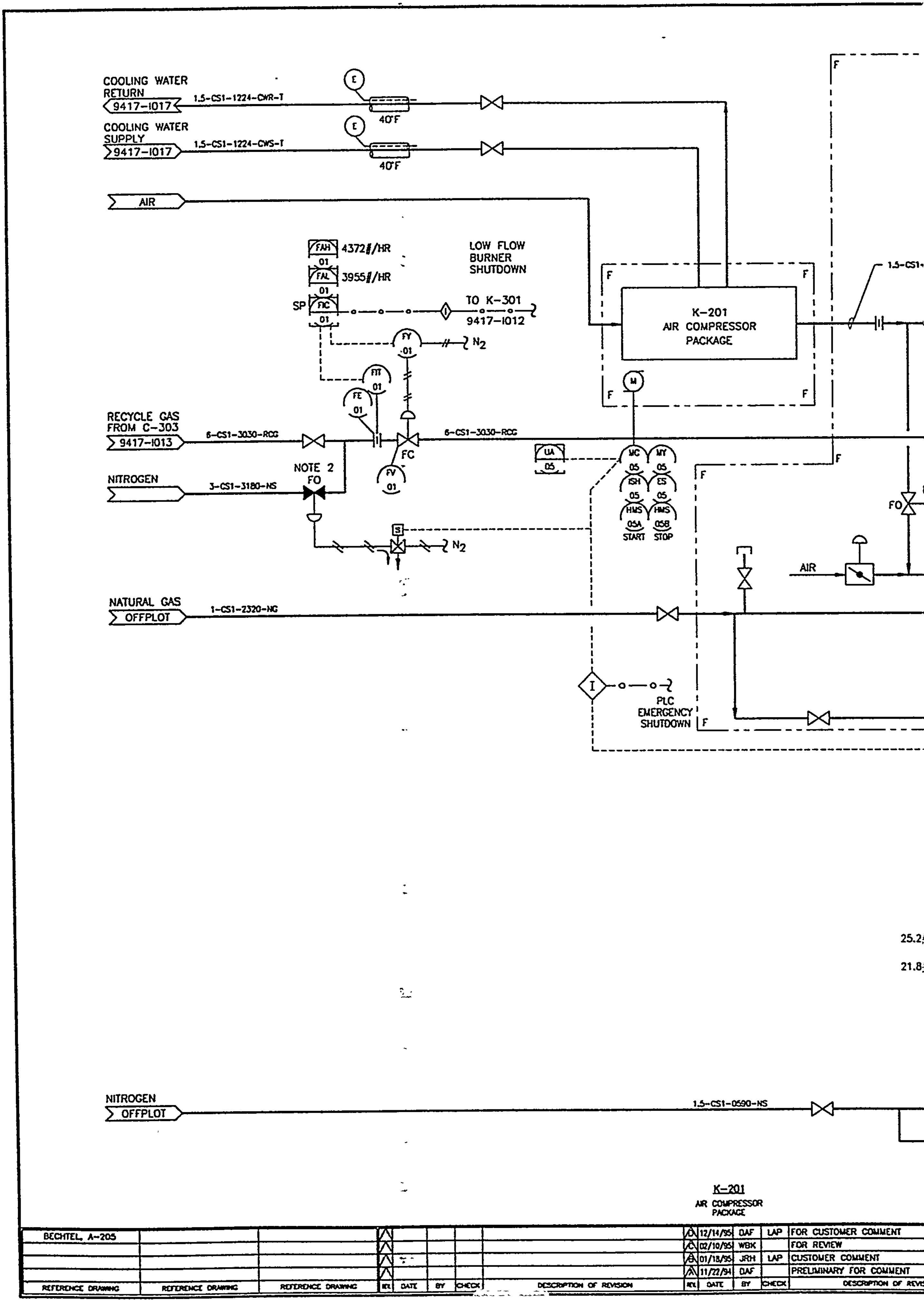
DAF | LAP

PIPING AND INSTRUMENT DIAGRAM
GASIFIER AUX HOT OIL SYSTEM SKID
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

NONE | 11/22/94

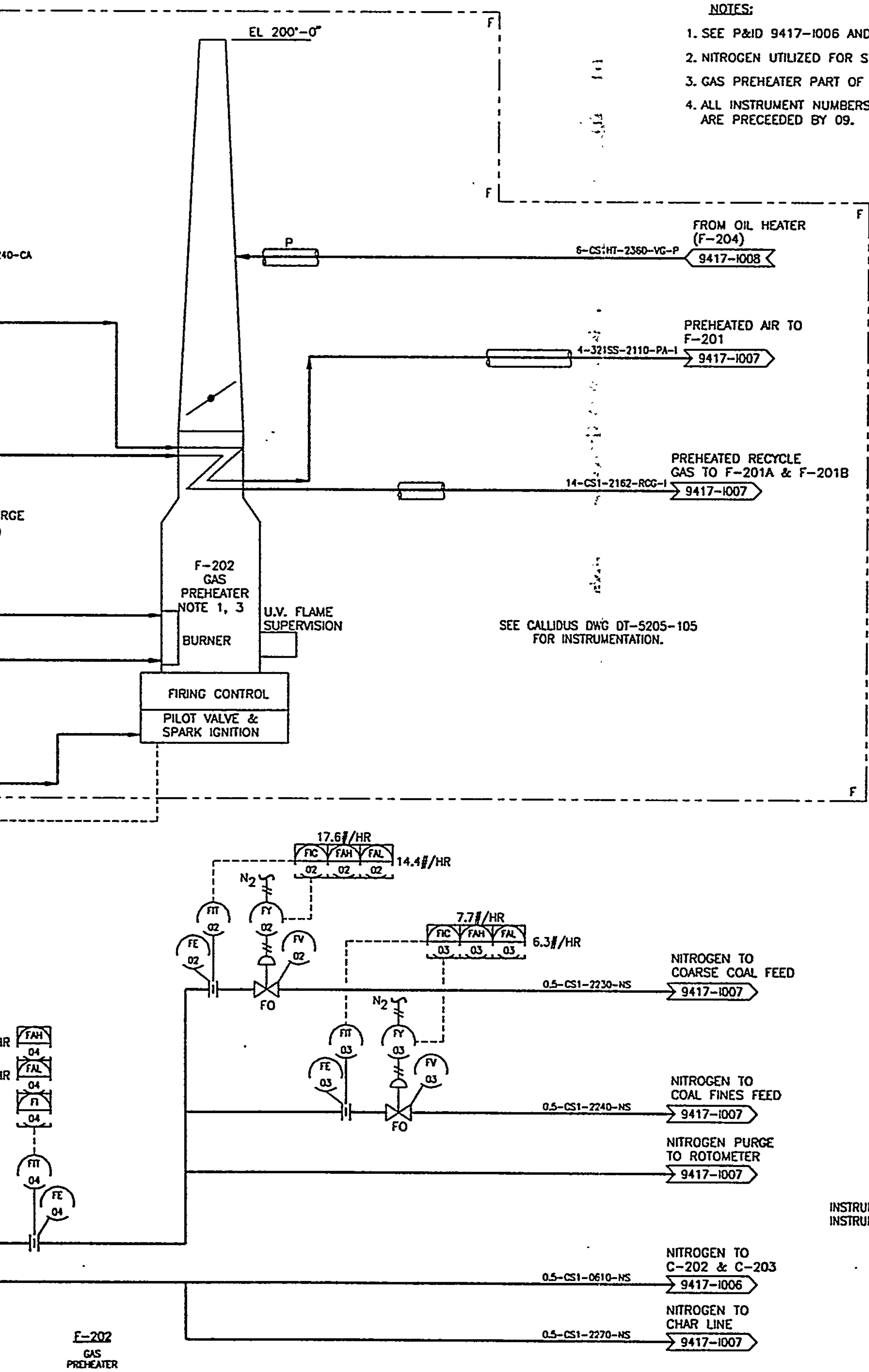
9417-I008 | D

9417 K:\9417\RELEASED\9417I008 12/14/95 13:52 ALAND


COOLING WATER RETURN
9417-1017
1.5-CS1-1224-CWR-T
40°F
COOLING WATER SUPPLY
9417-1017
1.5-CS1-1224-CWS-T
40°F
AIR
FAH 01 4372#/HR
FAL 01 3955#/HR
SP FIC 01
LOW FLOW BURNER SHUTDOWN
TO K-301
9417-1012
FY 01
N2
FIT 01
FE 01
RECYCLE GAS FROM C-303
9417-1013
6-CS1-3030-RCG
FC
FV 01
6-CS1-3030-RCG
NOTE 2
FO
NITROGEN
3-CS1-3180-NS
N2
K-201
AIR COMPRESSOR PACKAGE
M
UA 05
MC 05
MY 05
ISH 05
ES 05
HMS 05A START
HMS 05B STOP
1.5-CS1-
FO
AIR
NATURAL GAS
OFFPLOT
1-CS1-2320-NG
PLC EMERGENCY SHUTDOWN
25.2
21.8
NITROGEN
OFFPLOT
1.5-CS1-0590-NS
K-201
AIR COMPRESSOR PACKAGE
BECHTEL, A-205
REFERENCE DRAWING
REFERENCE DRAWING
REFERENCE DRAWING
REV DATE BY CHECK DESCRIPTION OF REVISION
12/14/95 DAF LAP FOR CUSTOMER COMMENT
02/10/95 WBK FOR REVIEW
01/18/95 JRH LAP CUSTOMER COMMENT
11/22/94 DAF PRELIMINARY FOR COMMENT
REV DATE BY CHECK DESCRIPTION OF REVISION

NOTES:

1. SEE P&ID 9417-I006 AND 9417-I008 FOR APPLICABLE NOTES.
2. NITROGEN UTILIZED FOR STARTUP
3. GAS PREHEATER PART OF PACKAGE 4
4. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 09.



INSTRUMENT NUMBERS USED: 01-05
INSTRUMENT NUMBERS NOT USED: 0

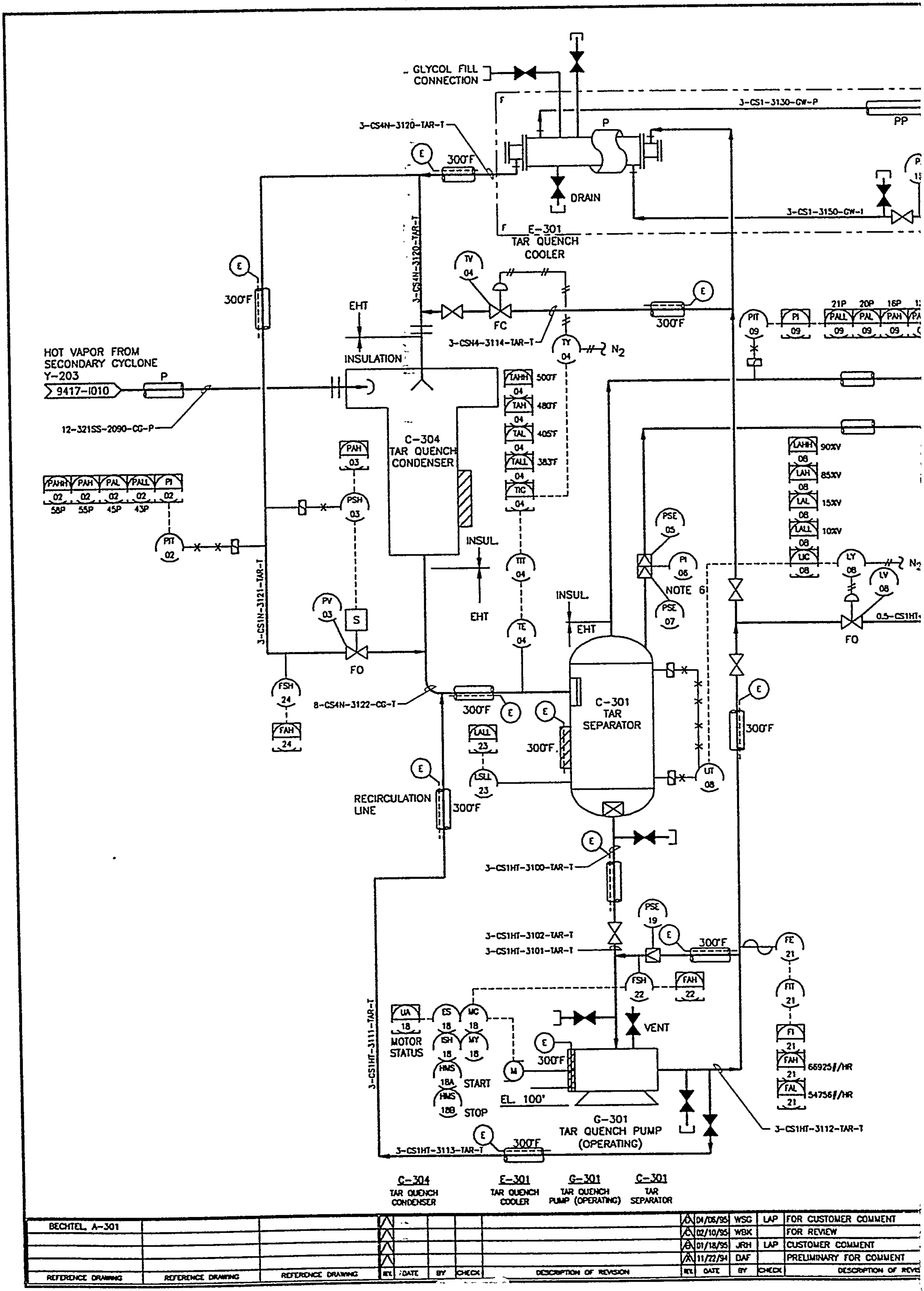
ROBERTS & SCHAEFER Company
ENGINEERS AND CONTRACTORS
CHICAGO - SALT LAKE CITY
9417

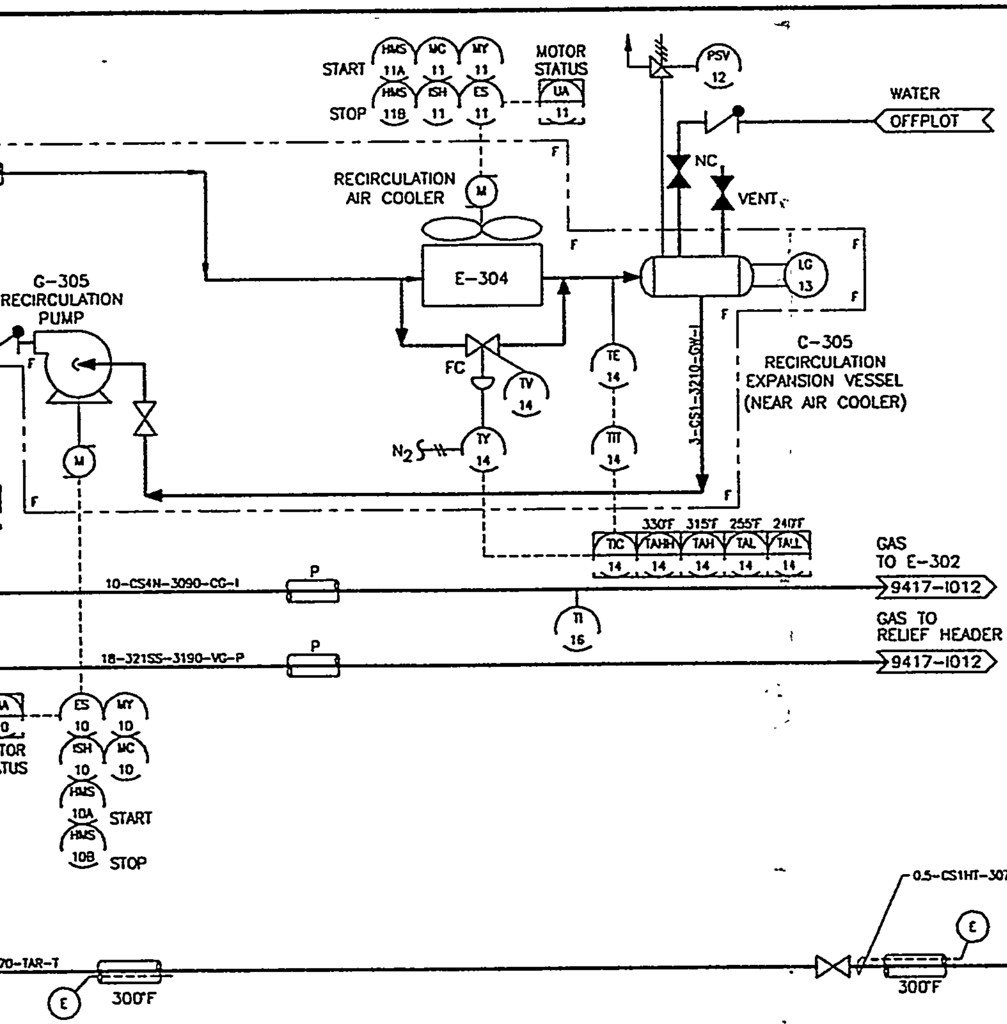
DRAWN BY DAF | DESIGNED BY LAP

PIPING AND INSTRUMENT DIAGRAM
GASIFIER AUXILIARIES
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

SCALE NONE | DATE 11/22/94
DRAWING NO. 9417-I009 | REV. D

9417 K:\9417\RELEASED\9417I009 12/14/95 13:53 ALAND


GLYCOL FILL CONNECTION
3-CS1-3130-GW-P
PP
3-CS4N-3120-TAR-T
P
300°F
DRAIN
3-CS1-3150-GW-I
E-301
TAR QUENCH COOLER
3-CS4N-3120-TAR-T
TV 04
FC
EHT
INSULATION
3-CS4-3114-TAR-T
TY 04
N2
300°F
PIT 09
PI 09
21P 20P 16P
PALL PAL PAH
09 09 09
HOT VAPOR FROM SECONDARY CYCLONE Y-203
9417-1010
12-321SS-2090-CG-P
C-304
TAR QUENCH CONDENSER
TAHH 04 500°F
TAH 04 480°F
TAL 04 405°F
TALL 04 383°F
TIC 04
LAHH 08 90%V
LAH 08 85%V
LAL 08 15%V
LALL 08 10%V
LIC 08
PAH 03
PAHH PAH PAL PALL PI
02 02 02 02 02
58P 55P 45P 43P
PSH 03
PIT 02
3-CS1N-3121-TAR-T
INSUL.
TIT 04
PSE 05
PI 06
NOTE 6
PSE 07
LY 08
LV 08
N2
0.5-CS1HT-
FO
PV 03
S
FO
EHT
INSUL.
EHT
TE 04
FSH 24
FAH 24
8-CS4N-3122-CG-T
300°F
C-301
TAR SEPARATOR
LALL 23
LSLL 23
300°F
LIT 08
300°F
RECIRCULATION LINE
300°F
3-CS1HT-3100-TAR-T
PSE 19
3-CS1HT-3102-TAR-T
3-CS1HT-3101-TAR-T
300°F
FE 21
FIT 21
FSH 22
FAH 22
3-CS1HT-3111-TAR-T
UA 18
MOTOR STATUS
ES 18
MC 18
ISH 18
MY 18
HMS 18A START
HMS 18B STOP
VENT
M
300°F
EL. 100'
FI 21
FAH 21 66925#/HR
FAL 21 54756#/HR
G-301
TAR QUENCH PUMP (OPERATING)
3-CS1HT-3112-TAR-T
3-CS1HT-3113-TAR-T
300°F
C-304 TAR QUENCH CONDENSER
E-301 TAR QUENCH COOLER
G-301 TAR QUENCH PUMP (OPERATING)
C-301 TAR SEPARATOR
BECHTEL A-301
REFERENCE DRAWING
REFERENCE DRAWING
REFERENCE DRAWING
REV. DATE BY CHECK DESCRIPTION OF REVISION
D 04/06/95 WSG LAP FOR CUSTOMER COMMENT
C 02/10/95 WBK FOR REVIEW
B 01/18/95 JRH LAP CUSTOMER COMMENT
A 11/22/94 DAF PRELIMINARY FOR COMMENT
REV. DATE BY CHECK DESCRIPTION OF REVISION



NOTES:

1. LOW POINTS, DEAD LEGS AND/OR POCKETS ARE TO BE AVOIDED IN RELIEF LINES AND ALL TRACED LINES.
2. REFER TO THE PROJECT INSULATION SPECIFICATION FOR DESIGN REQUIREMENTS. MAJOR EQUIPMENT INSULATION IS SHOWN ON THIS DRAWING.
3. SELLER SHALL FURNISH ALL HIGH POINT VENTS AND LOW POINT DRAINS, SOME OF WHICH ARE SHOWN IN THIS DRAWING.
4. PRESSURE GAUGE SHALL BE PEAK PICKING TYPE.
5. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 11.

INSTRUMENT NUMBERS USED: 1-24
INSTRUMENT NUMBERS NOT USED: 0,01,17,20

G-305 RECIRCULATION PUMP

E-304 RECIRCULATION AIR COOLER

C-305 RECIRCULATION EXPANSION VESSEL

ROBERTS & SCHAEFER Company
ENGINEERS AND CONTRACTORS
CHICAGO - SALT LAKE CITY
9417

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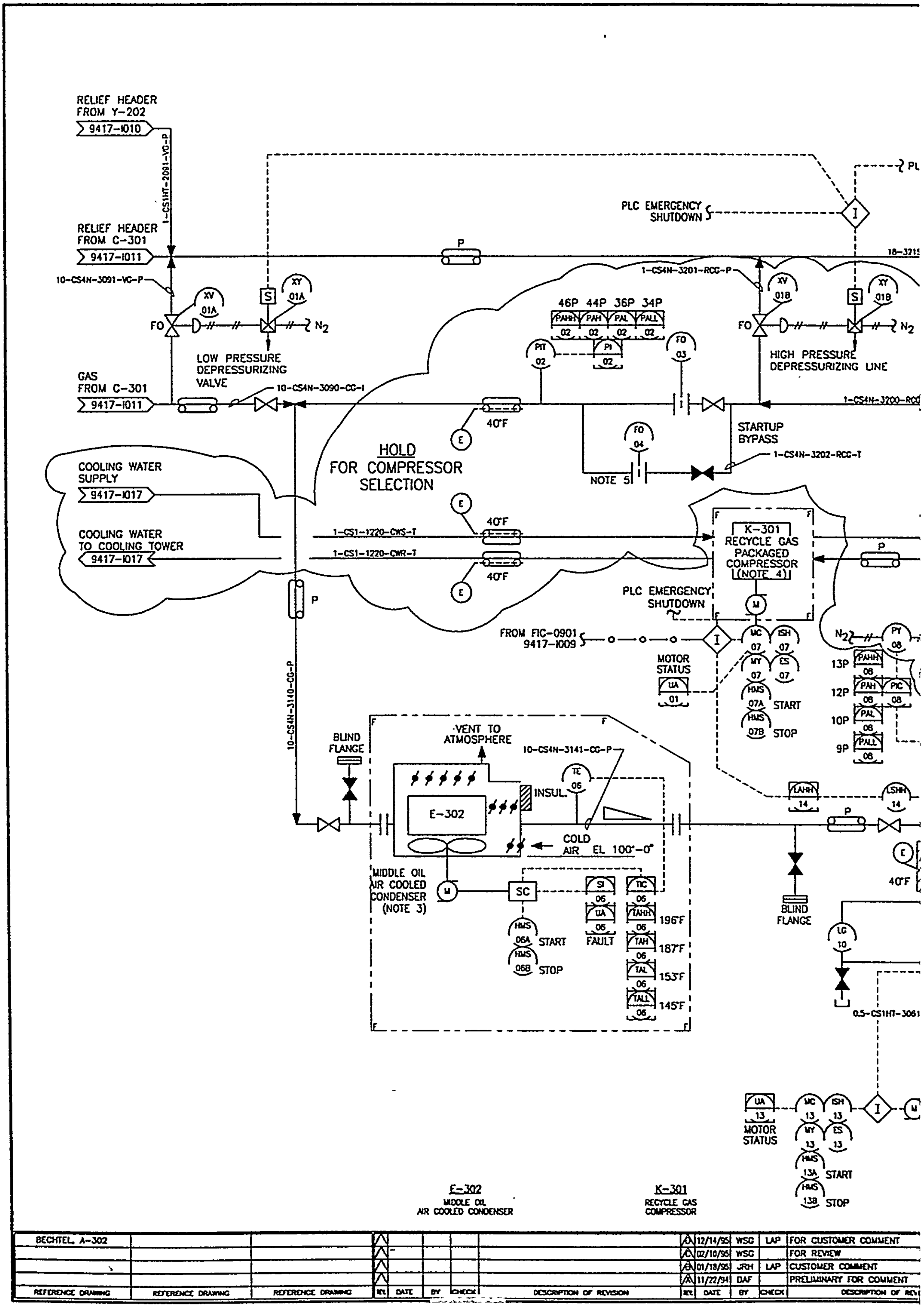
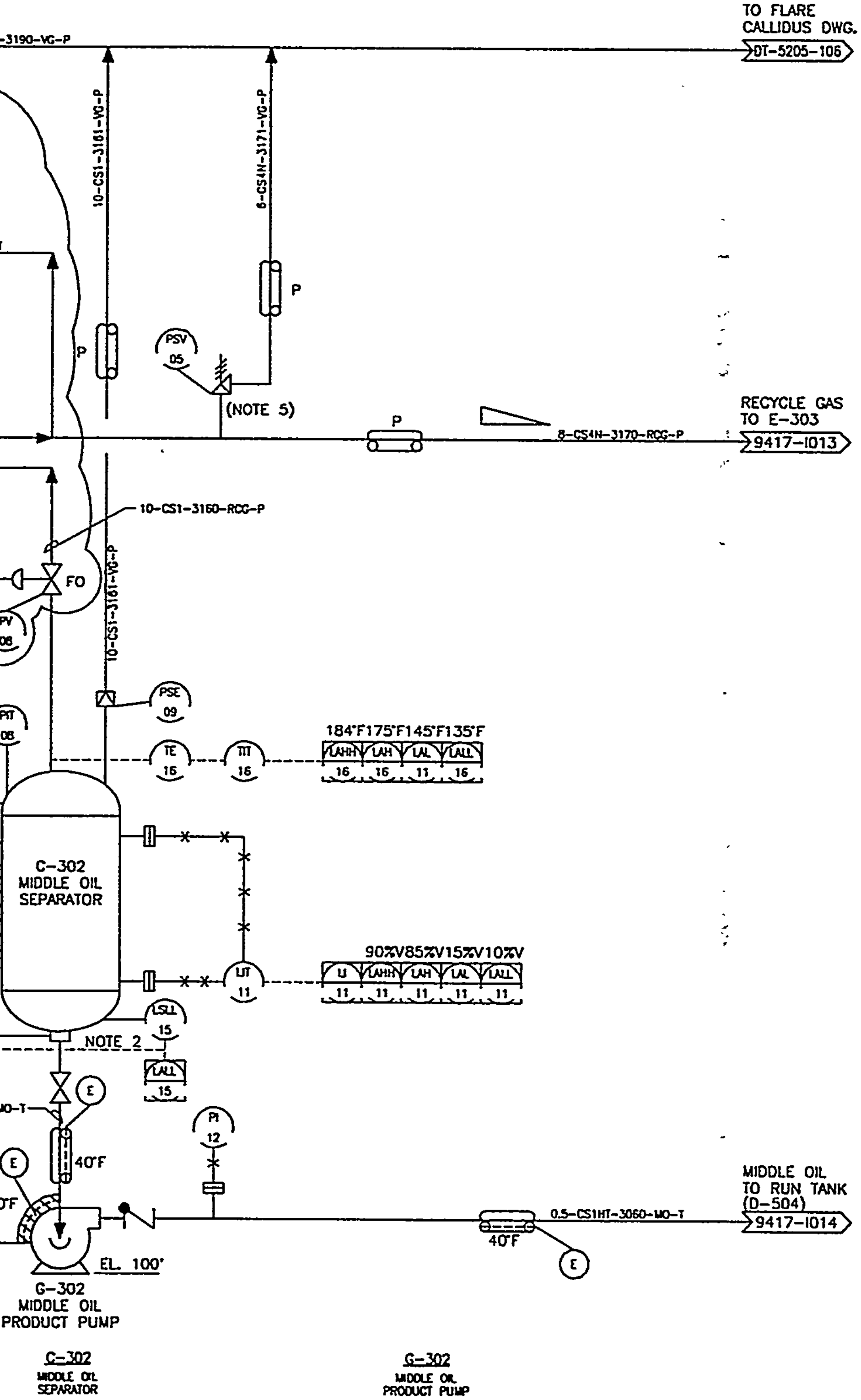
PIPING AND INSTRUMENT DIAGRAMS
LIQUIDS RECOVERY
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

SCALE NONE | DATE 11/22/94
DRAWING NO. 9417-I011 | REV. D

9417 K:\9417\RELEASED\9417I011 12/14/95 13:54 ALAND


RELIEF HEADER
FROM Y-202
9417-I010
1-CS1HT-2091-VG-P
RELIEF HEADER
FROM C-301
9417-I011
10-CS4N-3091-VG-P
PLC EMERGENCY
SHUTDOWN
18-321
1-CS4N-3201-RCG-P
XV
01A
XY
01A
S
FO
N2
LOW PRESSURE
DEPRESSURIZING
VALVE
46P 44P 36P 34P
PAHH PAH PAL PALL
02
PIT
02
PI
02
FO
03
XV
01B
XY
01B
HIGH PRESSURE
DEPRESSURIZING LINE
GAS
FROM C-301
9417-I011
10-CS4N-3090-CG-I
1-CS4N-3200-RCG
E
40°F
FO
04
STARTUP
BYPASS
1-CS4N-3202-RCG-T
NOTE 5
HOLD
FOR COMPRESSOR
SELECTION
COOLING WATER
SUPPLY
9417-I017
COOLING WATER
TO COOLING TOWER
9417-I017
1-CS1-1220-CWS-T
1-CS1-1220-CWR-T
P
K-301
RECYCLE GAS
PACKAGED
COMPRESSOR
(NOTE 4)
FROM FIC-0901
9417-I009
MOTOR
STATUS
UA
01
MC
07
ISH
07
MY
07
ES
07
HMS
07A
START
HMS
07B
STOP
PY
08
13P PAHH 08
12P PAH 08 PIC 08
10P PAL 08
9P PALL 08
10-CS4N-3140-CG-P
BLIND
FLANGE
VENT TO
ATMOSPHERE
10-CS4N-3141-CG-P
TE
06
INSUL.
E-302
COLD
AIR EL 100'-0"
MIDDLE OIL
AIR COOLED
CONDENSER
(NOTE 3)
M
SC
SI
06
TIC
06
UA
06
FAULT
TAHH
06
196°F
TAH
06
187°F
TAL
06
153°F
TALL
06
145°F
HMS
06A
START
HMS
06B
STOP
LAHH
14
LSHH
14
BLIND
FLANGE
LG
10
0.5-CS1HT-3061
UA
13
MOTOR
STATUS
MC
13
ISH
13
MY
13
ES
13
HMS
13A
START
HMS
13B
STOP
E-302
MIDDLE OIL
AIR COOLED CONDENSER
K-301
RECYCLE GAS
COMPRESSOR
BECHTEL A-302
REFERENCE DRAWING
REFERENCE DRAWING
REFERENCE DRAWING
NO. DATE BY CHECK DESCRIPTION OF REVISION
12/14/95 WSG LAP FOR CUSTOMER COMMENT
02/10/95 WSG FOR REVIEW
01/18/95 JRH LAP CUSTOMER COMMENT
11/22/94 DAF PRELIMINARY FOR COMMENT
NO. DATE BY CHECK DESCRIPTION OF REV



NOTE:

1. A STANDPIPE IS INCLUDED IN C-302 TO PROVIDE BOTTOM DRAW-OFF OF SOUR WATER DURING START-UP.
2. E-302 IS A FREEZE PROTECTED UNIT. HORIZONTAL SINGLE PASS TUBES ARE REQUIRED. FREEZE PROTECTION MAY BE BY AIR RECIRCULATION OR BY ELECTRIC SPACE HEATING TO EFFECT A CONSTANT AIR TEMPERATURE APPROACHING THE TUBE BUNDLES AT 140°F.
3. K-301 IS A SKID MOUNTED PACKAGED, SINGLE STAGE RECIPROCATING COMPRESSOR.
4. RELIEF VALVE & ORIFICE SHALL BE SIZED FOR 100% FLOW AT COMPRESSOR DISCHARGE.
5. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 12.

INSTRUMENT NUMBERS USED: 01-16
INSTRUMENT NUMBERS NOT USED: 0

ROBERTS & SCHAEFER Company
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CHICAGO - SALT LAKE CITY
9417

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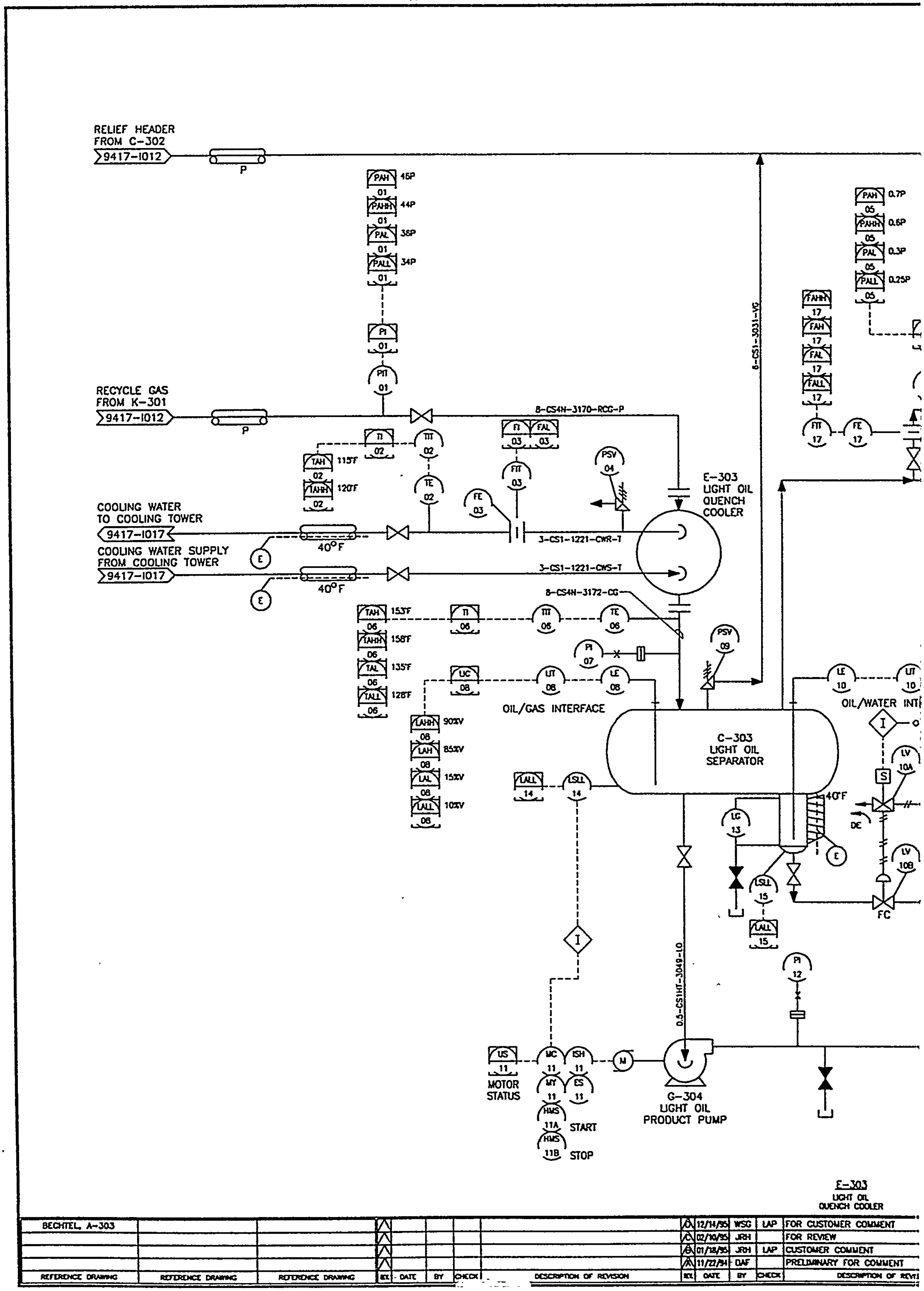
PIPING AND INSTRUMENT DIAGRAM
LIQUIDS RECOVERY
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

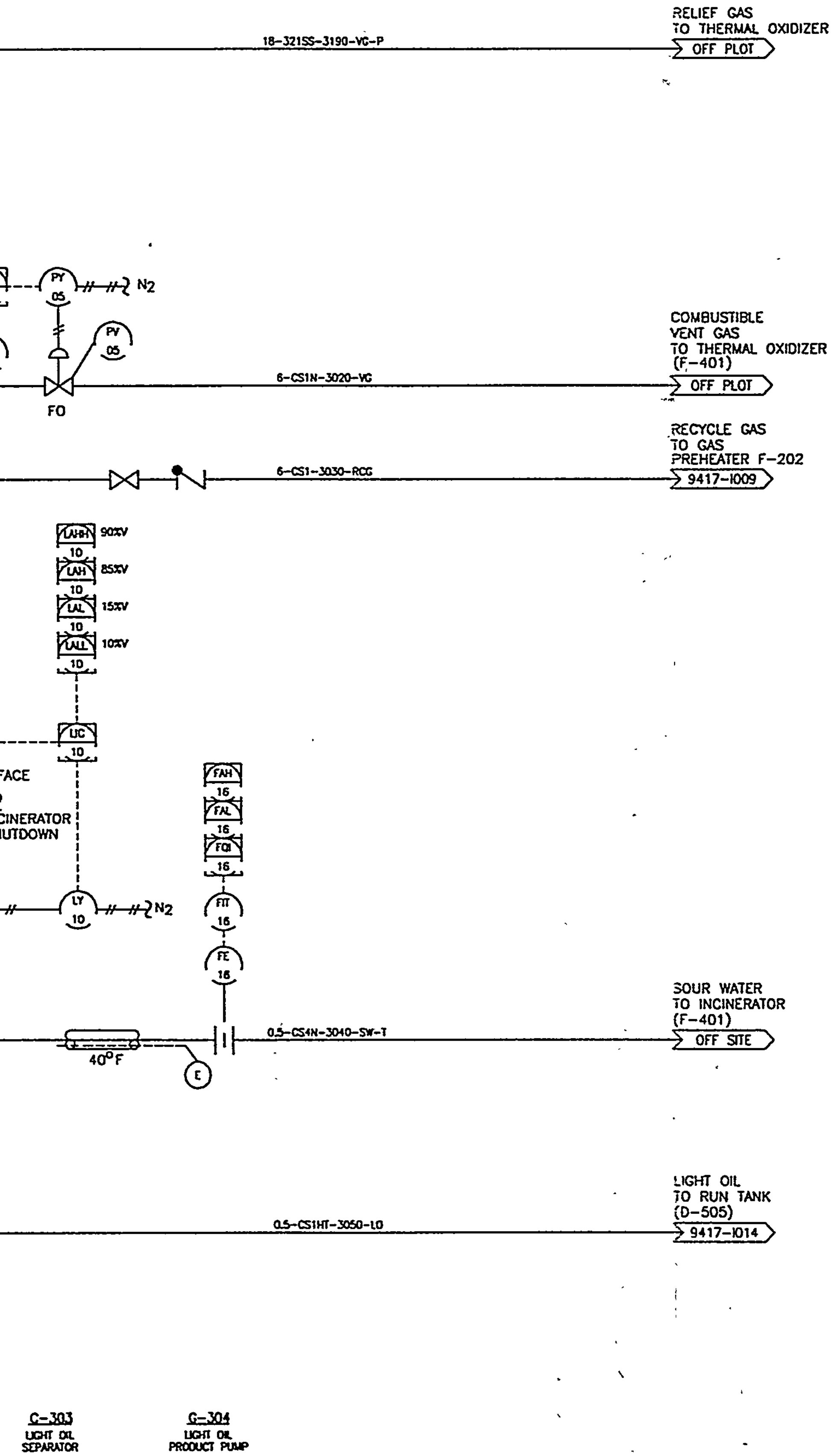
SCALE NONE | DATE 11/22/94
DRAWING NO. 9417-I012 | REV. D

9417 K:\9417\RELEASED\9417I012 12/14/95 13:55 ALAND


RELIEF HEADER
FROM C-302
9417-1012
RECYCLE GAS
FROM K-301
9417-1012
COOLING WATER
TO COOLING TOWER
9417-1017
COOLING WATER SUPPLY
FROM COOLING TOWER
9417-1017
40°F
8-CS4N-3170-RCG-P
3-CS1-1221-CWR-T
3-CS1-1221-CWS-T
8-CS4N-3172-CG
8-CS1-3031-VG
0.5-CS1HT-3049-LO
E-303
LIGHT OIL
QUENCH
COOLER
C-303
LIGHT OIL
SEPARATOR
OIL/GAS INTERFACE
OIL/WATER INT
G-304
LIGHT OIL
PRODUCT PUMP
MOTOR
STATUS
START
STOP
PAH 45P
PAHH 44P
PAL 36P
PALL 34P
TAH 115°F
TAHH 120°F
TAH 153°F
TAHH 158°F
TAL 135°F
TALL 128°F
LAHH 90%V
LAH 85%V
LAL 15%V
LALL 10%V
PAH 0.7P
PAHH 0.6P
PAL 0.3P
PALL 0.25P
FC
E-303
LIGHT OIL
QUENCH COOLER
BECHTEL, A-303
12/14/95 WSG LAP FOR CUSTOMER COMMENT
02/10/95 JRH FOR REVIEW
01/18/95 JRH LAP CUSTOMER COMMENT
11/22/94 DAF PRELIMINARY FOR COMMENT
REFERENCE DRAWING
REFERENCE DRAWING
REFERENCE DRAWING
REV. DATE BY CHECK DESCRIPTION OF REVISION

NOTES:

1. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 13.



INSTRUMENT NUMBERS USED: 01-17
INSTRUMENT NUMBERS NOR USED: 0

ROBERTS & SCHAEFER Company
ENGINEERS AND CONTRACTORS
CHICAGO - SALT LAKE CITY
9417

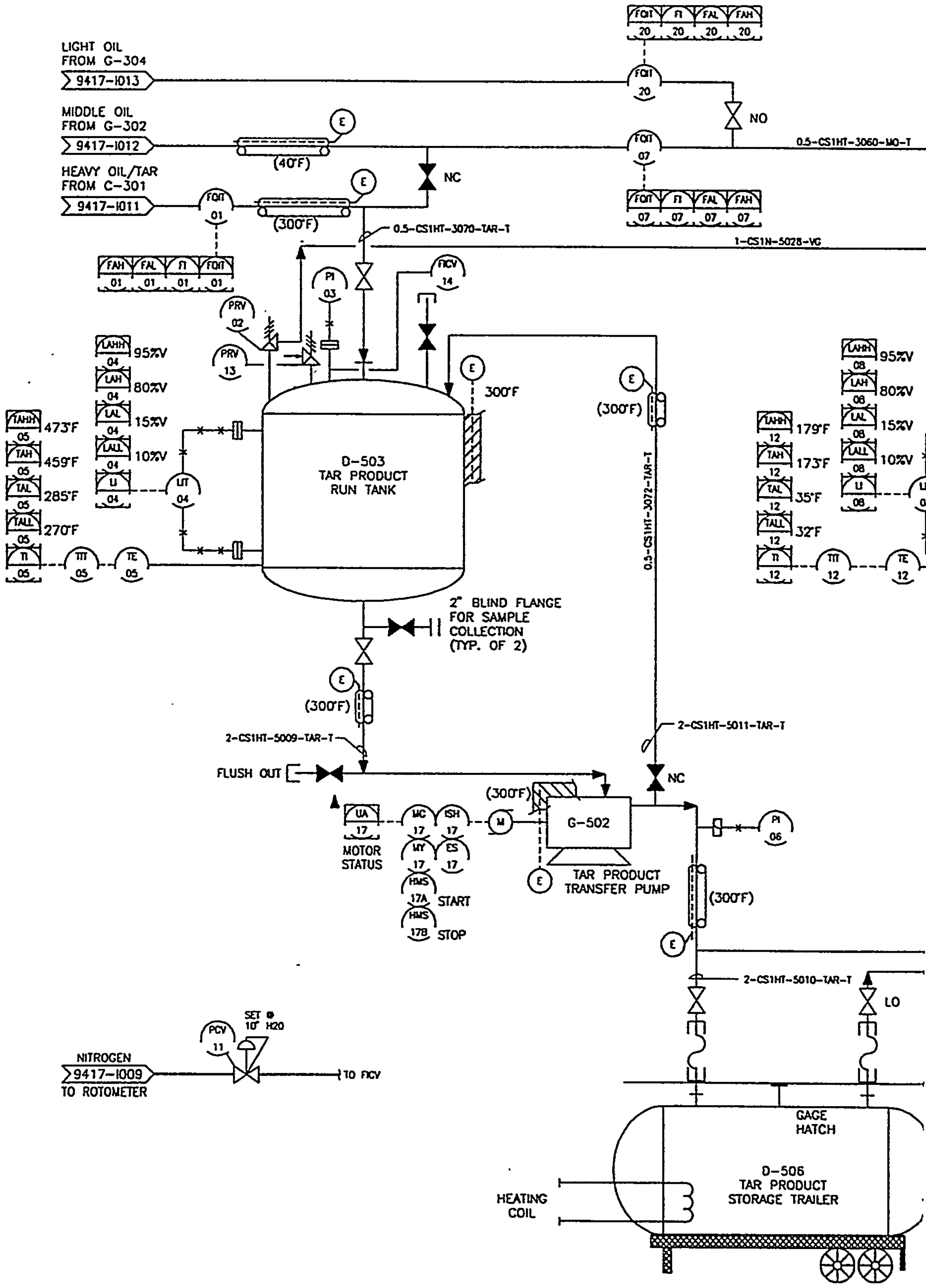
DAF | LAP

PIPING AND INSTRUMENT DIAGRAM
LIQUIDS RECOVERY
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

NONE | 11/22/94

9417-I013 | D

9417 K:\9417\RELEASE\9417I013 12/14/95 13:55 ALAND



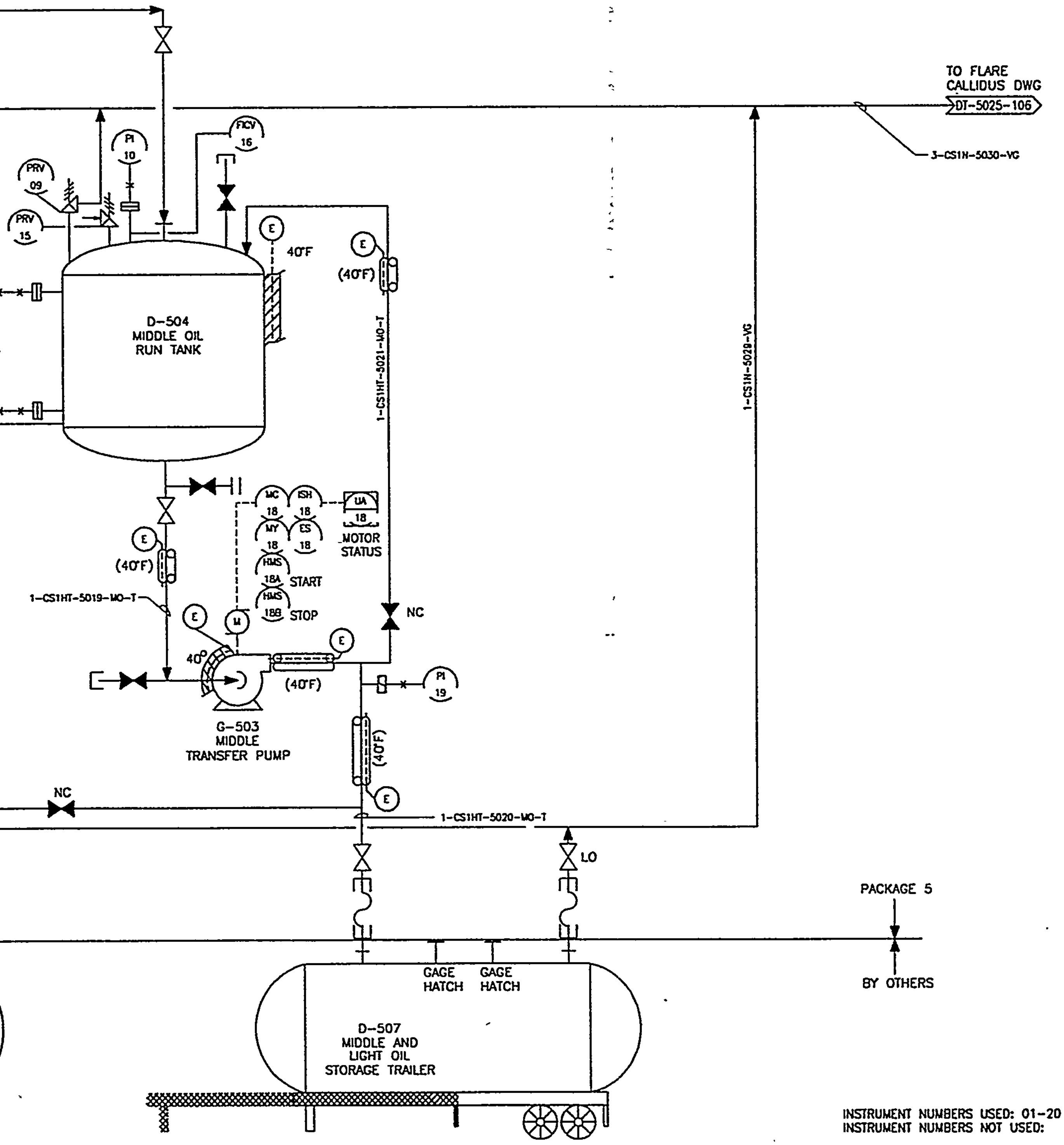
D-503
TAR PRODUCT
RUN TANK

G-502
TAR PRODUCT
TRANSFER PUMP

D-506
TAR PRODUCT
STORAGE TRAILER

BECHTEL, A-501								12/14/95	DAF	LAP	FOR CUSTOMER COMMENT
CALLIDUS, DT-5025-106								02/10/95	WSG		FOR REVIEW
								01/18/95	JRH	LAP	CUSTOMER COMMENT
								11/22/94	DAF		PRELIMINARY FOR COMMENT
REFERENCE DRAWING	REFERENCE DRAWING	REFERENCE DRAWING	REV.	DATE	BY	DESCRIPTION OF REVISION	REV.	DATE	BY	CHECK	DESCRIPTION OF REV

NOTE:
1. ALL INSTRUMENT NUMBERS ON THIS DRAWING ARE PRECEEDED BY 14.



INSTRUMENT NUMBERS USED: 01-20
INSTRUMENT NUMBERS NOT USED:

D-504 MIDDLE OIL RUN TANK | G-503 MIDDLE TRANSFER PUMP | D-507 MIDDLE & LIGHT OIL STORAGE TRAILER

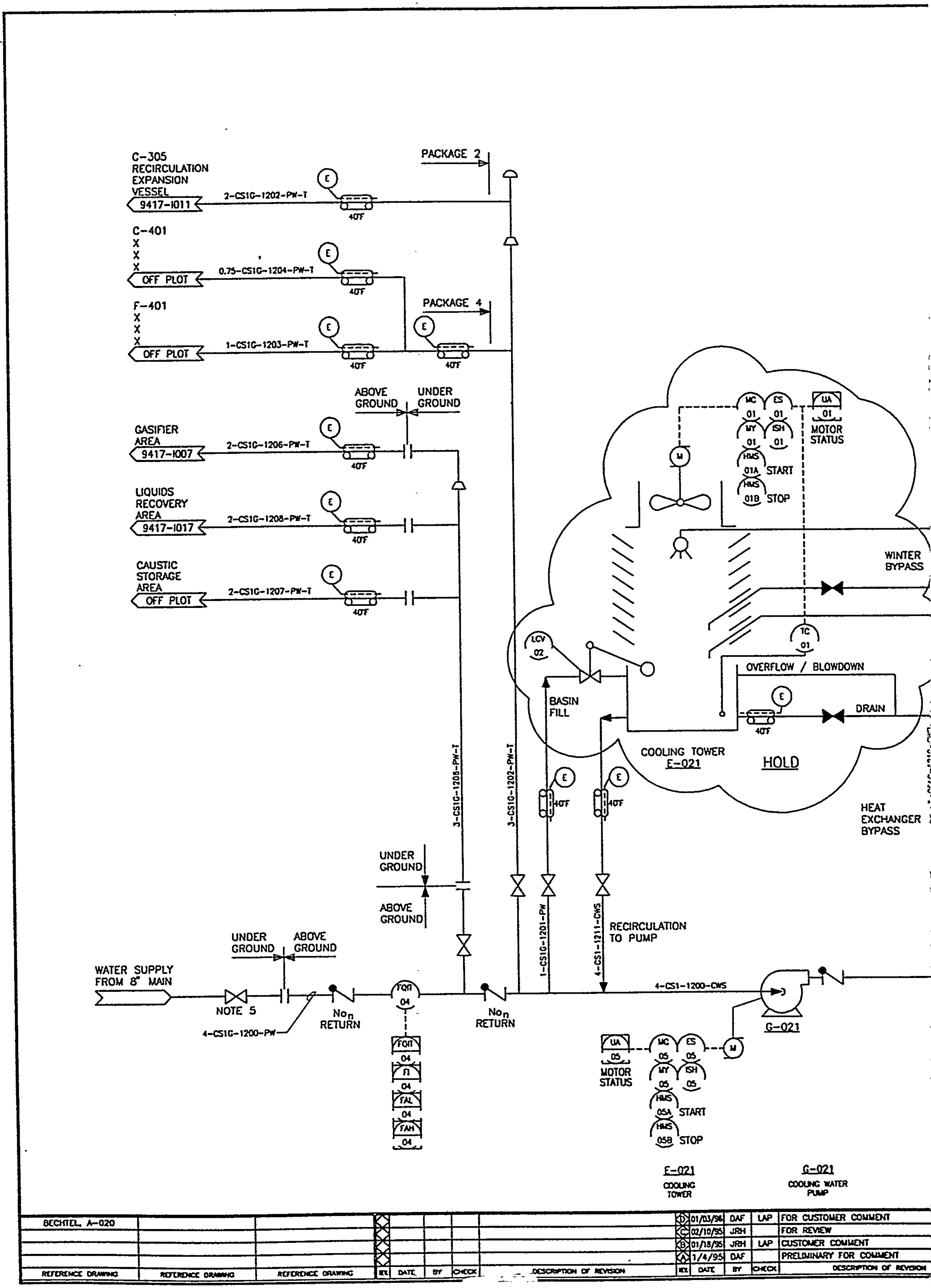
ROBERTS & SCHAEFER Company
ENGINEERS AND CONTRACTORS
CHICAGO - SALT LAKE CITY
9417

DAF | LAP

PIPING AND INSTRUMENT DIAGRAM
LIQUIDS STORAGE AND HANDLING
IGT MILD GASIFICATION PDU
CARTERVILLE, ILLINOIS

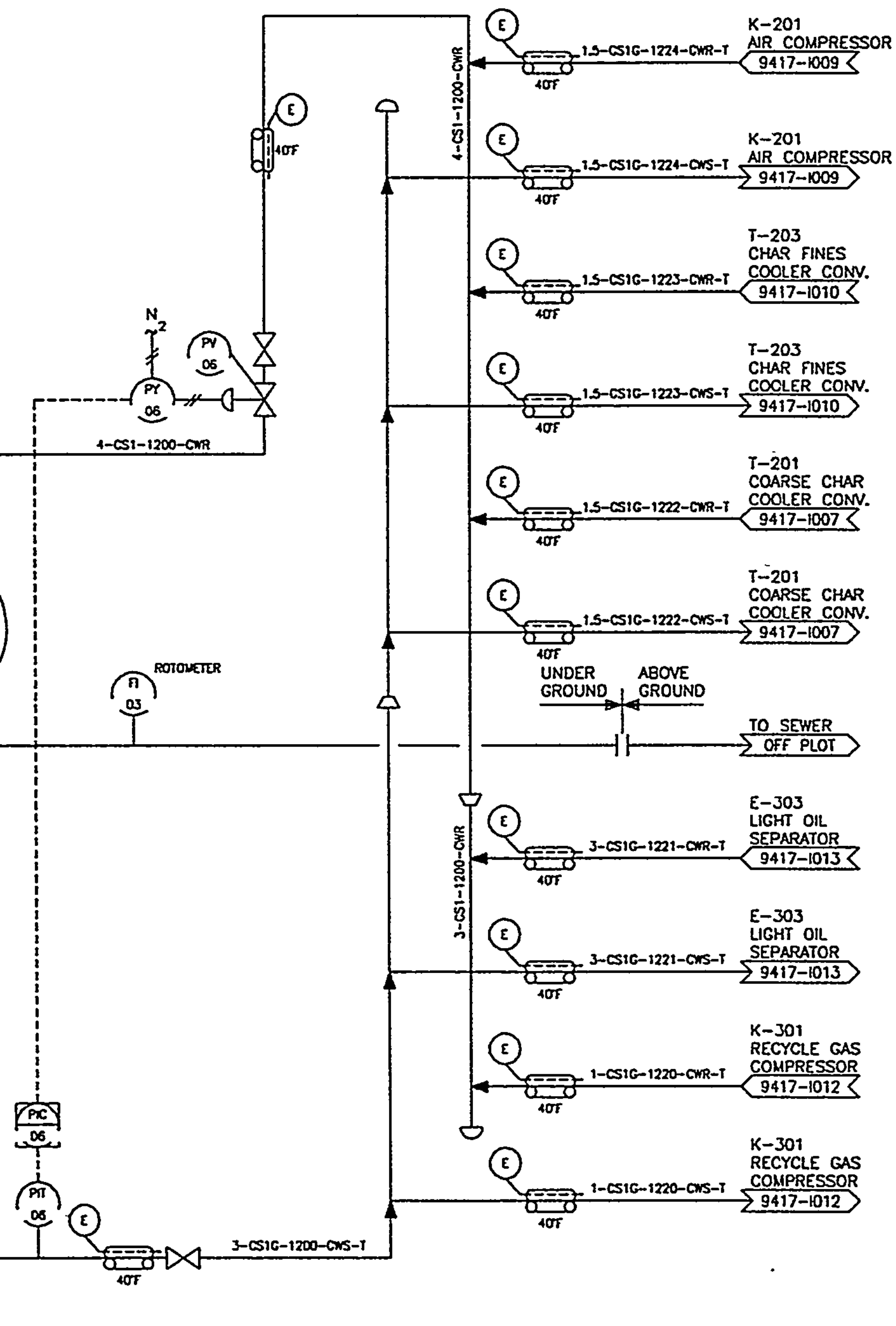
SCALE: NONE | DATE: 11/22/94
9417-I014 | D

9417 K:\9417\RELEASED\9417I014 12/14/95 13:58 ALAND


C-305
RECIRCULATION
EXPANSION
VESSEL
9417-I011
2-CS1G-1202-PW-T
40°F
PACKAGE 2
C-401
X
X
X
OFF PLOT
0.75-CS1G-1204-PW-T
F-401
X
X
X
OFF PLOT
1-CS1G-1203-PW-T
PACKAGE 4
ABOVE GROUND
UNDER GROUND
GASIFIER AREA
9417-I007
2-CS1G-1206-PW-T
LIQUIDS RECOVERY AREA
9417-I017
2-CS1G-1208-PW-T
CAUSTIC STORAGE AREA
OFF PLOT
2-CS1G-1207-PW-T
MC 01
ES 01
MY 01
ISH 01
HMS 01A START
HMS 01B STOP
UA 01
MOTOR STATUS
WINTER BYPASS
TC 01
LCV 02
OVERFLOW / BLOWDOWN
BASIN FILL
DRAIN
COOLING TOWER
E-021
HOLD
HEAT EXCHANGER BYPASS
3-CS1G-1205-PW-T
3-CS1G-1202-PW-T
UNDER GROUND
ABOVE GROUND
1-CS1G-1201-PW
4-CS1-1211-CWS
RECIRCULATION TO PUMP
UNDER GROUND
ABOVE GROUND
WATER SUPPLY FROM 8" MAIN
NOTE 5
4-CS1G-1200-PW
NON RETURN
FQIT 04
FQI 04
FI 04
FAL 04
FAH 04
NON RETURN
4-CS1-1200-CWS
G-021
UA 05
MOTOR STATUS
MC 05
ES 05
MY 05
ISH 05
HMS 05A START
HMS 05B STOP
E-021
COOLING TOWER
G-021
COOLING WATER PUMP
BECHTEL, A-020
REFERENCE DRAWING
REFERENCE DRAWING
REFERENCE DRAWING
REV. DATE BY CHECK DESCRIPTION OF REVISION
D 01/03/96 DAF LAP FOR CUSTOMER COMMENT
C 02/10/95 JRH FOR REVIEW
B 01/18/95 JRH LAP CUSTOMER COMMENT
A 1/4/95 DAF PRELIMINARY FOR COMMENT
REV. DATE BY CHECK DESCRIPTION OF REVISION

NOTES:

1. VENTS AND DRAINS ARE NOT SHOWN. SELLER SHALL FURNISH ALL HIGH POINT VENTS AND LOW POINT DRAINS.
2. ALL ABOVE GRADE PIPING MATERIAL SHALL BE HOT DIP GALVANIZED CARBON STEEL.
3. ALL STAGNANT WATER LINES SHALL BE ELECTRICALLY HEAT TRACED (60°F) AND INSULATED FOR FREEZE PROTECTION.
4. HIGH POINT AIR RELEASE/VACUUM VALVES SHALL BE FURNISHED ON ALL RETURN LINES ABOVE ELEVATION 128'-0"
5. NEW 4" BLOCK VALVE LOCATED AT EXISTING 8" WATER MAIN LINE.
6. SELLER SHALL FURNISH ALL PIPING TO AND FROM HEADERS LOCATED IN THE UTILITY PIPING CORRIDOR.
7. LOCATIONS OF EQUIPMENT ARE SHOWN ON PLAN AND ELEVATION DRAWINGS.
8. SS/EW = SAFETY SHOWER AND EYEWASH.
9. ONLY THE MAIN BRANCH LINES ARE SHOWN. SELLER TO PROVIDE SUPPLY AND RETURN LINES TO ALL EQUIPMENT REQUIRING COOLING.
10. ALL INSTRUMENT NUMBERS ON THIS DRAWINGS ARE PRECEEDED BY 17.



INSTRUMENT, NUMBERS USED: 01-06
INSTRUMENT NUMBERS NOT USED: 0

ROBERTS & SCHAEFER Company ENGINEERS AND CONTRACTORS CHICAGO-SALT LAKE CITY 9417	DRAWN BY DAF CHECKED BY APPROVED BY	DESIGNED BY DIRECTED BY CHJ	PIPING AND INSTRUMENT DIAGRAM WATER DISTRIBUTION SYSTEM IGT MILD GASIFICATION PDU CARTERVILLE, ILLINOIS
SCALE NONE	DATE 1/4/95	DRAWING NO. 9417-I017	REV. D

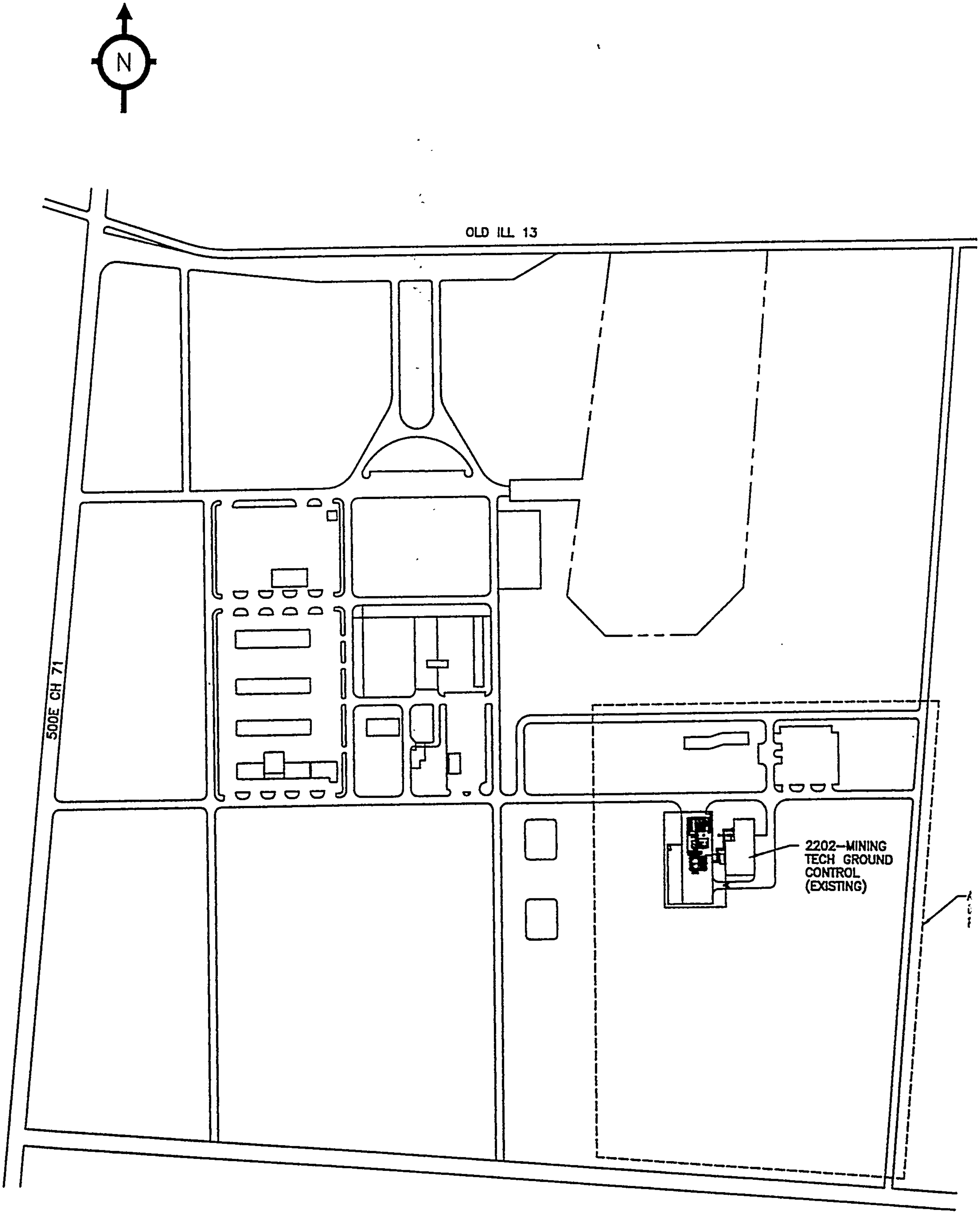
ACADNOTE:

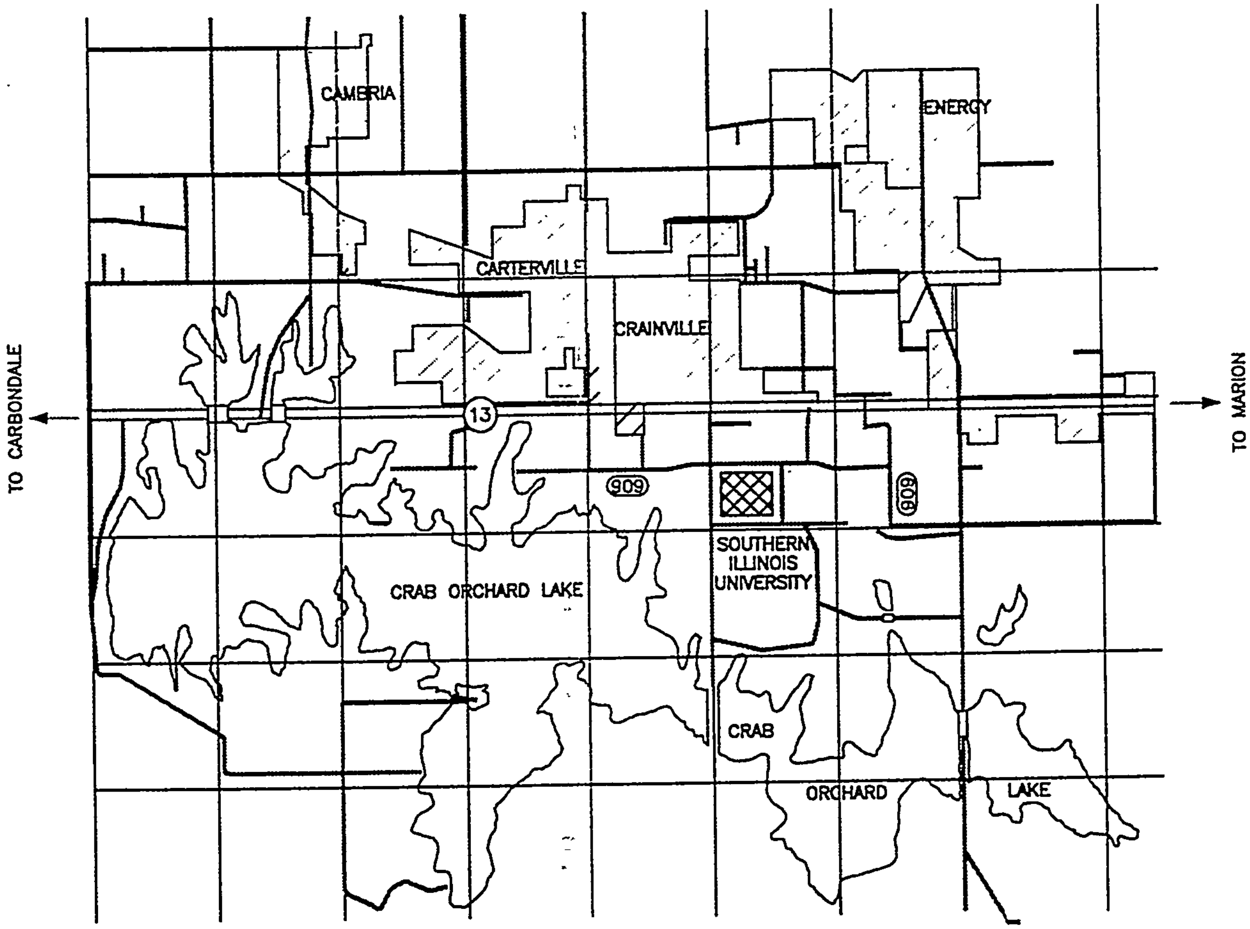
9417 K:\9417\RELEASED\9417I017 01/03/96 17:35 ALAND

GENERAL ARRANGEMENT DRAWINGS

The layout of the equipment at the site and in the structure are shown in the following site plan and general arrangement drawings. The site plan and general arrangement drawings are presented in Figure 29 to Figure 35. However, some of the drawings present incomplete details because of the termination of the PDU construction.

21785C01.DWG





AREA MAP
SCALE 1"=2000'

PPROXIMATE BOUNDARY
LINOIS COAL DEVELOPMENT
ARK

0		ISSUED FOR CONSTRUCTION

SCALE 1"=200'

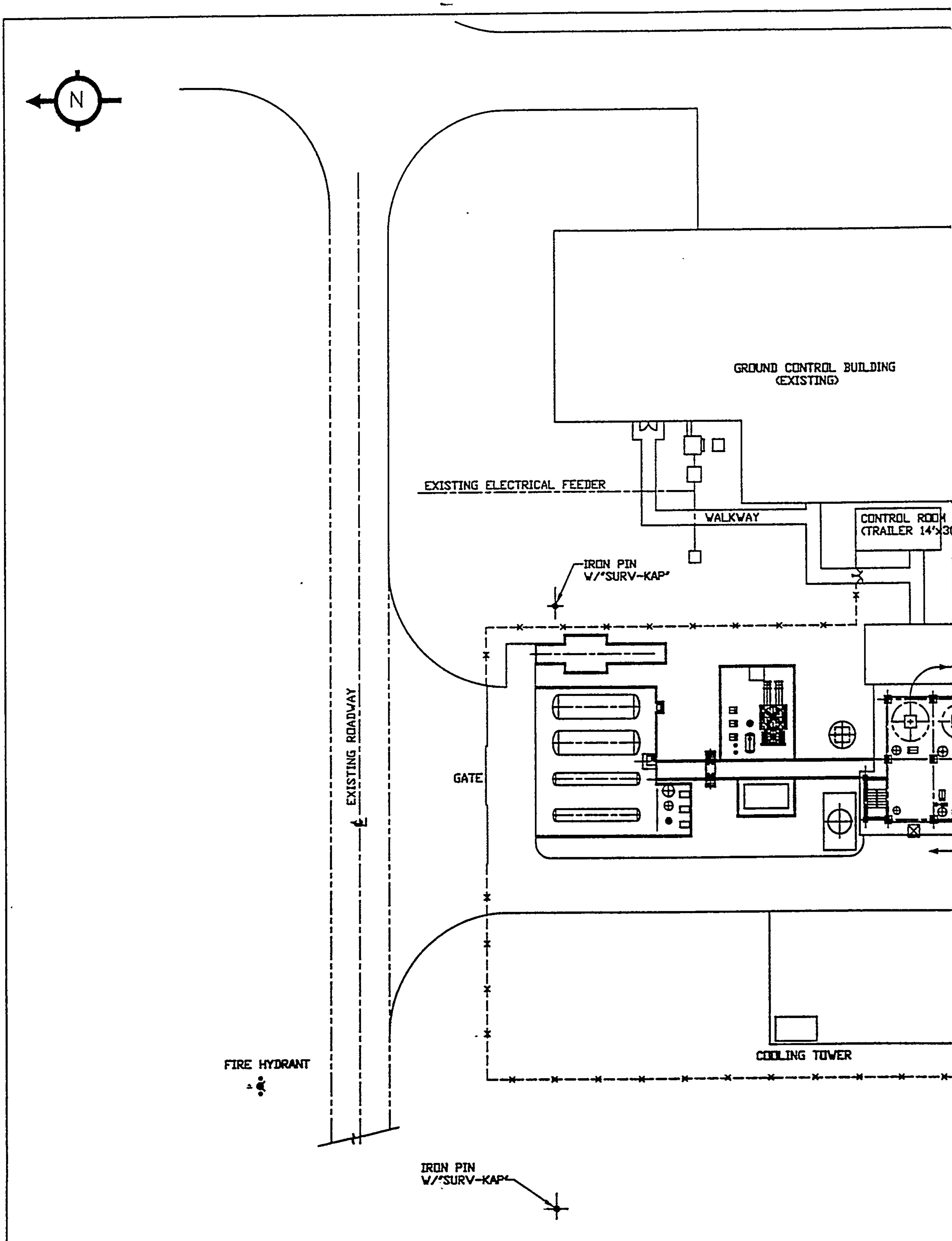
BECHTEL
SAN FRANCISCO

IGT MILD GASIFICATION PDU

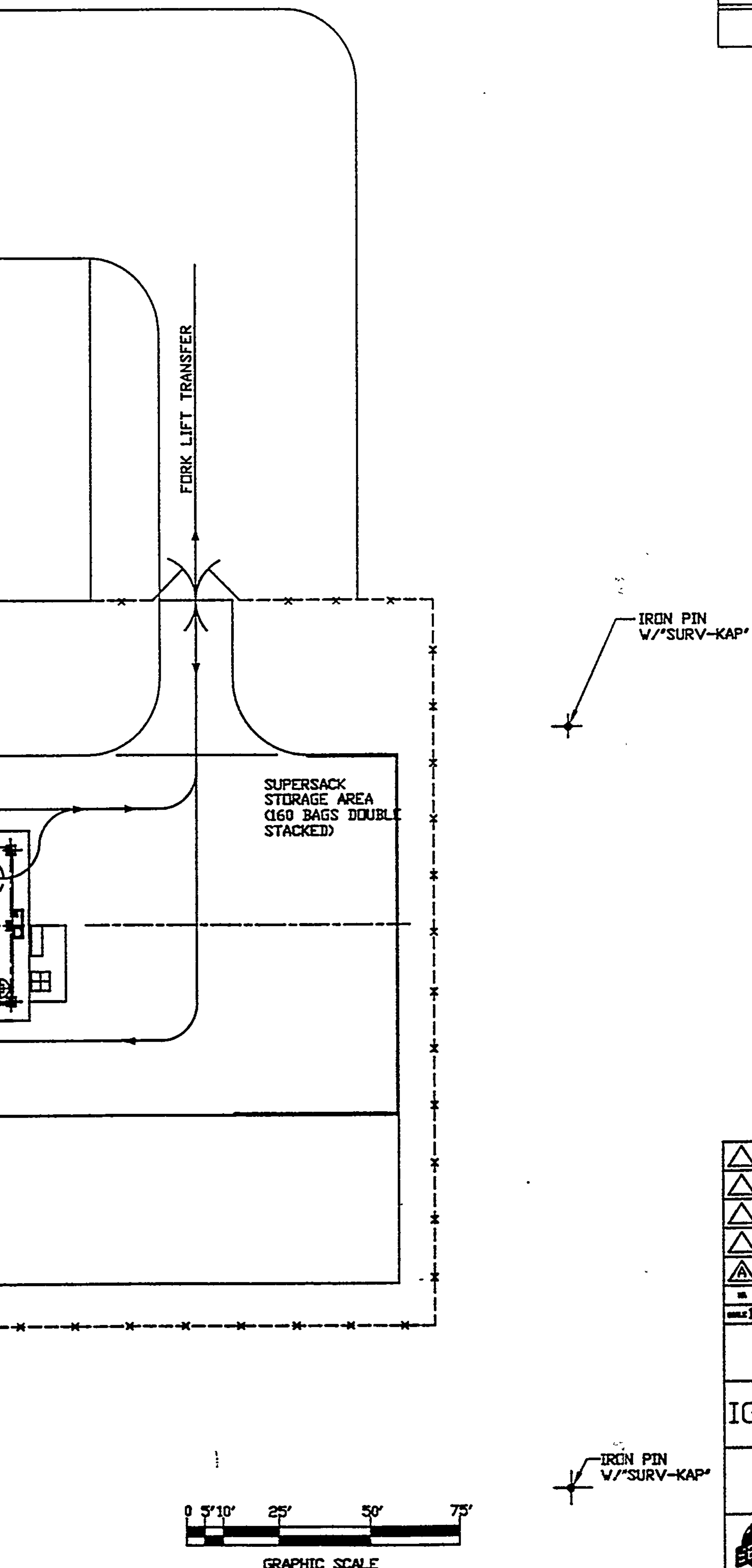
GENERAL SITE PLAN

JOB NO.	DRAWING NO.	REV.
21765	C-001	0

21765A03.DWG



REFERENCE DRAWINGS	
A-010	GENERAL ARRANGEMENT PLANS BELOW EL 120' & 140'



A	ISSUED FOR CONTRACT AWARD

1"=20'-0"
TMC/ACAD

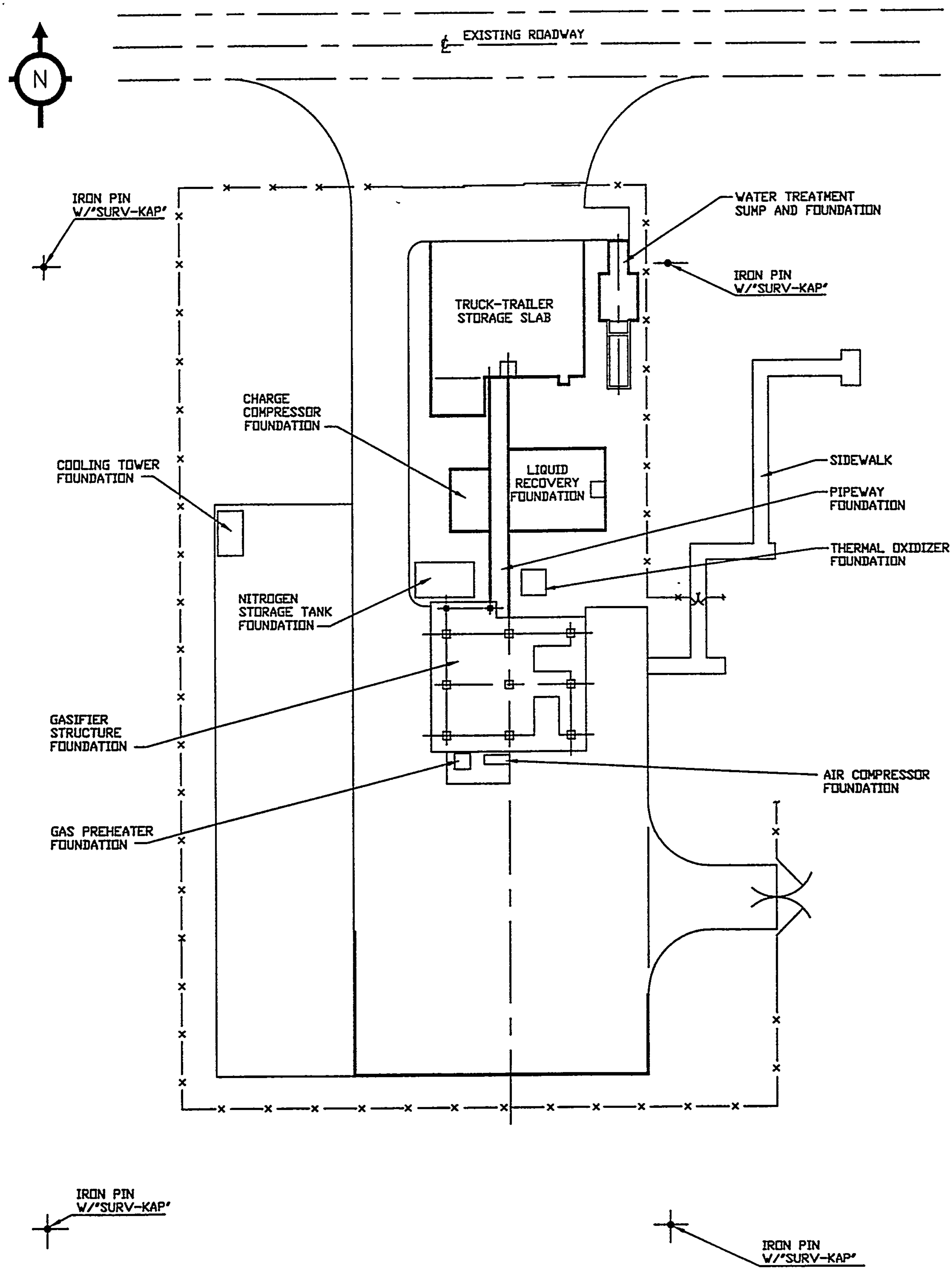
BECHTEL
SAN FRANCISCO

IGT MILD GASIFICATION PDU

SITE PLAN

JOB NO.	DRAWING NO.	REV.
21765	A-001	A

21765A03.dwg /11-Aug-1994 /15:22:05



2176SC02.DWG

		REF. DWGS
1	GASIFIER FOUNDATION STRUCTURE	C-040
2	TRUCK-TRAILER STORAGE SLAB	C-043
3	NITROGEN STORAGE TANK FOUNDATION	C-042
4	COOLING TOWER FOUNDATION	C-044
5	LIQUID RECOVERYFOUNDATION	C-042
6	CHARGE COMPRESSOR FOUNDATION	C-042
7	PIPEWAY FOUNDATION	C-042
8	WATER TREATMENT SUMP & FOUNDATIONS	C-043
9	THERMAL OXIDIZER FOUNDATION	C-044
10	GAS PREHEATER FOUNDATION	C-046
11	AIR COMPRESSOR FOUNDATION	C-046
12	SIDEWALK	C-046

0 ISSUED FOR CONSTRUCTION

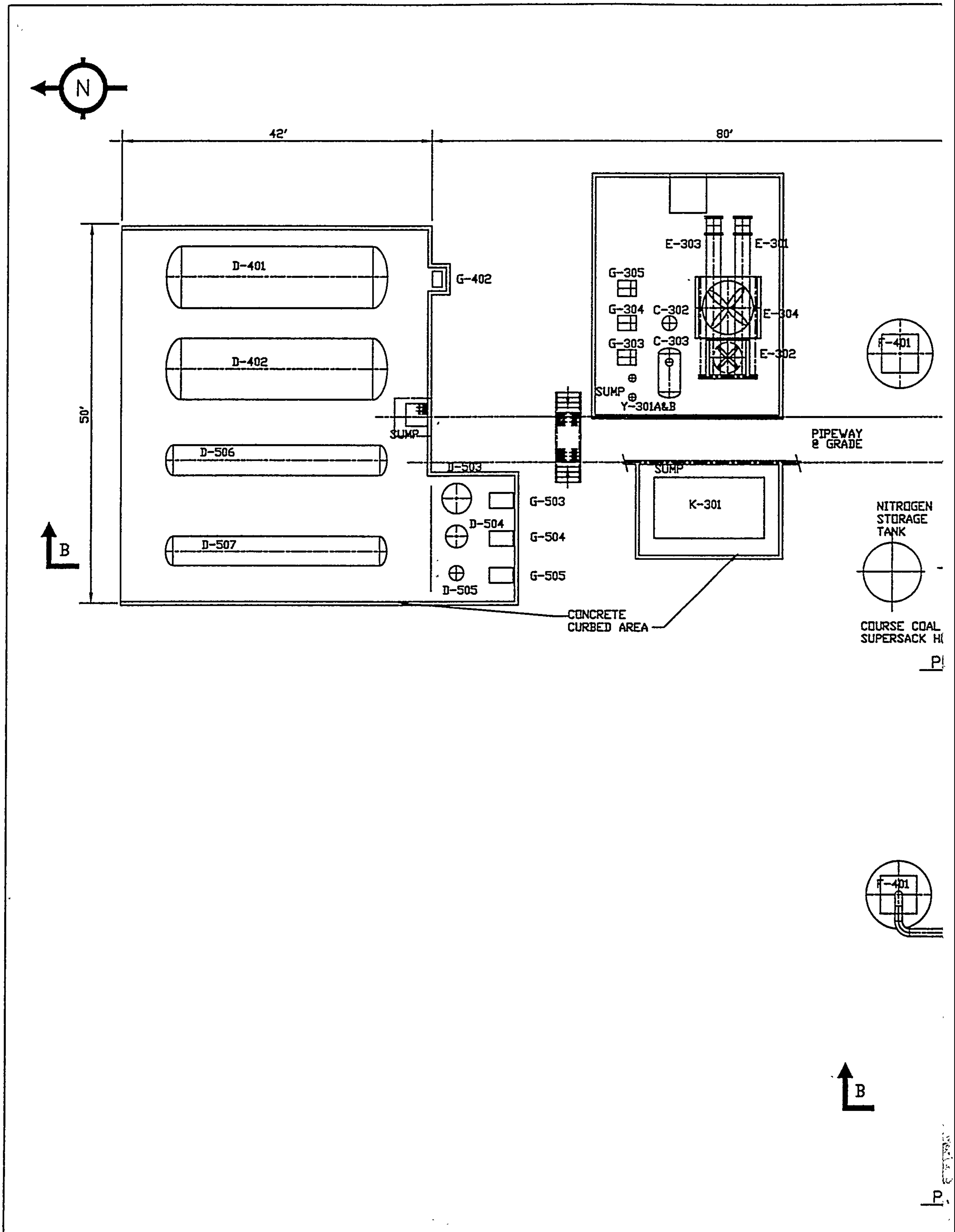
SCALE 1"=20'

BECHTEL
SAN FRANCISCO

IGT MILD GASIFICATION PDU

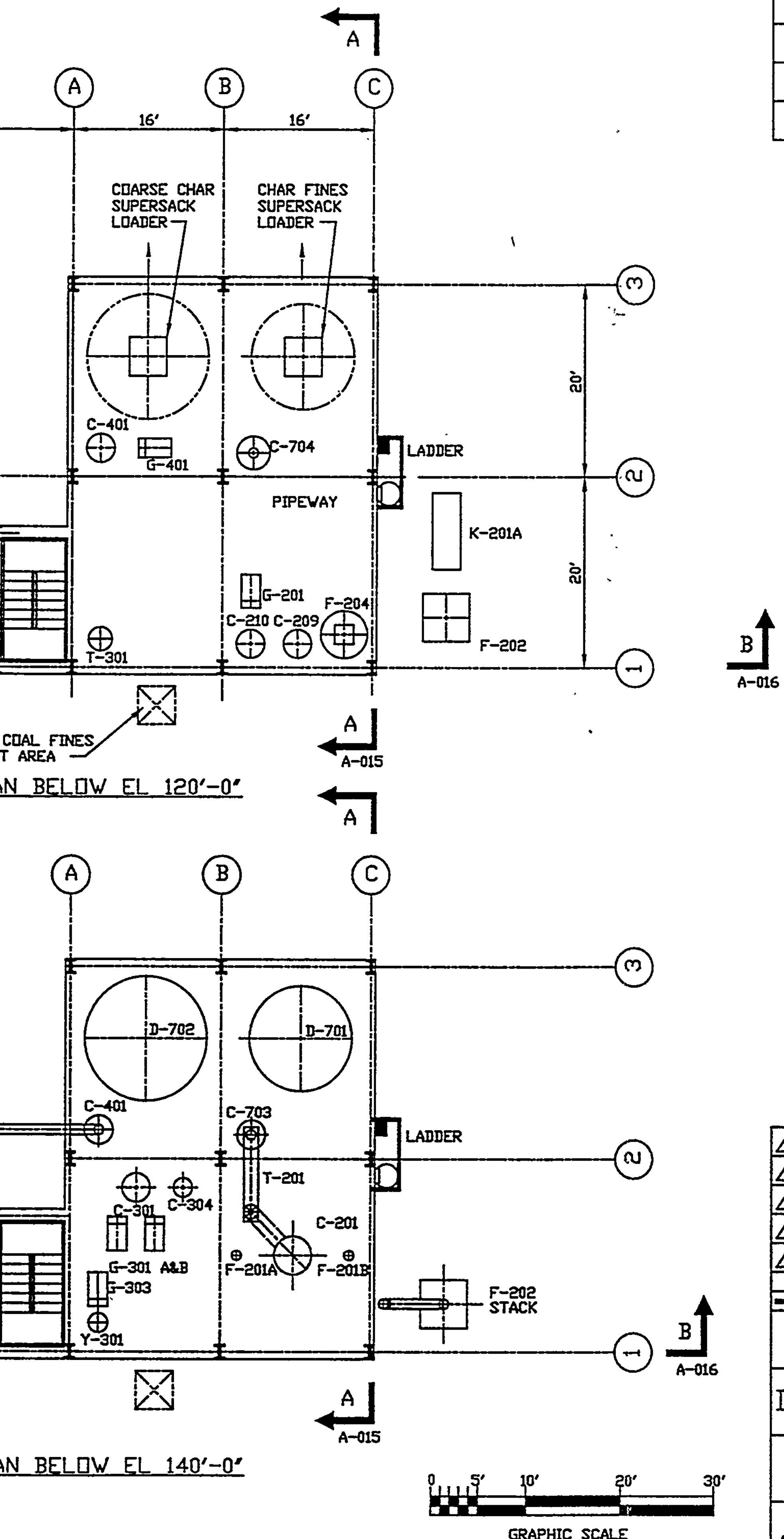
KEY PLAN

JOB NO.	DRAWING NO.	REV.
21765	C-002	0



21765A01.DWG

REFERENCE DRAWINGS		
A-001		SITE PLAN
A-011		GENERAL ARRANGEMENT PLANS BELOW EL 160',180' & 200'
A-015		GENERAL ARRANGEMENT SECTION A-A
A-016		GENERAL ARRANGEMENT SECTION B-B



ISSUED FOR CONTRACT AWARD

A

1/8"=1'-0"

TMC/ACAD

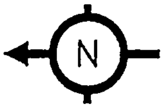
BECHTEL
SAN FRANCISCO

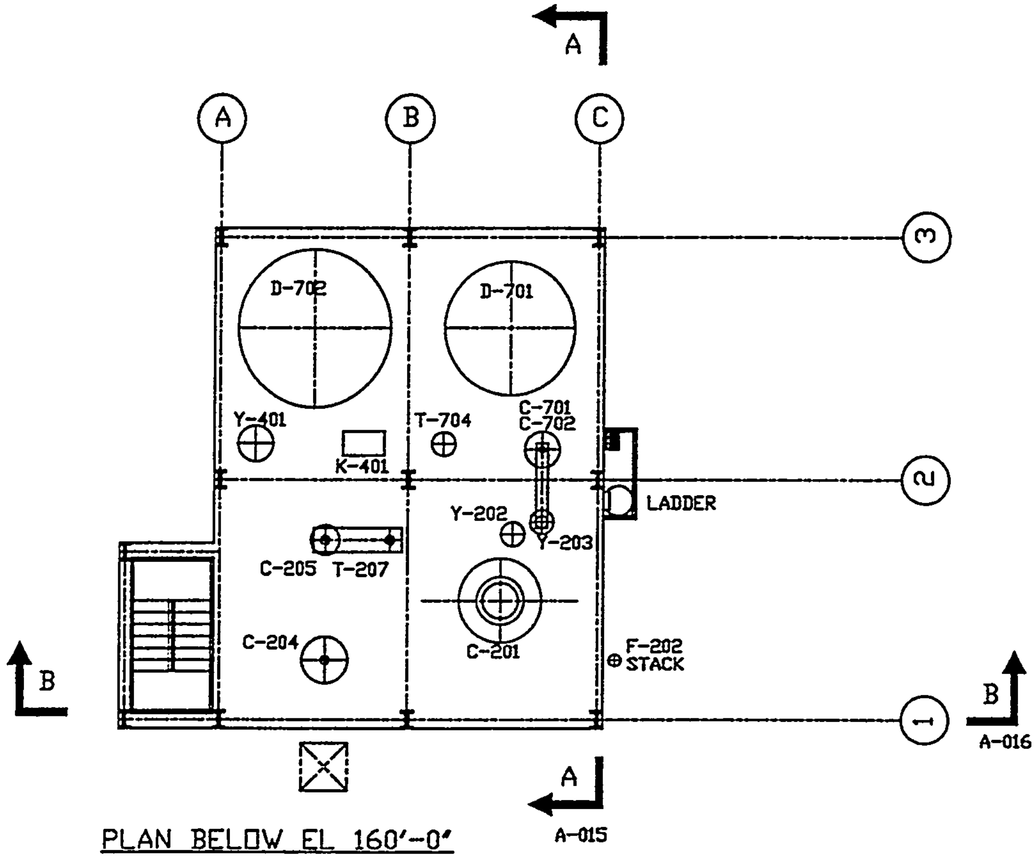
IGT MILD GASIFICATION PDU

GENERAL ARRANGEMENT
PLANS BELOW EL 120'-0" & 140'-0"

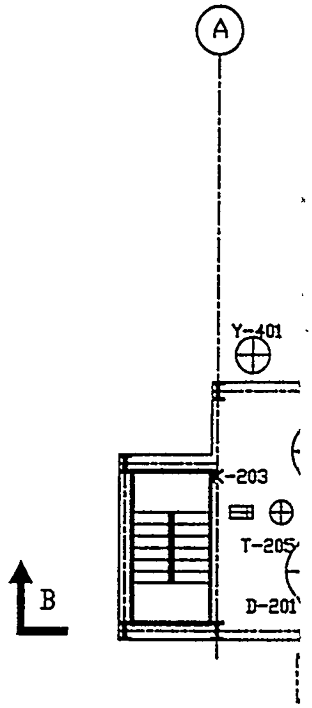
JOB NO.	DRAWING NO.	REV.
21765	A-010	A

21765A04.DWG

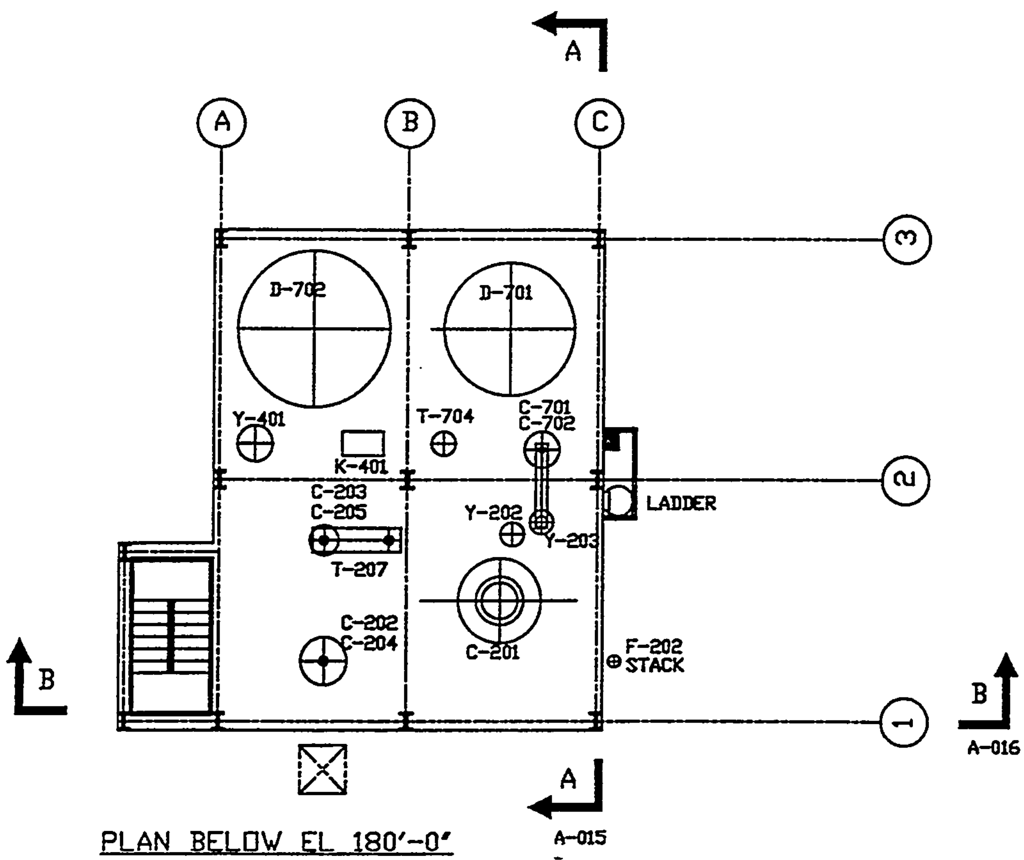




PLAN BELOW EL 160'-0"

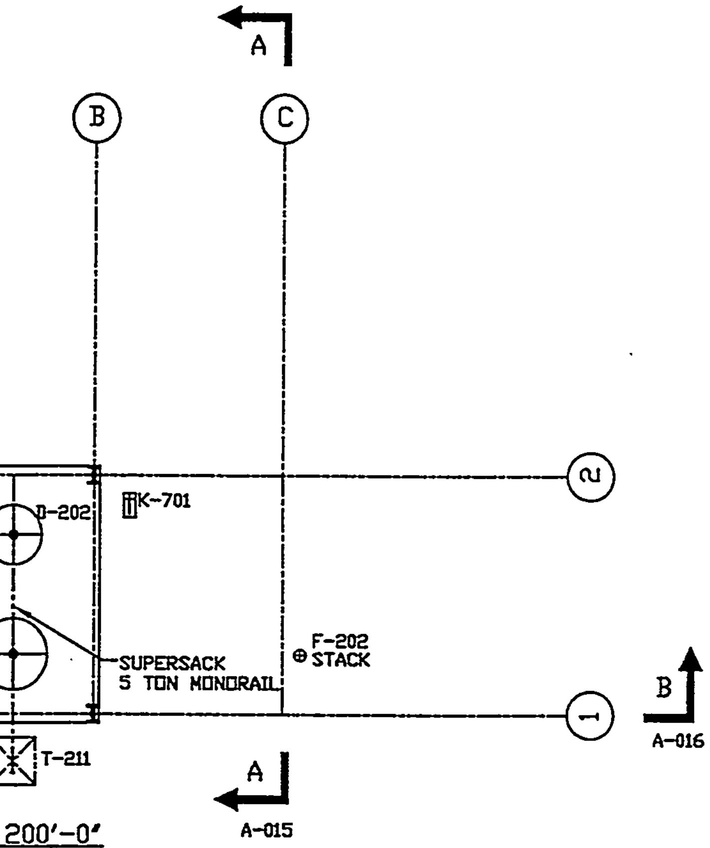


PLAN BELOW EL



PLAN BELOW EL 180'-0"

FOR GENERAL NOTES AND REFERENCES
SEE DRAWING A-010



A		ISSUED FOR CONTRACT AWARD

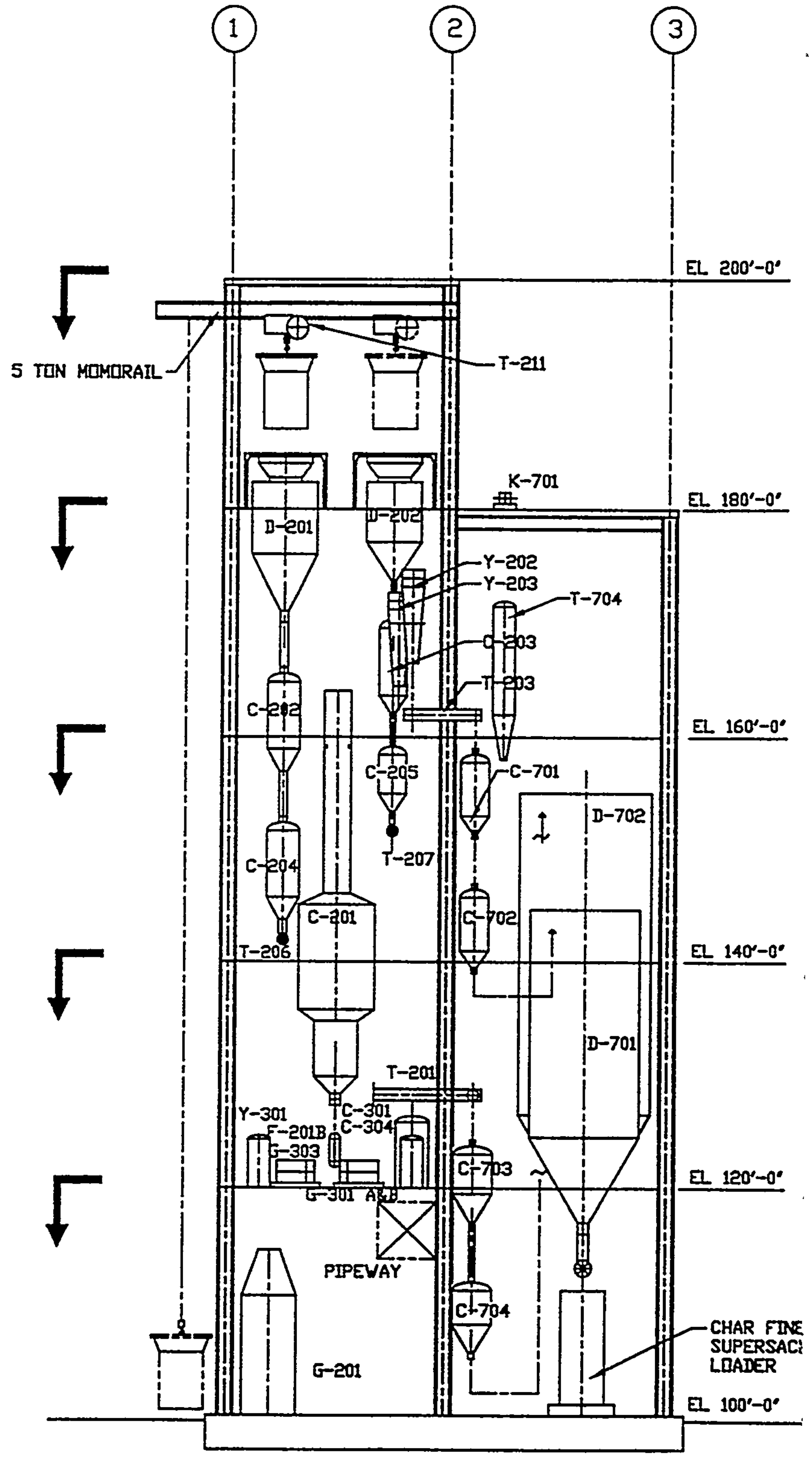
1/8"=1'-0" TMC/ACAD

BECHTEL
SAN FRANCISCO

IGT MILD GASIFICATION PDU

GENERAL ARRANGEMENT
PLANS BELOW EL 160',180' & 200'

JOB NO.	DRAWING NO.	REV.
21765	A-011	A



SECTION A-A

21765A02.DWG

FOR GENERAL NOTES AND REFERENCES
SEE DRAWING A-010

A-011

A-011

A-011

A-010

A-010

GRADE EL 99'-6"

0 5' 10' 20' 30'

GRAPHIC SCALE

A		ISSUED FOR CONTRACT AWARD	

1/8"=1'-0" TMC/ACAD

BECHTEL
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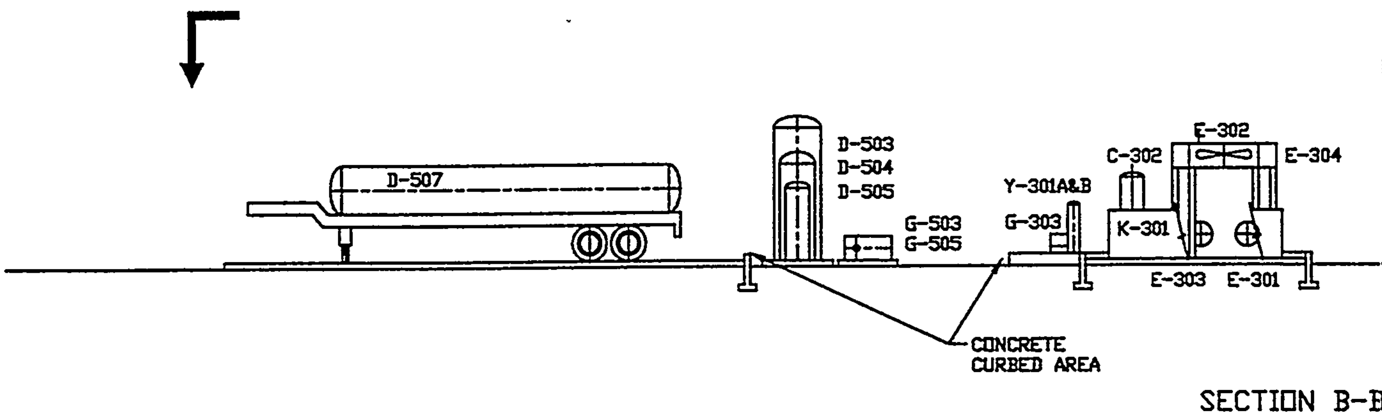
IGT MILD GASIFICATION PDU

GENERAL ARRANGEMENT
SECTION A-A

JOB NO.	DRAWING NO.	REV.
21765	A-015	A

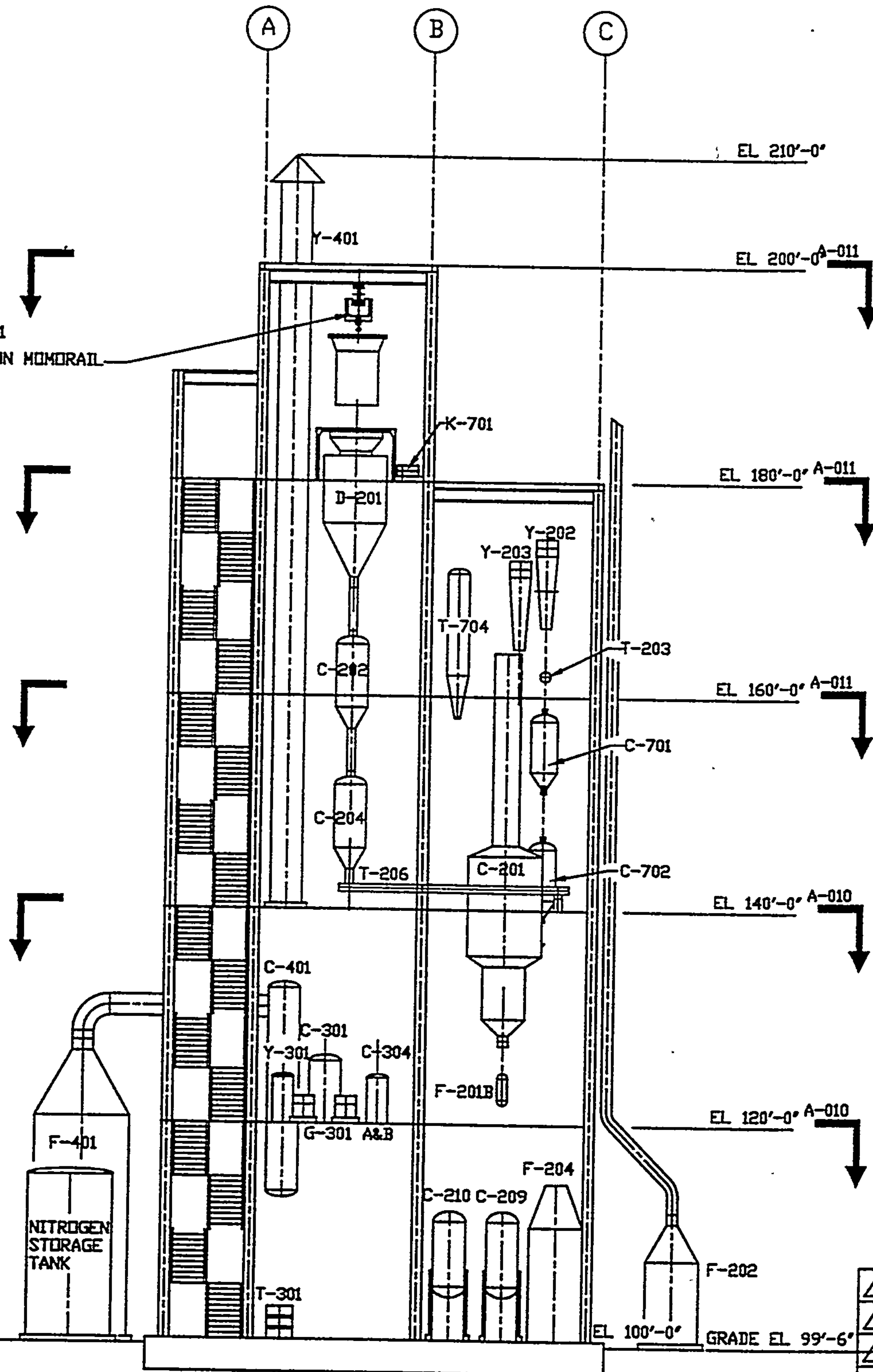
H G F E D C B A

21765A02.DWG



SECTION B-B

FOR GENERAL NOTES AND REFERENCES
SEE DRAWING A-010



GRAPHIC SCALE

ISSUED FOR CONTRACT AWARD

SCALE 1/8"=1'-0"

TMC/ACAD

BECHTEL
SAN FRANCISCO

IGT MILD GASIFICATION PDU

GENERAL ARRANGEMENT SECTION B-B

JOB NO.	DRAWING NO.	REV.
21765	A-016	A

PDU CONSTRUCTION DRAWINGS

The following list of drawings are not included in this report because they present details specific to the actual PDU site, equipment layout, and support structure and auxiliaries. The drawings presented in the previous sections show process design information as developed for the MILDGAS process in general. All of the PDU drawings will be archived at IGT.

The site-specific drawings not included in this report concern:

Site foundation plans

General underground site provisions

Electrical drawings

MCC data sheets

Material selection diagrams

Instrument power distribution

Power and conduit layout

Lighting layout

Grounding layout

Control room equipment layout

Instrument loop diagrams

PLC system layout

PLC logic flow diagram

Piping plans

Piping isometric drawings

Structural steel drawings

Vendor drawings for auxiliary equipment

References Cited

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[3] Wootten, J. M., Nawaz, M.; Duthie, R. G., Knight, R. A., Onischak, M., Babu, S. P., and Bair, W. G., "Development of An Advanced Continuous Mild Gasification Process for the Production of Co-Products Task 1: Literature Survey of Mild Gasification Processes, Co-Products Upgrading and Utilization, and Market Assessment," Topical Report for the period September 30, 1987 - January 31, 1988, submitted to US DOE Morgantown Energy Technology Center, Morgantown, WV, Contract No. DE-AC21-87MC24266, August 1988.

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[5] Private communication, Bethlehem Steel Company, Inc.

[6] Jüntgen, H., Klein, J., Knoblauch, K., Schröter, J., Schulze, J., "Conversion of Coal and Gases Produced by Coal Into Fuels, Chemicals, and Other Products," from *Chemistry of Coal Utilization, 2nd Supplementary Edition*, Chap. 30, 2071-2158, Elliot, M. A., Ed., New York, NY: John Wiley & Sons, 1981.

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[9] Knight, R. A., Gissy, J., Onischak, M., Carty, R. H., Babu, S. P., Wootten, J. M., and Duthie, R. G., "Development of An Advanced Continuous Mild Gasification Process for the Production of Co-Products, Task 4: Mild Gasification Technology Development System Integration Studies," Topical Report for the period April 1, 1989 - September 30, 1990, submitted to US DOE