Section 5

PROCESS DESCRIPTIONS

UNIT 01 - COAL PREPARATION

Process Flow Diagram 4-002 depicts the arrangement of equipment in this section, which incorporates one train of coal unloading, stacking, reclaiming, and conveying.

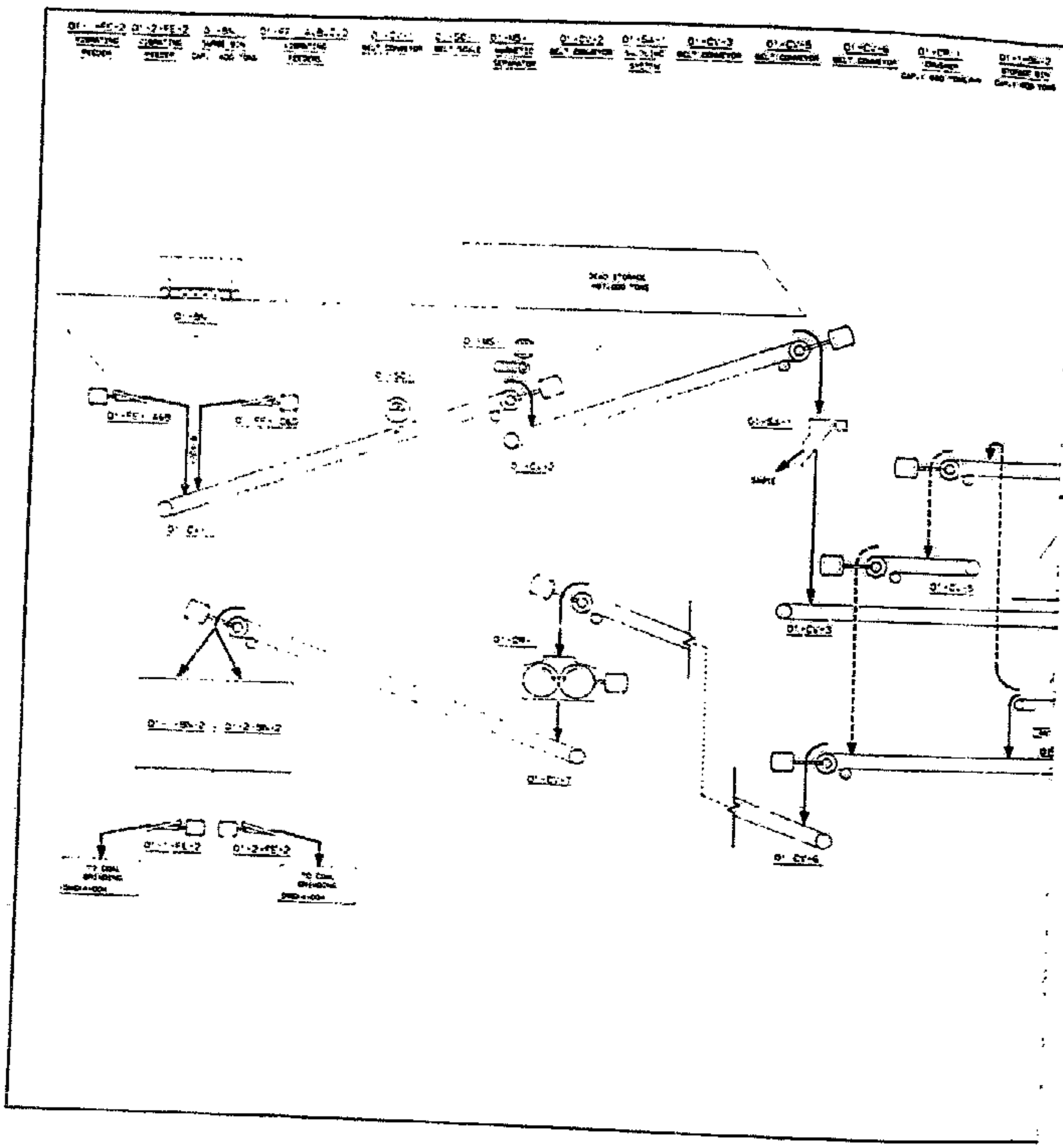
Washed 1-1/2 inch by zero Illinois No. 6 coal is received at the plant site by unit train. The coal is unloaded from 100-ton bottom dump cars into unloading hopper 01-BN-1, which provides about four minutes of storage based on the capacity of the stacking system at 6100 tons per hour. Four vibrating feeders, 01-FE-1A-D, withdraw coal from the hopper and place it on receiving conveyor 01-CV-1, while belt scale 01-SC-1 measures the actual conveyor transport rate. After passing a magnetic separator 01-MS-1 for protection of downstream equipment from miscellaneous metal fragments, the coal travels on sample tower conveyor 01-CV-2, which supplies sampling system, 01-SA-1. From 01-CV-2, storage conveyor 01-CV-3 transports the coal to double boom stacker 01-ME-1. The stacker travels on tracks and forms up to 1-1/2 day (24,355 tons) live storage piles on either side. The unloading and stacking system is designed to handle a three-day supply in eight hours.

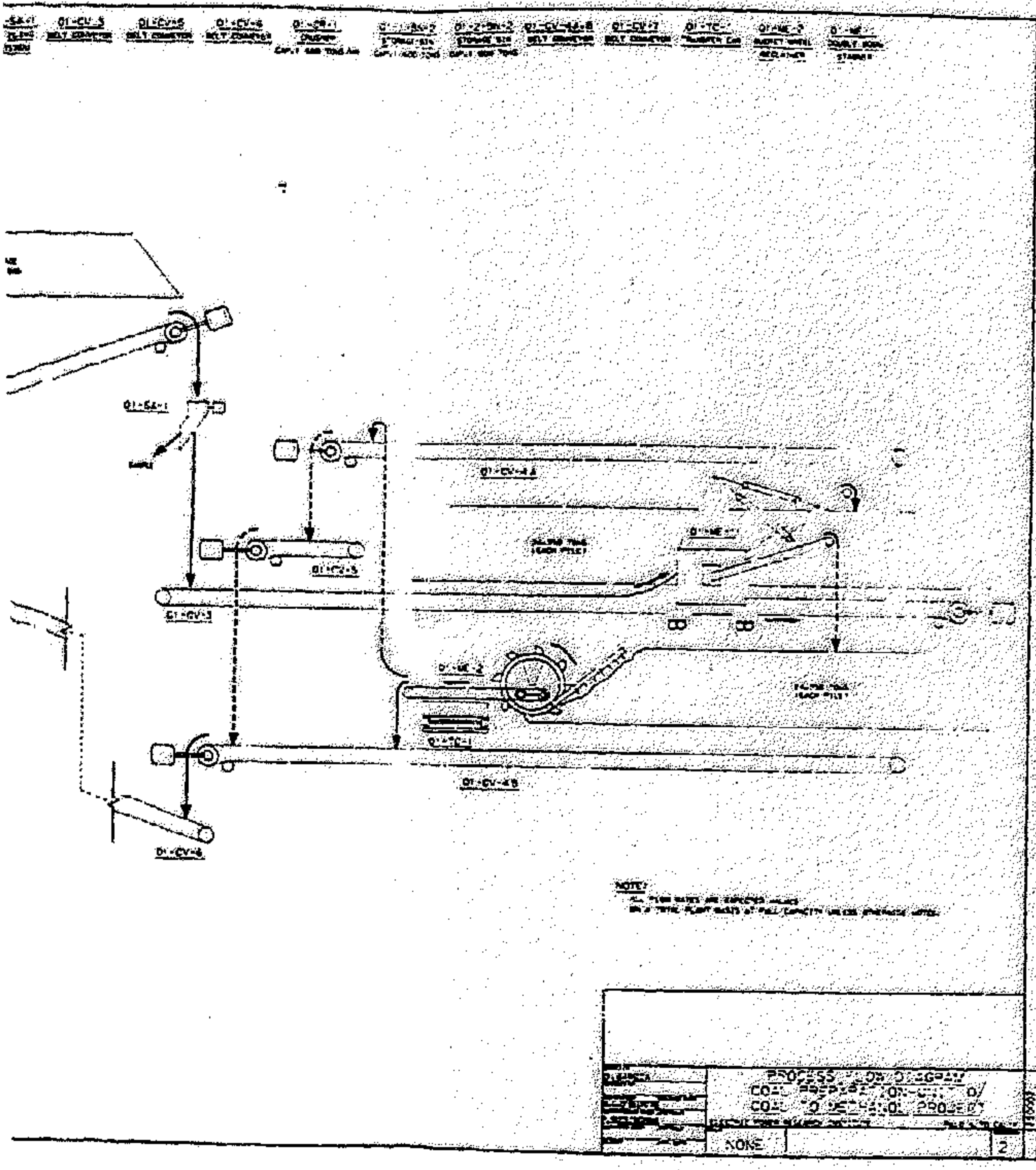
Spare for a reserve dead pile of 30-day storage is provided adjacent to the rail unloading station. The dead pile is sodded to minimize coal entrainment in rain water. Nevertheless, rain water runoff from this coal pile is collected and used in slurry preparation.

Coal is reclaimed from the storage piles by a bridge-type bucket wheel reclaimer 01-ME-2, rated at 680 tons per hour. This machine is moved between live storage piles as necessary by transfer car 01-TC-1. The wheel moves across the face of the pile, making an angle of repose cut across the many layers of coal, thereby blending the coal fed to the gasification plant. This blending provides more uniform gasifier operation. The reclaimer continuously moves ahead, reclaimed coal being carried on the bucket wheel conveyor to one of the two reclaim conveyors 01-CV-4A&B. Cross conveyor 01-CV-5 is employed when 01-CV-4A is in service to deliver coal to crusher conveyor 01-CV-6, which is located near 01-CV-4B.

Crusher 01-CR-1 is used to break down 1-1/2 inch by 3/4 inch coal, which would require longer residence times in the pulverizing equipment. Crushed coal conveyor 01-CV-7 delivers 3/4 inch by zero coal to s ge bins 01-BN-2, which provide a total of 1-3/4 hours of downstream throughput. Vibrating feeders 01-FE-2 supply the grinding mills.

All unloading and conveying systems are equipped with a dust suppression system consisting of water sprays aided by a wetting agent.





PROCESS FLOW DIAGRAM
COAL PREPARATION-UNIT 01
COAL TO METHANOL PROJECT

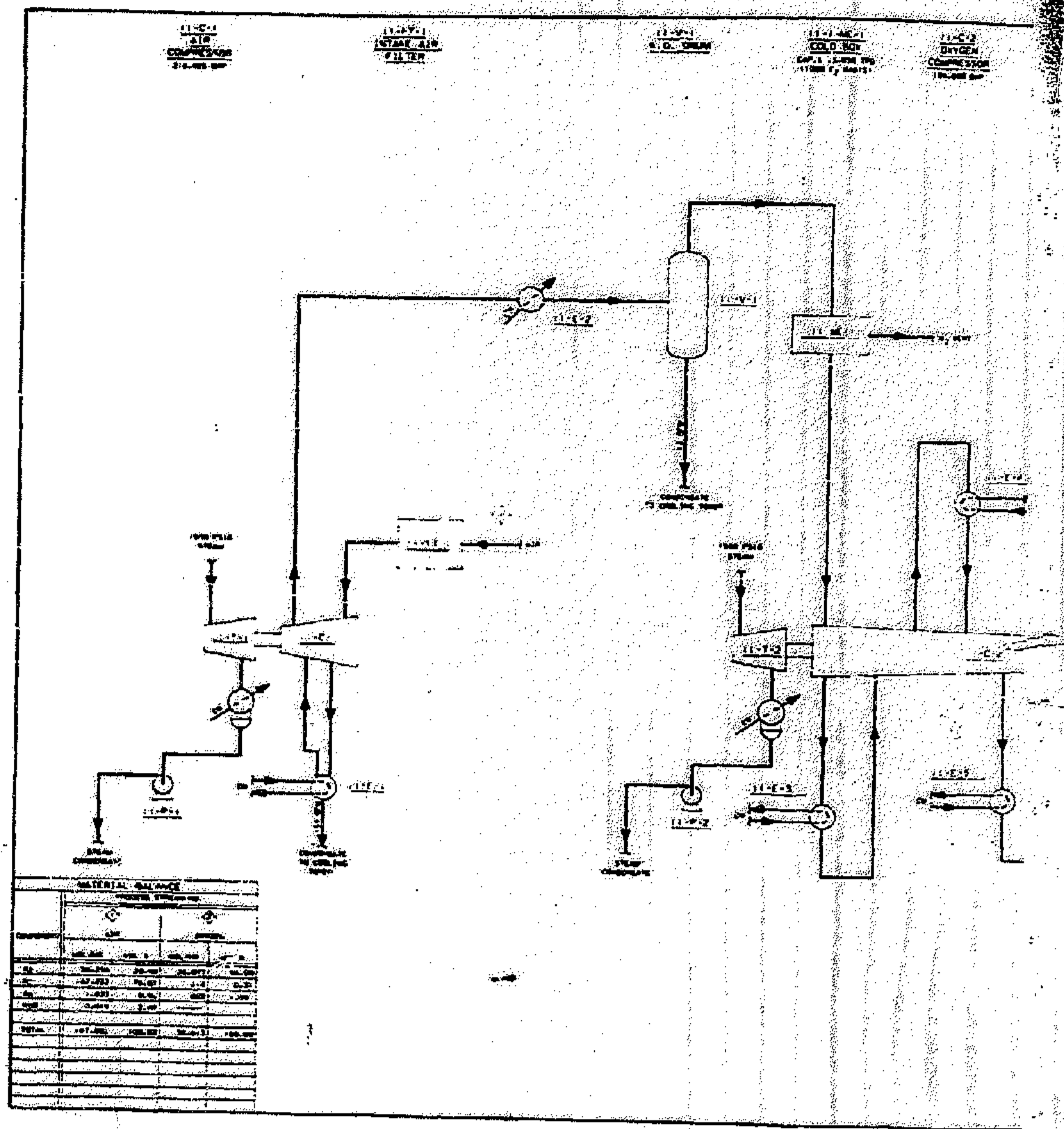
UNIT 11 - AIR SEPARATION

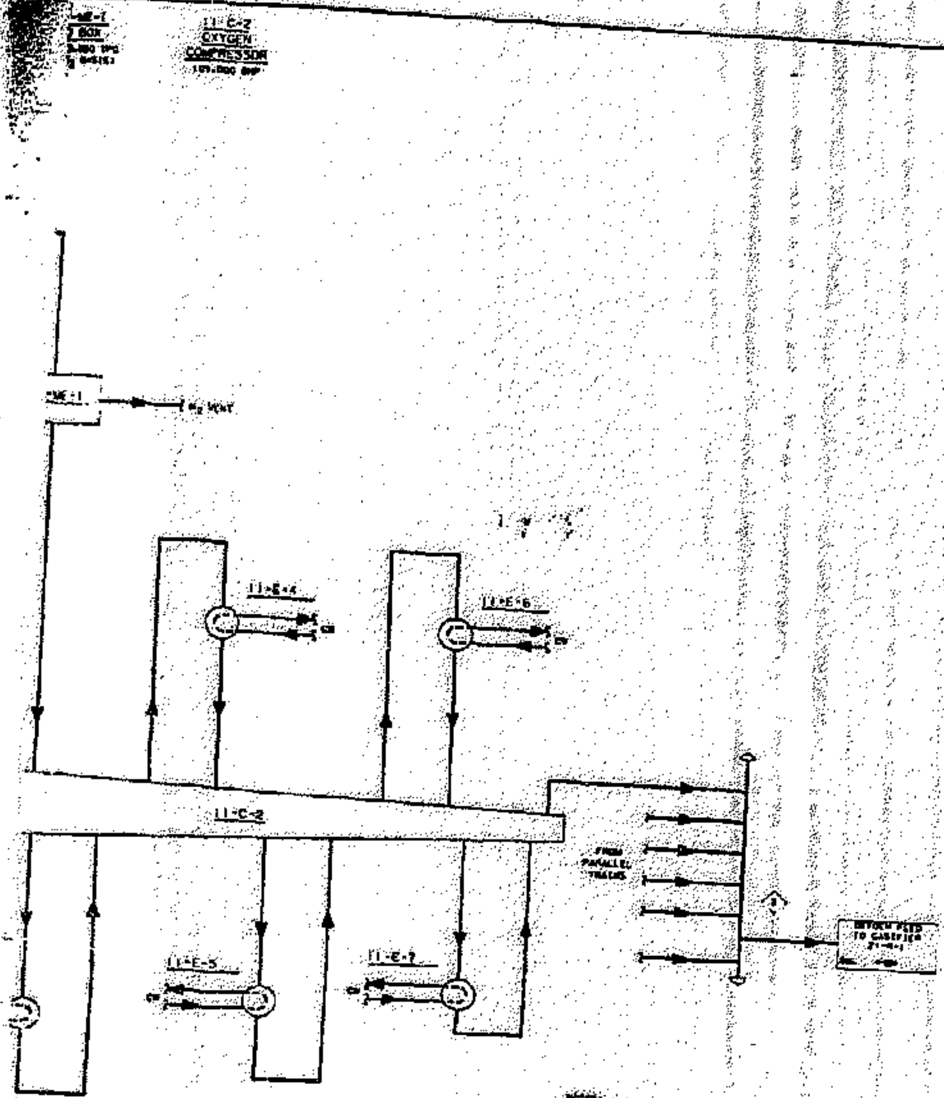
The air separation section comprises six equal trains to supply high-purity oxygen for use in the gasification area and nitrogen for use in the acid gas removal and product storage areas. Arrangement of equipment in this area is shown in Process Flow Diagram 4-003.

Conventional technology is used. Air compression and oxygen compression horsepower requirements are furnished by condensing-type steam turbines using high-pressure steam. Air compression is accomplished by two-stage axial-centrifugal compressors, while oxygen compression is accomplished by means of centrifugal compressors. Nitrogen compressor power requirements are supplied by electric motor drivers. Cold box technology is conventional and is available from several suppliers.

Each air separation unit produces 2310 tons per day (100 percent basis) of 98 percent oxygen. Liquid oxygen storage, of approximately 7000 tons, is provided with attendant cryogenic pumps and vaporizer. Storage is equivalent to approximately three days of rated capacity operation of a single train and is anticipated to adequately cover any outage of a cryogenic unit.

In addition, approximately 48 tons of high-pressure gaseous oxygen storage is provided. This quantity is sufficient for approximately thirty minutes of rated capacity operation of a single train and is estimated to be adequate time to commission the liquid oxygen vaporizing system.


AIR COMPRESSOR
INTAKE AIR FILTER
COLD BOX
OXYGEN COMPRESSOR
MATERIAL BALANCE



NOTES:

1. THIS FLOW DIAGRAM SHOWS ONE TRAIN OF SIX PARALLEL TRAINS.
2. ALL FLOW RATES, AND EQUIPMENT SPECIFICATIONS ARE ON A TOTAL PLANT BASIS AT FULL CAPACITY EXCEPT AS NOTED.

C. W. [illegible]
R.C. SNYDER

PROCESS FLOW DIAGRAM
AIR SEPARATION PLANT-UNIT 11
COAL TO METHANOL PROJECT

ELECTRIC POWER RESEARCH INSTITUTE

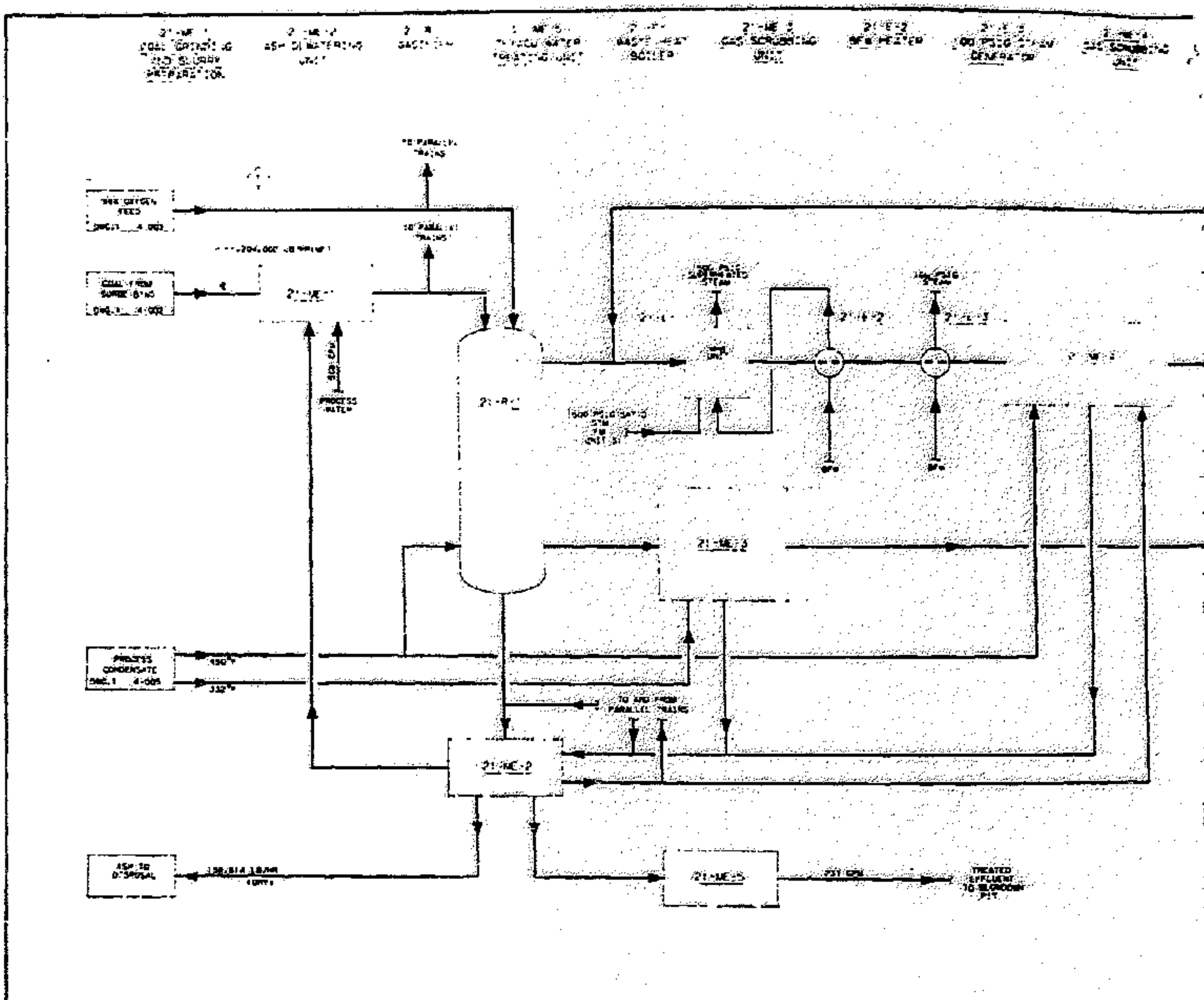
NONE | 575004-4-003 | 2

UNIT 21 - COAL GASIFICATION AND ASH HANDLING

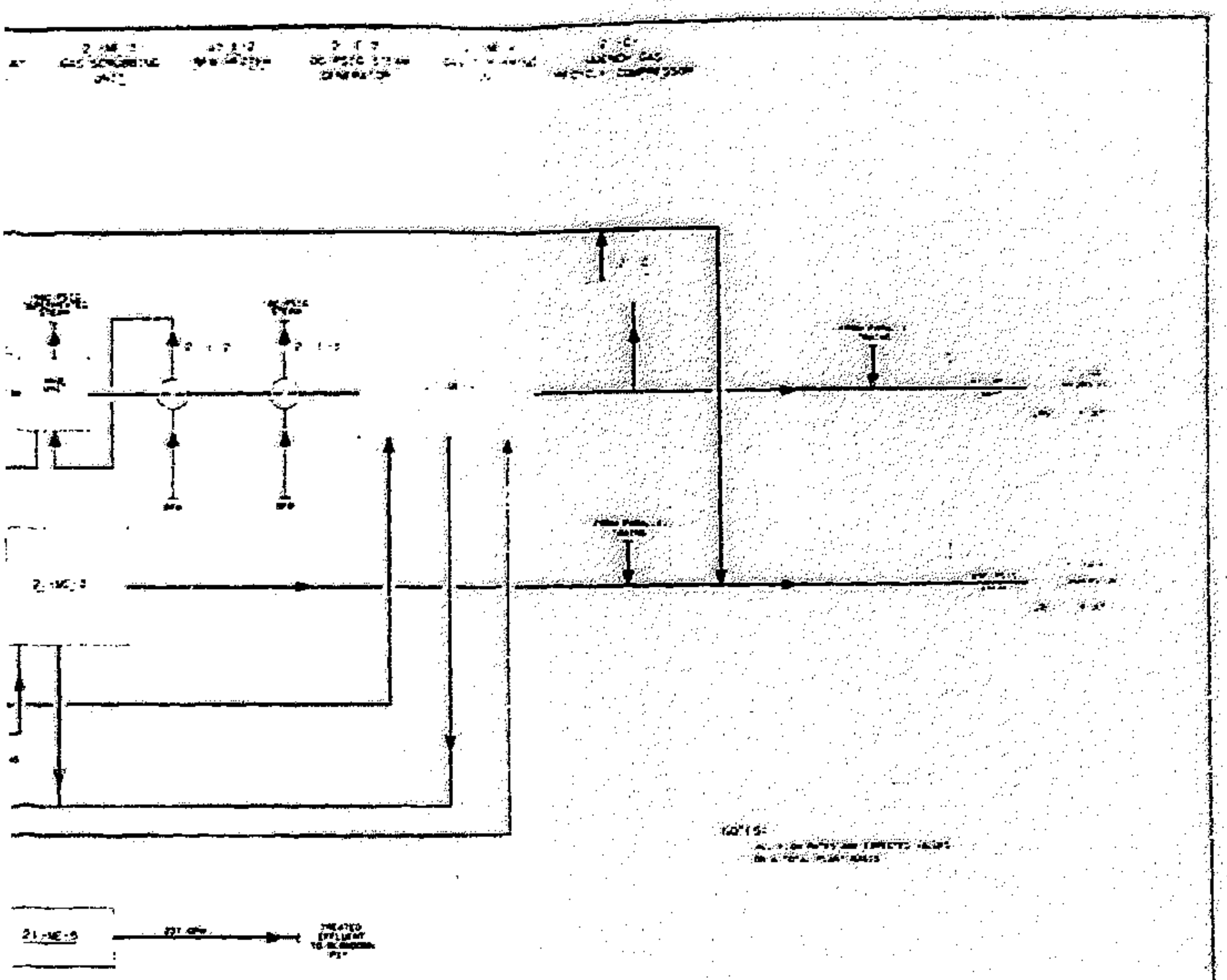
Coal from the handling and storage area is fed to the grinding mills, where it is ground in a two-stage operation. Two 50 percent trains are provided. Coal is then slurried with recycled process water and raw makeup water in a tank of about twenty-four hour capacity. The coal slurry is pumped by charge pumps to the gasifiers. The gasification and ash handling scheme is depicted in Process Flow Diagram 4-004. The number of gasification trains in this area is proprietary. The boxes in Drawing 4-004 represent proprietary sections of the Texaco coal gasification process and each contains several pieces of equipment.

The Texaco gasifier is a refractory-lined vertical vessel in which gasification takes place at elevated temperatures where the ash is molten. The carbonaceous portion of the feed is chemically converted via partial oxidation to a gaseous mixture consisting primarily of H_2, CO, CO_2, and H_2O. Two gaseous streams are produced by the Texaco gasifier: a high-temperature (unquenched) stream from which a large amount of high-level heat is recovered; and a quenched stream containing sufficient water vapor to furnish the chemical needs of the subsequent shift operation. The high-temperature gasifier effluent flows from the gasifier and is combined with quenched recycle gas from the downstream quenching vessel. This combined stream is then processed in a superheating-type waste heat boiler. This waste heat boiler recovers high-level heat from the gas, producing 1500 psig, 900°F steam. Each process gas stream is processed for the removal of finaly divided solids in quenching vessels. Following solids removal, a portion of the unquenched stream is combined with the quenched stream, and the combined stream is sent to the shift unit. The remainder of the unquenched stream flows to the COS hydrolysis unit.

Ash is withdrawn from the gasifiers, sent to the ash dewatering unit, then sent to disposal. Water recovered from the ash and particulates removed from the gas are recycled to the coal slurrying unit. Aqueous blowdown from the gasification unit is processed to an environmentally acceptable effluent in the Texaco waste water treating unit.



COMPONENT	PROCESS STREAM NO. 1 MOLS/HR	PROCESS STREAM NO. 2 MOLS/HR	PROCESS STREAM NO. 3 MOLS/HR
H_2		13,655	34,460
CO		17,743	53,440
CO_2		6,517	22,590
CH_4		178	246
N_2	114	254	492
Ar	522	272	410
H_2S		417	605
COS		27	34
O_2	36,077		
H_2O		13,047	51,[illegible]
TOTAL	36,613	50,490	196,073

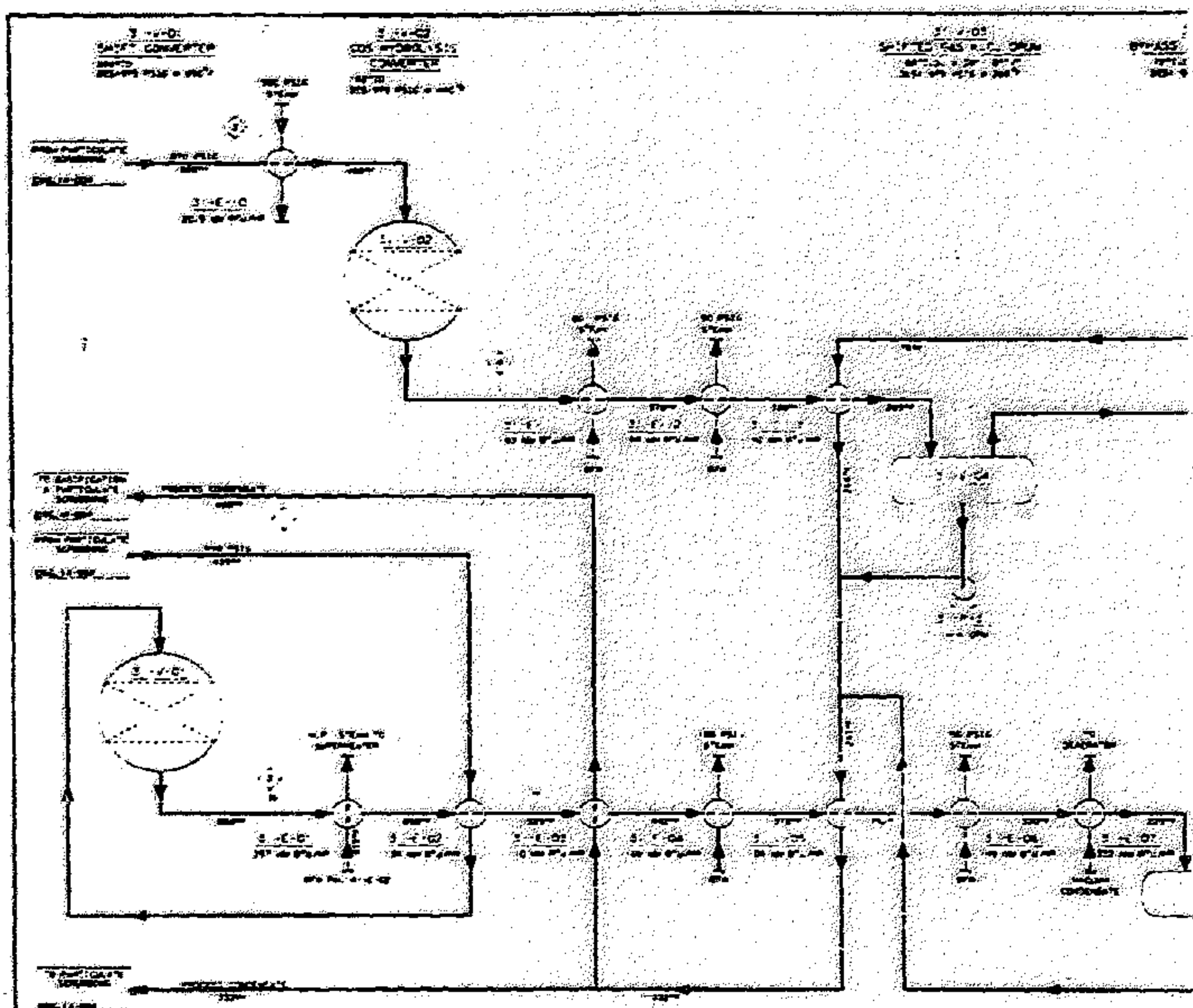


PROCESS FLOW DIAGRAM
GASIFICATION-UNIT 21
COAL TO METHANOL PROJECT

NONE	475004-4-C04	2

UNIT 31 - SHIFT CONVERSION

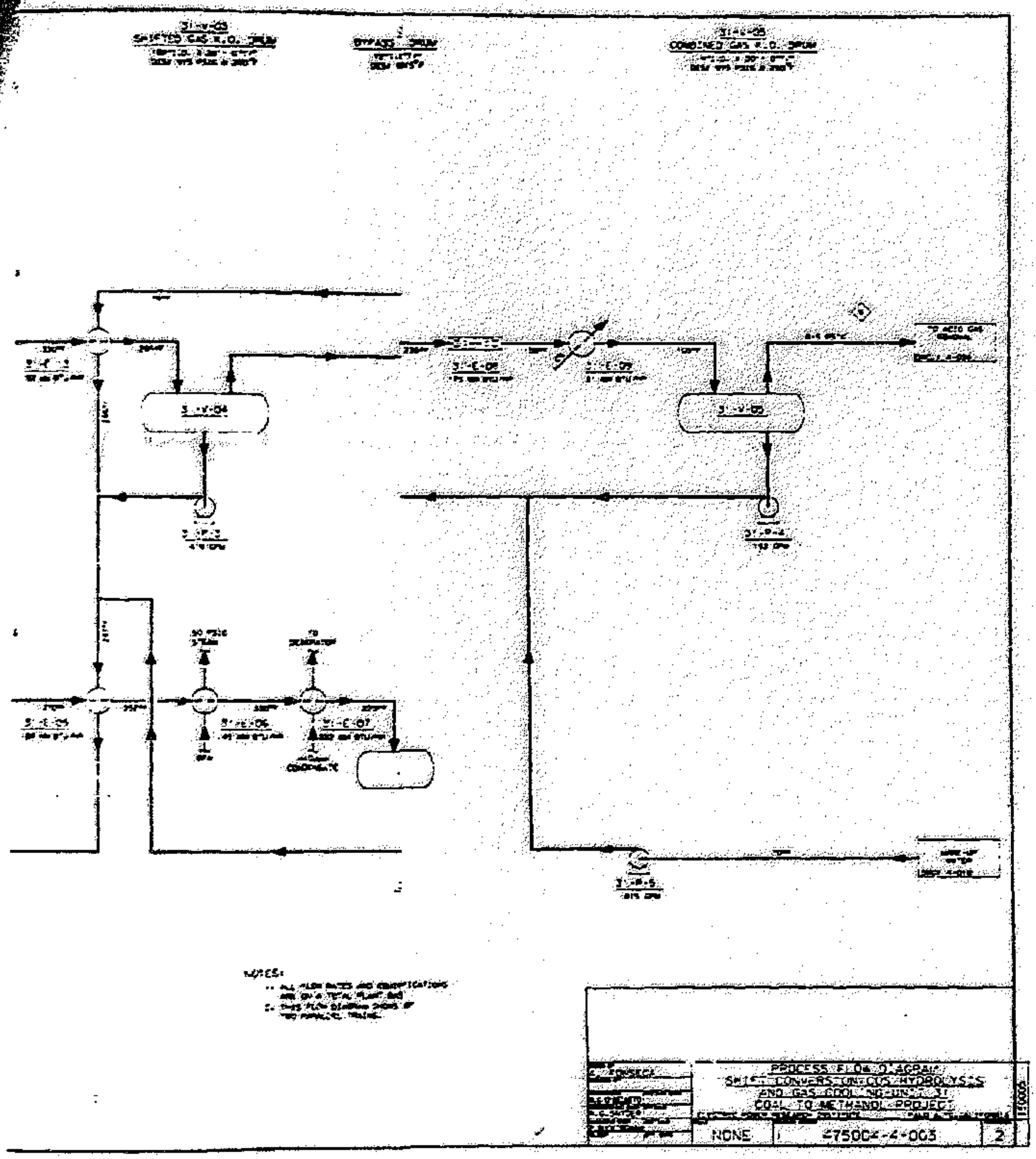
Process Flow Diagram 4-005 depicts the arrangement of equipment in the shift conversion section, where carbon monoxide is shifted to hydrogen via the water gas shift reaction in order to achieve the H_2:CO ratio required by the methanol synthesis unit. Due to the presence of substantial amounts of H_2S in the gas, a cobalt-molybdate shift catalyst offered by a number of different suppliers is used. Part of the gas produced by the gasification section is processed through the shift unit, while the remainder bypasses the shift unit to provide a means of controlling the H_2:CO ratio in the gas leaving the shift conversion section. This bypass gas stream undergoes the COS hydrolysis reaction in the hydrolysis unit, where COS is converted to H_2S in the presence of an activated alumina catalyst. The shift reaction is highly exothermic and substantial amounts of high-pressure steam are generated as the gas is cooled following the shift. An integrated heat recovery scheme involving makeup water heating, process-condensate heating, vacuum condensate heating, and low-pressure steam production is provided. Process condensate, collected from the cooled gas, is reheated and returned to the gasification section.



COMPONENTS (MOL/HR)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	410	412	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	417	[illegible]	[illegible]
COS	[illegible]	[illegible]	27		[illegible]
H_2O	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTES:

1. [illegible]
2. [illegible]


NOTES:
PROCESS FLOW DIAGRAM
SHIFT CONVERSION COS HYDROLYSIS
AND GAS COOLING UNIT 31
COAL TO METHANOL PROJECT
NONE
75004-4-003
2

UNIT 32 - ACID GAS REMOVAL

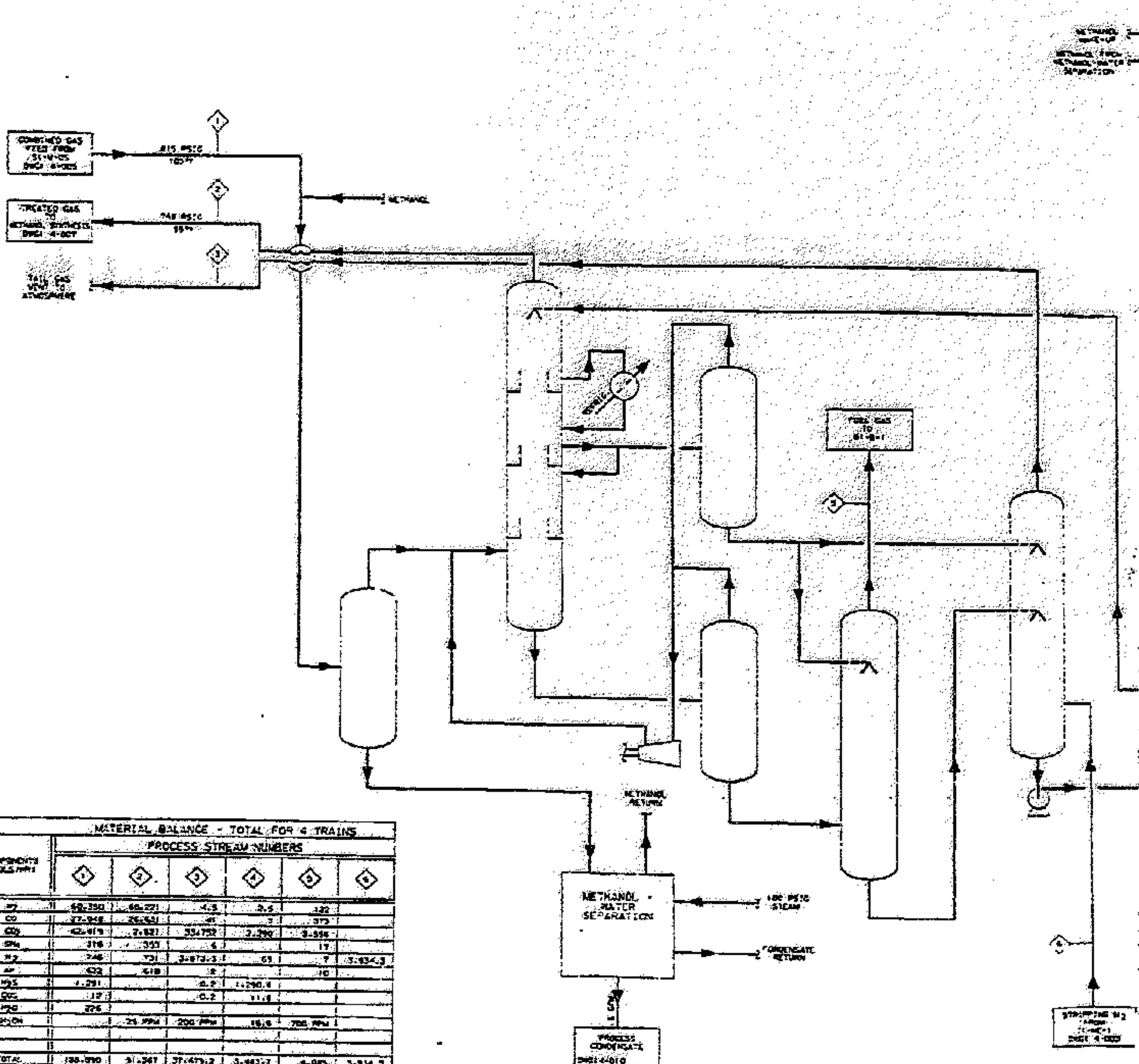
Cooled gas from the shift conversion unit is processed for the removal of acid gases using the Rectisol process licensed by Lotepro, as depicted in Process Flow Diagram 4-006.

Sulfur compounds and carbon dioxide are absorbed from the feed gas by contacting with methanol at low temperature. The treated gas leaves the unit free of sulfur compounds and low in carbon dioxide.

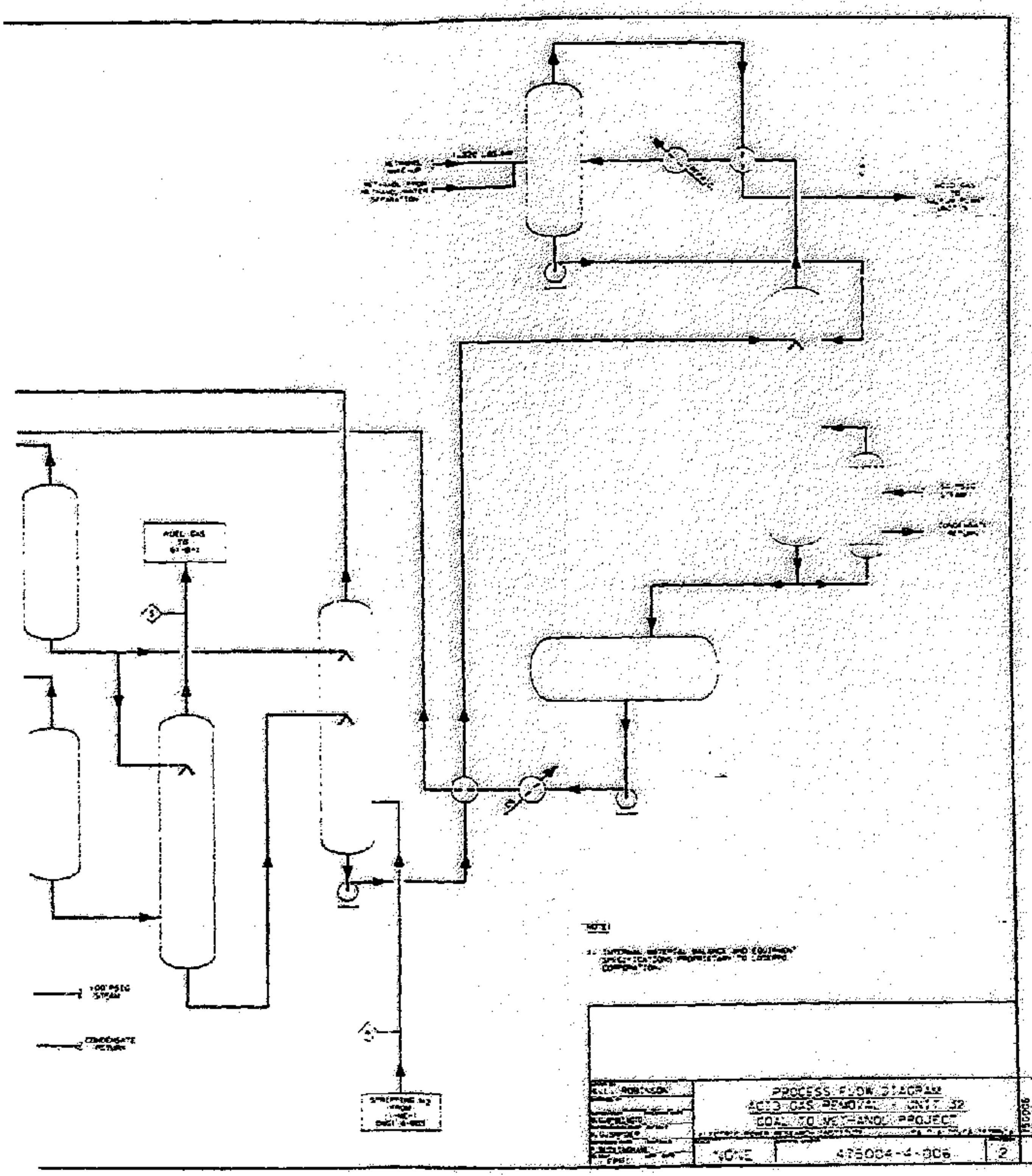
Absorbed gases are removed from the methanol in a three-step methanol regeneration operation, using pressure letdown, thermal stripping, and nitrogen stripping to remove absorbed gases. This regeneration operation yields two CO_2-rich off-gas streams and an H_2S-rich acid gas stream which is suitable for sulfur recovery in a Claus plant. One of the CO_2-rich off-gas streams contains substantial amounts of carbon monoxide and hydrogen and is used as fuel in the boiler plant. The other off-gas stream, consisting of primarily of carbon dioxide and nitrogen, is suitable for direct discharge to the atmosphere.

Since methanol exhibits a higher absorptive capacity for acid gases at low temperatures, solvent circulation rates are reduced by providing refrigeration to the scrubbing operation. The refrigeration requirements are supplied by a mechanical refrigeration system. Refrigeration compressor power requirements are met by condensing-steam turbines using 600 psig, 690°F steam.

A small amount of methanol is lost to the effluent gas streams. Makeup methanol is supplied from the methanol product storage area.



MATERIAL BALANCE - TOTAL FOR 4 TRAINS						
COMPONENTS (MOLS/HR)	PROCESS STREAM NUMBERS					
	1	2	3	4	5	6
H_2	69,350	69,221	4.5	2.5	122	
CO	27,948	26,651	41	3	375	
CO_2	42,419	7,821	33,752	2,290	3,995	
CH_4	316	353	4		17	
N_2	746	731	3,673.3	65	7	3,934.3
AR	432	418	2		10	
H_2S	1,291		0.2	1,290.8		
COS	12		0.2	11.8		
H_2O	226					
CH_3OH		25 PPM	200 PPM	15.6	700 PPM	
TOTAL	138,890	91,367	37,475.2	3,663.7	4,085	3,934.3



PROCESS FLOW DIAGRAM
ACID GAS REMOVAL - UNIT 32
COAL TO METHANOL PROJECT
NONE
2

UNIT 41 - METHANOL SYNTHESIS AND REFINING

Methanol Synthesis

The methanol synthesis and refining areas produce 10,927 ST/day of fuel-grade methanol. ICI's low-pressure methanol synthesis technology was used in the design of the synthesis unit. The methanol synthesis unit is depicted in Process Flow Diagram 4-007.

Synthesis gas at 768 psig from the acid gas removal area is divided into four equal streams and processed through four methanol synthesis units. The main components of each unit are a sulfur guard system, a recycle compressor, a multibed quench-type synthesis converter followed by a single-bed adiabatic synthesis converter, and a system of heat exchangers.

Synthesis gas entering each unit is passed through the desulfurizer drums which act as a sulfur guard for the methanol synthesis catalyst. A zinc oxide adsorbent is used to adsorb both H_2S and COS at ambient temperature. The two beds operate in series: when sulfur leakage through the first bed is noted, it is taken off-line, recharged with fresh adsorbent, then returned to service. Each of the two drums is designed to operate on stream for six months.

From the desulfurizer drums, the fresh feed gas combines with recycle gas and is compressed in the synthesis loop recycle compressor. The compressor is driven by a condensing steam turbine using 600 psig, 690°F steam.

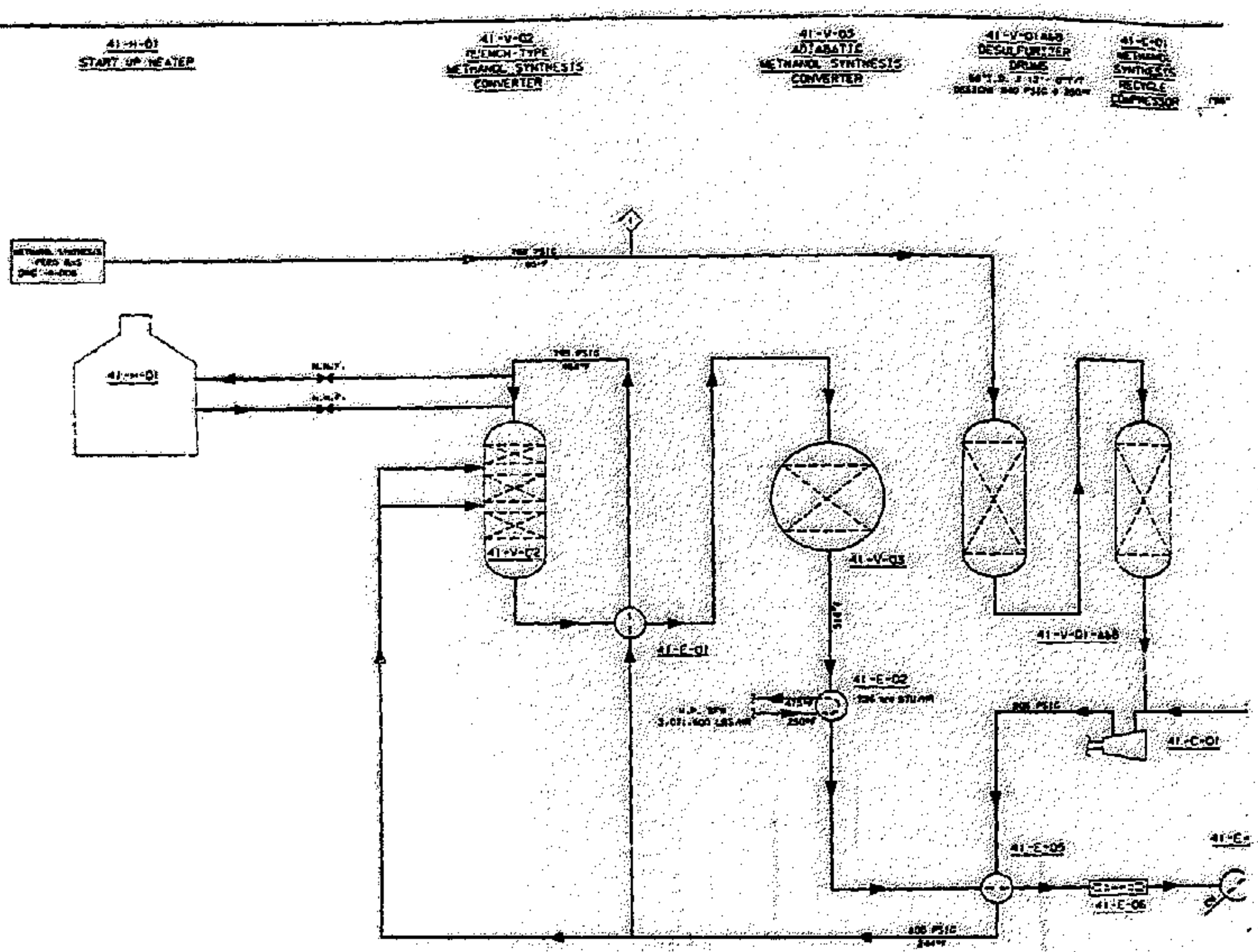
The compressed gas is preheated by exchange with the adiabatic converter effluent gas. The gas is then divided into two streams: a feed stream and a "warmshot" quench stream. The feed stream is preheated to reaction temperature via exchange with multibed converter effluent and is introduced into the first bed of the multibed converter. The quench stream is further divided into several streams which are injected into the converter between each of the catalyst beds in a series of "warmshot" interbed quenches. Each "warmshot" then joins the main flow to provide feed to the successive catalyst beds. The use of this "warmshot" design provides effective temperature control for the exothermic methanol synthesis reaction and enhances the thermal efficiency of the synthesis loop. The effluent from the multibed converter is cooled against the feed gas and introduced to the final catalyst bed in the adiabatic converter.

The outlet gas from the adiabatic converter contains methanol together with unreacted CO, H_2 and CO_2; inerts such as N_2, Ar, and CH_4; and by-products such as water, heavier alcohols, dimethyl ether, and other light ends. To separate the methanol from the unreacted gases the converter effluent gas is cooled to 105°F in a series of exchangers; a high-pressure boiler feedwater preheater, a converter feed-effluent exchanger, an air cooler, and a water-cooled trim cooler. The resultant two-phase mixture is separated in the high-pressure separator. The bulk of the unreacted gases are combined with fresh synthesis gas and recycled. Liquids are flashed at 55 psig in the low-pressure separator to release dissolved gases which are sent to the methanol refining area. The resultant crude methanol is then pumped to the methanol refining area.

Since a buildup of inerts (N_2, Ar, CH_4) results from the recycle of unreacted gases in the synthesis loop, a purge stream of gas is taken from the high-pressure separator to provide an outlet for these inerts. The purge streams from the four synthesis loops are combined and processed to recover hydrogen at 640 psig in a pressure-swing adsorption unit offered by the Linde Division of Union Carbide. The tail gas, consisting mainly of H_2, CO, CO_2 and CH_4, is sent to the fuel-gas collection drum to be used as boiler fuel. The recovered hydrogen is compressed with motor-driven reciprocating compressors, redistributed to the four synthesis loops, and combined with the suction stream of each synthesis loop recycle compressor.

The material and utility balances for the methanol synthesis section apply to average conditions expected over the life of the catalyst. They represent, then, middle-of-run conditions, not end-of-run. For a large four-train facility such as described herein, it should prove feasible to manage the catalyst so as to provide a staggered schedule for catalyst replacement. Additional head and capacity have been specified for each circulator to allow increased circulation during periods when the catalyst is approaching the end of its useful life.

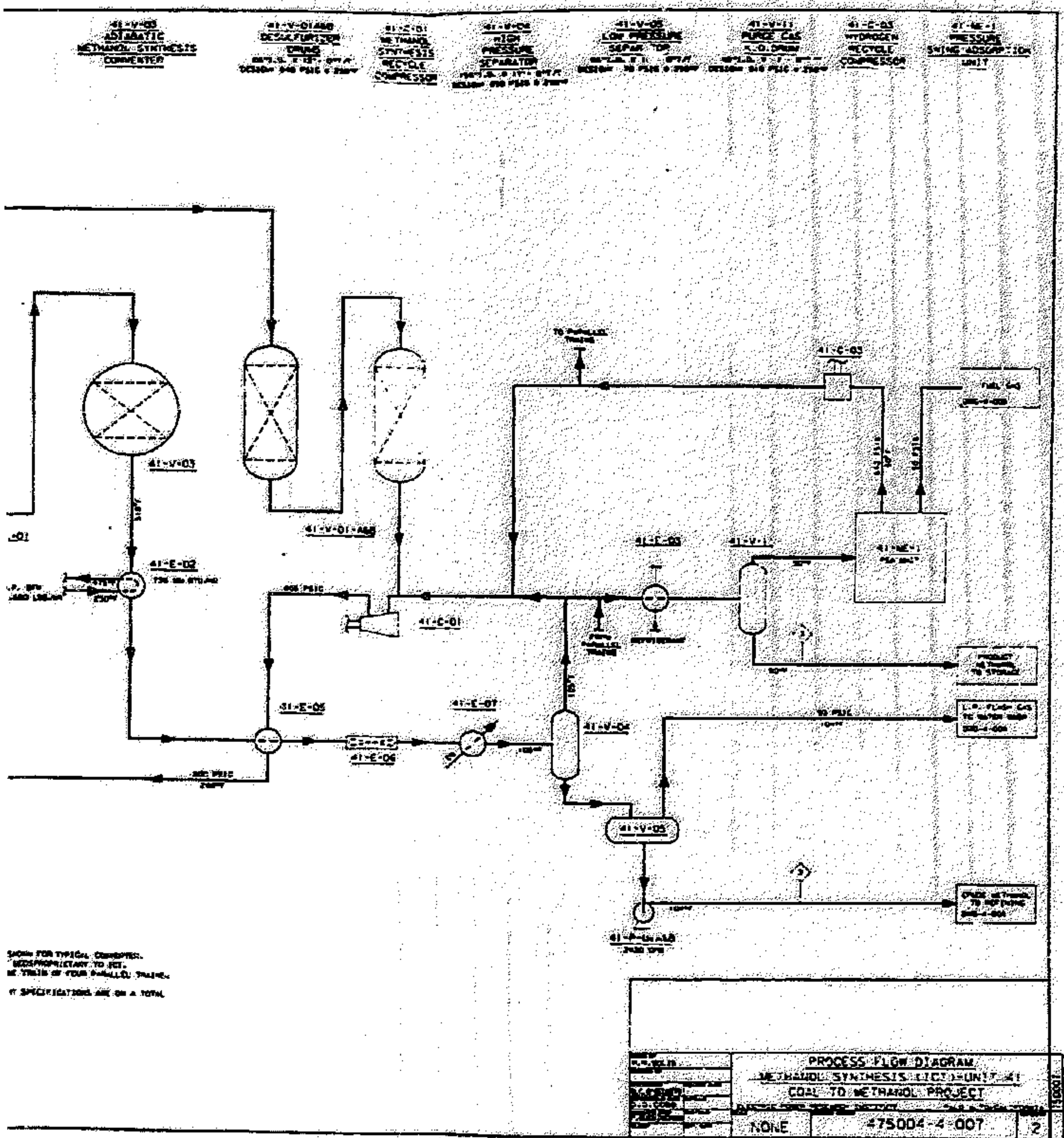
Had the plant efficiency been calculated for end-of-run instead of middle-of-run conditions, overall thermal efficiency would have been reduced by about one point from 57.86 to about 57 percent (based on HHV of product methanol).



MATERIAL BALANCE TOTAL FOR 4 TRAINS			
	1	2	3
COMPONENT	MOLS/HR	MOLS/HR	MOLS/HR
H_2	60,337	8.9	
CO	26,831	4.5	
CO_2	2,821	139.0	
CH_4	353	7.8	
N_2	731	2.5	
Ar	818	2.6	
CH_3OH		26,145.6	41
LIGHT ENDS		15.0	
IMPURITIES		15.0	
H_2O		2,344.0	
TOTAL	91,287	30,410.3	42

NOTES:

1. 41-V-02 FEED ARRANGEMENT SHOWN FOR TYPICAL CONVERTER. ACTUAL NUMBER OF CATALYST BEDS PROPRIETARY TO ICI.
2. THIS FLOW DIAGRAM SHOWS ONE TRAIN OF FOUR PARALLEL TRAINS EXCEPT 41-HE-1 (1 TRAIN).
3. ALL FLOWRATES AND EQUIPMENT SPECIFICATIONS ARE ON A TOTAL PLANT BASIS.


41-V-03
ADIABATIC
METHANOL SYNTHESIS
CONVERTER
41-V-01A&B
DESULFURIZER
DRUMS
41-C-01
METHANOL
SYNTHESIS
RECYCLE
COMPRESSOR
41-V-04
HIGH
PRESSURE
SEPARATOR
41-V-05
LOW PRESSURE
SEPARATOR
41-V-11
PURGE GAS
K.O. DRUM
41-C-03
HYDROGEN
RECYCLE
COMPRESSOR
41-ME-1
PRESSURE
SWING ADSORPTION
UNIT
41-V-03
41-E-02
41-C-01
41-E-05
41-E-06
41-E-07
41-V-04
41-V-05
41-C-03
41-V-11
41-V-01-A&B
PROCESS FLOW DIAGRAM
METHANOL SYNTHESIS (ICI)-UNIT 41
COAL TO METHANOL PROJECT
NONE
475004-4-007
2