Section 19

GREAT PLAINS GASIFICATION ASSOCIATES SNG FROM COAL PLANT: START UP AND OPERATION

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Section 1

INTRODUCTION

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Great Plains Gasification Associates (GPGA) is the United States' first commercial-sized synthetic fuel project based on coal conversion. It has come a long way since the early 70s (Table 1), but through the consortium's (Figure 1), dedication and preserverance, the project has finally come into being. The GPGA plant, meanwhile, has been started up on schedule and is now operating.

Coal conversion technology makes possible or enhances the use of the world's most abundant energy resource for a variety of industrial applications: SNG, fuel gas, electricity, methanol and other basic chemicals can all be made from coal. Via coal conversion, a dirty solid, laden with ash, sulfur, many other contaminants is turned into clean, well-defined products. In a process scheme for one of the above products, gasification is always the major step. This produces a crude gas, which is then further conditioned depending on the particular application. Commercially proven processes are available for the entire process chain, e.g., in the case of GPGA, gasification, carbon monoxide shift conversion, gas purification and methanation to name the most important ones. In the GPGA plant, all of these are Lurgi processes.
From an environmental point of view, the application of the "best available control technology" will ensure that coal conversion plants can be designed to meet today's rather stringent environmental requirements.

GPGA PROJECT — ABBREVIATED HIGHLIGHTS
1972 — 1984

MAY	1972	* ANR OBTAINED COAL OPTIONS
FEBRUARY	1974	* WATER PERMIT RECEIVED
JULY	1974	* 12,000 T. LIGNITE TO SASOLBURG, S.A. — TESTING
	1979	* BEGIN OF DETAILED ENGINEERING
JULY	1980	* PRESIDENT CARTER APPROVED A CONDITIONAL LETTER OF COMMITMENT — $ 240 MILLION LOAN GUARANTEE
AUGUST	1981	* PRESIDENT REAGAN AUTHORIZED DOE TO ISSUE CONDITIONAL LOAN GUARANTEE — $ 2.02 BILLION
AUGUST	1981	* FULL SCALE CONSTRUCTION COMMENCED
JANUARY	1982	* LOAN AGREEMENT EXECUTED
OCTOBER	1983	* BEGIN OF COMMISSIONING AND START—UP
FALL	1984	* ALL UNITS AND EQUIPMENT HAVE BEEN OPERATED

TABLE 1

GREAT PLAINS GASIFICATION ASSOCIATES
ORGANIZATION

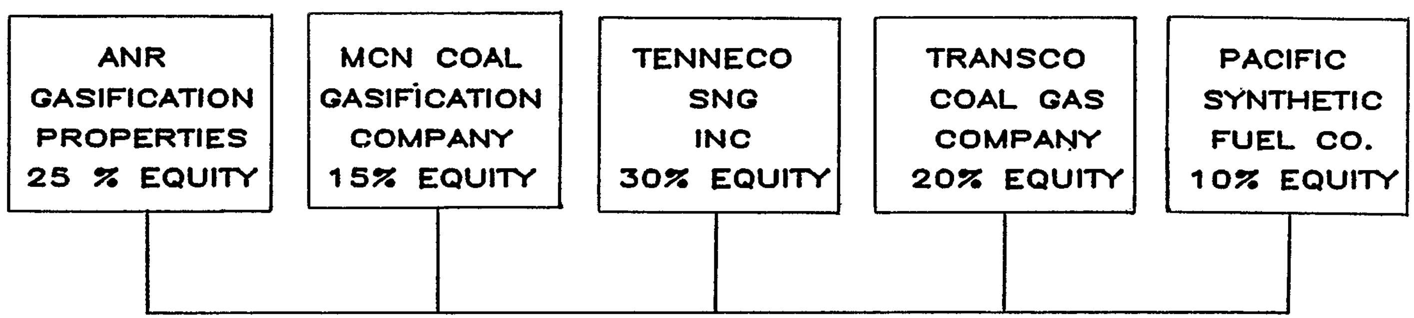

FIGURE 1

Section 2

THE LURGI ROUTE FOR COAL TO SNG

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SNG PRODUCTION

Figure 2 shows a simplified block flow diagram to illustrate the SNG production route. GPGA uses North Dakota lignite, surface mined in the "Freedom Mine" situated adjacent to the plant site. Run of mine coal is crushed and screened. Then 1/4-inch by 2-inch fraction is used for gasification while the undersize is conveyed to an adjacent Basin Electric power plant, Antelope Valley Unit No. 1.

A total of 14 Lurgi MK IV dry bottom gasifiers are installed. They are operated according to the fixed bed, countercurrent principle, using a mixture of steam and oxygen as the gasification agent. The operating pressure is 430 PSIG. Table 2 represents a typical gas analysis of the GPGA crude gas. Unlike the gas from other coal gasification processes, Lurgi crude gas contains a considerable amount of methane, in fact about 40 percent of the total methane leaving the plant. This is, of course, advantageous in that it necessitates much smaller methanation capacity. After particulates removal and cooling of the crude gas to 370^{o}F, part of it is converted catalytically in the shift conversion unit. Carbon monoxide shifting is required as the crude gas contains H_2 and CO at a ratio of approximately 2.5. For the downstream methanation process, however, an H_2/CO ratio of greater than three is required. Crude gas and converted gas are then cooled down separately to 95^{o}F, and mixed thereafter. In the gas cooling units, medium and low pressure steam is generated for in-plant use, and boiler feedwater is preheated. The latent heat of both crude and converted gas is thus utilized rather efficiently. The mixed gas is routed to the Rectisol Unit where naphtha, sulfur and most of the CO_2 are removed by washing the gas with methanol at very low temperatures. Sulfur recovery is via the Stretford process. The clean gas is then routed to

GPGA PLANT LIGNITE TO SNG
BASED ON LURGI COAL TO SNG PROCESS

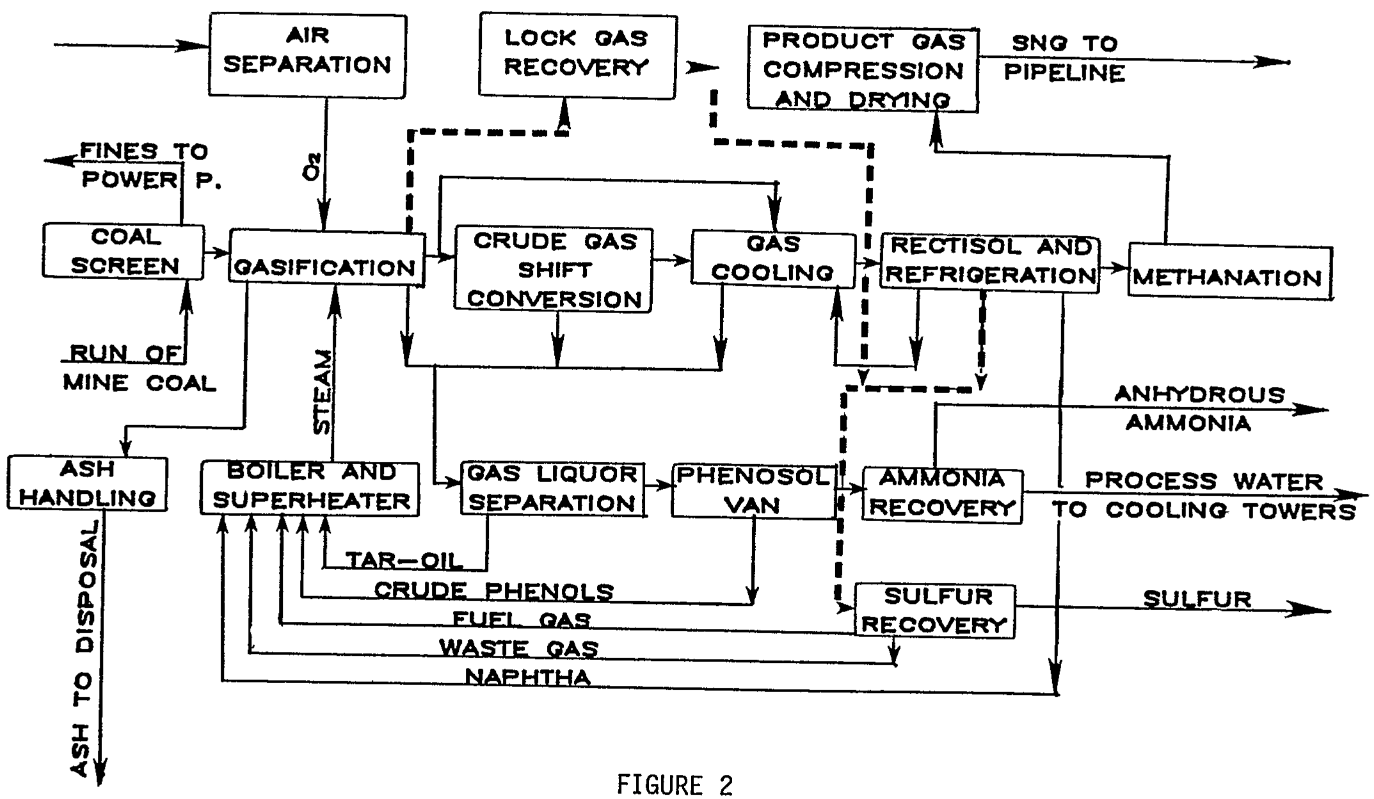

FIGURE 2

CRUDE GAS COMPOSITION

	DESIGN	ACTUAL
H_2 / CO	2.47	2.5
CO_2 + H S	33.0	32.0
CO	15.9	15.8
H_2	39.3	39.6
CH_4	11.0	11.8
C_NH_M	00.8	00.8
	------	------
	100.00	100.00

TABLE 2

the Methanation Unit where CO and H_2 are reacted catalytically to CH_4 and water. The product gas has a heating value of about 970 BTU per SCF. After drying and compression, it is fed into the pipeline.

THE GAS LIQUOR ROUTE

Upon cooling the crude and converted gas to 95^{0}F, water, tar oil, phenols, ammonia and other products from coal carbonization are condensed from the gas stream. These components are routed first to the Gas Liquor Separation Unit, where liquor is separated by gravity from the tar oil which is used as boiler fuel. The liquor then goes to a Phenosolvan Unit, where phenols are recovered. They too are being used as boiler fuel.

The dephenolized gas liquor is then treated in the Phosam plant where ammonia is recovered as a saleable product (anhydrous ammonia).

Phosam effluent water, finally, can be used directly as makeup for the cooling water system and is biologically treated in the cooling towers. The cooling water system is a rather unique process in that it combines biological treatment of stripped gas liquor within a cooling water system.

Use of the cleaned gas liquor as cooling water considerably reduces the water requirements of the plant, as approximately 30 percent of the gas liquor originates from lignite moisture which is thus made usable.

ADVANTAGES OF THE PROCESS SCHEME - SUMMARIZED

- Commercially proven processes are at work throughout the main process trains.
- For the feedstocks used, the Lurgi dry bottom gasifier's efficiency is second to none.
- Some 40 percent of total methane output is produced in the gasifier, resulting in accordingly lower methanation capacity requirements.
- High overall thermal efficiency of over 65 percent is achieved.

- SNG is produced under pressure, resulting in a lower compression energy requirement.
- Maximum re-use of water is achieved through work-up of gas liquor/coal moisture into cooling water.
- No by-products other than ash, sulfur and ammonia must leave this site.

Section 3

START-UP OF THE GPGA PLANT

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Start-up activities began with the handing over of the plant from construction to operations beginning with the water treating plant in August, 1983.

GPGA received the mechanically completed systems from American Natural Gas Company (ANG), the project administrators.

Next, the plant was thoroughly checked from an operating and safety point of view.

As it turned out, relatively few start-up modifications were required to ensure a "clean" start-up and safe operation of the process units. This is good evidence of the excellent cooperation between all parties involved - and indeed, there were quite a few:

- ANG (U.S.) as project administrators
- GPGA (U.S.) as owners/operators of the plant
- Parsons (U.S.) as licensors
- Lurgi (Germany) as licensors/engineers and start-up advisors
- Lummus (U.S.) as engineers
- Kaiser (U.S.) as engineers/constructors
- Sasol (S.A.), teamed up with Lurgi as start-up advisors
- Lotepro/Linde (U.S./Germany) turn key contractors
- Riley (U.S.) turn key contractors
- Others

The start-up of the SNG process units was GPGA's responsibility. A team made up of Lurgi and Sasol engineers were on-site to work as consultants to GPGA during the start-up.

Under GPGA's overall responsibility, the start-up of the SNG process units went along very smoothly, and in adherence to a rather tightly planned schedule. The fact that the first million manhours without a lost time accident was already achieved in December 1984 clearly demonstrates that even so large a complex can be started up with undue safety problems if a "safety first" philosophy is followed at all times.

OVERALL START-UP SCHEDULE PROCESS UNITS

Based on the plant's two-train concept, (see Figure 3) one train could be started while the other was still being mechanically completed - a major factor for GPGA's ability to stick to a rather tight schedule.

In sequential order, the units were started up as follows:

- Utilities (cooling water, plant air, steam, oxygen, coal and ash handling, etc.).
- Gasification/gas liquor separation.
- Gas cooling.
- Rectisol.
- At this point, the gas ex-Rectisol went to flare.

Next came

- CO shift conversion, and
- Methanation

As far as gas liquor dephenolization (Phenosolvan plant) is concerned, the start-up was not immediately required as the unit has a large buffer tank (two days at full gas production) in front of it.

Figure 4 shows an overall, bar chart type schedule for the start-up of the process units. The utilities took about ten months to commission and make reliable.

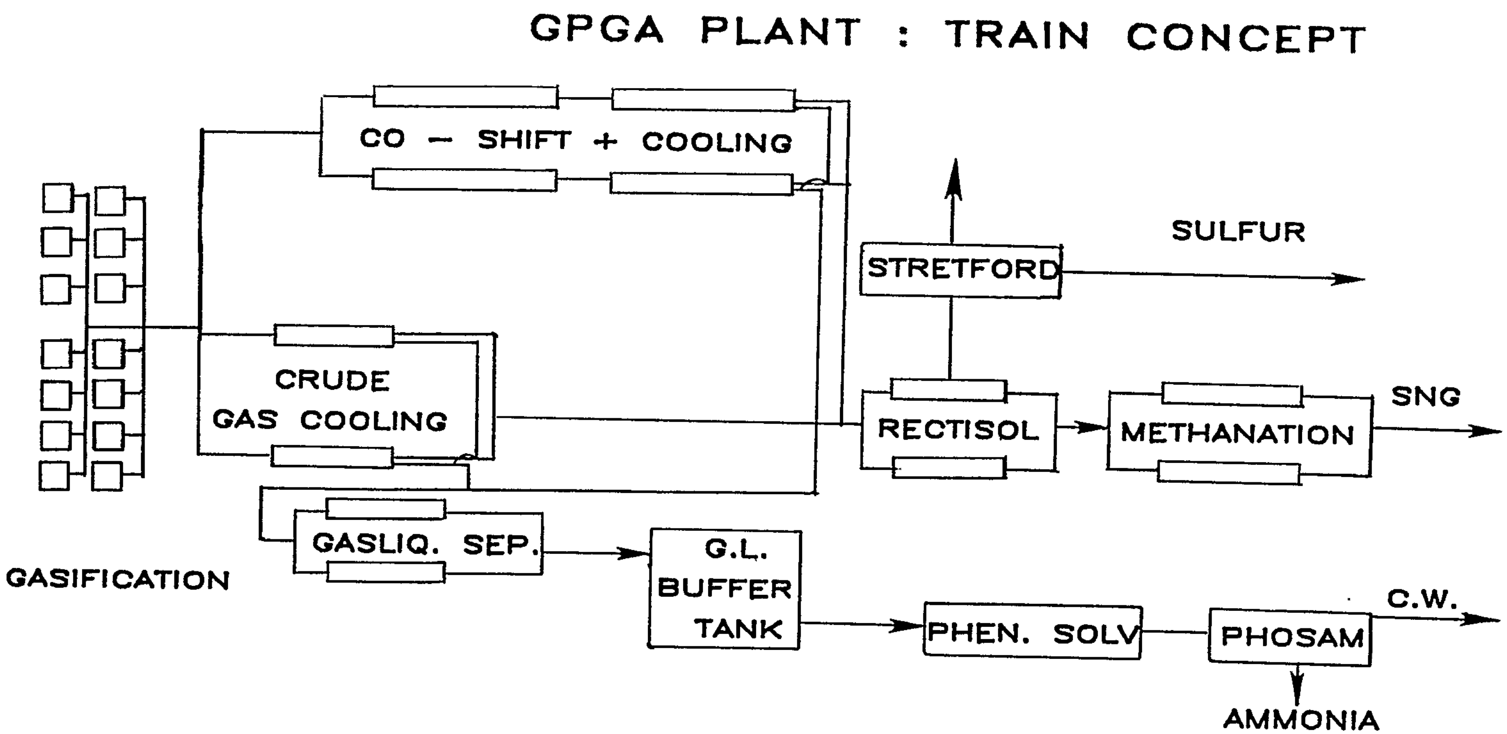
GPGA PLANT : TRAIN CONCEPT
CO - SHIFT + COOLING
SULFUR
STRETFORD
CRUDE
GAS COOLING
RECTISOL
METHANATION
SNG
GASLIQ. SEP.
G.L.
BUFFER
TANK
GASIFICATION
C.W.
PHEN. SOLV
PHOSAM
AMMONIA

FIGURE 3

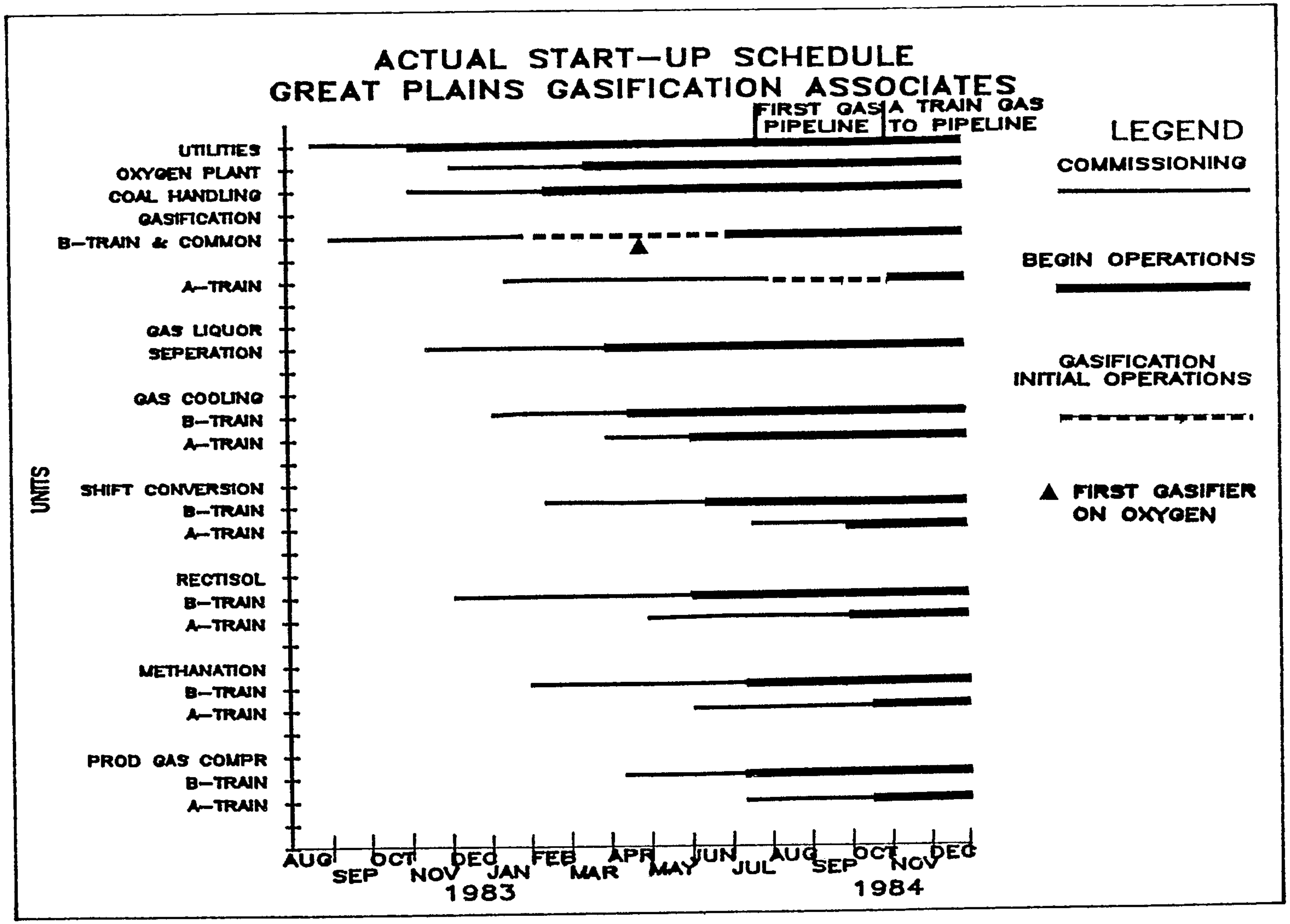
ACTUAL START–UP SCHEDULE
GREAT PLAINS GASIFICATION ASSOCIATES
FIRST GAS PIPELINE
A TRAIN GAS TO PIPELINE
LEGEND
COMMISSIONING
BEGIN OPERATIONS
GASIFICATION INITIAL OPERATIONS
FIRST GASIFIER ON OXYGEN
UNITS
UTILITIES
OXYGEN PLANT
COAL HANDLING
GASIFICATION
B–TRAIN & COMMON
A–TRAIN
GAS LIQUOR
SEPERATION
GAS COOLING
B–TRAIN
A–TRAIN
SHIFT CONVERSION
B–TRAIN
A–TRAIN
RECTISOL
B–TRAIN
A–TRAIN
METHANATION
B–TRAIN
A–TRAIN
PROD GAS COMPR
B–TRAIN
A–TRAIN
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1983
1984

FIGURE 4

The schedule shows that approximately seven weeks were required to bring the first train of seven gasifiers on line. After these seven weeks, there were few interruptions of gas production due to gasifier or instrument failures - a good demonstration of the Lurgi MK IV gasifiers' rather high availability.

Another quite interesting feature of Figure 4 is that for the start-up of the first train (including the gasifier train) approximately three and a half months were required. On the other hand, the second train (including the gasifier train) took only two and a half months to start, indicating both good progress on the learning curve and proof of the wisdom of adopting the two train concept.

The entire start-up period has proven that the processes installed in the SNG production route can be started up and operated safely. Of course, this does not mean that the only start-up effort was to push a few buttons and the plant would run. As in any similarly-sized installation, the main start-up effort was to get all the various pieces of equipment in shape for orderly operation. Among thousands of control loops, valves, pumps, seals, gaskets and drive units, some obviously just don't want to work, would rather abide by Murphy's Law. However, GPGA's operations and maintenance departments got the "trouble makers" quickly and efficiently under control, thus helping very significantly to maintain the start-up schedule.

START-UP OF GASIFICATION

Prior to starting up the first gasifier, the following has to be operative:

- Coal supply
- Utilities, including start-up air
- Ash removal
- One train of gas cooling and gas liquor separation
- Flare system

The gasifier is first charged with coal. This is then preheated with steam. After a certain temperature has been reached, air is injected. This causes the coal to ignite, followed by a gradual set-in of gasification reactions. The whole process can be closely monitored by analyzing the respective gas composition. Air operation, typically at 70 to 100 PSI, would normally last five to six hours. The gasifier would then be switched to oxygen and pressure would be increased to full operating pressure.

However, in order to familiarize the operating teams with the process, one gasifier was operated for several days on air.

On April 28, 1984, the first gasifier was switched over to oxygen operation, it was then brought up to full pressure (400-430 PSI) within hours, and to full capacity during the second day of operation. In the following weeks all the other gasifiers of the first train were started up for the first time at a rate of one gasifier a week. Further start-ups required much less time. During this period, cooled crude gas was mostly used in the boiler plant. The consumption of natural gas could thus be minimized.

At the same time, the operation of the first gas cooling train and the first gas liquor separation train was stabilized.

START-UP OF GAS LIQUOR SEPARATION

The actual start-up of the Gas Liquor Separation Unit comprises four major steps:

- Establish run down tank level for gas liquor injection into gasification.
- Allow separators to fill up.
- Start decanting tar oil.
- Start tar reinjection to gasification.

In gas liquor separation, the tar oil condensed in the waste heat exchangers of gasification and in the gas cooling section are separated from the gas liquor by gravity. For good separation, tar oil and gas liquor must not be emulsified. However, gas liquor did form an emulsion during the early days of operation on oxygen.

At this point, the first gas cooling train was not yet in operation. After the gas cooling train had been started and condensate from the gas cooling heat exchangers had been mixed with gas liquor from the first waste heat exchangers, the emulsion did break and proper separation was subsequently achieved. A few days later, tar oil product could be transferred as fuel to the boiler plant. A minor modification of gas liquor flow and heat exchange helped improve separation efficiency. The unit has been operating almost troublefree since then.

START-UP OF GAS COOLING

This unit serves to cool the crude gas from approximately 370°F to 95°F. In the process, lower boiling tar oil fractions and gas liquor will condense. The latter's main components are water, phenols, fatty acids, ammonia, H_2S, and some CO2 are also dissolved in the gas liquor. In the gas cooling unit, 60 and 25 PSI steam for in-plant use is raised and boiler feedwater is preheated. Major steps of the unit's start-up are as follows:

- Purge with nitrogen.
- Commission the L.P. steam, BFW and cooling water systems.
- Pressurize with crude gas.

The gas cooling unit came on line without any problems.

CO SHIFT CONVERSION START-UP

In the CO Shift Conversion Unit, CO is converted catalytically to H_2. The major start-up activities of the Shift Conversion Unit included the following steps:

- Purge with nitrogen.
- Heat up train/catalyst.
- Sulfide with a mixture of inert gas, steam, crude gas.
- Gradually cut out steam and inert gas.

Monitoring of the appropriate temperature will indicate the set-in of the shift reaction.

RECTISOL START-UP

In the Rectisol Unit the cooled crude gas is finally conditioned for the Methanation Unit. Naphtha, almost all CO_2 (down to approximately one volume percent), H_2S, COS and organic sulfur is removed from the mixed crude gas by washing it at low temperatures with methanol. Rectisol's main start-up steps were these:

- Purge and pressurize with nitrogen.
- Flush unit with water.
- Establish correct methanol levels.
- Start and stabilize methanol loops.
- Start refrigeration system to cool down the unit slowly.
- Start feeding crude gas.
- Cool down to operating temperatures.

No major problems did occur in this period and it did take but a few days until clean synthesis gas could be routed to the Methanation Unit. A later problem of organic sulfur buildup in the methanol, unique to North Dakota lignite, did occur after a few months operation.

METHANATION START-UP

In the Methanation Unit the H_2, CO and the CO_2 are converted catalytically to CH_4 and water. The CH_4 content of the feed gas to methanation passes through the unit unchanged, i.e., as an inert. The methanation reaction is highly exothermic. The heat of reaction is used to raise 1250 PSI steam which thus lowers the HP steam requirements for gasification. The methanation start-up included the following main steps:

- Purge with nitrogen.
- Start recycle loop.
- Heat up of catalyst bed.
- Reduce catalyst with hydrogen.
- Feed gas from Rectisol.

After these steps, gas first produced on April 28, 1984 in the Lurgi MK IV gasifiers, then partially shifted, then purified in Rectisol, was introduced into the Methanation Unit for the first time on July 23, 1984. Just five days later (July 28, 1984) indeed was a great day for GPGA in that for the first time, substitute natural gas was pumped into the pipeline.

START-UP OF PHENOSOLVAN

In the Phenosolvan Unit, phenols are extracted from gas liquor by I-propylether (IPE). Phenols are separated from IPE by distillation. Phenosolvan was started up according to the following procedure:

- Flush extractors, columns, filters etc. with water.
- Purge with nitrogen.
- Fill unit with gas liquor.
- Establish phenol levels.
- Establish IPE levels.
- Heat up distillation.
- Start extraction.

The Phenosolvan Unit came into operation without problems worth mentioning after the emulsion problems in gas liquor separation had been solved.

Section 4

INITIAL PLANT OPERATION

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Obviously, one cannot expect that so huge an industrial complex comprising a large number of both utility and process units will operate from the onset without problems. As is the case with each similarly sized plant, this one had its share.

Control system, mechanical equipment, trip system failures, etc. may cut out part or all of the SNG process units.

However, in order to minimize production losses, it is highly important that failures be both detected and fixed in less than 30 minutes, lest gasifiers have to come down. Within 30 minutes, the gasifiers can be restarted immediately, whereas after half an hour they have to be depressurized first and then restarted, which is, of course, more time consuming.

In case of a trip of a unit downstream of gasification, the gasifiers can stay in operation at minimum load and can be brought back to high load in a relatively short time. Thus, trips occurring upstream of gasification (such as in steam supply) would usually cause longer downtimes of the SNG production than would downstream trips.

However, GPGA managed within the first couple of weeks of the initial operating period to lower the duration of production interruptions due to equipment and other failures from days to hours. Likewise, the number of outages was reduced significantly to what is now a reasonable level for this stage of operation in a plant with 3,000 pieces of major equipment and 10,000 instrument loops.

SNG PRODUCTION RATES

After the start-up of the first methanation train (end of July 1984), SNG was produced at rates of approximately 50 MM SCFD (or 37 percent of design) until the end of October (see Figure 5). During this period, the SNG process units did trip several times, mainly caused by utility failures.

Also in this period, Process Operations felt more and more at home with both the individual processes and the entire process route. After the second SNG process train had been started up, the period began in which production rates were more or less pushed up continuously. By January 1985, SNG production rates as high as 116 MM SCFD had been reached, about 88 percent of design capacity. Except for Rectisol, the SNG process units can now be operated at design production levels.

At the time of writing this paper (January 1985), Rectisol still suffered from some problems in methanol distillation and regeneration. These are probably caused by a higher-than-expected amount of heavy sulfur compounds.

GPGA and Lurgi are actively working on overcoming these problems and we are sure that we will soon be able to report that Rectisol does live up to its reputation and the entire SNG process line is operating at design production rates.

EFFICIENCY OF SNG PRODUCTION

The GPGA plant has not yet been operated at design production rates. Also, the operating time since the start-up is rather short. Therefore, the overall efficiency could not yet be finally proven. However, in order to give at least an approximate figure for the efficiency of the Lurgi SNG production route (Table 3), heat and material balances around gasification and gas cooling, gas losses of Rectisol as well as the total electric power consumption were taken into account.

Tar oil, naphtha, phenols and lock gas are fired in boilers to produce 1100 PSI steam. The 1250 PSI steam produced in the methanation unit is superheated and used in gasification after first turning turbines in the Oxygen

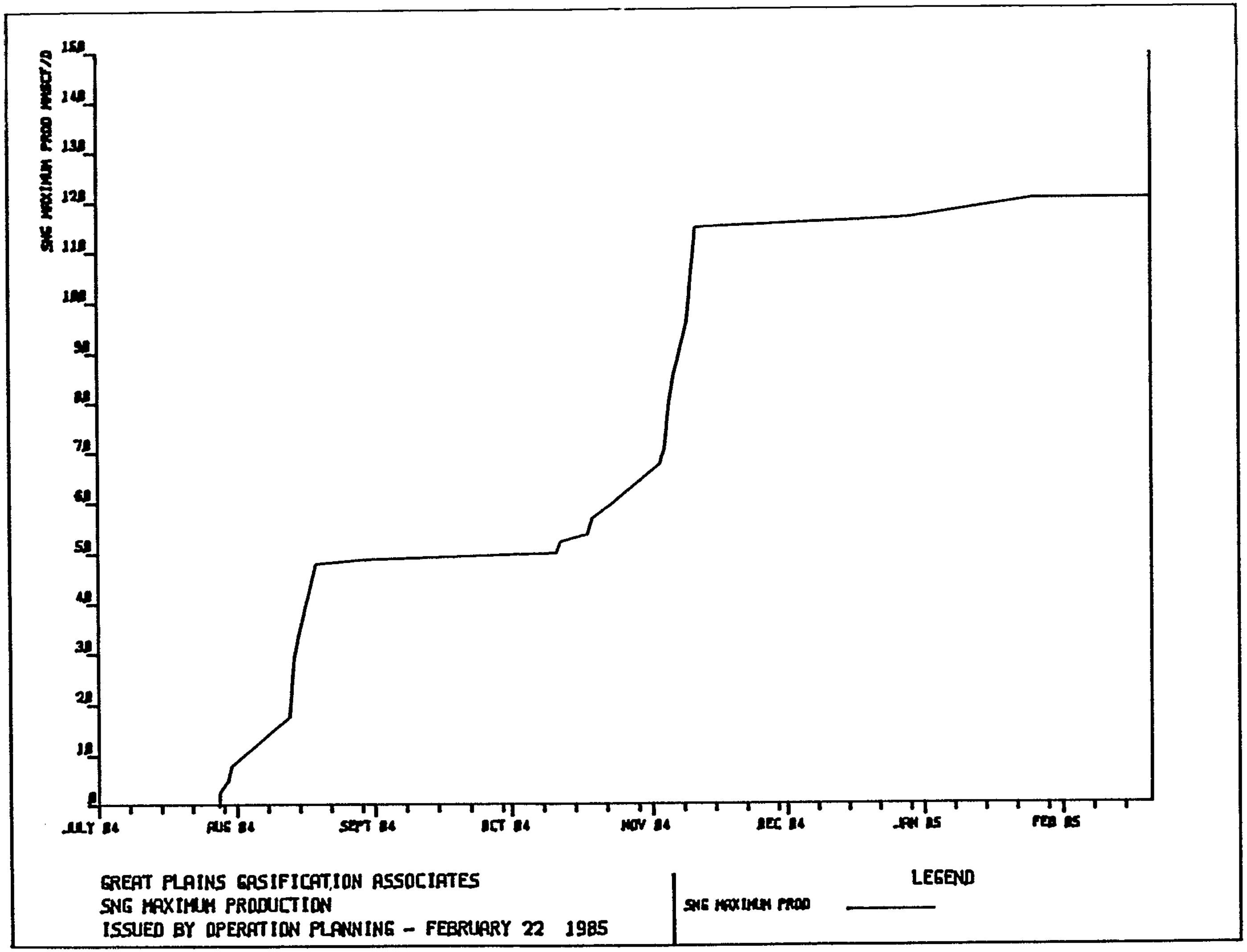
SNG MAXIMUM PROD MMSCF/D
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JULY 84
AUG 84
SEPT 84
OCT 84
NOV 84
DEC 84
JAN 85
FEB 85
GREAT PLAINS GASIFICATION ASSOCIATES
SNG MAXIMUM PRODUCTION
ISSUED BY OPERATION PLANNING - FEBRUARY 22 1985
LEGEND
SNG MAXIMUM PROD

FIGURE 5

OVERALL EFFICIENCY OF SNG PRODUCTION

<u>TOTAL ENERGY INPUT</u>

LIGNITE TO GASIFICATION	:	$190 * 10^9$	BTU PER DAY
EL. POWER – (75 MW)	:	$17 * 10^9$	BTU PER DAY

<u>TOTAL ENERGY OUTPUT</u>

SNG (137.5 MMSCFD)	:	$134 * 10^9$	BTU PER DAY

EFFICIENCY :

$$\frac{134 * 10^9}{207 * 10^9} = 0.648$$

$$= 64.8\%$$

TABLE 3

and Product Compression unit. Based on this data, the overall efficiency is 64.8 percent, defined as total energy input (i.e. coal + electric power) related to the SNG output.

We are confident that the efficiency given in Table 3 will be confirmed or improved on after more operating data are available.