



C. V. Chatterton
District Superintendent
Producing Department

**Standard Oil Company of California,
Western Operations, Inc.**
P.O. Box 7-839, Anchorage, AK 99510 • Phone (907) 279-9666

RECEIVED

MAR 8 1972

Conservation Division
U.S. GEOLOGICAL SURVEY
Anchorage, Alaska

March 6, 1972

EXPLOSION AND FIRE - PLANT 10
SWANSON RIVER FIELD - ALASKA

Combined Unit

Mr. Rodney A. Smith
Regional Oil and Gas Supervisor, Alaska
U. S. Geological Survey
P. O. Box 259
Anchorage, Alaska 99510

Mr. Homer L. Burrell
Chairman, Alaska Oil and Gas Conservation Committee
State of Alaska, Division of Oil and Gas
3001 Porcupine Drive
Anchorage, Alaska 99504

U. S. Fish and Wild Life Services
Bureau of Sport Fisheries
Kenai National Moose Range
P. O. Box 500
Kenai, Alaska 99611

Gentlemen:

Attached is a report, after investigation, of the explosion and fire in our Plant 10, Swanson River Field, occurring at 1:30 A.M., January 26, 1972.

By copy of this report to the addressees as shown we believe we have covered the agencies requiring notification and our joint participants.

Very truly yours,

C. V. CHATTERTON

cc: Mr. H. A. Slack - ATLANTIC RICHFIELD COMPANY
P. O. Box 360
Anchorage, Alaska 99510

Mr. B. J. Howard - MARATHON OIL COMPANY
P. O. Box 2380
731 "I" Street
Anchorage, Alaska 99501

Mr. E. F. Griffin - UNION OIL COMPANY OF CALIFORNIA
909 W. 9th Avenue
Anchorage, Alaska 99501

NOTED
MAR 8 1972
Rodney A. Smith

NOTED
MAR 13 1972
W. C. Wawicko

Engineering Department
San Francisco, California
February 15, 1972

EXPLOSION AND FIRE -- PLANT 10
SWANSON RIVER, ALASKA

ABSTRACT

On January 26, 1972 at 1:30 AM, there was an explosion in Swanson River Plant 10 Compressor Building, followed by fire in the Process Building. The explosion resulted in major damage in the Compressor, Process, Office and Control, and Meter Buildings. (See the attached Plot Plan.) Moderate to minor damage occurred at the LTS and deethanizer skids. Damage to the Pressure Maintenance Building, Shop Building, and other outlying buildings was confined to broken windows, doors, light fixtures, and distortion of exterior metal sheeting. The only significant fire in the Process area caused no major structural damage to major pieces of equipment or pipelines. Fortunately, the two operators on duty received only minor scratches and bruises.

It has been determined that the fuel for the explosion and fire came from a leak in the depropanizer reboiler located in Process Building A. This reboiler (Heat exchanger E-6) contains natural gasoline in the tube section and Therminol FR-1 (heat transfer medium) in the shell side. Both gasoline vapor and Therminol leaked from this reboiler. The heavy gasoline vapors "flowed" from the Process area through a corridor into the Compressor Building. The Therminol system and the compressors were shut down and the explosion occurred approximately five minutes after the compressors were shut down. The maximum force of the explosion was centered at K-4 compressor, but despite exhaustive investigation, the specific source of ignition has not been determined at this time. Investigation of possible sources of ignition are continuing as the area is cleaned and damaged equipment removed from the site.

CONDITIONS LEADING UP TO THE ACCIDENT

Approximately two weeks prior to the explosion, E-6 Reboiler tube bundle for the depropanizer column was replaced. The Reboiler assembly includes a spooled expansion bellows inside the shell. The expansion bellows spool was not replaced. After the reboiler was returned to service, there were minor recurring gasket leaks which were stopped by tightening the bolts securing the channel to the shell of the reboiler. The fixed tube sheet is made up with two gaskets -- one on the bottom of the tube sheet in a recess of the shell section flange, and the other on top of the tube sheet and channel section flange. One set of bolts stresses both gaskets.

About 10 days before the explosion, unusual high winds had caused a failure of the economizer section of the plant's Therminol furnace. Therminol is a liquid-phase heat transfer medium formerly called Aroclor. The economizer

section was cut from the line and the furnace was returned to service. During this down time, a plug developed in the Therminol line. Therminol with a pour point of 2° F cooled during this repair, so it became necessary to have a contractor come in and ram the line to clear it. The contractor's equipment was confined to the furnace for the first phase of clearing the line where pressure up to 400 psig was applied. The second phase involved an isolated section of the line down stream of the Therminol pumps and up stream of the furnace. The peak pressure was 1000 to 1200 psig. This was maintained for five minutes. No pressure appeared down stream of the Therminol furnace. Due to mechanical difficulty with contractor's high pressure truck, it was released and attempts at establishing recirculation continued with plant equipment. The Therminol system was still being cleared in preparation for returning the process equipment to operation, when the leak from E-6 reboiler occurred.

The Therminol furnace is located approximately 300 feet from the circulation pump and about 540 feet of circulation line is required to reach the deethanizer reboiler at the end of the main circulation header -- making a total line length of approximately 1100 feet. (See Plot Plan.) Two centrifugal pumps (supplemented by a small positive displacement gear pump) are normally used for circulation. The Therminol system is protected against over pressuring by a surge tank vented to the atmosphere, a pressure relief valve, and a relief valve bypass around the positive displacement pump.

About 11:00, PM January 25, 1972, the afternoon tour operator reported the following condition existed (refer to Sketch 1):

- a. The Therminol header was open for circulating through part of the header system and was being pressured by a centrifugal Therminol pump, P-5, (red line on Sketch 1).
- b. E-6 depropanizer reboiler was closed to circulation, but open to pressure - only the inlet valve was closed.
- c. E-302 deethanizer reboiler was also blocked off.
- d. 20.E-1 crude oil heater was isolated from the heating fluid system by blinds.
- e. V-405 Glycol Regenerator at the LTS skid was closed.

About 11:10 PM, January 25, 1972, the afternoon tour operator on duty cracked the Therminol inlet valve to E-6 depropanizer reboiler for approximately five minutes. The inlet nozzle warmed up to about 100°F -- warm to touch. The operator thought he had flow, so he closed E-6 reboiler inlet valve. The Therminol furnace outlet temperature was fluctuating around 400°F during this time. At approximately 11:20 PM, January 25, 1972, the morning tour operator for Plant 10 ("Operator P-10"), took over plant operation. He stated that they had Therminol at about 350°F returning to the furnace, so he figured that the system was warm enough to start circulation down to the deethanizer skid and he opened the valves at this skid. (Therminol should then be circulating back to the surge tank along the blue line on Sketch 1.) He then proceeded to make a tour of his plant and install necessary record charts, check compressor operation, etc. During this tour there were no noticeable irregularities in plant operations. After this routine plant tour the operator's attention was given to the Therminol

system. Time was approximately 1:00 AM, January 26, 1972.

Time: 1:00 AM, January 26, 1972 - Sequence of operation:

- a. The Operator P-10 on duty walked to the unit housing C-301 Deethanizer Column and E-302 Deethanizer Reboiler. He thought that there was flow there but there wasn't any heat. It was concluded after the investigation that Therminol wasn't moving through the lines.
- b. He came to Building A, which houses the Therminol circulating pump, surge tank and vent line, for a routine check. He noted an odor which he described as "chlorine" gas. This gas odor (possibly Hydrogen Chloride from high temperature decomposition of the Therminol) had been noted by the previous operator who had avoided the p-5 pump area directly under the surge tank because of the "chlorine" gas odor.
- c. At this point, he decided to check the Therminol surge tank located on a second deck level approximately 8 - 10' above Building A floor. He started climbing a ladder facing the north wall of Building A. Just as his head and shoulders were clearing the deck level the leak occurred. Liquid Therminol coming from behind him splashed off the wall, hit him in the face, and covered part of his body.

Note:
The reboiler leak was approximately 25' from this ladder and approximately 30" above the deck level. High pressure was required to spray liquid that distance.
- d. The Operator P-10 "hurried" down the ladder and into the control room approximately 230 feet away. He arrived in the control room, and asked the Pressure Maintenance Plant Operator ("Operator FM") who happened to be there to shut down the Therminol pump. A high concentration gas alarm had activated on E building. The Operator FM cleared the alarm panel, then went to the main electric panel and shut down the Therminol pump while Operator P-10 washed the Therminol from his eyes.
- e. Operator FM then returned from the switch gear room - (only a few seconds had elapsed) and got high concentration gas alarms on Building A and compressors K-1, K-2, K-3, and K-4. These alarms were almost simultaneous. (The high gas concentration alarms were set initially to activate at 20% of the lower flammable limit of the gas/air mixture.)
- f. Operator P-10 at this point shut down the Therminol furnace fire.
- g. Operators P-10 and FM returned to Building A to determine if the leak could be located and isolated. The leak was still blowing gas "with the odor" of chlorine - and drove the operators back when they tried to enter through the compressor building near K-1 compressor (remember, high gas concentration alarms had already sounded in this end of the compressor building). The operators then walked around to the north side of Building A. Here also attempts to enter were unsuccessful because of gas and fog, with the odor described as chlorine. After a concerted, but unsuccessful, effort

by Operator P-10 to enter with a wet cloth over his face, both operators were returning to the control room when they decided to shut down the compressors - but again, before this action was taken, they made another attempt to enter the compressor building and unload K-1.

- h. Time 1:25 AM - Compressors shutdown, and motor-operated valves closed in gas lines to the plant. The gas was diverted to flare. The decision was made to call the plant Foreman. The operators returned to the control room and cleared the compressor shutdown alarms.
- i. At this point, Operator PM had an alarm on K-14 compressor in his plant, and went (ran) over to the PM plant to check on it. Operator P-10 decided to go back to Building A to determine if the gas release was decreasing, and to make another effort at finding and shutting in the leak. The leak was still blowing. Operator P-10 decided to try to open the large sliding door on the north side of Building A to increase ventilation. As he was heaving on the door, ignition of the gas occurred. The large door protected him from flying parts. Operator Mi, returning from checking his plant, was on the south side of the office building. He was protected from flying metal by this building. Neither man was injured, except for slight scratches and bruises.

FOLLOWING THE FIRE JANUARY 27, 1972

The site was visited Thursday, January 27, 1972, by a team from Producing, including three persons from San Francisco, two from Producing and one from the Fire Protection Staff - engineering, San Francisco.

The source of fuel appeared obvious. It was believed that Reboiler E-6 had developed a leak -- so that gasoline from the depropanizer had pressured into the Therminol system and vented Therminol and hydrocarbon over the building. This was not the total story however. Inspection of the Process Building from the outside on Thursday showed a small fire at the top of E-6. Subsequent inspection after this small fire went out revealed the gasket which sealed the Therminol side at the top of E-6 had blown out of its seat over an 18 to 19 inch distance along the circumference of the flange.

The design of E-6 is such that one set of bolts stresses both the gasket sealing in the Therminol and the gasket which sealed gasoline in the head. In order to determine if gasoline had initially leaked from the tube side of E-6 into the shell (Therminol) side, the reboiler was removed intact and pressure tested with air with the following results:

- 1) At 80 psig air on the tube side, the gasket that seals the gasoline in the channel leaked badly to the outside. This confirmed that the main source of hydrocarbon vapor which fed the fire was from this gasket leak.
- 2) At 80 psig a barely detectable leak was noted from the tube side to the shell side.
- 3) At 100 psig a significant leak was noted and confirmed by installing piping on the shell nozzle and extending it into a bucket of water. An abundance of bubbles was created. This leak (observed by H. R. Coleman, R. V. Scott,

T. J. Bauer, A. B. Bristow, Jr., C. V. Chatterton, J. J. Dremer, and R. L. Mason) confirmed that gasoline could leak from the tube side into the Therminol side of E-6.

Prior to making these tests on E-6, checks were made at the deethanizer reboiler (E-302) to see if it may have leaked prior to the fire. E-302 was tested by venting the shell side, installing a pressure gage, blocking the shell inlet and outlet lines, thus subjecting the tube bundle to column pressure. There was no noticeable increase in the shell pressure, so it was assumed the tubes were tight at this time.

After the air tests were made on E-6, the investigation continued to determine why the shell-to-tube-sheet gasket blew out. Gaskets on both sides of the fixed tube sheet were removed for inspection. The top gasket was of interest because it leaked during the air test and because minor gasoline leaks had occurred during operation prior to the fire. The leaks prior to the fire had been stopped by tightening up on the flanges during operation. The shell-to-tube-sheet gasket was spiral wound metal, asbestos filled. The channel-to-tube-sheet gasket was a flat metal-jacketed asbestos. These gaskets were installed as specified and supplied by the manufacturer. The flat metal-jacketed gasket appeared to have been damaged prior to installation. There was a dent plus a crease possibly caused by other material that had fallen on the gasket or gasket seat. This creased section was probably the cause of the leaking problem that had been corrected by tightening before the fire. It has become apparent on close analysis of the two gaskets on the fixed tube sheet that both had crushed portions which had been unevenly loaded and overstressed. E-6 gasket surfaces were so designed as to make proper installation of spiral wound gaskets difficult. The fixed tube sheet diameter was not large enough by approximately 1/8" to completely fill the shell flange groove. Under the stress of tightening the flanges, the outer welds between leaves of the gasket may have broken, allowing the spiral gasket to literally blow out of the groove when pressured. The welds on the outer leaves were found broken during the investigation. This spiral wound gasket had no design features to prevent it from being overstressed. There was no spacer ring nor restrictive lugs on the flanges that would normally serve this purpose.

Even though both gaskets may have been "weakened," the fact remains that they were holding prior to the failure in the economizer section of the Therminol furnace. Thus it is concluded that the spiral wound gasket was subjected to abnormal pressure just before it was blown from its seat. A review of Sketch 1 (blue line) shows that under normal circulating conditions any pressure build-up in E-6 should be dissipated into the surge tank unless there was a plug in this line near the deethanizer skid. If such a plug existed, relief valve PSV-1946 (set for 130 psig) should have relieved high pressure back to the Therminol storage tank. However, after the fire PSV-1946 was plugged - It would not open when tested at 300 psig.

To understand how the abnormal pressure was generated and why it was not dissipated before the gasket blew out, it would be well at this point to review the known facts:

- A. E-6 Reboiler tube bundle and tube sheet gaskets leaked on test after the fire. E-6 Reboiler leaked from tube-side-to-shell on air test following

the fire.

- B. Liquid Therminol and gas leaked into the building from E-6.
- C. The leaking Therminol continued to flow from E-6 after the Therminol pump was shut down - this was observed by Operator P-10.
- D. Without a plugged line in the Therminol system, excessive pressure over 25-30 psig would have been released through the open vent above the surge tank. Also PSV-1946 set at 130 psig to protect E-6 was tested and found plugged.
- E. Without gas pressure on E-6 shell, Therminol could not have been projected 25 feet horizontally to splash the Operators P-10.
- F. According to the operators, Building A temperature will increase 20 to 25°F when the 400°F Therminol is being circulated as compared to the temperature when the Therminol system is shut down.

CONCLUSIONS:

From the above facts, it is concluded that liquid hydrocarbon, probably propane and butanes+, leaked into the shell side of E-6 reboiler from C-1 depropanizing column while the Therminol system was down for furnace tube repairs. After the furnace repairs were complete, sections of the Therminol system were pressured to establish flow. At approximately 11:00 PM, January 25, 1972, the system was closed up and efforts were being made to return it to service. Circulation had been established in a section of the line from Building A to the furnace. At approximately 11:15 PM, January 25, 1972, circulation was set for the Therminol main header from the furnace to the deethanizer column and return. The Therminol in the lines between the Furnace and Building A was about 400°F. When the valves were set to circulate past the deethanizer column, a plug occurred in the Therminol line somewhere near the deethanizer, thus effectively "closing in" the Therminol system between P-5 pump (check valve), the plugged line and the plugged PSV-1946 (see Sketch 1).

At this time (approximately 11:20 PM, January 25, 1972), temperature in Building A had been increased up to about 20°F by the circulating Therminol. Hot Therminol in the piping manifold was maintaining Building A temperature. The recorder chart from the Therminol system shows a jump from about 275°F to about 425°F between 11 PM and 11:20 PM. From 11:20 PM until the time the Therminol pumps were shut down just before the explosion, the Therminol temperature varied between 370°F and 445°F. It is concluded that the heat available from this hot Therminol raised the temperature in E-6 to the point where the expansion of the Therminol (4% per 100°F) or the increase in vapor pressure of the hydrocarbons (from the tube-to-shell gasoline leak) or both exerted sufficient pressure in the "closed in" system to displace the spiral wound gasket from E-6. When this spiral wound gasket blew out, the bolts were loosened, causing the flat metal-jacketed gasket to leak gasoline vapors into Building A. The Therminol continued to be propelled through the blown out gasket by vaporization of gasoline which had leaked into the shell side of E-6.

IGNITION SOURCE:

Both the San Francisco investigating team and District Engineering and Operating personnel searched the wreckage diligently for a possible source of ignition. The following three possible sources were identified:

- A. Flame patterns and carbon were found on a rod of K-4 Compressor. The packing is being analyzed to determine possible maximum temperature.
- B. Lights or conduit in Building A could have been broken by the liquid from the leak -- they were burned too much to tell when failure occurred.
- C. Electric lighting, heating fan motors, instrument air compressor drive, and electronic controls were, or may have been, operating as they were designed to do, even after emergency shutdown of the compressors. They are a possible ignition source only if some mechanical or electrical breakdown had occurred before the explosion. Damage to this equipment did not permit specific determination of its condition immediately before the explosion.

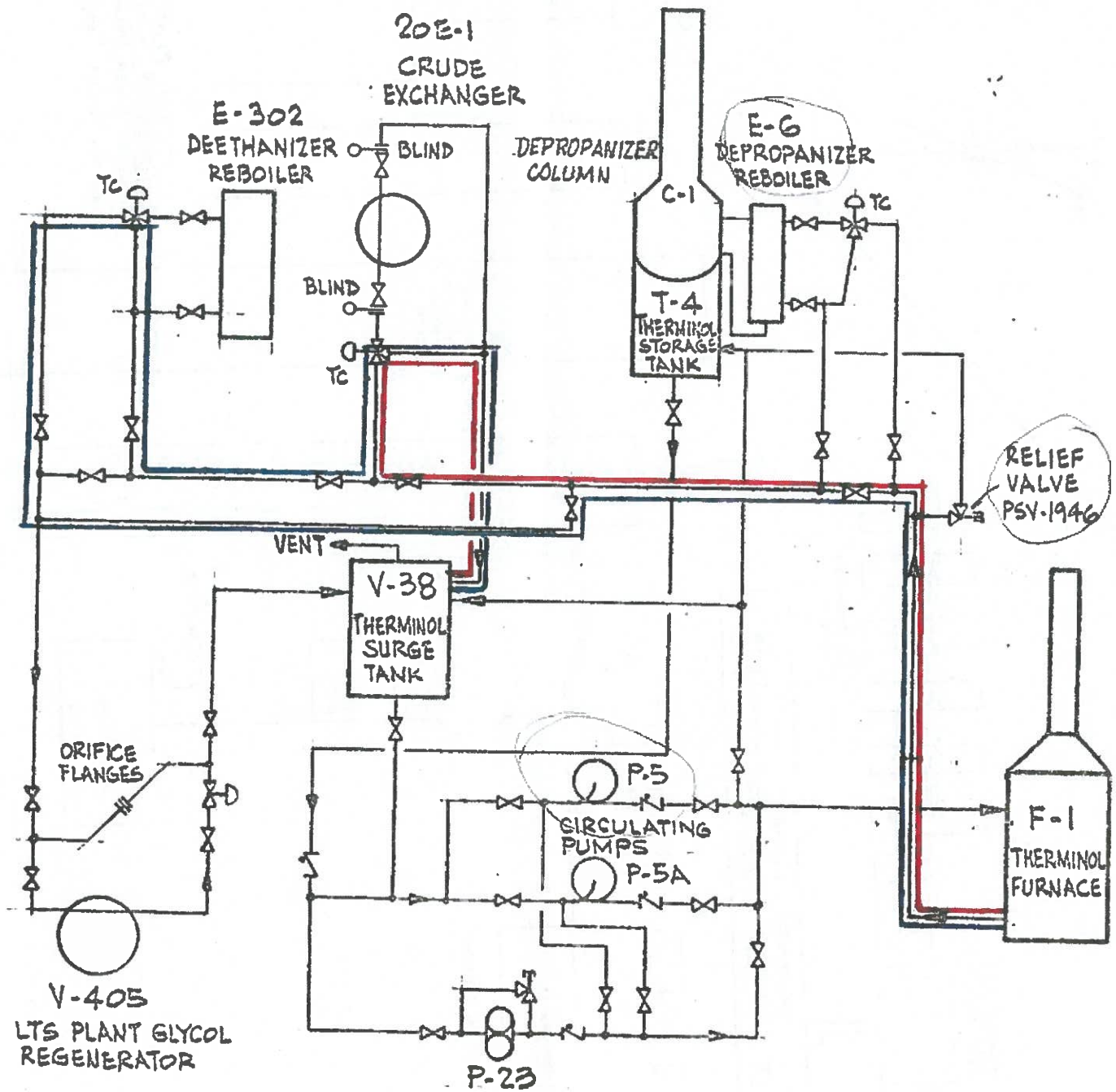
Although the investigation did not develop a definite source of ignition, efforts are still continuing to look for possible sources as the wrecked equipment is cleared away from the site.

H. R. COLEMAN

Attachments:

Plot Plan

Sketch #1, Flow Diagram



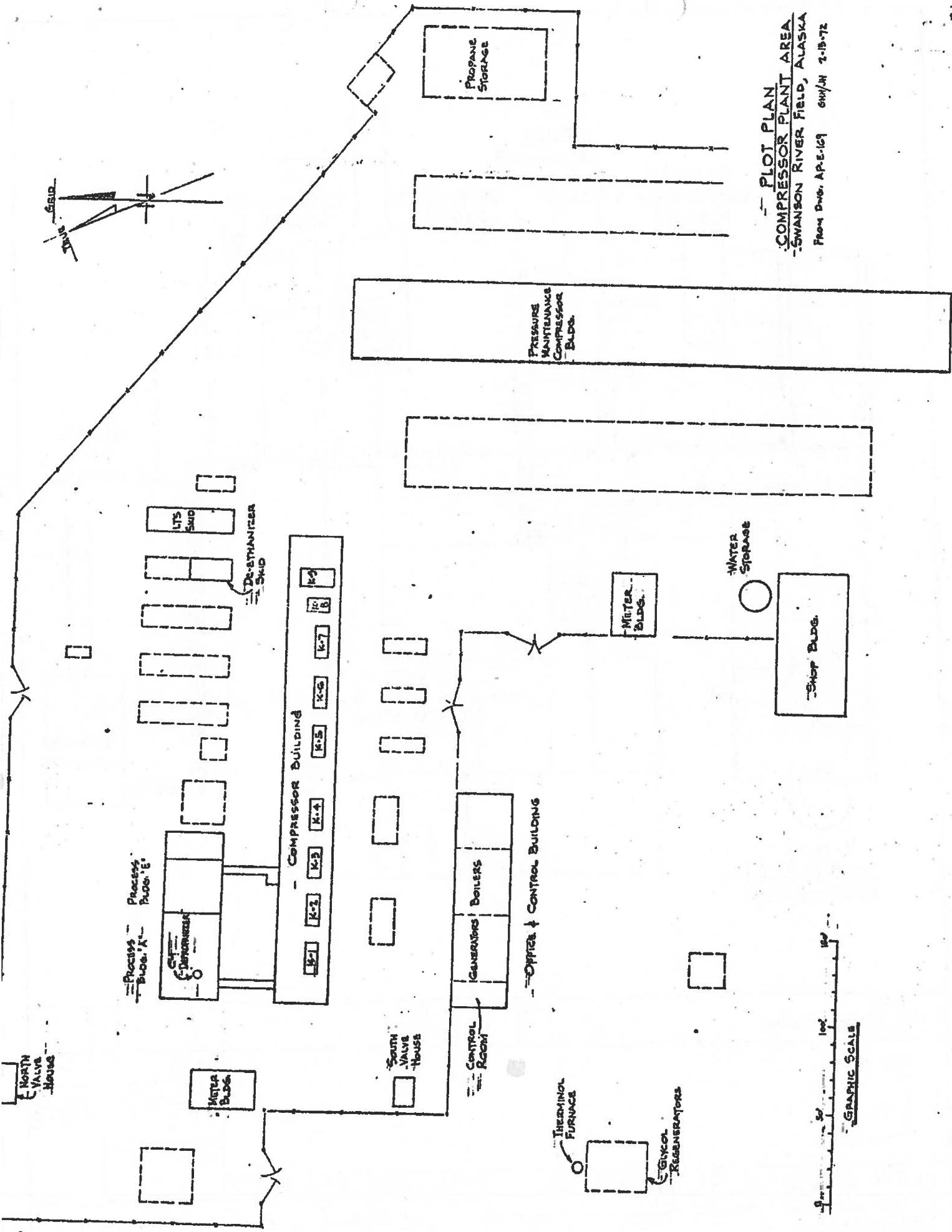
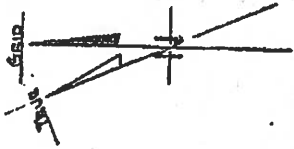
REV 1 RE-DRAWN 2-14-72 JH



DR. W.F.S. CH. _____
 DR. APP. _____
 ENGR. J.J.D. _____
 OPR'G. DEPT. APPROVED _____
 ENGR. DEPT. _____

FLOW DIAGRAM OF THERMINOL (AROCOR) SYSTEM
 SKETCH #1
 SWANSON RIVER FIELD ALASKA

SCALE NONE DATE 2-2-72
 W.O. 2431
 S.O. _____
 AP-C-140-1



-- PLOT PLAN
 -- COMPRESSOR PLANT AREA
 -- SWANSON RIVER FIELD, ALASKA
 FROM DWG. A.P.E.109 6/11/72

