12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Examples of good employee exposure control techniques associated with petroleum refining operations were identified. A site visit was made to Atlantic Richfield's Cherry Point Refinery (SIC-2911) near Ferndale, Washington on November 17, 1981. The exposure controls studied were the hydrogen-sulfide (H2S) monitoring system and preventive and routine maintenance procedures. The H2S monitoring system was a multichannel system which provided continuous independent monitoring at 18 locations. The sensors were based on an electrochemical polarographic cell. Sensors were set to trigger alarms if H2S concentrations exceeded 10 parts per million. Maintenance programs emphasized the control of fugitive emissions and prevention of equipment failures. Valves and flanges were monitored daily for leaks. An extensometer was used to monitor bolt tightening after repair or turnaround of heat exchanger heads. Vibration monitoring and equipment balancing/alignment programs minimized pump seal failure. Acoustic testing was used to inspect pressure vessel integrity while the vessel was still on stream.

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INDEPTH SITE VISIT REPORT
CHERRY POINT REFINERY

CONTROL TECHNOLOGY ASSESSMENT OF PETROLEUM REFINERY OPERATIONS

Contract No. 210-81-7102

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The findings presented are the result of two visits made to the Atlantic Richfield Cherry Point Refinery. Mention of company names or products in this report does not constitute endorsement by the National Institute for Occupational Safety and Health or by Radian Corporation.

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technologies which may be used to reduce occupational exposure to potentially toxic chemical substances and harmful physical agents. The primary purpose of this control technology assessment study was to identify and document examples of good employee exposure control techniques associated with a variety of petroleum refining operations.

During a preliminary visit conducted on November 17, 1981, several exposure control techniques of interest were noted at Atlantic Richfield's Cherry Point Refinery. A subsequent return visit was made to study indepth the Refinery's hydrogen sulfide monitoring system and its preventive maintenance procedures.

The indepth information obtained on these control techniques of interest will be documented in a final study report and disseminated to interested members of the petroleum refining industry and other industries to which it is applicable.

LIST OF TABLES

Special thanks go to Ralph Powell, Cherry Point Safety Manager, and Doris Wunsch, Cherry Point Health Specialist, and to the following engineering, operations, and maintenance personnel:

Chris Christmas - Inspection Supervisor
Jack Jackson - Machine Shop Superintendent
Ted Martin - Operations Engineer
David Shores - Contractor Coordinator
Ray Snover - Maintenance Manager

agents. The exposure controls studied at Cherry Point were its hydrogen sulfide monitoring system and preventive and routine maintenance procedures.

1.1 Study Overview

A major research area for NIOSH is the evaluation of control technologies which may be used to reduce occupational exposures to potentially toxic chemical substances and harmful physical agents. The primary purpose of this study is to identify and evaluate examples of good employee exposure control techniques associated with a variety of petroleum refining operations. The exposure controls studied include engineering controls, monitoring programs, personal protective equipment, and work practices.

During a preliminary visit conducted on November 17, 1981, a number of control techniques of interest were noted at the Cherry Point Refinery. A subsequent return visit was made to thoroughly document these control techniques. Information obtained in the visits to the Cherry Point Refinery will be presented in a final study report and disseminated to interested members of the petroleum refining industry and other industries to which it is applicable. Appropriate details also will be included as part of a catalogue for effective hazard control options being compiled by the NIOSH Engineering Control Technology Branch. These information transfer mechanisms are designed to promote the use of successful exposure control ideas in applicable industries.

control methods. Discussions were held with a number of Cherry Point employees to further document operating and control procedures. These employees included:

Ralph Powell - Safety Manager
Doris Wunsch - Health Specialist
Chris Christmas - Inspection Supervisor
Jack Jackson - Machine Shop Superintendent
Ted Martin - Operations Engineer
David Shores - Contractor Coordinator
Ray Snover - Maintenance Manager

All of the Cherry Point personnel were very helpful and their cooperation was greatly appreciated.

Exposure controls documented in each area studied are briefly described in the following summary paragraphs.

Hydrogen Sulfide Monitoring System

The hydrogen sulfide (H_2S) monitoring system used at the Cherry Point Refinery's sulfur handling facilities is a multichannel system which provides continuous independent monitoring at 18 locations. The sensors, which are manufactured by Mine Safety Appliances Company and based on an electrochemical polarographic cell, are located in areas that have the highest potential for a significant release of H_2S and in areas where operators, maintenance employees, and non-refinery personnel frequently are present.

1982), Refinery personnel report that a high level of satisfaction and confidence is associated with it. The system appears to be well-designed and implemented. In using state-of-the-art technology for sensors, controllers, alarms, and data handling, the Cherry Point Refinery has developed a highly effective control for one of the most hazardous chemical substances found in the petroleum refining industry.

Maintenance Procedures

The Cherry Point Refinery has in place several maintenance programs which emphasize controlling fugitive emissions and preventing equipment failure. Such programs contribute to reduced employee exposure to hydrocarbons and other hazardous materials by minimizing workplace concentrations and by decreasing the possibility of catastrophic equipment failure.

The Refinery monitors valves and flanges daily for leaks. Leaking equipment which can be permanently repaired while still in service or removed from service is immediately repaired. Other valves and flanges are temporarily repaired by injection of a thermosetting compound manufactured and applied by Furmanite.(R)

To prevent deformation and subsequent leaking in heat exchanger heads, the Refinery uses an ultrasonic instrument, an extensometer, to monitor and control bolt tightening after repair or turnaround. Refinery engineers have calculated elongation and

vibration monitoring and equipment allignment/balancing programs. Pumps and other rotating equipment are checked monthly to insure that their degree of vibration does not exceed Refinery specifications. Out-of-specification equipment is balanced in the Refinery machine shop and alligned in place before being put into service again.

Acoustic testing at the Cherry Point Refinery is used to inspect pressure vessel integrity while the vessel is still on-stream. Use of acoustic testing minimizes the time maintenance employees must spend in the confined space of opened reactor vessels. Additionally, it may detect early structural flaws which could eventually cause vessel rupture.

1.3 Report Outline

Each of the controls studied during the indepth site visit is discussed in more detail in the remaining sections of this report. Additionally, brief descriptions of the Cherry Point Refinery and its health and safety programs are provided:

Section 2.0 Refinery and Health and Safety Program Descriptions
Section 3.0 Hydrogen Sulfide Monitoring System
Section 4.0 Maintenance Procedures

The ARCO Cherry Point Refinery is located on approximately 430 acres near Ferndale, Washington. ARCO began operating the Cherry Point facility in 1972. The Refinery is one of the few "grass roots" complexes constructed in the United States since 1968. It was designed to run Alaskan crude brought in through port facilities located adjacent to the Refinery on the Georgia Straits of Puget Sound. However, until the completion of the Alaska pipeline, Canadian and other foreign crudes were processed at Cherry Point. Refinery crude through-put capacity is about 120,000 barrels per stream day (BPSD). Figure 2-1 is a simplified block flow diagram of refinery operations.

Crude offloaded from ships is pipelined about one mile to the Refinery from the port facility. In an atmospheric distillation tower (Crude Unit) and a vacuum distillation tower (Vacuum Unit) crude is distilled into six major streams: light hydrocarbons and gasoline, naphtha, stove oil, kerosene/diesel, gas oil, and resid. Light hydrocarbons and gasoline from the crude tower overhead are processed at a gas plant into plant fuel gas, liquified petroleum gases (propanes and butanes) and gasoline. Naphtha from the Crude Unit is hydrotreated for the removal of sulfur and nitrogen before reforming. The hydrotreated naphtha is then catalytically reformed to increase the octane before gasoline blending.

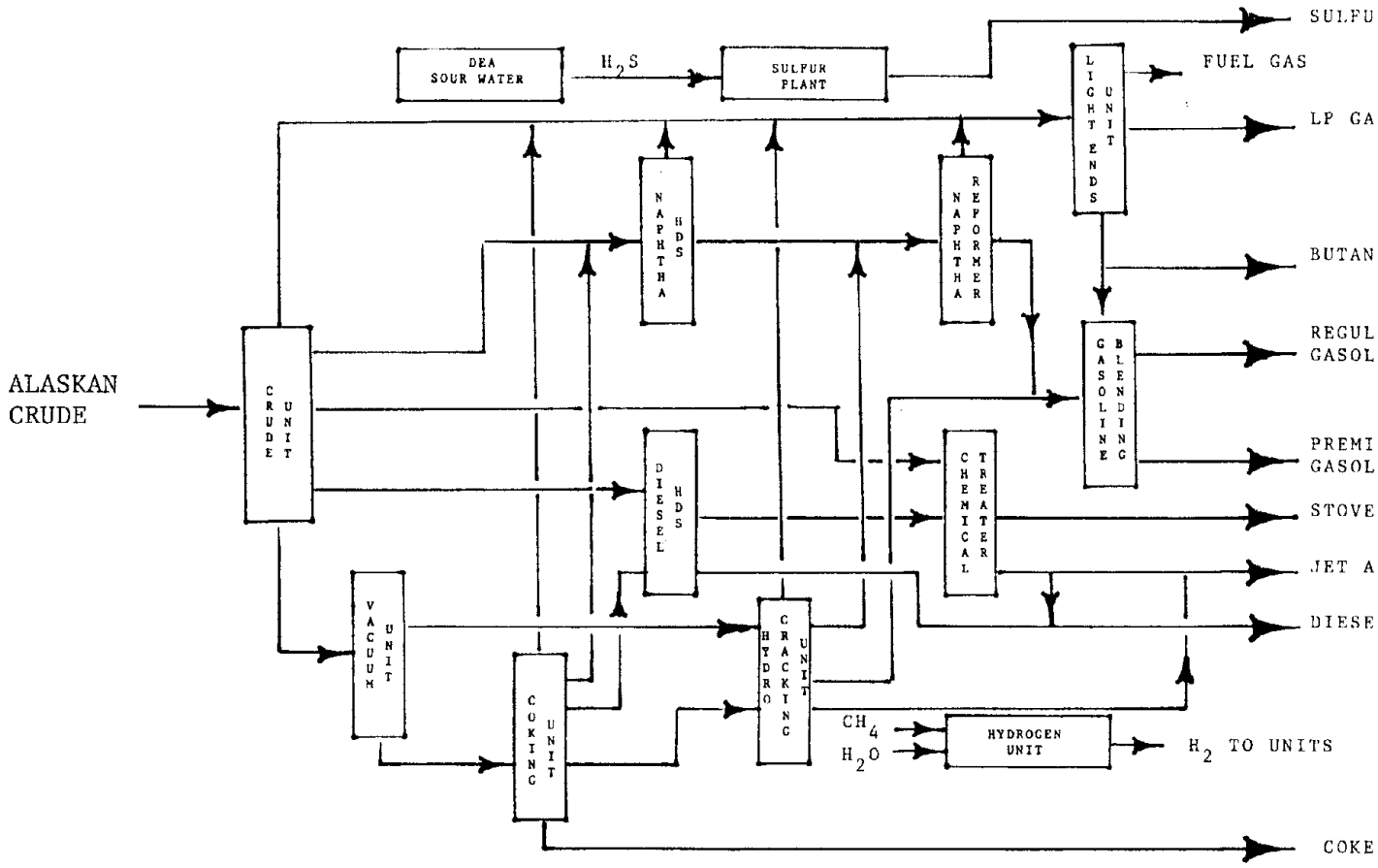


Figure 2-1 Cherry Point Refinery Flow Diagram

chemically treated and sold as fuels. Stove oil from the Coking Unit is also hydrotreated for sulfur removal at the Diesel HDS Unit and is sold as diesel fuels.

Gas oil from the Vacuum Unit and Coking Unit is catalytically cracked to lighter products in the Hydrocracker Unit. This high temperature-pressure unit produces gasoline blend stocks, naphthas which are reformed to a high octane gasoline blend stock and jet fuels. Hydrogen requirements for the Hydrocracking Unit are provided by the Hydrogen Unit and the Naphtha Reformer Unit. The Diesel HDS Unit and Naphtha HDS Unit hydrogen requirements are also provided by the Reformer and Hydrogen Units.

Hydrogen sulfide (H_2S) recovered using diethanolamine (DEA) from sour gas streams and stripped from sour water streams is converted to sulfur at a Claus plant. Plant waste water is treated for oil recovery at an API separator; is biologically treated by a trickling filter; and is clarified using clarifiers and clarification ponds. The treated water is discharged or reused in the refinery. Biological and oily sludges generated in the refinery are land farmed at the Refinery.

ARCO's Cherry Point Refinery has about 385 employees of which approximately 80 are maintenance personnel. Additionally,

maintenance crews work ten hour shifts four days a week.

2.2 Health and Safety Programs

Atlantic Richfield has an extensive corporate industrial hygiene program which is designed to "assess and control exposures (ACE) to hazardous chemical and physical agents" at each of its domestic refineries. The Cherry Point Refinery employs a full-time health specialist who works closely with the Refinery's safety department and corporate industrial hygiene staff to implement the ACE program.

The ACE program is designed to control employee exposure to hazardous materials and agents at or below the permissible exposure limits set by federal or state regulations. Additionally, the program provides for exposure assessment and control of nonregulated hazardous agents. The program is based on six major elements:

- Identification of all hazardous chemical and physical agents by workplace
- Employee exposure assessment
  - Exposure task evaluation
  - Determination of degree of exposure
- Control of unacceptable exposures
- Training and information

One ongoing program implemented at corporate and refinery levels is identification of hazardous chemicals and physical agents through the maintenance of Material Safety Data Sheets for all compounds used or produced in each ARCO refinery. The Cherry Point Refinery has implemented a policy stricter than the corporate policy in that it requires Material Safety Data Sheets to be on file prior to introduction of any chemical to the refinery complex.

Personal monitoring of routine operator procedures and major maintenance operations is conducted primarily for aromatic hydrocarbon exposure (benzene, toluene, xylenes). 3M-type passive dosimeters are used for full shift monitoring and charcoal tubes/pumps are used for short term monitoring (less than one hour). If sampling indicates high exposure levels, modifications in operating procedures or equipment are made. All sampling results are presented to and discussed with monitored employees and their supervisors.

Cherry Point management considers training and employee attitude to be the most important factors in reducing employee exposure. The Refinery's safety and industrial hygiene staff conducts annual training programs in hearing conservation, respirator usage, and chemical handling. The Refinery maintains a medical staff (two medical doctors on a contract basis and a full-time registered nurse and physician's assistant) which provides annual medical examinations for all employees.

All employees are issued long sleeve Nomex (R) coveralls upon employment. Employees must wear the fire-resistant coveralls at all times while inside the refining complex. At least one fire or emergency drill is conducted each month.

rotten eggs, hydrogen sulfide gas is considered to have poor warning properties. This is because it can paralyze the olfactory system so that its odor can no longer be detected. Some people cannot detect the odor at all.

Since dangerous quantities of hydrogen sulfide may be released into the workplace as a result of equipment failure, continuous monitors are used at the Cherry Point Refinery to detect hydrogen sulfide. This section presents a description of a new hydrogen sulfide monitoring and alarm system installed at the refinery in February of 1982.

3.1 Process Descriptions

The hydrogen sulfide monitoring system serves four processing areas all handling H_2S: Claus sulfur plant units with tail gas treaters, diethanolamine (DEA) and di-isopropylamine (DIPA) regeneration units, sour water stripping units and waste caustic neutralization unit. Since hydrogen sulfide gas is present in high concentration in many of the process streams, leaks and equipment failures can result in the release of dangerous concentrations of hydrogen sulfide into the workplace. Process descriptions for the units included in the hydrogen sulfide monitoring system are given in the following paragraphs.

SO_2 to make elemental sulfur ($2 H_2S + SO_2 = 3S + 2H_2O$). The Cherry Point Refinery uses a conventional three stage (catalytic reactors) unit followed by a tail gas treating unit.

Acid gases, primarily H_2S, from the DEA and DIPA generators, sour water strippers and caustic neutralization are treated for the removal of water and partially combusted in the main thermal reactor. The combustion products are cooled to recover some elemental sulfur formed at this point and remove water. The cooled gases are reheated and passed through a catalytic reactor and cooled again to condense out elemental sulfur and water. These steps are repeated twice again through two downstream heater-reactor-cooling sections to convert 98 percent of the H_2S to elemental sulfur. The tail gas from the last reactor cooling section goes to the tail gas treater for final recovery of unreacted H_2S and SO_2.

The tail gas treating unit catalytically converts any residual SO_2 to H_2S. The H_2S is then scrubbed with diisopropylamine from the tail gas before being vented to the atmosphere.

Potential for employee exposure to H_2S exists throughout most of the Claus plant, particularly from leaks in equipment containing H_2S and hot sulfur. Primary leak points would be at flanges, valves and pump or compressor seals.

the DEA in a reboiler-stripper. The regenerated DEA is pumped back to the individual unit contacting towers and the acid gases flow to the Claus sulfur plant for recovery of H_2S as elemental sulfur. Additionally, a small slip stream of lean DEA is continually treated to regenerate degraded DEA.

Rich DIPA (diisopropylamine) from the Claus unit tail gas treater is also regenerated in a reboiler-stripper to recover the absorbed H_2S. The lean DIPA is pumped back to the tail gas treater and the recovered H_2S flows to the Claus unit for conversion to element sulfur. A slip stream of DIPA is also continually treated to regenerate any degregated DIPA.

Potential for employee exposure to H_2S would come primarily from leaks to equipment containing the rich amine solutions and the recovered H_2S at pump/compressor seals, flanges and valves.

Sour Water Stripping

Process sour water streams containing dissolved H_2S and ammonia (NH_3) are collected and treated for removal of the H_2S and NH_3. The Cherry Point Refinery uses a reboiler stripping tower to remove both H_2S and NH_3 from the waste water at the same time. The waste water is further processed at the Refinery waste water treating plant and the recovered H_2S and NH_3 flow to the Claus unit where the H_2S is converted to elemental sulfur. Primary sources of H_2S leaks are from equipment items containing sour water and H_2S gas: sour water tanks; sour water lines, valves, pumps and exchanges; stripper tower; reboiler; and H_2S lines and valves.

which goes to the Claus units for recovery as elemental sulfur. Equipment items containing H_2S gas are potential sources for leaks: waste caustic tank, lines, valves and pumps; neutralization vat; and equipment conveying H_2S to the Claus unit.

3.2 Description of Monitoring System

The hydrogen sulfide (H_2S) area monitoring system used at the Cherry Point Refinery sulfur handling facilities is a multichannel system which provides continuous independent monitoring of 18 locations. The system consists of 18 independent area sensors; several multichannel controllers located in an instrument shelter; area, shelter, and control room alarms; and the Refinery central computer which handles the data generated. The electrochemical sensors and the multichannel controllers were manufactured by Mine Safety Appliance Company (MSA). The audio-visual area alarms, instrument shelter panel alarms and the central control room computer system alarms were developed by the Refinery.

The system was carefully selected and designed by Refinery personnel prior to installation. The new system replaced a 16-point lead acetate tape sensing system. The MSA system was selected after a six week trial against two other monitoring systems which used a metal oxide semi-conductor as the sensing element. The MSA system was selected because of its rapid sensor response time and its reliability in a high moisture environment.

The MSA sensor operates on the principle of an electrochemical polarographic cell. The cell electro-oxidizes hydrogen sulfide to sulfur dioxide (SO_2) as it diffuses through a gas porous membrane. The oxidation of H_2S to SO_2 creates an electrochemical signal proportional to the partial pressure of H_2S diffused into the cell and this signal is amplified to drive the meter and alarm systems.

Selection of sensor locations was based on input from Refinery maintenance, safety and engineering groups. The sensors are located near equipment where the highest concentrations of H_2S would be released and near equipment that had the highest probability for leaking. To determine the degree of hazard (leak rate and concentration) for each equipment area, dispersion calculations were developed using a method presented by Ledbetter (Ledbetter, J. O., "Exclusion area for safety from high-pressure sour gas leaks", AIHA Journal 39:586 (1978)). A relatively high density sensor pattern was selected due to the highly variable weather conditions in northwestern Washington.

Figure 3-2 presents a plot plan of the four processing areas covered by the H_2S monitoring system. Six sensors in the Claus Plant area are strategically located to detect H_2S leaks from the sulfur pits and converter equipment areas. Three sensors are located near the reboiler, flash drum and exchanger equipment areas in the DEA regeneration area. Three sensors are in the DIPA regeneration area, located near the DIPA regenerator, sour

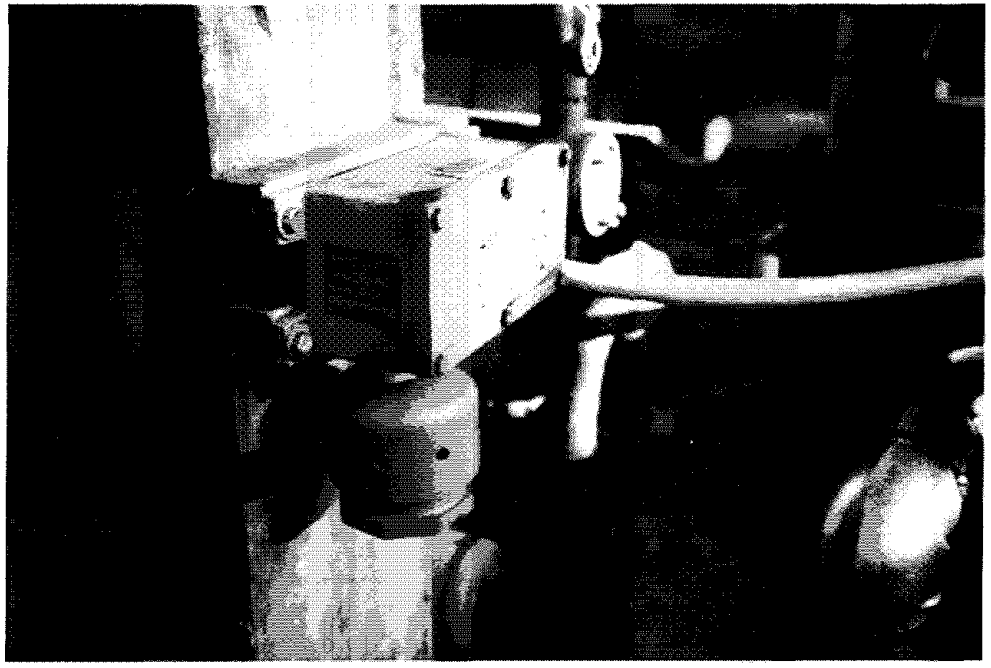


Figure 3 – 1
Electrochemical Sensor for H_2S Detection

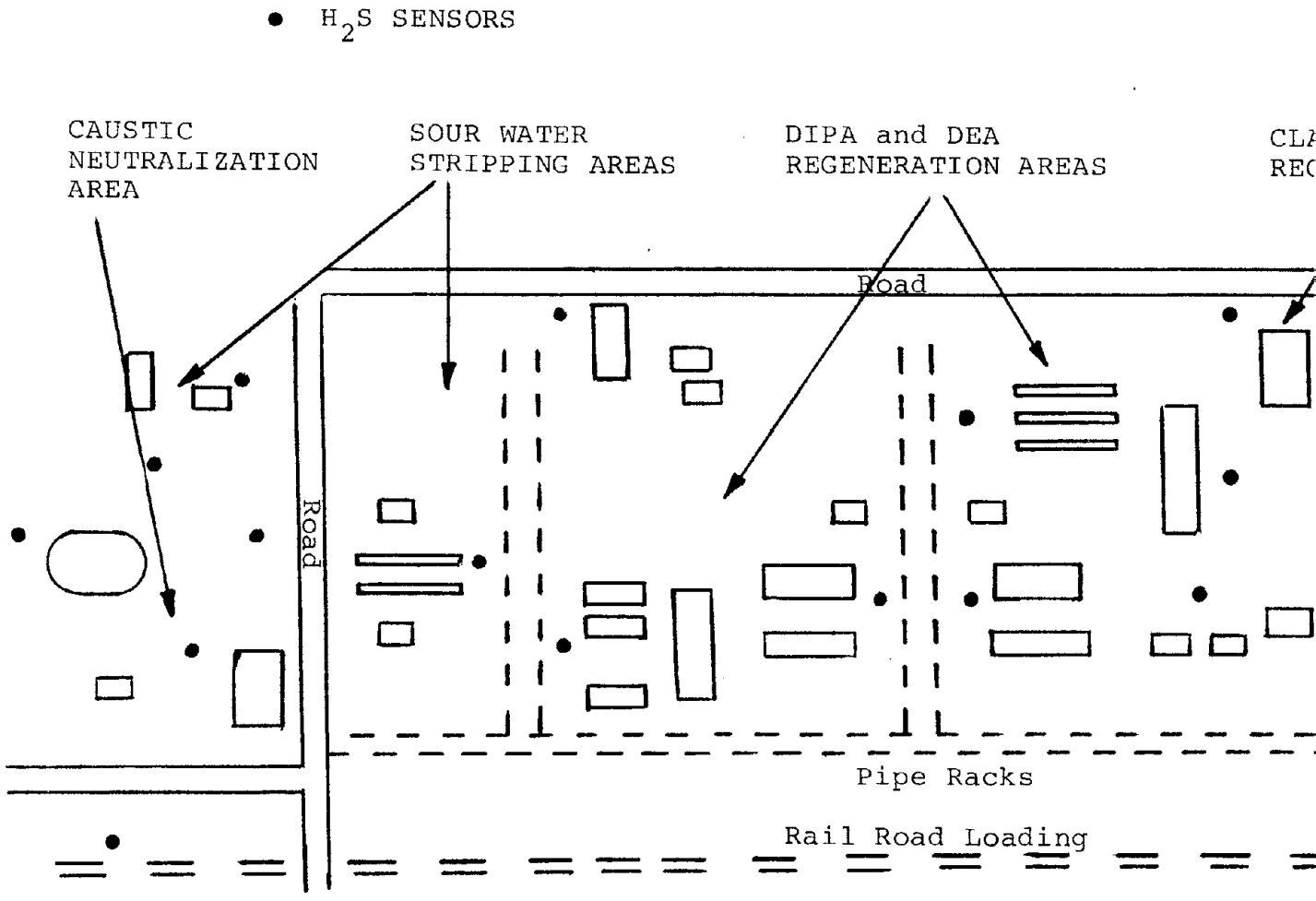


Figure 3-2 H_2S Handling Area Plot Plan

Warning and Alarm Systems

The 18 remotely-located H_2S sensors are tied into a group of controllers located in an instrument shed (Figure 3-3) at the corner of the Hydrocracking Unit. The shed is located midway between the H_2S processing areas and the central Refinery control room. This location allows area operators quick, safe access to the controllers during a detected H_2S release. An LED display built into each of the controllers continuously displays the H_2S concentration measured by each sensor. Also in the instrument shed is a panel board showing the location of each sensor in the four processing areas.

When one or more of the sensors detects an H_2S concentration greater than 10 ppm, the controller actuates the system alarms. These alarms include:

- Audible alarms in the caustic neutralization area and the central control room

- Flashing lights at the instrument shed (Figure 3-3) and one in each of the four processing area entrances (Figure 3-4).

- Flashing light for each of the sensors detecting over 10 ppm on the panel board in the instrument shed.

Additionally, the refinery central computer can display by CRT terminal or hard copy plot plans of the four processing areas showing the H_2S concentration at each sensor (Figures 3-5 a-d).

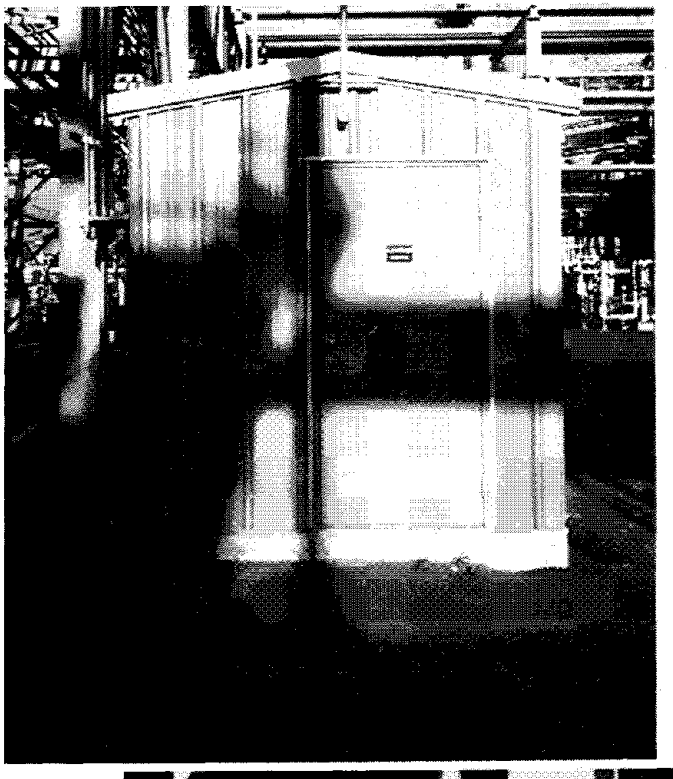


Figure 3 – 3
H_2S Monitoring System
Instrument Shed

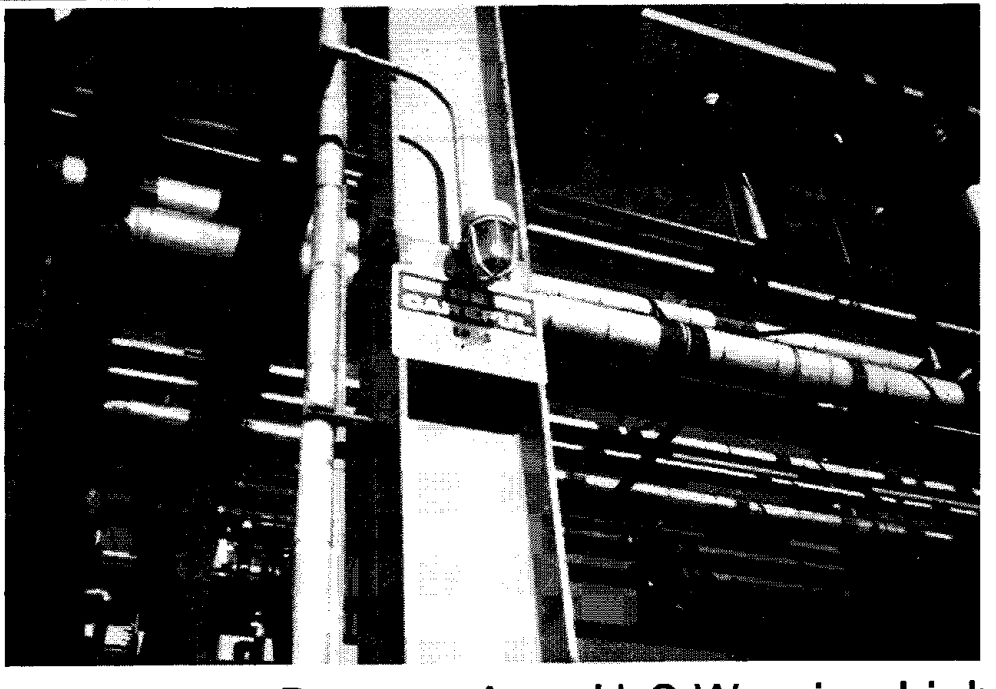


Figure 3 – 4 Process Area H_2S Warning Light

Computer Monitoring System

The Cherry Point Refinery uses a process control computer to aid operating personnel in controlling and tracking unit processes. The output from the H_2S monitor controllers is scanned once a minute by the process computer and the H_2S concentration at each sensor is stored in the computer. Presently, these one minute readings are stored as six-minute averages, one hour averages and 24 hour averages. Table 3-1 shows the reporting format for the six-minute, one-hour and daily averages for one of the H_2S sensors.

Four area plot plans showing the location of each H_2S sensor scanned each minute are also available on the computer. Figures 3-5 (a-d) present the format of each of the four plot plan areas covered by the H_2S monitoring system. These plot plans can be visually displayed one at a time either on the CRT and/or on hard copy from one of the central control room printers. Because the board operator for the H_2S handling areas is in radio contact with the unit operator, the board man can quickly relay updated H_2S levels monitored by the sensors during an alarm situation.

Calibration and Operation

Since the system's startup in February 1982, the Refinery has corrected a number of operating problems. Major problems

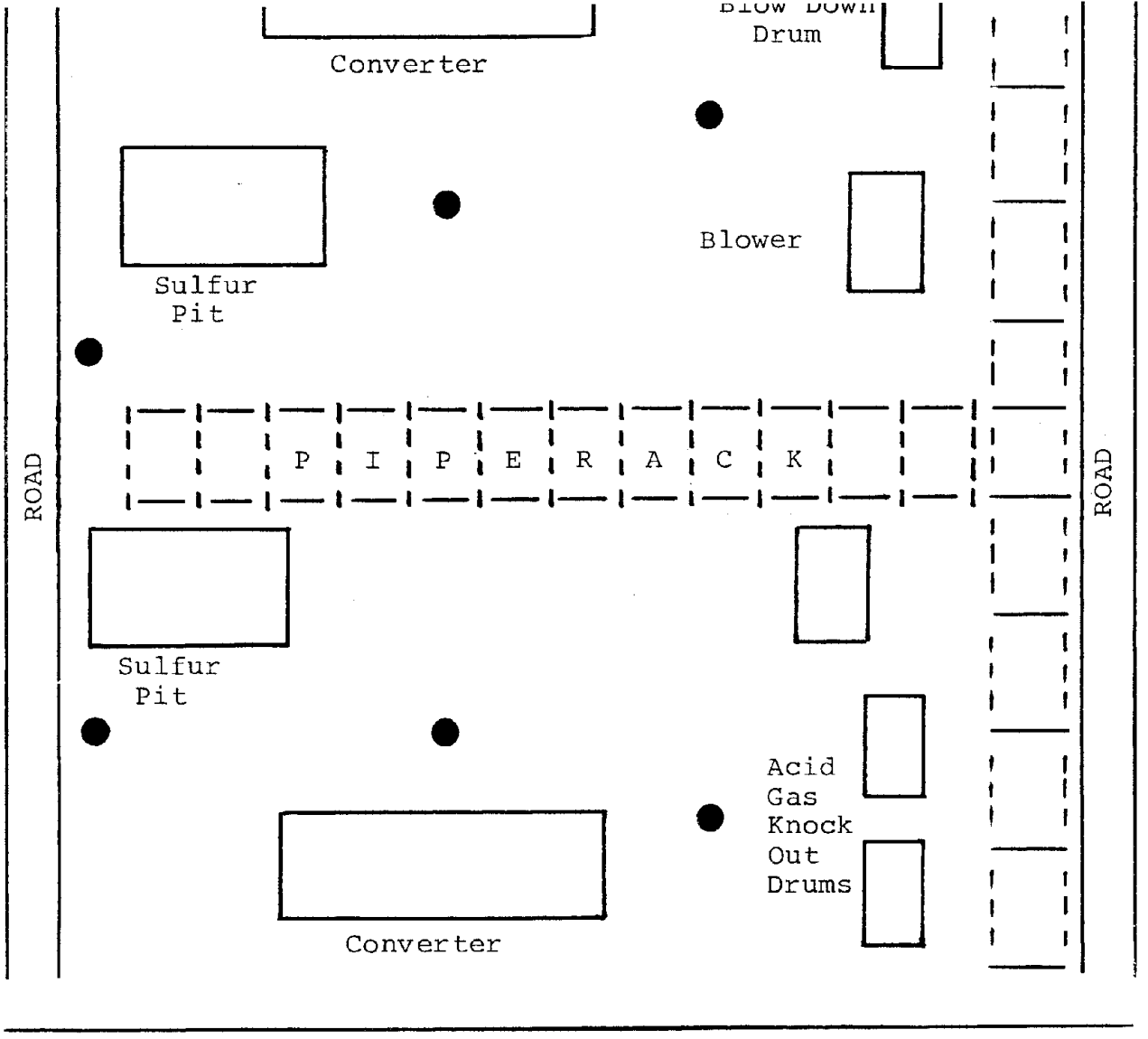


Figure 3-5a H_2S Monitors in Sulfur Recover Plants

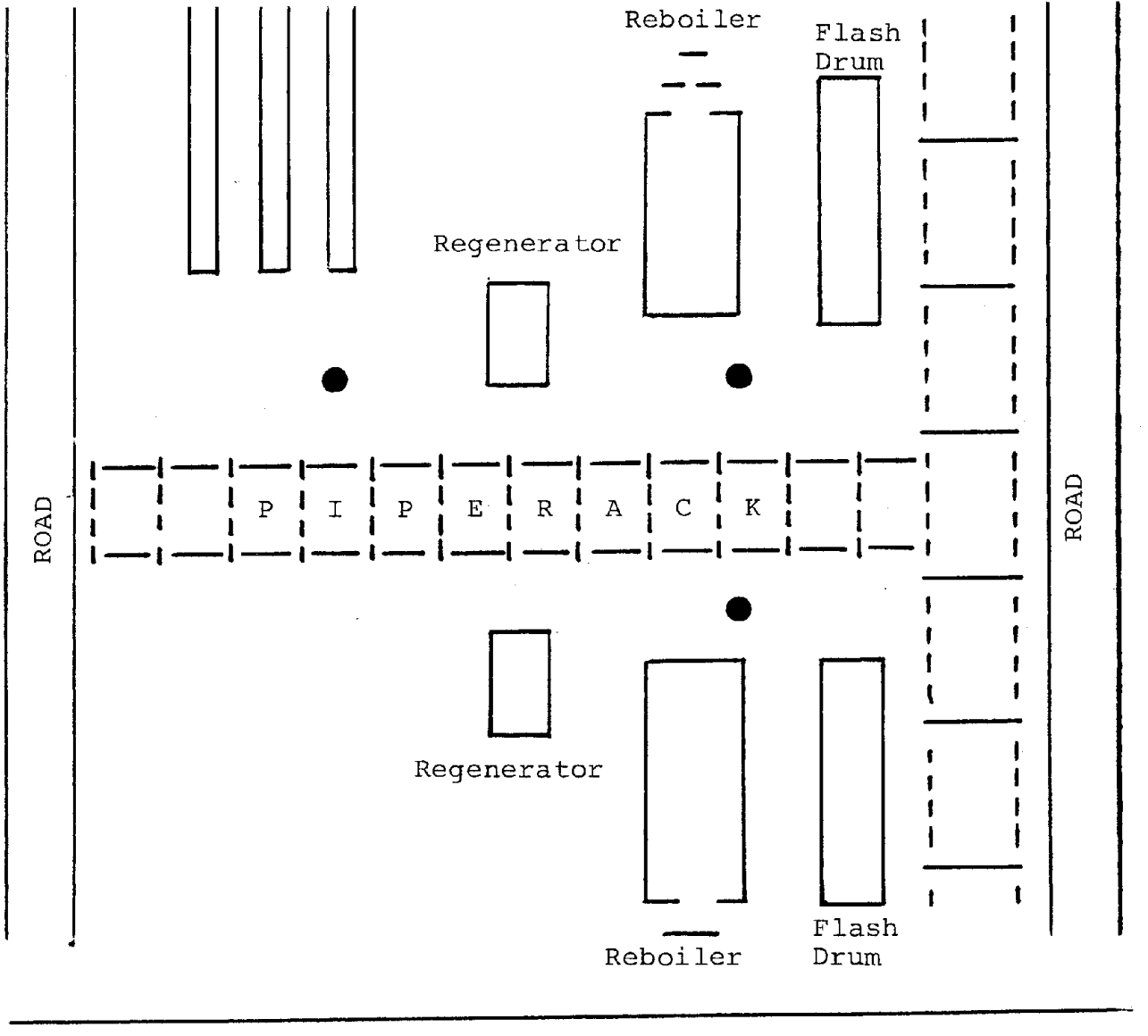


Figure 3-5b H_2S Monitors in DEA Regeneration Area

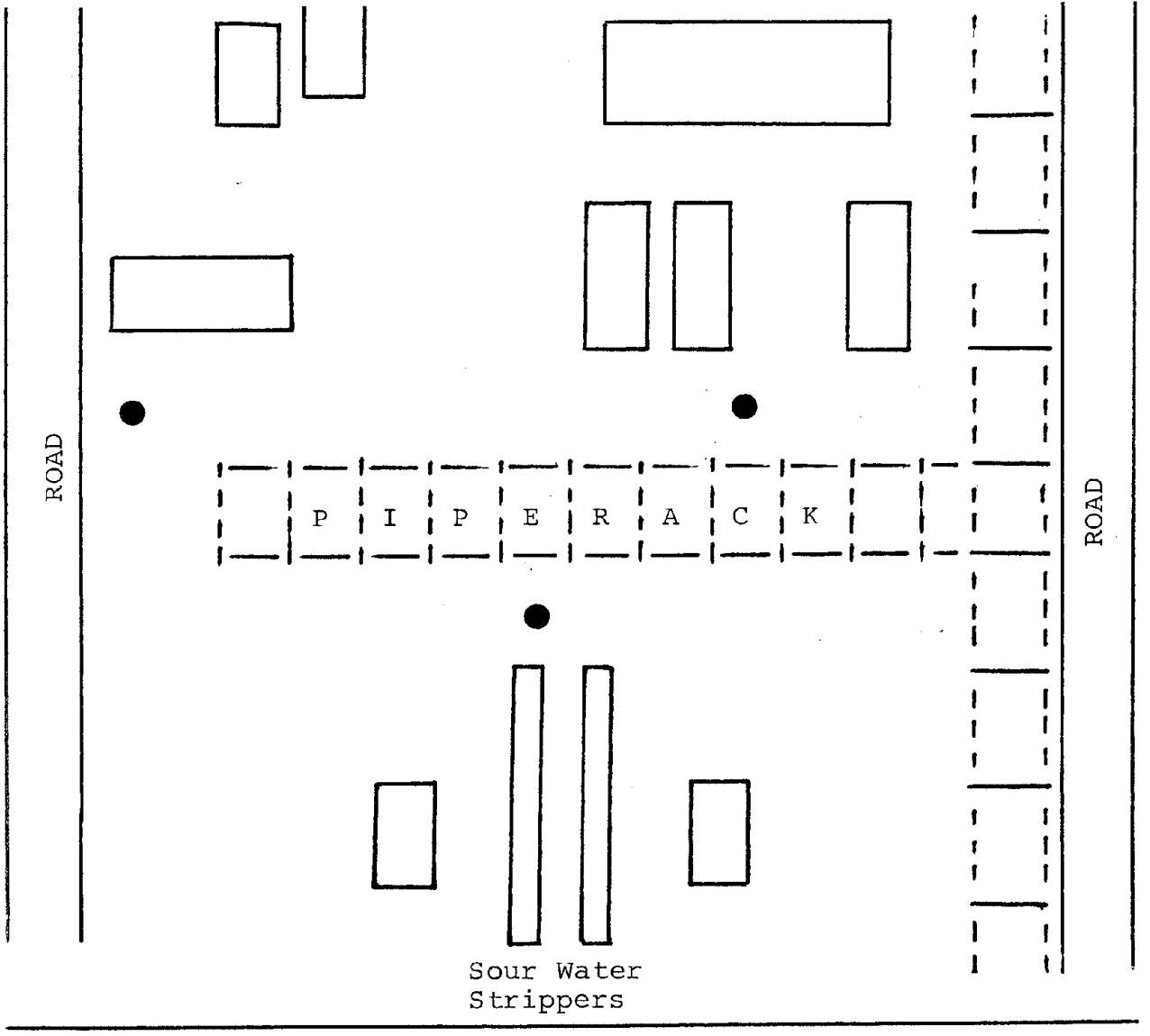


Figure 3-5c H_2S Monitors In DIPA Regeneration Area

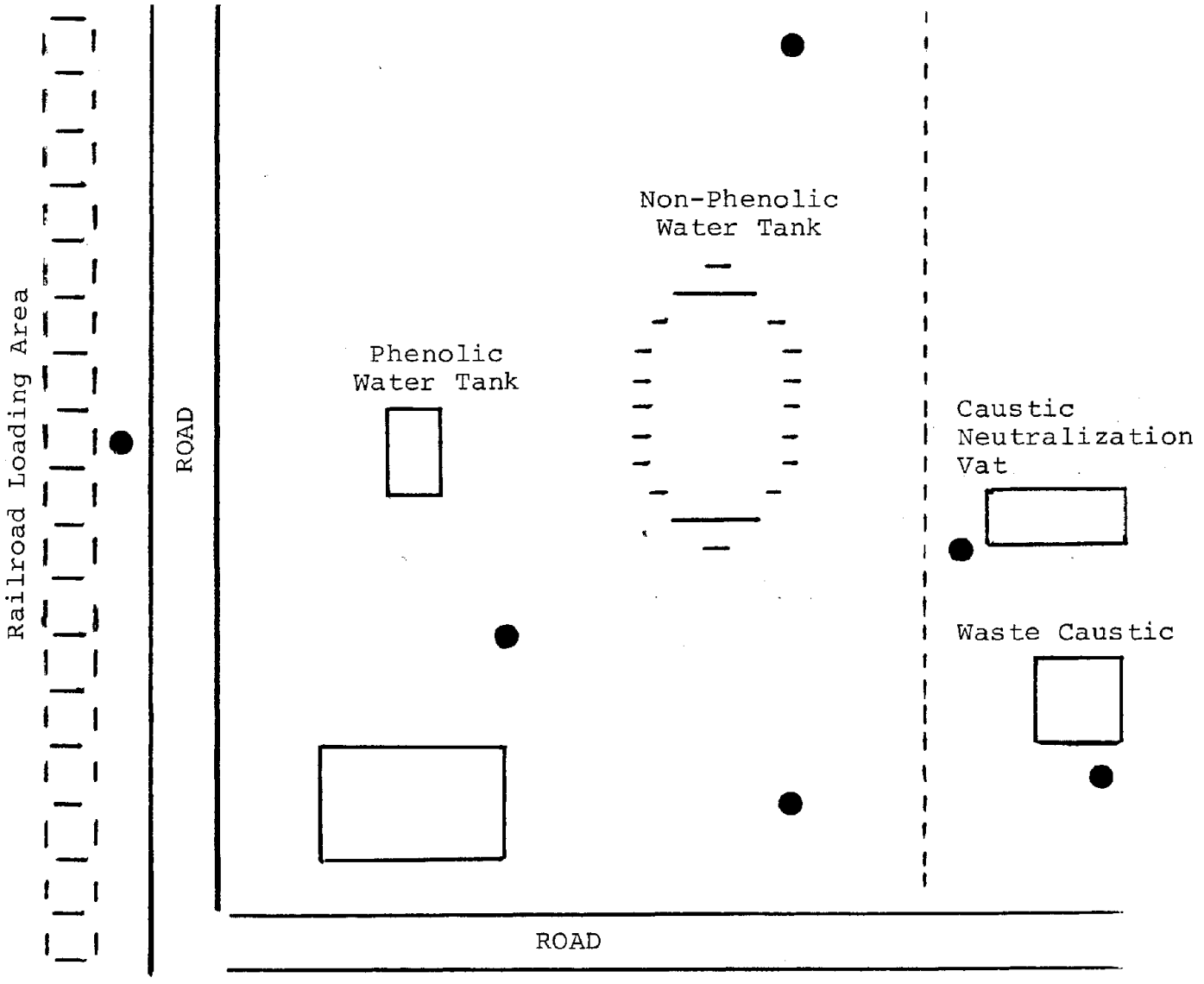


Figure 3-5d H_2S Monitors In Sour Water and Caustic Neutralization Areas

TABLE 3-1. COMPUTER PRINTOUT OF MONITOR #6 H_2S LEVELS

08-18-82

1038 08-18-82 PAGE PRINT CONSOLE 3

10:38:0

17AEX175 H2S MONITOR #6 TIME: 10:37

6 MIN. AVERAGE	10HR	09HR	08HR	07HR	06HR	05HR	04HR
57		1.142	.9271	1.659	.8773	.9114	.9103
51		1.169	1.459	1.349	.8790	.9137	.9241
45		1.079	1.479	1.143	.9074	.9207	.9074
39		1.389	1.479	.9959	.8848	.9108	.9097
PPM 33	.8466	3.340	1.282	1.008	.8750	.9375	.9184
27	.8680	1.079	1.353	.9039	.8657	.9236	.9109
21	.8535	1.033	5.299	.9317	.8657	.9328	.9126
15	.8530	1.405	1.572	.8964	.8692	.9195	.9155
09	.8727	1.322	1.446	.8854	.8998	.9224	.9166
03	1.078	.9108	1.461	.9004	.9259	.9120	.9138
HOUR AVERAGE	10HR	09HR	08HR	07HR	06HR	05HR	04HR
	.8586	1.405	1.743	1.098	.8833	.9210	.9132
	02HR	01HR	00HR	23HR	22HR	21HR	20HR
	.8974	.8942	.8967	.9134	.8843	.8794	.8747
	18HR	17HR	16HR	15HR	14HR	13HR	12HR
	.8468	.8279	.8116	.8166	.8271	.8361	.8477
DAY AVERAGE	TUE 17	MON 16	SUN 15	SAT 14	FRI 13	THR 12	WED 11
	.9245	.9304	.9935	.9021	.9081	.9417	.9253

- Short shelf life and long delivery time of sensor heads

However, early detection of a pump seal failure by the H_2S monitoring system has resulted in a high level of confidence in the system by the operating personnel.

The monitoring system is calibrated once a month using a standard gas. Each sensor is tested, as are the system's electronic functions. A test of one of the sensors during the indepth visit demonstrated the quick response capability of the chemical sensor and the system alarm functions (audible alarm in control room, process area light and computer functions). Two man days per month is required for calibration check.

Installation Costs

Refinery personnel designed the overall system and subcontracted the installation work. Items provided by vendors included: H_2S sensors and controllers, instrument shed, instrument shed panel board, and miscellaneous systems (e.g. alarms and lights). All computer programing was conducted by Refinery personnel on the Refinery's Foxboro central process computer. The total system cost was $190,000 (February 1982 dollars) which includes:

- Engineering

Sensor and controller costs alone are estimated at approximately $19,000.

3.3 H_2S Monitoring System Evaluation

The H_2S monitoring system recently installed at the Cherry Point Refinery is a highly sophisticated system. Operating personnel report a high degree of satisfaction with the new system which replaced a somewhat unreliable lead-acetate tape system.

Location of the system's 18 sensors provides a high degree of coverage over the four processing areas. Much effort went into locating the H_2S sensors in areas that have the highest potential for significant H_2S release and areas where operators, maintenance workers and non-refinery employees frequently are present.

An extensive alarm system provides a high degree of warning if H_2S levels greater than 10 ppm are detected. Each of the four processing areas has a visual (blinking light) alarm and the control room and the caustic neutralization area have audible alarms. The audible alarm at the caustic neutralization area is provided to warn non-refinery personnel (e.g. truck and rail car operators) who may not notice the light alarms. The Refinery is

Use of the Refinery computer to control the H_2S alarm system and handle monitoring data provides a high degree of emergency and long term monitoring information. If an H_2S alarm sounds, the control room board operator can get a color display of the unit area where the high H_2S level has been detected. The unit plot plan indicates the location of each detector and its H_2S level. This information is then relayed by radio to the unit operators. Additionally, the computer compiles one minute scan H_2S measurements for each sensor. These data are compiled into 6-minute, one-hour and 24-hour averages as are all other process data. In the future these data will be compiled in eight-hour and 12-hour averages (operator shifts are 12 hours at Cherry Point) for industrial hygiene purposes.

Due to failure problems with some of the chemical sensors and some difficulty in obtaining replacements quickly, the refinery plans to store several sensors onsite. Because the chemical sensors are only guaranteed a use and storage life of one year, all sensors will be replaced yearly. However, the rapid response time of the sensor and low cost ($400 each) have contributed to a high degree of satisfaction with the new system.

Area monitoring systems can be highly effective controls in reducing worker exposure to toxic substances. The Cherry Point Refinery's new H_2S monitoring system appears to be a well designed and implemented system. This system uses state-of-the art technology for sensors, controllers, alarms and data handling. The health hazard associated with H_2S is one of the petroleum refining industry's major concerns. The Cherry Point Refinery

minimizes the probability of catastrophic failure and reduces the need for unscheduled repairs. Some routine maintenance procedures, such as acoustic testing, may eliminate or substantially reduce situations where reactors or vessels must be opened and entered by maintenance personnel.

The Cherry Point Refinery has in place several maintenance programs which contribute to lowered employee exposure potential to hydrocarbons, hydrogen sulfide, superheated steam, and other hazardous materials. These programs, which emphasize controlling fugitive emissions and preventing equipment failure, are discussed in the following paragraphs.

4.1 Valve and Flange Leak Detection and Repair

Operations personnel at the Cherry Point Refinery check valves and flanges for leaks on a daily basis. The Refinery's primary method for determining "leakers" is visual detection. The monitoring program extends to valves and flanges in hydrocarbon, hydrogen, and steam service. First priority is given to detecting and repairing leaks in hydrocarbon service. The Refinery's Maintenance Department is notified daily by Operations as to which valves and flanges are leaking. Maintenance attempts to immediately repair valves which can be repaired while still in service. Typical repair techniques include tightening the packing or adding more rings.

via injection of a thermosetting compound to seal the leak. A number of firms provide this service; the Cherry Point Refinery has a separate maintenance contract with Furmanite(R). Details about Furmanite's(R) products and services are found in the brochure in Appendix A. Examples of flanges sealed with Furmanite(R) are shown in Figure 4-1.

At each unit turnaround, valves or flanges that leaked or displayed other types of problems are removed, inspected and repaired. Many times the cause of the problem in valves is use of incorrect packing or insufficient packing. All equipment that has been sealed with Furmanite(R) is removed and permanently repaired.

The Refinery Operations Department maintains a record of valves and flanges which have caused problems. This record is periodically reviewed by the operations staff to identify valves or flanges with chronic maintenance problems. An effort is made to determine and remedy the cause of these problems.

4.2 Exchanger Head Leak Prevention

Heat exchanger heads are well-known as chronic "leakers." Fugitive emissions from exchanger heads are a particular problem in high pressure refinery units servicing hydrogen or light ends (e.g. hydrocracking or reforming units). In many instances, such leaks are caused by exchanger head deformation during bolt tightening.

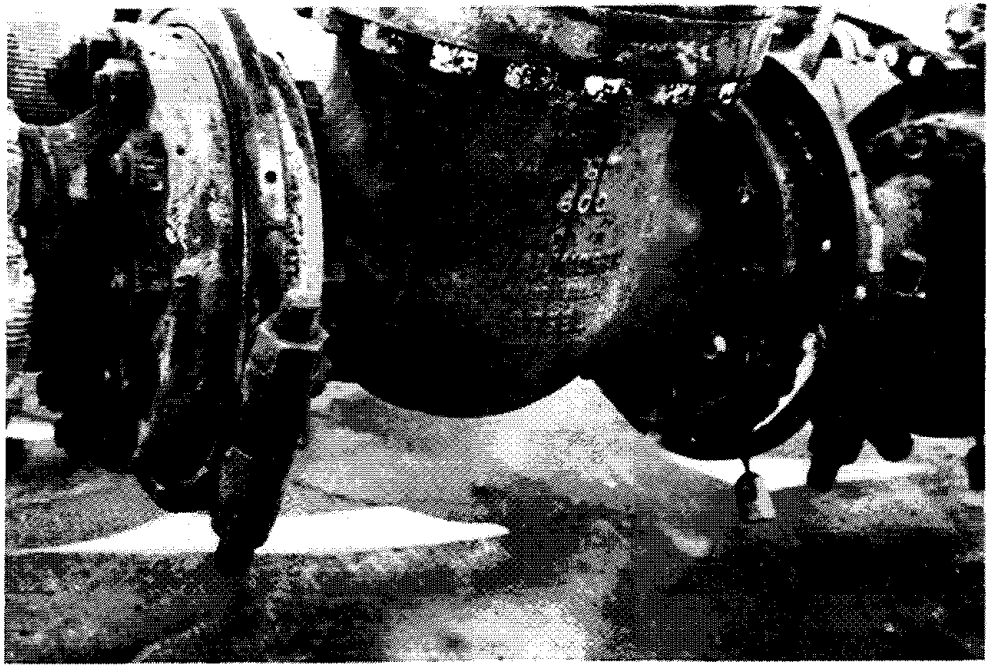


Figure 4 – 1

Steam Valve Flanges Sealed with Furmanite(R)

which measures bolt stretch, and a computer program which calculated optimum stretch for each type of bolt.

To determine bolt stretch, the Refinery uses an extensometer manufactured by Raymond Engineering, Inc. of Middletown, Connecticut. A pulser within the extensometer shocks a transducer which then delivers a brief, highly damped pulse of ultrasound to one end of the bolt. The pulse travels through the bolt, echoes off the far end and returns to the transducer. The extensometer measures the round-trip transit time for the signal and records it in the microprocessing component of the instrument. When the bolt is tightened (and stretched), the length of the path the signal must travel increases and this is measured by a proportionate increase in the transid time of the signal.

Cherry Point engineers said that the extensometer is used primarily to aid in tightening large or critical flanges and exchanger heads such as those in the Hydrocracking or Reforming Units (Figure 4-2). The instrument has been most useful to control tightening the 3-1/4" diameter bolts used on the Hydrocracking Unit exchanger heads. The instrument can be used on bolts at temperatures of up to 300^{o}F.

Cherry Point operations engineers initially calculated elongation and torque values for each bolt type in each application. Calculations were based on the bolt material, the gasket material, and the yield strength of the flange or exchanger head.

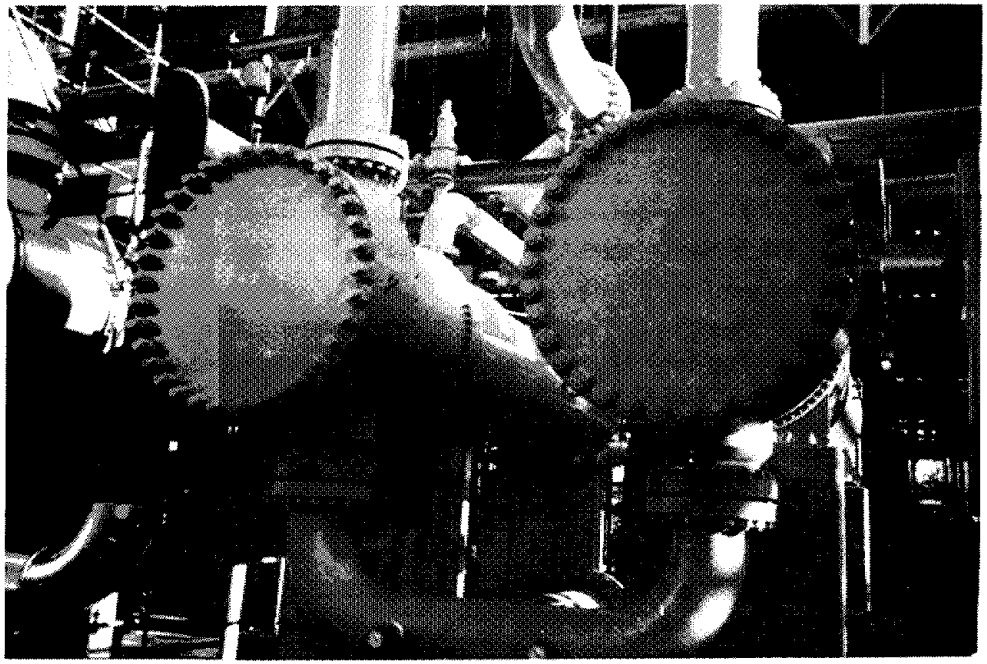


Figure 4 – 2

Heat Exchanger Heads in Hydrocracking Unit

being tightened in the field, the extensometer is applied and the degree of stretch is measured.

Bolts for each exchanger head are tightened gradually using a hydraulic torque wrench. During the first tightening sequences, bolts are tightened in a "star" pattern, i.e. bolts opposite each other across the exchanger head surface are tightened. In the final tightening sequence, bolts are tightened in a circular pattern around the exchanger head.

Use of the extensometer is more time-consuming than tightening bolts with a torque wrench alone (5 hours per exchanger head or flange versus 1 hour per head or flange). In some instances, to minimize turnaround time, the Refinery monitors the stretch on fewer bolts. However, a majority of bolts must be monitored so that the integrity of the exchanger head seal is maintained. Refinery engineers said that the extra time spent in careful bolt tightening often results in time saved in the long-term; a unit is brought onstream with minimal problems and does not have to be shut down due to leaking exchanger heads or flanges.

In general, Cherry Point engineers were satisfied with the extensometer. One problem existing in an older model such as the one owned by the Refinery is its susceptibility to moisture. Newer models being developed by Raymond Engineering are reportedly weather-resistant as well as lighter and easier to carry.

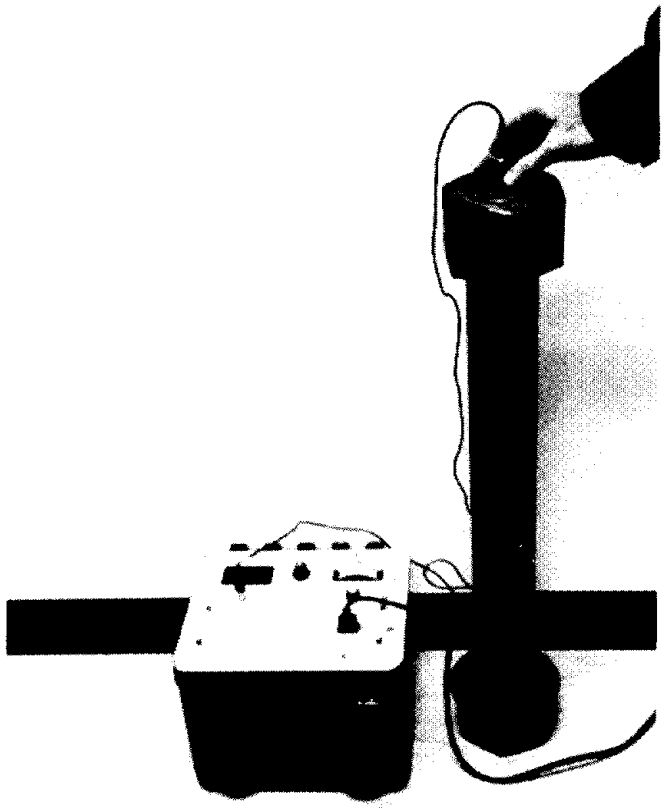


Figure 4 – 3

Extensometer Applied to 3¼ " – Diameter Bolt

Refinery is no exception to the corporate rule. The Refinery attributes its favorable pump seal maintenance record to its vibration monitoring and alignment/balancing programs.

When the Refinery initiated its vibration monitoring program in 1978, the maximum allowable vibration was 0.25 inches per second (IPS). The current maximum allowed is 0.10 IPS. Refinery personnel said that since the program began, the majority of pump failures have been due to worn bearings rather than seal failures. Pumps may run for over two years without major maintenance.

Twenty maintenance personnel permanently assigned to the Refinery's machine shop are responsible for analyzing vibration monitoring data and aligning or repairing out-of-specification equipment. The Refinery has an extensive training program to teach employees how to use vibration monitoring equipment and how to interpret vibration data.

Operators on each Refinery unit carry hand-held vibration monitors and check all pumps and compressors in each unit one time per month. Vibration information is sent to the Maintenance Department, which reviews the data and identifies out-of-specification equipment. If a pump is spared, it is removed from service and repaired immediately. If not spared, it is given high priority for repair during turnaround. Each pump, compressor or turbine is balanced every time it is brought in for maintenance, regardless of its vibration status.

The machine shop maintains detailed records of all pump and other rotating equipment failures. The records are stored in the refinery's computer and are accessed through a CRT terminal located in the machine shop. Figure 4-4 is an example of an equipment maintenance history for a heater fan turbine. Spare parts information and repair cost information also are computerized for each equipment item (Figures 4-5 and 4-6). These records are periodically reviewed by Maintenance and Operations personnel looking for problem trends.

4.4 Acoustic Testing

The State of Washington requires that all pressure vessels receive a biennial inspection. To avoid unnecessary shutdown and start-up of catalyst-containing pressure vessels, the Cherry Point Refinery uses acoustic testing to inspect these vessels while still on-stream. The pressure in the vessels is raised and lowered for short time periods while the unit is still in service.

Acoustic testing is used by the Refinery in trouble-shooting problems. Such testing locates even small cracks. Tests are usually conducted shortly before a scheduled turnaround. If cracks are found, materials can be ordered and repairs made during turnaround.

The Refinery has used acoustic testing to inspect its hydrocracker reactors, reformer reactors, coke drums, and some pipelines and piping systems. The cost of an acoustic inspection

08/17/82 016393

MAINTENANCE SYSTEM - EQUIP HISTORY INQUIRY BY EQUIPMENT NUMBER OPE
PA

EQ# CP010441502 SOUTH-HEATER NORTH-FAN TURBINE

JOB NBR	COST CTR.	DATE OPENED	FAIL CODE	C O M M E N T S
DUMMY	R814	800717		INSPECTED BEARINGS OK ANGLE GEAR BOX BO REPLACEI
DUMMY	R814	800717		GEAR BOX INPUT SHAFT FOR WOODARD GOVERNOR BEARIN
DUMMY	R814	800717		CLEAR .007 THRUST .010
30923	R814	810504	061	CHECKED BEARINGS RADIAL BEARING CLEAR .007 TEST
30923	R814	810504		GOVERNOR 3600 RPM OS TRIP 4000 RPM
36435	R814	810609	001	CHECKED TURBINE FOUND ANGLE GEAR BOX BO INSTALLE
36435	R814	810609		REBUILT UNIT
DUMMY	R814	820503		T.A. WORK. CLEANED BEARING BOXS. REPLACED RADIAL
DUMMY	R814	820503	061	ARINGS SOME SCORE MARKS. AXIAL THRUST BEARING GO
DUMMY	R814	820503		AXIAL THRUST .008" IB CLEAR .008" OB .008" INSPE
DUMMY	R814	820503		COUPLING OK. INSPECTED THROTTLE VALVE AND LAPPEI
DUMMY	R814	820503		SEATS. SENT WOODWARD GOVERNOR OUT FOR OVERHAUL.
DUMMY	R814	820503		PLACED ANGLE GEAR BOX. TEST RAN GOVERNOR 3577 RF
DUMMY	R814	820503		O.S. TRIP 3960 RPM.

END OF REPORT.

Figure 4-4 Example of Equipment Maintenance History

08/17/82 016412 PAGE 1

STORES INVENTORY - EQUIPMENT NUMBER INQUIRY (EQ-SPARE PARTS FILE) OP

EQ# CP010441502 DESC SOUTH-HEATER NORTH-FAN TURBINE

STK NO	SHORT DESCRIPTION	COST-CENTER	UNIT REQ	ON HND
7436419407	ASSEMBLY, VALVE STEM		1	4
7436495928	ASSEMBLY, EMERGENCY GOVERNOR DISC		1	1
7437087278	BODY, GOVERNOR & EMERGENCY VALVE		1	2
7438800968	COLLAR, THRUST		1	3
7438887379	COLLAR, STEAM BUNTER		1	2
7438892734	COLLAR, BUNTER		1	4
7439033304	DEFLECTOR, OIL		1	1
7439649810	END, TRIP ROD, EMERGENCY		1	1
7439909669	FOLLOWER, EMERGENCY VALVE PACKING		1	2
7440216013	GEAR, HUB CITY	RIGHT ANGLE DRIVE	1	0
7440305584	GEAR SET, 15T & 45T (3-1 RATIO)		1	2
7441808891	NUT, SHAFT		1	4
7441823965	NUT, PACKING, EMERGENCY VALVE STUFFING BOX		1	5
7441826224	NUT, EMERGENCY ADJUSTING SCREW		1	9
7442040965	PACKING, EMERGENCY VALVE		1	3
7442109679	PIECE, EMERGENCY VALVE FILLER		1	1

CONTINUED ON NEXT PAGE...

08/17/82 016412 PAGE 3

STORES INVENTORY - EQUIPMENT NUMBER INQUIRY (EQ-SPARE PARTS FILE) OP

EQ# CP010441502 DESC SOUTH-HEATER NORTH-FAN TURBINE

STK NO	SHORT DESCRIPTION	COST-CENTER	UNIT REQ	ON HND
7444636695	SPRING, VALVE STEM CUSHIONING		1	12
7444649342	SPRING, EMERGENCY VALVE		1	2
7444649482	SPRING, BACK LASH		1	2
7444690635	SPRING, GOVERNOR VALVE		1	3
7445884898	TRIGGER, EMERGENCY VALVE		1	2
7446408143	WEIGHT, EMERGENCY		1	1
9900000028	THIS STOCK # FOR EQUIPMENT HISTORY FILE ONLY		1	0

END OF REPORT.

Figure 4-5 Example of Spare Parts Inventory

```
MA01                                          08/17/82  016522
 MAINTENANCE SYSTEM - JOB ORDER INQUIRY                          OP
 JO# 41710  RPR STAB CHG PUMP OB SEAL
 STATUS  4                                    OPEN 041582 BY 10 CLOSE 051
 EQ# CP011729502     SKL   EST    ACT              INIT EST
 CC        R812      GRP   HRS    HRS              LAST EST
 PRI       1         08      0      0                        WTD
 PGM       000       12      0      0          REG HRS         0
 MAR       001       22     20      7          OT  HRS         0
 OAR       868       48      0      0              A R C O
 AFE       0000      28      0      0          LBR $           0
 CAT       000       14      0      0          MTL $           0
 SUB-CAT   000       05      0      0          PURCH $         0
 LBR ACCT  9237      39      0      0          RENTL $         0
 MTL ACCT  7928      00      0      0          MISC $          0
 CLB ACCT  7940      00      0      0              C O N T R A C
 CMT ACCT  7838      00      0      0          LBR $           0
 PURP      99        00      0      0              C O N T R A C
 TYP EX    10                                 LBR $           0
                                              MTL $           0

                          (PF1) EQ MASTER INQUIRY     (PF3) MATERIAL US
 (PA2) NEXT JO#           (PF2) EQ HISTORY INQ
```

Figure 4-6 Example of Equipment Repair Cost Summary

4.5 Maintenance Procedures Evaluation

Refinery maintenance employees have a high potential for overexposure to such hazardous materials as hydrocarbon vapors, hydrogen sulfide and residual heavy hydrocarbon materials. By developing programs which minimize scheduled and unscheduled maintenance activities, the Cherry Point Refinery effectively reduces the exposure risk to maintenance personnel. When maintenance is performed, it is usually done when a unit is not in service and when little or no hydrocarbon or other harmful vapors are present.

Additionally, the well-maintained equipment at the Cherry Point Refinery means reduced exposure to engineering and operations employees. Fugitive hydrocarbon emissions are substantially reduced by the Refinery's valve, flange, and pump maintenance programs. The potential for high exposure levels during a catastrophic failure is greatly reduced by the Refinery's vibration monitoring and acoustic testing programs.

APPENDIX A

The following brochure is reproduced by permission of Fumanite, Incorporated.

Furmanite seals leaks of steam, air, gases, water, hydrocarbons and chemicals — ON-LINE — without costly plant shutdowns or removing individual pieces of equipment from service!

As the largest and most successful service organization of its kind in the world, Furmanite has a history of leadership in on-line leak sealing and energy conservation. Developed in 1922 for the repair of steam leaks in the shipping industry, Furmanite leak sealing compounds, specialized equipment and associated technology have evolved greatly since their inception and have been applied with phenomenal success in oil refineries, conventional and nuclear power stations, chemical manufacturing plants, processing plants of all types, marine installations and numerous other applications.

The benefits of using Furmanite's leak sealing service are substantial and numerous:

- **plant shutdowns avoided** — and usually no reduction in operating pressure. This means no lost revenue and no problems caused by thermal cycling of the system.
- **energy is conserved** — of vital importance today! Further, the value of the energy saved is many times greater than the cost of Furmanite service.
- **lower cost than alternative methods.** In general, the Furmanite process is not only much faster but also considerably less expensive than conventional "tear-down" techniques.
- **plant safety is improved** and noise factors are decreased.
- **minimization of erosion damage** to pipelines and equipment from leaking steam or other substances.
- **service is available 24 hours a day, 7 days a week.** You can have service when you want it and when you need it without having to pay in-house staff to be on standby.

...STEAM LEAK...

...SEALED ON-LINE

The Furmanite service involves a highly effective leak sealing technique which is based on injection of a thermosetting compound directly into the source of the leak with the system operating at full pressure. The process can be used to seal leaks in flanges, valve glands and bonnets, screwed couplings, heat exchanger joints, unions, turbine casings, weld leaks, holes in pipes, expansion joints, fabricated tank joints and a wide range of other pressure system and process plant components. Vacuum leaks, although requiring particular care, can also be sealed by the Furmanite process.

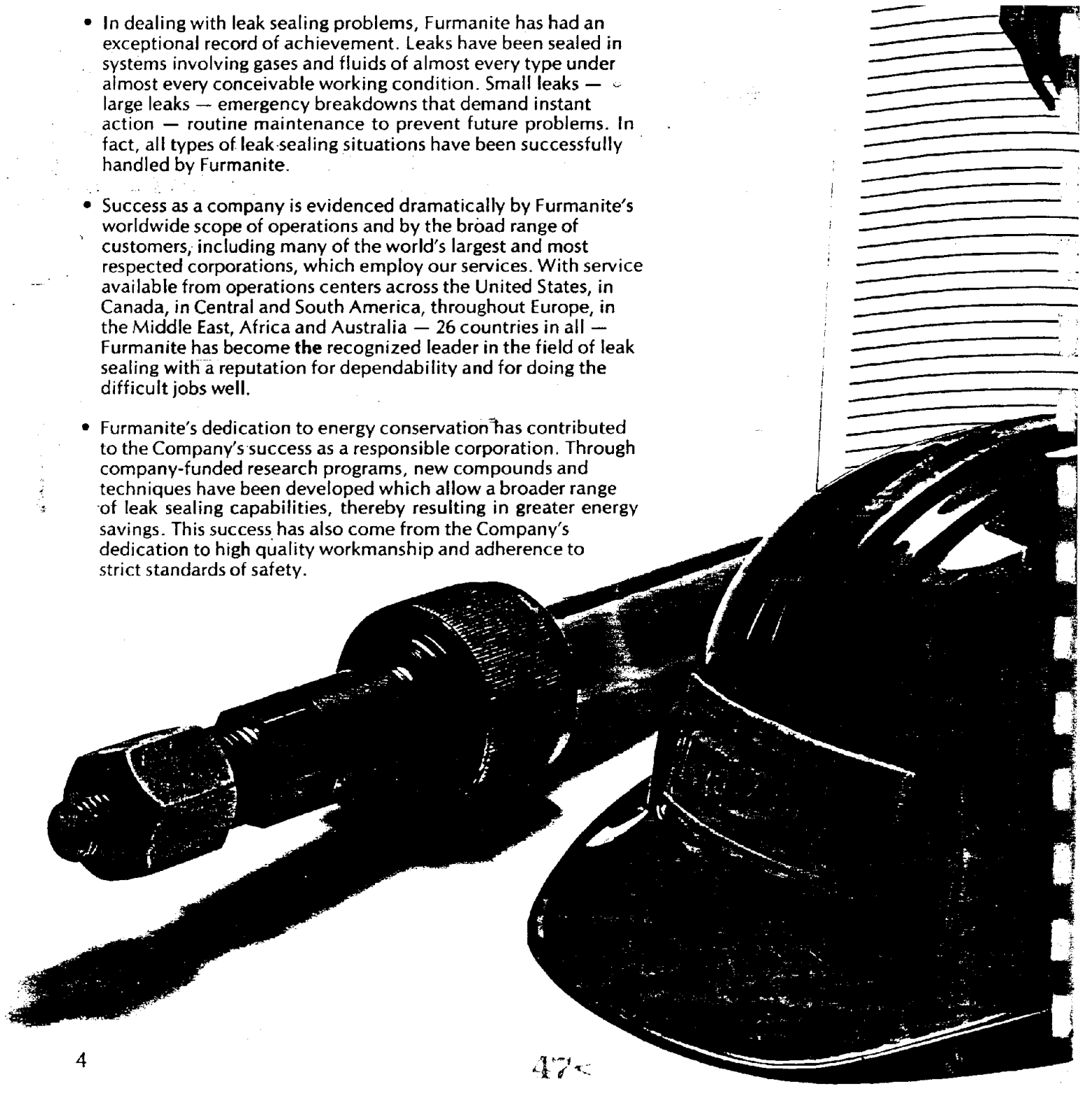
During injection, the Furmanite compound fills all of the grooves and pits in the faces of the joint and thereby eliminates the need to machine the mating surfaces. Once the Furmanite compound has cured, the integrity of the seal can be considered equal to or better than the original installation. For applications involving steam or other hot substances, the inherent heat in the system is used initia to soften the compound for the injection process and then to cure For low temperature situations, external heat is applied by using steam or flameproof electric heating tapes. Non-curing and cold-t compounds are also available for special applications. Today, Furmanite can seal leaks involving temperatures up to 600°C [1100°F] and pressures up to 5000 psi. Further, the Company has special compounds that are compatible with most fluids and chemicals.

Furmanite compounds are specially formulated so as not to bond the metal surfaces.

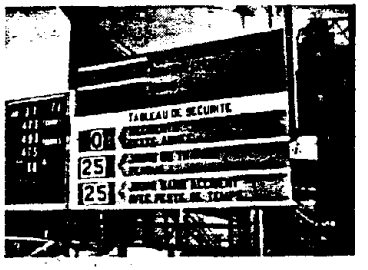
- In dealing with leak sealing problems, Furmanite has had an exceptional record of achievement. Leaks have been sealed in systems involving gases and fluids of almost every type under almost every conceivable working condition. Small leaks — large leaks — emergency breakdowns that demand instant action — routine maintenance to prevent future problems. In fact, all types of leak-sealing situations have been successfully handled by Furmanite.

- Success as a company is evidenced dramatically by Furmanite's worldwide scope of operations and by the broad range of customers, including many of the world's largest and most respected corporations, which employ our services. With service available from operations centers across the United States, in Canada, in Central and South America, throughout Europe, in the Middle East, Africa and Australia — 26 countries in all — Furmanite has become **the** recognized leader in the field of leak sealing with a reputation for dependability and for doing the difficult jobs well.

- Furmanite's dedication to energy conservation has contributed to the Company's success as a responsible corporation. Through company-funded research programs, new compounds and techniques have been developed which allow a broader range of leak sealing capabilities, thereby resulting in greater energy savings. This success has also come from the Company's dedication to high quality workmanship and adherence to strict standards of safety.



Difficult situations are dealt with safely and professionally every day.



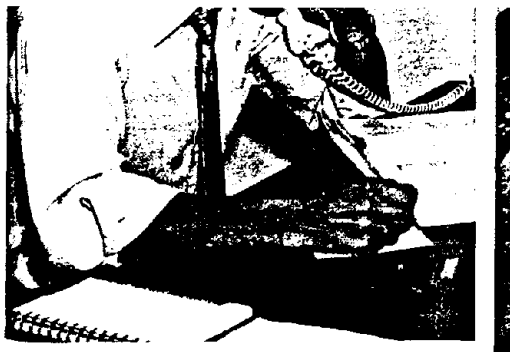
Worldwide scope of operations gives large and small customers immediate response.

Furmanite technicians maintain high safety standards throughout the course of each on-site leak-sealing assignment.

Companies use our services because Furmanite professional on-line leak sealing provides the **real** answer to the problem of leaks. Far more than being just normal service representatives, the Company's field technicians are backed by the resources of the worldwide Furmanite organization and the skills of many people in management, marketing, finance and other areas. The Company's technical resources include:

- research and development to create the most effective leak sealing compounds and techniques
- a competent full-time engineering staff to develop better methods and to stay well ahead of new technological developments in all of the industries serviced by Furmanite
- immediate access to the specialists at the Furmanite Technical Center for high-level back-up on the hard-to-solve problems that are encountered in the field
- custom fabrication of clamps and other special hardware
- the proper equipment required to do jobs quickly and safely

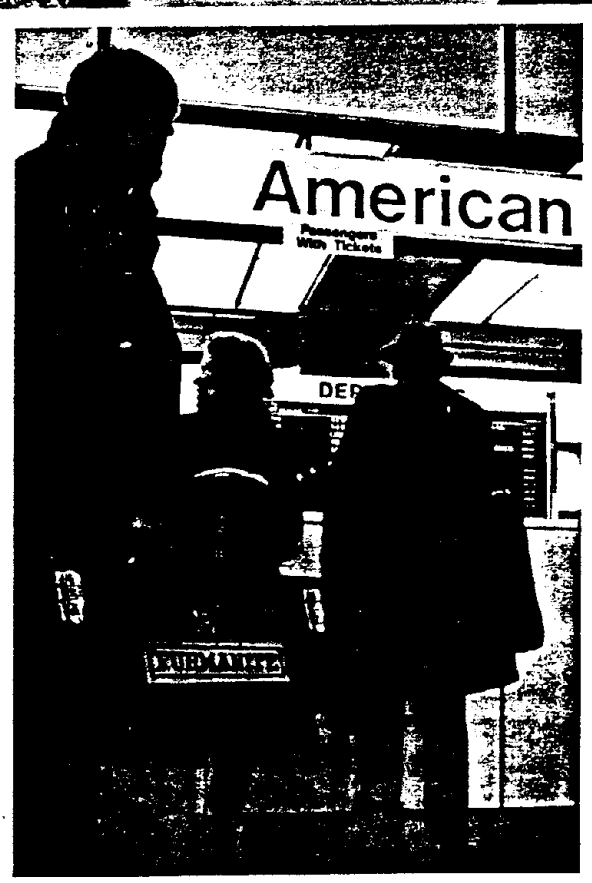
Above all, leak sealing requires highly qualified personnel. In this regard, the Furmanite technician ranks as the best in the business. Basically, he is a skilled mechanical specialist with a broad range of industrial experience. Further, he has passed the Company's rigorous system of selection and has been intensively trained to deal with the numerous types of leaks which he is likely to encounter in the field. On the job, he utilizes his training and experience to assess each individual problem. He then applies the best technique to successfully seal the leak. Foremost, he keeps your plant operating — without shut-down — and without loss of vital revenue.



Around the clock engineering support.

Professional design of quality hardware.

Complete machining and fabrication facilities.



Personnel fully equipped for job conditions.

24-hour emergency call-out.

pulp and paper mills, steel mills, chemical plants, institutions, marine installations, food processing plants, pipelines, etc. The most commonly sealed leaks are steam and boiler feedwater. Others include gases, hydrocarbons and a wide range of chemical products.

Service is provided by highly-qualified Furmanite personnel using vehicles which are fully equipped with all of the necessary compounds and injection equipment required to seal any of a wide variety of leaks. Most flange leaks can be sealed by "wire techniques". Where injection clamps are required, standard hardware for common ANSI flanges is kept in stock while special clamps, manufactured to the Company's rigid quality standards, are custom-produced on short notice.

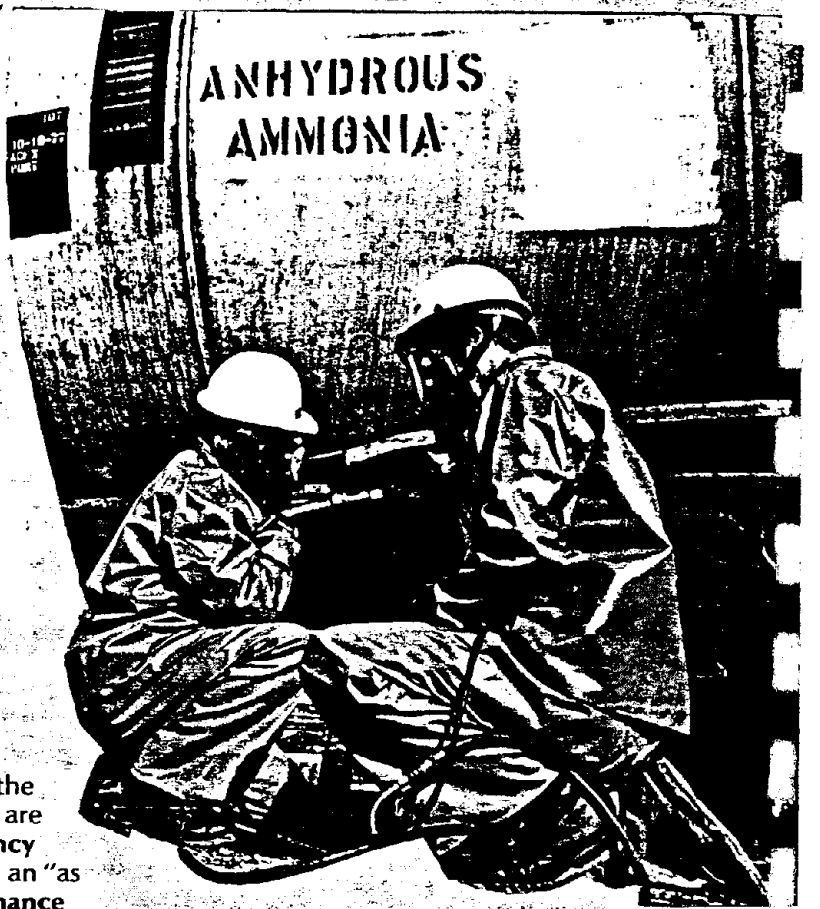
EMERGENCY SERVICE

When a leak occurs that requires immediate attention, Furmanite leak sealing service is as near as your telephone. In the many industrial areas where Furmanite operations centers are located, emergency service can be at your refinery, mill, plant or station soon after your call is received. For other areas, Furmanite teams will travel to your facilities by air and will have the solution to your problem underway as soon as they arrive.

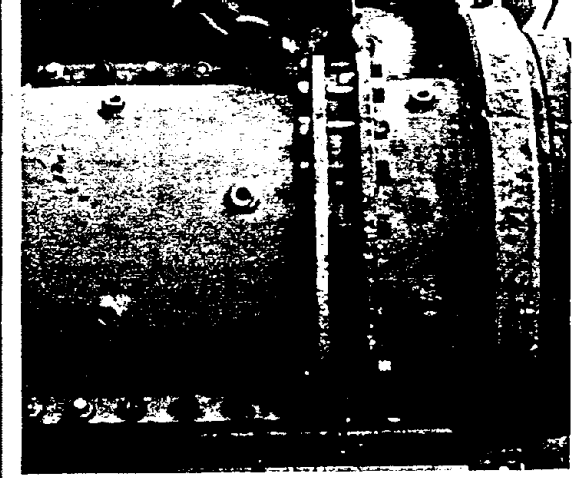
SERVICE CONTRACTS

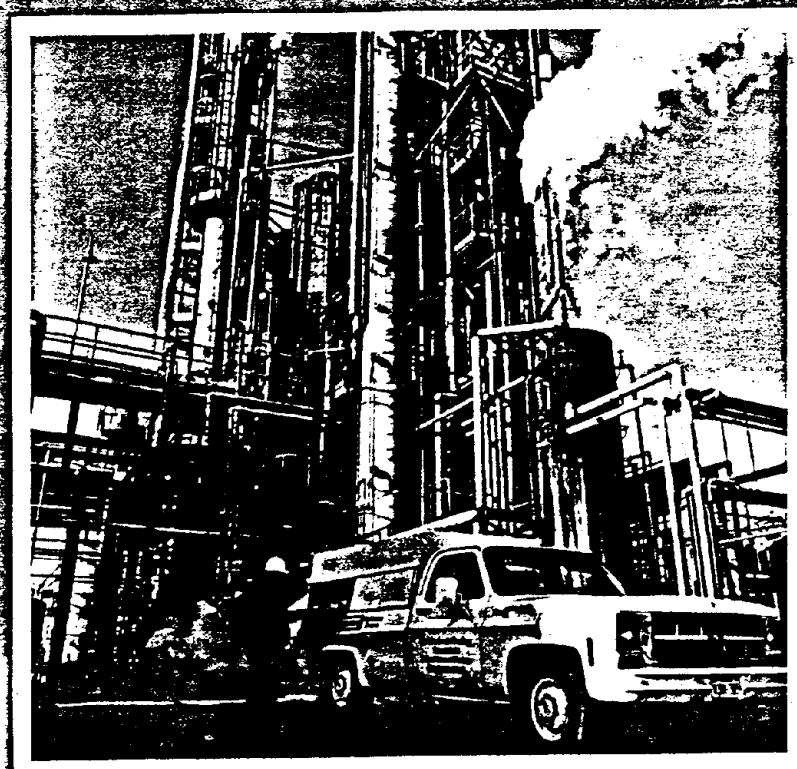
Rather than waiting until an emergency arises to first call Furmanite, many well-known companies have recognized the advantages inherent in Furmanite Service Contracts. These are available in two main forms: First, under a **blanket emergency service contract,** Furmanite provides emergency service on an "as and when required" basis. Second, under a **routine maintenance contract,** Furmanite provides a regularly scheduled routine maintenance for your facility to seal non-emergency leaks and to seek out and apply solutions to potential problems before they become serious or dangerous. With this second type of contract, Furmanite technicians are on site for a number of days each month for a predetermined cost for labor and expenses. Charges are made for materials only as they are required. Furmanite service contracts keep plants in continuous operation, save energy and money and improve the working environment.

Conformance to established industry standards.



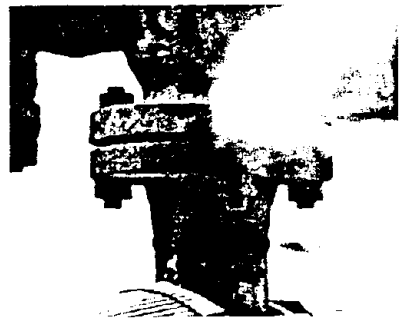
Full range of chemicals and job conditions handled safely on shore... and at sea.



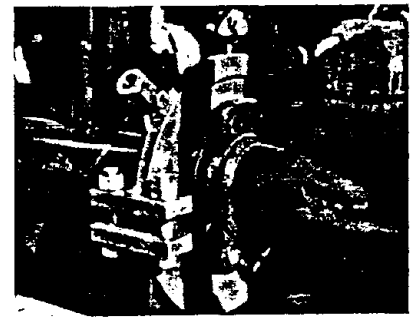


Furmanite technicians arrive on site fully equipped to handle leaks in any industry, in all climates, under high or low pressure, regardless of size.

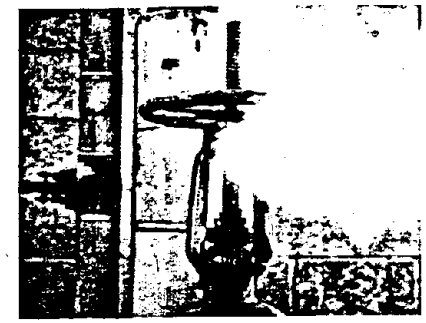
Flange Leaks

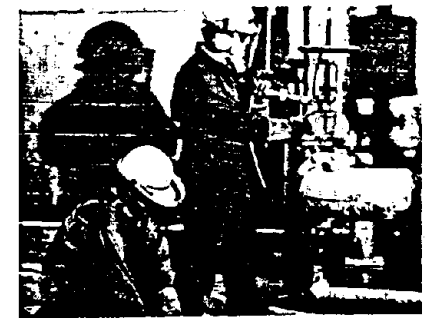


Clamps

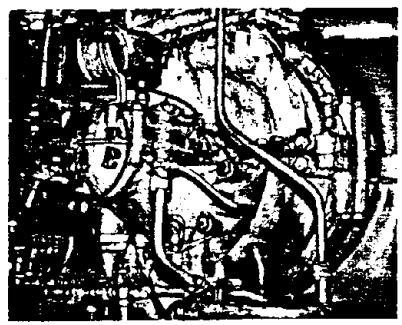


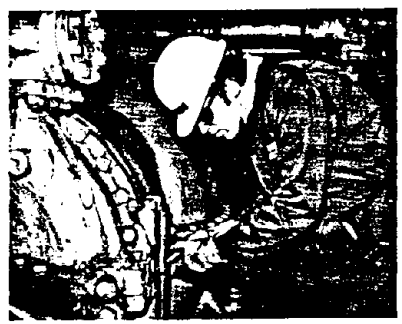
Valve Packing



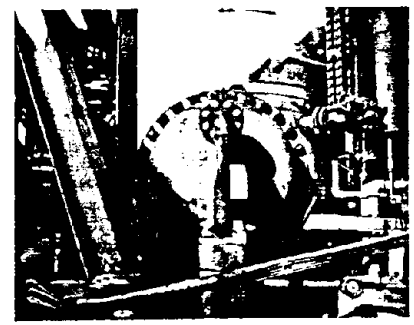


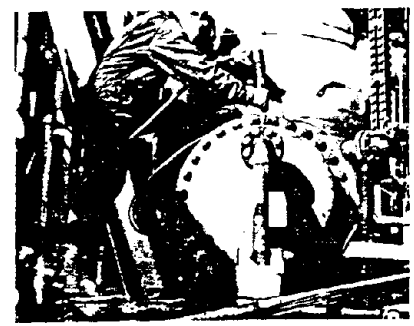
Turbines



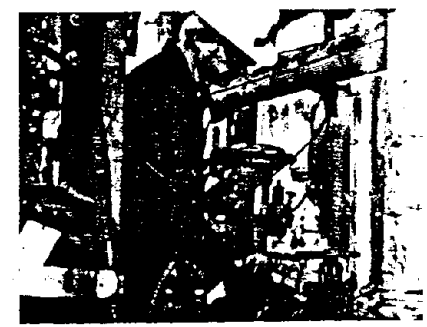


Heat Exchangers

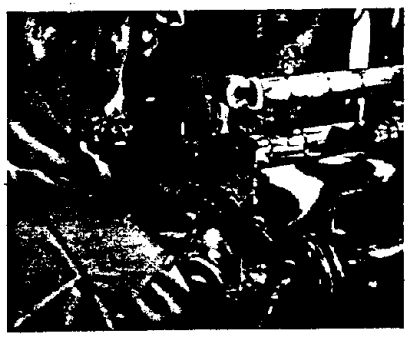




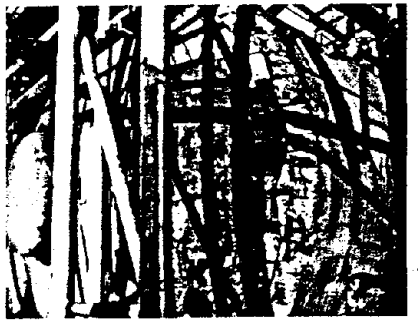
Bonnets



Enclosures

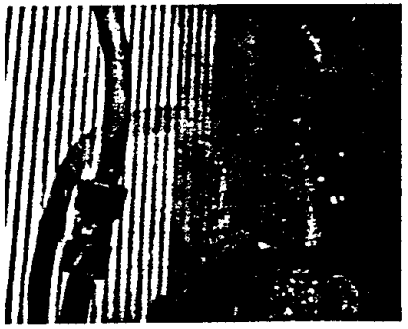


Surface Sealing

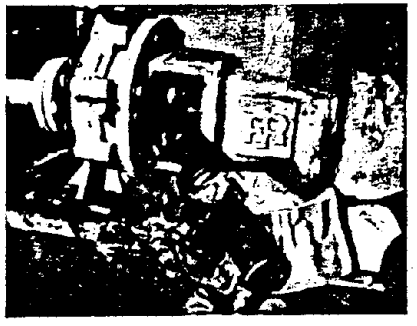


Expansion Joints

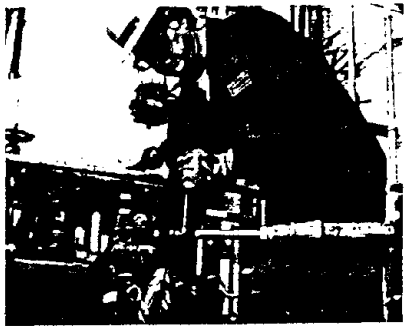
Steam tracing

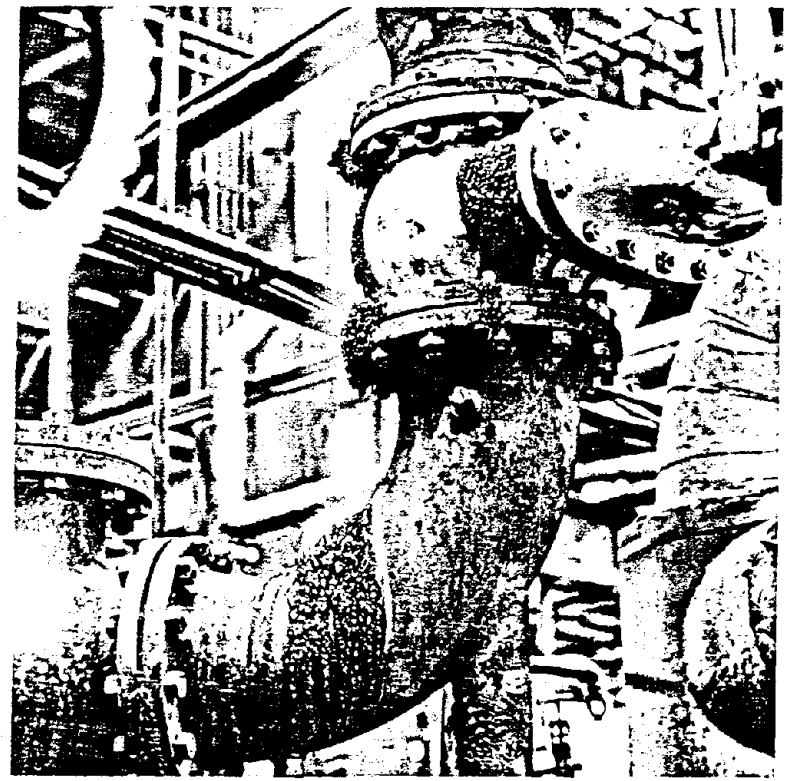


Rotating Shafts



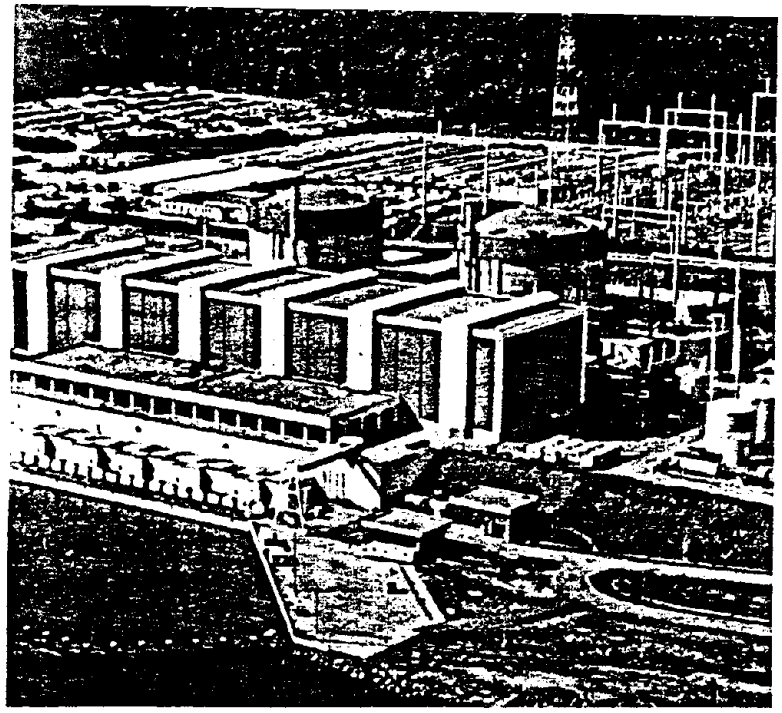
Valve Replacement





Furmanite leak sealing service is applicable to nearly every type of leak found in petrochemical plants and refineries. Examples of specific applications include:

- **STEAM LEAKS** in both heating and process steam systems.
- **HYDROGEN LEAKS** such as those found in hydro-cracker cycle gas systems.
- **FLUIDIZED CATALYTIC CRACKER [FCC UNIT] LEAKS** such as typically occur in the cycle gas system.
- **FCC UNIT SLIDE VALVE LEAKS.** Valves which previously had to be replaced or seal welded at great expense can now be sealed without shutting down the system.
- **HOT OIL LEAKS** for which Furmanite has developed special sealing compounds.
- **LEAKS OF HIGHLY CORROSIVE FLUIDS** such as in the HF Alkylation unit.
- **DISTILLATION COLUMN MANWAY LEAKS**
- **ALIPHATIC AND AROMATIC HYDROCARBON LEAKS** over the full range of normal operating conditions.
- **HIGHLY TOXIC CHEMICAL LEAKS** such as those in the process or flare systems. These are handled with the use of special safety equipment.
- **SULFUR EXTRACTION AND PHENOL PROCESSING SYSTEM** leaks.
- **SURFACE SEALING** of leaks in low pressure storage vessels such as tanks and piping systems. The process involves the application of a surface seal over cracks, holes, corrosion pits, eroded areas or other leak sources — without the necessity of welding.

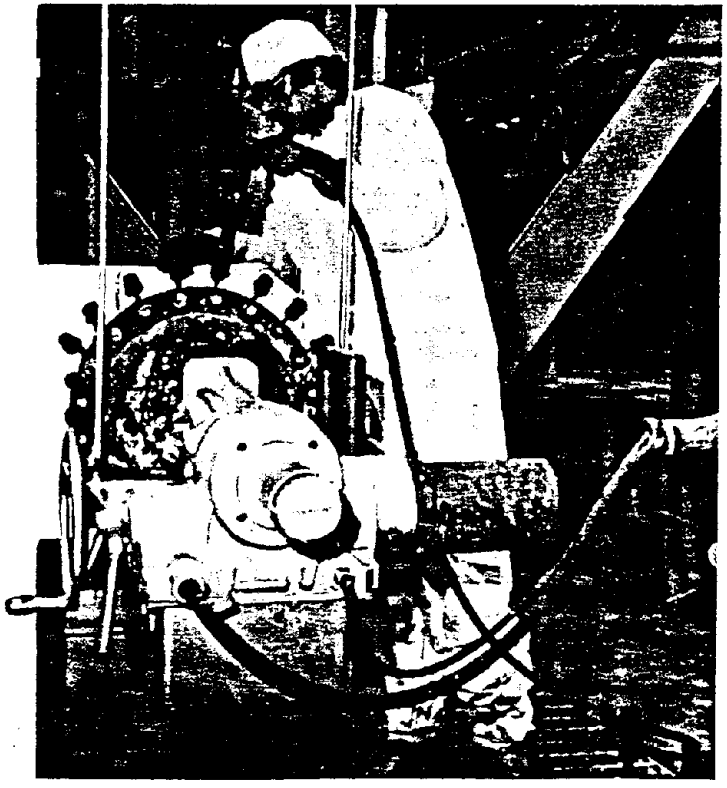


Keeping a nuclear power plant fully operational is mandatory if favorable generation economics are to be achieved. One method by which these plants are being kept fully operational is through on-line servicing. Furmanite pioneered this technology.

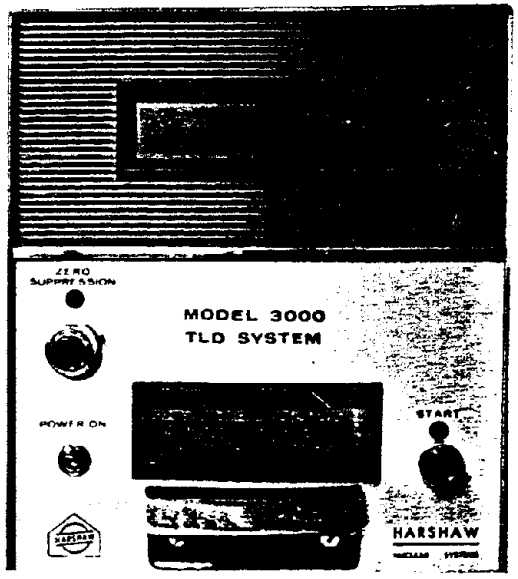
For safety-related components, Furmanite uses controlled nuclear grade compounds and applies them in accordance with written procedures. Further, the Company's Quality Assurance program has been audited and approved by representatives of numerous nuclear power plants.

To ensure that the Company remains at the forefront of this industry, Furmanite employs a staff of specialists with in-depth background in the nuclear field who provide leak sealing personnel with on-going training to a standard which conforms to, or exceeds, government regulations. In addition, Furmanite provides independent Health Physics monitoring of all company personnel.

Examples of applications of Furmanite's service in the nuclear power industry include:

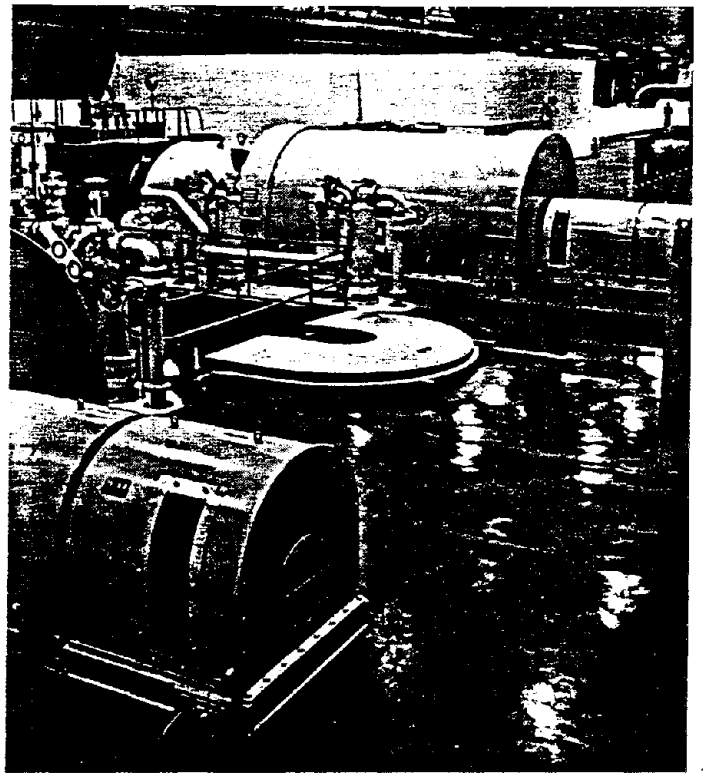


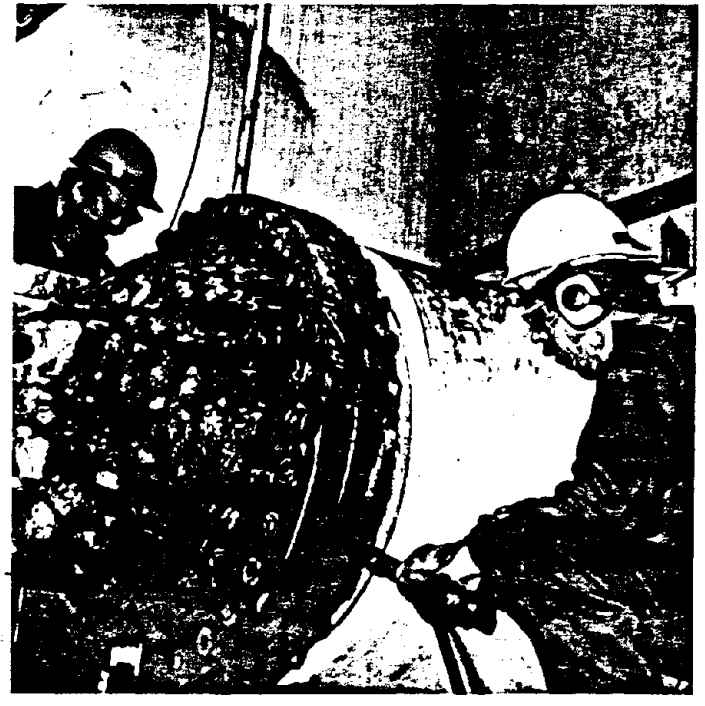
- **STEAM** and **FEEDWATER LEAKS** of all types.
- **BOILING WATER REACTOR [BWR]** and **PRESSURIZED WATER REACTOR [PWR] LEAKS** — both **INSIDE** and **OUTSIDE** of containment.
- **HEAVY WATER** (sulfide water systems).

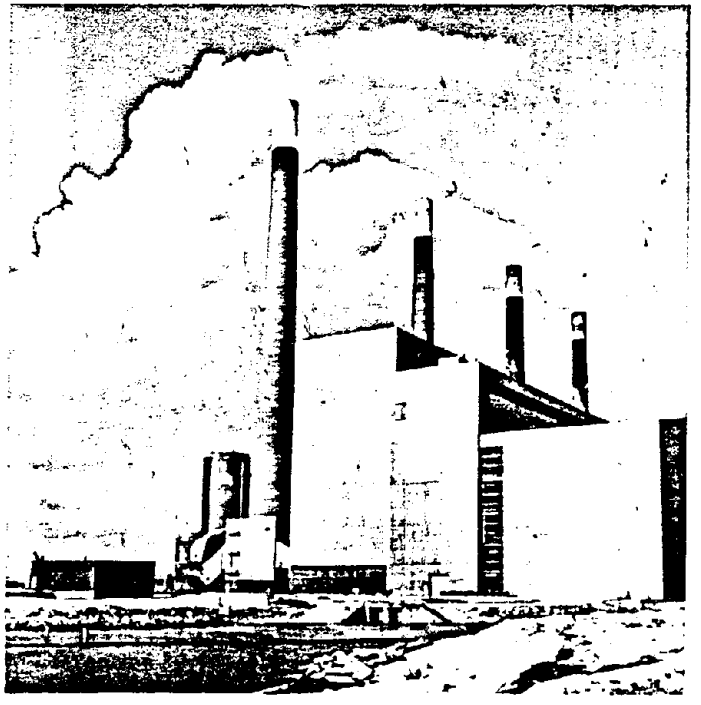


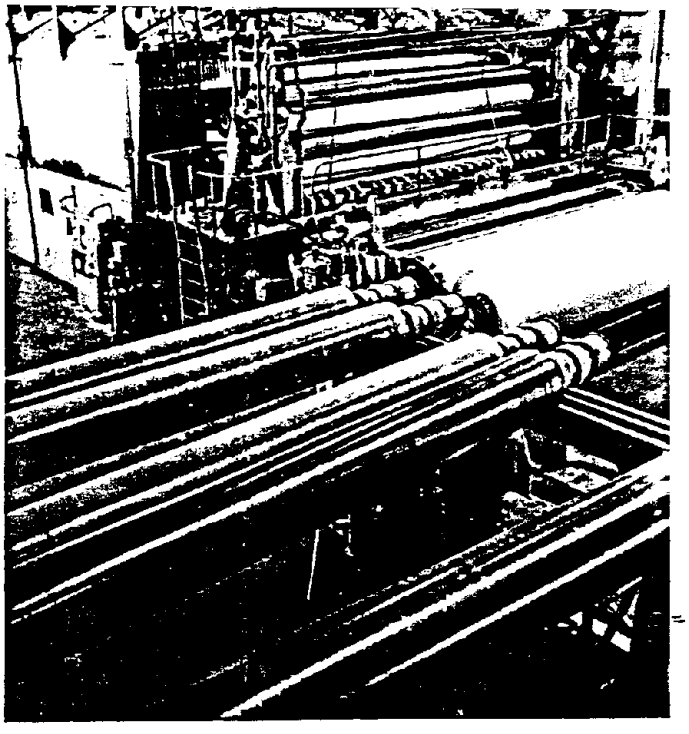
Furmanite has been sealing leaks in fossil fuel power plants for decades. Now, at a time when demand is growing and energy costs are soaring, the advantage of Furmanite on-line leak sealing is becoming increasingly more important to the power industry. Furmanite service and experience covers all aspects of leaks in:

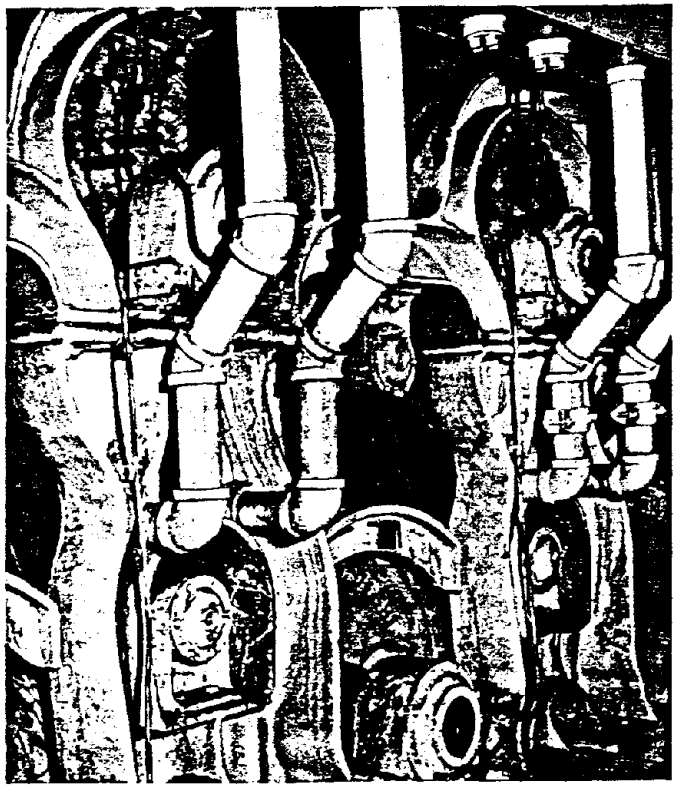
- **STEAM PIPING** in all segments of generating systems
- **BOILER FEEDWATER SYSTEMS**
- **SATURATED STEAM EQUIPMENT**
- **SUPERHEATED STEAM EQUIPMENT**
- **VACUUM** leaks on condensers
- **FEEDWATER HEATERS**
- **TURBINE CASINGS**
- **PULVERIZER SYSTEMS**
- **FLUE GAS SYSTEMS**
- **OIL SYSTEMS**
- **EXTRACTOR SYSTEMS**
- and **OTHER SYSTEMS OR EQUIPMENT**





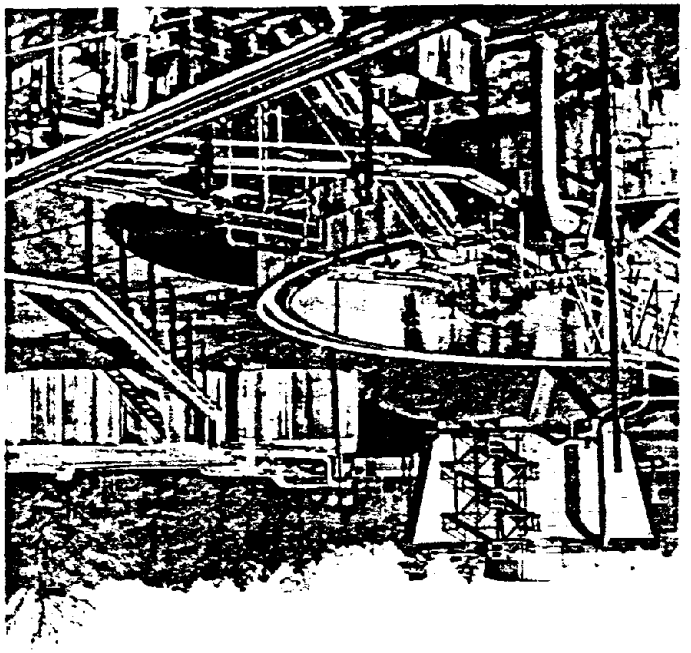


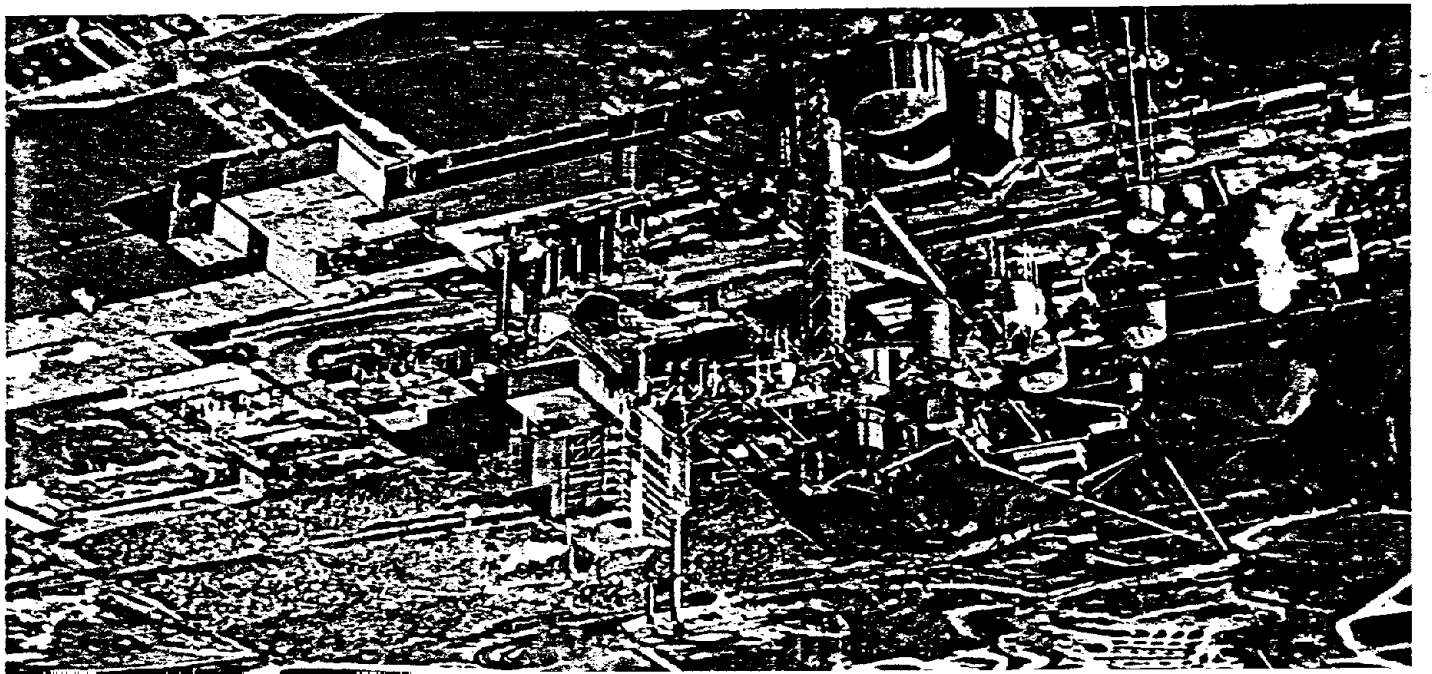


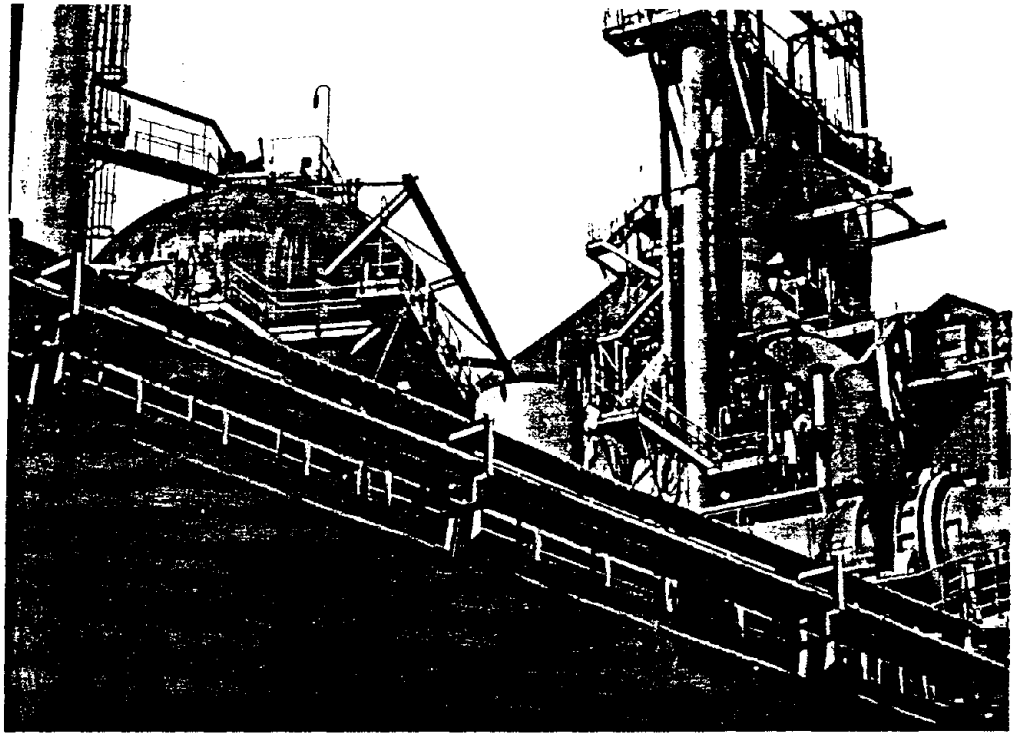


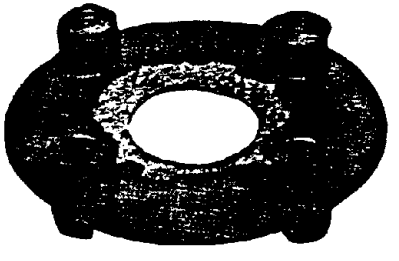
Papermaking has been described as consisting of just two basic operations — putting water into the furnish and then taking it out. However, as simple as this definition is, many problems can occur in the process. These include leaks. As in other industries, Furmanite leak sealing service is widely used by pulp and paper mills large and small. Applications include:

- **PIPING, VALVES** and other process system components for both low and high pressure steam
- **DRUM DRYER CYLINDERS**
- **YANKEE DRYERS**
- **RECOVERY BOILERS**
- **CONTINUOUS AND BATCH DIGESTERS**
- **TURBINES**
- **BLACK, WHITE AND GREEN LIQUORS**
- **PACKING FOR AGITATORS** and other slow turning shafts
- **CHEMICAL WASTE LINES**
- **CHLORINE SYSTEMS**
- **HOT AND COLD WASH WATER LINES**









A flange gasket formed on-line by the Furmanite process is readily removed.

applications

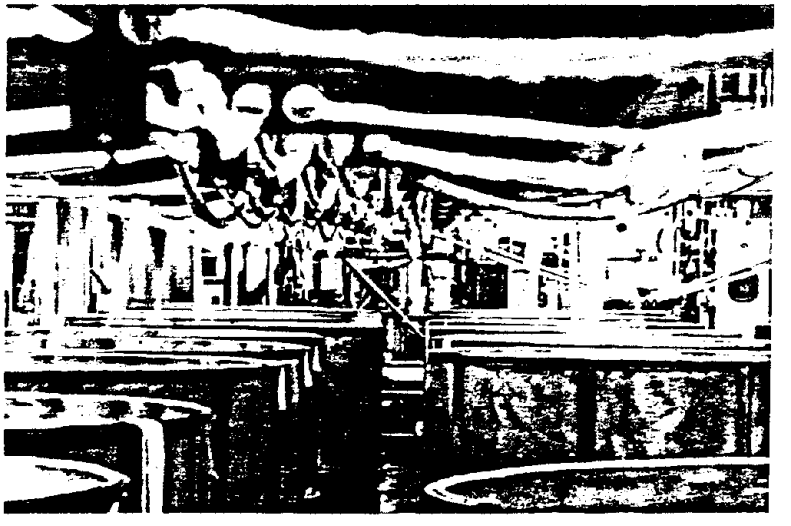
Today, steel companies face stiff competition in both the domestic and international markets. Hence, steel mill operators can little afford costly shutdowns to repair leaks in gas and fluid systems. Time and time again Furmanite's on-line leak sealing service has kept steel mills operational. Dedicated to keeping abreast of all technological developments in our industry, Furmanite will continue to serve the steel industry with on-line sealing of leaks in:

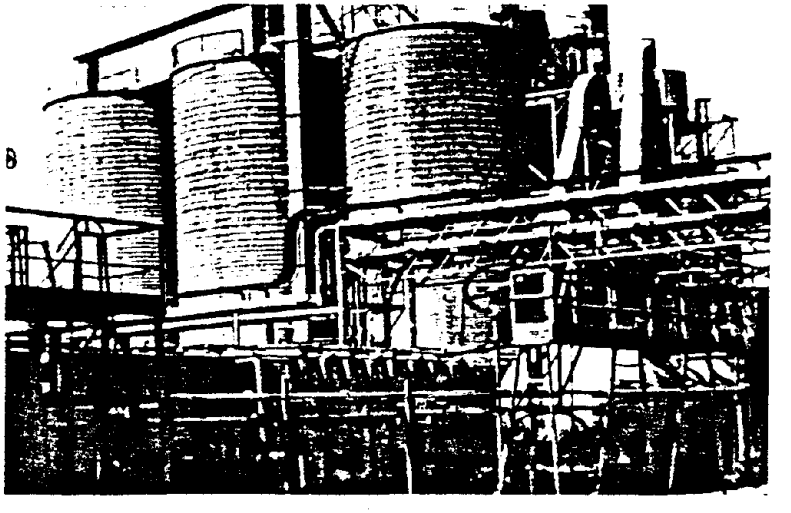
- **HOT AIR SYSTEMS**
- **COKE OVENS**
- **BLAST FURNACE GAS AND STEAM SYSTEMS**
- **OPEN HEARTH AREAS**
- **PHENOL AND BENZENE** in coke byproduct chemical streams
- **TOXIC CHEMICALS** such as SO_2 and H_2S
- **OTHER PROBLEM AREAS**

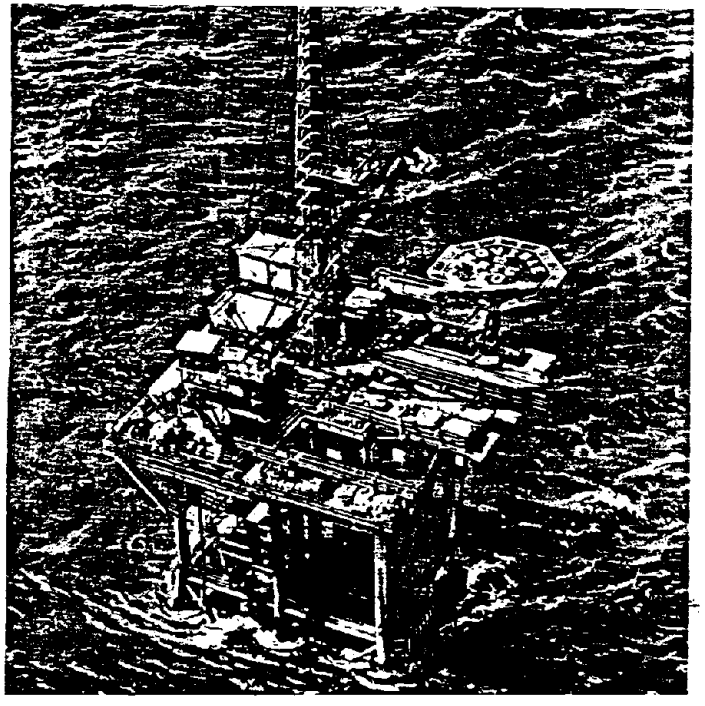
Like other process industries, the chemical industry strives for uninterrupted operation in order to attain desired production efficiencies. Hence, chemical plant managers rely heavily on Furmanite's on-line leak sealing service in order to eliminate the need for system shutdowns just to seal leaks. Furmanite's experience and capabilities in this area span numerous facets of the industry. For example:

- **THE RUBBER INDUSTRY.** Leaks in auxiliary support systems can disrupt or cripple flow on a production line. Such problems are ideally solved with the Furmanite process of leak sealing.
- **TEXTILE MANUFACTURING** where Furmanite service is applicable to leaks on air, steam, water, bleach, discharge and other lines and systems.
- **INORGANIC CHEMICAL COMPANIES** such as titanium dioxide and paint manufacturers who continually face the problems of leaks.
- **FERTILIZER PLANTS** in which the Furmanite on-line process is especially well suited to the sealing of leaks of high pressure ammonia, urea, carbamate, sulfuric acid and other fluids and gases.
- and **NUMEROUS OTHER CHEMICAL PLANT APPLICATIONS.**

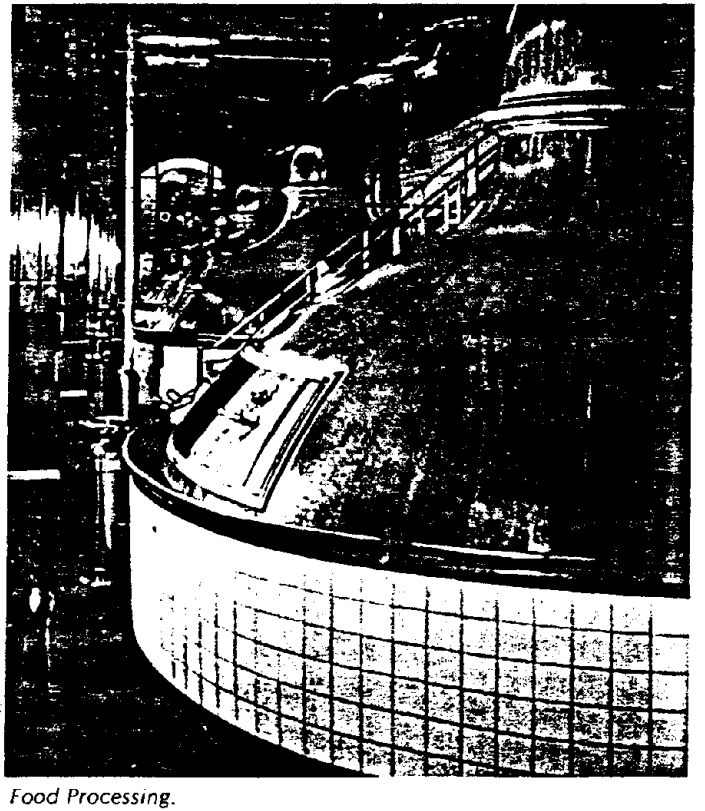
Photo courtesy of Goodyear Tire & Rubber Co.







Offshore platform.



Food Processing.

and services

The Furmanite on-line leak sealing method has been applied successfully in just about every industry which uses fluid transmission or pressurized fluid containment. The following are a few examples of other applications:

MARINE: While steam propulsion and fluid transmission systems on ships have been serviced by Furmanite for decades (both in port and at sea), this area of the Company's on-line leak sealing business continues to grow today. In addition, new marine applications such as off-shore drilling rigs are now being kept in service through application of the Furmanite process. For underwater work, Furmanite has several qualified divers among its field service personnel.

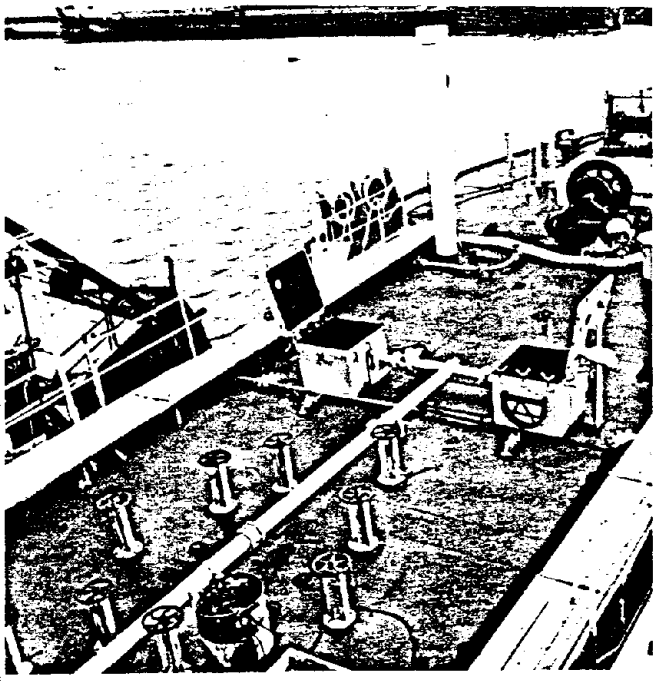
FOOD PROCESSING INDUSTRY: Steam, water, air and other fluid transmission and pressure systems abound in the food processing industry. In both direct production line equipment and auxiliary support systems, the Furmanite on-line leak sealing process can reduce costs, save valuable time and help maintain high productivity in this industry.

PIPELINES: Leaks in above-ground and sub-surface pipelines of all types have been successfully sealed by the Furmanite on-line process. As with applications in other industries, Furmanite has the capability to tackle leak sealing assignments for pipelines carrying water, gas, oil — or almost any other fluid.

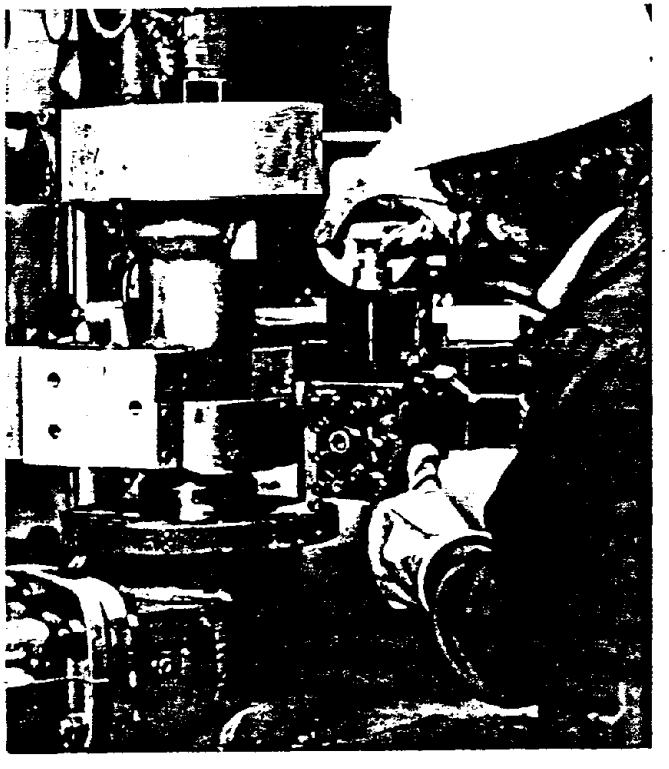
SPECIAL SERVICES: To broadly serve industry, Furmanite is continually involved in the development of companion services such as:

- **IN-SITU MACHINING**
- **IN-LINE VALVE REPAIR/REPLACEMENT**
- **JOINT SPLITTING**
- **SPECIAL COATING APPLICATIONS**

To list all of Furmanite's services would be an infinite task. Information or technical assistance relative to any potential application will be gladly provided on request.



Marine applications — in port... and underway.

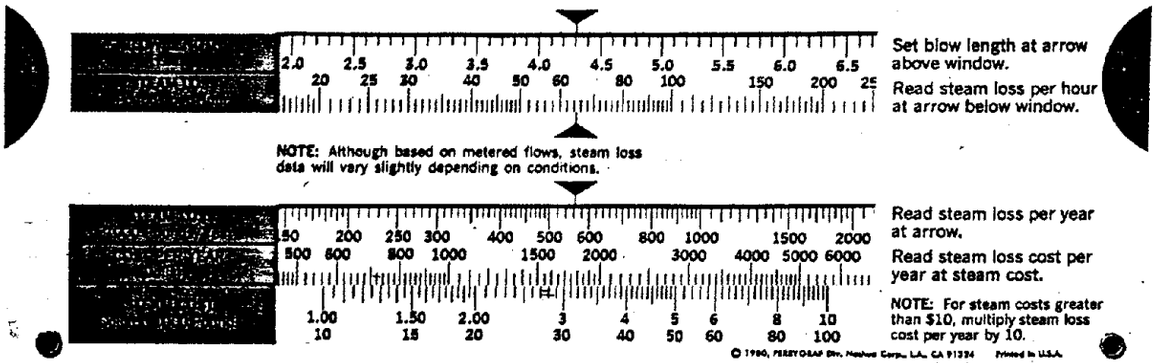


PIPELINES. *Photo courtesy of NC Machinery Co.*

saving you energy and lost production.

FURMANITE® **Seals leaks without shutdown.**

STEAM LOSS CALCULATOR



Steam Loss Calculator available on request.
Shows how much your steam leaks are costing your company.

Our professionally trained technicians can be dispatched anywhere in North and Central America. We have division offices in the following cities:

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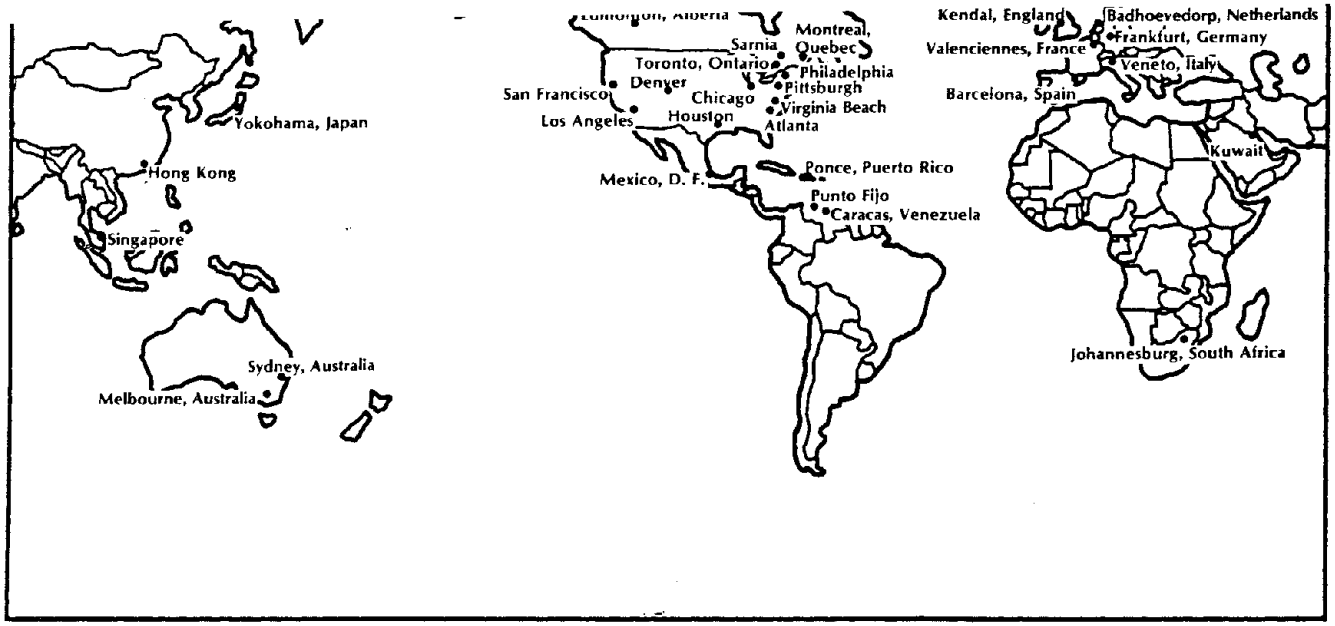
Denver
Houston
Philadelphia
Pittsburgh
San Juan
San Francisco
Toronto
Virginia Beach

These offices coordinate the scheduling of FURMANITE technicians who are located throughout their respective divisions. This enables us to provide you with the fastest and most reliable leak sealing service available.



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