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PLAINTIFF'S EXHIBIT
ARO-137

Final Project Report

No. 2 Open Hearth Fume Abatement

Projects 7185-1 & 7185-2

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May, 1971

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II. TASK FORCE STUDY & PROGRAM REQUEST

In 1964 Armco Steel Corporation requested Kaiser Engineers to prepare a report recommending basic criteria for the design of gas cleaning facilities for the Middletown Works #2 Open Hearth Shop. In a cooperative program with Armco personnel, measurements were made for dust emissions, effluent gas volume, temperature and gas composition. In addition, six different gas cleaning schemes were evaluated based on an engineering study and a series of visits to similar plants. The schemes included the following:

1. Centralized precipitator system with waste heat boilers and induced draft fans.
2. Same as 1 without fans. Waste heat boiler fans used to push gases through precipitator.
3. Centralized scrubber system with waste heat boilers.
4. Individual scrubbers without waste heat boilers and with gas cooling.
5. Same as 4 but without gas cooling.
6. Individual scrubbers with waste heat boilers and without gas cooling.

The reports showed the #5 scheme as the most attractive system based on capital cost.

In October of 1967, a new Task Force, consisting of Middletown Works Operating and Engineering personnel and Corporate Engineers, began a new investigation of gas cleaning facilities for the three natural draft furnaces of the #2 Open Hearth Shop at the Middletown Works. The objective of the Task Force was to examine all possibilities in order to develop a gas cleaning system that would meet cleaning requirements at the lowest possible cost without adversely affecting open hearth operations.

The investigation involved visits to open hearth scrubber installations, review of test data and the previous Kaiser Engineers' study, consultation with appropriate Armco personnel and discussions with equipment suppliers. The following paragraphs give a brief description of the Task Force investigations and conclusions.

The Task Force began by resolving the following points with Works Management:

1. The maximum furnace firing rate will be 170 MM BTU/hr.
2. The maximum lancing rate is 100,000 CFH of oxygen.
3. The value of waste heat steam does not justify waste heat boilers.

Based on the above operating conditions, as well as the tests conducted by Armco and Kaiser personnel in 1964, the following characteristics of the waste gas at the base of the existing stacks were established as the normal expected maximums:

Gas Volume - 62,000 SCFM (14% Moisture)

Gas Temperature - 1350° F. (Average)
1900° F. (Three Minute Peak)

Static Pressure - (-) 3.0" W.G.

Dust Concentration - 6 Grains Per Standard Cubic Foot Dry (During Oxygen Lancing)

The following maximum effluent concentrations were established, which are expected to comply with any state or local air pollution control requirements:

Dust Concentration - .05 Grains Per Standard Cubic Foot Dry (Instantaneous Loading)
- .03 Grains Per Standard Cubic Foot Dry (30 Minute Average Over Oxygen Lancing Period)

After visiting the two high energy scrubber installations, the Task Force directed engineering to prepare layout drawings and a budget estimate of a high energy scrubber system based on criteria set by the Task Force. The estimate was much higher than the 1965 study for the following reasons:

1. Experience at other scrubber installations indicates that the slurry cannot be recycled. A once-thru water system increased piping costs by approximately $250,000.
2. Over $1,200,000 in power distribution costs were not included in the 1965 study.
3. Escalation increased costs 22%.

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With this increased estimate, the Task Force again decided to investigate electrostatic precipitators. The following costs represent the approximate capital expenditures required for the alternate schemes that were investigated. These figures include the systems for furnace Nos. 12, 13, & 14 only. The Task Force felt that these estimates were sufficiently accurate for comparisons:

1. Individual high energy scrubber systems without gas cooling, approximate capital cost - $4,500,000.
2. Individual high energy scrubber systems with gas cooling, approximate capital cost - $5,500,000.
3. Precipitators preceded by individual air-to-air heat exchangers, approximate capital cost - $5,900,000.
4. Precipitators preceded by centralized air-to-air heat exchangers, approximate capital cost - $7,000,000.
5. Precipitators preceded by waste heat boilers, approximate capital cost - $8,650,000.

In order to compare the various alternatives, it should be noted that the scrubbers systems require an additional investment of $750,000 for water treatment facilities.

A conservative estimate of the anticipated operating cost of a high energy wet scrubber system versus the electrostatic precipitators with individual heat exchangers for three furnaces is as follows:

High Energy Scrubber System (Includes Water Treatment)

Operating & Maintenance		$ 150,000
Water		13,000
Power		270,000
Chemicals		17,000
	Total	$ 450,000/year = $.47/ton

Precipitator System with Individual Heat Exchangers

Operating & Maintenance		$ 175,000
Power		200,000
	Total	$ 375,000/year = $.39/ton

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In the opinion of the Task Force, an additional benefit of the high energy wet scrubber is that a scrubber system provides a much higher degree of system reliability than a precipitator system.

Based on these studies, the Task Force compiled a Task Force Report recommending the use of high energy wet scrubbers for furnace Nos. 12, 13 & 14 of the No. 2 Open Hearth Shop. The Task Force was issued in May, 1968, and the subsequent program request for $4,500,000 was approved by management in June, 1968.

In June, 1968, the same Task Force was initiated to investigate gas cleaning facilities for furnace Nos. 9, 10 & 11. The Task Force agreed to recommend the same high energy wet scrubber system that was recommended for furnace Nos. 12, 13 & 14, but the Isley draft dual stack arrangement had to be modified in order to install gas cleaning facilities.

The Task Force developed a symmetrical duct arrangement in which the gas could be directed to a scrubber system. A Task Force Report was issued in October, 1968, and the Subsequent Program request for $5,500,000 was approved by management in November, 1968.

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III. ENGINEERING REPORT AND PROGRAM REQUEST

Scope

The Engineering Report for Project 7185-1 (Formerly Project 7185), which covers furnace Nos. 12, 13 & 14, was issued in October, 1968. The Engineering Report for Project 7185-2 (Formerly Project 7188), which covers furnace Nos. 9, 10 & 11 was issued in December, 1968. The facilities of these two projects consist of six (6) individual high energy wet scrubber systems and auxiliary equipment necessary to remove particulate matter from gases exhausted from furnace Nos. 9 through 14 at the No. 2 Open Hearth Shop. All basic design criteria are in accordance with the recommendations of the Task Force.

The systems for furnace Nos. 9, 10 & 11, also include the basic design changes for the furnace controls and draft system as recommended by the Task Force to make the furnace operation compatible with scrubber operation.

The scrubber water is supplied by and returned to the water treatment plant described under Project 7183. The header for the scrubber water supply and return will be furnished by this project to column row 58 of the No. 2 Open Hearth Shop.

Since the power supply to the No. 2 Open Hearth Shop is not sufficient to carry the additional load of the scrubber systems, a new pole line and substation Nos. 605-E and 605-W are provided to provide power from substation 17 (near the Electric Melt Shop) to the scrubber systems.

For a detailed description of facilities see section IV.

Project Schedule

The original project schedule covering 7185-1 and 7185-2 is as follows:

Detail Design	-	Start October 1, 1968 Complete June 1, 1970
Procurement	-	Start November 1, 1968 Complete August 1, 1970

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Construction	-	Start June 1, 1969 Complete November 1, 1970
Testing	-	Start March 1, 1970 Complete November 1, 1970

Estimate and Appropriation Request

An appropriation request of $5,096,000 was approved by management to cover the gas cleaning facilities for furnace Nos. 12, 13 & 14 (Project 7185-1) in October, 1968.

An appropriation request of $5,494,000 was approved by management to cover the gas cleaning facilities for furnace Nos. 9, 10 & 11 (Project 7185-2) in January, 1969.

For details of the estimate, see section "Cost & Comparison to Estimate."

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IV. SYSTEM DESCRIPTION

Description of Equipment

The No. 2 Open Hearth Fume Abatement Facilities are located north (steel plant north) of and adjacent to the existing No. 2 Open Hearth Shop as shown on Drawings PR-3297-1987 and PR-3297-2039. (See Section X.)

On furnace Nos. 12, 13 & 14 each existing stack is blocked by means of a water cooled, butterfly type damper, located approximately 85 feet above grade. Below this damper, a refractory lined hot duct is tapped into the existing stack and routed horizontally to connect to the scrubber. A water cooled, butterfly type damper is installed in this duct and interlocked with the hot stack damper. The hot ductwork, by means of bellows type expansion joints and a toggle beam support, permits expansion in both the horizontal and vertical direction so as to transmit a minimum magnitude of force into the existing hot stack.

On furnace Nos. 9, 10 & 11, new double deck reversal dampers and an overhead hot duct connect the Isley stack bases to both the scrubber duct and a single ejector stack. The ejector stack and scrubber duct are equipped with water cooled, butterfly valve type dampers identical to those on furnace Nos. 12, 13 & 14.

The 316L stainless steel flooded disk type scrubber consists of a carbofrax lined flooded approach section, refrax lined throat section and partially lined carbofrax lower section with flanged connections for each. The scrubber is positioned vertically and connected by flanges to the refractory lined hot duct and flooded elbow. The 316L stainless steel flooded elbow is partially lined with acid brick and connected by flanges to the bottom straight side of the separator. The reinforced polyester lined separator has an acid brick lined bottom cone section, tangential inlet, baffle section, and a flanged top outlet. The reinforced polyester lined cold duct is connected to the top of the separator and bends vertically downward to the induced draft fan. The fan inlet is equipped with a louver type damper. The 316L stainless steel fan is a single width single inlet type with a 108 in. diameter rotor and driven by a 1750 H.P. motor. Vibration isolation joints are provided at the fan inlet and outlet to prevent fan vibration from being transmitted to the ductwork. A 316L stainless steel duct connects the outlet of the fan to the 135 foot high reinforced polyester lined cold stack. Sound attenuation material is installed in the duct section between the fan and stack as well as the lower 40 foot of the cold stack. A mist eliminator is installed in the stack to prevent the carry-over of fan spray water.

The scrubber water system consists of a classifier, pump tank, pumps and related piping and valves. A volume of 1350 GPM of scrubber water discharges from the bottom of the separator to the classifier which removes the large particles. The water overflows from the classifier to the pump tank and 1000 GPM is pumped through the flooded disk and 350 GPM is sent to the water treatment plant. A volume of 500 GPM is supplied from the water treatment plant to the wetted approach as make-up.

The damper cooling water supply is taken from the return header of the No. 2 Open Hearth cooling tower and pumped through the dampers and returned by gravity to the cooling tower.

Surveillance and control of the wet scrubber systems are maintained at individual control panels located in one of two centrally located instrument rooms. Each instrument room consists of an enclosed structure with approximately 300 square feet of floor area located at the charging floor level of the No. 2 Open Hearth Shop.

The electrical power is supplied from substation No. 17 which is located adjacent to the old electrical melt shop. The power is transmitted at 13,200 volts and carried by a single circuit wood pole line from substation No. 17 to the new substation No. 605-E which contains a line-up of 13.8 KV metalclad switchgear as well as a 2400 volt and a 480 volt substation to transform and distribute the power to the systems

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at furnace Nos. 12, 13 & 14. An additional substation, No. 605-W, contains a 2400 volt and a 480 volt substation, which are fed from substation 605-E, and transform and distribute the power to the systems at furnace Nos. 9, 10 & 11.

Description of the Process

At furnace Nos. 9, 10 & 11 upon leaving the furnace, the waste gases will pass through the appropriate slag pocket, checker chamber, flue, new double deck reversal damper, and existing Isley stack base. From this point the gases enter the new overhead hot duct connecting the Isley stack bases and proceed through the vertical, centrally located hot duct riser to a point approximately 75 feet above grade. The gases then pass through a horizontal hot duct and then vertically downward through the gas scrubber. The vertical hot duct riser contains a water cooled butterfly damper for controlling furnace pressure and isolating the gas cleaning system. In the event that the scrubber system is down, the waste gases will be diverted through the centrally located hot stack riser and Isley ejector. A water cooled butterfly damper is located just below the ejector to prevent the discharge of dirty gas to the atmosphere. The two water cooled dampers and the ejector fan are interlocked to prevent sealing the furnace off; to protect the gas cleaning equipment; and to provide the required draft when the bypass stack is selected.

At furnaces Nos. 12, 13 & 14, the waste gases enter the brick lined natural draft stack and proceed to a point approximately 75 feet above grade. At this point the gases are diverted horizontally through the hot duct, then vertically through the gas scrubber. In the event the gas scrubber is not operating, the waste gases are not diverted and discharge directly to atmosphere through the existing hot stack. The direction of gas flow is controlled by two (2) water cooled, butterfly valve type dampers. One (1) damper is located at the head of the

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horizontal hot duct run; the second is located in the hot stack just above the take-off to the gas scrubber. The two (2) dampers are interlocked to prevent the furnace from being sealed off.

The waste gases enter the gas scrubber, which consists of a flooded approach section, a throat section, and an exit or lower section. Water is injected into the flooded inlet section, to prevent thermal shock to the internal lining, and the throat section to clean the gases. The shearing action of the gas at the throat of the scrubber atomizes the water into millions of fine particles which collide with and capture the dirt particles. This action requires a high velocity which is the purpose of the throat section. The area of the throat is automatically adjustable to compensate for variations in gas flow. The throat section is designed to handle a maximum flow from the furnace of 225,000 ACFM at a temperature of 1350° F. The equipment is designed to maintain a pressure drop of approximately 47 inches of water column across the scrubber throat at maximum flow. A constant pressure, adjustable from 0 to (-) 3 inches of water vacuum, is maintained in the base of the hot stack ahead of the inlet to the scrubber system.

The water droplets and gas flow through the flooded elbow and enter the separator which separates the cleaning water with its entrained dirt particles from the gas stream. The gas temperature in the separator is approximately 165°F. saturated.

An induced draft fan, rated for approximately 150,000 ACFM at 57 inches of water differential, driven by a 1750 HP induction motor, drafts the gases from the separator, through the cold duct and discharges to the atmosphere through the sound attenuator and cold stack. The inlet louvers of the fan are automatically controlled to maintain constant inlet static pressure with an override control on high fan current.

The control system maintains a preset vacuum at the base of the existing stack and controls maximum current on the fan. A series of protective interlocks shut down part or all of the process automati-

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cally in case of trouble. Low draft shuts down the cleaning process while the fan continues to operate at a no-load condition.

Two separate control stations, with the various recorders and controllers for three (3) furnaces mounted on a separate semi-graphic panel boards, are located in the lean-to area on the operating floor of No. 2 Open Hearth Shop, at No. 13 furnace and No. 10 furnace.

The slurry system starts at the base of each separator where the scrubbing water with the entrained solids from the gas stream have been separated. The slurry discharges by gravity through a standpipe into a classifier. A water level is also maintained in the standpipe from the separator, during operation. This level has a head approximately equal to the fan suction pressure (about five (5) feet of water.)

The classifier removes the large particles that settle out and discharges them, as a sludge, into a dump box which is loaded onto a truck for removal and disposal. The partially clean water overflows from the classifier into a dirty water pump tank. Approximately 1350 GPM is pumped from this tank with approximately 350 GPM being diverted to a gravity return header and approximately 1000 GPM to the flooded disk at the throat section of the gas scrubber. The gravity return header conveys the water to the water treatment plant where it is treated and pumped to the flooded inlet of the gas scrubber. The necessary controllers and recorders for the slurry system are mounted on the semigraphic panel boards located in the instrument rooms.

For flow diagrams and general arrangement drawings, see section X.

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V. ENGINEERING

Design Engineering

A number of firms provided engineering services for this project. The firms involved in design engineering and their areas of responsibility are as follows:

Kaiser Engineers, Inc. Kaiser Center, 300 Lakeside Drive Oakland, California 94604	General design engineering & design & detail engineering for the power distribution system to the project area.
Research-Cottrell, Inc. P.O. Box 750 Bound Brook, New Jersey 08805	Design & detail engineering for all phases of the gas cleaning systems.
Degremont-Cottrell, Inc. P.O. Box 750 Bound Brook, New Jersey 08805	Piping & electrical design engineering for Research-Cottrell.
Holley, Kenney, & Schott, Inc. 921 Pennsylvania Avenue Pittsburgh, Pennsylvania 15222	Electrical design & detail engineering for Research-Cottrell .
Fibercast Company P.O. Box 968 Sand Springs, Oklahoma 74063	Plastic piping design & detail engineering for Research-Cottrell.
McGraw Construction Company P.O. Box 369 Middletown, Ohio 45042	Foundation design & detail engineering for Research-Cottrell & miscellaneous design & detail engineering.
Loftus Engineering Corp. One Oliver Plaza Pittsburgh, Pennsylvania 15222	Design & detail engineering on the revisions to the Isley systems on furnaces #9, 10, & 11.

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Drawings

Compiled below is the breakdown of drawings, by types, prepared by each of the major design contributors:

Kaiser Engineers, Inc.

Drawing type	Number
Scoping	17
Architectural	4
Structural	7
Electrical	35
Total	63

Loftus Engineering Corp.

Drawing type	Number
Civil	3
Mechanical	9
Structural	8
Electrical	2
Instrumentation	2
Total	24

Research-Cottrell, Inc.

Drawing type	Number
Scoping	7
Civil	6
Mechanical	51
Structural	172
Piping	36
Electrical	80
Instrumentation	20
Total	372

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McGraw Construction Co.

Drawing type		Number
Mechanical		10
Structural		3
Piping		5
Electrical		24
	Total	42

Consultants

The following firms provided technical consulting services:

Loftus Engineering Corp. One Oliver Plaza Pittsburgh, Pennsylvania 15222	Consultants on controls & instrumentation for Open Hearth operation
Bolt, Beranek & Newman, Inc. 50 Moulton St. Cambridge, Mass. 02138	Consultants on noise measurement & control
Structural Dynamics Research Corp. 5729 Dragon Way Cincinnati, Ohio 45227	Consultants on structural analysis & design of the I.D. fans
E. D'Appolonia Consulting Engineers, Inc. 15 Duff Road Pittsburgh, Pennsylvania 15235	Consultants on bearing capacity of the soil

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VI. PROCUREMENT

The major equipment suppliers are as follows:

1. Research-Cottrell, Inc.

High energy scrubbers	Kaiser P.O. No. 7185-2173
Mist eliminators	
Cold ductwork	Total contract price including all equipment and engineering services - $1,765,500
Hot ductwork	
Cold stacks	
Hot stack dampers	
Dirty water pumps	
Air receivers	

2. Allis-Chalmers Manufacturing Company — Kaiser P.O. No. 7185-2072 - $257,500

   13.8 KV switchgear

   2400 V unit substations

   480 V unit substations

3. Westinghouse Sturtevant Division

   Induced draft fans & motors — Armco P.O. No. MJD-498712-P - $716,000

4. Westinghouse Electric Company

   Motor control centers R-C P.O. No. SC-152-22013 Cost under No. 1

   Substation #17 switchgear — Kaiser P.O. #7185-2086 — $34,600

5. Blaw-Knox Company

   Double deck reversing valves — Armco P.O. No. MCK-522769-R $92,500

6. Stacey Manufacturing Company

   Hot ductwork (Isley conversion) — Armco P.O. No. MDG-7185-807-RP $157,500

7. C-E Refractories

Refractory lining (installed) Armco P.O. No. MMS-7185-895-RP $145,000

8. Leeds & Northrup Company

Instrumentation RC P.O. No. SC-152-24C1 Cost under #1

9. Eckel Industries, Inc.

Sound attenuation Armco P.O. No. MCK-7185-930-C $82,500

10. Ceilcote

Corrosion resistant linings Armco P.O. No. MCK-7185-953-C $149,000

11. Fibercast Company

Scrubber water piping R-C P.O. No. SC-152-14S1 Cost under No. 1

12. Electro-Trace Corp.

Heat trace Armco P.O. No. MJH-7185-1207-C $11,500

13. Duriron Company

Scrubber water pumps R-C P.O. No. SC-152-1881 Cost under No. 1

14. Allied Pump Corp.

Sump pumps R-C P.O. No. SC-152-18811 Cost under No. 1

15. Dorr-Oliver, Inc.

Classifiers R-C P.O. No. SC-152-18E1 Cost under No. 1

16. Singer - GPE Controls, Inc.

Hydraulic controllers R-C P.O. No. SC-152-14T1 Cost under No. 1

17. Fisher & Porter Co.

Level controllers R-C P.O. No. SC-152-24C1-B Cost under No. 1

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VII. CONSTRUCTION & STARTUP

Contractors and their areas of work on the project are as follows:

Prime contractor responsible for structural, mechanical, and electrical installation - McGraw Construction Co., 1st National Bank Building, Middletown, Ohio 45042.

Gunnite lining in the hot ductwork - C-E Refractories, Valley Forge, Pennsylvania 19481.

Corrosion proof glass lining in the cold ductwork and the cold stack - The Ceilcote Company, Inc., 140 Sheldon Road, Berea, Ohio 44017.

Construction work commenced on May 5, 1969. Important points in the progress of the project and the dates they occurred are listed below:

Oct. 7, 1969	-	Pole line from substation #17 to substation #605E was completed.
Nov. 6, 1969	-	Fume Abatement Circuit from substation #17 was energized.
April 7, 1970	-	Furnace #9 revised Isley system went into operation.
April 17, 1970	-	Furnace #10 revised Isley system went into operation.
April 18, 1970	-	Substation #605E was energized.
Aug. 12, 1970	-	Furnace #14 scrubber system went into operation.
Aug. 19, 1970	-	Substation #605W was energized.
Aug. 23, 1970	-	Furnace #11 revised Isley system went into operation.
Sept. 9, 1970	-	Furnace #9 scrubber system went into operation.
Oct. 14, 1970	-	Furnace #10 scrubber system went into operation.
Oct. 19, 1970	-	#9, 10, & 14 scrubber systems were shut down and rework started on all the I.D. fan wheels.
Dec. 10, 1970	-	Furnace #9 scrubber system went back into operation.
Dec. 11, 1970	-	Final Safety Inspection
Dec. 13, 1970	-	Furnace #11 scrubber system went into operation.
Dec. 14, 1970	-	Furnace #12 scrubber system went into operation and all operating stacks were equipped with scrubbers.
Dec. 26, 1970	-	Furnace #13 scrubber system went into operation.
Jan. 1, 1971	-	Furnace #10 scrubber system went back into operation.
Jan. 9, 1971	-	Furnace #14 scrubber system went back into operation.

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May 5-21, 1971 - Performance tests conducted by Armco and Research-Cottrell indicated that scrubber efficiencies exceeded guaranteed levels.

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VIII. CHANGES & ADDITIONS

The combination of rapidly varying furnace pressure and sensitive pressure controller made the use of automatic pressure control on the Isley systems impractical. The situation was remedied by using a signal dampening card in the furnace pressure transmitter.

After systems #13 & 14 structural steel was erected, we discovered that many of the beam to column connections were fabricated as moment connections while the structure had been designed for non-moment connections. The connections would have transmitted excessive stresses to the columns and therefore had to be revised.

The I.D. fan stainless steel housings were to have been factory assembled. When they were put together, many of the flanges would not mate. The flanges had to be cut and refitted.

After the fan rotors were installed it was discovered that none of the rotors had been properly placed on the shaft and sufficient clearance was not provided between the edges of the fan blades and the inlet cone. The inlet cone had to be trimmed to provide the proper clearance.

After the I.D. fans were assembled the vendor became concerned about the quality of welds on the fan rotors. Close inspection revealed that many of the welds were faulty and would have to be ground out and rewelded. This work was done under the supervision of the vendor and the results were inspected by Armco Research Personnel. Many of these problems with the I.D. fan fabrication and much of the resulting on-site work to correct the problems could have been eliminated through inspection, by Armco personnel, of the fabrication and assembly of the equipment at the factory.

The I.D. fans were closely observed after they were placed in operation and in less than a month's total running time cracks developed in #14 I.D. fan blades. A strenuous testing program was then instituted by Armco and Structural Dynamics Research Corporation, Cincinnati, Ohio. The fan blades were found to be overstressed. The high stresses resulted from an unintentional eccentricity of the blades. The following modifications were made to lower the stress levels: the ear on the inlet side of the blade was removed, a second gusset was added to strengthen the blade, the dampening ring which connected successive blades was removed. These changes resulted in acceptable stress levels.

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Immediately after the initial start-up of the recirculating water system, several of the fibercast pipe flanges broke at the joint where the flange is epoxied to the pipe. This problem occurred only with 14" and larger pipe. The flanges for this larger pipe were bored with an oversized hole and, in many cases, the flanges were not placed symmetrically on the pipes, and this resulted in voids between the pipe and flange at the epoxy joints. All of the 14" and larger pipe was taken down and returned to the vendor for testing and refabrication.

The majority of the scrubber water (1000 gpm) flows through a vertical, 17' long, 10" diameter pipe which also is the connecting shaft between the flooded disc and the hydraulic cylinder which raises and lowers the disc. The water was fed to the scrubber shaft by a 5' long, 10" diameter hose which ran perpendicular to the shaft. The shaft was laterally supported top and bottom by a packing gland. The force exerted by the expansion of the hose under pressure caused the shaft to severely rub against the packing and eventually against the gland itself, which scored the shaft and impaired operations. The hydraulic cylinder was also rigidly mounted and the play in the shaft caused the seals to wear out and the cylinder rod to bend. The following steps were taken to remedy these problems: the 10" hose was replaced with two 6" hoses which were looped into a manifold on the shaft; the packing glands were replaced with bronze bearings and the bearing sections of the shaft were machined; the hydraulic cylinder and cylinder mounting arrangement were replaced with a new cylinder, with a longer stroke, which was mounted with flexible connections top and bottom.

There is no water seal between the scrubber shaft and casing at the top of the casing and this resulted in a continued leak. This problem was solved with the installation of a splash guard, attached to the shaft, which diverted water away from this area.

Experience with scrubbers of this type at other plants indicated that there would be an erosion problem at various areas on the shaft casing. Wear plates in the form of two half pipes bolted together were installed around the casing. Inspections have shown that these plates were indeed required.

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As water flows up through the center of the flooded disk, it strikes a cone which disperses the water equally to all areas of the disk. Initially the clearance between the disk and the bottom of the cone was $3\frac{1}{2}$". This dimension was dictated by the size of the nuts on the center bolt which held the cone in place. Experience with other flooded disk scrubber systems has shown that this large of a clearance may result in improper water distribution and reduced scrubber efficiency. To insure proper water distribution we procured smaller nuts and reduced the clearance to $1\frac{1}{4}$".

The dirty water tank is equipped with a displacer type level transmitter. The mud buildup in the tank occasionally plugged up the bottom port of the displacer tube and resulted in a false signal. The port was extended to the center of the tank which was kept cleaner by more turbulent flow, and a water purge was installed on the bottom port.

The draft, flow, and temperature recorders with built-in alarm circuits supplied for this project were prototypes which were under development when they were procured for this project. After several months of operation, it became apparent that the circuit cards in the recorders were overheating. This overheating was causing the alarm circuits to frequently trip and signal an off-limit condition that actually did not exist. In addition, the make-shift connecting cable required by the presence of the alarm circuits, was susceptible to damage by being pinched between the stationary recorder case and slide-out chassis. This resulted in several short circuits, or open circuits if the terminal connection became loose. The vendor changed some of the components on the alarm cards and this took care of the heat problem. The cables were rerouted and the cable clamps tightened so that the pinching was eliminated.

The instrument panels containing the various recorders and controllers were specified to be wired with the power to each of the instruments fed separately so that each instrument was independent of the others. Instead

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the panels were wired with all the instruments in series. The wiring was changed after the panels were installed. An Armco inspection of these panels at the factory could have saved quite a bit of additional work.

The water flow transmitters were equipped with a purge system to keep the transmitters and impulse lines clean and prevent corrosion. The purge water comes from the main softened unfiltered water line which also feeds many other areas of the plant and thus has a varying pressure. The constantly changing pressure of the purge water made it impossible to keep the transmitter calibrated. This problem was solved by installing a pressure regulator in the purge line ahead of the transmitter, to provide a constant pressure at that point.

Wafer type check valves were used above the dirty water pumps. The check valve has a rod attached to the top of it which keeps the valve from opening too far and becoming wedged. Immediately above the valve was a spoolpiece made of reinforced plastic pipe. The check valve above the operating pump has a tendency to chatter and the beating of the rod against the plastic pipe resulted in a hole in the pipe. The plastic pipes were replaced with stainless sections which solved the problem.

A wafer type check valve was also installed in the return line to the water treatment plant at the main return header. After operating for less than a week, the check valve became stuck in the open position. Examination of the valve showed that it was plugged with mud. A check valve which is dependable in this type of service could not be found so the check valve was replaced with a manual shutoff valve. This valve is closed if that particular system is to be shut down for an extended time period. It provides 90 - 100% shutoff.

Wafer type butterfly valves were used extensively as shutoff valves in this system. These valves depended on an interference fit between the seat and disc to provide a seal. They were not dependable. The

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most critical areas requiring complete shutoff were the individual supply lines to each system which all come off the main header. The original butterfly valves at these locations were replaced by a heavier built butterfly valve with a positive seat. This valve has proven to be good for slurry service of this type.

Isolation joints were installed on each side of the dirty water pumps. The piping on the outlet side of the pump was left free to move to prevent overstressing the plastic pipe. This freedom of movement also allowed the isolation joint to expand beyond its recommended limits. To prevent eventual failure of the isolation joint retainers were placed on the joint to limit the maximum elongation to an acceptable value.

The 1750 horsepower induced draft fan drive motors were supplied with an external lubrication system to comply with Armco standard practice. The vendor maintains that the motors will operate satisfactorily without an external lubrication system. This lubrication system was provided with flow switches which were set to annunciate an alarm if the oil flow dropped below a certain point. Since the flow being sensed was quite small, the switches were required to be quite sensitive and as a result were also quite fragile. They proved to be impractical for the application and were eliminated from the system.

The coupling between I.D. fan shaft and motor shaft was equipped with a spacer which was to be placed between the ends of the two shafts to prevent a thrust force on the motor bearings. After several weeks of service, some of the inboard fan bearings began to develop dirty oil. This was attributed to wearing of the thrust collar in the inboard fan bearing which was in turn caused by the presence of the spacer in the coupling. The spacer was removed from all the couplings which remedied the problem. With or without the spacer the most important point is to make sure the motor is free to operate at its electrical center.

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Initially, the cooling water for the fan bearings, hydraulic system heat exchanger, and the various purge systems was supplied from the existing cooling towers at #2 O.H. This water was not returned to the O.H. cooling systems. As a result the cooling towers required additional make-up water, which increased chemical costs. To prevent this, a new 4" softened unfiltered water line, originating at the water treatment plant, was run along the entire length of the Open Hearth building. The cooling lines for each gas cleaning system were tied into this header.

Both the dirty stack ductwork and the gas cleaning ductwork contain large water cooled butterfly valves measuring seven feet in diameter and four inches thick. These valves are internally ported to provide optimum cooling and to insure that the valve disc remains full of water if the flow is cut off. As a result the valve must be installed according to the porting arrangement marked on the valve. Out of the twelve valves installed on the project, three were installed backwards, and one of these had been marked improperly at fabrication. Two of the improperly installed valves ruptured while under low flow conditions. As a result, the internal construction and physical orientation of all the valves were checked and the faulty ones were corrected. Substantial checking and rechecking should be required on installation of critical equipment such as this.

The walls of the ductwork between the fan and cold stack and the bottom 40 feet of the cold stack are lined with fiberglass sound attenuation insulation. The fiberglass pillows are held in place by perforated metal sheets which in turn were fastened to supporting angles by screws. The supporting angles are welded to the walls of the ductwork and stack. All of the metal exposed to the gas stream was specified to be 316L stainless steel to prevent corrosion. The screws supplied to fasten the perforated metal sheets to the supporting angles

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were not 316 L stainless steel. The screws corroded away, the perforated metal came loose, and the fiberglass bags either fell into the stack or were blown out the top of the stack. The damaged insulation was replaced and all of the perforated metal sheets were welded in place.

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IX COST AND COMPARISON TO ESTIMATE

A cost and comparison to the estimate by detailed chart of accounts is not practical for this project because of changes in accounting procedures. The original estimate for projects 7185-1 and 7185-2 were estimated based on the Kaiser accounting procedure in which the fee and much of the indirect management costs are covered by the 7100 indirect management account. However, McGraw was made the general contractor after the appropriation was approved and under the McGraw accounting procedure all fee and indirect management costs are charged directly to the project. Also, much of the gas cleaning equipment, instrummetation, power and control equipment, piping and design were purchased as a turnkey job from Research-Cottrell and cannot be accurately distributed in the original chart of accounts.

Because of the changes in accounting mentioned above, only the direct costs can be compared. The original estimate of total direct costs was 9,891,400 and the final cost for the same accounts is 7,578,000. The underrun, based on direct costs only, is therefore $2,313,400.

Even though the costs cannot be accurately compared to the original chart of accounts, there are significant deviations from the estimate that cannot be explained by the reasons given above. The following is a general summary of the known major variations from the original estimate.

Section 000 accounts - Removal & Relocation -	Estimated Cost	$ 66,800
	Actual Cost	90,700
	Overrun	23,900

The overrun in this account is due primarily to unforseen removal work and to additional reinforcement of the #2 OH columns required by the conductor conduit bank and piping runs which are supported from these columns.

Section 200 accounts - Structures -	Estimated Cost	$ 273,100
	Actual Cost	174,200
	Underrun	98,900

The only structural account which overran was the instrument room account. This can be attributed to larger rooms than originally planned and the fact that they required air conditioning. The large underrun in this account resulted mainly because I.D. Fan enclosures and a toilet and locker room were not built but were included in the initial estimate.

Section 400 accounts - Equipment -	Estimated Cost	$ 6,038,900
	Actual Cost	5,825,100
	Underrun	213,800

This account includes, among other items, the cost of the portion of the project purchased from Research-Cottrell. Besides equipment, Research-Cottrell also furnished the majority of the piping and design engineering for the project. If these items could be broken out to their appropriate accounts the underrun would be even larger. The underrun shown above is primarily the result of a better price on gas cleaning equipment than was estimated and a substantial reduction in quantities of excavation and concrete placement from the estimated amounts.

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Section 700 accounts - Piping -	Estimated Cost	$ 607,400
	Actual Cost	380,500
	Underrun	226,900

The actual underrun in this account is less than shown above because most of the piping was purchased on the turnkey contract in the section 400 account. A portion of the above underrun reflects the use of fibercast pipe rather than rubber lined steel pipe. The main header pipe sizes were also much smaller than initially estimated because the use of the Research-Cottrell scrubber allowed a greater amount of recirculation at the scrubber.

Section 800 accounts - Electrical -	Estimated Cost	$ 1,526,000
	Actual Cost	1,062,500
	Underrun	463,500

The electrical work was estimated as a subcontract. The majority of the underrun can be attributed to the fact that the general contractor also did the electrical work which improved coordination of the job and eliminated an additional fee.

Section 900 accounts - Contingency and Start-up -	Estimated Cost	$ 1,379,200
	Actual Cost	97,000
	Underrun	1,282,200

None of the contingency ($1,150,900) was used. The underrun in the start-up account was the result of fewer start-up problems than anticipated, and because the costs of vendor assistance were included in the turnkey contract in the section 400 account.

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X GENERAL ARRANGEMENT DRAWINGS

PR-3297-1987	Gas Cleaning System, Fce. Nos. 12, 13 & 14 - Plan
PR-3297-1992	Gas Cleaning System, Fce. Nos. 9, 10 & 11 - Plan
PR-3297-1988	Gas Cleaning System, Fce. Nos. 12, 13 & 14 - Cross Section
PR-3297-1993	Gas Cleaning System, Fce. Nos. 9, 10 & 11 - Cross Section
PR-3297-1998	13.8 KV Switchgear & Electrical Control House (605-E) Layout
PR-3297-2003	Electrical Control House (605-W) - Layout
PR-3297-2000	Power Line Location to Open Hearth Electric Control Room

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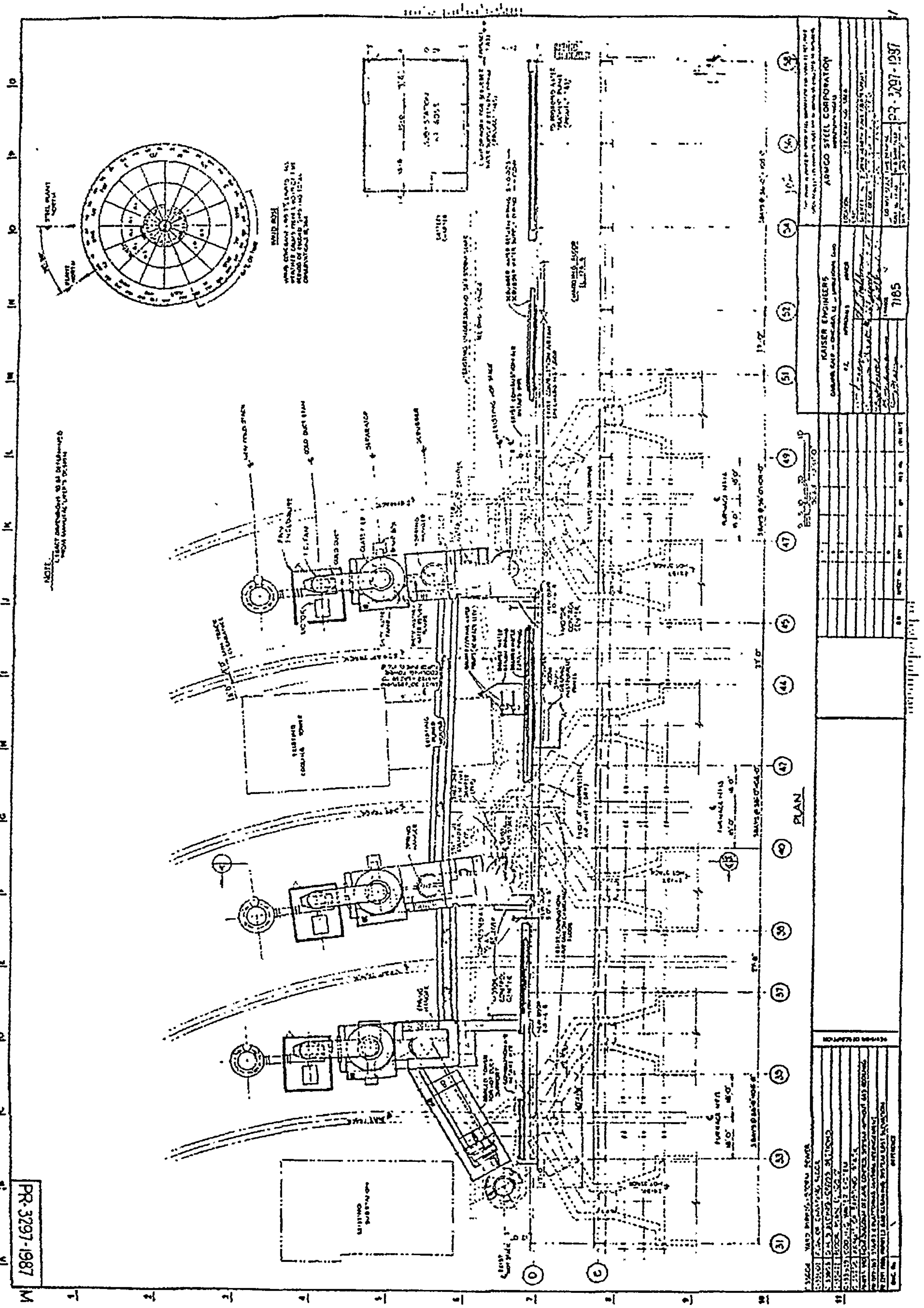
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ARMCO STEEL CORPORATION
PR-3297-1987

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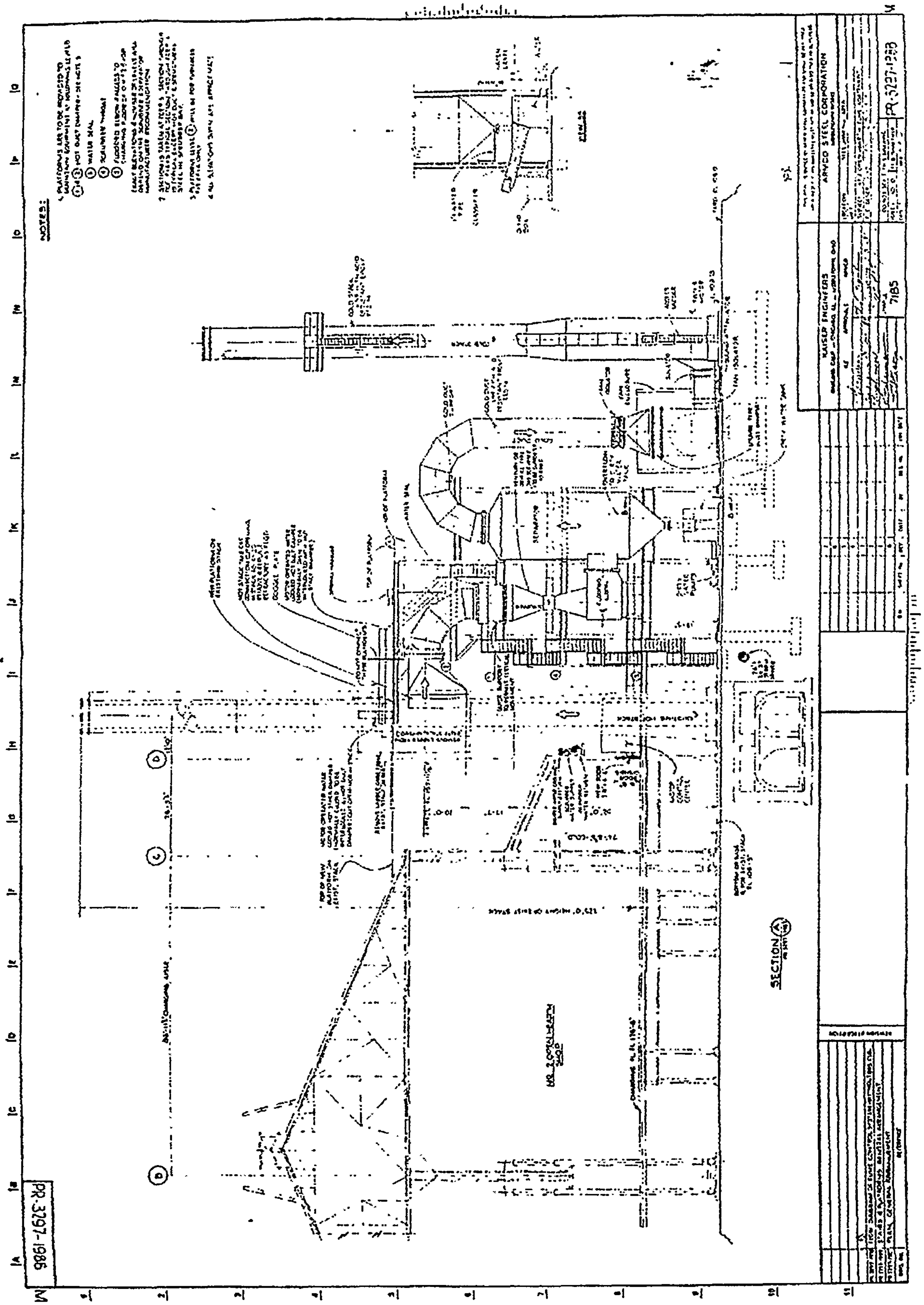
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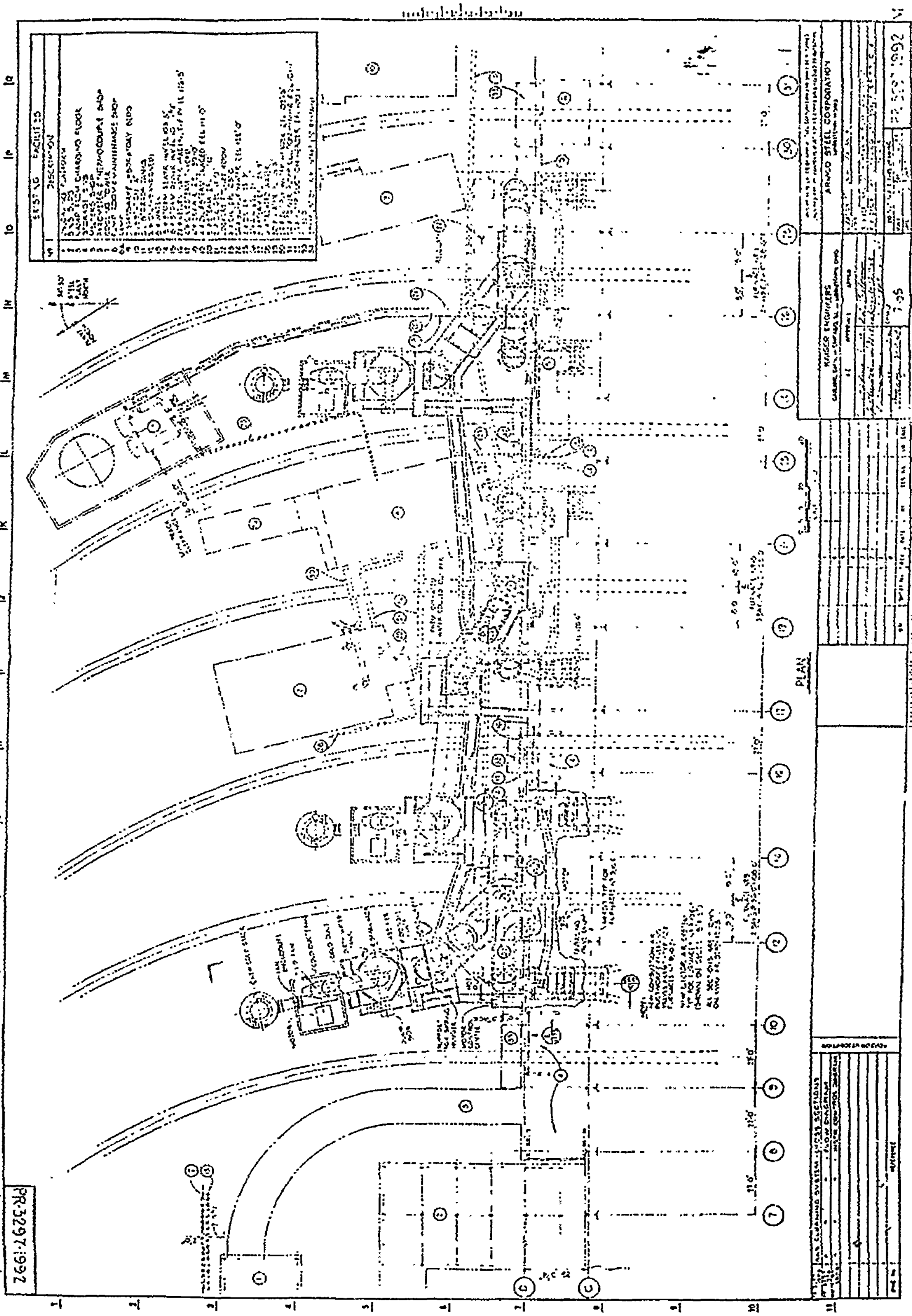
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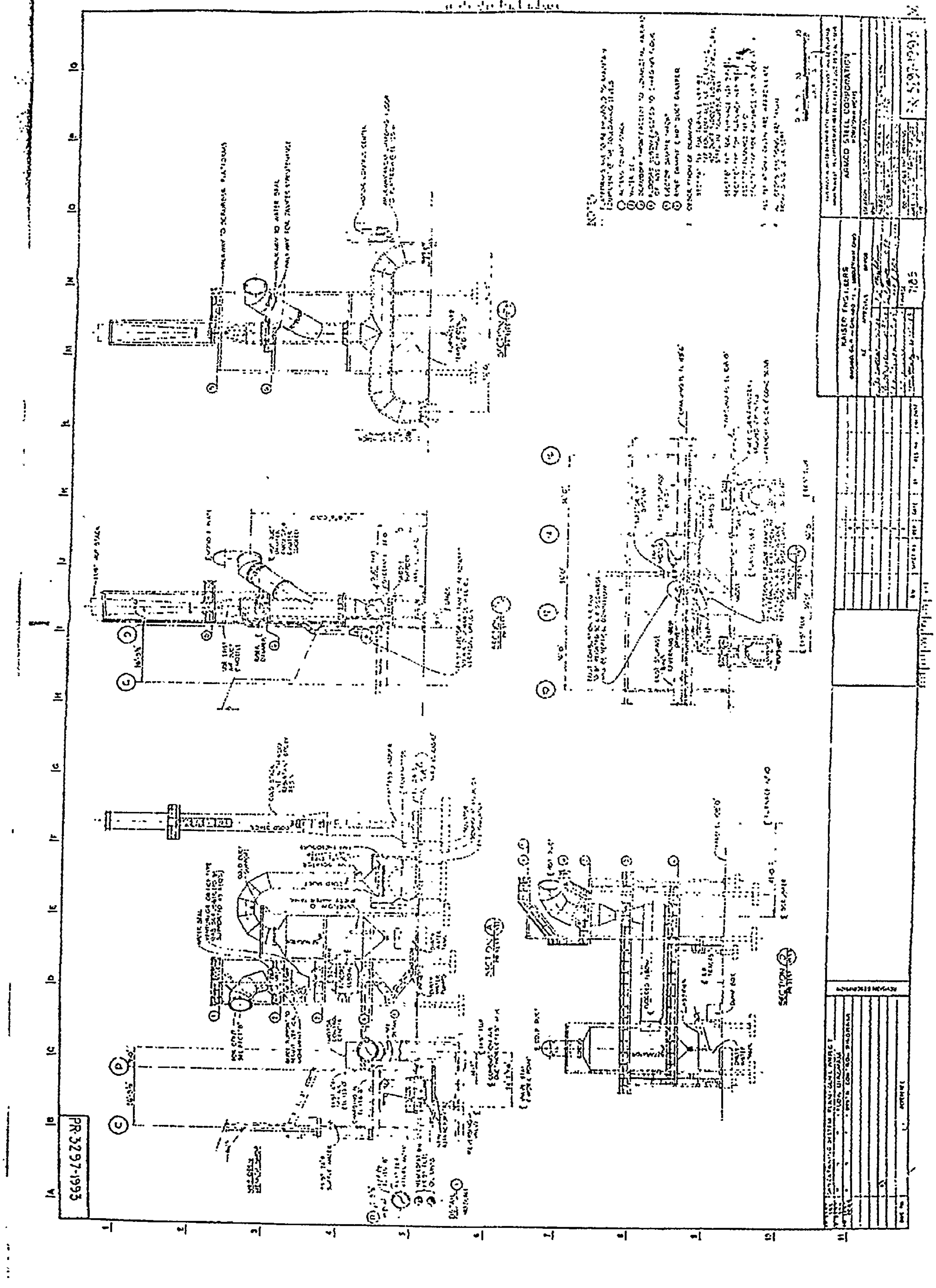
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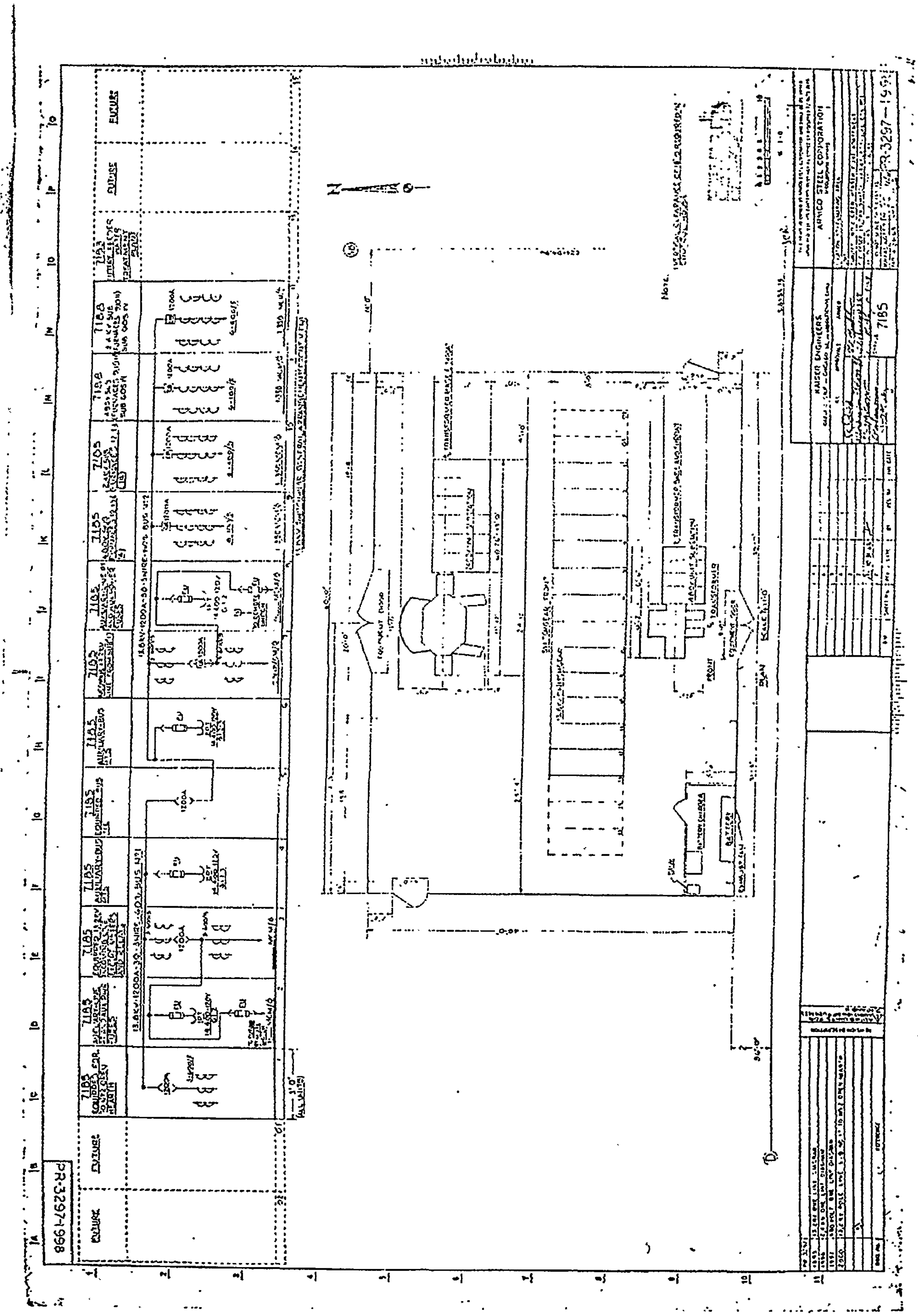
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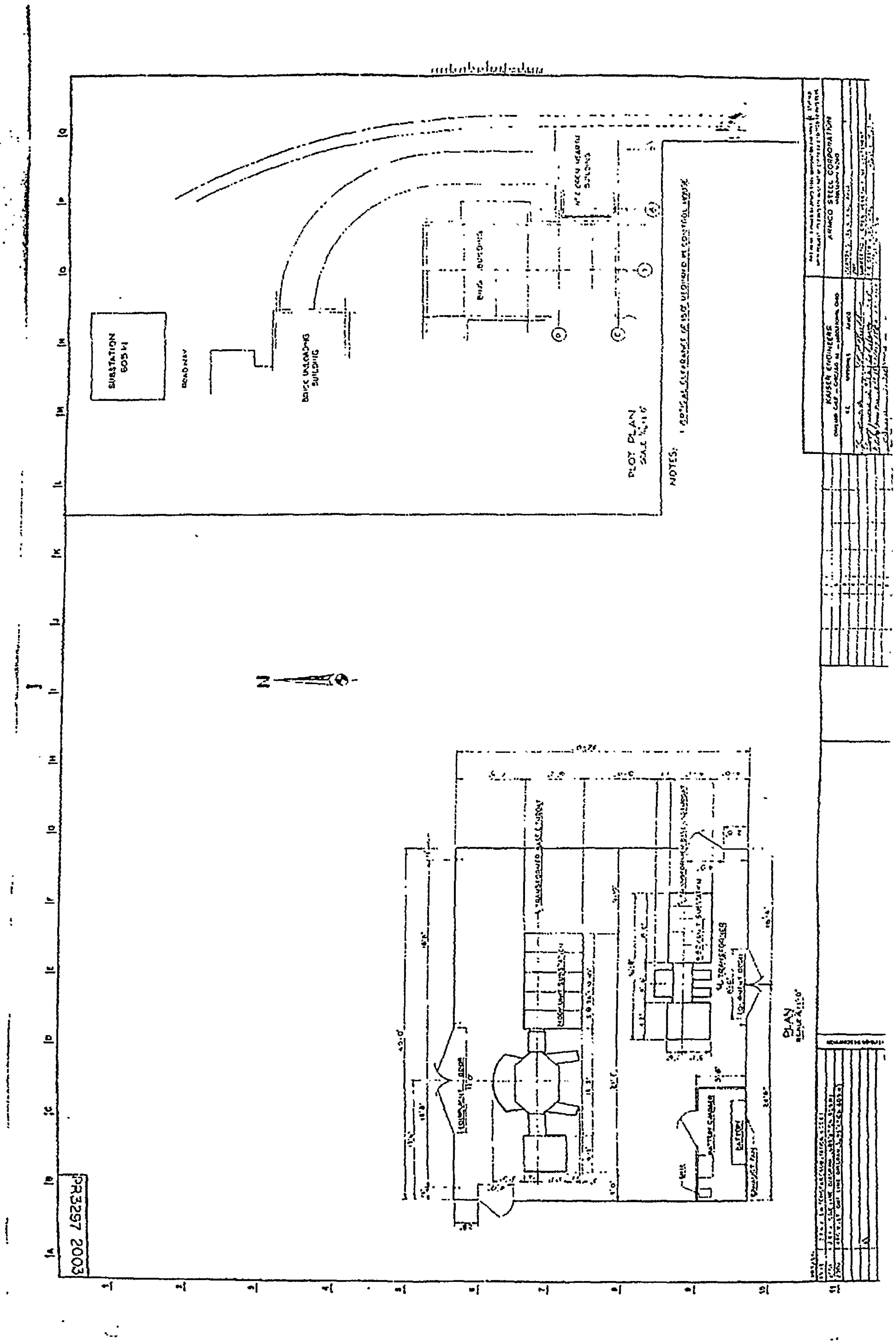

PR3297 2003
SUBSTATION
ROADWAY
BRICK UNLOADING BUILDING
PLOT PLAN
NOTES:
PLAN
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