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STUDY MISSION TO JAPAN
TRIP REPORT

JULY 1983

Transportation
Research Institute

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FOREWORD

The purpose of this report is to present the results of one of the research projects which was initiated by the members of the Ship Production Committee (SPC) of the Society of Naval Architects and Marine Engineers (SNAME) and financed largely by government funds through a cost sharing contract between the Maritime Administration of the United States Department of Transportation and Newport News Shipbuilding. The effort of this project was directed to the research of improved methods and hardware applicable to shipyard welding in the U.S. shipyards.

Special acknowledgement is made to the members of the Welding Panel SP-7 of the SNAME Ship Production Committee, whose search to improve welding technology is not limited by national boundaries and whose quest for knowledge prompted the project. B.C. Howser and M.I. Tanner of Newport News Shipbuilding are Panel Chairman and Program Manager, respectively.

Sincere appreciation and gratitude are extended to the management and staffs of the Japanese companies visited for allowing the group into their facilities, for sharing their information, and for all the courtesies provided during the visits.

SNAME/SPC WELDING PANEL SP-7

W. C. Alexander
Avondale Shipyards, Inc.

* B.L. Alia
American Bureau of Shipping

L.C. Delk
Livingston Shipbuilding Co.

D.L. Forrest
Bath Iron Works Corporation

R.A. Hay
Peterson Builders, Inc.

J. Hendrickson
Marinette Marine Corporation

R.G. Hirsch
Norfolk Naval Shipyard

E.J. Holler
U.S. Coast Guard

B.C. Howser
Newport News Shipbuilding

L.G. Kvidahl
Ingalls Shipbuilding

J.P. Maciel
Todd Pacific Shipyards
Los Angeles Division

M. Moore
Fraser's Boiler Service

T.P. Myers
Bethlehem Steel Corporation
Sparrows Point Shipyard

M.Y. Nakata
Todd Pacific Shipyards
Seattle Division

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NAVSEA

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Mare Island Naval Shipyard

S.E. Pollard
Lockheed Shipbuilding & Const.

E. Propsom
Peterson Builders, Inc.

T.J. Pruitt
Tacoma Boatbuilding Company

R.K. Richie
National Steel & Shipbuilding Co.

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Maritime Administration

P.J. Seaman
FMC Corporation

F. Spinella
General Dynamics
Quincy Shipbuilding Division

I.L. Stern
American Bureau of Shipping

M.I. Tanner
Newport News Shipbuilding

J.C. West
Bethlehem Steel Corporation
Beaumont Shipyard

R.A. Whannell
Bay Shipbuilding Corporation

A.R. Zimmerman
Norfolk Shipbuilding & Dry Dock Co.

*Promoted to General Manager,
ABS Technical - Replaced on panel
by I.L. Stern

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SECTION I

On Monday, November 29, 1982, a delegation departed from the United States to undertake a "Study Mission to Japan." The study mission was comprised of five persons, four of whom are members of the SNAME/SPC Welding Panel SP-7, the sponsors of the project. The participants were:

B.C. Howser, Manager of Welding Engineering, Newport News Shipbuilding (NNS), Newport News, Virginia, Panel Chairman of the SP-7 Welding Panel.

Bruno L. Alia, Chief Surveyor, American Bureau of Shipping, (ABS), New York, New York, Panel Member

Charles L. Null, Head, Metals Branch, Naval Sea Systems Command, (NAVSEA) U.S. Navy, Washington, D.C., Panel Member

R.K. Richie, Chief Welding Engineer, National Steel and Shipbuilding Company, (NASSCO) San Diego, California, Panel Member

R.P. Pruden, Manager, Welding Projects, Newport News Shipbuilding (NNS), Newport News, Virginia.

This study mission was established as a research project by the Welding Panel and as such was funded jointly by the Maritime Administration and the shipbuilding industry. The cost of R.P. Pruden's participation was borne entirely by Newport News Shipbuilding.

The study mission had its inception a number of years ago with two Welding Panel projects to research and evaluate "Fitting and Fairing Devices in Shipbuilding" and "Welding Robots in Shipbuilding". It was decided that the panel needed to know more about foreign competition.

Based on information supplied by U.S. Navy personnel in Europe and the American Bureau of Shipping (ABS), it was decided that a delegation should visit the Italcantieri Conglomerate in Italy. The Italians had visited Kockums in Sweden and key shipyards in Japan, observed their methods, improved on them and tailored them to their own needs. The net result of this, according to U.S. Navy information, was that the Monfalcone shipyard (one of the Italcantieri Conglomerate) was "built from scratch" and was considered to be the most modern

shipyard in the world. Contact was made with Italcantieri as well as two shipyards in Yugoslavia, and tentative approval was obtained for a visit.

The proposed trip was postponed during the lengthy transfer of program management from Sun Ship to Newport News Shipbuilding. After the transfer was completed, the idea of a foreign study mission was revived. Based on information provided by ABS as to the small amount of ship construction activity occurring in Europe, it was decided that a mission to Japan would be much more productive. This idea was presented to the panel and the Japanese Study Mission was approved.

It was established early in the planning stages of the mission that the group did not desire a center aisle walk through of a shipyard shop with a social hour afterward. They preferred instead to visit actual production areas, to observe welding and welding related technology, and then to meet in group and/or one on one discussions of what had been observed.

Because of its worldwide communication network and its establishment in the major shipyards of the world, the ABS was requested to provide assistance in planning the mission and in providing liaison between the participants and the Japanese shipyards.

ABS agreed to assist and were provided with a list of welding and welding related major interest items which the group wished to observe and a list of possible companies to be visited. Those lists are provided below:

Major Interest Items

- .Automatic fabrication systems (pipe-foundations-hangers, etc.)
 - a. handling, prepping, positioning, welding
- .Fitting and fairing devices (shop - ship)
 - a. plates, pipe, shapes
- .Narrow Gap Welding (fixed station - portable)
 - a. hull structure, pipe, machinery components
- .Electroslag welding (crawler - guide tube)
 - a. plates, castings, shapes
- .Robotic welding (fixed station - portable)
 - a. continuous arc welding - seam tracking

- Weld joint preparation (pipe - plate)
 - a. plasma, laser, machining, blasting, grinding, etc.
- Pipe welding (shop - ship)
 - a. automatic, semi-automatic, manual
 - b. fixed station - orbital
- Foundry casting operation (ship components)
 - a. upgrading/repair welding
 - b. propeller repair
- Welding processes (application)
 - a. gravity feed welding
 - b. gas metal arc - pulse arc - welding
 - c. stud welding
 - d. overlay welding (small components)
 - e. flame spray welding
- Automatic welding of primary barrier of cargo/storage tanks for liquid natural gas (LNG)

Companies To Be Visited -Location

- Hitachi Shipbuilding - Maizuru
- Ishikawajima-Harima Ind. - Tokyo
- Mitsubishi - Nagasaki
- Mitsui Engr. & Shipbuilding Co. - Tamano
- Oshima Shipbuilding Co. - Oshima
- Namura Shipbuilding Co. - Imari
- Hakodate Dock Co. - Hakodate
- Osaka Transformer Co. - Osaka
- Japan Welding Research Institute - Osaka
- Hitachi, Ltd. - Hitachi

Concurrent with the ABS efforts, the Maritime Administration was requested to assist in preparing the trip itinerary and establishing contact with the Japanese companies which were to be visited. At the request of the Maritime Administration, Washington, D.C. Mr. Michael Someck, Maritime Attache, American Embassy, Tokyo, Japan accepted responsibility for final preparation for the trip. Mr. Someck obtained the services of Koki Tachibana, Special

Technical Representative, ABS, Tokyo and together they prepared the trip itinerary which provided the group with visits to shipyards and shipbuilding related organizations that satisfied all of the delegation's original requests. One of these two gentlemen accompanied the group as interpreter, guide, liaison and provided whatever other assistance was needed on each plant visit. All of the logistics of the trip such as hotel reservations, train and airline reservations and tickets, restaurant recommendations, etc. were handled by Messrs. Somek or Tachibana. Their help allowed the group to devote their time to the technical aspects of the trip. The success of the mission was due in large part to the efforts of both Mr. Someck and Tachibana and a debt of gratitude is owed to both of these gentlemen for their dedication and untiring efforts on behalf of the group.

Trip Itinerary

"Study Mission to Japan"

Monday, November 29, 1982
Depart USA

Tuesday, November 30, 1982
Arrive Tokyo

Wednesday, December 1, 1982
Briefing

Thursday, December 2, 1982
Kobe Steel Ltd
Fujisawa, Kanagawa

Friday, December 3, 1982
Nippon Steel Corp.
Sagamihara, Kanagawa

Monday, December 6, 1982
Sumitomo Heavy Industries, Ltd.
Oppama, Kanagawa

Tuesday, December 7, 1982
Hitachi, Ltd.
Tsuchiura, Ibaraki

Wednesday, December 8, 1982
Nippon Kokan K.K.
Tsu, Mie

Thursday, December 9, 1982
Osaka Transformer K.K.
Osaka

Friday, December 10 1982
Kobe Steel, Ltd.
Takasago, Hyogo and
Kawasakijuko
Kobe, Hyogo

Monday, December 13, 1982
Ishikawajima-Harima
Aioi, Hyogo

Tuesday, December 14, 1982
Mitsui Zosen
Tamano, Okayama

Wednesday, December 15, 1982
Nakashima Propeller Co., Ltd.
Jodo, Okayama

Thursday, December 16, 1982
Hitachi Zosen Corp.
Ariake, Kumaoto

Friday, December 17, 1982
Mitsubishijuko
Nagasaki

SECTION II

THURSDAY DECEMBER 2, 1982

WELDING DIVISION OF KOBE STEEL LTD.

FUJISAWA, KANAGAWA

Kobe Steel, Ltd. is a diversified conglomerate with a number of plants in Japan, employing some 30,000 persons and producing a wide range of products ranging from coated electrodes to complete complex industrial plants packaged for export.

The Technical Department of the Kobe Steel Welding Division is manned by some four hundred engineers and technicians and is the largest welding research facility in Japan. Since 1940 when the Welding Division first succeeded in developing a high quality coated electrode, they have been a leading manufacturer of welding consumables.

Kobe Steel Welding Division now-produces about 70 percent of the welding consumables used in Japan. In 1981 Japan produced 368,000 tons of consumables as compared to 484,000 tons in the United States. The production of flux cored wire was reported to be 6000 tons in Japan as compared to approximately 32,000 tons in the U.S. in 1981. However, the production rate of flux cored wire is expected to increase rapidly in Japan.

A number of demonstrations were provided for the "Study Mission" group including the following:

.Robots - A solid wire, butt welding demonstration by a Kobe produced robot called Arc Man was provided. The six axis robot employs an arc sensor and work has been completed on an articulated wrist which allows greater flexibility and access of the welding torch. The present market for this robot is in the production of farming and construction equipment.

- Electrogas Welding (EGW) - This process is being used on a narrow groove (3/16 inch width) 40° single bevel joint. Fixed backing is provided in combination with a conventional sliding copper front shoe. There are 150 sets of this equipment in Japanese shipyards being primarily used for 5/8 inch to 1 inch thick side shell, transverse bulkheads and longitudinal bulkheads. Electrogas welding is replacing electroslag in many instances since the Japanese claim better welding speeds and the capability of welding plates with more shape than is possible with electroslag.

- Gas Tungsten Arc Welding (GTAW) - Various studies are underway with GTAW, one featuring a new product which has been available since late 1982. A mechanized, cold wire fed, hand held gun is attached to a GTAW torch. The unified mounting is adjustable, permitting a variety of GTAW applications, with the wire feeder having inching as well as automatic feed capability.

- Aluminum Narrow Gap (NVA) - Kobe demonstrated a vertical GMAW system which can weld 2 3/4 inch plating complete in 20 weld passes using .064 inch filler wire. The machine provides mechanized travel with oscillation and travel speed which is approximately 6 to 10 inches per minute.

- One Side Welding (OSW) - Research with flux/sand/copper backing (FCB) is being carried out with this system although it is being reliably used at most Japanese shipyards for panel line application. We were advised that since 1969, 116 units employing this system have been installed. Much work is concentrated on flux development to improve bead shape. There has been good success as evidenced by the surface appearance of production welds at various Japanese shipyards.

- Long Electrode Spacing for Tandem Submerged Arc Welding - A new effort has been started utilizing long electrode spacing for tandem submerged arc welding. In this procedure the trailing electrode is separated from the leading electrode by a distance of 20 to 40 inches thus reducing additional heat input effects of both electrodes. This procedure reduces the deterioration of notch toughness in the heat affected zone (HAZ), thereby making this method especially suitable for low temperature service steels. A new flux, PFL-1, having a lower electrical resistivity to slag than conventional fluxes, allowing the arc of the trailing electrode to be easily initiated and maintained, was developed for this procedure.

- Fiber Asbestos Backing (FAB) - This process was demonstrated for one sided welding utilizing a special flexible backing material. The system is mainly used for erection welds , welding curved plates and short flat runs of weld. The FAB backing material is 2 1/4 inches wide x 5/8 inch thick x 24 inches long and consists of multi layer construction. The outside layer is a waterproof film for moisture prevention, a layer of corrugated cardboard pad for maintaining uniform contact pressure, a layer of refractory material for fire resistance, a layer of solid flux for controlling back head height, a layer of glass tape for back bead formation, and a layer of double side adhesive. The adhesive tape needs to be supplemented with holding devices such as magnets to prevent deterioration of the backing material due to the heat and pressure of the welding arc.

ŽFiber Brick Backing (FBB) - This material is composed of glass fiber tapes, heat resisting bricks, aluminum adhesive layer, and protective paper. The glass fiber tape is for back bead formation, heat resisting bricks for controlling back bead height and aluminum adhesive tape for attaching to the reverse side of the weld groove. This system is designed especially for CO₂ gas shielded semi-automatic welding and is easily attached by the aluminum tape, requiring no supplementary magnets, wedges, etc. Since it is flexible in the longitudinal direction, it can be applied to curvatures; it is also very light. A demonstration revealed excellent back bead surface appearance with uniform height.

- Flux Cored Arc Welding (FCAW) - Several new wires have been developed for Kobe's line of flux core wires. All are seared wires manufactured with a typical crimping design, employ a rutile flux and offer good impact properties at minus 60°C. Work is under way to develop a wire which will produce 110 Ksi tensile strength.

FRIDAY DECEMBER 3, 1982

NIPPON STEEL CORPORATION PRODUCTS R & D LABORATORIES
SAGAMIHARA, KANAGAWA

This R & D Laboratory is actively engaged in several projects and planned demonstrations were presented.

.Separated Heat Input Type One Side Submerged Arc Welding - This setup has already been partially described in the report on Kobe Steel and was displayed at various other locations during the tour. This procedure is of interest to potential users who are concerned about the total heat input or the effect of the tandem arcs on the properties of the HAZ. With this process, a specially designed flux is used which allows approximately 40 inches of spacing between the arcs of the leading and trailing electrodes. This large spacing reduces the concentrated heat as is experienced in conventional tandem arc SAW. The consequent reduction of concentrated heat provides for less grain coarsening and for better HAZ toughness properties. It can be used on quenched and tempered steel weld joints, achieving weld joint properties equivalent to the minimum properties of the base material.

.Simplified Electroslag Welding with Non-Consumable Elevating Tip (SESNET) - The SESNET process uses typical consumable nozzle type equipment except that the mechanism has been simplified and weighs only 26 1/2 pounds. It is planned for butt and fillet welds in 1/2 inch to 1 inch thick plates, employing a rather narrow groove angle for higher welding efficiency. In this process, the solid filler wire is fed through a non-consumable guide tube which is automatically moved upward by a DC Thyristor motor as changes in welding current are detected. This process is limited to welds approximately 3 1/4 feet long and could possibly be used for bottom longitudinal and other framing members.

- Vibratory ElectroGas Arc Welding (VEGA) - The VEGA process is an automatic vertical-up welding process where the welding arc is mechanically vibrated in the thickness direction of the plate at 50 to 100 cycles per minute. Demonstrations were made with a 13/16 inch thick, quenched and tempered steel (SPU-50Q), using approximately 200,000 joules/inch heat input. The process is highly efficient due to the narrow gap joint use and provides excellent weld metal properties because of the low heat input. Properties in the weld have been verified to produce Charpy impact values of 26 foot/pounds at minus 60°C using EG-60 filler wire. With the SPU-50Q steel, HAZ properties of about 72 foot/pounds at minus 15°C have been reported. ABS is collaborating with Nippon Steel regarding the development and potential use of the EG-60 filler wire in connection with the ABS/MarAd Program.

- Special Coating for Gravity Feed Electrodes - EX-4 is a special coating type electrode for flat and horizontal fillet welding. It is used extensively in the very popular gravity feed welding process. These electrodes are very high deposition type, producing excellent bead shape of equal leg without undercut. They are characterized as producing less fume than conventional electrodes of this type.

- Seamless Flux Cored Wire - This program is involved with the manufacture and testing of a seamless flux cored (titania) wire for use with gas shielding. The wire is reported to have good feeding characteristics, good anti-corrosion properties and low diffusible hydrogen in the weld metal. It is also reported to produce little fuming. The wire is designed for welding mild steel and high tensile steel for shipbuilding, machinery, rolling stock, bridges, etc.

- Gas Pressure Welding of Steel Pipe - This is an experimental project whereby small diameter pipe is hydraulically pressed together after having been heated to a prescribed temperature with a special gas ring torch. The demonstration of this equipment using one inch pipe with 0.112 inch wall, indicated that the pipe could be cut, fitted and welded in a matter of minutes. The process should have potential in the gas industry.

MONDAY, DECEMBER 6, 1982

SUMITOMO SHIPYARD - OPPAMA

The Oppama Shipyard of Sumitomo Heavy Industries, Ltd, designed for building super large ships, is constructed on reclaimed land at Oppama, Yokosuka, situated at the entrance to Tokyo Bay. Since the first ship completion in September 1972, the Oppama Shipyard has delivered a large number of modern ocean going vessels. A unique feature of this shipyard is its dual-entrance building dock, with intermediate caissons, where two huge ships can be built at the same time, and the ships are alternately launched as they are completed.

Steel plates are received at dockside at the unloading quay. Plates are stored in the stockyard, recalled, shot blasted and marked in sequential control by computer. Only a one week stock is maintained at the yard and this is controlled with the steel mill by computer. Maximum size plates are 73 feet long x 16 feet wide and these long, wide plates are typically only used for ULCC Construction.

The yard uses the Sumitomo Egg-box assembling system. This system consists of an egg-box automatic assembling apparatus which inserts longitudinal frames into small slits in transverse frames. These slits are precision cut with numerically controlled plasma cutting machines, and several automatic welding machines vertically fillet weld each intersecting point. The yard has a panel line equipped with the OSW -FCB system. No flux cored welding is used at the present time. Of the total weight of welding consumables used, 30 percent is for SAW; 30-40 percent is for SMAW; and 30 percent is for GMAW.

A spacious pre-erection yard enables joining of subassemblies and advance outfitting of ships to a great extent. A system called GAMMA (Grand Assembly in Mechanical Mould Apparatus) is aimed at transferring on land a substantial portion of in-dock work. The system assembles huge panel blocks into single three dimensional blocks. Two 300 ton gantry cranes permit lifting of 600 ton large sub-assemblies into the building dock. These assembly areas are along dock side and are covered with portable sheds.

The yard has six NC cutting machines, two of which are plasma. Plasma cutting is generally restricted to steel plate, less than approximately 3/4 inch thick, and for aluminum. The yard has an automatic pipe facility. This facility is equipped with automatic cutting machines and semi-automatic and automatic flange welders. The pipe shop has two lines; one for large (greater than 4 inches) and one for small diameter pipe (up to 4 inches pipe size). In the assembly area the use of GTAW with open root is employed for the first pass followed by GMAW welding.

A very large self propelled semi-submersible mobile drilling unit was nearing completion. It is designed for minus 30°C service temperature and therefore has many critical areas of the unit which must meet stringent base material and weld Charpy V notch toughness properties at minus 60°C.

Some items of interest noted of the Oppama Shipyard:

- A 5-10 minute meeting is held each morning by each foreman with his crew of approximately ten people.
- Elevators/moving steps are used aboard ships to move people on and off.
- Sub-contractors are used to help maintain a stable work force.

TUESDAY, DECEMBER 7, 1982

HITACHI CONSTRUCTION MACHINERY COMPANY, LTD. TSUCHIURA WORKS

The Tsuchiura Works, one of the many manufacturing plants of Hitachi, Ltd. was established in 1974. Covering approximately 100 acres, it is one of the most advanced factories for the manufacture of heavy construction equipment and industrial machinery in the world. It is comprised of two main divisions, one devoted to the production of construction machinery such as earth movers, bucket loaders and cranes and the other devoted to the production of industrial equipment such as pumps, compressors, blowers, transmissions and refrigeration machinery. It is also the site of the Hitachi Mechanical Engineering Research Laboratory.

There are presently 22 welding robots in use in the construction machinery plant with plans for this number to be increased to 29 robots in 1983. Hitachi manufactures a welding robot called " Mr. Aros" and there is great company incentive to use these units in their own factories. This robot is equipped with a non-contacting visual sensor which provides it with the ability to correct its own track to compensate for deviations in joint geometry and welding track according to pre-programmed instructions. The robot can be taught by locating only two points for straight line welding and five points for welding corners. Once taught, it can weld an infinite number of identically shaped pieces.

Hitachi also manufactures a spray painting robot which is a high performance machine that combines the ability of a skilled worker with the accuracy and durability of a machine. Some of its features include automatic control by remote operation, its movement can be coordinated with a moving line, requires no more floor space than a human and has the ability to be instantly switched to four other programs.

An automatic weld overlay apparatus has been developed to replace the previous manual method of austenitic stainless steel overlay welding for the inside surface of pump casings. This machine, using the plasma welding process, is

pre-programmed for the location and number of weld passes. The welding torch automatically shifts after each pass according to the preset value and welding speed is automatically kept constant in like manner even if radius of gyration is changed while welding.

An automatic gas cutting and robot welding work center is in operation for making heavy section branch or nozzle connections to drums. The process is marketable and is described in a paper "Automation of Gas Cutting and Multi-pass Welding Process for Pressure Vessel Nozzles Utilizing An Industrial Robot" Present welding programs can accommodate a wide range of diameter ratios by simply inputting diameter, thickness and bevel angle information. At present, the unit can accommodate nozzles of 4 inches to 28 inches diameter, fitted to drums of 20 inches to 78 inches diameter.

WEDNESDAY, DECEMBER 8, 1982

NIPPON-KOKAN KABUSHIKI KAISHA (NKK)
TSU CITY

Tsu Shipyard of Nippon-Kokan Kabushiki Kaisha is one of three shipyards of the NKK industrial complex, which includes, in addition to the Shipbuilding Division, a Steelmaking Division and a Heavy Industries Division. The Steelmaking Division is one of the worlds largest.

The Tsu Shipyard was started in 1968 to spearhead a new era in shipbuilding, with a facility having a capacity for building ships of 500,000 dwt; one of the largest in the world. The shipyard features CANALOCK - the worlds first dual-end dock system. This revolutionary new system permits the construction of a 500,000 dwt ship together with additional bow or stern sections. It allows ships ranging in capacity from 200,000 to 250,000 dwt to be built in tandem and launched from opposite ends of the dock.

Planning of the yard was based on building six of the 250,000 dwt ships per year. For the past few years the yard has diversified and has constructed various smaller ships, product carriers, LPG carriers and offshore structures.

Automtic welding equipment in use includes two automatic one side welding stations and three automatic fillet welding machines (line welders). In addition the Tsu Research Laboratory is working on development of Robots for welding.

Presently under construction were several jackup drilling units with the leg structure constructed of quenched and tempered high strength steel. Matching strength tandem submerged arc welds are achieved when welding HT 90B (114 Ksi yield strength) base material. The wire flux combination KW 103B/KB80C results in weld deposit of 2.8% Ni, 0.85 Ci, 0.42 Mo, 0.05C, 0.31Si, 1.63 Mn, 0.008 N, 0.006P and 0.002 S. The low carbon, phosphorous and sulfur, together with the alloy addition produces high strength weld deposit with excellent toughness in the weld and HAZ at temperatures down to minus 40°C. Heat input is in the

range of 95-128 Kj/in. The problems with hydrogen cracking have been minimal and Nippon personnel also indicated an extremely low 0.35 ML/100g of diffusible hydrogen in the weld metal with the KW-103B/KB80C wire flux combination.

The Tsu yard has used the narrow gap GMAW process for heavy steel structure with machined or milled joint edges. The process used employs a high speed rotating arc which is achieved by rotating an electrode nozzle to which an electrode tip with an eccentric wire guiding hole is mounted. The primary reason for the rotating arc is to ensure uniform side wall fusion. The system demonstrated at the Tsu Research Laboratory of NKK had automatic seam tracking using an arc sensor with real time correction of the arc characteristics. Detailed reports of the process can be found in International Institute of Welding (IIW) documents as follows: IIW SG. 212-527-82, IIW X11-B-82, and IIW X11C-C-033-82.

.Automated Arc Light Intensity Control System of Weld Bead Formation in One Side SAW - A system is being developed at the Tsu Research Laboratory based on the intensity of the arc light as detected on the back side of the weld joint by photo sensors. This system was observed in a laboratory set-up by the study mission group, not in production. A complete description of the system may be found in the September 1980 issue of "Welding and Metal Fabrication" Magazine. The system attributes are as follows:

.Self driving backing carriage system for total backing support and detection of welding behavior information.

.Feedback for a welding current control system for maintenance of uniform back bead width

.Feedback for a cold wire addition control system for maintenance of uniform nugget height

In this system, the welding current of the lead electrode is controlled to maintain constant intensity of arc light which passes through the keyhole of the weld pool and backing glass fiber tape. It then is detected at the back side of the weld joint by photo sensors mounted in a sliding copper shoe. This control ensures constant properly filled back bead width. Also, when the welding current is altered by the feedback current control, a cold wire feeding device has been coupled with the feedback current control so that the proper

weld fill and reinforcement are maintained. This system has been reported to maintain both a constant back bead width and reinforcement height on one side welded joints having poor groove accuracy.

THURSDAY DECEMBER 9, 1982
OSAKA TRANSFORMER COMPANY, LTD.
OSAKA

Osaka Transformer Company, Ltd. (OTC) was established in 1919. In its formative years OTC concentrated all of its efforts in making small-size distribution transformers on the mass production basis and supplying them to the market at reasonable prices. This basic policy resulted in great success and within a few years, OTC not only owned a major domestic share of the distribution transformer market but had also expanded its line into bigger power transformers.

After having gained fifteen years of experience in transformer production, OTC again expanded its business into the field of AC arc welders in 1934. Since then, its production of welders has grown continuously. Today, OTC is the leading manufacturer of transformers and electric welders in Japan.

At Osaka there exists a welding school in which various elementary welding processes are taught to clients as well as a demonstration and instruction on new equipment.

A number of Thor welding robots were displayed and were being checked prior to shipment to customers. The Thor robot is a five axis machine which permits free setting of welding torch position. The teaching operation is based on linear and circular interpolating which permits straight line welding by teaching only two points on the line and circular line welding by teaching three points on the arc of the circle. The machine features high repeatability **and allows for $\pm 0.1\text{mm}$. position reproducibility.**

A complete brochure of welding equipment product lines was provided.

FRIDAY DECEMBER 10, 1982

KAWASAKI HEAVY INDUSTRIES - KOBE WORKS

Kobe Dockyard, one of the older shipyards in Japan, was established in 1886. Since that time, it has built many types of small and medium size commercial ships including oil tankers, ore carriers, LPG carriers, bulk carriers, car carriers, RORO ships, container ships, etc. In addition, this yard builds destroyers and submarines for the Japanese Navy and is equipped to repair all types of ships, both commercial and Navy. As is common with a number of Japanese shipyards, Kobe Works also has a Machinery Division where diesel engines, boilers, turbines, etc. are manufactured. Approximately 2300 persons were employed there during the time the group visited this facility.

Kawasaki Heavy Industries, Ltd. has developed its own technology as a pioneer manufacturer of industrial robots and Kawasaki Unimate is engaged in cooperative research and development under technical tie-up with Unimation Corporation of America. As a member of the Kawasaki group, the yard shares in this agreement with Unimation but has no robots in use in the shipyard and none are planned in the near future.

The welding process breakdown is generally as follows: fifty-five percent SMAW of which approximately twenty-five percent is gravity welding, twenty-five percent is GMAW of which seventy percent is FCAW, and the remaining twenty percent is SAW. The high percentage use of SMAW is due to the age of the yard, the types of ships under construction and repair and the amount of higher strength steels being used.

Oxy-acetylene is used for cutting, principally due to the amount of cutting being done on higher strength steel. (HY110 - a quenched and tempered nickel alloy steel).

When welding on the HY 110 steel, moisture resistant electrodes are used with a general four hour exposure being permitted. There are provisions to restrict the exposure period to 1-2 hours in high humidity conditions. A paint marking system is used on the electrodes to monitor exposure time.

Submarine hulls are fabricated with 115 Ksi yield steel and it was indicated that for future submarine hull designs they were considering 180 Ksi yield steel. The pressure hull frames for submarines are welded with GMAW. The spray mode is used in the flat position and the pulsed mode for out of position welding. The pressure hull butt joints are welded by automatic GTAW using conventional double-V weld joints.

All pressure hull butt welds are 100 percent radiographically inspected and 30 percent of the welds are also inspected by ultrasonics. All hull frames are external and the attachment welds are 100 percent ultrasonic inspected.

Results of research to correct corrosion problems in oil and gas pipe and tubing, both production and transmission, were presented in papers given at various Offshore Technology Conferences (OTC). The papers are:

1980 - OTC #3891 - Corrosion Problems of Pipeline and Solution

1981 - OTC #4153 - The Development of Corrosion Resistant Tubing

1982 - OTC #4200 - The Development of a Joint for Metal-Lined Tubing

A booklet of welding research papers prepared by Kawasaki was furnished to the group. Included in the booklet is a paper on welding thick aluminum plates for fabricating spherical aluminum tanks for LNG carriers. Another paper discusses the effect of loading rate on fracture toughness and concludes that for 9 percent Ni quenched and tempered steel, loading rate has little or no effect above the transition temperature (upper shelf) but has a significant adverse effect below the transition temperature.

The Welding Research Laboratory at Kobe is engaged in several research programs which relate directly to higher strength steels, materials used in LNG and LPG service, underwater welding and cutting and electron beam welding. A booklet describing this work was furnished and refers to the following studies:

Researches for Application

1. Study on welding procedure of tanks for LNG carrier and storage
2. Study on welding procedure of LPG tanks
3. Study on automatic welding of ultra high strength steels for submarines
4. Study on welding procedure of deep submersible research vessel
5. Study on welding procedure of high strength steels for penstocks
6. Study on welding procedure of gas holder
7. Research and development of underwater welding and cutting
8. Research and development of all position automatic welding
9. Application of EB welding to;
 - a) aircraft parts
 - b) machinery parts
 - c) fitting parts for special ship
10. Development of Tight Fit Pipe

The shipyard intends to build a deep submergence rescue vehicle (DSRV), the first such vessel built in Japan. The pressure hull of the vessel supposedly is to be constructed of ultra-high strength steel. Some use of titanium is planned, though this was not clearly defined. Delivery date is set for March 1985.

FRIDAY DECEMBER 10, 1982

KOBE STEEL - TAKASAGO WORKS

The Takasago plant, largest plant of Kobe Steel's Machinery Division, was established in 1905 and presently provides employment for some 3500 persons. This facility has metallurgical, design and production facilities. The plant produces such products as propellers, crankshafts, propeller shafts, rudders and rudder stocks, stern frames, heavy industrial machinery and pressure vessels.

The plant has the capability of making 400 ton forgings which is the largest capacity in Japan. Kobe produces 35 percent of the world market for built up crankshafts with a current production rate of 20 per month. About 200 solid crankshafts are produced each month for medium speed diesel engines.

Steel castings and forgings, of proven quality and workmanship, are produced from the worlds largest ingots. Cast and forged products include pressure vessels, pressurizers and cooling water circulating pumps. These are supplied to large numbers of overseas manufacturers of nuclear power generating equipment.

In addition to the nuclear power industry, gigantic hydro, steam and gas turbine power plants are being constructed all over the world and large size steel castings and forgings for these plants are provided by Kobe Steel. Kobe Steel is the worlds biggest producer of propellers and makes bronze, special cast iron and cast steel, solid and controllable pitch propellers. The propeller shop has a nine axis NC Milling Machine capable of machining 440 inch diameter propellers weighing up to 130 tons. Kobe Steel also bears the distinction of being the largest titanium melting plant in Japan.

MONDAY DECEMBER 13, 1982

ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD. (IHI) AIOI WORKS

The IHI Aioi Works Complex is comprised of the (a) Aioi shipyard undertaking the building, rebuilding and repair of ships and construction of bridges and other steel structures (b) the Aioi Diesel Engine Works which also serves the entire IHI complex with its casting foundry and (c) the Aioi Boiler Works which produces land and marine boilers, pressure vessels and other plant components. These three facilities employ approximately 5000 persons.

Panel line welding at the shipyard is with the SAW process using FCB. This combination forms a one side welding system that produces excellent results. Very little back side repair is needed, due primarily to the excellent joint fit-up and flatness of the plates. It was common to see forty to sixty feet long panels being fitted for welding using only two fitting aids (dogs) for panel alignment.

A second application of one side submerged arc welding is employed with a flux asbestos backing. This is used for curved shell assembly seams and butts and seams of hull blocks at the erection stage. The FAB system of backing consists of a layer of glass tape, a layer of solid flux and a layer of asbestos board; all of which is enclosed in a waterproof plastic film.

Electrode gas welds are employed for side shell plating (ABS grades A,D, AH and DH steels). A single vee joint is used and fit-up is good with root openings ranging from 3/8 inch to 3/4 inch. This range of root opening appears to be compensated for, based on the appearances of the completed weld.

There is considerable use of laydown welding, (we call it "firecracker" welding; it is called Yokooki at IHI). It is employed for fillet welds in longitudinal and transverse frames of double bottoms. This is a process wherein 8 or 10 - one meter electrodes are laid down at the joint, end to end and connected to a single power source. An electric welding current is transmitted through each rod by connectors, progressively initiating and extinguishing the arc for each electrode in the system as the welding process melts the rod and forms the fillet. This process is used on mild steel and high tensile steel and is reputed to be cost effective.

A considerable amount of horizontal fillet welding is performed by Micro-Wire submerged arc welding (MISA). The MISA welder is a very small, lightweight welder used for mild steel and high tensile steel, welding deck and deck longitudinals, bottom and bottom longitudinals and corrugated bulkheads. Filler wire is 1/16 inch diameter.

Quite a bit of SMAW, downward progression, was observed for vertical fillets and some butt welding using 5mm low hydrogen electrodes. The yard reports excellent results and good operator appeal due to ease of application, both for single and multipass operations.

At the Boiler Works within the complex, narrow gap welding is used for making girth welds in the drum sections.

A very interesting Ultrasonic Test (UT) technique has been developed and is in use at Aioi for small pipe inspection. The system employs two UT probes which are mounted on a split ring orbiter that fits around the pipe to be inspected. The operator then manually rotates the probes and a paper printout of the inspection is recorded automatically. The printout indicates a go/no go situation. For the go situation, the pipe is acceptable and the inspection is complete. For the no go situation, the inspection requires further manual probing to determine if the weld is rejected. The limits of acceptability are usually set precisely to the requirements and welds which exhibit no go situations are usually rejected and removed rather than carrying out an extensive exploration of the weld; thus saving time and keeping production moving.

TUESDAY DECEMBER 14, 1982

MITSUI ENGINEERING AND SHIPBUILDING COMPANY, LTL. TAMANO WORKS

The Tamano Works of Mitsui Engineering and Shipbuilding is comprised of three divisions; (1) Shipbuilding Division; (2) Steel Structures Division and (3) Process Plant and Machinery Division. The company was established in 1917 and has grown over the years to its present employment level of approximately 6300 persons with an additional 46 subcontracting companies employing some 3100 persons.

The Shipbuilding Division is comprised of two sections: (1) The Newbuilding Section and (2) the Ship Repair Section. The new construction section has the capacity to build tankers and ore carriers up to 140,000 dwt, as well as ships requiring high technology such as multi-purpose cargo ships, refrigerated cargo ships, container ships, LNG and LPG carriers. In addition, naval ships and craft, offshore oil drilling rigs and other specialized equipment for oceanographic development, also constitute its major products.

The Ship Repair Section, with its 150,000 dwt capacity floating dock and well equipped mooring quays, can handle repairs and remodeling of ships of all types. The Ship Repair Section is very proud of its reputation for high quality work, having been designated as an authorized "Hull QA Yard" by several classification societies.

The Steel Structures Division has built various steel structures such as penstocks, lock gates, bridges, large tanks, etc. Combining its steel structure technology with its shipbuilding techniques, the Steel Structures Division is now active in the field of building oceanographic equipment, such as ocean platforms, oil drilling jacket modules and sea berths for large ships, as well as various structure for use in ports and harbors.

The Industrial Machinery and Plant Engineering Division manufactures rotary machinery, electric machinery, cranes, chemical plants, boilers, heavy

machinery for casting and forged products and diesel engines.

Among the many "firsts" accomplished by the Shipbuilding Division of Mitsui is included the building of the world's first automated cargo ship, followed by the world's first diesel driven, three engine, three shaft, super high speed container ships. It was here that for the first time in Japan, the ship type offshore oil drilling rig was built. During the time that the "Study Mission" group visited this complex, a large semi-submersible and two jack-up type offshore mobile rigs were under construction, as well as a 40,000 dwt car carrier capable of carrying 4300 cars was nearing completion.

For the construction of the lattice type legs of the jack-up units, the cutting of the tubulars for T and K joints was excellent, resulting in excellent fit up, with full penetration welding around the entire joint including the heel area.

In the cutting shop area, a manual line is provided where small, portable, semi-automatic (easily lifted with one hand) oxy-acetylene cutting machines were employed to make frames and cutouts in sections. For cutting frames, one operator handles 2 or 3 machines. Small metal templates were used to facilitate straight cuts for hand held cutting. We were told that operators were not allowed to do free hand cutting, but must use something to hold the torch tip steady in order to make accurate cuts.

A large amount of flux cored CO₂ welding is carried out in the shipyard. A new type filler wire (Kobe DW-200) is being used which is reputed to provide good weldability over primed surfaces (zinc 1000 F8) and yields welds without blowholes. Vertical down welding is used for many fillet welded connections.

All panel plates are joined by one side welding with the FCB system, yielding results of excellent surface quality.

Plate edges which are to be joined at the erection stage are coated with an anti-corrosion coating which is reputed to be about 3 mils thick and lasts about 20 days.

This yard also makes extensive use of the line heating process to form complex shapes. The process is being successfully utilized to get stiffeners in place on curved assemblies and is responsible for some of the excellent fit up we observed. A bow section, approximately 10 feet x 40 feet with double curvature on both port and starboard sides , was installed in one piece utilizing line heating for forming. This resulted in a reduction of welding as well as a job with excellent appearance.

As an interesting sideline, the Tammano Works are located at the foot of small mountains and tunnels have been cut through these mountains within the works to reduce travel time. Approximately one half the inhabitants of the city of Tamano are employed by Mitsui.

WEDNESDAY DECEMBER 15, 1982

NAKASHIMA PROPELLER COMPANY, LTD.
OKAYAMA

Nakashima Propeller Company, Ltd. had its beginning in 1926 at Okayama as a foundry to make machinery parts. In 1935, the "Nakashima Foundry Works" was formed to make propellers for fishing boats. In 1967, the company moved to its present location and the company name was changed to its present form.

The company is principally a family business, having as its major owners four Nakashima brothers and the son of one of the four brothers. In terms of personnel, it is a relatively small company, having only 300 employees. Despite its relatively small size, it is one of the most modern plants for ship propellers in the world. Only bronze propellers are cast here and at the time of the Study Mission visit, it supplied approximately 40 percent of the propellers for Japanese shipyards. This equates to roughly 20 percent of the world's supply of propellers. The plant also supplies stainless steel propellers which are furnished by vendors and machined by Nakashima.

All propeller designs are by computer and the designs are fed directly to numerically controlled (DNC) milling machines to provide automated machining.

The facilities are equipped with a spectrographic analysis system which provides chemical analysis in 40 seconds to support the casting operation. Analyses are taken at several intervals prior to pouring a casting to control the chemistry of the pour. The rapid readings permit alloying as required prior to pouring without overheating.

Nakashima provides a full range of controllable pitch propellers for both commercial and naval vessels.

A paper, "Experiments On A Series Of Highly Skewed Propellers" (HSP) was discussed. This paper contains information on the fatigue endurance limit of highly skewed propellers and makes comparisons with conventional designs. The paper also discusses the problem of high stress in the HSP when in the full astern thrust condition.

Nakashima propeller repair procedures were discussed and generally follow the ABS guidelines for repairing bronze propellers. Nakashima expressed some reservations about the proposed ABS requirement that the entire surface of each new propellers be examined by dye penetrant test (DPT). They expressed the belief that this was not necessary and that such inspection should be limited to critical areas only.

THURSDAY DECEMBER 16, 1982

HITACHI ZOSEN - ARIAKE WORKS

The Ariake Works is the largest and most modern plant of Hitachi Zosen. It was completed in 1974 and contains approximately 5,000,000 sq. ft. of area, two thirds of which are devoted to shipbuilding and offshore equipment manufacture and one-third to land use machinery manufacturing. The shipbuilding facility is very versatile; capable of producing small and medium size ships, as well as ultra large ships, including LNG carriers, bulk carriers and tankers. Offshore structures which have been built include offshore platforms, oil drilling rigs and jacket modules.

The Land-Use Machinery Division is equally capable of manufacturing a wide range of products such as high temperature and high pressure vessels, towers and tanks.

Electrogas welding is used for vertical parallel body midship side shell sections. In addition, it was being utilized to weld sloped hopper sides for ore carriers. The plating sloped upward about 35°-45° from the tank top plating. Fixed backing tapes were employed on the underside with a typical copper sliding shoe on the top side. The weld surface appearance on both the top and under side were good.

A considerable amount of seamless flux cored wire is used at the Ariake Works, as well as at a number of the other Japanese shipyards, for structural applications. The seamless wire is reported to be about 30 percent more expensive than conventional seamed flux core wire, but has the following advantages:

- (a) Low diffusible hydrogen in the weld metal; a reported 0.5 ml/100g.
- (b) Excellent feeding characteristics
- (c) Little fluttering of the wire tip
- (d) Copper coated for low fume emission during welding.

Despite these features, no flux cored welding is used for pipe. Instead, most of the pipe welding is done by the semi-automatic GMAW solid wire process.

Wherever possible, the yard uses the one side welding process with the FCB system, but due to the types of units under construction, there was limited opportunity to apply it. Even so, experimental work was being carried out in an effort to narrow the gap (reduce the volume of the weld joint by reducing the included angle of the plate edge bevels) with its consequent reduction of welding time and consumables for the one side process.

A small, portable, mechanized burning machine-Tanaha Kochee-was being used in the shops and yards with very good quality cuts and ease of handling. Two and sometimes three machines are used by a single operator.

The Ariake yard is equipped with a large panel line and plates are ordered to an 81 feet x 13 feet maximum size. Typically, this is the size plate used for ULCC'S. The yard uses the egg box method of construction. Mechanized automatic fillet welding machines (flux cored wire) are used to make connections between frames and longitudinals. Also, there is an experimental program underway in an attempt to use Robots to weld side and bottom longitudinals at the erection stage.

FRIDAY DECEMBER 17, 1982

NAGASAKI SHIPYARD AND ENGINE WORKS OF MITUSBISHI HEAVY INDUSTRIES

The Nagasaki Shipyard is made up of two plants. The Main Plant, which began as a foundry in 1855 and is one of the oldest shipbuilding facilities in Japan and the Koyagi Plant which is one of the newest and most modern. The two plants have the capability to build ships ranging from small escort vessels for the Japanese Navy to tankers and bulk carriers of 1,000,000 dwt. In addition to these, they also build steel structures, bridges, oil drilling rig jackets and other marine structures. They are presently building 3 LNG carriers of 125,000 M³ capacity and of the spherical aluminum tank type.

The Shipbuilding Departments of the company have strongly promoted the improvement of welding techniques, especially the automation of welding processes. Mitsubishi is proud of the fact that the 5 shipyards owned by the company have the highest percentage of automated welding in the whole Japanese shipbuilding industry.

The shipyards at Nagasaki, both the Main Plant and Koyagi Plant, employ the conventional welding processes as well as some of the automatic processes as follows:

- Automatic Non-Gas Vertical Fillet Welder - This is an automatic upward progression fillet welding machine. The AC current is raised at a certain cycle so that enough penetration and bead width are obtained in the period of high current, while the molten metal is cooled in the period of low current to prevent the drooping of the bead. A flux cored filler wire is used which provides a gas shield for the molten weld puddle. It is used for welding connections between transverse and longitudinal members.
- Automatic CO₂ Gas Arc Vertical Welding - This is a method of fully automatic CO₂ gas shielded vertical welding performed with program controlled oscillation of the welding head. Automatic one side welding is also possible with this process using backing material. This equipment provides welds of good quality, smooth appearance and excellent mechanical

properties. The process is mainly used for vertical welding of joints in bulkheads, hopper tank tops and internal members.

.Automatic Horizontal Welding - This is a method of electro-gas welding applied horizontally. Attaching the copper backing bar on the reverse side, automatic welding is performed on the front side using solid wire protected by shielding gas. The weld is molded on the face side using a sliding copper shoe.

A considerable amount of one side welding is performed using the submerged arc welding process, both single wire and multi-wire systems. This type welding is accomplished with the backing systems already described in the report such as FCB, FBB and FAB. A SAW process for one side welding of thin plates is performed using a water cooled sliding copper shoe as backing in conjunction with a roller device for aligning the plates for welding.

MHI has developed a technique for covering a ship's hull with thin tile-like plates of a special anti-fouling copper alloy using a specially developed adhesive material. The process is experimental and is being evaluated on a small yard shuttle boat which is pulled out of the water for examination every two months. Nagasaki employees were reluctant to talk about this project and MHI declined to provide information on it when requested by Mr. Someck, Maritime Attache.

The visit to this plant concluded the study mission visits to Japanese industry.

SECTION III

GENERAL OBSERVATIONS OF THE "STUDY MISSION"

Robots - At the present time, Japanese shipbuilding, has not been taken over by robots. As a matter of fact, there were no welding robots being used in any of the shipyards visited by the study group. In addition, the group was told that there are no active plans in the near future for shipyard welding robots. However, there were ongoing studies of robots in shipbuilding for evaluation purposes. We were given information at Kobe Research Center that a small, portable type robot capable of working in small areas of a ship is on the drawing boards and will be in Japanese shipyards in approximately one and one-half years.

There were some robots performing welding in a pressure vessel facility and a large number were welding in a construction equipment manufacturing plant. In these facilities, each welder operated two machines. The welder used a teaching head or the robot traced the weld path and then made the weld. Feeler sensors or sensors using light reflection pattern were used for joint guidance.

At a welding equipment manufacturing plant, part of an assembly line for the manufacture of Datsun automobiles was under test with approximately 60 robots in use, primarily for welding.

Automation in Welding - The degree of automation in shipbuilding welding, aside from robots and as measured by weight percentage of welding consumables, is similar to the more automated shipyards in the United States. In 1982 the percentage of manual metal arc welding with stick electrodes was approximately twenty-five percent, semi-automatic welding accounted for approximately 55 percent and automatic welding accounted for 20 percent. This contrasts vividly with the figures for 1977 which indicated that 60 percent of all welding was done manually, with semi-automatic and automatic sharing equally the remaining 40 percent. The bulk of the change since 1977 has been in the semi-automatic mode and in the flux cored and pulsed gas metal arc processes.

Pipe Shops - The pipe shops in the facilities we visited were, for the most part, fully automated with extensive facilities for welding flanges onto pipes. There appears to be a larger number of flanged joints used in Japanese Shipbuilding than in the U.S. and in the shops where these are welded, it is done with automatic machines with four welding heads, welding the inside and outside of the flanges simultaneously. Unfortunately, much of the fixed station automatic welding equipment in the pipe shops was idle during our visit, due to lack of work.

Joint Preparation - Both plasma-arc burning and oxy-acetylene or oxy-propane burning are used for edge preparations in the automatic panel lines. When preparing plate in the construction areas, small, semi-automatic burning machines are used, with one operator handling two or three machines. There is very little free hand burning, with all burning operators required to use guides to hold the torch tip steady so that accurate cuts can be made.

Fit-Up and Fitting and Fairing Devices - The joint fit-up in all the Japanese yards was exceptional which increases the effectiveness of automatic equipment. For example, 40 to 50 feet long assemblies were held in place with two fitting aids (dogs), with very close fit-up for tacking and one side submerged arc welding. The accurate cutting, fitting and flame forming contributed to the excellent fit-up. The as received plate from steel mills in Japan is very flat with little or no waviness. Other than automatic frame and panel lines, manual fitting aids in use were much the same as in most U.S. yards. The difference is that an aid for a particular type fitting is standardized and is used for that type fitting in all the Japanese yards.

No tack welded fitting aids are used in sub-assembly fabrication unless it is absolutely necessary. The pulling, pushing, alignment, fairing etc., is done with devices such as porta-powers, electro-magnets, vacuum hold downs, hydraulic jacks, etc. This practice provides savings in the conservation of labor and materials by eliminating preparation of the aids, elimination of labor and materials to attach them, remove them and repair of the sites after removal.

The Japanese generally do not use mechanical means of forcing materials to bring them into fair; instead, the line heating technique is used which results in a much better looking quality job and eliminates built in stresses. Because of the use of this technique and the practice of accuracy control from the very start of fabrication, fit-up of units at erection presents no problems.

Submerged Arc Welding - Descriptions of most of the welding processes used in Japan have already been noted in Section II and included were several variations of the submerged arc welding process. What has not been noted is that all the Japanese SAW flux being used had a large percentage of iron powder added which stabilized the arcs and increased deposition. In addition to metal powder in the flux, most yards used metal powder additions in the weld joint with all SAW welding, both single and multiple arcs. This technique reduces distortion and improves productivity.

One Side Welding - The use and quality of one side welding in Japanese shipyards is exceptional and this is the general method of welding for panel lines. At every yard the results were either excellent or very good with a minimum amount of repair. The general use of this system in Japan is in marked contrast to the practice in the U.S. at the larger yards.

Gravity Feed Electrodes - The Japanese use the large diameter gravity feed electrodes very extensively on mild and high tensile type steels. Their construction method (egg box) and product mix is such that the panel shops do not have gantry fillet welders and instead use gravity feed electrodes. Many refinements to the gravity feed electrode holders have been developed to increase utilization and one welder typically keeps 4-8 jigs operating at the same time.

In Japan, this process is considered semi-automatic. Where in the United States we would consider it necessary to have a number of long stiffeners to employ this process, the Japanese use it if the length to be welded is equivalent to the deposit of one gravity feed electrode.

Egg Box Construction Method - Most of the yards visited use this method of construction. It appears that accuracy and dimensional control are more easily facilitated using this method.

Automatic Multi-Head Tack Welder - Automatic tack welders are in use with 10 welding heads to make simultaneous tacks of controlled length and sizes. This machine is moved across the assembly on rollers.

Specialized Techniques for Welding LNG Tanks - Several specialized techniques for welding both thick aluminum spherical and the thin membrane type LNG tanks were demonstrated. The LNG tanker market in Japan is still active and significant R&D is directed to this market. Horizontal position electrogas welding is employed for heavy section groove welds. GMAW using 1/16 diameter wire is used for vertical position welding with associated higher deposition rates.

Measurement of Diffusible Hydrogen in weld Metal - Many methods have been used to measure the diffusible hydrogen in weld metal. The Japanese have developed a method that is equivalent to the mercury method, which is the accepted standard. The new method is simple, clean and safe. This method, using a gas chromatography, has been in use for two years in Japan and a draft JIS Standard, Dec. No. II-A-J61-82, has been prepared. The chairman of the U.S. AWS Committee on this subject has recently obtained a Japanese unit and his results to date, using this unit, have been satisfactory.

Electron Beam Welding (EBW) - The Kawasaki works at Kobe had an extensive lab type shop for making electron beam welds. It included the conventional hard vacuum chamber and a unique partial vacuum setup for welding long structural components. It was indicated that EBW was being used on high strength Q and T high toughness steels which were heat treated after welding, but they had toughness problems on this type of welding when it was not heat treated afterwards.

Plasma Arc Strip Cladding - A unit was demonstrated which uses a plasma arc system to melt a strip under a molten flux for cladding, with less penetration and dilution of the base material. This method also had a high deposition rate. The lower dilution rate is a very important factor in the corrosion resistance of the cladding.

Welder Training - Japanese yards train welders for 6 months and almost all of their new employees have a high school education. Employees are generally hired for their working lifetime. However, shipyards also contract with companies who supply welders and other workers for a limited time to allow for the business cycle changes. In contrast, U.S. shipyards train welders about seven weeks. Most of these trainees have a poorer educational background than their Japanese counterparts and generally stay with the company on the average two-five years.

Facilities - There are over 5,000 shipyards in Japan but a large part of the shipbuilding tonnage is constructed in the shipyards of seven major shipbuilding companies. Many of the shipbuilding facilities, particularly the older yards, have other heavy construction activities in or adjacent to their facilities, such as pressure vessels, boilers, diesel engines, bridges, etc., which helps maintain a constant workload. Several new yards were built in the 1969-1974 era specifically for large volume oil tankers with special features to optimize their construction, such as an automatic egg crate jig for welding the longitudinal and transverse frames to the hull plating on tankers. These new facilities have a very small workload for their very large specialized capacity. The building docks in the new shipyards are very large, ranging in size up to 3000 feet long by 300 feet wide at the Koyagi Works, which equates to a maximum shipbuilding capacity of 1,000,000 dwt. The Japanese government, in an effort to keep the larger yards with those building docks from driving smaller yards out of business in the current market, has restricted the use of these building docks.

GOVERNMENT ROLE

Japanese Navy Work - The ship construction for the Japanese Navy is kept underway at five to seven yards with varying construction schedules of 1 to 2 years. At least 4 to 5 yards have active destroyer building capacity and three yards have submarine building capacity. We were told that political consideration was taken into account on the location and scheduling of ship contracts. The fit-up and welding on the naval surface ships was of the same high quality as in the commercial ships. However, due to security requirements we were not allowed to observe construction of submarine hulls.

After having visited eight shipbuilding facilities throughout Japan, a few things became obvious as to how the Japanese succeed in outdoing most of the other shipbuilders in the world. First of all, they have no magic secrets as is popularly conjectured in various publications. They are, instead, a relatively small nation faced with seemingly insurmountable obstacles to have allowed them to reach the level of achievement they now enjoy. Having relatively few of the world's natural resources and having to import a large percentage of everything they need to survive, including food, makes it appear; however, that magic is involved. The simple fact of the matter is that the Japanese make the maximum use of their available technology.

A great deal of the technology that is applied in Japanese shipbuilding today is technical information that has been gathered from outside of Japan, has been thoroughly researched, standardized and cooperatively shared by the Japanese shipbuilding industry. This is in direct opposition to the practice in the United States where information is jealously guarded and very little cooperation takes place between shipyards.

Several research centers were visited, all of which were well equipped and manned to research almost anything in the field of shipbuilding technology. It was our understanding that these research centers are government funded.

Another obvious reason for Japanese shipbuilding success is the amount of advance planning that is done and the attention that is given to implementing the plan once it has been adopted.

It is quite evident that dedication to quality is not merely a slogan but is a philosophy to live by in Japanese shipyards. Each employee works as accurately as he can to perform his job as nearly perfect as is possible. An illustration of this point is the welder. After completing all welding on a given job he cleans the weld, clean sweeps the work area, removes blowers and lines, etc. and in effect provides first line inspection on the completed welds. There is a great loss in respect if obvious defects or unwelded areas are not found by the welder. Quality circles were quite evident, with some of the shops having exhibits of accomplishments along with information about that particular program, its purpose and the people who had been involved. These quality circles no doubt contributed partly to the excellent quality of the workmanship observed in all of the shipyards visited. The excellent quality can also be attributed to the stability of the work force (lifetime employment) and the greater amount of training afforded Japanese workers, as well as proper planning.

Each assembly shop seemed to have one man in charge of the whole shop, with supervisors under him supervising approximately 20 persons. The supervisor is in charge of and responsible for all crafts in his area of the shop. Work aboard ship is handled differently, with craft supervisors having responsibility for only those persons in their particular craft, e.g. welder supervisors for welders, fitter supervisors for fitters.

All of the research centers and shipyards in Japan have been given the following as their most important goals for 1983 we were told at the Tamano Works of Mitsui Engineering and Shipbuilding Company. They are:

1. Electron Beam Welding
2. Methods of improving weld joints and saving manhours
3. High speed welding such as resistance welding
4. Campaigning to improve the company reputation and improving quality

Finally, the Japanese appear to place more resources into application engineering in the welding technology area than is done in the United States. This results in fuller utilization of available technology in the field. All work is preplanned in minute detail and all systems appear to work as planned.

Also, the interface between the shipyard trades (layout, cutting, fitting and welding) is coordinated so that the excellent fit-up of weld joints is possible. It was also noted that the steel and filler metal manufacturers have extensive application engineering resources allotted for the utilization of their products in shipbuilding applications.

K O R E A

KEY

- Tokyo 1
- Fujisawa 2
- Sagamihara 3
- Oppama 4
- Tsuchiura 5
- Tsu 6
- Osaka 7
- Takasago 8
- Kobe 9
- Aioi 10
- Tamano 11
- Jodo 12
- Ariake 13
- Nagasaki 14
- Nagasaki 15

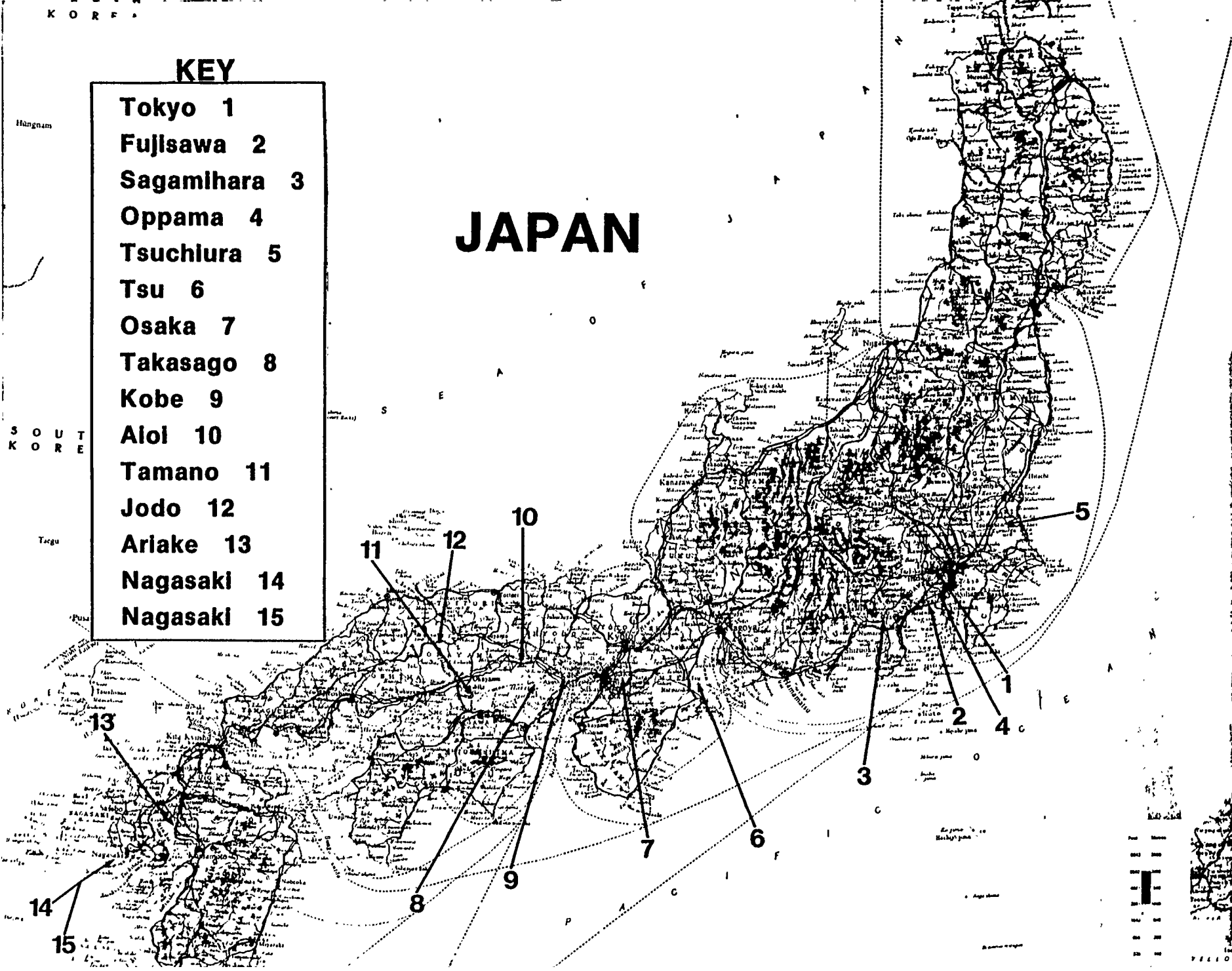
JAPAN

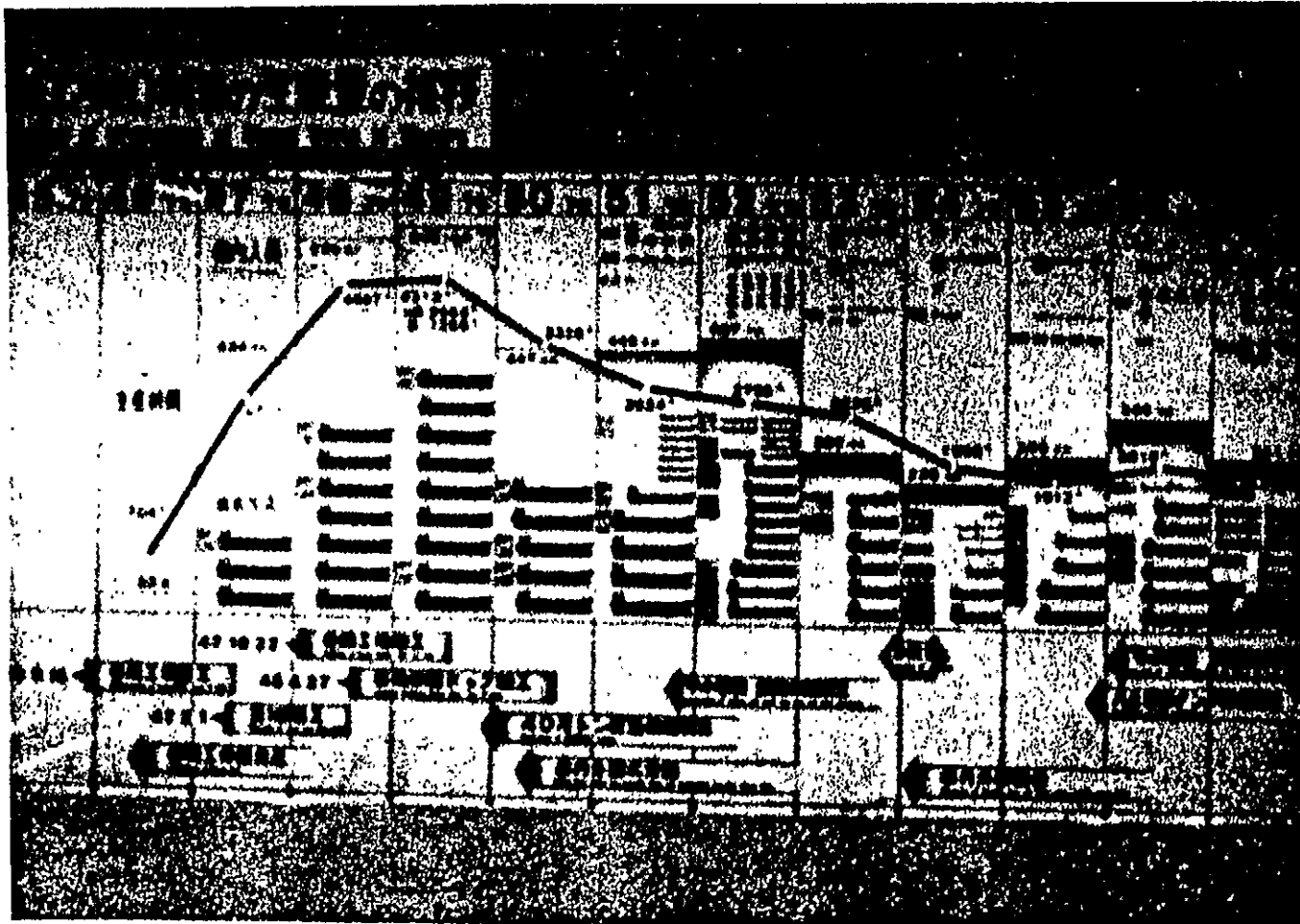
Hangnam

S O U T H
K O R E A

Taeju

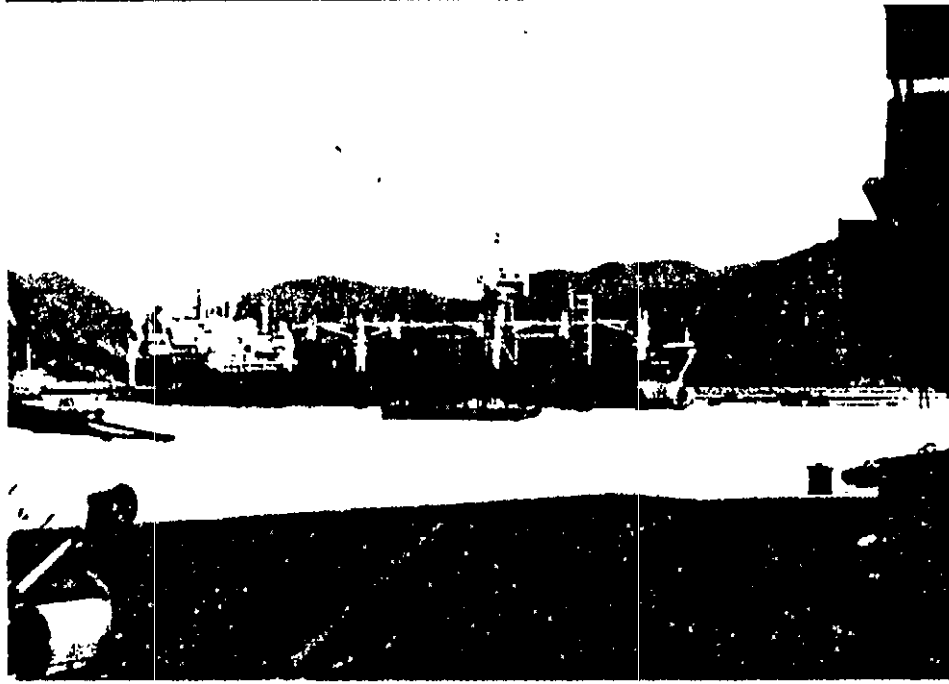
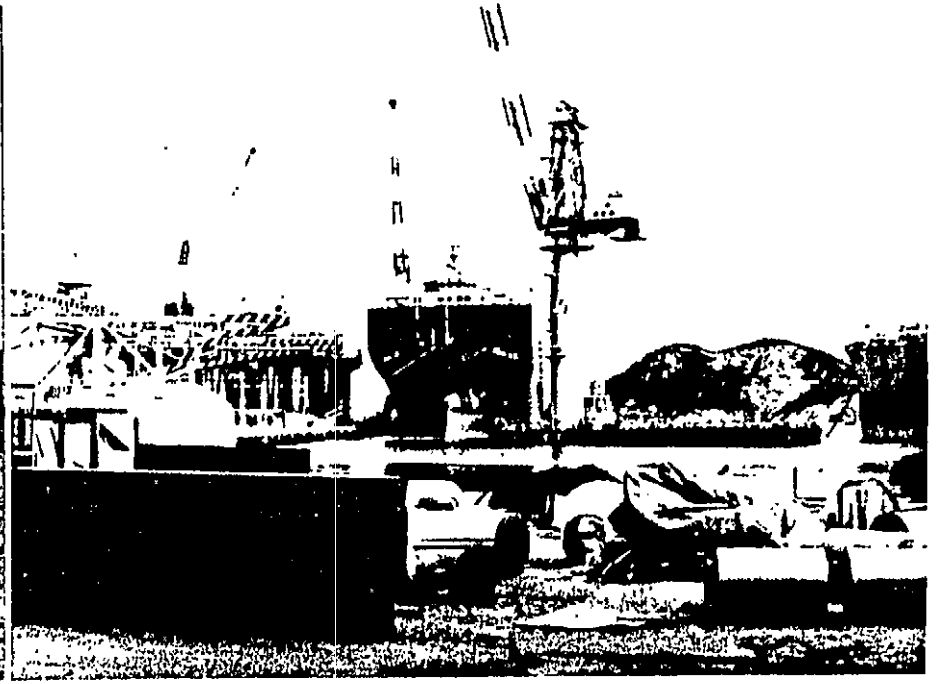
Pusa

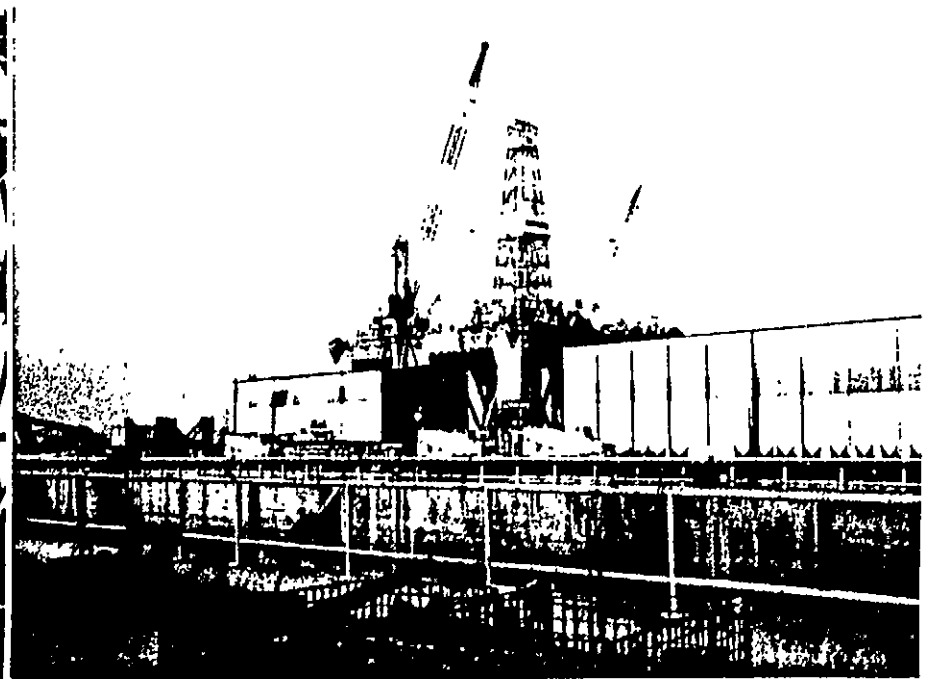
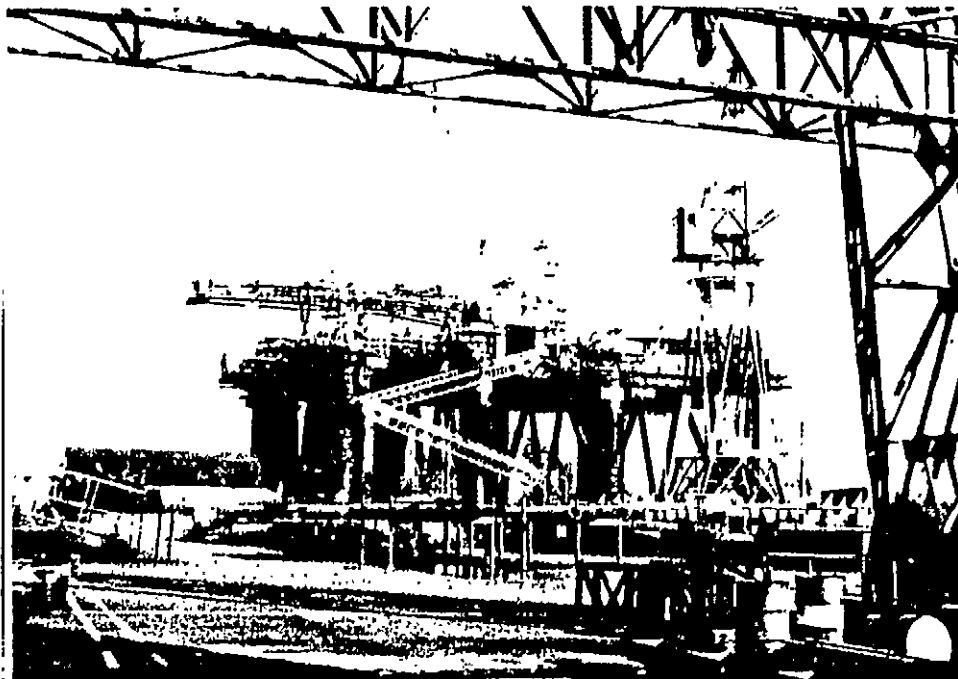
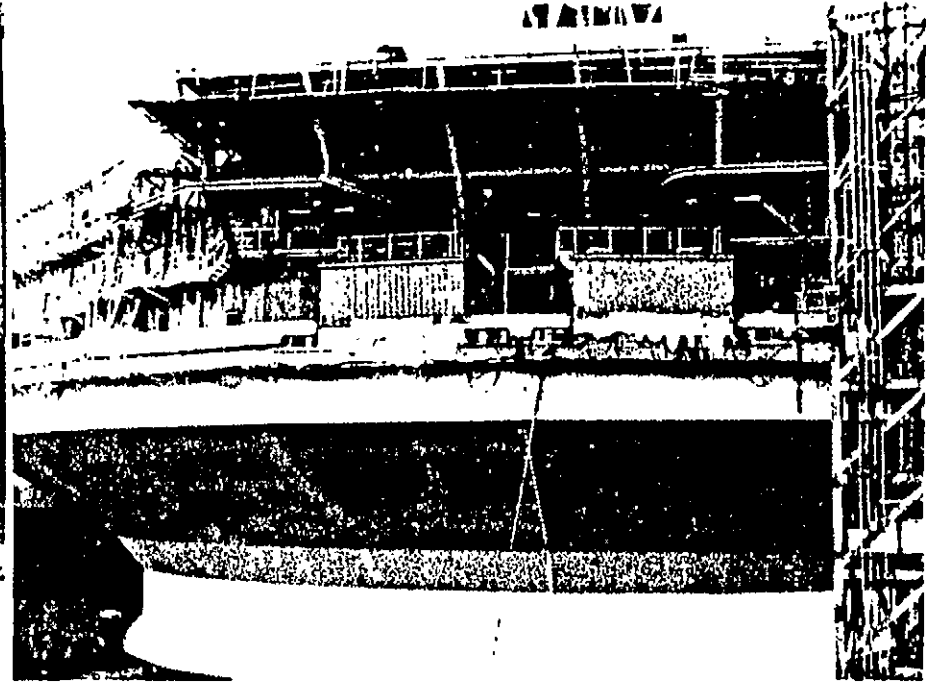




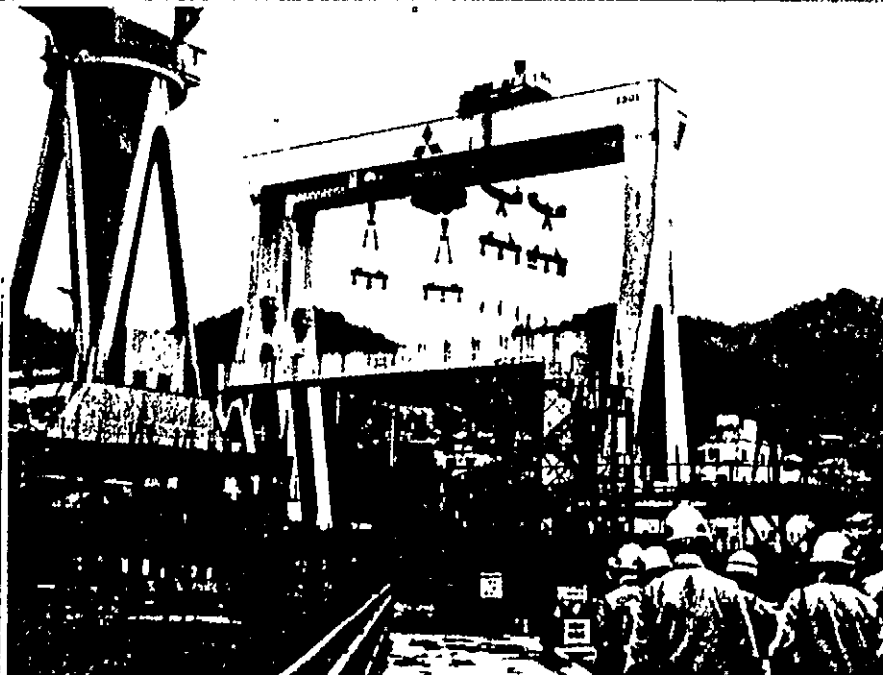
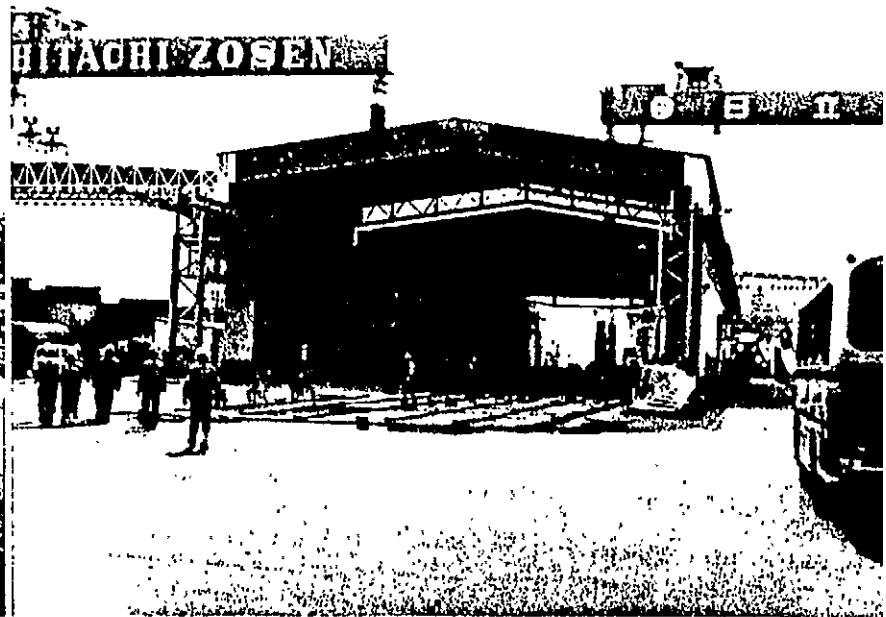
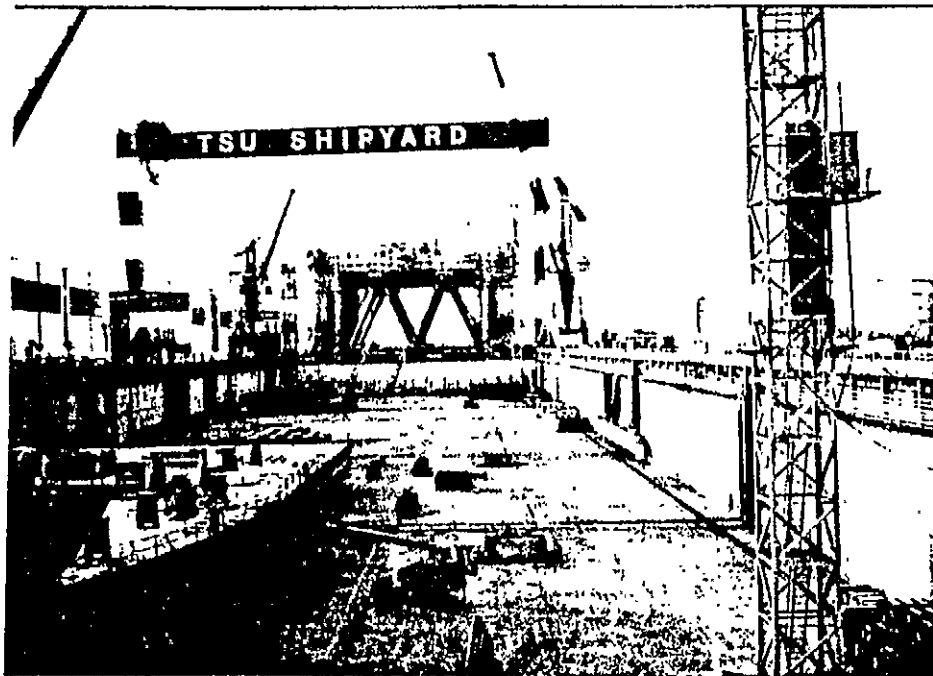
JAPANESE SHIPBUILDING BOOM

1972 - 1981

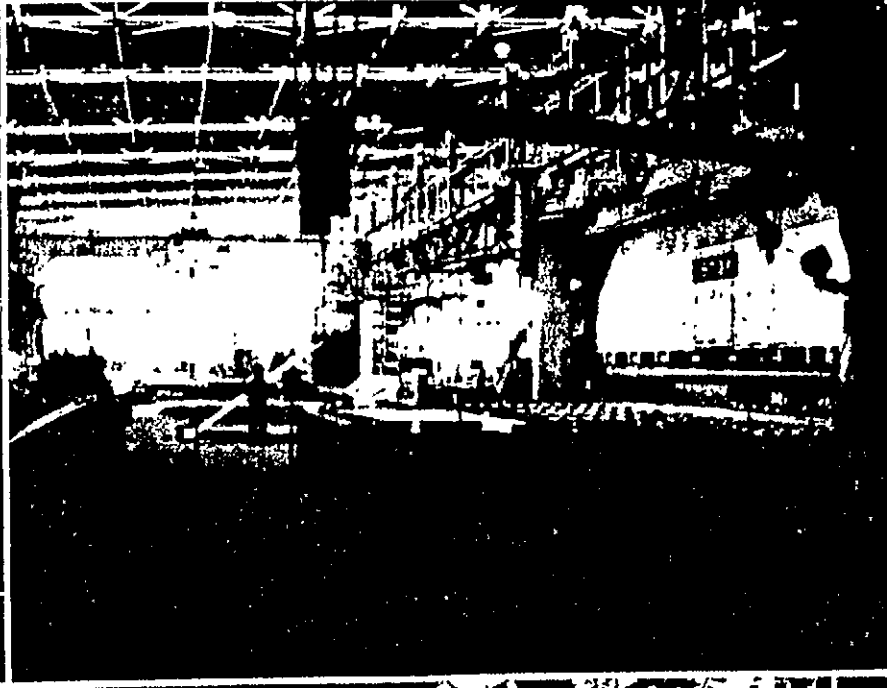




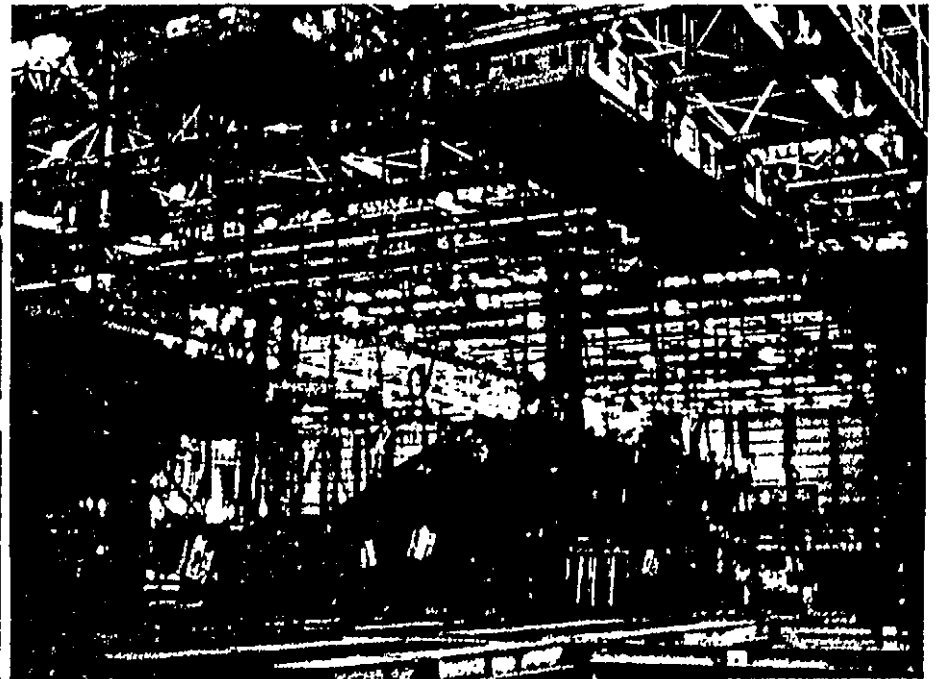
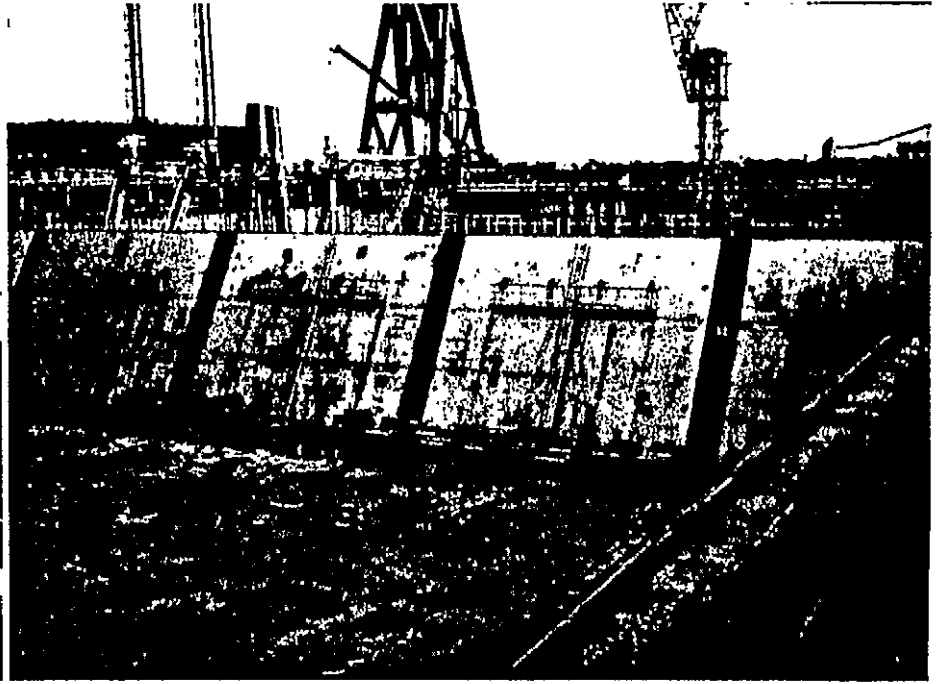
Typical Types of Vessels Under Construction



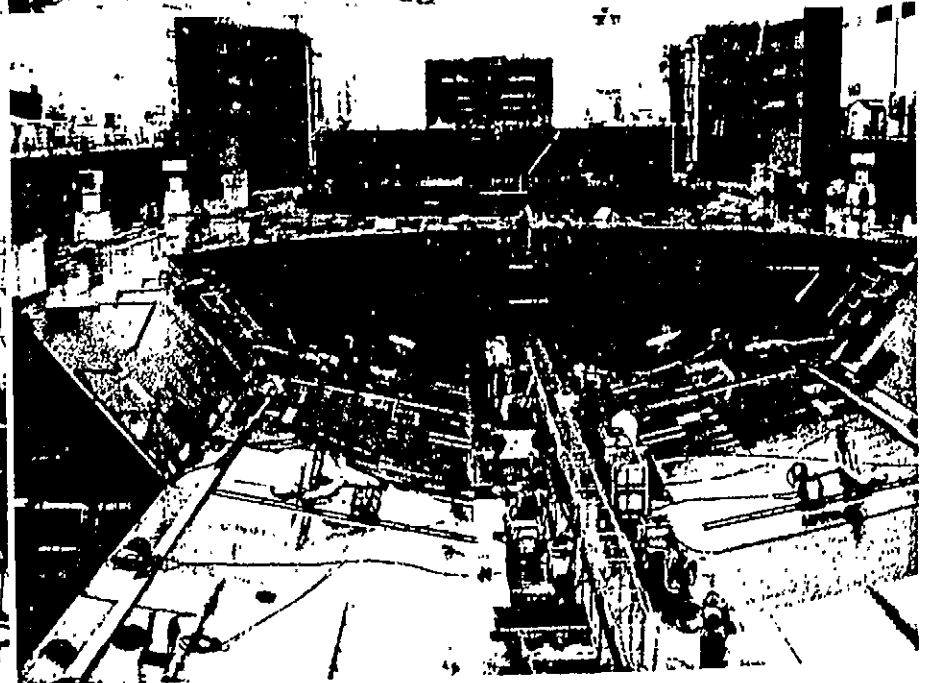
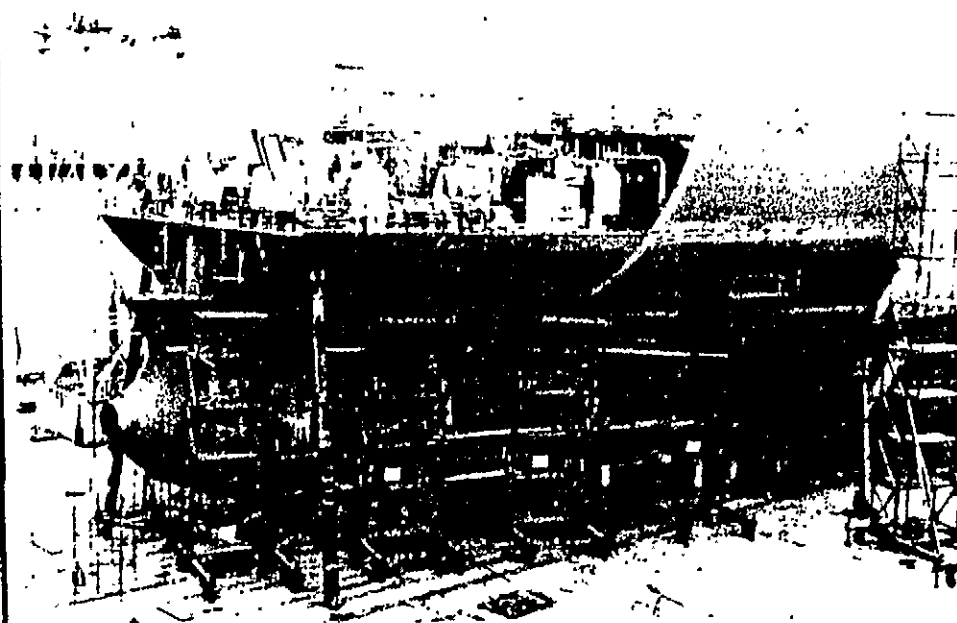
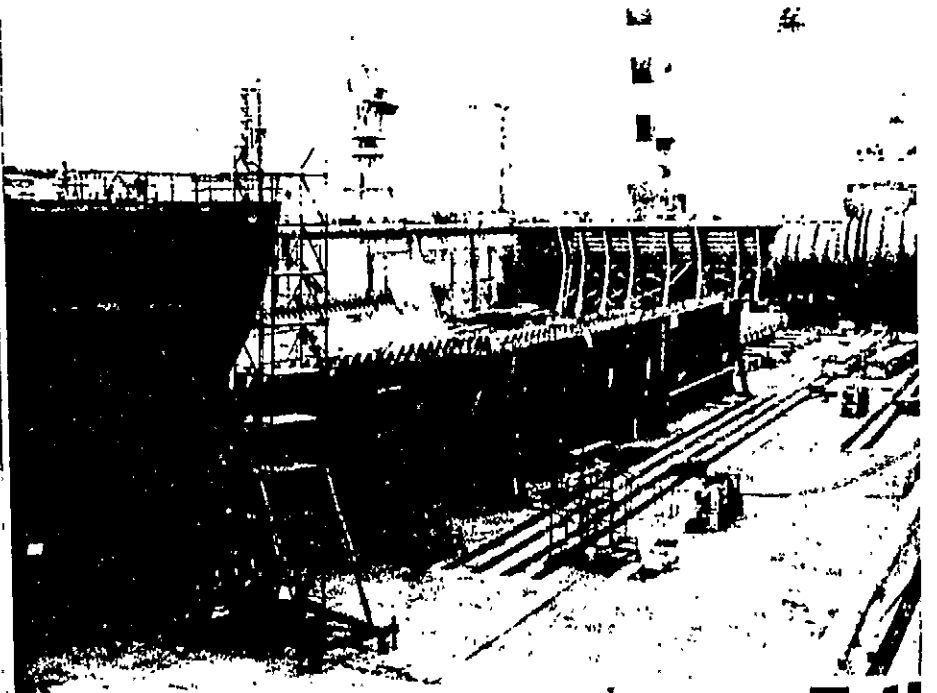
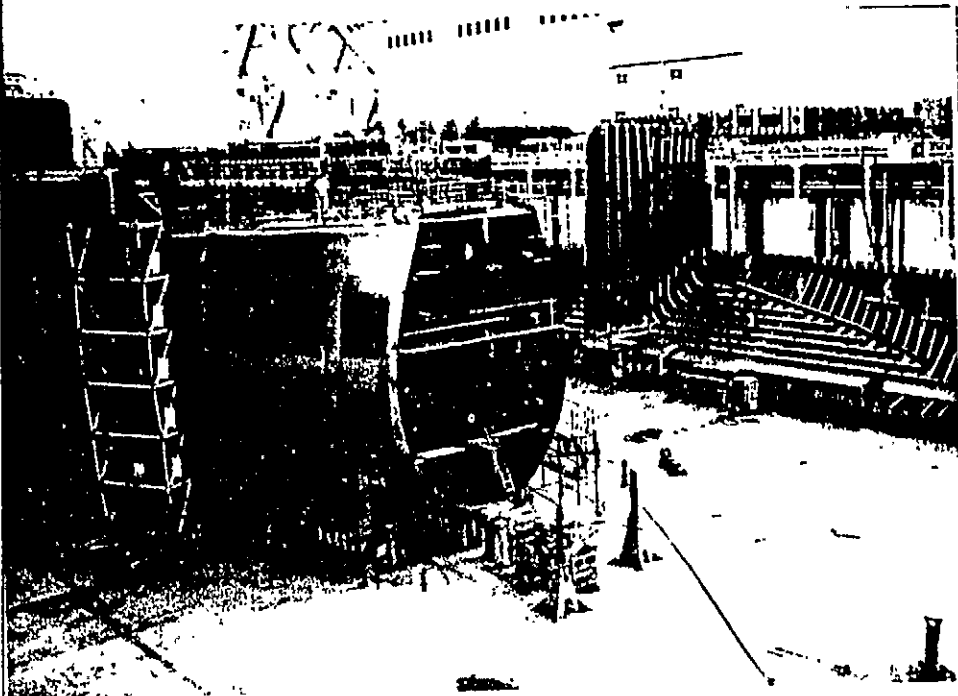
Shipbuilding Facilities



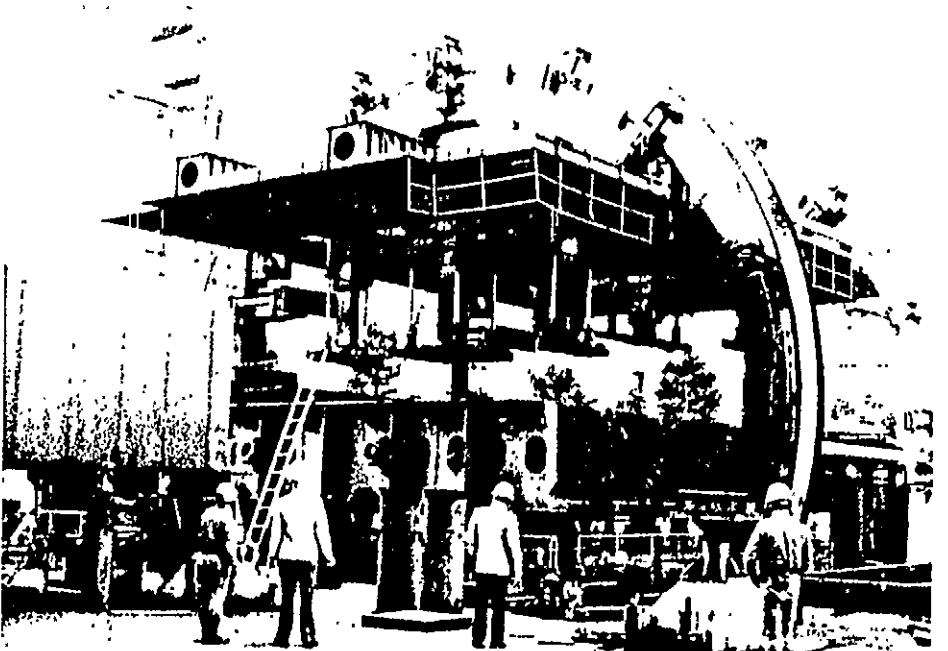
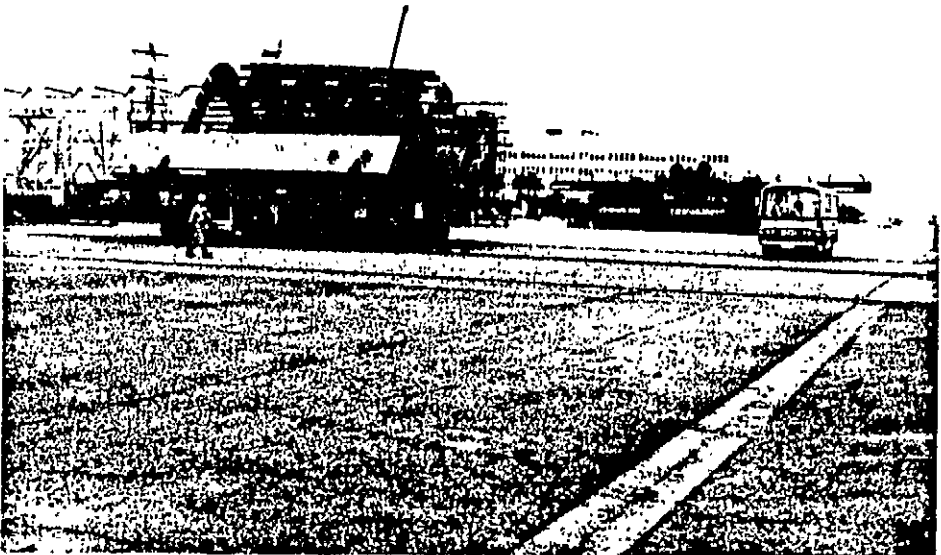
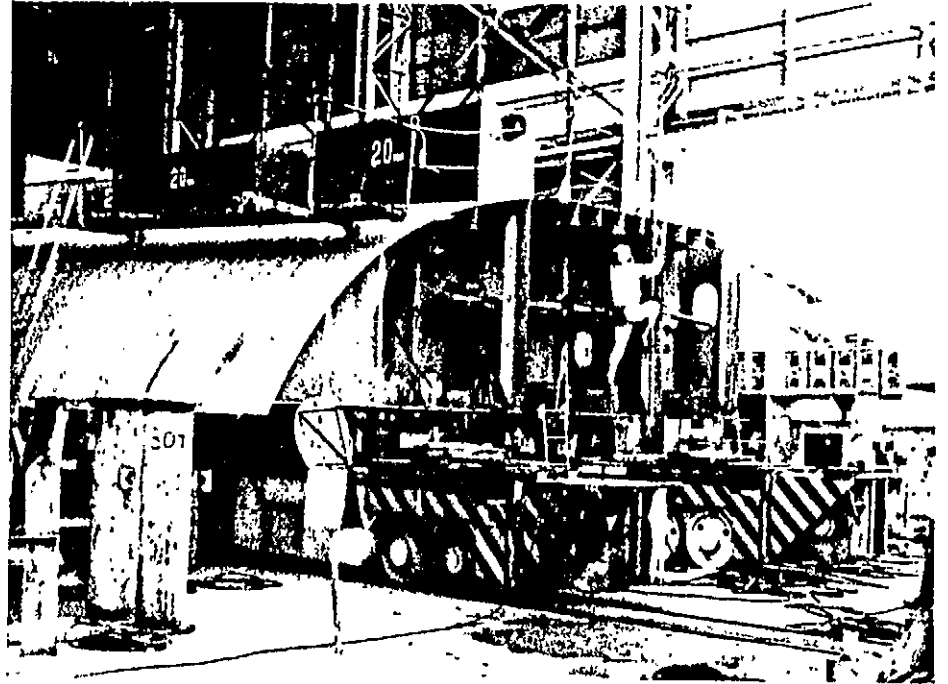
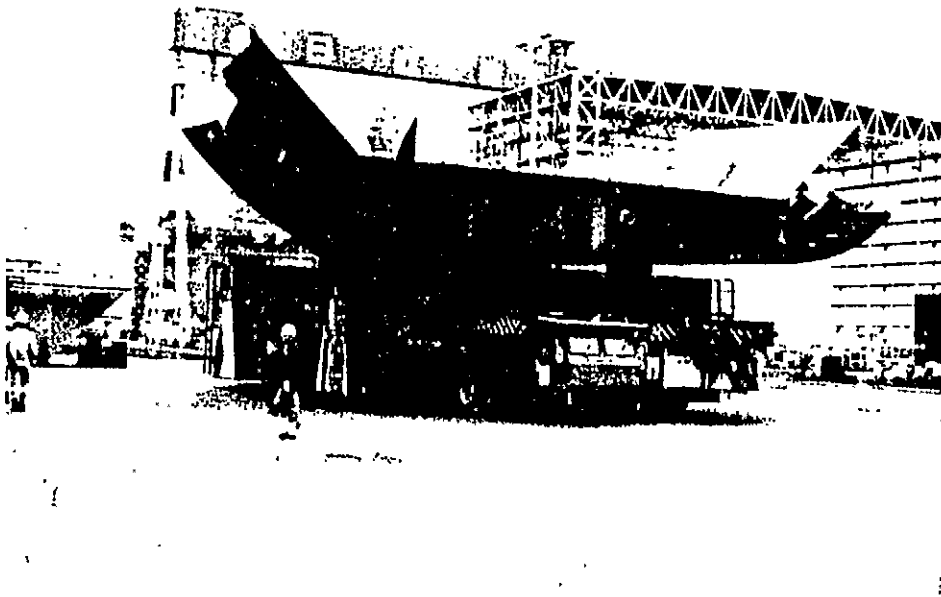
Shipbuilding Facilities



Shipbuilding Facilities



Dry Dock Construction



Sub Assembly Transporters

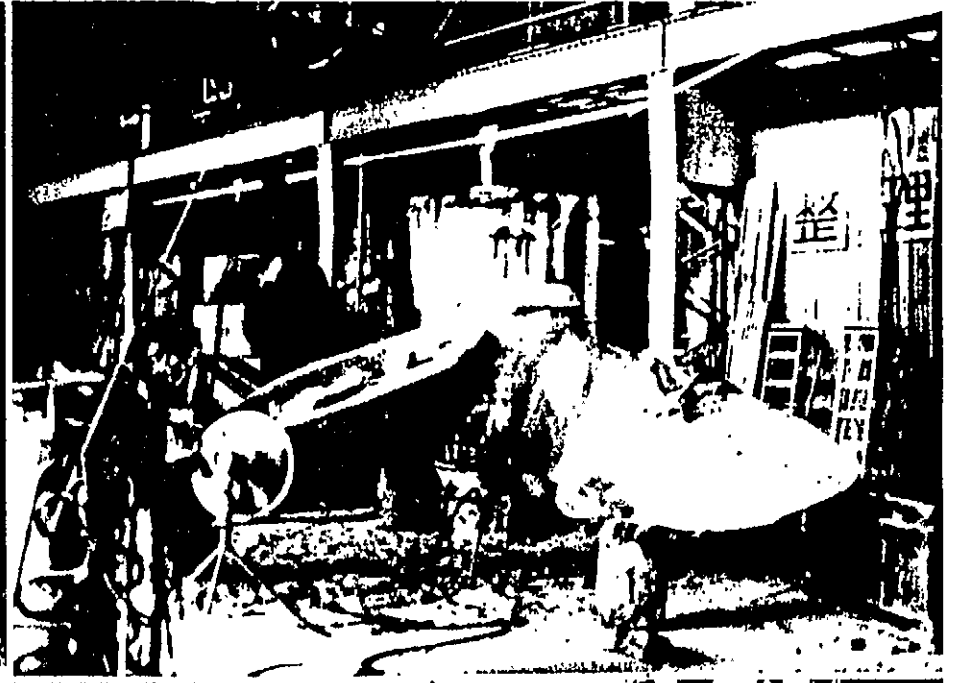
Note support stanchions still attached during movement

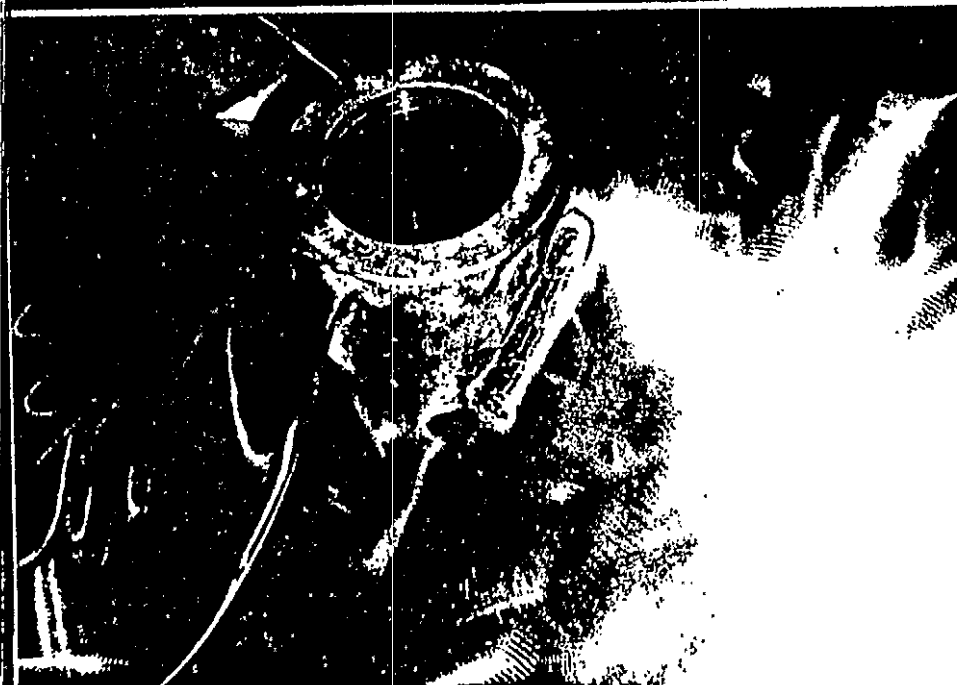
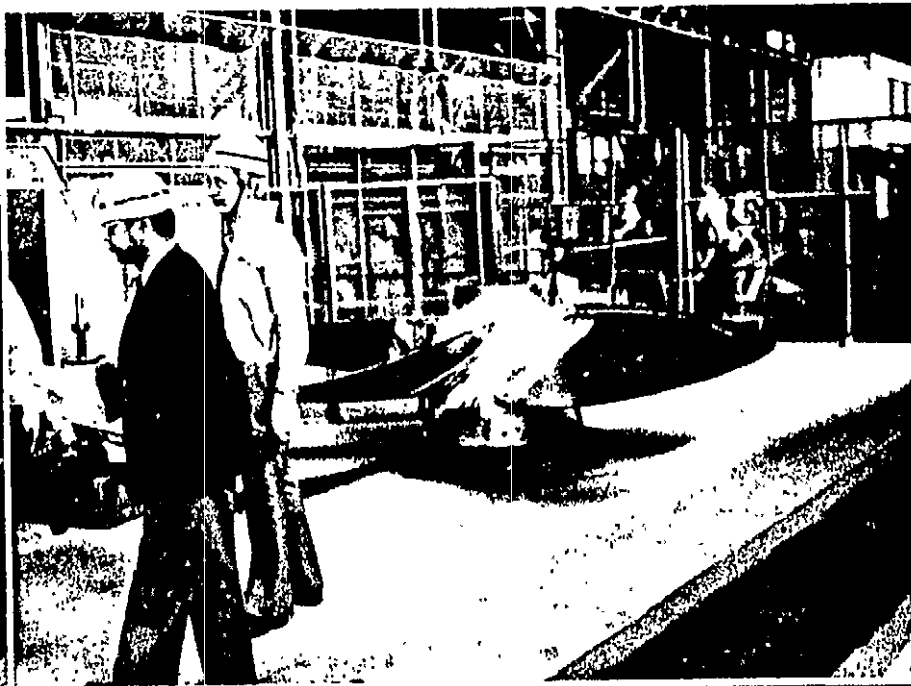
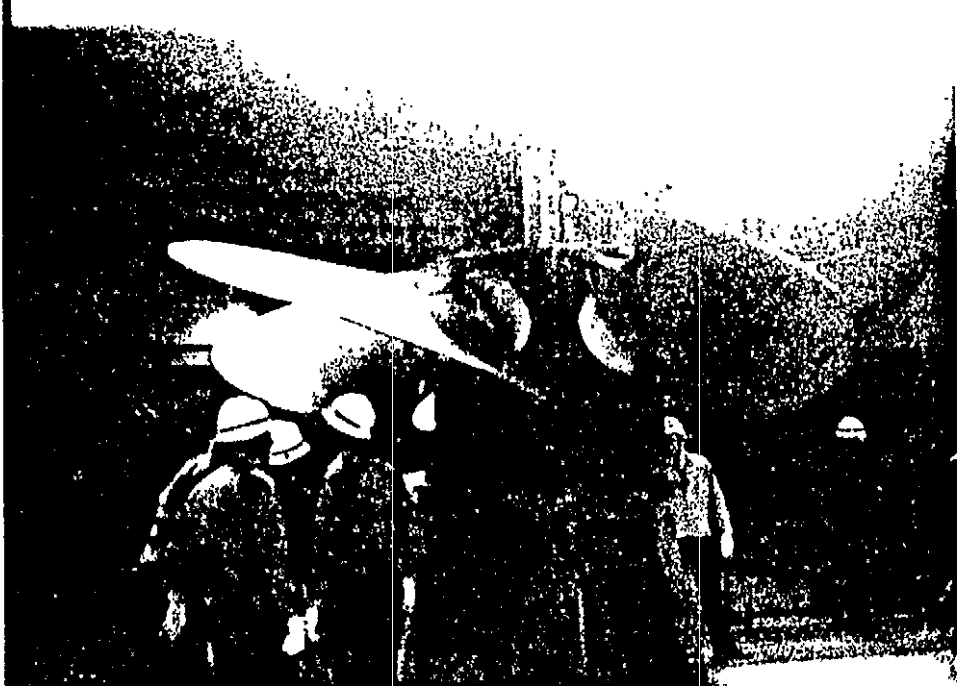
26 and 27

Sub Assembly Built in Shop

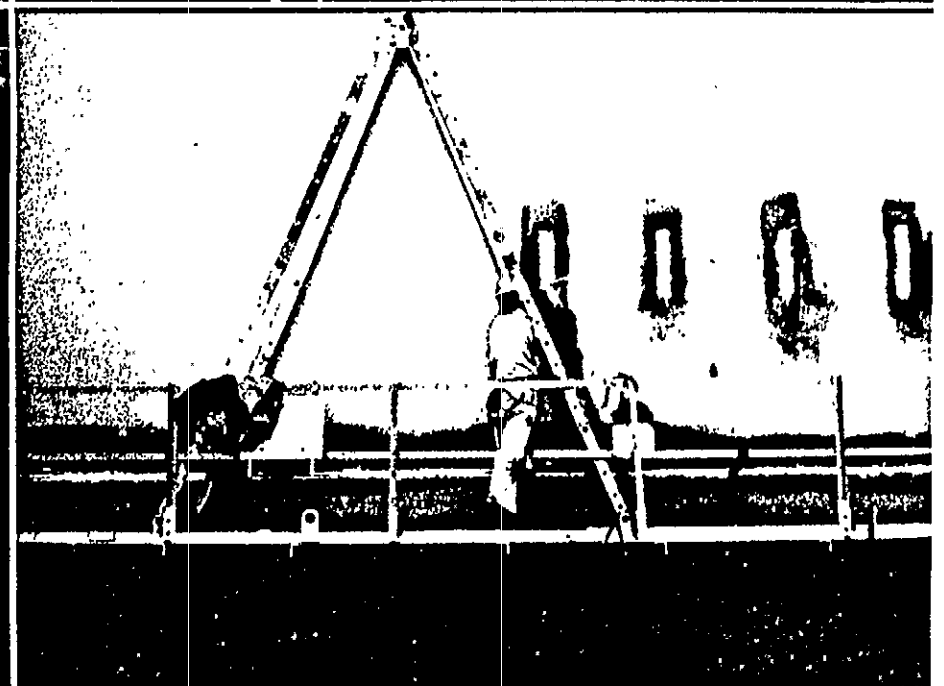
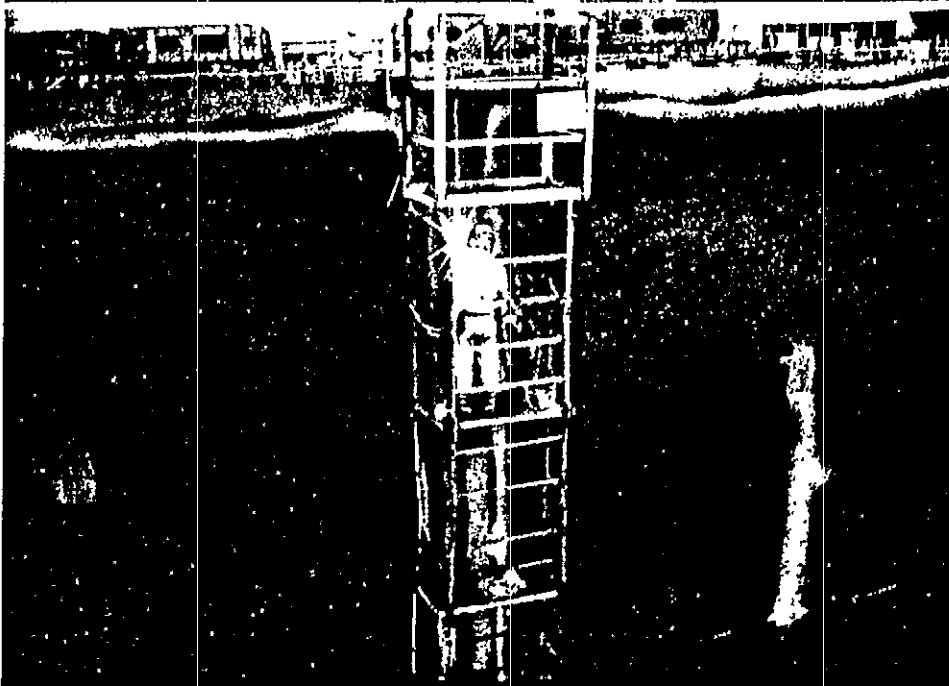
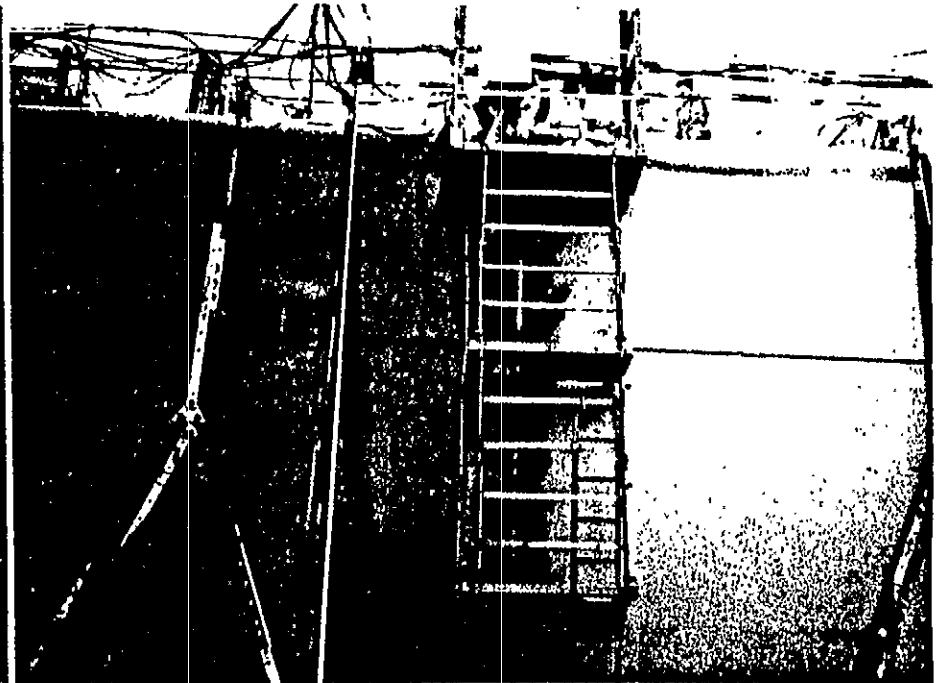
Sub assembly turning rig to allow all downward welding

28 and 29





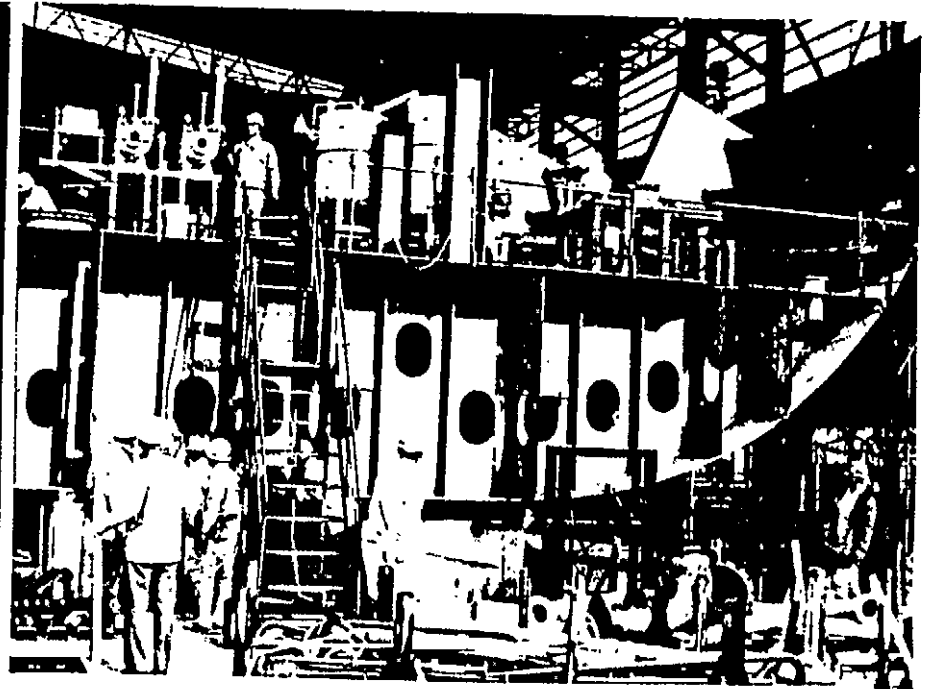
Propeller Manufacture and Repair



Personnel Staging

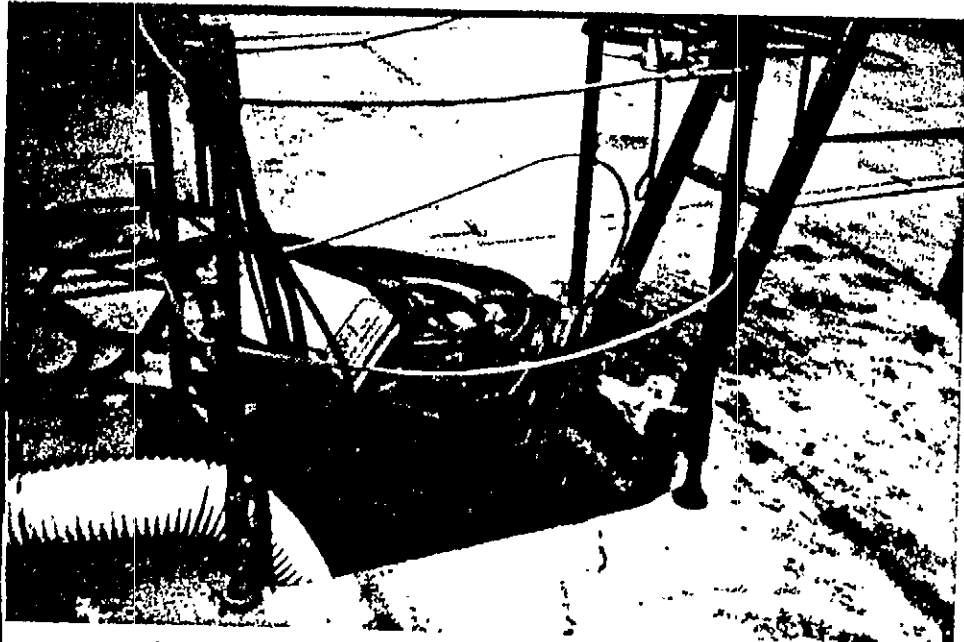


Note protection of equipment against construction damage.



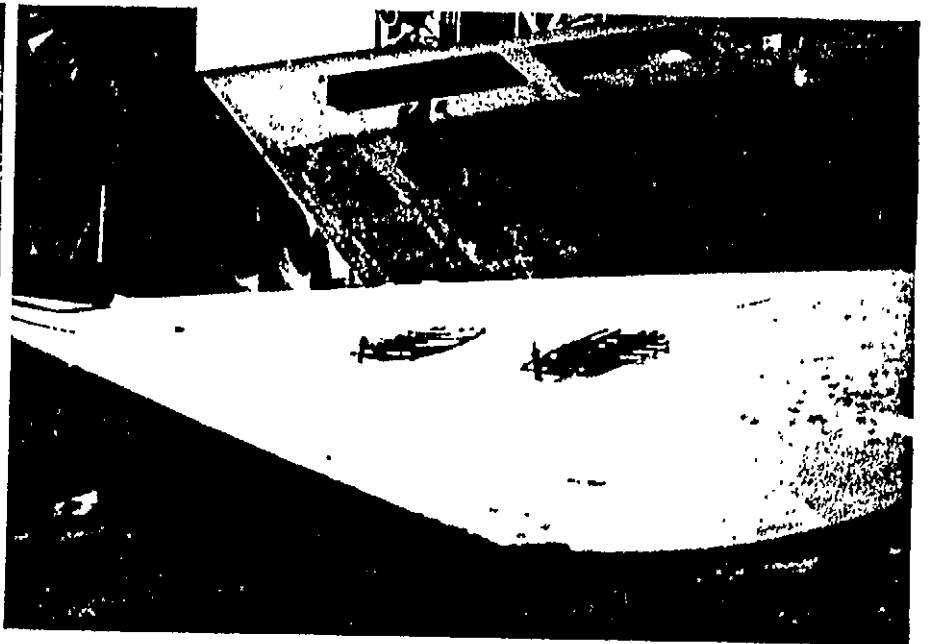
On Block Pre-Outfitting

42 and 43



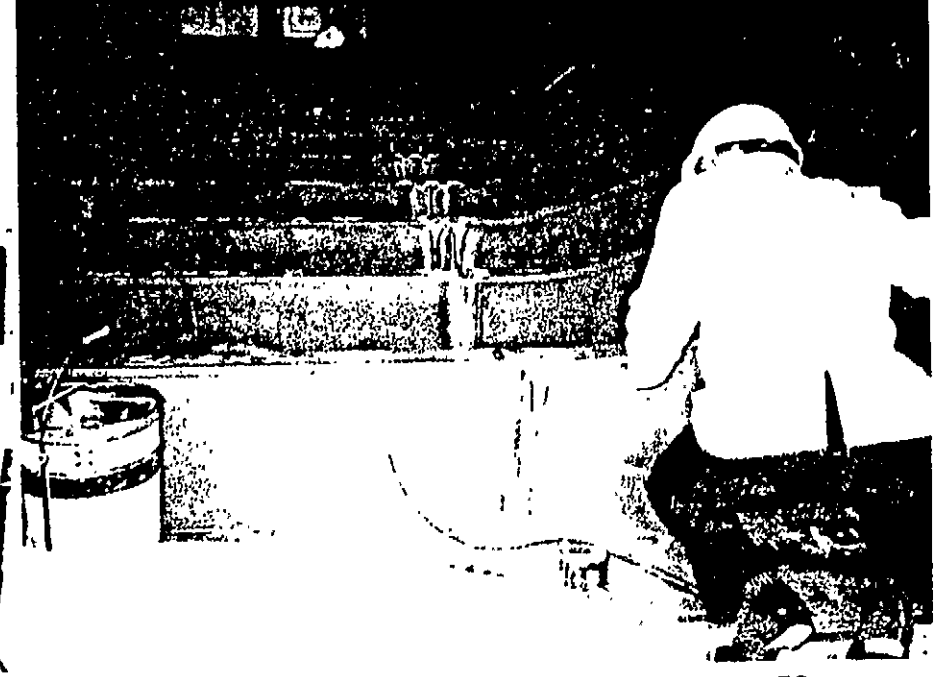
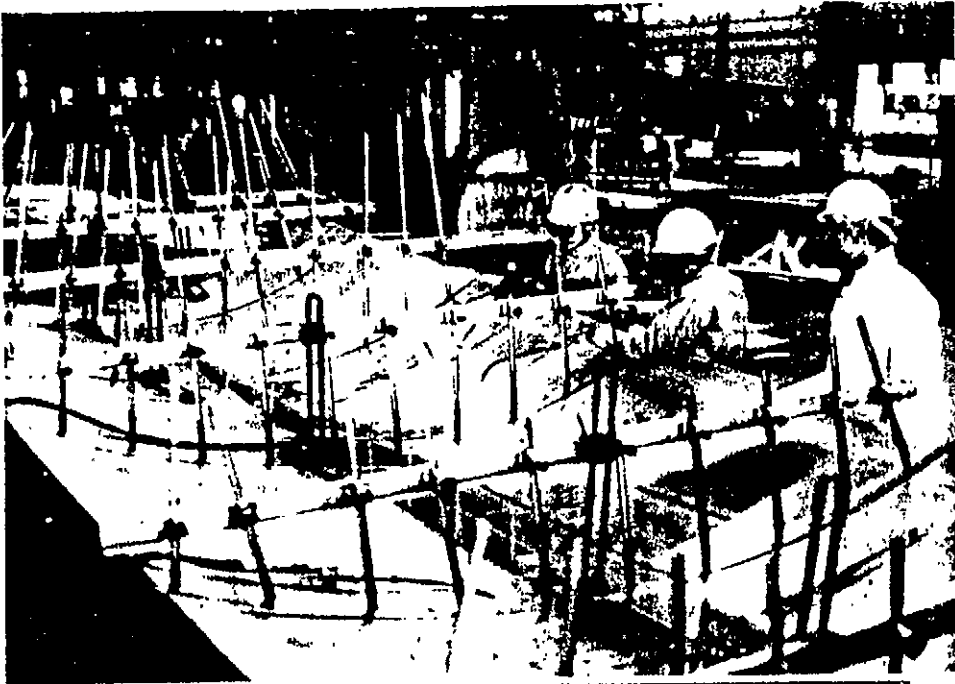
Access Opening Protected by Non-Welded Structure

44

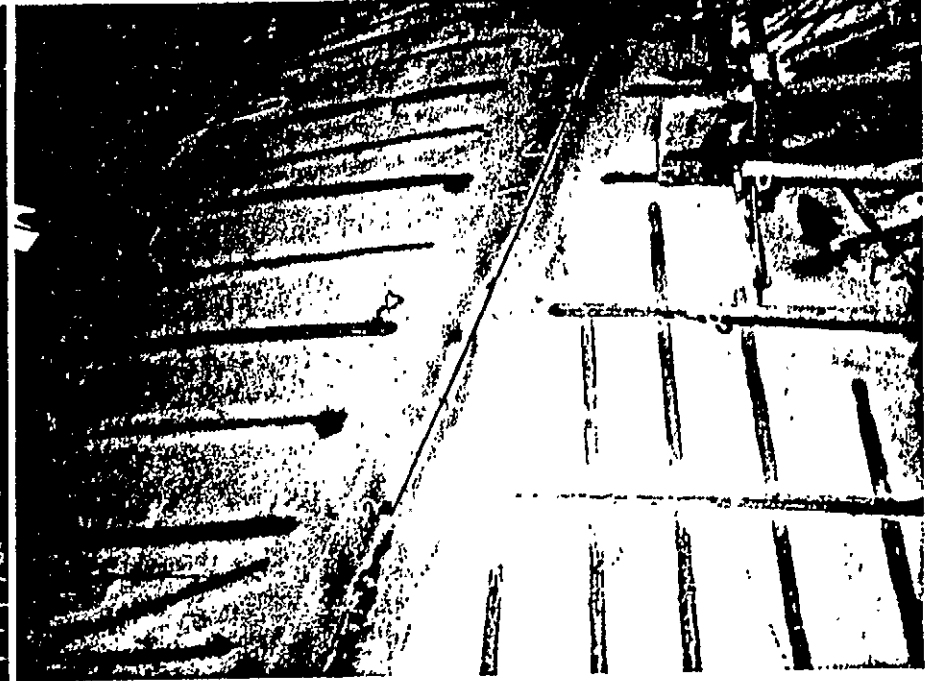
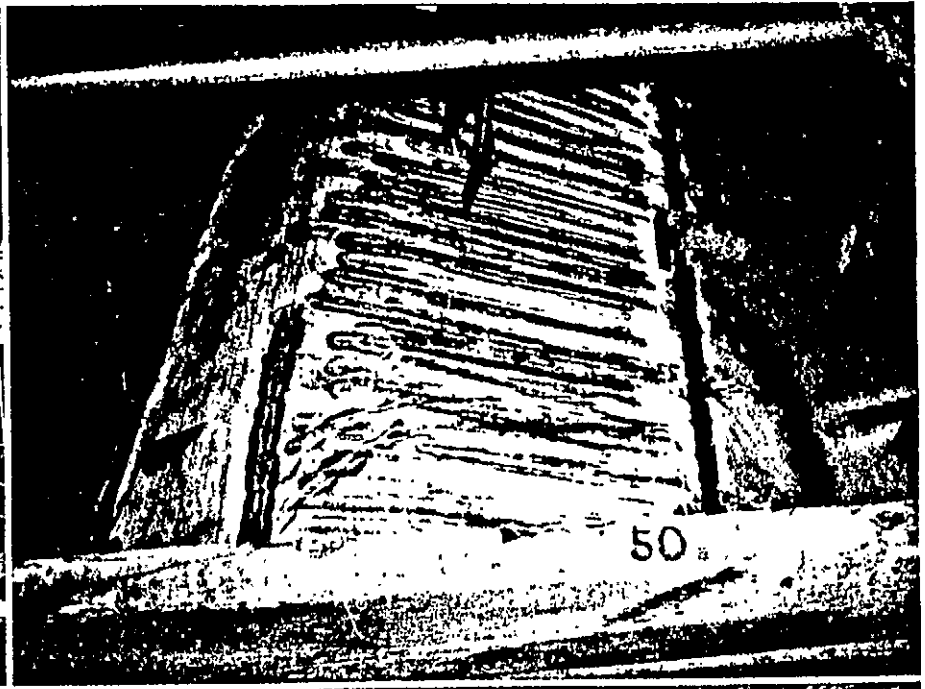


45

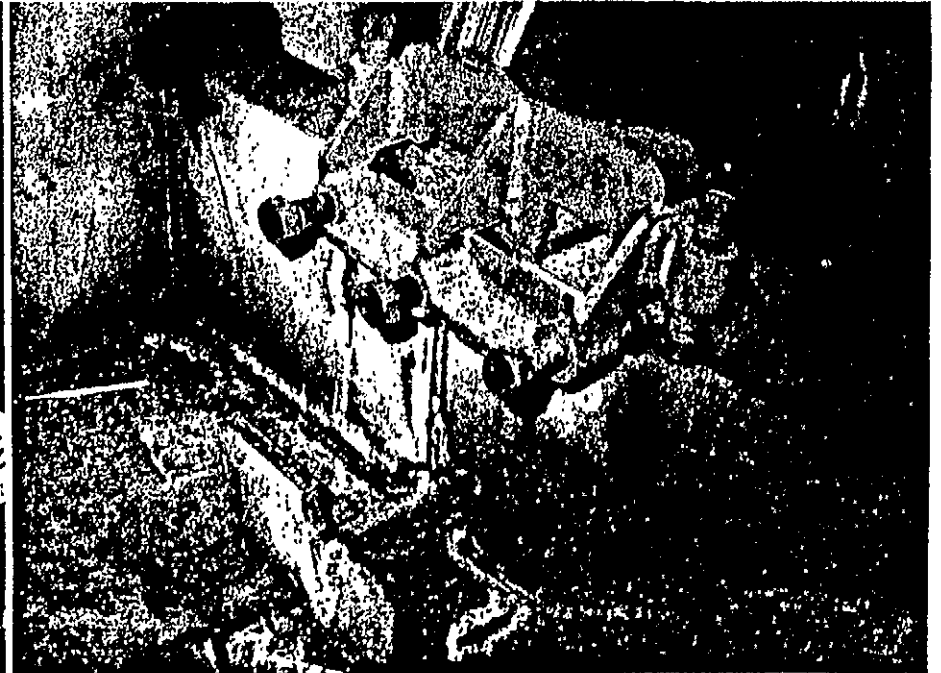
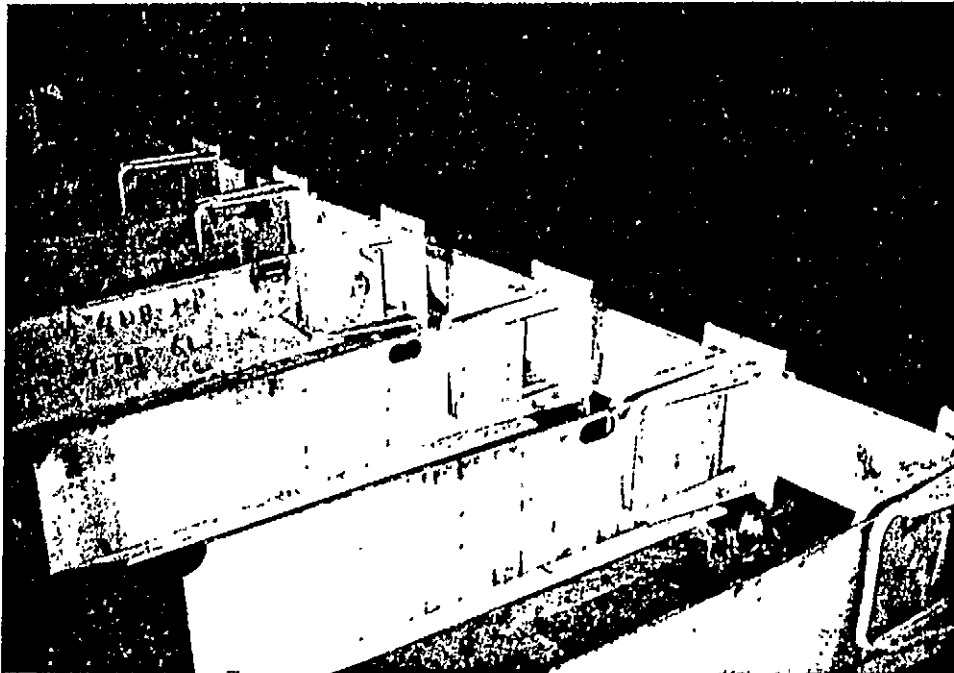
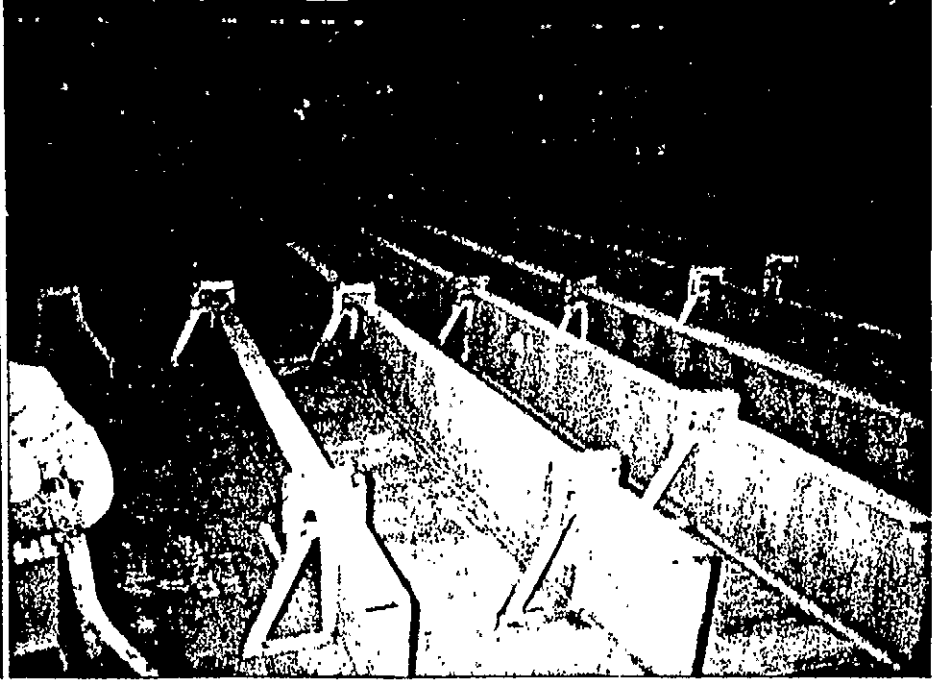
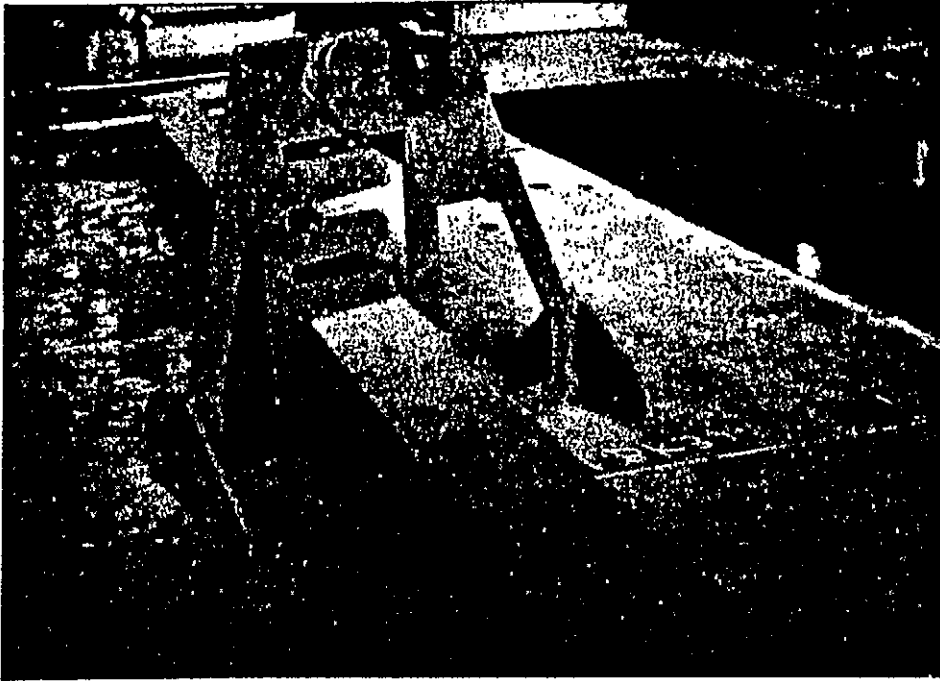
46



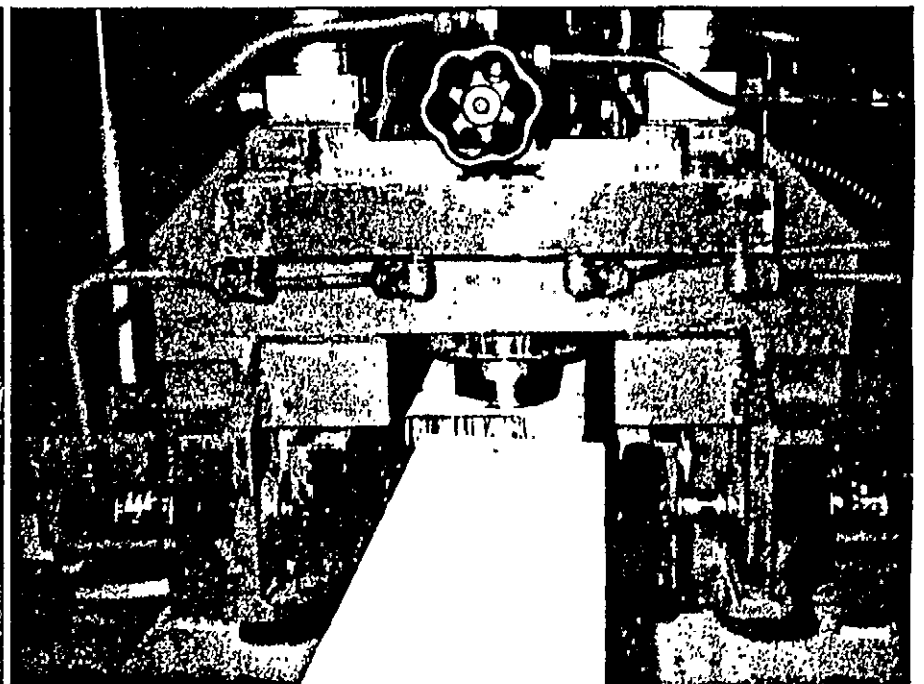
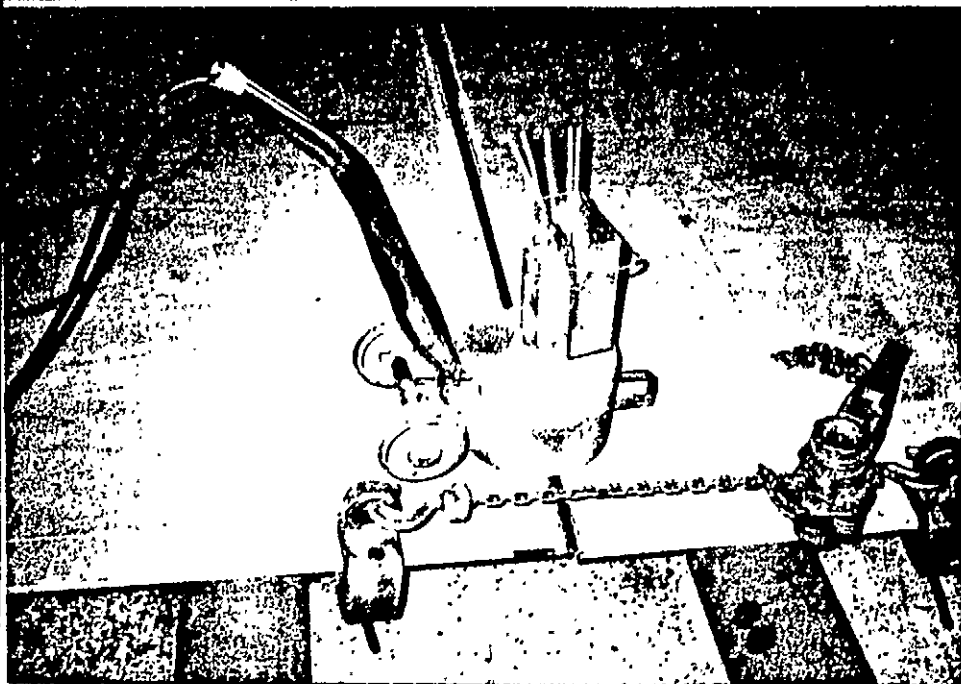
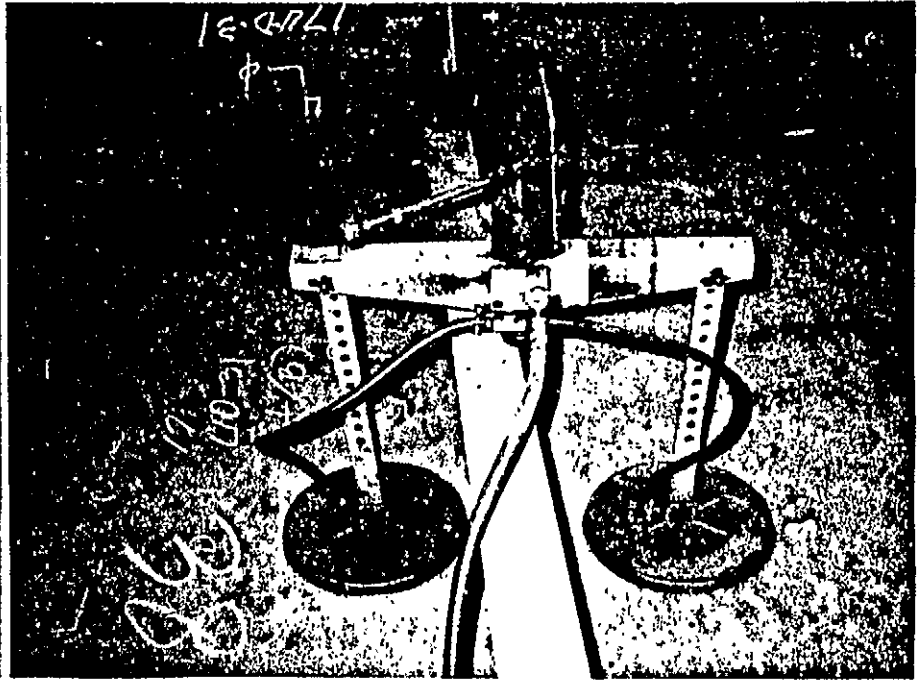
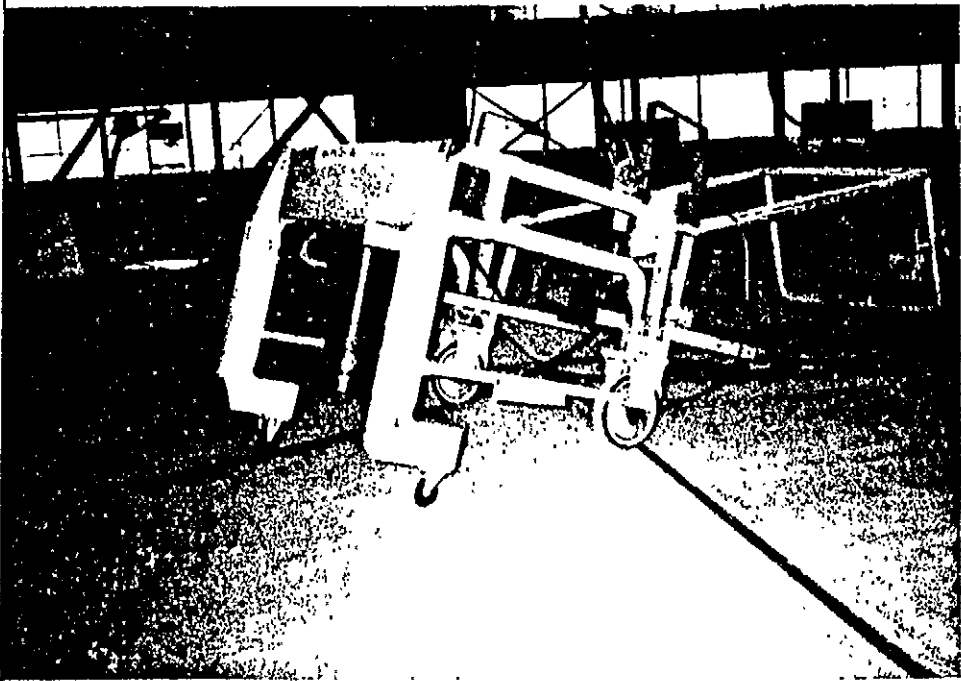
Line Heating and Accuracy Control



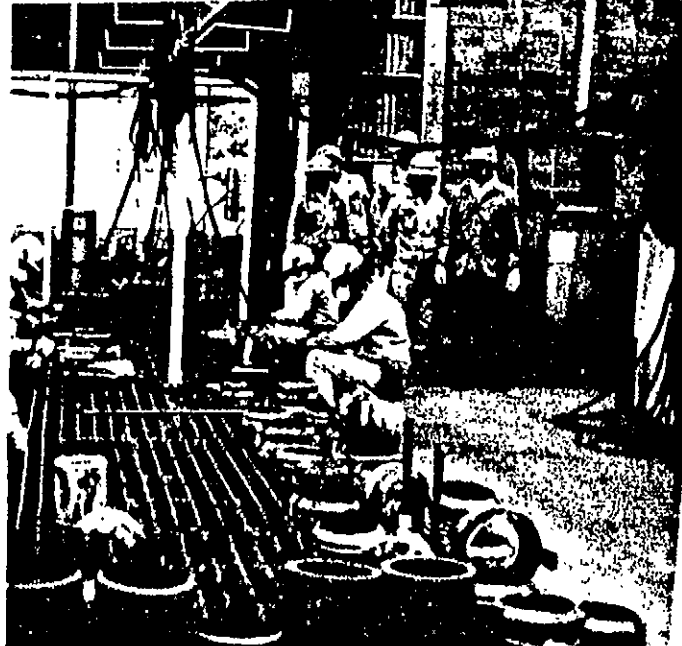
Line Heating and Accuracy Control



Fitting and Fairing Devices

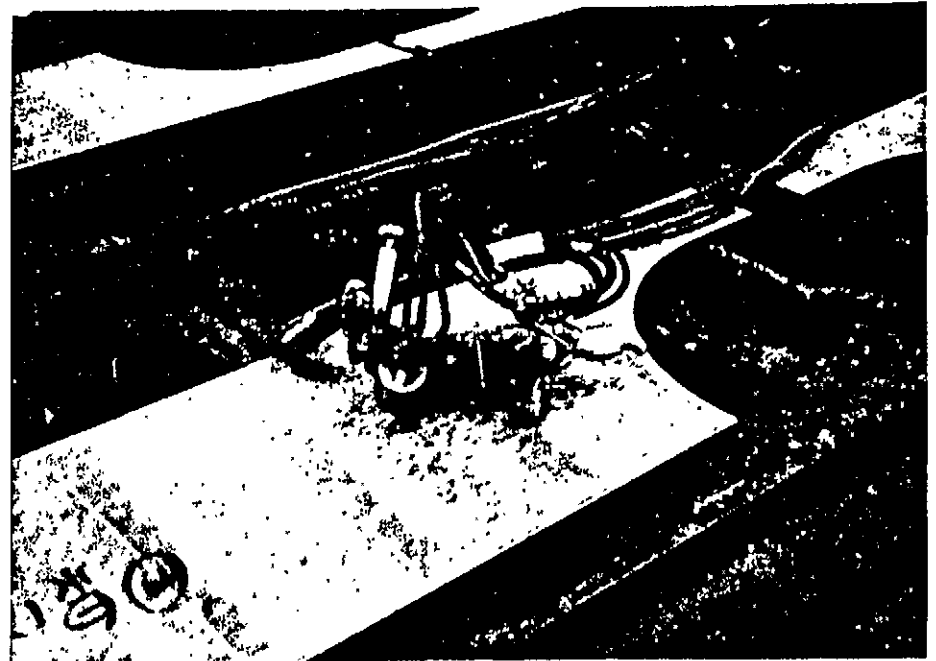


Fitting and Fixing Devices



Training Burners

62



Burning Machine

63



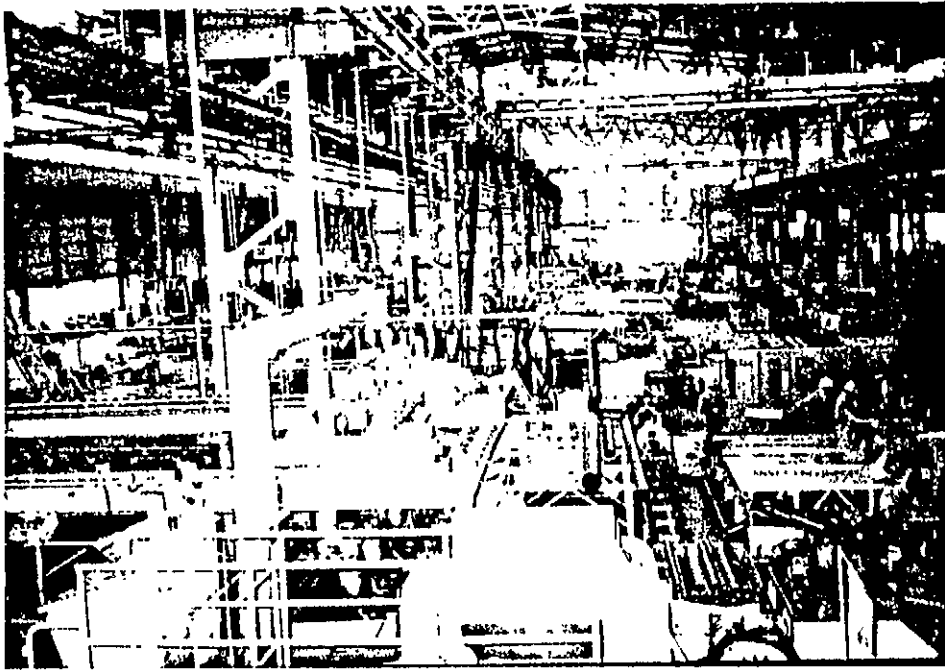
Burning Template

64



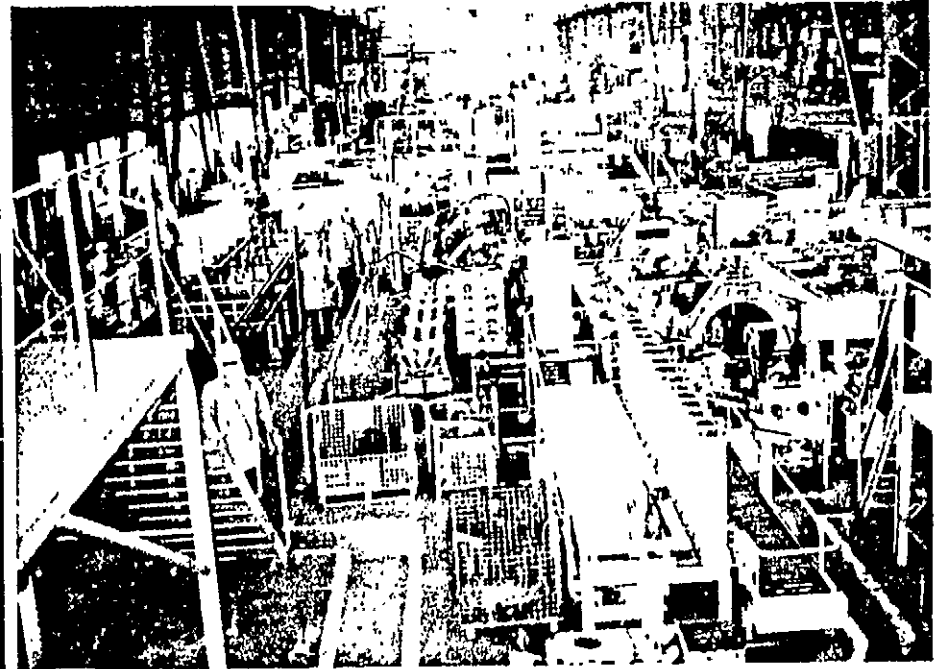
Training Welders

65



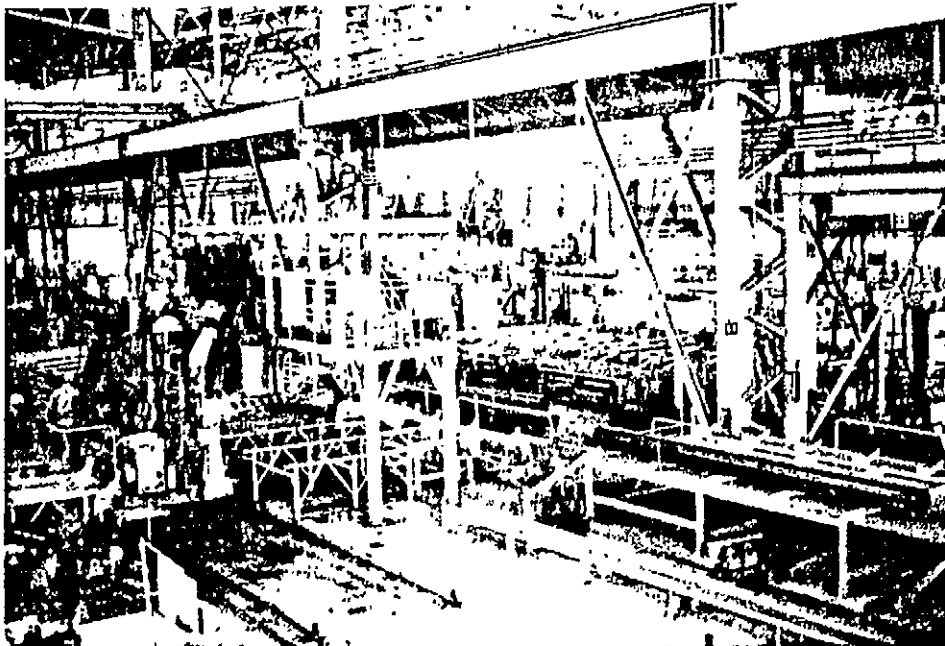
Automated Pipe Shop

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Automated Pipe Shop

67



Automated Pipe Shop

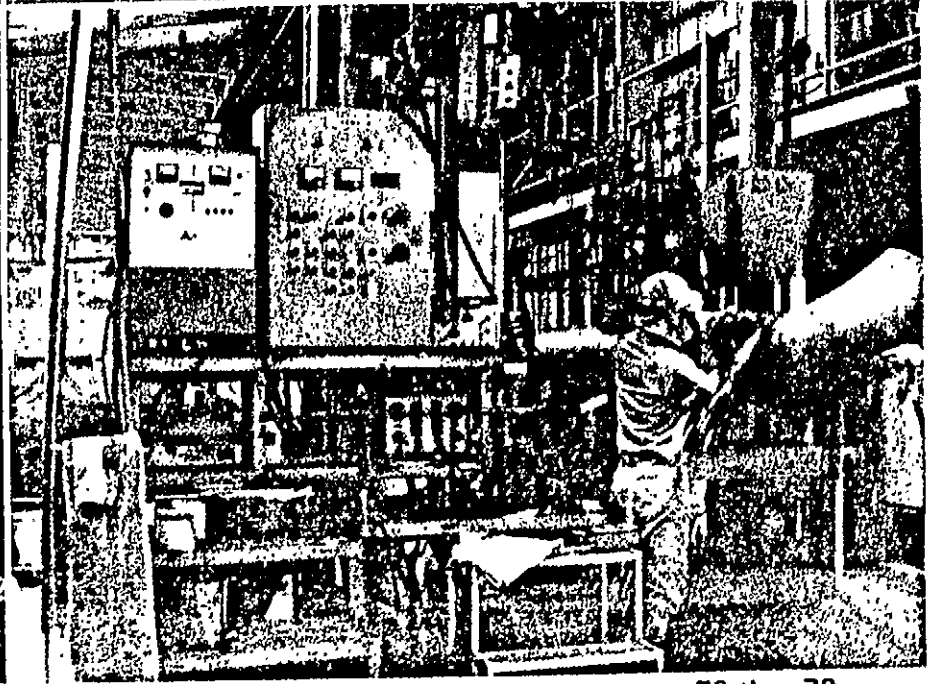
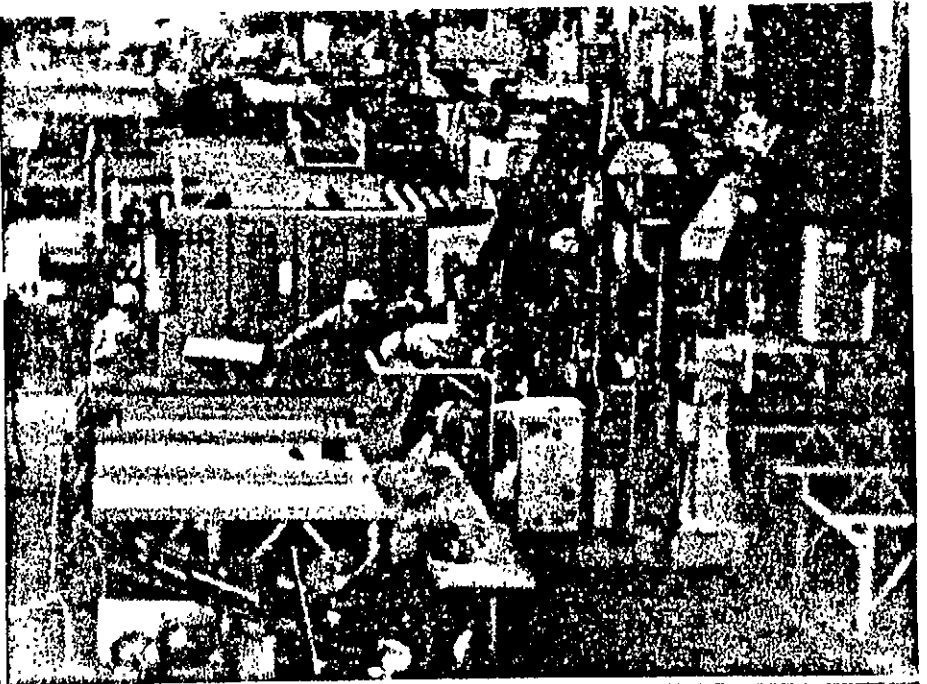
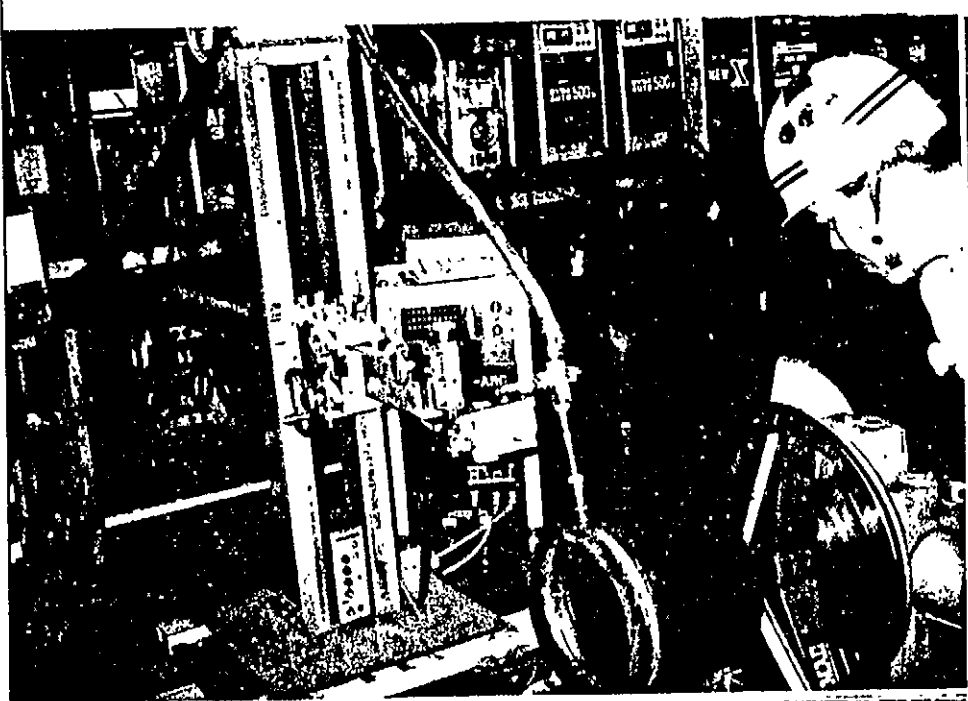
68



Automatic Pipe Welding

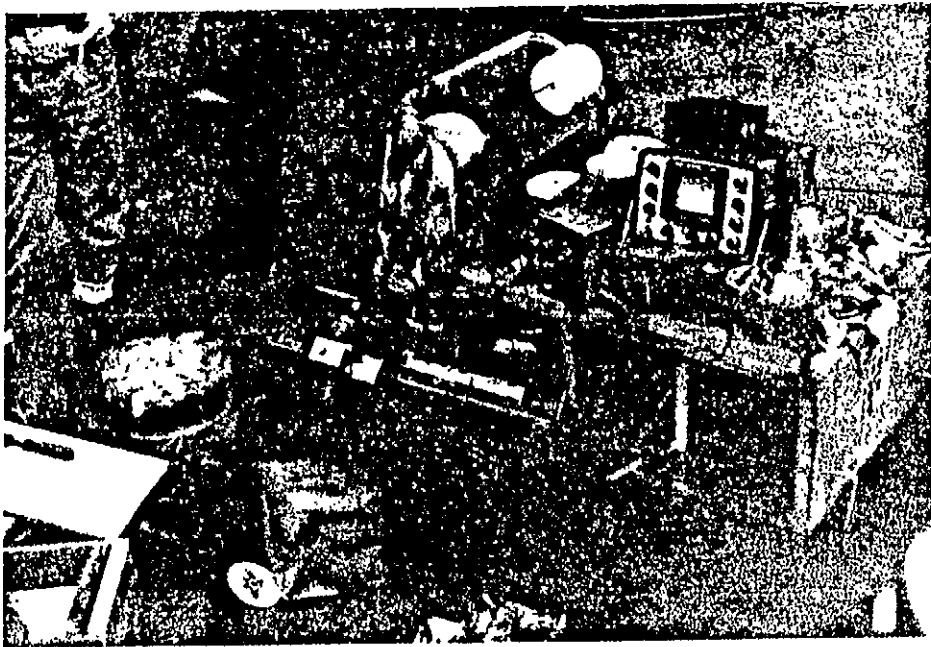
Note safety and health equipment
room by operator.

69



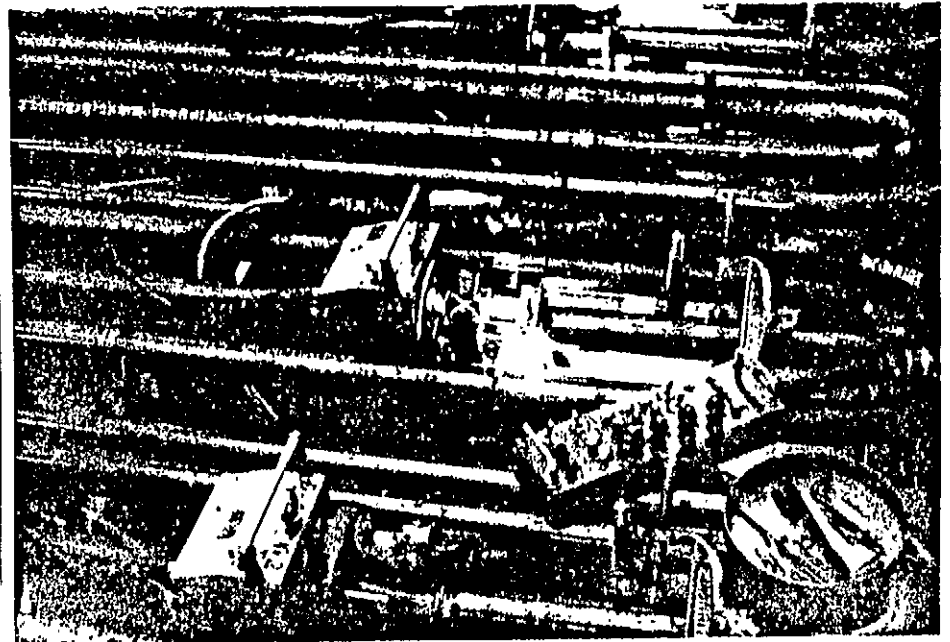
Note the safety and health equipment

Automatic Pipe Welding Stations



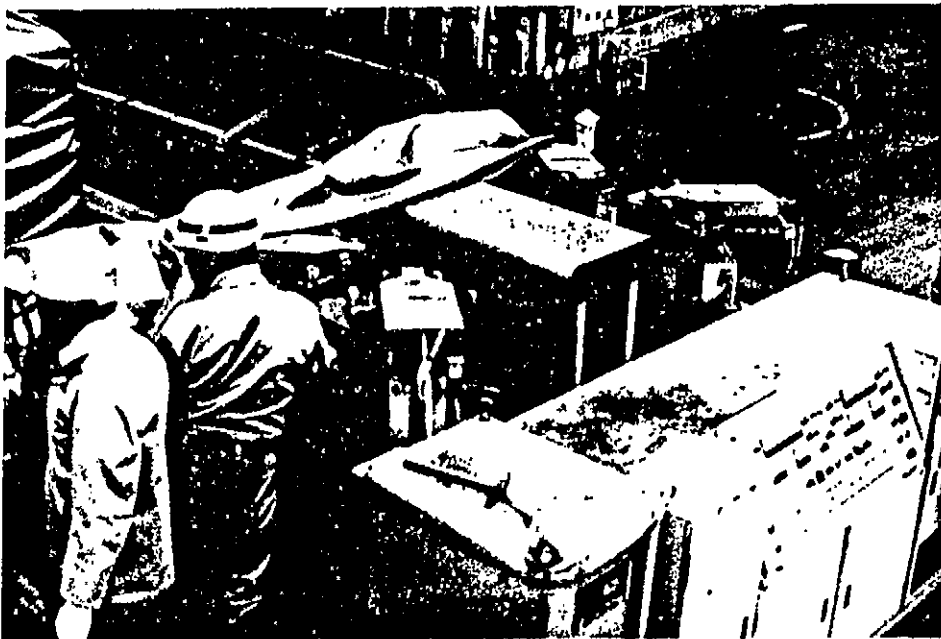
Automatic Ultrasonic Testing (UT)

74



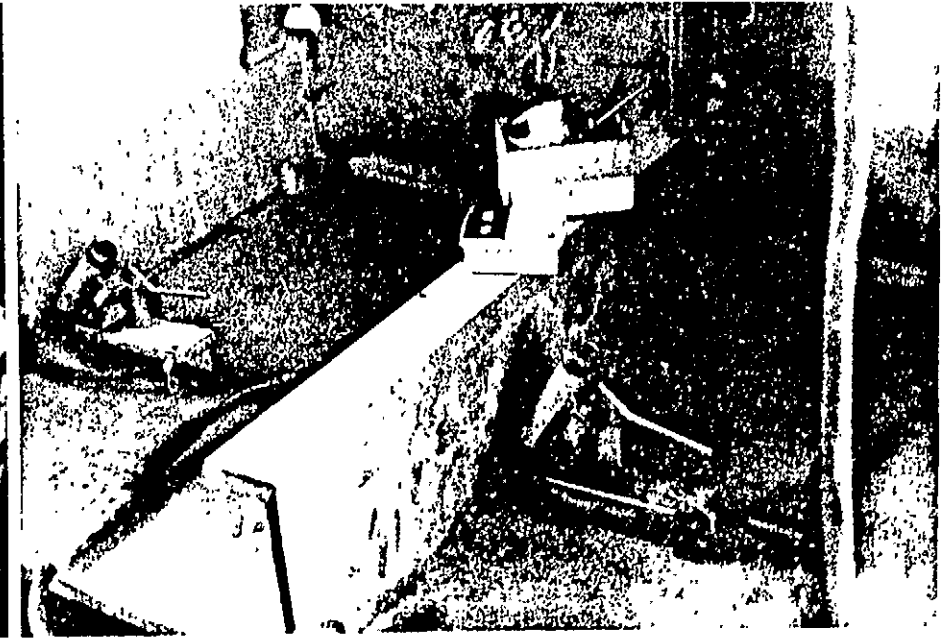
Orbital Pipe Welder

75



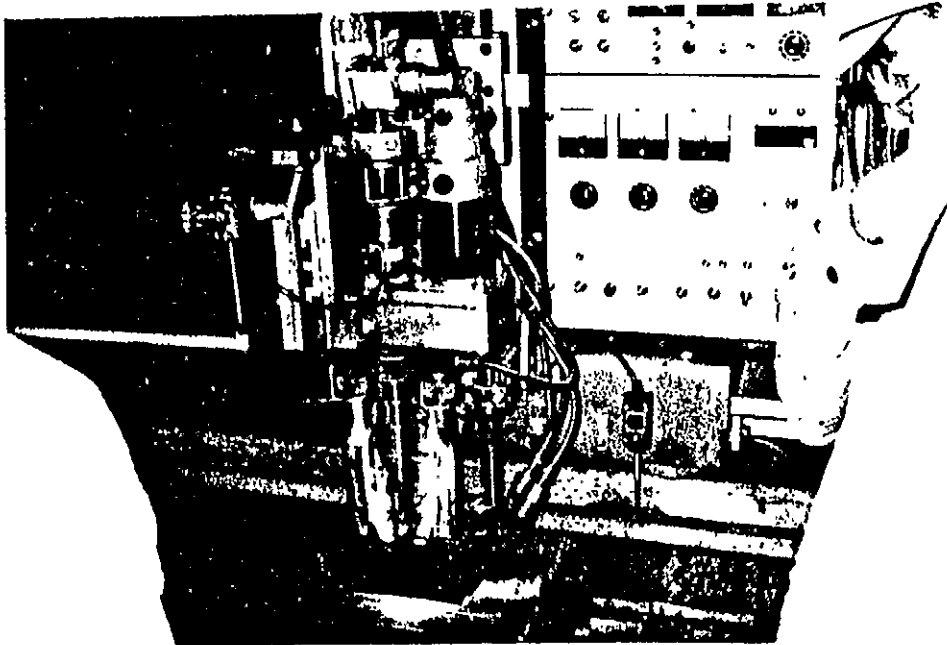
Egg Crate Welder

76

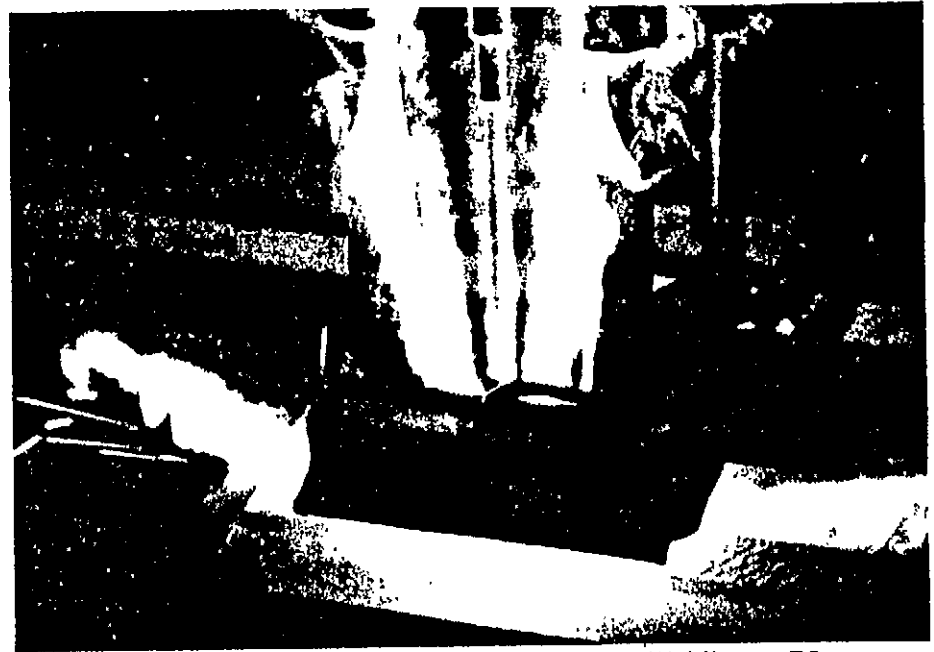


"Firecracker" Welding

77



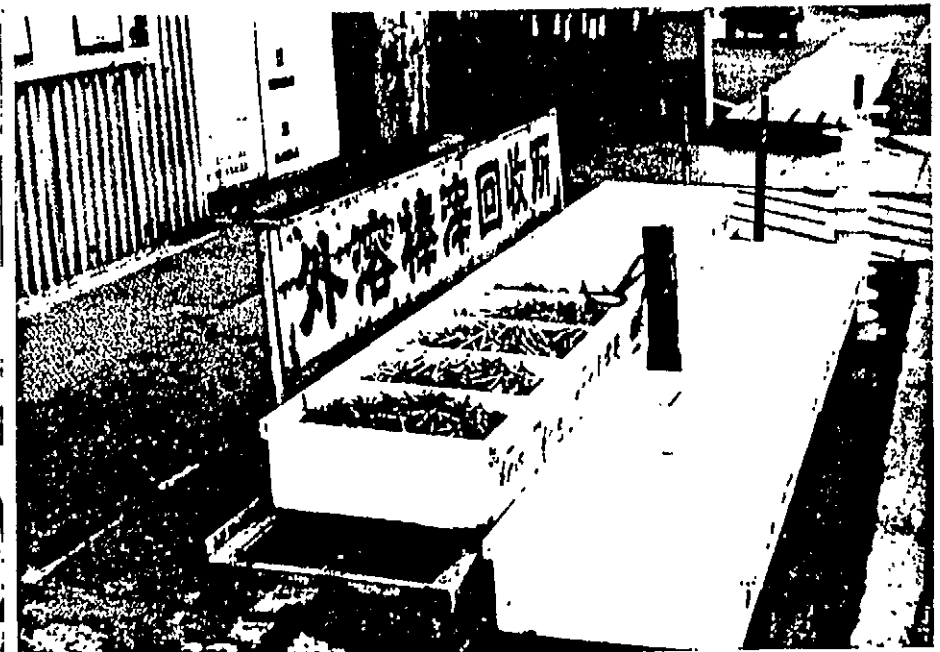
Eccentric Spinning Wire Method Narrow Gap Welding 78



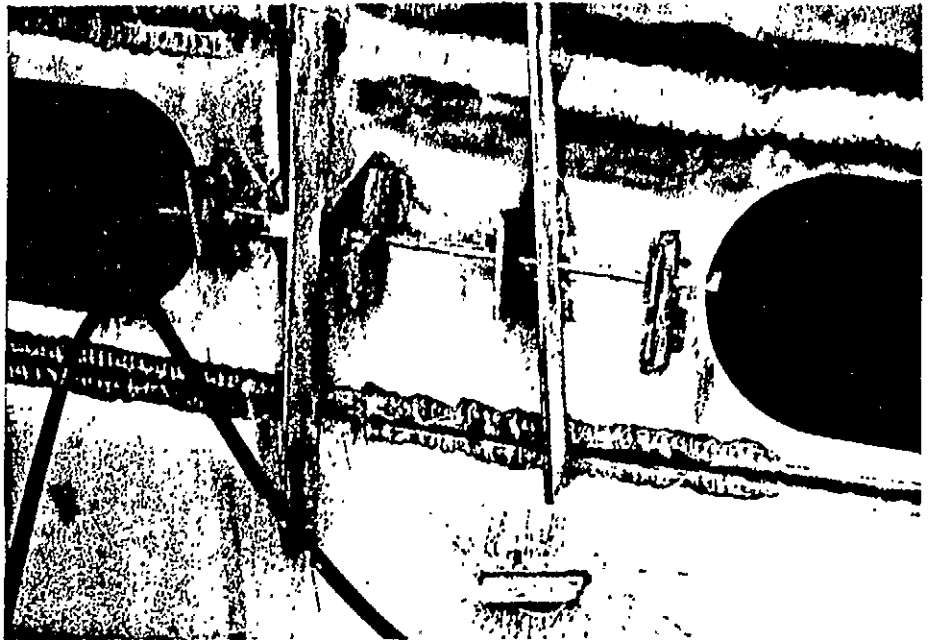
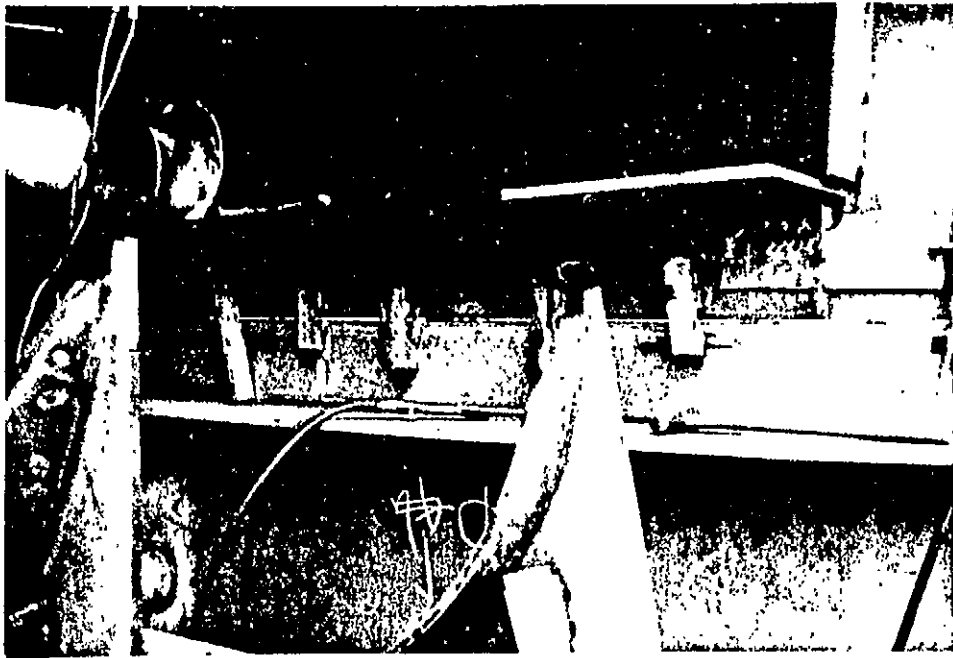
Eccentric Spinning Wire Method Narrow Gap Welding 79

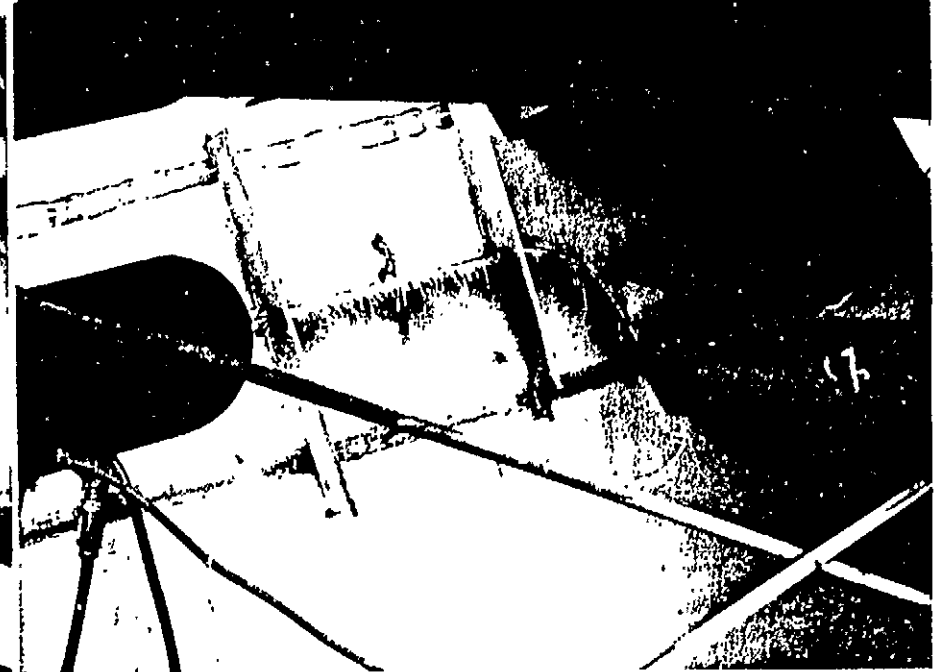
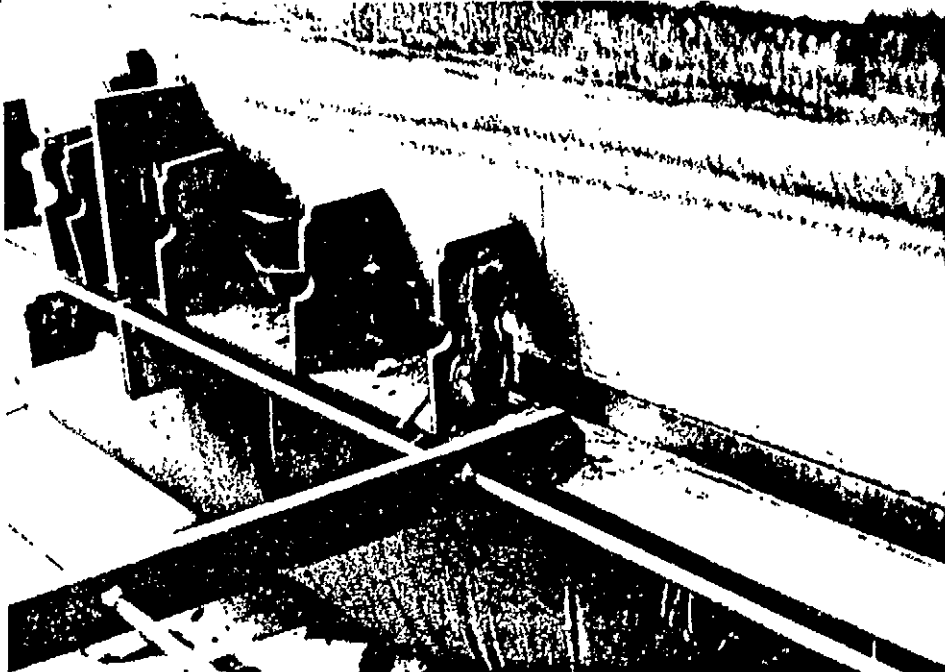
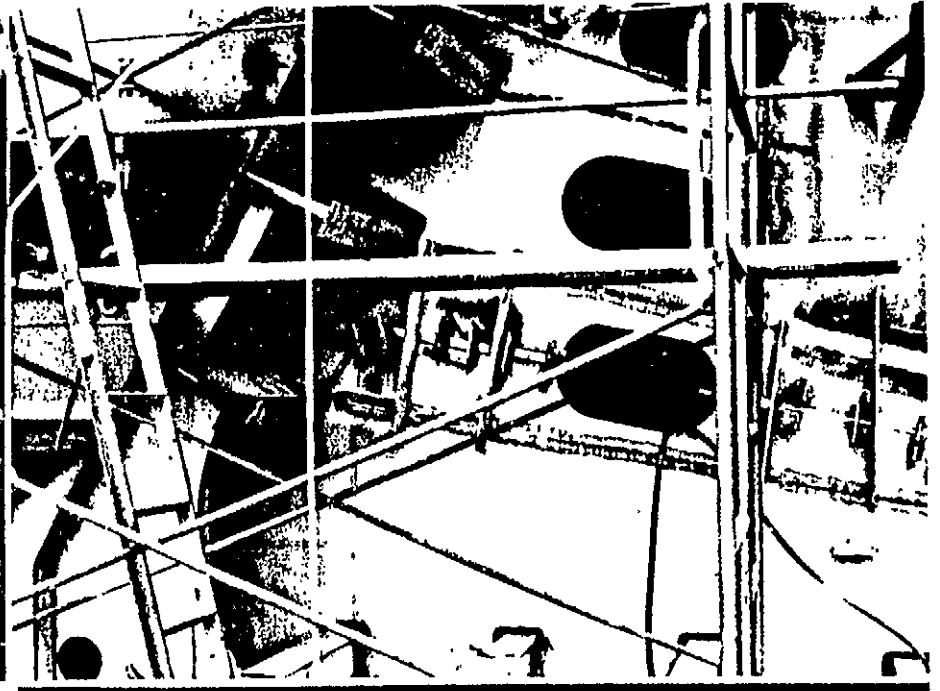
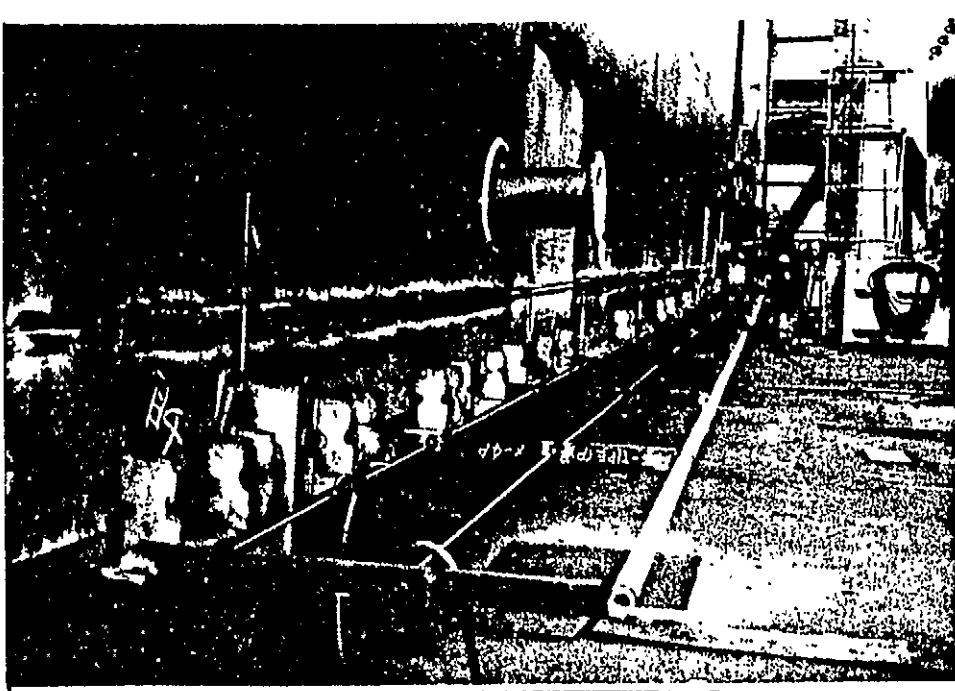


Equipment Gantry Note safety and health equipment 80

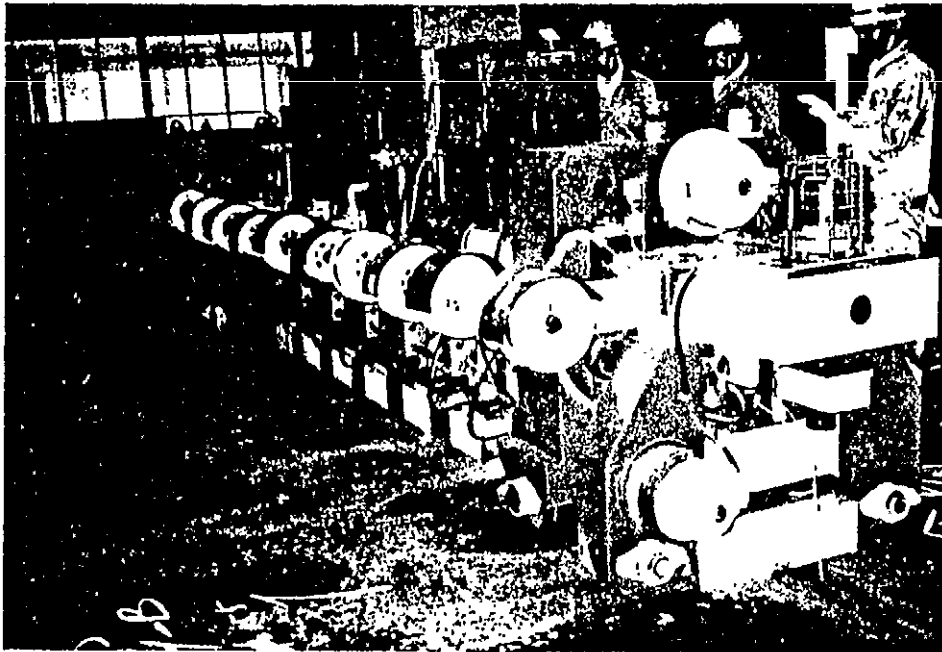


Good Housekeeping Note electrode stubs and wire reels 81



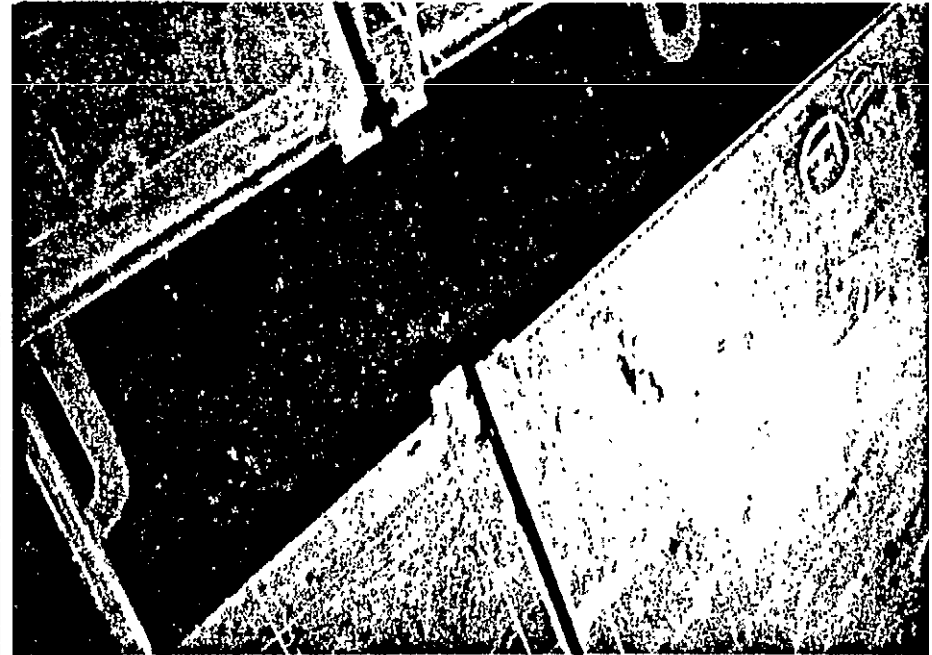


Make-Up, Gouging and Welding of Second Side Weldments



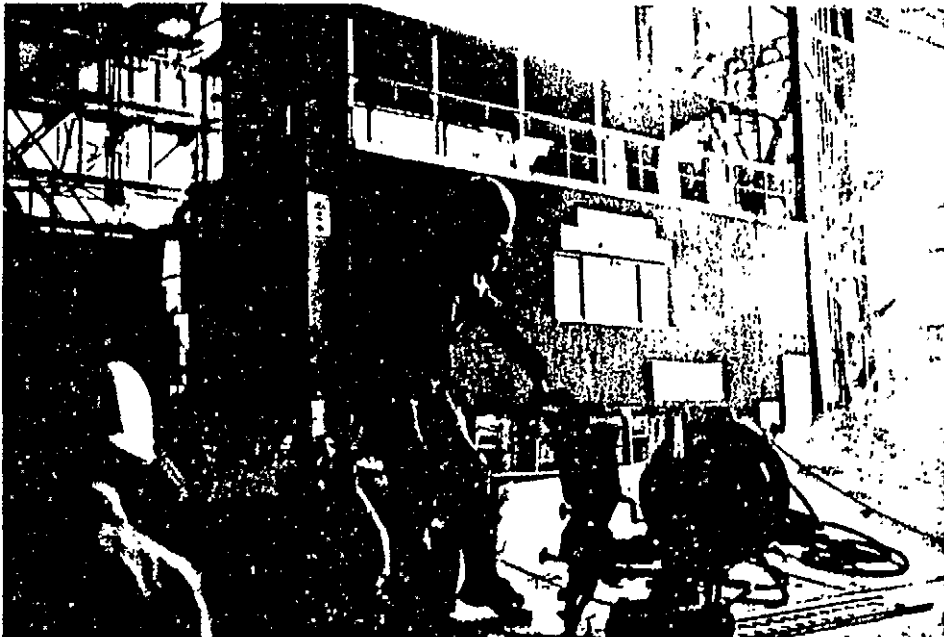
Multi-Head Automatic Tack Welder

90



Run On/Off Tabs

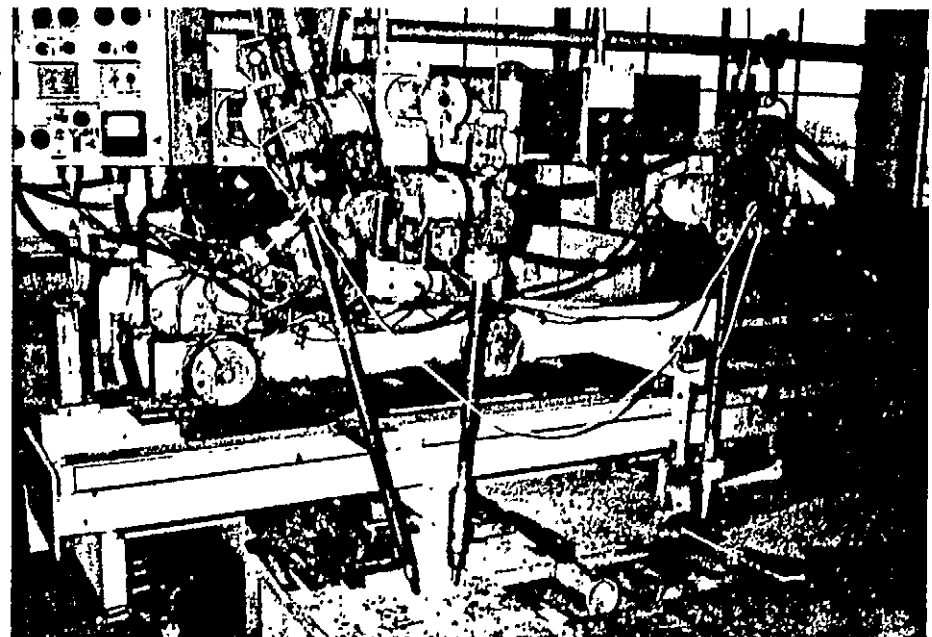
91



Submerged Arc Welding Operator

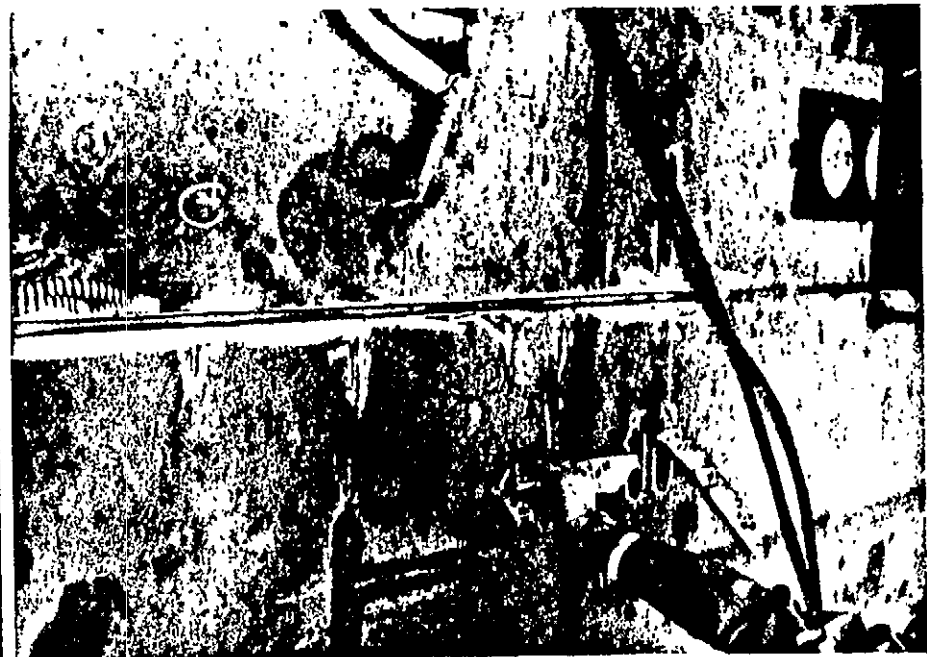
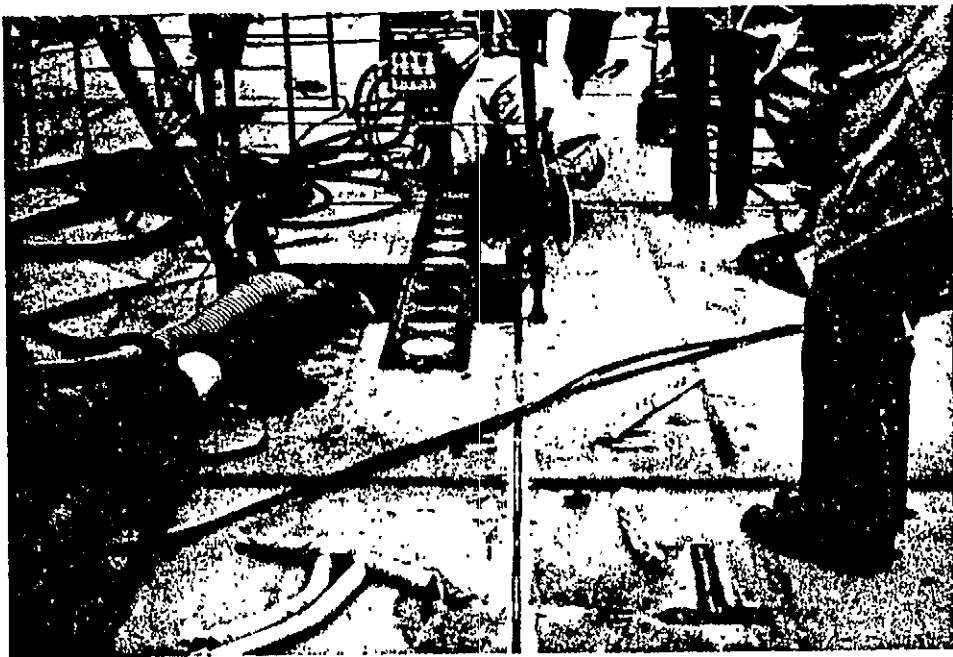
Note safety and

92



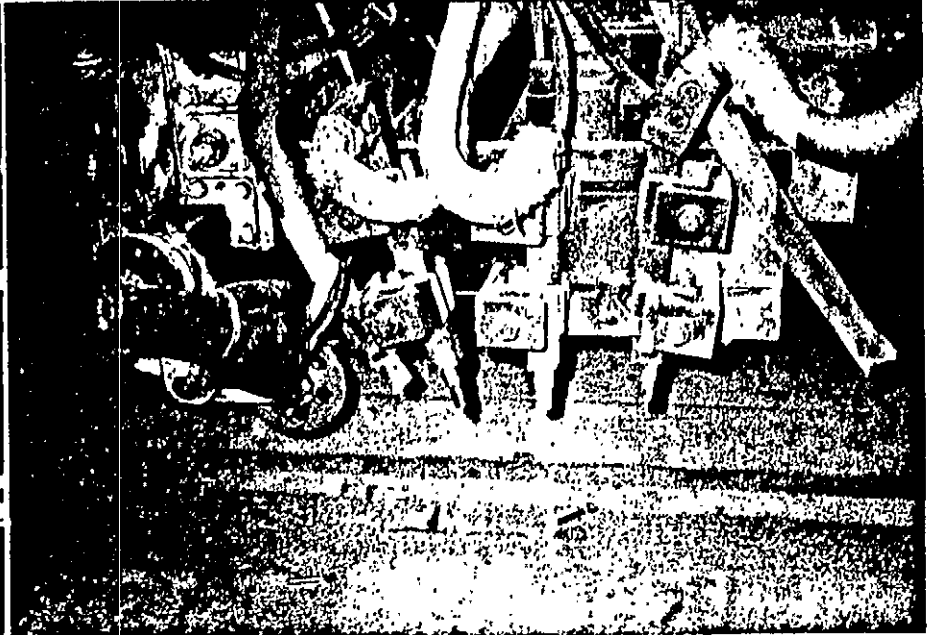
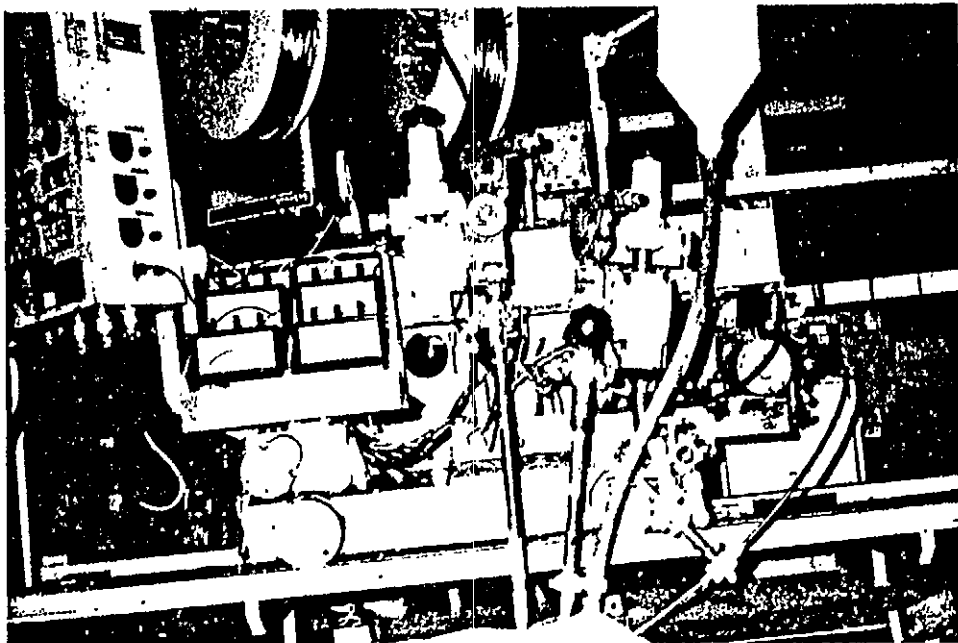
Separated Heat Input SAW Machine

93



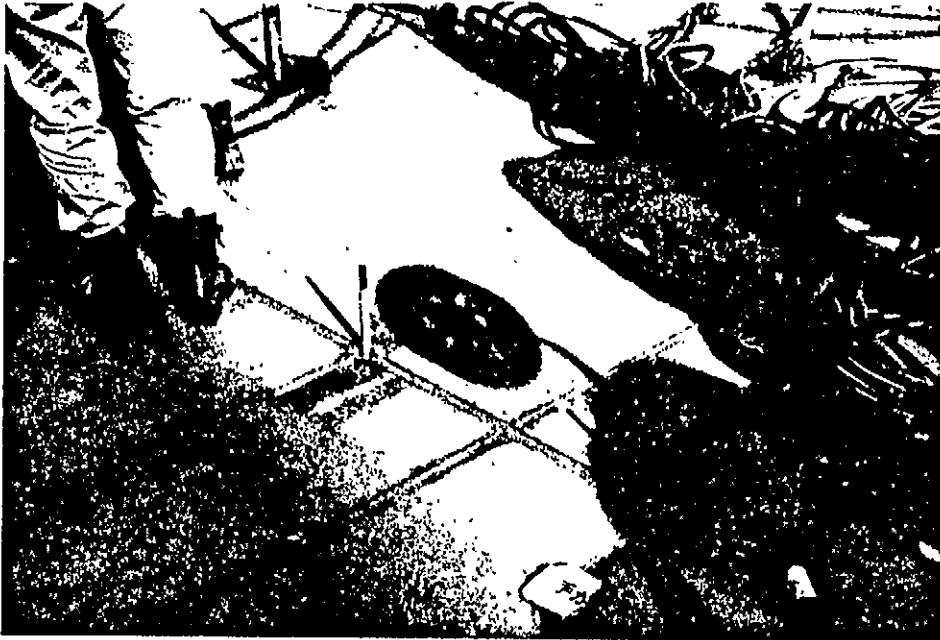
SAW with Metal Powder Added

94 and 95



Multi Wire SAW

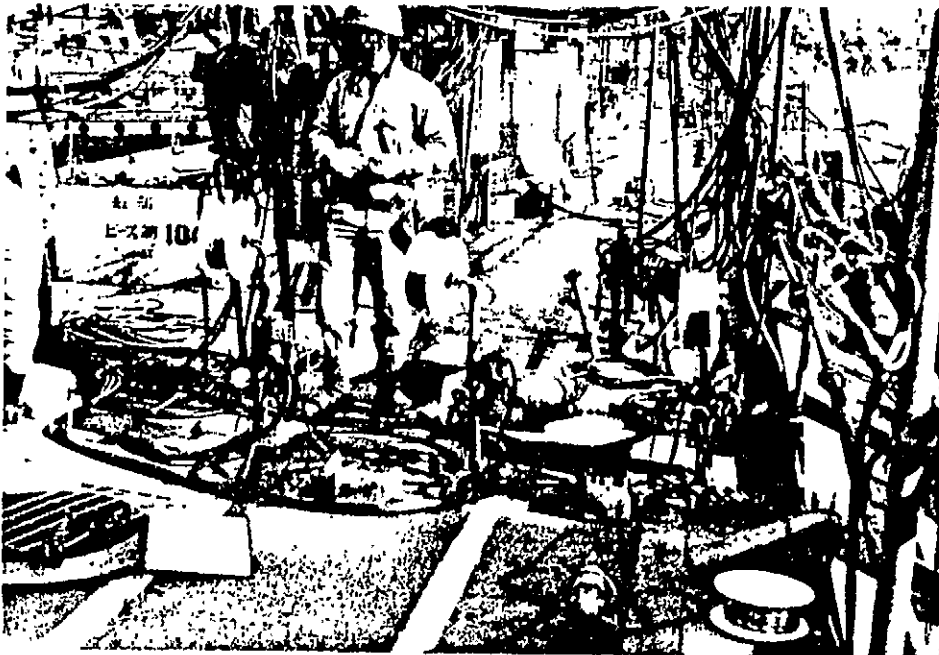
96 and 97



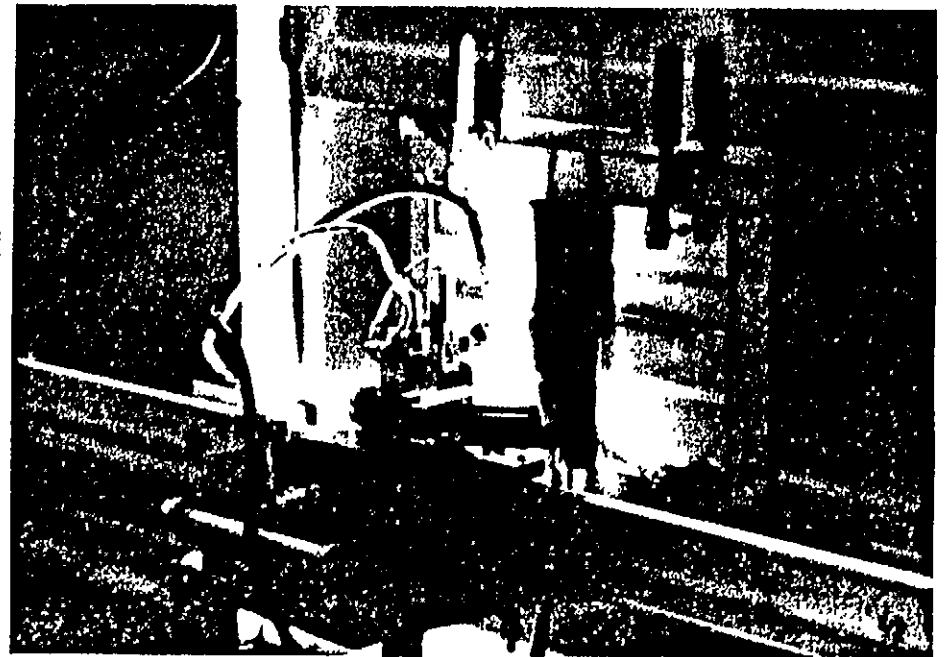
Consumable Guide Electroslag Welding 98



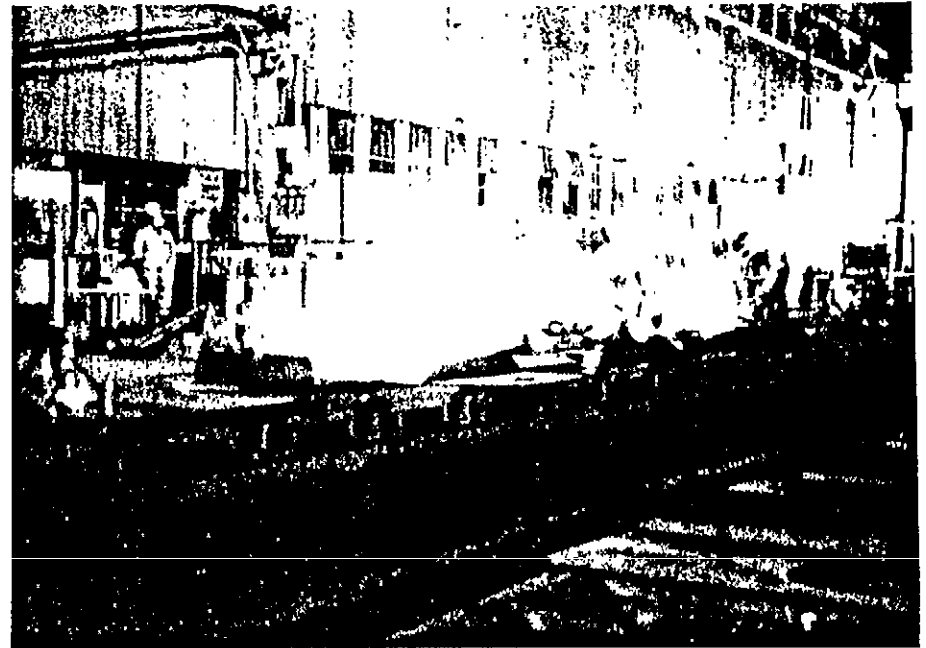
Consumable Guide Electroslag Welding 99



Consumable Guide Electroslag Welding 100

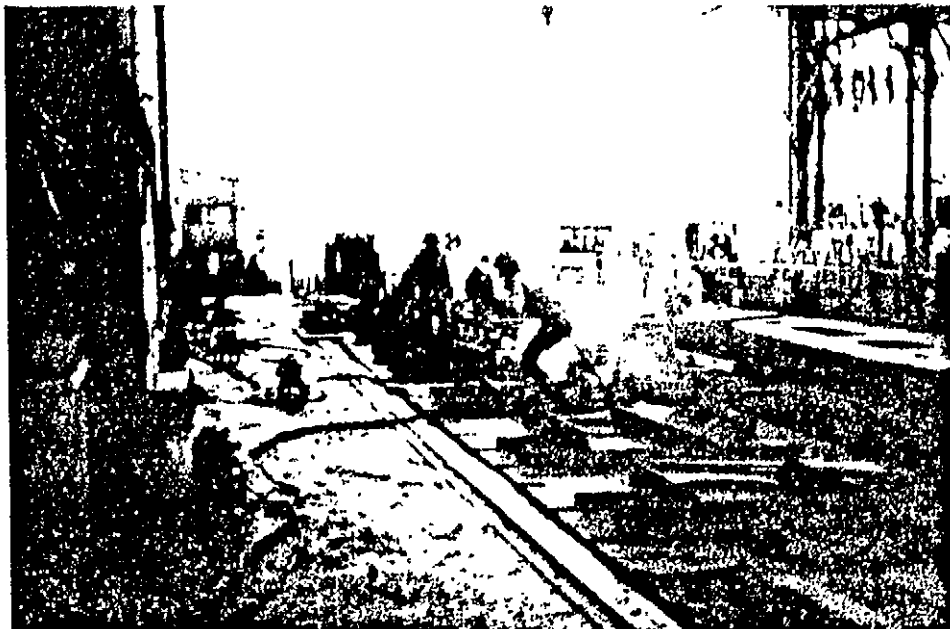


Automatic Welder-Membrane Type Primary LNG Barrier 101



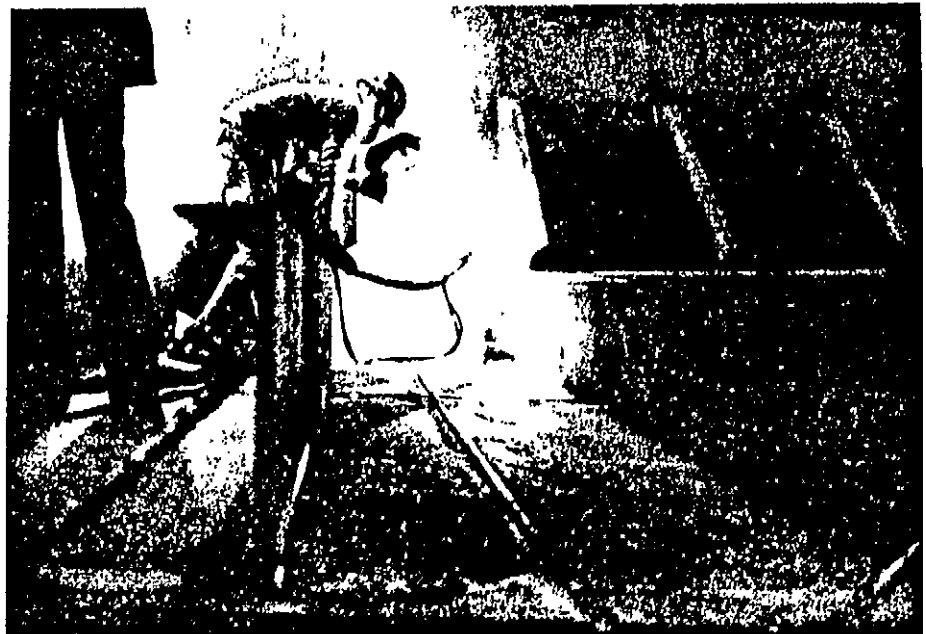
Gravity Feed Welding Production Line

102 and 103



Gravity Feed Welding Production Line

104

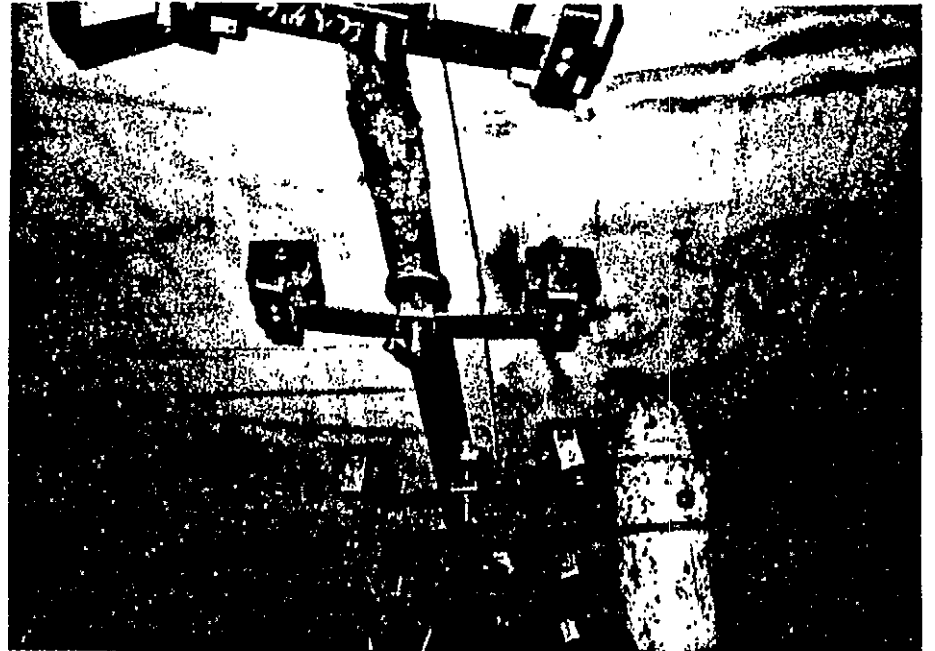


Automatic Midget Fillet Welder

105



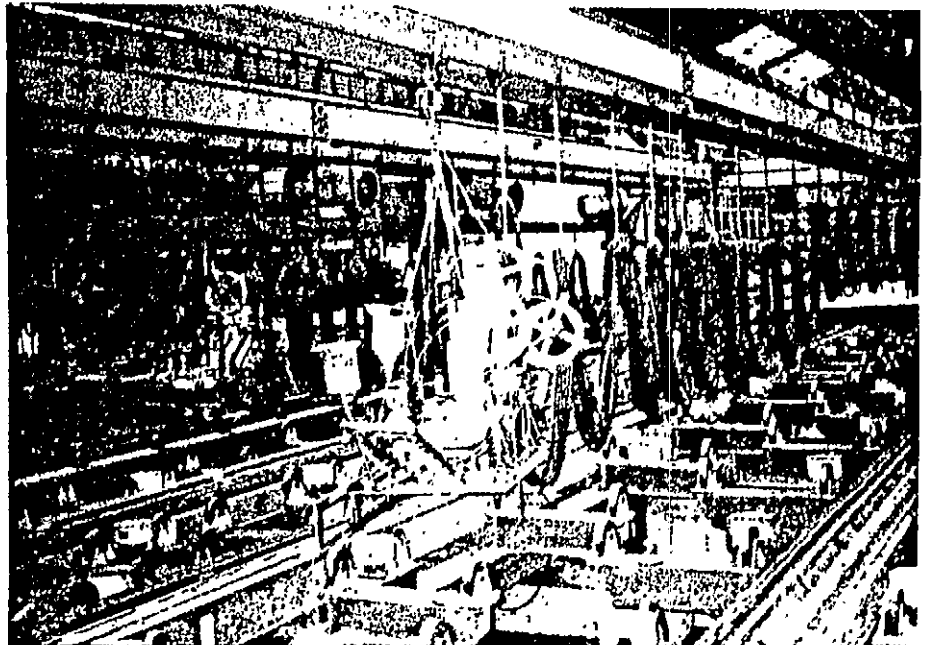
Second Side of One Side Welding 106



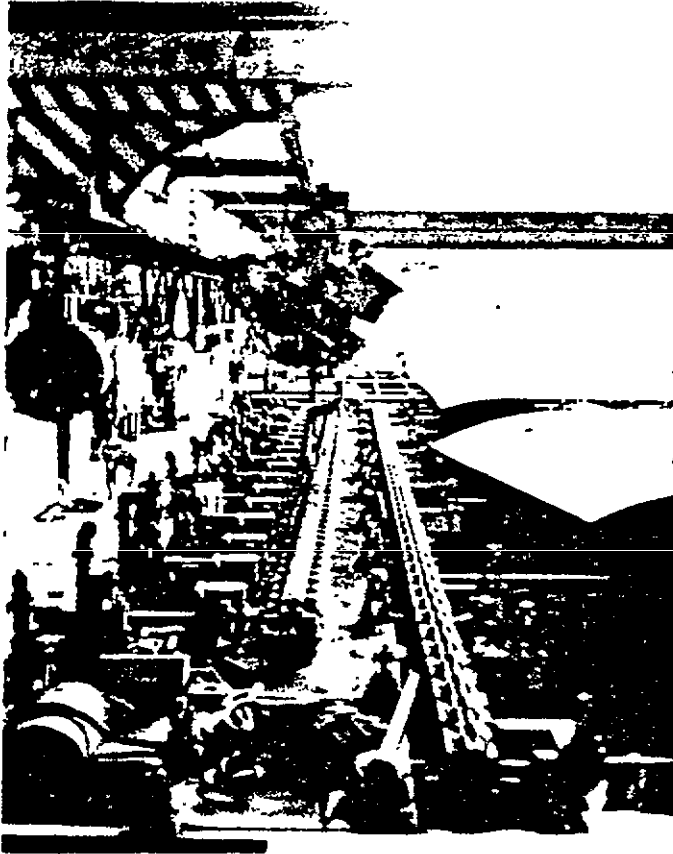
Back Up Attachment Method-One Side Welding 107



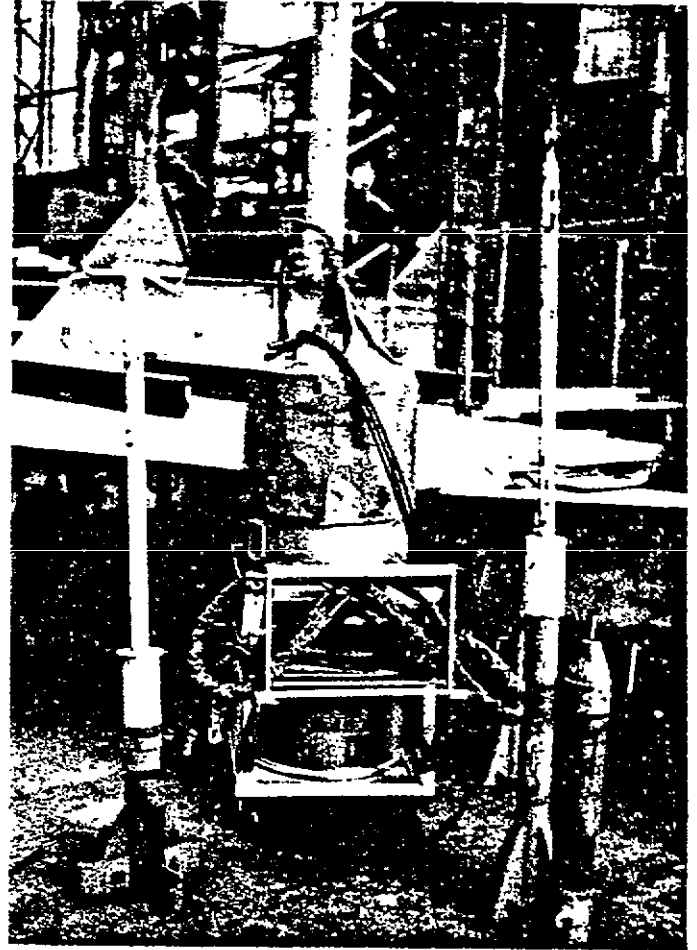
One Side Welding Stations



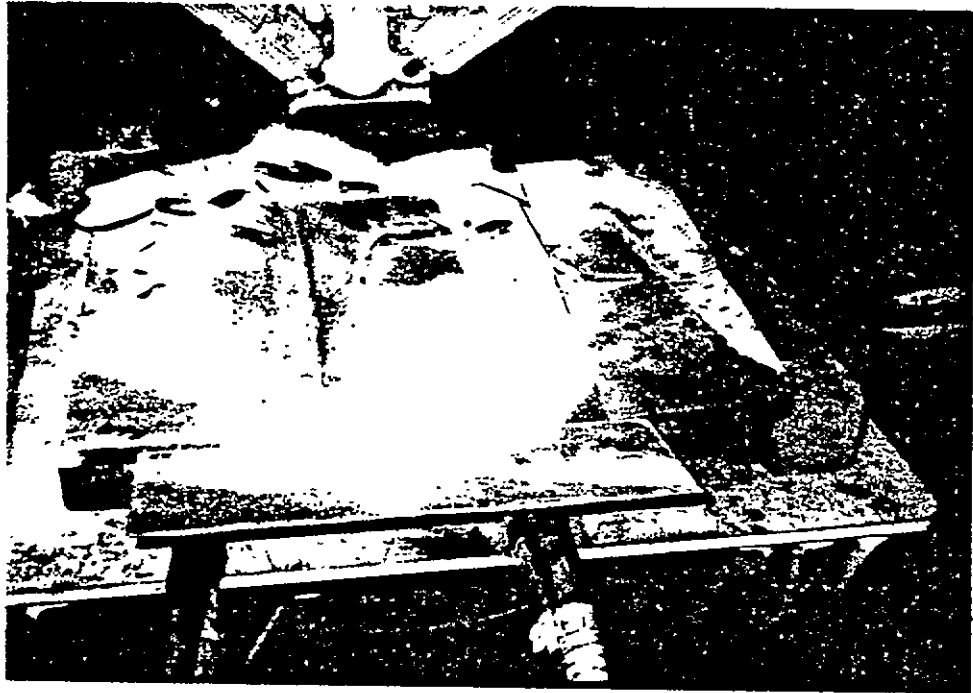
108 and 109



One Side Welding Stations (Cont'd) 110



Bulk Wire Drum for Remote Wire Feed 111

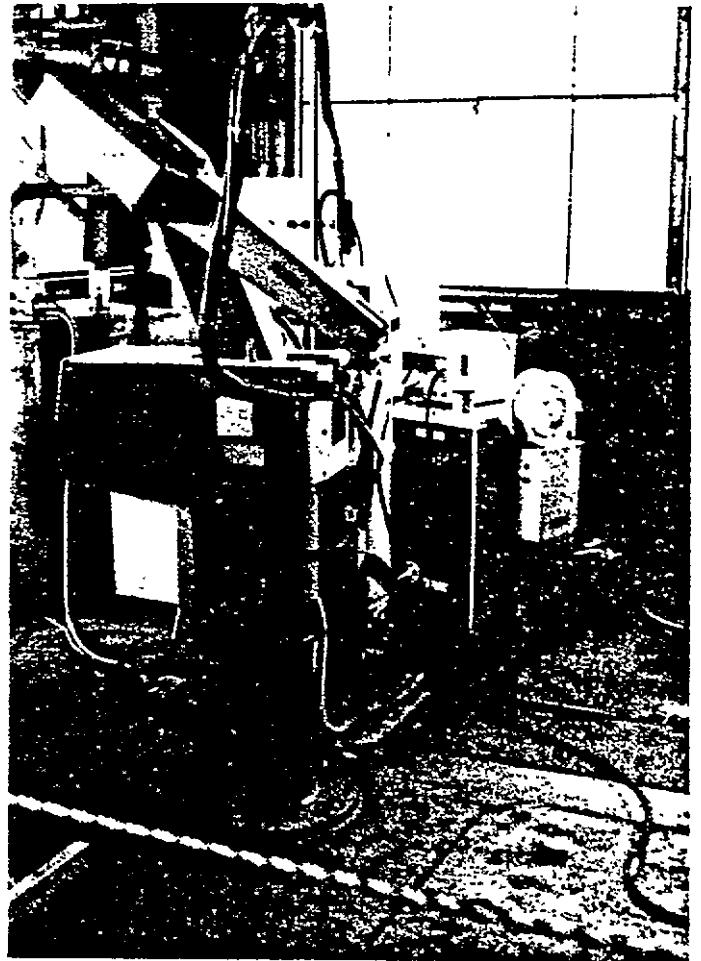


Plasma Arc Strip Overlay



Narrow Gap Pipe SAW

113



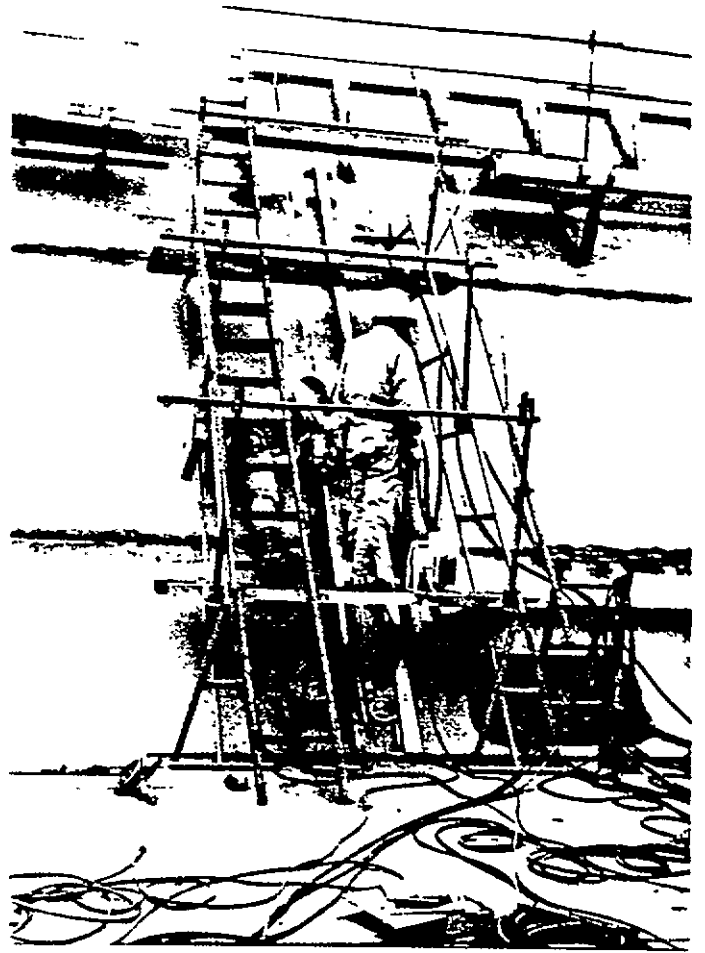
Welding Robots

114



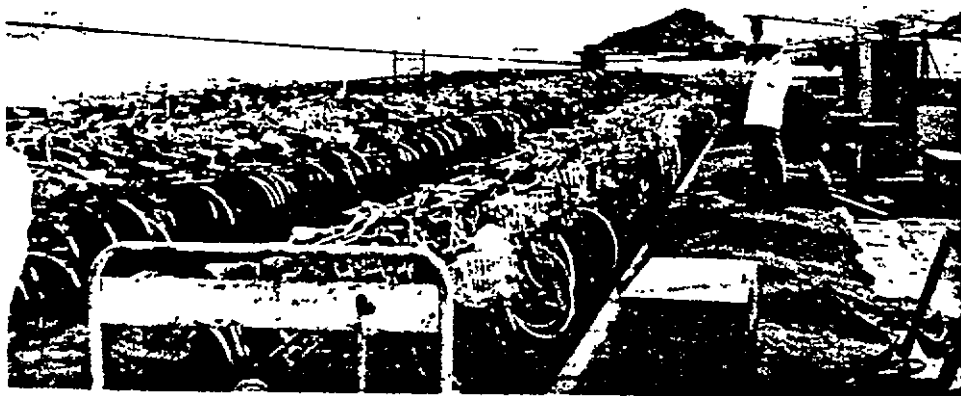
Welding Robots

115



Electrogas Welding

116 and 117



Employee Parking Lot

118