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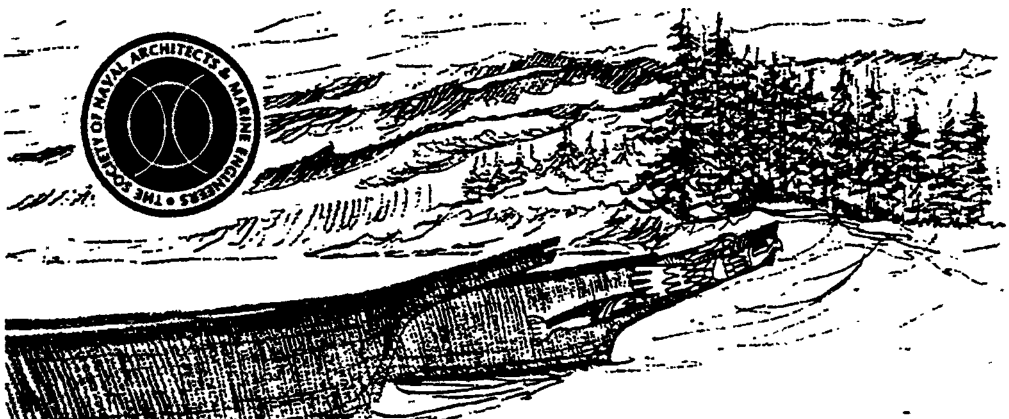

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Development of Integrated Shipyard Pipe Production Facility

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Jesse Engineering Company of Tacoma, Washington is the parent company of the Wallace Coast Machinery Company, which has designed and built pipe bending machines for many years. Working on a pipe bending machine application led to a complete pipe production modernization project in Southern China. Engineers jointly developed the design specifications for the machinery and automated controls.

Piping runs in shipboard designs are rarely the same. Each pipe assembly that is processed in a shop is different. The shipyard had developed a sophisticated computer system that identified and technically described every pipe or ventilation spool on the ship. The pipe shop however, was essentially a manual operation. Pipes were routed manually through the shop, welding was done manually, and pipes were bent using standard pipe benders.

The overall engineering requirement was to automatically collect and sort the pipe processing requirements; route and track each spool through the shop; and provide automated bending, cutting, flange welding, and bending of the pipes.

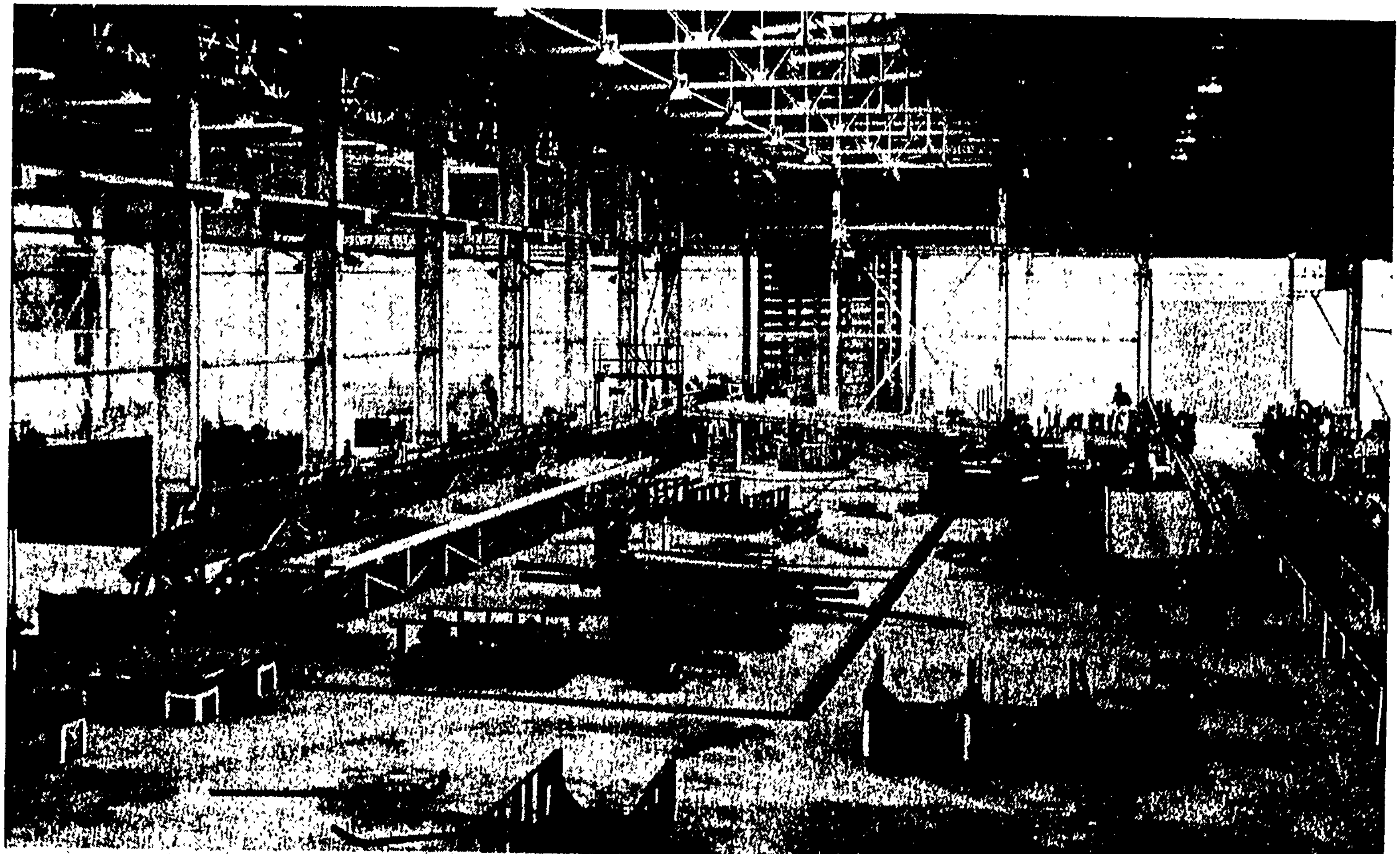
GENERAL DESCRIPTION SHIPYARD SYSTEM

The new factory layout uses three production lines. The small line handles pipes from 15 to 50mm (1/2" to 2"), the medium line from 65 to 150mm (2 1/2" to 6"), and the large line from 200 to 500mm (8" to 20"). The small and medium lines are semi automated production lines with similar equipment. All pipe transfer operations on the large line are manual and the equipment is basically manually operated.

For ease in presentation this paper only describes the medium line. Figure 1 shows the medium line as installed. Figure 2 shows the equipment layout of the medium line with arrows showing the production flow.

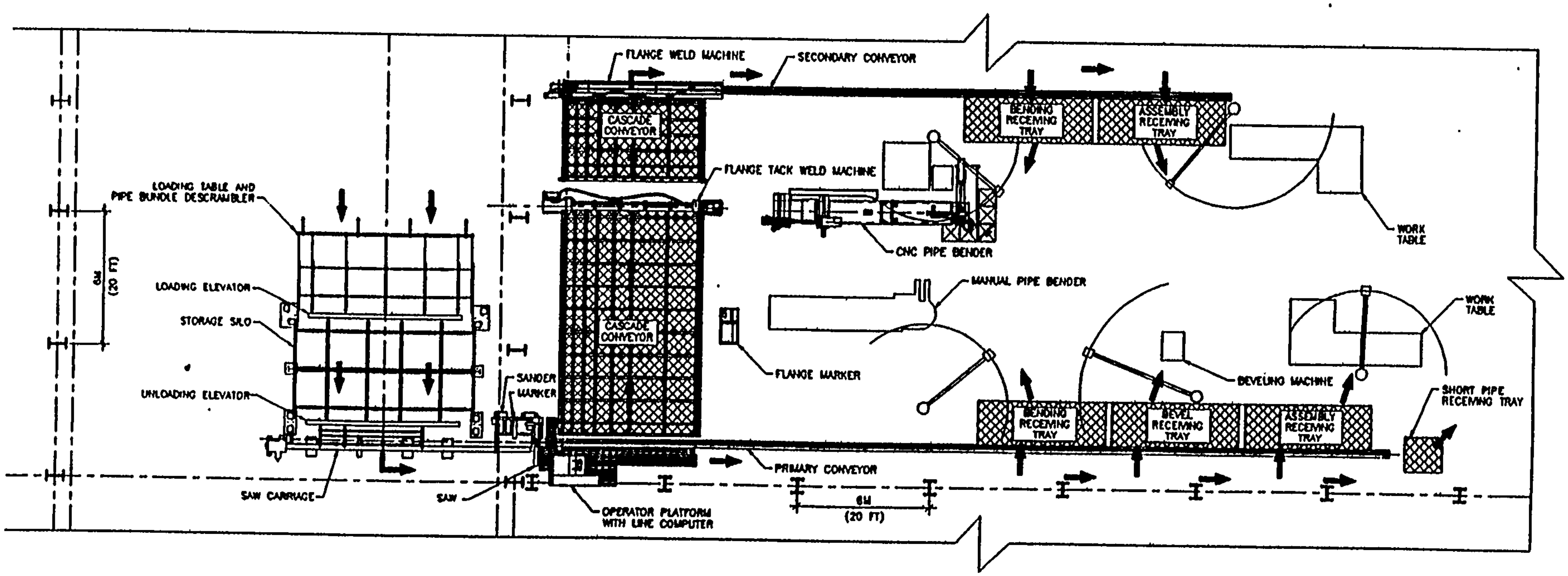
The medium line is designed to produce 41,000 cut pipe spools per year or 17 per hour. Each pipe has particular end treatments, and many have holes or saddles. Pipe assemblies are completed in the facility ready for installation aboard ship. 14 cut pipes per hour are sent to the automatic flange welding station and 6 pipe spools per hour are bent in the CNC Pipe Bender.

Figure 1



Medium Line Machinery

Medium line machinery, showing new installation at shipyard facility.



LAYOUT OF MEDIUM LINE

FIGURE 2

All pipe production activity is scheduled in the office using a 486-PC computer. The cutting and bending schedules are transferred to the line control computer and the CNC pipe bender control computer on the factory floor. Production status data from these computers are sent back to the office computer. Figures 3 and 4 are simplified information flow diagrams for the medium line.

Accommodating long production runs using pipes of the same diameter, thickness, and material was a key design consideration. This provides two major advantages.

1. Equipment can be designed with manual setups for different size pipes. The time involved making these equipment changes detracts little from the overall production rate if the changes are made infrequently. This also reduces the automatic mechanisms required. The machinery is simpler and less expensive to manufacture and maintain than fully automated equipment which can make all size changes automatically.

2. The greater number of cut pipe pieces that can be nested onto the uncut pipe inventory at one time results in less pipe waste.

OPERATING FEATURES

Bundles of the same size pipe are placed on the storage silo loading table. The pipes are ordered on the loading rack by the descrambler mechanism.

They are automatically transported to the appropriate storage tray in the silo by the loading elevator.

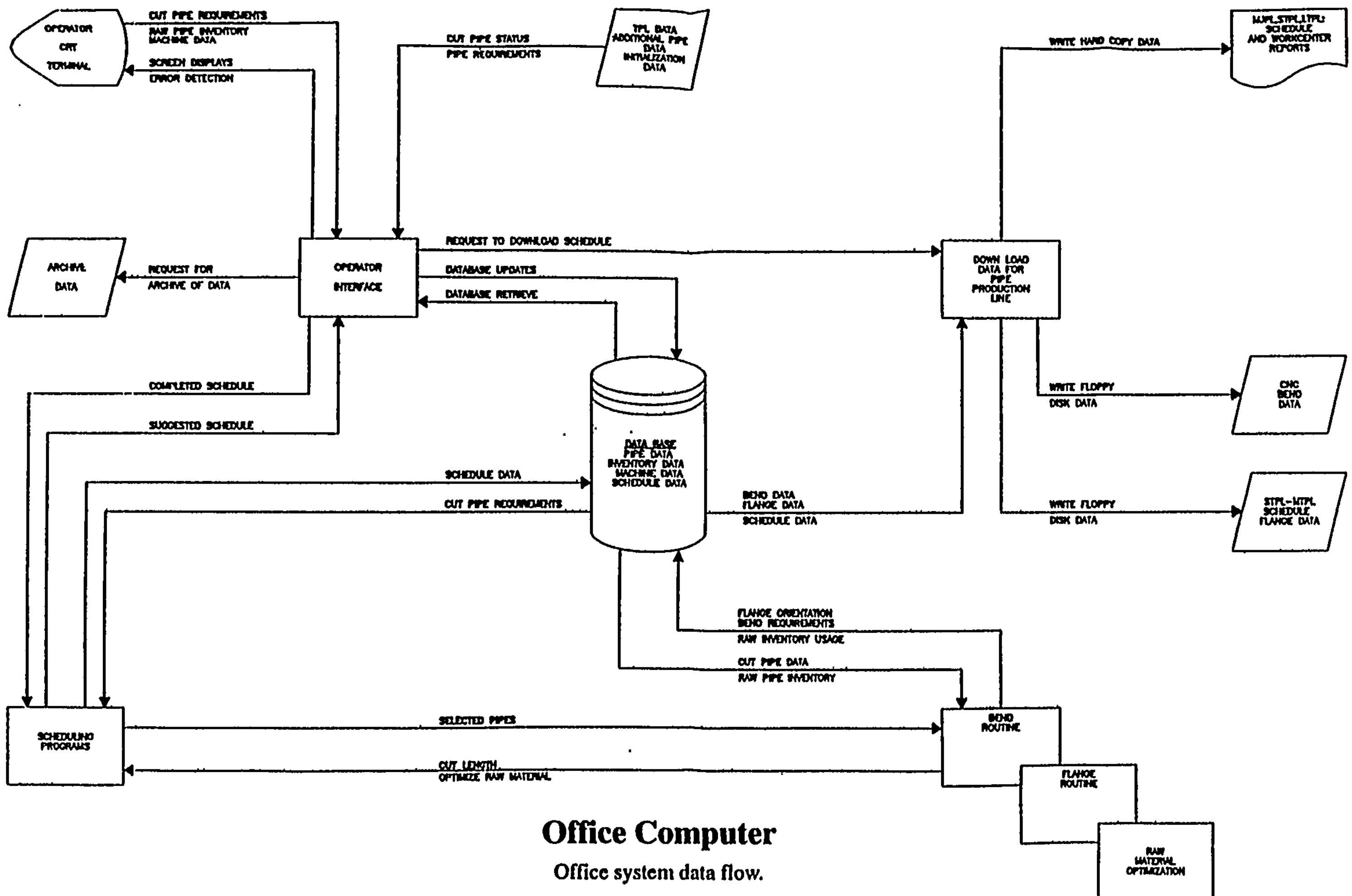
Pipes to be processed are automatically scheduled and efficiently nested onto the stored pipe inventory. The correct size pipes are automatically drawn from inventory. Each pipe piece is then automatically cleaned (sanded) for welding as required; marked by an ink jet printer; saw cut to the correct length; and conveyed to one of six stations for further processing. Pipes are automatically marked with unique pipe numbers assigned by the shipyard. Each pipe is also marked with a series of numbers indicating its work flow sequence. Flanges are automatically engraved with the associated pipe numbers at the flange marking station.

The correct flanges are aligned and mounted to the cut pipe pieces in the flange tack welding machine. They are tack welded and conveyed to the flange welding machine.

The pipe is positioned in the flange welding machine and four automatic welding guns simultaneously weld the two flanges to the pipe.

The CNC Pipe Bender stores all of the scheduled bends in its computer memory including the machine setups. The operator selects a pipe from the bender collection table, enters the pipe number marked on it, loads the pipe, and the bender performs the bends.

The work station sequence numbers show the work sequence in which a pipe piece must flow on the factory floor. End beveling, hole cutting, saddle cutting, and final assembly are typical work station areas.

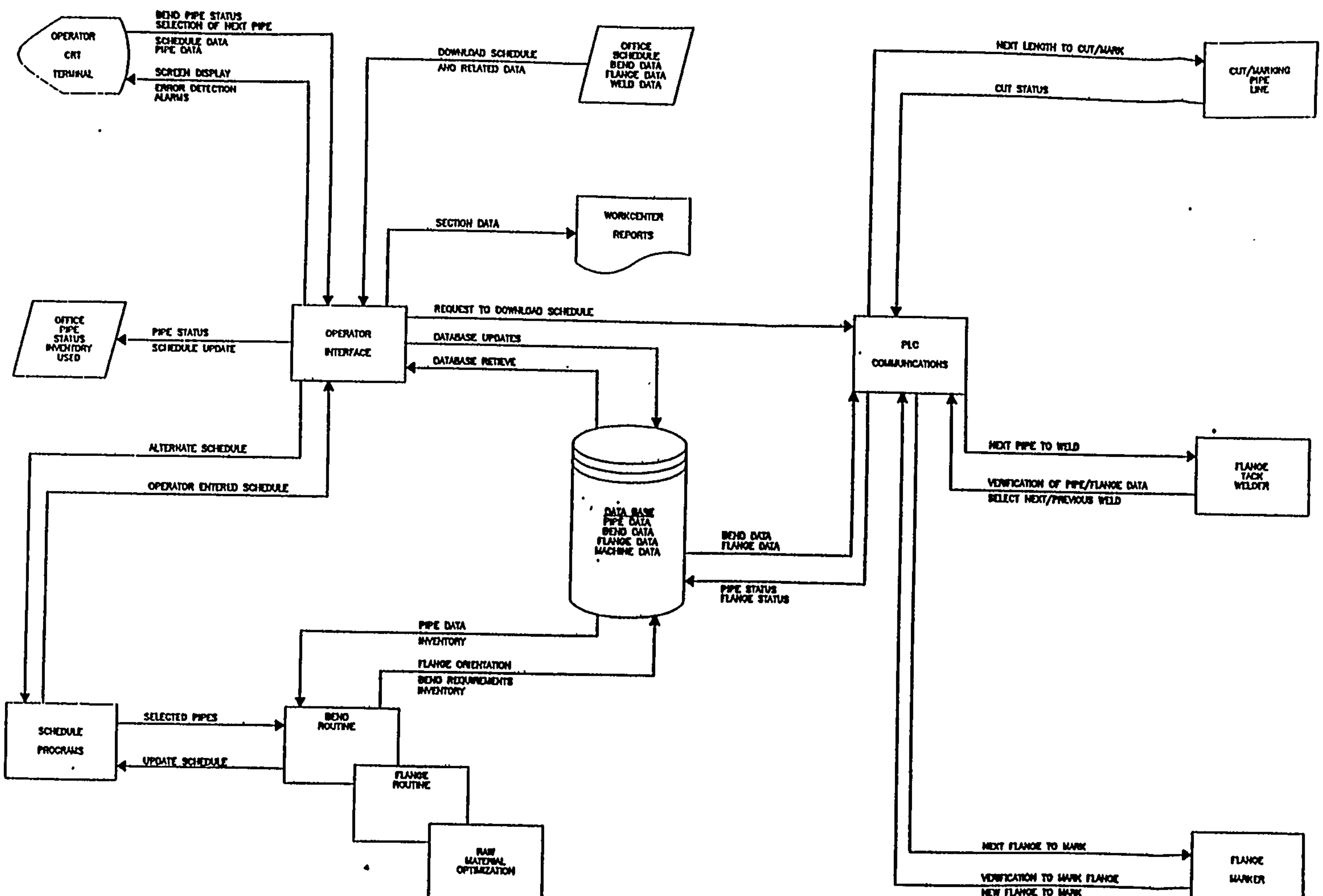


Office Computer

Office system data flow.

Fig. 3

Figure 3



Line Computer

Line control computer data flow.

Fig. 4

Figure 4

Work station operators are provided computer printouts listing the pipes which have been scheduled for their work station and pertinent information concerning each piece.

The line control computer and the CNC pipe bender control computer send pipe status back to the office computer. Automatic status information includes: pipe is cut, flange is marked, flanges are tack welded, and pipe bent. This status information is used by the office computer operators to either reschedule the pipe or move the pipe data to an archive file.

DESIGN FEATURES

computer System

The control program uses a commercially available database program as the basic scheduling tool. Data for each cut pipe is entered at the office PC or can be entered by means of floppy discs. The discs are developed *by* the shipyard's engineering and production departments. The engineering department provides the technical data for the pipe including its number, its bend definition, and its end treatments. The production department provides the routing sequence through the shop for each cut pipe and its required date.

Automatic data look-up tables keyed to pipe size, bend data, and end requirements simplify the entry requirements for each cut pipe. These look-up tables provide data required by the various machines.

The production schedule and all necessary data is passed to the line control computer and the CNC pipe bender control computer.

The schedule data is passed from the control computers to Programmable Logic Controllers (PLCS) which control the automated, sequential functions of the various machines.

Special Programs

The pipe bending program converts the desired bend requirements into machine instructions for bends, carriage tangent moves, and carriage chuck rotations. The bend instructions produce the desired finished bent pipe. The bend instruction calculations consider pipe spring back and provide for over bending to insure the finished bends are the desired angles. The tangent lengths between bends are also adjusted to insure the final total spool length is as specified. Pipe material spring back values are used as the basis for these calculations. The spring back values are determined and entered by the operators. An important output of this program is the cut-length of each pipe. It is an adjusted length that insures the flange to flange length of the finished pipe spool is correct after it is bent.

The cutting optimization program is an adaptation of a proprietary program used to order and cut steel shapes. The program uses an iteration process to fit cut pieces onto the inventory in a manner that minimizes pipe waste.

A special flange orientation program was developed to calculate: (1) The required offset angle between flanges on a cut pipe such that holes continue to be aligned after the pipe is bent; and (2) the initial pipe rotation required at in the bender to cause the flange holes at each end of the pipe to line up correctly aboard the ship. The flange orientation aboard the ship is set by rules provided by the shipyard. The input bend data for each pipe spool includes its X Y Z projection lengths on a shipboard coordinate system. The data also indicates flange orientation of 2 holes up or 1 hole up. The shipyard already characterized all of their pipe bending coordinates in a shipboard coordinate system. Knowing the shipboard orientation of the bent pipes is a necessary requirement for this type of program.

The data base program presents a suggested list of cut pipes to the office computer operator sorted by pipe size and prioritized by required date. The operator approves or changes the list. The selected pipes are automatically nested and scheduled for cutting. The operators have the ability to change this schedule at the office computer *or* at the line computers.

Line Computer Communications

The line computer is an industrialized 386 PC and communicates with the PLC using a Data Highway network. This provides the means for the line computer to send. and receive data for processing the pipe. The PLC can alert the operator through the line computer of any equipment failures or error conditions that may occur while the pipe is being processed.

After a pipe is selected for processing by the operator the line computer sends the rack location to retrieve the pipe, length of the pipe, where each operation on the pipe is to be performed (sand, mark, cut), and the location where the pipe is to be kicked off the conveyor. The PLC sends status to the line computer as the PLC retrieves the pipe from the rack location and processes the pipe. In turn the line computer updates the data in the local database to reflect the status of the raw material inventory and the current status of the cut pipes.

The line computer also provides communications to the ink jet marker. When the PLC has positioned a pipe to be marked, it sends a signal to the line computer to initiate the marking of the pipe. The line computer sends the required commands to the ink jet marker to perform the mark. When the mark is completed, the line computer signals the PLC to continue processing. A similar system is used at the Flange Marking and Flange Tack Welding machines. These machines have a key pad and small display. The. operator signals the line computer when to start a selected process. The line computer then sends the proper commands to the PLC .

Storage System

The Medium Line storage silo (See Figure 5) stores more than 600 pipes. 15 different sizes between 5M (16ft.) and 8M (28ft) long are stored in 15 sloped storage trays. It is a steel silo approximately 8M (26ft) high, 9.5M (31ft) wide and 6M (20ft) deep.

Storage Silo

Shows unloading elevator and pipes in the trays.

Figure 5

The pipes are deposited in the trays by the loading elevator and roll to a stop at the other end. Bundles of the same size pipe are loaded on the feed table. The loading elevator individually transports the pipes to their designated trays. The unloading elevator is sent to the appropriate slot by the line control computer where it automatically strips a single pipe from the tray and deposits it in the saw line carriage. The elevators are similar in design and are driven by electric motors. Various pneumatic arms on the elevators accomplish the pipe transfers. There are no actuators located on the silo.

Saw System

The saw carriage (See Figure 6) consists of a series of grippers, some configured for rotation and others for longitudinal transporting of the pipe. The grippers are designed to self-center pipes of any diameter. Three transporting grippers pick the selected pipe from the unloading elevator and swing the pipe to the carriage center line axis. A pneumatic, rotatable chuck moves forward and grips the pipe. The chuck positions the pipe for all operations. A position seeking AC motor drives the carriage and pipe to precise linear locations within a tolerance of +/- lmm. Each pipe piece is first cleaned by a 6" belt sander in the areas to be welded, and then marked by an automatic ink jet marker before it is cut.

The pipe is cut while it is rotating using a band saw. This insures a straight cut and also eliminates any saw burrs on the outside of the pipe.

The pipe breaks a sensing light beam as it is moved forward by the chuck. This sensor sets all pipe measurements. The computer calculates sequential stops as it moves forward to be sanded, marked, or cut. The longitudinal or radial grippers are air operated and grip or relax depending on the pipe motion. The grippers swing completely out of the way to allow the chuck to pass. There is a radial gripper on the outfeed side of the saw. The saw outfeed conveyor also automatically adjusts its height to the bottom edge of the pipe being sawed. The conveyor is fitted with an adjustable fence that holds the pipe in line as it rotates under the saw. The saw line conveyor is a chain conveyor that automatically transports the cut pipe pieces to one of five kick-off locations. Air operated kick-off arms automatically sweep the pipe to holding tables or other conveyors. The work flow sequence number assigned to the pipe piece determines the kick-off it is sent to.

Tack Weld Statien

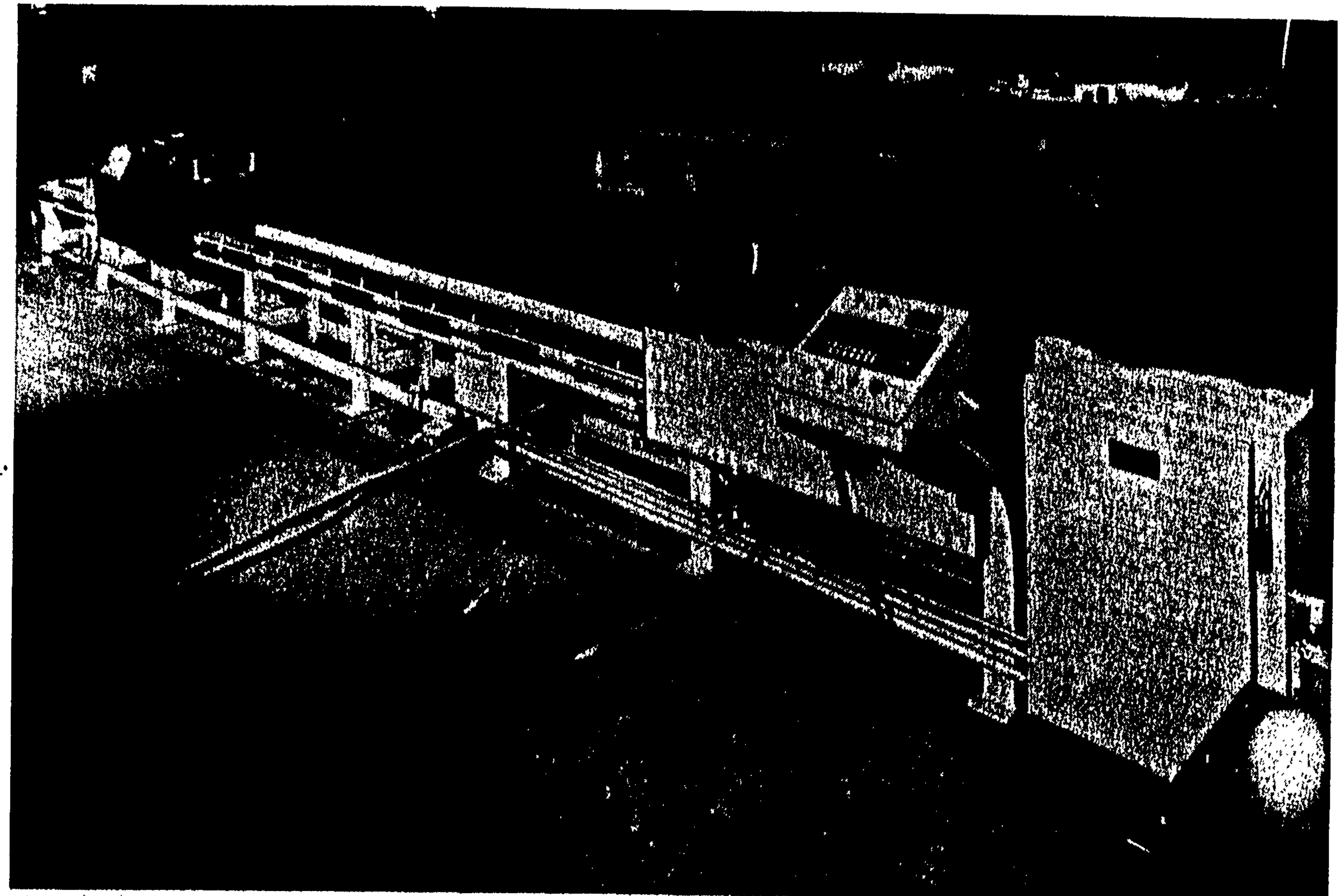
Pipes that are to be flanged are sent to kick-off #1. They roll down a computer controlled, pneumatically operated, cascade conveyor. The conveyor can store up to 10 cut pipes and delivers them individually to the tack weld machine. The tack weld machine has two scrolling type chucks operated by air motors (See Figure 7 & 8).

Figure 6

Saw Line

Shows pipe being processed, #1 kickoff, cascade conveyor, manual control panel, band saw, outfeed gripper, saw carriage, large self-centering grippers holding pipe; chuck holding pipe, unloading elevator, and storage silo.

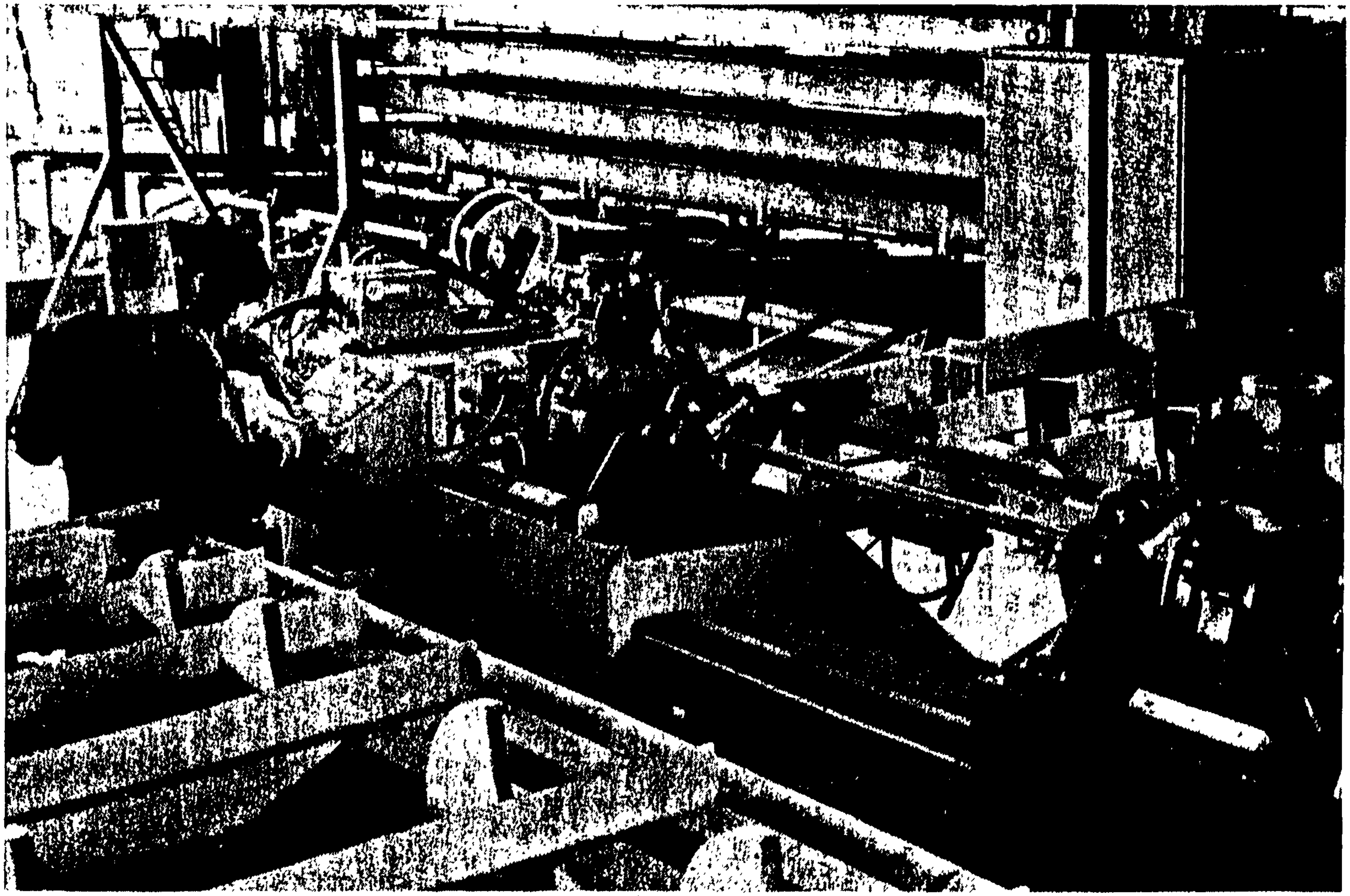
Figure 7



Tack Welding Machine

Shows self centering grippers, chucks, control panel, and remote I/O cabinet for data communications with the line computer.

Figure 8



Flange Tack Weld Machine

Shows pipe centered in the gripper, flanges in the chucks pushed on to the pipe, cascade conveyors on the loading and unloading side of the machine.

The chucks are mounted on air actuated slides which move toward or away from the positioned pipe. There is a fixed and a movable carriage assembly. An AC electric motor automatically positions the movable carriage. The home position of the movable carriage is close to the fixed carriage. A digital display shows the operator the number of the next pipe as well as the setup information required. The operator places a pipe spacing ring and an indexing pin on each chuck face. This setup is the same for each size of pipe. The operator places the flanges in the chucks with the indexing pins through one of the flange holes. The flanges are held flush against the chuck by magnets imbedded in the faces. The operator uses a push button to close the chuck jaws. The operator manually sets the required flange hole offset angle using a digital readout. The system was designed to set the flange offset angle with .1 degree. The movable carriage automatically positions itself to accept the pipe piece waiting in the cascade conveyor. Grippers, similar to those used on the saw line carriage, pick the pipe from the cascade conveyor and center it between the chucks. The chucks are automatically pushed forward by the air cylinders positioning the flanges on the pipe. The operator manually tack welds the flanges to the pipe.

When the tack welding is completed the chuck jaws automatically open, the chucks are retracted, and discharge arms automatically move the pipe to another cascade conveyor. The movable carriage positions itself for loading the next flange.

Flange Welding Station

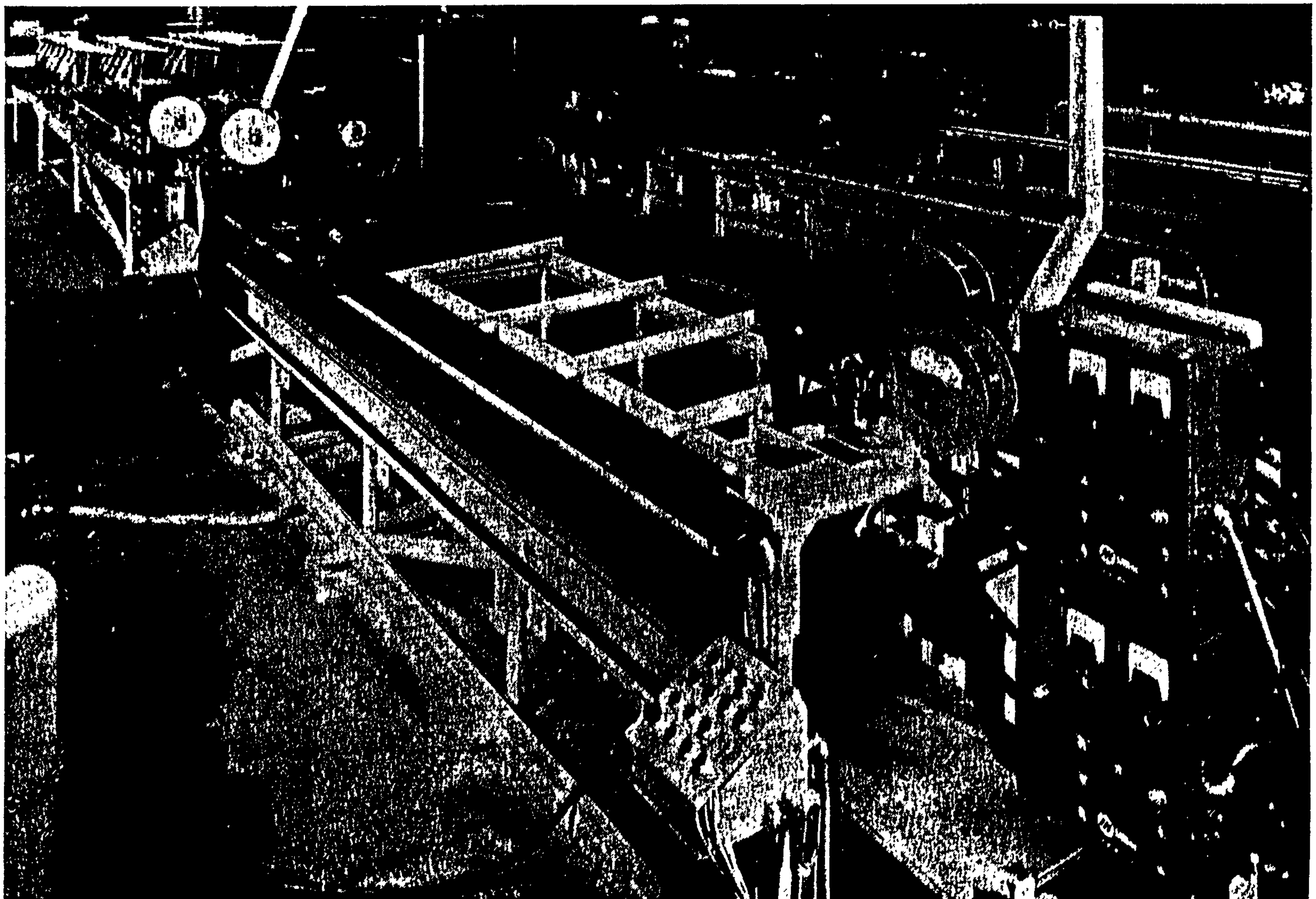
The flange welding machine (See Figure 9) uses 4 commercially available, automatic welding machines. There is one fixed and one movable carriage with two guns mounted on each carriage. The guns are on air operated arms which swing the guns into or away from the work area. The guns are manually adjusted for a particular pipe/ flange configuration and will hold that adjustment as they are swung in and out of the work area. Guide rollers ride the work pieces and keep the guns in position while the pipe turns.

The operator aligns the movable carriage with the incoming pipe. The pipe automatically rolls onto the carriages and rests on 4 turning rolls. The pipe is automatically positioned and the four weld heads swing down. The operator insures the heads are positioned correctly then starts the welding process. The pipe rotates under the weld heads. When the weld is completed the operator turns off the welding machines. The operator makes all weld settings and can manually operate any or all the heads as required. The roller arms automatically lower the welded pipe to the secondary conveyor at the completion of welding for transport to one of two kick-offs.

Flange Marking Machine

Pipe numbers are permanently engraved on the flanges using a commercially available automatic marking machine (See Figure 10).

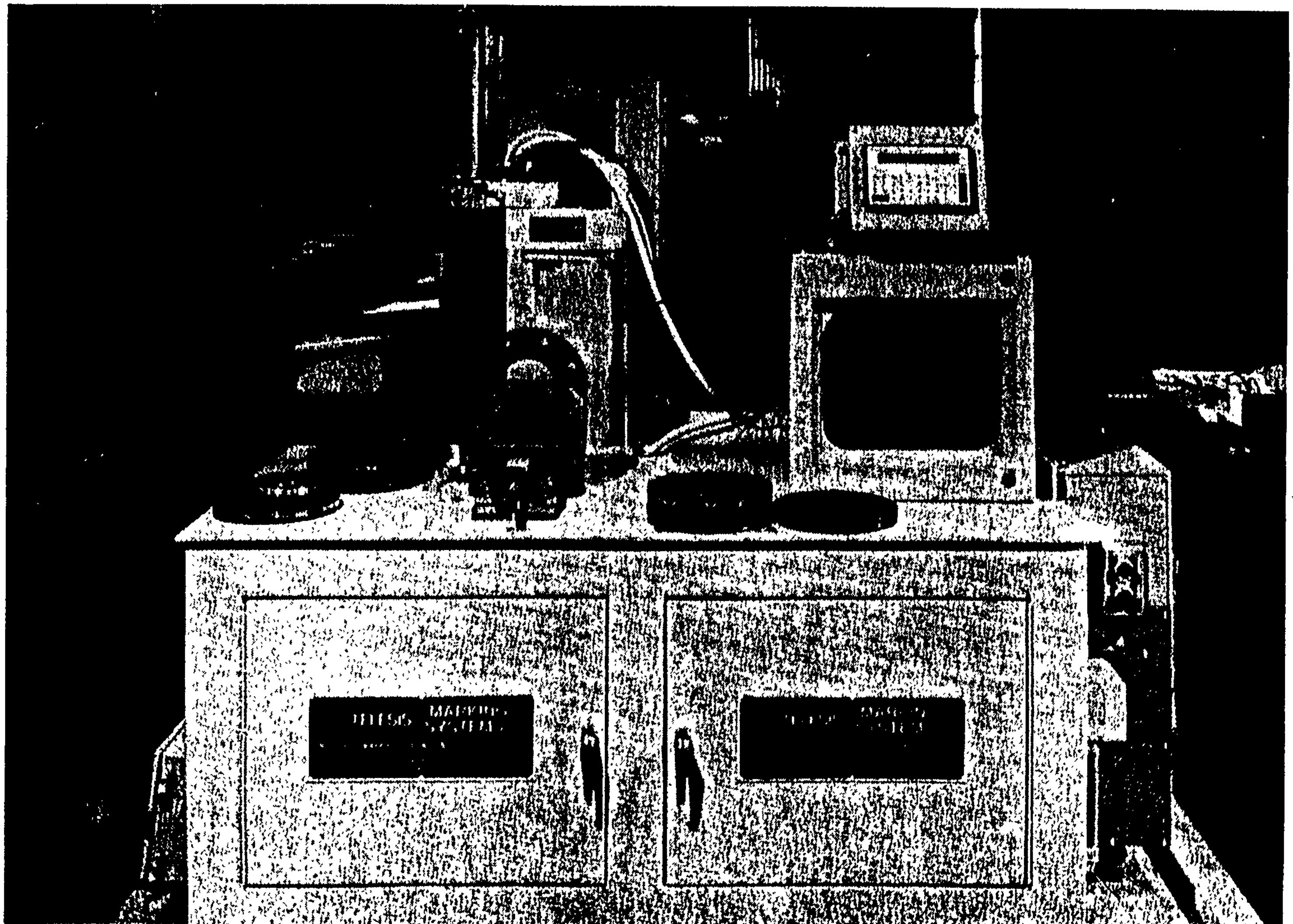
Figure 9



Flange Welding

Shows pipe set for welding, 4 welding machines, secondary conveyor integral with welding machine, and control consoles.

Figure 10



Flange Marking Station

Shows automated Pin Marker, control panel, and video monitor.

The machine consists of a computer control module, an automatic positioning arm, an automatic rotating chuck, and an air operated pin stylus that makes a mark in the metal. The flanges are mounted on the rotating chuck. The arm automatically swings over the center of the flange edge, the stylus is turned on, and the proper characters are engraved into the flange.

The starting position of the arm and the character size are preprogrammed into the machine. The line computer sends the marking machine the character string to be stamped and the pattern name to be used.

A digital display prompts the operator with the next scheduled flange number, its specification data, and its destination. The operator mounts an appropriate flange on the chuck and pushes a button. The flange is automatically marked.

CNC Bending Machine

The medium line uses a 1006 CNC Pipe Bending Machine (See Figure 11). The basic machine comes with the ability to load- and store bend requirements by number for later recall. The machine has automatic spring back compensation and automatic radial growth compensation as a standard feature. This application required bending pipes already cut to length and flanges welded on both ends. The following changes were made to the standard machine.

1. Provided a scrolling hydraulic chuck which could grip flanges as well as pipes. The chuck has an indexing slot in the face that accepts an indexing pin inserted through a flange hole. This provides for manual indexing of the flange. The flange hole is indexed within .1 degree.

2. Provided a laser hole finding device. This device drops in front of the flange after the pipe is loaded. The pipe is automatically rotated and the laser device signals the bender computer when it detects the edges of a hole. This provides for automatic indexing of the flange.

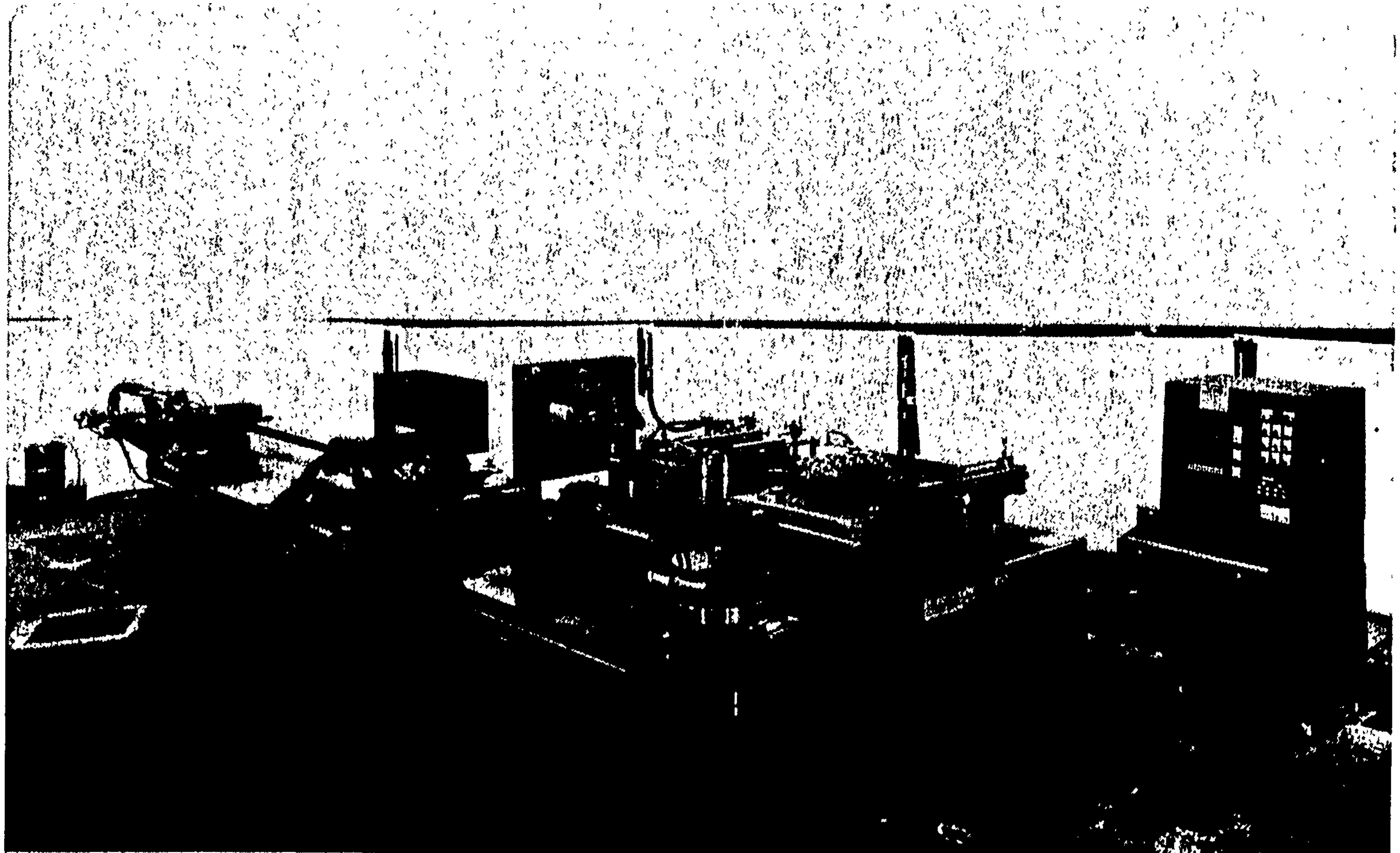
3. Provided a computer interface that accepts the precalculated and prescheduled bending information from the office computer.

The operator selects a pipe from the collection station and reads its pipe number. The number is located on the bender computer screen. The ~ screen automatically displays the bender information required for that pipe. The operator insures the bender is setup properly and loads the pipe. The bender automatically makes the proper 3 dimensional bends.

ADDITIONAL FEATURE

A system has been developed that incorporates an automatic pipe measurement device as part Of the storage silo loading elevator. The length of each pipe is measured as it is loaded on to the elevator and the value automatically recorded by the line control computer. The cutting program considers the length and location of each pipe in the rack as it calculates the optimum nesting arrangement.

Figure 11



CNC Pipe Bender

Shows CNC pipe bender, control console with the control computer, modified chuck and laser hole finder under its hood.

CONCLUSION

The equipment described in this paper was designed, manufactured, and delivered to the shipyard within 9 months of the contract date. Combining state of the art automation with manual operations produced an efficient system using simple and reliable machines. The productivity rate of the working line is high. Overall shipyard efficiency is increased by automatically linking the pipe shop scheduling data, the shipyard production data, and the engineering requirements data.

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