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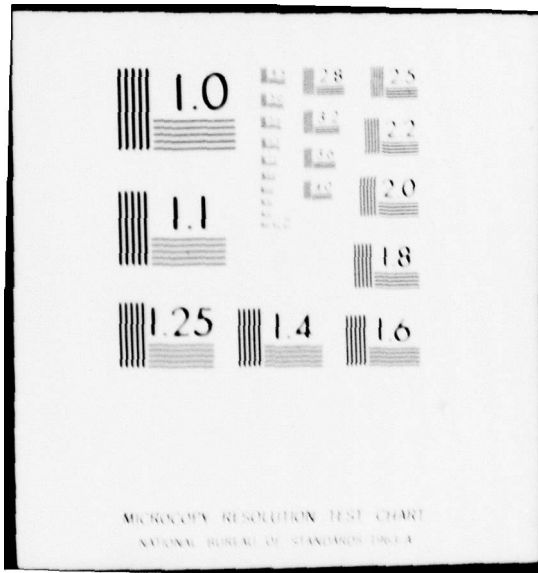
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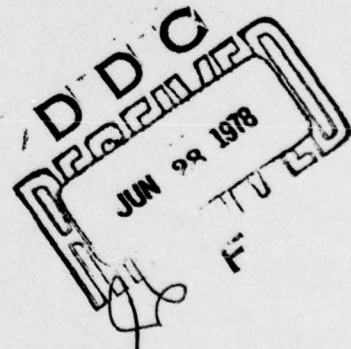
6 SPECIALIZED PIPELINE EQUIPMENT.

10 Ben Hanamoto

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PREFACE

This report was prepared by Ben Hanamoto, Research General Engineer, Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering (USA CRREL).

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Technical review of this report was done by Kevin L. Carey of USACRREL.

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## SPECIALIZED PIPELINE EQUIPMENT

by

B. Hanamoto

### INTRODUCTION

The construction of the 800-mile Trans-Alaska Pipeline from Prudhoe Bay on the North Slope and Beaufort Sea to the terminal at Valdez on the Gulf of Alaska is a project unlike any that has been undertaken before. The combination of varied arctic terrain conditions, severe climatic conditions, conservational and environmental restraints, rigid scheduling, and a complex management-contractor system makes this a unique venture.

The partitioning of the pipeline into five sections, each with a prime contractor, has placed a requirement on each section of having on hand all equipment and machinery needed to complete all phases of the pipeline construction. The contractor in section 5, Morrison-Knudsen, responsible for the terminal at Valdez and the line north for about 150 miles, is utilizing over 1500 pieces of equipment of which 600 are classified as heavy equipment<sup>1</sup>. The total amount of equipment on the entire line is estimated at over 2500 pieces of heavy equipment (dozers, backhoes, cranes, scrapers, dump trucks, etc.). This total includes the usual pieces required for trenching, earth moving, and pipe handling, as well as specialized items for pipe preparation and finishing. Some of the specialized equipment are newly designed prototypes with not all the bugs entirely eliminated. Also, some of the equipment is overly designed in complexity and sophistication and underdesigned to cope with the harsh arctic environment.

The varied terrain conditions, including those encountered only in the north (tundra, muskeg, permafrost, and areas of deep thaw and unstable ground), present varying demands on the types of equipment to be used. The restrictions placed by environmental and conservational considerations on the allowable changes and modifications to the terrain add to the already complex construction task. Two types of terrain have to be considered, with conditions where the soil is classified as either thaw stable or thaw unstable. In a stable soil, thawing of the surrounding ground does not bother the stability of the pipeline. In this type of soil, below-ground pipe installations using conventional burial methods are employed. However, in unstable soil, the thawing of the surroundings causes settling and affects the stability of the line; therefore, the above-ground mode of pipe installation is used. The two modes are divided about 50-50.

The above-ground pipeline requires vertical support members (VSM's) and H-bents or support crossbars with sliding pipe saddles (Fig. 1) and anchors (Fig.2) at each of the support members. The total number of VSM's is estimated at 80,000. They are 18-in. (457-mm-dia) piles driven

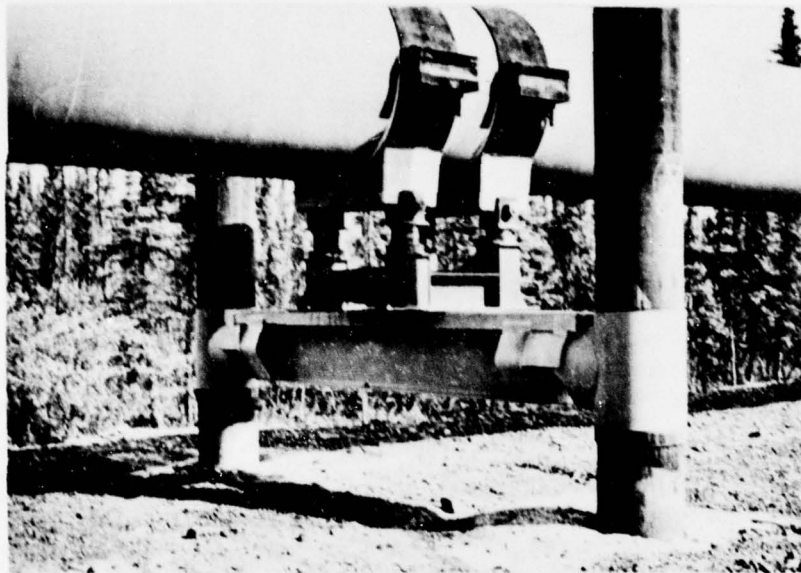


Figure 1. Pipe Saddle Support at Vertical Support Members.

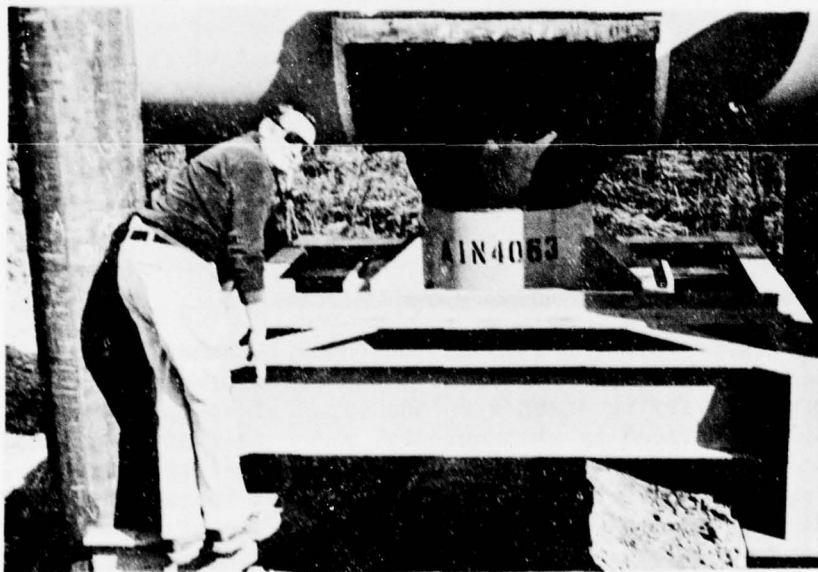


Figure 2. Pipe Anchor Support at Vertical Support Member.

or installed in predrilled holes (Fig. 3), depending on the soil conditions. Installing VSM's is said to deviate the most from warmer climate pipeline construction practices".

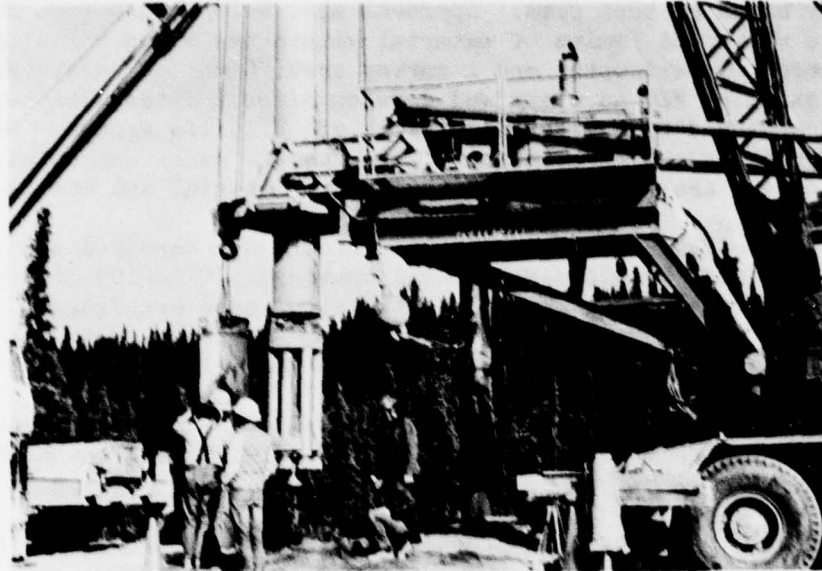


Figure 3. Drilling, Predrilled Holes for Vertical Support Members.

The objective of this paper is to give a description of some of the specialized equipment used in the construction phase of Trans-Alaska Pipeline. The area of specialization is the pipe preparation before welding and one area each in below and above-ground pipe installation.

#### CONSTRUCTION SEQUENCE

To give a brief overview of the construction task for the pipeline, the construction sequence and observations of a Field Surveillance Officer (FSO) for the State of Alaska Pipeline Coordinator's Office will be presented (personal communication). The construction sequence is for a 10-mile stretch on state land. It is assumed that a preliminary survey and general route selection have been completed by the Alyeska Pipeline Service Company, and approved by the General Technical Staff of the State of Alaska Pipeline Coordinator's Office, and that the notice to proceed has been given. The sequence of a construction phase of the pipeline follows:

##### Above-ground construction (Vertical Support Members)

A. Two each of materials and disposal sites are requested. Material sites for workpads and spoils disposal sites are tentatively

selected by Alyeska geologists. Layout drawings are prepared and legal descriptions issued. Permit is requested, reviewed and land/material sale is completed. Time to complete: 30 days. Quality of material is checked by means of test pits. Approval must be obtained from State FSO to explore value and limits of material within the sites. Equipment and men required: 1 helicopter and 1 survey crew; time: 2 days. Permit/field memo is issued by FSO to clear and develop sites. Sites must be acceptable and approved by Environmental/Fish and Wildlife groups. Based on above information and restrictions placed on the owner companies, clearing and development are allowed to start at both material and disposal sites.

B. Right-of-way construction zone widths are surveyed and staked in accordance with previously approved drawings. Clearing limits are established at the same time the construction zones are flagged. Equipment and men required: 1 helicopter and 1 survey crew; time: 2 weeks.

C. Field memos are issued on a foot-by-foot basis for clearing, with consideration for environmental, fish and wildlife, and aesthetic concerns.

D. Slash, over-burden and undesirable material are either burned or taken to disposal sites as provided by stipulations.

E. Clearing is started (for an average 10-mile spread). Equipment: 3 bulldozers, 6 support vehicles (fuel man hauls, etc), 1 hydroax, 1 burn pit; men: 15; time: 3 weeks.

F. Workpad construction begins after separate approval by FSO on a foot-by-foot basis. Restaking must be done prior to construction since clearing has eliminated limit markers.

G. Workpad material hauling starts (for an average 10-mile work spread). Equipment: 12 scrapers, 6 belly dumps, 4 (9.2 m<sup>3</sup> 12 yd<sup>3</sup>) front-end loaders, 5 bulldozers, 10 support vehicles (pickups, mechanics trucks), 4 motor patrols (blades), 2 rollers (vibrators); men: 58 construction type and 2 survey crews; time: 100 days.

H. Resurvey is conducted for VSM location; men: 2 survey crews for 10 days; FSO to inspect and issue field memos.

I. VSM equipment (Fig. 4) is installed. Equipment: 4 drill rigs, 8 support vehicles; men: 46; time: 75 days.

J. Pipe is welded. Equipment: 6 welding skids, 10 support vehicles, 6 side-boom tractors, 1 pipe bender with support vehicle; men: 60, time: 30 days.



Figure 4. Vertical Support Member Installation.

K. VSM support is placed and pipe is intalled (Fig. 5). Equipment: 1 crane, 4 side boom crawlers, 6 support vehicles; men: 8 and 1 survey crew; time: 10 days.



Figure 5. Vertical Support Member Supports; Installation of Pipe.

L. Pipe insulation is installed (Fig. 6). Equipment: 1 module handler, 1 unfolder, 1 manipulator, 2 mobile cranes, 6 support vehicles; men: 20; time: 30 days.

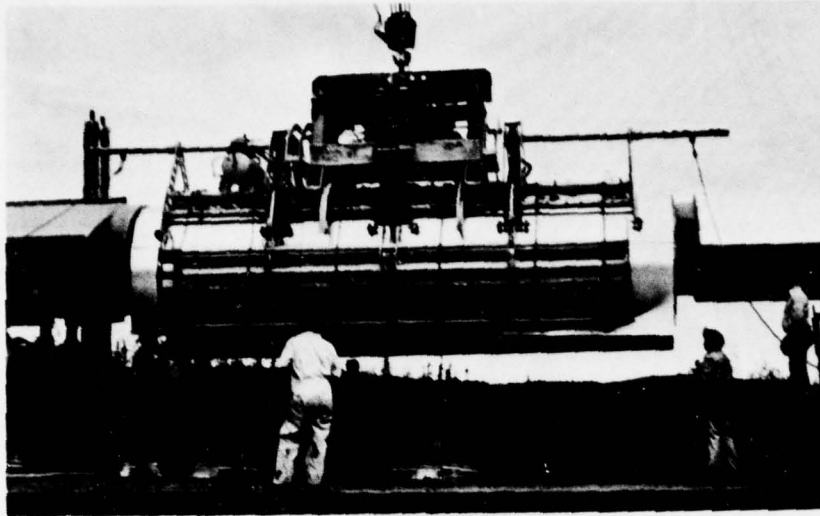


Figure 6. Pipe Insulation.

Below-ground pipe installation

Sequence items A-G under above-ground construction apply. In addition, the following are required:

H. The centerline of trench is resurveyed. Equipment: 1 support vehicle; men: 1 survey crew; time: 5 days.

I. Ground is excavated for standard burial of pipe. Equipment: 4 backhoes, 1 small bulldozer, 4 support vehicles; men: 16; time: 53 days.

J. Bedding material is prepared for pipe burial (Fig. 7). Equipment: 2 crusher plants/screen plants, 4 front-end loaders, 4 bulldozers, 4 scrapers or 40 yd<sup>3</sup> belly dumps, 8 support vehicles; men: 35; time: 40 days.

K. Bedding and padding (including spoils disposal) are placed. Equipment: 1 pickup, conveyor, 2 front-end loaders, 1 small bulldozer, 2 compactors, 15 20-yd<sup>3</sup> dump trucks, 1 motor pool; men: 35; time: 35 days.

L. Pipe is installed with welding done above ground (Fig. 8). Equipment: 6 welding skids, 10 support vehicles, 6 side-boom crawlers, 1 bender unit with support vehicle; men: 60; time: 30 days.

M. Pipe is taped (Fig. 9). Equipment: 2 taping machines, 2 heaters, 2 pipe cleaners, 6 side-boom crawlers; men: 25; time: 14 days.



Figure 7. Material Site.



Figure 8. Pipe Welding.

N. Cathodic protection is installed (Fig. 10). Equipment: 1 side-boom crawler, 1 anode skid; men: 4; time: 28 days.

O. Backfilling of the trench is done using existing material (Fig. 11). Equipment: 2 bulldozers, 2 front-end loaders, 4 support vehicles; men: 12; time: 10 days.

The data above do not include:

1. Valve sites and installation
2. Revegetation



Figure 9. Pipe Taping.



Figure 10. Cathodic Protection Installation.

3. Cut-and-fill operation for other than semilevel area. Minor hills/valleys are included (not over 60 ft in height from level on both sides)

4. Final test (hydrostatic) of completed line





Figure 11. Trench Backfilling.

#### SPECIALIZED EQUIPMENT

The variety of equipment needed can be seen from the foregoing description. For both the above- and below-ground pipe installation, specialized equipment is being used, and the following describes the equipment and machinery used, in three construction phases of the pipe installation.

##### Pipe Bending

The changes in elevation as well as in direction of the pipeline require the bending of the 80-ft (24.4-m) welded-section straight pipe delivered to the installation site. An average of 90 to 100 bends/mile have been made in many previous pipelaying projects<sup>3</sup>. In Alaska the number of bends is expected to be higher than 100/mile (1609 m). After the survey determines the degree of bend at any given location, the "overbend," "sag," or "side bend" is marked on the pipe section. The bending unit travels the line, bending each section of pipe as required.

The general design specifications for the bender require it to have a bend capability of up to  $13.5^\circ$  for 48-in. (122-cm) maximum-diameter pipe, of wall thickness from 0.462 in. (1.17 cm) to 0.750 in. (1.90 cm). The equipment is to operate in temperatures down to  $-30^\circ\text{F}$  ( $-34^\circ\text{C}$ ). Four 14-in. (35.6-cm)-diam hydraulic cylinders, capable of withstanding 4000 psi ( $2.76 \times 10^7 \text{ N/m}^2$ ) pressure, supply the actual bending force. The stroke capability of the cylinders is about two times as much angle overbend as the maximum bend angle. A generator supplies power to operate the unit as well as power to operate the heaters for the bender engine, bender

cylinders, bender hydraulic fluid tank, and mandrel hydraulic fluid tank. A heated cabin is also provided for the machine operator. All contact surfaces on the bender are coated with a thin film of polyurethane to minimize damage to the protective coating on the pipes while being bent. Although heavy-walled pipe may be bent without any internal backup, the thin-walled, high-tensile pipe being used for this project makes it necessary to use a mandrel to support the inside of the pipe being bent (Fig. 12). The mandrel sits in the bending machine stiffback shoe until the pipe joint is brought through the pin-up side into the machine (Fig. 13).

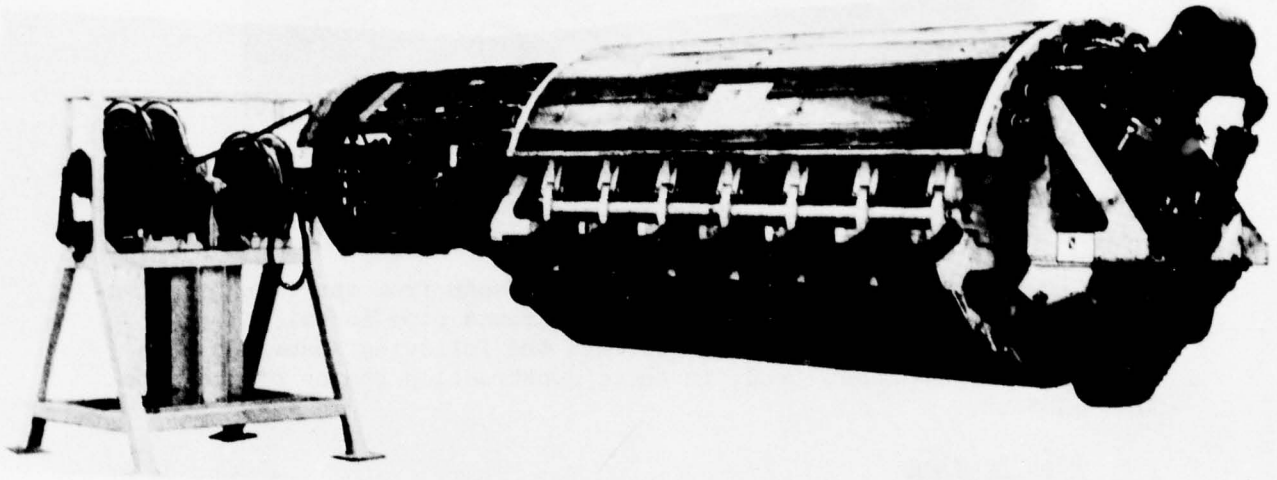


Figure 12. Pipe Bending Mandrel.

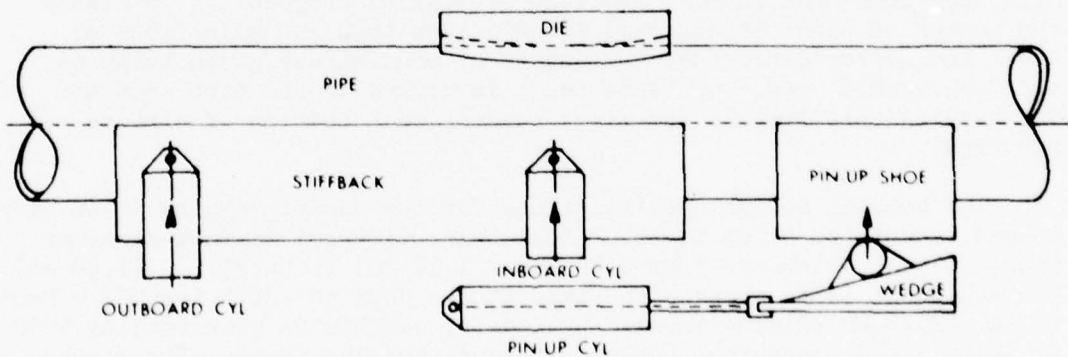


Figure 13. Pipe Bender System Sketch.

The operation of the mandrel is described below with the aid of Figure 14. After the pipe is brought in, the mandrel moves under its own power into the pipe on large elastomer-coated drive wheels (2, Fig. 14),

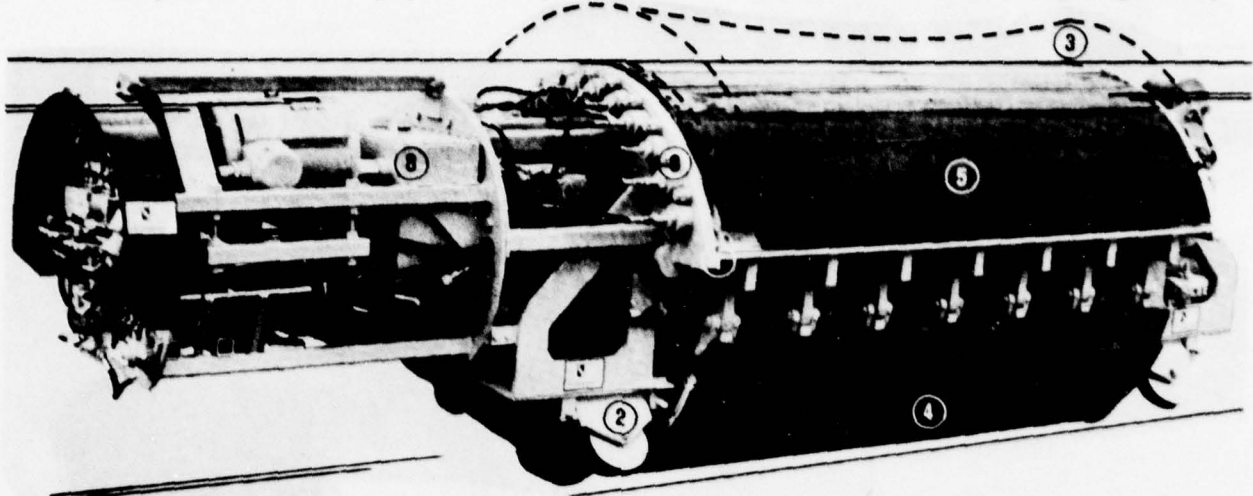


Figure 14. Mandrel Operation.

driven by hydrostatic motors, and located under the bending die (3, Fig. 14). The expander sections (4, Fig. 14), joined together by flat steel springs, are extended by individual hydraulic cylinders and locked into position. External, elastomer-coated steel strips (5, Fig. 14) on top of oil filled packers (6, Fig. 14) protect the pipe and absorb and distribute the buckling stresses. The mandrel "packs" the pipe as it bends around the die, preventing the pipe from buckling and flattening. After lowering the stiffback and pin-up shoe, the mandrel is released by retracting the expander sections. As the pipe is pulled back by the winch one increment, the mandrel is moved forward the same distance. The pipe is now ready for the next bend increment. All operations of the mandrel are remotely controlled from a console. The prime mover (8, Fig. 14) is an electric hydraulic system. Some specifications for the 48-in. (1219-mm) mandrel are: height 172 in. (4,369 mm) and weight 12,000 lbs (5443 kg). The units used on the pipeline are produced by the CRC Crose International Incorporated of Houston, Texas.

The pipe bender (Fig. 15) is also produced by CRC and its operation is described with the aid of Figure 16.

a) The pipe is moved into the machine and positioned under the die at the point where the bend is to start, 3, Fig. 16.

b) The mandrel on the inside of the pipe is expanded, 2, Fig. 16.

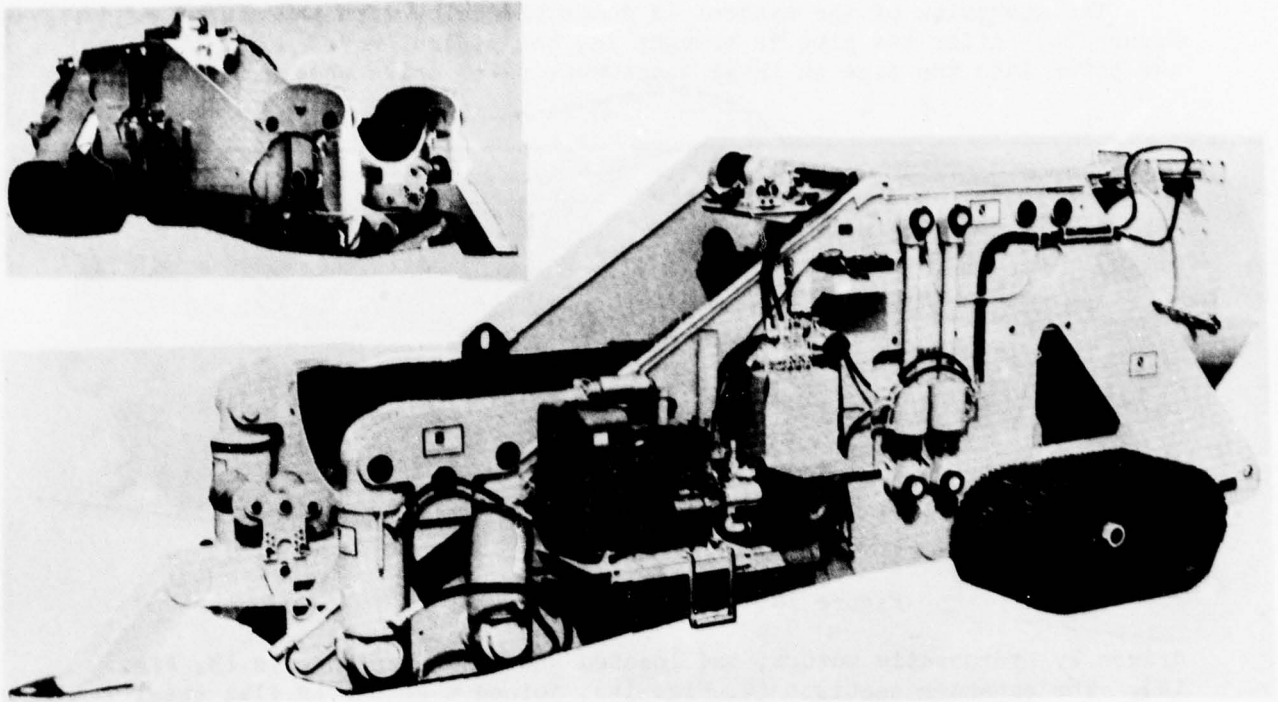


Figure 15. Pipe Bender.

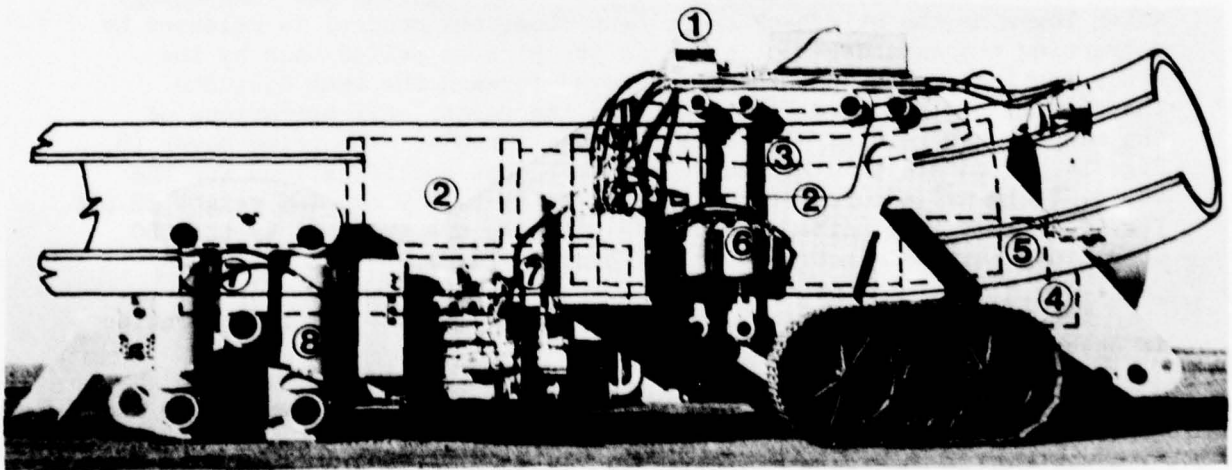


Figure 16. Bender Operation.

c) The pin-up cylinder forces the wedge, 4, Fig. 16, under the pin-up shoe, 5, Fig. 16, to raise it and to secure it against the pipe.

d) The inboard cylinder, 6, Fig. 16, on the stiffback, 7, Fig. 16, pulls the stiffback up and pushes the pipe against the die.

e) With the die acting as the fulcrum, the outboard cylinders, 8, Fig. 16, pushes the end of the stiffback up, bending the pipe.

f) After each bending operation, the pipe is moved through the machine an increment and the operation is repeated until the desired angle of bend is achieved.

g) The pipe is always moved toward the pin-up shoe when bending, thus keeping a straight portion of the pipe in the stiffback.

h) The longitudinal weld in a bend section should be near the horizontal axis of the pipe.

i) The maximum radius of the bend for field cold bends will be 30 pipe diameters, 1440 in. (36.6 m).

j) Tangents approximately 6 ft in length are preferred on both ends of cold bends.

k) The pipe diameter shall not be reduced at any point by more than 2-1/2% of the nominal diameter and the completed bend shall pass the specified sizing pig.

Some specifications for the bender are:

Power unit	Diesel, 108 hp (80,500 W) at 2350 rpm
Hydraulic system	3000 psi (2.109 x 10 <sup>6</sup> kg/m <sup>2</sup> )
Valving	2 in. (5 mm)
Winch	Hydraulically driven

Dimensions:

Height	133 in. (3.38 m)
Length	407 in. (10.34 m)
Width	144 in. (3.66 m)
Weight	129,900 lb (58,920 kg)

Capacities (with mandrel):

Maximum bend	15° in 40 ft (12 m) length 0.6°/arc ft (0.3048 m)
Average radius	100 ft (30.5 m)

The bending operation along section 3 near Fairbanks is shown in the following figure (Fig. 17).

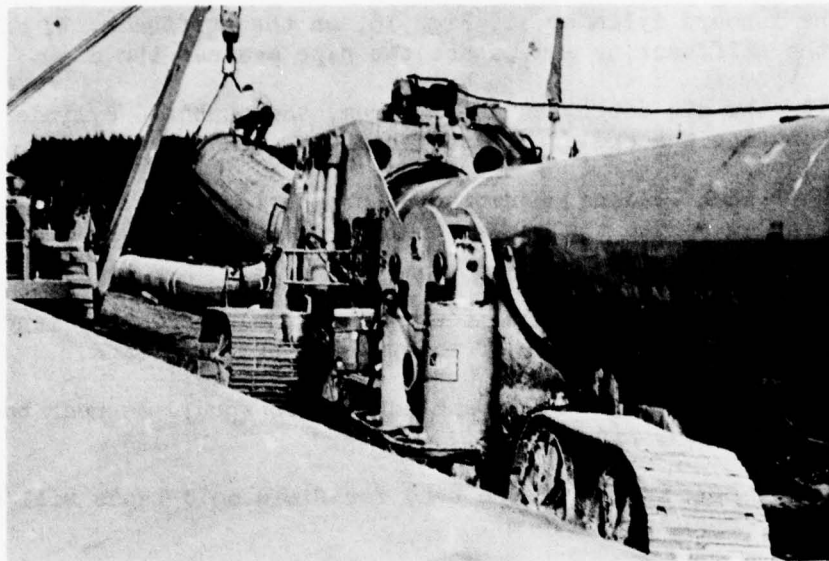


Figure 17. Bending of Pipe.

#### Pipe Taping

The pipe-taping machine is basically used to apply varying widths of protective tape to below-ground pipe. The taping units used on the line were produced by Mid-Continent Pipeline Equipment Company of Houston, Texas. The system is composed of two subsystems: the prime and tape machine, and the pipe-heating system. In observations along section 3 (Fairbanks area) and section 4 (Ft. Greely area), propane-fired heaters were used (Fig. 18). Gangs of three heaters supported and moved by side-boom crawlers (Fig. 19), with fuel tanks (Fig. 20) mounted on the tractors, heated the pipe ahead of the taping unit. Two gangs of heaters advancing ahead of the taper heated the pipe to between 230° and 250°F (110° and 121°C), the required bonding temperature of the protective tape being used. With all units of the taping operation working properly, pipe taping rates of 12 ft/min (3.7 m/min) can be maintained.

The complete taping operation is shown in Figure 21, with a rotary brush pipe cleaner in the front (background) followed by the heaters and the taper (foreground). The crew for this operation stopped operations at the end of October 1975 because the heaters could not keep the pipe hot enough for the following taper (personal communication). An induction heating system is also available which consists of a diesel engine power

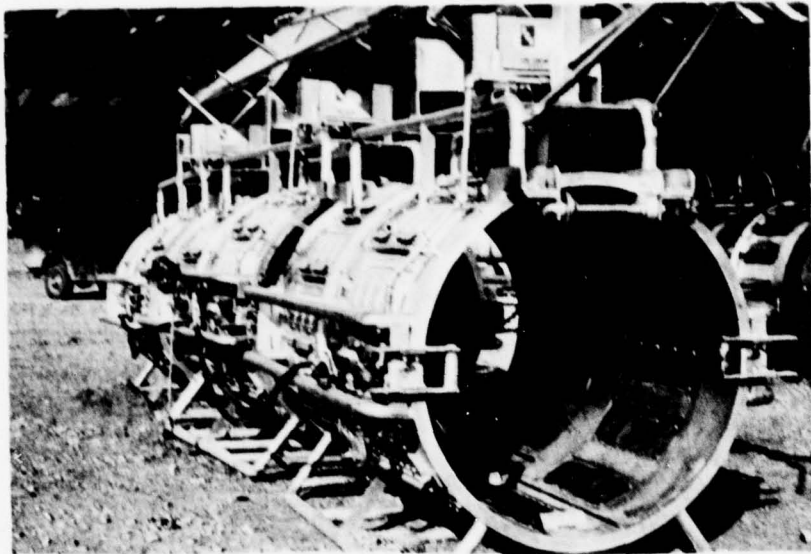


Figure 18. Propane heater.



Figure 19. Heater gang.

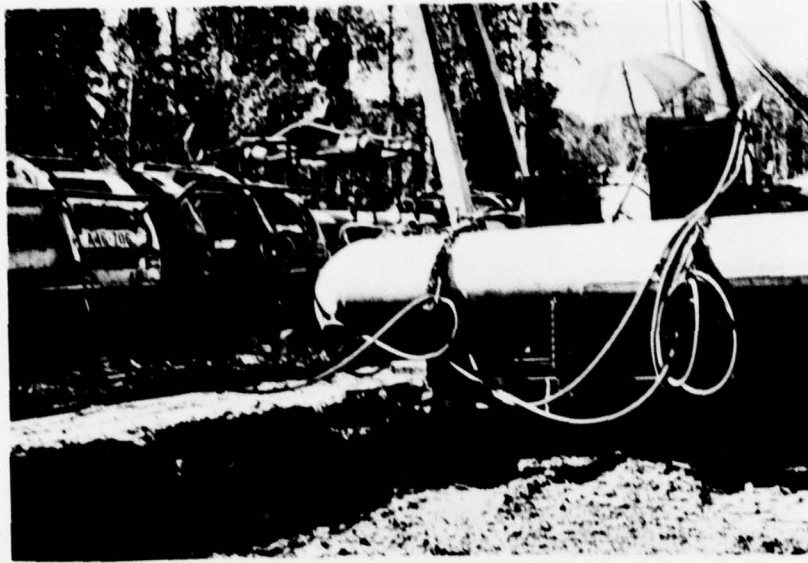


Figure 20. Propane Fuel Tank.



Figure 21. Pipe Taping Unit in Operation.

source, a generator, and a heat station comprising transformers, capacitors, voltage regulator and induction coil heaters. When used, this unit is mounted directly ahead of the prime and tape unit.

The prime and tape machine (Fig. 22) is mounted behind the crawler wheels used to move the frame on which the prime and tape machine is mounted. The priming head, located immediately behind the crawler wheels, is operated through a series of chains and sprockets that rotate the primer cage. Priming rugs are attached to the cage to spread the primer (approximately 3 mils thick) evenly over the entire surface of the hot pipe.



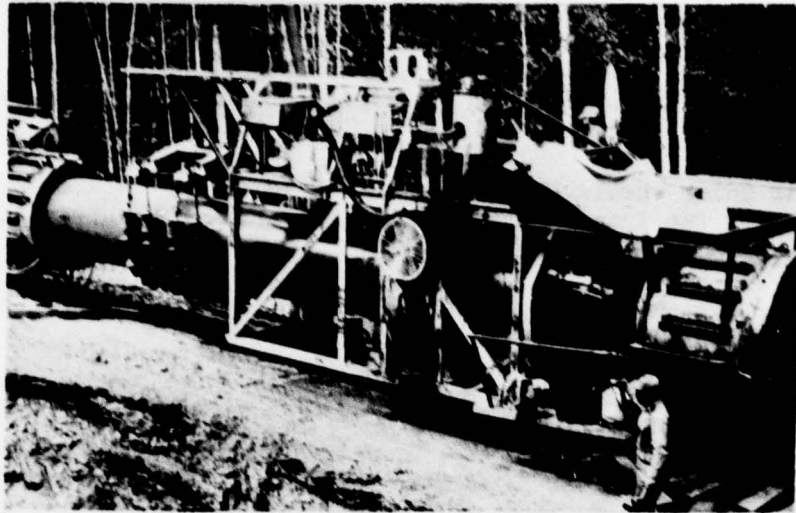


Figure 22. Prime and Tape Machine.

A fan system removes excess primer fumes. There is a 6-ft drying gap between the priming system and the taping station. The taping station is also operated by chains and sprockets and a variable speed control device. The speed control device controls the tape wrap overlap and the speed of tape application and is located at the rear of the priming station. The entire unit is held coaxial to the pipe by means of a stringer, through which cables, held in tension by the side boom tractor, are inserted. The major integral components of the prime and tape wrap unit are the following:

1. Frame - The unitized frame serves as the structural support for all the components. The frame also has a hinged operator platform on the right-of-way side.
2. Priming station - A rotating circular primer cage is located near the center of the frame. Primer rugs attached to this cage distribute the primer on the pipe. A 30-gal (113.6-l) primer tank with an internal agitator feeds the primer onto the pipe for spreading by the rugs.
3. Taping station - A rotating taping station is located on the rear of the frame. As the wrapping head rotates, tape is automatically spiraled onto the pipe. Two tape assemblies, which include the tape arm, rewind arm and pressure roller, are furnished. A roll of tape is placed on each arm, and as the tape is fed onto the pipe, the backing paper is automatically rewound for eventual discard. Then the tape is pressed onto the pipe by the pressure rollers.

4. Upper drive assembly - Four chain and sprocket driven polyurethane crawler wheels allow the machine to be driven along the pipe. A lower set of crawler wheels can be utilized to provide extra traction on inclined terrain.

5. Rear idler wheels - Upper and lower idler wheels are located near the rear of the frame. These keep the machine concentric with the pipe.

6. Power system - A diesel engine mounted on top of the frame provides the necessary power for the unit.

Some controls for the taping machine include:

1. Wheel-drive transmission - Three gear ratios are provided for selective control of forward line-travel speed. Reverse is also provided for backing the unit when necessary.

2. Engine clutch operating lever - This control starts or stops the taping head, primer head, and power to the drive wheels simultaneously. The hydraulically-driven blower and exhaust fans continue to run while the engine is running since the hydraulic pump is driven directly off the rear of the engine.

3. Fan circuit - Fan and blower are connected in series. a) Fan circuit relief valve: this valve is set for 1500 psi ( $1.03 \times 10^7$  N/m<sup>2</sup>) maximum pressure, b) Directional control valve: this valve starts or stops the fan and blower, c) Exhaust fan speed control valve: this valve controls flow in the hydraulic circuit for slowing the fan as the valve is opened.

4. Primer flow control valve - There are two controls for primer flow: the master flow valve and a fine control valve for fine adjustment of primer being applied to the pipe.

5. Crawler wheel clutch - Engages or disengages the drive crawler wheels.

6. Wrapping head clutch - Engages or disengages the wrapping station.

7. Ratchet, idler wheel - Is engaged to hold machine true with pipe so that tape lap will not be off.

8. Wrapping head speed control - The speed of rotation of the wrapping head relative to the speed of the machine along the pipe is controlled by the ratio control knob on the variable speed control

device. In effect, this adjustment controls the overlap of the tape in bends and also makes possible the use of various width tapes.

A general view of the taping operation is shown in Figure 23. The taping operation near the Chatanika River north of Fairbanks in May of 1976 used an after burner heater following the taper for ensured tape bonding (Fig. 24).



Figure 23. Taping Scene, setting up.

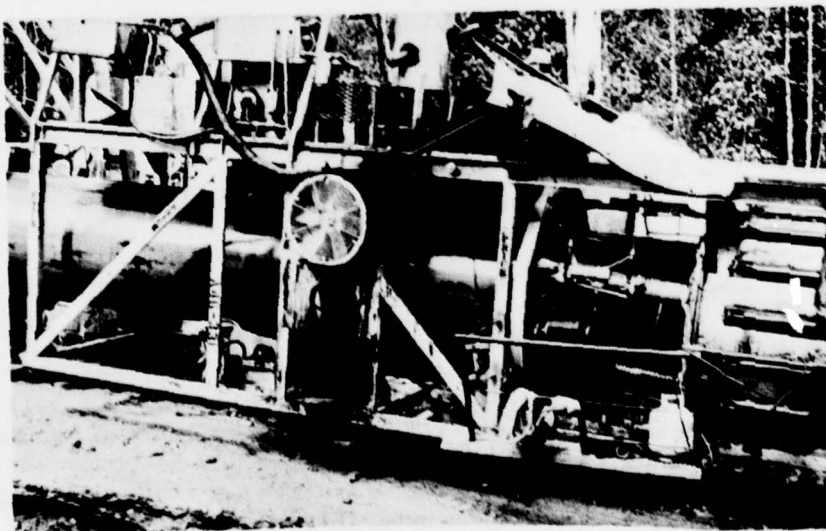


Figure 24. Taping After-burner.

### Above-Ground Pipe Insulation

The above-ground pipe insulating material is installed after the welded sections of the pipe have been installed on the vertical support member (VSM) and crossbar sliding saddle or anchor support members (Fig. 25). The insulation consists of sheets of 15-ft (4.57-m-wide) by 24-ft

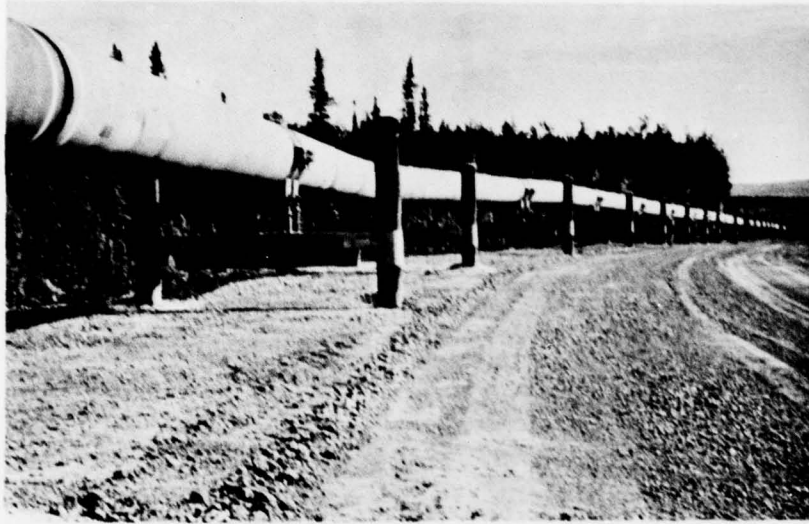


Figure 25. Above-Ground Pipe Ready for Insulation.

(7.32-m-long) by 3-3/4-in. (9.52-cm-deep) fibrous blankets bonded to a galvanized steel outer jacket weighing about 700 lb (3114 N). A molded fiberglass insulating module is also installed at each of the VSM saddle or anchor points. The module halves are approximately 5 ft (1.5 m) high, 3.5 ft (1.1 m) wide and 12 ft (3.7 m) long and weigh 400 lb (1779 N). They consist of a urethane foam core with a fiberglass reinforced plastic inner and outer skin. Both insulators are supplied by the Owens-Corning Fiberglas Corporation. The two main pieces of insulation-handling and installing equipment are the unfold and manipulator of the large insulation sheets. A module installation unit is also required. The units are produced by the American Chain and Cable Company of Salem, Illinois.

The module halves are emplaced by means of a crane and a holding device. A module handler has been used which consists of a self-contained vacuum system mounted on a load beam from which two vacuum lifting pads are suspended. A remote 460-volt, 3-phase, 60-hz power source is required. Less sophisticated, but as effective, a crane and a spreader bar and hook system was also being used (Fig. 26).

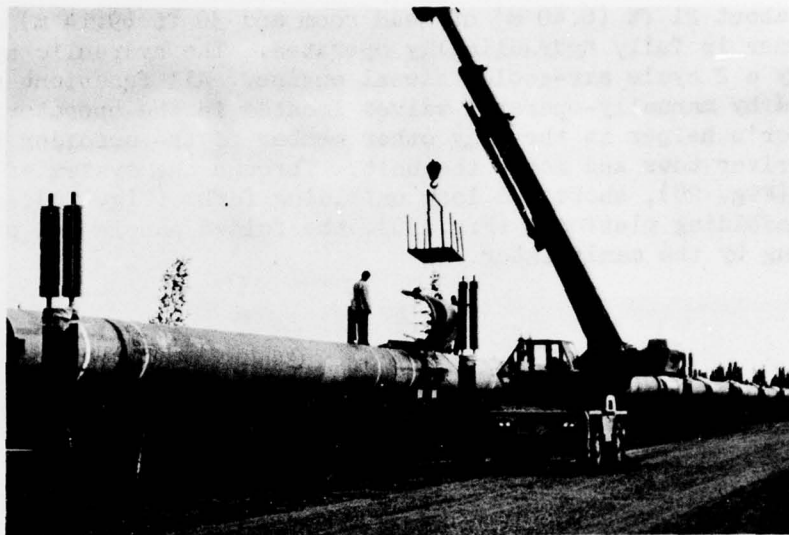


Figure 26. Module Installation.

The unfolder, as the name implies, performs this function on the pallet-mounted sheets which are folded into approximately 8-ft (2.44-m) x 24-ft (7.32-m) panels, stacked 8 panels to a pallet (Fig. 27).



Figure 27. Stacked Panels of Folded Insulation (Background).

Highway hauling restrictions dictated the 8-ft (2.44-m) width which required folding of the sheets. The unfolder is mounted on an 8-ft (2.44-m-wide) and 40-ft (12.2-m-long) flat bed trailer. The operating space

requires about 21 ft (6.40 m) of head room and 30 ft (9.14 m) of width. The unfolder is fully hydraulically operated. The hydraulic system is powered by a 2 cycle air-cooled diesel engine. All functions are controlled by manually-operated valves located in the operator's cab. An operator's helper is the only other member of the unfolder crew. A tractor driver tows and moves the unit. Through the system of a raising platform (Fig. 28), short and long unfolding forks (Fig. 29), and movable unfolding platforms (Fig. 30), the folded panels are prepared for lifting by the manipulator.

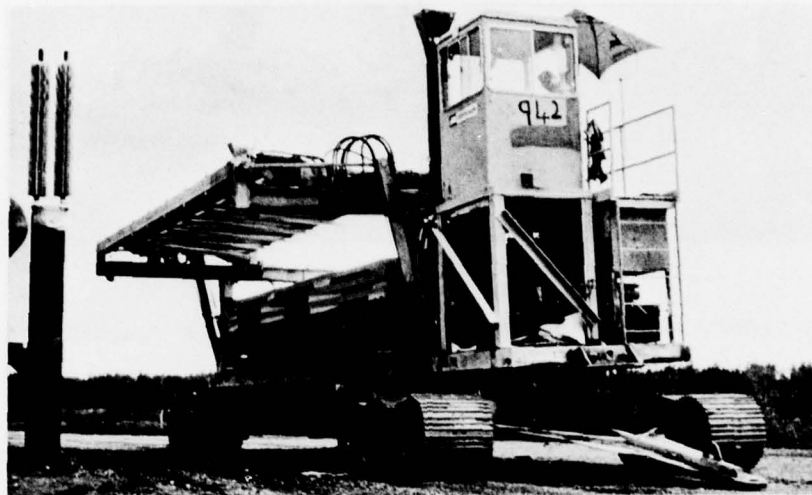


Figure 28. Unfolder and Raising Platform.

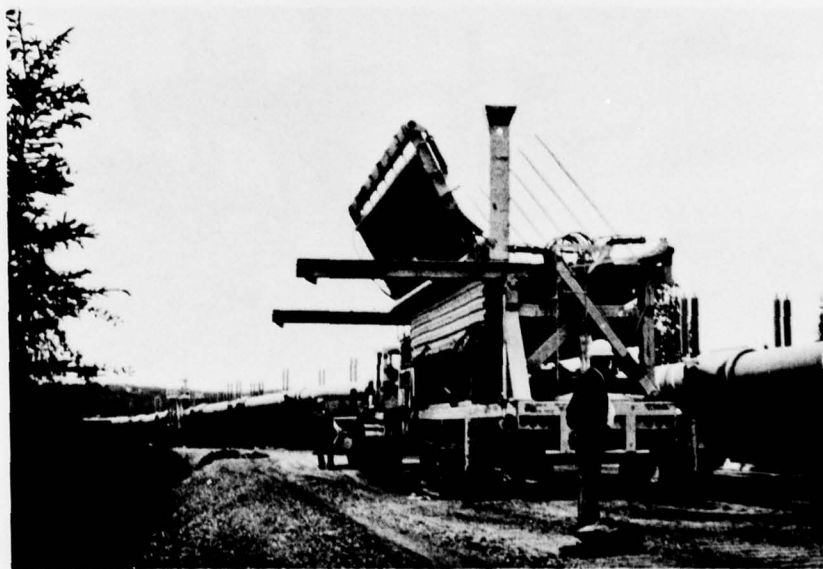


Figure 29. Unfolding Forks.



Figure 30. Panel Ready for Lifting.

The manipulator is suspended from a mobile crane hook (Fig. 31). The unit is totally self-contained with hydraulic unit, vacuum system,

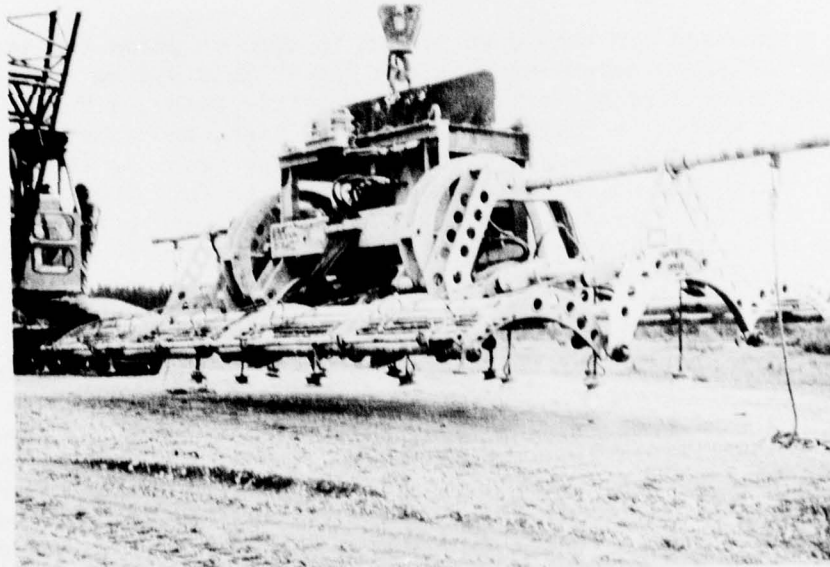


Figure 31. Manipulator Suspended from Mobile Crane.

compressed air blow-down system, and controls as one unit. The remote unit is a 460-volt, 3-phase, 60-hz electrical power source. The push-button control box is mounted in the crane cab. The electrical power and control cables are connected to the manipulator through cable reels

mounted on the crane boom. The unit weighs 12,000 lbf (53,378 N). The lifting of the unfolded insulation sheets is accomplished through four rows of vacuum pads. The vacuum pump is an oil-less rotary vane-type pump with vanes made of precision-ground hard carbon. The vacuum system incorporates two parallel circuits with each circuit piped in an alternating manner to every other pad. The intermediate pads are connected directly to the main vacuum control valve. The outer pads are connected to the main control valve through two selector valves. The central pads are connected to the main control valve through two other selector valves.

With the vacuum pump running, vacuum is directed to the pads when the vacuum control valves are de-energized. With the vacuum pumps running and the vacuum control valve energized, exhaust air is directed to the pads supplying air pressure required for quick load release. Each vacuum pad is equipped with a 3-way manual hand-operated shut-off valve for individual selectivity. The vacuum system is set up so that vacuum is directed to selected pads to prevent loss of load during an electrical power failure. This vacuum is supplied by a vacuum reserve system. The main vacuum control valve is a single solenoid type, direct-acting, 4-way, 2-position valve. The valve is in the vacuum "on" position when the solenoid is de-energized and in the vacuum "off" position when the solenoid is energized.

The compressed air blow-down system is used to purge the vacuum line of any moisture accumulated in the line. This system consists of an air compressor directly driven by an electric motor, a Tanner (trade name) de-icer system, a 30-gal (113.6-l) air tank, and valving. Air from the compressor is charged with the de-icing agent as it enters the air tank. Pump-up time to charge the air tank to full pressure of 95 psi ( $6.55 \times 10^5 \text{ N/m}^2$ ) is 3.5 minutes. Vacuum lines are purged after each lift to prevent moisture accumulation or, if temperatures are below 32°F (0°C), to prevent freezing in the lines.

The hydraulic system provides two circuits, one to wrap the panels around the pipe and another to rotate the wrapped panel so that the seam is accessible for riveting. The system incorporates a 7.5-gal/min (26.5-l/min) Hydrel gear pump rated at 2500 psi ( $1.72 \times 10^7 \text{ N/m}^2$ ), directly driven by a 15- (11.2-kw), 1170-rpm electric motor and mounted on fluid reservoir. All hydraulic control valves are mounted on the reservoir (main relief, pump, directional control, holding flow control and bleed-off valves), with all piping placed inside the reservoir to reduce external leakage. Four cylinders, each with a 3.25-in. (8.26-cm) bore, 2-in. (5.08-cm) rod and 25-in. (63.5-cm) stroke, perform the wrapping operation. Two cylinders are used per side. After the panel is lifted (Fig. 32), and as it is being swung over the pipe, the panel is bent into a U shape (Fig. 33). After placement on the pipe (Fig. 34), the panel is wrapped around the pipe (Fig. 35). Each pair of cylinders is



controlled by a separate set of valves, so that both sides may be operated at the same time or individually. After the panel is wrapped on the pipe, the seam-rotating cylinders are activated to rotate the seam 90° for the seam riveting (Fig. 36). This completes the manipulator's function and it returns to the unfold to pick up the next panel. All control functions are tied in with appropriate blue and red high-intensity flashing strobe lights. Blue indicates a "go" system. The red "stop" strobe lights are wired in parallel with a safety "yelper" to alert the ground crew. Two guyline operators are required during the swing-over and positioning sequence. The final operation is the sealing of the panel joints (Fig. 37). The finished line (Fig. 38), shows an in-line valve and the closed cycle ammonia refrigeration system inside the VSM.

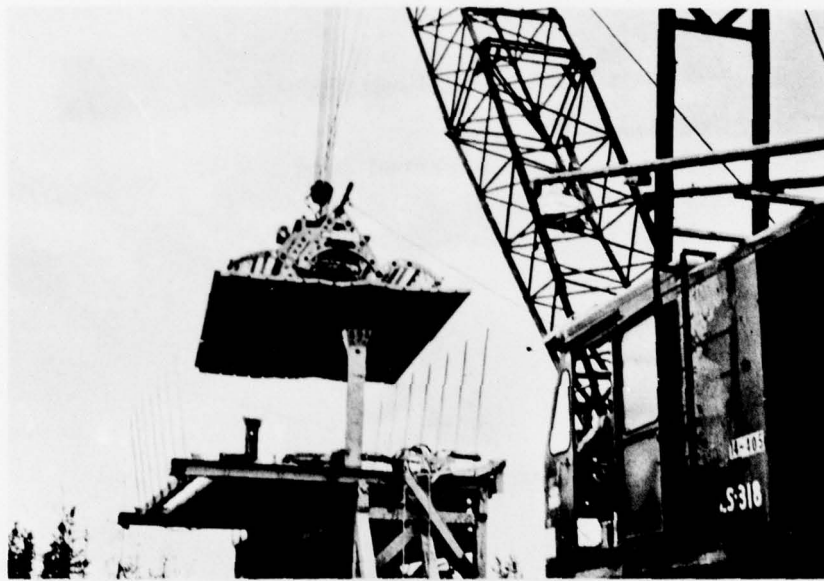


Figure 32 Lifting Panel.

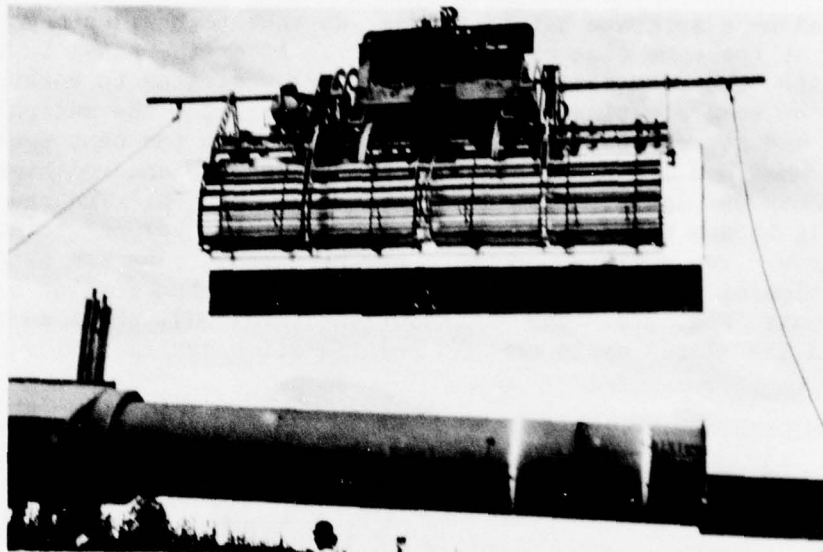


Figure 33. U - shaped Bend.

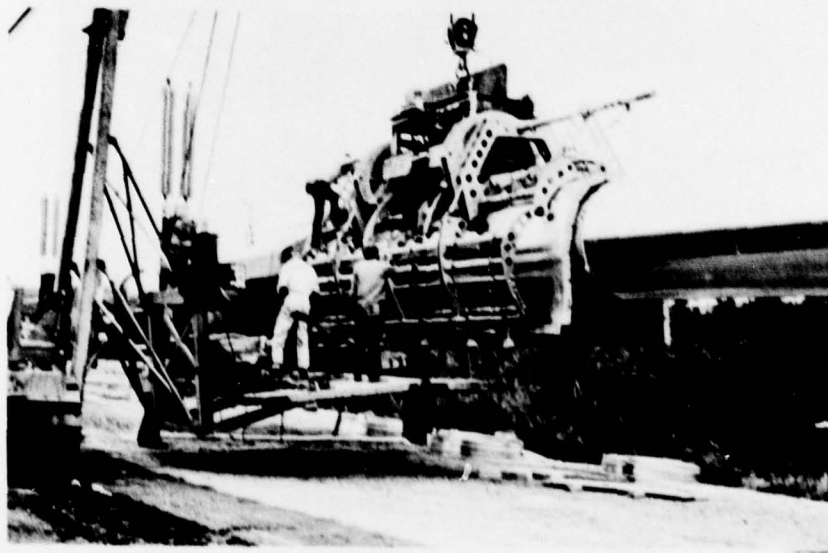


Figure 34. Insulation Panel on Pipe.

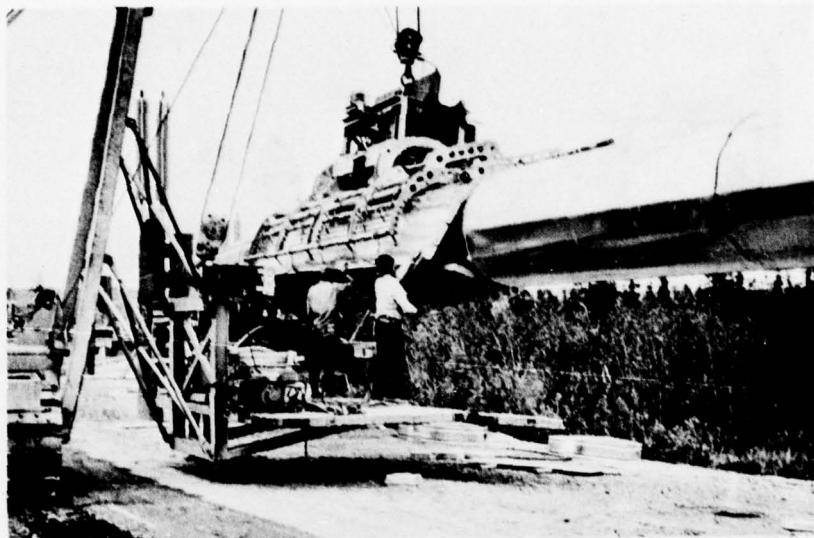


Figure 35. Wrapping Panel Around Pipe.

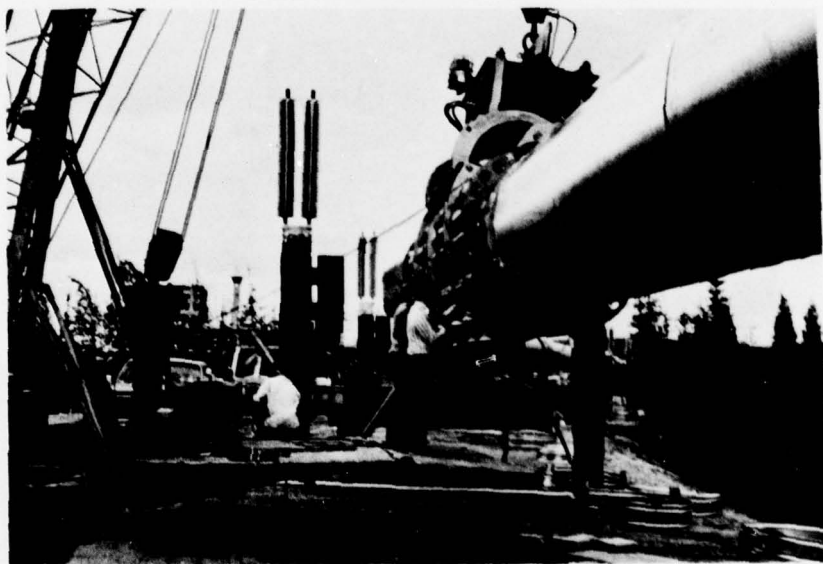


Figure 36. Riveting Seam.



Figure 37. Panel Joint Sealing.

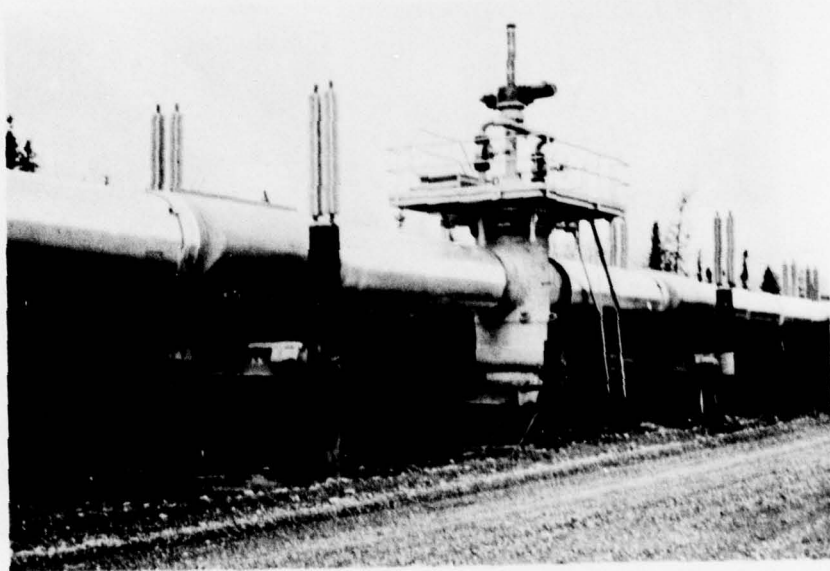


Figure 38. Finished line.

## CONCLUSION

The preceding has presented descriptions of specialized equipment used on the Alaska Pipeline project. The magnitude of the project can be realized if the other general pieces of construction equipment needed for a project such as this pipeline are considered. The total number of items exceeds 8000 units. A schedule calling for the completion of the line and flow-through by 1977, the harsh climate and environment, the environmental and conservational restrictions, the remoteness and isolation of some work camps, and a full work force numbering over 20,000 all add up to a project with unique problems, solutions, construction techniques, and one from which valuable experience and information can be gained for future work in the far north.

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