

NASA/ASM George Washington Symposium

"WELDING, BONDING, AND FASTENING"

Williamsburg, Virginia

May 31, 1972

**N74 30946**

Session 6, Welding Techniques

3. "ELECTROSLAG AND ELECTROGAS WELDING", By Hallock C. Campbell

Director of Research and Technology, Arcos Corporation, Phila., Pa.

The structures described in this paper won't fly,...but electroslag and electrogas welding could well have been used to build the transporter that carries the Apollo/Saturn rocket along its first mile toward the moon; and these processes are used to weld the presses that form NASA vessels, and the storage tanks, ships, barges, bridges, and buildings involved in numerous NASA projects. Not everything NASA touches actually flies.

These two new joining methods perform welding in the vertical position, and therein lies the secret of their impressive advantages in material handling, in weld preparation, in welding speed, in freedom from distortion, and in weld soundness. Once the work has been set in the proper vertical position for welding, no further plate handling is required. Overhead cranes need not be recalled to turn the plates over, as would be required in multi-pass downhand welding. The molten filler metal is held in place by copper shoes or dams, and the weld is completed in one pass.

Comparing a single pass weld in 11-inch plate with the laborious 1200 passes required in a manual weld, makes obvious how many advantages will accrue from single pass welding. Plate preparation requires no U-grooves or complicated bevels with root faces: merely a straight flame-cut edge, to give a 90° butt joint or recently a single-vee joint with open root. The gap to be filled is less than 1¼ inches wide no matter how thick the plates, hence welding progresses rapidly. Commonly some 35 lbs. of metal are deposited per hour by each wire used; in electroslag welding with three wires the deposition rate is over 100 lbs. per hour. Not uncommonly electroslag and electrogas welds are completed in one-fifth the time required by other welding methods.

The great advantage of electroslag welding is weld quality, resulting from metallurgical refining of the filler metal by the slag, and from the directional solidification of the weld from below upwards, rejecting non-metallic impurities into the slag bath. The metal solidifies as a clean sound weld, remarkably free from distortion.

As mentioned already, a weld pool between vertical plates will have to be constrained by dams. For oil and water storage tanks, for structural steel beams, and for various small assemblies, it is sufficient to use thick copper bars on the side of the joint remote from the welding machine, or even on both sides (in consumable nozzle welding). On the working side (or on both sides), water-cooled sliding shoes are used, whose rise is coordinated with the upward solidification of the weld. Into the pocket so created the filler metal

is guided by a snorkel reaching over the top of the near shoe, or by a consumable guide centrally located within the joint gap.

Between plates  $1\frac{1}{2}$  to 5 inches thick or thicker, the process employs an electrically conductive molten slag pool, about  $1\frac{1}{2}$  inches deep, which melts the filler metal and the edges of the plates by its high temperature ( $3000^{\circ}\text{F}$ ), hence the name electroslag welding. In electroslag welding there is no arc once the slag pool has been established.

In welding plates  $\frac{1}{2}$  to 3 inches thick the process is electric arc welding, shielded with  $\text{CO}_2$  or argon gas, hence the name electrogas welding. A small amount of flux is frequently used to improve the surface of the weld, since it lubricates the moving shoe.

To feed wire through a consumable nozzle requires little equipment. Figure 1 shows a weld being set up for demonstration, before view of the nozzle becomes blocked by the copper shoes.

To use travelling shoes and a snorkel, controls are provided which can climb a mast or track placed beside the work. Mechanical controls used earlier for oscillation and dwell have since been replaced by solid state electronics. Figure 2 shows a portable slag/gas machine equipped with one water-cooled shoe, which climbs a standard track. In this case copper backing bars must be preplaced against the far side of the joint to contain the weld pool.

For welds more than 5 or 6 inches thick, two or more wires are fed into the slag by sophisticated equipment which reaches through the joint to hold the far shoe in place. Figure 3 shows a laboratory set-up from the far side. Water and gas connections to the shoe are evident. The arm is free-floating in two horizontal directions, and self-tracking along the joint. One of the first production applications of a 2-or 3-wire machine in this country was that shown in Figure 4, the preparation of plates of HY80 wider than any plates Lukens Steel Co. can roll, to make a blank from which to spin nose cones for submarines.

A typical application of electrogas welding is the welding of storage tanks, such as the group of surge towers at the Oahe Dam in South Dakota. The vertical seams in these towers were all welded with electrogas welding machines which could be mounted on carriages hung from the top of the tank being constructed. Figure 5 shows a cage being swung into position. These tanks were welded with square butt preparation, but current practice for oil storage tanks, whose plates vary from  $\frac{1}{2}$  to  $1\frac{1}{4}$  in. thick, is a Vee groove preparation with root gap  $\frac{3}{16}$  in. backed by a single copper bar (typically 1 in. x 4 in. x several feet long). The angle of vee differs for the several plate thicknesses, to give in each case a face opening  $\frac{7}{8}$  in. across, closed by the water-cooled shoe carried by the traveling machine. A single filler wire is fed into this pocket and protected by inert gas or CO<sub>2</sub> flowing from orifices in the shoe and the wire guide. The wire is oscillated by the equipment to distribute the arc heat uniformly over the weld pool.

A typical three wire application of electroslag welding is that shown in Figure 6, a structural frame destined for a mammoth hydraulic press. Figure 7 shows a 15 inch thick sub-assembly, ready to be joined along two 6-foot seams. Figure 8 will be recognized by ASM members as the cover picture on Metal Progress magazine in December 1967. At this stage one of the lower seams is being completed. Figure 9 shows the completion of the upper seam. Regularly four such seams are completed in five working days, including assembly and disassembly of the equipment. This job welded by submerged arc would take four to six weeks.

Another important application of electroslag welding is the assembly of stainless steel pump casings for nuclear power plants. The circumferential seam in Figure 10 is rotated downwards past the electroslag welder, which stands stationary until the tangent discharge pipe is reached, when rotation is halted and the welding equipment rises.

Repairs to shafts and spindles are commonly made by electroslag welding. Figure 11 shows the weld preparation for a 9 in. diameter shaft. Note the run-off tabs, which provide a rectangular weld area. The excess metal is cut off after the shaft has been welded. A large spindle is shown in Figure 12, a repair so thick that two 2-wire welding machines were brought to the joint, one on each side. Figure 13 shows the welding in progress.

To summarize this brief survey of an extensive subject, stressing in particular the ways in which electroslog and electrogas welding fit into the theme of this Symposium, these new joining methods

save weight, (of course—so does any welding method);

they save time, in weld preparation;

they save labor, in material handling;

they save time, again, in the welding operation itself;

they produce a sound, undistorted weld, because it is completed in one symmetrical pass and is solidified directionally with rejection of impurities into the discarded slag.

I think it will pay many of you to adapt these processes to your own joining applications.

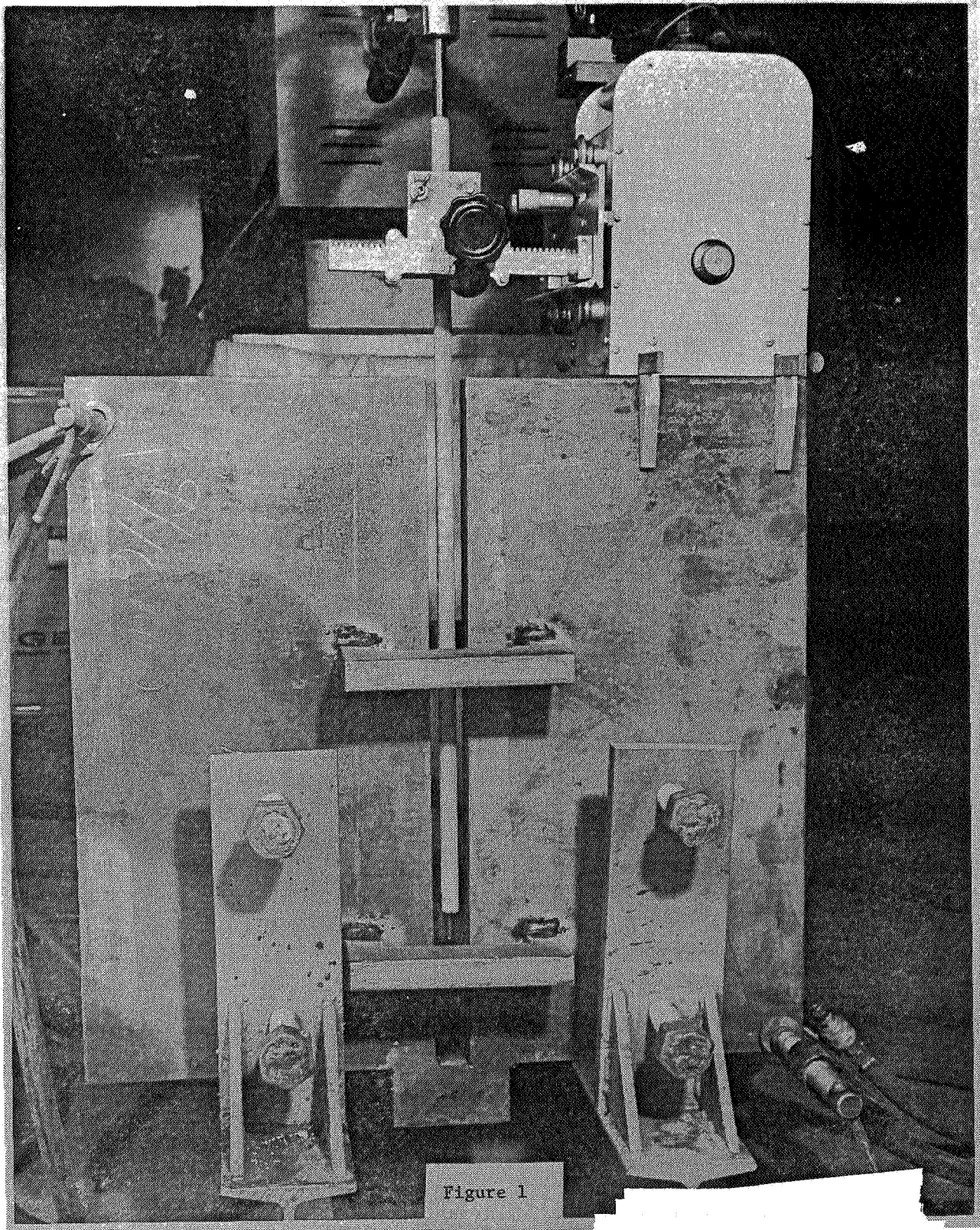


Figure 1

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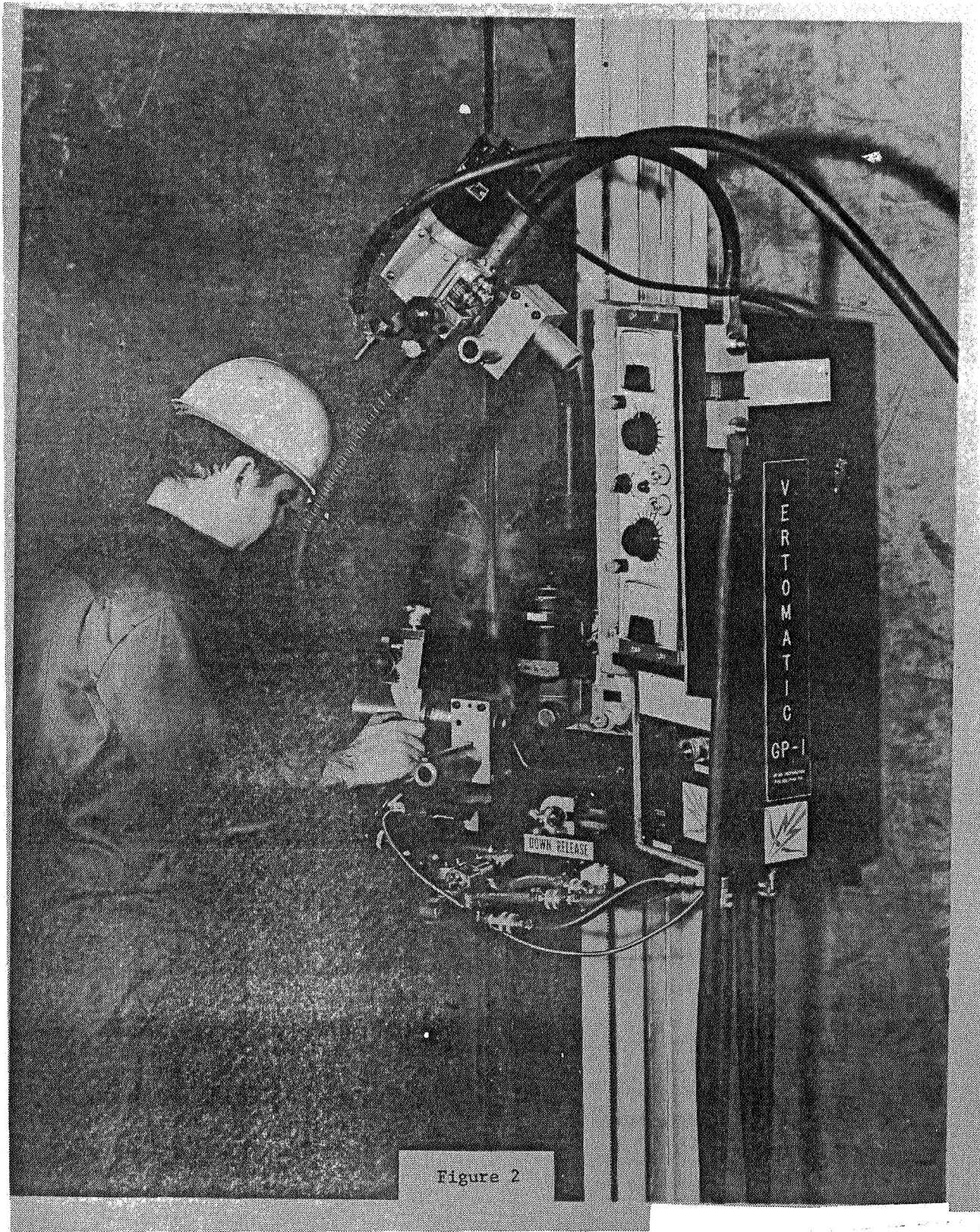


Figure 2



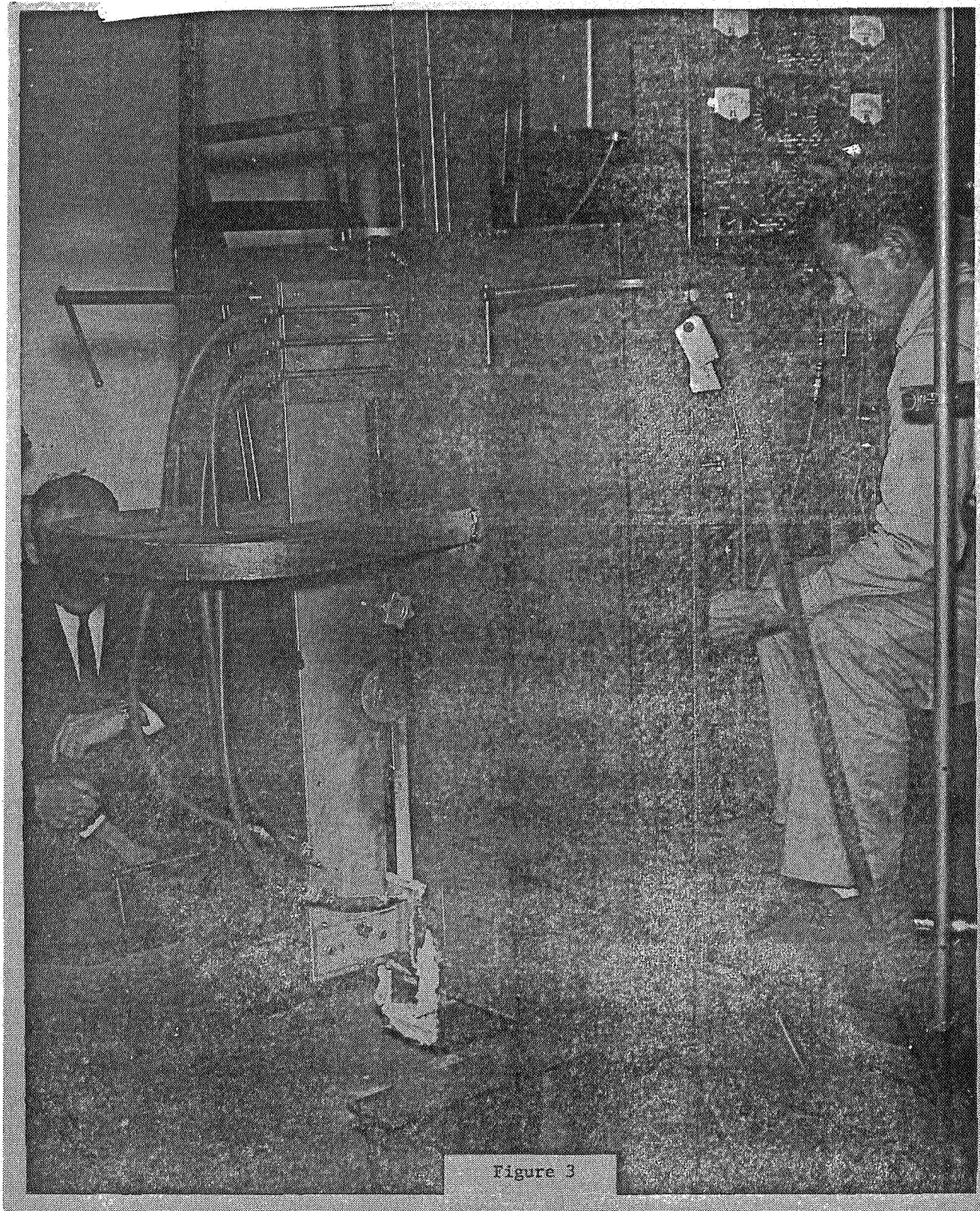


Figure 3

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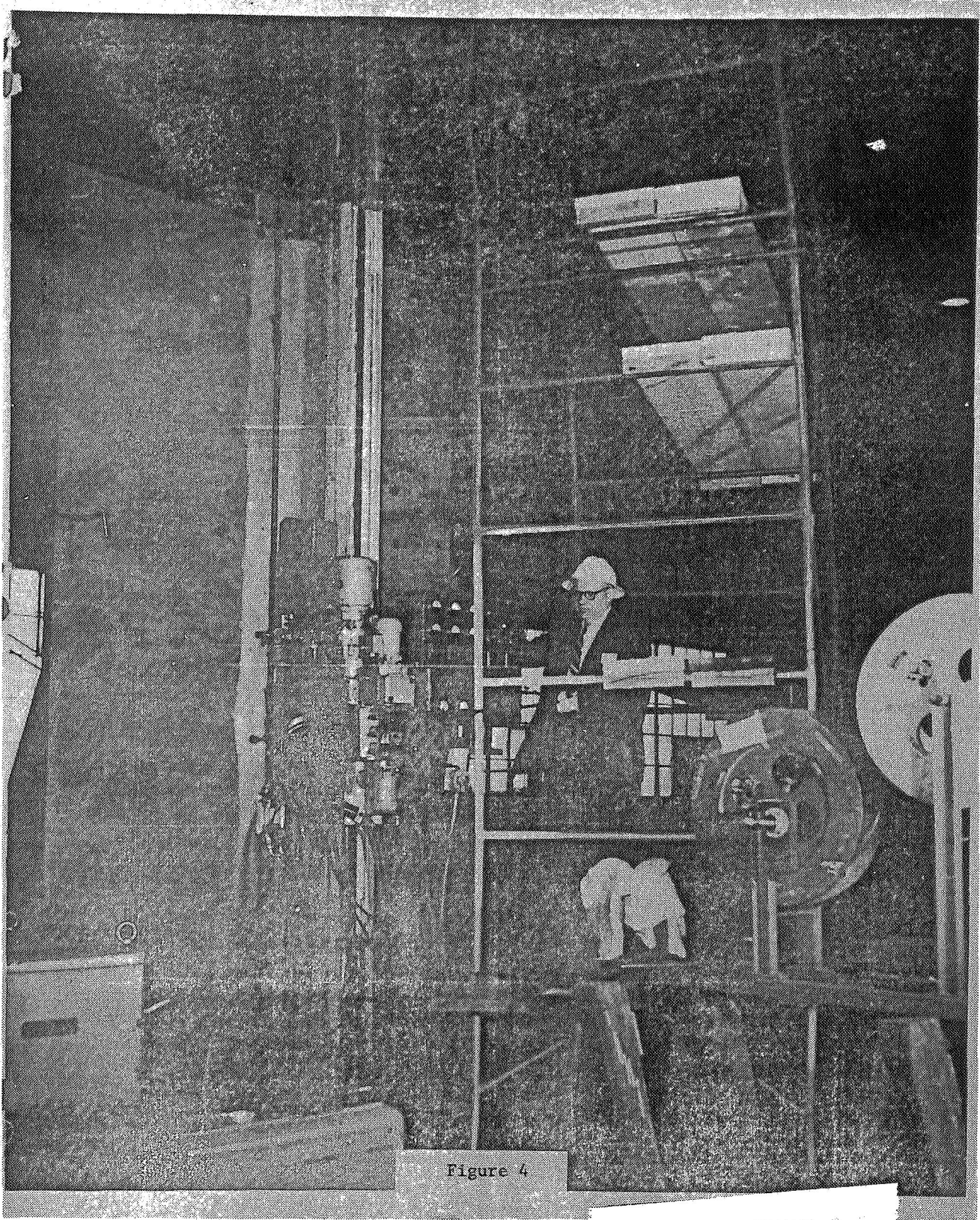


Figure 4

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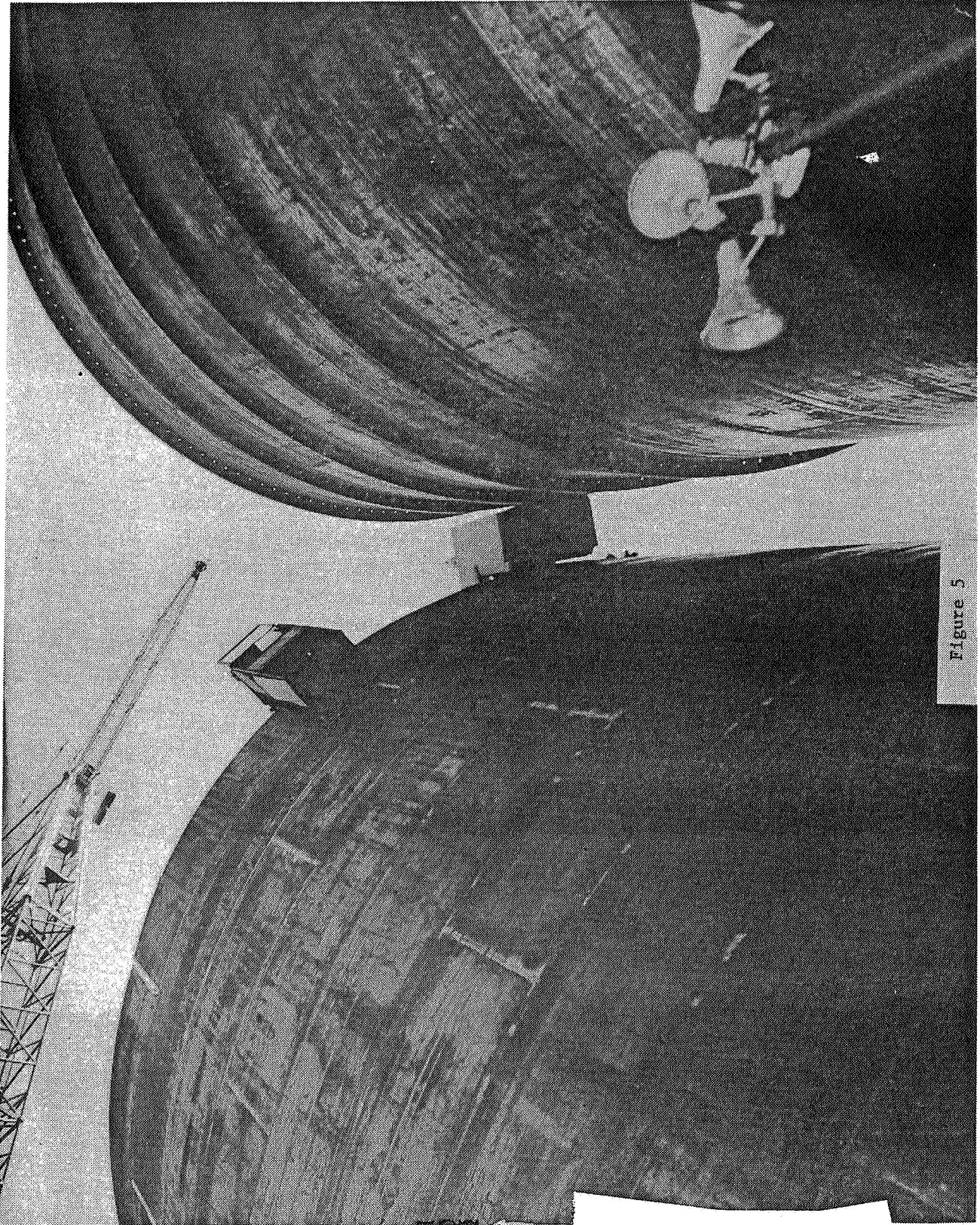


Figure 5

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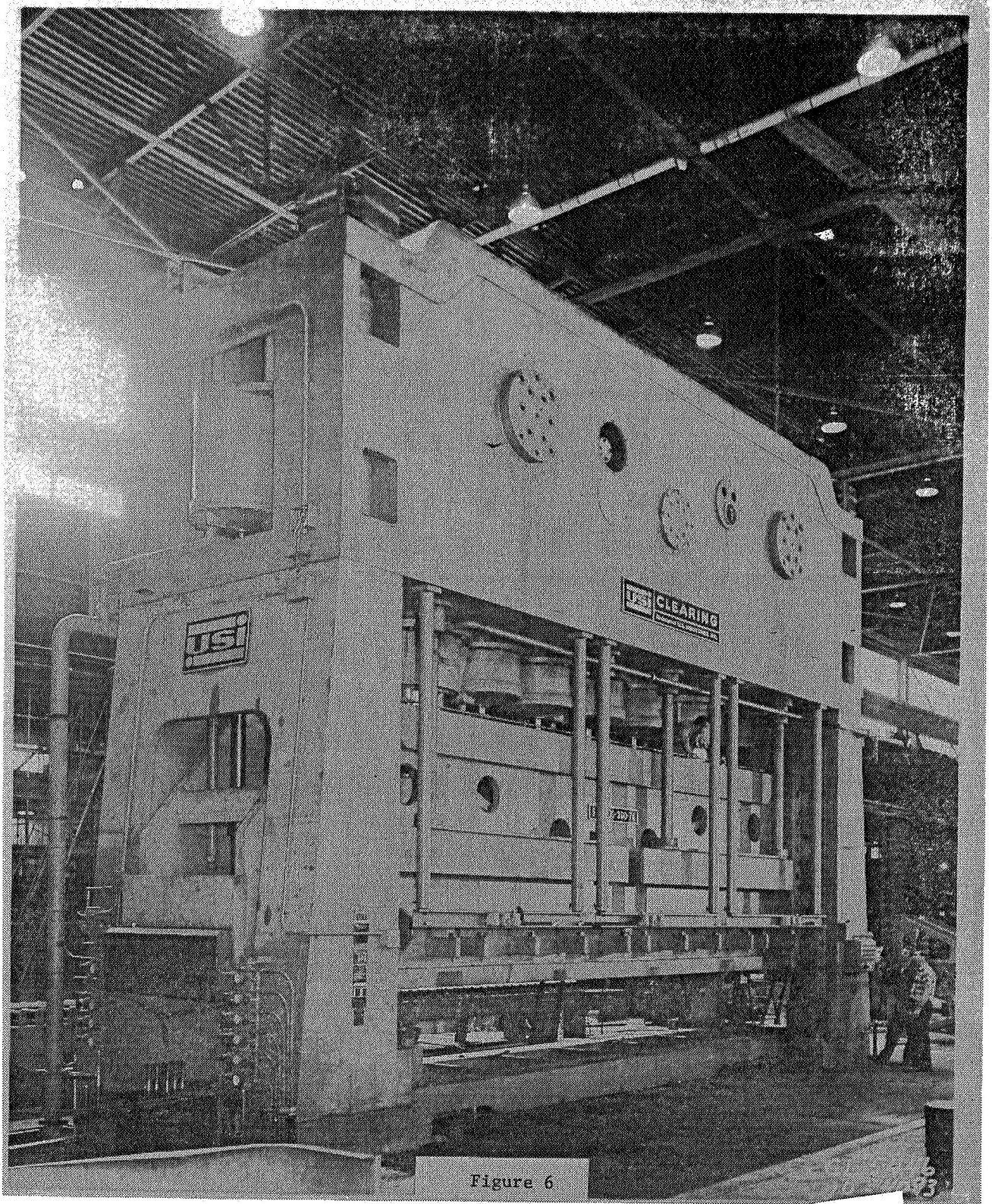


Figure 6

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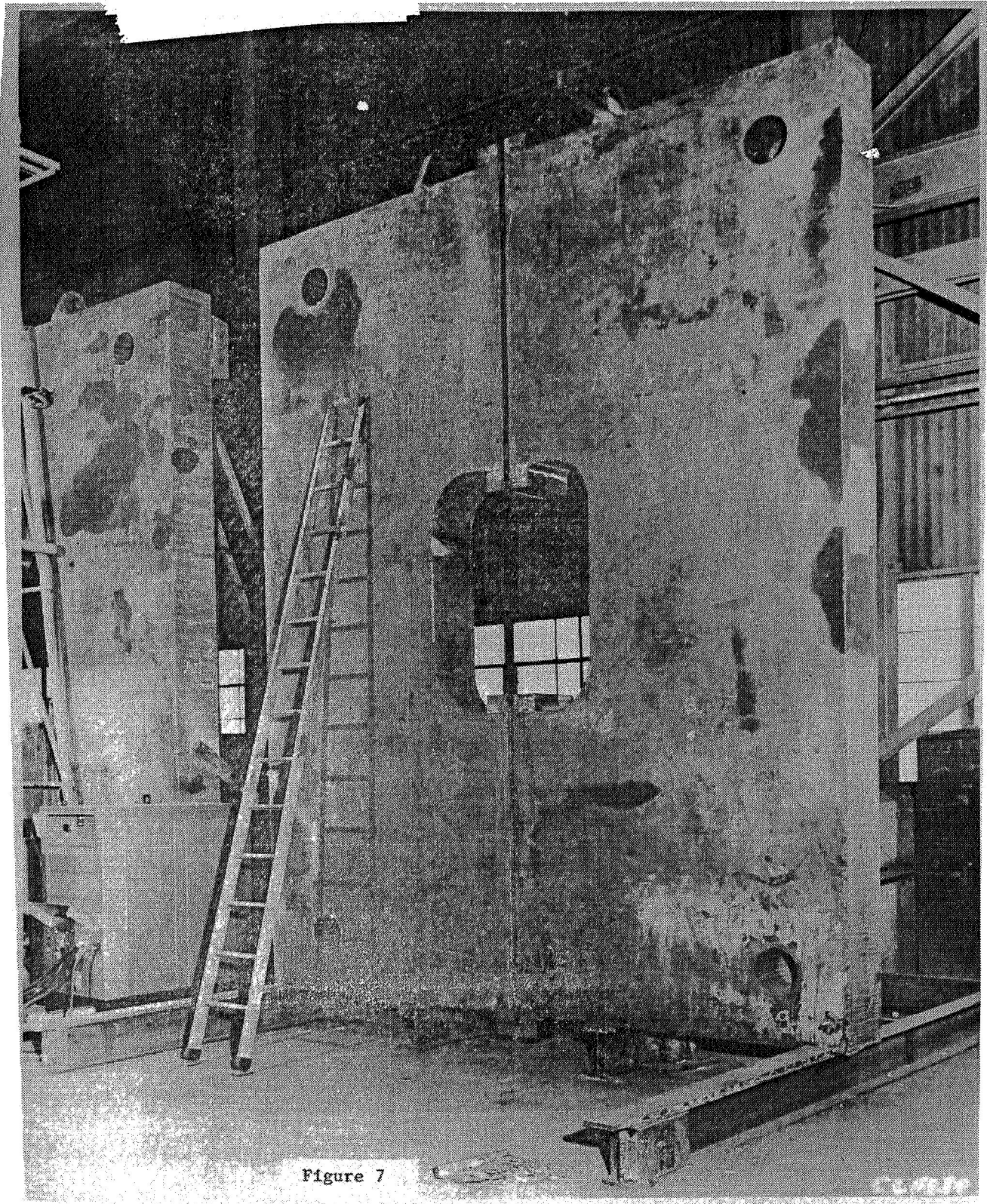


Figure 7

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*The Next 40 Years in Materials*

# METAL PROGRESS

DECEMBER 1967

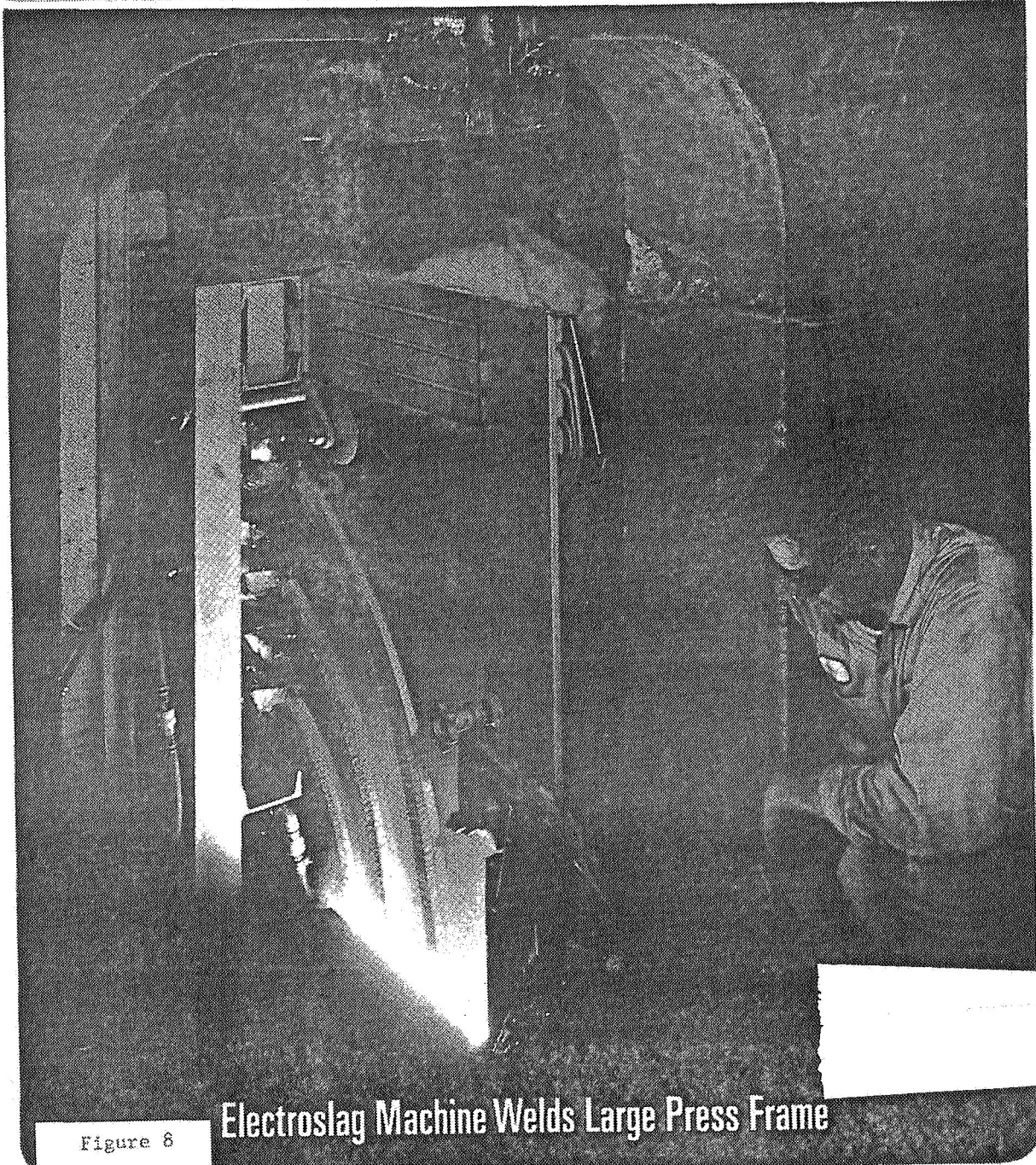


Figure 8

Electroslag Machine Welds Large Press Frame

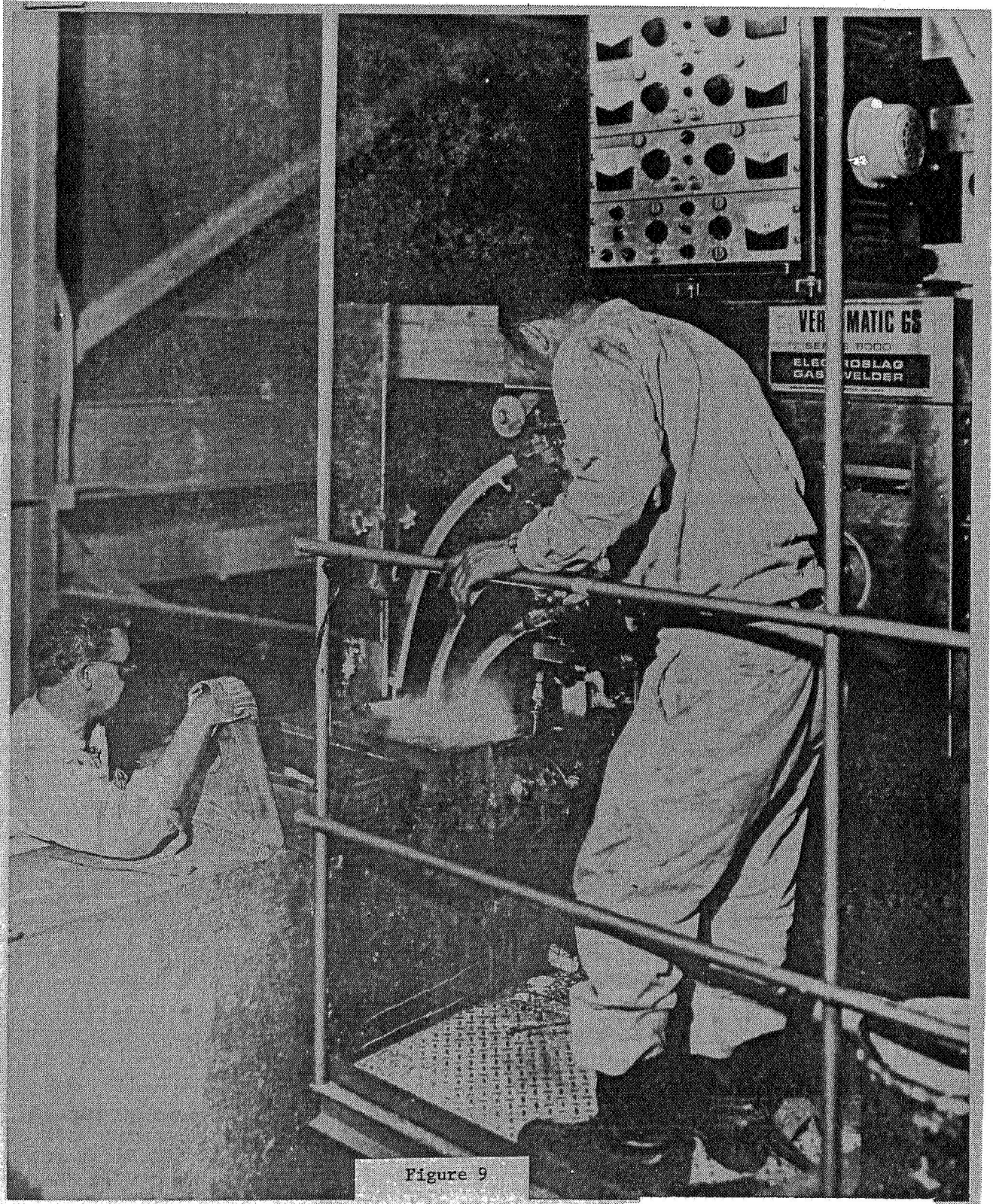


Figure 9

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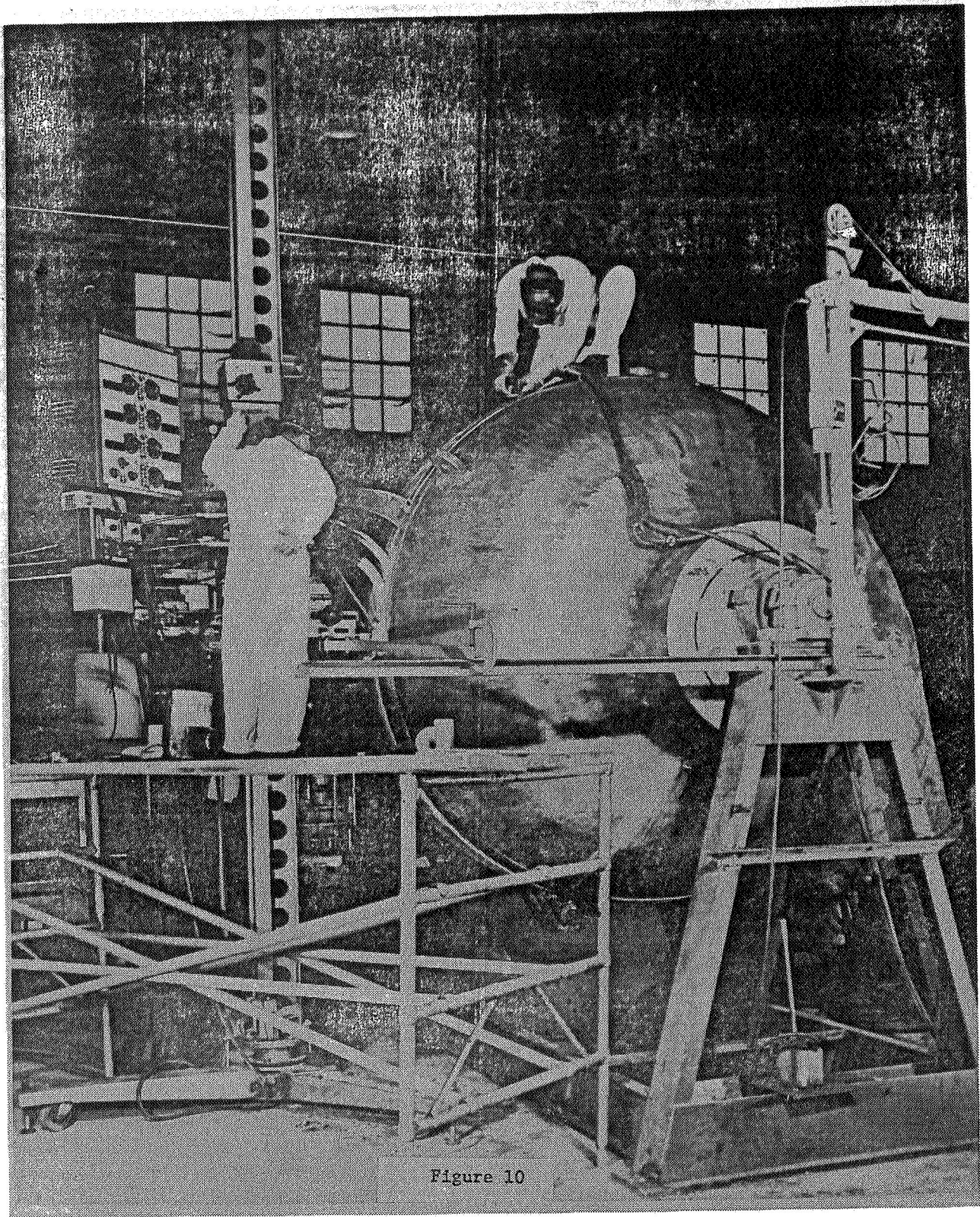


Figure 10



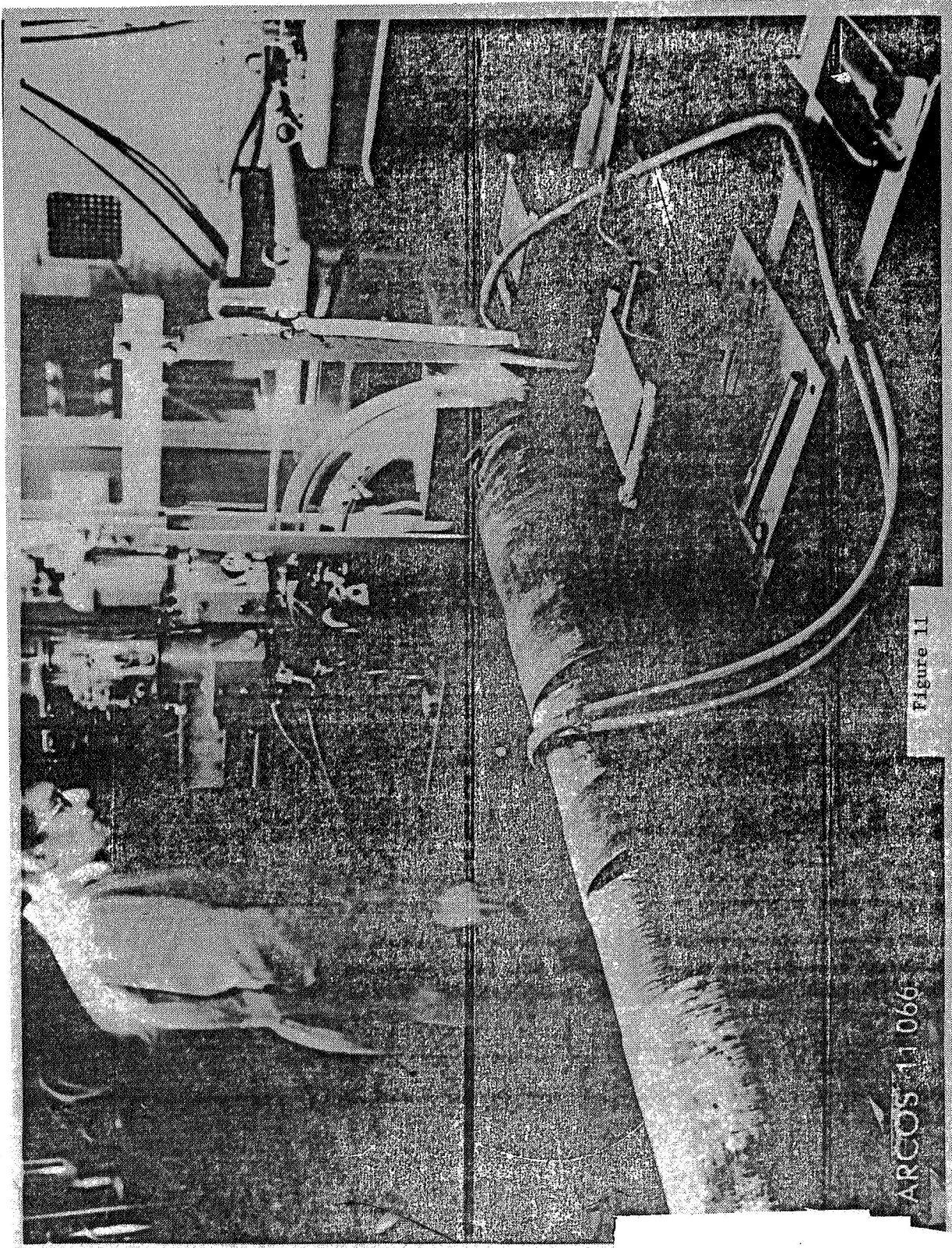


Figure 11

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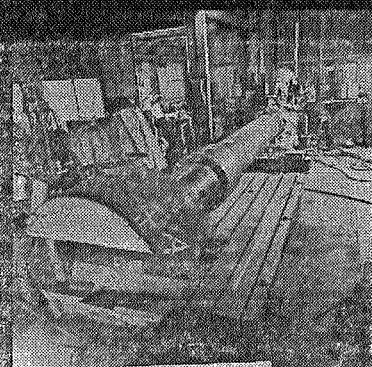
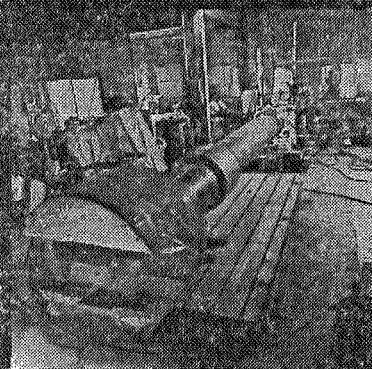
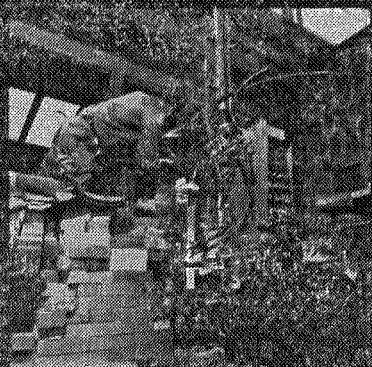
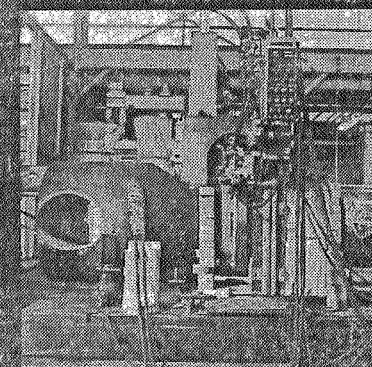
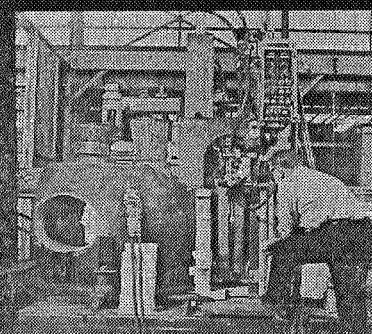
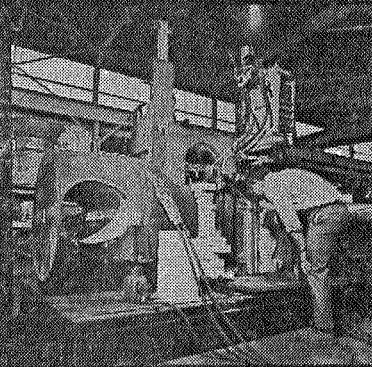
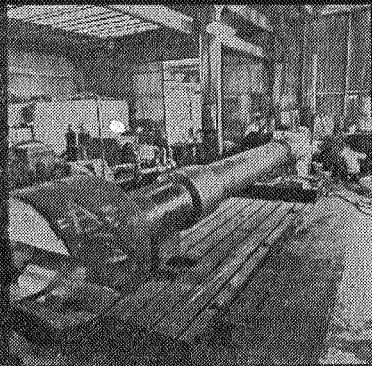
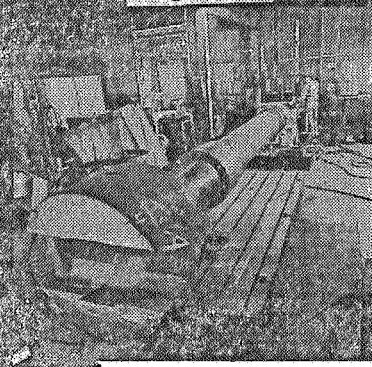


Figure 12



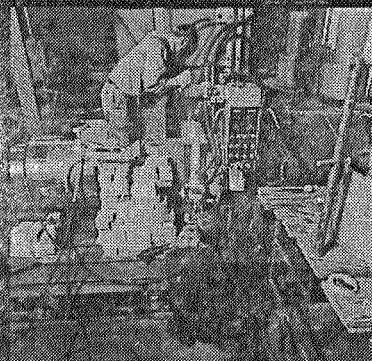


Figure 13

