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DEVELOPMENT STATUS FOR ARC GUIDANCE, WELD OBSERVATION SYSTEMS, AND A REVIEW OF PROCESS CONTROL PARAMETERS

MR. W. WALL (MSFC)

Same paper entitled "MSFC Welding"

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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HUNTSVILLE, ALABAMA 35812

IN REPLY REFER TO: R-ME-MEA

February 27, 1969

Mr. David L. Christensen
Research Associate
University of Alabama
Research Institute
P. O. Box 1247
Huntsville, Alabama 35807

Dear Mr. Christensen,

Enclosed is a copy of the paper "Development Status for Arc Guidance, Weld Observation Systems, and a Review of Process Control Parameters" which may have been renamed "MSFC Welding" to shorten the title. In any event, it was presented in September, 1964, and published shortly afterwards in a booklet with several other papers presented at the conference.

If I can be of further assistance, please feel free to contact me at any time.

Yours very truly,

W. A. Wall

W. A. Wall

1 Enclosure

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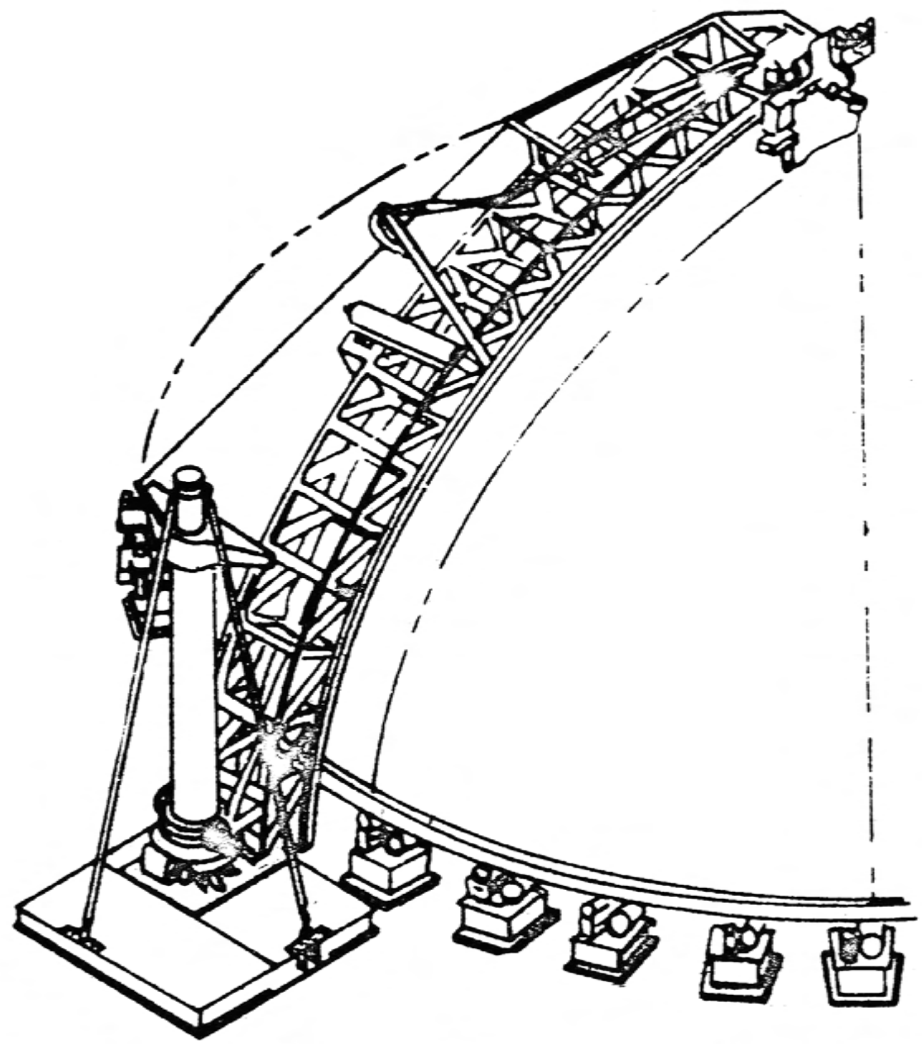
INTRODUCTION

I want to tell you something about our experience with arc guidance, remote weld observations systems, and some electrical aspects of our S-IC welding equipment. The S-IC vehicle, as you know, is no small item. To rely on tooling for joint tracking accuracy sometimes stretches the limit of practicality. Likewise, observation of the weld process is no longer an outpost check in the passing traffic; now the torch traverses the seam to make the weld, and the technician must move with it. For example, the weld carriage in Figure 1 moves up the meridian weld on this bulkhead welding fixture. A second example, Figure 2, shows a weld carriage, or so-called skate, moving around a container, and the operator moving with it. The final success of such fixtures as our bulkhead assembly tool will greatly depend upon automatic arc guidance, weld observation systems, and closed loop controlled weld parameters to eventually allow the welder to operate from a remote console.



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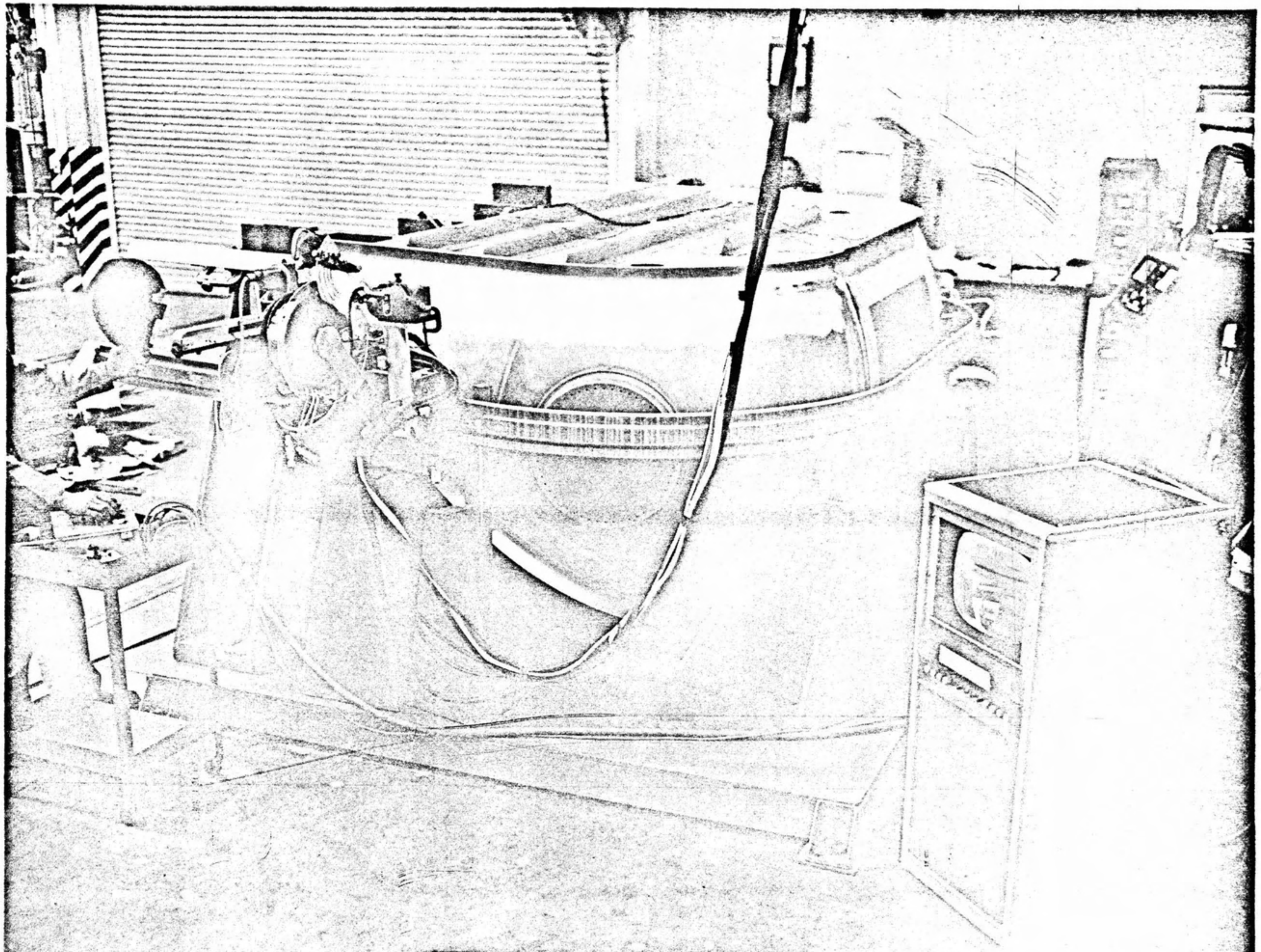
WELD OPERATION (GORE ASSEMBLIES)



LIGHTWEIGHT TOOLING WITHOUT
BACKUP BAR

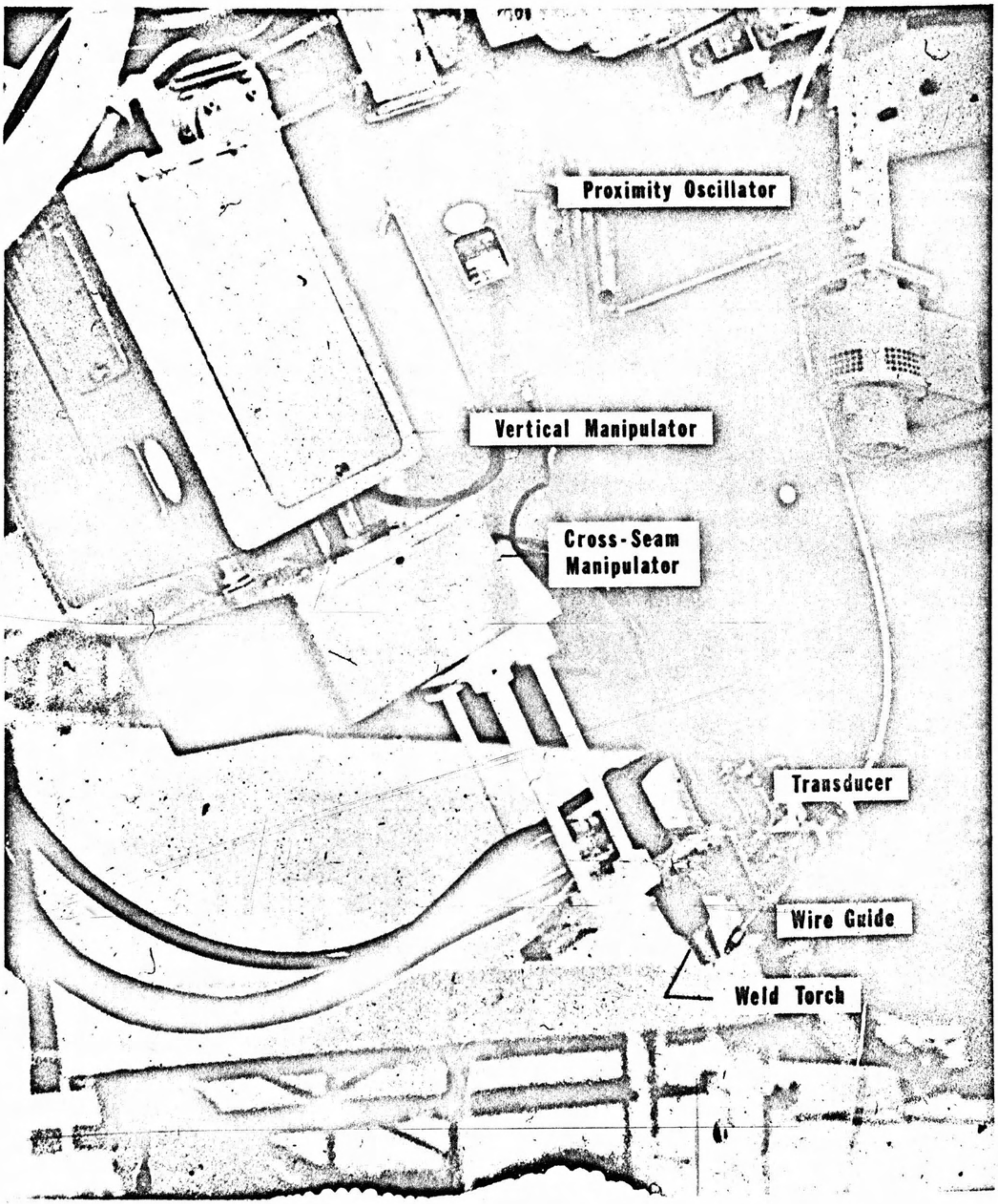
TRANSDUCER SYSTEMS

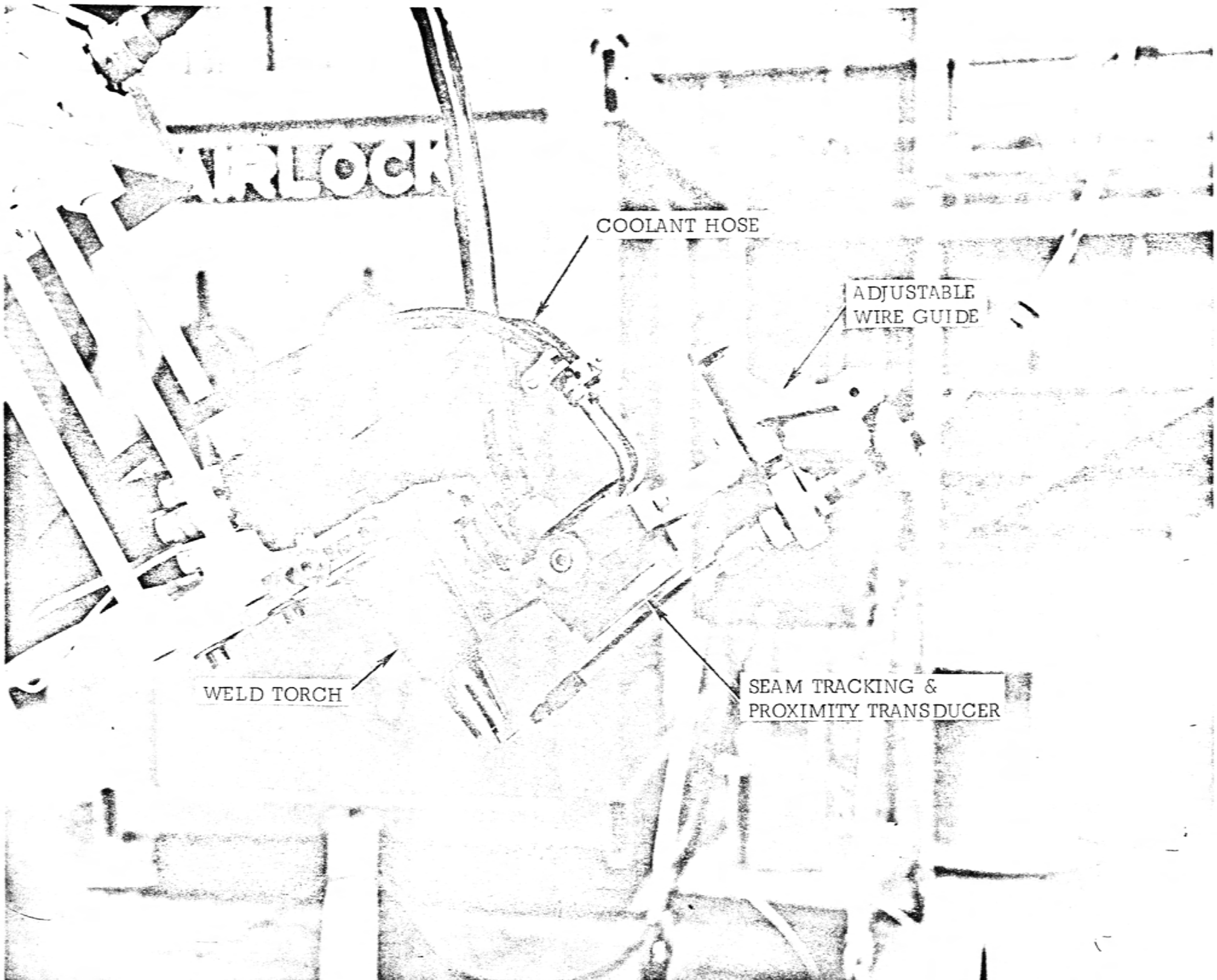
One solution to joint tracking lies in an eddy current transducer system. Figure 3 shows such a unit installed on a gore segment weld fixture. This unit is suspended directly from the weld carriage. The boxes containing the proximity and seam tracking servo mechanism can be seen in the left hand corner.

Figure 4 shows a transducer installed on the welding torch. In MIG welding the transducer is used for both seam tracking and proximity control. It is used for seam tracking only in TIG welding with arc voltage supplying the proximity control.

If the weld plates have zero offset (Figure 5) the unit will track the joint within ± .005 inch. Under offset conditions of .040 inch, which is beyond our design limitations, the unit tracks within ± 1/32 inch. There is a total range of 2 inches cross-seam and 4 inches proximity movement in the maximum travel speed of cross-seam and proximity is about 5 inches per minute. This will give you some idea of the inaccuracy which can be tolerated in fixturing.

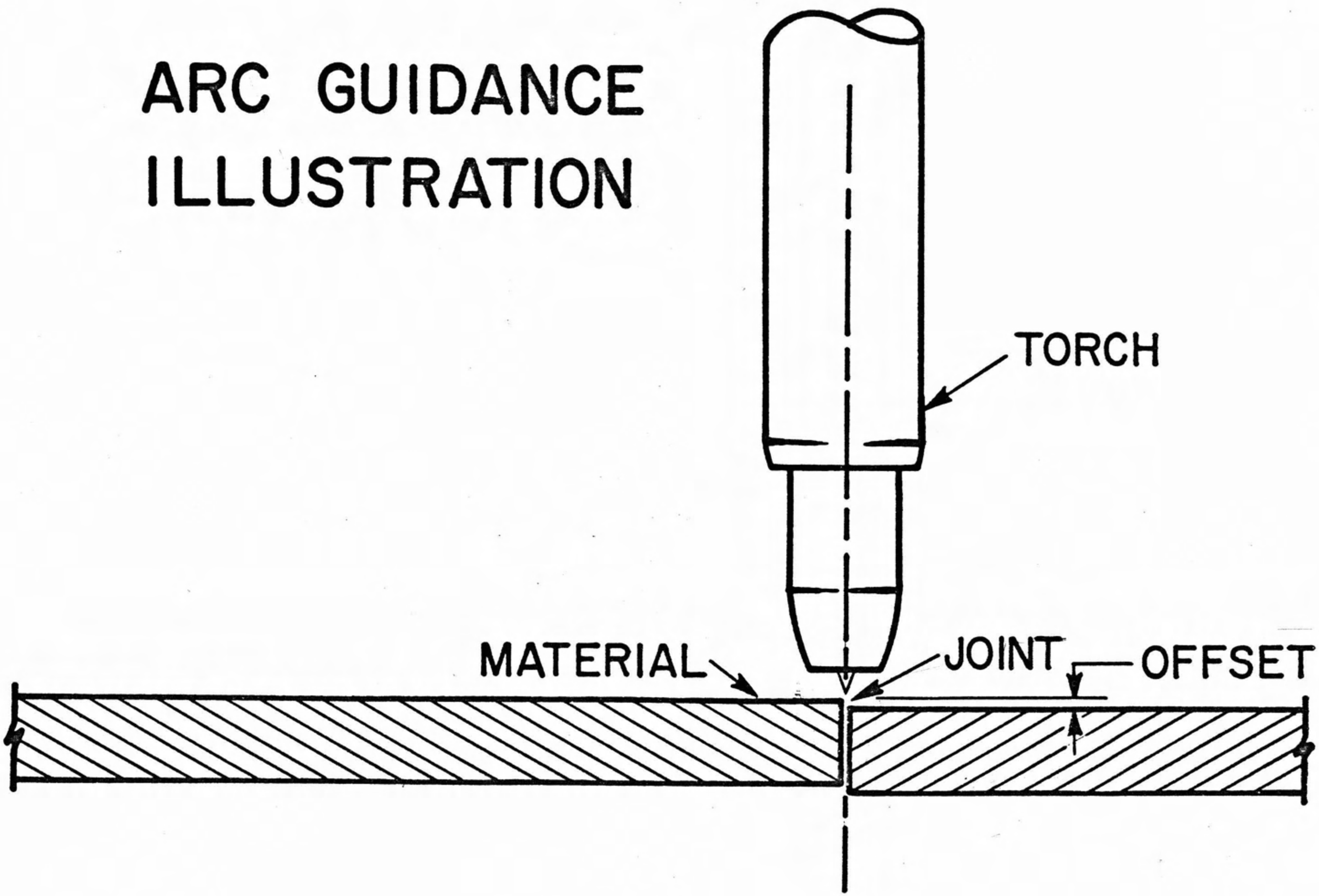
However, the principles of a low frequency eddy current transducer require the weld backing to be a non-magnetic material, such as stainless steel, ceramics, etc. Tack welds, if used for jigging, are a source of trouble.


Proximity Oscillator
Vertical Manipulator
Cross-Seam
Manipulator
Transducer
Wire Guide
Weld Torch



IRLOCK
COOLANT HOSE
ADJUSTABLE WIRE GUIDE
WELD TORCH
SEAM TRACKING & PROXIMITY TRANSDUCER

ARC GUIDANCE ILLUSTRATION



CAYUGA SYSTEM FOR ARC GUIDANCE

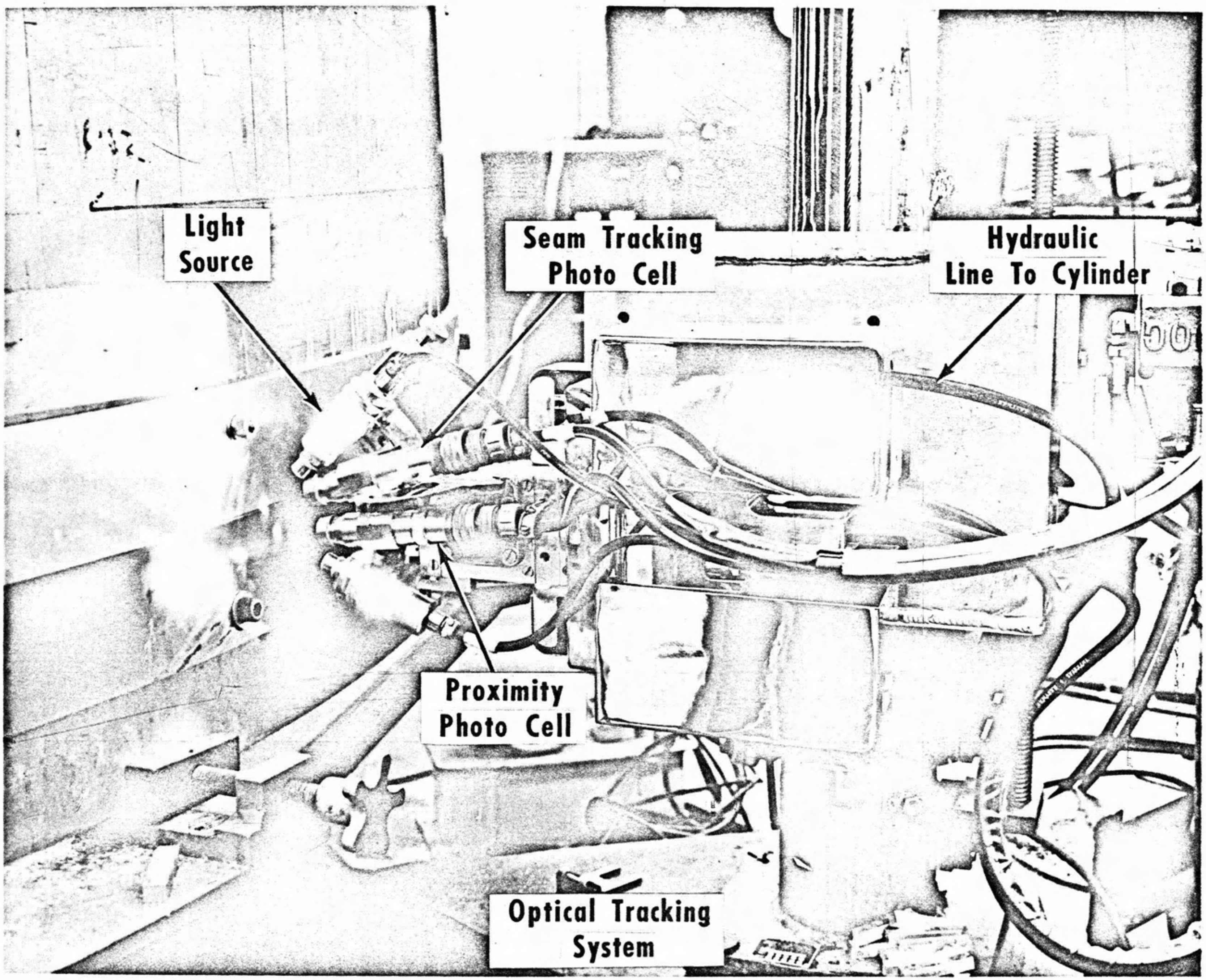
We also are evaluating a guidance system development by the Cayuga Company. The principle is quite different from the eddy current transducer system. First of all, light beams and photo cells make up the intelligence complex. The unit shown in Figure 6 has a two axis control; proximity and seam tracking. We are considering a third control consisting of lead and lag torch angles.

The systems work equally well on square butt or prepared joints. A small chamfer on one plate edge (Figure 7) is necessary on square butt joints for seam tracking. To track the seam, a spot of light is focused on a plate edge. Any lateral deviation from this null position upsets the quantitative balance of the two photo cells. The servo mechanism is then signalled to bring the torch back to position.

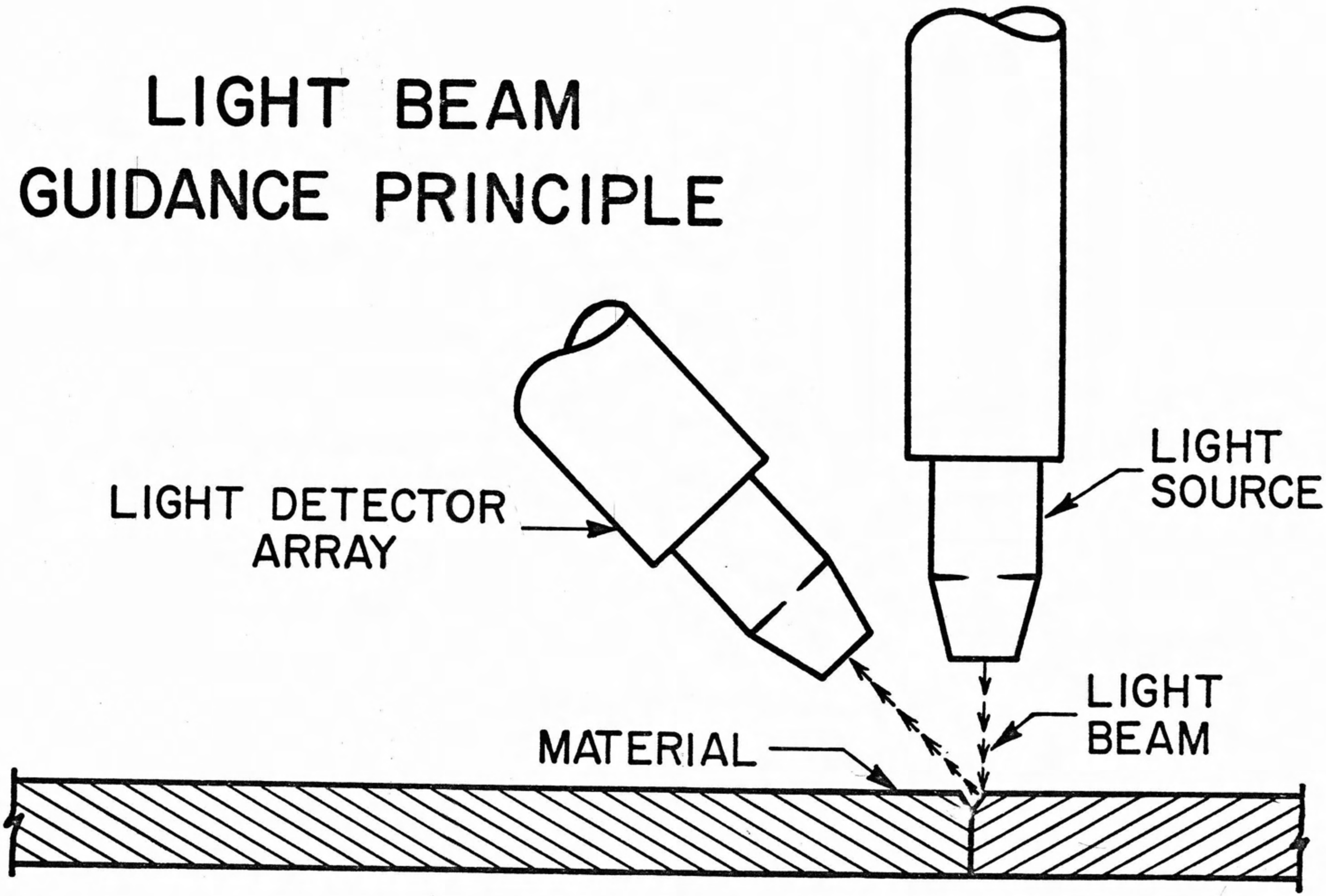
The servo system consists of a hydraulic pump and miniature cylinders operating at about 500 psi. This provides a very rapid response; something like 500 inches per minute. The cylinder response is proportional to the signal intensity; thus, in the null position the unit is effectively locked in place.

The proximity control follows a similar principle. A light beam makes an acute angle to the photo cell. A change in the distance of the torch to the work changes the location of the light spot relative to the cells, again upsetting the quantitative balance.

The system is not influenced by magnetic fields, types and thickness of material, or arc illumination. However, there are limitations of significance. One limitation is that the tracking light spot is on one plate only and cannot


Light Source
Seam Tracking Photo Cell
Hydraulic Line To Cylinder
Proximity Photo Cell
Optical Tracking System

LIGHT BEAM GUIDANCE PRINCIPLE



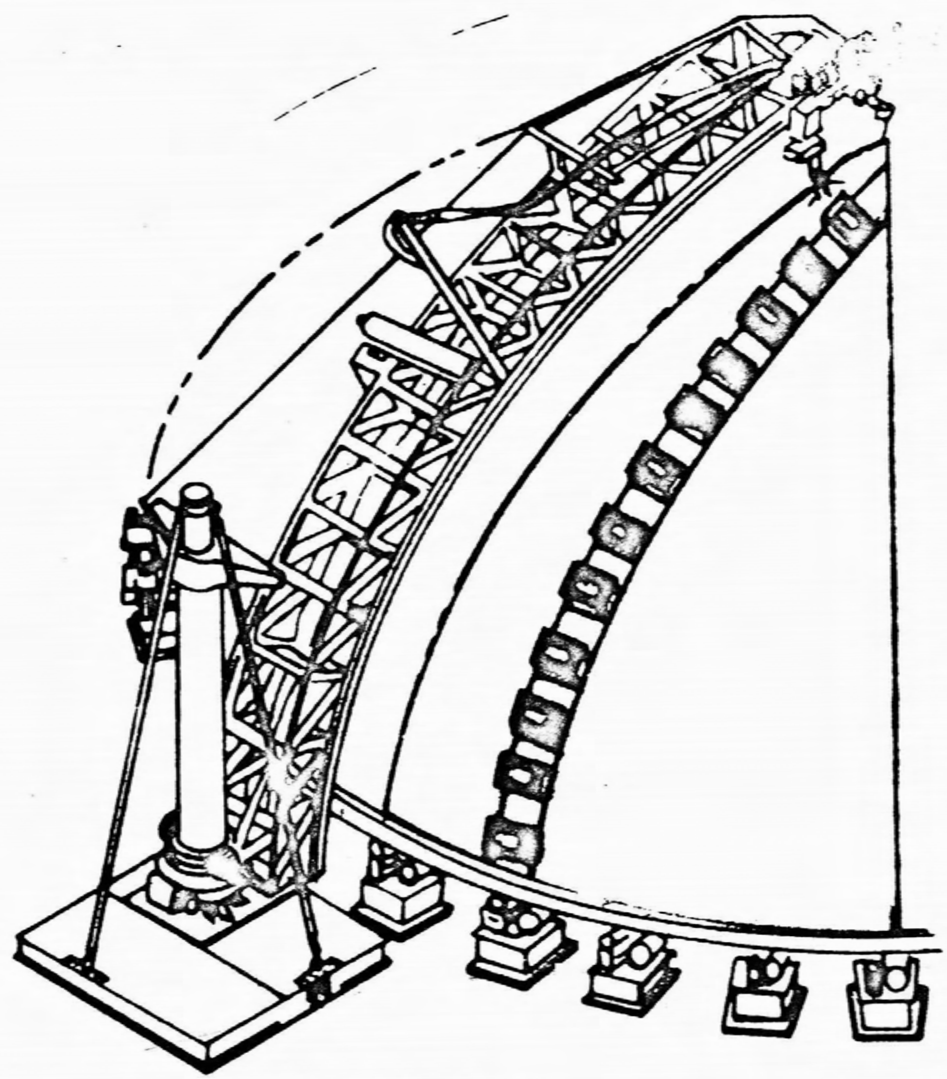
distinguish or compensate for offset or gap. Also, tack welds on the crown side of the joint erase the plate edge definition and the optical system will follow not the seam but rather track the side of the tack weld. The most objectionable point is that the system presently depends on hydraulic actuators which are subject to periodic leakage of hydraulic fluid. Seepage of hydraulic fluid on a weld joint could seriously damage a vehicle part.

In spite of these limitations, the optical system more nearly approaches true automation. I mentioned a planned three-axis control. This is to be used on a light weight skate for welding irregular shapes. Actually, we have added a fourth dimension of travel speed, controlled by a transducer running on the work surface. I believe this to be a significant step forward in dynamic detection and correction in contrast to conventional static memory programming.

REMOTE WELD VIEWING

With the fixture stationary and torch moving, we naturally create the problem of the operator's viewing the arc weld. The meridian weld on the bulkhead fixture shown in Figure 8 is an excellent example of this problem. If a technician or welder is to monitor the weld with the usual welder's shield, he must climb up a special rope ladder.

We have tried both close circuit television and fiber optics as a solution to remote monitoring of arc welding. Presently, we are planning to evaluate a close circuit television system made by General Electric. This system is similar to the one demonstrated at Douglas Aircraft in April of this year. Our other approach to this problem is the use of fiber optics. The fiber optic viewer of Figure 9 consists of a flexible cable containing approximately 500,000 glass fibers and a focusing lens assembly on each end. Figure 10 illustrates a projection screen type viewer which is more convenient for operator use since the picture is actually projected on an etched screen. The principle advantages of fiber optics are its ability to transmit color, its ruggedness, and its reliability. The major disadvantage is the fact that approximately one-half of the light gathered in the cable is lost every 5 feet; therefore, it can be seen that, due to transmission losses, the distance over which fiber optics can be used is definitely limited.



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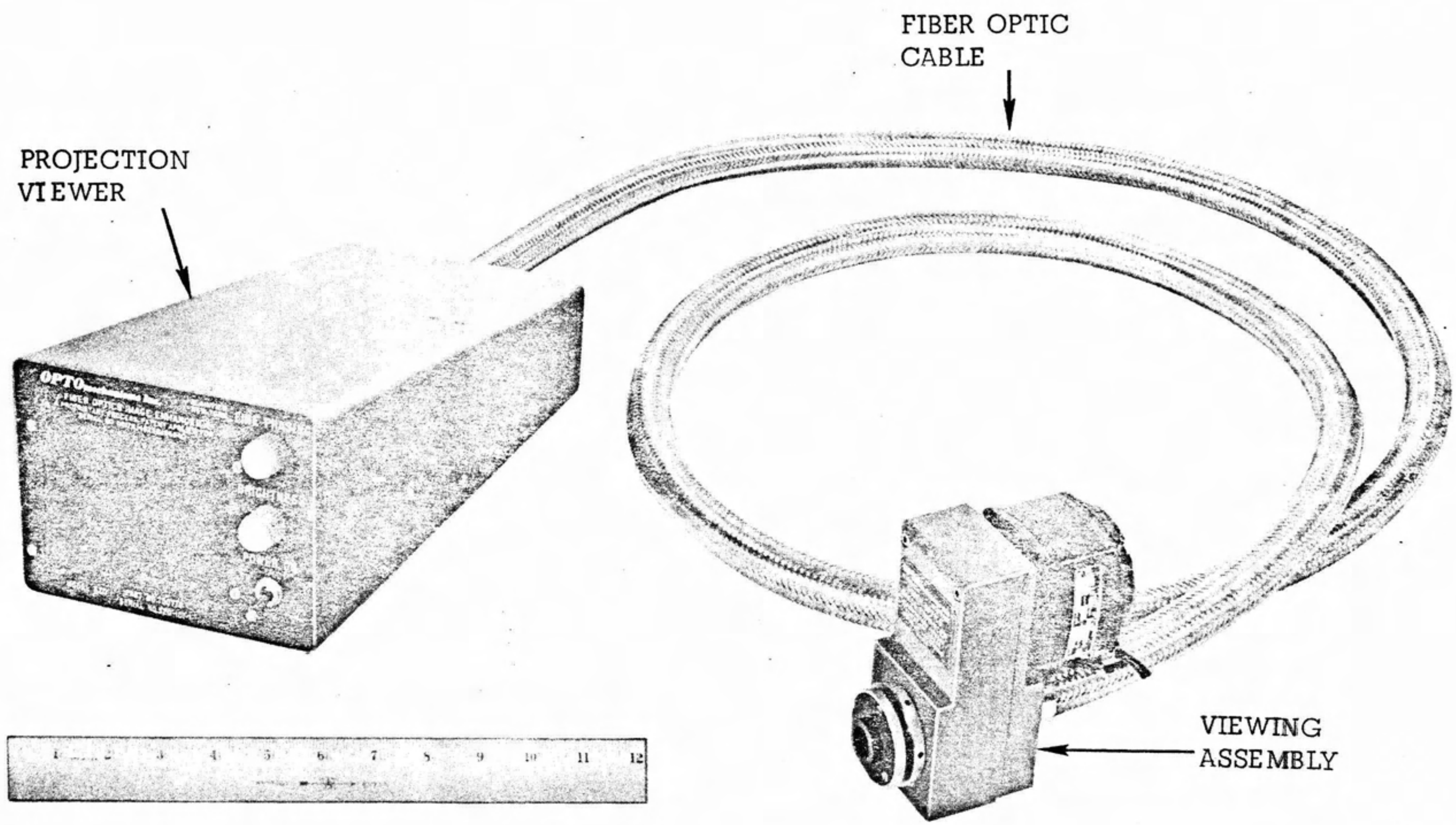
WFA-302-7020

WFA-302-7040
MiT-302-7078
MiT-370-7079
MiT-370-7501

WELD OPERATION (GORE ASSEMBLIES)

BINOCULAR EYEPIECE
VIEWING LENSE & PRISM
ADJUSTABLE POLAROID FILTER
FIBER OPTIC CABLE



FIBER OPTIC VIEWER WITH
IMAGE ENHANCER

ELECTRICAL WELDING EQUIPMENT

Our decision to erect the tank structure in a vertical position meant that we had to extend our welding technique. Three years ago, high quality mechanized welds were made almost exclusively in the flat position. Today, we are making welds of equal quality in the vertical and horizontal attitude. Obviously, this means more freedom in choice of vehicle design and the manufacturing approach.

All major welds on the S-IC will be made with the TIG process on square butt joints. We weld up to 0.5 inch material single pass and 0.4 inch plate with weld backing. One inch plate is welded with one pass on each side. For instance, representative machine settings for a one inch plate weld are as follows, Figure 11; 482 amperes $\pm$ 1.5 percent, 11.75 volts $\pm$ 1.5 percent, 3.9 inches per minute travel speed $\pm$ 5 percent and approximately 6 ipm wire feed speed. Using precision equipment we obtain a 99 percent confidence level of 40,000 psi ultimate weld strength, or higher, above the design minimum of 35,000 psi. But such success has only been possible through the advent of precision weld equipment. The major equipment manufacturers have been highly responsive to our needs. At most weld stations of the S-IC, we have equipment which satisfies the requirements shown in Figure 12. Obviously, if we are to have precision welding, we must also have precision recording. The recorders which are proposed to furnish for the S-IC welding equipment will have the characteristics shown in Figure 13. One item of interest to engineers is the slow speed transducers which are proposed for

1-INCH PLATE WELD PARAMETERS

TIG PROCESS

1-PASS EACH SIDE

CURRENT________________482 AMPERES ± 1.5%

VOLTAGE________________11.75 VOLTS ± 1.5%

TRAVEL________________3.9 IPM ± 5%

WIRE FEED________________6 IPM AVERAGE

SATURN V, S-IC

MIG-TIG ELECTRICAL WELDING CONTROL PARAMETERS

PERFORMANCE: CLOSED LOOP ±1% OF SETTING TOLERANCE

- A. CURRENT
- B. WIRE FEED
- C. TRAVEL

VOLTAGE: ± .15 VOLT FOR TIG WELDING

RATING: 600 AMPERES 100% DUTY

TIMERS: UP TO 2 MINUTES ON:

- A. VOLTAGE UP AND DOWN SLOPE
- B. CURRENT UP AND DOWN SLOPE
- C. SEQUENCE
- D. PURGE
- E. TRAVEL
- F. WIRE
- G. CRATER FILL

SATURN V, S-IC

WELDING INSTRUMENTATION PARAMETERS

FUNCTION	RECORDING ACCURACY
CURRENT	± .3 PERCENT-RANGE AS REQUIRED
VOLTAGE	± .3 PERCENT-RANGE 10 TO 15 VOLTS
TRAVEL SPEED	± 1 PERCENT-RANGE 0-10 AND 0-15 IPM
WIRE FEED SPEED	± 1 PERCENT-RANGE 0-10 AND 0-15 IPM

accurately recording these low travel and wire feed speeds. At this time we have two transducers under development. One transducer is a special multipole tachometer with a linearity of better than 1 percent, but a ripple factor of 4 percent. A second system is based on the principle of a servo mechanism and will have a planned accuracy of better than $\pm$ 1 percent and a ripple factor of no more than 1 percent. These transducers will require less than 1 oz-in of driving torque and operate directly on the work, or wire, as required to detect slippage.

CONCLUSION

It is hoped that these very general remarks will form a basis for communicating our mutual problems in this area. Obviously, a vast amount of technology will be required to relieve the manufacturer of the burden and expense of heavy fixed tooling for short run operations. While numerical control has its place, it does not appear very practical or attractive in the welding of large space vehicle parts. As containers become larger and shapes more complicated, hard tooling becomes very expensive. The answer appears to be electrical control from transducers which sense the instantaneous needs and correct the parameters as required.