CLOSED-CIRCUIT TELEVISION ARC GUIDANCE ADAPTER KIT FOR A COMPUTERIZED WELDING SKATE

FINAL REPORT

August 1970

Lockheed

HUNTSVILLE RESEARCH & ENGINEERING CENTER
LOCKHEED MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
HUNTSVILLE, ALABAMA

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Contract NAS8-24638

by

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Resident Director

FOREWORD

This final report documents the results of a 13-month, three-phase effort to design, develop and furnish equipment to render and integration and moderization of an existing computerized welding skate with CCTV Arc Guidance. The essential tasks involved modification of an existing Torch Angle Manipulator to a revision B configuration; and the design, development and integration of an adaptor kit to accommodate remote CCTV viewing of the weld area. This effort was performed under Contract NAS8-24638 by Lockheed's Huntsville Research & Engineering Center for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama. Work was performed during the period 2 June 1969 through 1 July 1970 by Lockheed/Huntsville's Systems Engineering department, Mr. A.S. Dunbar, Manager. Project Engineer was Mr. R.B. Wysor, Supervisor, Advanced Development section. Lead Engineer for the design and development efforts was Mr. K.W. Heimendinger, who was assisted by Messrs. M.C. Krause and N.O. Wages for analysis and drafting efforts. Fabrication efforts were under the supervision of Mr. R.A. Wyman.

Contracting Officer's Representatives for this program were Mr. Roy A. Taylor, Principal, and Mr. William A. Wall, Jr., of the MSFC Science and Engineering, Manufacturing Engineering Laboratory.

SUMMARY

Preliminary design of the Closed-Circuit Television Guidance Adapter Kit was completed. The kit consists of four subsystems: (1) an illumination head; (2) viewing optics and illuminators; (3) proximity control system; and (4) wire-feed mechanism. The total kit weighs approximately 12.9 pounds of which 6.5 pounds are suspended on the torch angle manipulator. This load is not expected to cause any appreciable change to the existing servo systems.

Illumination of the weld seam is provided by a split-bundle flexible light guide with 0.32 cm (1/8 in.) diameter legs (illuminators). The distance between the illuminators is adjustable between 5.08 cm (2 in.) and 8.25 cm (3-1/5 in.). The illuminators provide at least 1200 centerbeam footcandles at 5.08 cm (2 in.) distance from the illuminator. The adapter kit is capable of maintaining the illuminators in constant proximity to the work surface while following a 15.24 cm (6 in.) minimum weld radius at a maximum welding speed of 127 cm (50 in.) per minute.

The viewing optics utilize a single 90-degree viewing prism and lens to view the 5.08 cm (2 in.) by 8.89 cm (3-1/2 in.) viewing area. The kit utilizes a single imagescope bundle, in a very flexible covering, to interface the objective lens mounted on the illumination head to the closed-circuit television camera mounted on the skate. The total viewing optic system provides a minimum resolution of 50 line pairs per millimeter. The single imagescope bundle with its flexible cover reduces the packing problem and cost of replacement.

The provimity control system utilizes a sensor capable of ± 5 mm (0.002-in.) tolerance when located 0.25 cm (0.100 in.) from the work surface. The sensor, together with a lightweight direct current micromotor mounted on the illumination head, provides precise proximity positioning of the illuminators and viewing optics.

Hardware modifications to the existing torch angle manipulator (Modification B) and the wire-feed mechanism are relatively minor. The thicker torch beam and longer beam pivot pin are necessary to provide proper mounting for the illumination head support and wire-feed guide support. A double preloaded bearing arrangement is used to reduce tracking instability and vibration. The wire-feed guide support is longer to allow the lowering of the torch mount 5.72 cm (2-1/4 in.) and to allow the wire-feed mechanism to be mounted below the torch. The wire-feed mechanism's modifications consist mainly of a modified guide and tip. The guide utilizes a 153-degree bend with the same radius as the standard (45-degree bend) with a tip that is twice as long as the standard 1.90 cm or 3/4 in. The longer tip reduces the wire curvature being fed to the torch.

This design provides a near optimum adapter kit for adapting the Closed-Circuit Television Arc Guidance System to the torch angle manipulator and is the basis for the final design.

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Section 1
INTRODUCTION

The expense of holddown tooling for welding double-contour parts and the need for automatic precision welding on the Saturn-IC booster multicell tanks led to the development of a computerized welding skate by NASA/MSFC Manufacturing Engineering Laboratory (MEL). Other research by NASA/MSFC/MEL led to the development of a Closed-Circuit Television (CCTV) Arc Guidance System. The integration of these two systems would provide a precise and completely automatic method for welding contoured surfaces. The system would be practical and the need for backing tooling and precise skate alignment would be eliminated.

The computerized welding skate and the CCTV Arc Guidance System have both been proven at MSFC Manufacturing Engineering Laboratory. Under the terms of this contract, Lockheed has developed a CCTV Arc Guidance Adapter kit for the computerized welding skate to meet the requirements of MSFC Specification MR&T-SK-1214 (Ref. 1). The kit provides an illumination head (light source and CCTV camera viewing optics carrier), imagescope for remote viewing of the weld seam by the CCTV, precise control of the illumination head, and modifications to the cold-wire feeder and welding head manipulator for integration with the Adapter Kit and Torch Angle Manipulator.

In this report, Section 2 contains the system description of the CCTV Arc Guidance Adapter Kit. Sections 3 and 4 contain the considerations and analysis of major components used in the design. Section 5 describes the modifications required for the Revision B Torch Angle Manipulator and the changes necessary to adapt the kit to the torch angle manipulator. Discussion of the system checkout and evaluation is presented in Section 6. Conclusions and recommendations are presented in Section 7.

Section 2
SYSTEM DESCRIPTION

The system described herein is the CCTV Arc Guidance Adapter Kit developed for the computerized welding skate. The illumination head (light source and viewing optics platform), viewing optics, proximity control system, and cold-wire feeder compose the four major subsystems. The assembled system is shown in Fig. 2-1. Photographs of the hardware developed and fabricated in this program are shown in Figs. 2-2 through 2-6. In these photographs the components are mounted on a metal fixture simulating their relative locations on the welding skate (Fig. 2-1). Although each subsystem is discussed separately in the following sections, their combined interaction causes the guidance system to function properly. Modifications to the existing torch-head manipulator needed in addition to Modification B are discussed in Section 5.

2.1 ILLUMINATION HEAD

The illumination head serves primarily as a platform for the light sources (illuminators) and viewing optics. The illuminators must maintain a constant distance from the work piece in order to provide proper seam illumination. The viewing optics must maintain a constant focus on the illuminated seam. This is accomplished by maintaining the illumination head a fixed distance from the seam. Thus, by mounting the illuminators in a fixed configuration in relation to the viewing optics and then maintaining the illuminators at the proper distance from the seam, both jobs are accomplished with a single platform and single control system. The illumination head also serves as a platform for the proximity sensors, and the dc gearmotor and drive system.

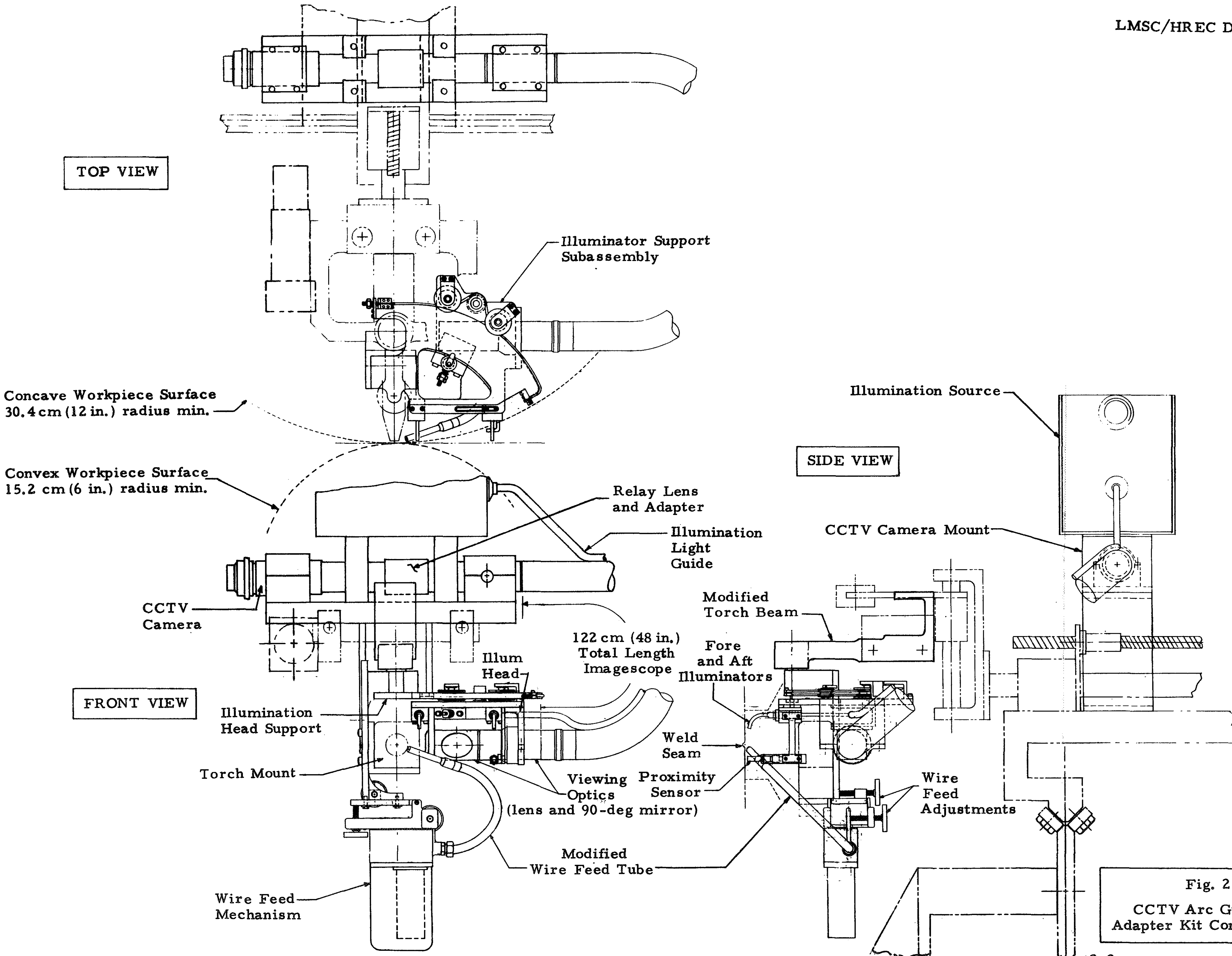

Fig. 2-1
CCTV Arc Guidance Adapter Kit Configuration

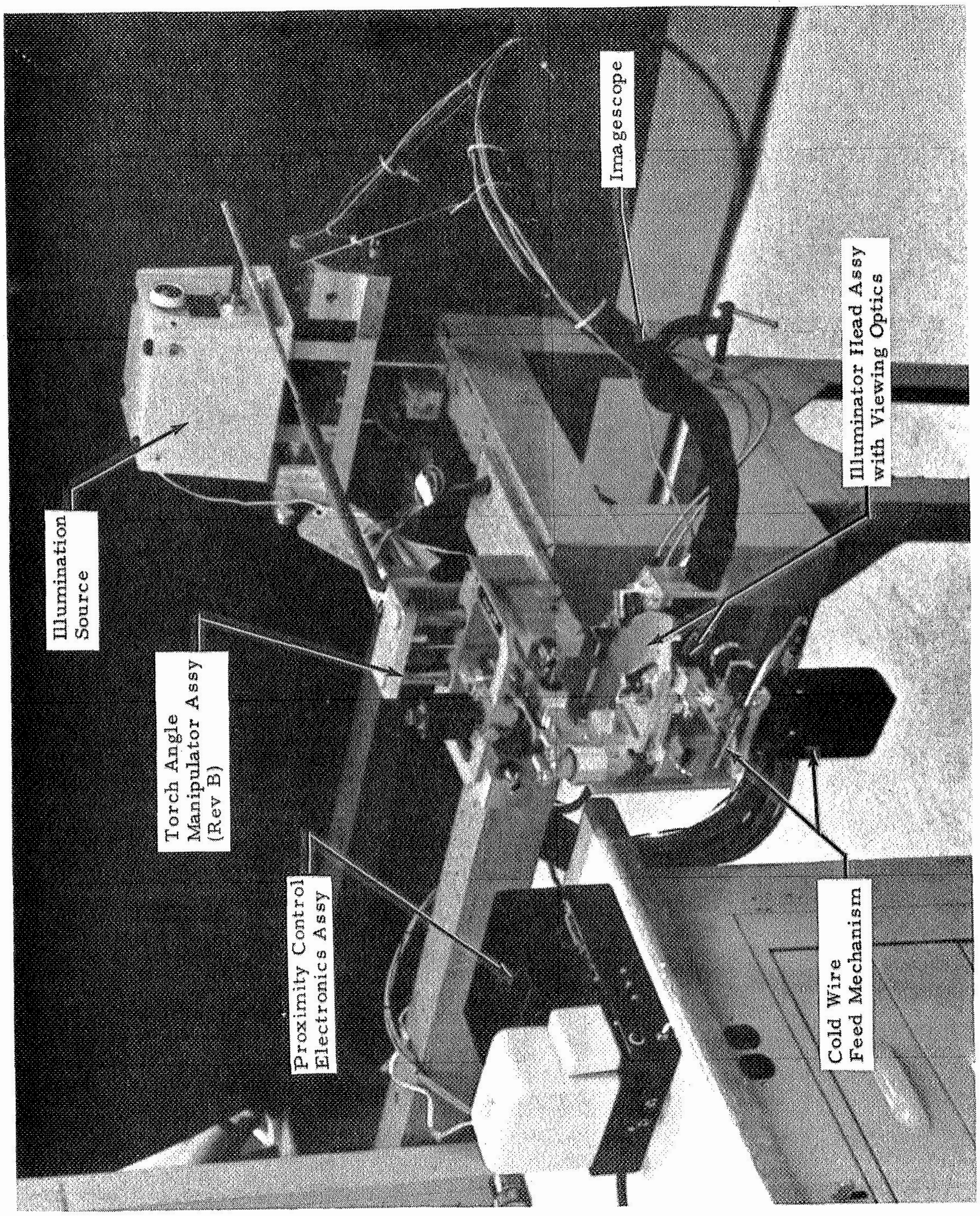

Fig. 2-2 - CCTV Arc Guidance Adapter Kit Assembly

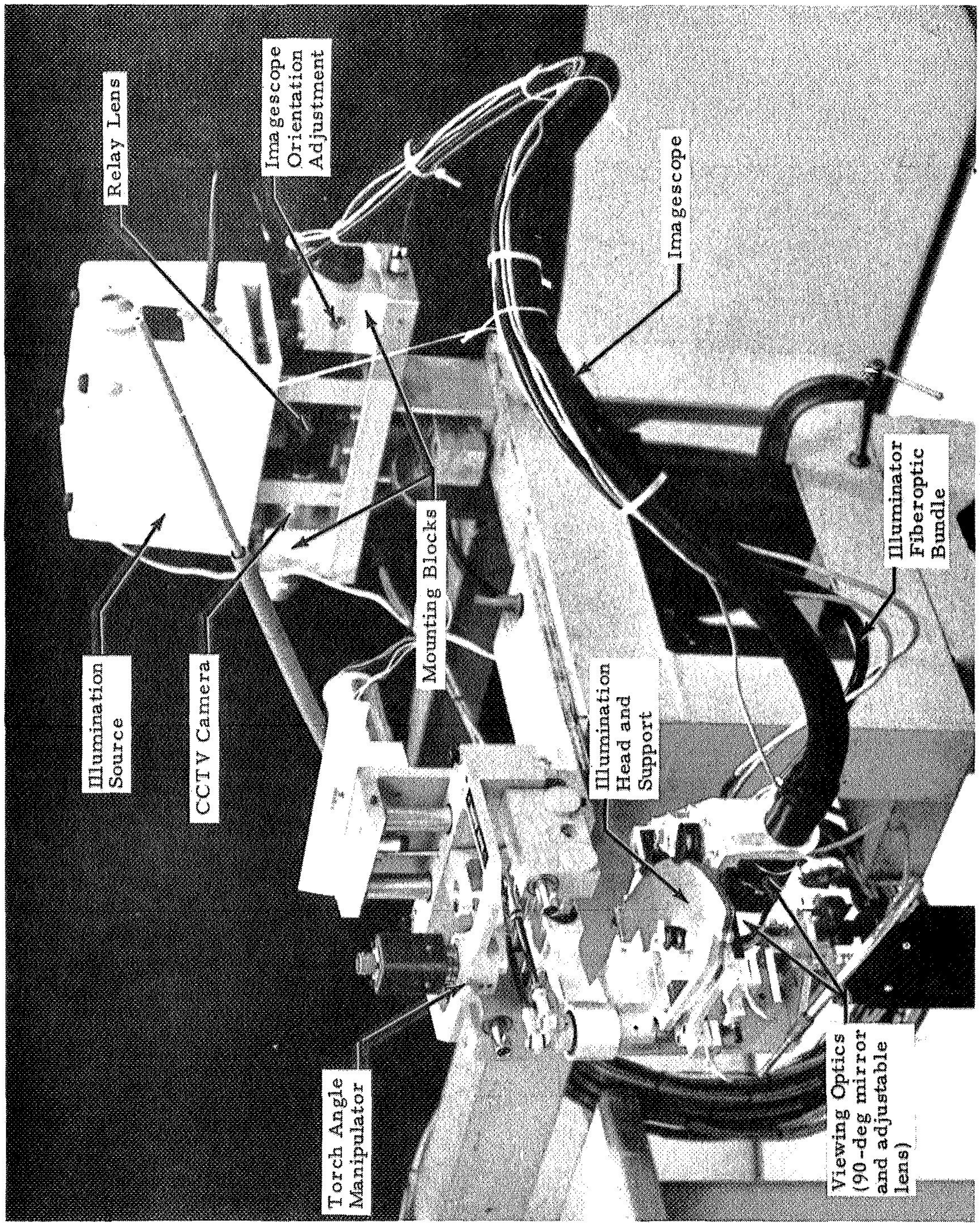

Fig. 2-3 - Close-Up of CCTV Arc Guidance Adapter Kit

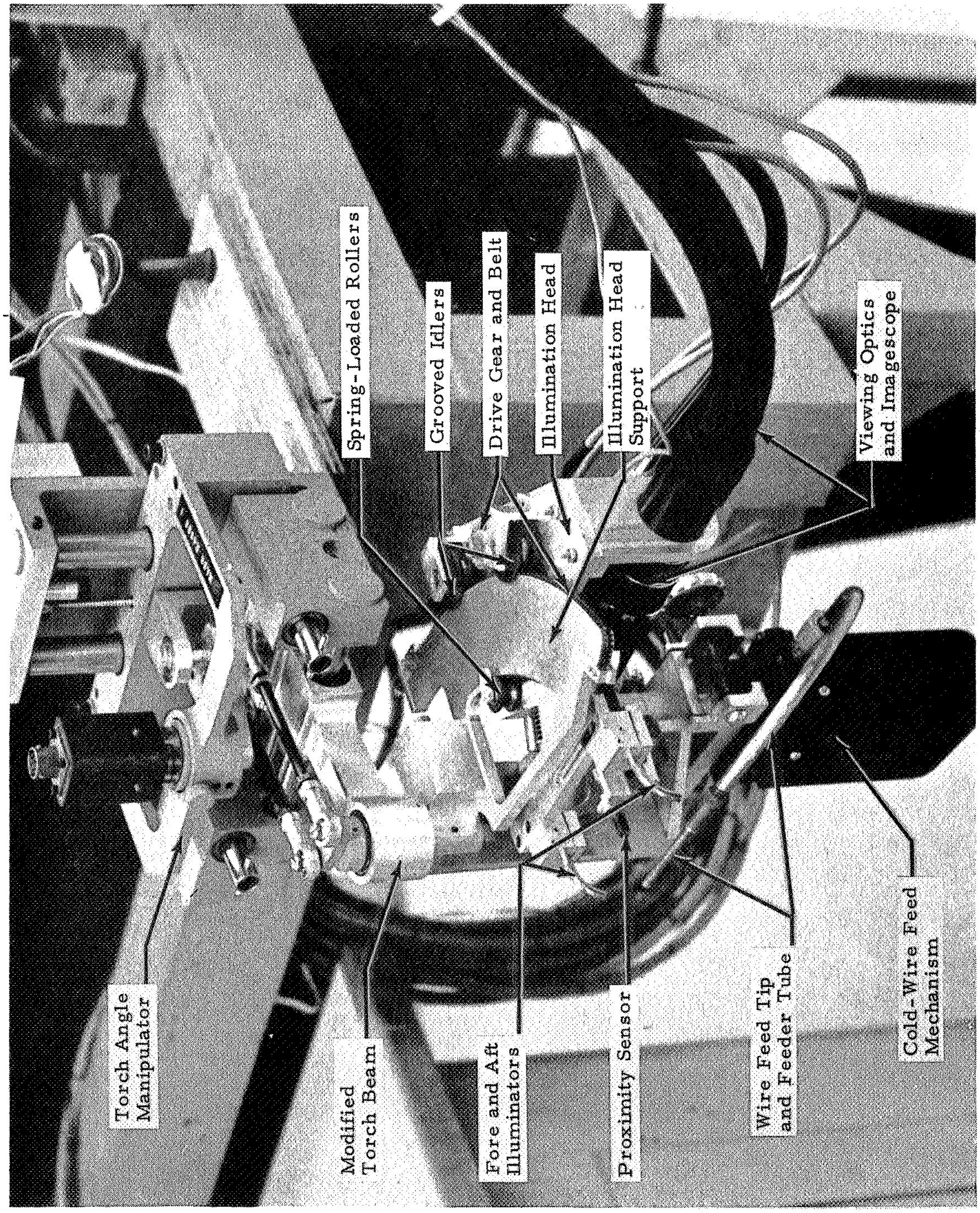

Fig. 2-4 - Close-Up of Illumination Head and Cold-Wire Feed Mechanism

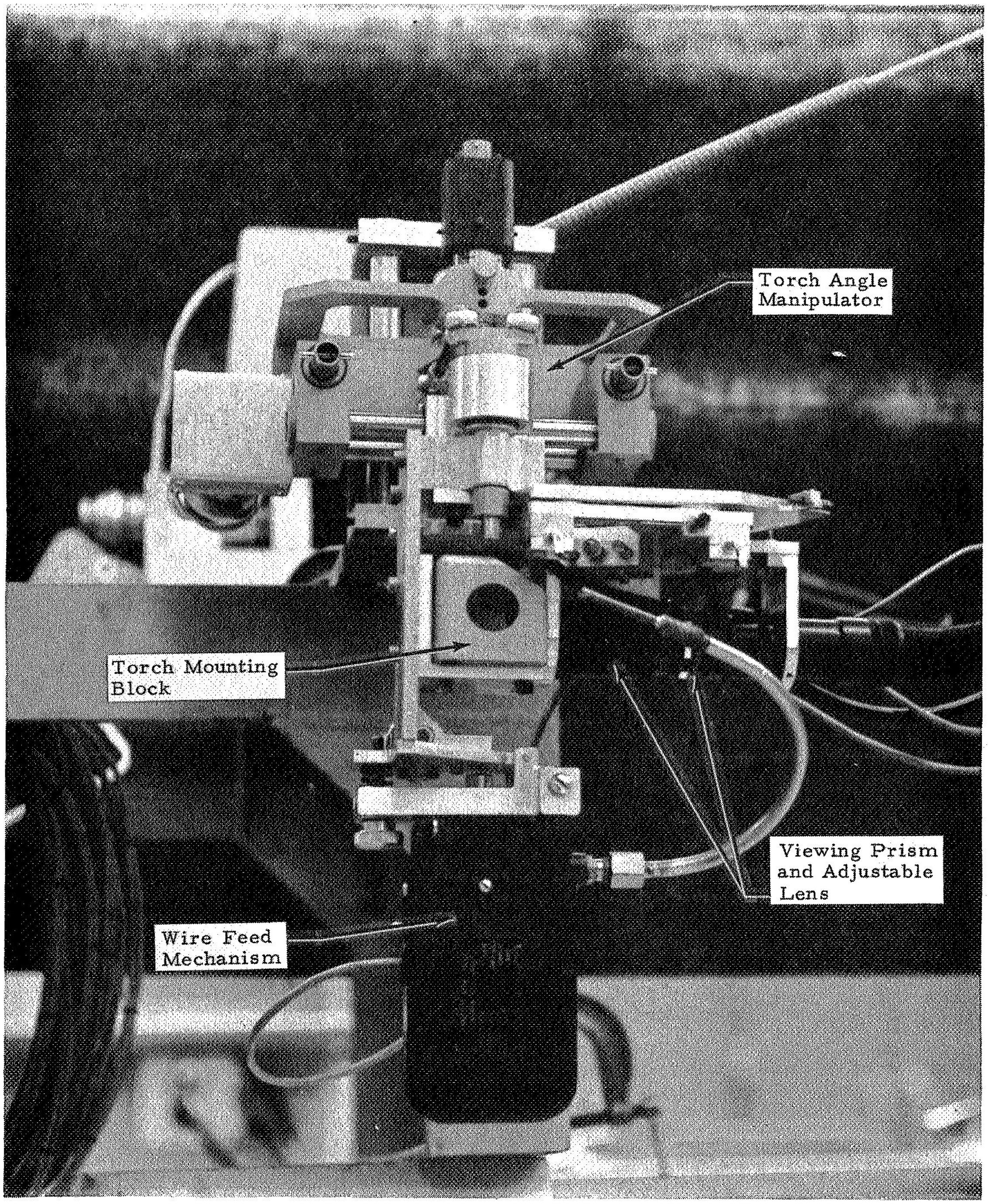

Fig. 2-5 - Front View of Illumination Head and Cold-Wire Feed Mechanism Assembled to Torch Angle Manipulator

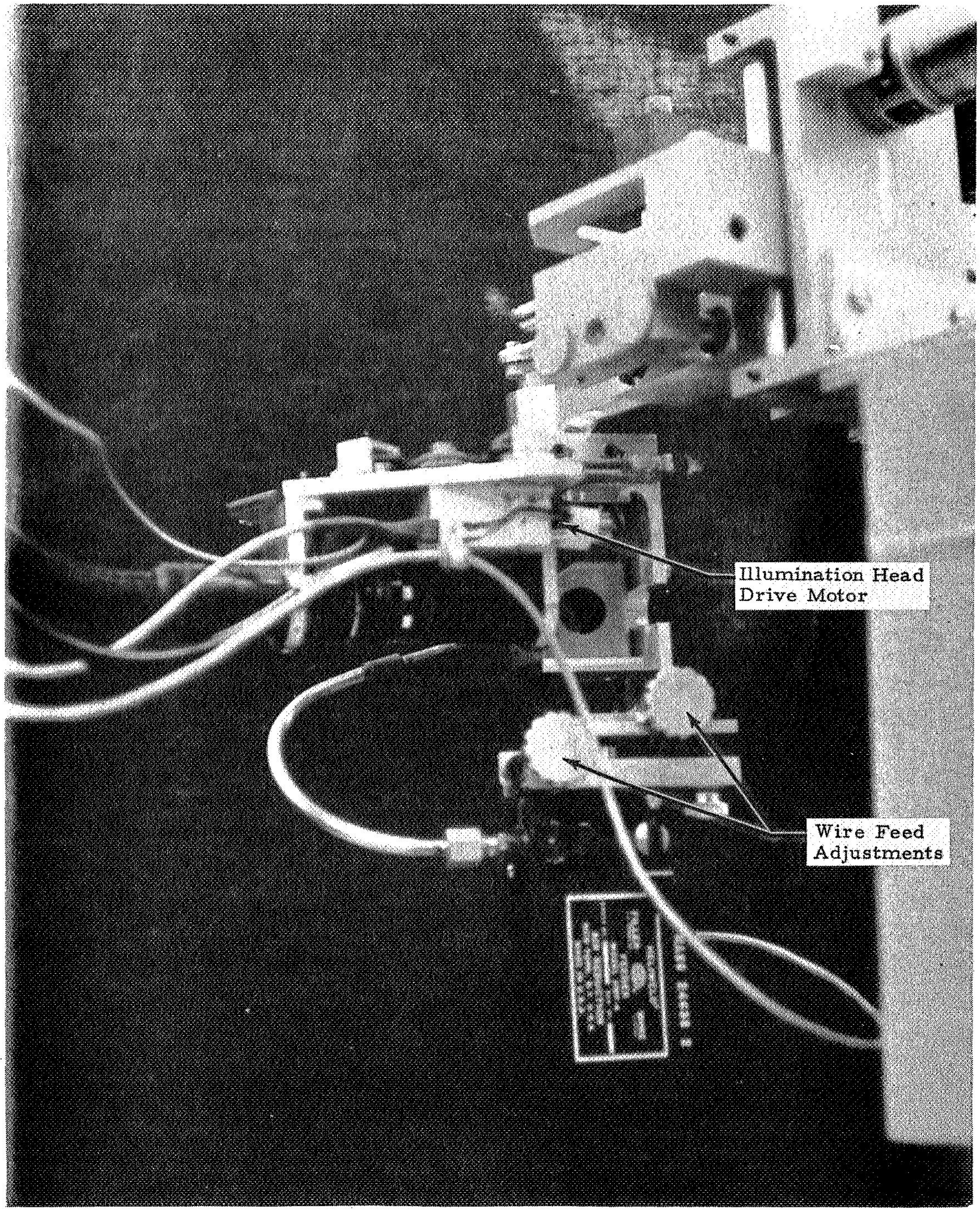

Fig. 2-6 - Aft View of Illumination Head and Cold-Wire Feed Mechanism Assembled to Torch Angle Manipulator

The illumination head, Figs. 2-1 through 2-4, is a plate which rotates -29 deg to +16 deg about a center of rotation 2.06 cm (13/16 in.) forward of the point of rotation of the torch head. The illumination head rotates independently of the torch head. This is necessary so that the illuminators maintain a constant proximity from the work piece for all specified conditions. This includes minimum work curvature radii (Ref. 1) of 15 cm (6 in.) when the torch is located on the convex side of the work and of 30 cm (12 in.) when the torch is located on the concave side of the work as shown in Fig. 2-1. The torch head will rotate ± 40 deg so as to remain perpendicular to the work surface while following the work curvature. However, the torch head can travel ± 40 deg rotation and travel to the stop. Limit switches may be provided to interrupt drive voltage to the motor and prevent damage to the drive system.

The illumination head support (Fig. 2-4) mounts to the torch beam and rotates with the torch. This support platform has a groove along its 6-in. outer radius for the drive belt and a 45-deg cam roller guide. The illumination head is suspended from the support platform by two grooved idlers and a spring loaded roller. The drive belt, which performs the two-fold function of support and power transmission, is loaded laterally in shear between the support groove and the idler grooves. The roller is adjustable to control the load between the three suspension points.

Under certain eccentric loading conditions the idlers may tend to pull off the drive belt, therefore Vespel* support washers are provided as a safety backup. Friction losses are minimized by the use of ball bearings on all shafts.

The drive belt is looped around the 1.90 cm (3/4 in.) drive pulley and attached to the illuminator support. A belt tension adjustment is provided. The drive gear is driven by a dc micromotor, Type 050/010 (Appendix A), through a set of bevel gears. The use of the drive belt system eliminates all but minor backlash in the reduction gears and the bevel gears. The gearmotor is mounted rigidly to the illuminator head (Fig. 2-6).

*DuPont trademark.

Two illuminators are provided as shown in Figs. 2-1 and 2-4. The aft illuminator located 2.54 cm (1 in.) from the torch is the primary illumination source for the guidance system. The forward illuminator adjusts from 5.08 cm (2 in.) to 8.25 cm (3-1/4 in.) from the aft illuminator. It is used as an alternate guidance source when the work piece is tack welded prior to final welding. The adjustment between illuminators is necessary to span the length of the tack weld.

The two illuminators (Figs 2-1 and 2-4) are an integral part of a split-bundle flexible light guide six feet long, with two 0.318 cm (1/8 in.) diameter legs. The split bundle, together with a standard commercially available illumination source* (Figs. 2-2 and 2-3), provides proper light intensity. Illumination intensity from such a system is 1200 centerbeam footcandles minimum, measured 5.08 cm (2 in.) from the end of each of the 0.318 cm diameter legs. The 0.318 cm diameter legs are metal clad at the ends with a 75-deg bend. This provides the specified incident angle on the weld joint for proper illumination. The illumination source mounts above the CCTV camera on the welding skate yoke. The flexible light guide is routed along the imagescope. Detail specifications for the twin illumination sources are given in Appendix B.

2.2 VIEWING OPTICS

The viewing optics for the CCTV Arc Guidance Adapter Kit monitors a 5.04 cm (2 in.) x 8.9 cm (3-1/2 in.) seam area 2.22 cm (7/8 in.) in front of the torch. Mounting the viewing optics rigidly to the illumination head, with the lens and mirror centerline 12.1 cm (4.75 in.) from the work surface, provides the proper object distance and continuous focus of the viewing area. Other pertinent dimensions and specifications which were developed during this program are given in Appendix C.

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*American Optical Company, Model K-150.

The viewing optics, as shown in Figs. 2-1 through 2-5, consists of a 90-deg viewing mirror, an adjustable objective lens, and a single-bundle imagescope four feet long. Also, a relay lens and adapter interfaces the imagescope with the "D" lens mount of the CCTV camera as shown in Fig. 2-3. The standard single-bundle fiberscope provides a resolution of 45 to 50 line pair per mm and adapts to the specified 8-mm format. It also offers lower replacement cost should the original imagescope be damaged. The imagescope covering is a flexible Teflon convoluted hose covered with nylon braid. The relay lens end of the imagescope provides a one-revolution adjustment for orienting the viewing area image properly with the camera. Also, the adjustable lens on the viewing area end has a focus adjustment and a lens opening adjustment.

The CCTV camera is a General Electrodynamics ED 6038A television instrumentation camera with a 12.7 mm (1/2 in.) vidicon head. The camera is 3.81 cm (1-1/2 in.) o.d. x 13.2 cm (5-3/16 in.) long, excluding the lens, and weighs 0.4 kg (14 oz). The adapter is threaded to conform to the "D" mount on the camera. A relay lens attaches to the adapter and the imagescope to focus the image from the imagescope to the vidicon head. This assembly is mounted on a rugged frame on the welding skate yoke as shown in Fig. 2-1 and simulated in Fig. 2-3.

2.3 PROXIMITY CONTROL SYSTEM

Figure 2-7 shows the proximity control system block diagram. An Electro Products Model 4947A miniature proximity sensor and modified Model 55.121 proximity amplitier provide an analog signal voltage. (See Appendix D.) This voltage is used to position the illumination head. The proximity sensor (Figs. 2-1 and 2-4) is rigidly connected to the forward illuminator. Thus, they both have the same 2-in. to 3-1/4-in. adjustment from the aft illuminator. The sensor and the illuminators maintain a position of 0.100 in. from the work surface. Signal amplification and power necessary to drive the dc motor are provided by Opamp Laboratory's operational amplifier Model 420 and power supply Model 523. A double-ended Micro-Mo 050/010* dc motor with an 05/2* (485:1) slip-on

*See Appendix A.

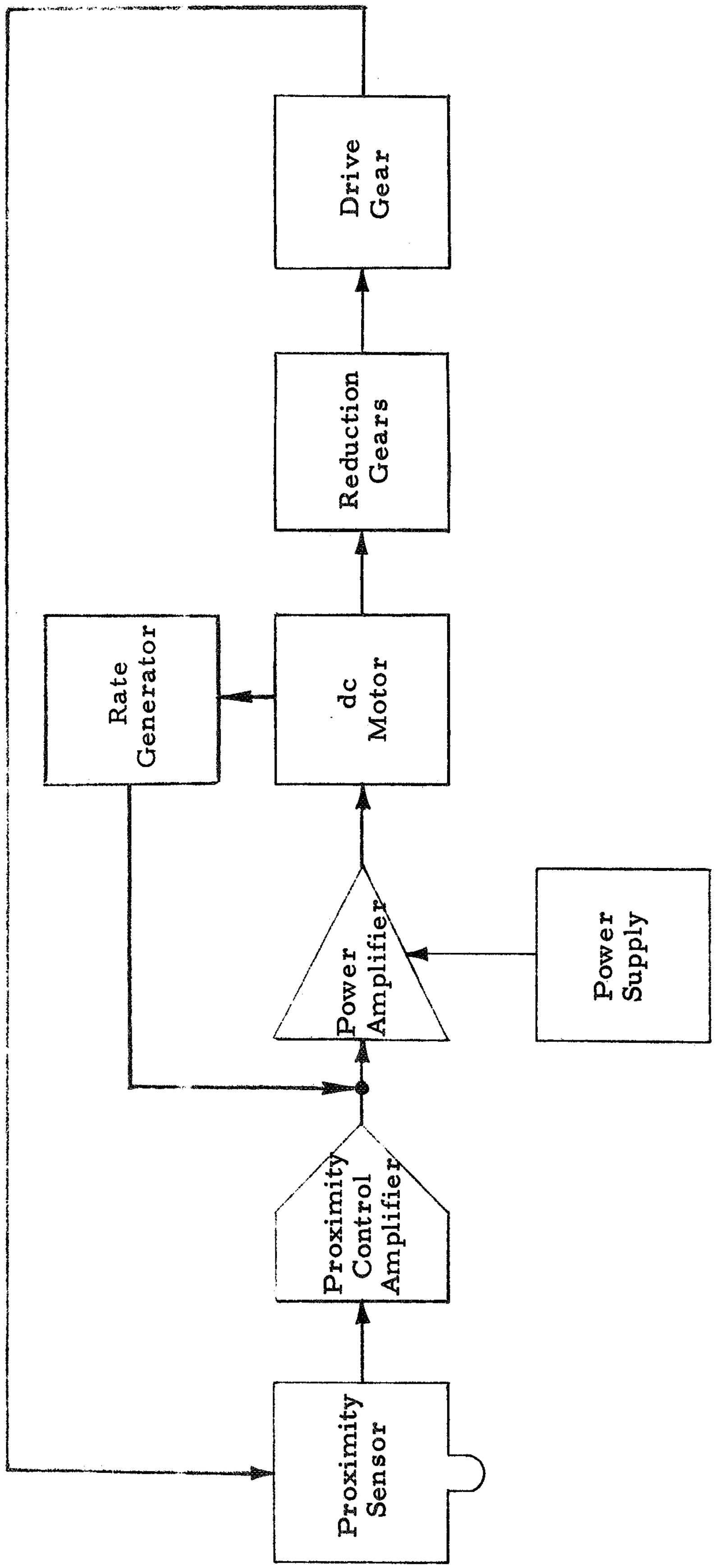


Fig. 2-7 - Proximity Control System

reducer on one shaft and an 057/004 tachogenerator on the other provides the power to the drive gear on the illumination head and the rate feedback necessary for proper servo control. The gearmotor is lightweight and measures 19 mm diamter by 39.7 mm long, including the tachogenerator. Thus, it mounts directly on the illumination head and uses bevel gears to govern the drive gear.

2.4 WIRE-FEED MECHANISM

The Airco Model HMF-A-2304-0300 wire-feed mechanism is properly positioned with respect to the torch in order to feed the wire into the weld. This positioning required modification to the location of the feed mechanism, as well as to the feed mechanism itself. As shown in Figs. 2-1 through 2-6, the wire-feed mechanism is located below the compensator beam and the torch mount. The wire-feed guide feeds the wire to the torch at the specified 18-deg angle on the side opposite the illuminators. This minimizes illumination interference. The position of the wire-feed mechanism and guide relative to the torch remains constant for all maneuvers of the torch. The modified feeder provides fine positioning adjustments as does the standard feeder. Small gauge wires (routed along the fiberoptics) connect the wire-feed motor to the skate terminal board. This eliminates the loading on the wire-feed mechanism by the heavy gauge industrial wire. The heavy gauge industrial wire connects the terminal board to the wire-feed controller. The modified wire-feed guide (Appendix E) has a 3-in. radius bend, the same as that of the standard guide. The modified guide contains a 160-deg bend, while the standard contains only a 45-deg bend. The tip of the modified guide is twice as long as the standard tip to reduce optic interference. Reflective interference is minimized by finishing the wire-feed guide and tip with a flat black finish.

Section 3
OPTICS CONSIDERATIONS

The illumination and viewing optics systems were anticipated to be a straightforward design problem. The original concept centered around two viewing lenses to view the total viewing area. A readily available split-bundle fiberscope enhanced this concept and reduced the CCTV camera interface problem. The confined working envelope and required maneuverability of the illumination head, however, were not compatible with the bulk and stiffness of the split-bundle fiberscope. After numerous telephone discussions and an engineering conference with an optics vendor a workable system was obtained as described in Section 2.

3.1 VIEWING OPTICS

The viewing optics required a resolution of 50 line-pairs per mm minimum, an 8-mm format, and the ability to view a 5.1 cm x 8.9 cm seam area. The size of the viewing area with the confined working space suggested two possible approaches – prisms (or mirrors) or fiber optics. Both techniques were to use two lenses to view the seam area.

The prism system, as shown in Fig. 3-1, was abandoned after study showed that:

1. Object distances and focal lengths of available optics were not compatible for obtaining an adequate system for the CCTV to view.
2. There was not adequate room for mounting the CCTV camera below the torch-angle manipulator.
3. Motion compensation would be more complicated if viewing field distortion was to be eliminated.

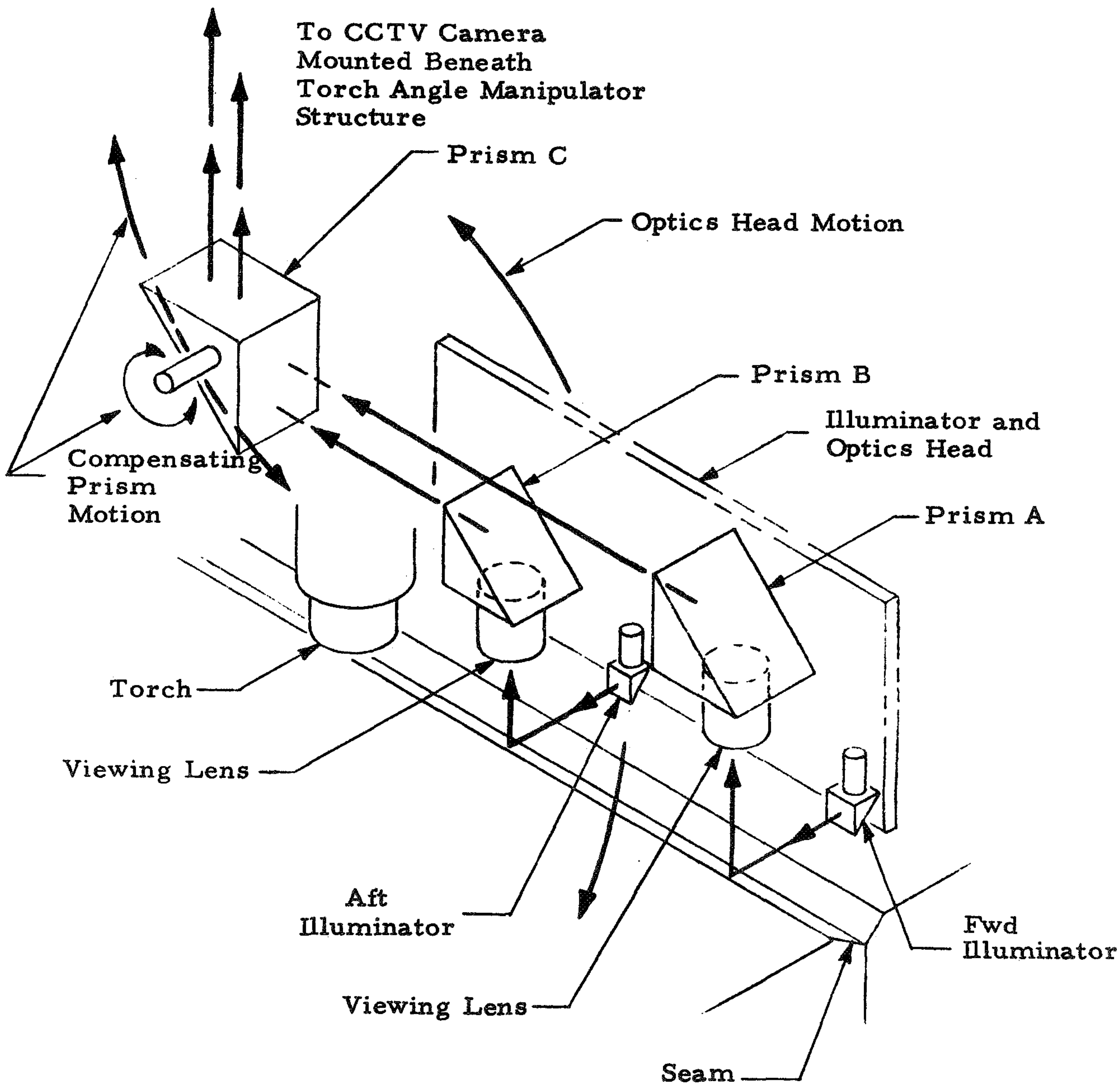


Fig. 3-1 - Seam Viewing Optics — Prism Configuration

The second technique, as shown in Fig. 3-2, utilizing two lenses with fiberscopes was pursued. A split-bundle fiberscope was available on special order (approximately $5000 each) and ideal for use with the two-lens technique. This allowed the camera to be mounted on the skate. Standard lenses with an object distance of 5 cm that were compatible with the fiberscope were not available; however, two compatible lenses with object distances of 10 cm were found. Positioning the optics and fiberscope within the working envelope was impossible unless a 90-deg bend within the envelope could be accomplished. The minimum bend radius of the fiberscope coupled with the fixed dimensions of the optics prevented this. The fact that there were two of everything to be fitted in the small envelope complicated the problem.

A workable system was finally developed which utilizes some of the concepts from both original approaches. It consists of a single 90-deg viewing mirror rigidly mounted to the illumination head 12 cm from the work surface, a single wide-angle lens, a single, four-foot, fiberscope bundle, a relay lens, and a C-D mount adapter to adapt the 16 mm system to the 8 mm CCTV camera. This system has a minimum resolution of 50 line pairs per mm, a 16 mm format which allows the camera to view the total 2 in. x 3-1/2 in. seam area and automatically maintains focus on the light spots. It also offers simplicity in packaging within the available working envelope and a low replacement cost ($2200) should the original fiberscope be damaged.

It was also determined that the fiberscope needed a more flexible covering than that offered by the standard braided stainless-steel covering. This reduces the torque loading on the illumination head. Many coverings were investigated. The one chosen is a convoluted Teflon hose with nylon braid. This affords both the flexibility and the protection needed. Specifications for the finalized design are presented in Appendix C. At least three suppliers were found qualified for this system. The Bendix Imagescope System was selected on the basis of minimum costs. Test results of this system are described in Section 6.

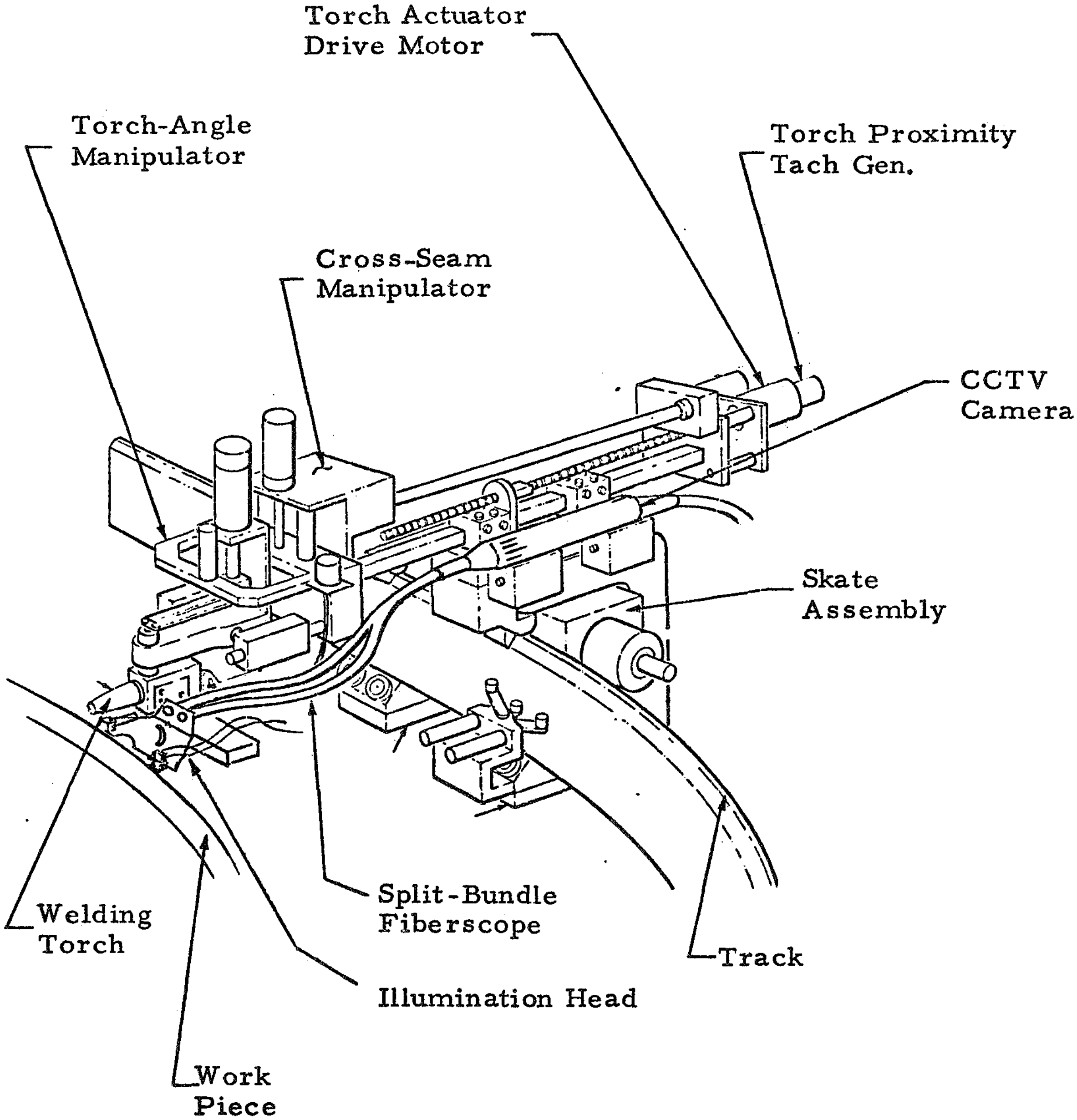


Fig. 3-2 - Split-Bundle Fiberscope Configuration

The CCTV camera and relay lens attached to the imagescope are mounted as an assembly in an aluminum framework. This assembly is mounted on the welding skate frame just over the torch proximity drive screw. This orientation and location, as shown in Figs. 3-3 and 2-1, was selected to minimize weight and bending loads on the illumination head through the full range of angle and displacement adjustments. The mounting arrangement was designed to minimize loads in the camera, relay lens and imagescope connections by using aluminum saddle blocks for the camera and imagescope ends. (See Figs. 2-1 and 2-3.)

3.2 ILLUMINATION SOURCES

Proper illumination of the seam requires a minimum light intensity of 1000 centerbeam footcandles at a distance of 5.1 cm (2 in) from the end of the source. The distance between light sources must be adjustable from 5.1 cm (2 in) to 8.9 cm (3-1/4 in.).

The possibility of using lens tip incandescent lamps on the illumination head was investigated. Several commercially available tungsten lamps with rated end candlepower of 3800 to 5000 footcandles were tested. They are operated at rated voltage of 16V to 48V. To use these lamps and maintain the proper incident angle, custom-made image conduit with a 75-deg bend must mate to the lamp. To replace a burnt-out lamp, the image conduit must be locked firmly in place and not be bonded to the lamp. This imposes packaging problems since the lamps are large and do not have close tolerances on length. Thus, they would have to be completely enclosed in a large custom-made holder. The concentrated power inside the holder would make it excessively hot. This would be apparent on changing a burnt-out bulb or adjusting the distance between sources.

The present technique in use, fiberoptic light guides, was also investigated. A split-bundle light guide 1.83 m (6 ft) long with two 3.18 mm (1/8 legs offers the best system. See Fig. 1 of Appendix B. Used together with a

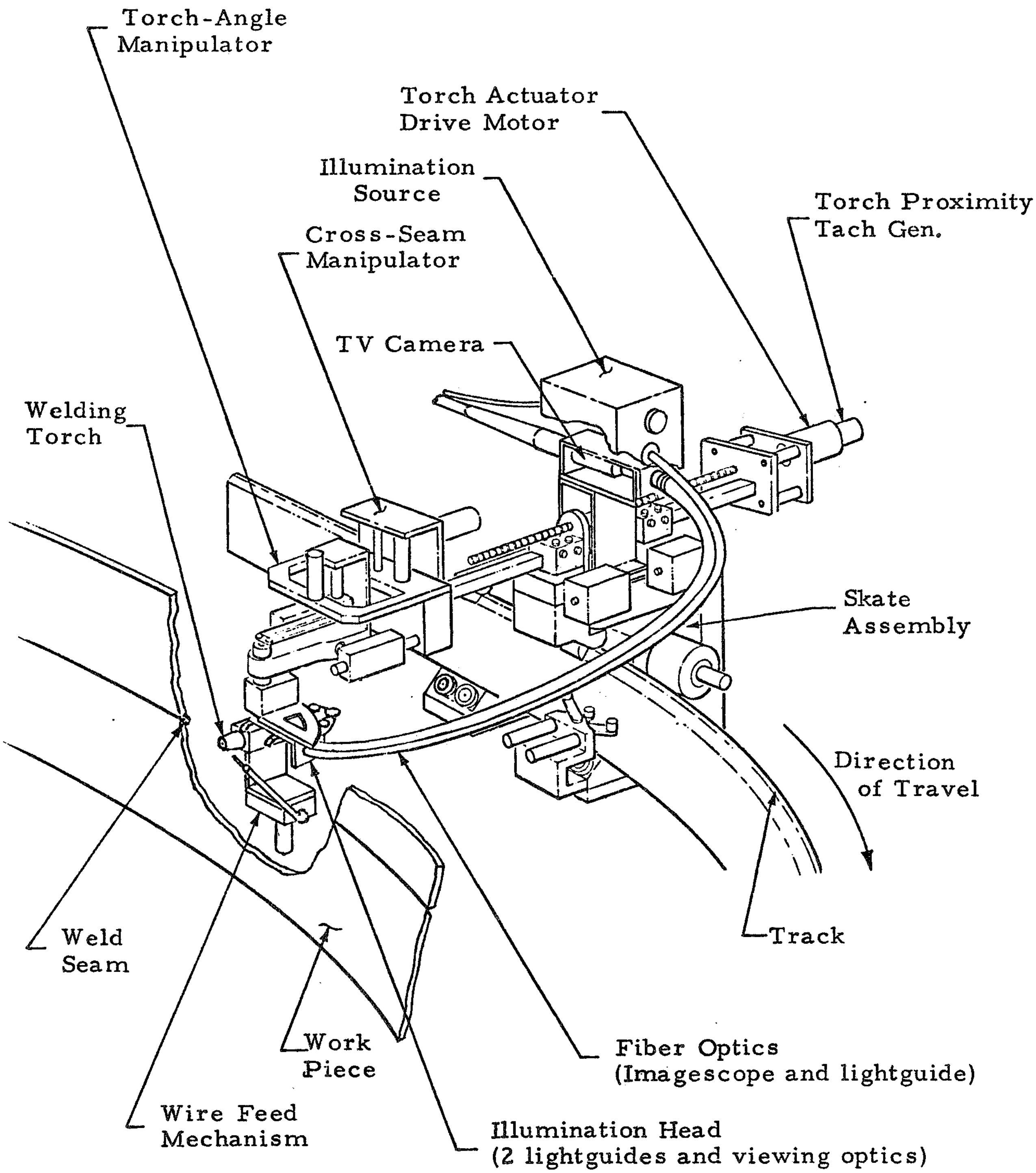


Fig. 3-3 - Computerized Welding Skate with CCTV Arc Guidance single illuminator, it offers a variable intensity up to 1470 center-beam foot-candles (Fig. 3-4) when measured 5.1 cm from the end of the light guide. The two 3.18 mm legs have metal-clad ends, each with a 75-deg bend. Thus, a simple clamp holds the light guide in place. The light source will be mounted on the skate above the CCTV camera, with the same orientation. The light guides are easily routed out of the way with the CCTV fiberscope bundle.

Several vendors for the twin illuminator sources as specified in Appendix B were found qualified. The vendor selected was the American Optical Company which supplied a fiber optic twin light guide for assembly with their Model K-150 light source. This system performed very satisfactorily in the final system checkout.

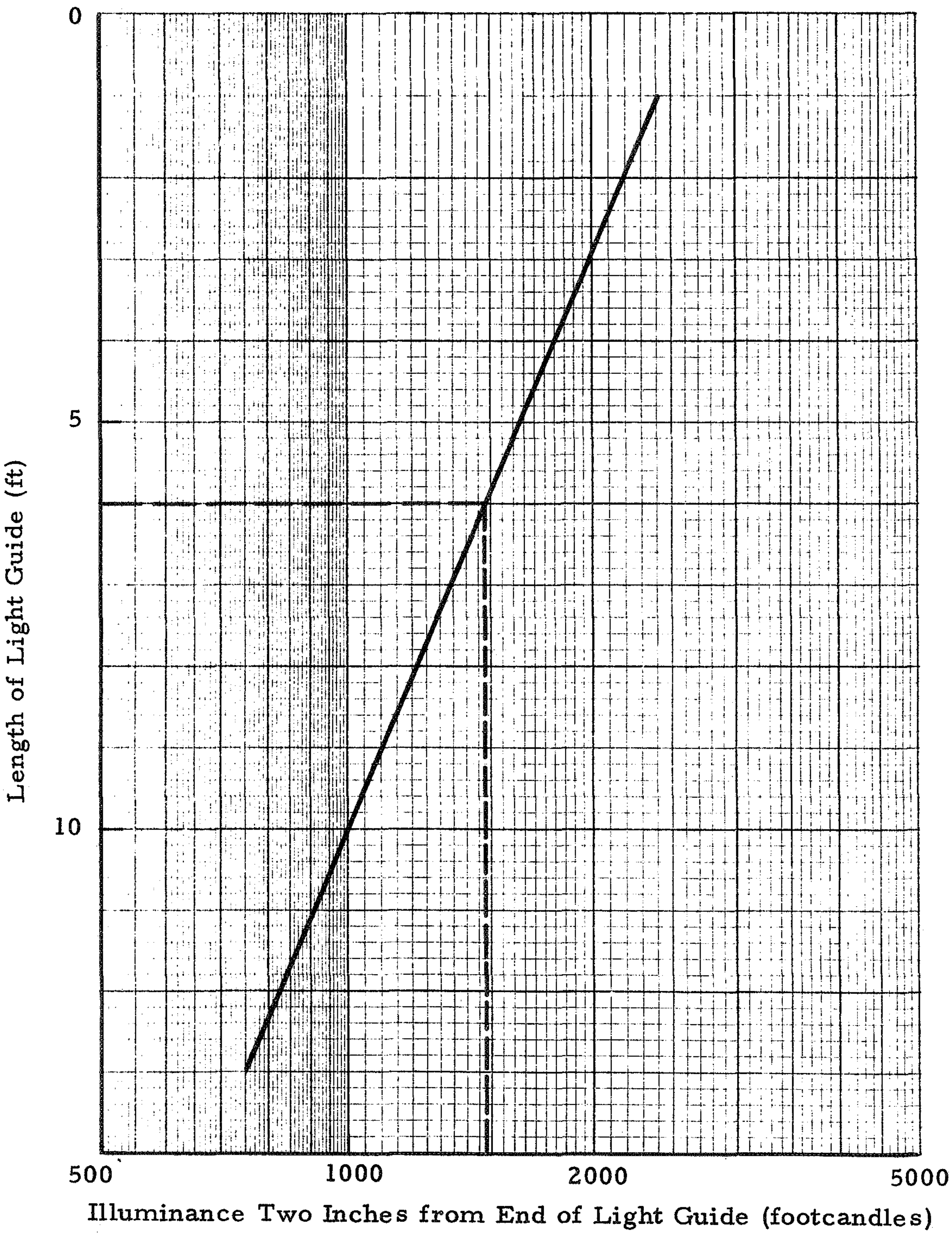


Fig. 3-4 - Illumination at a Surface by the AO K150 Illumination Source and the AO 1/8-Inch Diameter Light Guide

Section 4
CONTROL SYSTEM ANALYSIS

The analysis of the control system was divided into three tasks: (1) determine actuator requirements to drive the illumination head; (2) choose a dc motor with proper reduction gear ratio (gear motor) to drive the actuator; and (3) choose a proximity sensor system with adequate control power to drive the motor.

4.1 ACTUATOR DESIGN

To find an actuator to drive the illumination head, it is first necessary to determine the center of rotation and the amount of rotation of the illumination head. The illuminators must maintain a constant proximity to the work for a minimum work curvature radii of 15 cm (6 in.) when the torch is located on the convex side of the work as shown in Fig. 2-1 and of 30 cm (12 in.) when the torch is located on the concave side of the work as shown in Figs. 2-1 and 4-1. The maximum amount of rotation occurs between the concave radius and the convex radius when the illuminators are fully extended (3-1/4 in. apart). This is shown in Fig. 4-1. The center of rotation of the illumination head is located 13/16 in. in front of the torch. For the convex radius, the illumination head rotates -25 deg. For the concave radius, the illumination head rotates +12 deg. Rotation allowances of -29 deg to +16 deg provide a margin of safety for the illuminators and the drive system.

A cam slot in the illumination head support (Fig. 2-1) provides the +16 deg to -29 deg rotation about the proper center of rotation. To drive the illumination head with minimum mechanical loss, a 1/4-in. diameter linear actuator (ball screw) was investigated. To prevent mechanical binding, the axis of the linear actuators must lie tangent to the arc traced by the point where the actuator connects to the illumination head. This required position

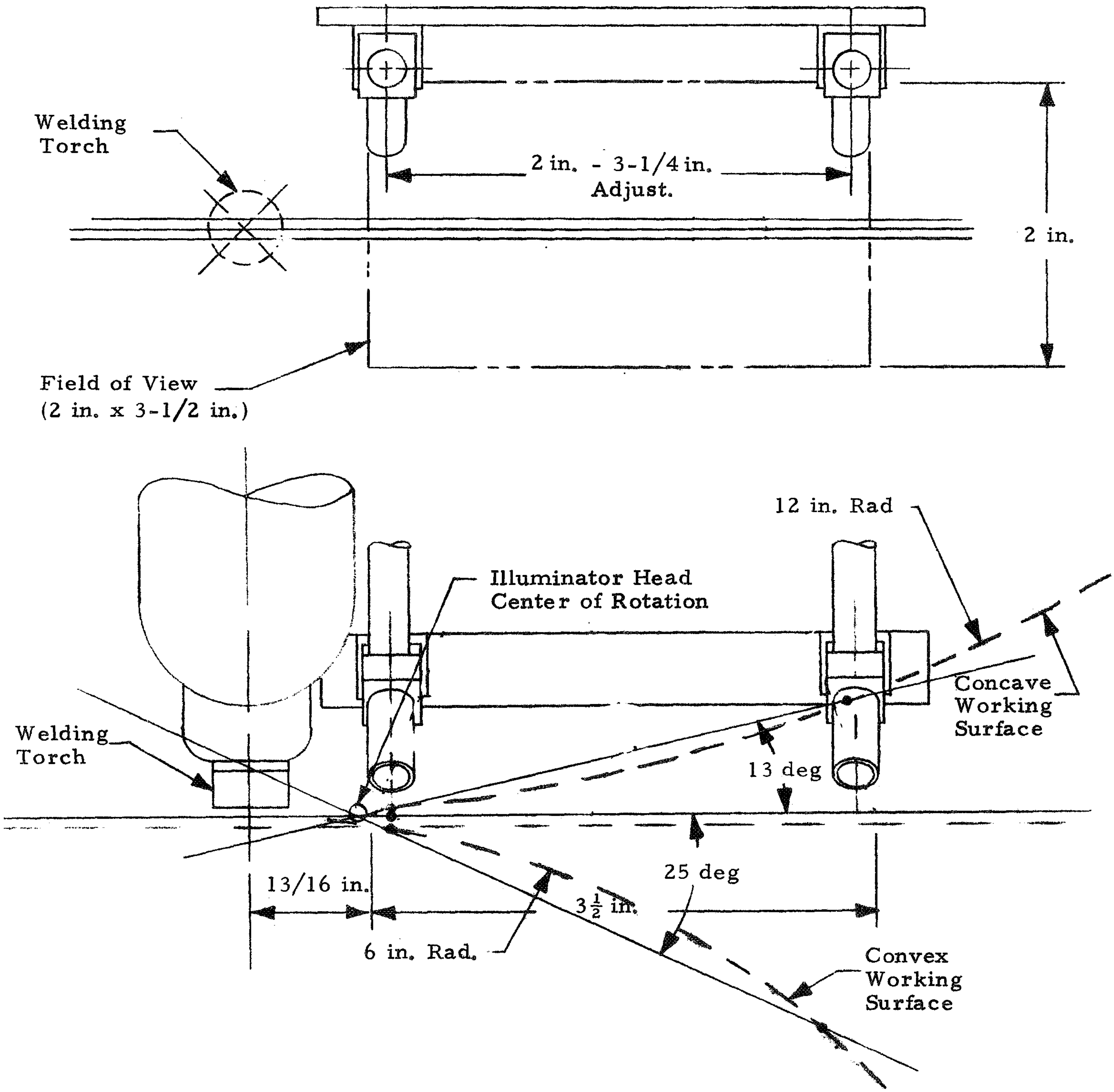


Fig. 4-1 - Welding Adapter Viewing Area

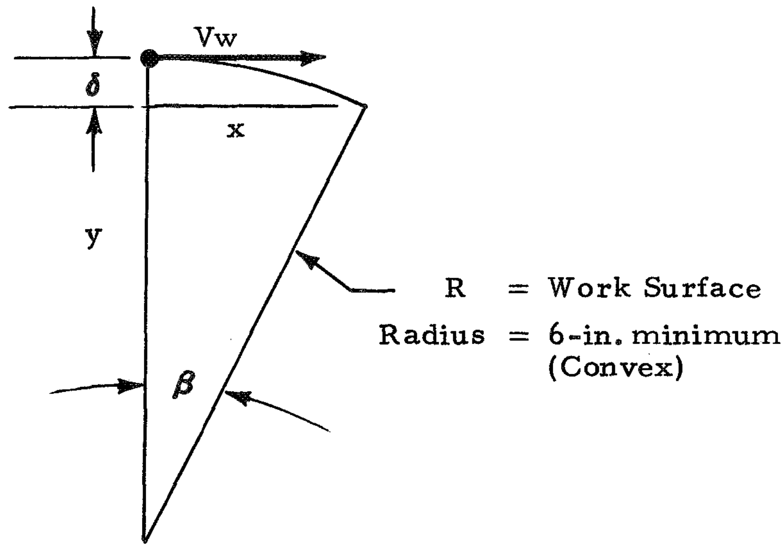
plus the length of the linear actuator to drive the illumination head to the -29-deg extreme results in a length of actuator extending 5 in. in front of the illumination head when welding a straight surface. Direct interference between the fiberscope and the actuator would result. Such interference would lead to catastrophic damage to one or both. The viewing optics orientation cannot change if the optics are to stay within the limits of the working envelope. Thus, either the linear actuator had to be repositioned or a new type actuator found. Repositioning the linear actuator would result in mechanical binding or create interference problems. Thus, a new type of actuator was needed.

The rotation of the illumination head about a center of rotation lends itself to a gear actuator. This is provided by a positive drive belt and geared pulley. A three-point suspension consisting of two grooved idler pulley and attached to the illuminator support. The drive belt has almost negligible backlash and also provides a load transfer member. The drive gear is driven by a dc motor through a set of bevel gears.

4.2 GEAR MOTOR REQUIREMENTS

Determining the response time, torque and speed of rotation necessary to drive the illumination head was the first step in selecting the proper gear motor (dc motor with slip-on reduction gears). The design proximity tolerance, δ, assumed to maintain the optics in proper focus is ± 0.020 in. This tolerance should not impose design problems for the optics system and should be reasonable for the illuminator head control system. The response time necessary to maintain this tolerance at a maximum welding speed of 50 in./min (Ref. 2) is found from Fig. 4-2 and as follows:

$$\Delta t = \frac{R \sin\beta}{Vw} = \frac{0.491 \text{ in.}}{0.5 \text{ in./sec}} = 0.590 \text{ sec}$$



$$\cos\beta = \frac{y}{R} = \frac{5.98}{6.00} = 0.966 \text{ for } \delta = 0.020 \text{ in.}$$

Fig. 4-2 - Proximity Tolerance to Maintain Focus

The loads on the system are composed of friction, inertia and bending moment. The bending moment is induced by the stiffness of the casing of the fiberscope. The weight of the illumination head is 3.5 lb which effects the system through the friction loading only. To overcome this friction of the system in moving the illumination head requires a torque of 4.5 in.-oz output from the gear motor.

The maximum rotation speed occurs under worse case conditions; i.e., the system welding at maximum weld speed abruptly changes from a 12-in. concave surface to a 6-in. convex surface (see Fig. 4.1). The illumination head begins to rotate at the tangent of the curves, while the torch travels an additional 22-deg arc of travel in 5.53 sec before reaching the tangent point. Thus at 50 in./min maximum welding speed, the illumination head must rotate at a rate of 7.98 deg/sec from

$$\omega = \frac{44.2 \text{ deg max. rotation}}{5.53 \text{ sec}} = 7.98 \text{ deg/sec}$$

Also, the corresponding gear motor output must be 21.3 rpm.

Attaching the gear motor directly to the illumination head and drive gear eliminates the need for a flexible drive and a mounting location on the skate. To accomplish this requires a small-size motor. Such a gear motor is an Escap 15 micromotor with type C-15 metal slip-on reduction gears. The motor with a 485:1 gear ratio cam provides 19.4 in.-oz output at 18.5 rpm. The inertia torque of the system with this gear ratio is 1.75×10^{-4} in.-oz from the following equation.

$$T = I\alpha = \frac{I\,(Vw^2)(G.R.)}{R \sin\beta \; (r_{d.g.})}$$

This torque has a negligible effect on the starting time of the motor, which is 0.06 sec.

The Swiss-made, precision, gear motor requires 2 Vdc at 0.5 amp maximum (1 watt), weighs 2.6 oz and costs less than $35.00. The additional 17.2 in.-oz available from the motor is capable of handling 220 in.-oz bending moment about the illuminator head center of rotation. This appears to be a reasonable allowance for torque induced by the fiberscope hardware.

4.3 SENSOR AND ELECTRONICS SELECTION

The control system performs properly if the proximity sensor has the required sensitivity and response. Although 360 degree-of-freedom rollers can do the job, the electronic proximity sensor is preferred. Not only is it more sensitive and faster in response, but it does not have to be in contact with the work piece. Thus, workpiece preparation is minimized.

Such an electronic proximity sensor is the Electro Products model 4947A miniature proximity sensor, together with the Model 55.121 proximity control amplifier. The proximity sensor is 1/4-in. diameter and 1-1/2-in. long. Its sensitivity is $\pm$0.002 in. at 0.100 in. from the work which is approximately 10 times the required sensitivity. Unit cost is less than $25.00. The proximity control amplifier must be used to energize the sensor. It also provides a control relay. The control relay does not provide adequate control since this system requires proportional voltage control to the motor to maintain the $\pm$0.002-in. tolerance. Only an analog signal voltage can accomplish this. Modifying the model 55.121 control amplifier by tapping the analog control voltage to the relay switching transistor provides an analog voltage signal of 0.16 Vdc to 2.71 Vdc. However, the current available is only tenths of a milliampere whereas the motor requires 500 milliamperes maximum. Using an operational amplifier with power supply similar to Opamp Labs Model 415 and Model 523, respectively, provides sufficient power to the motor. Cost of the operational amplifier and power supply is less than $60.00 total.

4.4 STABILITY ANALYSIS OF THE PROXIMITY CONTROL SYSTEM

A stability analysis of the proximity control system in the CCTV Arc Guidance Adapter Kit as described in the Phase I report (Ref. 3) was performed. The analysis shows that a limit cycle may be expected from the proposed loop. The addition of appropriate tachometer feedback to the control loop eliminates the limit cycle characteristic. The compensated system exhibits improved linear characteristics with 0.0667 sec as the longest time constant.

4.4.1 Analysis Without Tachometric Feedback

The proposed control loop may be represented in block diagram form as shown in Fig. 4-3. As previously implemented, backlash exists in the drive gear as well as in the bevel gear, and the total backlash width is 0.0112 radians.

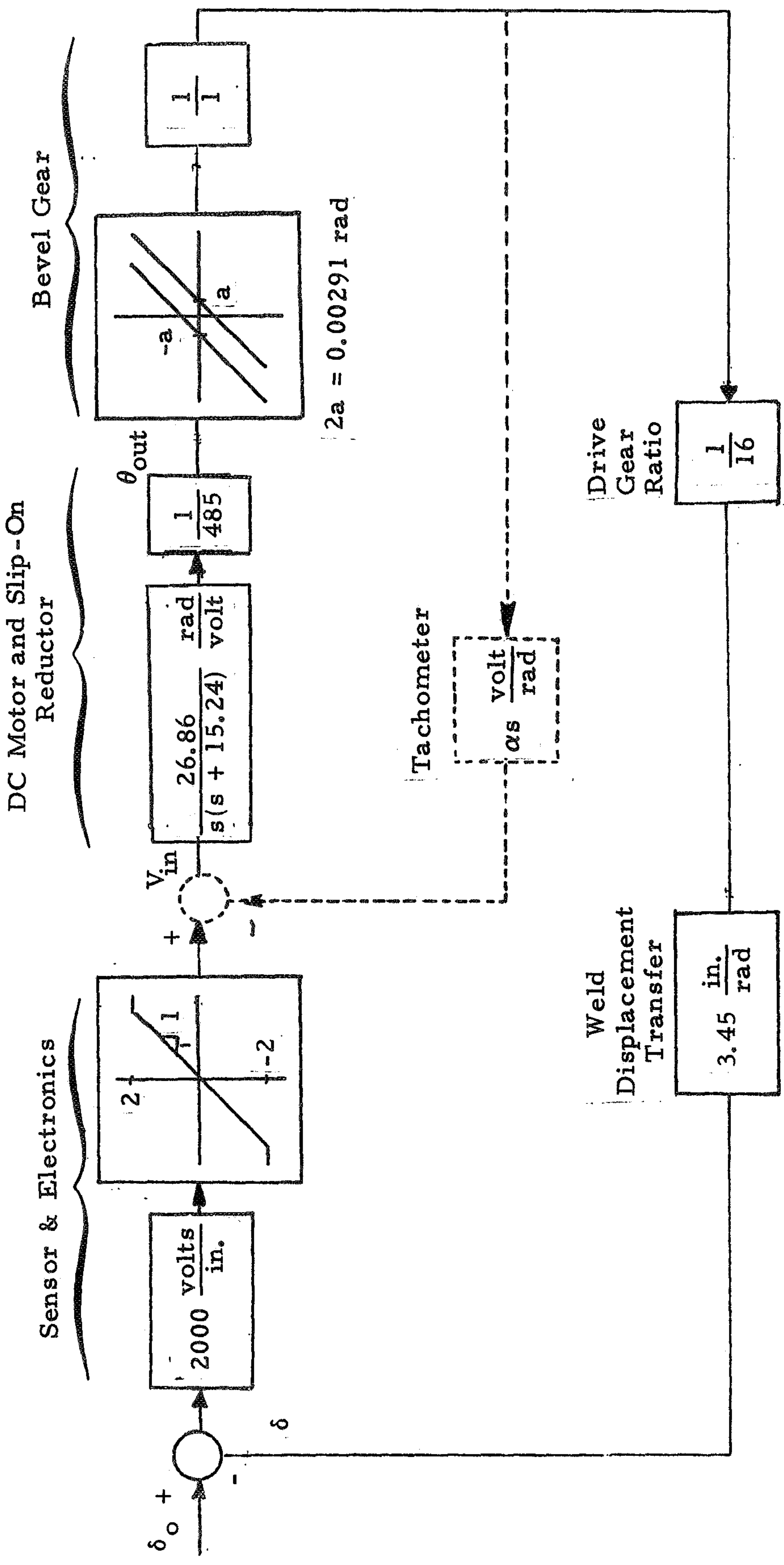


Fig. 4-3 - Block Diagram of Control Loop
(Dotted portion indicates rate feedback.)

The proposed drive system will decrease the backlash in the gears to 0.00291 radian. To perform an analysis for limit cycles, the backlash and limiter may be combined to form the composite nonlinearity shown in Fig. 4-4. The resulting plot of the linear system transfer function and the negative inverse of the describing function on a Nichol's chart are shown in Fig. 4-5. As shown, a limit cycle is predicted at a frequency of about 70 rad/sec, with an amplitude at the input to the backlash of $5a = 0.00725$ radian ($a = 0.00145$ radian). The output waveform would, therefore, be approximately 0.00135 radian in magnitude. To avoid an intersection without compensation, a gain reduction in the forward loop of 36 dB or more is required. This would not necessarily eliminate the limit cycle since any deviation from the nominal parameter values assumed could cause the system to limit cycle. An RC network could be added to reshape the locus with a smaller decrease in gain required. However, the lack of assurance that a limit cycle would not exist makes this approach less desirable than the one that follows.

4.4.2 Tachometric Feedback

If tachometric feedback is introduced as shown by the dotted portion of Fig. 4-3, properly choosing the tachometer gain will assure the absence of a limit cycle. If the control zero resulting from the tachometer occurs at a lower frequency than the pole of the transfer function of the motor, the resulting frequency locus is always to the right of the -90-deg asymptote of the negative inverse describing function, as shown in Fig. 4-5. The linear portion of the system (neglecting the limiter temporarily) has the transfer function

$$G_c(s) = \frac{26.85\alpha\left(s + \frac{431}{\alpha}\right)}{s\,(s + 15.24)}$$

Therefore, in order to be assured of the absence of a limit cycle, it is sufficient to require that

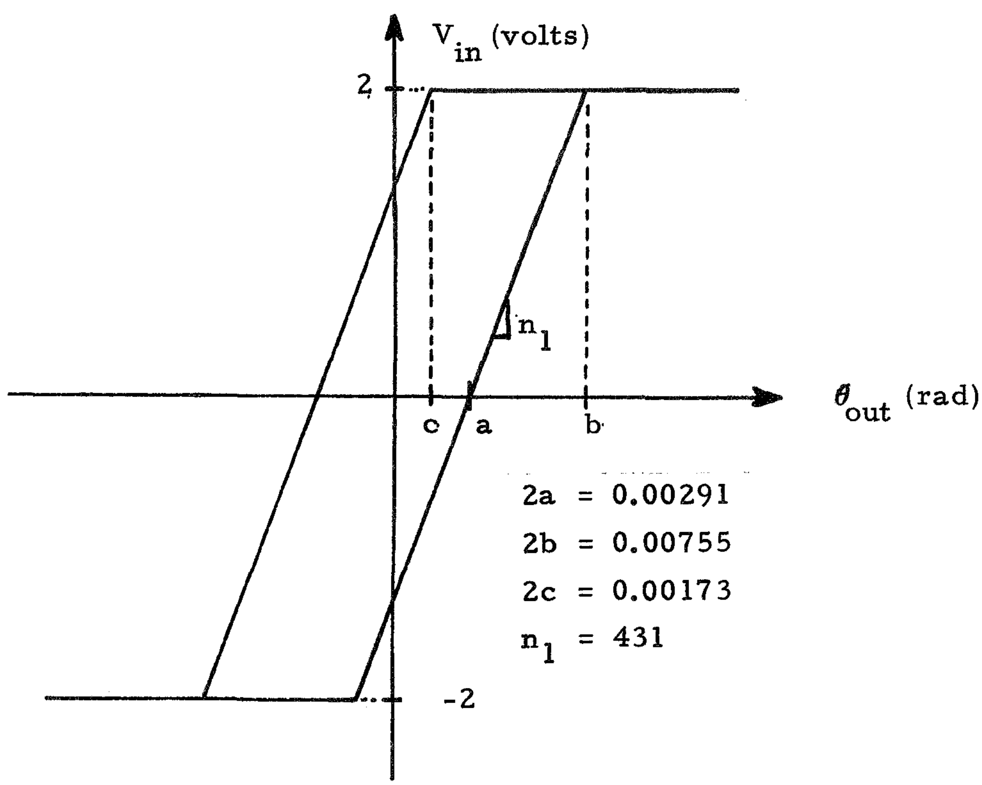


Fig. 4-4 - Equivalent Nonlinearity for Use in Describing Function Analysis

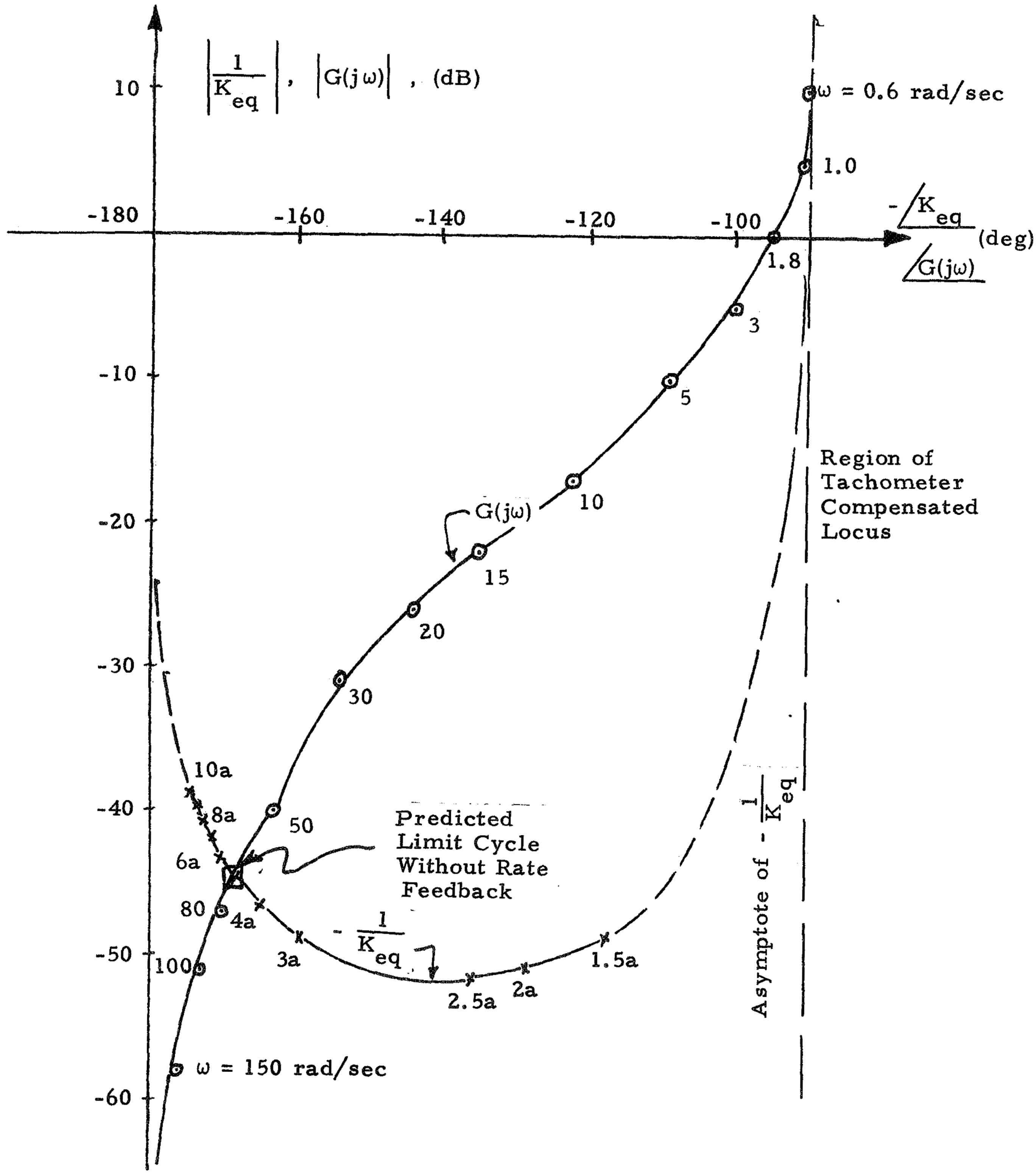


Fig. 4-5 - Nichol's Chart of Nonlinear System

$$\frac{431}{\alpha} < 15.24$$

or

$$\alpha > \frac{431}{15.24} = 28.3 \text{ volts/rad/sec}$$

$$= 2960 \text{ volts/1000 rpm}$$

An operational amplifier will thus be necessary, since the sensitivity of available tachometers is less than 5 volts/1000 rpm. In particular, a tachometer with an output of 3 volts/1000 rpm could be used, together with an operational amplifier (or amplifiers) having a gain of 1000. This represents the near minimum value of rate feedback and corresponds to a control zero at $s = -15$. The resulting overall system is shown in Fig. 4-6. The linear system transfer function is

$$\frac{11580}{s^2 + 786s + 11580}$$

and the denominator yields an overdamped response, the factored result being

$$\frac{11580}{(s + 15)\,(s + 771)}$$

The longest time constant of the system is thus 1/15 sec = 0.0667 sec. The starting time constant of the motor is 0.0570 sec.

For physical system implementation, the question arises concerning where to return the tachometer voltage that is obtained at the input to drive gear. Since the proximity sensor and the proximity control amplifier are actually a single unit, the tachometer voltage, suitably amplified, must be returned to a summing point at the input to the power amplifier. In order to be sure that the dc motor is not driven beyond its operation range, the output of the power amplifier will be limited to ± 2 volts.

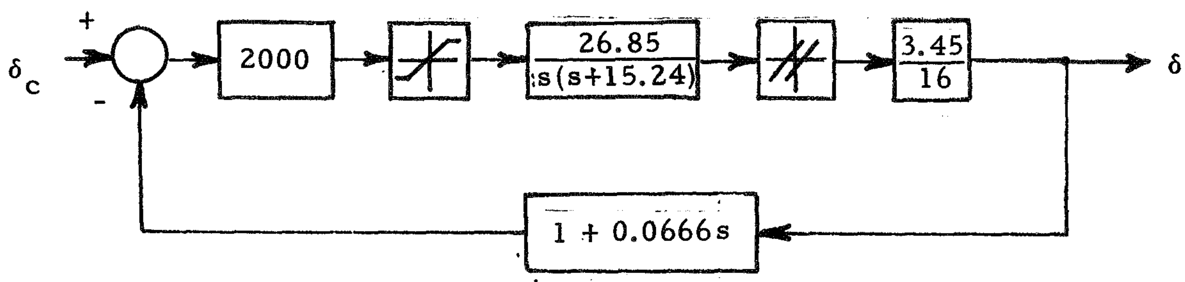


Fig. 4-6 - Rate Feedback Compensated System

Section 5
MECHANICAL ANALYSIS

The CCTV Arc Guidance Adapter Kit for the existing Modification B Torch Angle Manipulator and Skate was analyzed to determine the effects on the existing servo system and any necessary changes to the existing hardware.

5.1 SERVO SYSTEM EFFECTS

Table 5-1 presents a summary of the increased loading on the existing servomotors caused by the weight and configuration of the adapter kit. The servomotors on the manipulator are affected by the 104-oz weight of the adapter kit. The increased friction and torque on the skate motor is induced by the 104-oz eccentric load of the adapter kit plus the weight of the CCTV camera and illumination source mounted on the skate. This total weight is 206 oz. The increased torque loads on the manipulator servomotors are small enough that their effect on the servomotors should be negligible.

Table 5-1
INCREASED SERVOMOTOR LOADING

Motor	Added Weight	Induced Moment	Friction	Total Increased Motor Torque Load
Skate	206 oz*	Not Computed	Not Computed	Additional torque induced by 206 oz eccentric load
Cross-Seam Manipulator	104 oz	NA	nil	1.15 in.-oz
Torch-Angle Manipulator	104 oz	416 in.-oz	nil	0.91 in.-oz
Torch Actuator	104 oz	NA	nil	2.30 in.-oz

*Includes 104-oz adapter kit plus CCTV camera, illumination source, partial fiberscope weight, and CCTV camera adapter and relay lens.

5.2 HARDWARE MODIFICATIONS

Modification B was accomplished as per NASA drawings and specifications. See Fig. 5-1. Modification B reorients the gear motors in the horizontal plane by use of 90 degree bevel gears, and incorporates the use of a ball screw linear actuator for torch angle manipulator drive. One noteworthy exception to the Modification B specification is in material substitution as per Appendix F and corrected on the NASA drawings. These material substitutions were more readily available and were sufficiently equivalent in physical characteristics.

Modifications to the existing torch angle manipulator (Modification B) include the torch beam and beam pivot pin, the torch mount, and the wire-feed guide support. The increased load of the adapter necessitates a thicker torch beam and thus a longer beam pivot pin. The new torch beam accommodates the wire-feed guide support and the illumination head support. A double preloaded bearing arrangement is used to provide a more stable platform support. The physical size and required locations of the illuminators and viewing optics necessitate the lowering of the torch mount 2-1/4-in. below its original position. Lengthening the wire-feed guide support accommodates the lowering of the torch mount. It also allows the proper positioning of the wire-feed mechanism below the torch.

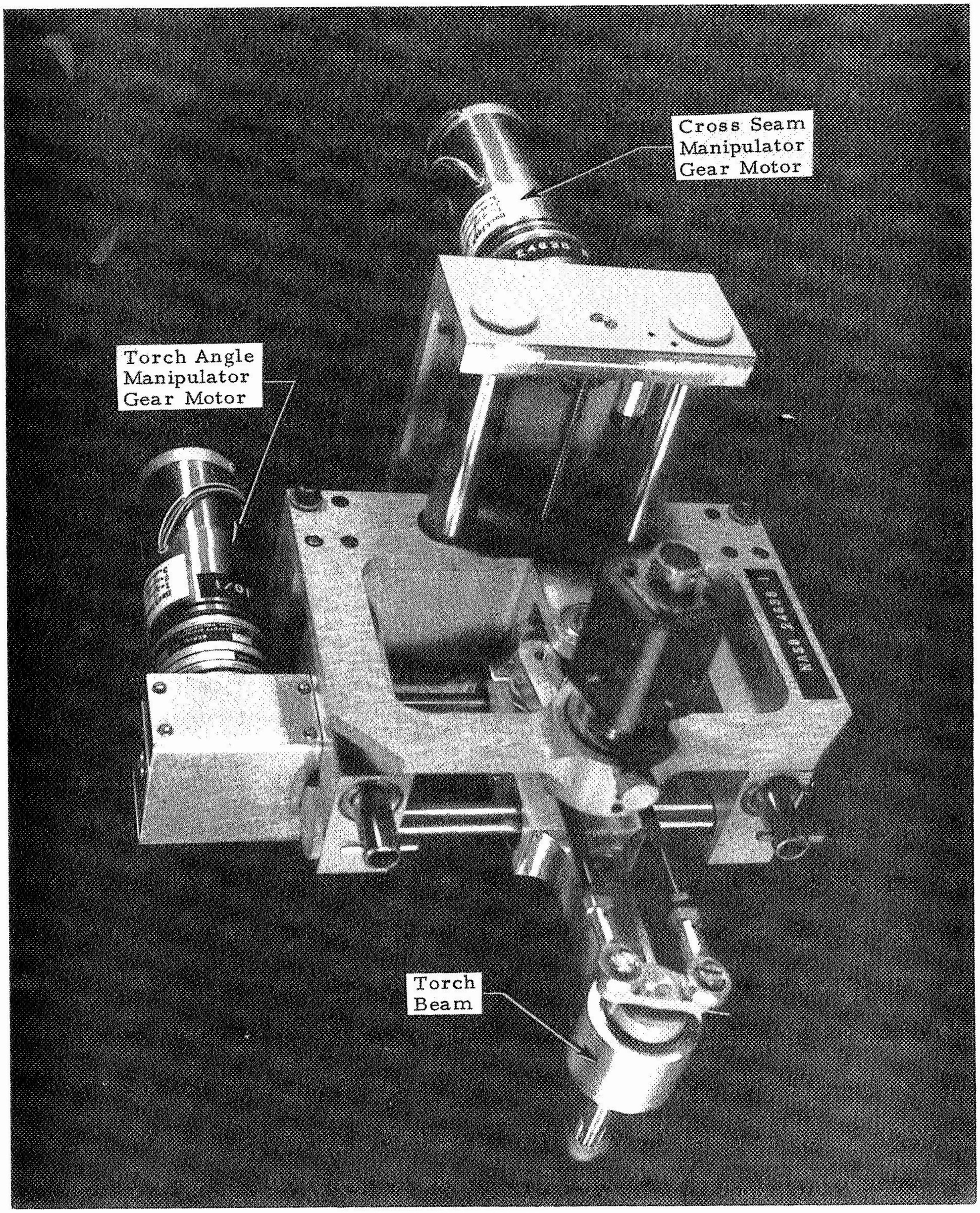


Fig. 5-1 - Torch Angle Manipulator, Modification B Configuration

Section 6
SYSTEM CHECKOUT AND EVALUATION

6.1 ADAPTER-IMAGESCOPE EVALUATION

Upon receipt of the viewing optics from the vendor, an acceptance test was performed. The viewing optics did not meet specifications as shown in Fig. 6-1 and were returned to the vendor. There were two major problem areas. The imagescope cover (braided stainless steel) was too stiff for the prescribed application. The CCTV camera adapter did not mate with the prescribed 6038A CCTV camera. As a result of the latter, the system could not be connected to the camera system to see if the prescribed viewing area could be seen.

Another acceptance test was performed upon receipt of the revised viewing optics. The new imagescope covering was a convoluted Teflon hose with a nylon braid outer covering. This allowed for the prescribed flexibility and bend radius. The CCTV camera adapter mated with the camera and a CCTV camera system test was performed with NASA equipment. The system still tested unsatisfactorily as the prescribed 2 in. x 3-1/2-in. viewing area could not be seen (Fig. 6-2). The viewed area was only 1-1/2 in. x 2 in. on the viewing surface. A new wider angle lens was obtained through the vendor, and the system again tested with the NASA camera system. A satisfactory test resulted and the viewing optics system was accepted.

6.2 ADAPTER ELECTRONICS

6.2.1 Checkout Results

The servo power amplifier circuit was built as shown in Fig. 6-3. This circuit included the rate generator feedback (Fig. 6-3a) with an amplifier to

Para. No.*	Specified Value	Measured Value	Remarks
1.0/ 7.0	Imagescope, relay lens, objective lens, "C" mount to "D" mount adapter, and 90° side view adapter to mate with CCTV camera 6038A.	The mating of the system to the camera was impossible due to the improper "C" to "D" mount adapter configuration. (See Note 1.)	Unacceptable (See Note 1)
2.1 2.2	55 inches 48 ± 1/4 inches	54-7/8 inches 48-1/8 inches	Acceptable Acceptable
3.0	4-6 lb	4.5 lb	Acceptable
4.0	45 to 50 line pairs per mm minimum	31 lp/mm maximum (See Note 2.)	Acceptable
5.1 5.2 5.3	1.5 inch minimum 175 oz-in. max. at both +52° and -65° deflection 20 oz-in. maximum	2.5 inch 450 oz-in at +52° 650 oz-in at -65° 45 oz-in.	Unacceptable Unacceptable Unacceptable
6.0	2" x 3.5"	(See Note 3)	
9.0	Must meet specs of Para. 5.1 through 5.3.	See results of Para 5.1 through 5.3.	Unacceptable

*Reference LMSC/HREC Specification No. 5150717, Revision A, dated 12 November 1969 (Appendix C).

NOTES:

1. The configuration received is that quoted by Bendix in answer to our specification LMSC/HREC 5150717, Rev. A, dated 12 Nov. 1969. However, the "C" mount to "D" mount adapter provided does NOT mate the relay lens to the CCTV camera specified in Para. 7.0. The relay lens and adapter are too large in diameter to fit inside the lens holder. Thus, the adapter is not properly configured to interface with the Model 6038A camera.
2. Tested by NASA with a standard high contrast 1951 USAF resolution target and two identical lenses. Resolution was determined by eye. Standard test procedure (as per Bendix) requires one end of fiber bundles to be in contact with resolution target with film of emersion oil and the inspection to be made at other end with microscope. NASA agrees that resolution will no doubt be better than 45 lp/mm and therefore feels that the resolution is acceptable.
3. Unable to test system with camera to check Para. 6.0 as per Para. 1.0 and 7.0.

Fig. 6-1 - Results of Acceptance Test for Remote Viewing Optics for CCTV Arc Guidance Adapter Kit (NAS8-24638)

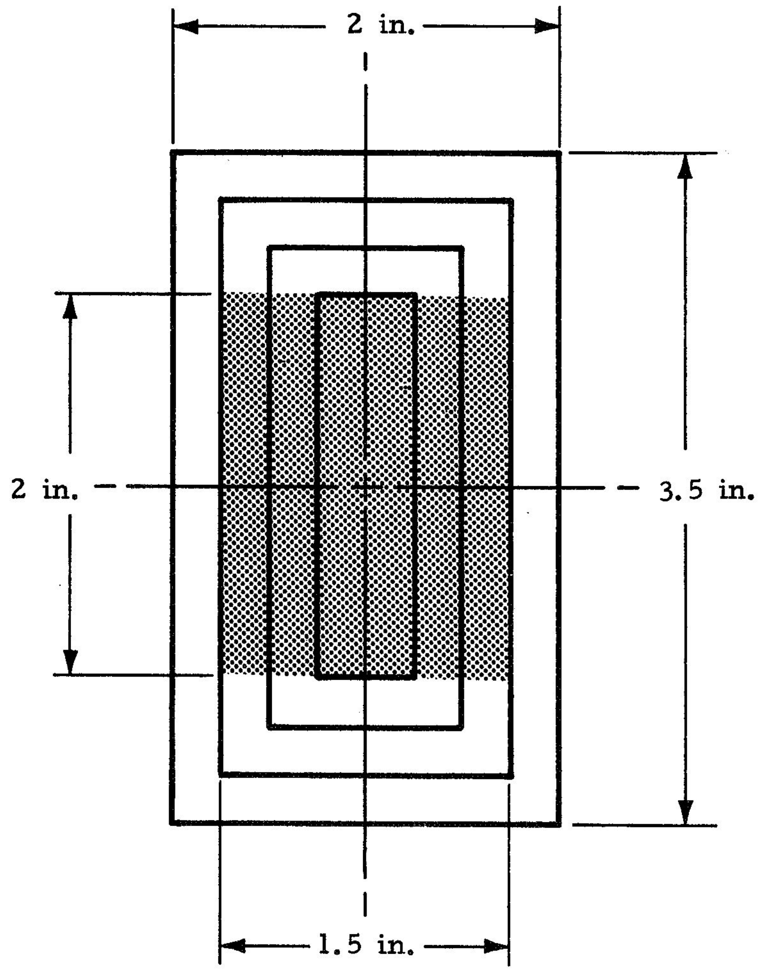


Fig. 6-2 - Specified CCTV Camera Viewing Area
(shaded portion is what CCTV camera "sees")

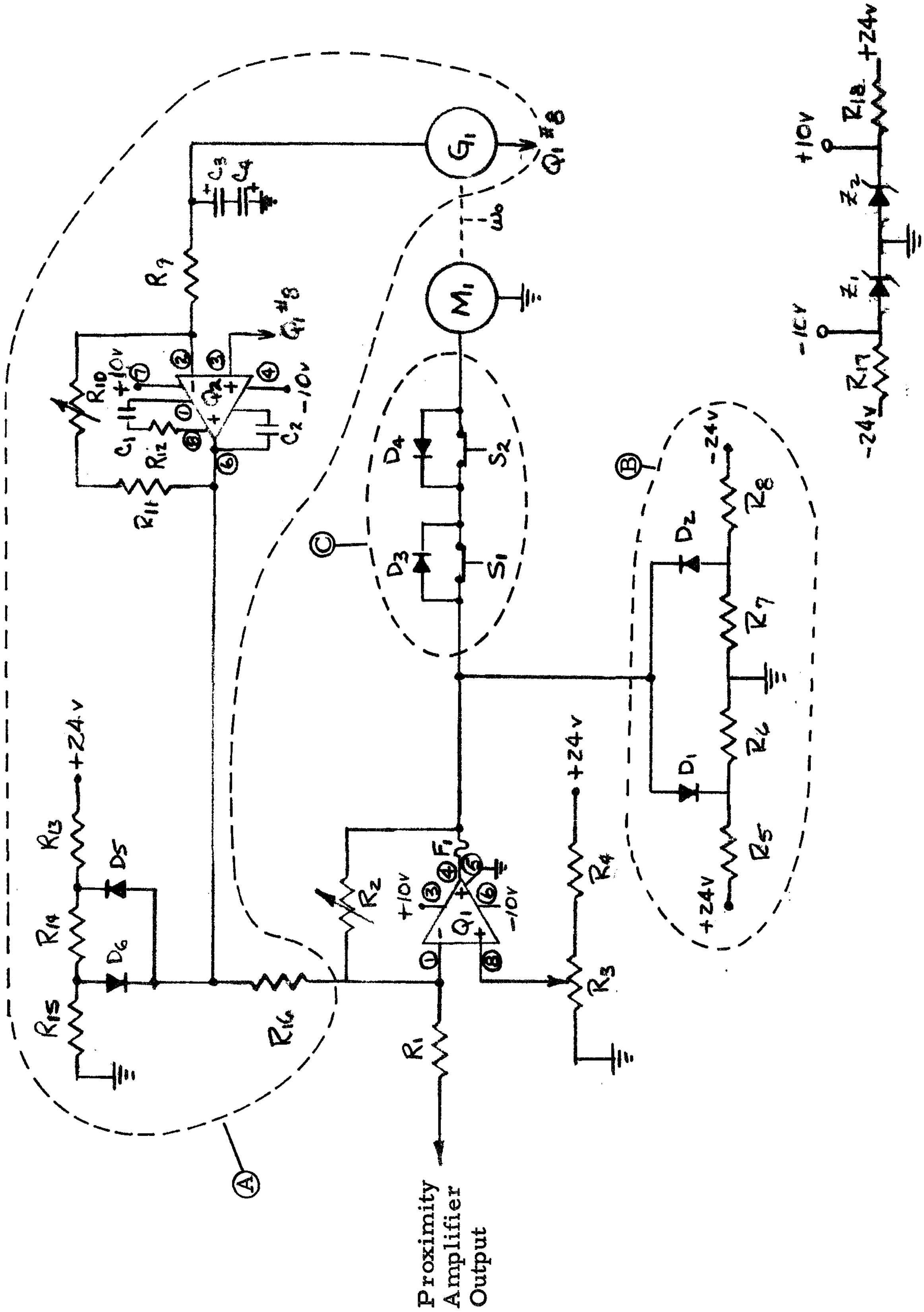


Fig. 6-3 - Servo Power Amplifier Schematic provide the proper gain and voltage limiters (Fig. 6-3b) and stop switches for motor protection. Upon completion of fabrication, the servo system was thoroughly tested in the lab under simulated welding conditions with the following results:

1. Because of the friction loading and the imagescope stiffness, rate feedback does not appear to be necessary. During the test no instability was observed. Therefore, (A) of Fig. 6-3 has been disconnected from the input to Q_1. However, under actual welding conditions this same friction loading and imagescope stiffness may require a replacement motor with more torque. If this occurs, the feedback loop may be needed and can be easily reconnected.

2. With the use of rate feedback no longer required, the voltage limiter (B) of Fig. 6-3 was no longer required for motor protection. The limiter is still in tact with diodes D and D_2 removed. If needed, they can be easily reconnected.

3. The motor was purposely run into the stops and allowed to stall with no damage to any equipment. There appears to be no immediate danger to the dc drive motor; however, the power should be cut off by the operator as soon as the motor stalls in the stop. Following this procedure, the need for the cumbersome stop switches, (C) of Fig. 6-3, is eliminated. However, the diodes have been shorted and left in place. Should the need for a higher torque, higher voltage motor occur, the limit switches may be needed. Thus, by simply removing the diode shorts, the system is ready to go.

4. The proximity signal is taken from the point V_o, Fig. 6-4. None of the following stages or the relay is used in the control system. After repeated testing with rapid changes, the signal V_o deteriorated to the point that motor would shut down. Further investigation showed that the coil L_2 was the cause. L_2 has been removed from the proximity amplifier.

6.2.2 Electronics Recommendations

Should the need for a motor with more starting torque be required, it is recommended that a Type 250/1055 (Appendix A) in a double-ended configuration and a 485:1 reducer be used. Such a motor is available from Micro-Mo Electronics of Cleveland, Ohio. The 250 is the same diameter as the present 050 motor but is 8-mm longer and weighs 8-grams more. The

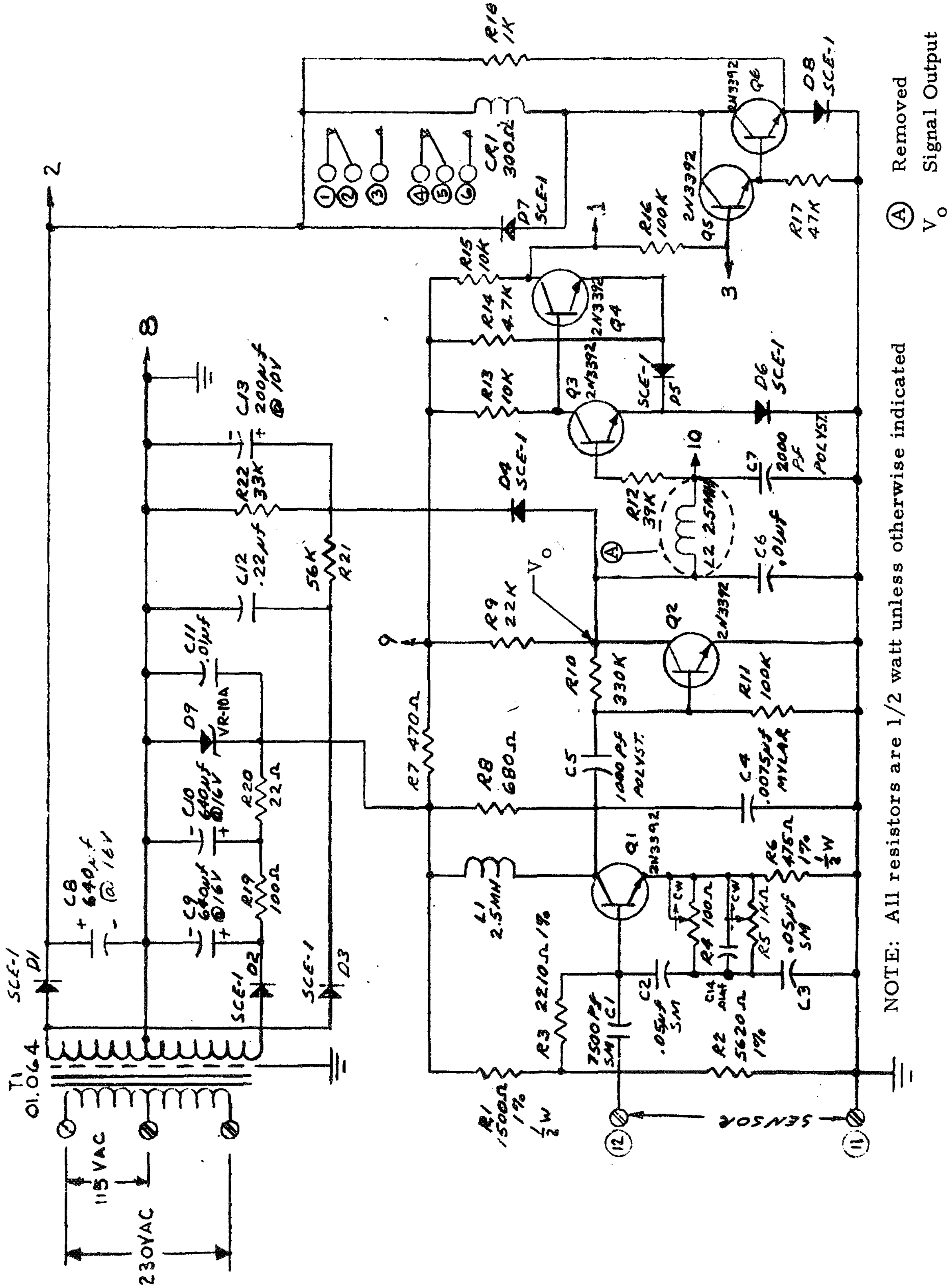


Fig. 6-4 - Proximity Amplifier Schematic double-ended configuration will allow for the use of rate feedback should it be needed. The generator, coupling and housing used on the present configuration can be readily adapted to the 250 model.

The 250 motor requires 12 Vdc operation voltage. Thus, another power amplifier will be needed. A Model 440KR power amplifier (Appendix G) is available from Opamp Labs of Los Angeles, California, for $35.00. The octagonal pin arrangement is identical to the Model 420, and the same circuit can be used with one modification. The Model 440KR can accept the full power supply voltage without stepping down to 10 volts. Thus, a simple wiring change will put the new amplifier in operation.

6.3 MECHANICAL SYSTEM CHECK

Mechanical checks of the optics platform were conducted to determine the loading capability of the suspension system. Initial operation of the platform indicated excessive loading on the idlers. Due to eccentric loading of the optics, the moment imposed on the carriage tends to force the outermost idler off the drive belt. Although still supported by the Vespel washer, the system had greatly increased friction forces.

By positioning the upper Vespel washers closer to the support platform (0.005 clearance unloaded) any eccentric or reload would force the washers to support the load and keep the idlers in the correct position in relation to the drive belt.

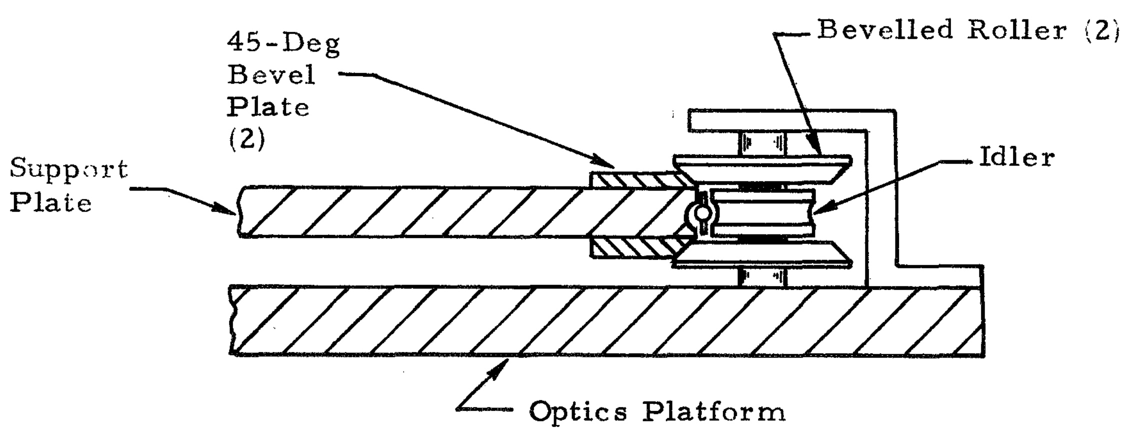
Further tests showed the required torque at the drive gear under various loads:

Unloaded (platform only)	5.25 in.-oz
1000 gm at main support	7.00 in.-oz
1500 gm at main support	8.50 in.-oz

Therefore, the system should be capable of handling the imposed loads due to the weight of the system. With the optics correct to the platform, there are still loading problems due to the torsional and bending limits of the imagescope at the extreme head position. The torsional torque is caused by the vertical location of the ends of the fiberscope. A spring support for the optics bundle is added to eliminate the loading, particularly in the normal operating range.

Further tests were run in which the leveled roller was biased as the primary load carrying member. A much lower torque requirement was mated with the free running roller. As an improvement to the basic design, the following recommendation is made:

> Replace the Vespel washer-idler support arrangement to 45-deg level rollers. The load is carried by the leveled roller with the idler used to guide the drive belt. (See sketch.)



Section 7
CONCLUSIONS AND RECOMMENDATIONS

A dependable and accurate CCTV Arc Guide Adapter Kit has been designed and developed. The prototype hardware has been built and meets the minimum NASA specifications. However, due to unexpected torque loading of the imagescope on the optics platform, the Swiss motor presently used has too low a starting torque. The low starting torque results in the system stalling in two extreme cases. One occurs with the actuator arm almost fully extended with the illumination head trying to drive in the positive direction (starting at about + 35 deg), and the other occurs with the actuator arm almost fully retracted with the illumination head trying to drive in the negative direction (starting at about -35 deg). Since this is only 5 deg short of the expected working limits, it is doubtful that these cases would actually occur during welding.

To completely eliminate this problem, it is recommended that a double-ended Type 250/1055 motor be purchased to replace the present 050/010 motor. The new motor has three times the starting torque as the latter. The same gear reducer and tachogenerator can be used, and the new assembly can be housed in the present motor mount without modification. The new motor requires 12 volts which is not available from Model 420 operational amplifier. A replacement amplifier Model 440KR is available for approximately $35.00 from Opamps Labs, Inc., and can be used in the same octal plug without wiring modifications. The modifications would provide more than adequate power to operate the system over the full specific range, including the extremes.

Section 8
REFERENCES

1. Wall, W. A., "Specification MR&T-sk-1214, Criteria for the Integration of a CCTV Arc Guidance System with a Computerized Welding Skate," Marshall Space Flight Center, Huntsville, Ala., 1969.

2. Dunbar, A. S., "Contract NAS8-24638, CCTV Arc Guidance Adapter Kit for a Computerized Welding Skate, Monthly Progress Report," LMSC/HREC D149115, Lockheed Missiles & Space Company, Huntsville, Ala., 16 July 1969.

3. Heimendinger, K. W., "Closed-Circuit Television Arc Guidance Adapter Kit for a Computerized Welding Skate," LMSC/HREC D149188, Lockheed Missiles & Space Company, Huntsville, Ala., September 1969.

Appendix A

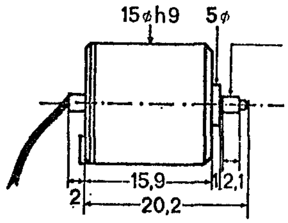
DC-MICROMOTORS

SYSTEM FAULHABER

Micro Mo Electronics,
Incorporated

Lee Dale Building
3691 Lee Road
Cleveland, Ohio 44120
Telephone 216 / 752-5599

Type 050/010



Measures of pinion:
z = 9 teeth
m = 0.20
D tip = 2.34 — 0.015
D root = 1.42 — 0.015
correction factor: x = + 0.35
a = 20°, involute

Diameter		15 mm
Length of casing		16 mm
Weight		12 g
Max. output	P	0,24 W
Armature resistance	Ro	4 Ohm
Operating voltage	U	2 V
No-load speed	n_L	16300 rpm
Specific speed	n_S	8450 rpm/V
Starting torque	Md_K	5,6 cmp
Friction torque	Md_R	0,2 cmp
Specific torque	Md_S	11,6 cmp/A
Max. efficiency	η	71%
Armature moment of inertia	θ	$1{,}9 \cdot 10^{-4}$ cmps^2
Starting time constant	τ	$57 \cdot 10^{-3}$ s

Slip-on reduction gears ratios:
3,45:1; 11,8:1; 41:1; 141:1; 485:1; 1670:1; 5750:1; 19800:1.

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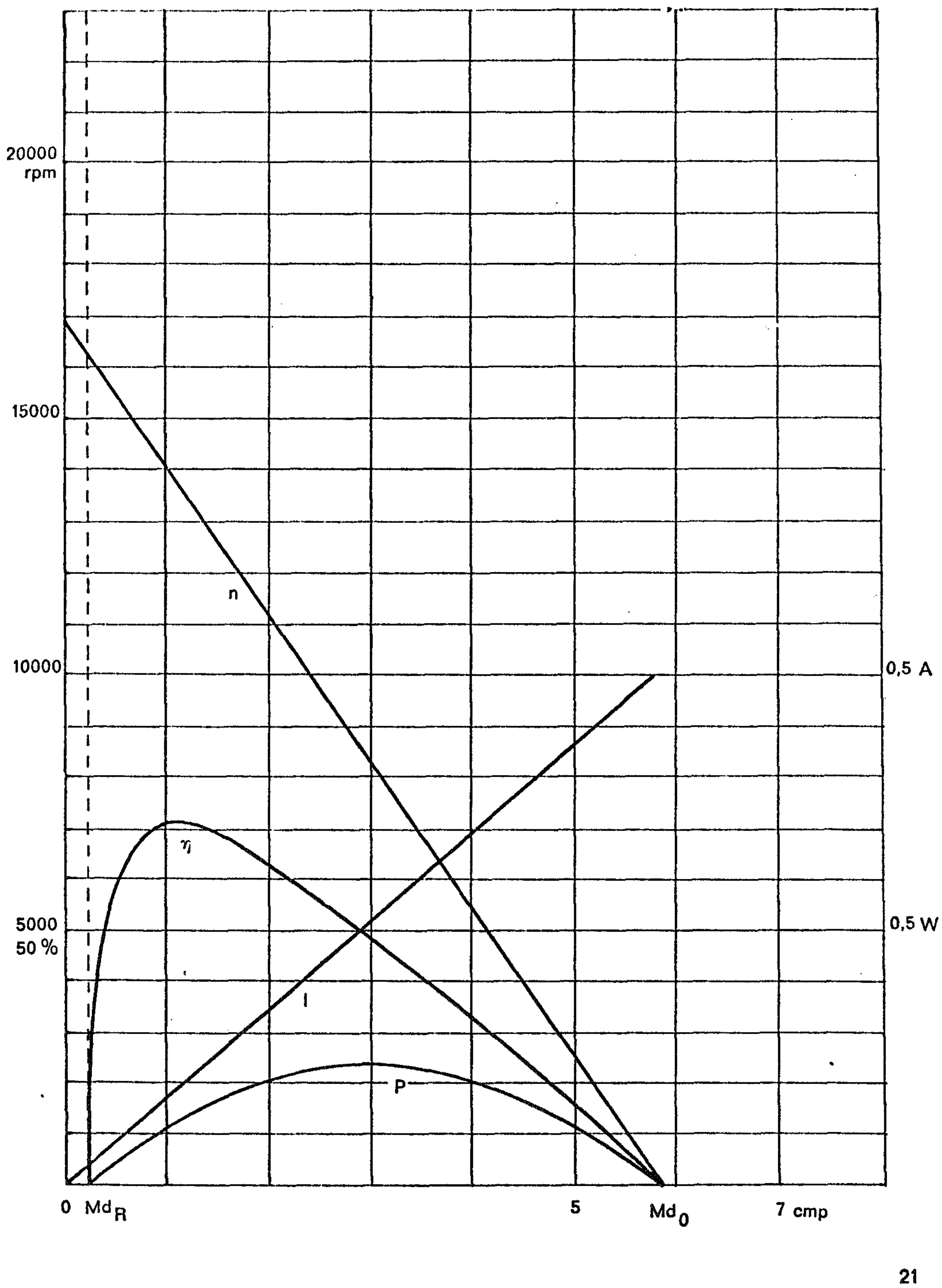
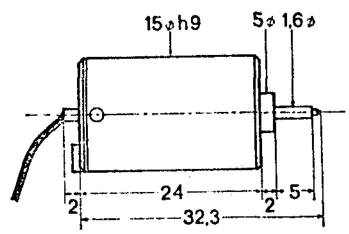

20000
rpm
15000
10000
5000
50 %
n
η
I
P
0,5 A
0,5 W
0
Md_R
5
Md_0
7 cmp
21

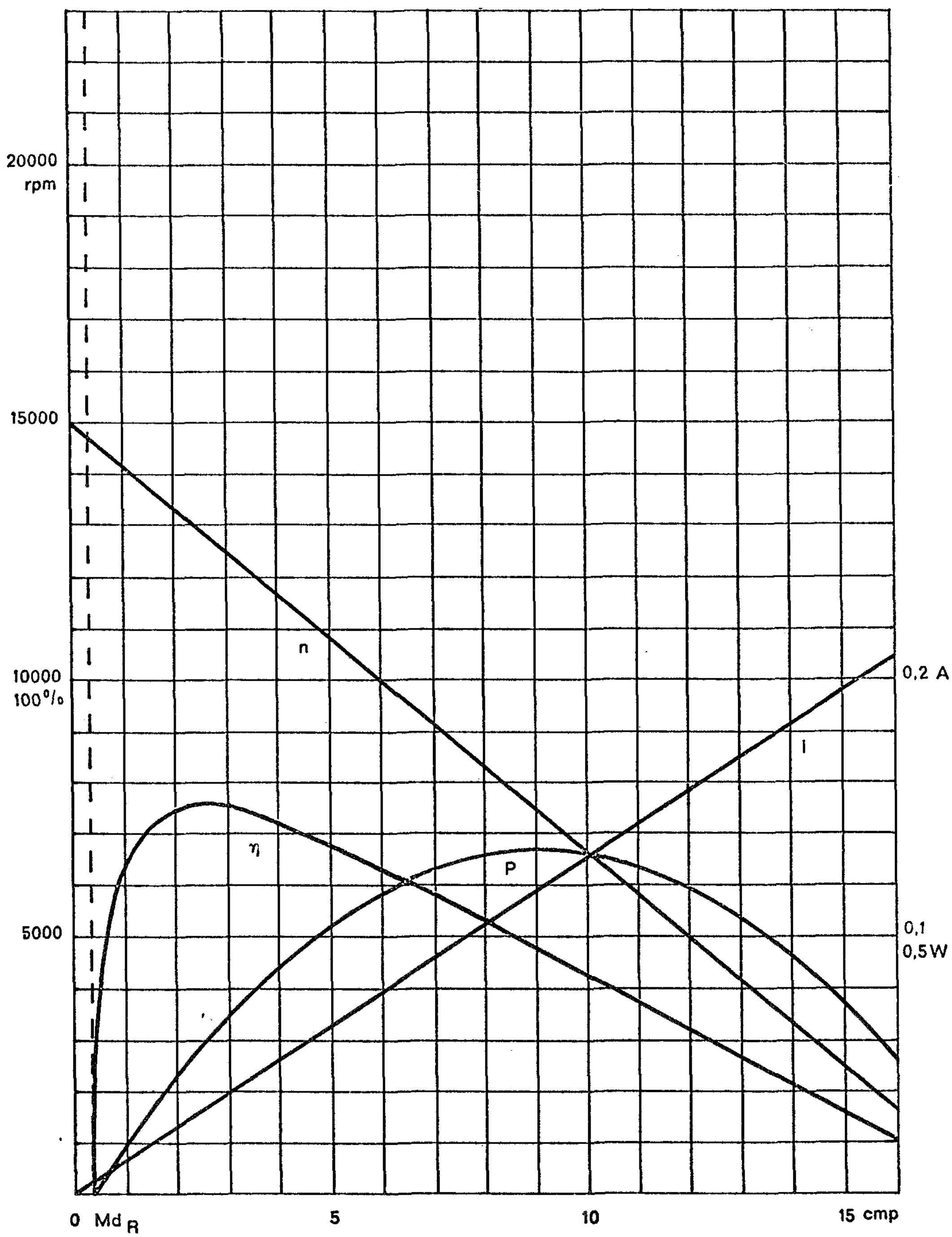
Type 250/1055



Diameter		15 mm
Length of casing		24 mm
Weight		20 g
Max. output	P	0,66 W
Armature resistance	Ro	52 Ohm
Operating voltage	U	12 V
No-load speed	n_L	14730 rpm
Specific speed	n_S	1250 rpm/V
Starting torque	Md_K	17,57 cmp
Friction torque	Md_R	0,31 cmp
Specific torque	Md_S	78 cmp/A
Max. efficiency	η	75%
Armature moment of inertia	θ	$4 . 10^{-4}$ cmps^2
Starting time constant	τ	$35 . 10^{-3}$ s

Slip-on reduction gears ratios:
3,45:1; 11,8:1; 41:1; 141:1; 485:1; 1670:1; 5750:1; 19800:1.

26



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Appendix B

SPECIFICATION

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT TWIN ILLUMINATION SOURCES

SPECIFICATION

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT TWIN ILLUMINATION SOURCES

(Revision A to: LMSC/HREC 5150716)

12 November 1969

PREPARED BY: K. W. Heimendinger
Research Engineer

APPROVED BY: R. B. Wysor, Supervisor
Advanced Development Section

A. S. Dunbar, Manager
Systems Engineering Department

Specification

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT TWIN ILLUMINATION SOURCES

SUMMARY

This specification establishes the requirements for a remote viewing optics system for a CCTV Arc Guidance Adapter Kit. The adapter kit will integrate a CCTV arc guidance system with a computerized torch angle manipulator and welding skate. The end product shall be a fully operational welding skate with CCTV arc guidance capable of welding contoured and double contoured surfaces.

The system requires a remotely located CCTV camera to view a 2-in. by 3.5-in. area located on the work piece in front of the torch. The view area may be flat or cylindrical with as much curvature as 12-in. concave radius or 6-in. convex radius. The object is a joint to be welded, the edges of which are chamfered at 40 deg, a minimum of 0.010-in. wide. The CCTV arc guidance system utilizes two bright illumination spots reflected off of the joint in the viewing area for guidance control. Then two spots are provided by a flexible split-bundle light guide and a single illumination source.

LIGHT GUIDE REQUIREMENTS

1.0 SYSTEM CONFIGURATION

The two illumination sources shall be provided by a single, flexible, six-foot split-bundle light guide.

2.0 SIZE

2.1 The total length of the light guide shall be six feet.

2.2 The split in the bundle shall occur 7-in. from the output end.

2.3 The two output legs shall be 1/8-in. diameter fiber bundles.

2.4 One output leg shall be 7-in. long, the other 5-in. long as shown in Fig. 1-A.

2.5 The metal clad output end of each leg has 75-deg bend of 0.5-in. radius and has overall length of 1.5 in., as shown in Fig. 1-B.

2.6 Dimensional tolerances are as listed in Fig. 1.

3.0 WEIGHT

The weight of the light guide shall be one pound maximum.

4.0 ILLUMINATION INTENSITY

The illumination intensity at the output of each leg with the single illumination source shall be a minimum of 1200 centerbeam footcandles when measured at a distance of two inches from the output end.

5.0 MINIMUM BEND RADIUS

The minimum bend radius shall be 1.5-in.

ILLUMINATION SOURCE REQUIREMENTS

6.0 SIZE AND WEIGHT

The illumination source shall be 6-in. high, 5-in. wide, and 8-in. long and weigh 3.5 pounds.

7.0 POWER

The illumination source power shall be 115 Vac, 60 Hz.

8.0 INTENSITY

8.1 The intensity of the illumination source shall be sufficient to meet the requirements of paragraph 4.0.

8.2 The intensity control of the illumination source shall have a variable from off to full intensity.

9.0 LAMP LIFE

The illuminator shall utilize a cooling fan to provide a lamp life at full voltage of 15 hours, for 110-120 volts, 60 cycles A.C.

10.0 PROTECTIVE COVERING

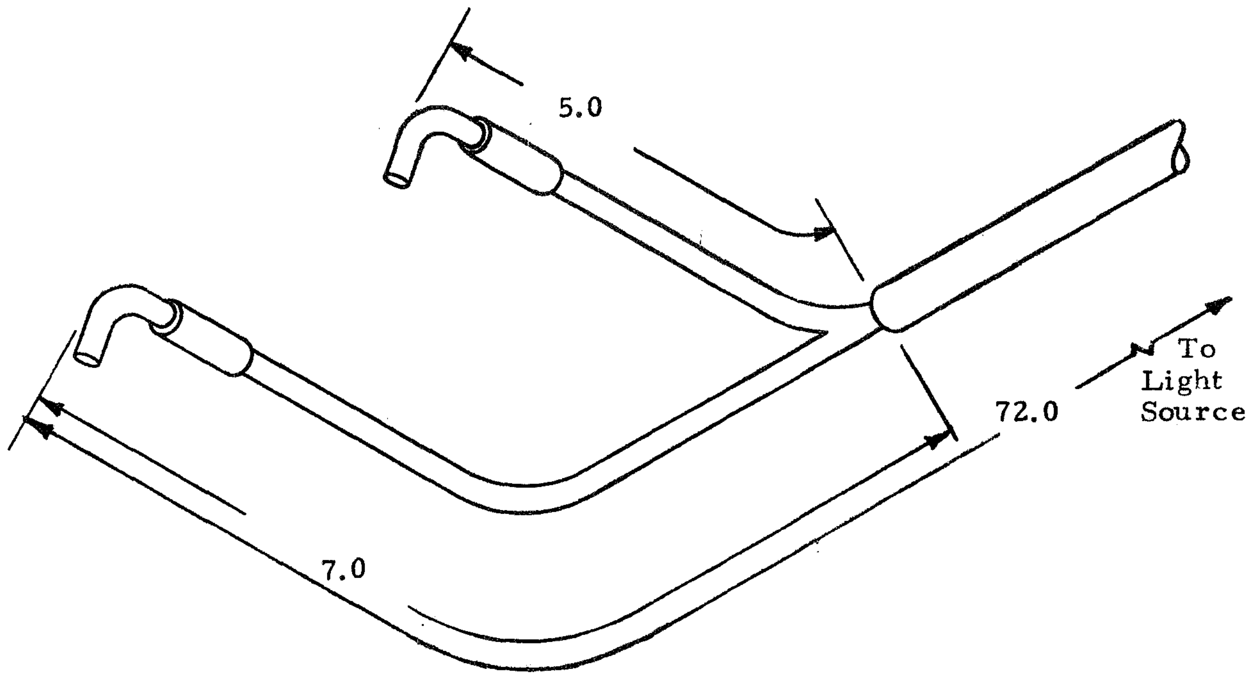
The light guide shall be enclosed in an adequate protection covering that will protect the fiber from breakage and meet the specifications of Pars. 5.0.

NOTE: All dimensions in inches.

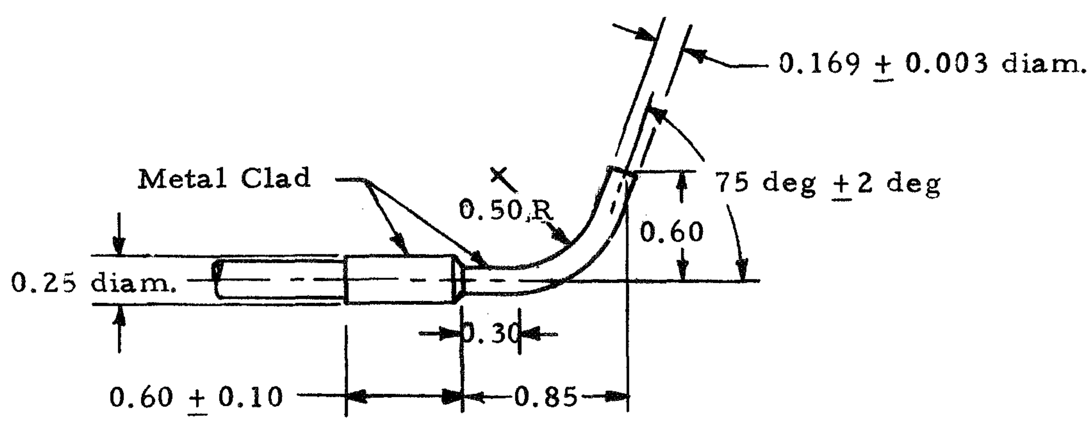
Tolerances (unless otherwise noted)

.x ± 0.2

.xx ± 0.05



A



B

Fig. B-1 - Split-Bundle Flexible Light Guide

Appendix C

SPECIFICATION

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT REMOTE VIEWING OPTICS

SPECIFICATION

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT REMOTE VIEWING OPTICS

(Revision A to: LMSC/HREC 5150717)

12 November 1969

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Specification

CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT REMOTE VIEWING OPTICS

SUMMARY

This specification establishes the requirements for a remote viewing optics system for a CCTV Arc Guidance Adapter Kit. The adapter kit will integrate a CCTV arc guidance system with a computerized torch angle manipulator and welding skate. The end product shall be a fully operational welding skate with CCTV arc guidance capable of welding contoured and double contoured surfaces.

The system requires a CCTV camera (General Electrodynamics Corporation of Garland, Texas, Model 6038A Instrumentation Camera) to be remotely located from the welding torch. A fiber optic plus viewing optics, adapters, etc., are needed for the camera to view a 2-in. by 3.5-in. area located on the work piece in front of the torch. The viewed area may be flat or cylindrical with as much curvature as 12-in. concave radius to 6-in. convex radius. The viewed object is a joint to be welded, the edges of which are chamfered at 40 deg, a minimum of 0.010-in. wide. Light from the welding arc is parallel to the seam and does not interfere appreciably with the system as breadboarded.

REMOTE VIEWING OPTICS SYSTEM REQUIREMENTS

1.0 SYSTEM CONFIGURATION

The remote viewing optics system shall consist of a flexible, four-foot fiber optics Imagescope, relay lens system, objective lens, adapter "C" mount to "D" mount, and adapter-side view 90 deg, necessary for the CCTV camera to remotely see the viewing area.

2.0 SIZE

2.1 The nominal length of the system from the CCTV camera to the working envelope shall be 55.0 inches (Fig. 1).

2.2 The flexible fiber optic shall be 48-in. long.

2.3 The vendor shall supply interface drawings providing total assembly outline, dimensions, and mounting provisions for the distal and proximal ends of the assembly. Limit viewings optics outline dimensions are as shown in Fig. 1.

3.0 WEIGHT

An itemized weight breakdown of the remote viewing optics system shall be provided by the vendor. Since weight is critical, a light-weight system (4 - 6 lb) is desired.

4.0 RESOLUTION

The minimum resolution of the total system shall be 45 to 50 line pairs/ millimeter.

5.0 MINIMUM BEND RADIUS AND STIFFNESS OF FIBER OPTICS

5.1 The minimum bend radius shall be 1.5-in.

5.2 The maximum stiffness at the viewing optics connection shall be 175 oz-in. about the working envelope pivot point at maximum deflection (Para. 8.2) and in the plane of the bend.

5.3 Torsional loads induced by twisting the fiber optics to maximum deflection (Para. 8.2) at the working envelope interface shall be 20 oz-in. max.

6.0 VIEWING AREA

The viewing area shall be 2-in. wide by 3.5-in. long as shown in Fig. 1

7.0 CCTV CAMERA

The CCTV camera is a General Electrodynamics Corporation ED 6038A Instrumentation Camera. It requires a "D" mount lens (8-mm format). The camera is located with respect to the working envelope as shown in Fig. 1.

8.0 WORKING ENVELOPE REQUIREMENTS

8.1 Objective lens can be located within the working envelope shown in Fig. 1 and positioned to view the prescribed viewing area.

8.2 Welder requires envelope to pivot about the prescribed pivot point (Fig. 1) from +52 deg (counterclockwise) to -65 deg (clockwise) to follow minimum weld radii.

9.0 PROTECTIVE COVERING

The fiber optics shall be enclosed in an adequate protective covering that will protect the fibers from breakage and meet the specifications of Para. 5.0.

NOTE: All dimensions in inches.

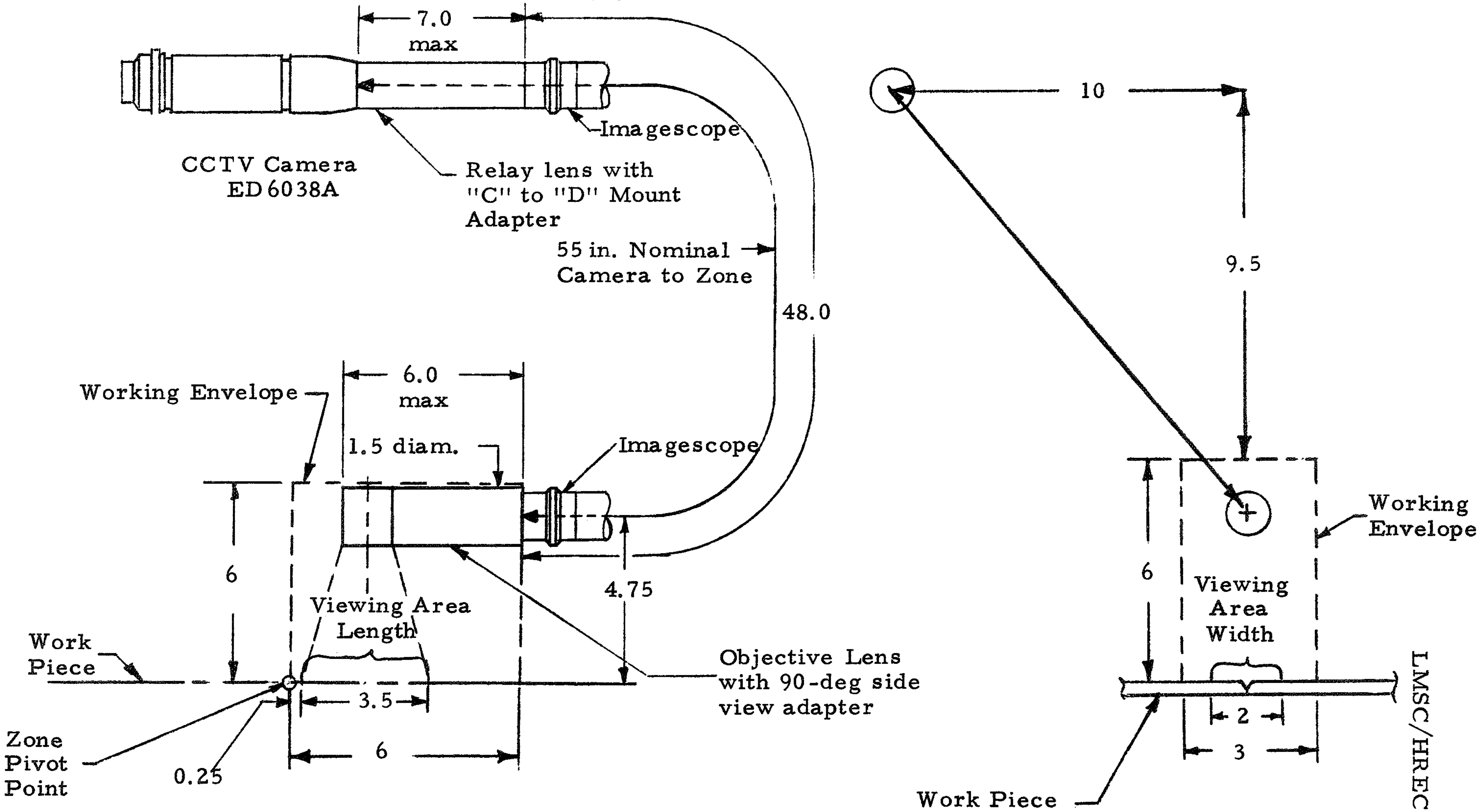

Fig.C-1 - Working Envelope to Camera Configuration

Appendix D

OPERATING INSTRUCTIONS FOR ELECTRO PRODUCTS LABORATORIES' MODEL 55.121 PROXIMITY CONTROL UNIT

ELECTRO

OPERATING INSTRUCTIONS

52.151
12-10-68

MODEL 55.121 PROXIMITY CONTROL UNIT

CONTENTS

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ELECTRO

OPERATING INSTRUCTIONS

52.142
Rev. 11/1/67

MODEL 55.121 TRANSISTORIZED CONTROL AMPLIFIER

GENERAL

An ELECTRO Proximity Switch is a system consisting of a proximity control amplifier, a sensing head and connecting cable; appropriate time delay modules are available when required. When any conducting metal of sufficient mass or sensed area is within the field of the sensing head, a relay in the control amplifier is actuated to perform the desired control function. The sensed object does not have to be in motion; it only has to be within the field of the sensing head to actuate the relay. (See page 4 for definitions of terminology.)

The Model 55.121 Transistorized Proximity Control Amplifier basic unit is capable of operating from -40°F (-40°C) to 176°F (80°C) with negligible drift in sensitivity. Only 15 seconds warm-up time is required for the control to stabilize. Relay actuation, or pull-in, time is within 10 milliseconds after the sensing of metal, and de-actuation, or drop-out, time is within 25 milliseconds after the metal leaves the sensing field. Maximum operating speed is 600 cycles per minute.

Sensing heads recommended for use with the Model 55.121 Control Amplifier include all of the ELECTRO standard proximity sensing heads designed for the transistorized control amplifiers.

Connecting cables are supplied as integral parts of sensing heads designed for use with transistorized control amplifiers, and are usually 10 feet in length as standard. However, cables up to 150 feet long may be used. If cables less than 10 feet long yield less than optimum results, contact the Factory for instructions.

Time delay modules are available for use with the Model 55.121 Control Amplifier in delayed-make (slow make, quick break) or delayed-break (quick make, slow break) time ranges up to 10 seconds. These optional modules are plugged into an existing socket on the control amplifier; and no further wiring or circuit modification is required.

MOUNTING INSTRUCTIONS

CONTROL AMPLIFIER
The control amplifier should be mounted in a readily accessible area that is relatively vibration free. Detailed mounting dimensions are attached. (See Fig. 1.) With Model 58.335 Cover -- with this optional cover, the control amplifier requires a panel space of 5" x 7" with a 3" depth clearance. (See Fig. 2.) Without Cover -- when used without the protec- cover, above, the control amplifier may be panel mounted or mounted directly into the optional Model 58.334 JIC enclosure (NEMA 12) which measures 8" x 6" x 3½". (See Fig. 3.)

SENSING HEADS
Mounting methods for the various sensing heads are shown in Drawing 58.222, attached. For the most dependable operation, the sensing head should be mounted as close as possible to the actuating object. As a general rule, the sensing distance should not be greater than the diameter of the sensing head for ferrous objects, and less for non-ferrous or stainless objects due to reduced sensitivity to these materials. Sensitivity, however, to some thin aluminum, such as foil, is good, as evidenced in applications such as film cueing, etc.

WIRING CONNECTIONS

SENSING HEADS
Connect the sensing head cable to Control Amplifier Terminals Nos. 11 and 12 with the shield to Terminal 11 and the center conductor (white) to Terminal 12. If the cable has a black wire, it is not functional with this control, and it should be connected to the "dead" Terminal No. 10 or may be taped back along the cable to avoid accidental contact with ground or the control.

RELAY TERMINALS
Relay contacts are brought out to Terminals 1 through 3 and 4 through 6. Terminals 3 and 6 are "common", 2 and 5 are "normally open" and Terminals 1 and 4 are "normally closed" relay contacts.

LINE POWER
The Model 55.121 Proximity Control Amplifier is designed for operation on either 115V or 230V 50/60 Hz line power; 115V should be connected to Terminals 8 and 9, and 230V connects to Terminals 7 and 9.

SENSITIVITY ADJUSTMENT

The control amplifier has "COARSE" and "FINE" screwdriver adjustable sensitivity controls

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near Terminals 10-12. The coarse adjustment compensates for variations in sensing heads and cable lengths while maintaining a relatively wide adjustment range on the fine control. Once the "COARSE" adjustment is set for a given sensing head, cable and application, only the "FINE" adjustment is normally used to set the sensitivity or sensing distance.

TO ADJUST SENSITIVITY

1. Rotate both "COARSE" and "FINE" controls full clockwise.
2. Place object to be sensed at the maximum sensing distance from the sensing head that is to be encountered in the application.
3. Rotate the "COARSE" adjustment counterclockwise until the relay de-energizes and then clockwise again until the relay just energizes. Set the control 5° to 10° further clockwise. The relay should now be energized
4. Rotate the "FINE" adjustment counterclockwise until the relay de-energizes. Then rotate the adjustment clockwise until the relay just energizes. The sensitivity controls are now adjusted for static or low speed operation.
5. Note: Check setting by removing sensed object. Relay should de-energize. If it does not, mounting metal or other extraneous metal may be within the sensing field, and it will be necessary to remove such interferences or re-position the sensing head to operate under reduced sensitivity.

<u>For sensing at high speeds</u>, of closely spaced objects, and/or where variations in nominal sensing distance are encountered, sensitivity adjustment should be made under dynamic conditions. For satisfactory setting it is necessary to simulate maximum and minimum sensing conditions. Due to the many possible applications and the differences from set-up to set-up, no fixed procedure can be given, but proper sensitivity settings are usually developed relatively easily through experimentation. However, in extreme cases the following general suggestions can serve as a guide.

1. With machine or equipment operating at speed, simulate the maximum spacing condition, that is, the greatest distance from the sensing head that the actuating object(s) must be sensed. After setting the "COARSE" control as in Step <u>3</u>, above, determine the <u>range</u> of adjustment of the "FINE" control that affords dependable relay action. To do this, turn the "FINE" control clockwise to increase sensitivity to the maximum that permits consistent relay action. Note the control setting with reference to the position of the screwdriver slot. Now rotate the control counterclockwise to decrease sensitivity to the minimum that permits consistent relay action. Note the position of the screwdriver slot at this setting. The difference in the indicated positions of the two settings is the <u>range</u> of adjustment.
2. Now simulate the minimum spacing condition, or the least distance from the sensing head that the actuating object(s) must be sensed. Without altering the "COARSE" adjustment, determine the range of adjustment of the "FINE" control at this distance, following the procedure given above.
3. The maximum distance and minimum distance adjustment ranges as determined above should overlap. In this case, the proper final adjustment of the "FINE" control is at the midpoint of the overlapping part of the two ranges.
4. If the ranges do not overlap, or if the "FINE" control cannot be adjusted to operate at both minimum and maximum spacing, then the spacing between the sensed objects must be increased and/or the distance from the objects and the sensing head must be decreased. Repeat Step <u>1</u> through Step <u>3</u> to establish the final adjustment.

<u>TEMPERATURE AND LINE VOLTAGE VARIATION EFFECTS</u>

CONTROL AMPLIFIER

The Model 55.121 Proximity Control Amplifier is extremely stable with temperature variation, and over a range of from -40°F (-40°C) to 176°F (80°C) drift in sensitivity is negligible within normal operating range of the sensing head. (See Fig. 4.) Change in sensitivity with line voltage variations of from 105 VAC to 130 VAC or 210 VAC to 260 VAC is also negligible. (See Fig. 5.)

SENSING HEADS

ELECTRO Proximity Sensing Heads may be operated at temperatures up to 176°F (80°C). Although the sensing head itself will withstand temperatures of 225°F, it is the insulation of the standard cable that sets the low limit. In general, sensing heads are more susceptible to temperature change than the Model 55.121 Control Amplifier, but sensitivity changes due to temperature vary considerably with sensing head model, material sensed, sensing distance, etc., and no specific data can be given here.

<u>RELAY CHARACTERISTICS</u>

OUTPUT

The DPDT relay used in the Model 55.121 Control Amplifier has contacts rated at 100,000 operations at 10 amperes, 115 VAC or 28 VDC with a resistive load. Contact life at a typical 4 amps, 115 VAC, resistive is 500,000 operations, and 10,000,000 at no load.

RESPONSE TIME

Actuation time of the relay is 10 milliseconds, and de-actuation time is 25 milliseconds. System operating speeds up to 600 operations per minute may be obtained.

<u>TIME DELAY</u>

Both delayed-make (slow make, quick break) and delayed-break (quick make, slow break) time delay modules are available for use with the Model 55.121 Proximity Control Amplifier. These are plug-in modules that use existing sockets on the amplifier, so no rewiring or other circuit modification is required. The time delay modules are optional accessories. The table below shows module model numbers and time delay ranges.

Time Delay Range	Delayed-make Module No.	Delayed-break Module No. (with Pulse Stretching)
.015* to 0.1 sec.	76.022	
.030* to 0.1 sec.		76.026
.05 to 1.0 sec.	76.023	76.027
.05 to 10.0 sec.	76.024	76.028

* Includes relay response time. Module delay is .005 sec.

The delayed-make module will energize the relay after the set delay period only if a sensing head signal ("metal near") has been maintained for the entire delay period. The relay will be de-energized within 25 milliseconds after the sensing head signal has been removed ("metal away"). If the "metal near" signal is removed before the end of the delay period, the relay will not energize, nor will repetitive "metal near" signals shorter than the delay period cause the relay to be energized.

The delayed-break module will energize the relay within 10 milliseconds after the beginning of a 5 microsecond or longer sensing head signal ("metal near"). After the sensing head signal has been removed ("metal away") the relay will remain energized for a time period established by the set time delay period plus the relay de-actuation time -- a minimum of 30 milliseconds in the case of the 76.026 module. Note that the "pulse stretching" effect of the delayed break module permits the Model 55.121 Control Amplifier to give a dependable relay closure with only a 5 microsecond dwell time rather than the 10 millisecond dwell time required by the 55.121 without the delayed-break module.

Complete operating instructions 52.148 are packed with each time delay module.

TROUBLE SHOOTING

Most system operating difficulties are the result of misadjustment or misapplication, and are not due to faults in the electronic circuitry. The following simple procedures will correct the most probable causes of malfunction. If they do not, contact your Electro Representative for further advice and instructions.

Caution: Use a meter with 20,000 ohms/volt DC and 5,000 ohms/volt AC or greater sensitivity for all voltage and resistance measurements.

SYMPTOM I - Relay does not energize with metal present at face of sensing head.

A. ARE CONNECTIONS RIGHT?
See that all connections are made to the proper terminals and that they are tight.

B. IS LINE POWER PRESENT?
Make sure line voltage is present at the control amplifier terminals and that the AC voltage is within 105 V to 130 V or 210 V to 260 V, as applicable.

C. IS SENSITIVITY ADJUSTMENT CORRECT?
Readjust both "COARSE" and "FINE" sensitivity adjustments according to these operating instructions.

D. IS TIME DELAY OPERATIVE?
Remove time delay module and check control amplifier for normal operation. If all right, plug in time delay module and readjust according to instructions. If still inoperative, substitute known operable module and check again.

SYMPTOM II - Relay does not release when metal is removed from the sensing field.

A. ARE CONNECTIONS RIGHT?
See that all connections are made to the proper terminals and that they are tight.

B. IS SENSING HEAD CLEAR?
Make sure there is no build-up of metal chips or slivers on or near the sensing head.

C. IS SENSITIVITY ADJUSTMENT CORRECT?
Readjust both "COARSE" and "FINE" sensitivity adjustments according to these operating instructions.

D. ARE THERE SHORTS OR OPENS IN SENSING HEAD AND CABLE?
Make a continuity check on the sensing head and cable. Infinite resistance will indicate an open, or break. Shorts are more difficult to determine because typical resistance of various model sensing heads ranges from 1 to 14 ohms, so other than dead short circuits in cables may not be immediately apparent. A more reliable check is to substitute a known operative sensing head and cable and recheck the control for operation.

E. IS TIME DELAY OPERATIVE?
If applicable, follow the procedure under "D", Symptom I.

SYMPTOM III - Operation is intermittent.

A. ARE CONNECTIONS RIGHT?
See that all connections are made to the proper terminals and that they are tight.

B. IS LINE POWER PRESENT?
Make sure that line voltage is present at the control amplifier terminals, that it is within prescribed limits and that it is not interrupted.

C. IS SENSITIVITY ADJUSTMENT CORRECT?
Readjust the sensitivity adjustments according to these instructions. If the system is then operational at intervals, the trouble probably is one of the following:
   1. Nominal sensing distance is too great.
   2. Parts to be sensed are too closely spaced.
   3. Variation from nominal spacing is too great.
   4. Temperature variation at the sensing head is too great.

D. ARE SENSING HEAD AND CABLE ALL RIGHT? Substitute a sensing head and cable that are known good and check the control for proper operation.

E. IS TIME DELAY OPERATIVE? If applicable, follow procedure under "D", Symptom I.

PROXIMITY SWITCH TERMINOLOGY -- DEFINITIONS

Actuating object - The part or piece of ferrous or non-ferrous metal being sensed.

Control amplifier - The portion of a proximity switch containing the oscillator, amplifier, power supply and associated circuitry which will, on the detection of metal, (1) actuate a relay in the control amplifier in relay output types, or (2) provide a change in output voltage in electronic output types.

Drift - The change in sensing distance at a given sensitivity setting caused by variations in sensing head or control amplifier temperature, line voltage, long term operation, etc.

Dwell time - The time the actuating object remains within the sensing field.

Metal away - The condition in which there is no actuating object within the sensing field.

Metal near - The condition in which an actuating object is within the sensing field.

On-Off differential - (Hysteresis) The difference in sensing distance between the point where the relay energizes as the actuating object approaches the sensing head and the point where the relay de-energizes as the actuating object departs from the sensing head.

Proximity switch (inductive) - A device that detects the presence of a specific actuating object at a predetermined distance from a reference point. It consists of a sensing head connected by a cable to a control amplifier.

Pulse stretching - An effect produced by delayed-break time delay modules by which dependable relay operation is attained with a metal near signal of dwell time shorter than normal relay actuation time.

Relay actuation time - The time required after entry of an actuating object into the sensing field to accomplish full relay contact transfer. May also be called energizing time or pull-in time.

Relay de-actuation time - The time required after departure of an actuating object from the sensing field to accomplish full relay contact transfer. May also be called de-energizing time, drop-out time, release time.

Repeatability - The variation in sensing distance at which an actuating object is detected over repeated operations at a given sensitivity setting.

Sensing distance - The pre-set distance from the sensing head at which an actuating object will be detected. This distance is determined by the setting of the sensitivity adjustments in the control amplifier.

Sensing field - The field of radiation from the sensing head within which an actuating object can be detected.

Sensing head - The enclosed remote oscillator coil that radiates the sensing field to detect the actuating object.

Sensitivity - The ability of a proximity switch to sense an actuating object in relation to distance. Sensitivity is adjustable with controls in the control amplifier, but sensitivity will vary with size and material of the object, environment, type of sensing head, etc.

Stability - The resistance to changes in sensing distance (drift) caused by variations in temperature, line voltage, etc., at a given sensitivity setting.

Time delay, delayed-make - An adjustable interval introduced between detection of the actuating object and relay pull-in through use of a delayed-make time delay module. May be called slow make, quick break or on-delay.

Time delay, delayed-break - An adjustable interval introduced between the removal of an actuating object from the sensing field and relay drop-out through use of a delayed-break time delay module. May also be called quick make, slow break or off-delay. This module also provides the pulse stretching effect.

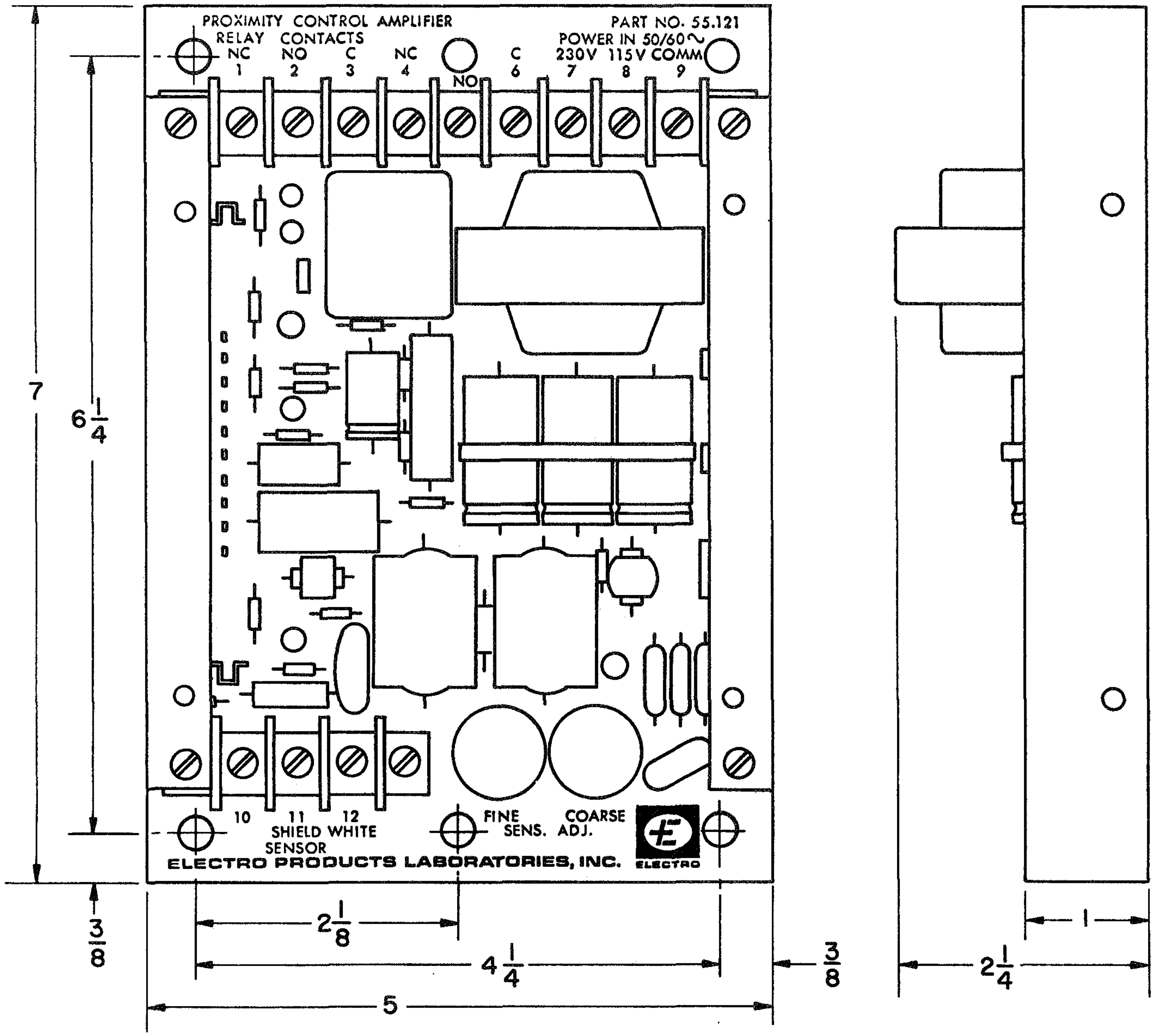


Fig. 1. Mounting dimensions Model 55.121 Proximity Control Amplifier.

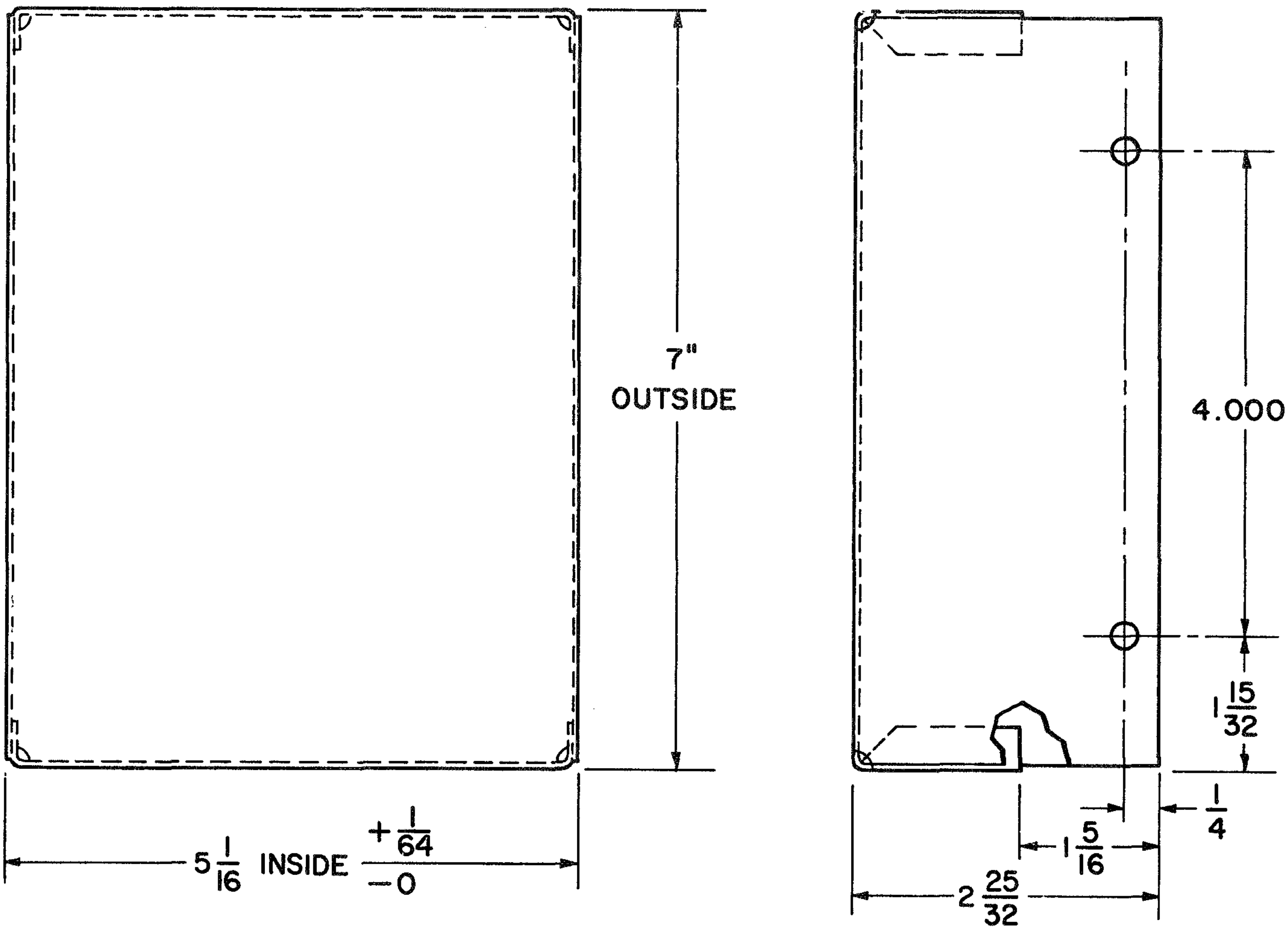


Fig. 2. Dimensions Model 58.335 Cover

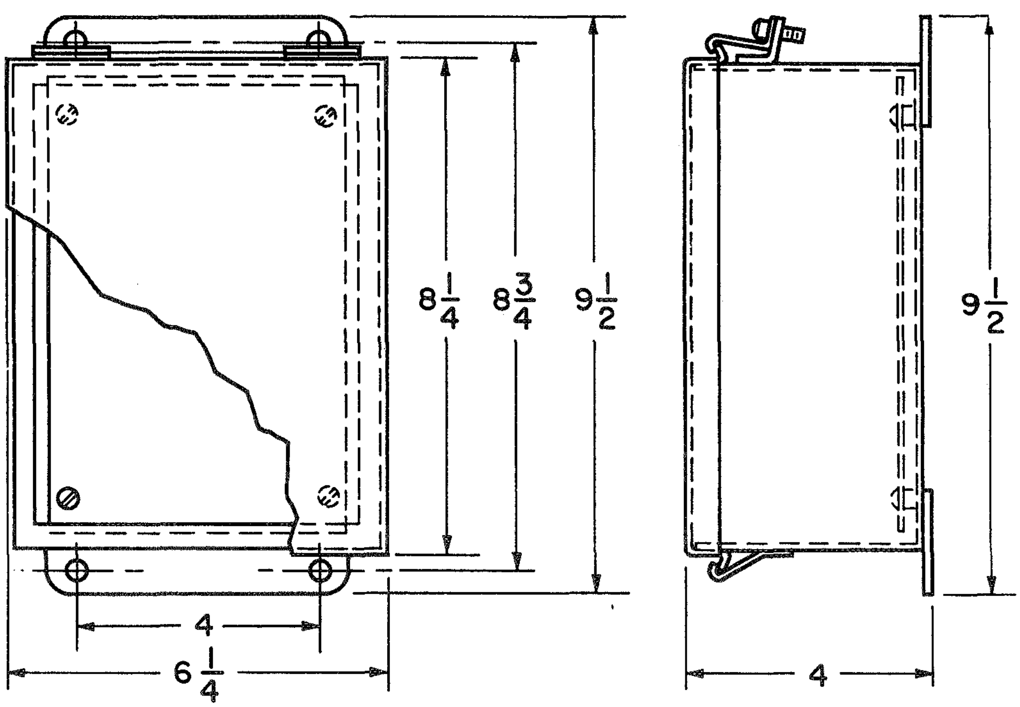


Fig. 3. Mounting dimensions Model 58.334
JIC Enclosure (NEMA 12).

TYPICAL PERFORMANCE CURVES -- MODEL 55.121 CONTROL AMPLIFIER

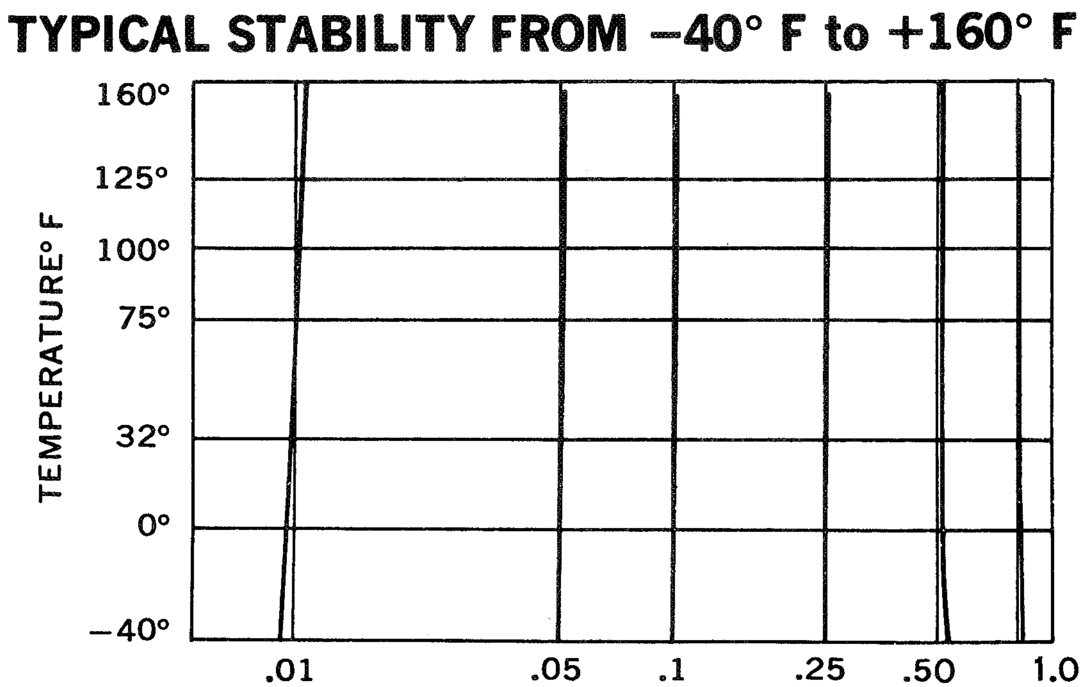
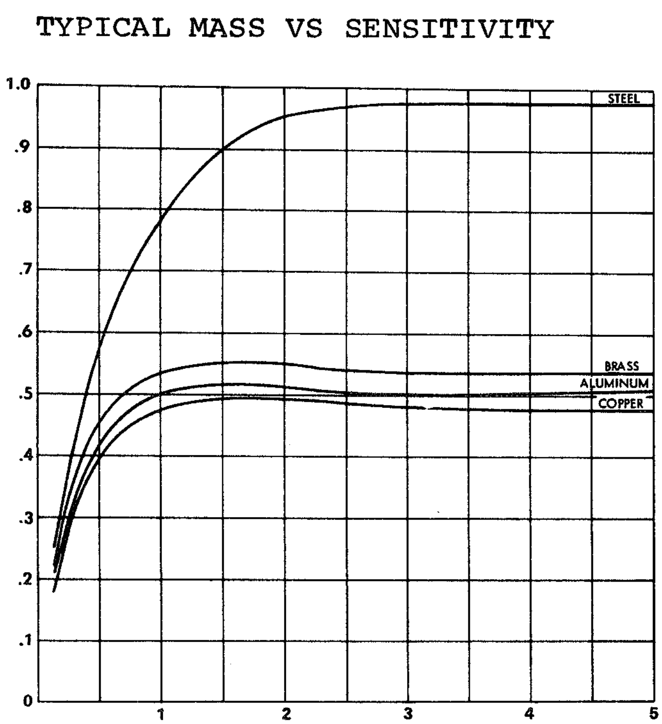


Fig. 4 SENSING DISTANCE, INCHES



g. 6 ACTUATOR SQUARE IN INCHES

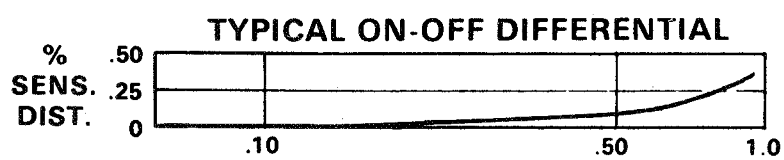


Fig. 7 SENSING DISTANCE, INCHES

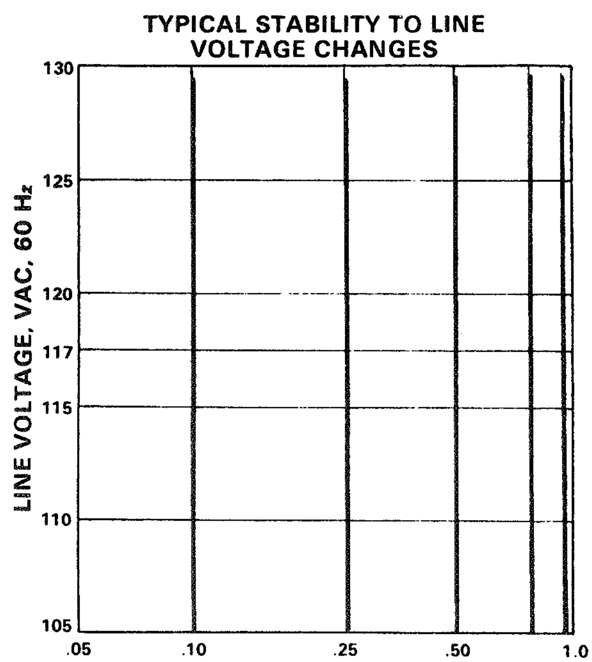


Fig. 5 SENSING DISTANCE, INCHES

Test Conditions:
All tests made with Control Amplifier and Model 4943-A Sensing Head at room temperature with a 2" square steel actuator and 117VAC, 60 Hz line, with exception of the condition varied according to requirements of each test.

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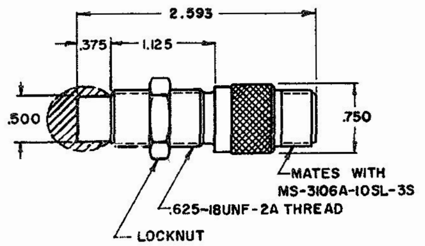
REPLACEMENT PROXIMITY SWITCH SENSING HEADS

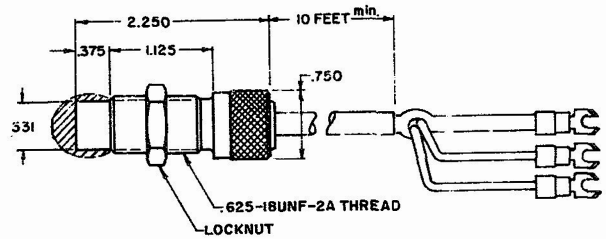
FOR USE WITH VACUUM TUBE & TRANSISTORIZED CONTROL AMPLIFIER OF THE 4900 SERIES

58171

MODEL 4910AN

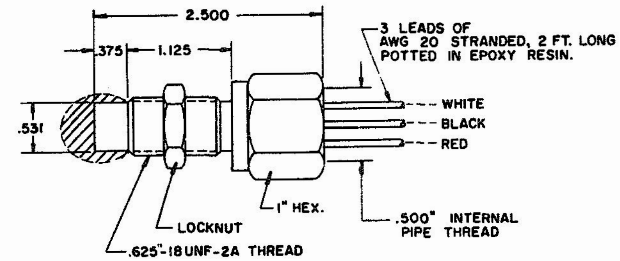


MODEL 4910BL

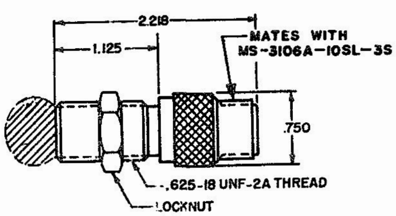


TERMINATED WITH SPADE TERMINALS FOR #6 SCREW

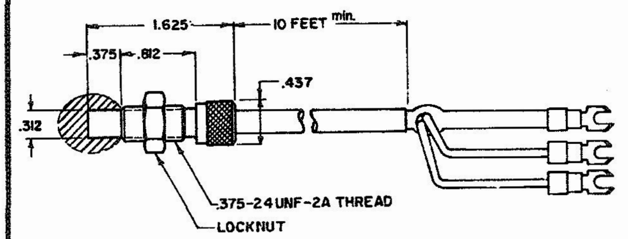
MODEL 4910HLB



MODEL 4911

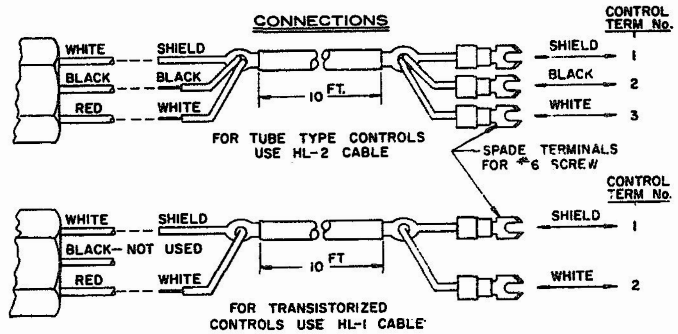


MODEL 4913BL

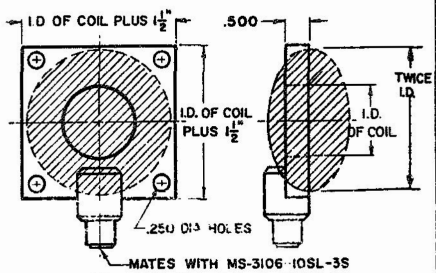


TERMINATED WITH SPADE TERMINALS FOR #6 SCREW

CONNECTIONS

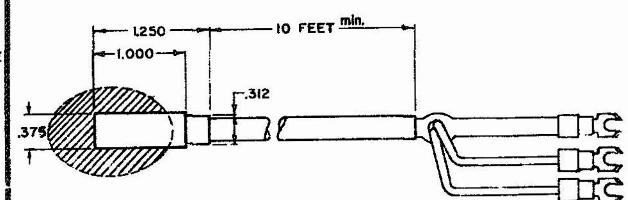


MODEL 4922



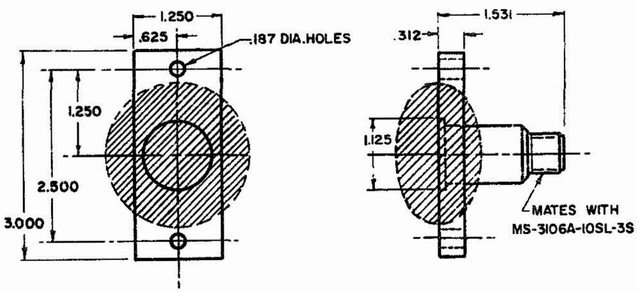
I.D. OF COIL TO BE SPECIFIED BY CUSTOMER.

MODEL 4914BL



TERMINATED WITH SPADE TERMINALS FOR #6 SCREW

MODEL 4915B



NOTE 1. DIMENSIONS SHOWN ARE BASIC, NO TOLERACES ARE IMPLIED.

NOTE 2. SENSING FIELD SIZES AND SHAPES ARE APPROXIMATE. THESE FIELDS ARE AFFECTED BY THE SETTING OF THE SENSITIVITY ADJUSTMENT AS WELL AS BY THE PRESENCE OF METALS NEAR THE PROBES. GOOD PRACTICE IS TO KEEP MOUNTING METAL AS FAR FROM THE SENSING END AS POSSIBLE.

REV. 10-22-68.

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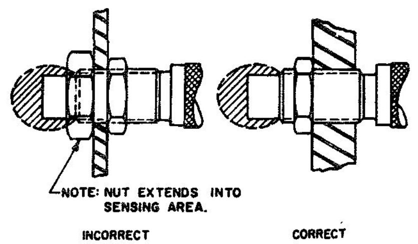
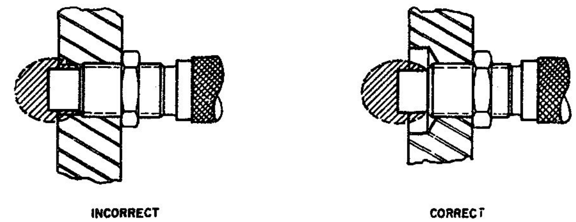
HINTS FOR MOUNTING PROXIMITY SWITCH SENSING HEADS

58222

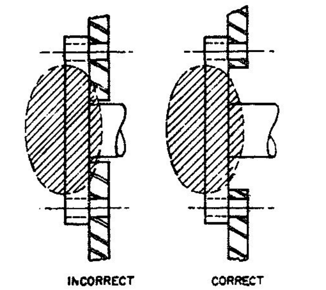
USE OF LOCKNUTS ON MODELS 4910, 4913 & 4943



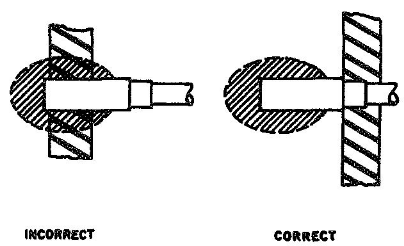
RECESSED MOUNTING OF MODELS 4910 & 4913



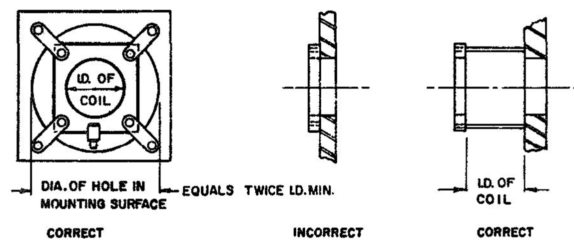
MOUNTING METHOD FOR MODEL 4915B



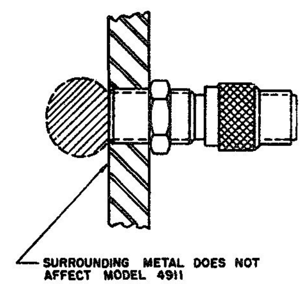
MOUNTING METHOD FOR MODELS 4914 & 4944



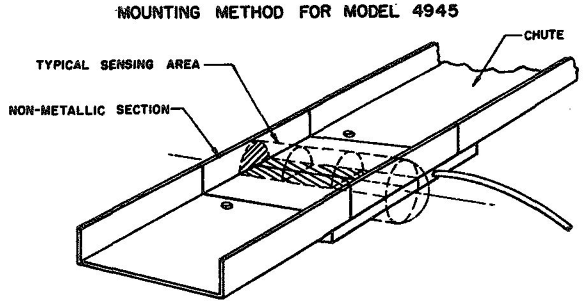
MOUNTING METHOD FOR MODEL 4922



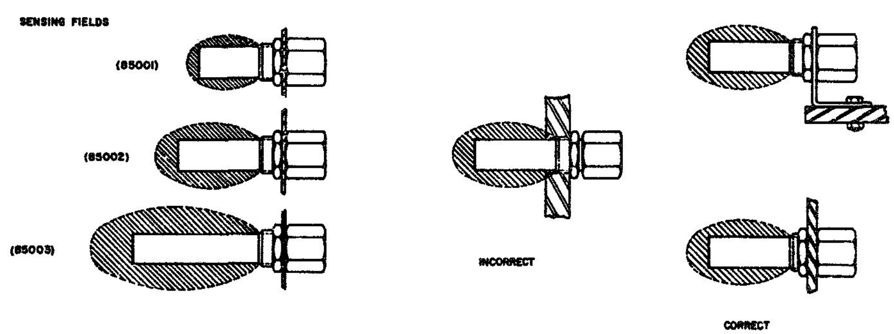
MOUNTING METHOD FOR MODEL 4911



MOUNTING METHOD FOR MODEL 4945



MOUNTING METHOD FOR MODELS 85001, 85002 & 85003



NOTE 1. NO MOUNTING METAL SHOULD COME WITHIN SHADED AREA. ALL MOUNTING SURFACES SHOWN ARE METAL.

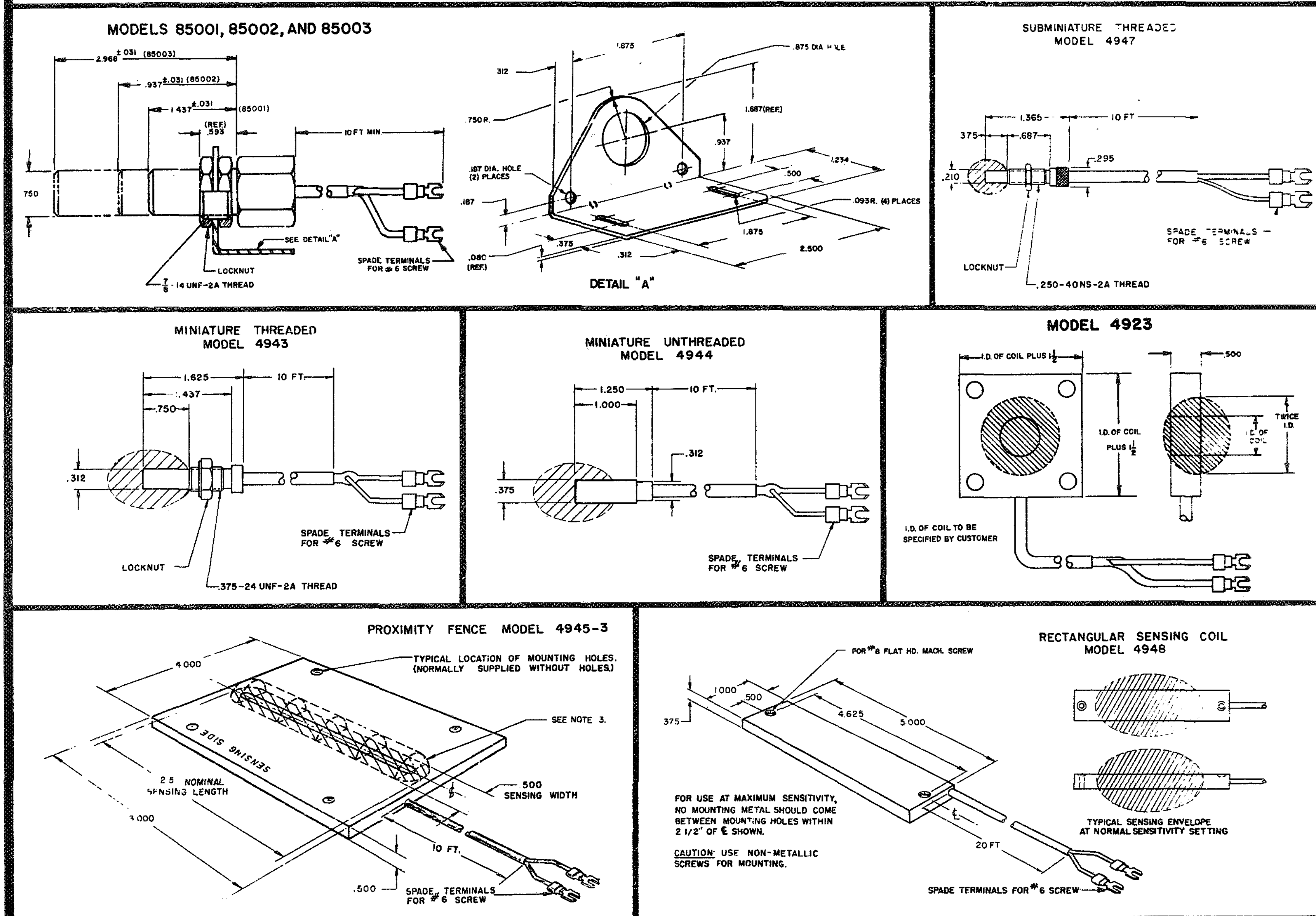
NOTE 2. SENSING FIELD SIZES AND SHAPES ARE APPROXIMATE. THESE FIELDS ARE AFFECTED BY THE SETTING OF THE SENSIVITY ADJUSTMENT AS WELL AS BY THE PRESENCE OF METALS NEAR THE PROBES GOOD PRACTICE IS TO KEEP MOUNTING METAL AS FAR FROM THE SENSING END OF THE PROBE AS POSSIBLE.

REV. 10-23-68

ELECTRO PRODUCTS LABORATORIES, INC.
6125 WEST HOWARD STREET, CHICAGO, ILL 60648

SENSING HEADS
FOR USE WITH TRANSISTORIZED CONTROLS

58224



NOTE 1. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES & ARE BASIC.
NOTE 2. SENSING FIELD SIZES AND SHAPES ARE APPROXIMATE. THESE FIELDS ARE AFFECTED BY THE SETTING OF THE SENSITIVITY ADJUSTMENT AS WELL AS BY THE PRESENCE OF METALS NEAR THE PROBES. GOOD PRACTICE IS TO KEEP MOUNTING METAL AS FAR FROM THE SENSING END AS POSSIBLE.
NOTE 3. THE ENVELOPE DEPICTED EXTENDS SIMILARY FROM UNDERSIDE OF THE SENSOR. USE THE PROPER "SENSING SIDE" AFFORDS ABOUT .125" GREATER SENSING RANGE THAN USE OF THE WRONG SIDE. NO MOUNTING METAL SHOULD COME WITHIN A 2" RADIUS OF CENTER OF "TYPICAL SENSING ENVELOPE" SHOWN.

REV. 10-23-68

Appendix E

SPECIFICATION

WIRE FEED GUIDE TUBE ASSEMBLY, CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT

SPECIFICATION

WIRE FEED GUIDE TUBE ASSEMBLY, CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT (LMSC/HREC 5150718)

19 September 1969

PREPARED BY: K. W. Heimendinger
Research Engineer

APPROVED BY: R. B. Wysor, Supervisor
Advanced Development Section

A. S. Dunbar, Manager
Systems Engineering Department

Specification

WIRE FEED GUIDE TUBE ASSEMBLY, CLOSED-CIRCUIT TELEVISION (CCTV) ARC GUIDANCE ADAPTER KIT

SUMMARY

This specification establishes the requirements for the wire feed guide tube assembly for a CCTV Arc Guidance Adapter Kit. The adapter kit will integrate a CCTV arc guidance system with a computerized torch angle manipulator and welding skate. The end product shall be a fully operational welding skate with CCTV arc guidance capable of welding contoured and double contoured surfaces.

The system requires the relocation of the filler wire feed unit Model HMF-A, Package Unit 2304-0300 in order to accommodate the CCTV camera object viewing lens and associated equipment needed to view the weld seam. To do this requires the standard wire feed guide tube assembly be modified. Such an assembly is shown in Fig. 1.

WIRE FEED GUIDE TUBE ASSEMBLY REQUIREMENTS

1.0 SYSTEM CONFIGURATION

The wire feed guide tube assembly shall consist of a guide tube, tube liner, tip and tip liner (if required).

2.0 REFERENCE

The reference for Fig. 1 shall be the outside plane of the nut No. 2310 1252 when the guide tube assembly is securely fastened to the wire feeding unit. The vendor shall provide the dimensions from the reference to the wire feed unit.

3.0 LENGTH AND DIAMETER

3.1 The overall design length of the assembly shall be 9.90 in. (2.45 in. radius) measured along the centerline as shown in Fig. 1. A maximum overall design length of 11.37 in. (3.00 in. radius) can be allowed as per Para. 4.0.

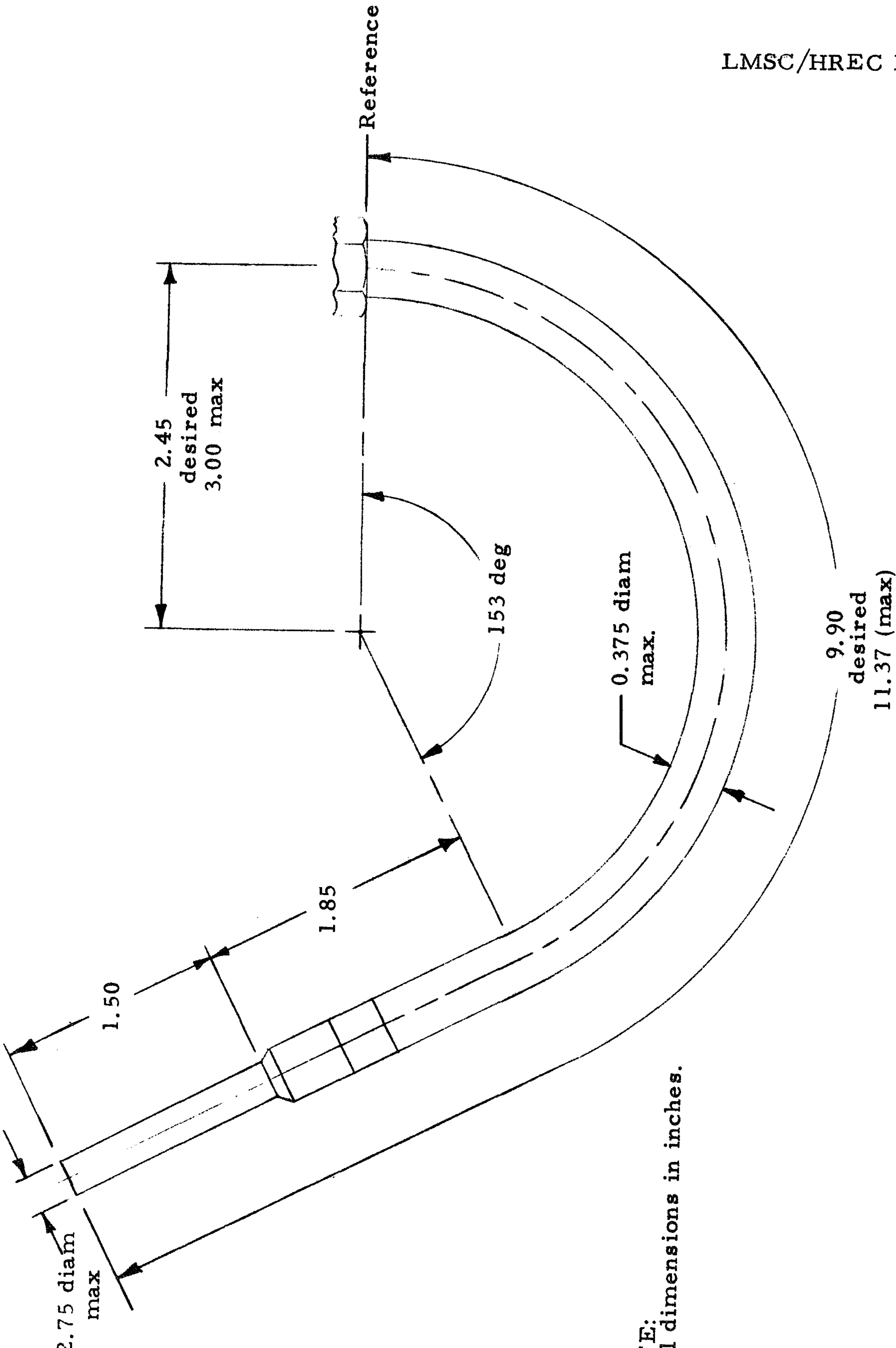
3.2 The length of the tip end shall be 1.50 in. to minimize optical and illumination interference.

3.3 The outside diameter of the tip shall be 0.275 in. maximum.

3.4 The outside diameter of the guide tube shall be 0.375 in. maximum.

4.0 CURVATURE

4.1 The curvature of the guide tube assembly shall be a bend of 153 deg from the reference.



NOTE:
All dimensions in inches.

Fig.E-1 - Wire Feed Guide Tube Assembly

4.2 The design radius of curvature shall be 2.45 inches to the tube center-line, but a radius of 3.00 inches maximum can be allowed.

5.0 PLANE ROTATION

The plane of feed shall be rotated 45° as shown in Fig. 2.

6.0 WIRE REQUIREMENTS

The feeder shall feed a filler wire 1/16 inch diameter of Alloy 2319.

7.0 LINER

7.1 The tube liner shall conform to paragraphs 6.0 and 4.0.

7.2 A tip liner shall be provided if required.

8.0 FINISH

The tube guide and tip shall be coated with a flat black finish that will resist the welder heat and minimize reflected light.

9.0 FILLER-WIRE FEED UNIT

The filler-wire feed unit is a Heliweed model HMF-A Package Unit 2304-0300.

10.0 PERFORMANCE

The friction of the assembly shall be such as to allow the full speed range of the feeder with the wire specified in paragraph 6.0.

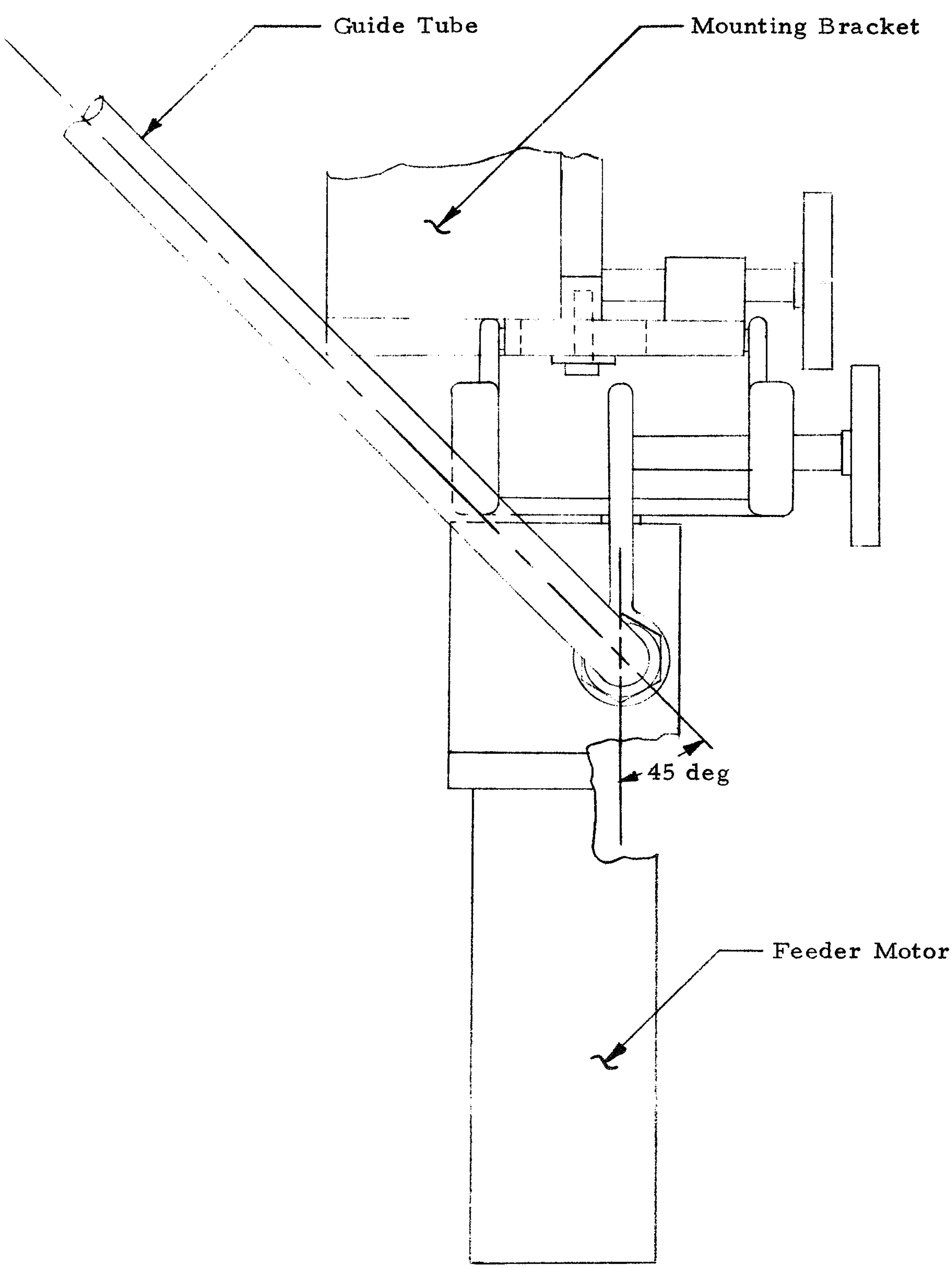


Fig.E-2 - Wire Feed Guide Tube Plane Rotation

Appendix F

MATERIAL SUBSTITUTIONS

Appendix F
MATERIAL SUBSTITUTIONS

The following material substitutions are to be made in Revision "B" of the welding torch angle manipulator. These substitutions are now readily available and are sufficiently equivalent in physical characteristics.

Drawing Number/Name	Was	Substitute
801-1-0/Compensator Beam Assembly	5083-H343	7075-T651
801-1-3/Drive Link	7178-T6	7075-T651
801-1-7/Drive Rod, Link	7178-T6	7075-T651
801-1-15/Motor Mount	7178-T6	7075-T651
801-1-19/Torch Beam	7178-T6	7075-T651
801-1-27/Servo Motor Cover	7178-T6	5052-H34

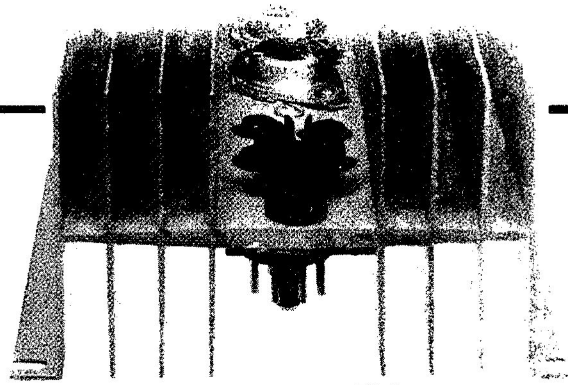
Appendix G

MODEL 440 DIFFERENTIAL D.C. OPERATIONAL POWER AMPLIFIER

LMSC/HREC D162545

MODEL 440K KIT
50 WATT RMS
DIFFERENTIAL
D.C. THRU AUDIO
OPERATIONAL POWER AMPLIFIER

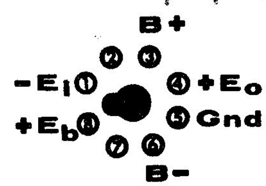
OPAMP LABS
172 S. Alta Vista Blvd.
Los Angeles, Calif. 90036
(213) 934-3566



DESCRIPTION

The Model 440 Differential D.C. Operational Power Amplifier consists of an OPAMP 4009 driving a dual class AB power amplifier. There is no crossover distortion. This amplifier is intended for use as a servo motor or D.C. thru audio power amplifier. It may be used in audio applications with either a single polarity or bipolar power supply. It has an output capability of 50 watts RMS. The entire amplifier is constructed on the octal plug-in heat sink. The circuitry is isolated from the case.

(STANDARD OCTAL PLUG)



ELECTRICAL CHARACTERISTICS

Power Supply Voltage	±15V	±25V	±36V
Power Supply Current (Standby)	±12mA	±20mA	±30mA
Operating Temperature Range (Case)	−55°C to +85°C	−55°C to +85°C	−55°C to +85°C
Internal Power Dissipation (Standby)	360mW	1 W	2 W
Open Loop Voltage Gain	500	650	800
Unity-Gain Bandwidth	2 MC	2 MC	2 MC
Input Offset Voltage	±100mV	±100mV	±100mV
Input Bias Current	0.2μA	0.2μA	0.2μA
Input Impedance	20K	20K	20K
Input Common Mode Voltage Range	±10V	±20V	±30V
Equivalent Input Drift (R_S = 10K)	±0.5mV/°C	±0.5mV/°C	±0.5mV/°C
Equivalent Input Noise	20μV	20μV	20μV
Common Mode Rejection Ratio	80 DB	80 DB	80 DB
Output Impedance (Open Loop)	0.1 ohm	0.1 ohm	0.1 ohm
Output Voltage Swing/Load	±12V/3 ohms	±22V/4 ohms	±30V/8 ohms
Output Slewing Rate	5V/μS	5V/μS	5V/μS
Full Power Output (−3 DB)	D.C. to 25 KC	D.C. to 25 KC	D.C. to 25 KC
Maximum Output Current	10 amps	10 amps	10 amps
Peak Output Power	50 watts	100 watts	100 watts
Maximum RMS Output Power	25 watts	50 watts	50 watts

DISTORTION

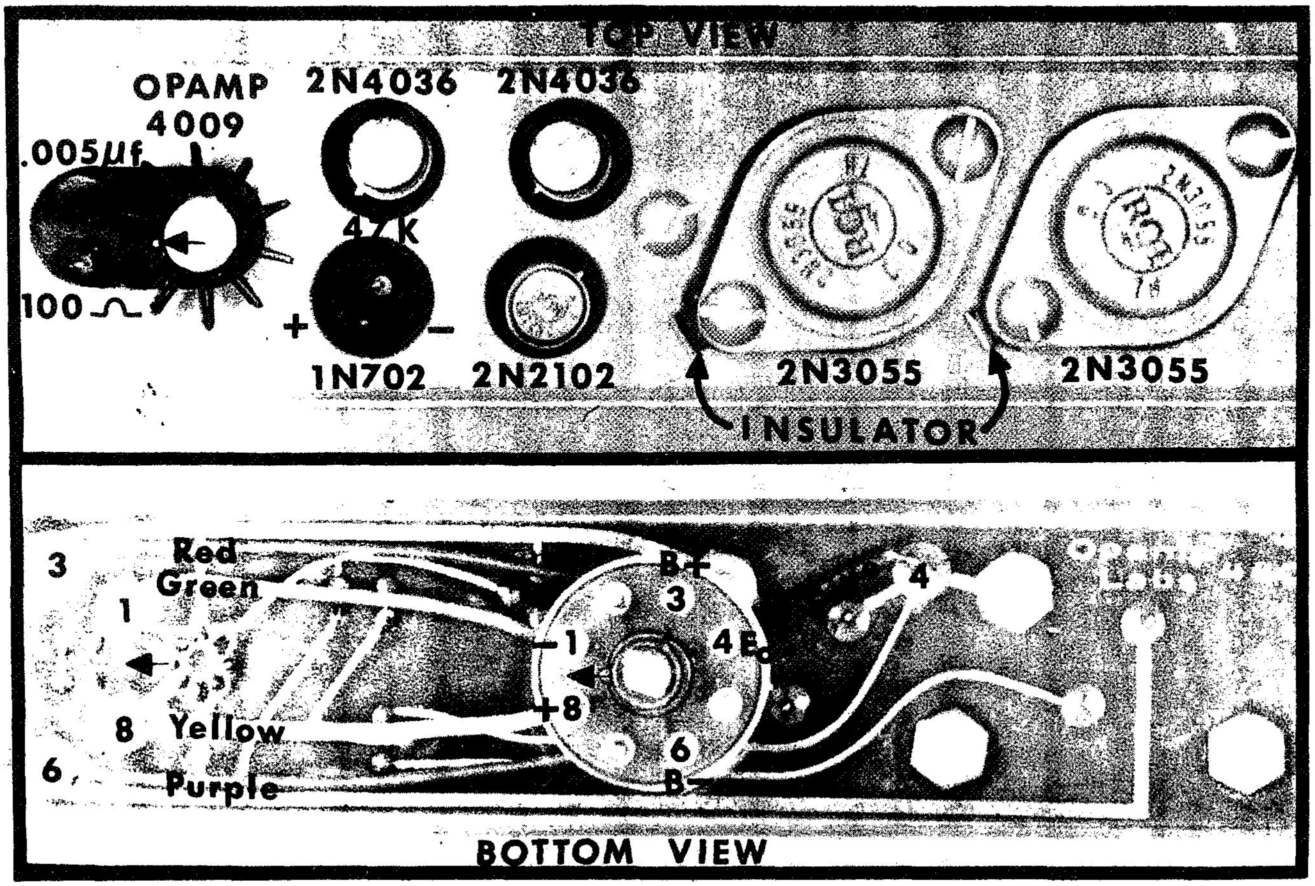
Total Harmonic <0.5%
Intermodulation <0.5%
} at any power supply voltage and output power level.

SIZE: 4¾" x 5½" x 2-5/8" Seated Height

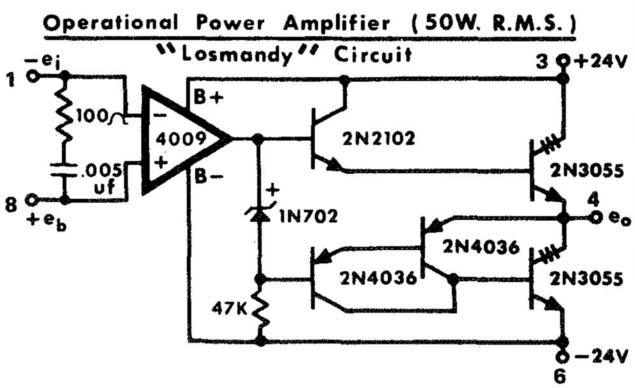
WEIGHT: 20 Ounces

KIT PRICE: $30.00

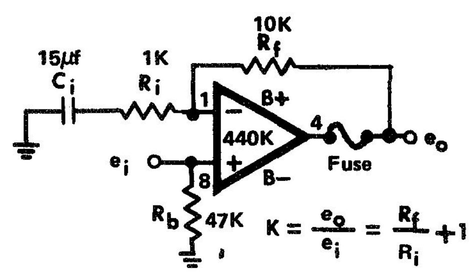
(SEE OTHER SIDE FOR ASSEMBLY AND APPLICATIONS)



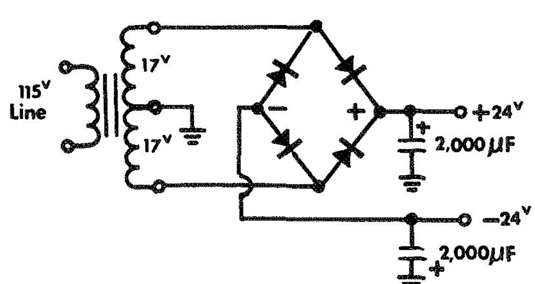
MODEL 440K SCHEMATIC DIAGRAM



TYPICAL APPLICATION (Gain = 11)



±24 VOLT POWER SUPPLY (Full Wave)



Available as Model 523, $30.00
3¼" x 5¼" x 4¼" H, ±24V @ 2 Amps