If you have issues viewing or accessing this file contact us at NCJRS.gov.

71-NI-AX-147-G

MF-1

Technical

Report

Final Report
F-C3157

FLEXIBLE OPTICAL INSPECTION DEVICE

August 1972

By

R. J. Gibson
John A. DeBenedictis

Under

LEAA Management Control No. P71-168

Prepared for

U.S. Department of Justice
Law Enforcement Assistance Administration
National Institute of Law Enforcement
and Criminal Justice
Washington, D.C. 20530

78762

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
BENJAMIN FRANKLIN PARKWAY · PHILADELPHIA, PENNA. 19103

Technical

Report

Final Report
F-C3157

FLEXIBLE OPTICAL INSPECTION DEVICE

August 1972

By

R. J. Gibson
John A. DeBenedictis

Under

LEAA Management Control No. P71-168

Prepared for

U.S. Department of Justice
Law Enforcement Assistance Administration
National Institute of Law Enforcement
and Criminal Justice
Washington, D.C. 20530

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES
BENJAMIN FRANKLIN PARKWAY • PHILADELPHIA, PENNA. 19103

TABLE OF CONTENTS

I. INTRODUCTION

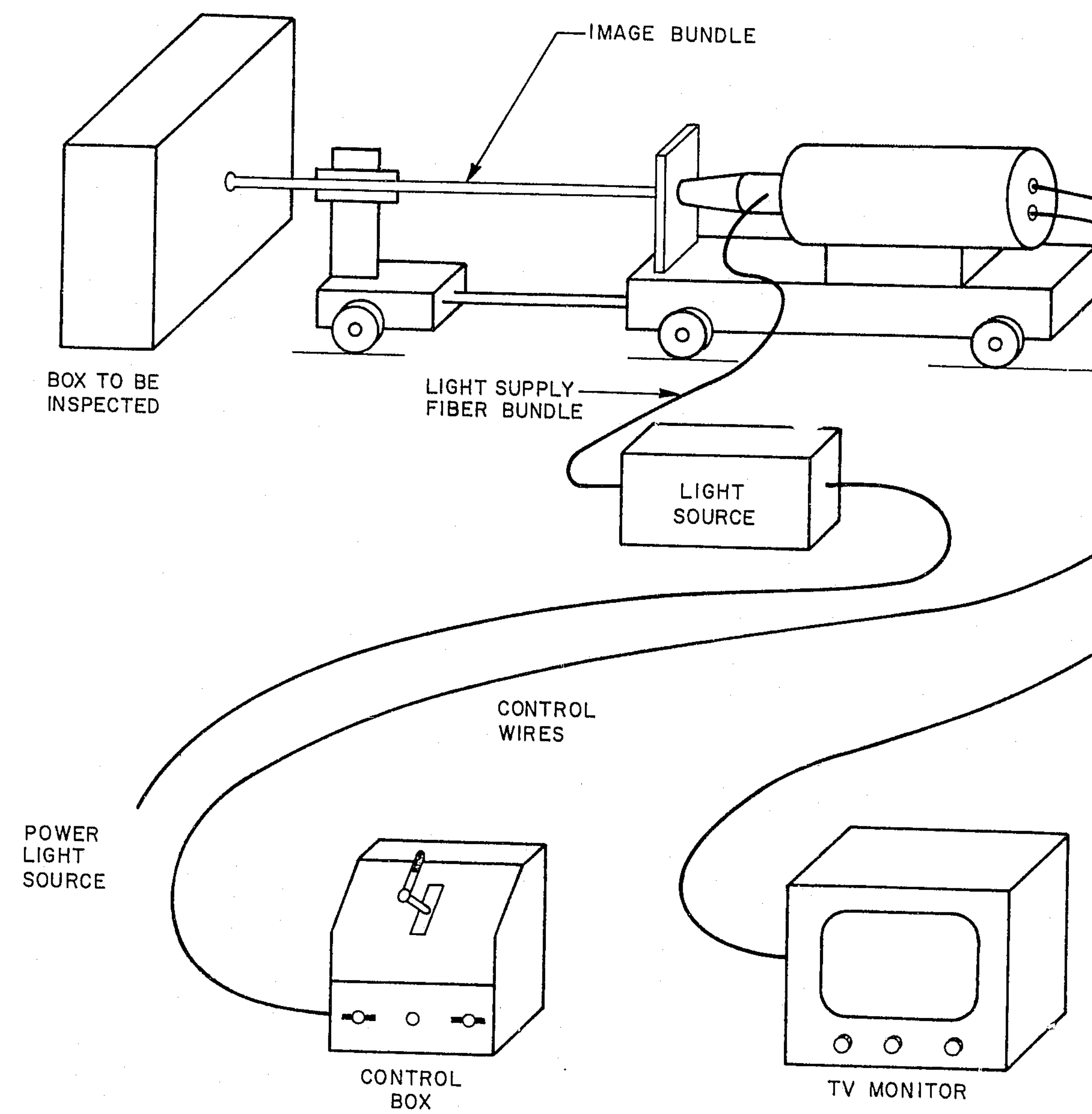
This report covers the Fourth and Final Quarter 1 May 72 to 31 Aug. 72 (inc. 1 month approved extension) of the activity on the Flexible Optical Inspection Device (FOID) under development for the Law Enforcement Assistance Administration.

Design and Fabrication of the FOID was completed. Several control circuits were evaluated. The unit was demonstrated and tested under simulated operating conditions. Recommendations are made for future accessories and improvements.

II. FLEXIBLE OPTICAL INSPECTION DEVICE DESCRIPTION AND DESIGN

1. General Description

The inspection device consists of a fiber optics imaging bundle, remotely controlled with respect to penetration (horizontal travel) rotation, bend of tip and focus, TV camera to relay the image produced, a light source, a control box, and a TV monitor. These components are interconnected to permit remote entry through a small (3/8" diameter) hole in the package to be inspected. After entry, the viewing tip of the fiber bundle can be rotated, bent and focused to permit a large volume of the package to be inspected. This is accomplished safely and remotely by long control electrical cables separating the inspection carriage and camera from the monitor and control box. (See Fig. 1) The monitor relays the image seen by the tip of the optics bundle to the viewer while the tip orientation is controlled by a special control "joystick". This "joystick" enables the viewer to maintain his concept of the bundle tip and know in which direction and at what angle it is pointing. (see Fig. 2). The bend angle ($\pm$ approx. 90°) and rotation angle ($\pm$ approx. 90°) of the tip is nearly in one to one correspondence with the control handle. Well over a full forward hemisphere can be covered by this control because of the approximate 52° viewing cone of the bundle lens. The motors controlling bend and rotation are servo controlled so that placing the control handle in a desired position causes the motors to drive the tip to a corresponding position and then stop. Hence, control is easily and knowingly accomplished. One can then visualize just what portion of the interior of the package is being viewed. Focus of the image is accomplished by simply viewing the image on the monitor and holding the focus control over until the image is sharp. It is similar in operation and "feel" to that used on almost any otical instrument. Focus range is from approximately 1/4" to infinity. Figure 3 shows how the initial height, angle and penetration distance of the fiber bundle can be adjusted. This is also shown in photographs in Figures 4 and 5. In Figure 6, we see the device in operation. The fiber bundle has been remotely inserted into the large package at the end of the table. The monitor shows that it contains a small tissue box 4"x4"x5" at the bottom. The probe is looking vertically downwards. The small letters "DISPOSABLE" are less than 1/8" high and have a line width approximately 1/32".



F-C3157

Figure 1. System Diagram Inspection Device.

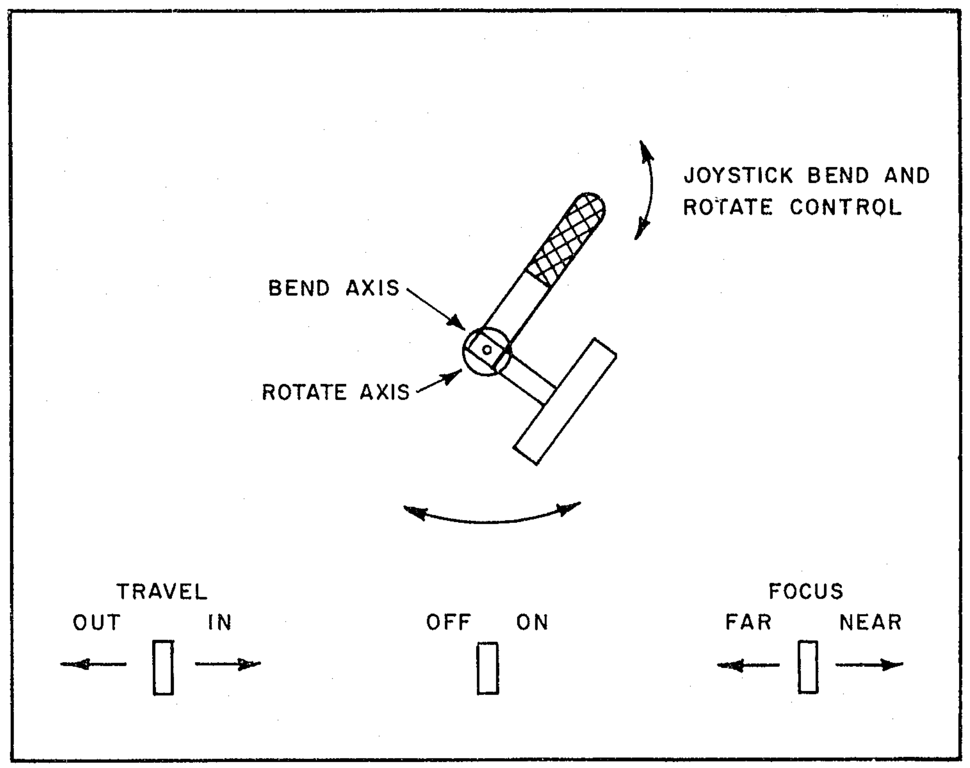


Figure 2. Control Panel Layout

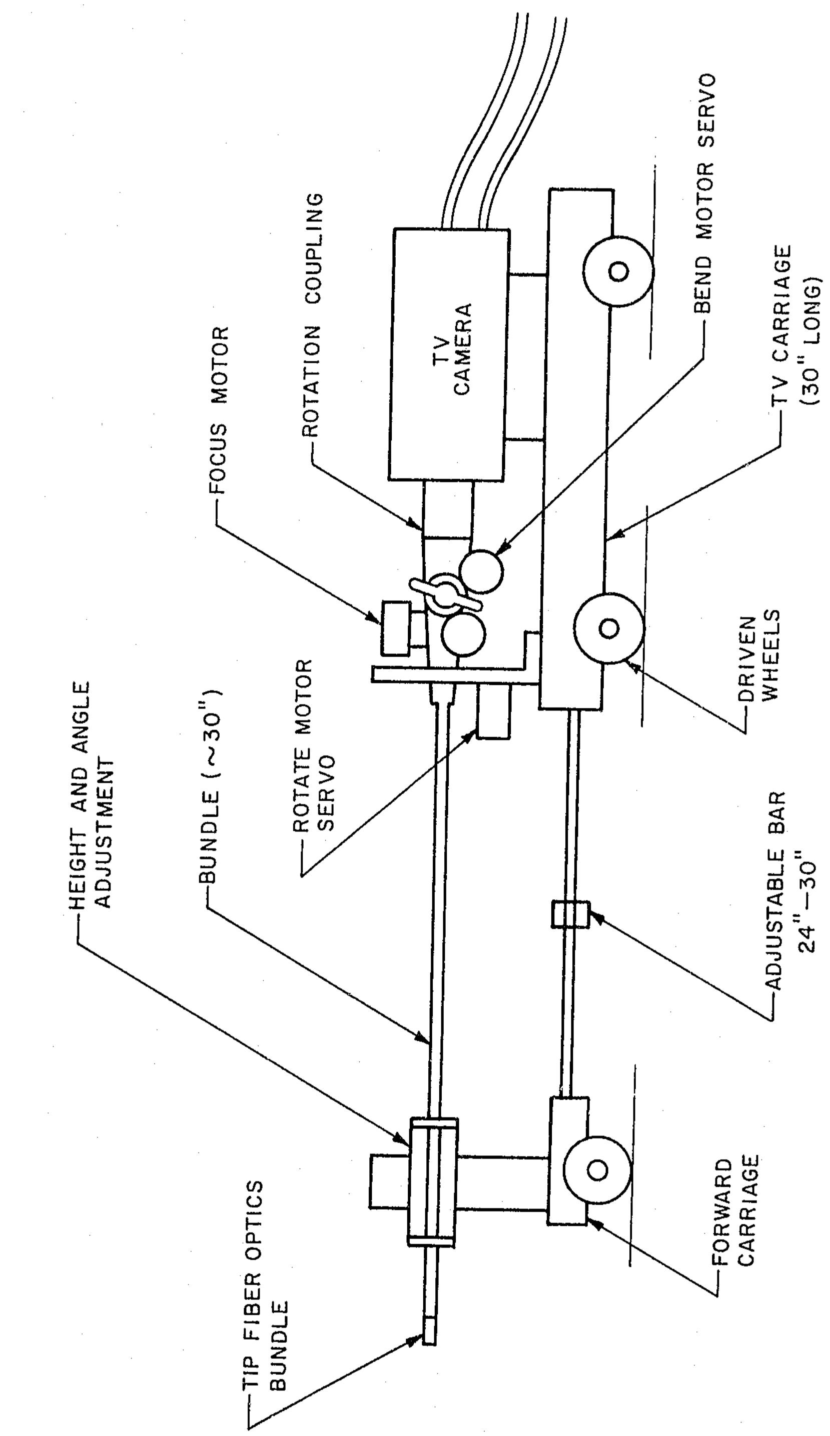
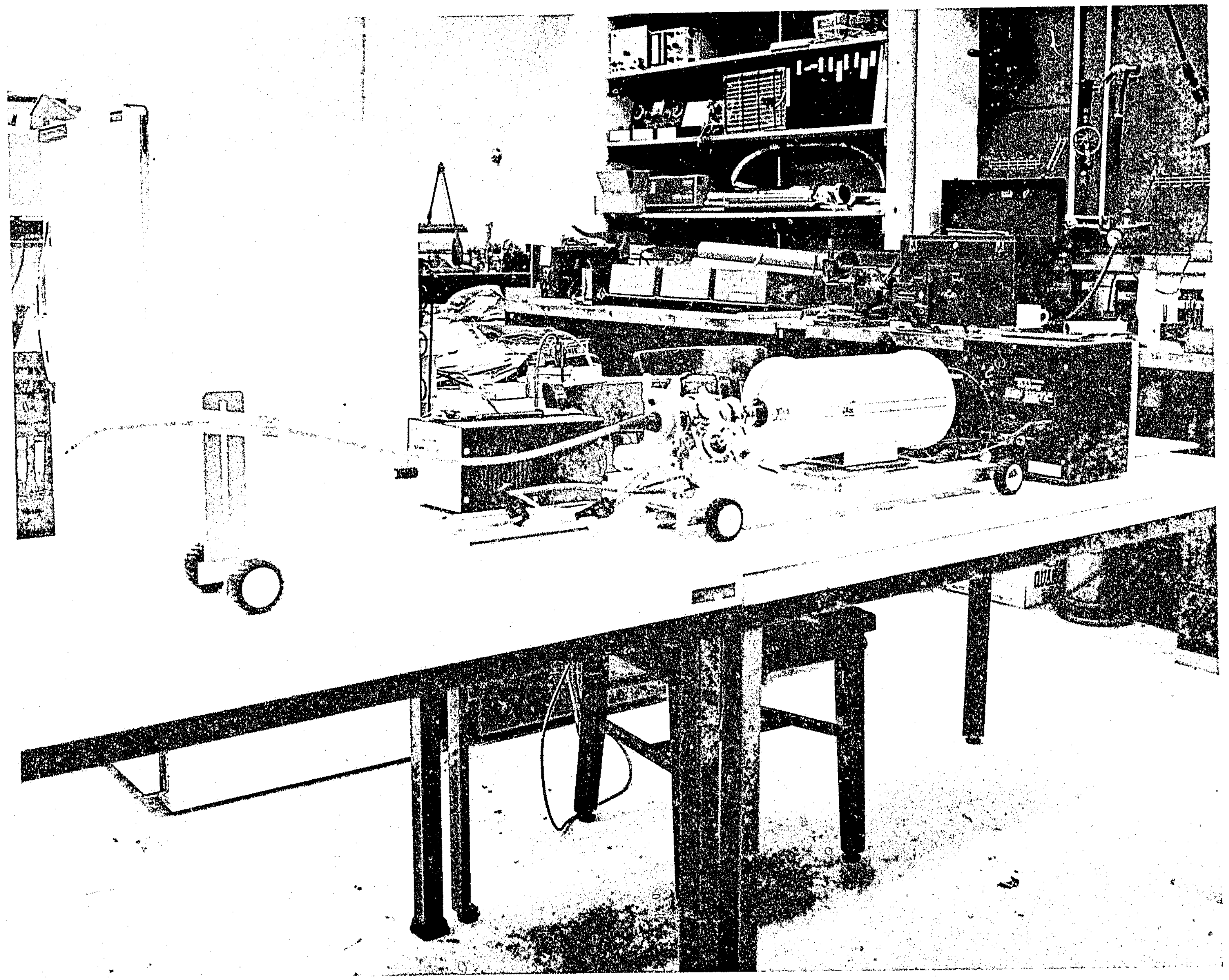


Figure 3. Inspection Device Fiberscope Carriage Diagram



F-C3157

Figure 4. Flexible Optical Inspection Device - Complete System.

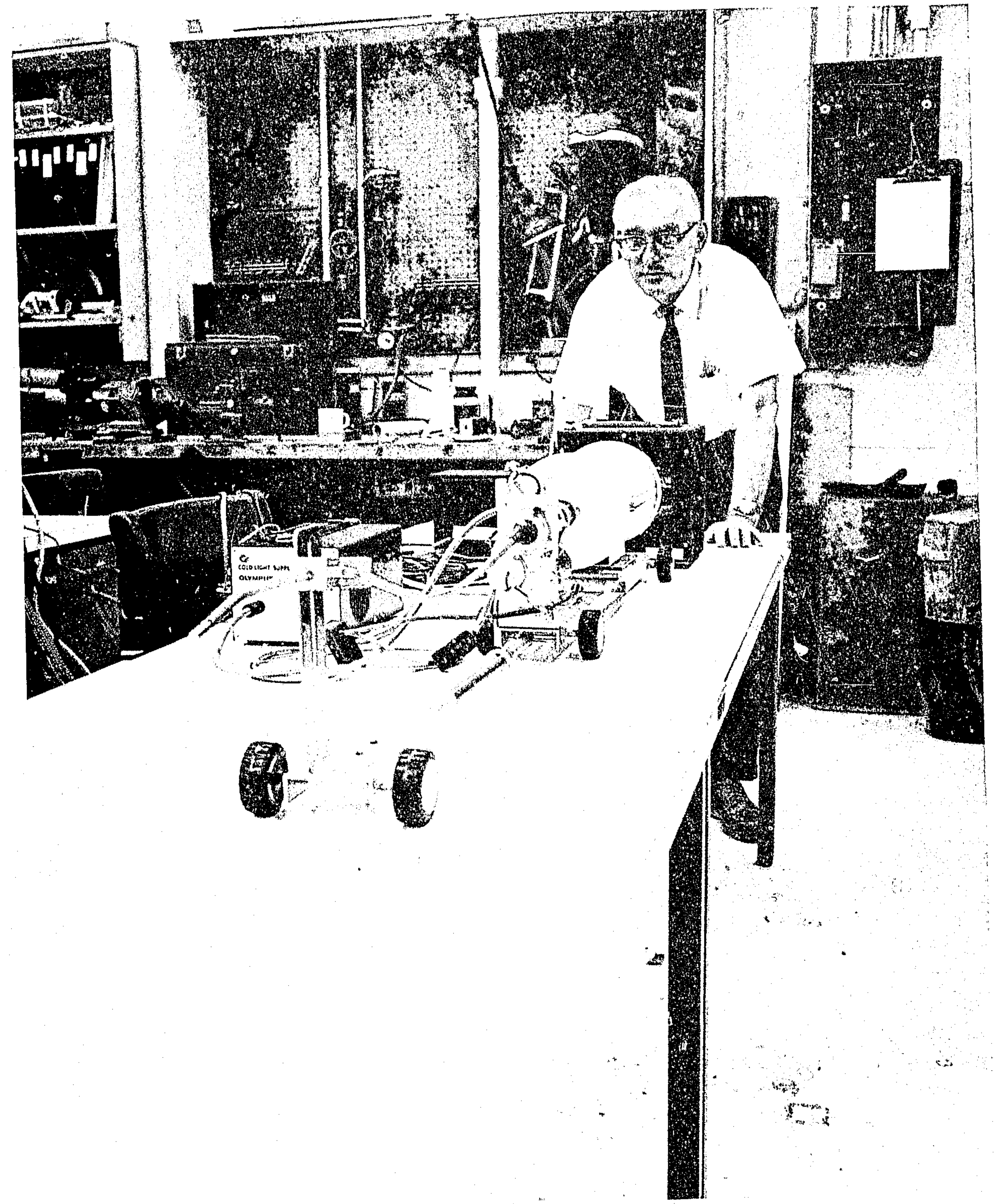


Figure 5. Flexible Optical Inspection Device - In Operation

F-C3157

Figure 6. Inspection Device in Operation Showing Contents of Package on Monitor.

2. Description of Circuit and Components

It is very important in the operation of an inspection device to preserve the orientation of the operator with respect to the device or object which he is observing. When a remote viewing device is used, it is very easy to confuse left and right, up and down and even mix these two directions. A number of simple control circuits were discarded because they were open-ended, that is, they did not give a reference to the operator. The present system utilizes a two axis control servo rotation and bend which allows the operator to immediately discern from the control position exactly in which direction the tip is viewing. This required the development of a circuit, which was simple and reliable. The probe motor positions are separately monitored by potentiometers geared to the drive. The voltages produced from these potentiometers are matched by the voltages produced from the "joystick" potentiometers. When these voltages are the same, zero error signal is present at the 741 amplifier and hence no output voltage. The polarized relay moves to its neutral position and the motor drive stops. If the two potentiometers are not in the same relative position, an error voltage either plus or minus is produced which actuates the relay to the proper position to cause the motor to drive the probe to the same position as the "joystick" handle. Suppose the probe is looking straight ahead, but it is desired to look at say, an angle of two o'clock and upwards at 45°. The control handle is placed in just that position, rotated to the two o'clock position and pressed downwards to 45° from neutral. The two drive motors then are actuated and operate until the probe is looking in the set direction. They then stop. The control has a very natural action and good human factor "feel". The photograph of Figure 6 shows the "joystick" handle being operated. The probe tip is positioned at 12 o'clock and about 45° down. Photograph Figure 7 shows a close-up of the control box with the "joystick" control. The complete circuit diagram is given in Figure 8 and shows the circuits for all four motor circuits. Only two servo circuits are required, one each for bend and rotate.

Photograph Figure 9 shows the two motors and gear drive trains for the bend and rotate axes before assembly. Figure 10 shows the complete assembly with all four motors, gear drives and position potentiometers on carraige and attached to TV Camera. An adapter is shown connecting the camera to the fiberscope. The adapter as supplied by the manufacturer produced a very small image (about 1/4 monitor screen area) of the fiber bundle on the monitor screen. It was necessary to calculate a different relay lens to be placed between the fiberscope and vidicon face. This larger focal length lens was obtained and mounted in the adapter. An extention tube was required to produce an in focus image. This is seen attached directly to the camera. The image now fills approximately 1/2 of the monitor screen area. This increase in image size reduced the light intensity at the vidicon face and caused a somewhat weaker monitor image. Several TV cameras were tested to find one which would operate well at the low light levels obtained. The Dage camera as shown was

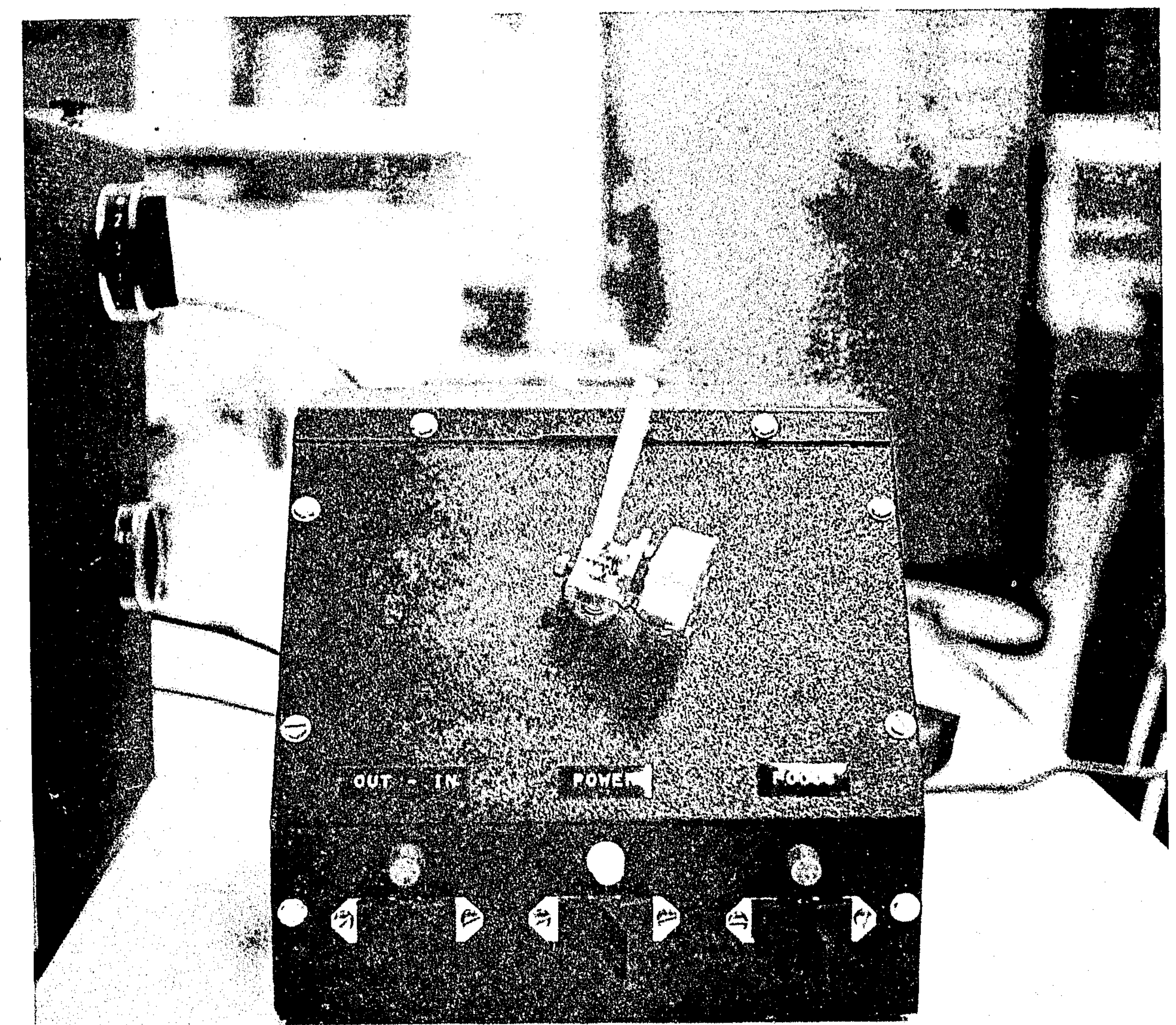


Figure 7. Control Box Showing "Joystick".

F-C3157

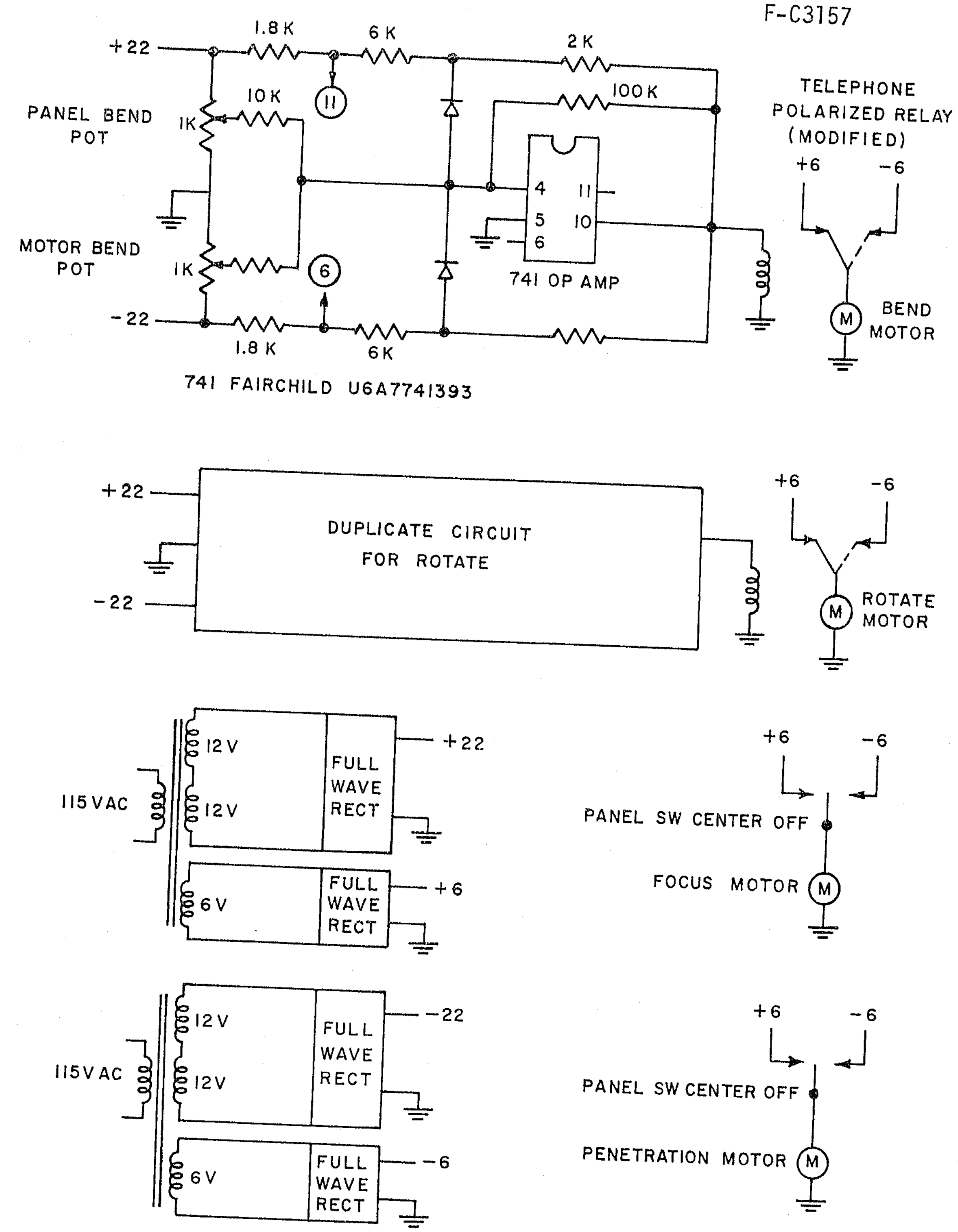
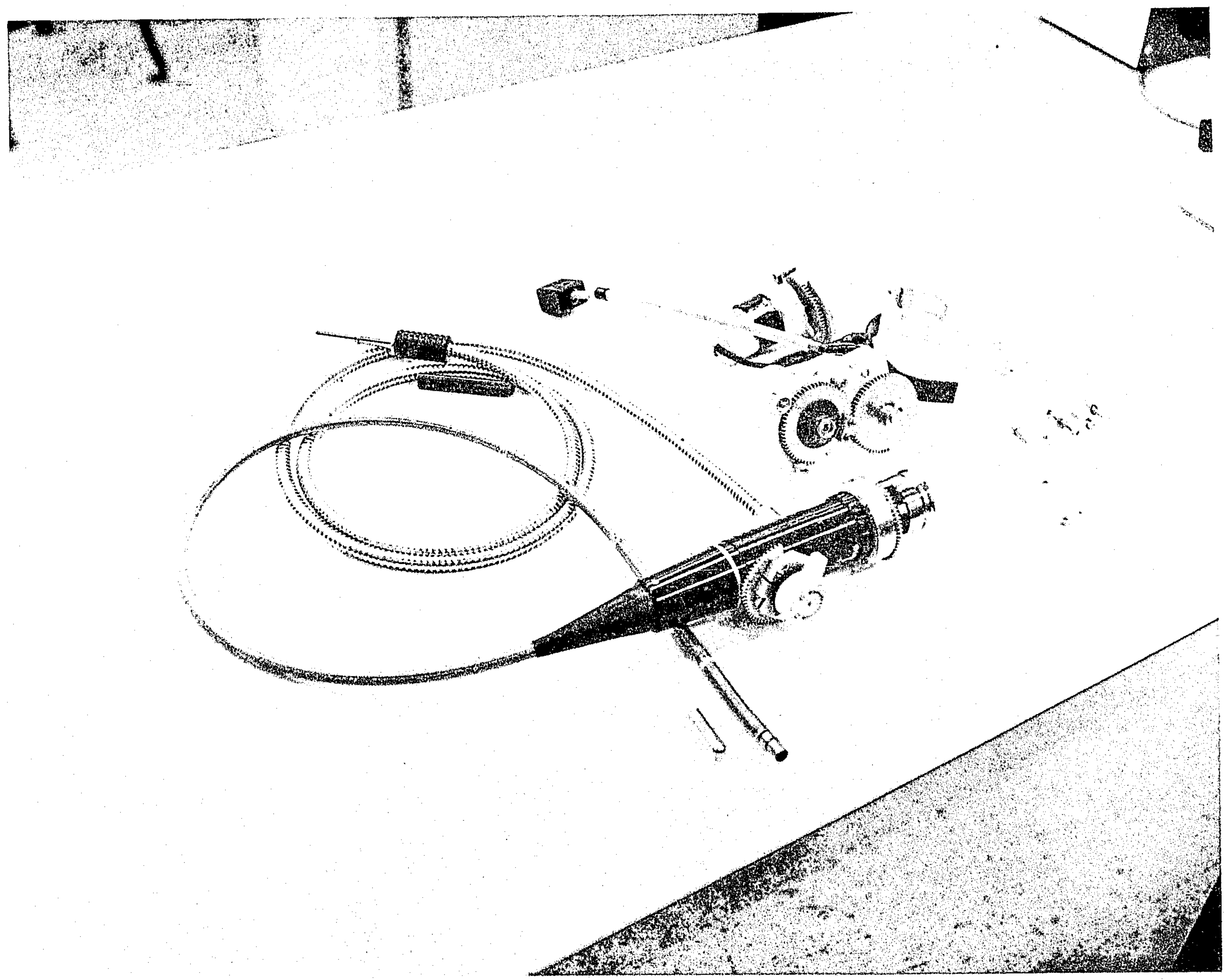
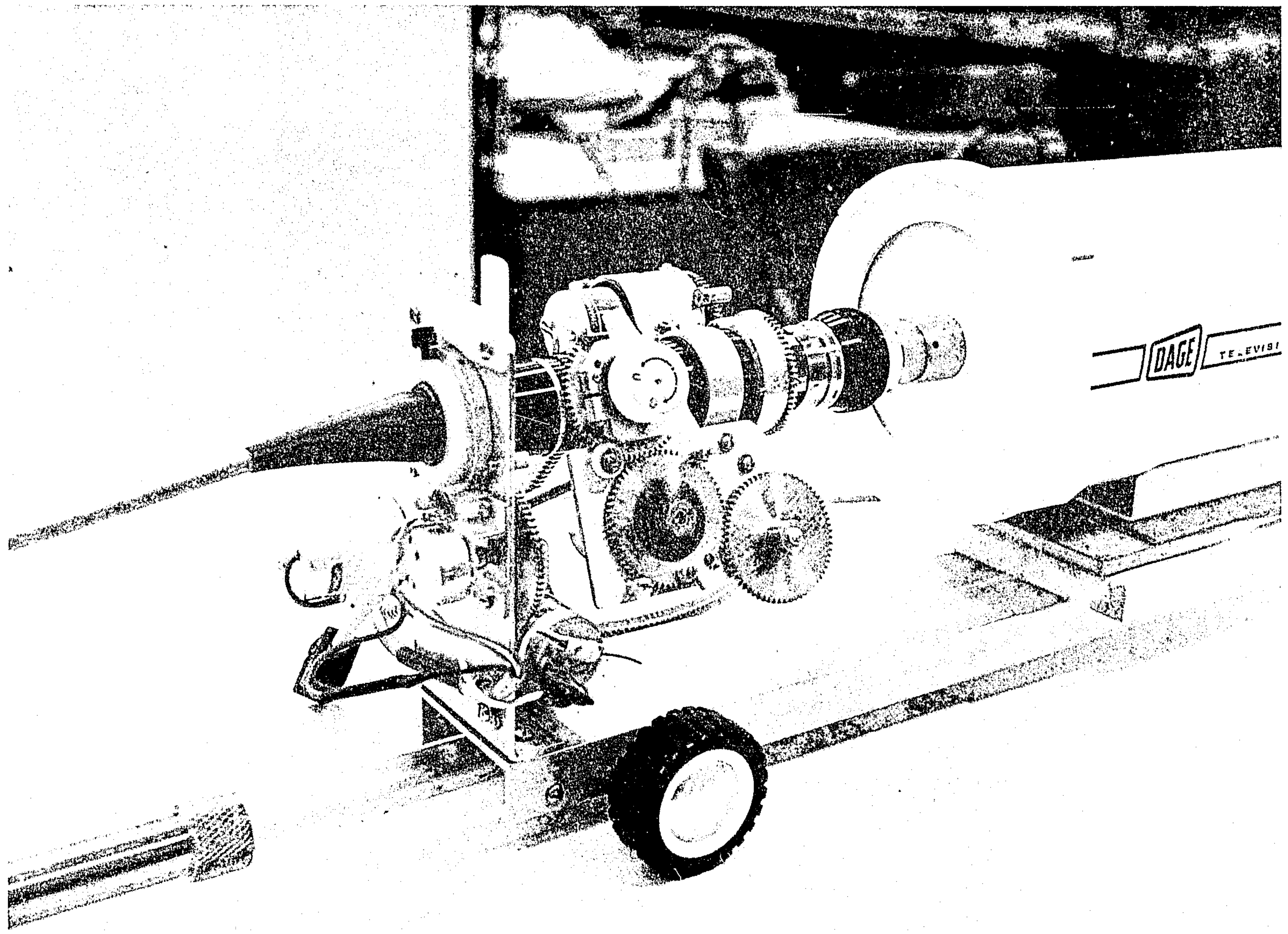


Figure 8. Circuit Diagram Motion Controls and Position Servos.



F-C3157

Figure 9. Rotate and Bend Motors and Gear Drives Before Assembly to Fiberscope.



F-C3157

Figure 10. Complete Drive Mechanism Close Up. Showing Four Drive Motors and Gear Trains.

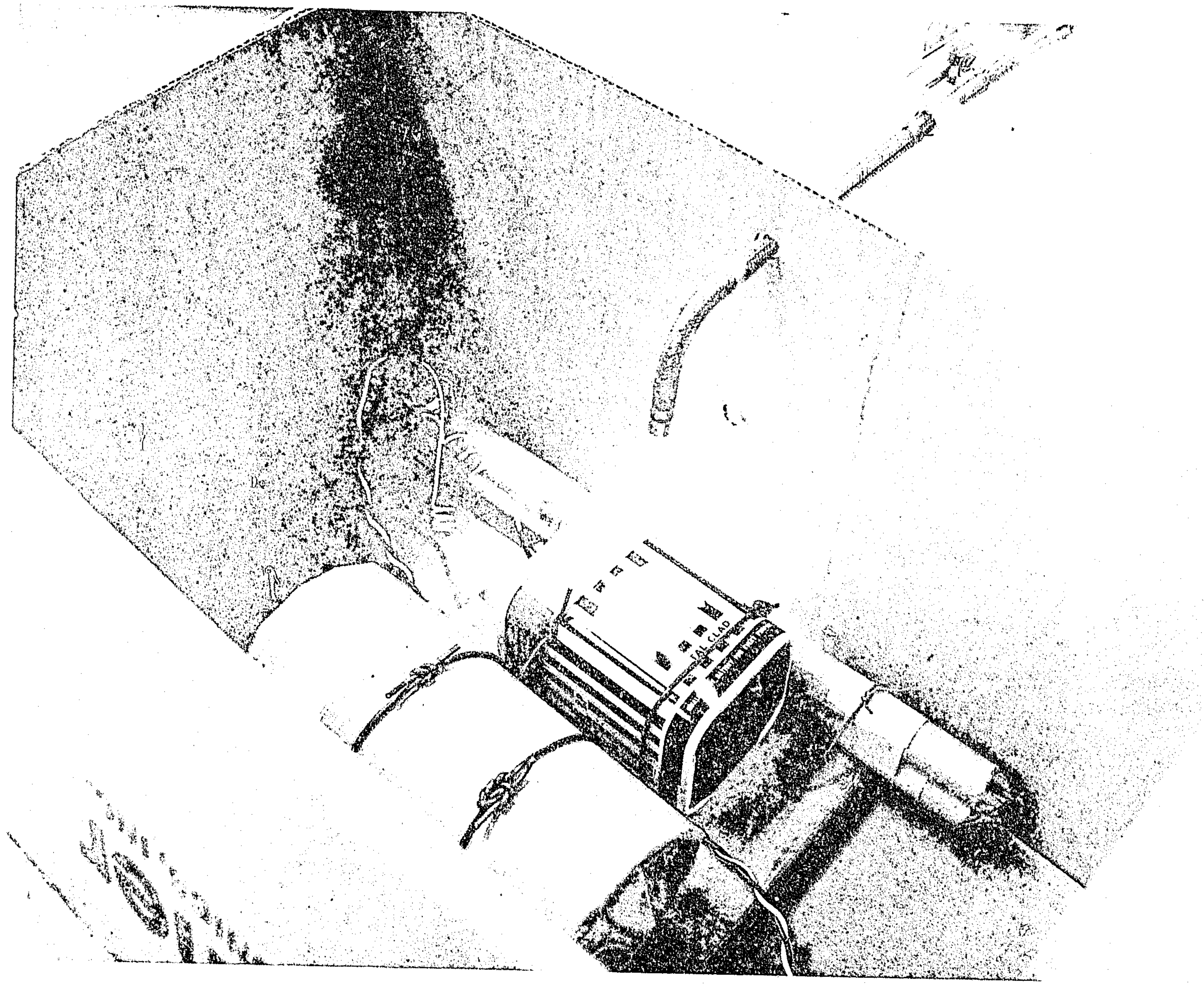
found to give an image superior to other cameras. This camera was purchased and used in the system. At greatly increased cost, very low light level cameras are available. Depending on the application, it may be desirable to use this solution. An alternative solution to the low light level would be to use a more intense light source. At present, the light source is 150 watts and increase to 500 watts is relatively inexpensive in comparison to a special low light level TV camera. However, for our present purpose the light source and Dage camera is more than adequate especially if the probe tip can be placed within about 6" from the object it is viewing.

III. TESTS AND OPERATING PROCEDURES

Several boxes and containers were prepared simulating containers which might be investigated with this device. One of these is shown in photograph Figure 11. The printing and wires were clearly seen on the monitor picture and the probe tip was easily manipulated through a large volume of the box. A number of operators practiced with the controls and found that with a few minutes practice, reasonable control could be accomplished and the probe directed in any direction in which it was possible to be placed with confidence. If the inspection device is used however, to investigate a dangerous container, it is suggested that someone with several hours of experience operate it. Under the simulated conditions in which the testing was carried out, no penalty occurred if a wrong move was made. The procedure which evolved for an examination is as suggested below.

Set up inspection device and test all controls to see that they are operating properly. Make any necessary adjustments to camera and monitor. Position probe within about one inch of opening in container with distal end of probe horizontal and directly in line with opening. The picture on the monitor will show opening clearly and in center of the square format. Make sure carriage, when it moves, will insert probe into opening at a 90° angle to surface of package. Retreat to remote control box and monitor. Operate travel or penetration switch to "IN". Carriage and probe tip will move toward opening which will rapidly appear to grow larger on monitor. If image of hole remains in center of format, the probe will enter the hole squarely.

If not, bring carriage back and reposition as required. When probe is properly positioned, enter hole in package about 1/2 inch. Examine monitor picture. If nothing appears to be in the way, the probe can be cautiously inserted further. When the probe has been inserted about 2-1/2" to 3" into the hole, the bend control can be operated.

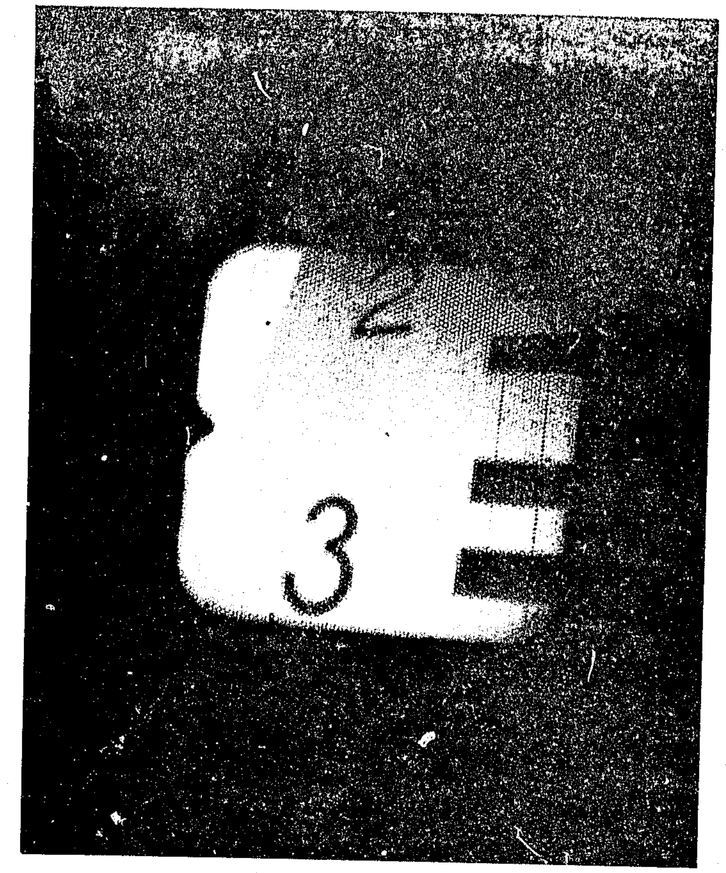


F-C3157

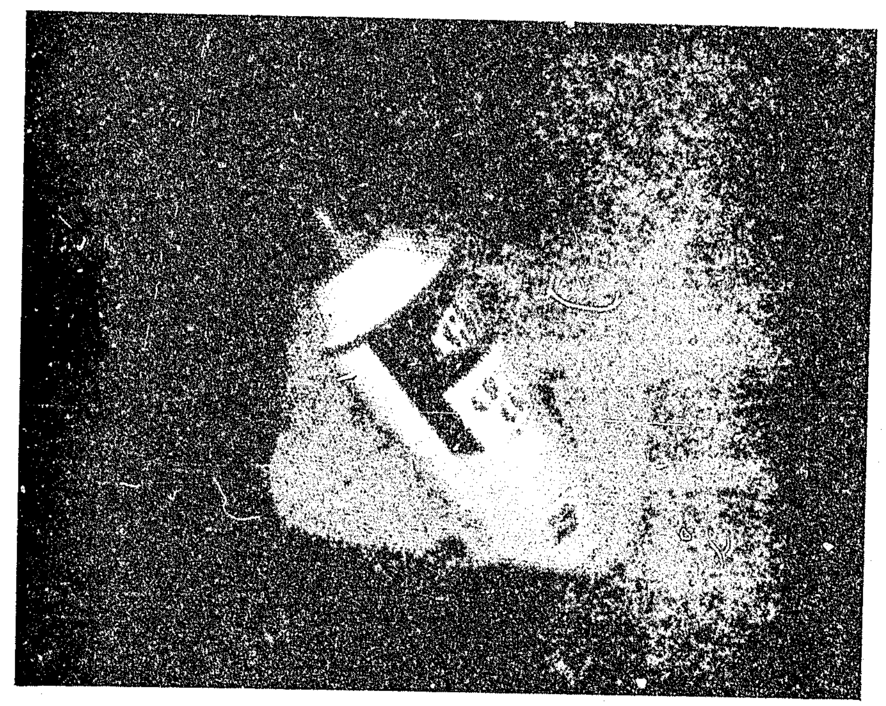
Figure 11. Simulated "Bomb". Showing Fiber Optic Probe Inserted Through Small Hole in Side of the Box. Wire and Printing were Clearly Seen on Monitor.

This should be done, say, downwards if hole is near top of box. Manipulate, bend and rotate, control (Joystick) slowly and in small increments to examine contents. Focus through focusing range to bring into sharp view both near and far contents. Continue in this manner using travel switch to examine all of the interior that can be seen. The whole examination, thus, should be done cautiously and methodically making notes as required. Polaroid camera pictures may be made of the monitor to preserve any items of importance. They will appear similar to those shown in Figure 12a and b and Figure 6. When examination is completed and before attempting to withdraw probe tip, *be sure the bend control is set in the straight position.* This will prevent the probe tip from hooking the box through the opening and prevent it moving the container. It will also prevent the tip from mechanical forces which might break the control wires. The fiber bundle is fragile containing in addition to the glass fibers, a tiny optical system with focus and bend wires and cams. Be especially careful when handling the bundle not to let it whip and hit a hard object.

Having straighted the tip by means of the controls - the entire carriage is backed away ("out") from the container bringing the tip of the probe out. When the hole again can be seen on the monitor, you know that the probe has been removed from the box. This completes the inspection procedure. It is not difficult and can be carried out fairly rapidly.



(a)



(b)

Figure 12. Pictures Through Fiberscope of a) Test Chart, b) Can of Spray Paint.

IV. DEMONSTRATIONS AND VISITS WITH LAW ENFORCEMENT OFFICERS

1. Visits with Law Enforcement Officers

Arrangements were made with Captain Martin of the Philadelphia Police Force Bomb Disposal Unit for a demonstration of the Flexible Optical Inspection Device. Due to a police emergency, this appointment was cancelled but on August 16th Lieutenant John Quinn and Officer William Stewart of the Philadelphia Bomb Disposal Squad visited our laboratories and were given a demonstration of the unit. They were shown how to operate the unit and did so with no difficulty. A very valuable discussion followed. Their comments and suggestions will be reviewed in the section on Evaluation. We also carried out a successful demonstration for another law enforcement agency and again received valuable comments and suggestions.

2. Demonstration for Local News Media

With the approval of Mr. Lester Shubin, *Contract Monitor*, LEAA, the local TV Station, KYW, TV-3 made a short segment for their news program of the operation of the inspection device. They showed the device and had a short interview with Mr. J. A. DeBenedictis as to its purpose and rational behind its development. The result was fairly straight news and was probably good public relations for both LEAA and The Franklin Institute. There has been no comment from the public on the news item.

3. A Visit to the U.S. Naval Explosive Ordnance

The Disposal Facility at Indianhead, Md. was made in the early stages of the project. We had been informed that this agency had experience with the use of fiber optics in their work. This visit did not prove to be very useful because by this time we had accumulated more experience than they had. They agreed that it was difficult to develop specifications for a fiber inspection device since each application was so different. They were helpful in reinforcing our belief that a simple inexpensive device would find many applications for the police and military.

4. A Visit with the New York Police Department (Lieutenant Neal and Sargent Letege)

The visit with the NYPD Bomb Disposal Unit could not be carried out as desired because they were involved with activities of the Republican Convention in Miami. We hope they will be able to examine the inspection device prototype after it has been delivered to LEAA.

5. Trip to Los Angeles Police Department

A very useful visit was made with the Los Angeles Police Dept. (Assistant Chief R. B. Gaunt, Head, Bomb Disposal Unit and other Officers) D. A. Wolfer, Chief, Foreusic Chemistry who heads the crime lab and is responsible for evaluating equipment for all phases of police work was most enthusiastic about the fiberscope. A number of suggestions and comments were made by these officers and they will be incorporated in the discussion section.

V. EVALUATION, DISCUSSION AND RECOMMENDATIONS

1. Evaluation

A. Personnel from the U.S. Naval Explosive Ordnance Disposal Facility at Indianhead, Maryland were helpful in solidifying our design philosophy that it is impossible to specify and define a specific mission for a fiber optic bomb inspection system. Each bomb threat investigation has its unique idiocyncrasies, therefore, the investigator must have at his disposal as many useful alternatives as practical. The system resulting from this grant represents a sophisticated first generation device which affords the user maximum safety, the ability to determine if the bomb is disarmable and the versatility for a crew of experts to acquire real-time on-line knowledge so that a concensus can be generated.

B. The Los Angeles Police Department (LAPD) assembled an elite crew of bomb disposal experts and crime lab personnel to evaluate our system. They too supported our basic philosophy and confirmed that our cognizant of bomb disposal techniques and problems is essential to intelligent systems design. They were impressed with the resolution and manipulability of the probe. In fact, they suggested that we could sacrifice resolution. Constructive criticisms included:

(1) System is too expensive.

(2) Mechanism is not structurally field worthy.

(3) Bundle diameter should be reduced.

(4) Metal sheathing is a potential hazard.

(5) The need for a hole is a problem.

The fiber optic bundle itself represents the most expensive component of the system (perhaps 75%). Unfortunately, this component is exposed to the blast area should the bomb explode during investigation. Mass production and state-of-the-art advances are certain to reduce fiber optic costs, however, the cost will undoubtedly remain high in respect to other system components in the foreseeable future. Savings are attainable by degrading the specifications on resolution, thereby allowing the purchase of a

less expensive camera and monitor (as well as fiber optic bundle). However, this approach was not considered adviseable for the prototype model which is designed to prove the concept and explore alternate uses. The electronic control box can be greatly simplified with high precision relays. Solid state circuits currently drive the control motors but future versions will incorporate simplified control circuits. The relays were not included in the prototype due to their unavailability (delivery is a minimum of eight weeks). Although the cost of the system remains fairly high, it can be minimized and it can certainly be justified by virtue of the fact that it is extremely safe to operate, gives the bomb disposal personnel valueable information and the fiber optic bundle is extremely versatile for police work as will be discussed under "Recommendations".

The mechanism can easily be redesigned to be more field worthy. The potentials are vast and the technology is straight forward. Time and money limitations forced the emphasis to be placed on operational characteristics instead of durability and aesthetics. Future work will include these and many other features.

The bundle diameter can be reduced from .315 inches to .235 inches with presently available probes. The smaller diameter was not used in the prototype because it significantly reduced resolution. However, as the LAPD personnel pointed out; reduced resolution may in fact be acceptable. Smaller diameters than .235 must await future state-of-the-art developments in the miniaturization of fiber optic control bundle mechanisms.

Metal sheathing does present a potential hazard if the bomb is triggered by a double wrapping of tin foil for example. This problem can and will be eliminated in future systems with a thin coating of plastic. This will increase the diameter slightly but is considered reasonable.

The need for a hole is an unavoidable problem. Although this problem was defined as outside the scope of our current study we have accumulated ideas on its solution through our research and conferences. The most promising approaches are:

(1) Shoot a hole in the box using a rifle held by a sand bag barrier and triggered remotely with a line tied to the trigger. (The projectile would be a wooden pellet).

(2) Design a remote carriage (much like the prototype system without the fiber optics) to allow remote control of a mechanism to puncture, cut, drill, blast or whatever a hole in the box. The safest area to cut is a corner of the box since this is the most difficult area from which to detonate.

LAPD went on to caution us that typical bomb disposal units are looking for optimum and universal solutions to bomb disposal work. They cite that attitude as unrealistic but none-the-less a serious problem faced by the researcher. An intelligent educational approach is essential to insure that a sophisiticated system such as this is used effectively.

Another extremely valid and useful concept generated by LAPD is that the probe itself would be perhaps even more useful in other forms of police activity. For instance, homicide investigators often have difficulty in locating a bullet which has penetrated as wall and fallen between panels or locating weapons which have been dropped down drains or sewers. Narcotics investigators would find the probe useful for searching automobile trunks, glove compartments, dashboards and undercarriages as well as contraband hidden in drains or water traps to preclude detection by dogs.

C. Personnel from a federal agency visited FIRL to inquire about our system. They were very interested with the fiber optic bundle itself and requested further information. They referred us to the 69th Explosive Ordnance Disposal Facility at Valley Forge Pennsylvania for an overall system evaluation.

D. The Philadelphia Police Department (PPD) visited our facility after we added the low light level television camera to our system. Suggestions they generated which were not redundant included:

(1) Depth of penetration of the probe should be shorter.

(2) Add an interlock switch so that the dolly does not "bump into" the box.

(3) Slower speeds are desireable.

Depth of penetration refers to the fact that the probe must pass approximately 1 1/2 inches into the box before it can effectively be manipulated. PPD personnel contend that 90% of the explosive devices range in size from an attache case down to a cigar box. We do not feel this

criticism compromises the usefulness of the system because if one were to enter the narrow portion of the box, a view from the periphery of the hole would suffice. Should one enter from the long axis, the probe would function normally.

The addition of an interlock switch is an excellent suggestion and can be accomplished at a small cost.

Slower speeds may or may not be desireable. Since each situation is unique, a variable speed control is in order. This in fact was considered and will be a part of future systems. Again, the added cost is small.

Other pertinent comments included:

(1) Joystich control is a great idea.

(2) This is smallest remote system.

(3) Develop a "remote listener".

(4) Develop a "remote handler".

(5) Develop method to disintegrate nichrome wire.

The "joystich" was designed to eliminate operator vertigo experienced by personnel using fiber optic probes in the aerospace and medical fields. It is difficult to maintain orientation without this innovation. PPD's other comments will be discussed under recommendations.

E. The opinions and suggestions of the New York Police Department and the Washington D.C. Police Department were solicited, however, we were unable to make arrangements for a conference before the termination of this contract. Hopefully, future studies and developments will include their departments.

2. Discussion and Recommendations

A. FIRL, based upon our past experience, current research in fiber optics and crime counter measures and conferences with numerous law enforcement agencies enthusiastically supports the basic concept of safe bomb inspection proven by this system and strongly desires to optimize the system parameters as well as pursue parallel and equally useful schemes generated by this study.

Currently, the system makes use of the finest manipulable fiber optic bundle available. It contains a high quality television camera and monitor (super low-light level cameras are available at a greatly increased cost). The remote control electro-mechanical system is a workable prototype with great potentials for optimization. Potential additions to the system which are NOT recommended until field use proves them essential include:

(1) Color television (to read resistor color codes etc.)

(2) Video tape recorder (training and permanent record)

(3) Extremely low-light-level T.V. camera

(4) Smaller diameter fiber optic probe

(5) Blast shielding expensive items (most expensive item is the bundle itself).

Potential additions which are recommended at this time include:

(1) Microswitch to cut drive power when the assembly is about to contact the box

(2) Relay drives in place of multi-component solid state circuits

(3) Steerable carriage

(4) Remotely adjustable probe tip delivery system

(5) Variable motor speed controls

(6) Ruggedized mechanical design

(7) Protective housing

(8) Efficient storage and carrying assembly.

All of the recommended additions are straight forward and require minimal development. They are essentially electromechanical design in nature and could be accomplished in a short time span.

B. Other recommendations which presented themselves as a result of this study and which warrant further research and development efforts include:

(1) A concerted effort to disseminate information in an understandable and useable manner to all law enforcement agencies (this may include periodic local seminars as well as newsletters). This should include all government agencies to generate constructive feedback and hence more effective uses of the system.

(2) A lightweight remote controllable cart (much like the concept of our current device with recommended additions) to be used to approach the bomb, listen to it with sensitive stereophonic microphones and to agitate, rotate, lift and possibly move it to a bomb container. This system would not use the fiber optics (therefore, it would be inexpensive) but would have the closed circuit television guidance for safety. Since most bombs are attache case size or smaller, this device would be a sound alternative to the fiber optic system when it is not convenient to put a hole into the box. Current bomb handling schemes are awkward and cumbersome sleds which would remain useful only for large containers. This device could also be equipped with remotely controllable wire cutters and hole punchers of one sort or another. The concept could eventually be expanded into a complete evaluation scheme which is 100% remote control. For instance, when an investigative team comes upon the scene they could select a safe remote location, set up their monitor and then:

(a) Dispatch a small, steerable carriage using closed circuit television (CCTV) for guidance to approach the bomb and listen to its contends as well as survey the surroundings.

(b) Recall the listener, equip it with x-ray equipment, return to the scene and take x-rays.

(c) Recall carriage, examine x-rays and determine to:

(1) return carriage equipped with hole maker (wooden pellet, drill, sandblaster, etc.)

(2) return carriage with package handling devices.

(d) Should C1 be the course of action, then the fiber optics can be employed. Should C2 be utilized, the bomb can be placed in a bomb container for transportation or agitated to determine if it is safe to remove.

(3) Other uses of this equipment should be developed. In addition to other police department uses as mentioned (homicide, narcotics etc.) one can envision package inspections at airports, truck terminals and post office facilities. As possible uses are explored many more will undoubtedly present themselves.

APPENDIX

COMPONENT SPECIFICATIONS:

Olympus Industrial Fiberscope Model IF
Model JF8D1-10 Nominal dia. .315 inches
Nominal length 33 inches

Remote focus
Angle of field 52°
Depth of field 10 mm to ∞
Illumination - light transmission thru light guide bundle
Eye piece magnification 12.5 x
Objective focal distance 2.6 mm
F number f/2.8
Image fiber dia. and length 17μ (micron) x 1 meter
Light fiber dia. and length 30μ x 2.5 meter
Distal End outer diameter 8 mm
Bending section 120° up and 120° down
Length Bending section 60mm

Purchase price $3280.00

Olympus Cold Light Supply Model ILK 150W
Halogen light (110V,60 cycle)

Purchase price $195.00

TV Camera - Dage RGS-50 Camera
6 9/16" dia. x 13" long, wt 9 lbs
lens mount type C, UHF coax connector
Temp limits -40°F to +122°F
Humidity to 95%
Pressure to 10,000 ft

Input voltage 110V, 60 cycle 17 watts
Sweep rate 15750 $H_z \pm 50$ over temp. range -4° to 122°F
Scan-random interlace - temp. compensated
Sensitivity - usable pictures down to 0.4 foot lamberts
Resolution: 600 lines center, 375 min. at corners
Automatic light range 5 to 20,000 ft. lamberts will produce less than 2:1 change in output video.

RF output - compatible with channel 2 thru 6 tunable
RF or video, freq. stability ± 0.25 MHz
75Ω source-load, 10,000μV output level

Purchase price 325.00
without lens

F-C3157

TV Monitor 9" SANYO, compatible with Dage camera - Std. monitor

Purchase price $150.00

Drive motors Hausen Mfg. Co. (Four)
Magnatore 6 V.D.C. model 41-14
Gear head reduction to 4.58 rpm
Flange mount -

INDUSTRIAL SURVEY

A list of the leading manufacturers of fiber optics was compiled and inquiries made via letter and telephone. Those companies contacted were:

1. American Cystoscope Makers, Inc.
   Pelham Manor
   New York, New York 10803
   Tel: 914-738-4800

2. American Optical Corporation
   Fiber Optics Division
   Sturbridge, Massachusetts
   Tel: 617-764-3211

3. Applied Fiber Optics & Scientific Specialities, Inc.
   45 River Street
   Southbridge, Massachusetts 01550
   Tel: 617-765-9121

4. Astro-Optics
   4718 Pennypack Avenue
   Philadelphia, Pennsylvania
   Tel: 215-DE8-5713

5. Barr & Stroud Limited
   Caxton Street
   Glasgow W3 Scotland
   Tel: 041-954-9601

6. Bausch & Lomb Incorporated
   Bausch Street
   Rochester, New York 14602
   Tel: 716-232-6000

7. Bendix Mosaic Fabrications Division
   Galileo Park
   Sturbridge, Massachusetts 01518
   Tel: 617-347-9191

8. Dyonics
   71 Pine Street
   Woburn, Massachusetts 01801
   Tel: 617-935-5900

9. Ealing Corporation
Optics Division
2225 Massachusetts Avenue
Cambridge, Massachusetts 02140
Tel: 617-491-5870

10. Electro Fiberoptics Corporation
45 Water Street
Worcester, Massachusetts 01604
Tel: 617-791-7391

11. Flexi-Optics Lab
117 Dover Street
Somerville, Massachusetts 02140
Tel: 617-776-0520

12. Image Optics*
571 Worcester Road
Natick, Massachusetts 01760
Tel: 617-653-0119

13. Iota Gem Fiberoptics Corporation**
28 Teal Road
Wakefield, Massachusetts

14. Machida Medical Institute Co., Ltd.
(Represented by American Optical Corp.)
Tokyo, Japan

15. Olympus Corporation of America
Two Nevada Drive
New Hyde Park, New York 11040
Tel: 516-488-3880

16. Optics Technology
901 California Avenue
Palo Alto, California 94304
Tel: 415-327-6600

The literature received from those companies which responded was studied and follow-up contacts were made.

---

* Moved, left no forwarding address
**Did not respond to inquiry

MEDICAL REFERENCES
1961 - 1971

BELBER, J. P., Duodenal Bulb Visualization, etc., Gastroint Endosc, 17:34-5, August 1970

BROYLES, E. N., Fiber Optics Gastroscope, Trans. Am. Brondio, Esophagological Association, Dalls, Texas, May 1-2, 1962

BURKE, E. L., Examination of the Esophago-Gastric Function Area, etc., Gastroint Endosc, 16:30 Passim, February 1970

BURNETT, W., An Evaluation of Gastroduodenal Fiberscopes, V. Britain Soc. Gastroenterology, 3, 361, 1962

CLOUSE, J. C., Gastric Leiomyomas: Clerical X-Ray and Gastroscopic Features and Report of Two Cases, AM Osteopath Association 70:364-8, December 1970 Issue Not Rec.

CURTIS, L. E., Hirschowitz Bl & Peters CW, A Long Fiberscope for Internal Medical Examinations, J. Opt. Soc. Am., 47, 117, 1957

DEAN, A. C., Clinical Evaluation of a New Fiberoptic Colonoscope, Lancet 1:550-2 March 14, 1970

DEAN, A. C., Fiberoptic Colonscope, Lancet 1:1108, May 23, 1970

HETT, J. H. & CURTIS, L. E., Fiberoptics Duodenoscope & Ureterscope, J. Opt. Soc. Am., 51, 581, 1961

HIRSCHOWITZ, B., A Fiberopitc Flexible Esophogoscope, Lancet 2, 388, 1963

KASUGAI, T., Gastric Biopsy under direct vision by the Fiber Gastroscope, Gastroint Endosc, 15:33-9, August 1968

KASUGAI, T., Recent Instrumental Development of Fiber Gastroscopes with a Light Guide System, Gastroint Endosc 15:224-7, Passim, May 1969

KATZ, D., Fiber Gastroscopy: Fact and Fiction, Amer. J. Dig. Dis 12:1185-8, November 1967

LOPRESTI, P. A., A New Fiberoptic Esophagagostroscope, Am J. Dig. Dis 16:31-7, January 1971

LOPRESTI, P. A., Successful Examination of the Esophogus and Stomach with a New Fiberoptic Instrument, Gastrointest Endosc 17:103-4, February 1971

OI, I., Fiberduodenoscopy and Endoscopic Pancreatocholangrography, Gastrointest Endosc, 17:59-62, November 1970

OTAKI, A. T., Experience with the Fiberscope Gastrocamera, Amer J. Gastroent, 51:187-99, March 1969

OVERHOLT, B. F., Clinical Experience with the Fiber Sigmoidoscope, Gastroint Endosc, 15:27, August 1968

QUINT, R. H., Endoscopic Instrumentation, Clin. Obstet, Gynec., 12:463-83, January, 1969

SHEARMAN, D. J., Clinical Evaluation of the Olympus Duodenscope, Lancet 1:726-9, April 10, 1971

SINGER, H. C., Retroversion as a Routine Gastroscope Maneuver, Gastrointest Endosc 17:112-4, Passim, February 1971

STEMPIEN, S. J., Fiberscopic Gastroscopy in Benign Pyloro-Duodenal Stenosis, Gastroint Endosc, 14:194-6, May 1968

STRUB, I. H., Gastroscopy - A Re-Evaluation, Am J. Gastroenterology, 40, 75, 1963

TAKAGI, T., Small Caliber Fiberscope for Visualization of the Urinary Tract, Biliary Tract and Spinal Canal, Surgery 64:1033-8, December 1968

UMEDA, N., Gastricbiopsy under direct vision, etc., Gastroint Endosc 16:135-8, February 1970

NON-MEDICAL REFERENCES

Applications of Fiberoptics #22696, FIRL Library

Diffractional Field Distortion and Crosstalk in Guided Optical Multibean Transmission, Public Information Document #7503, May 1971

The Expanding World of Fiberoptics, Jack Kloots, Optical Spectra, June 1971 p. 29-34

Fiberoptic and the Analytical Chemist, ANAL Chem 41: Sec. p. 26A-30A, February 1969

Fiberoptic Bundles as Transmission Lives for Laser Beams, Electronics 41:133-4 December 23, 1968

Fiberoptics in USSR, Public Information Document #6288, 1968

Fiberoptics for Vehicles Automobile Engineering 59:116-9, May 1969

Fiberoptic Point Sources - Boyd, A.P. Optics 8:73-4, January 1969

Fiberoptic Polychromator - Combes & Gallagher, A.P. Optics 7:857-9, May 1968

Fiberoptics: Principles and Applications - Kapany, N.S., New York Academic Press 1967

Fiberoptic Probes Should Help in Cancer Detection, Product Engineering 39:32-3, July 1968

Fiberoptic Seminar #22702, FIRL Library

Flexible Linkage System - Gibson, R., J., FIRL Public Health Reports, Vol. 81, No. 9, September 1966

High Speed Facsimile has Fiberoptic Cathode Tube, Product Engineering 38:73, October 23, 1967

Human Factors in Teleoperator Design and Application - Johnsen & Corliss, Wiley Interscience, J. Wiley, New York, New York

Industrial Manipulators - Mosher, Scientific American, Vol. 211, October 64, p. 88-96

Machines for Visual Data Processing in Clinical Medicine, Public Information Document #9974, June, 1971

More Light on Light, Engineering 205:177-9, February 2, 1968

Optical Instruments, Public Information Document #10884, July 1971

Plastic Fiberoptics - Brown & Derick, A.P. Optics, July 1976, August 1968, February 1969

Plastic Fiberoptics - Meade, SAE J. 75:67-72, December 1967

Summary of Development of Optical Waveguides & Components, Public Information Document #15508, 1967

Two-Dimensional Manual Control System, NASA SP-128, 1966, p. 159-180

Use of Fiberoptics - Allen, Aircraft Engineering 41:33-6, Mary 1969

Wavelength Multiplexing in Fiberoptics - Koester, Opt. Soc. Am. J. 58-63-70 January 1968

Fiberoptics, Gibson, R. J. and Hinkle, J. G., Franklin Institute Report sponsored by the Department of HEW, NIH and the Pew Foundation, 1961.

Bombs and Bombing - Brodie, T. G., C. C. Thomas

Bombs and Incendiaries - Pike, E. A., C. C. Thomas

Explosives and Bomb Disposal Guide - Leny R., C. C. Thomas 1971

Explosives and Homemade Bombs - Staffel, Major J., C. C. Thomas 1972

Report Bibliography (#080904) Defense Documentation Center, Defense Supply Agency Cameron Station, Alexandria, Va. 22314

TM 91385216 Army Publication, Washington, D. C.

END