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ORNL/TM-5714

Laboratory Services Series
A Master-Slave Manipulator Maintenance Program

R. G. Jenness
R. E. Hicks
C. D. Wicker

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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PLANT AND EQUIPMENT DIVISION

LABORATORY SERVICES SERIES

A MASTER-SLAVE MANIPULATOR MAINTENANCE PROGRAM

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Date Published: December 1976

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CONTENTS

LABORATORY SERVICES SERIES
A MASTER-SLAVE MANIPULATOR MAINTENANCE PROGRAM

R. G. Jenness, R. E. Hicks, and C. D. Wicker

ABSTRACT

The volume of master slave manipulator maintenance at Oak Ridge National Laboratory has necessitated the establishment of a repair facility and organization of a specially trained group of craftsmen. Emphasis on cell containment requires the use of manipulator boots and development of precise procedures for accomplishing the maintenance of 287 installed units. A very satisfactory computer programmed maintenance system has been established at the Laboratory to provide an economical approach to preventive maintenance.

MANIPULATOR HISTORY

Nearly 30 years ago, when it became apparent that many radioactive materials being used at Oak Ridge National Laboratory could be safely handled only by using remote handling equipment, a pair of Model 4 manipulators were purchased. With the growth of isotope research, the increase of chemical processing, the need for chemical analysis, and research with transuranium elements, manipulator requirements have grown from those two relatively primitive units to over 280 units of 11 different models. (See Appendix A)

Some of the newer units weigh over 450 kg. and are capable of performing intricate operations remotely inside a shielded cell. The variety of required functions range from the delicate operation of assembling fuel pellets so small they must be handled with tweezers to operating equipment weighing as much as 1000 kg. This work variety includes making precision measurements, machining of parts, sawing, pressing, welding, analytical sampling, and chemical processing, or almost every operation required in a modern laboratory.

Some manipulators are three-piece units (Model A, Appendix A) that operate through a sealed transfer box mounted in the cell wall to maintain a gastight seal for the inert atmosphere within the cell. These units have some other excellent features, one being that the master end units are interchangeable with other master end units. The slave units can be lifted with a crane inside the cell and interchanged. While this capability is helpful in some cases it has resulted in the slave units becoming so contaminated they must be repaired in the operating building through glove ports in a glove maintenance area. This requirement greatly increases the maintenance problems, time, and costs.

Other models have stainless steel tapes running from the slave hand over a series of pulleys through the cell wall and down to the master hand. The slave end of this type unit can be canted straight out so it can be pulled out of the cell wall into a plastic sleeve for repair or replacement. These units are sometimes rebooted or repaired in the building (In a double-contained area with filtered exhaust) by millwrights wearing up to 4 pairs of surgical rubber gloves, 4 pairs of shoe covers inside of a full plastic suit with air supplied through an attached hose. In those cases the contamination on the manipulators is primarily the alpha type. If it is necessary or desirable to bring the unit to the shop for decontamination and repair, a procedure (Page 6) is established for this operation.

The manipulator repair group has grown along with this program until it now consists of 11 specially trained millwrights, 1 electrician, and 1 supervisor. This volume of manipulator work has also made necessary the design and building of special facilities and tools for decontamination and repairs.

MAINTENANCE HISTORY

The original approach to manipulator maintenance was on an "as-needed" basis. Units remained in operation until a failure occurred and the manipulator was inoperable. As the number and different models of manipulators increased, it became necessary to obtain maintenance history information on each unit, and a Manipulator Work Sheet (See Appendix B) was put into use. These work sheets provided data that were used to develop an organized maintenance approach. Spare parts inventory was determined; weak points of certain units were identified; unit maintenance costs became available; the advisability of interchanging right-hand and left-hand units became apparent; and the basic idea of preventive maintenance became a reality. Experience began to show that if minor adjustments are made from time to time some of the more serious difficulties are alleviated.

A computer-programmed maintenance system was introduced to achieve more effective manipulator performance. (See Appendix C) This program includes a monthly check on each installed unit. Tape and cable tension are measured and adjusted; all motions are checked for possible malfunctions; and linkages are inspected for wear or out-of-tolerance conditions.

OPERATION PROBLEMS

Most manipulator maintenance problems are the result of over-loading, chemical action resulting from decontamination and general wear conditions from long term usage.

In general, to minimize manipulator maintenance, select the proper model to meet job requirements and then design the cell and in-cell equipment so that the weight handling capacity is never exceeded. A standard Model 8 manipulator is the most reliable unit unless special conditions require the extended reach of a Model E or the greater weight handling capacity of a Model D or F. Other models may be necessitated by cell design or requirements of in-cell environmental control.

It should be noted that manipulator abuse by inexperienced or careless operators can result in high maintenance costs. An operator training program is a worthwhile investment compared to manipulator maintenance costs.

Due to an inherent design, when a force is pulling down on the slave end (extending Z motion) such as picking up a weight the load is divided over the 4 wrist tapes. Conversely, when a force is pushing up the slave end (compressing Z motion) the load is carried by the 2 counterweight tapes and the unit is capable of only 1/2 the rated lifting capacity. When the slave hand is used for a twisting motion the force is carried by only 2 wrist tapes and the other two wrist tapes have a tendency to slacken. If a unit is required to twist a valve handle located on a side wall the tape pulley bank is then functioning in a vertical position and the slack tapes can slip to the next lower pulley. After this has occurred any subsequent operation of the manipulator will cause these tapes to break and the unit must be removed from the cell for repairs.

Effects of decontamination can be minimized by the use of boots to protect the units from in-cell environment. These are effective only if the boots are replaced immediately after they become torn or damaged. At ORNL a two piece boot has been designed making it possible to change the lower section (the part where over 90% of failures occur) without removing the manipulator from the cell. In cells where this boot can be used costs of boots and replacement can be reduced by over 75%. An added advantage for this type of boot is the much shorter time the cell is out of service. This replacement removes the cell from service about 15 minutes. Changing a conventional one piece boot requires about 3 hours unless the manipulator is contaminated to the point where it must be transported to the shop for decontamination; this would require one to two days. It is possible with proper precautions in over 50% of the boot changes to clean the slave hand and replace the boot in the cell without transporting the unit to a decontamination facility.

Model 8 manipulators contain over 200 small ball bearings (Models E and F contain an even greater number) that are attacked by cleaning solutions. The cleaning agents dissolve bearing lubricants which must be replaced or the unit will be out of service immediately due to bearing failure. A super penetrating lubricant that will penetrate sealed bearings is available in spray containers, and is in use at ORNL to alleviate bearing problems.

At the Laboratory maintenance costs due to wear from long term usage are reduced by a very complete inspection when a unit is removed from a cell. All doubtful tapes, cables, worn sheaves, and rough running bearings are replaced.

The manufacturer of manipulators furnishes a repair manual for each model showing wiring diagrams, tape schematics, exploded views, parts lists, and complete procedures for dismantling and reassembly. In addition, the manufacturer has provided schooling to train maintenance personnel in this type of work.

PROCEDURE FOR DECONTAMINATING MANIPULATORS

The manipulator is pulled from the cell on a specially designed stainless steel pulling rig. (See Appendix D) The slave end is pulled into a plastic sleeve, keeping it sealed at all times to contain any loose contamination. When the unit has been removed from the cell a second plastic sleeve is pulled over the slave end and sealed with tape. After the pulling rig and all the outside plastic is checked by a Health Physicist, it is rolled into a stainless steel lined van for protection while it is transported to the repair facility. (See Appendix E)

At the shop, the slave end is canted out straight and the outside plastic sleeve is attached to the entry port of a stainless steel decontamination glove box. (See Appendix F) The slave end is then pushed all the way into the box and washed down with a cleaning solution pumped into the glove box with a pressure washer at 3.5 MPa. This pump unit also has a control for mixing the solution to the desired strength.

The cleaning solution is then rinsed off with another high-pressure pump with hot water (60°C) at 6.9 MPa. This technique occasionally leaves a black oxide coating on some aluminum parts of the manipulators which is removed with diluted nitric acid and immediately rinsed with the high-pressure hot water. This rinse must be very complete and last long enough (about 15 minutes) to heat the unit to where it will dry from its own heat.

When the unit is dry (approximately 30 minutes) it is pulled from the glove box back into the plastic sleeve that was on the outside and was attached to the entry port of the box. This procedure is monitored by a Health Physicist. The unit is then checked through the plastic for any significant penetrating radiation. If none is found, the plastic is split at several places (one at a time) so the Health Physicist can get a smear to check for alpha contamination. While this check is made, the sleeve remains attached to the glove box so the air flow is from the outside through the hole that is cut in the plastic and into the box. The plastic is removed and the entire unit is checked and smeared according to established procedures. (See Appendix G) A report of smear contamination test results is written and the unit is tagged.

The unit is sprayed with a high-penetrating lubricant which displaces moisture from the sealed bearings. Now the unit is ready for dismantling and repair. After repair the slave end is covered with a plastic sleeve and rolled to the door where the rig and unit are checked again by a Health Physicist. After this operation, the manipulator is placed in standby as a spare.

Prior to placing a manipulator back into cell service and after all other repairs are made, it is given a final electrical grounding check as per ORNL Safety Procedure 2.2 (See Appendix H).

FACILITIES

The manipulator repair facility has approximately 560 square meters of floor space which is divided into four areas of operation (See Appendix I). Two of these areas are used for contaminated repairs, and the other two are used for clean repairs and boot fabrication. The contamination area containing two decontamination glove boxes is equipped with a controlled air balance system that maintains the boxes at a negative pressure with respect to the room. The boot development and fabrication area contains three spray hoods, two heat sealing machines, and the necessary layout tables.

DEVELOPMENT ACTIVITIES

The manipulator crew has pioneered safe procedures for removal, transporting, decontaminating, and repair of manipulators (some units reading over 1000 R/Hr.). The members have also influenced the design of new model manipulators and have designed and installed several improvements on in-service units.

This group reworked three Model "G" manipulators to greatly increase the working strength for a special research project in one ORNL facility. The original stainless steel tapes were removed and alterations were made to allow the three units to operate using stainless steel cable. These modifications incorporated the compactness of a "G" unit with the strength of a heavy-duty unit and thus provided assistance in completing an urgent research project.

Information obtained from the work sheets and programmed maintenance led to the development work that resulted in the following items:

A. Load Cells for Azimuth Cables

Load cells, consisting of extension springs and terminals, are installed around the left and right azimuth cable on the master side of the manipulator to maintain tension of the cables on pulleys under loaded conditions. This assures the azimuth cables remain engaged in the pulley grooves. (See Appendix J)

B. Power Grip

The power grip is mounted atop the master boom tube, with a grip force up to 156 N. After installation, the operator has the option of using either the power grip or the manual grip, without interference from the other.

A power grip package consists of the following parts:

1. 45 mm x 152 mm air cylinder
2. 6 mm, 2-way, normally closed solenoid valve
3. On-and-off toggle switch
4. Bracket for cylinder
5. 4.76 mm x 5.0 mm x 203.2 mm long manipulator

tape attached to cylinder ram and tong tape, using 2 tape clamps. (See Appendix K)

C. Boots

Manipulator covers (boots) were developed for several reasons, primarily to protect the manipulators from contamination and corrosive atmospheres, enabling maintenance to be performed more economically. The boot also functions as a containment barrier, acting as a seal which separates the cell area from the operating area.

Procedures for boot fabrication are found in ORNL-TM-1326 "Urethane Manipulator Gauntlets."

D. Boot Support Ring for Models 8 and E

The boot support ring mounts at the wrist housing inside the gauntlet and gives the boot support. By preventing the boot from sagging and drooping around the wrist and tong area more freedom of operation of the manipulator and increased boot life are realized. (See Appendix L)

EQUIPMENT

1. Manipulator Truck

This is an enclosed (inside measurements - 4.127 m long x 2.31 m wide x 2.62 m high) van-type truck of 15,000 GVW Class with a stainless-steel liner to facilitate decontamination. It is also equipped with a hydraulic-powered tailgate for loading and unloading. This lift is capable of handling up to 1580 kilograms.

2. Decontamination Glove Boxes

   Stainless steel glove boxes long enough (4.11 m) to contain the slave end of a manipulator in the extended position.

3. High-Pressure Pumps

   A. A pressure washer is used for pumping a cleaning solution into the glove boxes at 3.5 MPa.

   B. High-Pressure pump is used to pump hot water (60°C) at 6.9 MPa to rinse off cleaning solution.

4. Pulling Rigs

   Stainless-steel dollys of a modified "A" frame design on wheels with a hydraulic cylinder to raise and lower the manipulator. These rigs are used to install and remove the unit from the cell and also to transport and hold the manipulator for decontamination and repair.

5. Clamps and fixtures to hold Model "G" manipulator in position for retaping and repair.

CONCLUSION

The procedures, facilities and equipment described in this paper have made it possible to organize a maintenance function that is very responsive to research commitments requiring remote maintenance.

Methods developed here at ORNL for the removal of contaminated manipulators from the cell and transporting them to the shop for decontamination and repair are safe, efficient and complete.

The ability to accomplish the required maintenance using these facilities and equipment has been developed to a very acceptable level from an economic point of view.

The decontamination facilities are well designed and do an excellent job of removing radioactive material, however, there is a continuing search for a cleaning agent capable of removing these contaminated materials without causing a reaction with the manipulator bearings and aluminum parts.

APPENDIX A

MODELS AND CAPABILITIES OF MANIPULATORS

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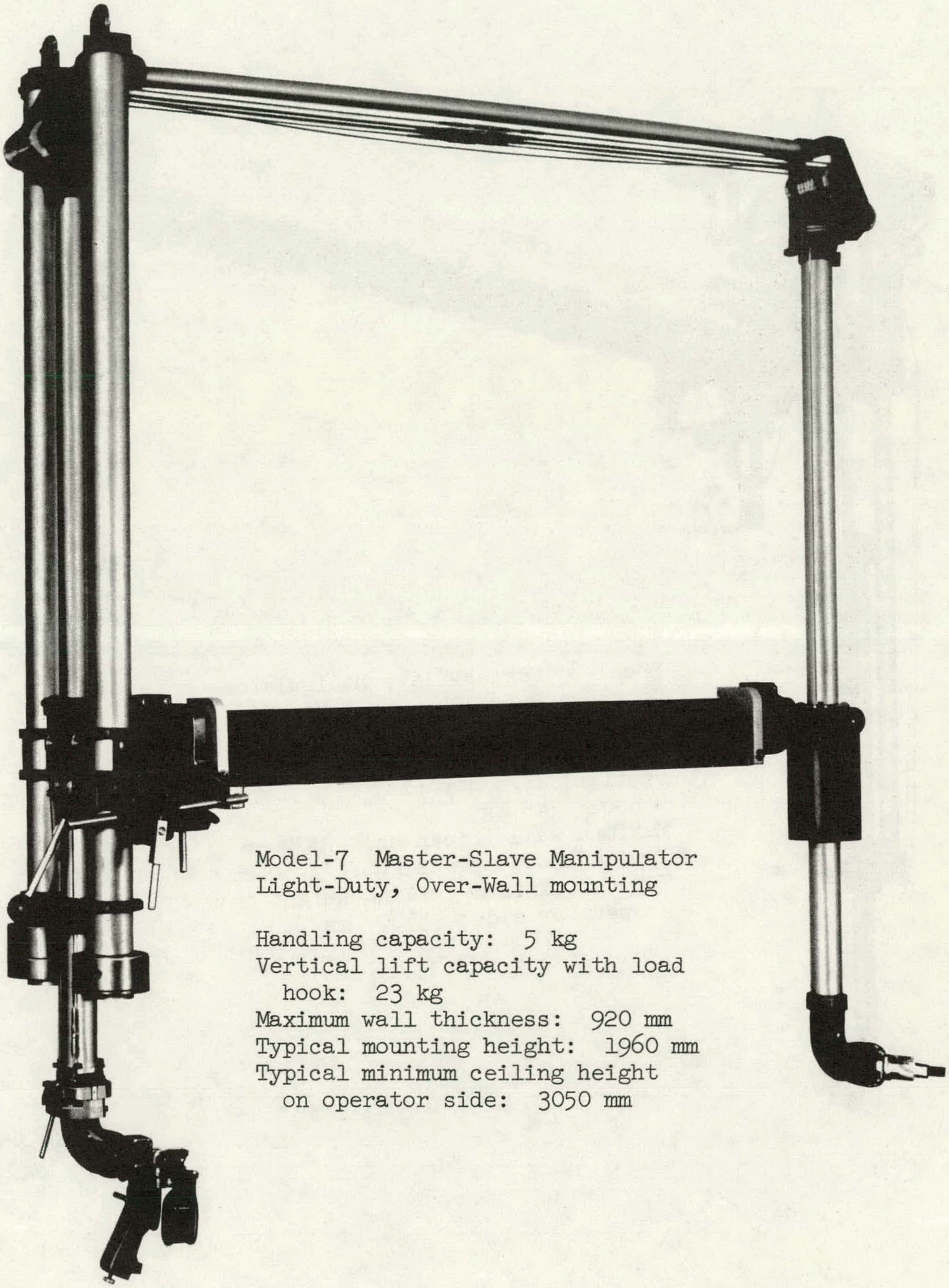
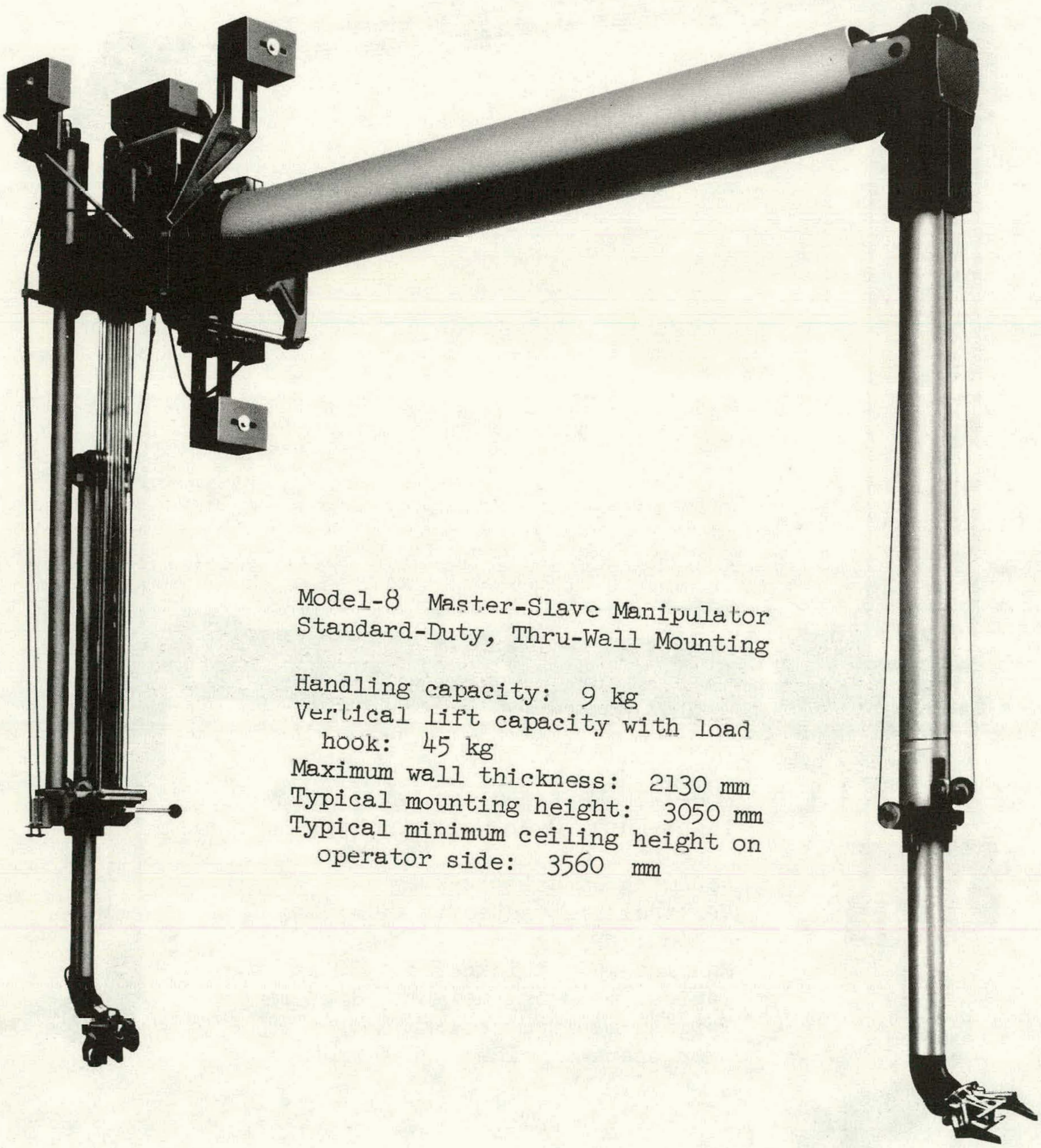


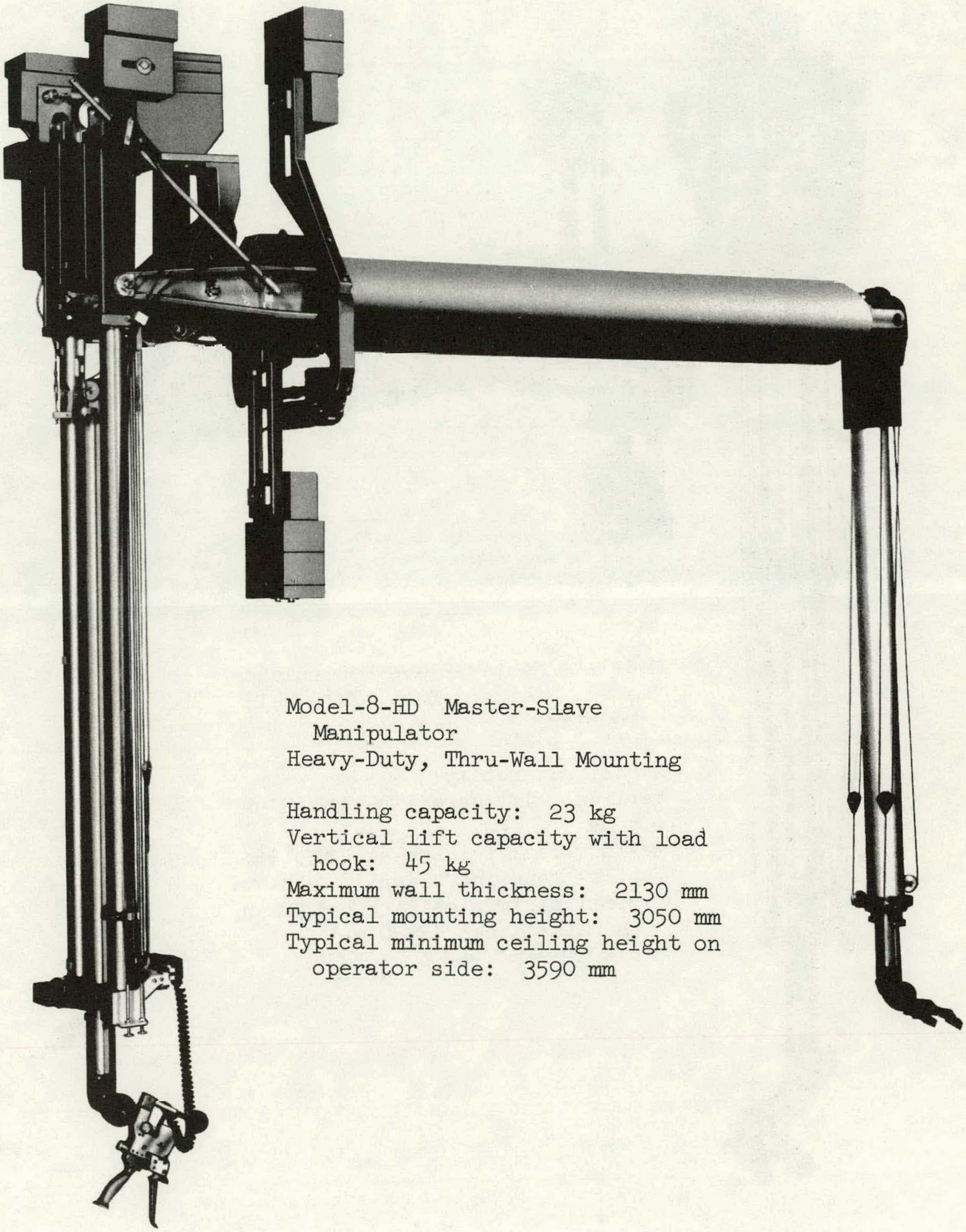
Model-7 Master-Slave Manipulator
Light-Duty, Over-Wall mounting

Handling capacity: 5 kg
Vertical lift capacity with load
hook: 23 kg
Maximum wall thickness: 920 mm
Typical mounting height: 1960 mm
Typical minimum ceiling height
on operator side: 3050 mm



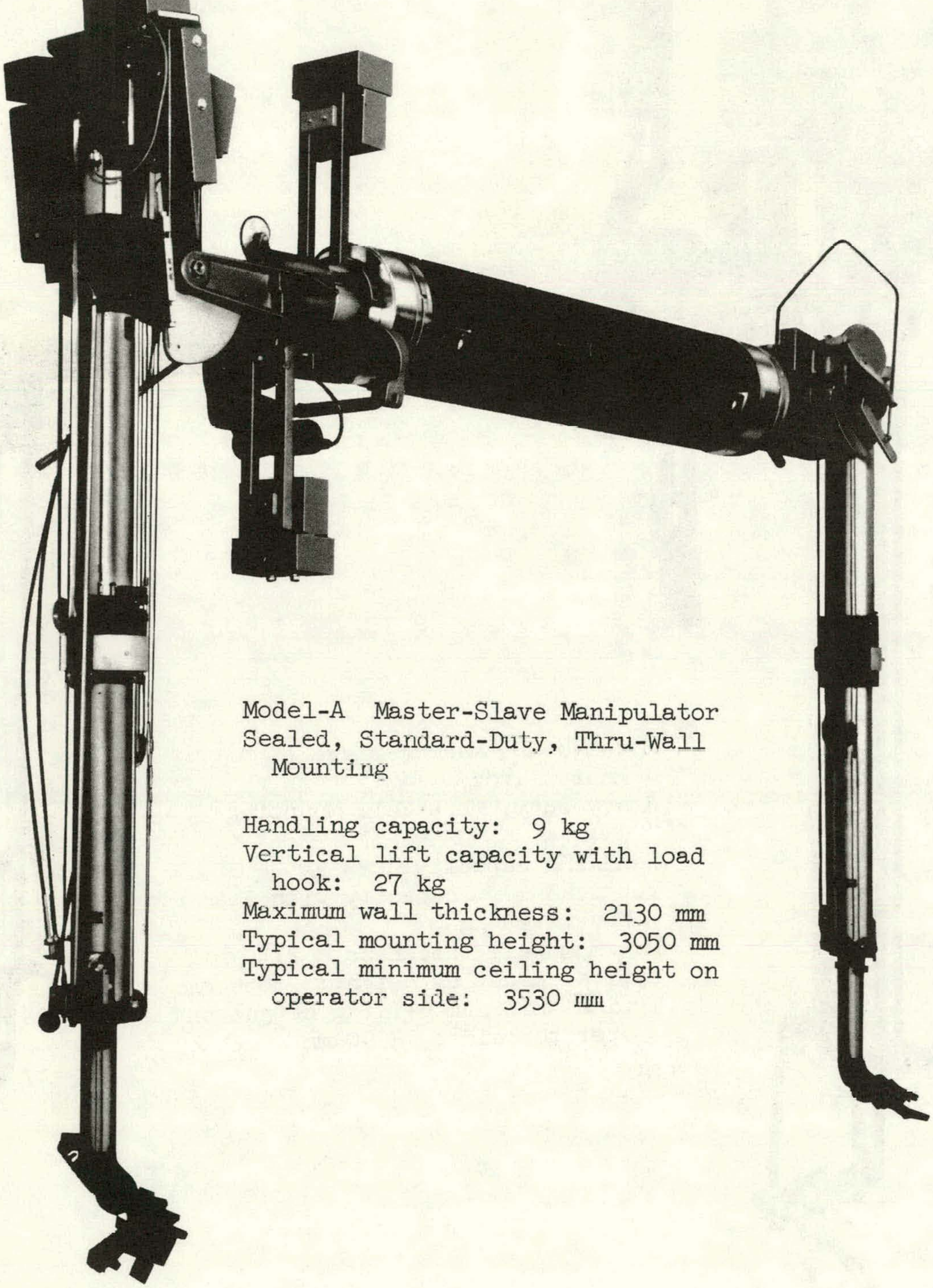
Model-8 Master-Slave Manipulator
Standard-Duty, Thru-Wall Mounting

Handling capacity: 9 kg
Vertical lift capacity with load
hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on
operator side: 3560 mm



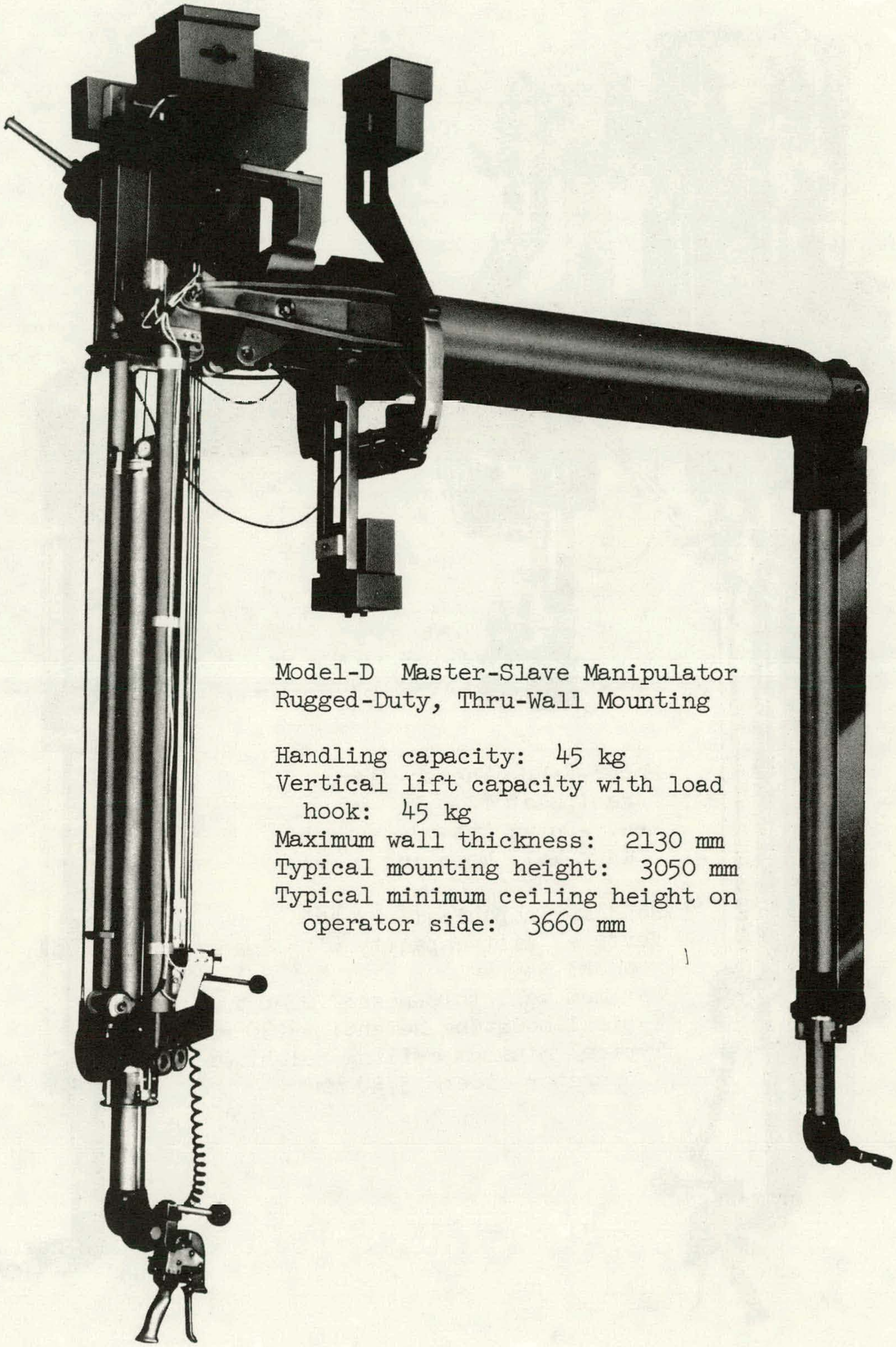
Model-8-HD Master-Slave
Manipulator
Heavy-Duty, Thru-Wall Mounting

Handling capacity: 23 kg
Vertical lift capacity with load hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on operator side: 3590 mm



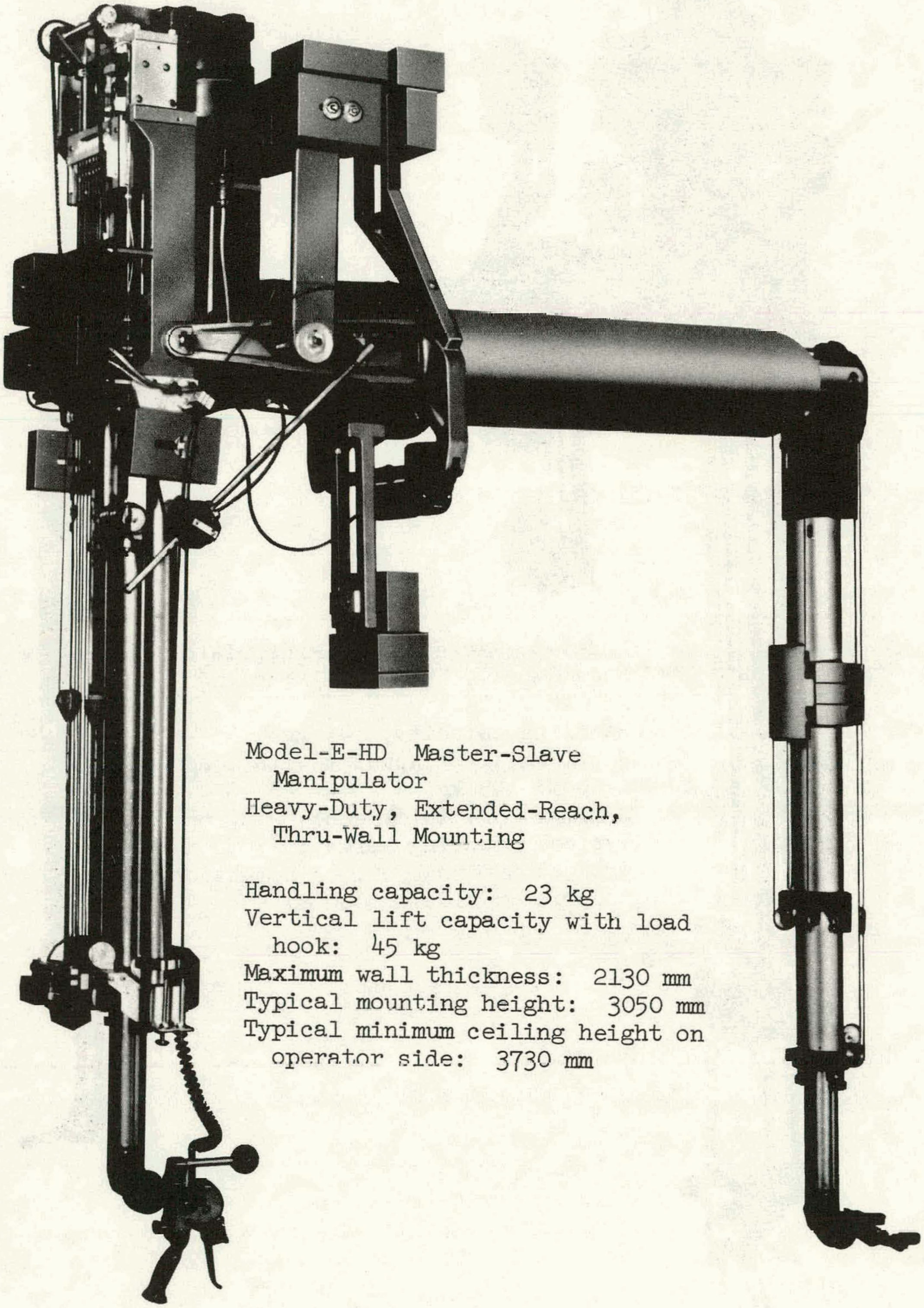
Model-A Master-Slave Manipulator
Sealed, Standard-Duty, Thru-Wall Mounting

Handling capacity: 9 kg
Vertical lift capacity with load hook: 27 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on operator side: 3530 mm



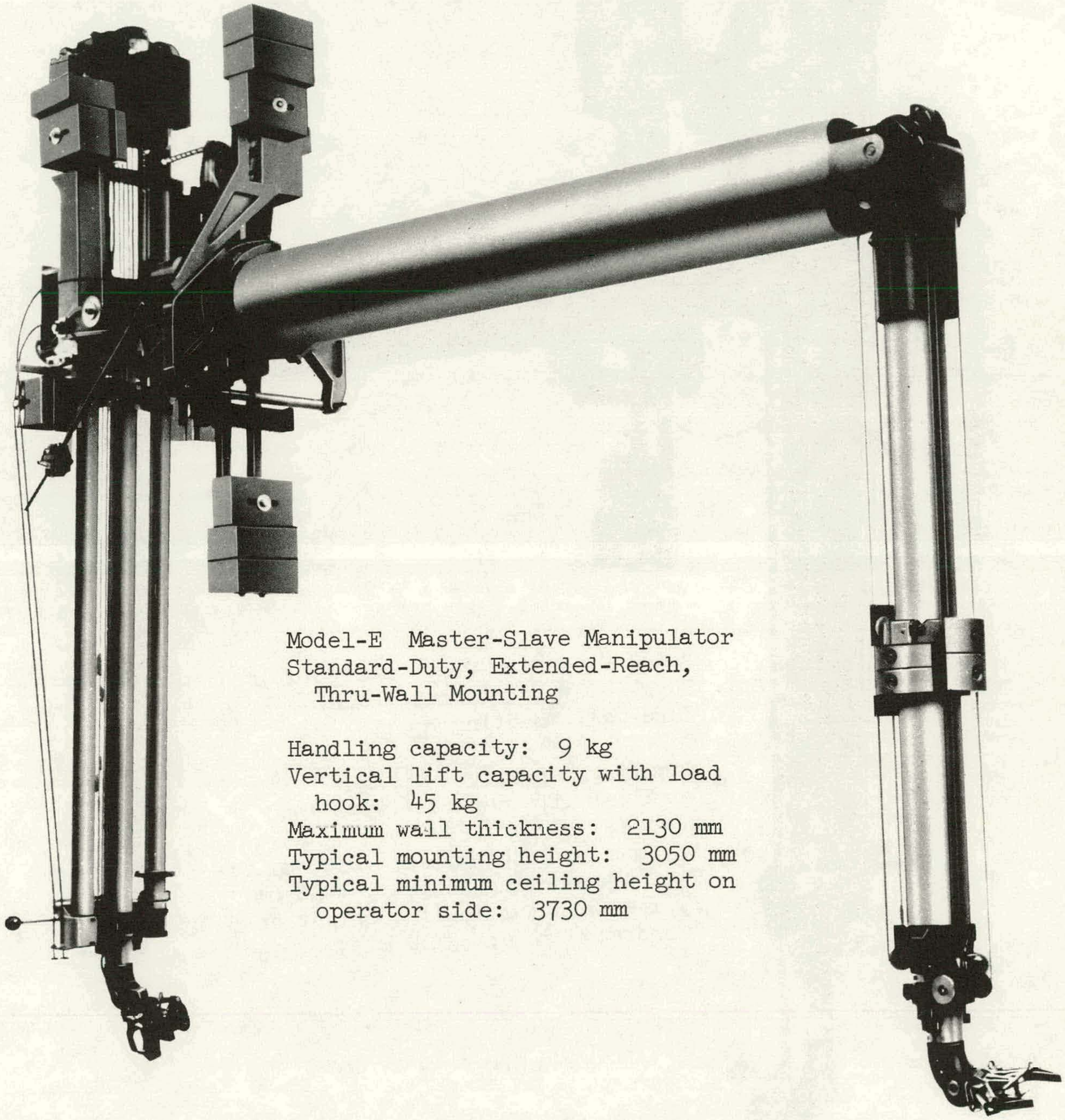
Model-D Master-Slave Manipulator
Rugged-Duty, Thru-Wall Mounting

Handling capacity: 45 kg
Vertical lift capacity with load
hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on
operator side: 3660 mm



Model-E-HD Master-Slave
Manipulator
Heavy-Duty, Extended-Reach,
Thru-Wall Mounting

Handling capacity: 23 kg
Vertical lift capacity with load hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on operator side: 3730 mm



Model-E Master-Slave Manipulator
Standard-Duty, Extended-Reach,
Thru-Wall Mounting

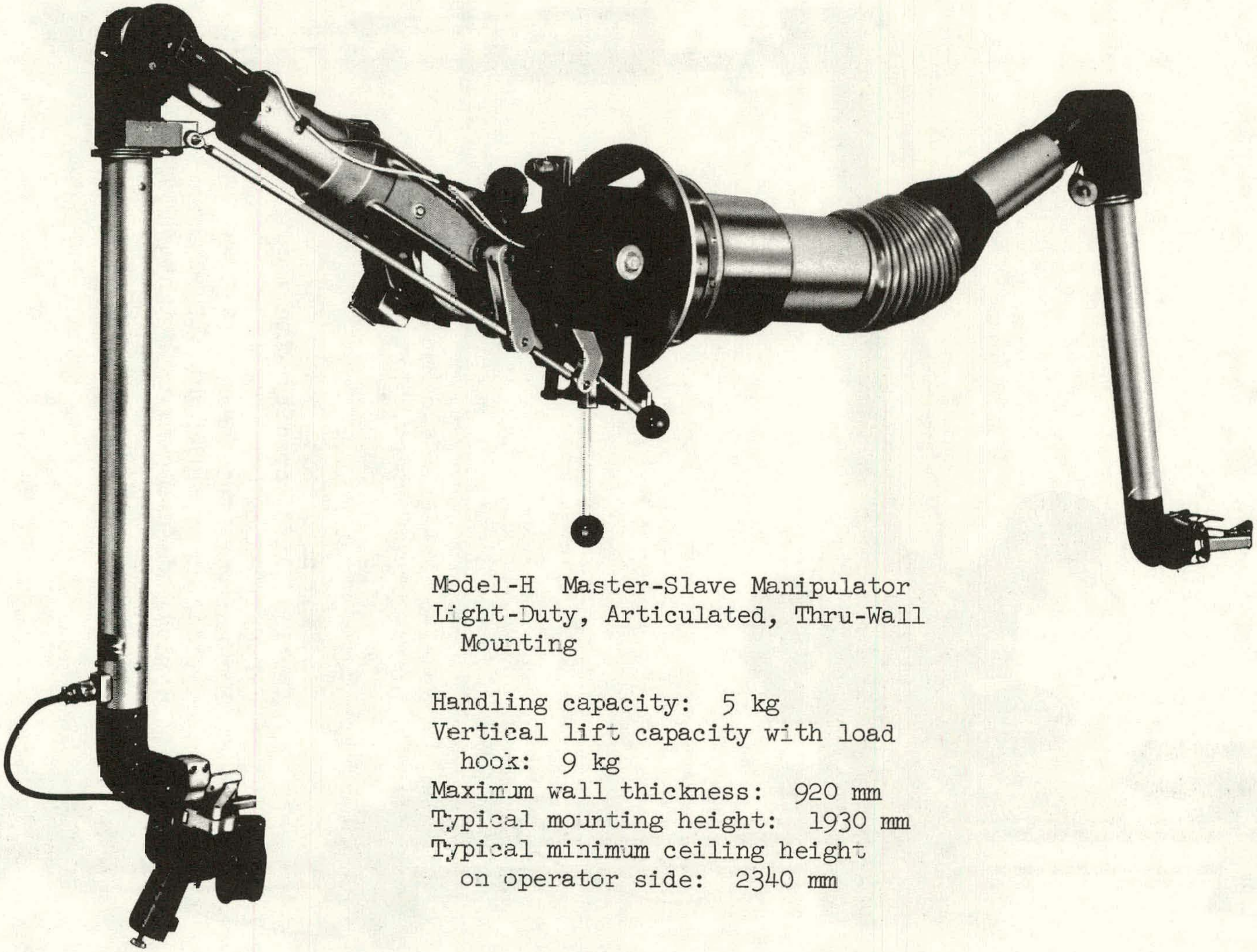
Handling capacity: 9 kg
Vertical lift capacity with load hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on operator side: 3730 mm

Model-F Master-Slave Manipulator
Rugged-Duty, Extended-Reach,
Thru-Wall Mounting

Handling capacity: 45 kg
Vertical lift capacity with load
hook: 45 kg
Maximum wall thickness: 2130 mm
Typical mounting height: 3050 mm
Typical minimum ceiling height on
operator side: 3710 mm

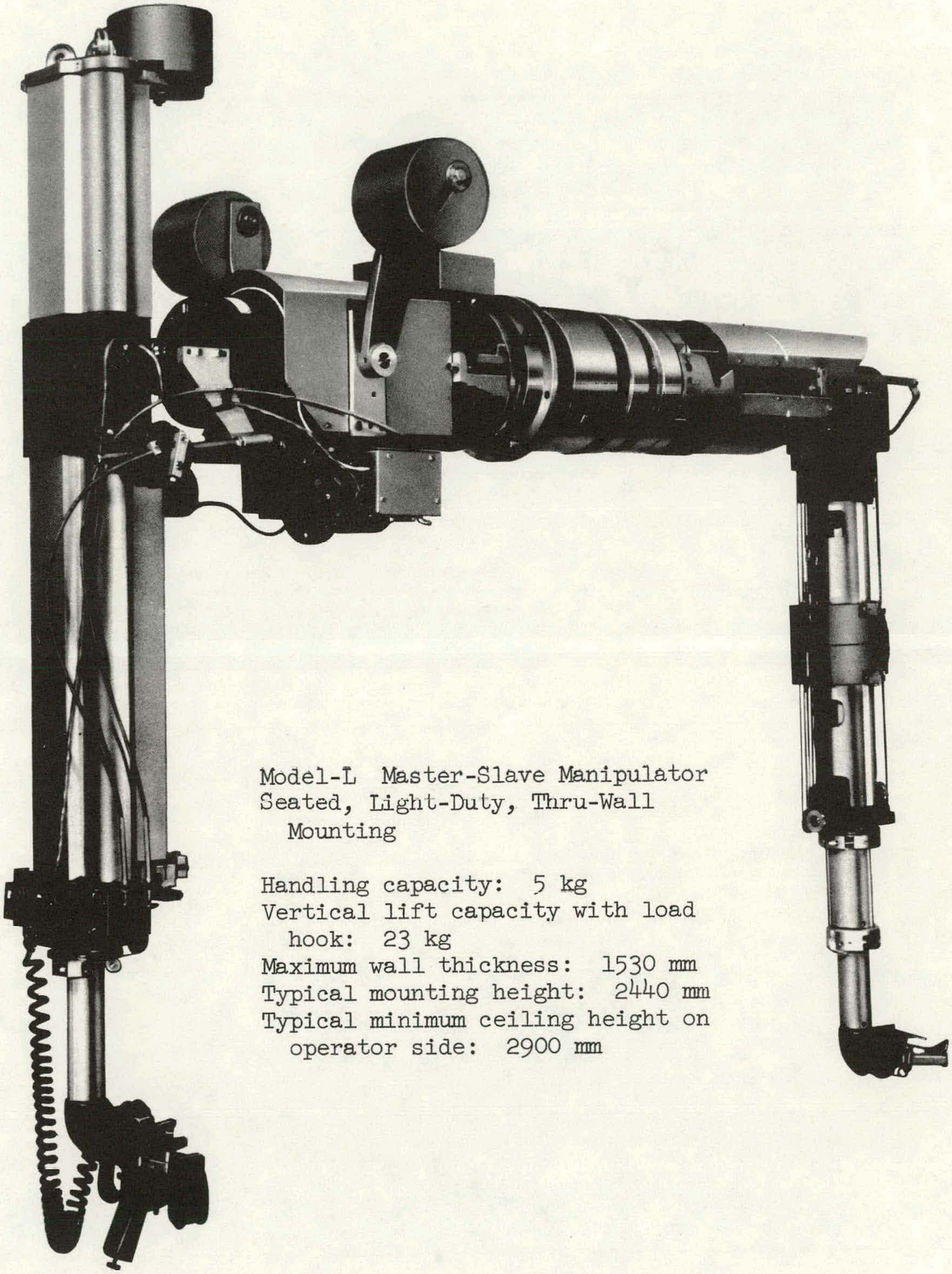
Model-G Master-Slave Manipulator
Light-Duty, Compact, Thru-Wall
Mounting

Handling capacity: 5 kg
Vertical lift capacity with load hook: 23 kg
Maximum wall thickness: 1530 mm
Typical mounting height: 2440 mm
Typical minimum ceiling height on operator side: 2840 mm



Model-H Master-Slave Manipulator
Light-Duty, Articulated, Thru-Wall
Mounting

Handling capacity: 5 kg
Vertical lift capacity with load hook: 9 kg
Maximum wall thickness: 920 mm
Typical mounting height: 1930 mm
Typical minimum ceiling height on operator side: 2340 mm



Model-L Master-Slave Manipulator
Seated, Light-Duty, Thru-Wall Mounting

Handling capacity: 5 kg
Vertical lift capacity with load hook: 23 kg
Maximum wall thickness: 1530 mm
Typical mounting height: 2440 mm
Typical minimum ceiling height on operator side: 2900 mm

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APPENDIX B

MAINTENANCE WORK SHEET

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MANIPULATOR WORK SHEET

			Date
Model	Cell	Position	Building
Serial Number:	Master	Slave	Transfer Box

Customer's Remarks

Work Performed

Parts Replaced

Mechanic's Name	Date

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APPENDIX C

PROGRAMMED MAINTENANCE CARDS

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PROGRAMMED MAINTENANCE FOR WEEK OF MAY 17, 1976 FOREMAN JENNESS
QUALITY LEVEL 4

LOCATION EQUIPMENT DESCRIPTION PROPERTY JOB ORDER
3042- 30 080 MOD 8 MANIPULATORS (4) AT ORR CELL OP

ITEM	POINT OF SERVICE	LUB FTNG NO	FREQ	REMARKS
1	CK OPER WITH PUSH PULL GAUGES		M	
2	CLEAN TAPES.CK TENSIONS		M	
3	CLEAN BOOMTUEE CAM ROLLERS		M	
4	MAKE MINOR ADJUSTMENTS		M	
6	MAKE GENERAL INSPECTION		M	
7	DETERMINE NEED OTHER REPAIRS		M	
8	REPORT UNUSUAL CONDITIONS TO		M	
9	A.A.WALLS 3026D BLDG		M	
10	CK COUNTERWEIGHT RETAINERS		M	

PROG. MAINTENANCE NUMBER

1 BLDG. 5 6 ROUTE 7 8 LOC. 10

EQUIPMENT MAINTENANCE RECORD

DATE SCHEDULED

51 56

PROG. MAINTENANCE 57

REPAIR 58

11 ADDITIONAL MAINTENANCE INFORMATION 49

TIME ON THIS JOB-TOTAL MANHRS.

59 HOURS MIN. 63

DATE COMPLETED 64 69

☐ EQUIPMENT NOT SERVICED THIS TIME 50

MATERIAL COST 70 74

BADGE NO. 75 79

UCN-10046B
(3 9-71)

SEE OTHER SIDE FOR INSTRUCTIONS

PUNCH 4 IN COLUMN 80

PROG. MAINTENANCE NUMBER

1 BLDG. 5 6 ROUTE 7 8 LOC. 10

EQUIPMENT MAINTENANCE RECORD

DATE ON PROG. MAINT CARD 51 56

PROG. MAINTENANCE 57

REPAIR 58

11 ☐ GREASE ADDED	21 ☐ TRAP CHECKED	31 ☐ VISUAL INSP	41 ☐ BRAKES CHECKED
12 ☐ OIL CHECKED	22 ☐ TRAP REPAIRED	32 ☐ CONTROLS CKD	42 ☐ BRAKES ADJ
13 ☐ OIL ADDED	23 ☐ FILTER CHECKED	33 ☐ BATTERY SPG	43 ☐ CONTRL VLVE ADJ
14 ☐ OIL CHANGED	24 ☐ FILTER CLEANED	34 ☐ WATER ADDED	44 ☐ CHECK BRUSHES
15 ☐ BELT CHECKED	25 ☐ FILTER REPLACED	35 ☐ BATTERY REPL	45 ☐ REPLACE BRUSHES
16 ☐ BELT ADJUSTED	26 ☐ PACKING ADJ	36 ☐ SWITCH CHECKED	46 ☐ CK OPERATION
17 ☐ BELT REPLACED	27 ☐ GLAND REPACKED	37 ☐ SWITCH REPAIRED	47 ☐ LEAK TEST
18 ☐ STRAINER CLND	28 ☐ DRAINED WATER	38 ☐ SWITCH REPLACED	48 ☐ CHEM TREATMENT
19 ☐ DIRT LEG CLND	29 ☐ CHECKED REFRIG	39 ☐ CK FLEX DUCT	49 ☐ CK GLYCOL CONT
20 ☐ EQUIPMENT CLND	30 ☐ REFRIG ADDED	40 ☐ TEST RUN	50 ☐ REPAIR LEAKS

TOTAL MANHOURS 59 HOURS MIN. 63

DATE COMPLETED 64 69

MATERIAL COST 70 74

INITIALS 75 77

UCN-10046
(3 11-73)

PUNCH 2 IN COL. 80

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APPENDIX D

MANIPULATOR PULLING RIG

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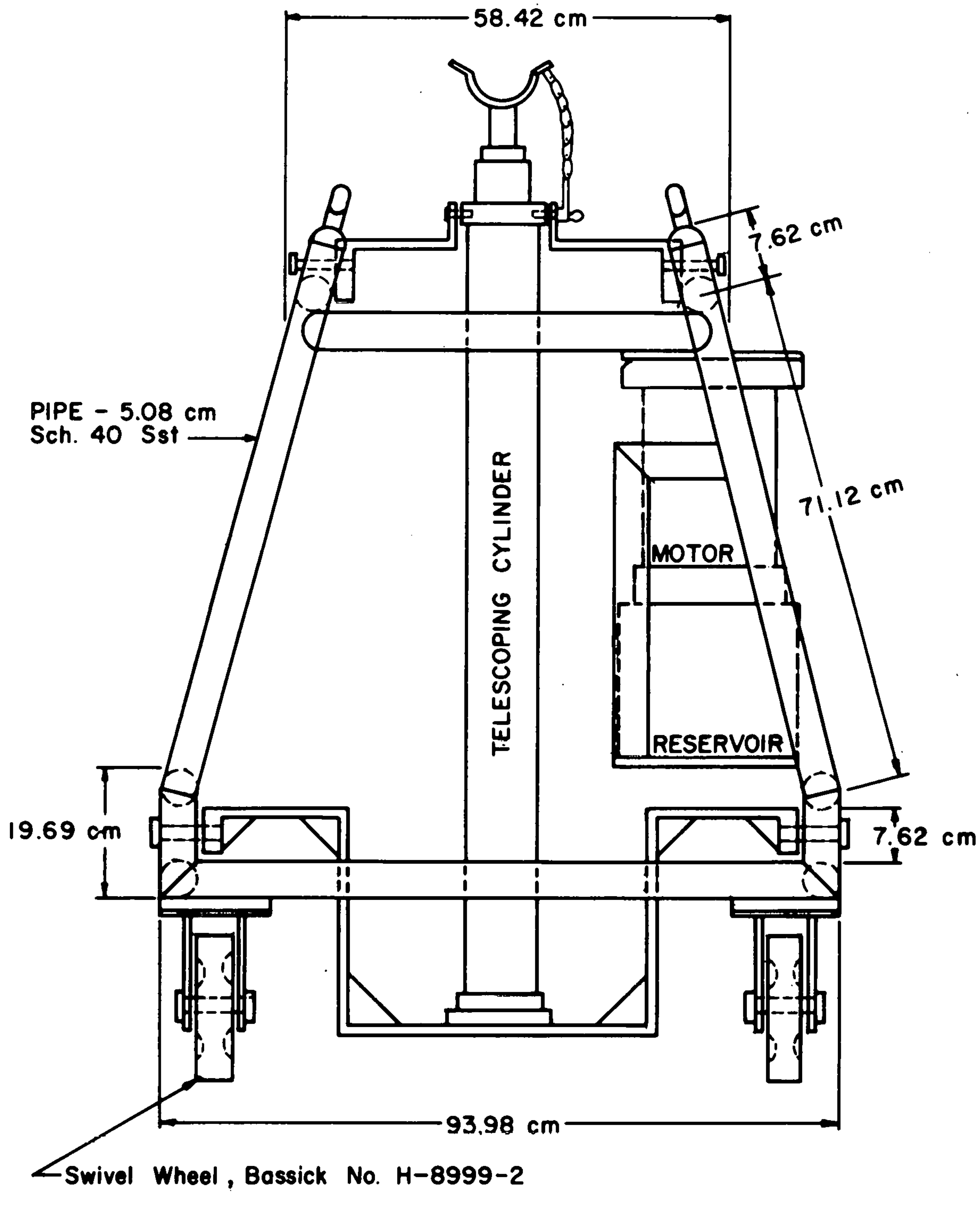
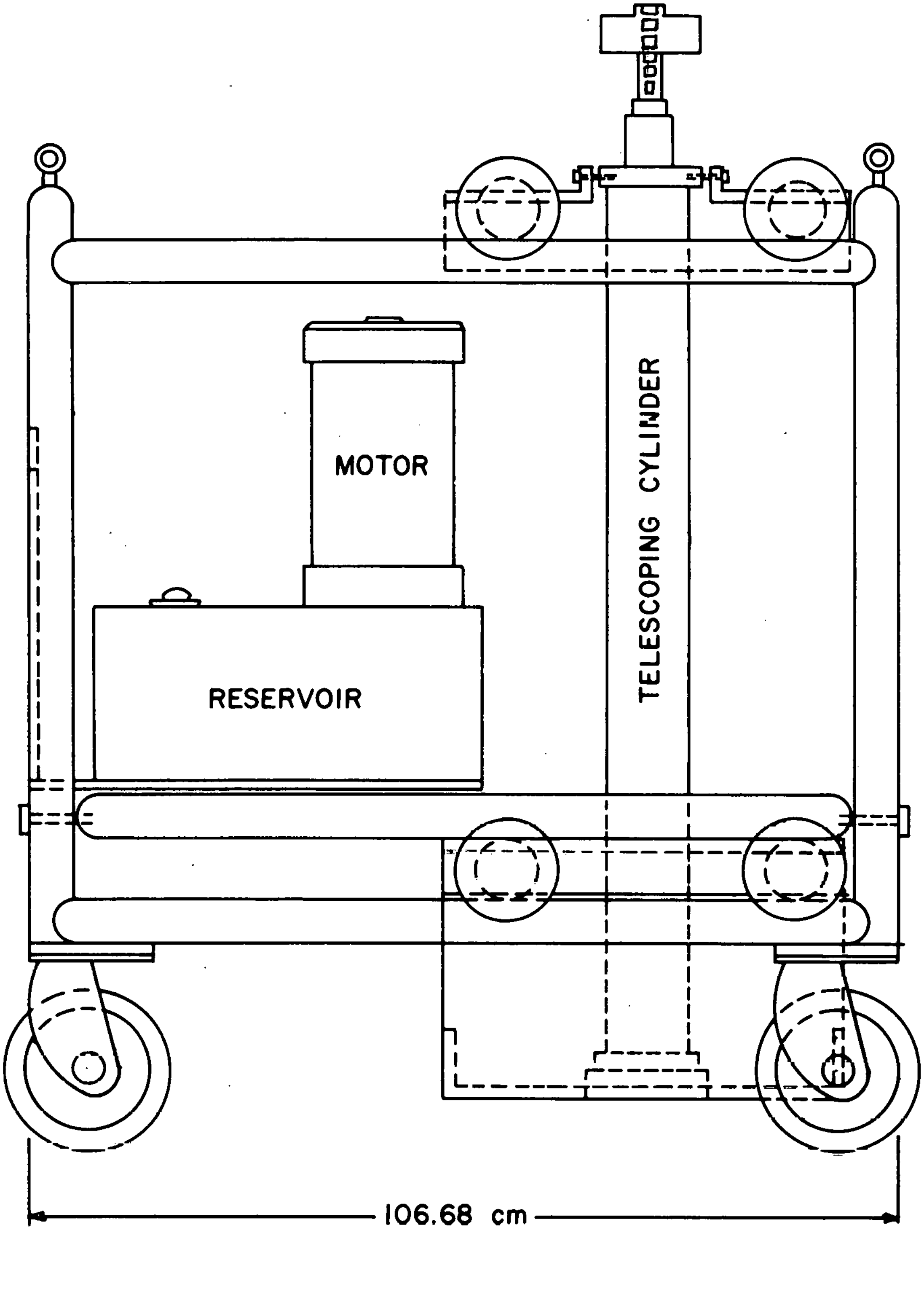

58.42 cm
7.62 cm
PIPE - 5.08 cm
Sch. 40 Sst
TELESCOPING CYLINDER
MOTOR
71.12 cm
RESERVOIR
19.69 cm
7.62 cm
93.98 cm
Swivel Wheel, Bassick No. H-8999-2

END VIEW



SIDE VIEW

APPENDIX E

TRANSPORT VAN

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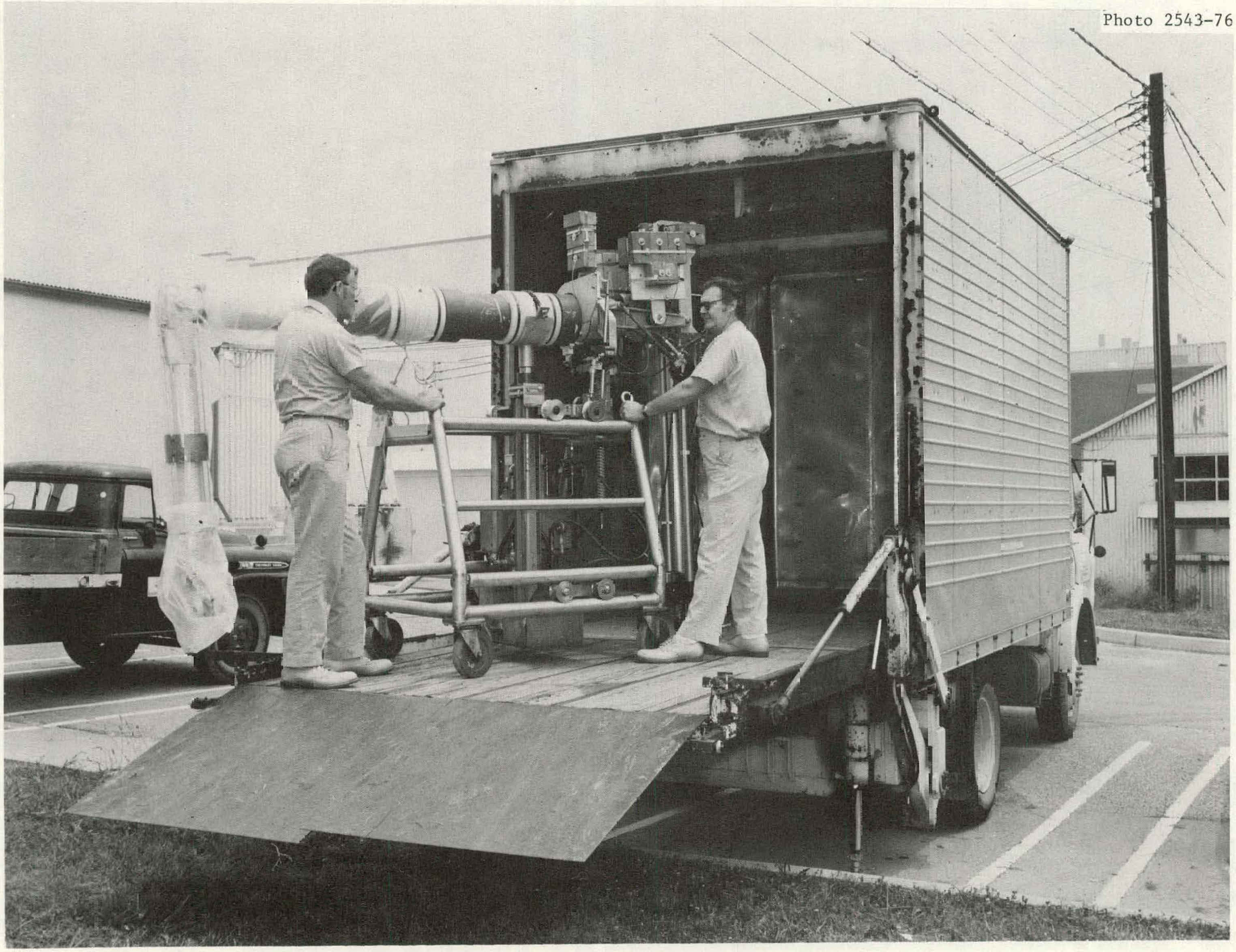
Photo 2543-76



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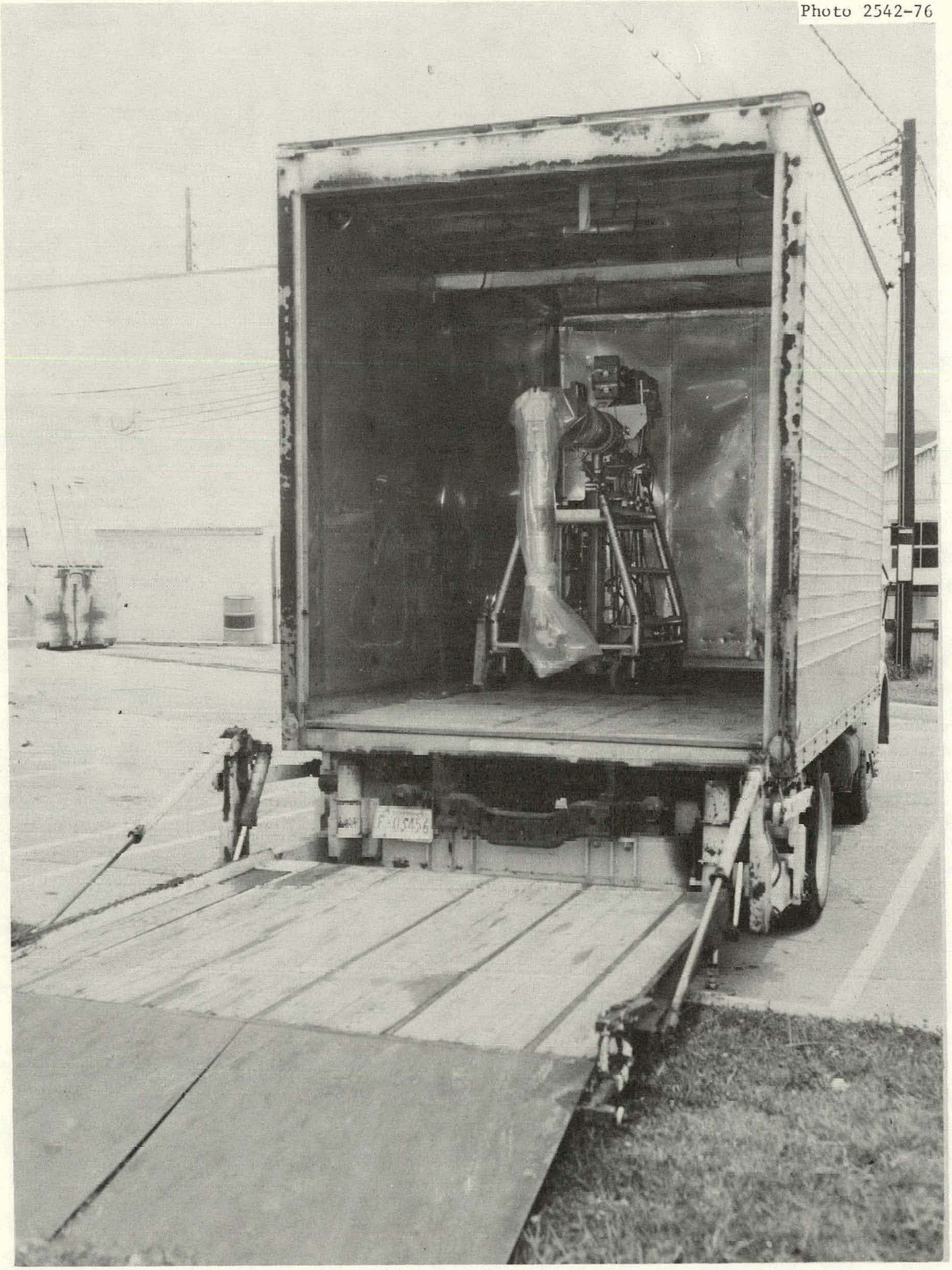

APPENDIX F

DECONTAMINATION GLOVE BOX

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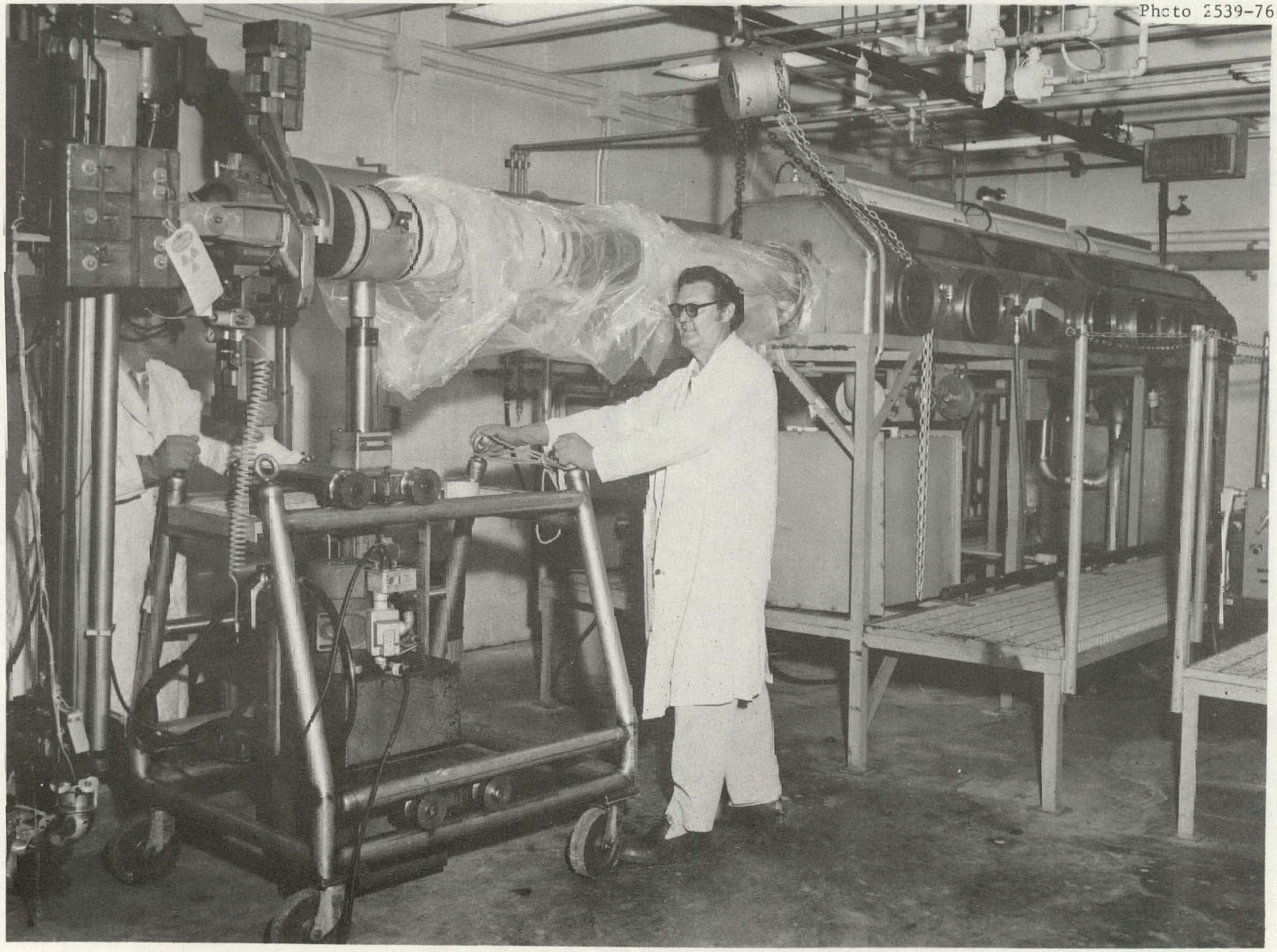

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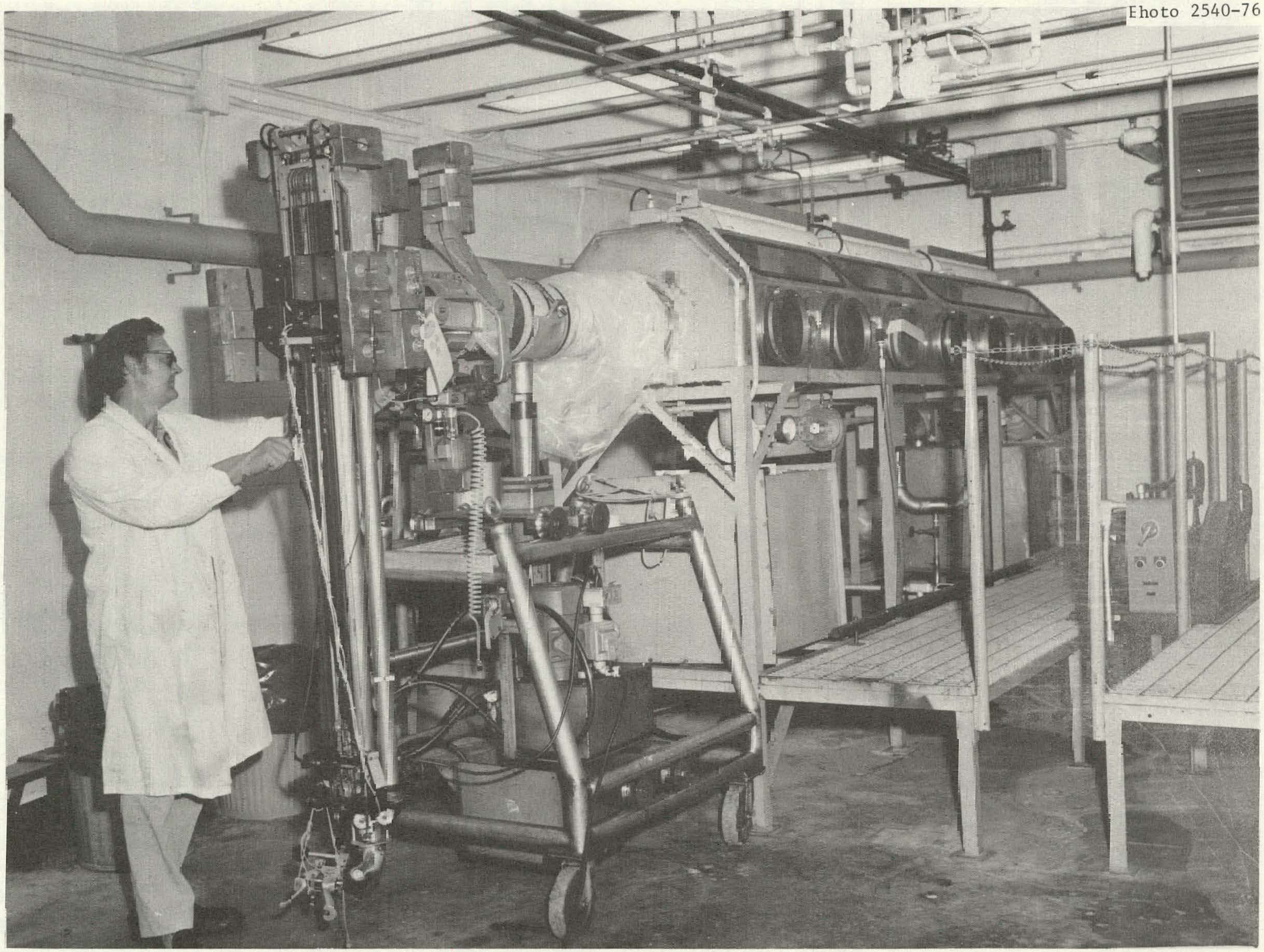

APPENDIX G

HEALTH PHYSICS CHECK SHEET

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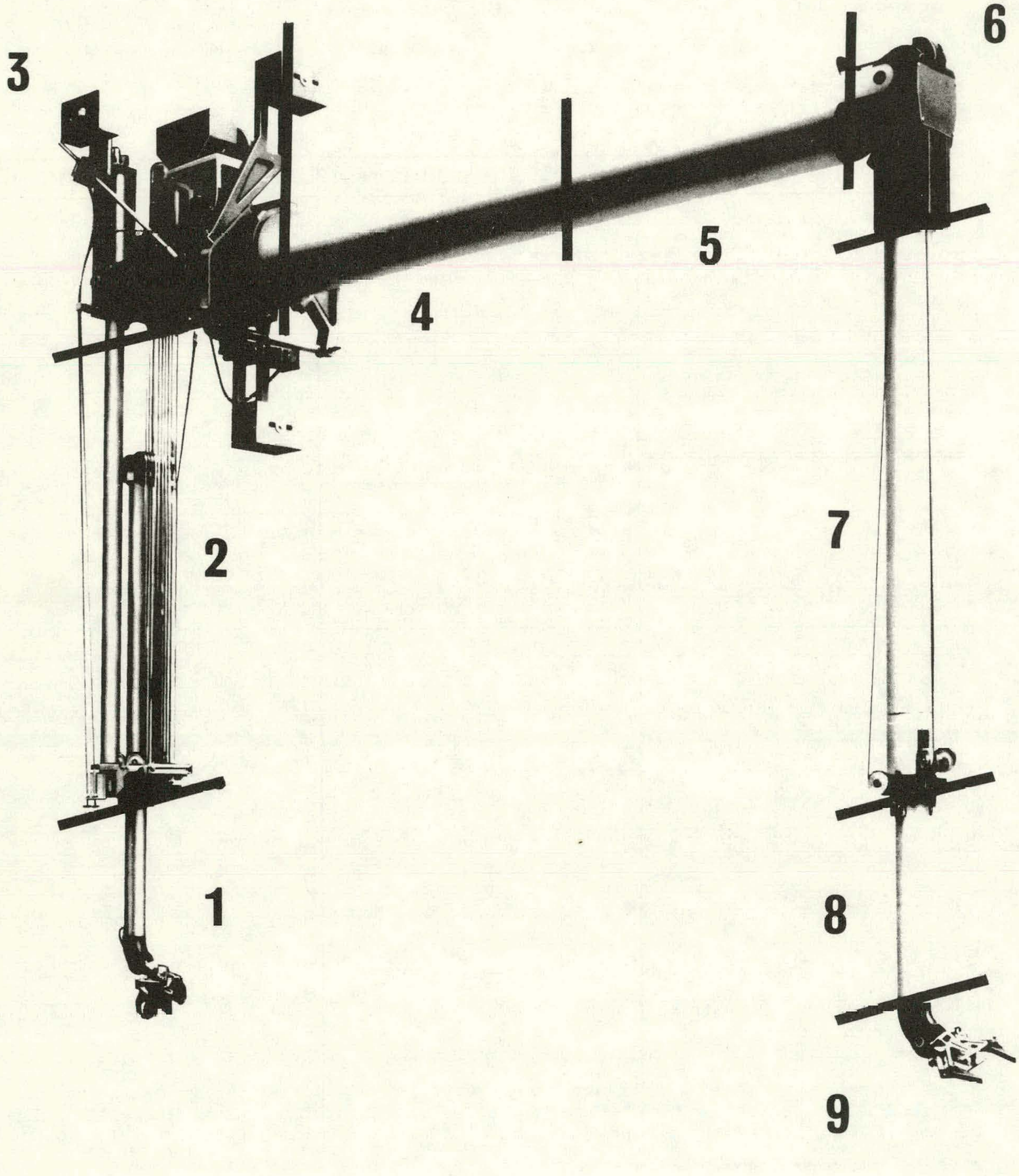
SMEAR SAMPLE DATA

NAME (HP&S)	PHONE	BLDG. NO. (HP&S)	LOCATION (SMEARS TAKEN)	DATE
SMEARS NUMBERED: From To	RESULTS REQUIRED: Date Time		DATE COUNTED	COUNTER OPERATOR
GIVE D/M ONLY ON SMEARS OVER: ______ d/m α ______ d/m β	REMARKS:			

α	β	LOCATION (*)	α	β	LOCATION (*)	α	β	LOCATION (*)
1			34			67		
2			35			68		
3			36			69		
4			37			70		
5			38			71		
6			39			72		
7			40			73		
8			41			74		
9			42			75		
10			43			76		
11			44			77		
12			45			78		
13			46			79		
14			47			80		
15			48			81		
16			49			82		
17			50			83		
18			51			84		
19			52			85		
20			53			86		
21			54			87		
22			55			88		
23			56			89		
24			57			90		
25			58			91		
26			59			92		
27			60			93		
28			61			94		
29			62			95		
30			63			96		
31			64			97		
32			65			98		
33			66			99		

UCN-1632 *(*) Give only if required.*
(3 7-67)


3
6
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APPENDIX H

ELECTRICAL GROUNDING CHECK

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MANIPULATOR
ELECTRICAL TEST RECORD

Model No. ____________________ Building No. ____________________

Serial No. ____________________ Cell No. ____________________

Date ____________________ Inspected By ____________________

READINGS

IMPEDANCE (OHMS)

POINT		START*	FINAL*	COMMENT
A	(Cord Cap or Power Inlet)			
B	(Trunk Tube)			
C	(Boom Tube)			
D	(Control Handle)			

*These readings below 0.5 ohm shall be recorded in "Final" column. If any point reads above 0.5 ohm, record the reading in the "Start" column and proceed with wire and connection search. When the proper correction(s) have been made, record the final reading, and state correction(s) made in the comment column.

Safety Precautions

Approved By: Date:

Next Test Due:

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APPENDIX I

REPAIR FACILITY LAYOUT

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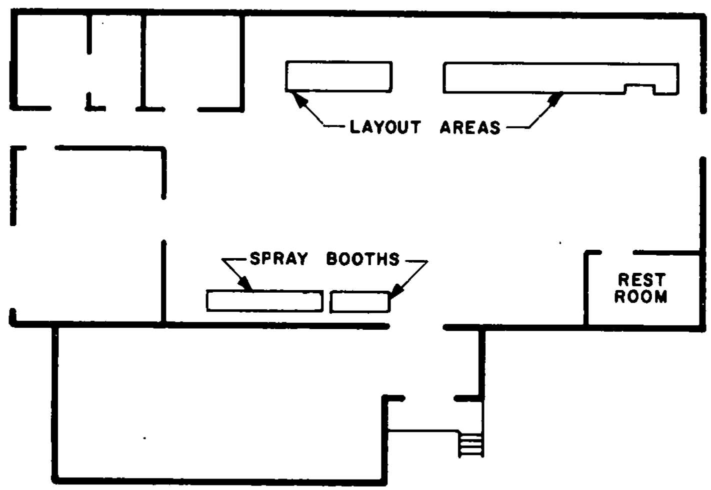
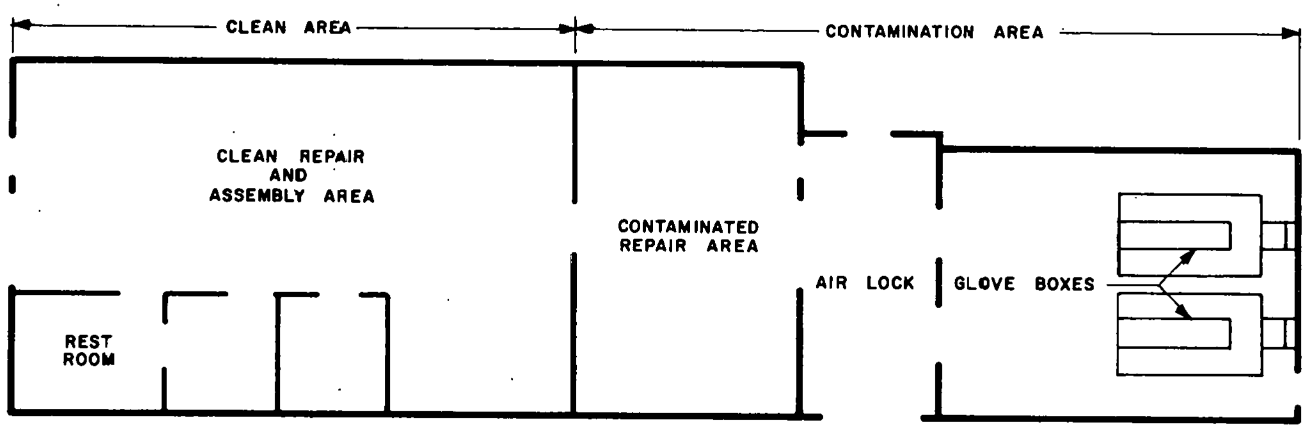


BOOT FABRICATION SECTION : BUILDING 3502



MANIPULATOR REPAIR FACILITY : BUILDING 3074

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APPENDIX J

CABLE TENSIONING DEVICE

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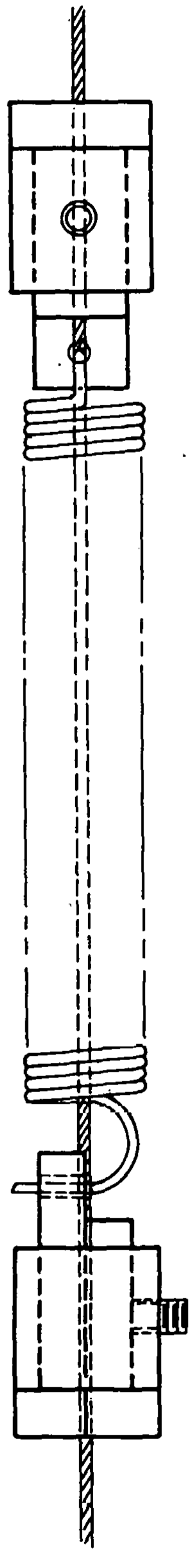

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APPENDIX K

POWER GRIP DEVICE

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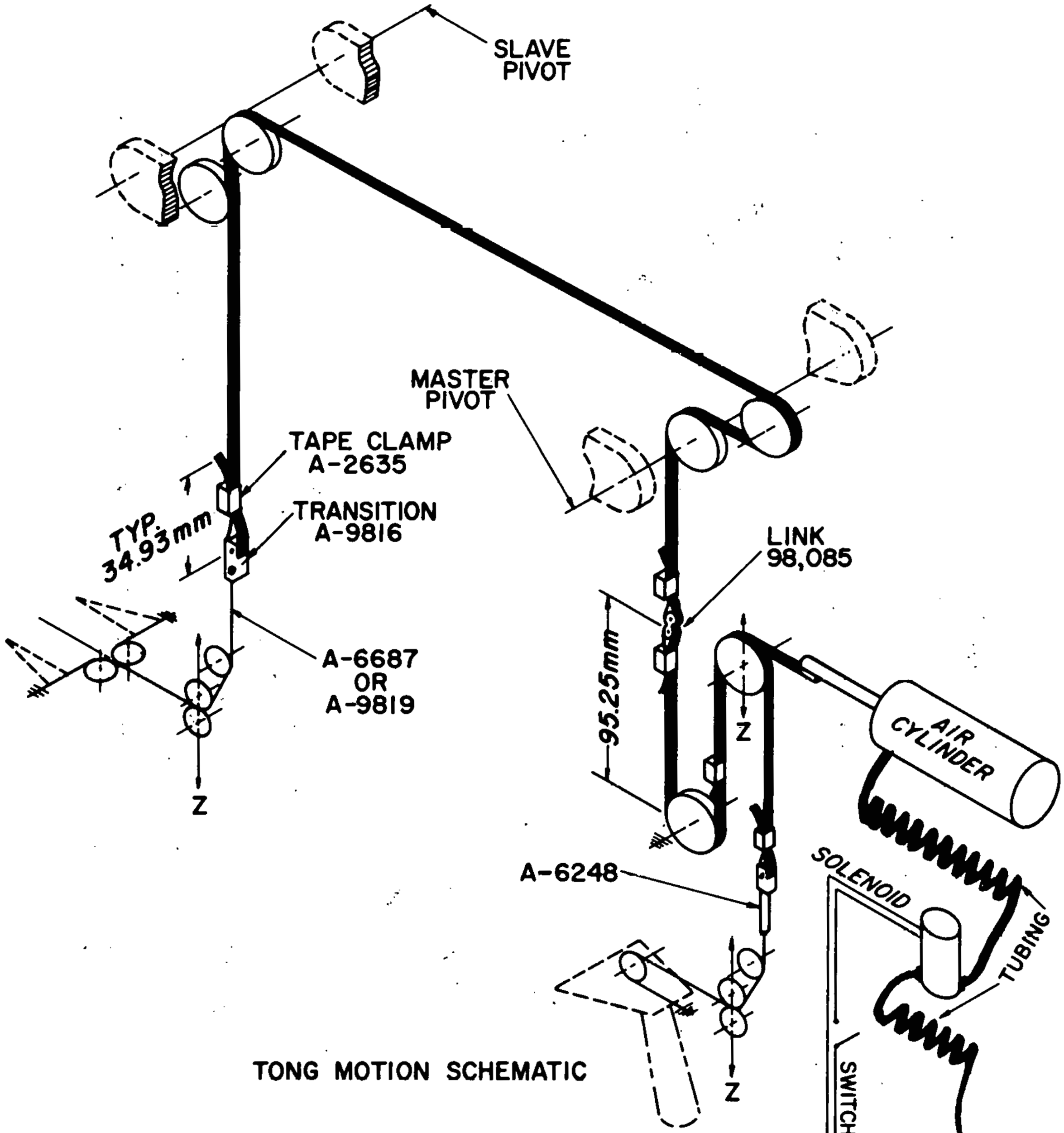
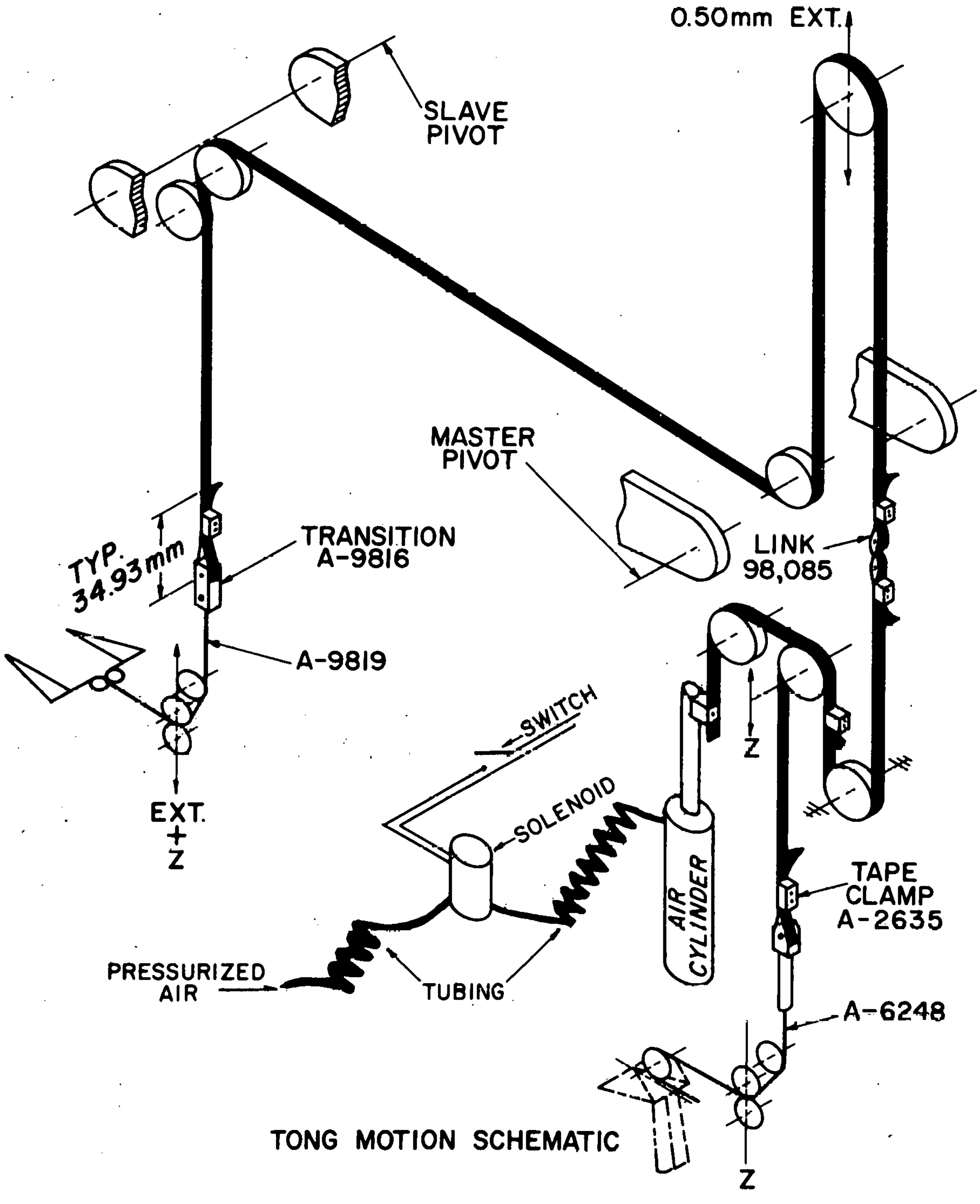


TONG MOTION SCHEMATIC



TONG MOTION SCHEMATIC

APPENDIX L

BOOT SUPPORT RING

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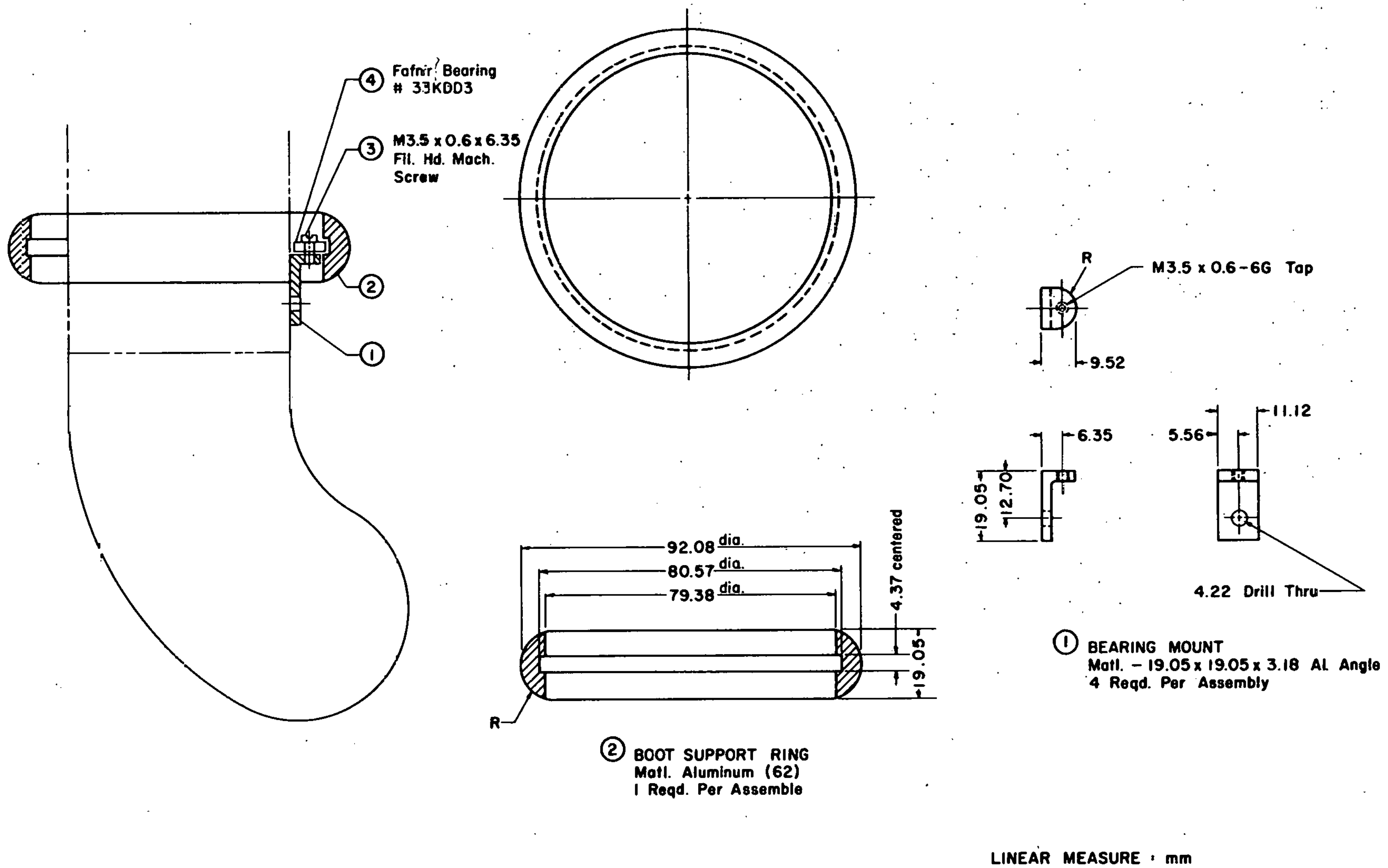

4 Fafnir Bearing # 33KDD3
3 M3.5 x 0.6 x 6.35 Flt. Hd. Mach. Screw
2
1
R
M3.5 x 0.6-6G Tap
9.52
6.35
11.12
5.56
19.05
12.70
4.22 Drill Thru
92.08 dia.
80.57 dia.
79.38 dia.
4.37 centered
19.05
R
1 BEARING MOUNT
Matl. - 19.05 x 19.05 x 3.18 Al. Angle
4 Reqd. Per Assembly
2 BOOT SUPPORT RING
Matl. Aluminum (62)
1 Reqd. Per Assemble
LINEAR MEASURE : mm

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