Precision Devices, Ltd. 2304 OAKWOOD AVENUE, N. W.
HUNTSVILLE, ALABAMA 35810

CR-170923

(NASA-CR-170923) LOW GRAVITY EXPERIMENT FOR STUDYING A ROTATING FLUID HAVING A FREE SURFACE Final Report (Precision Devices Ltd.) 33 p HC A03/MF A01 CSCL 20D
N84-12413
Unclas
G3/34 42548

FINAL REPORT

to

GEORGE C. MARSHALL SPACE FLIGHT CENTER

(Low Gravity Experiment for Studying a Rotating Fluid having a Free Surface)

Contract No. NAS8-35481
DCN 1-3-ES-26516

prepared by

O. C. HOLDERER

October 29, 1983

Distribution:

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AT 01	1
AS 24 D	3

Approved:

Charlie Schaefer

Charlie Schaefer, ED 42

Fred Leslie

Fred Leslie, ED 42

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FIGURES:

A. SUMMARY:

The contract award occurred on July 14, 1983. This was followed by technical discussions with the contracting officer's representatives and the design of an apparatus tailored to the specific objectives of the experiment. The requirements of the 'JSC Reduced Gravity Aircraft User's Guide' had to be met with least interference of the test goal. By early September 1983, the concept and drawings were approved in a meeting with the CORS, and procurement of structural raw materials and commercial components was initiated. Fabrication was finished by the end of October and "bench" tests confirmed the proper function of all mechanical and electrical devices comprizing the total unit. A stress analysis was prepared to document the structural adequacy for safe use on the KC 135 aircraft. A single load proof test of the most critical load case was performed at the site of Precision Devices, Ltd. and was witnessed by the CORS.

B. DESCRIPTION OF APPARATUS

1) Mechanical

A reduced scale drawing of the test cell assembly is shown in Fig. 1. The rotating table is mounted with two shielded ball bearings to a hollow shaft. This allows the routing of electrical wires and a co-ax cable from the spinning table to the slipring assembly. The table is machined from 1/2" aluminum plate, it is 16" in diameter and features a .250" Dia. dowel in the center which protrudes approx. 1/8" above the table surface. It's purpose is to center the test cell on the table. The test cell is held to the table with two toggle clamps. The lights and overhead camera are supported on 1" Dia. solid aluminum columns. The interchangeable cameras are supported in a height-adjustable open frame, bridging the two columns. The special 16 mm camera is shown on Fig. 3. Because of the requirement for camera interchangeability and good balance (C. G, on centerline), each camera is mounted to a special C-shaped mounting bracket which is fitted with two machined trunions assuring accurate location over the table, yet allowing camera tilt angle adjustment. To assure good balance, the C-shaped camera mounts feature omnidirectional means for counterweight attachment. A special double-gimbaled balancing fixture is furnished to facilitate the balancing. The turntable is driven by a speed-adjustable gear motor through a timing belt. Since the timing belt and the worm gear of the electric motor cannot slip, the cogged drive wheel at the motor was provided with a safety clutch. The clutch protects the motor and the drive train should the table get stalled or be forced against the motor. The drive motor is mounted to the side of the sturdy swivel frame which supports the dual ball bearings of the turntable. The off-center mass of the motor is compensated for by an adjustable counterweight on the opposite frame side. Two more, non-adjustable counterweights (lead disks, 7 lbs. ea.) are attached to the underside of the swivel frame to assure a positive, gravitational restoring moment for all anticipated test conditions, e.g. even when the camera is in the uppermost position. - The swivel frame hangs in the cradle. Small shielded ball bearings minimize friction between these two structures, so that the turn table centerline remains "stable" as the aircraft pitches for the zero-g maneuvre.- It had been suggested at the inital planning meeting to allow for the option to free-float the entire test cell assembly for a more perfect "zero-g". This has been accomplished by bolting the cradle to a submount. Two nylon rope tethers limit the possible excursion of the test cell assembly away from the submount. The submount is bolted to the aircraft floor with four 3/4" special fasteners furnished by JCC. The mounting holes match the prescribed 20" x 20" pattern. - A roll bar cage surrounds the entire test cell assembly without impeding the tilt of the turning components. The roll bar is attached with 4 bolts to the cradle frame, it weighs only 38 lbs. because it is made from thin-walled steel tubing. It's welded construction provides ample rigidity for carrying the total assembly by using the roll cage horizontal members as handles. The roll bar is shown in Fig. 2, drawing No. MS 783-1. For proper bolt hole match-up, the red-banded end of the cage should be on the red-dotted side of the base-cradle. - The test-cell proper is fabricated from acrylic or polycarbonate (Plexiglass and Tuffak respectively). Various inserts and baffles provide for a great variety of fluid chamber configurations which are shown in Fig. 4, A through J. The nominal dimensions for the fluid chamber outlines are given in millimeters.

2) Electrical

The electrical circuitry is rather straight forward and uncomplicated, it is shown in the wiring schematic, Fig. 5. Terminal strips are provided at the camera base plate, underneath the turntable, on the swivel bracket side and on top near the motor, and finally inside the control box. Note the custom-built slipring assembly which features 16 poles (silver rings and dual wipers) plus a special rotating terminal for the co-ax transmission cable to the T. V. camera. The slipring assembly is located between the two 'gravity' counterweights under the swivel frame. In the "as delivered" status, there are 3 vacant sliprings for future use. - Two shielded light fixture mount to the table columns and they may be mechanically adjusted for optimal lighting. Ordinary light bulbs (120V) fit the fixture sockets. A pair of 40 W bulbs (furnished) yield an

illumination level of approx. 125 foot candles (use f-stop 6.3 at 24 frames cine for ASA 400 film). It is suggested not to use light bulbs over 75 Watts for safe heat dissipation. The lights are individually controlled from the control box panel. - The turntable rotation rate is monitored with an electronic tachometer. A search of the commercial market did not locate a suitable device. Therefore, a hand-held tachometer with a large LED display, high accuracy, and a range of 1 to 10,000 RPM was purchased for disassembly and repackaging, so that the sending unit is now separate from the electronic computer and display. A 6 V D.C. power supply was built into the display unit to avoid the nuisance of replacing batteries. The sender is driven directly by the armature of the electric drive motor, which is 22.5 times faster than the table. Thus, the tachometer display must be divided by 22.5 to yield true table RPM. See Fig. 11
The special 16 mm camera (see Fig. 3 and Fig. 5) and the T. V. camera require 24 and 12 V D. C. respectively. D. C. power is available in the KC 135 aircraft, however for the sake of simplicity of operation, a precision D. C. power supply (Fig. 7) was incorporated in the control box. A selector switch provides either 24 or 12 V. D. C. to the camera terminal. The voltage selection is shown by marked red LED's.

The motor speed is controlled with a commercial controller made by the Bodine Corp. The controller is matched to the drive motor, it's diagram is shown in Fig. 8. To save space, the on-off switch of the controller has been tapped to serve as the main power supply switch for the total system. The switch is DPST, breaking the neutral as well as the "hot" side of the 120 V AC supply. The green wire keeps the system grounded (bonded). In addition to the motor controller and the D.C. power supply which are of commercial origin, other components in the control box are custom arranged. See Fig. 10 for a front view of the master control panel. An RCA T. V. signal tape recorder can be mounted adjacent to the control box and a convenient power cord storage and fused outlet is provided for the recorder. A co-ax cable terminates near the recorder mounting rail.

C. OPERATION

It is suggested to ship the entire unit, with the roll bar cage mounted in place, in a suitable crate (not furnished). For ground testing, a zero-lock plate is provided to keep the swivel frame steady. This plate should not be used for shipping purposes, rather it is suggested to tie the camera support frame to the roll bar cross braces with twine. -
A custom spare parts and accessory box is furnished; it has compartments for "dummy" disks and baffle disks for the test cell. There are also spare tie rods, spacers, counterweight washers and screws. A special wrench is provided for the main bearing unit (over slip ring assembly) and the special nut holding the camera mounting plate to the mounting sleeves. Note that these sleeves are held to the 1" Dia. columns by means of setscrews which fit into countersinks along the column. These countersinks are spaced exactly 1" apart for automatic parallel positioning relative to the turntable. Other items in the accessory box are a zero-lock plate, a gauge for accurate positioning of the camera support bracket in the camera balancing fixture, a variety of spare bolts and a set of Allen wrenches for all sizes encountered in the assembly. Not included, but needed for disassembly are conventional screwdrivers and wrenches (1/2"and 9/16").
The operation is self-evident. It is best to start out with all switches "off", the motor speed potentiometer in the zero position and the motor directional switch in the 'brake' position.

After connection to a grounded 120 V AC receptacle, the unit is activated turning the main power switch on. Telltale LED's will show if 24 or 12 V DC will be supplied to the camera terminal, adjust voltage select switch as needed, hence the DC power supply may be turned on (green LED lights up). Turn on the lights and tachometer as desired. Start table by turning directional selector switch, then advance speed control potentiometer knob to desired position. Activate 16 mm camera with the appropriately marked switch. (Note: in the 24 frame mode, this switch stays "on" for the duration of filming. For any other film speed, flip switch to "on" only briefly, camera will keep running until switch is briefly turned "on" again).
Maintenance is not required for extended periods of time and the above outlined procedure does not have to be followed verbatim, because of the various safety features in the controller (soft start - stop), the mechanical safety clutch. Since the lights and the power supply to the tachometer are 120 V, the unit should never be operated without the provided insulating shields in place to cover the terminal strips. Of course, the control box cover should not be removed without first disconnecting all power.

D.

STRESS ANALYSIS SUMMARY:

The structural adequacy of a test cell assembly (Dwg. MS 783-1) for a 'Low Gravity Experiment for Studying a Rotating Fluid having a Free Surface' (NASA-MSFC contract NAS8-35481), has been analyzed. It has been determined that the requirements of the 'JSC Reduced Gravity Aircraft User's Guide' are met with ample margines of safety. Very conservative assumptions were used in the appended working-paper-calculations, e. g. a welding efficiency of only 50% was assumed, and distributed loads were treated as concentrated loads. The highest stress level for the 9 "g" forward case (an emergency case!) was found to be 7,836 PSI which constitutes a safety margin of 2.7 against yield of the material.

O. C. Holderer

....

O. C. HOLDERER, Precision Devices, Ltd.

October 29, 1983

Precision Devices, Ltd.

DESIGN • ENGINEERING • PRODUCTION OF ELECTRO-MECHANICAL SYSTEMS AND PROTOTYPES

2304 OAKWOOD AVENUE, N.W.
HUNTSVILLE, ALABAMA 35810
TELEPHONE: 534-~~XXXX~~ 4310

E.

October 31, 1983

SINGLE FORCE LOAD TEST

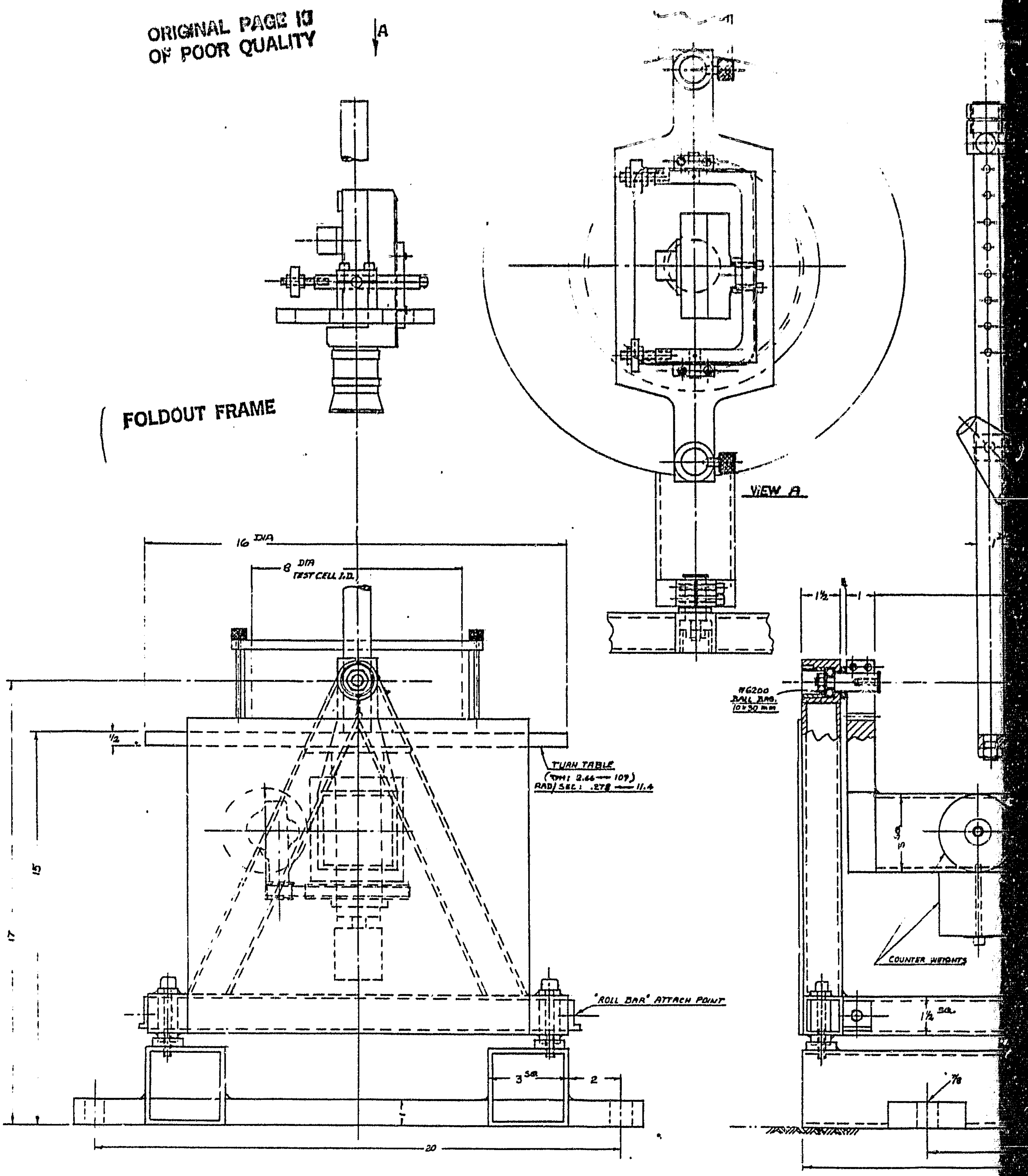
Ref.: Contract NASA-MSFC NAS8-35481

A simulated load test of the cradle (see stress analysis, page 1 of working papers) was performed. Using a special hook and load cell, a 500 lbs. (439 lbs. was calculated maximum) load was applied as shown. The structure sustained this load without permanent deformation or other indication of damage. The test was witnessed by the undersigned:

O. C. Holderer
....
O. C. HOLDERER, Precision Devices, Ltd.

Charlie Schaefer
....
CHARLIE SCHAEFER, ED 42

Fred Leslie
....
FRED LESLIE, ED 42


A
VIEW A
16 DIA
8 DIA TEST CELL I.D.
TURN TABLE
(RPM: 2.66 — 109)
RAD/SEC: .278 — 11.4
#6200 BALL BRG. 10x30 mm
COUNTER WEIGHTS
"ROLL BAR" ATTACH POINT
1½ SQ.
3 SQ.
2
20
15
17
½
1½
1

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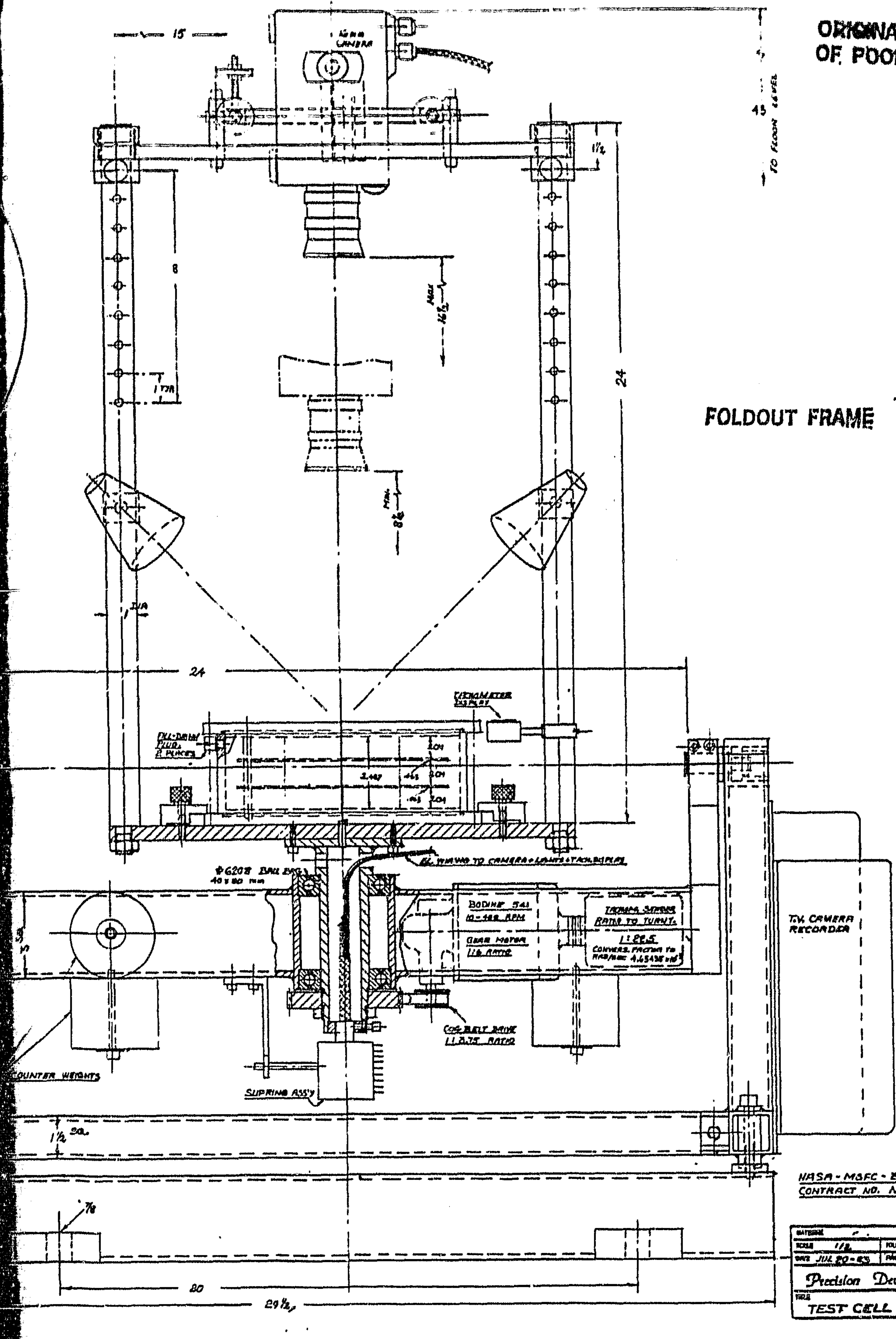
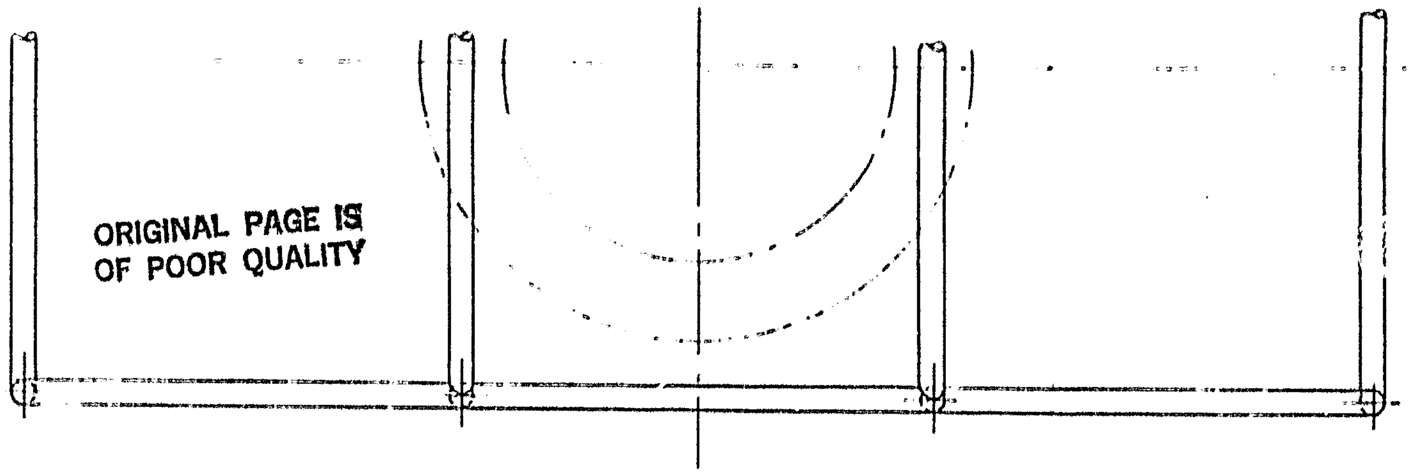
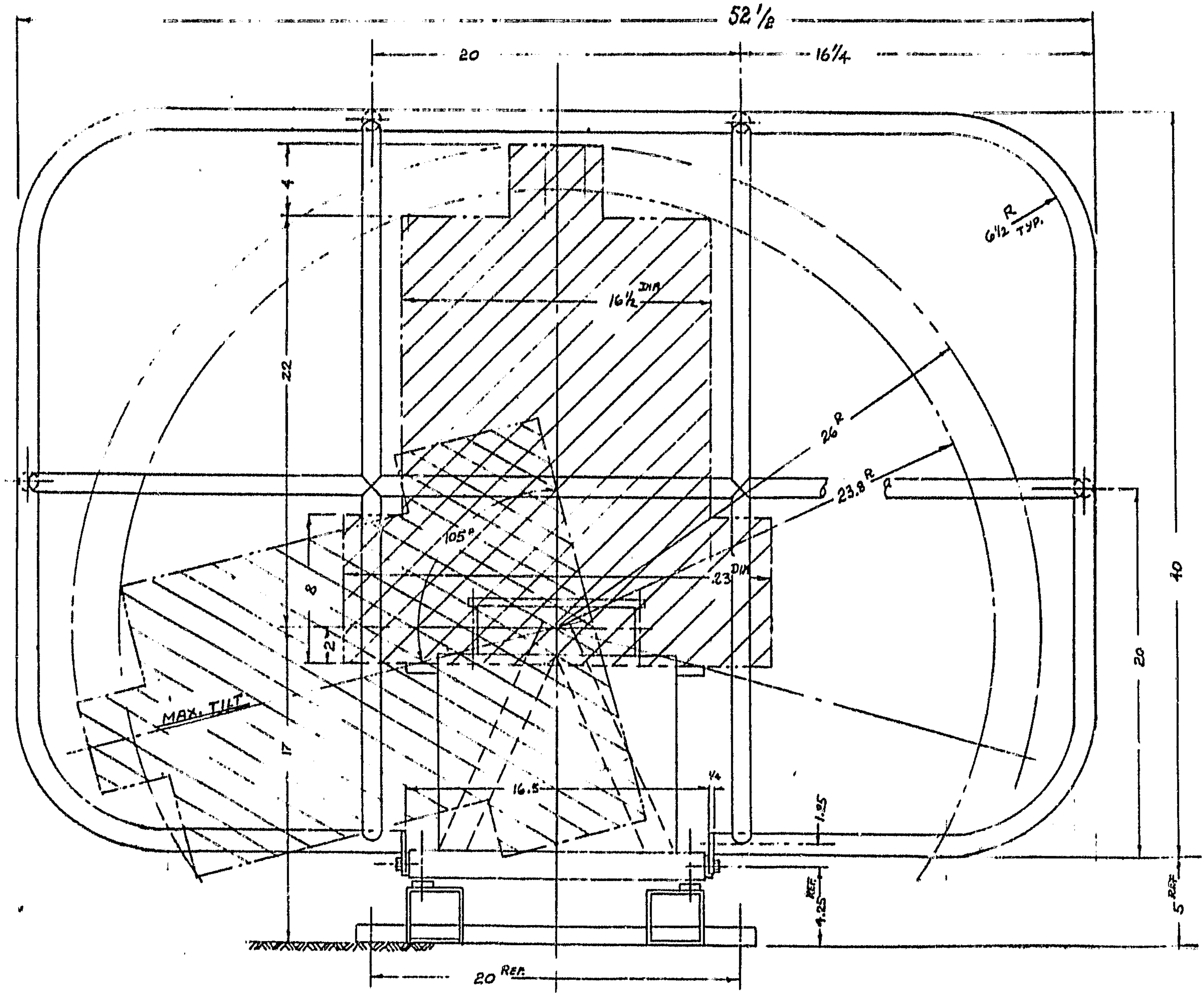


FIG. 1

NASA - MSFC - ED 42
CONTRACT NO. NAS 8-35481

MATERIAL –			REVISION
SCALE 1/8	FOLIO –		APPROVED
DATE JUL 20-83	FINISH –		DRAWN BY OCH
Precision Devices, Ltd.		7204 OAKWOOD AVENUE, N. W. HUNTSVILLE, ALABAMA 35810	
TITLE TEST CELL ASS'Y			DWG NO. MS 783-O





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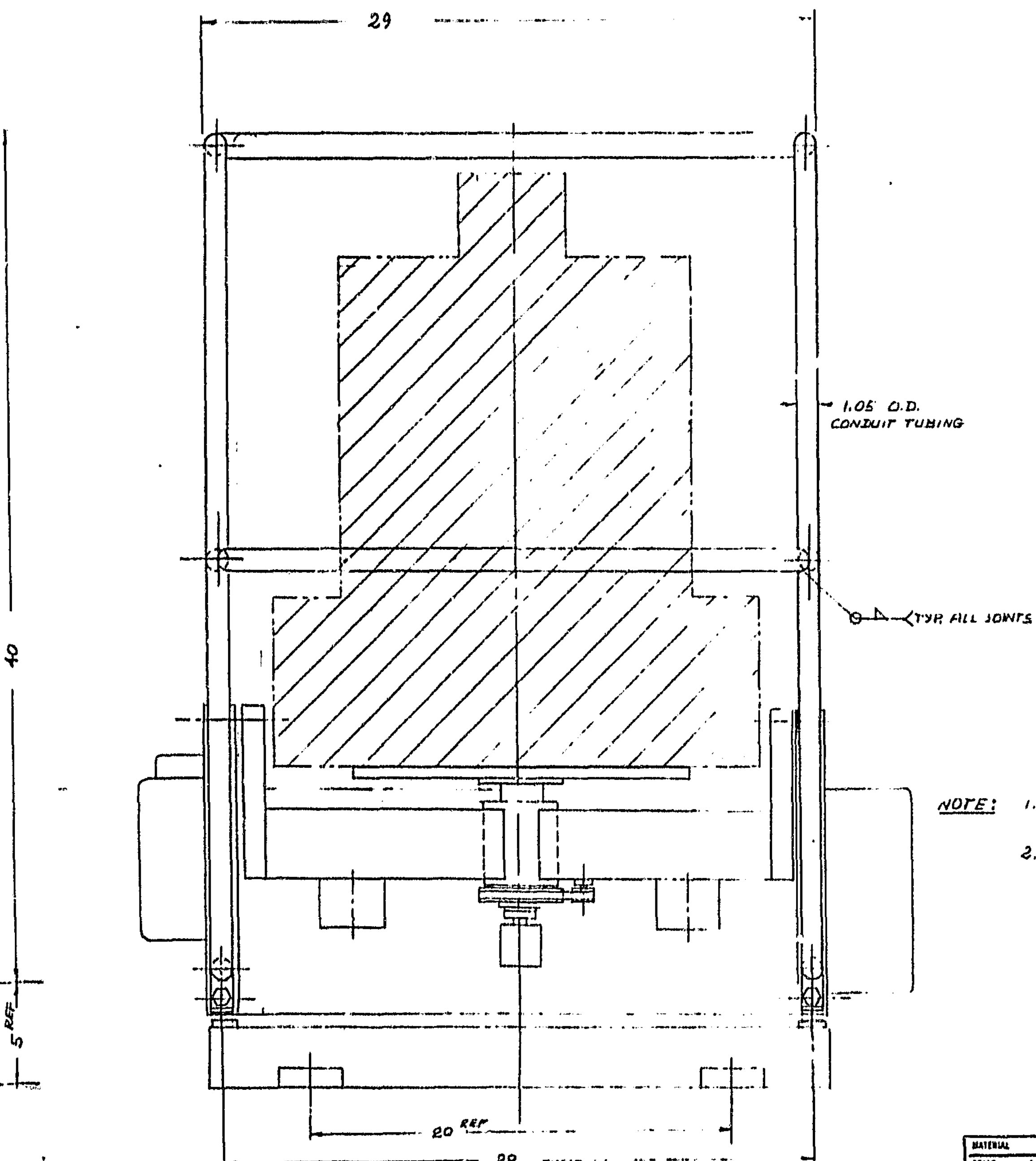

NOTE: 1. FOR NASA MSFC - ED 42
CONTRACT NAS 8 35481

2. SHADED AREAS BOUNDED BY
PHANTOM LINES REPRESENT
ROTATING STRUCTURES,
SEE DWG. MS 783-0

FIG. 2

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Precision Devices, Ltd.	2301 ... AVENUE, N.W., HUNTSVILLE, ALABAMA 35810	
TITLE ROLL BAR		DWG NO. MS 783-1

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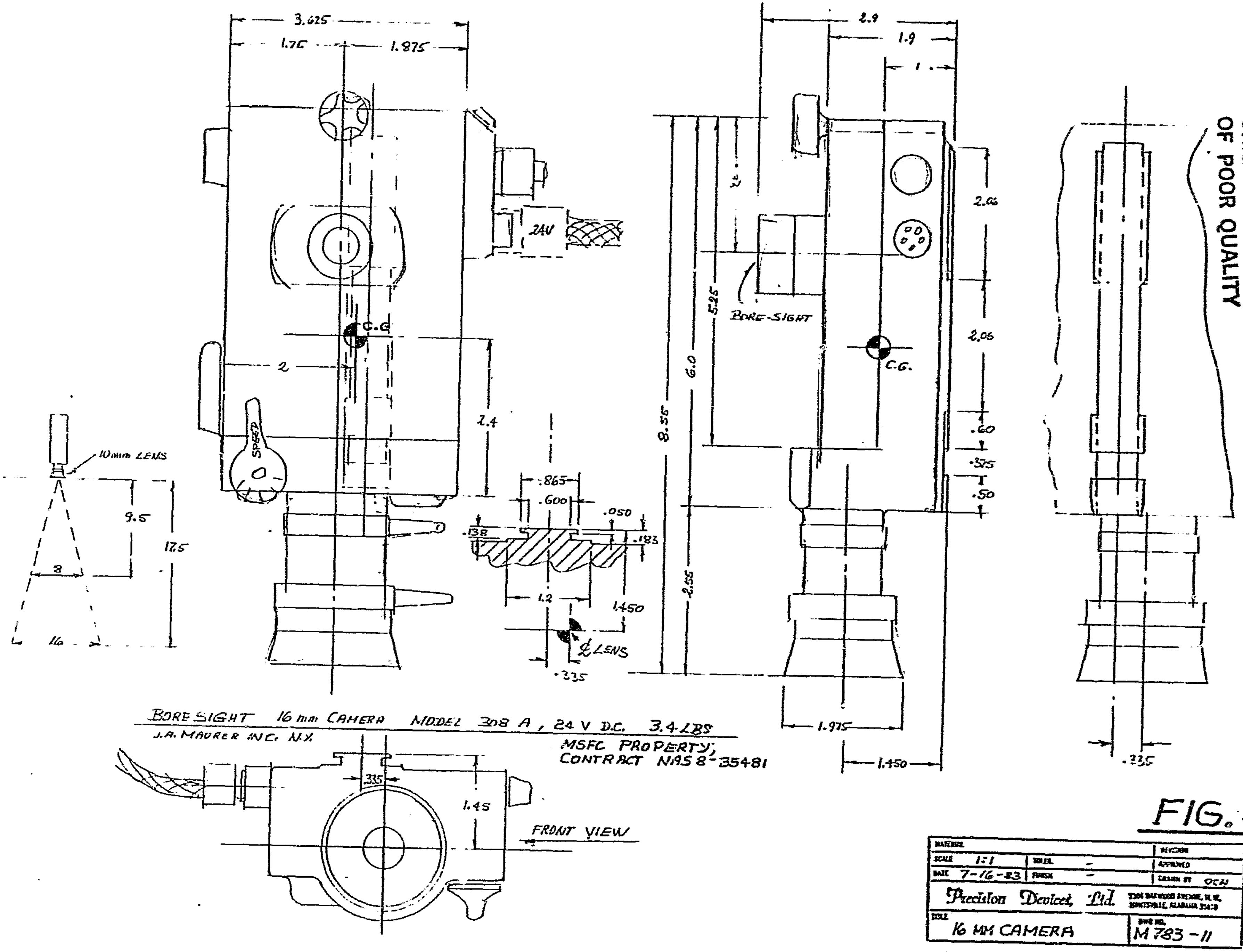

FIG. 3

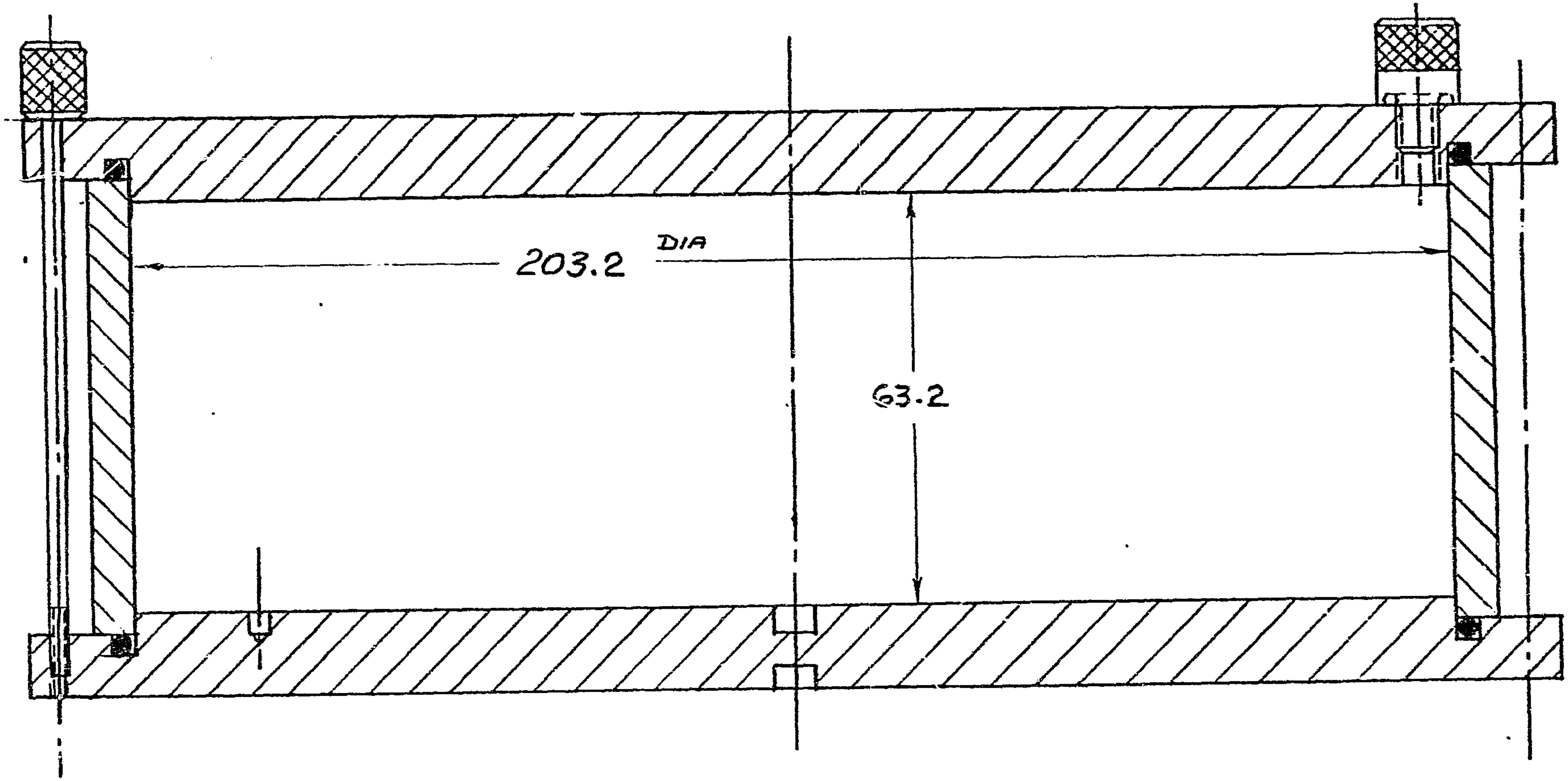

FIG. 4

TEST CELL

CONFIGURATION A

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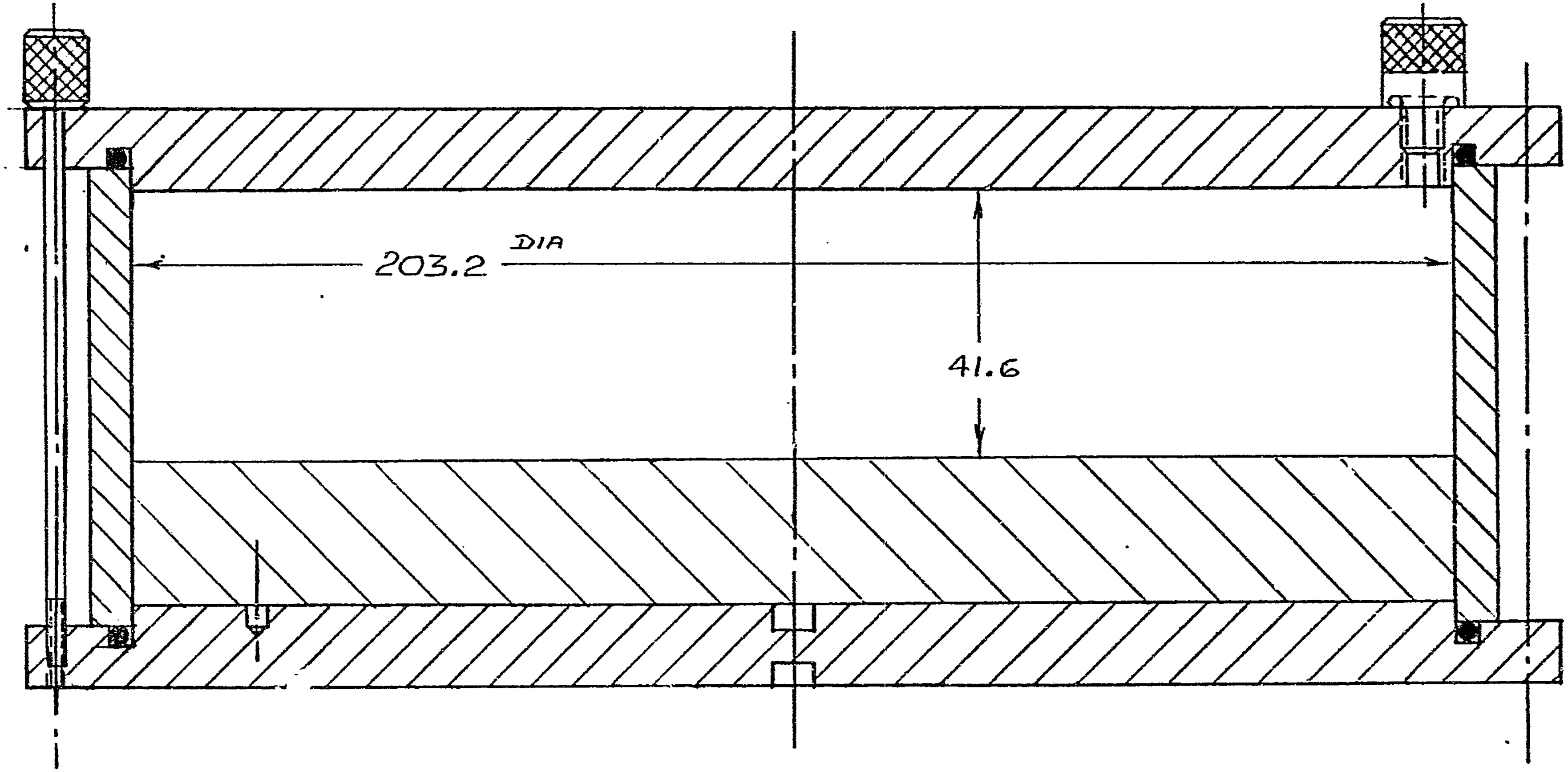
HUNTSVILLE, ALABAMA 35810

OCH. SEP. 20 '83 NASA-MSFC CONTR. NAS 8-35481



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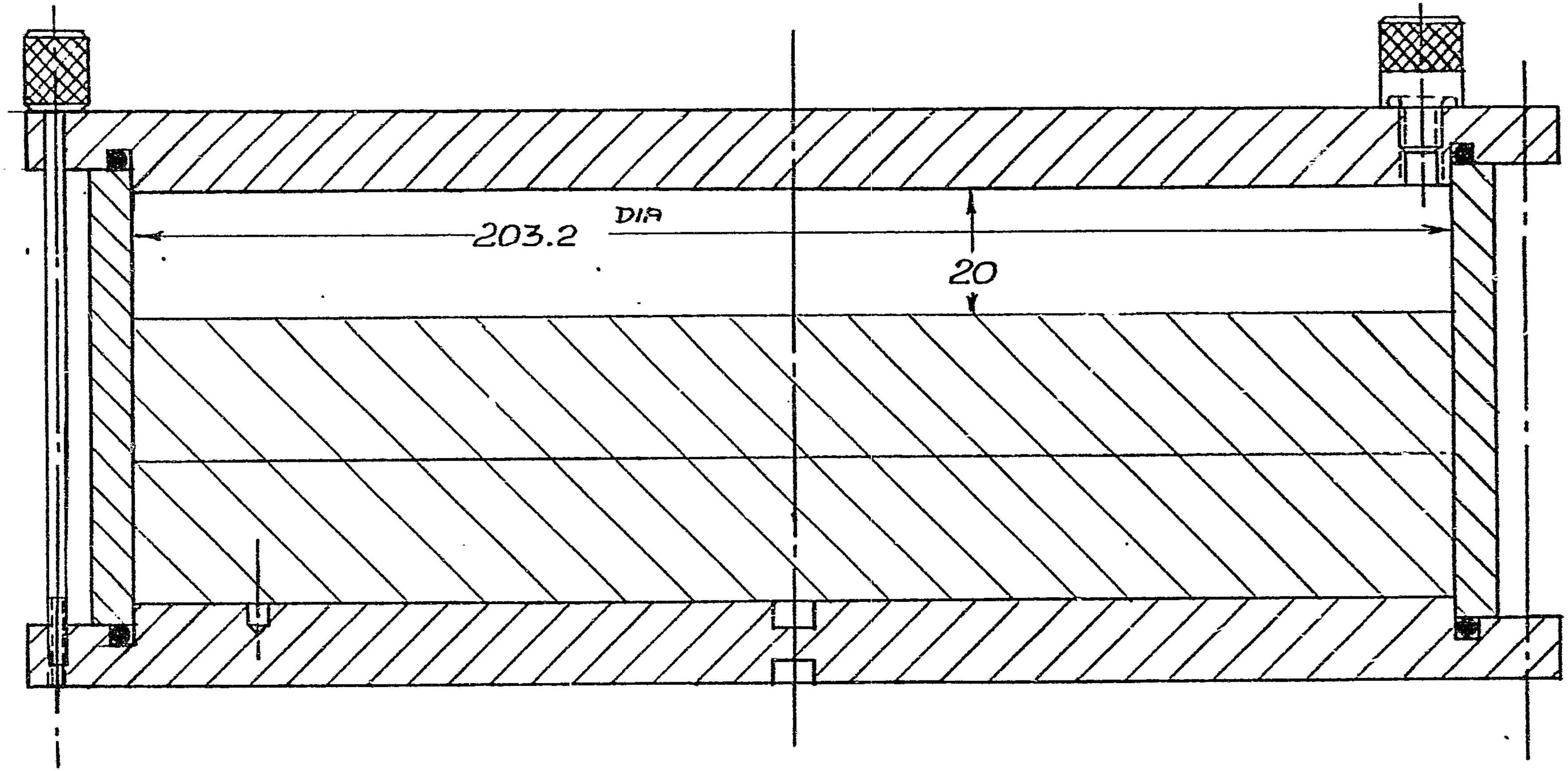
TEST CELL

CONFIGURATION B



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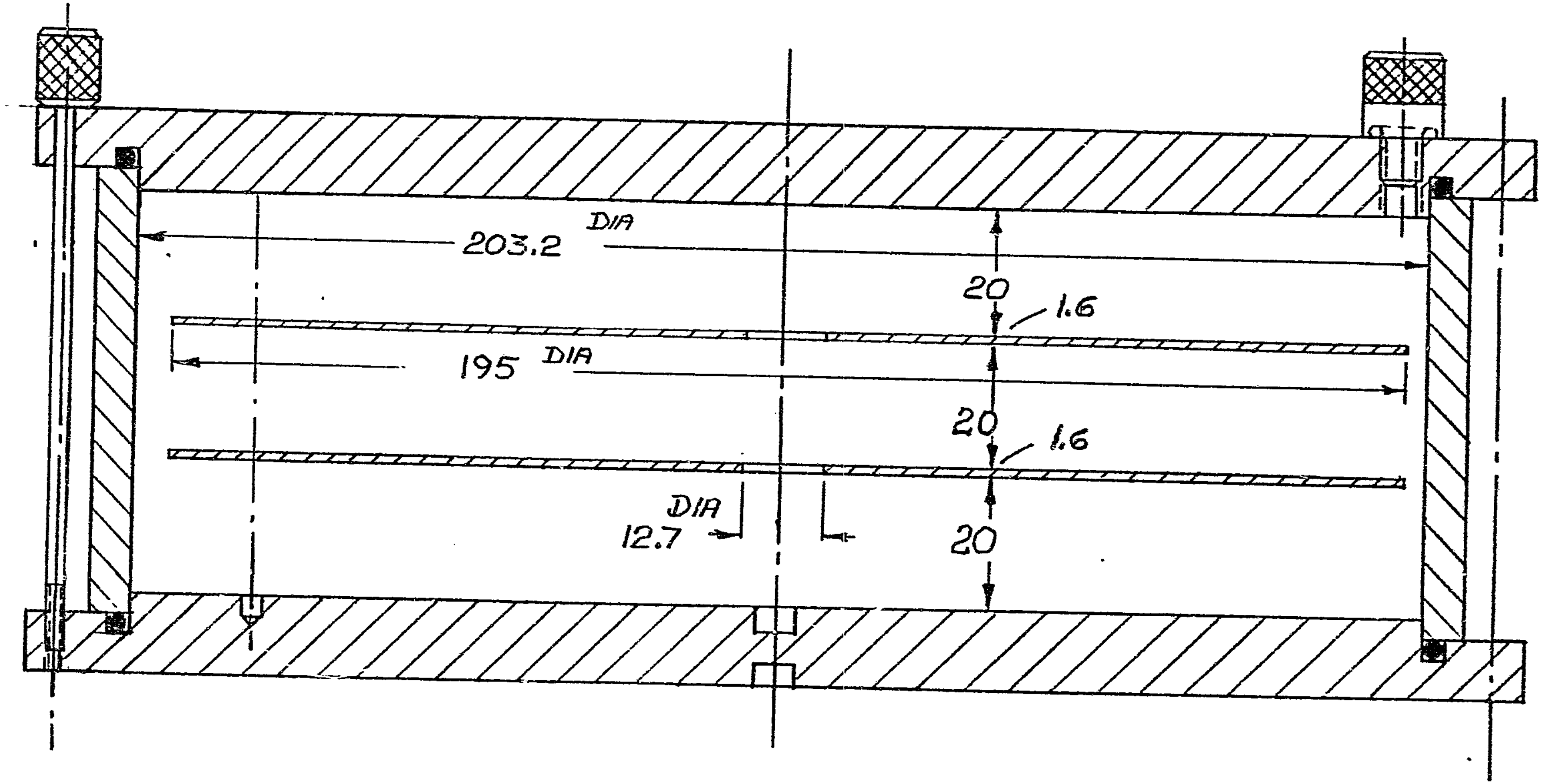
TEST CELL
CONFIGURATION C



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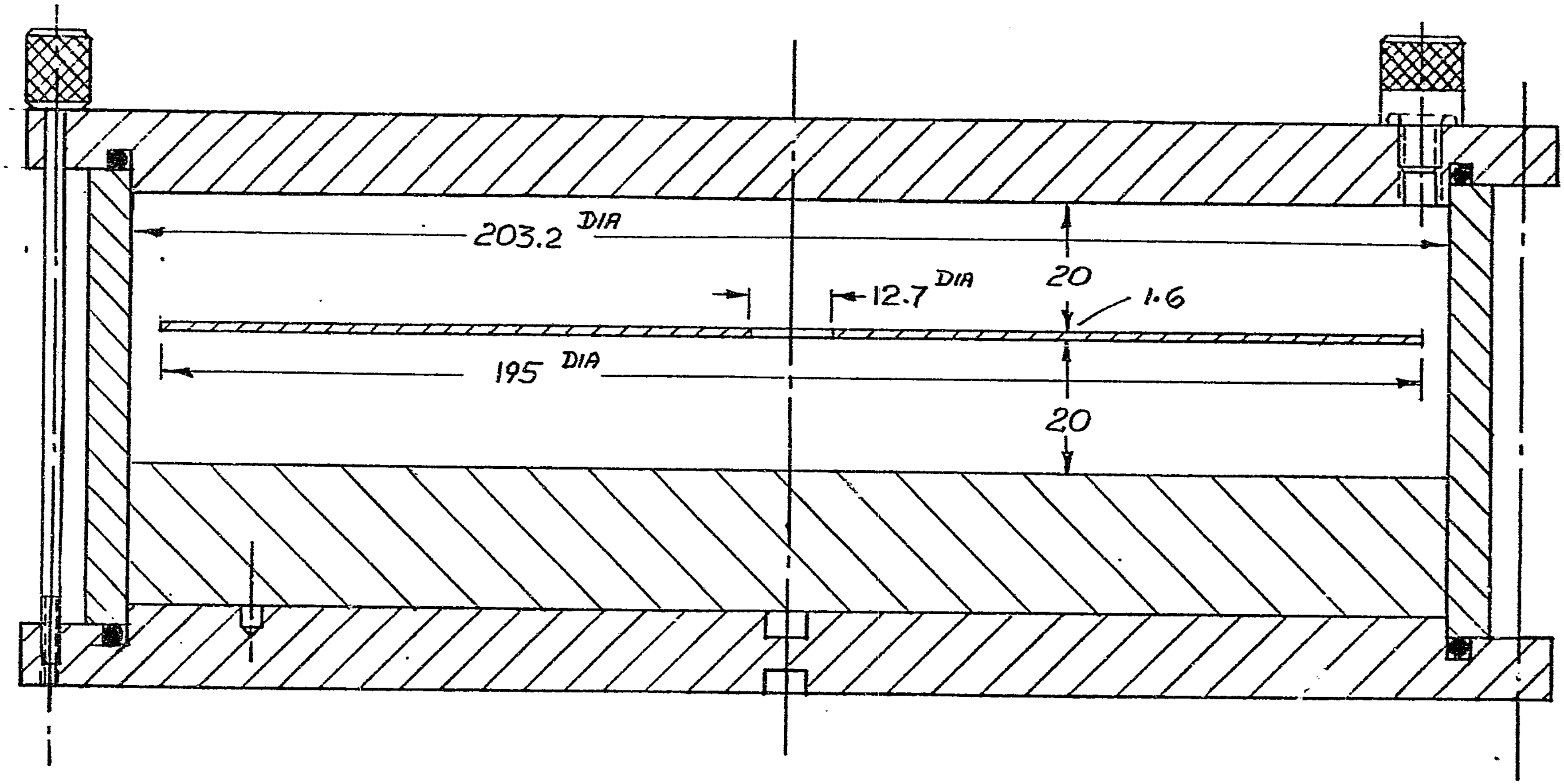
HUNTSVILLE, ALABAMA 35810
OCH. SEP. 20 '83 NASA-MSFC CONTR. NAS 8-35481

TEST CELL

CONFIGURATION D



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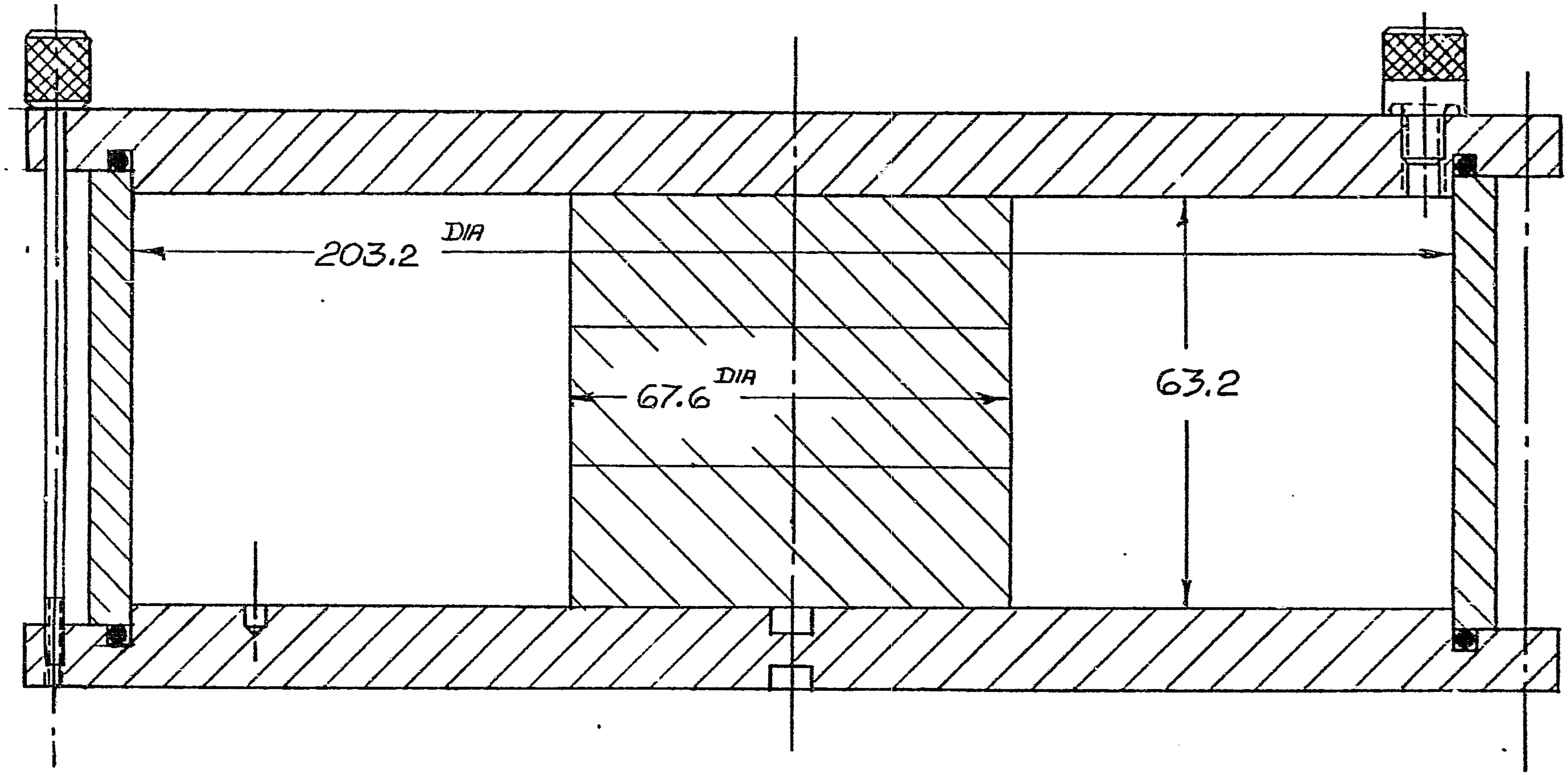
CONFIGURATION E



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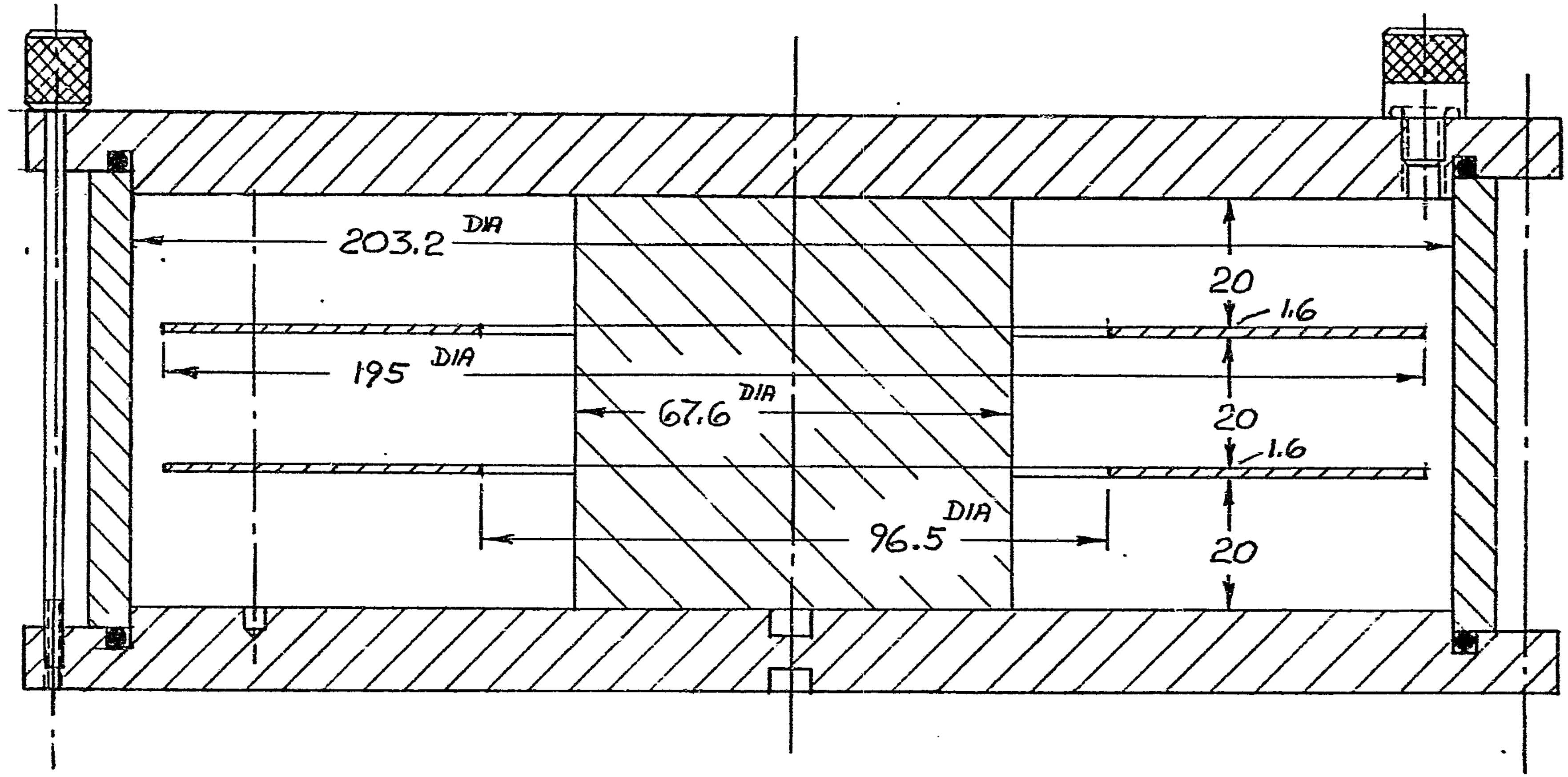
CONFIGURATION F



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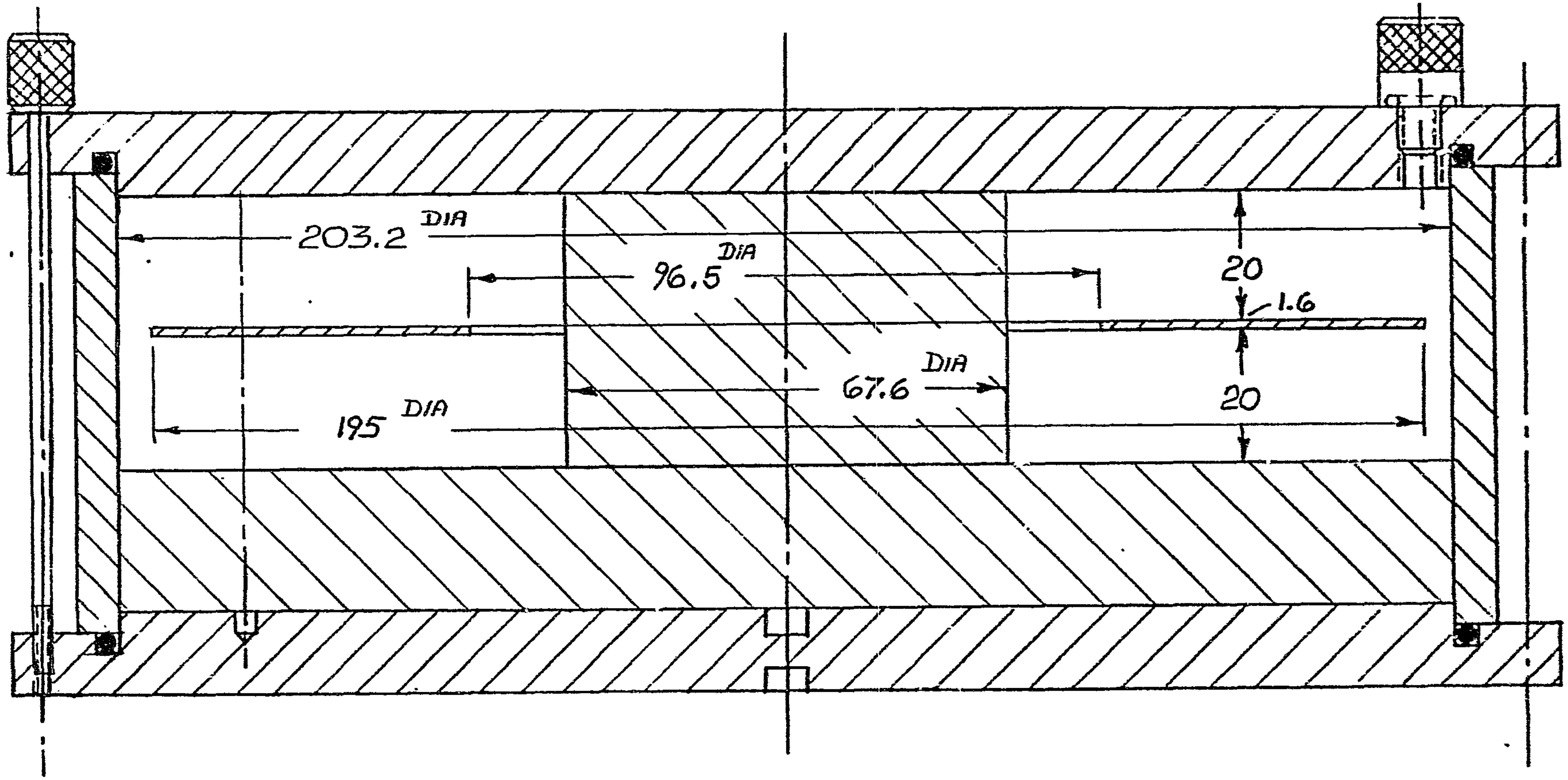

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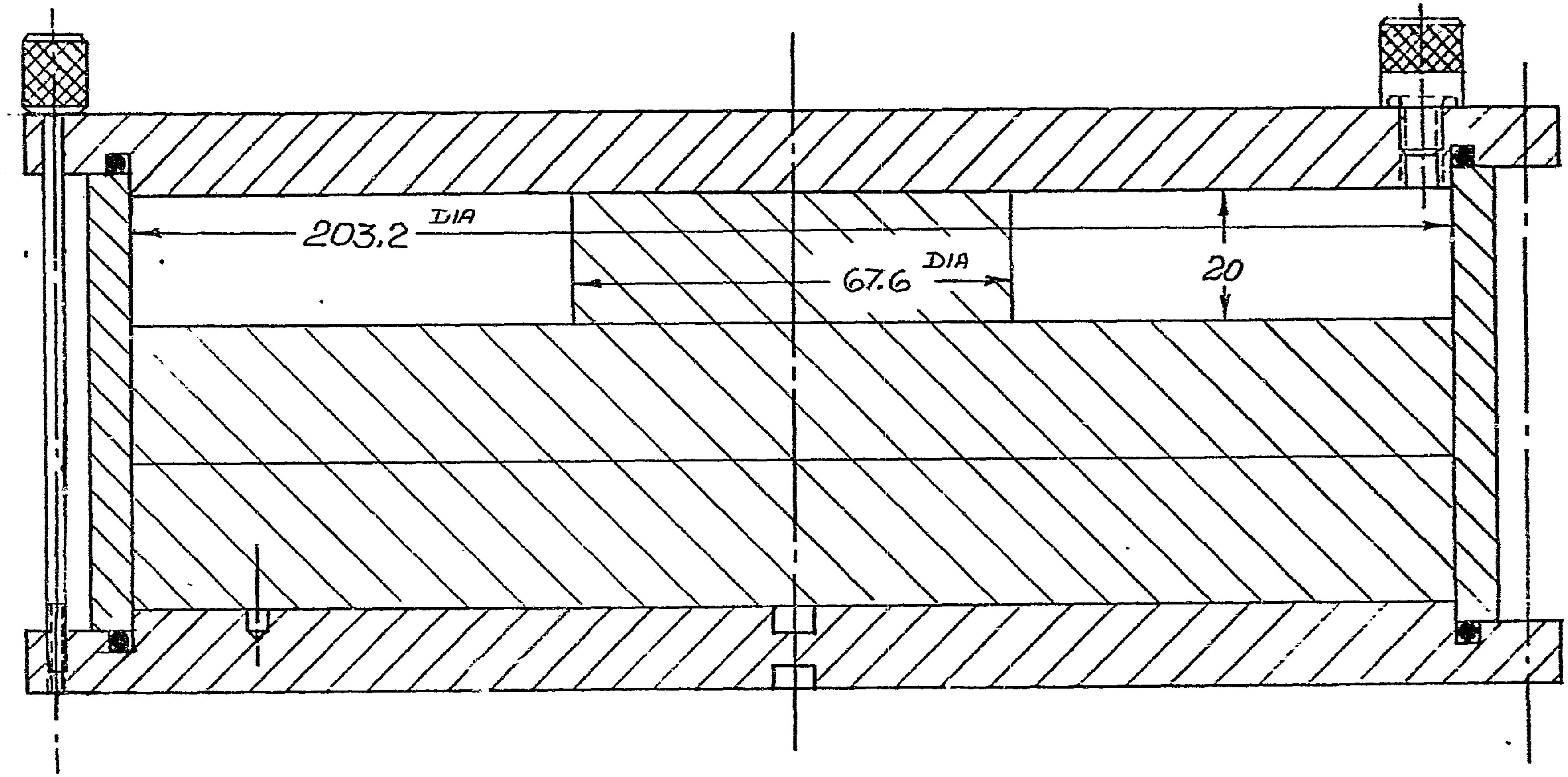

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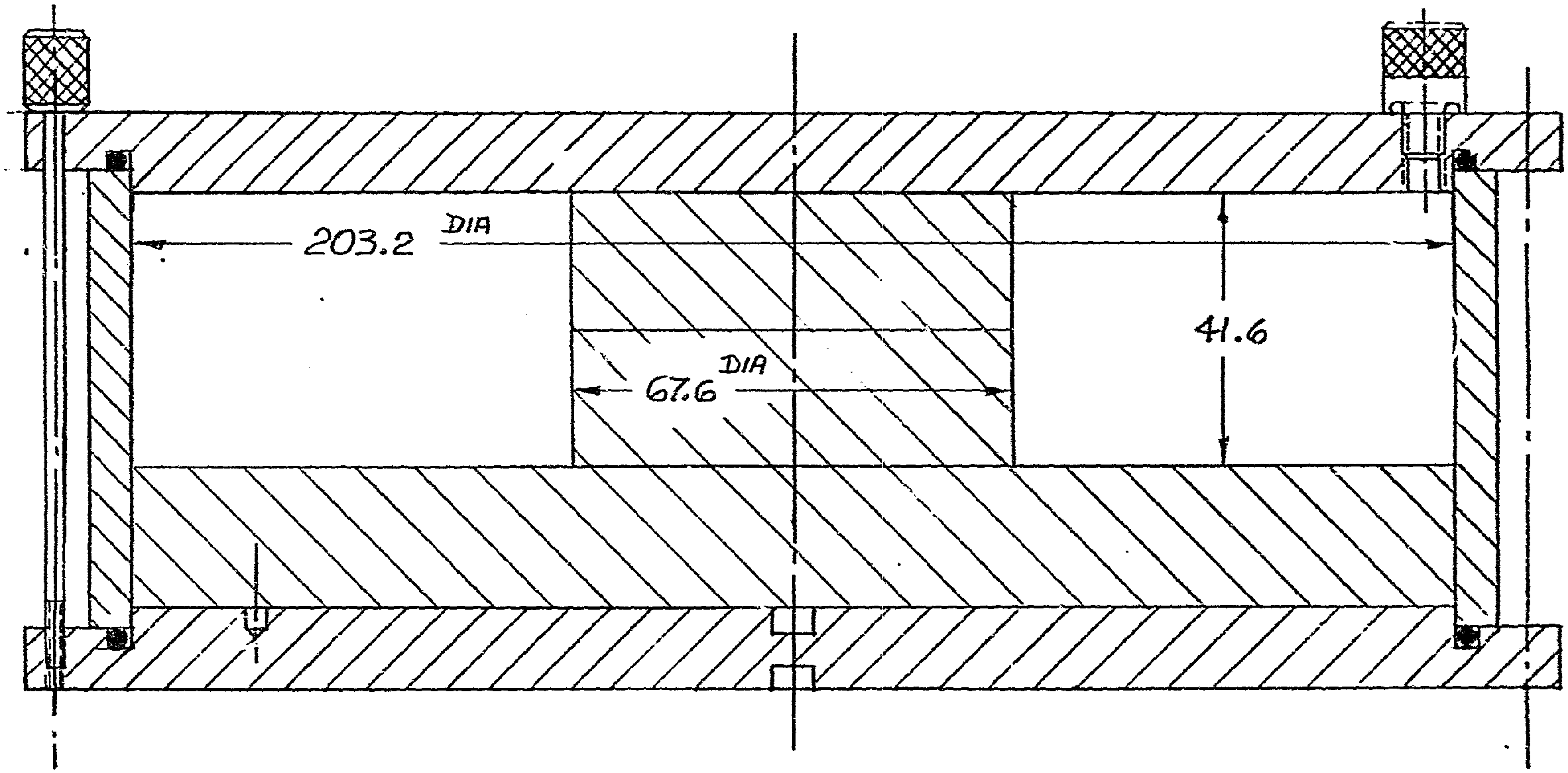
CONFIGURATION I



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HUNTSVILLE, ALABAMA 35810

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CONFIGURATION J

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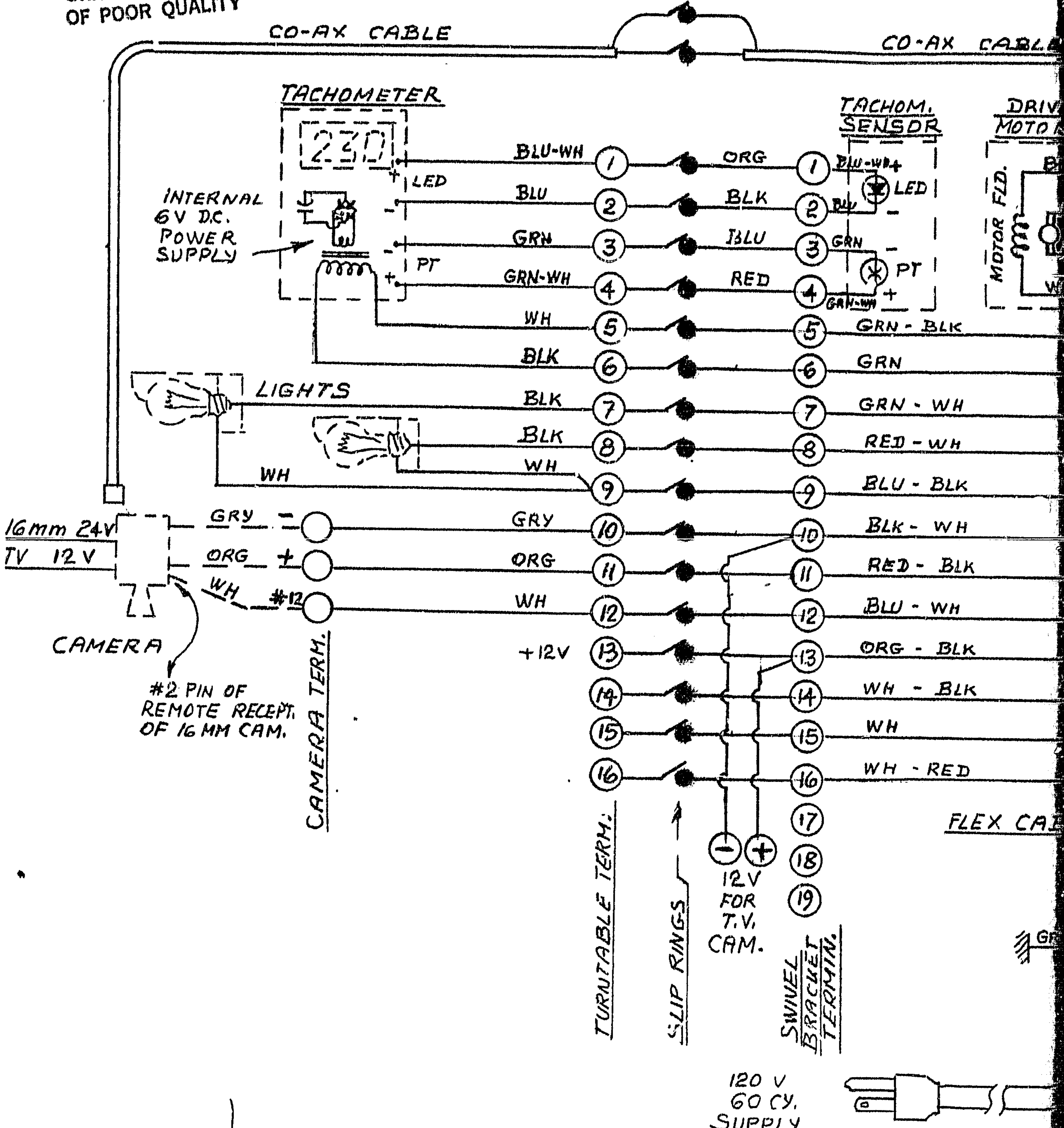

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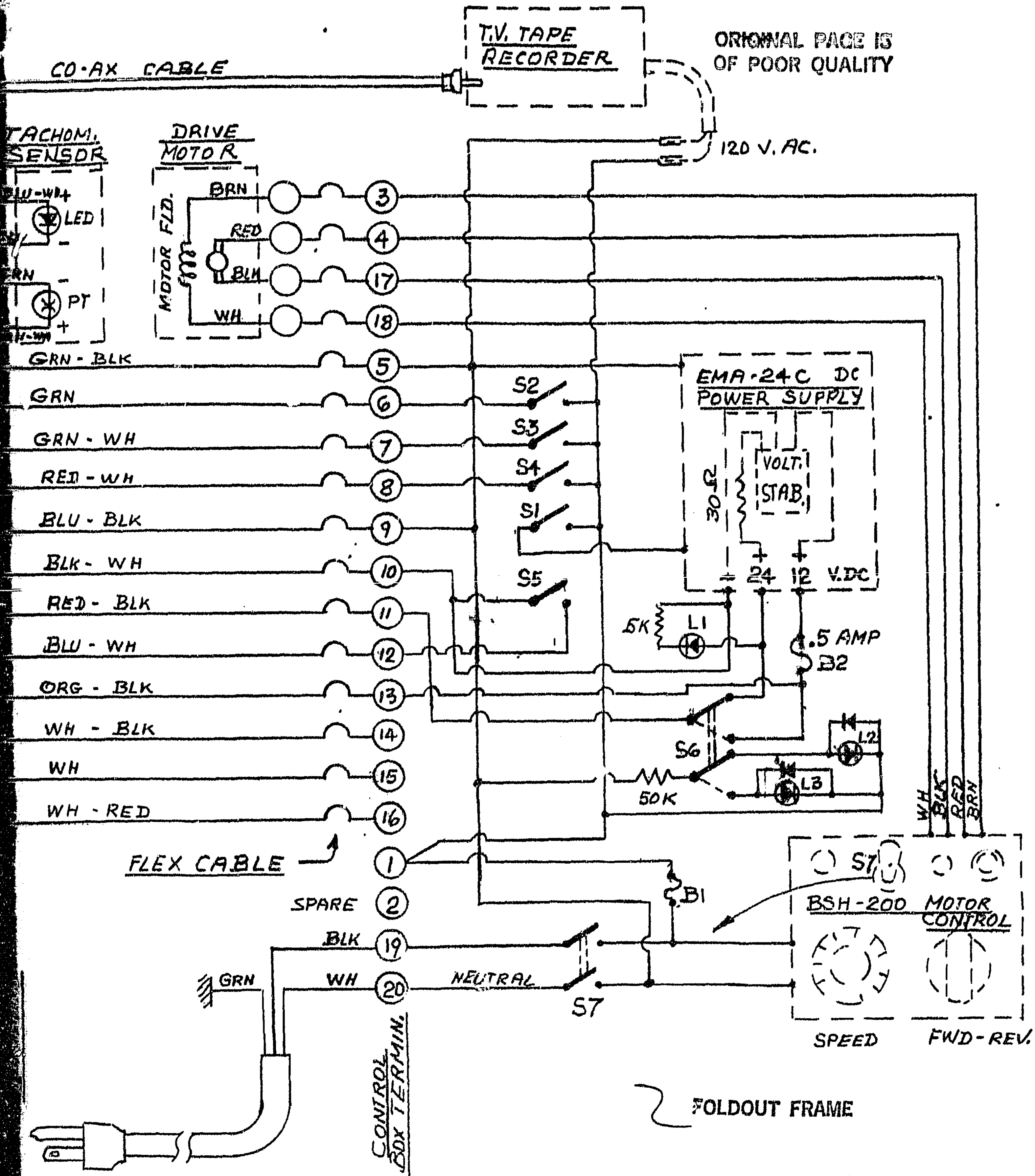

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FIG 5

WIRING SCHEMATIC

INSTRUCTION MANUAL

DIGITAL HAND TACHOMETER

Model HT-331 (0~9,999rpm)

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ONO SOKKI CO., LTD.
Tokyo, Japan

We would like to thank you for purchasing the HT-331 Digital Hand Tachometer and urge that you read this manual carefully before using so that you may get the most out of your new instrument.

Features

The HT-331 is an accurate hand held tachometer that uses an internal optical slit and sensor mechanism to detect and count the rpm of rotating shafts. This method places a very small load on the shaft being measured and results in a rugged instrument with high repeatability.

This HT-331 makes one measurement every per second which is three times the speed of normal clockface type tachometers and repeats measurements automatically. The digital display covers the entire range from 1 to 9,999 rpm without range switching with an accuracy of ±1rpm and an easy to read display.

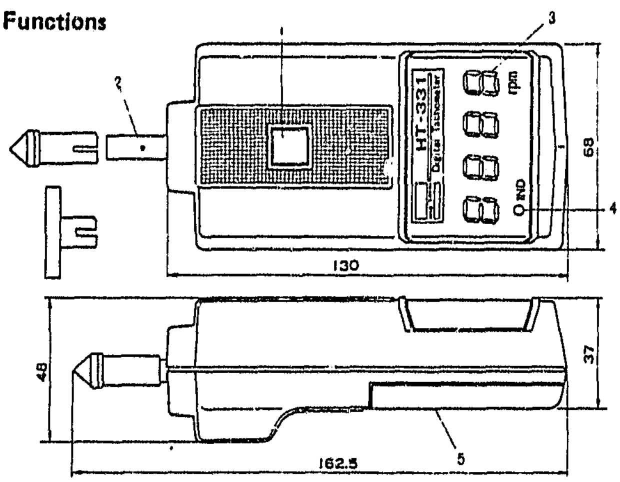
By use of the optional circumferential ring circumferential speed may also be measured with the HT-331.

Specifications

Measurement range :	0 ~ 9,999rpm
Display :	4 digit LED display
Measurement time :	1 second
Accuracy :	±1rpm
Power source :	AA cell x 4
Operating temperature :	0 ~ 45°C
Storage temperature :	–20 ~ +60°C
Weight :	260g (9.2 oz), including batteries
Dimensions :	165 x 68 x 48mm including standard tip.
Accessories :	Hardened rubber conical tip (KS-300) 1 Instruction Manual 1

THIS INSTRUMENT WAS MODIFIED TO INCORPORATE A POWER SUPPLY (6V DC. .2 A) AND THE SENDER WAS SEPARATED FROM THE DISPLAY AND I.C. BOARD

Names of Parts and Functions



1 Power Switch
Pressing this switch applied power to the HT-331 and readies it for use.

2 Sensor Shaft
Fitted with the conical or circumferential tip this shaft is used to pick-up the rpm or circumferential speed respectively of the shaft being measured.

3 Display
This large LED display is used to read directly the measured value in rpm or circumferential speed.

4 Battery LOW Lamp
This lamp comes on when the battery voltage is about to become too low for useful measurements. When this lamp lights it is time to replace the batteries.

FIG. 6

TACHOMETER

POWER/MATE CORP.
514 S. RIVER STREET, HACKENSACK, N.J. 07601
PHONE: (201) 440-3100 TWX: (710) 990-5023

POWER SUPPLY APPLICATION AND MAINTENANCE DATA EMA "C" CASE

SPECIFICATIONS

INPUT: 105 to 125 VAC or 210 to 250 VAC at 47 to 63 Hz. Derate output current 10% for 50 Hz operation.
DC OUTPUT RATINGS: See Voltage/Current Rating Chart. Unit is rated for full current output at temperature between 0°C and +40°C and is linearly derated from +40°C to 65% of the full output at +71°C.
REGULATION: Line regulation is rated at 0.05% for a 10% input voltage change and load regulation is rated at 0.1% for a zero to full load change.
OUTPUT RIPPLE: Better than 1 m V RMS; 3 m V peak to peak typical.
OVERLOAD PROTECTION: Self restoring current limiting (foldback type) is standard.
TEMPERATURE COEFFICIENT: ±0.005%/°C typical. ±0.02%/°C maximum.
COOLING: Convection cooled. Moving air is recommended when mounting in a confined area.
MOUNTING: The open frame mounts on any one of three surfaces
OUTPUT VOLTAGE ADJUSTMENT
The output of all Econo/Mate II power supplies may be adjusted by means of a potentiometer located on the printed circuit board. The potentiometer is labeled 'EO ADJ'. During the adjustment procedure, monitor the DC output voltage by connecting a meter across the output terminals.
INPUT CONNECTIONS
When operating with 115 VAC input, place a jumper between transformer terminals one (1) and two (2) and also between three (3) and four (4). Then connect the AC primary leads to terminals one (1) and four (4) as shown in Fig. 1.
When operating with 230 VAC input, place a jumper between transformer terminals two (2) and three (3) and connect the AC primary leads to terminals one (1) and four (4) as shown in Fig. 2.
SECONDARY TRANSFORMER CONNECTIONS
On certain models it will be necessary to connect the transformer secondary to the PC board before adjusting the output voltage. This is accomplished by soldering the loose wire attached to the PC board to the appropriate tap on the transformer.
LOCAL SENSING
ECONO/MATE II power supplies are factory wired for local sensing. Sensing terminals are located on the PC board. A jumper connecting the DC output and sensing terminals provides local sensing as shown in Fig. 3.
REMOTE SENSING
Remote sensing is a standard feature. To sense the output voltage directly at the load, disconnect the jumpers between the DC output terminals and sensing terminals. Connect the load to the DC output terminals. Then wire the (+) and (−) sensing terminals respectively across the load as shown in Fig. 4. This permits sensing directly at the load.

VOLTAGE/CURRENT RATING CHART

MODEL	RATING
EMA-5/6C	5V@6.0A
	6V@5.0A
EMA-9/10C	9V@3.8A
	10V@3.6A
EMA-12/15C	12V@3.0A
	15V@2.8A
EMA-18/20C	18V@2.5A
	20V@2.3A
EMA-24C	24V@2.3A

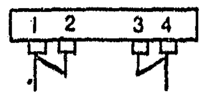


Fig. 1

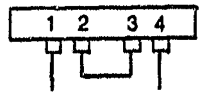


Fig. 2

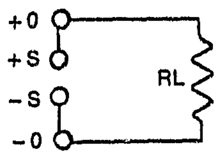


Fig. 3

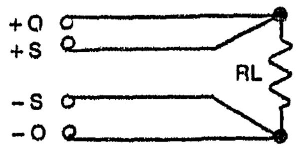
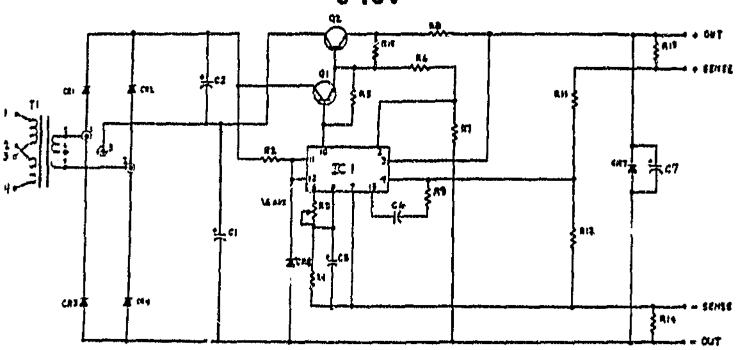


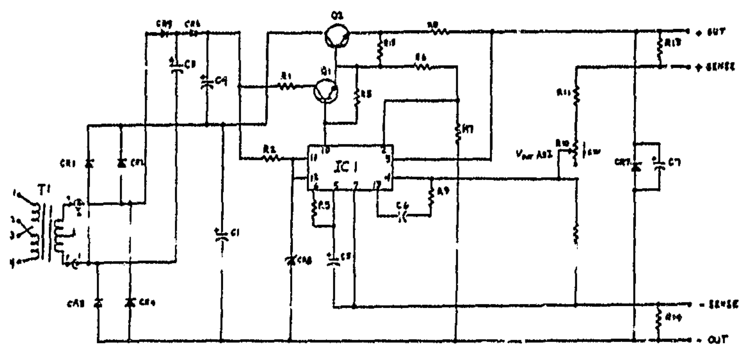
Fig. 4

SCHEMATIC

5-10V



12-24V



SCH. REF.	PMC PART NUMBER	DESCRIPTION	5/6	9/10	12/15	18/20	24
C1	CE223015	22,000MFD, 15V	1				
C1	CE103025	10,000MFD, 25V		1			
C1	CE682035	6,800MFD, 35V			1		
C1	CE147263	4,700MFD, 50V				1	1
C2	CE410800	1000MFD, 16V	1				
C2	CE233700	330MFD, 35V		1			
C3	CE233700	330MFD, 35V			1		
C3	CE265700	220MFD, 50V				1	1
C4	CE233700	330MFD, 35V			1		
C4	CE625700	220MFD, 50V				1	1
C5	CT247500	4.7MFD, 35V	1	1	1	1	1
C6	CD310200	.001MFD, 500V	1	1	1	1	1
C7	CE410800	1,000MFD, 16V	1				
C7	CE233700	330MFD, 35V		1			
C7	CE682035	6,800MFD, 35V			1		
C7	CE625700	220MFD, 50V				1	1
CR1	DR003000	1AMP, 200V	1	1			
CR1	DR039000	5AMP, 100V			1	1	1
CR2	DR003000	1 AMP, 200V	1	1			
CR2	DR039000	5 AMP, 100V			1	1	1
CR3	DR085000	MR751, DIODE	1	1			
CR3	DR039000	5 AMP, 100V			1	1	1
CR4	DR085000	MR751, DIODE	1	1			
CR4	DR039000	5 AMP, 100V			1	1	1
CR5	DR003000	1 AMP, 200V			1	1	1
CR6	DR003000	1 AMP, 200V			1	1	1
CR7	DR039000	5 AMP, 100V	1	1	1	1	1
CR8	DZ211600	1N4752A DIODE		1	1	1	1
IC1	QI001500	I.C.	1	1	1	1	1
Q1	QP001300	TRANSISTOR 64502	1	1			
Q1	QS055000	TRANSISTOR 2N2102			1	1	1
Q2	QF001300	TRANSISTOR 64502	1	1	1	1	1
R1	RF210109	100 OHM, 3W, 5%			1		
R1	RE215100	150 OHM, 2W, 5%				1	
R1	RE222100	220 OHM, 2W, 5%					1
R2	RC215100	150 OHM, ½W, 10%	1	1			
R2	RC227100	270 OHM, ½W, 10%			1		

SCH. REF.	PMC PART NUMBER	DESCRIPTION	5/6	9/10	12/15	18/20	24
R2	RE210200	1K OHM, 2W, 10%				1	
R2	RF215200	1.5K OHM, 3W, 5%					1
R3	PF220201	2K OHM, 3W, 20%	1	1			
R3	RC311500	1.15K OHM, 2W, 1%			1	1	1
R4	RC334800	3.48K OHM, 2W, 1%	1	1			
R5	RB227200	2.7K OHM, ¼W, 5%	1	1	1	1	1
R6	RB212100	120 OHM, ¼W, 5%	1				
R6	RB215100	150 OHM, ¼W, 5%		1			
R6	RB262100	620 OHM, ¼W, 5%					1
R7	RB243100	430 OHM, ¼W, 5%	1				
R7	RB210200	1K OHM, ¼W, 5%		1	1		
R7	RB268200	6.8K OHM, ¼W, 5%				1	
R7	RB212300	12K OHM, ¼W, 5%					1
R8	RF050000	05 OHM, 3W, 5%	1				
R8	RF200150	.15 OHM, 3W, 5%		1	1		
R8	RF200200	.2 OHM, 3W, 5%				1	
R8	RF200240	.24 OHM, 3W, 5%					1
R9	RB233200	3.3K OHM, ¼W, 5%	1	1	1	1	1
R10	RC386600	866 OHM, ½W, 1%	1	1			
R10	PF220201	2K OHM, 3W, 20%			1	1	1
R11	RC310200	1K OHM, ½W, 1%			1		
R11	RC315001	1.5K OHM, ½W, 1%				1	1
R12	RC386600	866 OHM, ½W, 1%		1			
R12	RC320500	2.05K OHM, ½W, 1%			1		
R12	RC311500	1.15K OHM, ½W, 1%					1
R13	RB210000	10 OHM, ¼W, 5%	1	1	1	1	1
R14	RB210000	10 OHM, ¼W, 5%	1	1	1	1	1
R15	RB210100	100 OHM, ¼W, 5%	1	1			
R15	RB218100	180 OHM, ¼W, 5%			1		
R15	RB222100	220 OHM, ¼W, 5%				1	1
T1	TA2811901	TRANSFORMER	1				
T1	TA2811902	TRANSFORMER		1			
T1	TA2811903	TRANSFORMER			1		
T1	TA2811904	TRANSFORMER				1	
T1	TA2811905	TRANSFORMER					1

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FIG 7 POWER SUPPLY

PR-0556

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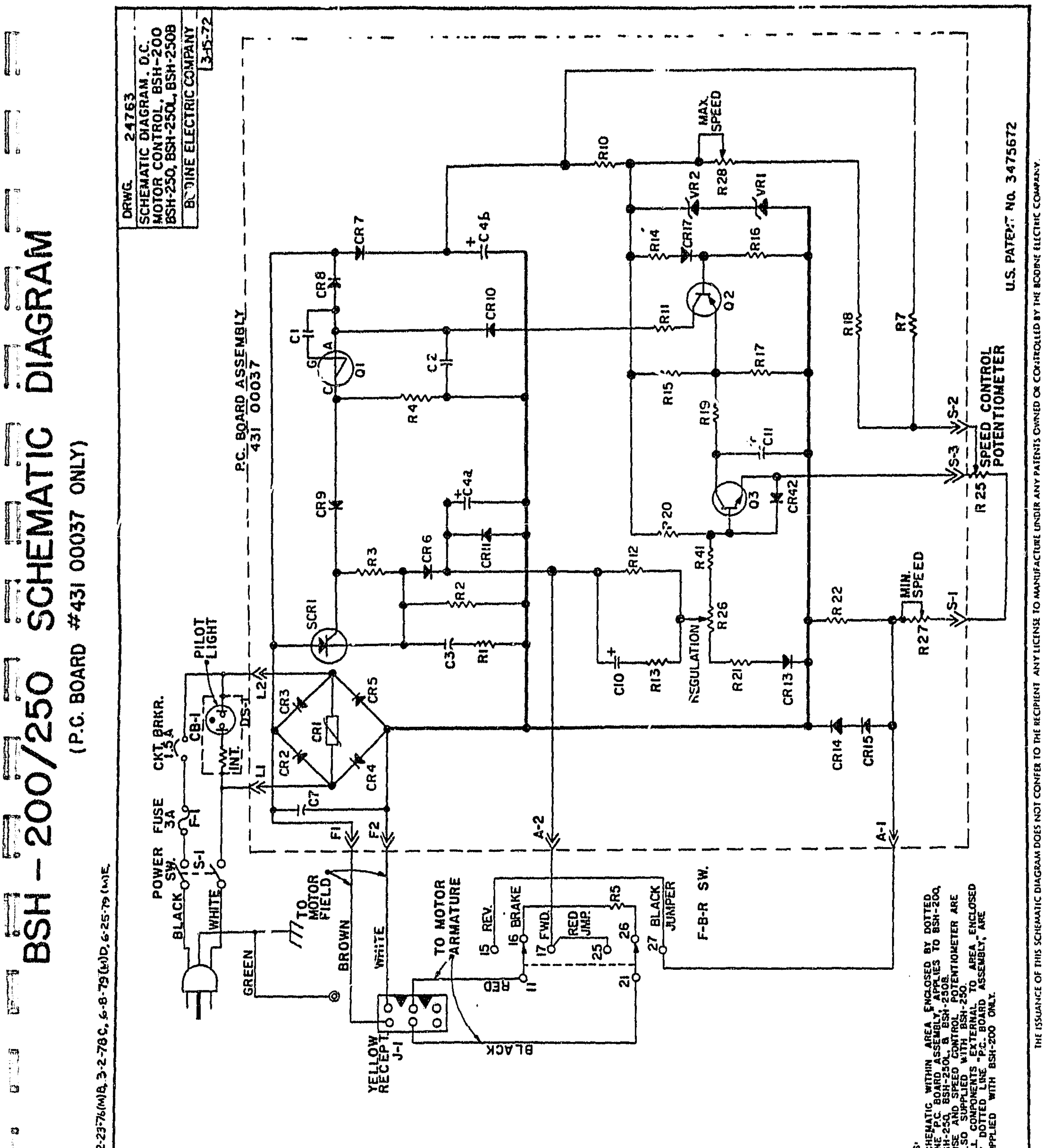
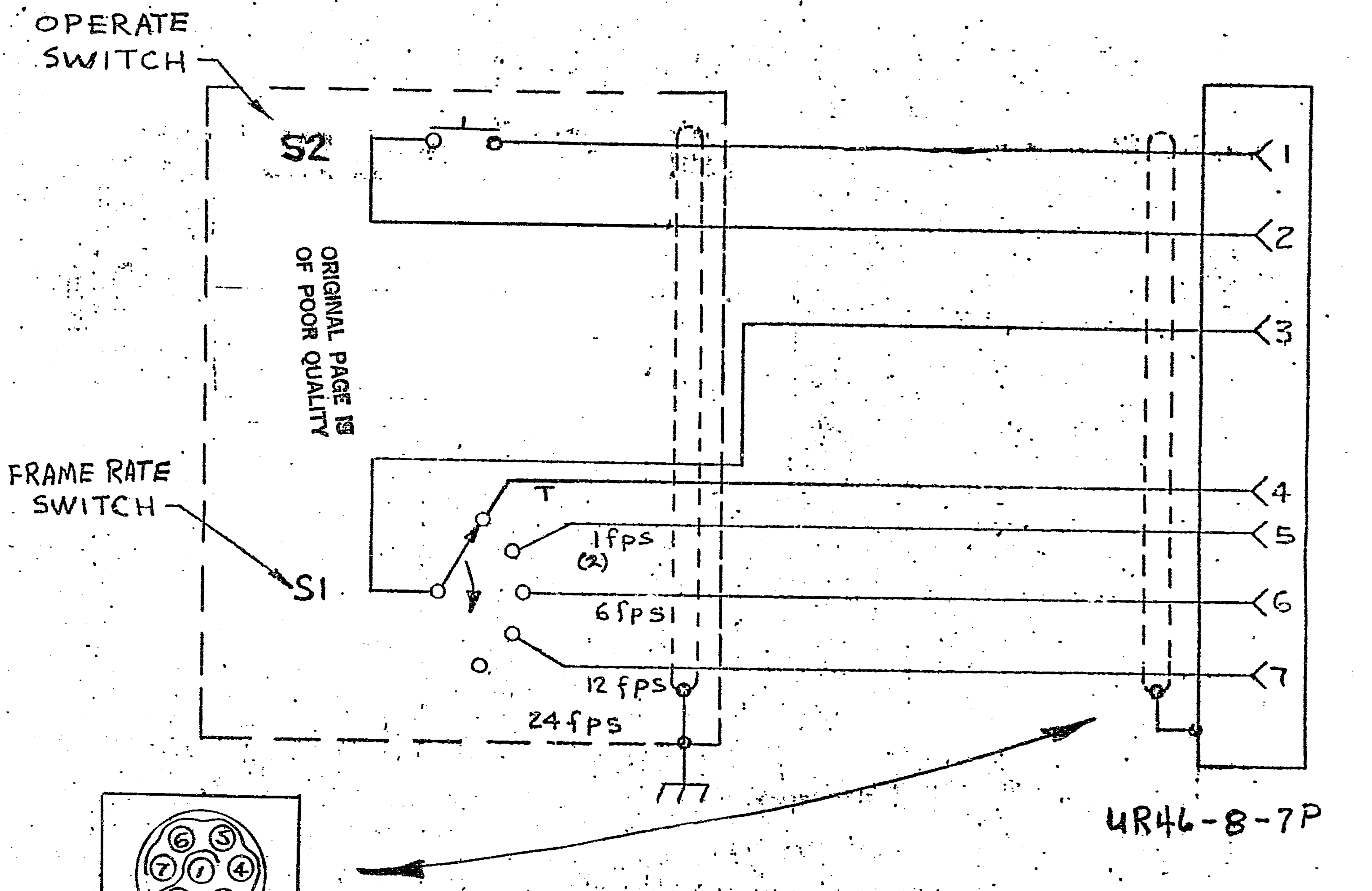


FIG. 8

MOTOR CONTROL



16mm Data Acquisition Camera Remote Control Schematic (JSC DWG.)

FIG. 9

CAMERA SCHEMATIC

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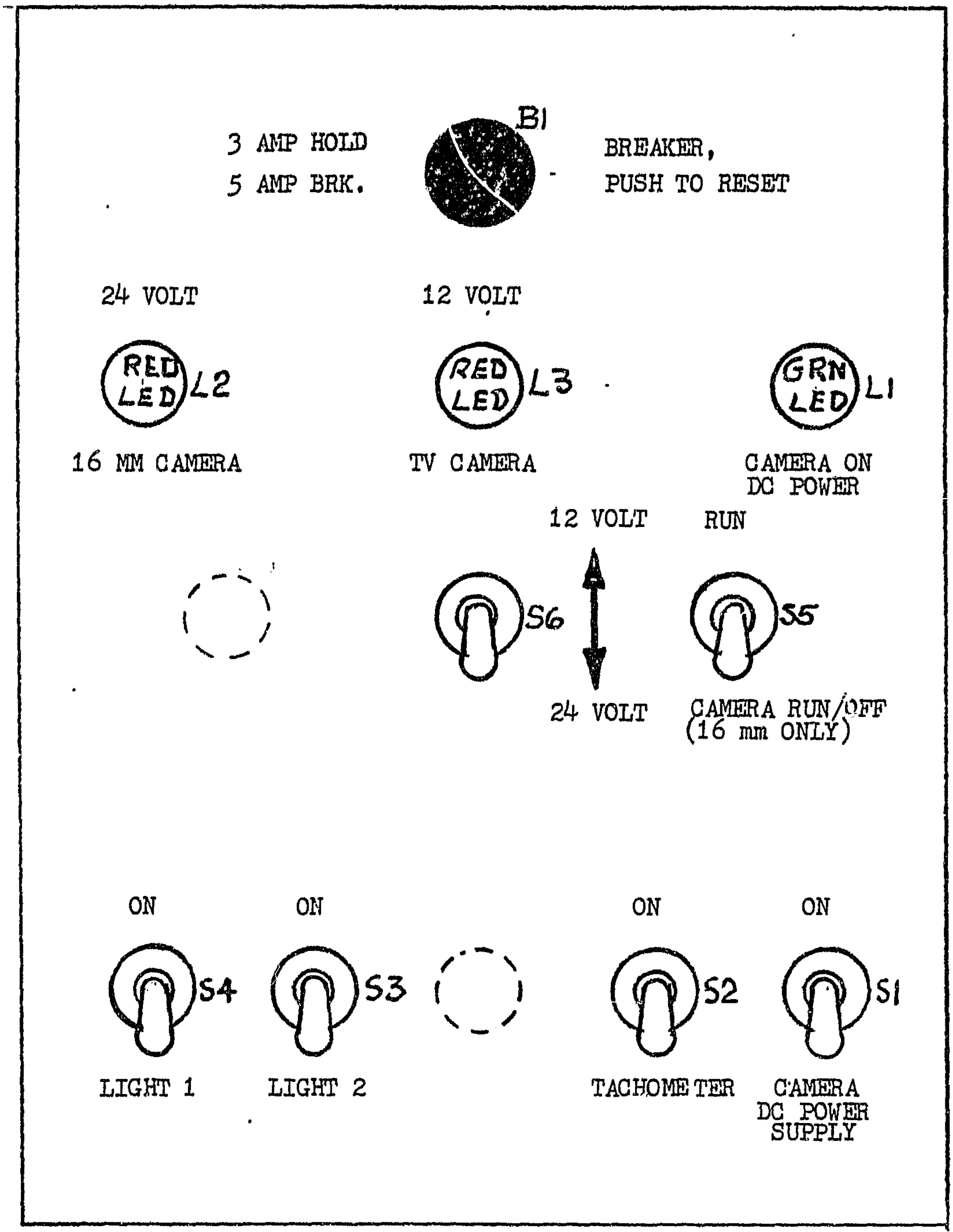

FIG. 10

CONTROL PANEL

ROTATIONAL SPEED CHECK

Motor Speed	Observed Motor RPM from approx. 30 readings over 1 min. period			Max. Deviation from avg. %	Average Table RPM	Average Table r d/sec.
	Max.	Min.	Avg.			
10	130	116	123	5.6	5.47	.57
20	380	366	373	1.9	16.6	1.74
40	901	884	893	1	39.7	4.16
60	1472	1456	1464	.6	65	6.8
80	2007	1992	2000	.4	88.9	9.3
100	2451	2437	2444	.3	109	11.4

FIG. 11