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Power
Module
Control
Moment
Gyro

Summary
Report

30 April 1979

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SECTION 1.0

POWER MODULE CMG APPLICATION STUDY RESULTS

1.0 DESIGN MODIFICATIONS

1.1 Directed Modifications

The directed design modifications to the Skylab/ATM CMG for application to the Power Module include the following:

(a) New rotors of a different material, in accordance with MSFC Spec. 522A, with high resistance to stress corrosion cracking. The selected material is Custom 455-H1000.

(b) Incorporation of the spin bearing retainer fix determined during post Skylab Mission activities.

(c) Improvement in the speed pickoff through the use of pickoff thermal cycling screening tests.

(d) Incorporation of Unlimited Gimbal Freedom on both axes using Slip Ring Assemblies (SRA).

(e) Incorporation of on-orbit replacement capability for the CMG Assembly and the Inverter Assembly (IA).

1.2 Additional Modifications

As a result of a review of the Skylab Mission support activities, it was decided to incorporate a Dual Range Speed Output for telemetry into the IA to additionally aid in health status monitoring during the Power Module Mission.

2.0 CMG HARDWARE IMPACT

2.1 General

The hardware effort applicable to the conversion of the Skylab/ATM CMG subsystems to Power Module CMG subsystems consists of incorporating the design modifications, deleting unused hardware where necessary and refurbishment. These efforts are briefly described and listed in the tabulations that follow.

2.2 CMG Assembly (With EA)

The design modifications impact the Inner Gimbal and Rotor Assembly (IGRA), the Sensor Pivot Assemblies (Inner Gimbal and Outer Gimbal), the Frame (Mounting Ring) and internal CMG Assembly electrical wiring.

2.2.1 IGRA

The modification impact on the IGRA includes the incorporation of new rotors (of a different material - Custom 455-H1000), spin bearings with new retainers and magnetic speed pick-ups which are thermal cycle screened. In addition, a new design internal IGRA wiring harness will be incorporated as a result of the incorporation of unlimited gimbal freedom using slip rings. This is necessary to reduce the number of rings required in order to fit the Slip Ring Assembly into the Sensor Pivot Assemblies without changing their major housings, shafts, etc. (i.e. minimum impact). This will be partially accomplished by deleting the unused spin bearing high level heater circuit wires from the IGRA and changing the number of spin motor wires from 3 per phase to 2 per phase and still retain adequate current carrying rating. The low level spin bearing heater circuit will remain. This deletes 15 wires that would have to be carried across the CMG gimbal axis pivots on slip rings. Lastly, the IGRA internal wiring harness will concurrently be changed to eliminate the need for soldering or unsoldering operations when the spin bearings are installed. This will facilitate ease of any assembly or dis-assembly operations that may be required in the future and avoid the potential for bearing contamination.

2.2.2 Sensor Pivot Assemblies (IG and OG)

The modification impact on the Sensor Pivot Assemblies includes the incorporation of unlimited gimbal freedom using Slip Ring Assemblies (SRA) in each pivot assembly. Studies determined that a sixty (60) ring SRA would be the maximum size, of conservative design (rings, redundant brushes, insulating blocks, lubrication and bearings, wire size and wire input/exit arrangement), that could be accommodated without major housing/shaft changes (i.e. minimum impact). Further study showed that the 60 rings would be sufficient for the Power Module CMG as a result of the deletion of unused or unnecessary circuits. These deletions include the following:

2.2.2 (Cont'd)

(a) The IGRA high level heater circuit and fewer spin motor leads described in 2.2.1.

(b) Deletion of the Control Law Resolver and Linear Resolver circuits. These resolvers are mounted in the Sensor Pivot Assemblies along with the Desaturation Resolver. The three resolvers will physically remain in the Sensor Pivot Assemblies, as before, but the circuits/wiring of the Control Law and Linear Resolvers will not be used. The Desaturation Resolvers will be used to output gimbal angle data in accordance with the interface information in Section 3.0.

(c) Deletion of the limit switch circuits associated with gimbal stops.

The same 60 ring SRA will be used in the Inner and Outer Gimbal Sensor Pivot Assemblies for commonality. Mechanical changes involve deletion of devices associated with mechanical stops, deletion of the flex leads and deletion of the center electrical connector on the centerline of the pivot axis of rotation. Pivot assembly leads will exit on a pigtail arrangement thus deleting a set of electrical connector pins in internal CMG wiring. This center connector is deleted to accommodate the SRA in each pivot assembly.

2.2.3 Frame (Mounting Ring)

The frame will be modified slightly to accommodate CMG orbital replacement capability as indicated by concept in Section 6.0.

2.2.4 Internal CMG Electrical Cables

These cables will be new designs as a result of the wiring changes discussed previously. The cable runs are supported on the frame, outer gimbal and inner gimbal.

2.3 Inverter Assembly (IA)

This unit is impacted by the incorporation of IA orbital replacement capability (see concept in Section 6.0) and providing a dual range speed output for telemetry. The present speed circuit module will be replaced by a dual range speed circuit module with appropriate wiring change to output data in accordance with the interface information in Section 3.0.

The tabulations that follow indicate the effort to be accomplished to provide the design modifications, necessary deletions and refurbishment for the Power Module program.

POWER MODULE CMG APPLICATION STUDY RESULTS

(CONT'D)

	DESIGN MODIFICATIONS	REFURBISHMENT

• IGRA (WHEEL ASS'Y)	• NEW ROTOR
	• BEARING RETAINER FIX
	• SPEED PICK-OFF SCREENING TESTS
	• NEW WIRING HARNESS
		• DELETE -
		  • MECHANICAL STOPS
		  • HIGH LEVEL HEATERS
		• TEARDOWN, INSPECT, REBUILD
		• RETEST -
		  • AS FOR ATM
		  • PLUS 1000 HOUR BEARING AND LUBE NUT SCREENING

POWER MODULE CMG APPLICATION STUDY RESULTS

(CONT'D)

	DESIGN MODIFICATIONS	REFURBISHMENT

• SENSOR PIVOTS (I.G. & O.G.)	• INCORPORATE SRA'S
	• NEW WIRING
	• REPLACE CAM FOLLOWER COVER WITH FLAT PLATE
		• DELETE -
		  • FLEX LEADS & SHAFT STOP PIN
		  • LIMIT SW's, CAMS, FOLLOWERS
		  • USE OF CONTROL LAW RESOLVERS
		  • USE OF LINEAR RESOLVERS
		• TEARDOWN, INSPECT, REBUILB, RETEST
		  • AS FOR ATM

POWER MODULE CMG APPLICATION STUDY RESULTS

(CONT'D)

	DESIGN MODIFICATIONS	REFURBISHMENT
• ACTUATOR PIVOTS (I.G. & O.G.)	• NONE	• TEARDOWN, INSPECT, REBUILD, RETEST - • AS FOR ATM

POWER MODULE CMG APPLICATIONS STUDY RESULTS

(CONT'D)

	DESIGN MODIFICATIONS	REFURBISHMENT
• OUTER GIMBAL AND FRAME	• NONE FOR OUTER GIMBAL • FRAME - INCORPORATE ORU CAPABILITY	• DELETE - • MECHANICAL STOPS • TEARDOWN, STRIP PAINT, NDI, RE-PAINT, REUSE
• COVERS	• NONE	• TEARDOWN, STRIP PAINT, NDI, RE-PAINT, REUSE
• THERMAL BLANKETS	• IF REQUIRED	• NEW
• CMG CABLES	• NEW PER SUBSYSTEM WIRING	• NEW

POWER MODULE CMG APPLICATIONS STUDY RESULTS

(CONT'D)

	DESIGN MODIFICATIONS	REFURBISHMENT
• IA (INVERTER ASS'Y)	• DUAL RANGE SPEED OUTPUT FOR TELEMETRY • ORU CAPABILITY	• INSPECT AND REWORK AS NECESSARY • RETEST AS FOR ATM
• EA (IG & OG SERVOS)	• NONE	• INSPECT AND REWORK AS NECESSARY • RETEST AS FOR ATM

SECTION 2.0

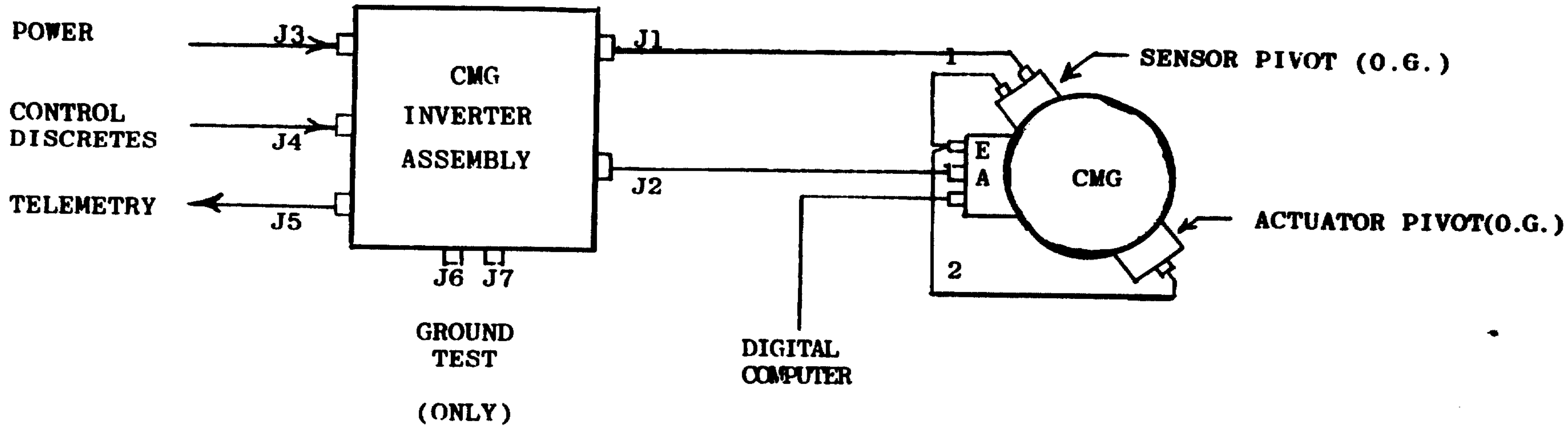
POWER MODULE CMG
INTERFACE INFORMATION

- FOR POWER MODULE APPLICATION
  - DESIGN MODS. TO THE SKYLAB/ATM CMG (MA 2300)
  - CABLE SCHEMATIC
  - ELECTRICAL INPUT/OUTPUT LIST
- SKYLAB/ATM CMG
  - DESCRIPTION
  - CMG ASS'Y DWG. 50M22136
  - CMG IA DWG. 50M22137
  - CMG THERMAL BLANKET DWG. 50M22151

MAJOR DESIGN MODIFICATIONS
TO THE MA 2300 DGCMG (DGCMG)
FOR THE POWER MODULE APPLICATION

- NEW ROTORS OF A DIFFERENT MATERIAL.
- SPIN BEARING RETAINER FIX.
- UNLIMITED GIMBAL FREEDOM-ADD SLIP RINGS.
- ORU CAPABILITY.
- DUAL RANGE SPEED OUTPUT FOR TELEMETRY
- NEW CMG ASS'Y INTERNAL WIRING AND CABLES.
- DELETE UNUSED COMPONENTS AND WIRING;
    - MECHANICAL STOPS, FLEX LEADS, LIMIT SWITCHES, CAM FOLLOWERS ETC.
    - HIGH LEVEL HEATERS
    - "CONTROL LAW RESOLVERS" AND "LINEAR RESOLVERS".

POWER MODULE CABLE SCHEMATIC - CMG/CMGIA



NOTES: 1) CMG CABLES 1 AND 2 ARE INTERNAL CMG ASS'Y CABLES ONLY.

2) CMGIA CABLES J_1, J_2, J_3, J_4, and J_5, ARE SPACECRAFT CABLES.

POWER MODULE

CMG/CMG ELECTRONICS ASSEMBLY

INPUT/OUTPUT LIST

Inputs

FUNCTION	DESCRIPTION	SCALE FACTOR	SOURCE
Outer Gimbal Rate Command	0 TO ± 5 VDC, Floating	± 5 VDC = ± 7 deg/sec	Digital CMPTR
Inner Gimbal Rate Command	0 TO ± 5 VDC, Floating	± 5 VDC = ± 7 deg/sec	Digital CMPTR
Resolver Excitation	10V, 4.8 kHz. FOR GIMBAL ANGLE RESOLVERS.		CMGIA
CMGEA Power	28 VDC; 10V, 4.8k Hz FOR IG & OG SERVO.		CMGIA

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POWER MODULE

CMG/CMG ELECTRONICS ASSEMBLY (CONTINUED)

Outputs

FUNCTION	Discription	Range	Destination
Inner Gimbal Resolver-Sine	0 TO 8.5V, 4.8 kHz (Into 10K ohms Load)		Digital CMPTR
Inner Gimbal Resolver-Cosine	0 TO 8.5V, 4.8 kHz (Into 10K ohms, Load)		Digital CMPTR
Outer Gimbal Resolver-Sine	0 TO 8.5V, 4.8 kHz (Into 10K ohms, Load)		Digital CMPTR
Outer Gimbal Resolver-Cosine	0 TO 8.5V, 4.8 kHz (Into 10K ohms, Load)		Digital CMPTR
Resolver-Signal Keying	10V, 4.8 kHz		Digital CMPTR
Inner Gimbal Tachometer	56.55 Volts = 1 rad/sec		CMGIA
Outer Gimbal Tachometer	56.55 Volts = 1 rad/sec		CMGIA
CMGEA Chassis Grnd.	---		CMGIA
CMG FRAME TEMP.	2K ohm, Thermistor		CMGIA
CMG Shield	---		CMGIA

POWER MODULE
CMG INVERTER ASSEMBLY
INPUT/OUTPUT LIST

Inputs

FUNCTION	DESCRIPTION	SOURCE
Power Input non-maneuvering	24 TO 32 VDC 150 Watts*	PM Power Supply
maneuvering	24 TO 32 VDC 0-160 Watts	Duty Cycle 1% (Mostly gg
Heaters	24 TO 32 VDC 52 Watts	Duty Cycle 50% Desat)
Commands		
CMG Wheel On		
CMG Wheel Off		
CMG Wheel Brake On		
CMG Wheel Brake Off		
CMG Servo AMP On	28 VDC, Discrete	Digital CMPTR
Evacuation Value Open		TM
Evacuation Value Close		Manual Controls
Bearing Heater Command		
Auto Sutdown Inhibit		
Wheel Speed	30 Pulses per Revolution	CMG Sensor Pivot
Bearing No. 1 Thermistor	10,000 OHMS At 25°C	CMG Sensor Pivot
Bearing No. 2 Thermistor	10,000 OHMS At 25°C	CMG Sensor Pivot
Evac Valve Open Indication	28V, Discrete	CMG Sensor Pivot
Connector Shield		CMG Sensor Pivot
CMG Frame Temp	2K OHM, Thermistor	CMGEA
Inner Gimbal Tachometer	56.55V = 1 rad/sec	CMGEA
Outer Gimbal Tachometer	56.55V = 1 rad/sec	CMGEA
CMGEA Chassis Gnd		CMGEA

*240 Watts peak during 12 hour run-up.

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POWER MODULE

CMG INVERTER ASSEMBLY (CONTINUED)

Outputs

Function	Description	Range	Destination
Wheel Current			
A Phase	0 TO 5 VDC	0 TO 3 Amps	TM/Display
B Phase	0 TO 5 VDC	0 TO 3 Amps	TM/Display
C Phase	0 TO 5 VDC	0 TO 3 AMPS	TM/Display
CMG Wheel Speed	0 TO 5 VDC	0 TO 10 KRPM	TM/Display
CMG Wheel Speed	0 TO 5 VDC	8 TO 9 KRPM	TM/Display
Bearing #1 Temp	0 TO 5 VDC	-10^{o}TO + 100^{o}C	TM/Display
Bearing #2 Temp	0 TO 5 VDC	-10^{o}TO + 100^{o}C	TM/Display
Bearing Temp Alert(Caution)	28 VDC, Discrete	160^{o}F = On	TM/Display
CMG Wheel/Servo Indication	28VDC, Discrete		TM/Display
Auto Shutdown Inhibit Indicator	28V DC, Discrete		TM/Display
Evac Valve Open Indication	28V DC, Discrete		TM/Display
CMGIA Temp	2k OHM, Thermistor		TM/Display
Outer Gimbal	2k OHM, Thermistor		TM/Display
Sensor Pivot Temp (FRAME)			
Inner Gimbal Tachometer	0 - 6.9 VDC	56.55VDC = 1 rad/sec	TM/Display
Outer Gimbal Tachometer	0 - 6.9 VDC	56.55VDC = 1 rad/sec	TM/Display
Resolver Excitation	10V, 4.8k Hz		CMGEA
CMGEA Power	28VDC; 10V, 4.8kHz IG & OG Servo		CMGEA
CMG Wheel Power	130V, 455 Hz, 3 Ø		CMG Sensor Pivot
24 Watt Bearing Heater Side 1	28VDC		CMG Sensor Pivot
24 Watt Bearing Heater Side 2	28VDC		CMG Sensor Pivot
Evacuation Value Open Command	28VDC, Discrete		CMG Sensor Pivot
Evacuation Value Close Command	28VDC, Discrete		CMG Sensor Pivot
28V. DC Excit. For Evac. Valve	28VDC		CMG Sensor Pivot
Power to External Load	28V, 800 Hz		not used
Power to External Load	130V, 455 Hz, 3 Ø		not used
Power to External Load	10V, 4.8k Hz		not used

MA 2300 DOUBLE GIMBAL CMG (DGCMG)

	CMG	CMGIA (Inverter Assembly)
MODEL IDENT:	NASA P/N 50M22136 Bendix P/N 2120100	NASA P/N 50M22137 Bendix P/N 2121500

SPACEFLIGHT QUALIFIED: Yes. See Table 2.2-5

PROGRAM: Skylab - ATM Contract NAS8-20661

TOTAL HOURS FLOWN: *270 Days (Skylab Mission). See attached Life Testing Summary, Table 2.2-3.

MTBF: See attached Summary, Table 2.2-4

QUANTITY BUILT FOR PROGRAM: 12

* Plus Re-activation Mission; From 6/8/78 to ____________.

GENERAL DESCRIPTION

ATM CONTROL MOMENT GYRO CONTRACT (SKYLAB MISSION)

The Bendix, Navigation & Control Division was under contract to NASA/Marshall Space Flight Center to deliver large double gimbal control moment gyros for the Apollo Telescope Mount (ATM) Program. This unit has a momentum storage capability of 2300 ft-lb-sec. and operates at a speed of approximately 9,000 RPM.

Figure 2.2-1 is a photograph of the ATM CMG in flight configuration and Figure 2.2-2 shows the unit with its top cover removed thereby exposing a view of its gimbals, pivots and the innermost evacuated cavity which houses the inertia wheel. The gimbal drive electronics box is shown externally mounted on the frame.

Basically, the CMG is a gyro wheel, spin motor and bearing assembly in an inner gimbal mounted in an outer gimbal, which in turn is mounted in a frame and cover base assembly. The inner gimbal and frame are interconnected by pivots. Each pivot contains a set of bearings, a resolver assembly and flex leads in a housing to form a Sensor Pivot Assembly on one side and a set of bearings, a DC Torquer, DC Tachometer and a gear package in a housing to form an Actuator Pivot Assembly on the other side. Various miscellaneous parts are mounted on the gimbals and frame assemblies. A gimbal drive servo electronics box is mounted externally on the CMG frame. In addition to the CMG, Bendix furnishes an Inverter Assembly with each ATM CMG to form one CMG subsystem. This is a separate electronics box to furnish AC power, control circuits and conditioning electronics for telemetry and astronaut display. Figure 2.2-3 is a simplified block diagram showing the elements and interfaces of the Bendix furnished ATM CMG Subsystem. Table 2.2-1 and Table 2.2-2 lists the CMG Subsystem external physical and performance characteristics. Table 2.2-3 summarizes our excellent life testing to date.

Bendix CMG's are assembled and tested in the same clean room facilities and by the same expert personnel as was the Saturn ST-124 platform and Pershing missile platform. Figures 2.2-4 and 2.2-5 are photographs of these areas.

Under this contract, BNC also developed a Torque Measurement Fixture (TMF) which has been used with all of our CMG's. The TMF is used to measure CMG reaction torques transmitted to the mounts. The TMF consists of a mounting ring, which houses the CMG. The mounting ring is supported quadrantally by four torque sensing beam assemblies, which in turn are mounted to a concrete block (See Figure 2.2-6). The concrete block is isolated from the floor by

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air pads to eliminate any background vibration pickup. The four torque sensing beam assemblies contain an array of semi-conductor strain gages, which are wired into a wheatstone bridge configuration. The sensors are used to sense triaxial forces and moments transmitted to the mount by the CMG. A photograph of the TMF is shown in Figure 2.2-7.

The natural frequency of the TMF is 59 HZ and it has a threshold torque sensing of $\angle$0.01 ft. lbs. Sensitivity of the torque output per axis is 2500μv/ft-lb. Range of torque outputs is 0.01 ft-lb to 200 ft-lb.

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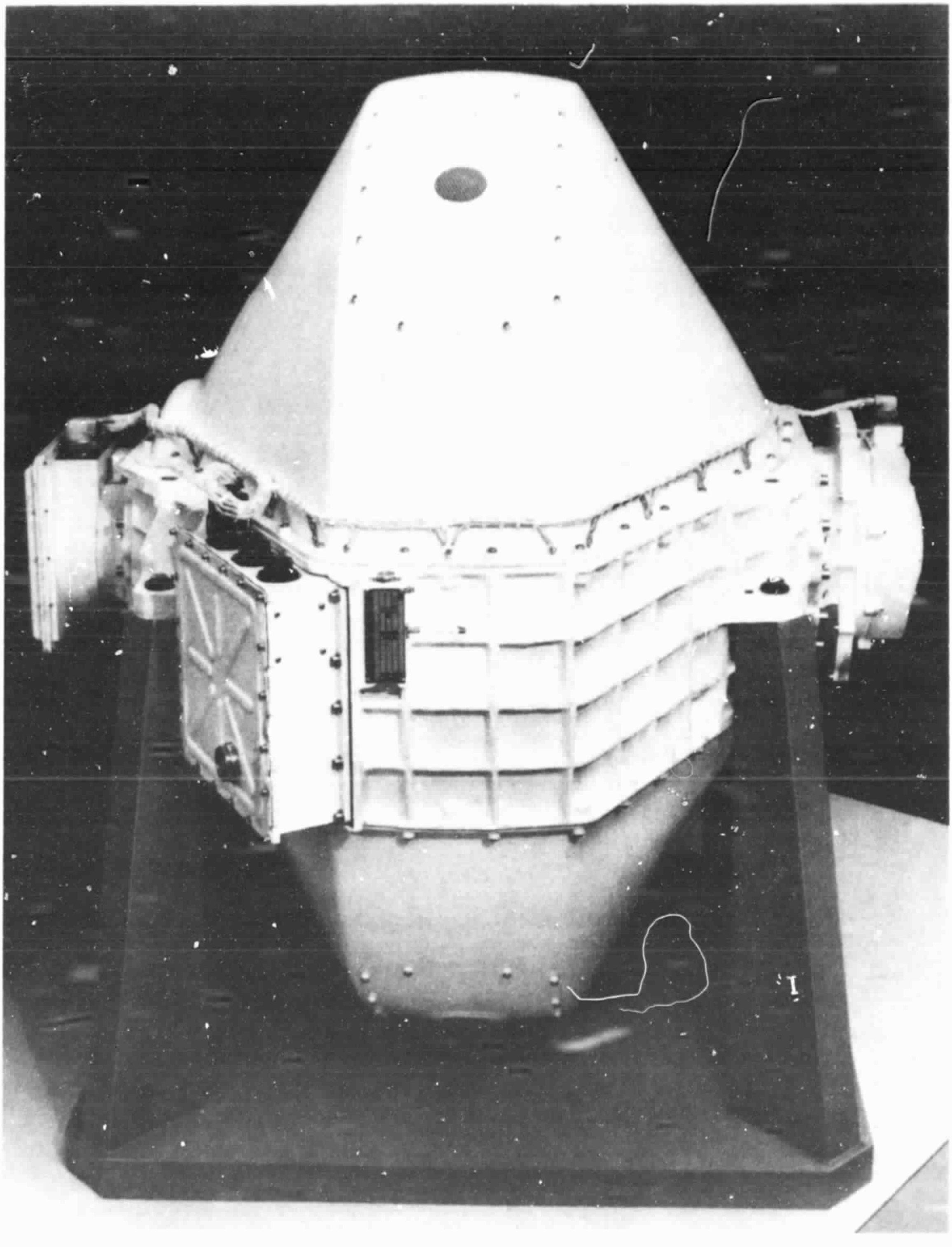

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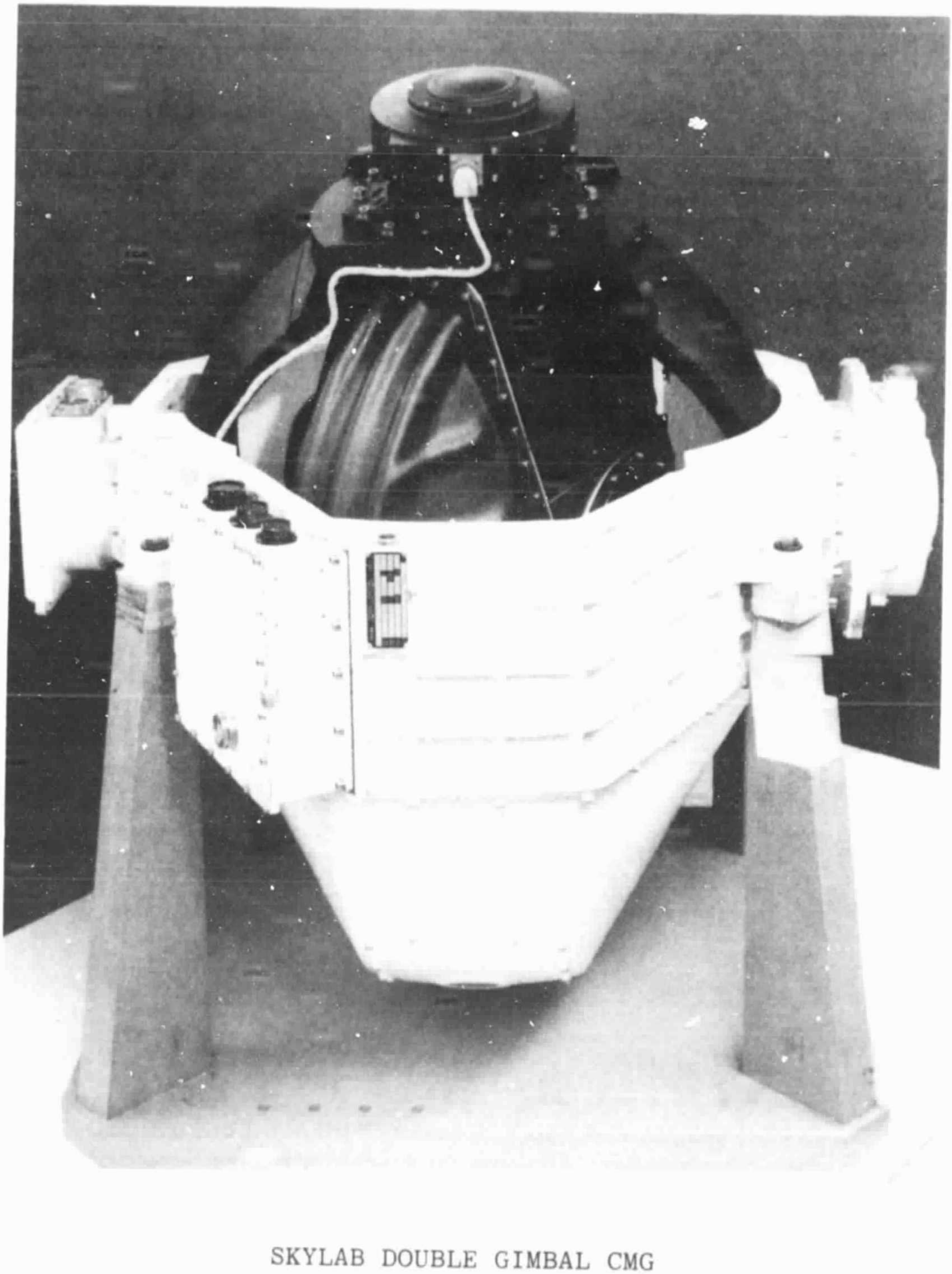

SKYLAB DOUBLE GIMBAL CMG

CMG SUBSYSTEM BLOCK DIAGRAM

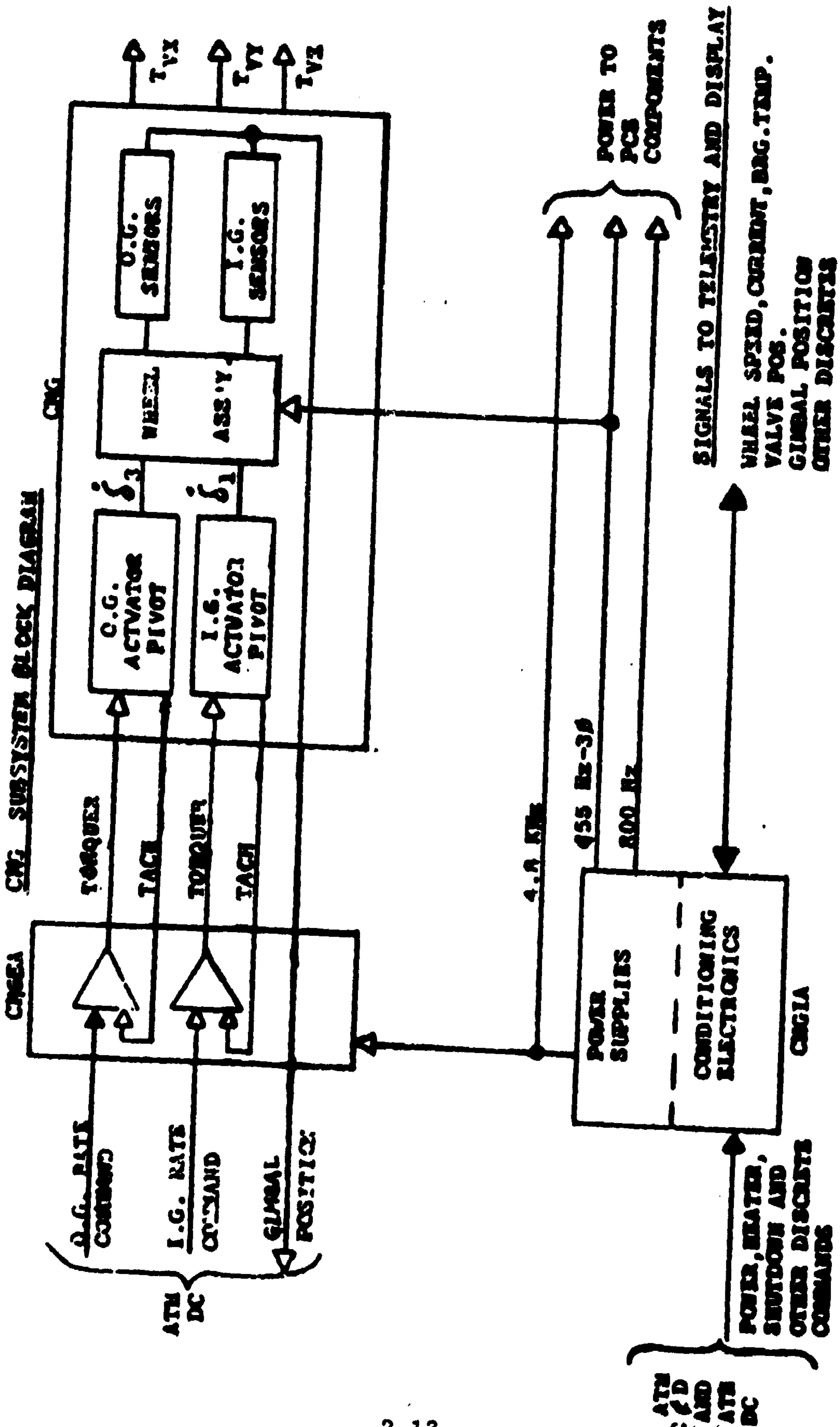

FIGURE 2.2-3

SKYLAB/ATM CMG SUBSYSTEM

EXTERNAL PHYSICAL CHARACTERISTICS

CMG		CMGIA	
SIZE:	39" X 41 7/8" X 38 5/8"	SIZE:	25" X 22 1/2" X 3 1/2"
WEIGHT:	418 Lbs.	WEIGHT:	49 Lbs.
MOUNTING:	Four Point C.G.	MOUNTING:	16 Point Bolt Attach.
EXTERNAL FINISH:	Pyromark (White)	EXTERNAL FINISH:	Pyromark (White)
	e = 0.9 Nom.		e = 0.9 Nom.
	α = 0.25 Max.		α = 0.25 Max.

SUBSYSTEM WEIGHT: 467 Lbs. (One CMG and IA)

TABLE 2.2-1

SKYLAB/ATM CMG SUBSYSTEM CHARACTERISTICS

Stored Angular Momentum		2300 ft-lb-sec
Maximum Output Torque (Simultaneous 2 gimbals)		122 ft-lb
Degrees of Freedom		2
Maximum Gimbal Rate	Inner Gimbal	4 deg/sec
	Outer Gimbal	7 deg/sec
Gimbal Rotation (Mech. Stops)	Inner Gimbal	$\pm$ 80 deg.
	Outer Gimbal	$\pm$ 175 deg.
Bandwidth (Over Gimbal Angle Range and over 0.2 deg/sec to 3.5 deg/sec comm. range)		4 HZ to 10 HZ
Power at Nominal 28V. line (on orbit)		
Wheel Spin Control (2 motors)	- at Speed	80 Watts
	- Spin Up peak	170 Watts
	- DC Brake	28 Watts
Gimbal Control - Both at 3.5 deg/sec - peak		170 Watts
Spin Bearing Heater Control - peak		52 Watts
Other Inverter Assembly Functions - peak		70 Watts
Wheel Spin Up Time (28 V. Line)		14 hrs. max.
Wheel Decelleration Time (DC Braking)		5 hrs. max.

IGRA:

Rotor	Rimmed Disk of Maraging Steel
Rotor Diameter	22 in.
Rotor Weight	145 lbs.
Rotor Operating Speed (Synch. Speed 9100 RPM)	9,000 RPM
Spin Motor	2 Three Phase Dual Cage Induction Motors.

Monitors:
- Bearing Thermistors
- Wheel Speed
- Cavity Pressure for Ground Test Use
- Bearing Vibration for Ground Test Use

Each Actuator Pivot Assembly:

Gear Ratio	56.6 to 1
Torque Motor (Brush Type)	Inland T5793A, 7 ft-lb
Tachometer (Brush Type)	Inland TG2815A, 1V./Rad./Sec.

Each Sensor Pivot Assembly:

Flex Leads	
Gimbal Position Pickoff	3 Resolvers
Gimbal Excursion Limit Switches	

TABLE 2.2-2

ATM CMG SUBSYSTEM - LIFE TESTING SUMMARY

IGRA (WHEEL ASSEMBLY)	- IGRA'S built to date:	15 Units	
	Total Hours IGRA's:		100,000
	"Zero G" Life Test Fixtures on Run:	8 Units	
	Total Hours "Zero G":		250,000
	Cumulative Total Hours:		350,000
	Maximum Hours on a Single Test Unit:		33,000
	Units with Hours in Excess of 20,000:	10 Units	
ACTUATORS (TORQUER/TACH AND GEAR PACKAGE)	- One wet lube Actuator, Narrow Gear Design has completed 300 days of real time testing at MSFC.		
	Two wet lube flight configuration actuators completed 300 days of accelerated life testing.		
	One wet lube flight configuration actuator completed 300 days of real time life testing.		
FLEXLEAD ASSEMBLY	- Room temperature and low temperature life test performed and demonstrated life capability grossly in excess of 10 years.		
FULL CMG'S	- Three CMG's (S/N 1, 2, 3) have been in use at MSFC on their motion simulator for the past three years without any significant problems. Cumulative total hours.		100,000
	- Three CMG's (SN5,6,7) - Skylab Mission. Cumulative total hours in Orbit.		17,000 *
	- Six CMG's (SN4,8,9,10,11,12) - Total hours		23,000

* Plus Re-Activation Mission 6/8/78 to ________

TABLE 2.2-3

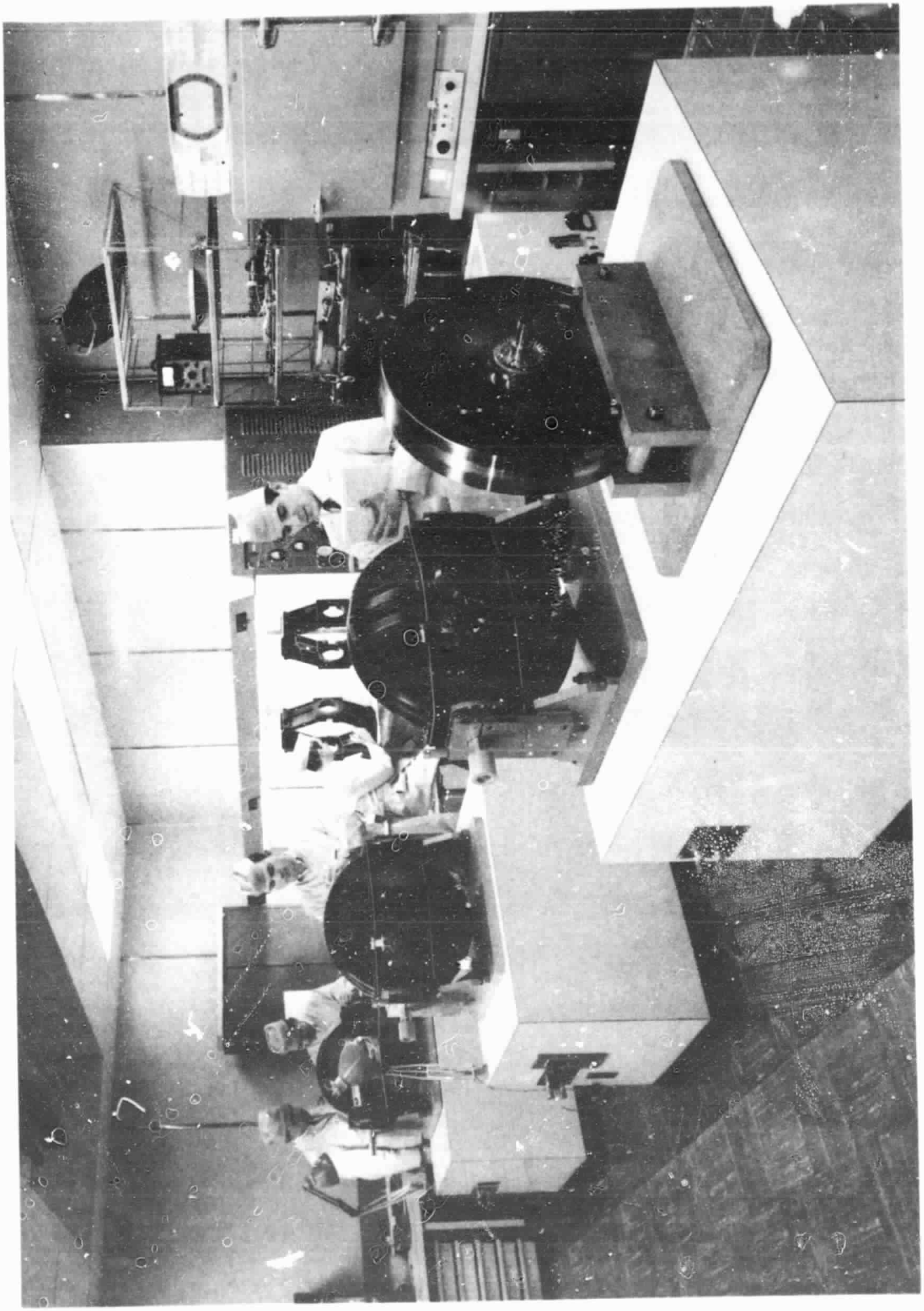

FIGURE 2.2-4

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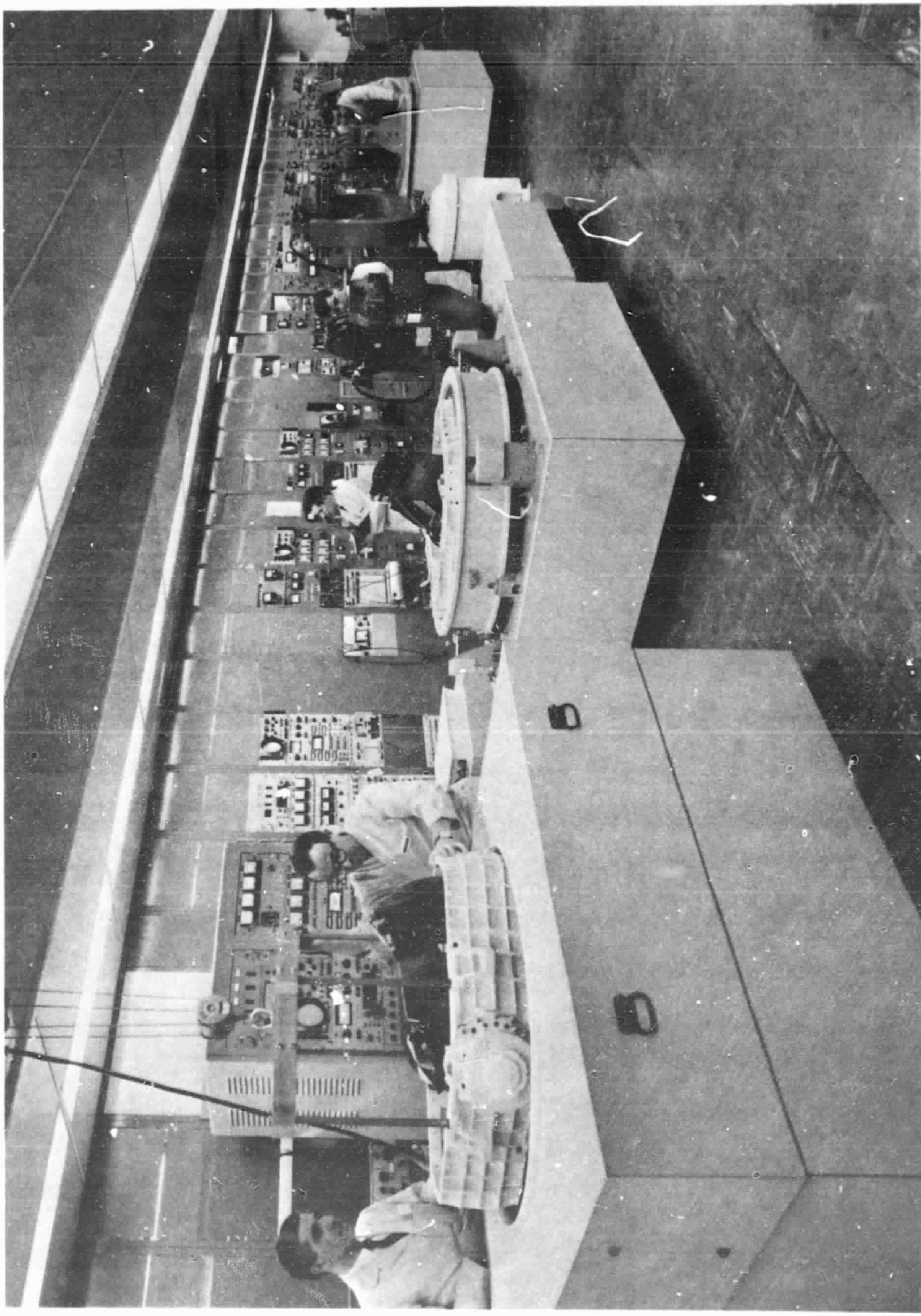

CMG TEST AREA

FIGURE 2.2-5

ATM CMG SUBSYSTEM RELIABILITY SUMMARY

	FAILURE RATE	MTBF	FAILURE* RATE (NET)	RELIABILITY P**
CMG	35.33 PPMH	28,301 HR.	9.71 PPMH	0.9456
CMGIA	17.21 PPMH	58,109 HR.	4.07 PPMH	0.9768
SYSTEM (2 OUT OF 3 SUBSYSTEMS)	---	---	---	0.9834

* Criticality Considered
** For 240 day mission

NOTE: The Above Failure Rates Used 1969 Failure Rate Data.

TABLE 2.2-4

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ATM CMG SUBSYSTEM ENVIRONMENTS
(NOTE: UNITS LOCATED ON ATM RACK-EXTERIOR OF SPACECRAFT)
QUALIFICATION

	CMG	CMGIA
GROUND CONDITIONS		
HIGH TEMP.	+74°C SOAK +38°C OPERATING	+74°C SOAK +74°C OPERATING
LOW TEMP.	-48°C SOAK 0°C OPERATING	-48°C SOAK -48°C OPERATING
THERMAL SHOCK	74°C, -48°C, 74°C 3 CYCLES; 5 MIN. BETWEEN SOAK TEMPS.	74°C, -60°C, 74°C 3 CYCLES; 5 MIN. BETWEEN SOAK TEMPS.
HUMIDITY	5 CYCLES: 38°C, 50% R.H. FOR 6 HRS. 5 HRS. TO 25°C AND R.H. TO 100% 8 HRS. TO 21°C WITH RELEASE OF WATER 4 HRS. TO 38°C AND R.H. TO 41% 1 HR. AT 38°C AND R.H. TO 50%	SAME AS CMG
MECHANICAL SHOCK	15g. PEAK, 10 MS., HALF SINE	15g. PEAK, 10 MS., HALF SINE
LAUNCH-BOOST CONDITIONS		
ACOUSTIC VIB.	TABLE I	TABLE I
ACCELERATION	8g. ANY AXIS	10g ANY AXIS
VIBRATION	TABLE II	TABLE II

TABLE 2.2-5

ATM CMG SUBSYSTEM ENVIRONMENTS

QUALIFICATION

		CMG	CMGIA
FLIGHT CONDITIONS			
THERMAL VACUUM:			SAME AS CMG.
HOT EXTREME	-	PRESSURE: 1×10^{-6} MMHG. EFF. HEAT SINK: 35°C	
COLD EXTREME	-	PRESSURE: 1×10^{-6} MMHG EFF. HEAT SINK: -62°C*	
RFI		MIL-I-6181D	MIL-I-6181D

*POWER TURNED ON PRIOR TO LOWERING TEMPERATURE

TABLE 2.2-5 (CONTINUED)

ACOUSTICAL - VIBRATION ENVIRONMENTS

TABLE I. Acoustical

Major zone: Payload, internal, to shroud

One-third octave band acoustical specification in db re: 2×10^{-4} dynes/cm^2

Test duration: High level - 2.0 minutes
Low level - 1.0 minute

One-third octave band geometric mean freq. (cps)	Internal Sound Pressure High Level (db)	Low Level (db)
5.0	138.5	118.0
6.3	140.0	121.0
8.0	141.5	124.0
10.0	142.5	126.5
12.5	143.5	128.0
16.0	144.5	129.5
20.0	145.5	131.5
25.0	146.0	133.0
31.5	146.0	134.5
40.0	146.5	135.5
50.0	146.5	136.5
63.0	146.0	137.5
80.0	145.5	138.5
100.0	143.0	139.0
125.0	140.0	138.0
160.0	136.0	135.0
200.0	132.5	133.0
250.0	130.0	131.0
315.0	128.0	129.0
400.0	124.0	126.0
500.0	121.0	123.0
630.0	118.0	120.0
800.0	115.0	117.0
1000.0	112.0	113.5
1250.0	109.0	110.0
1600.0	105.5	106.0
2000.0	102.5	102.5
2500.0	99.0	99.0
3150.0	95.0	95.0
4000.0	92.0	91.5
5000.0	89.0	87.5
6300.0	85.0	84.0
8000.0	81.0	80.0
10000.0	78.0	76.0
Overall sound pressure level	156.5	147.0

TABLE 2.2-5 (CONTINUED)

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TABLE II - VIBRATION

A. Specification 2-Input to -Z, +Z, and -Y CMG, Mounting Lugs of Rack Mounted Control Moment Gyros (CMG)

1. Vehicle Dynamics Criteria

Flight Axis (5-30 Hz @ 3 oct/min)

5- 13 Hz	@ .29 Inches D.A. Disp.
13- 30 Hz	@ 2.5 g's peak

Lateral Axis (5-30 Hz @ 3 oct/min)

5- 12 Hz	@ .20 Inches D.A. Disp.
12- 30 Hz	@ 1.5 g's peak

2. Sine Evaluation Criteria (20-2000 Hz @ 1 oct/min)

20- 90 Hz	@ .0024 Inches D.A. Disp.
90 - 2000 Hz	@ 1.0 g's peak

3. High Level Random Criteria (1 min/axis)

20 Hz	@ .000040 g^2/Hz
20- 90 Hz	@ + 9 dB/oct
90- 140 Hz	@ .0036 g^2/Hz
140- 360 Hz	@ + 9 dB/oct
360- 460 Hz	@ .065 g^2/Hz
460- 2000 Hz	@ -12 dB/oct
2000 Hz	@ .00018 g^2/Hz

Composite - 4.7 grms

4. Low Level Random Criteria (4 min/axis)

20 Hz	@ .0000050 g^2/Hz
20- 90 Hz	@ + 9 dB/oct
90- 140 Hz	@ .00047 g^2/Hz
140- 360 Hz	@ + 9 dB/oct
360- 460 Hz	@ .0086 g^2/Hz
460- 2000 Hz	@ -12 dB/oct
2000 Hz	@ .000025 g^2/Hz

Composite - 1.7 grms

5. Shock Criteria - Flight

No shock test required

TABLE 2.2-5 (CONTINUED)

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TABLE II - VIBRATION - SPECIFICATION R - 3 - C

B. CMGIA Criteria

Input to components mounted on ATM Honeycomb Shear Panel (Quarter Panel). Total weight of components per panel greater than 100 pounds but less than 200 pounds

1. Vehicle Dynamics Criteria

Flight Axis (5-30 Hz @ 3 oct/min)

5- 13 Hz @ .29 Inches D.A. Disp.
13- 30 Hz @ 2.5 g's peak

Lateral Axes (5-30 Hz @ 3 oct/min)

5- 12 Hz @ .20 Inches D.A. Disp.
12- 30 Hz @ 1.5 g's peak

2. Sine Evaluation Criteria (20-2000 Hz @ 1 oct/min)

20- 90 Hz @ .0033 g^2/Hz
2000 Hz @ 1.3 g's peak

3. High Level Random Criteria (1 min/axis)

	20 Hz @	.00030 g^2/Hz
20-	90 Hz @	+ 9 dB/oct
90-	150 Hz @	.023 g^2/Hz
150-	285 Hz @	+ 9 dB/oct
285-	500 Hz @	.15 g^2/Hz
500-	2000 Hz @	-12 dB/oct
	2000 Hz @	.00059 g^2/Hz

Composite - 8.3 grms

4. Low Level Random Criteria (4 min/axis)

	20 Hz @	.000070 g^2/Hz
20-	90 Hz @	+ 9 dB/oct
90-	150 Hz @	.0058 g^2/Hz
150-	285 Hz @	+ 9 dB/oct
285-	500 Hz @	.038 g^2/Hz
500-	2000 Hz @	-12 dB/oct
	2000 Hz @	.00015 g^2/Hz

Composite - 4.2 grms

5. Shock Criteria - Flight

No shock test required

TABLE 2.2-5 (CONTINUED)

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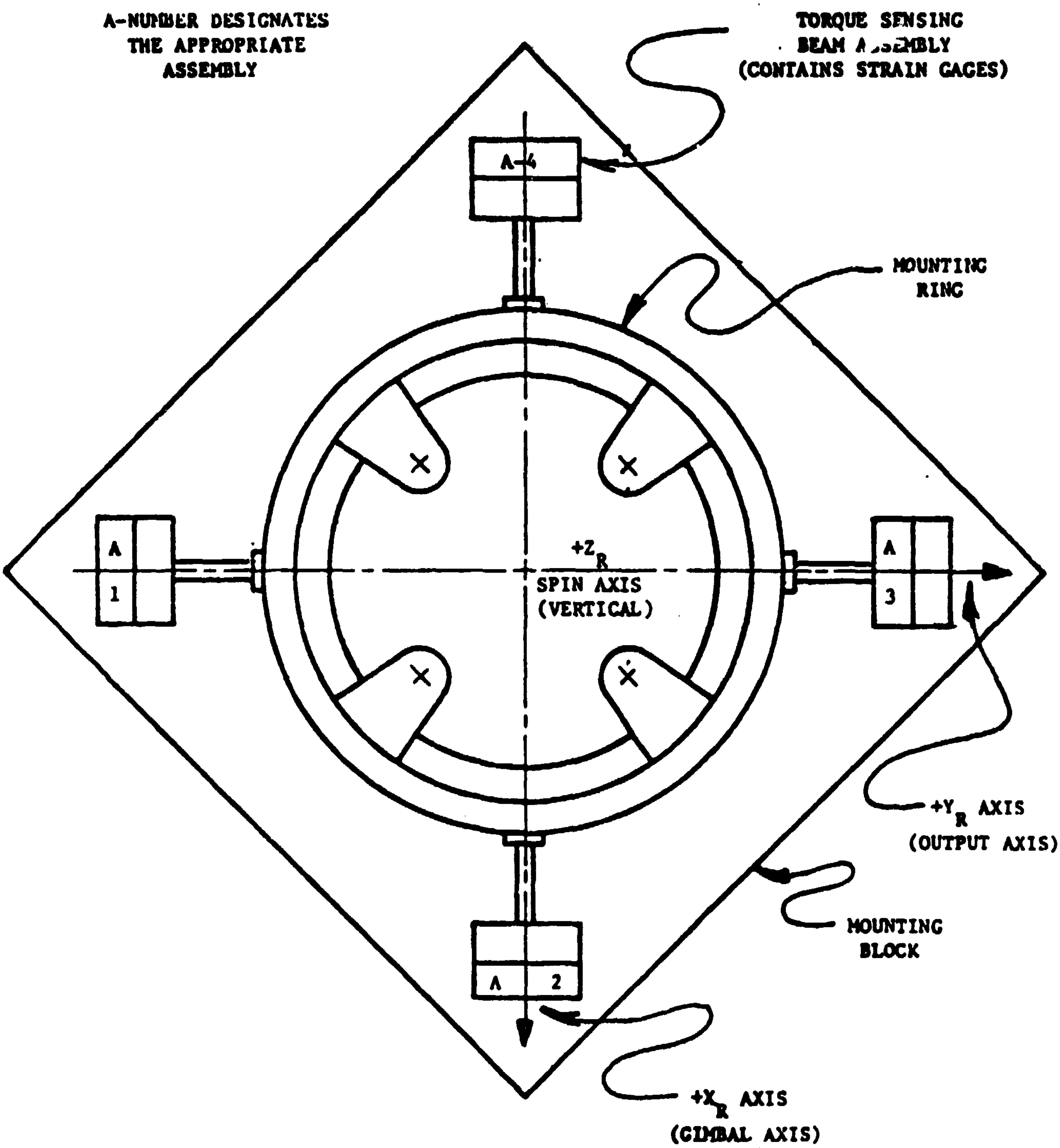
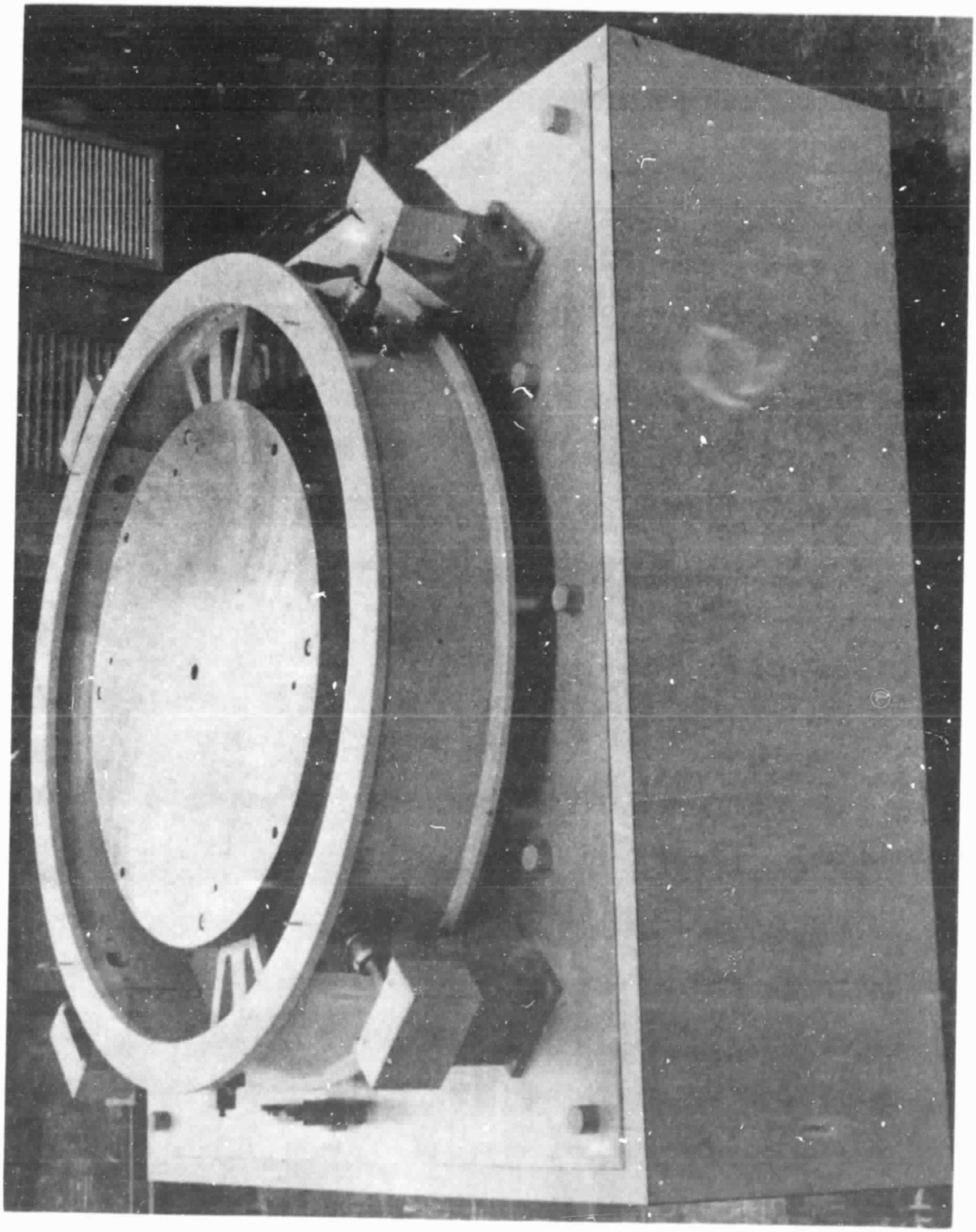


FIGURE 2.2-6 - TORQUE MEASUREMENT FIXTURE (TMF)



TORQUE MEASURING FIXTURE

SECTION 3.0

POWER MODULE CMG
REFURBISHMENT PROGRAM
MAJOR MILESTONE SCHEDULE

	CMG CONTRACT MONTHS ARO
PDR	1
CDR	5
UNIT #1 DELIVERY TO MSFC	22
UNIT #2 DELIVERY TO MSFC	23
UNIT #3 DELIVERY TO MSFC	24
UNIT #4 DELIVERY TO MSFC	25

SECTION 4.0

POWER MODULE CMG RELIABILITY ESTIMATE

The estimated net failure rate for one CMG Assembly and one Inverter Assembly is given in Table 4-1. The basis for this estimate is provided in the table notes starting with the final ATM CMG contract reliability predictions in 1970 and 1971.

	NOTE #1		NOTE #2		NOTE #2 & #3	
	TOTAL FAILURE RATE(PPMH)	NET FAILURE RATE(PPMH)*	TOTAL FAILURE RATE(PPMH)	NET FAILURE RATE(PPMH)*	TOTAL FAILURE RATE(PPMH)	NET FAILURE RATE(PPMH)*
CMG ASS'Y (MINUS ETI)	36.1 33.1	9.7	8.3	2.0	5.7	2.0
INVERTER # (MINUS ETI)	15.9 12.9	4.1	2.8	0.6	2.6	0.6

ETI = ELAPSED TIME INDICATOR
# ADJUSTED FOR SMALL AMOUNT OF REDUNDANCY INTERNAL TO INVERTER.
* ADJUSTED FOR CRITICALITY USING FMECA's CITED IN NOTE #1.

NOTE #1 - FAILURE RATES OBTAINED FROM:

(1) FAILURE MODE AND CRITICALITY ANALYSIS OF THE INVERTER FOR THE CMG SUBSYSTEM (RE 71-157), JUNE 1971.
(2) FAILURE MODE AND CRITICALITY ANALYSIS OF THE CONTROL MOMENT GYROSCOPE ASSEMBLY FOR THE CMG SUBSYSTEM (RE 70-294), JULY 1970.

NOTE #2 - BASED UPON MIL-HDBK-217B FAILURE RATES, ASSUMING THE QUALITY LEVELS:

INTEGRATED CIRCUITS - MIL-STD-883, CLASS B
TRANSISTORS & DIODES - JAN TX V
CAPACITORS & RESISTORS - ESTABLISHED RELIABILITY, LEVEL R

NOTE #3 - CERTAIN CIRCUITRY REMOVED FROM THE ATM CMG CONFIGURATION FOR THE POWER MODULE APPLICATION.

TABLE 4-1

SECTION 5.0

POWER MODULE CMG
LIMITED LIFE ITEMS

A list of limited life items for the CMG and IA is provided below. The class of items listed are those involving potential for wear, fatigue or degradation in mechanical properties over long time periods or repeated use such as assembly and dis-assembly operations on earth.

1.0	In the CMG Assembly (CMG)
1.1	IGRA (Inner Gimbal and Rotor Assembly)
1.1.1	Spin Bearings and Lubricant
1.1.2	Dynamic Lubrication Nut/Lubricant
1.1.3	Vacuum Cavity Seals
1.1.3.1	Top and Bottom Cover Seals
1.1.3.2	End Cap Seals (2)
1.1.3.3	Evacuation Valve Assembly Seal
1.2	Evacuation Valve
1.2.1	Drive Motor Brushes
1.2.2	Microswitches
1.2.3	Lubrication
1.3	Actuator Pivot Assemblies (Inner and Outer Gimbal)
1.3.1	Gimbal Bearings and Lubricant
1.3.2	Gears, Gear Bearings and Lubricant
1.3.3	Torquer Brushes
1.3.4	Tachometer Brushes
1.3.5	Output Shaft Seal
1.3.6	RFI Grounding Ring
1.4	Sensor Pivot Assemblies (Inner and Outer Gimbal)
1.4.1	Gimbal Bearings and Lubricant
1.4.2	Slip Ring Assembly
1.4.3	Output Shaft Seal

1.4.4	RFI Grounding Ring
1.5	Electronics Assembly (EA)
1.5.1	RFI Gasket
1.6	Frame
1.6.1	Elapsed Time Indicator
1.7	CMG Top and Bottom Covers
1.7.1	Cover Mounting Screws (and Access Cover Screws)
1.7.2	RFI Cover/Frame Gaskets
1.8	Overall CMG Assembly
1.8.1	Mounting Bolts
1.8.2	Thermal Blankets

2.0	In the Inverter Assembly (IA)
2.1	RFI Gasket
2.2	Relays
2.3	Elapsed Time Indicator

SECTION 6.0

POWER MODULE CMG
ON-ORBIT REPLACEMENT APPROACH

Both the Inverter Assembly (IA) and the CMG's with their gimbal rate servo Electronic Assembly (EA) are planned to be replaced as units (ORU's). Preliminary concepts have been developed for orbital changeout. The IA will incorporate manually operated fasteners (captive mounting bolts) and electrical connectors (five on orbit) and a handle (or handles) for manipulation by a crewman. Drawing 5105591-9 (Inverter Assembly Concept Drawing, Orbital Replacement) depicts this approach.

The CMG with EA will require both the RMS and Extra-Vehicular Activity (EVA) for changeout. For the RMS purpose, a grapple fixture is made a permanent part of each CMG structure. This approach is depicted on Drawing 5105590-9 (CMG Assembly, Concept Drawing, Orbital Replacement), which also depicts manually operated fasteners (captive mounting bolts), electrical connectors (three to engage/disengage) and handles for manipulation by a crewman. The CMG changeout scenario could be as follows:

(a) RMS attaches to CMG grapple fitting.

(b) Fasteners and electrical connectors are released by EVA.

(c) RMS moves CMG to tie-down point within the shuttle cargo bay.

(d) Fasteners are secured by EVA.

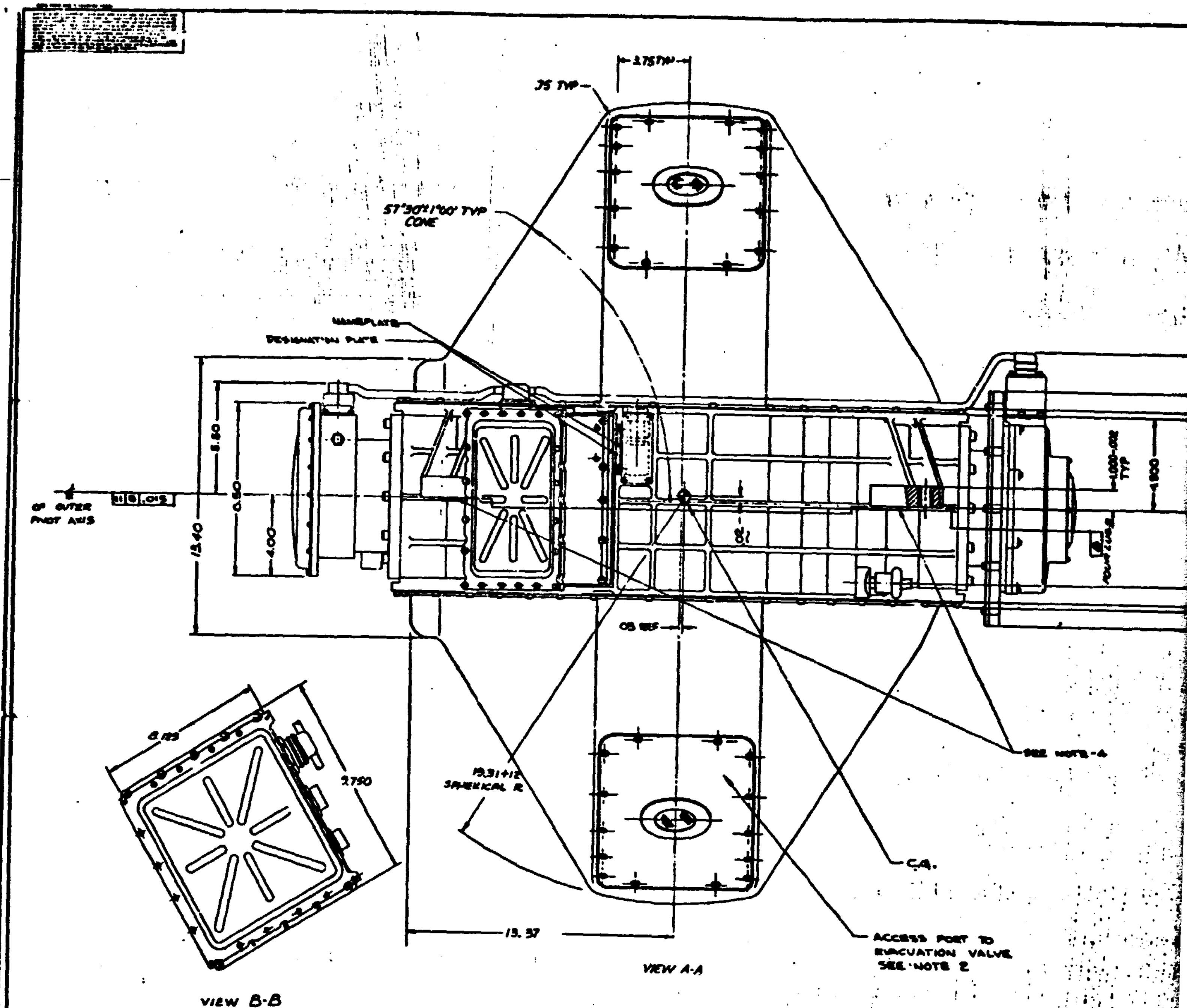
(e) RMS attaches to replacement CMG in cargo bay.

(f) Fasteners are released by EVA.

(g) RMS moves CMG to its place on the Power Module.

(h) Fasteners and electrical connectors are secured by EVA.

(i) RMS is removed from CMG.



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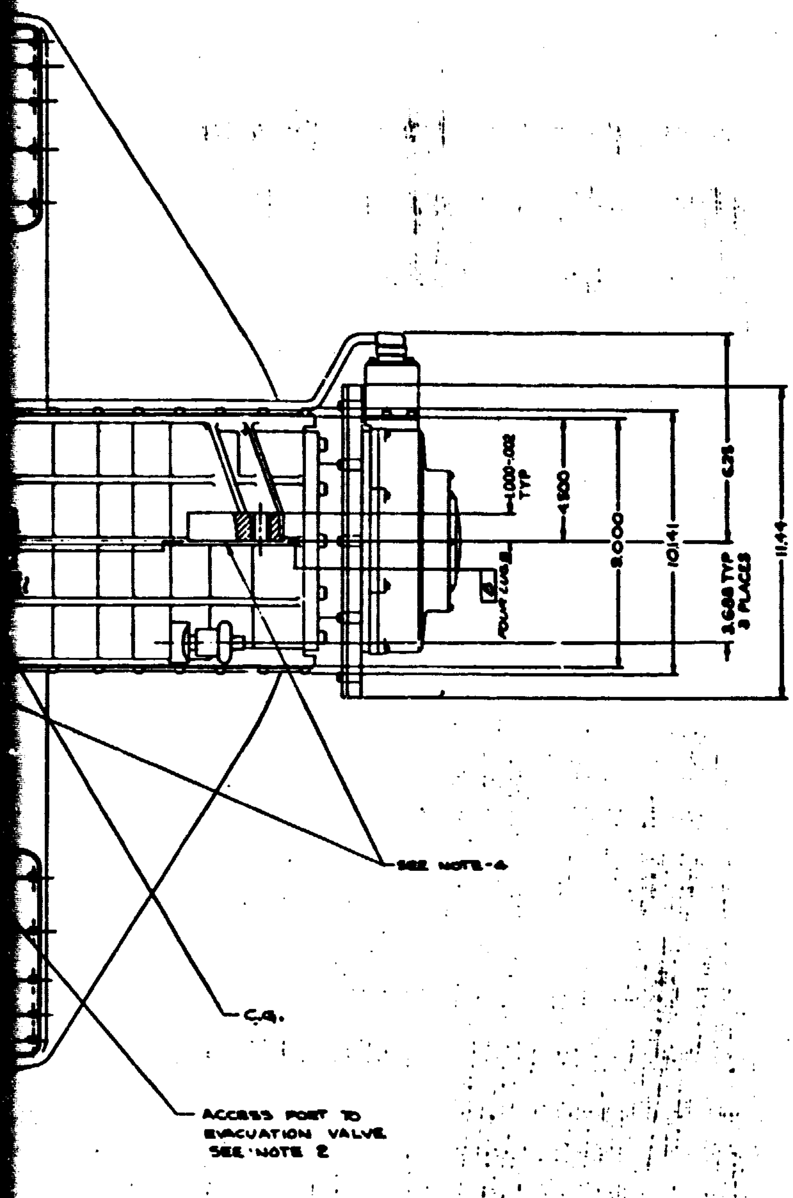
Zone	Sym	Description	Date	Approved
	A	CET 19488-E ADDED NAMEPLATE		
	B	CP-T 218143-E UPDATED TO SHOW FILTERS		
	C	[illegible]		



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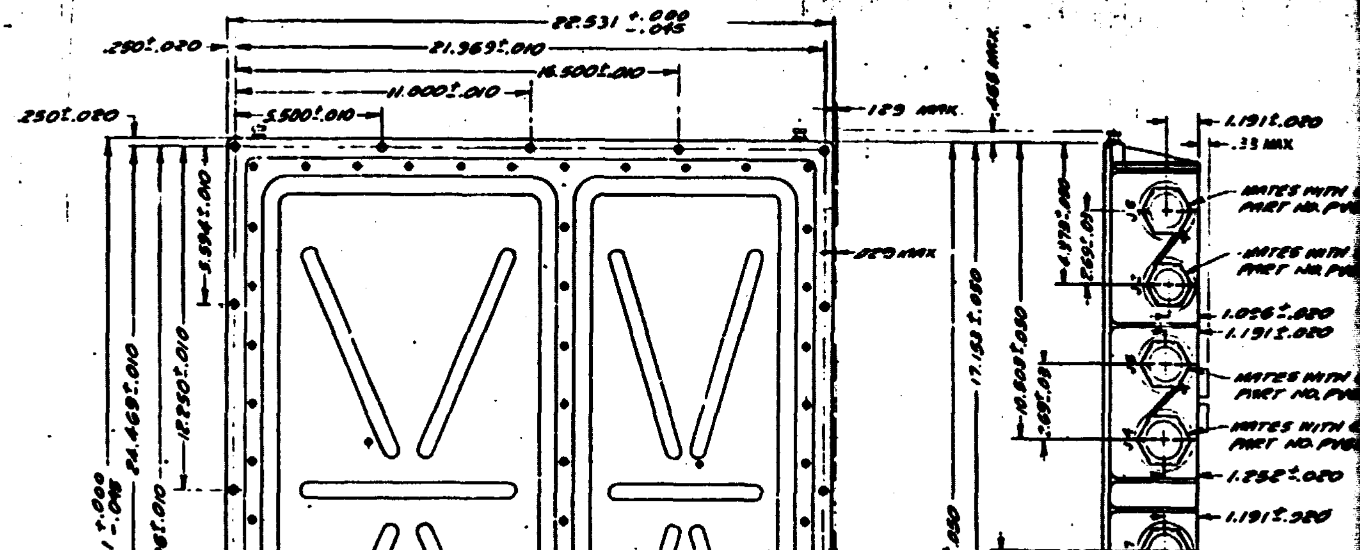
CENTRAL MOMENT GYRO ASSEMBLY	GEORGE C. MARSHALL SPACE FLIGHT CENTER	E 50M22136
NASA		

CMG-6A



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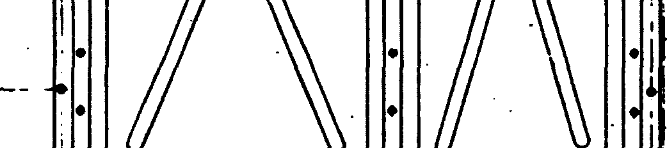

VENDOR NAME & ADDRESS	VENDOR PART NO.
THE BENDIX CORPORATION NAVIGATION & CONTROL DIV. TETERBORO, N.J. 07608 CODE IDENTIFICATION 91315	SEE TABULATION

NOTES:

1. DURING VACUUM BAKE (HEATER OFF) THE TEMPERATURE OF THE CMG-1A SHALL NOT BE PERMITTED TO EXCEED +160°F.
2. DO NOT REMOVE THIS ITEM FROM ITS [illegible] SHIPPING CONTAINER UNLESS IT IS IN A PROTECTED ENVIRONMENT EQUAL TO A CLEAN AREA.
3. REMOVE THE [illegible] PROTECTIVE PLASTIC COATINGS BEFORE MOUNTING [illegible] CLEANING.
4. THE EXTERIOR OF THE COMPONENT SHALL BE INSPECTED AND, IF REQUIRED, CLEANED IN ACCORDANCE WITH THE ATM CLEANLINESS REQUIREMENTS DOCUMENT, [illegible] REV C. [illegible] EXTERIOR FINISH OF THIS COMPONENT IS [illegible] WHITE THERMAL PAINT, AND ANY SPECIAL HANDLING AND/OR CLEANING PROCEDURES MUST BE [illegible].
5. THE CLEANED COMPONENT SHALL BE THERMAL VACUUM BAKED AT A MAXIMUM VACUUM CHAMBER WALL TEMPERATURE OF [illegible] C FOR A TIME PERIOD NOT TO EXCEED 96 HOURS.
6. THE COMPONENT [illegible] AND COVER SCREWS ARE NOT TO BE LOOSENED.

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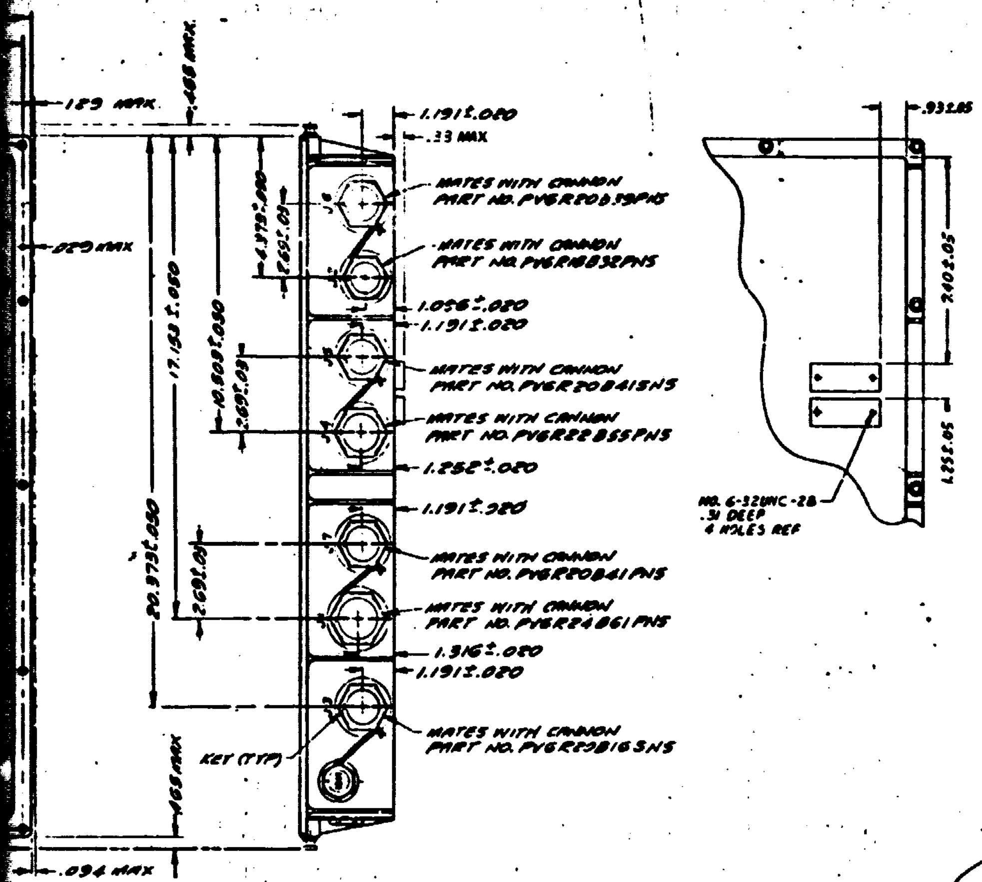

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2121500-19	50M22137	S/N 4
VENDOR PART NO	MSFC PART NO	SERIAL NO

SPECIFICATION CONTROL DRAWING

CONTROL MOMENT GYRO INVERTER ASSEMBLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

E 50M22137

CMG-1A

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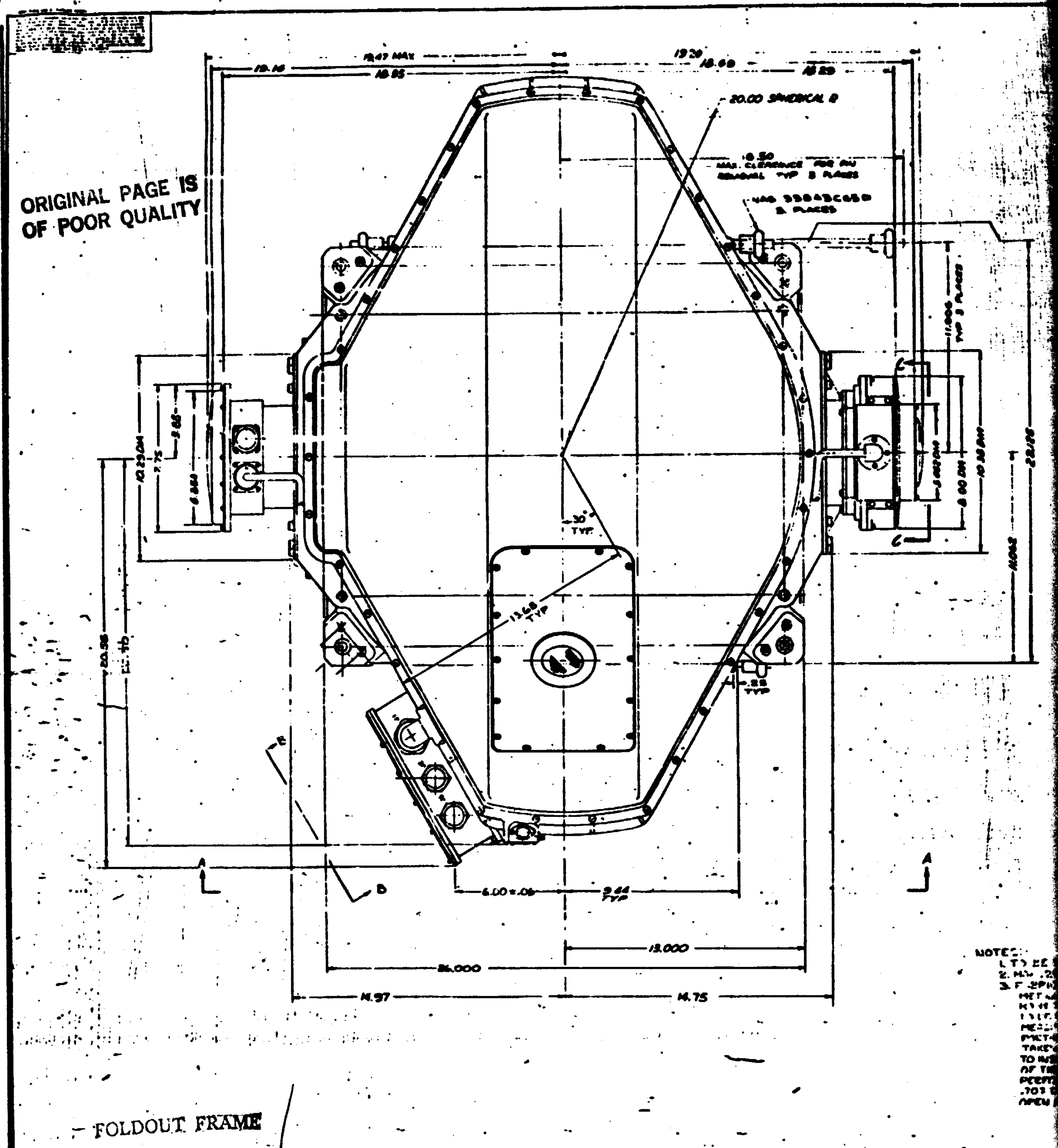

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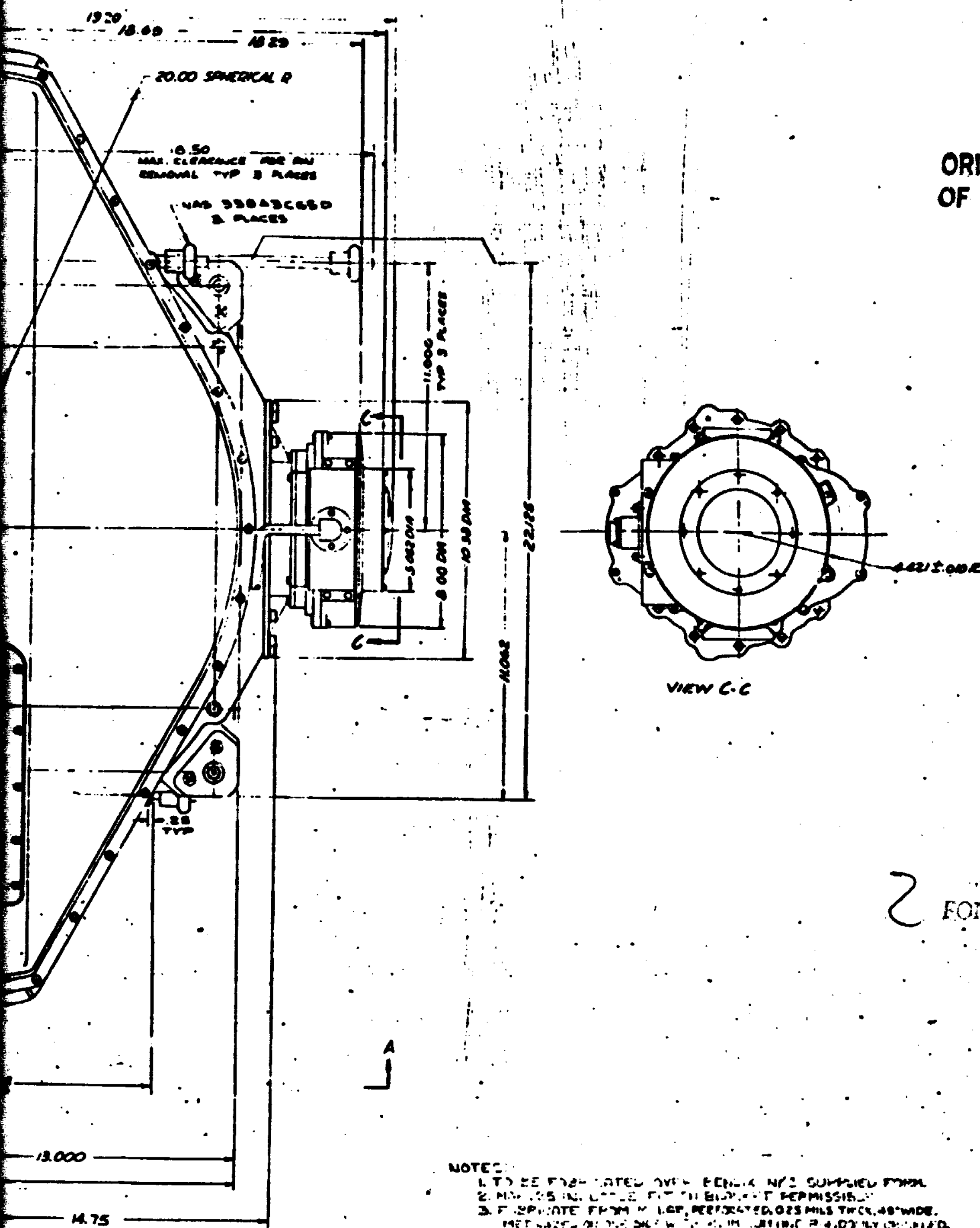

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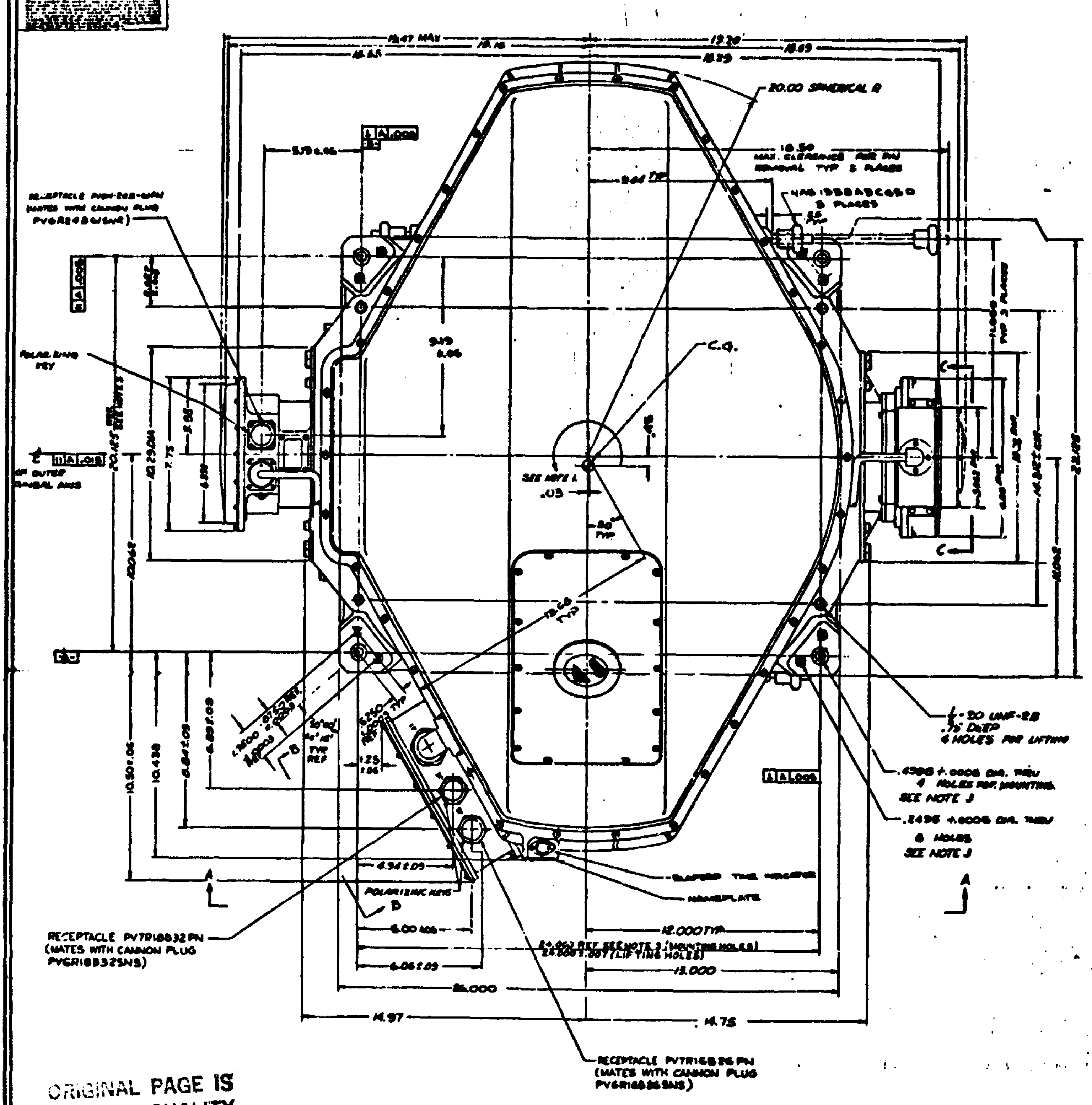
NOTES:
1. TO BE FABRICATED OVER BENDIX NFS SUPPLIED FORM
2. MAX .25 IN. LITTLE FIT IN BLANKET PERMISSIBLE
3. FABRICATE FROM MYLAR, PERFORATED, .025 MILS THICK, 48" WIDE. METALIZED ON ONE SIDE WITH ALUMINUM [illegible] TOTAL HEMISPHERICAL SURFACE EMITTANCE OF [illegible] SIDE [illegible] 0.23 AND NOT TO EXCEED 0.04. THE EMITTANCE MEASUREMENTS [illegible] TO BE MADE BY [illegible] EMISSIVITY MEASUREMENTS SHALL BE TAKEN EVERY 50 FEET ACROSS THE WIDTH OF THE MATERIAL TO INSURE UNIFORMITY OF THE EMITTANCE VALUES. CERTIFICATION OF THE EMITTANCE VALUES SHALL BE ATTACHED TO EACH ROLL. PERFORATIONS TO BE .0375 DIAMETER HOLES [illegible] .707 DISTANCE ON SIDES TO PROVIDE BETWEEN 1.4-1.5 PERCENT OPEN AREA. ([illegible] YDS. PER ROLL)(FSN 5999-[illegible])

BLANKET



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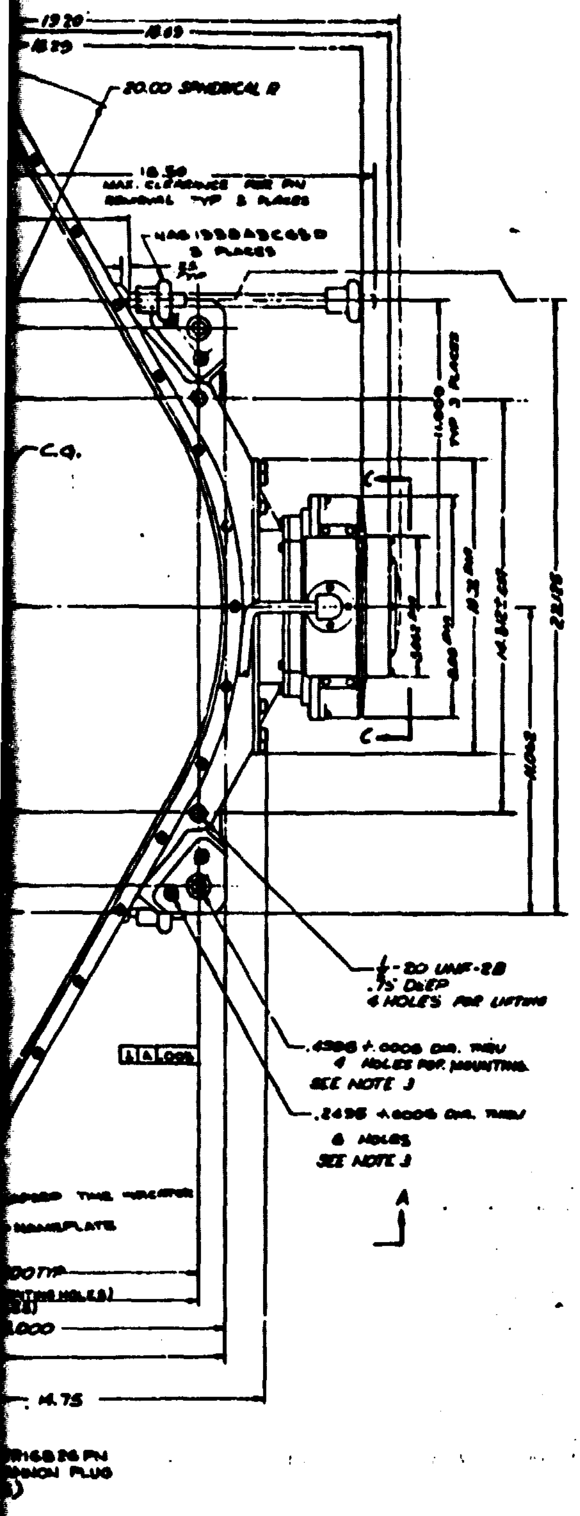
VENDOR NAME & ADDRESS	VENDOR PART NO.
THE BENDIX CORPORATION NAVIGATION & CONTROL DIV. TETERBORO, N.J. 07608 CODE IDENTIFICATION 79315	SEE TABULATION

FOLDOUT FRAME

		REVISIONS		
	A	CRT 186816-2 ADDED VIEW C-C AND DIMENSIONS SEE SHEET 2		
	B	CRT 812143-2 UPDATED TO SHOW FILTERS SEE SHEET 2		
	C	[illegible]		
	D	[illegible]		



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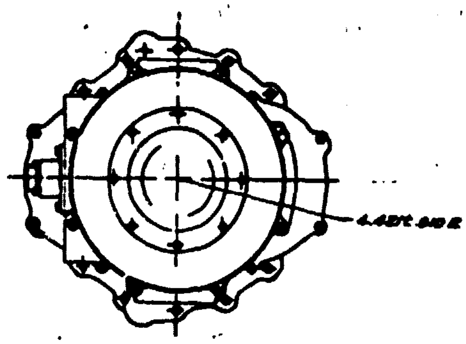

VIEW C-C

NOTES:

1. DIRECTION OF ROTOR ROTATION SHOWN WITH INNER GIMBAL IN 0° POSITION
2. EVACUATION VALVE LOCATED ON INNER GIMBAL MATES WITH PART NO. 4046-E SNAP-TITE INC. UNION CITY, PA.
3. GAUGE PINS OF GAGE 812143-1 MUST FREELY PASS THRU 12 MOUNTING HOLES.
4. LID MOUNTING SURFACES FLAT WITHIN .005 AND ALL FOUR (4) MOUNTING SURFACES IN SAME PLANE WITHIN .010.
5. FOR THERMAL BLANKET INSTALLATION SEE DRWG NO. 50M 22101

8120100-29	50M22136	[illegible]
8120100-19	50M22136	S/N 4
VENDOR PART NO	MSFC PART NO	SERIAL NO

SPECIFICATION CONTROL DRAWING

CONTROL MOMENT GYRO ASSEMBLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

E 50M22136

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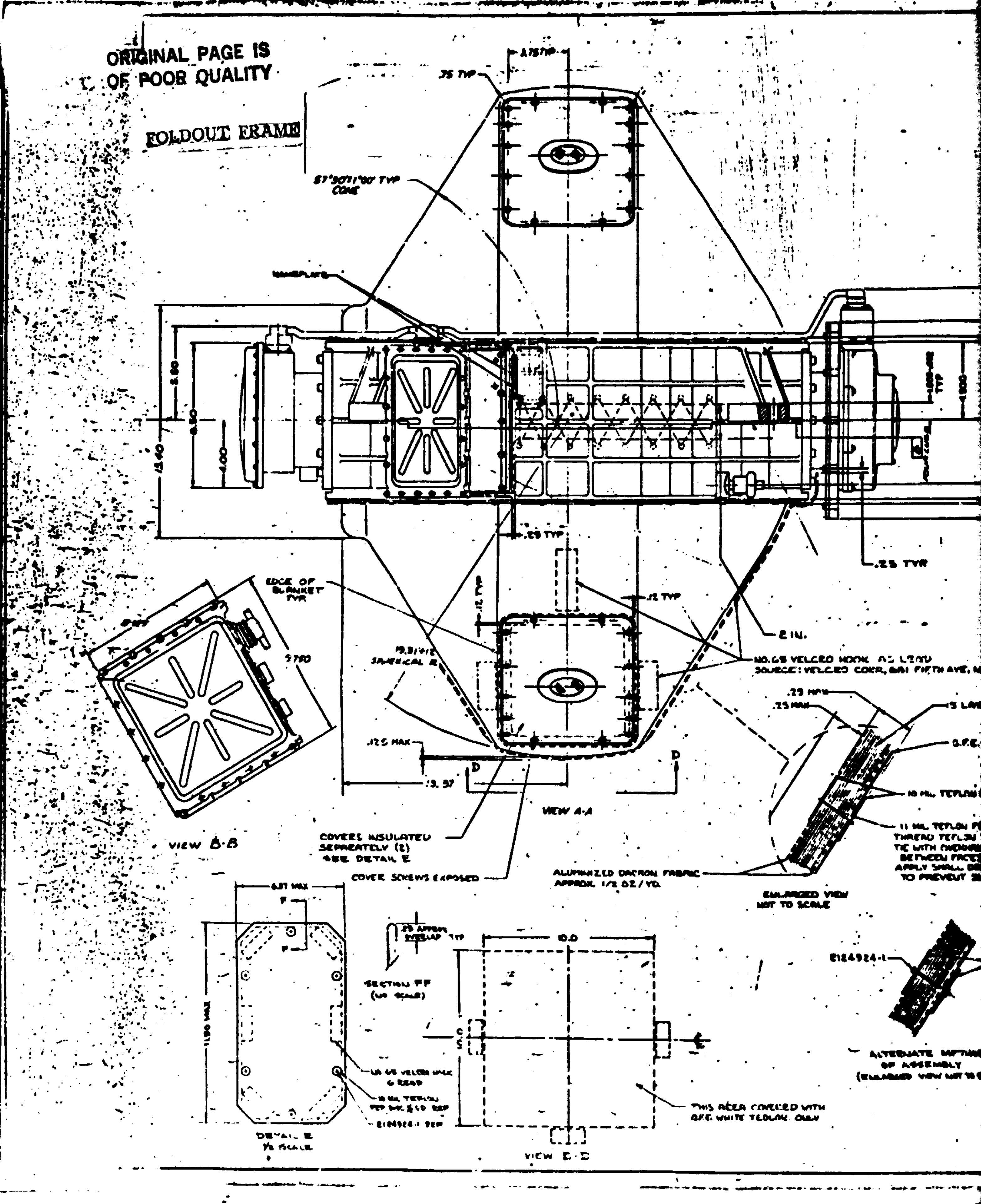

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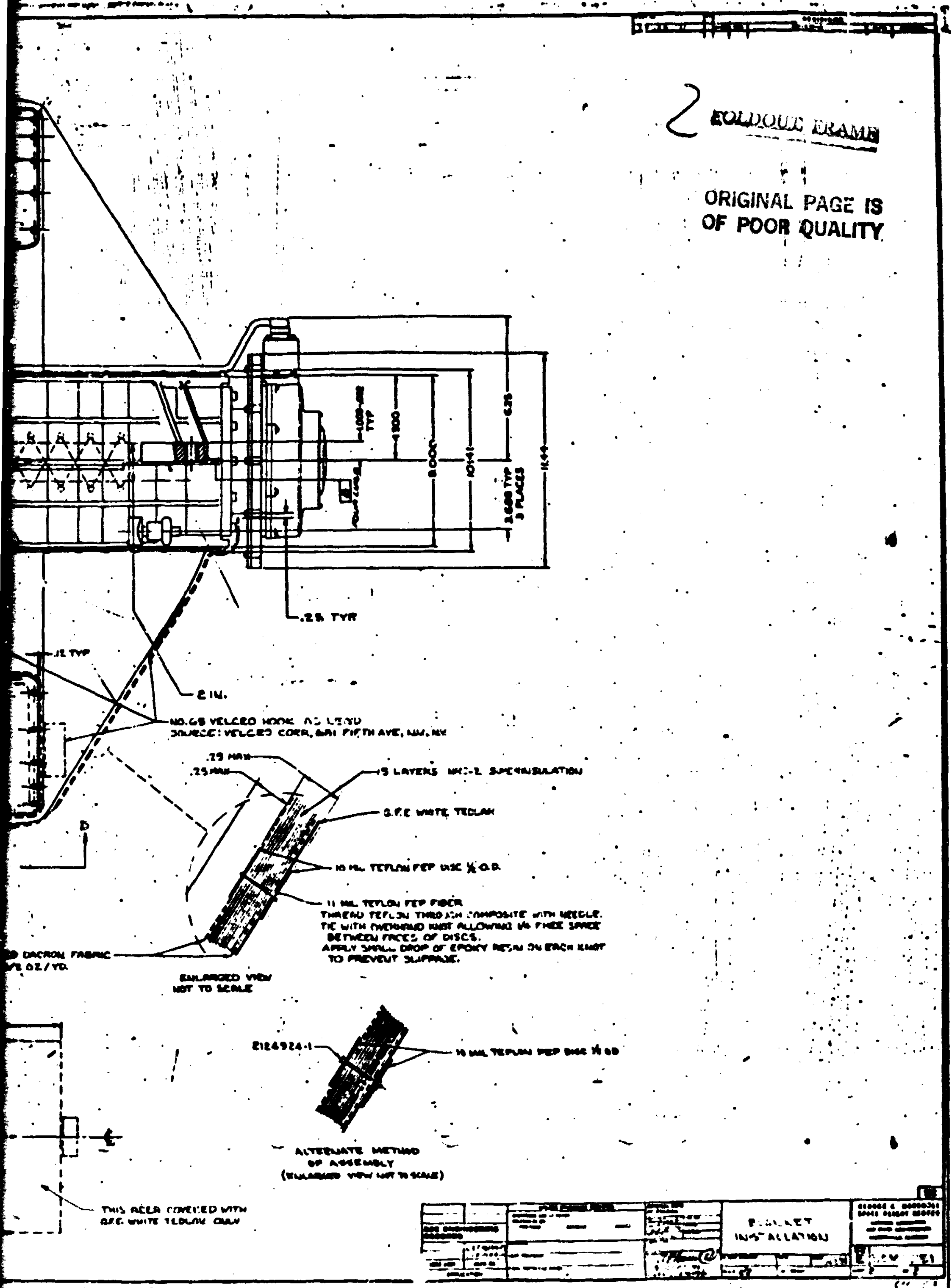

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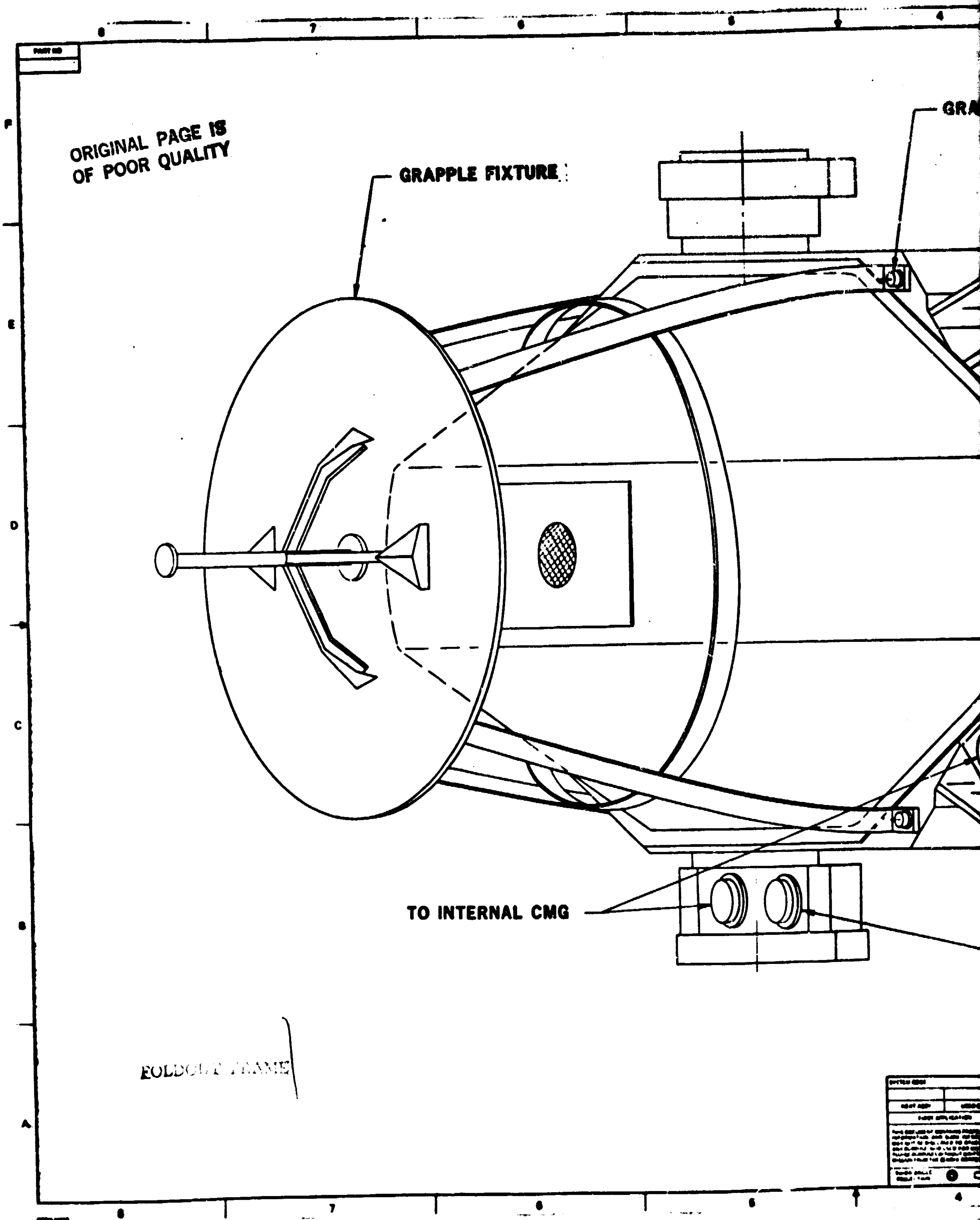

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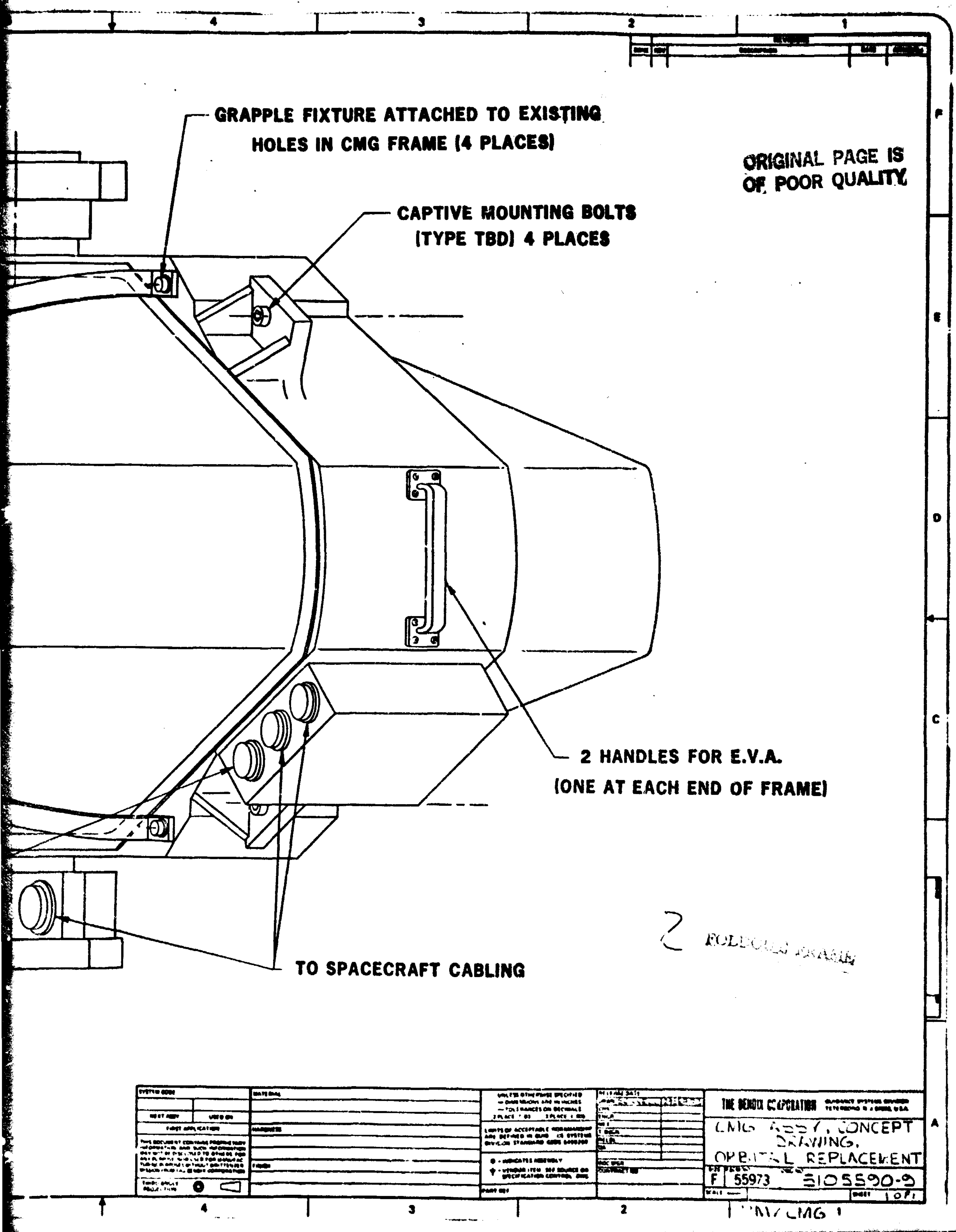
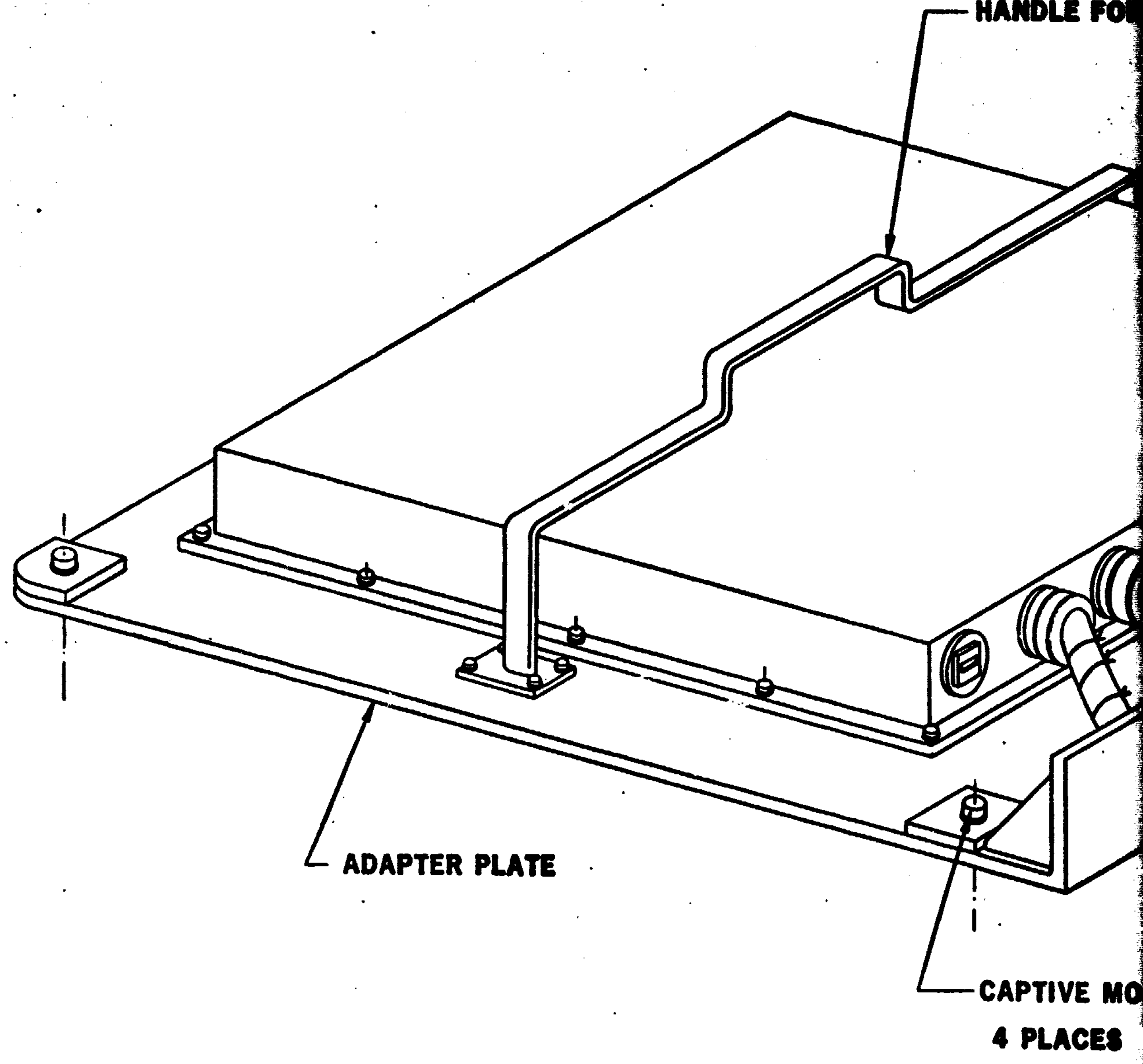
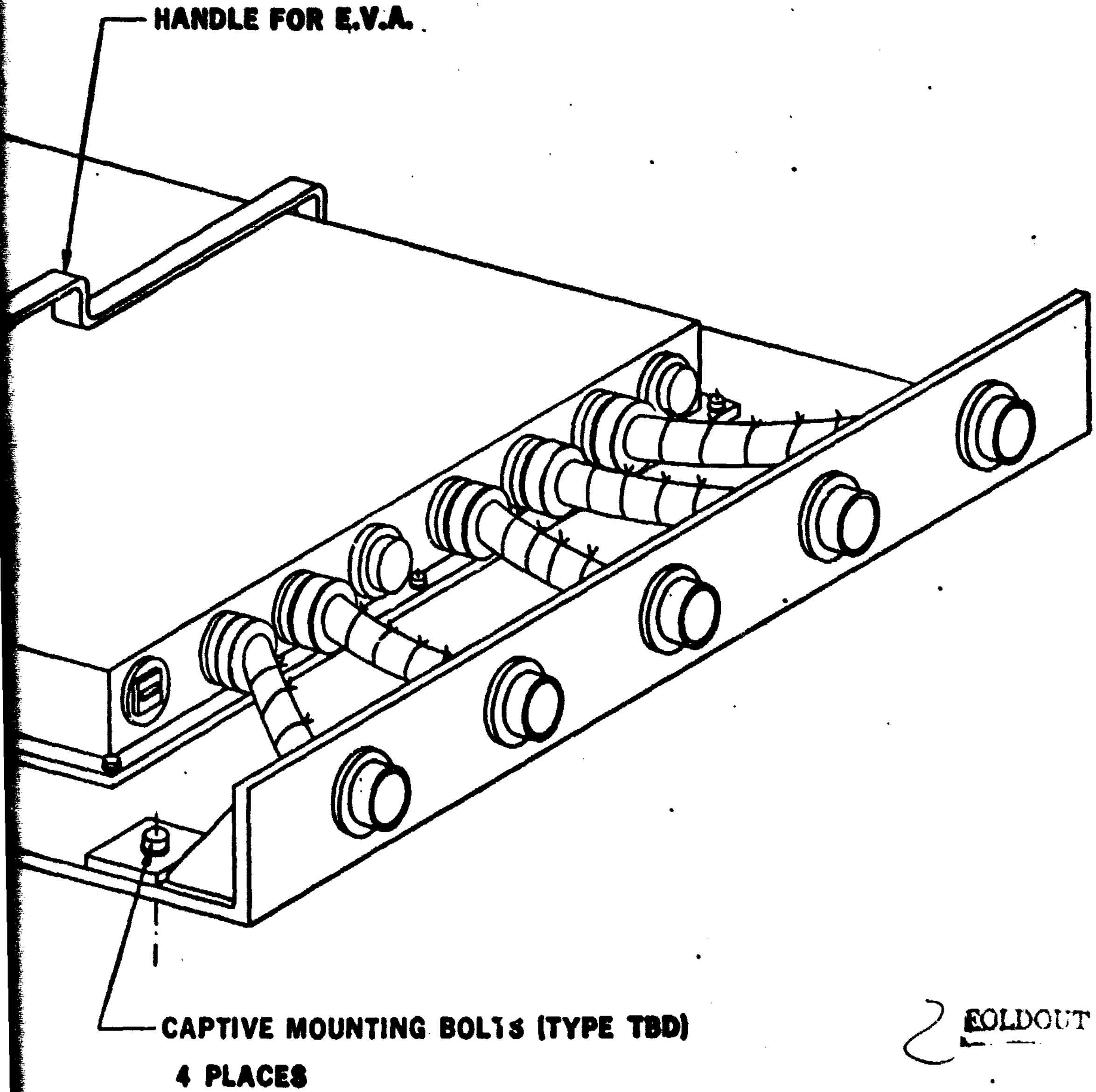



HANDLE FO
ADAPTER PLATE
CAPTIVE MO
4 PLACES



THE BENDIX CORPORATION

INVERTER ASSY CONCEPT DRAWING ORBITAL REPLACEMENT

F 55973 5105591-9