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**USAF SCHOOL OF AEROSPACE MEDICINE
CENTRIFUGE FACILITY:
TECHNICAL INFORMATION**

Robert J. Irish, Senior Airman, USAF

September 1988

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**USAF SCHOOL OF AEROSPACE MEDICINE
Human Systems Division (AFSC)
Brooks Air Force Base, TX 78235-5301**



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NOTICES

This final report was submitted by personnel of the Systems Engineering Branch, Crew Technology Division, USAF School of Aerospace Medicine, Human Systems Division, AFSC, Brooks Air Force Base, Texas, under job order 7930-17-01.

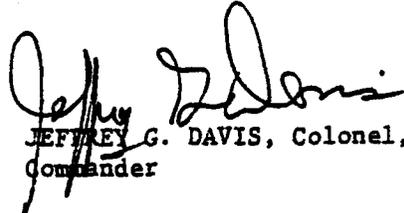
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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.


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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This technical report contains information about the USAFSAM centrifuge that includes systems specifications such as performance data, payload restrictions, and data acquisition capabilities. Proof testing procedures are included for new fixtures and equipment; and a complete set of drawings of the gondola fixture are provided.							
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USAF SCHOOL OF AEROSPACE MEDICINE CENTRIFUGE FACILITY:
TECHNICAL INFORMATION

INTRODUCTION

The centrifuge facility described in this report is located at the USAF School of Aerospace Medicine (USAFSAM), Brooks AFB, Texas. This unique facility provides a ground-based simulator capable of producing a high rate of G onset (up to 6 G/s), as well as a high G (up to a 30 G) acceleration environment. The mission of this facility is to support physiologic and medical research on the effects of high acceleration, to develop and test new types of life-support equipment for use in modern aircraft, and to train the aircrews of high-performance aircraft in the proper techniques required to resist G-induced loss of consciousness (GLOC) during high-G maneuvers.

The purpose of this report is to provide technical information to prospective users of the USAFSAM centrifuge who can use the information in their preliminary research design.

Any questions regarding the USAFSAM centrifuge facility may be directed to:

Chief, Systems Engineering Branch
USAFSAM/VNS Bldg 170
Brooks AFB TX 78235-5301

GENERAL DESCRIPTION

The USAFSAM centrifuge facility is housed in a building divided into three floor levels. The upper level contains the operation control center and data acquisition system that provide for observation, control, and monitoring of centrifuge systems and test subjects by the centrifuge operating and medical specialists. The middle level is a circular pit in which the principal components of the centrifuge are mounted. These components include the rotor arm and the fixtures for carrying either human test subjects or equipment. The lower level contains the four 250 horsepower direct current (DC) motors, driveshafts, sliprings, and the lubrication oil unit (Fig. 1).

The centrifuge system, shown on the middle level in Figure 1, is comprised of a power head, rotational arm, gondola, and equipment fixture. The gondola, which is mounted at a 6.1 m (20 ft) radius from the center of arm rotation, is designed to accommodate human subjects and may also be used for unmanned equipment tests. The equipment fixture, mounted at a 3.9 m (13 ft) radius, is of open air design and may also be used for testing equipment.

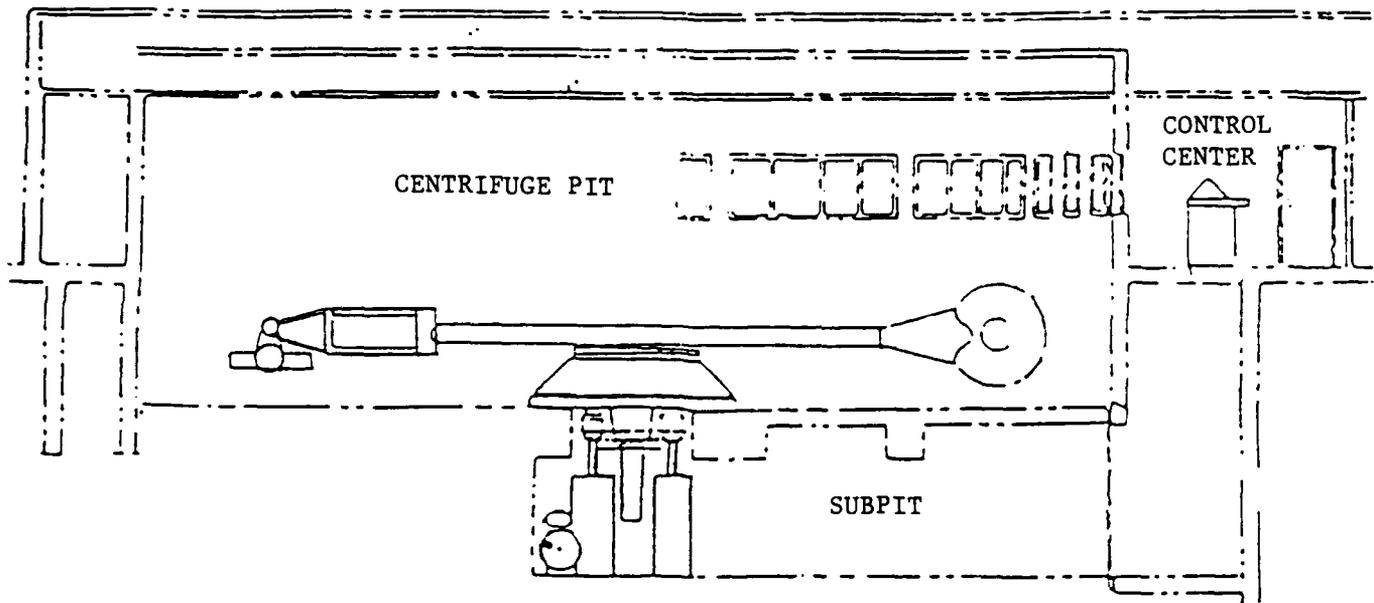


Figure 1. Centrifuge facility.

TECHNICAL DISCUSSION

The USAFSAM centrifuge is used to generate acceleration forces (G-forces) similar to those encountered during flight and air combat maneuvers. These forces are generated through the use of the rotating arm and free swinging gondola, or equipment ring. The rotating arm produces the centrifugal force or radial G, and the free swinging action of the gondola or equipment ring orients the subject such that the resultant G vector is aligned with the subject's Z axis producing $+G_z$ (Fig. 2).

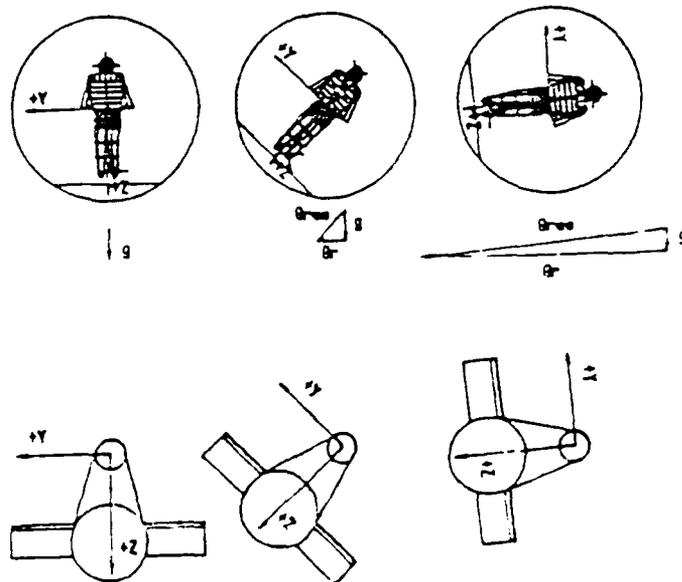


Figure 2. Free swinging gondola and equipment ring.

The equipment ring may be free swinging or fixed, so that the equipment is subjected to pure radial G. This arrangement is done by installing support bars. In this configuration the radial G vector is on the +Y axis (Fig. 3).

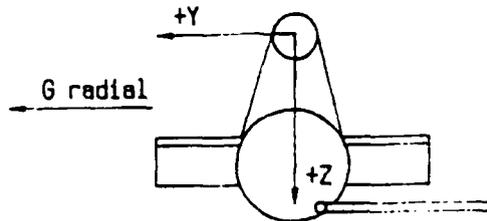


Figure 3. Fixed equipment ring.

CENTRIFUGE SPECIFICATIONS

The centrifuge drive allows a maximum rotor arm speed of 66 rpm, which translates to 30 radial Gs on the gondola end and 20 radial Gs on the equipment end. The output torque of the DC drive motors allows for a maximum G onset of 6 G/s with 0.2 G overshoot. This information is summarized in Table 1.

TABLE 1. CENTRIFUGE SPECIFICATIONS

Rotor arm dimensions	6.1 m (20 ft) from pivot point to gondola center. 3.9 m (13 ft) from pivot point to equipment end center.
Rotor arm speed	0 to 66 rpm
Rotor arm braking system	Regenerative, dynamic, and air, independently operable
Primary electric power	480 V, 3-phase, 60 Hz
G level capability	Variable 1 to 30 G
Onset rate	0 to 6 G/s average from 1 to 13 radial G
G resolution	+0.1 with 0.2 G overshoot
Control modes	Manual (operator or test subject) and computer programmable (closed loop)
Duty cycle	10-min continuous duty

GONDOLA FIXTURE SPECIFICATIONS

The centrifuge gondola assembly is comprised of a rotating barrel and a yoke. This system's construction is designed to hold a 13,607.7 G-kg (30,000 G-lb) payload, and is balanced to hold 680.39 kg (1500 lb) statically. The added allowable payload is a function of the desired G level and the amount of standard equipment in the gondola (Tables 2 and 3). The gondola specimen chamber can be accessed through an overhead hatch and a door, each measuring 1.83 m (6 ft) long by 1.22 m (4 ft) high. The chamber itself is approximately 1.83 m (6 ft) long and 1.83 m (6 ft) wide at its widest point (Appendix).

TABLE 2. ALLOWABLE PAYLOAD DATA

<u>G Required</u>	<u>Allowable Payload kg(lb)</u>	
30.0	237.23	(523.00)
29.0	252.86	(557.48)
28.0	269.63	(594.43)
27.0	287.63	(634.11)
26.0	307.01	(676.85)
25.0	327.95	(723.00)
24.0	350.63	(773.00)
23.0	375.28	(827.35)
22.0	402.17	(886.64)
21.0	431.62	(951.57)
20.0	453.59	(1000.0)
19.0	453.59	(1000.0)
18.0	453.59	(1000.0)
17.0	453.59	(1000.0)
16.0	453.59	(1000.0)
15.0	453.59	(1000.0)
14.0	453.59	(1000.0)
13.0	453.59	(1000.0)
12.0	453.59	(1000.0)
11.0	453.59	(1000.0)
10.0	453.59	(1000.0)
9.0	453.59	(1000.0)
8.0	453.59	(1000.0)
7.0	453.59	(1000.0)
6.0	453.59	(1000.0)
5.0	453.59	(1000.0)
4.0	453.59	(1000.0)
3.0	453.59	(1000.0)
2.0	453.59	(1000.0)
1.0	453.59	(1000.0)

TABLE 3. GONDOLA FIXTURE SPECIFICATIONS

Total weight	1,764.47 kg (3,890 lb)
Standard equipment Gondola and Yoke	298.0 kg (657 lb)
Additional payload allowed to 20 G	453.59 kg (1,000 lb)
Additional payload allowed at 30 G	237.23 kg (523 lb)
Gondola dimensions	5.12 m (16.81 ft) long 1.83 m (6 ft) in diameter
Specimen chamber	1.83 m (6 ft) long 1.83 m (6 ft) in diameter

EQUIPMENT END

The equipment fixture is of open air design and is located opposite the gondola on the centrifuge arm. The equipment fixture can hold any piece of equipment which can be bolted down, is not heavier than 68.04 kg (150 lb), nor larger than .914 m (3 ft) in height, width, or length (Table 4).

TABLE 4. EQUIPMENT FIXTURE SPECIFICATIONS

Total weight	544.31 kg (1,200 lb)
Maximum payload	226.80 kg (500-lb) free swinging 181.44 kg (400-lb) ring fixed
Payload at 20 G	4,535.92 G-kg (10,000 G-lb)
Specimen size limit	.914 m x .914 m x .914 m (3 ft x 3 ft x 3 ft)

DATA ACQUISITION CAPABILITY

The data acquisition capability of the centrifuge consists of two 8 channel strip-chart recorders, two 14-channel magnetic tape recorders, and a DEC PDP11 which is capable of digitizing 16 channels of data simultaneously with a centrifuge run (Table 5).

TABLE 5. DATA ACQUISITION SPECIFICATIONS

Slip rings	20 twisted pair in gondola available 20 twisted pair on equipment end available
Strip-chart recorders	Two 8 channel recorders 12 channels available
Mag-tape recorders	Two 14 channel recorders 11 channels available on each
Digitizing capability	DEC PDP11, 16 channels sampling rate 200 samples/s
Power available in gondola	120 VAC, 115 VAC 400 Hz 3 phase Delta or Y, DC dual-power supply

PROOF TESTING PROCEDURE

The following procedure defines the design, use, and proof testing of all test fixtures, experiments, and other equipment to be mounted and/or operated on the USAFSAM Centrifuge. All test fixtures, experiments, and other equipment shall be designed with a yield strength of at least 150% of the maximum planned loading during experimental runs. Experiments using existing equipment will be limited to a maximum load of 67% of the equipment's design yield strength. All test fixtures, experiments, and other equipment will be proof tested at 150% of the maximum planned load and inspected for deformation and failures. The Engineering Support Function will review all design data before proof testing; the Systems Engineering Branch will approve all test fixtures, experiments, and other equipment before installation or operation on the centrifuge.

CENTRIFUGE WEIGHTS BREAKDOWN

Table 6 contains a complete list of all the gondola and yoke standard equipment. This list includes all equipment that is either permanently installed or normally left in the gondola.

Table 7 is a complete list of all added equipment or equipment which may be used for one test run and then removed for the next run. This equipment weight would be considered as additional payload.

TABLE 6. CENTRIFUGE WEIGHTS LISTING

<u>Item</u>	<u>Weight kg(lb)</u>		<u>Qty</u>	<u>Total kg(lb)</u>	
Gondola/Yoke Assembly					
Yoke	1262.8	(2784.0)	1	1262.8	(2784.0)
Gondola	501.7	(1106.0)	1	501.7	(1106.0)
Total				1764.5	(3890.0)
Yoke Standard Equipment					
Damper	15.42	(34.0)	1	15.42	(34.0)
Damper mounts	11.34	(25.0)	1	11.34	(25.0)
Damper shocks	4.08	(9.0)	4	16.33	(36.0)
Air conditioner	39.00	(86.0)	1	39.00	(86.0)
Total				82.10	(181.0)
Gondola Standard Equipment					
Rails	30.84	(68.0)	1	30.84	(68.0)
Equipment racks	31.30	(69.0)	1	31.30	(69.0)
Insulation	11.34	(25.0)	1	11.34	(25.0)
Patch panel	7.71	(17.0)	1	7.71	(17.0)
Terminal box	5.44	(12.0)	1	5.44	(12.0)
Audio amp	2.72	(6.0)	1	2.72	(6.0)
Mech accel panel	.91	(2.0)	1	.91	(2.0)
Accelerometer	.45	(1.0)	1	.45	(1.0)
Accel power sup	4.54	(10.0)	1	4.54	(10.0)
Press cal system	8.16	(18.0)	1	8.16	(18.0)
Fluor light bal	4.88	(10.8)	1	4.88	(10.8)
Fluor light	5.44	(12.0)	1	5.44	(12.0)
Speaker panel	3.63	(8.0)	1	3.63	(8.0)
Damper washer	4.99	(11.0)	1	4.99	(11.0)
Door air cyl	9.07	(20.0)	1	9.07	(20.0)
Air res. & mount	11.34	(25.0)	1	11.34	(25.0)
Heat & AC control	2.27	(5.0)	1	2.27	(5.0)
110 VAC system	4.54	(10.0)	1	4.54	(10.0)
AC dist panel	2.27	(5.0)	1	2.27	(5.0)
Color camera	1.59	(3.5)	1	1.59	(3.5)
Pan tilt	11.45	(25.3)	1	11.45	(25.3)
Pan tilt stand	3.63	(8.0)	1	3.63	(8.0)
Ventilation fan	1.81	(4.0)	1	1.81	(4.0)
Gould amp rack	19.05	(42.0)	1	19.05	(42.0)
Gould amps	1.81	(4.0)	2	3.63	(8.0)
Dual power supply	15.08	(33.3)	1	15.08	(33.3)
Check 6 system	2.38	(5.3)	1	2.38	(5.3)
Master caution	2.26	(5.0)	1	2.26	(5.0)
Light bar mount	3.63	(8.0)	1	3.63	(8.0)
Total				216.36	(477.0)

TABLE 7. ADDED EQUIPMENT

<u>Item</u>	<u>Weight kg(lb)</u>	
ACESII seat	48.08	(106.0)
ACESII plate	47.17	(104.0)
Art seat & plate	113.40	(250.0)
Foot rest plate	7.71	(17.0)
F15 foot rest	4.99	(11.0)
F16 foot rest	11.11	(24.5)
Art seat foot rest	9.98	(22.0)
Side mockup	15.42	(34.0)
Sm monitor stand	10.88	(24.0)
Sm monitor	29.48	(65.0)
Lg monitor stand	16.10	(35.5)
Lg monitor	43.54	(96.0)
Side stick base	1.81	(4.0)
Side stick	5.22	(11.5)
F16 stick W/PS	12.70	(28.0)
Center stick	1.36	(3.0)
Straight light bar	1.36	(3.0)
Curved light bar	3.63	(8.0)
Curved light bar controller	3.18	(7.0)
G-valve transducer	1.36	(3.0)
G-valve solenoid	1.93	(4.2)
Alar G-valve	1.02	(2.2)
HFRP G-valve	3.63	(8.0)
SKAG valve	2.15	(4.8)
G-valve mount	1.02	(2.2)
G-valve inlet	.68	(1.5)
E-valve new	4.99	(11.0)
E-valve old	8.62	(19.0)
CRU 73 regulator	2.04	(4.5)
Safety valve	11.34	(25.0)
Bottle racks	3.97	(8.8)
Bottle small	29.48	(65.0)
Bottle large	58.96	(130.0)
Bottle regulator	3.40	(7.5)
Validyne	2.04	(4.5)
Impedance	5.90	(13.0)
Subject & gear	90.72	(200.0)

APPENDIX
CENTRIFUGE DRAWINGS

(Note: All dimensions are in inches.)

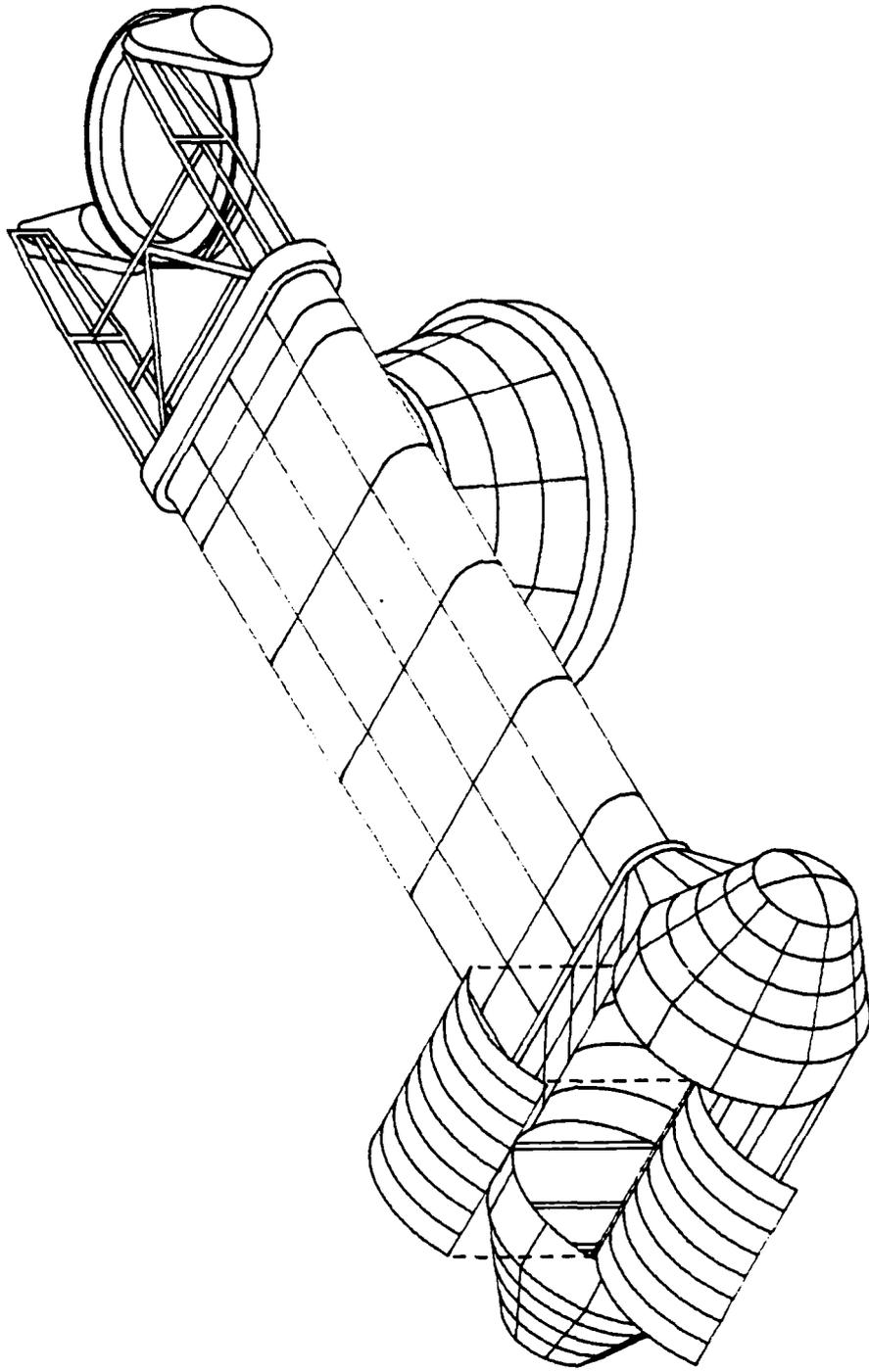


Figure A-1. The USAFSAM Centrifuge (Isometric).

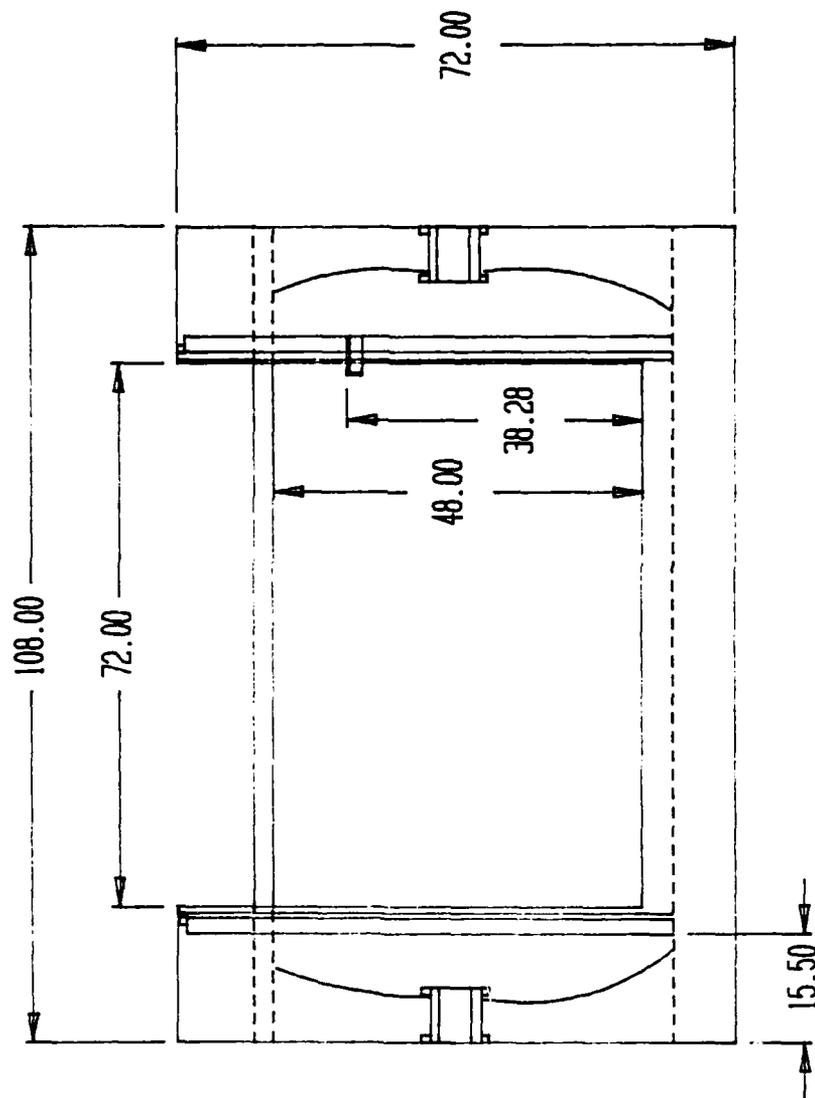


Figure A-2. Gondola - side view

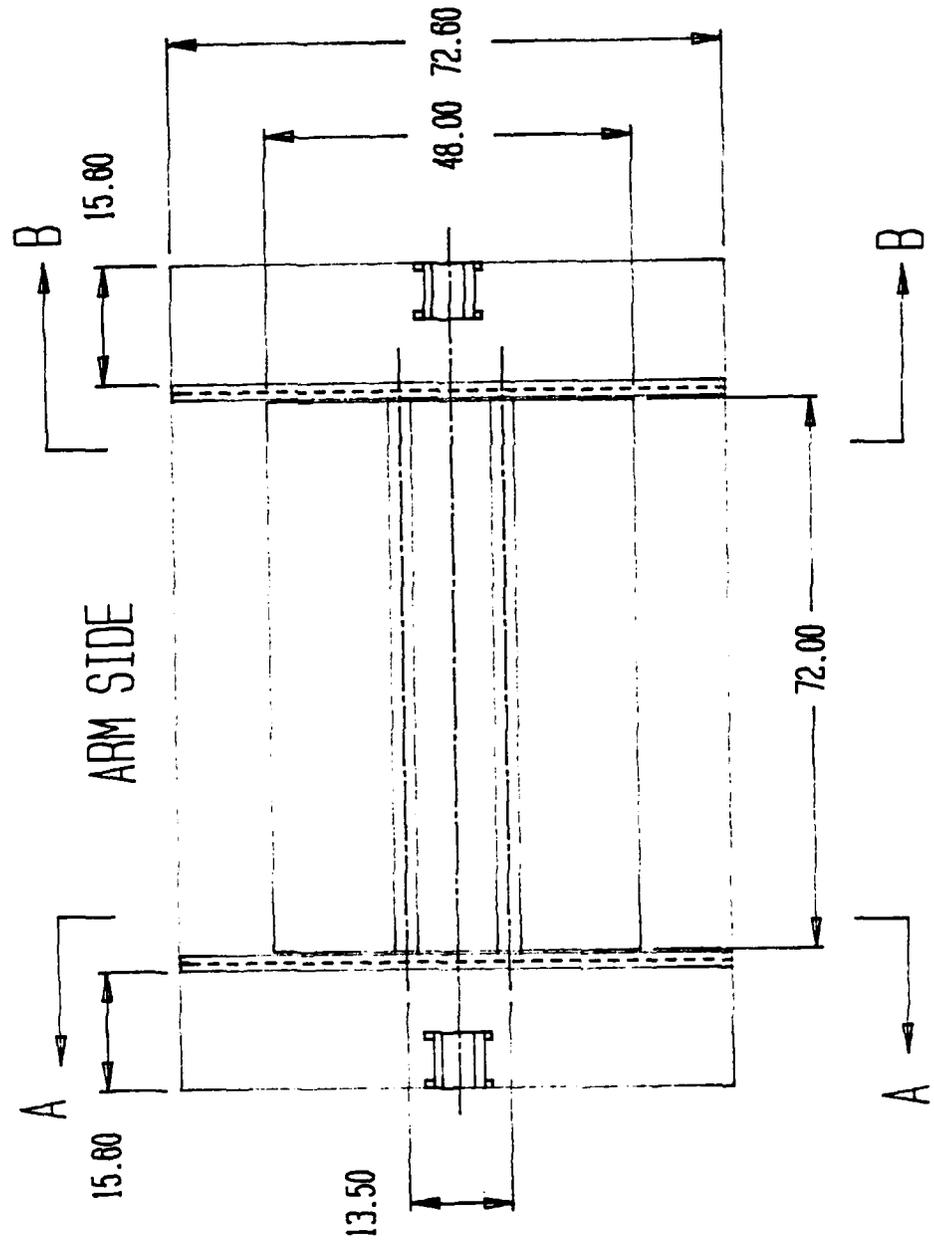


Figure A-3. Gondola - Top view.

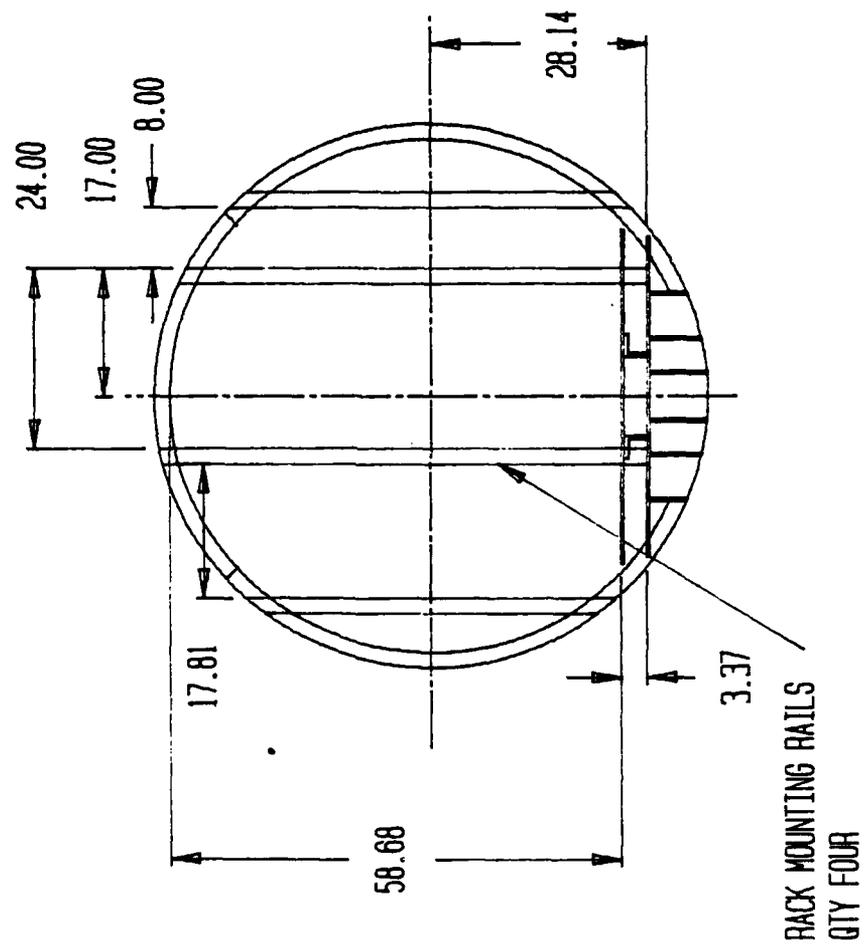


Figure A-4. Gondola - section A-A.

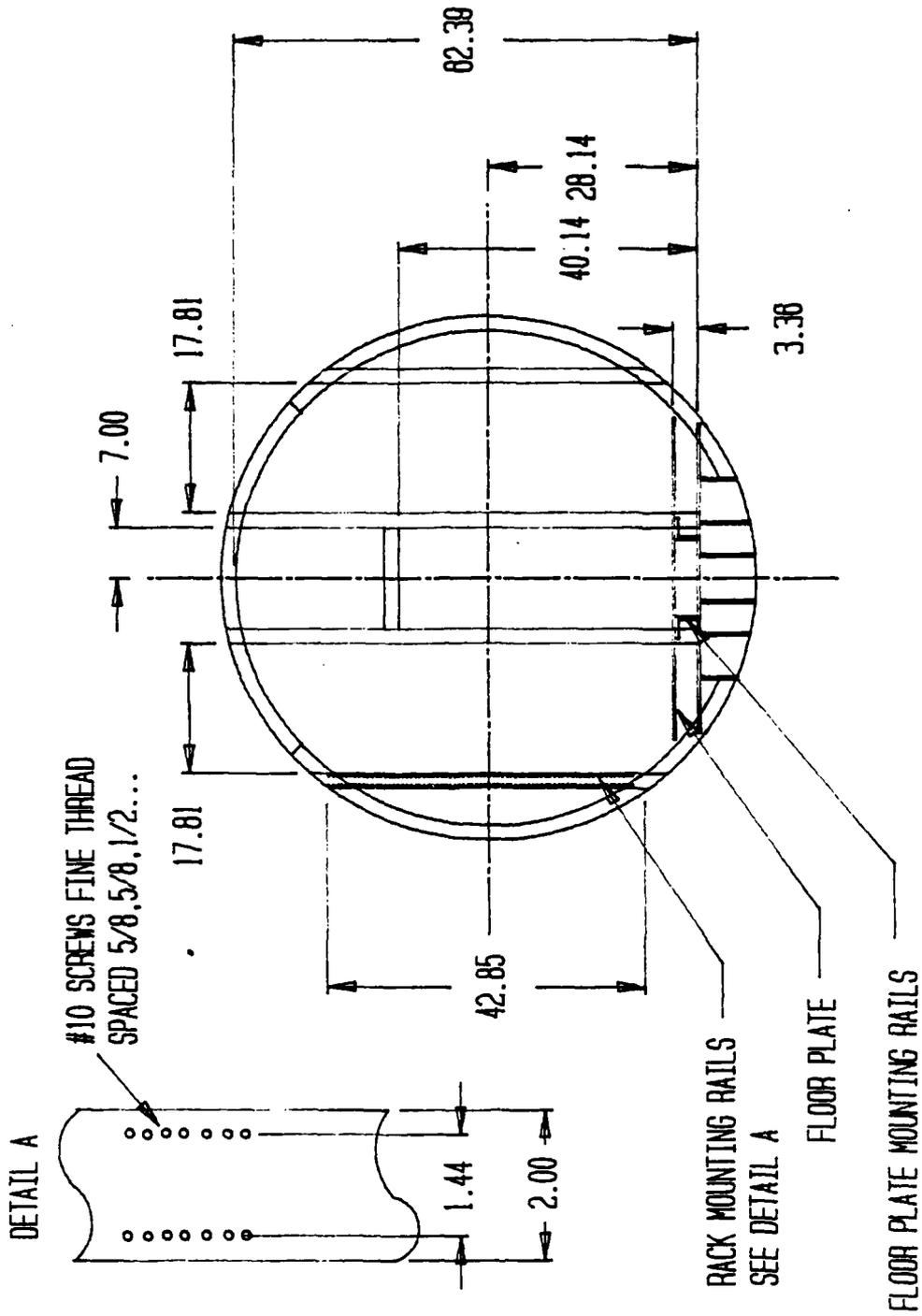


Figure A-5. Gondola - section B-B

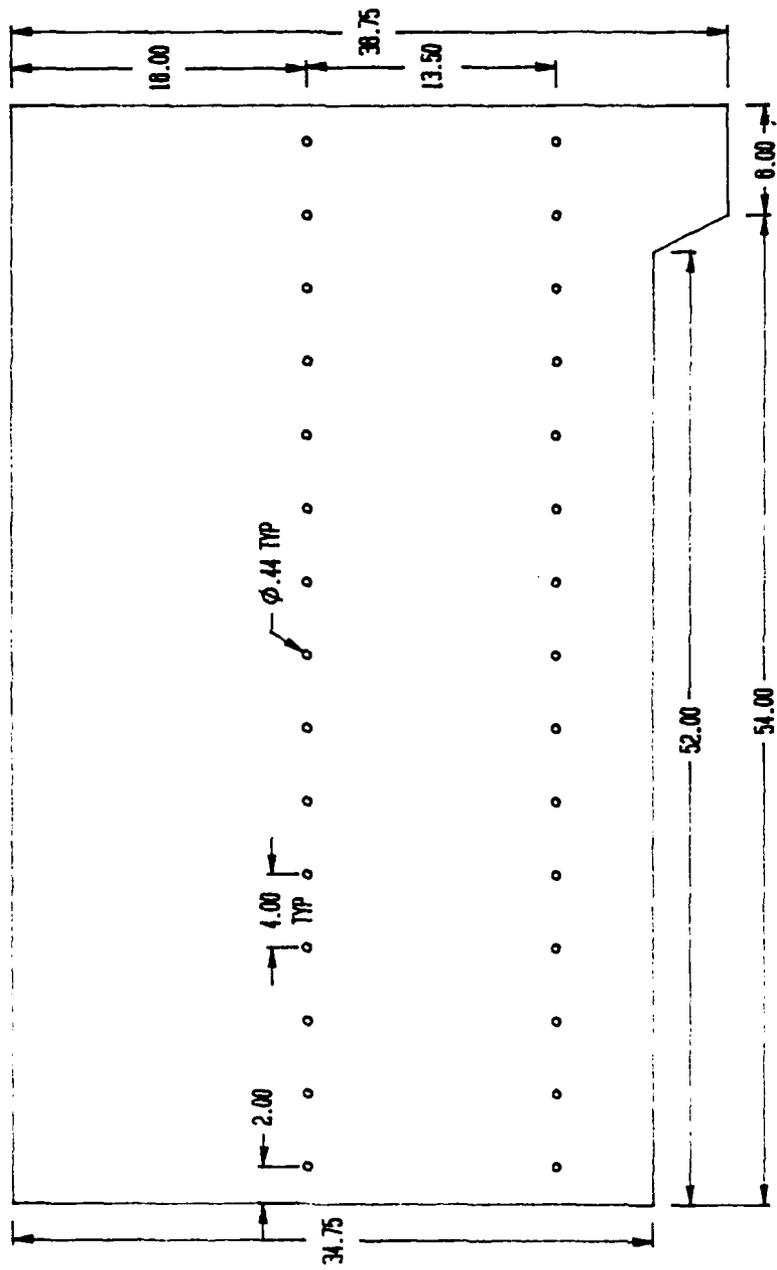


Figure A-6. Gondola floor plate.