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DESCRIPTION AND SUMMARY OF QUALIFICATION TESTING OF THE IMP-I ATTITUDE CONTROL SYSTEM AND YO-YO DESPIN SYSTEM

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PURPOSE

The purpose of this report is to describe both the Attitude Control System and the Yo-Yo Despin System in the flight configuration as installed on the IMP-I spacecraft. No attempt is made to present a history of design development except where actual engineering tests were performed. Certain pertinent and useful information is included from which the operation and performance of the systems may be determined. Both component and system testing is summarized in an effort to demonstrate compliance with safety and functional requirements and to assure flight quality systems. Problem areas and corrective actions are also included.

ATTITUDE CONTROL SYSTEM

The Attitude Control System (ACS) for the IMP-I spacecraft is a cold gas system utilizing Freon-14 as a propellant and incorporates much of the technology developed for the AIMP-E system. Since this is a spin stabilized spacecraft, all operations are commanded from the ground but shut off automatically.

A 10% partial pressure of Helium is added as a tracer gas to aid in the leak detection procedures during assembly and for check out of the system prior to launch. A maximum total leak rate of 10^{-3} STD CC per sec. of the propellant has been established as acceptable, which amounts to 0.25 lb, of FREON-14 per year.

The ACS is capable of performing three main functions during the spacecraft mission; spin up, orient, and despin. These all serve to maintain the spin axis orientation perpendicular to the ecliptic plane and the 5.4 RPM spin rate throughout the required one year lifetime of the spacecraft. The vast majority of the propellant is to be used for spin up during the EFM antenna deployment, first to 150 feet and then to 200 feet. If the need arises, there is sufficient fuel to completely retract the EFM antennas from the 150 foot position.

Redundancy is achieved by a series-parallel arrangement of the solenoid valves for each function. The complete failure of any one valve will not fail the entire system either by eliminating one function or by depleting the fuel supply. Actuation, duration and pulsing of the valves is controlled electronically and is synchronized with the spin period.

Temperatures are controlled by a combination of surface coatings and thermal blankets and are expected to be maintained between -5 C and +40 C for various components. One special feature of the system is a rotating joint which eliminates the need for flexible tubing in the area of the boom hinges.

The total weight of the pneumatic portion of the ACS, including the propellant, is approximately 40 pounds. The flight fuel quantity is to be determined from the final mass property measurements and mission requirements. To aid in installation, the system is divided into five major modules; two tanks diametrically opposed to each other in order to maintain balance; a shelf assembly which can be leak checked before installation; and two valve-nozzle assemblies mounted on booms to give a 7.13 foot thrust moment arm. With a specific impulse of 45 lb.-sec. per lb. for Freon-14 and 35 millipounds of thrust, the flow rate is calculated to be 8 × 10^{-4} lb. per sec. for each nozzle.

This is a medium pressure system with a maximum allowable working pressure of 1800 psig at 23°C and a safety factor of 4. When filled to capacity with 19 lb. of Freon-14, this provides a maximum of 860 lb.-sec. of total impulse with 90% Freon and 10% Helium. The pressure is regulated to 40 psig before passing through the swivel joint, solenoid valves, and nozzles. Both high and low gas pressures are monitored by means of pressure transducers, and the gas temperature is monitored by means of a thermistor located in a probe in one of the tanks. The system is filled through a check valve, and the gas is filtered before entering the regulator. Excess downstream pressure is vented through a relief valve on the regulator.

The installation of the ACS on the spacecraft is described by GSFC DWG. GJ1064200. All normal servicing details are described in IMP-I-D-4.1.2 Attitude Control System (ACS) Operations.

During ground check out of the ACS, the performance and operation of the solenoid valves may be monitored through a test connector on the diode electronics pack on the end of each boom, and by a set of low pressure transducers installed as G.S.E. between the solenoid valves and the nozzles. Thus a current trace and pressure profile may be obtained for each solenoid and for each function of the ACS.

ACS COMPONENT DATA

Gas (Propellant)	
90% by partial pressure	Freon 14 (CF_4)
molecular weight	88.01
specific volume, 70F, 1 atmos	4.4 cu. ft./lb.
specific impulse	45 lb. sec./lb.
10% by partial pressure	Helium
Hi Pressure	
Tanks (2 ea.) mfg.	Sargent Ind., Airite Div.
part number	6853
material	6AL-4V Titanium
volume (ea.)	447 cu. in.
burst pressure — design	7200 @ 165 F
— test	9100 @ 70 F
weight (ea.)	6.2 lb.
Lines	
material	304 SS MIL 6845
size	1/4 OD × .035 wall
Temperature probe mfg. (2 ea.)	MSB/GSFC
material	303 SS
Thermister mfg.	YSI
part number	44006
Fill port check valve mfg.	Nupro
part number	SS-4C-25
cracking press.	25 PSID

Filter mfg.	Nupro
part number	SS-4F-2
particle size	2 microns
Regulator mfg.	Carleton Controls
part number	1-59-00-5
ports	MS-33514 E4
inlet pressure	300-1800 PSIG
reference	ambient
outlet pressure	40 ± 2 PSIG
flow rate	6 lb./hr. CF_4
seat material	Vespel SP-1
relief pressure	54 ± 2 PSIG
flow rate	0.2 lb./hr. CF_4
seat material	4404 Silicone
weight	0.45 lb.
Transducers	
type — potentiometer	inc. pressure
high pressure mfg.	Conrac
part number	461319
range	0-2000 PSIA
weight	.25 lb.
low pressure mfg.	Bourns
part number	443
range	0-75 PSIA
weight	.13 lb.

Low Pressure

lines	
material	6061-T4 AL ALY
size	1/4 OD × .028 wall
swivel joint mfg.	MSB/GSFC
part number	GD 1063874
solenoid valves (12 ea.) mfg.	Wright Components, Inc.
part number	15457-2
power @ 26 VDC	2 watts
pull in volts @ 40 PSIG	20 VDC
drop out volts @ 40 PSIG	5 VDC
flow @ 2 PSID	10^{-3} lb./sec. CF_4
seat material	Parker C147-7 Neoprene
weight ea.	.25 lb.
nozzles (6 ea.) mfg.	MSB/GSFC
type	Conical
inlet half angle	45 deg.
outlet half angle	10 deg.
throat diameter	.026 in.
area ratio	100:1
manual valves mfg.	Hoke
part number	D3251G4A

General

tube fitting type	Swagelok
o-ring material	Parker C147-7 Neoprene

thrust	.035 lb.
leak rate conversion factor	
Helium to Freon-14	× 0.213

SUMMARY OF TESTING AND SPECIFICATIONS

Tanks

Purchased per GSFC Spec. Control Dwg. GD1063682. Welded Titanium sphere, 9.760 in. dia., 447 cu. in., 0.110 in. wall thickness, 6.2 lb. weight, max. working pressure of 1800 psig.

Each unit, S/N 0001 thru 0010, was inspected, tested and documented by the MFG as follows:

Material—Mill test report and certification for material, heat number, grain size and chemical analysis. Tensile properties measured before and after heat treating for each specimen.

Processes—All welds inspected radiographically (X-Ray) and with penetrant by MFG. All cleaning, aging and finishing performed according to MFG specifications.

Acceptance Tests—Examined for conformance to GSFC specification concerning physical dimensions, weight and leakage (with helium at 300 psig). Volume was measured before and after exposure to a proof pressure of 2700 psig. for 3 minutes.

Qualification Test—In addition to the above testing, tank S/N 0007 was subjected to a design qualification test consisting of examination of product, cycle life test

(100 cycles 0 to 1800 psig.), vibration, acceleration, shock and burst test. Documentation supplied by the MFG reported a burst pressure of 9100 psig. at 70°F. All of the above testing was completed by 3-21-69.

The flight tanks were subsequently inspected and cleaned by GSFC prior to installation on the spacecraft.

Temperature Probes

Temperature probe bodies, S/N 1 thru 4 and 11 thru 15, were hydrostatically proof tested to 4000 psig., and S/N 5 and 16 were tested to 10,000 psig. without evidence of failure. These tests were performed by GSFC on 9/30/69, request no. 1340-33, and prior to thermistor installation. Thermistors are bonded in place per GSFC Dwg. GD1074085. Additional tests were performed to demonstrate the feasibility of placing a temperature probe inside the tank. These tests were completed, with satisfactory results, by GSFC on 5/2/69, request no. 1340-16.

Tubing and Fittings

All stainless steel tubing (type 304 CRES) and fittings (Swagelok 316 CRES) used on the ACS are standard items and rated by the MFG for a max. allowable working pressure of 4000 psig. and a burst pressure in excess of 12,000 psig. No testing was performed by GSFC on these items; however all such hardware was inspected and cleaned prior to installation on the spacecraft.

Transducers

The high pressure transducer is a standard item designed with a case burst pressure greater than 8000 psig. The low pressure transducer is also a standard item designed with a case burst pressure greater than 240 psig. No further testing was performed by GSFC; however, all units have been inspected, cleaned and calibrated by GSFC.

Check Valve and Filter

Both the check valve and filter are standard items and rated by the MFG for a max. allowable working pressure of 3000 psig. Check valves S/N 05 and 06 and filters S/N 05 and 06 were tested together for leakage and flow rates by GSFC, request no. 1340-12 completed 2-6-69. The units were tested at ambient temperature and at -10°C with helium, and in all cases the leak rate was less than 10^{-6} SCC/sec. and the flow rate much greater than that required by the regulator. A minimum burst pressure verification test was also performed by GSFC, request no. 1340-51 completed 12-9-70, from which it was determined that the assembled configuration of check valve, filter and connecting manifold has a burst pressure greater than 8000 psig. at ambient temp. Items used in this test were check valve S/N 06 and filter S/N 06. The flight components have been inspected and cleaned prior to installation on the spacecraft.

Pressure Regulator

This regulator is a standard design modified by the MFG to conform to GSFC Spec. Control Dwg. GD1063687. The inlet portion of the regulator is designed to have a burst pressure in excess of 7200 psig. The outlet pressure is regulated to 40 ± 2 psig. with excess pressure vented through a relief valve designed to open at 54 ± 2 psig. The MS style inlet and outlet ports were replaced by GSFC with tube outlet fittings. Acceptance tests on all units were performed by GSFC, request no. 1340-23, to verify operating and environmental specifications concerning regulated pressure, relief pressure and flow rate, at temperatures of +60°C, ambient and -10°C, and inlet pressures ranging from 200 to 1400 psig. Regulator S/N 2 was also tested at -45°C. The above tests were performed in a vacuum chamber with no appreciable external leakage detected from the regulator.

The flight spare shelf assembly with regulator S/N 2 was tested with Helium at 1200 psig. and found to have a total leak rate of 3×10^{-10} SCC/sec. It was then proof tested with Freon-14 (with 10% Helium) for 10 minutes at 2700 psig. and found to have a leak rate of 2×10^{-10} SCC/sec.

Manual Valves

The manual valves are standard items rated by the MFG for a working pressure of 3000 psig., and a burst pressure greater than 12,000 psig. Valves, S/N 09 and 10, were helium leak tested by GSFC, request no. 1340-14 completed 3-18-69. The leak rate, across the seat and through the valve packing, was found to be less than 10^{-6} SCC/sec. for all tests. The flight valves were inspected, cleaned and the o-rings lubricated prior to installation in the ACS.

Swivel Joints

The swivel joints were designed by GSFC, and are normally cleaned, assembled and leak tested just prior to installation. S/N 01 and 02 have been Helium leak tested to 40 psig. at +50°C, ambient and -40°C; cycled 100 times; and proof pressure tested to 60 psig. by GSFC, request no. 1340-17 completed 4/24/69. The leak rate was found to be less than 2×10^{-6} SCC/sec. for all tests.

Tubing and Fittings

The aluminum (6061-T4) tubing and fittings (Swagelok) used on the low pressure portion of the ACS are standard items and rated by the MFG to have a burst pressure greater than 1000 psig. No testing was performed by GSFC on these items; however, all hardware was inspected and cleaned prior to installation on the spacecraft. In addition, all tubing and fittings to be exposed to sunlight in orbit are polished to a high luster finish as a thermal coating.

O-Rings

All o-rings used in the ACS are Parker C147-7 Neoprene material and are standard sizes. Each o-ring is inspected, cleaned and lubricated with Dow Corning (silicone) High Vacuum grease before assembly. No testing was performed on these items. In the event it becomes necessary to disassemble any component, the o-rings are to be replaced at the time of reassembly.

Solenoid Valves

The solenoid valves are a standard design modified by the MFG to conform to GSFC Spec. Control Dwg. GD1063684. All units were disassembled, inspected, cleaned, and the sliding surfaces polished by GSFC. Inlet and outlet filter screens were installed at the time of reassembly. All units were acceptance tested by GSFC, request no. 1340-25, to verify operating and environmental specifications concerning leak rate, flow rate, current trace, pressure profile and response time at temperatures of ambient, -35 C and +60 C. Each unit was also proof tested to 60 psig. On the acceptable valves, the helium leak rate was found to be less than 10^{-10} SCC/sec. Valve #48 was statically leak tested with Freon-14 at -70 C and found to have a gross leak which sealed up again when the valve was returned to ambient temp.

One valve (labeled "TEST") was qualification tested by the MFG to demonstrate design specification performance as follows: Proof tested to 90 psig.; pull-in and drop-out voltage measurement; internal leakage determined to be less than 10^{-7} CC/sec. (CF_4); insulation resistance measurement; vibration; low temperature functioning at -40 F; high temperature endurance at +125 F; and endurance cycling to 2.5 million cycles.

Although a small number of valves were found to be unacceptable and were returned to the MFG for rework, only the valves with the best test results were chosen for flight and flight spare hardware. Low leak rate at cold temperature was the primary criteria for this choice.

Valve #30 displayed excessive delay, approximately 100 ms., in opening response time, especially at cold temperatures, and was retested by GSFC, request no. 1340-52, completed 11-23-70. This same condition has since been observed on a few of the other flight and flight spare valves, but to a lesser degree, and thus further testing was warranted. Although the problem was most severe on the first pulse after several days of non-operation, there was a tendency to return to normal after a small number of successive pulses. This valve was tested at -20 C and an undervoltage of 20 volts and this was found to be one definite cause for delayed opening. It was then tested at -35 C and an inlet pressure of 200 psia. which also produced considerable delay in opening. However, neither of these conditions, undervoltage nor over pressure, existed at the time the problem was observed during system testing, and can be eliminated as being non-critical condition. Finally, the valve was disassembled, examined for burrs, nicks, scratches, blistered plating or any other impediment to plunger motion.

When none was found, it was thoroughly cleaned and reassembled without lubrication on the o-ring. After a 5 hour cold soak at -20 C, the valve was pulsed several times under nominal conditions of 26 volts and 45 psia. inlet pressure, and appeared to function properly on every pulse. Thus the delay in opening response time, in this case, was attributed to a migration of o-ring lubricant to the valve plunger and seat assembly where, at low temperatures, it becomes sticky and requires additional solenoid force to open the valve. The effect of this migration will vary considerably from one valve to another due to manufacturing and assembly clearances, slight differences in solenoid forces, and a variation in the amount of lubricant applied to the o-rings. However, it is undesirable to use unlubricated o-rings because of the increased leak rate at all temperatures. It was concluded, therefore, that since the response delay has been confined solely to the first one or two pulses, it constitutes a lesser hazard than would the increased leakage.

Freon-14 Propellant

Each container of Freon-14 was tested by the MFG for purity and a moisture content of less than 2 p.p.m. prior to shipment, and a sample was tested and verified by GSFC after delivery. A portion of this Freon was transferred to four GSFC containers at a higher pressure, and these were tested on 7-16-7 for moisture content and found to have a dew point less than -100 F. The pressure-temperature relationship for Freon-14, both for 100% Freon and for a mixture with a 10% partial pressure of helium, was investigated experimentally by GSFC, request no. 1340-41, and found to compare satisfactorily, within 5% of the theoretical values obtained from the Martin-How Equation for Freon-14. At the time of the above test, an accurate measurement of the ACS tank, S/N 0006, volume, with temperature probe and fittings installed, was made and found to be 7328 ml. (447 cu. in.).

Nozzles

A series of tests was performed by GSFC, request no. 1340-9, in order to determine the optimum nozzle design for the ACS. Various nozzle angles, area ratios and chamber pressures were examined, at ambient temperature, using both Freon and nitrogen; and the specific impulse was measured for each case. The flight nozzle configuration was further tested by GSFC, request no. 1340-21, and found to deliver a specific impulse of 44.6 sec. with Freon-14 at 25°C, 40 psia. and a thrust of 33 millipounds. All nozzles were inspected, polished and cleaned prior to installation in the ACS.

SYSTEM TESTING

During ground checkout of the ACS, the performance and operation of the solenoid valves may be monitored through a test connector on the diode electronics pack on the end of each boom, and by a set of low pressure transducers installed as G.S.E. between the outboard solenoid valves and their respective nozzles. Thus a current trace and pressure profile may be obtained for each solenoid and for each function of the ACS.

It is also possible, as conditions permit, to monitor the tank pressure and regulated downstream pressure by means of G.S.E. cable and connectors attached to the high and low pressure transducers on the shelf assembly. Similar pressure readings may also be obtained through a test connector on the ACS

Electronics card or through telemetry when the spacecraft is configured for such and the spacecraft power is on.

Similarly, tank temperature readings may be obtained either through telemetry or a G.S.E. attachment to one of the two temperature probes since only one probe is hard wired into the spacecraft electrical harness.

Venting of the ACS is normally done through the outlet valve and outlet port with the shut off valve open.

A helium leak (sniff) test is performed as a regular part of any ACS filling operation, and is also required at various stages of spacecraft qualification and testing.

Flight System

The flight ACS was assembled, except for the Valve-Nozzle assemblies, on the ETU spacecraft and filled to a proof pressure of 2700 psig. on 11-17-69. The Valve-Nozzle assemblies were subjected to a magnetic field measurement on 1-9-70, and installed on the ETU on 1-12-70. Vibration tests of the total pressurized system were completed 1-23-70. Leak measurements, cold storage and thermal-vacuum tests were completed 2-20-70; and an ACS boom deployment test was conducted on 3-12-70. Following this, the ACS was vented and removed from the ETU, and valve #30 was replaced with valve #45. Response times, polarity and current traces were obtained for all the flight solenoid valves on 7-8-70. The ACS was installed on the Flight Unit spacecraft, and was subjected to a temperature test at -10 C, ambient and +40 C, which was completed by 6-19-70. The ACS was again vented and then proof tested to 2700 psig. on

7-16-70. On 9-21-70 the system was vented to 1298 psig. at 5.5 C and leak checked. The spacecraft vibration was completed on 9-30-70 and another leak check performed at this time. The underspin and overspin series of boom deployment tests were successfully completed on 10-20-70. Thermal-vacuum tests of the fully integrated flight spacecraft were completed 11-15-70, including functional operation of the ACS at ambient, -10 C and +40 C. Subsequent testing consists of solar simulation, final mass measurement and balancing, random vibration, magnetic deperm and calibration.

Prior to shipment to the launch facilities, the ACS is to be vented to a pressure of approximately 200 psig. in order to avoid any possible contamination of the system while minimizing the safety hazard. Pre-launch operations consist of refilling the ACS to the flight pressure, functioning the system to verify operation, and a final leak check. In orbit, tank temperature and pressure, regulated pressure and solenoid (S/N 14) temperature will be monitored on a regular basis through telemetry. On the flight spare system, the solenoid thermistor is located on valve S/N 40.

Flight Spare System

All components in the high pressure portion of the flight spare ACS were individually proof tested to 2700 psig. prior to installation on the ETU spacecraft. The ETU, with ACS assembled, installed and filled, completed vibration testing on 7-8-70. A leak test, polarity check and current trace were performed on 7-10-70; and boom deployment tests were successfully completed on 8-18-70. Thermal-vacuum tests to flight spare levels of +40 C and -25 C were completed on 10-6-70, and the flight spare ACS components considered qualified at that time. In the event any of the high pressure components of the flight unit ACS are replaced by either flight spare components or new pieces, such as tubing or fittings, the ACS is required to be proof tested to 2700 psig. before being considered qualified.

The spare ACS was vented and removed from the ETU spacecraft, and the shelf assembly and both valve-nozzle assemblies were installed on the air bearing facility to undergo a performance and system calibration test under simulated orbit conditions of vacuum, moment of inertia, spin rate, three degrees of freedom of motion, sun pulse and telemetry. Although the test was terminated on 12-2-70 due to support equipment failure, the data obtained indicated good correlation with the calculated performance which is approximately 1.5° of precession per command and 1.5 RPM spin rate change per command for the flight spacecraft with the EFM antennas retracted. With the EFM antennas extended to 200 feet, the spin rate change per 64 sec. command is calculated to be 0.06 RPM.

YO-YO DESPIN SYSTEM

The Yo-Yo despin system used on the IMP-I is very similar to that used on previous IMP spacecraft, but has been modified to incorporate the potted dimple motors used on the S^3 spacecraft. The system consists of a pair of weights, cables and release mechanisms located in diametrically opposed facets in order to maintain balanced torques during despin. Each weight is approximately 0.42 lb. and attached to a 28.75 foot cable. Weight release, initiated 2 sec. after third stage separation, is accomplished by firing two, for redundancy, Hercules DM 27A0 dimple motors in each facet, which pull the pin holding the weight in place. Normally, all four dimple motors are fired simultaneously, but electrical redundancy is designed to fire at least one dimple motor in each facet to insure that both weights are released together. With each cable wrapped twice around the spacecraft, it is estimated that the despin time from 40 RPM to 15 RPM will be approximately 3.6 sec. Nominal cable tension at installation is to be 10 lb., and the maximum tension during despin is expected to be 15.7 lb. The final release angle of the cable is 90° to the tangent at the periphery of the spacecraft. Aluminum swaged end fittings are used on the 3/64 dia., 7 × 7 stranded, non-magnetic, stainless steel cable. The precise flight Yo-Yo weight values will be determined from final mass property information on the spacecraft.

The installation of the Yo-Yo Despin System on the spacecraft is described by GSFC Dwg. GJ1064372. Other handling information is provided in IMP-I-D-4.1.5 Yo-Yo System and Dimple Motor Installation document.

DIMPLE MOTOR DATA

Manufacturer:	Hercules Powder Co.
Part Number:	DM 27 A0
Lot Number:	HEP-2-1
Date of Manufacture:	5-70
Date and Number Received:	6-1-70 87 units
Wire Leads:	#24 AWG copper, solid
Case:	Brass
Seal:	Kovar glass; hermetic soldered type
Bridge Resistance:	0.2-0.8 ohm, wire type
Ignition:	Lead Styphnate type

Main Charge:	LMNR/black powder type
Test Current:	10 ma. max.
Max. Nonfire Current:	0.50 amp., one 30 sec. pulse
Min. Fire Current:	1.0 amp.
Recommended Firing Current:	2-3 amp.
Ignition Time:	3 ms. at 2 amp.
Temperature Range:	-65 F to +70 F
Reliability:	99 + %
Output:	0.11 in. against 8 lb. load in 15 ms.

SUMMARY OF TESTING

Dimple Motors

Each dimple motor was stamped with a serial number and subjected to both visual and X-Ray examination. Measurements were then made for bridge wire resistance, on the order of 0.40 ohms, as well as resistance of case to shorted bridge wires which was established to be greater than 100,000 ohms for all units. A quantity of 56 units was then potted per GSFC Dwg. GC1061994 and subjected to another bridge wire resistance measurement. As a part of the T&E lot qualification requirements for pyrotechnics, 12 units were subjected to a vibration test at prototype levels, followed by another resistance measurement. Six of these units were then placed in a thermal vacuum chamber and fired at the end of a 12 hour cold soak at a temperature of -60 C. The other six units were similarly fired after a 12 hour hot soak at +50 C. It is standard procedure to fire the dimple motors only while acting against a predetermined load, usually 8 lb., in order to avoid possible rupture of the dimple motor case. It should be noted that, due to limited availability, the number of dimple motors subjected to thermal vacuum testing is one half the quantity specified by T&E and represents the omission of 12 unvibrated units. A total of 25 additional units have been successfully fired during various aspects of integration and spacecraft testing. Further details are available in IMP-I-D-4.6.7 Pyrotechnic Record.

Release Mechanisms

The following tests were performed by GSFC, request no. 1340-43, completed 5-14-70. All critical components of each mechanism were marked with matching serial numbers, and all eight hooks were reworked and polished to provide a 90° cable release angle. Four units, S/N 01, 02, 04 and 05 were then assembled in a fixture to simulate the flight conditions of 10 lb. cable tension and a weight representing the 1.25 g centrifugal force due to spinning at 40 RPM. In this configuration, measurements were made of the force required to release the weight and it was found to be less than 3 lb. for all assemblies. One unit, S/N 03, was loaded with one live dimple motor and securely positioned in a fixture so that when the dimple motor was fired, it was found that an 8 lb. weight load was raised a distance of approximately 0.18 in. Two dimple motors were then installed in unit S/N 01, assembled in flight configuration, and fired to successfully release the weight under a 10 lb. tension load. Similarly, one dimple motor was fired in unit S/N 02 to successfully release the weight under a 10 lb. tension load, and thus demonstrate a redundant capability. Subsequently, four units, S/N 01, 02, 04 and 05, were potted with electrical connectors in place as shown by GSFC Dwg. GD1064321, and delivered for installation on the spacecraft. Units S/N 04 and 05 have been assigned as the flight units, and S/N 01 and 02 were installed on the ETU spacecraft and may be considered as flight spare units.

System Testing

The Yo-Yo Despin System testing on the ETU spacecraft consisted of a nominal and an overspin release sequence in the Dynamic Test Chamber (DTC). In all such tests, it was necessary to reduce the cable length to 1/2 wrap, approximately 7 feet, in order to allow complete cable-hook release before the weights would strike the chamber wall. This also minimized the effect of gravity by shortening the overall despin sequence time. In as much as these tests provided little spin rate change data, such information is left entirely to calculations which have demonstrated considerable reliability through past experience. The nominal test was performed in the flight configuration using 4 dimple motors and estimated flight weights released at 40 RPM. For the overspin test, the weights were released at 50 RPM by firing 2 dimple motors, one in each release mechanism, to also demonstrate the redundant capability. These tests were successfully completed on 7-20-70 and 7-22-70 respectively. With the ETU configured with the full two cable wraps and the spacecraft located in the thermal vacuum chamber at a temperature of -50 C, the weights were released by firing two dimple motors in an effort to verify operation at low temperature. This was a static test of the release mechanisms and was successfully completed on 10-8-70.

Yo-Yo Despin System testing on the flight unit spacecraft consisted of a simulated systems functional test, on 9-23-70, in order to verify the spacecraft circuitry and command system. The integrated spacecraft, with two cable wraps, was then subjected to vibration testing and the Yo-Yo weights released, in a static condition, on 9-30-70. Following this, the spacecraft was placed in the DTC and, on 10-2-70, was spun up to 40 RPM and the Yo-Yo weights released with 1/2 cable wrap. Special oversize weights were used for this test in an effort to simulate the maximum flight cable tension expected during the despin phase while using only 1/2 cable wrap. However, it was noted that the cable terminal fittings at the weights failed due to excess bending moment stress shortly after release. This condition is attributed to the fact that the center of gravity of the larger weights was considerably offset from the cable attach point thus producing a large bending moment. Although this situation does not exist on the flight system, the fittings have been redesigned and calculations show that the expected stresses will be well within the allowable limits. An overspin test, with the ETU spinning at 50 RPM in the DTC on 12-15-70, demonstrated the durability of the new design. As in all previous tests, the despin weights and cables were severely damaged upon impact with the chamber wall. Other tests on the flight spacecraft consisted of an underspin boom deployment test on 10-7-70 and a repeat underspin boom deployment test on 10-19-70. In both cases, only drop off Yo-Yo weights were released, without cables, to verify the timing sequence. Finally, a thermal vacuum test was performed on 11-3-70, during which the weights were again statically released by firing four dimple motors. Flight despin weight values will be determined accurately following the final weights, moments of inertia and balance measurements on the spacecraft at GSFC. Pre-launch operational checks at ETR will consist of firing four dimple motors and releasing the weights, in a static condition, in order to verify system integrity prior to launch. Following this, the four flight dimple motors will have bridge wire resistance measurements made and be installed in the Yo-Yo Despin System on the spacecraft.

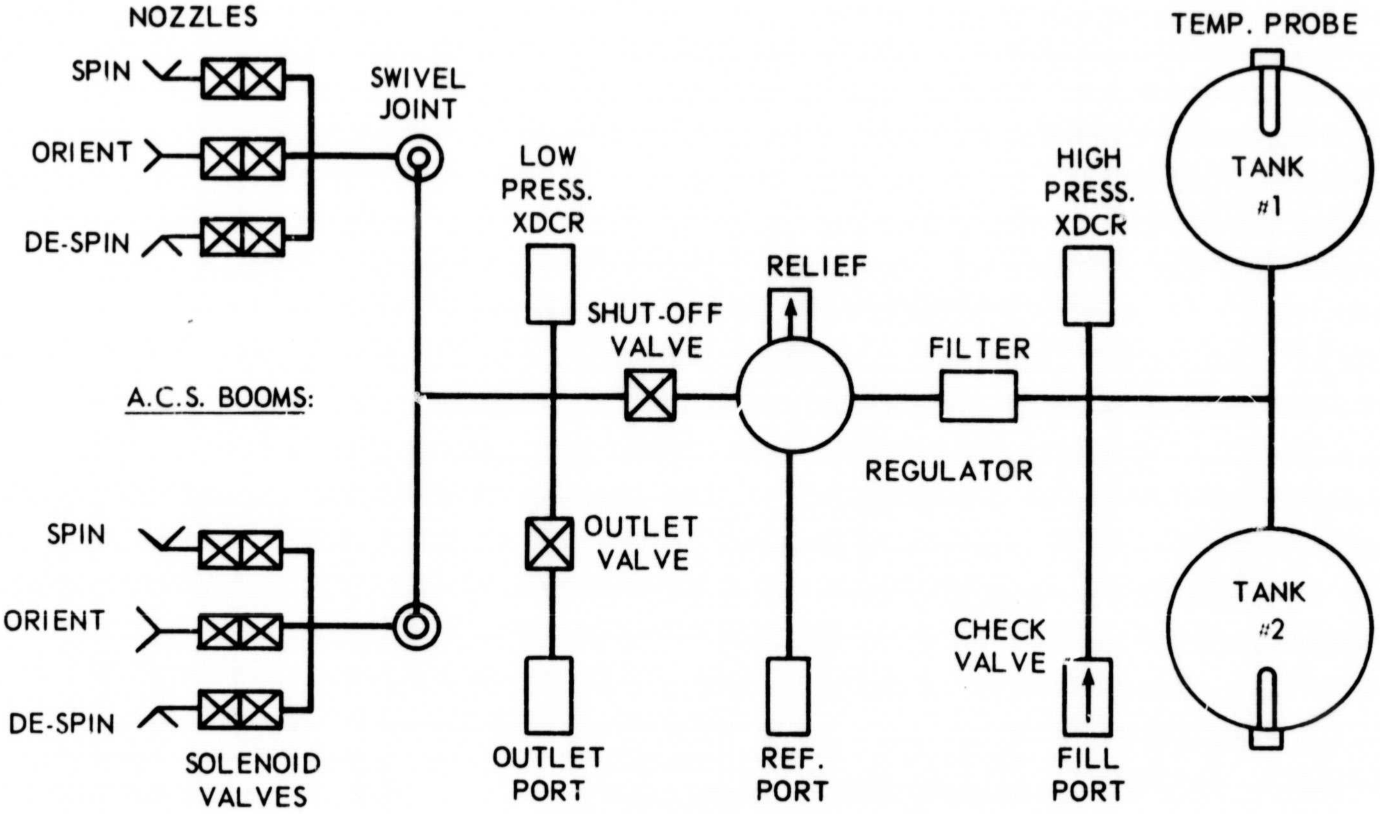

Figure 1. ACS Schematic

WRIGHT COMPONENTS, INC. P/N 15457 AXIAL SOLENOID VALVE
GSFC DWG. GD 1063684

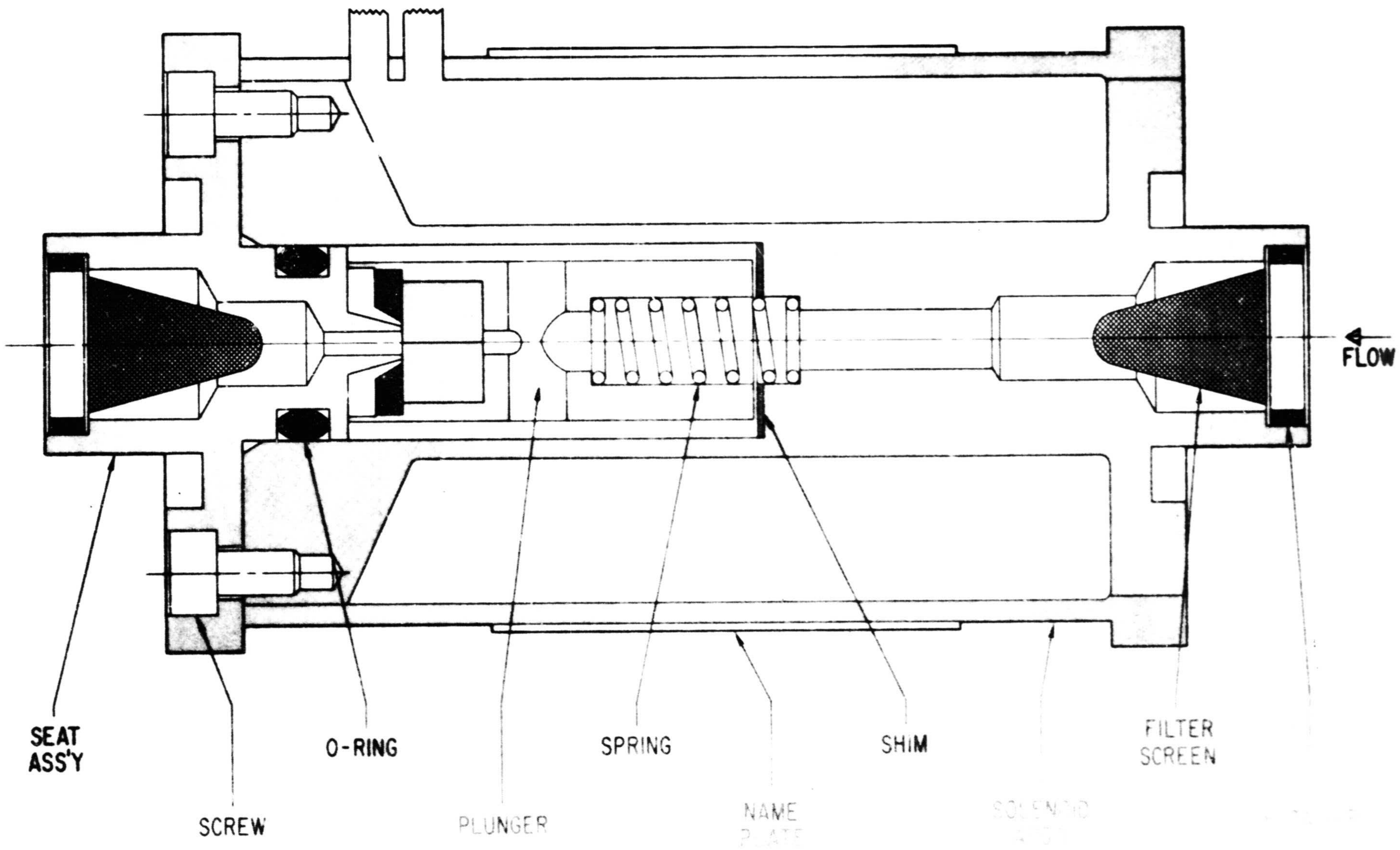

Figure 2. Axial Solenoid Valve

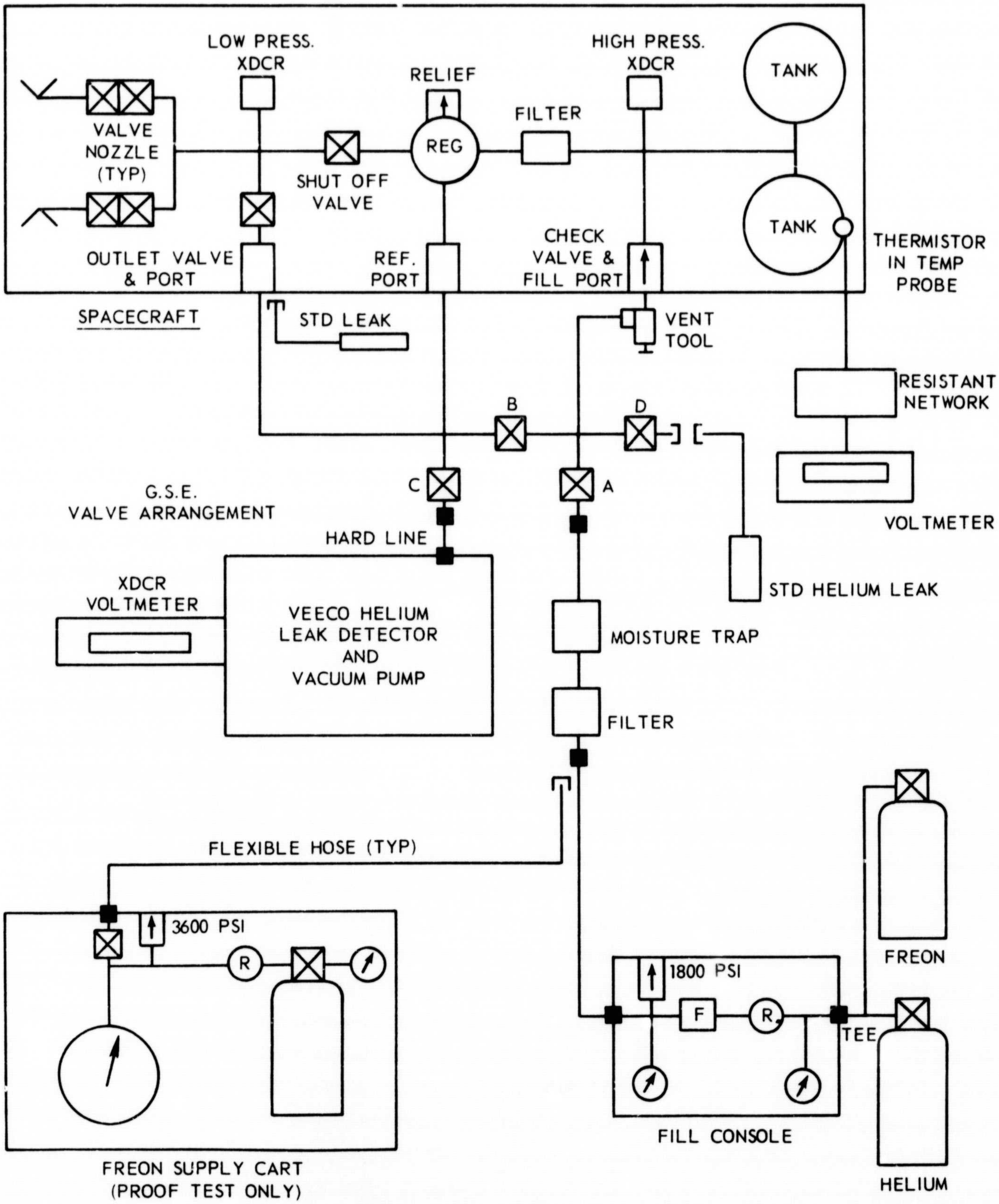

Figure 3. ACS Fill Procedure Equipment Setup

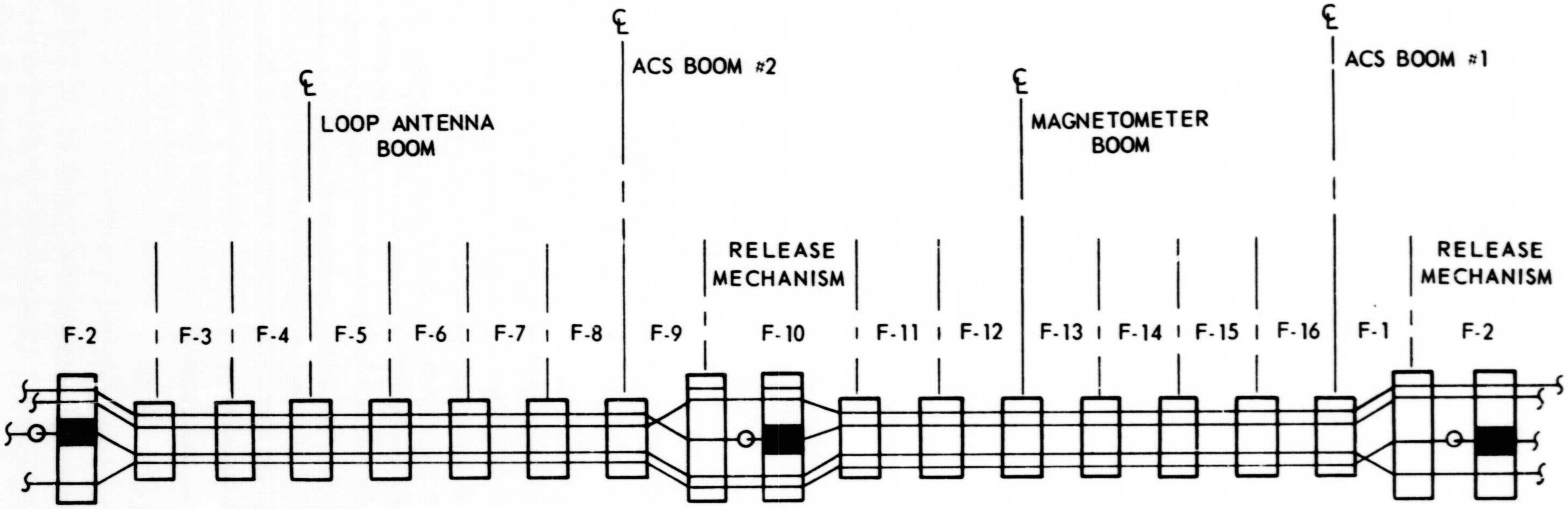

Figure 4. Schematic Cable Routing Two Wraps

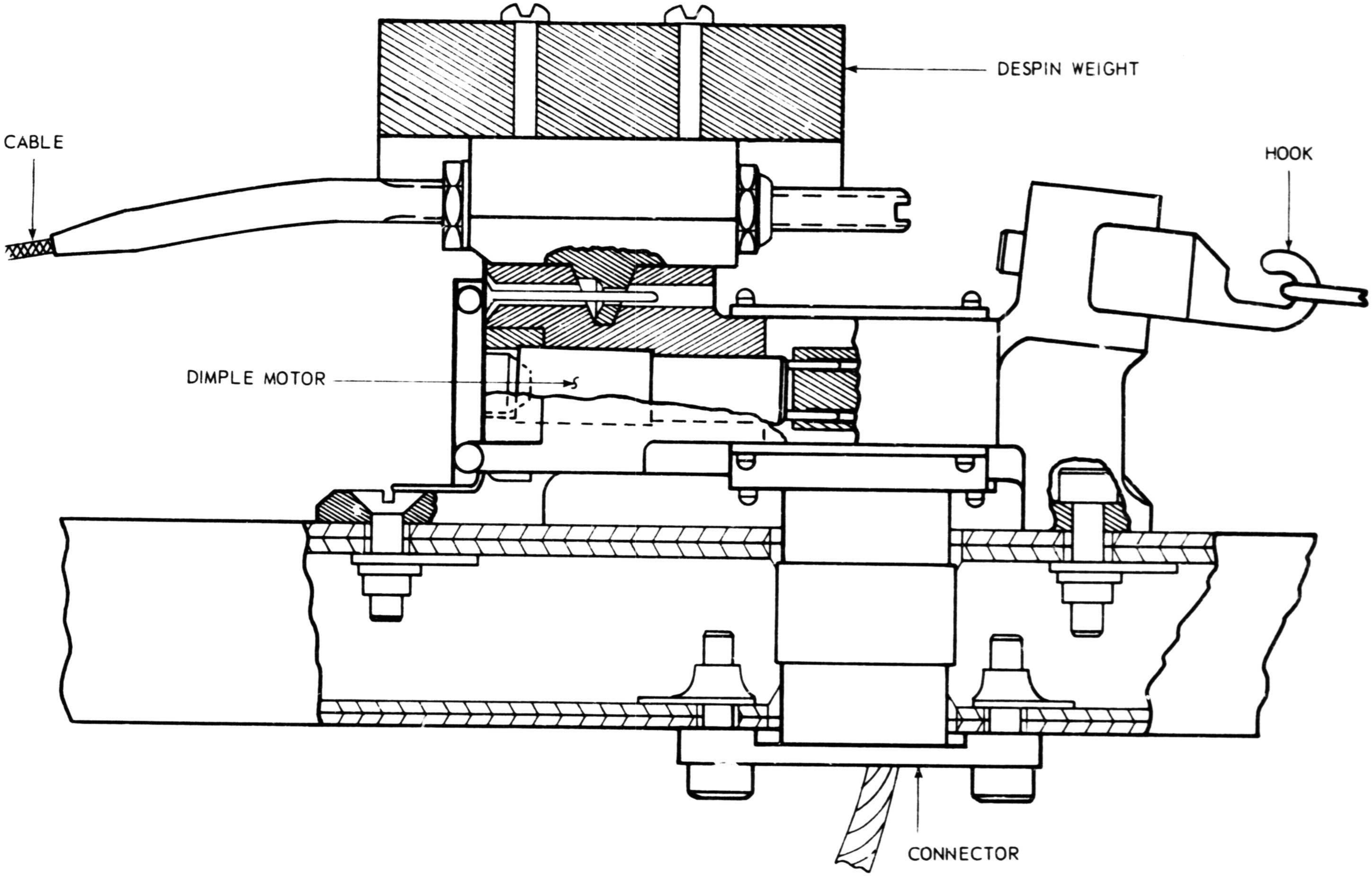

Figure 5. Weight Release Mechanism

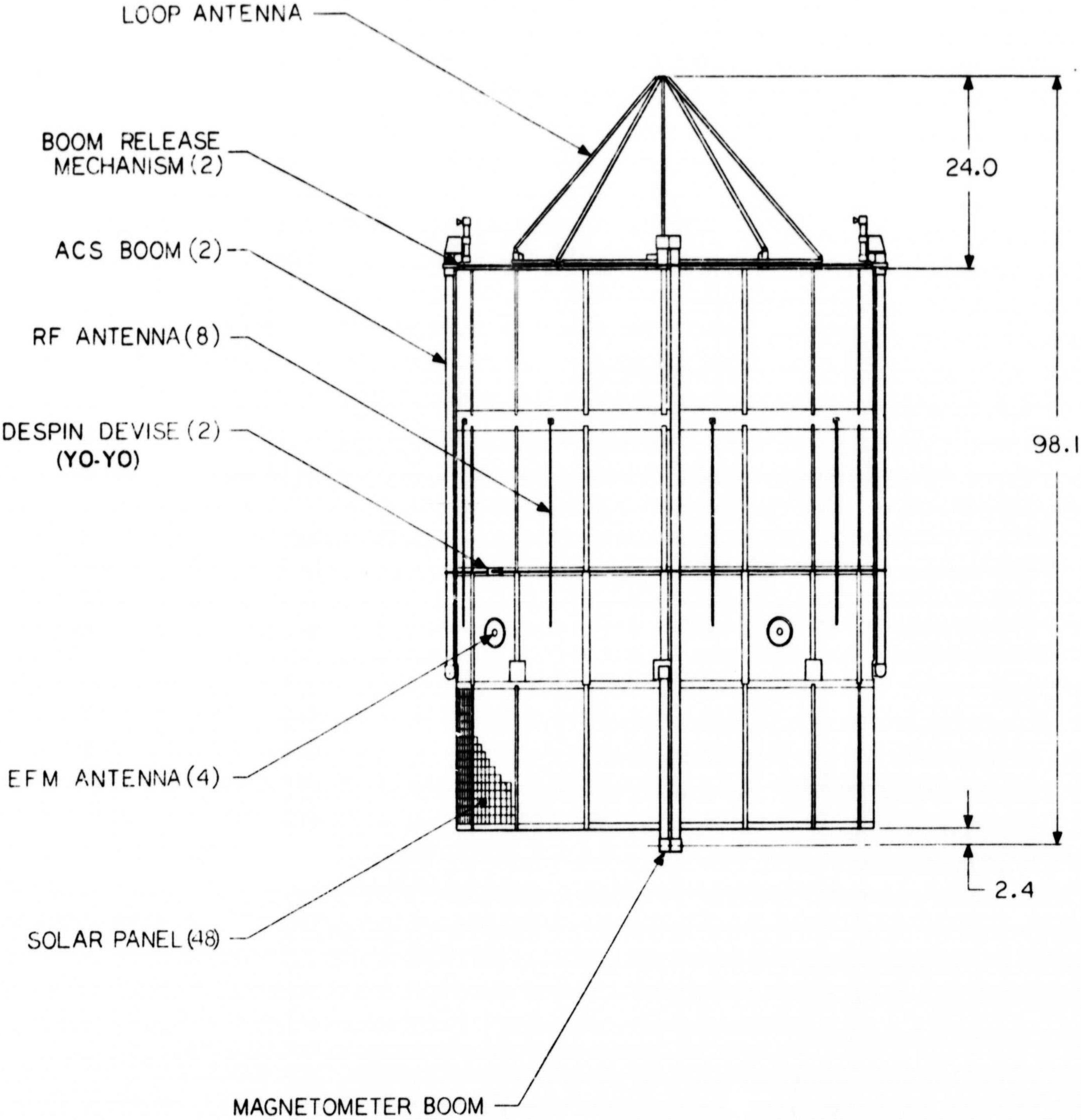

Figure 6. IMP-I +X Side View Folded Configuration

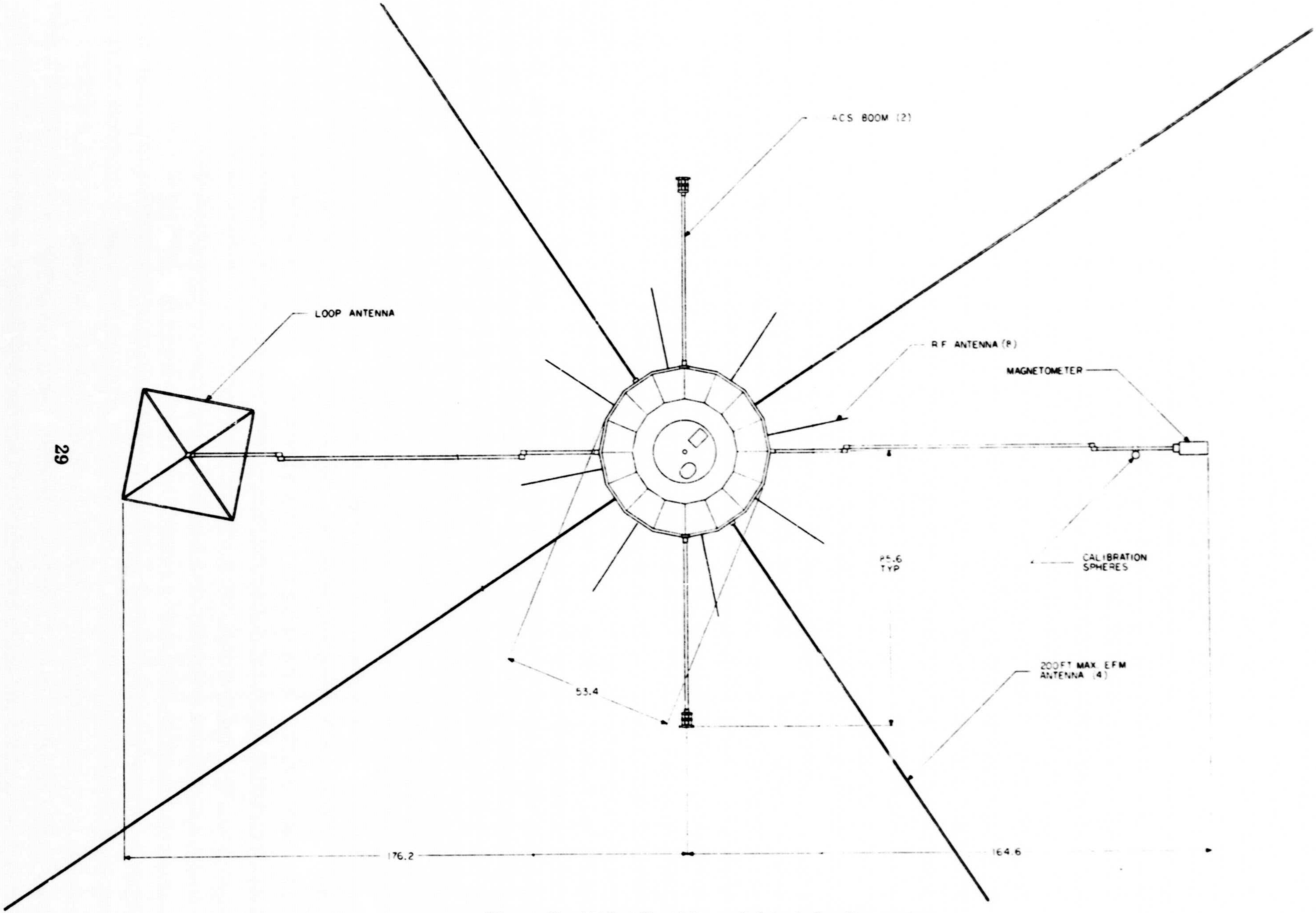

Figure 7. IMP-I Top View Orbital Configuration