Satellite Positive-Ion-Beam System

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The Satellite Positive-Ion-Beam System (SPIBS) is being developed as a charge-ejection payload for the Air Force SCATHA (spacecraft charging at high altitude) satellite P78-2. SPIBS will allow controlled ejection of xenon ions as part of a systematic investigation of satellite charging. The system generates ion-beam currents of approximately 0.3 and 1.0 mA at a beam voltage of 1 kV, and currents of about 0.7 and 2.0 mA at 2 kV. Redundant filament neutralizers are provided to allow full or partial beam neutralization and an independent source of electrons. The neutralizers can be biased at 10 levels from -1 kV to +1 kV with respect to satellite ground. This paper describes the engineering model design, and presents ion source, expellant, and power processor test results.

Introduction

MEASUREMENTS made on satellites at synchronous orbit altitude have shown that their surfaces occasionally become highly charged as a result of energetic electrons in the ambient.[1,2] Spacecraft ground potentials on the order of tens of kilovolts relative to the ambient plasma have been measured, with the highest charging occurring during periods in which the spacecraft was directly illuminated by the Sun. Observations of the performance of equipment on satellites in synchronous orbits have indicated that spacecraft charging causes serious equipment damage.[3] To study this phenomenon directly, the SCATHA (spacecraft charging at high altitude) satellite, is scheduled to be launched into a near synchronous orbit during 1979.[4]

The payload of the SCATHA satellite will include, in addition to instrumentation to accurately measure the ambient plasma and spacecraft charging, two charged-particle ejection systems.[4] These systems are planned to be used to investigate the effect of spacecraft-to-ambient-plasma potential differences and methods of controlling spacecraft charging. An electron gun will be used to swing the vehicle potential positive or to return the vehicle potential to ambient potential.

The Satellite Positive-Ion-Beam System (SPIBS) will be used to emit electrons, beams of positive ions, or beams containing both positive ions and electrons. The object is to make SPIBS an instrument that can be used to create several different spacecraft ground-to-ambient-plasma potential differences. Each of these charge-ejection modes will include a range of both emitted current and particle energy modes. With these choices, controllable by ground command, it is expected that SPIBS will be used to swing the spacecraft ground either positive or negative with respect to the ambient plasma. In conjunction with other SCATHA payloads, it will also be used to investigate a variety of techniques for returning or maintaining spacecraft ground near the potential of the ambient plasma. There were two major determinants of the SPIBS design. The first, minimum performance specification was derived from an analysis of published results of measurements on two synchronous satellites ATS-5 and ATS-6.[5,6] The second determinant, limitations on SPIBS maximum weight and power, was dictated by the then current design of the SCATHA satellite.

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Requirements

The performance and functional requirements of SPIBS are summarized in Table 1. The ion-beam-current levels, chosen to be greater than the maximum photoelectron emission expected from SCATHA spacecraft grounds, were set at 0.3, 1, and ≥2mA. The upper value was chosen to provide a dynamic range for possible ion-beam currents consistent with power and weight limitations.

Table 1 SPIBS requirements and engineering model characteristics

Parameter	Requirement	Engineering Model
1. Ion Beam		
a. Current, mA	0.3 to 2.0	0.3 to 2.0
b. Energy, keV	1 to 2	1 and 2
2. Input Power, W		
a. Maximum startup	60	55
b. 1 mA beam, 1 keV	25	30
c. 2 mA beam, 2 keV	–	45
d. Full beam and biased neutralizer	–	55
3. Expellant	Noble gas	Xenon
4. Weight	7.8 maximum	7.4
5. Operating Life, hr	300 minimum	>300
6. On/Off Cycles	200 minimum	>200
7. Neutralizer		
a. Control	Ion beam on or off	On/off control
b. Emission range	2 μA to 2 mA	2.5 μA to 2.5 mA
c. Biasing	– 1 kV to + 1 kV	– 1 kV to + 1 kV in 10 steps
8. Ion Source Enclosure and Cover	Pre-flight test capability	Blowoff cover
9. External Magnetic Field	< 1 Gauss at 10 cm	1 Gauss at 12 cm
10. EMI	MIL STD 461 A	AFGL to test
11. Vibration	20 g rms random	AFGL to test
12. Decel grid	Shielding from space plasma	Decel grid operated at PPA ground potential

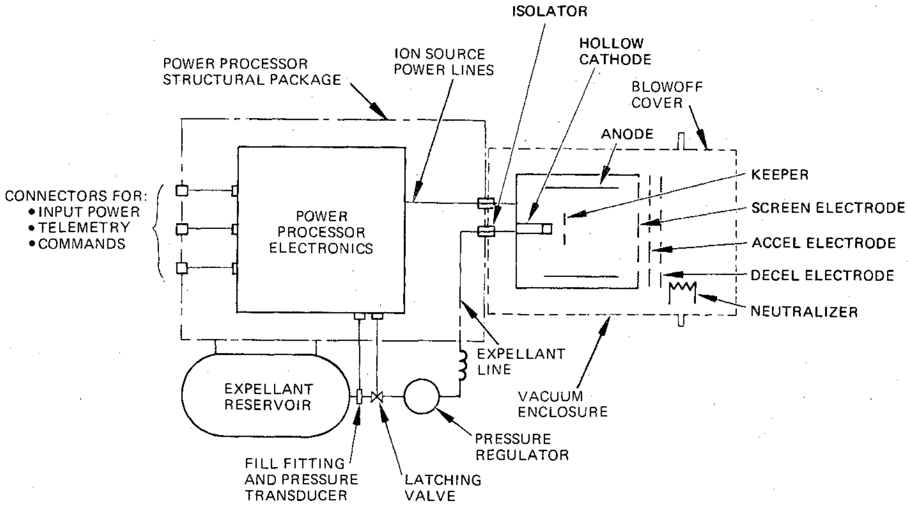


Fig. 1 **Block diagram of the SPIBS.**

To minimize interference with other SCATHA experiments, the SPIBS structure exposed to the ambient plasma must be kept close to spacecraft ground potential. This translates into the requirement for a grounded-surface (decel grid) following the ion-accelerator grid.

A breadboard model and an engineering model have been built and tested. The test results described in this paper indicate that all functional requirements have been satisfied. The engineering model is currently being used for qualification testing, and the flight model is in fabrication.

SPIBS Instrument Description

The requirements and goals outlined in the previous section led to the system shown schematically in Fig. 1. The basic system consists of an ion-source assembly, an expellant assembly, and a power processor. Xenon gas is delivered to the porous plug in the source at 7 psia through a pressure regulator and latching valve from a reservoir initially charged to about 800 psig. Power for the ion source expellant assembly valve, analog telemetry, and command functions are provided by the power processor assembly (PPA). The PPA circuitry is packaged on conventional circuit cards within a structural enclosure. An ion-source vacuum enclosure, with a cover that is opened by use of electroexplosive devices, provides protection for the ion source until it is operated in space. This blowoff cover is designed to allow for complete ground checkout of the ion source and system before launch.

Ion thruster technology was used to develop the ion source in the areas of ion optics, cathode and discharge chamber design, and expellant line high-voltage isolation. Positive xenon ions extracted from a Penning-type discharge plasma are accelerated electrostatically to high velocity. The discharge is operated at the beam potential to allow the ions to exit at near ground potential. In the discharge plasma, ions are formed by collisions between atoms and electrons. A conventional hollow cathode is used to generate the electrons, which are then accelerated into the plasma by means of the discharge voltage. An axial magnetic field is used to restrict electron flow radially and increase electron-atom collisions. Downstream of the ion accelerating structure is a neutralizer in the form of redundant thermionically emitting filaments. Depending on the requirements of the satellite experiment, the neutralizer could be used to neutralize all or a fraction (including zero) of the ion beam. The neutralizer can be biased to ±1000 V to control satellite potential relative to the space plasma.

System Description

A schematic of SPIBS is shown in Fig. 2 to indicate the general electrical interconnections between the ion source and the PPA. Additional system functions and interfaces are

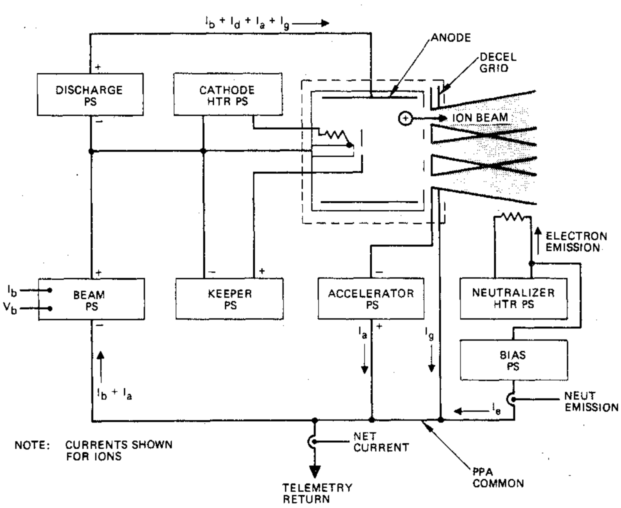


Fig. 2 **Schematic of SPIBS for ion source and power processor.**

illustrated in Fig. 3. These figures show the locations of key measurements, current paths, and the grounding approach. Layout and isometric drawings are presented in Fig. 4 and 5, respectively, to illustrate the SPIBS instrument configuration. Overall dimensions of the package are 49 × 23 × 13 cm; the engineering model weight is 7.4 kg. Several features of the blowoff cover can be noted, including the open and closed positions, and the ion beam collector to be used during ground checkout.

Major characteristics of the SPIBS instrument are presented in Table 1. Ion-current range and energy are consistent with the requirements discussed previously. Input power levels shown are based on testing experience with the breadboard ion source and PPA. The ion source can be operated with or without the neutralizer, and the neutralizer can be operated without the ion beam. Five neutralizer electron emission levels from 2 μA to 2.2 mA can be obtained. For additional flexibility in studying satellite potential control, the neutralizer can be biased at 10 levels from -1000 to +1000 V with respect to satellite ground (telemetry return). The minimum operating life and on/off cycle requirements have been demonstrated with the breadboard system. The expellant reservoir is sized for about 2000 h of operation.

Command capability being implemented is indicated in Table 2. The 29 ground commands provide great flexibilty in SPIBS flight operation and allow for convenient ground testing. The cathode can be heated at either of two levels, corresponding to initial conditioning of a new cathode (level 2) or to lower-power normal startup (level 1). Commands 6

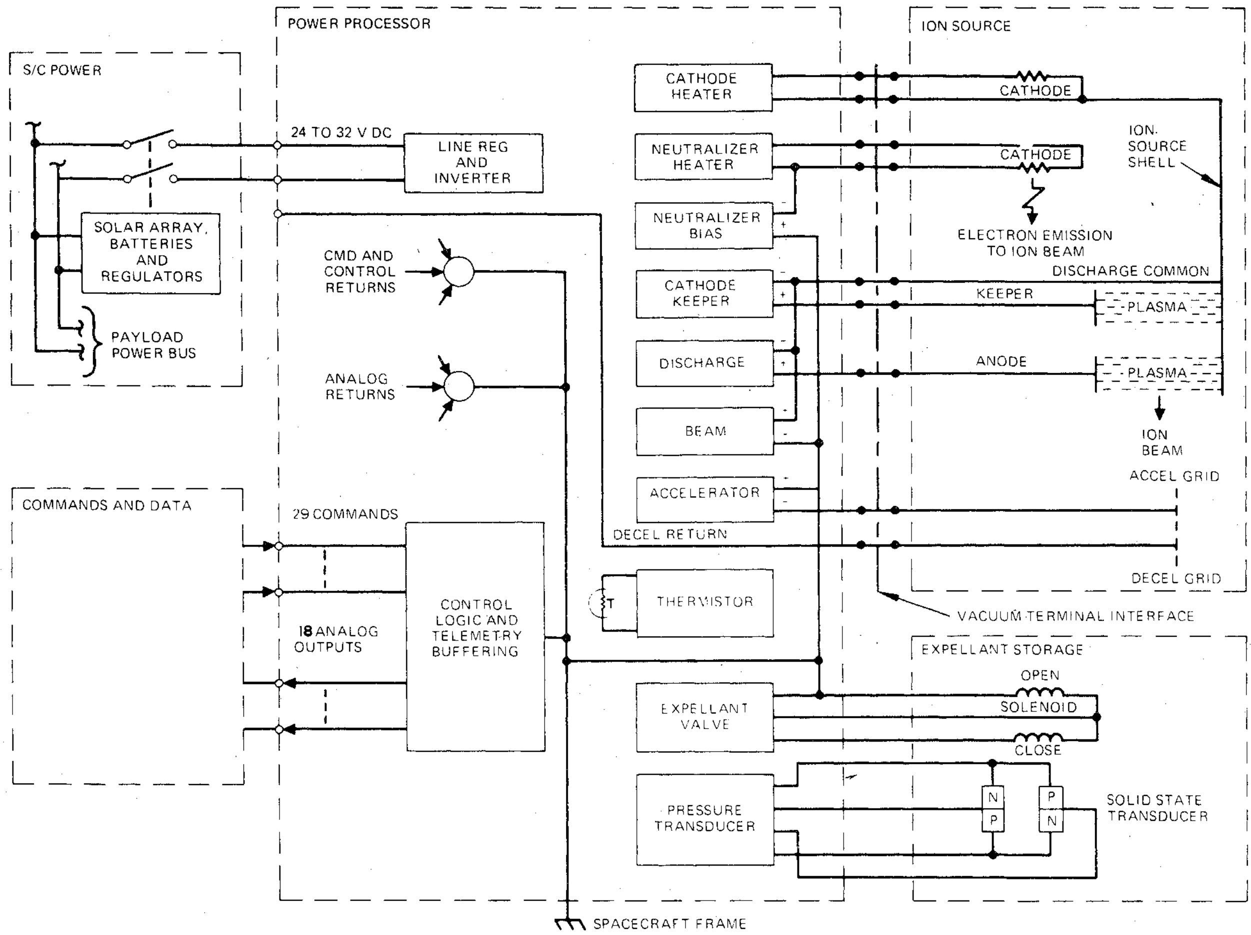


Fig. 3 System interface diagram.

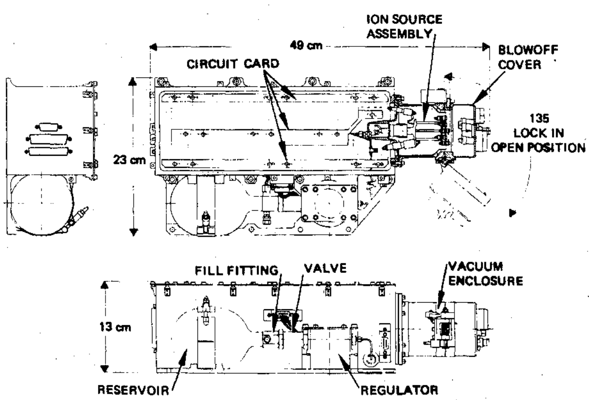


Fig. 4 Layout drawing of SPIBS.

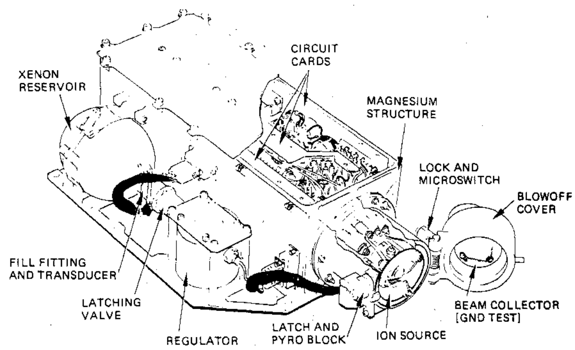


Fig. 5 SPIBS isometric drawing.

and 7 turn on and off the cathode keeper supply and the beam/accel. power supply. For evaluation testing, these supplies can be turned off separately by commands 10 and 28, respectively. Through commands 16 and 17, the neutralizer heater supply can be connected to either of the redundant filaments.

Analog telemetry outputs are provided as shown in Table 3. These 18 outputs allow a relatively complete evaluation of SPIBS operation and performance. Except where noted, the telemetry is expected to be accurate to $\pm 5\%$ over the normal operating range; higher accuracy is provided for the beam current. Two other important currents, the neutralizer emission and the SPIBS net current, are measured by bipolar electrometers. The electrometers are designed to operate between -2.5 and +2.5 mA (plus corresponds to a net electron flow off the filament). The bipolar feature is required only for detecting the net current to ground, but the two electrometers are identical to simplify design and fabrication. For currents (positive or negative) greater than $2 \mu A$, the electrometer outputs will be accurate to $\pm 10\%$ of the true current. In additon to the primary outputs defining source operation, telemetry is also provided for expellant reservoir pressure and PPA housekeeping. Not listed inTable 3 are two flags used for defining bias voltage polarity and blowoff cover position (open or closed).

Ion-Source Assembly

The SPIBS ion-source assembly (ISA), as illustrated in Fig. 6, includes the ion source, neutralizer filaments, and a vacuum enclosure endplate. The major elements of the source are 1) ion optics, 2) source body, which supports the magnets and anode, and 3) cathode-isolator-porous plug (CIP). The CIP subassembly supports the keeper and interfaces with the expellant assembly.

The ion source consists of a 3.6-cm cylindrical discharge chamber with a concentric cylindrical anode. A hollow

Table 2 Command capability

Command	Function
1. Instrument on[a]	Turns on instrument power
2. Instrument off[a]	Turns off all instrument power
3. Expellant valve open	Opens solenoid valve
4. Expellant valve closed	Closes solenoid valve
5. Cathode heater preheat	Turns on the cathode heater to Level 1 and turns on discharge supply
6. Ion gun power on	Turns on the ion gun power
7. Ion gun power off	Turns off the ion gun power
8. Beam voltage Level 1	Sets the beam power supply to 1000 V
9. Beam voltage Level 2	Sets the beam power supply to 2000 V
10. Keeper off	Turns the keeper supply off
11. Discharge current and neutralizer emission Level 1	Sets the discharge current reference to achieve 20 mA current; sets neutralizer emission level to 0.4 mA
12. Discharge current and neutralizer emission Level 2	Sets the discharge current reference to achieve 125 mA; sets neutralizer emission level to 1.2 mA
13. Discharge current and neutralizer emission Level 3	Sets the discharge current reference to achieve 200 mA; sets neutralizer emission level to 2.2 mA
14. Neutralizer emission Level 4	Sets neutralizer emission level to 2 μA
15. Neutralizer emission Level 5	Sets neutralizer emission level to 20 μA
16. Neutralizer No. 1	Selects neutralizer filament No. 1
17. Neutralizer No. 2	Selects neutralizer filament No. 2
18. Neutralizer heater on	Turns on the neutralizer cathode heater
19. Neutralizer heater off	Turns off the neutralizer heater
20. Neutralizer bias off	Turns off the neutralizer bias power supply
21. Neutralizer bias positive	Sets the neutralizer bias for positive polarity
22. Neutralizer bias negative	Sets the neutralizer bias for negative polarity
23. Neutralizer bias Level 1	Turns on the neutralizer bias to 10 V
24. Neutralizer bias Level 2	Turns on the neutralizer bias to 25 V
25. Neutralizer bias Level 3	Turns on the neutralizer bias to 100 V
26. Neutralizer bias Level 4	Turns on the neutralizer bias to 500 V
27. Neutralizer bias Level 5	Turns on the neutralizer bias to 1000 V
28. High voltage off	Turns off the beam and accel power supplies
29. Cathode conditioning	Turns on the cathode heater to Level 2

[a] In the SPIBS instrument, "instrument on/off" is implemented by connecting or disconnecting 28 = V input power.

Table 3 Analog outputs (telemetry) and actual value for full scale (5V)

Channel No.	Description	Actual Value for 5 V Output, ± 5%
1	Beam current	2.5 mA (± 2%)
2	Beam voltage	2500 V
3	Discharge current	250 mA
4	Discharge voltage	50 V
5	Keeper current	250 mA
6	Keeper high voltage	1000 V
7	Keeper low voltage	50 V
8	Cathode heater current	5 A
9	Accel current[a]	2.5 mA
10	Decel current[a]	2.5 mA
11	Neutralizer heater current	5A
12	Neutralizer bias voltage	1000 V
13	Neutralizer emission[b]	2.5 mA (± 10%)
14	SPIBS net current[b]	2.5 mA (± 10%)
15	Tank pressure	1500 psia
16	Power processor temperature	See calib curve[c]
17	PPA ac inverter current	1.5 A
18	PPA ac inverter voltage	50 V

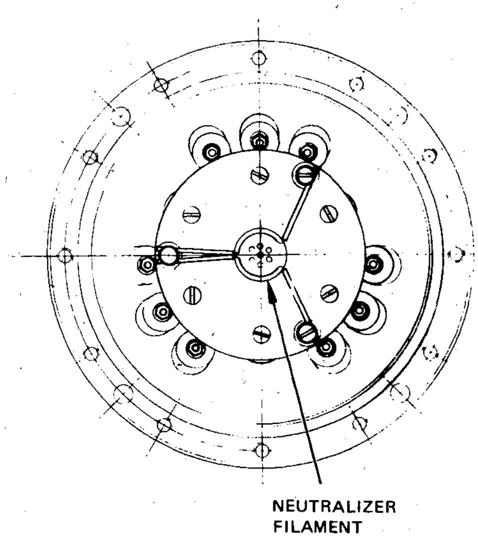
[a] To indicate anomolous conditon.
[b] In three ranges: 2.5-25 μA; 25-250μA; 250 μA-2.5 mA.
[c] T_{min} 0 = 60°C at 5 V. T_{max} = 100°C at 0.4 V.

cathode-keeper assembly is located at the end of the discharge chamber cylinder; the optics assembly is at the exit end of this cylinder. The ion source is cantilevered from three insulated feedthroughs attached to the vacuum enclosure endplate. The feedthroughs are tilted toward the centerline of the source at a 10-deg angle to form a rigid conical support base. This configuration allows the use of a small endplate, while maintaining sufficient clearance for the isolator assembly which lies within the conical space formed by three isolators. Nine wiring insulator feedthroughs are arranged in a circular pattern around the enclosure endplate. These are also tilted toward the axis to allow sputter shields to be placed on the source end of the electrical feedthroughs.

The ion optics design incorporates several novel features, including a single-aperture steel decel grid and graphite screen and accel grids. Steel was selected for the decel to reduce the external magnetic field created by the ion-source magnets. Graphite was selected for the seven-aperture screen and accel grids to minimize charge-exchange sputtering. A single-aperture decel grid was selected to minimize the trapping of sputtered accel material, which in early tests was found to cause a significant buildup on the decel and subsequent shorting. The decel, accel, and screen grid aperture diameters are 1.27, 0.12, 0.15 cm, respectively. Grid-to-grid spacings of 0.04 to 0.05 cm are used.

The neutralizer filaments are mounted from the decel grid using shielded insulators. The filament material is tantalum with yttrium added to reduce brittleness.[7] A filament length of 1.27 cm and a diameter of 0.18 mm has been found to combine low heater power, adequate emission, and reasonable operating temperature.

The CIP plug subassembly uses the technology developed for the 8-cm mercury thruster.[8,9] Xenon gas flowrate to the source is determined mainly by the porous plug, which reduces the pressure from 7 psia to a few Torr. The porous plug, fabricated from tungsten with a density of 80%, is 0.32



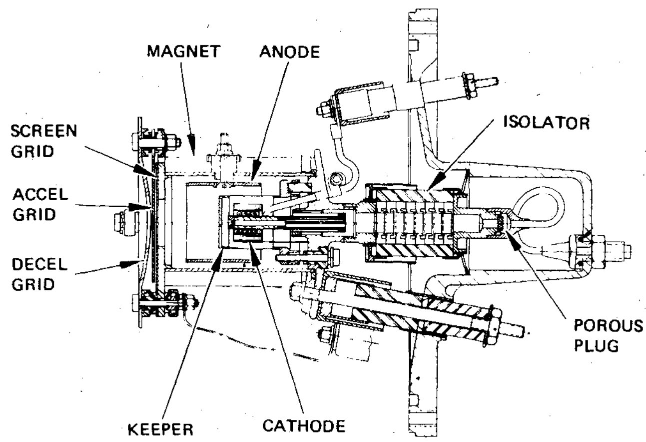


Fig. 6 Ion-source assembly layout drawing.

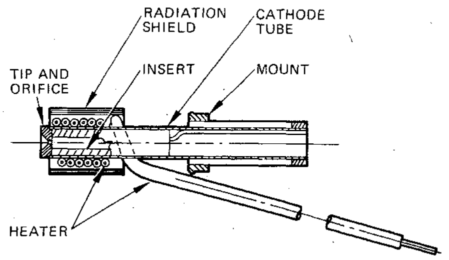


Fig. 7 Cathode assembly design.

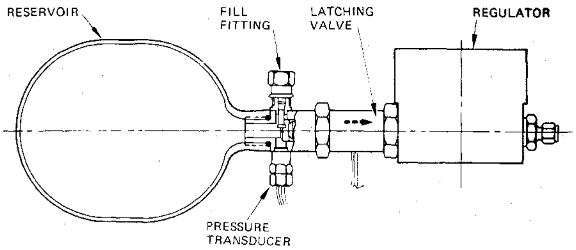


Fig. 8 Expellant assembly drawing.

cm in diameter and about 0.14 cm thick. The plug is electron-beam welded into a tantalum housing, with the sides electron-beam sealed so that the gas flows through the full plug thickness.

The high-voltage isolator consists of an Al_2O_3 outer shell flanged on both ends, with alternating ceramic rings and stainless-steel mesh disks within the inner passage.[8,9] The disks function as barriers to electrons accelerated by the electric field gradient. Within each gap, the applied field gradient is below the minimum required for Paschen breakdown. The flanges provide a means for attaching the isolator to the porous plug (upstream) and the cathode (downstream).

The structural part of the isolator subassembly is the alumina outer housing. Since alumina can withstand only very limited bending or tension loads, the isolators are mounted in compression. Compressive loading of the isolator housing is provided by the belleville washer between the upstream flange of the isolator and the enclosure endplate.

The cathode design is illustrated in Fig. 7. This cathode is similar to the 5-cm and 8-cm ion-thruster cathodes with a modified mount.[8,9] The cathode assembly inlcudes a re-entrant-type mount; this has the effect of increasing the thermal conduction path length and decreasing the thermal loss. The cathode is mounted to one end of a central passage through the endplate of the source body. The other end of the central passage is attached to the isolator.

The cathode insert is made of oxide-impregnated porous tungsten. It is attached to the cathode tube by four rhenium wires that are brazed to the insert and spot-welded to the tube. This approach was selected after an evaluation of rolled tantalum foil inserts and other impregnated configurations.

Expellant Assembly

The expellant assembly (EA) stores, regulates, and delivers xenon to the ion source assembly at a pressure of 7 psia. At this pressure, the porous plug in the CIP limits the flowrate to about 30 cm^3/h at STP (30 mA equivalent). A drawing of the EA is presented in Fig. 8 to indicate the design approach.

The reservoir is a Department of Transportation (DOT) rated commercial aircraft part. When filled to 800 psi, this reservoir contains about 50 standard liters of xenon. At the design flowrate, this will provide about 2000 h of operation. Attached to the reservoir, as shown in Fig. 8, is a fitting used for filling and a pressure transducer.

The latching valve requires about 1.0 A at 28 V to open and about 0.1 A to close; power is applied for 100 ms. The regulator will control from the initial pressure down to less than 15 psi (30 psia). Thus, virtually all the gas in the reservoir can be used.

Power Processor Assembly

The function of the PPA is to operate and control the ion source, operate the expellant valve, provide telemetry data, and accept commands from the satellite. This section describes the design being implemented to meet the requirements shown in Table 4 and the characteristics discussed in previous sections. Simplicity, low cost, and minimum development risk have been emphasized.

A functional block diagram of the PPA, shown in Fig. 9, indicates the general power processing technique. Input power is first regulated at 21 V dc. A 25-kHz square-wave synchronized inverter then produces 42 V rms ac for each power supply. Saturable reactortype power supplies are generally used.

The major feature of this design is the achievement of electrical isolation between the input power lines, the command lines, the telemetry, and the outputs of the various supplies. The isolation of the command lines is obtained by using relays. The relay coils provide electrical isolation, and magnetic latching provides nonvolatile storage of the received commands. The isolation between the input and telemetry lines is achieved by transformer and, where required, includes isolated voltage-sense windings and a current telemetry, respectively.

Table 4 Power supply requirements

Power Supply No.	Power Supply Name	Type	Maximum Voltage Relative to S/C GND, V	Maximum Power		Typical Power		Regulation, ±%	Range of Control
				Current, A	Voltage, V	Current, A	Voltage, V		
1	Cathode heater	ac	+2000	4.5	6	0	0	Loop	1.0 to 4.5 (I)
2	Cathode keeper	dc	+2000	0.2	25[a]	0.15	20	5 (I)	0.05 to 0.2 (I)
3	Discharge	dc	+2000	0.20	40	0.13	30	5 (I)	0.01 to 0.20 (I)
4	Beam	dc	0	3×10^{-3}	2000	1×10^{-3}	1000	5 (V)	1000 to 2000 (V)
5	Accelerator	dc	0	1×10^{-3}	600	2×10^{-5}	300	5 (V)	Varies with beam voltage
6	Neutralizer heater	ac	±1000	3	3	2.5	2.5	Loop	10 to 30 (I)
7	Neutralizer bias	±dc	0	3×10^{-3}	1000	1×10^{-3}	0	5 (V)	10 to +1000 V

[a] 1000 V open circuit.

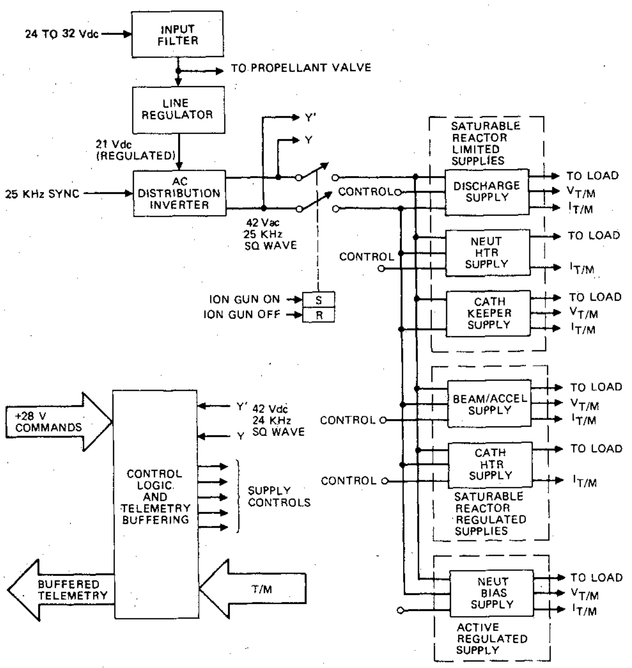


Fig. 9 Power processor assembly: block diagram.

Supplies for discharge, neutralizer heater, and cathode keeper are fixed set-point supplies, and each is current-limited by a saturable reactor for short-circuit protection. The beam/accel and cathode heater supplies use saturable reactors both for controllability and current limiting. The neutralizer bias supply is transistor regulated. The line regulator is a "buck" switching regulator; it converts the unregulated 24 to 32 V input bus to regulated 21 V dc. An input filter is required to prevent the ripple current generated by the line regulator from appearing on the input power bus lines.

The PPA circuits are packaged on three cards, as shown in Fig. 5. Components are mounted on both surfaces of the magnesium channel-section structural member. Both the terminal strips and the magnetics are bonded to the plate. Without magnetic mounting studs, a relatively large area is made available for component mounting. A qualification vibration test of a section of a typical loaded circuit card was succesfully performed to evaluate this packaging approach.

The breadboard PPA has been tested against the electromagnetic interference (EMI) requirements of MIL STD 461A. Except for a few high-frequency ranges, the SPIBS unit met the conducted emission requirements; tests for input line susceptibility were also successful.

SPIBS Test Results

Several tests were performed during the SPIBS development process to evaluate the performance of various assemblies and to verify design techniques. The types of tests include the following: 1) ion-source electrical performance, PPA integration, endurance, startup cycling, vibration of ion optics, and operation in blowoff cover; 2) expellant regulator performance with ion source, latching valve operation, and pressure transducer calibration; and 3) power processor operation, assembly breadboard electrical efficiency, functional evaluation of all circuits, ion-source integration, endurance using ion source, EMI, commands and telemetry, and sample circuit card vibration.

Ion-Source Assembly

Representative ion-source performance data are shown in Fig. 10 showing beam current as a function of discharge current at two beam voltages. The desired beam current is obtained by selecting one of three discharge current levels. Since beam current also varies slightly with beam voltage, a total of six current levels can be obtained. This figure also

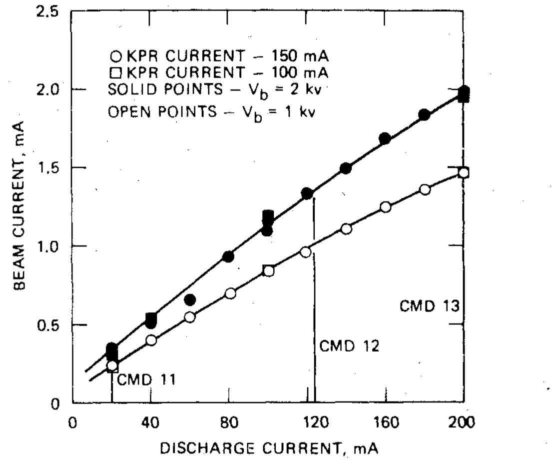


Fig. 10 Typical beam-current vs discharge-current characteristics.

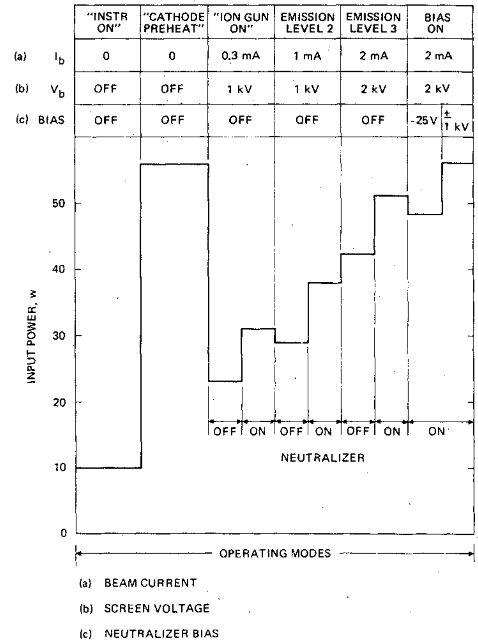


Fig. 11 SPIBS input power as a function of operating mode.

illustrates that performance is relatively insensitive to keeper current.

Several 200- to 300-h endurance tests were conducted to evaluate various aspects of the source design. After those tests, a 600-h test was conducted to verify the engineering model ion optics design. In addition, startup (on/off) tests to evaluate cycling capability were performed with several cathode insert configurations. Approximately 400 cycles were conducted with the engineering model insert design; there was no apparent change in characteristics. Most performance, endurance, and cycle tests were accomplished using the breadboard PPA.

A vibration test to qualification levels was performed on the ion optics subassembly mounted to a representative source body. The primary purpose of this test was to assure that the graphite grids and tantalum filaments are satisfactory dynamically. No difficulties were encountered, and an engineering model optics design baseline was thereby established.

To further verify the engineering model system design, an ion-source test was performed with the blowoff cover closed and the pumpout port open. This type of test simulated ground checkout operation, in which a vacuum station will be used to pump the xenon gas through the cover pumpout port.

Beam currents up to 1 mA with a beam voltage of 1 kV were obtained without difficulty.

Expellant Assembly

The critical portions of the engineering model expellant assembly were successfully tested both separately and with the ion source. Both the regulator and latching valve were used during the 600-h ion source test. In that test, xenon from a standard lecture bottle was expended from 600 psig down to ≈ 10 psig. The type of pressure transducer selected for the engineering model system was calibrated over the expected pressure range; it was stable within $\pm 10\%$ over a temperature range from -40 to +80°C.

Power Processor Assembly

The most lengthy testing of the PPA has occured in conjunction with ion source endurance testing. Virtually all functional aspects of the PPA have been evaluated, including 1) basic operation of the ion source over the full power range, 2) operation and control of the neutralizers, 3) biased operation of the neutralizer, 4) operation of both electrometers, 5) operation from simulated ground commands, and 6) calibration of telemetry outputs. Based on this relatively extensive testing of the breadboard, the PPA circuit design was finalized for flight model fabrication.

The PPA packaging concept was evaluated dynamically. A 16-cm length of a circuit card was assembled using the proposed engineering model fabrication techniques. Magnetics and terminal strips were bonded to the magnesium plate, dummy components were installed and the card was conformally coated. A qualification level vibration test was conducted without incident.

EMI tests were performed on the breadboard for conducted emissions and susceptibility using MIL STD 461A as a reference. Filters added to the line regulator were found to satisfy the major requirements. Slight changes to the line regulator control response were implemented to meet susceptibility requirements.

System Operation

The SPIBS elements were tested individually, in pairs, and as a system. A good indication of system performance is shown in Fig. 11, in which input power is presented as a function of operating mode. These data were taken with the breadboard system. The first command, "instrument on," activates the line regulator and ac distribution inverter to allow housekeeping functions to be monitored. The "cathode preheat" command turns on the cathode heater and discharge supply. After a few minutes (typically, 1 to 5 min), keeper voltage is applied and the discharge ignites. When the discharge voltage falls below 40 V, the cathode heater is automatically turned off. From this point on, a wide range of options are available for beam current, beam voltage, neutralization, and biasing. A few of the typical modes are illustrated in Fig. 11. Although biasing is illustrated only for full beam power, the complete bias range of ± 1 kV can be used with any beam current or voltage setting. Since the systems can be operated as an ion source alone, as a neutralized ion source, and as an electron source alone, each with and without biasing, a total of 290 operating modes are available with SPIBS.

Conclusions

The work described in this paper resulted in the design and construction of a satellite ion-ejection instrument. The flexibility of this instrument should make it a valuable tool in the study of a satellite charging on SCATHA and on other space vehicles. The SPIBS design provides a life of more than 300 h and satisfies the SCATHA saltellite instrument requirements on weight, power, EMI, and quality assurance. The instrument has been designed and built to have the following features:

1) Ability to eject an unneutralized ion beam having a current range 0.3-2.0 mA at beam energies of 1 and 2 keV.

2) Ability to eject a partially or fully neutralized ion beam having the above current and voltage range.

3) Ability during beam operation to use a neutralizer that can be biased from -1kV to +1kV relative to spacecraft ground.

4) Ability to emit electrons, without an ion beam, from the neutralizer filament that can be biased from -1 kV to +1 kV relative to satellite ground.

5) Ability to detect neutralizer emission and net currents (ions or electrons) between the SPIBS instrument and satellite ground down to a level of 2 μA.

6) Operation with xenon to avoid possible expellant interactions with the satellite.

7) Provisions for ground operation of the ion source and system during the satellite integration phase.

With the basic characteristics of the SPIBS instrument having been demonstrated, additional experimental and analytical investigations are now needed to assess the interaction of SPIBS with the satellite.

It is anticipated that charge exchange between the ionized and neutral xenon leaving SPIBS will reduce the flux of energetic ions emitted from the satellite. As a result of the charge exchange ions, subsequent flux of SPIBS component surface material can also be expected. Tests to determine the composition, flux, energy distribution, and beam properties of charged and uncharged particles are currently underway. However, Faraday probe measurements made during the investigation of the effectiveness of the heated filaments as beam neutralizers indicated that energetic ions were still a significant portion of the ejected beam.

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