Review of SERT II Power Conditioning

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The Sert II power conditioning was required to meet severe operating conditions: operation in vacuum, potential differences of 4000 v, and frequent and unavoidable thruster arcs. Techniques intended to provide satisfactory, reliable performance for a period of at least six months are discussed. They include "open-to-vacuum" construction of magnetic components, automatic overload protection, conformal coating, and aluminum coated insulating sheets as barriers. The performance of the successful power conditioning system to date is discussed.

Introduction

THE power conditioning system described here was developed to power a 1 kw mercury ion thruster on the orbital SERT II spacecraft.[1,2] A brief description of the power conditioner (*P/C*) is included herein, but the reader is directed to a more detailed coverage by Hoffman et al.[3] The *P/C* used for the 1964 SERT I mission incorporated a sealed, pressurized enclosure to ensure proper operation during its 1-hr useful mission life. The SERT II system was specifically designed to perform a 6-month mission. Protection of the *P/C* from external and internal arcs is covered in detail; current-limiting and momentary supply shutdown were two techniques used successfully. Open-to-vacuum construction was selected as the most likely to achieve success for a long-term space mission. The extent to which open-to-vacuum construction techniques were used are described.

Late in the development program, failures due to internal arcing began occurring. This was particularly frustrating due to the precautions already taken. The subsequent investigation showed that outgassing was not the cause of the failures. Success was achieved only after the addition of insulation inside the *P/C*. Although the effects of our corrective techniques are still under investigation, some design guidelines are drawn. The success of the design is further demonstrated by its performance in flight.

Power Conditioner Description

The solar cell array provides a nominal d.c. voltage output of 60 v during full-beam thruster operation. The *P/C* converts this into nine different electrical outputs totalling approximately 860 w for the thruster. The major amount of electric power is delivered at 3000 v, 0.25 amp d.c. Nominal conversion efficiency is 87%.

The *P/C* without cover is shown in Fig. 1. With the cover, it is 20.5 in. (52 cm) long, 10.5 in. (26.7 cm) wide and 5.5 in. (14 cm) high and weighs 32 lb (14.5 kg). The nine electrical outputs are terminated on 13 ceramic feedthroughs. The *P/C* is bolted to the spacecraft radiator, which is sized to maintain a temperature less than 120°F at rated operating conditions.

Table 1 lists the rated outputs from the *P/C* for each of the nine supplies, and the typical operating values for each electrical supply. Some of the power supplies (V5, V6) have outputs that vary proportionately with input voltage. The neutralizer bias supply "V9" is an experiment and is not required to operate the thruster. Telemetry outputs are provided to indicate the condition of individual supplies.

Supplies and Operating Modes

The master inverter that provides power to all supplies except V5 and V6 high voltages is a modified Jensen inverter[4] that operates at a nominal 8 kHz. The heater supplies receive power from the master inverter. All three heater supplies, main vaporizer (V2), cathode heater (V3), and neutralizer heater-vaporizer (V7) use magnetic amplifiers (mag amp) to control output power by pulse width modulation. Control of these supplies is by feedback signals as shown in Fig. 2. The screen (V5) supply consists of three modified Jensen inverters.[4] Each provides one-third of the output voltage. The rectified outputs are connected in series to obtain the required +3000 v. A fourth redundant inverter can be commanded to operate in the series string if one of the other inverters fail. The accelerator supply (V6) is similar to the individual V5 inverter module except the output is negative 1800 v d.c. The anode supply (V4) consists of a transformer and full wave bridge rectifier powered by the master inverter. It uses mag amp control to provide voltage regulation and current limiting. The voltage can be set any of three values by ground command. The cathode keeper supply (V10) consists of a transformer and series inductor powered by the master inverter with a full wave diode bridge for rectification. Open circuit voltage is nominally 400 v. This drops to approximately 15 when the thruster keeper fires. Both the V4 and V10 supplies float at the V5 potential, +3000 v d.c. The neutralizer keeper supply (V8) consists of a transformer and series inductor powered by the master inverter. The output is rectified by a full-wave diode bridge. The series inductor limits the current. The neutralizer bias supply (V9) provides both positive and negative biases. For positive bias, neutralizer emission current flows through zener diodes to cause a 25- or 50-v bias. For negative bias, an auxiliary circuit consisting of a transformer powered by the master inverter is used. The bias level is selected by ground command.

The thruster requires that the supplies be turned on sequentially. Interlocked command relays are used. First, a

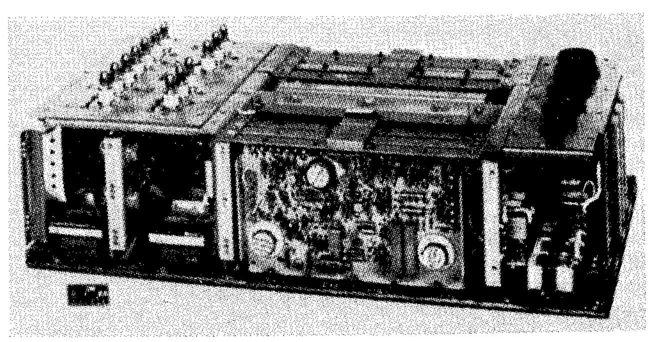

Fig. 1 Power conditioner without cover.

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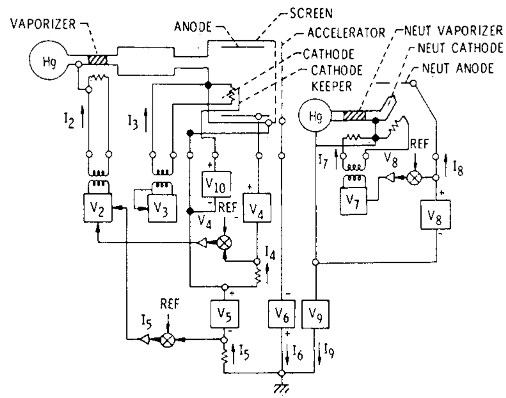

Fig. 2 Power conditioner block diagram.

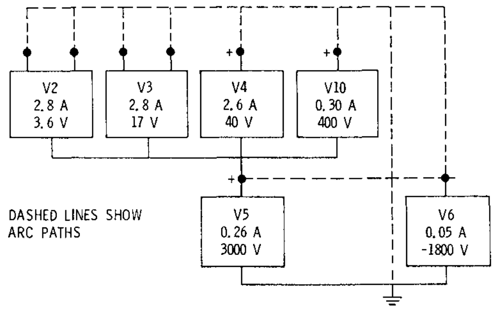

Fig. 3 Possible arc paths in ion thruster.

preheat command is given to start the master inverter, thus energizing the V3, V4, V7, V8 and V10 supplies. Second, the *propellant command* applies power to the thruster vaporizer by activating the V2 supply. Finally, the *operate command* allows V5 and V6 inverters to start by removing shorts from stop windings and activating a base drive pulse generator.

Control Circuits

A voltage proportional to the anode current (I4) is applied to the input of the comparator op amp. This signal controls the V2 mag amp to provide a controlled discharge in the thruster. This control is connected only in the propellant mode. A 10-ohm resistor in the ground return to the V5 high-voltage supply provides a feedback signal proportional to beam current. This is compared with a fixed reference at the input of a comparator op amp. This signal causes the V2 mag amp to control the beam current. Command relays select the three reference values for beam control at 75 ma, 200 ma, or 250 ma. A signal proportional to the V8 voltage is compared to a selectable reference potential. This signal causes the V7 mag amp to control the neutralizer keeper voltage (V8). The threshold voltage at which control begins is set by command relays which select specific reference potentials. Two V8 control points are available, 28 v and 22 v. The *P/C* overload integrater provides for an automatic shutdown when it reaches its peak value. Resumption of operation must be by ground command through the normal startup sequence. This shutdown function can be disabled from the ground.

Operation of System during Thruster Arcing

The ion thruster has a combination of close spacings and a plasma which is highly conducive to periodic arcing. Some of these arcs will self extinguish, but many will continue until the power source is interrupted.[5] Figure 3 indicates some of the arc paths possible in a thruster. There are two high-voltage supplies (V5 and V6) plus four more supplies (V2, V3, V4 and V10) which float at high voltage. This combination of supplies can result in a variety of overload conditions due to arcing. An arc from either the V5 or V6 supply to ground results in an overload or short on a single supply. An arc from any of the floating supplies to ground results in an overload on that supply plus one on the V5 supply. Also, both supplies will be subjected to the current from the supply with the highest current rating. As seen in Table 1, three of the floating supplies have current ratings at least ten times larger than the V5 supply. An arc from one of the floating supplies to the negative V6 supply results in an overload on three supplies. The supplies in the *P/C* must be protected from all of the aforementioned overloads.

The SERT II *P/C* protection was designed on the following basis: each supply must be capable of a) withstanding a short circuit across its terminals for an indefinite period of time, b) having either of its output terminals shorted to ground, and c) being shorted to any other supply. In addition, all supplies except the neutralizer supplies have 6000-v isolation between primary and secondary circuitry.

The heater supplies (V2, V3, and V7) use mag amp control to provide a constant power to a fixed resistive load. Therefore, they have *built-in current limits* and can operate into a short circuit indefinitely. The two keeper supplies (V8, V10) are required to provide either a few hundred volts at low currents (5 ma) or a few tens of volts at higher currents (200–300 ma). To provide this drooping type of characteristic as shown in Fig. 4, an inductor is placed in series with the primary. This provides built-in current-limiting for these supplies.

The anode supply (V4) uses a mag amp to provide controlled voltage to the load. By the addition of an extra control loop, this same mag amp is used to provide current-limiting as well. The resulting characteristic is shown in Fig. 5.

Table 1 Electrical output requirements

Output supply	Rated outputs[a]				Typical operating[a]			
	Voltage, v		Current, amp	Power, w	Voltage, v		Current, amp	Power, w
Propellant feed vaporizer, V2	3.6	ac	3.0	10.8	1.78	ac	1.7	3.0
Cathode, V3	17	ac	3.4	57.8	5.2	ac	1.5	7.8
Anode, V4	45	dc	2.6	117	37.4	dc	1.7	63
Screen, V5	3000	dc	0.26	780	3000	dc	0.255	765
Accelerator, V6	−1800	dc	0.05	90	−1550	dc	0.0019	3.0
Neutralizer cathode and neutralizer vaporizer, V7	13	ac	3.4	44.2	5.8	dc	1.9	11.0
Neutralizer keeper, V8	30	dc	0.23	7	23	dc	0.183	4.2
Neutralizer bias, V9	50	dc	0.25	13	0		0	0
Cathode keeper, V10	20	dc	0.35	7	11.7	dc	0.30	3.5
Total power				1126.8				860.5

[a] For nominal input voltage of 60 v dc.

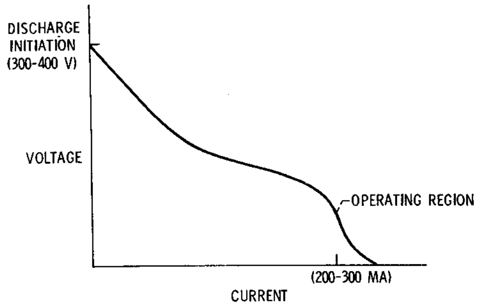

Fig. 4 Keeper supply volt-amp characteristic.

The anode supply has the highest current rating of any of the supplies in the *P/C*. This causes additional problems particularly during a V4 to ground arc. As shown in Fig. 3, the path for the arc current is through the V5 supply as well as through the V4 supply. Although the V4 supply has its built-in protection due to the current-limiting of the mag amp, the V5 supply is not protected for this high value of current. The output of the V5 supply consists of four bridge rectifiers in series with a 10-ohm current sensing resistor to provide a high signal-to-noise ratio and an accurate sensing of beam current. An additional series resistance of 25 ohm was also added. This resistance along with the voltage in the bridge rectifiers provides the current limiting protection from the V4 to ground arc. A series resistance was also used in the V6 supply to limit currents during arcs such as V5 to V6 or V4 to V6. Since the normal load current of V6 is only 1 or 2 ma, this can be done with little effect on efficiency.

The protection of the high-voltage supplies from arcs is accomplished by turning the supplies off momentarily (blink-off technique). As discussed by Stover[5] many high-voltage arcs which occur in a thruster will not be extinguished until the power source is turned off. Therefore, besides providing protection for the supply, the blink-off technique causes the arc to be extinguished. While the high-voltage supplies are off, there is no beam coming from the thruster, and the ions are no longer focused by the two high-voltage plates. However, ions (in excess of full beam levels) are still being produced in the thruster chamber since the other supplies are still on (V2 is turned off with V5 and V6, but the thermal lag is much too long for any reduction in Hg flow during a single blink-off cycle). When the high voltages are turned back on, the excess and defocused ions cause an overload in the V5 supply for a short period of time. Figure 6 illustrates what a cycle would be like with an overload on the V5 supply. The supply turns off very rapidly, 1.0 msec, upon the occurrence of the arc. The supply remains off for 100 msec. (The off time was evaluated with a thruster from 10 msec to 5 sec with no noticeable difference in operation.) Upon turn-on there is an overload on the screen current (I5) for a few milliseconds. A delay of ~10 msec has been placed in the trip-off circuit to overcome this overload. If this delay were not present, the trip-off circuit would continuously cycle until

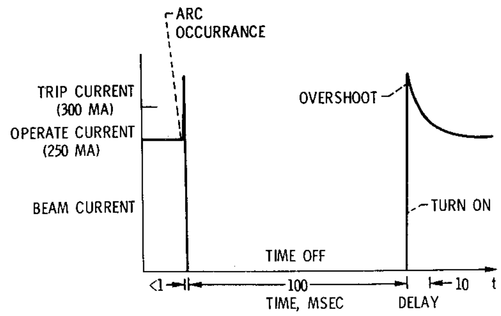

Fig. 6 Beam current overload cycle.

the thermal lag in the vaporizer (V2 load) had reduced the Hg vapor level in the thruster to a low enough value so that I5 would no longer overload upon turn-on. This phenomenon is much more likely to occur with V5 than V6 since the accelerator current (I6) trip level is approximately 25 times the normal operating level while the I5 trip level is only 1.2 times its normal operating level. Since these are protective trip levels the over design of the V6 supply is apparent.

Open-to-Vacuum Design

The voltages between various components and terminals mounted within the *P/C* can vary over a wide range. Some circuits are at a few kilovolts, positive or negative. Others have alternating voltages with peak values ranging between a few volts and a few kilovolts. The current capability can also vary over a wide range. One high voltage circuit will deliver only 50 ma. Another, at <100 v (the power input circuit), will deliver up to 20 amp. It is plain that we must provide a dielectric medium within the *P/C* to prevent breakdown and arcing between circuits. The insulation system must prevent breakdown and arcing 1) during six months in orbit (at 10^{-4} torr) and during preflight testing both in air (760 torr) and in vacuum tanks (10^{-6} torr), 2) over a range of temperatures from $-30°C$ to $+120°C$, for example, in cyclic thermal-vacuum testing, and 3) after the *P/C* has been subjected to vibration and shock during preflight tests and launch.

An open-to-vacuum insulation system was chosen. Space qualified encapsulation and potting compounds were used only where absolutely necessary. During some preflight tests, the *P/C* would be at room ambient pressure. Under vacuum conditions the *P/C* interior would vent down to a pressure near that of the outside environment. Vacuum dielectric strength is excellent; it can be as high as 10^5 v/cm. Possible problems with this system are diffusion of mercury plasma or vapor into the *P/C* and local pressure concentrations within the *P/C*. But whether or not the *P/C* is vented to vacuum, some of the output potentials must be exposed to the vacuum environment. They will be exposed at the *P/C* feed-through terminals, or if those are insulated, then at the thruster. Therefore, somewhere within the spacecraft we could expect similar problems whether or not we chose this *P/C* insulation system.

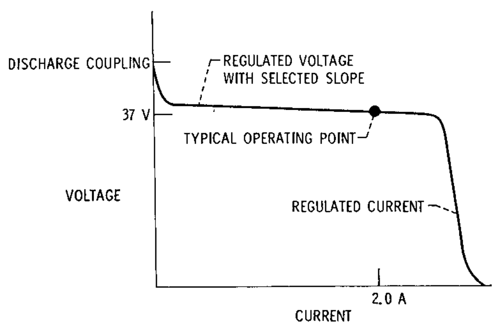

Fig. 5 Anode supply volt-amp characteristic.

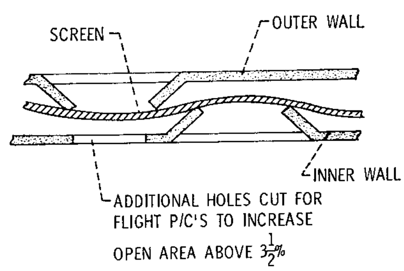

Fig. 7 Cross section at vent holes through double wall cover of *P/C*.

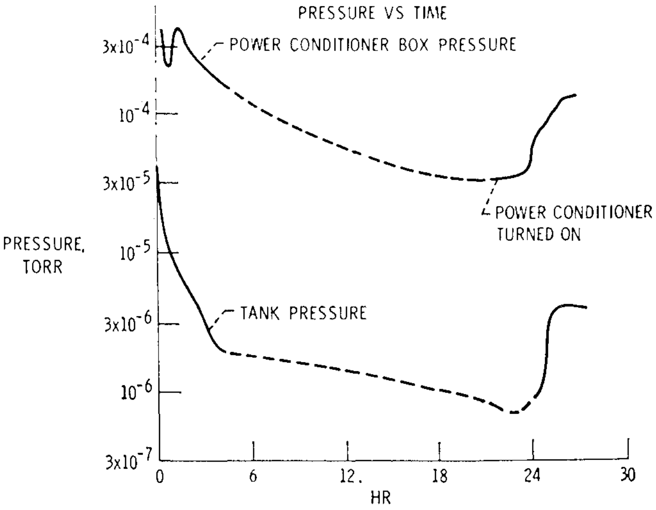

Fig. 8 Venting tests on experimental model.

There is a direct line-of-sight spacing between high-voltage transformer terminals and low-voltage transistor terminals. There is also a direct line of sight between these terminals and the P/C baseplate which is at spacecraft potential. A minimum spacing between terminals and the baseplate of 1 cm is maintained in the layout of the P/C. In these locations the insulation strength of vacuum is relied upon entirely to prevent breakdown and arcing.

The main cover is vented with about 200 $\frac{3}{8}$-in.-diam. screened holes. These holes are made in double wall panels with either 9 or 12 holes per panel. A cross section is shown in Fig. 7. About $3\frac{1}{2}\%$ of the cover surface is open through these holes. These vents were designed to carry the outgassing load from inside the P/C at about 1×10^{-4} torr pressure drop. This pressure is low enough to provide good dielectric strength in orbit and during tests in vacuum tanks. Figure 8 (curves of pressure vs time) shows the measured performance of these vents (although adequate, this is not the way the P/C was flown. As explained later, arcing problems, believed to be caused by inadequate outgassing, prompted making half of the holes extend through the double wall). Obviously, local pressure within the P/C will be affected by location of the vent holes and the major sources of outgassing. Also flow restrictions and entrapped gasses can affect local pressure.

In general, the materials used in the P/C should have 1) low volatile content 2) rapid release volatiles, and 3) low long-term outgassing rates. The high-voltage wire in the P/C is silicon rubber insulated with a semiconductive coating between the wire and its insulation. Low-voltage wire is Teflon† insulated. Components are bonded to circuit boards and the baseplate with RTV (DC3145). Circuit boards are glass melamine coated with epoxy varnish.

Internal Arcing Investigations and Solutions

The internal arcing problem was elusive because of the way it gradually manifested itself. It caused failures in first one area of the P/C and then another. These failures will be discussed in about the same order they occurred.

The screen supply (V5) modules are each equipped with a 10-amp fuse in their input. The purpose of this fuse is to remove any defective module from the d.c. input bus. These screen supply fuses began to fail during tests in vacuum. The failures usually occurred at the time of high-voltage startup or during a thruster arc. These failures occurred randomly throughout the development phase in both experimental and prototype P/C's. We suspected that current surges at high voltage turn on could be the cause of the failures. It was also possible that the V5 fuses used were defective. Lab tests later showed that neither suspicion was right. Start-up transients were gentle and well within the rated fuse capacity. Likewise, the fuses were found to meet the manufacturer's specifications for current ratings and opening times. These failures of the V5 screen supply fuses remained unexplained until later in the investigation.

† Trademark, DuPont Company.

As the prototype test program continued the P/C was plagued with recurring failure of another component, the rectifying diodes in the anode supply (V4). As stated earlier, the anode supply produces about 40 v d.c. at 1 to 3 amp and is floated at the V5 screen potential. Again, these failures usually occurred during startup or during arcs. Two parallel supporting test programs were initiated to find and cure these failures, a smaller program to continue investigating the V5 fuse problem, and a larger one to investigate and solve the anode supply diode failures.

In the course of the anode failure testing, a P/C was run in a small vacuum tank where it could be viewed and its electrical parameters could be measured and recorded. Arcs were seen, so we aimed a camera at the area of interest, opened the shutter and operated the P/C. When an arc indication appeared on the telemetry, the film was advanced and developed. It was during this testing that the last and most fearsome manifestation of the internal arcing problem occurred. A P/C was being tested under high vacuum conditions. The startup was normal through preheat and propellant mode. When high-voltage turn-on was attempted, a large current transient was recorded on the input bus and an immediate automatic shutdown occurred. There was serious damage to everything in the anode supply area; the primary side of the anode supply transformer had arced to ground. Apparently, the failures were associated with a phenomenon that was most evident at high-voltage startup and provided a momentary conduction path. The following were considered as possibilities.

Outgassing

Outgassing was the leading contender early in the investigation. Theories as to the source of the outgassing ranged from leaking components to gas trapped on the many surfaces of the P/C. Tests were run measuring gas pressure inside and outside the P/C during a pump down. Figure 8 shows that the inside pressure remained about 10^{-4} torr above the tank pressure. We placed baffles in the suspected areas inside the P/C to isolate these areas but we were unable to locate any specific source of gas by this technique. We forced helium gas into a P/C in the hope that it would permeate the gas trap and then later be detected by a helium leak detector. Again the results were negative. Various hermetically sealed components such as electrolytic capacitors and encapsulated devices were tested for material leakage. No leakers were found.

Attempts were made to identify the products exuded by a P/C while it was heated in a vacuum. A scanning mass spectrum analyzer was used. Its output showed N_2, water, and some heavier molecules believed associated with RTV polymers. To reduce the postcure outgassing of these polymers we increased the high-temperature bake in vacuum to 240°F for 100 hr. Some substances in the P/C could reabsorb gases when exposed to atmosphere, so we modified the P/C test procedures to include a 12-hr vacuum bake at 140°F prior to each startup. Also the flight spacecraft was modified to include heaters to warm up and outgas the P/C in orbit prior to operation. We also increased the venting rate of the P/C's by redesigning the cover vent holes for straight-through flow. (Postlaunch testing showed that although the added cover holes increased the P/C venting rate, they were not necessary for successful operation.)

Magnetic Fields

It was the primary terminals of the anode supply transformers that received the most damage during the internal power arcs. These transformers are powered by a single 8-kHz oscillator and their secondaries are at high voltage. A theory was advanced that possibly the stray magnetic flux from these transformers could cause charged particles in the area to be accelerated, thus promoting secondary ionization. This could cause breakdown of the low-voltage bus to ground. Magnetic surveys showed that the a.c. fields were ~3 gauss rms. The d.c. field in the area of the V4 anode supply inductor was 80 gauss. We thought we had finally found the cause of the failures until it was demonstrated that the failures still occurred with the inductor removed.

Electric Fields

In the open-construction design the empty space between components has a certain dielectric strength. It was speculated that under "real" conditions, a combination of electric field gradient, spacing, and pressure environment may permit arcing, in spite of the fact that our present gas discharge knowledge predicted that our high-voltage component spacing was adequate. Therefore, fine wire mesh electrostatic shields were made to cover the high-voltage terminals. We reasoned that if the fields could be terminated away from the low-voltage bus, any breakdowns occurring would be extinguished before causing secondary arcs. Initially, little success was achieved, because it was hard to make the complex shapes necessary to provide shielding while avoiding shorting out the critical terminals.

Conformal coating had been considered for our *P/C* circuits and components, but its use had been limited to the back side of the printed circuit boards. Conformal coating had not been applied to all exposed terminals, because we felt that its application would be hard to control and could even become a source of gas if it contained bubbles. Now we became willing to accept the coating problems if the added dielectric would reduce the internal arcing. All high- and low-voltage exposed terminals in the *P/C* were coated to a nominal thickness of 5 mils to provide 18,000-v dielectric protection. The coating was Magna Coating and Chemical Corporation's Laminar X500 3C-23, clear polyurethane. The properties include dielectric constant, 2.7; and dielectric strength, 3700 v/mil. Upon operating the *P/C* in the test chamber the problem did not reoccur in the V4 areas but further testing revealed continued arcing in the V5 area. Close examination of this area revealed spots where either no coating had been applied or sharp edges thinned the coating to an inadequate thickness. We concluded that the geometry of the parts in the V5 area prevented complete coating and adequate thickness build-up on points and edges.

We looked for something that could overcome these failings and decided on aluminized, Kapton‡ film. The 5-mil film would give 36,000 v of dielectric protection when used double thickness. We folded the material with the aluminized sides facing inward. This film was used in several other applications on the SERT II spacecraft. The Kapton proved to be relatively easy to work with and provided the dual function of terminating the electric field on the grounded conductive side and providing additional isolation in the Kapton substrate. It was used only where close and line-of-sight spacing existed between high- and low-voltage terminals.

In the course of disassembling the *P/C*'s to conformally coat the inner circuits we noticed that there were evidences of arcing on the inner circuit boards. The arcs occurred

‡ Trademark, DuPont Company. This polyimide H-film, 5 mils thick, was coated with evaporated aluminum on one side. The properties of Kapton include dielectric constant, 4.0; dielectric strength, 3600 v/mil; and tensile strength, 20,000 psi at 20°C.

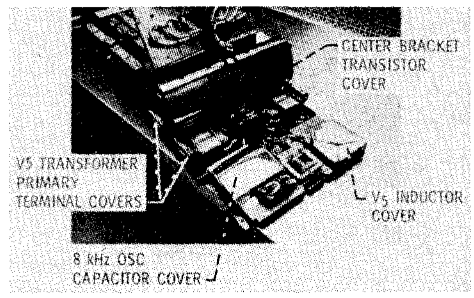

Fig. 9 Power conditioner with barriers installed.

between high voltage transformer terminals in the center of the *P/C* and the screen-supply V5 control board. Arcs on this board accounted for V5 fuse failures. Conformally recoating these inner circuit boards and adding a double layer of Kapton barrier between the offending terminals stopped the breakdowns in this area. Based on the positive results of the conformal coating and Kapton barrier tests these two fixes were incorporated into the flight *P/C*'s.

Flight Configuration

The final *P/C* configuration is shown in Fig. 9. Kapton barriers were used to cover each of the V5 module transformer primary terminals. Also the V5 inductors located on the vertical end bracket and the 8 kHz capacitors and fuses on the same bracket were housed in small Kapton enclosures. The V5 transistors mounted on the middle vertical bracket in the high voltage end of the *P/C* were covered by a piece of Kapton draped over the bracket and secured by the terminal plate. Finally, a barrier was installed between the center section supplies and the screen supply printed circuit board. The barriers were carefully designed to vent freely.

Although the barriers were successful, the materials used are not recommended for new designs, because 1) Kapton has poor tear resistance (special stress relief methods are required to prevent tears from starting); 2) the adhesive of the $1\frac{1}{2}$-mil Kapton tape used to attach some of the barriers can develop carbon tracks at voltages well below the Kapton breakdown voltage, and the adhesive of the tape tends to trap air bubbles; and 3) the thin aluminum coating of the Kapton is easily damaged by scratches and sharp folds. For new designs, it is recommended that metal barriers coated with insulation be used.

Space Operation in Comparison with Ground Testing

The *P/C* performance in space has been perfect to date without exception. All supplies are powering their thruster loads well within their specified ranges. Thruster arcs are occurring on an average of four per day and the *P/C* is safely handling these overloads with no apparent adverse effects. All control loops are stable and the measured operating parameters are constant within the telemetry resolution. The passive thermal design of the spacecraft is allowing the *P/C* to operate with its baseplate at 98.6°F and its internal area at 110°F. The anticipated operational limit was 120°F and the test limit was 140°F. The input voltage to the *P/C*, highest at no-load, beginning of mission, did not reach the maximum anticipated level. It was expected to reach 78 v but never exceeded 72 v. Therefore, voltage stress, especially on the unregulated high voltage supplies, was less than planned and qualified for. The power efficiency calculated from measured values in flight is 87.5% compared to a design goal of 87%.

Flight performance compares very well with ground testing. All operating values equal those obtained during ground testing where the *P/C* and thruster were mounted in their flight configuration on the spacecraft in a vacuum tank. Although certain test conditions on the ground resulted in more frequent thruster arcs, the arcs during long uninterrupted tests compare favorably with the number recorded in flight.

Concluding Remarks

The development of a reliable power conditioner (P/C) for SERT II was not undertaken with the idea of advancing the state-of-the-art in electronic power conversion equipment. Nevertheless, development within the flight constraints resulted in some advances worth noting. The high voltages with their resulting arcs posed some design problems. Current limit protection proved adequate in all areas where used. The interruption of the high voltages when an arc occurs and their subsequent reapplication to restart the beam, although simple in concept, proved very successful.

Although its adequacy was questioned at times, the open-to-vacuum construction of the P/C proved to be quite satisfactory. It also made disassembly and repair during development much easier. Our results show that it is not difficult to design components and their layout to get good venting.

The internal arcing problems that did occur during development could not be attributed to a failing of the open-to-vacuum design. On the contrary, our testing only tended to show that outgassing was not the cause. It was concluded that the existence of a good vacuum and spacing alone are not enough to prevent breakdowns. A better insulating medium must be provided. Conformal coating with polyurethane may provide this as well as surface protection. Conformal coating of all high- and low-voltage conductors is believed to be effective for the following reasons: 1) ambient plasma is isolated from bare terminals; 2) the coating suppresses photoelectric and secondary electron emission; 3) surface contamination breakdown from such things as solder flux is prevented; 4) the coating may inhibit field emission by space charge effects; and 5) it prevents shorts due to metal chips. But if surface geometry is complex and sharp corners exist, conformal coating may not be adequate in itself. Barriers made of aluminized insulating sheets provide the added protection. Although the fix on SERT II is not recommended for new design, the principles employed are recommended. To this end, the low and high voltages must be physically separated by a barrier. Wherever possible this barrier should be a part of the structure.

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