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SELENIDE ISOTOPE GENERATOR *for the* GALILEO MISSION

Galileo-1632

TELEDYNE ENERGY SYSTEMS

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Pictured on the cover is Galileo's drawing of the solar system, which includes the four satellites of Jupiter he discovered in the 1600's. A Renaissance professor, inventor and astronomer, Galileo perfected the telescope with which he made his Jupiter discoveries. The 1982 NASA mission to Jupiter is named in his honor. Like Galileo and his telescope, the NASA mission to the far reaches of outer space will be contributing to Mankind's never ending quest for knowledge.

SELENIDE ISOTOPE GENERATOR

for the GALILEO MISSION

GDS DISASSEMBLY REPORT

TES-2865-26

NOVEMBER 1978

Prepared for the U.S. Department of Energy
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GDS DISASSEMBLY REPORT

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NOVEMBER 1978

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GDS DISASSEMBLY REPORT

A. INTRODUCTION

The original plans for GDS called for seat-in of the thermoelectric module after which performance characteristics of the generator would be determined. This was to be followed by a life test and finally the generator was to undergo a random vibration test. However, during the seat-in operation, it was observed that the normalized power output peaked at 86.7 watts on July 26, 1978 then began to decrease uniformly at about 0.2 watt/day. This rate of degradation continued for about 25 days, then the decrease became greater and at the same time more erratic. Finally on September 12 the generator went to open circuit. By manipulating the load conditions from transistorized-to-resistor-to-transistorized again it was possible to reestablish the output power from the generator. However, on September 18 the load voltage was adjusted to provide an output current of 0.5 amperes in order to eliminate the thermal cycles resulting when the generator went from near-matched load to open circuit. Figure 1 summarizes the output power, open circuit voltage and internal resistance profiles during this period of time while the generator was at near-matched load and operating at nominal hot and cold junction temperatures of 850°C and 150°C, respectively.

The most reasonable explanation for the observed behavior of the generator at this time is believed to be that caused by hangup of the followers in the cold end hardware, especially those of the P-legs. Hangup of this type could cause large contact resistances between the elements and the shoes. Why the P-legs should be affected more than the N-legs is not yet understood, but it could be related to a high rate of sublimation of selenium from the leg or to deformation of the leg due to creep.

FIGURE 1. GDS PERFORMANCE SUMMARY

Instrumentation on four N and P-legs confirms the general predictions of 3M that the N-leg performance is affected by the gadolinium foil causing the resistance and Seebeck voltage to decrease, and the P-leg resistance increases due to follower hangup. These trends were observed during the early degradation when the output power was decreasing smoothly. Figures 2 and 3 present the resistance and average Seebeck voltage of the instrumented N and P-legs, respectively, during this period of time. The trends of Figures 2 and 3 agree well with the observed changes in output power of the generator.

These observations lead to the decision to diagnostically disassemble GDS in order to determine the cause of the degradation. A plan¹ was formulated and reviewed both internally and externally by members of DOE, FI, JPL and Sandia. Based on the work plan and the reviewers comments, two procedures were prepared. The first procedure² detailed cool-down of the generator to room temperature and the second procedure³ described the method of disassembly.

B. COOLDOWN OF GENERATOR

On September 27 cooldown of GDS-1 began. Before this time the generator was operating at 850/150°C hot and cold junction temperature at a load current of 0.5 amperes. Numerous electrical checks were made to verify that the heater, instrumentation and power output connectors were not causing the observed problems. Next, three gas samples were taken using an improved gas sampling manifold with welded fittings. Earlier samples taken during seat-in had used a manifold with numerous swagelok fittings. Four more gas samples were taken during cooldown when the hot junction was at 700°C. The analysis of three early gas samples is shown in Figure 4A. The Gollob and 3M analyses were made on samples taken simultaneously

1. TES memorandum SIG-DST-1514, "GDS Diagnostic Disassembly Work Plan."

2. TES engineering work order 3-112, "Shutdown of GDS-1."

3. TES engineering work order 3-113, "Disassembly of GDS-1."

FIGURE 2. AVERAGE SEEBECK AND RESISTANCE OF N-LEG IN GDS

FIGURE 3. AVERAGE SEEBECK AND RESISTANCE OF P-LEG IN GDS

and the MRC analysis was made on a sample taken immediately after filling the generator. All three analyses indicated the presence of air and in the case of 3M's analysis, a large amount of water vapor. There is doubt that these analyses are representative of the gas in the generator because of the physical effect the oxygen and water vapor would have on the generator performance. Analyses made of samples taken with the improved manifold are shown in Figure 4B. They indicate that the only significant constituents of the gas are helium and xenon. No measurable amounts of oxygen, nitrogen, water vapor and carbon dioxide were present in the samples.

The generator was cooled down to a hot junction temperature of 230°C by reducing heater power and maintaining the housing at about 80°C using the circulating bath heater. Resistance of the thermoelectric module and the insulation resistance was monitored continuously. The insulation resistance remained low (< 1 ohm) and the thermoelectric resistance fluctuated from 1.6 ohms to several thousand ohms.

At 230°C hot junction temperature the generator was evacuated using the turbomolecular pump and a hot leak test was performed. However because of the large background of helium coming from the generator, the best leak rate that could be measured was less than 5.4×10^{-6} scc He/sec. This leak occurred only at the swagelok nut on the top valve. (This same joint had shown a leak rate of 3.6×10^{-7} He/sec when the first leak test was made during the out-gassing operation.) After the generator was evacuated, the insulation resistance began to vary erratically from 1 ohm to about 2000 ohms. The thermoelectric resistance continued to display the same erratic pattern as before.

GAS ANALYSISA. PRIOR TO COOLDOWN (ORIGINAL MANIFOLD)

<u>CONSTITUENT</u>	<u>GOLLOB (8/30)</u>	<u>3M (8/30)</u>	<u>MRC/ (7/18)</u>
N ₂	3200 ppm	140 ppm	4070 ppm
O ₂	750	30	1110
Ar	48	—	50
CO ₂	< 50	130	<150
H ₂	< 20	—	<60
H ₂ O	< 30	240	< 30
He	79+%	—	78.5%
Xe	19.8%	—	21.0%

B. DURING COOLDOWN (IMPROVED GAS SAMPLING MANIFOLD)

<u>CONSTITUENT</u>	<u>GOLLOB (9/27)</u>	<u>MRC (9/27)</u>	<u>BCL (10/2)</u>
N ₂	< 4 ppm	< 20 ppm	< 20 ppm
O ₂	< 4	< 20	< 20
Ar	14	< 20	—
CO ₂	< 100	< 60	< 5
H ₂	11	50	—
H ₂ O	—	< 20	< 100
He	72+%	74.8%	—
Xe	27.6%	25.2%	—

C. SAMPLE RETAINED

1. ONE SAMPLE TAKEN AT 850/150 °C
2. THREE SAMPLES TAKEN AT 700/150 °C.
(ONE OF THESE SAMPLES WAS DELIVERED TO 3M ON 11/14 FOR ANALYSIS.)

FIGURE 4. GAS ANALYSES

The generator was cooled the rest of the way to room temperature by cooling the housing and then removing the remaining heater input power. As this was occurring, the residual gas from the generator was monitored using the partial pressure analyzer. The amount of nitrogen increased to a partial pressure of 9.5×10^{-8} torr, while the helium partial pressure decreased until it was almost undetectable (4×10^{-10} torr). No oxygen was observed; hence, an increased air leak was not suspected. However, the helium leak test after the generator was at room ambient confirmed that the leak rate through the swagelok connection mentioned earlier had indeed increased to 5×10^{-5} scc He/sec. The remainder of the generator (excluding this joint) had a measured leak rate of 2×10^{-7} scc He/sec. This generator leak rate could have been the result of helium permeation through the enclosure bag in the vicinity of the leak in the swagelok nut. It is likely that the generator exclusive of the leaking fitting had a leak rate much less than 10^{-7} scc He/sec and that the leak at the fitting became larger due to differential contraction of the aluminum, brass and stainless steel components in the swagelok fitting as the housing cooled down.

The generator was filled with argon, removed from the outgassing station and x-rayed in the region of the thermoelectric module. Because of the platinum IHF, no significant details of the module could be observed in the radiographs.

C. DISASSEMBLY OF GENERATOR

On October 12 the generator was placed on the jig bore machine as shown in Figure 5 to remove the weld on the upper (heater) cover. Resistance of the thermoelectric module and insulation resistance were monitored continuously during all operations. The module resistance was about 2-4 ohms during most of the disassembly and increased to 11-12 ohms after removal of the IHF. The insulation resistance remained less than 10 ohms until removal of the IHF. At that time the resistance of the thermoelectric circuit to the hot frame increased to 50-100 K ohms. The resistance to the housing remained at about 10 ohms.

FIGURE 5. MACHINING TOP COVER WELD

The upper cover was difficult to remove and after several unsuccessful attempts using a cover puller, the housing was returned to the jig bore machine where the upper portion of the housing was removed by machining until the cover came loose. Figures 6 through 11 show the disassembly of the heater compartment. In Figure 6, the upper cover is removed showing the Min-K 1400 disc, SIG30059-001. Notice that three wires were not in the wire slot as shown by their marks on the disc. Figure 7 is a view of the grafoil disc after removal of the Min-K 1400 disc. The bottom of the CBCF-3 disc, SIG30059-003, is shown in Figure 8. The white deposit around one of the holes for the heater leads appears to be from the varglass sleeving. Figure 9 shows the top of the heater assembly. Figure 10 is a view of the partially disassembled heater block assembly. A view into the bottom of the IHF is given in Figure 11. The thermocouple at the bottom has become diffusion bonded to the IHF. The bottom surface of the IHF appears thermally etched. Locations where the eight holes in the bottom of the heater block faced the bottom of the IHF appear as darker stains on the surface of the IHF.

After sealing the heater compartment with a polyethylene bag, the housing was returned to the jig bore machine to remove the weld on the lower (converter) cover. Less machining was necessary to free this cover than for the top cover. Figure 12 shows the cover lifted exposing the Min-K 1400 disc, SIG30059-007. The power output and instrumentation leads were cut and selected leads were reconnected to a receptacle to permit monitoring of the thermoelectric resistances. Figure 13 shows the graphite disc, SIG30059-017, and edges of the CBCF-4 and Min-K 1800 rings after removing the Min-K 1400 disc. Removal of the graphite and grafoil discs exposes the CBCF-3 disc, SIG30059-005, as shown in Figure 14. Notice the two thermocouples laying on the top surface of this disc. They are not located in the machined slot but have been embedded into the CBCF-3. It appears that a 7-8 degree rotation of the CBDF-3 disc occurred, probably during assembly after welding the bottom cover. Figure 15 shows the bottom of the IHF after removing the CBCF-3 and graphite discs.

FIGURE 6. TOP COVER REMOVAL

FIGURE 7. MIN-K 1400 DISC REMOVED SHOWING GRAFOIL PIECES - TOP END

FIGURE 8. BOTTOM OF CBCF-3 DISC REMOVED FROM TOP END

FIGURE 9. TOP OF HEATER BLOCK ASSEMBLY AFTER REMOVAL OF CBCF -3 DISC

FIGURE 10. HEATER BLOCK DISASSEMBLED TO SHOW HEATERS

FIGURE 11. VIEW INTO IHF SHOWING THERMOCOUPLE BONDED TO BOTTOM

FIGURE 12. BOTTOM COVER REMOVED

FIGURE 13. MIN-K 1400 DISC REMOVED SHOWING SIDE INSULATION AND
GRAPHITE DISC - BOTTOM END

FIGURE 14. CBCF-3 DISC WITH THERMOCOUPLES EMBEDDED INTO SURFACE - BOTTOM END

FIGURE 15. END OF IHF VIEWED AFTER REMOVAL OF INSULATION DISC - BOTTOM END

In Figure 16 the CBCF-4 ring, SIG30010-007, has been removed. Notice the zircar gasket segments along the top edge of the lower CBCF-4 ring still in place. In Figure 17 the lower CBCF-4 ring, SIG30010-005, with the hot getter attached has been removed. Notice the dark ring (blue in color) on the Min-K 1800 ring in the area where the zircar blanket was located. The hot getter is shown in Figure 18. The surface of the getter appeared very clean as it had during assembly. Figure 19 shows the converter end after removing the Min-K 1800 ring. The springs are visible in some regions and in others they have been covered with a zircar blanket. Figure 20 shows the Min-K 1800 ring, SIG30058-001, containing the cold getter. The getter had some light stains on the surface. Figure 21 shows the converter after removal of the zircar blankets. Notice the marks on the end of the IHF. They correspond to the bonded thermocouple and heater block hole marks described before on the opposite side of the bottom plate. Eight legs were exposed by removing the Fiberfrax insulation at this time. Figure 22 shows these elements. Notice the cracked N-leg (large springs and larger diameter leg) at one end.

The converter end was covered and the housing was placed on the jig bore machine again to remove the IHF weld. The outside of the housing was machined away until the IHF was loosened. Figure 23 shows the housing with the IHF removed. The IHF is shown in Figure 24. Notice the two blisters on the graphite emissive coating. The first zircar ring, SIG30010-001, has been removed in Figure 25. Figure 26 shows this first zircar ring with the platinum wires used to hold the broken ring together. In Figure 27 the second zircar ring, SIG30010-003, has been removed. Notice the dark (blue in color) ring at the bottom of the Min-K 1800 ring. Figure 28 shows the end of the module after removal of the Min-K 1800 ring.

FIGURE16 . FIRST CBCF-4 RING REMOVED - BOTTOM END

FIGURE 17. SECOND CBCF -4 RING CONTAINING HOT GETTER REMOVED - BOTTOM END

FIGURE 18. CBCF-4 RING WITH HOT GETTER - BOTTOM END

FIGURE 19. VIEW OF MODULE AFTER REMOVAL OF MIN-K 1800 RING - BOTTOM END

FIGURE 20. MIN-K 1800 RING WITH COLD GETTER - BOTTOM END

FIGURE 21. VIEW OF MODULE WITH ALL NON-MODULE INSULATION
REMOVED - BOTTOM END

FIGURE 22. VIEW OF EIGHT LEGS AFTER REMOVAL OF INSULATION - BOTTOM END

FIGURE 23. TOP END AFTER REMOVAL OF IHF

FIGURE 24. ISOLATION HOT FRAME (IHF)

FIGURE 25. TOP END AFTER REMOVAL OF FIRST ZIRCAR RING

FIGURE 26. FIRST ZIRCAR RING WIRED TOGETHER WITH PLATINUM

FIGURE 27. SECOND ZIRCAR RING WITH HOT GETTER REMOVED - TOP END

FIGURE 28. VIEW OF END OF MODULE AFTER REMOVAL OF MIN-K 1800 RING

Fiberfrax insulation was then carefully removed from around the outer legs at each end of the module. Many visual observations were then made, all of which are recorded in the Quality log. Also numerous color photographs were taken which are also included in the log. Resistance measurements were made and recorded in the log of each segment and each pair of legs at the ends of the segments.

The module was radiographed again. The x-rays indicated numerous large displacement of P-legs. Since the displacement was detected by observation of the hole in the hot shoe under the P-leg, displacement of N-legs could not be detected. Observations of the radiographs were documented by Quality Engineering in a memorandum⁴.

Both ends of the module were carefully sealed and the housing was placed on the jig bore machine. The upper end of the housing was removed to within 0.5 inch of the edge of the module. The inside diameter was machined until the step to the module was removed. This operation was performed in preparation for removal of the module from the housing. The housing was then turned over and the lower end was cut off to within 0.5 inch of the edge of the module.

D. OBSERVATIONS AND MEASUREMENTS ON THE MODULE

A series of closeup color photographs were made of all legs on both ends of the module and is included in the disassembly log. In addition, numerous photographs were taken of the exposed legs. Figures 29 through 32 show the elements at the top of the module and Figures 33 through 36 show the elements on the bottom of the module. Numbers (1 to 52) inscribed on the bottom of the POCO hot frame are used to identify the legs on both ends and segments are identified by numbers (1 to 26) inscribed on the bottom end of each segment. Enlargements of several legs from the bottom of the module are shown in Figure 37 (N-leg #11), Figure 38 (P-leg #37), Figure 39 (N-leg #12), Figure 40 (P-leg #5), Figure 41 (P-leg #14),

4. TES memorandum, QUA-ETC-1185, "Review of Radiographs-GDS-1 Disassembly."

FIGURE 29. TOP OF MODULE SHOWING ELEMENTS 1 THROUGH 16

FIGURE 30. TOP OF MODULE SHOWING ELEMENTS 17 THROUGH 30

FIGURE 31. TOP OF MODULE SHOWING ELEMENTS 31 THROUGH 44

FIGURE 32. TOP OF MODULE SHOWING ELEMENTS 45 THROUGH 52

FIGURE 33. BOTTOM OF MODULE SHOWING ELEMENTS 47 THROUGH 52
AND 1 THROUGH 8

FIGURE 34. BOTTOM OF MODULE SHOWING ELEMENTS 9 THROUGH 20

FIGURE 35. BOTTOM OF MODULE SHOWING ELEMENTS 21 THROUGH 34

FIGURE 36. BOTTOM OF MODULE SHOWING ELEMENTS 35 THROUGH 46

and Figure 42 (P-leg #13). Numerous significant observations were made of the exposed legs which have been recorded in Table 1. Most of these observations can also be seen in the series of photographs, Figures 29 through 42.

A map of the observed cracks and chips in each N-leg was made and is recorded in the log. An attempt was made to correlate the location and orientation of the cracks to misalignment of the legs. However, although some legs showed cracks at shear points on misaligned legs, many legs had cracks where no misalignment was seen.

Measurements of the diameter of numerous legs were made. The N-leg had a uniform average dimension from hot to cold end of 0.318 inch which is slightly larger than the 0.315 inch quoted by 3M. The P-leg diameter varied from 0.270 inch at the hot end to 0.261 inch at the middle to 0.268 inch at the cold end. The measured values may be influenced at the hot and cold ends due to interference of sublimation material and extruded copper. A more accurate value can be obtained with the elements removed from the module. However the measurements tend to support the contention that mushrooming of the P-legs has taken place.

During operation of GDS-1 the electrical short to the housing was determined to be between thermocouples #15 and #16. After disassembly the short was determined to be in the vicinity of thermocouple #7. The reason for this change can not be explained at the present time; however, if during further disassembly at 3M the cold straps are cut between neighboring segments and these resistance tests are repeated, a better understanding of the situation may be obtained.

The last measured thermoelectric segment resistances are given in Table 2. The latest thermoelectric circuit resistance measurement was 11 ohms. The module to hot frame resistance was 138 K ohms and the module to housing resistance was 7 ohms.

The resistance of all the exposed pairs of legs were measured. The average N-leg resistance was 6.7 milliohms with the range being 3.7 - 10.9 milliohms. The average for the P-leg was 29.5 milliohms with the range being 13.8 - 43 milliohms. While measuring the resistance of the elements, P-leg #25 on the bottom of the module was observed to move.

FIGURE 37. N-LEG #11 ON BOTTOM OF MODULE

FIGURE 38. P-LEG #37 ON BOTTOM OF MODULE

FIGURE 39. N-LEG # 12 ON BOTTOM OF MODULE

FIGURE 40. P-LEG #5 ON BOTTOM OF MODULE

FIGURE 41. P-LEG #14 ON BOTTOM OF MODULE

FIGURE 42. P-LEG #13 ON BOTTOM OF MODULE

TABLE 1
OBSERVATIONS ON EXPOSED LEGS OF GDS MODULE

- MISALIGNMENT WITH HOT/COLD SHOES⁽¹⁾
- LEGS TILTED AWAY FROM THE RADIUS⁽¹⁾
- DEPOSITS ON COLD STRAPS AND FOLLOWERS⁽²⁾
- ORANGE RING AROUND N-LEGS (ONE RING APPEARED WHITE)⁽²⁾
- CRACKS/CHIPS IN N-LEGS (LONGITUDINAL AND TRANSVERSE)⁽³⁾
- COPPER EXTRUSION AT COLD END OF P-LEGS⁽²⁾
- BRIDGING AROUND P-LEG PARTITION⁽²⁾
- DEPOSITS ON EDGES OF BeO DISCS⁽²⁾
- DARK CRYSTALLINE DEPOSITS ON HOT END OF P-LEG⁽²⁾
- BULLET NOSING OF HOT END OF BOTH P-LEG SEGMENTS⁽²⁾
- P-LEG HOT SEGMENT HAS LARGER DIAMETER THAN COLD SEGMENT⁽³⁾
- MUSHROOMING OF P-LEG JUST BELOW PARTITION⁽³⁾
- INDIVIDUAL INSTANCE OF P-LEG UNDERCUT AT COLD END⁽³⁾
AND WITH DARK PURPLE RING AROUND COLD END.

SOLUTIONS TO PROBLEMS

- (1) IMPROVED COLD END HARDWARE BEING PUT ON TEST.
- (2) SUBLIMATION TO BE RESTRICTED BY WRAP AND W/Re CAP.
- (3) CAUSE AND PLAN TO RECTIFY YET TO BE ESTABLISHED.

TABLE 2

ELECTRICAL RESISTANCE OF THERMOELECTRIC SEGMENTS

<u>SEGMENT NO.</u>	<u>RESISTANCE (MILLIOHMS)</u>	<u>SEGMENT NO.</u>	<u>RESTISTANCE (MILLIOHMS)</u>
1	185	14	109
2	355	15	145
3	260	16	145
4	5700	17	148
5	107	18	154
6	98	19	140
7	150	20	150
8	175	21	166
9	280	22	184
10	150	23	760
11	145	24	150
12	140	25	295
13	87	26	255

This was the only leg which was disturbed during any of the tests or handling.

E. SAMPLES AND COMPONENTS FOR ANALYSIS

Numerous samples and scrapings of foreign particulates and deposits were taken when encountered during disassembly of GDS-1. In addition, several of the components of the generator have been identified as candidates for analysis. Table 3 is a listing of the samples taken by TES. Of these samples, the following have been selected for detailed analysis:

<u>Sample No.</u>	<u>Analysis Proposed</u>
6 & 7	Chemical analysis of any "wire" components
10	Chemical analysis of deposit
12	X-ray diffraction of deposits
14	X-ray energy analysis

The other samples listed in Table 3 will be microscopically examined to characterize their physical appearance and recommendations for further analysis will be based on these observations.

The following non-module components have been identified for detailed analysis based on visual observation of the piece parts during disassembly:

1. Hot getters.
2. Cold getters.
3. "Blue-gray" surface discoloration on hot side of Min-K 1800 rings.
4. Distribution of selenium (if any) and other impurity elements within the side insulation piece parts.

A detailed test plan⁵ has been prepared identifying the purpose and approach for the diagnostic evaluation of these components.

5. TES memorandum SIG-WB-1593, "Proposed Test Plan for the Diagnostic Evaluation of Selected Non-module GDS Component Parts."

TABLE 3
GDS-1 DISASSEMBLY/ANALYSIS
LISTING OF SAMPLES TAKEN BY TES QUALITY

<u>NO.</u>	<u>DESCRIPTION</u>
1	DEBRIS FOUND ON LEDGE AFTER TOP COVER REMOVED.
2	T/C INSULATION (VARGLOSS)
3	INSULATION PACKING ADJACENT TO HEATER BLOCK.
4	DEPOSIT ON HEATER BLOCK, NEAR HTR. POWER LEAD ENTRY
5	FLAKE ON CBCF-3 (TOP COVER)
6	DEBRIS FOUND UNDER BOTTOM COVER (AFTER REMOVAL)
7	DEBRIS FOUND AFTER BOTTOM COVER REMOVAL.
8	FIBERFAX INSULATION ADJACENT TO T/C IN CBCF-4
9	CHIPS ON T/E RING.
10	DEPOSIT ON Ag INTERFACE OF IHF.
11	DEBRIS ON ZIRCAR ADJACENT TO IHF
12	DEPOSITS ON COPPER STRAPS ADJACENT TO PACKING.
13	CHIPS FROM COLD FRAME.
14	Hi-Fi PAPER AT EDGE OF T/E MODULE.

During the disassembly of GDS-1, 3M personnel were in attendance and also gathered samples of interesting deposits. These samples are listed in Table 4. The samples will be examined under a microscope and then be subjected to a microprobe analysis.

F. DISASSEMBLY OF GDS YET TO BE DONE

As described before, the housing was cut down and the inner step to the module removed in preparation for removal of the module. This operation, subsequent testing of the module and division of the module, will be carried out at 3M.

After removal of the module, the segments will be electrically disconnected. After numerous electrical tests of the thermoelectric circuit, the segments are to be divided among 3M, TES, JPL and GA for further testing according to a proposed plan⁶.

G. CONCLUSIONS

The basic reason for disassembly of GDS-1 was to determine the cause for the rapid degradation of the output power. Unfortunately, at this time, it is not possible to relate the observations to direct causes for the degradation. However some positive statements can be made which have an impact on the flight program. First, the outgassing and gas management techniques were shown to be adequate to maintain clean conditions within the generator. Second, the non-modular components within the generator including the receptacles on the housing were not affected by the thermal environment during operation of GDS-1. Third, a significant amount of sublimation of the P-legs has occurred during the relatively short life of 2000 + hours as shown by the bullet nosing of the legs and deposits on the cold end hardware. The fact that the generator atmosphere was not 100% xenon may have some bearing on this observation but the statement is still accurate. Fourth, all exposed N-legs

6. Letter from W. E. Osmeyer to L. Lanni, dated November 7, 1978, ref. 2865-2131.

TABLE 4
LISTING OF SAMPLES TAKEN BY 3M DURING GDS DISASSEMBLY

<u>SAMPLE</u>	<u>DESCRIPTION</u>
1	GRAY FLUFFY MATERIAL LAYING ON GRAFOIL ADJACENT TO CBCF-4 RING.
2	GRAY FLUFFY MATERIAL LAYING ON SURFACE OF CBCF-4 , 180° FROM POWER LEADS.
3	GRAY SURFACE DEPOSIT ON EDGE OF MIN- K 1800 ADJACENT TO CBCF-4
4	GRAY BLACK POWDER ON Pt-30Rh/CBCF-4
5	GRAYISH - BLUE DEPOSIT ON ALUMINUM HOUSING ATOP T/E SEGMENT NEAR POCO NO'S 11/12.
6	LIGHT MAZE DEPOSIT ON Pt-30Rh IHF ON OPPOSITE SIDE OF HOLES IN HEATER.
7	BROWN DEBRIS ON SILVER INTERFACE OF IHF BIMETAL RING.
8	DARK DEPOSIT ON TOP END OF I.D. OF HOUSING NEAR MODULE.
9	CRYSTALLINE MATERIAL ON INSULATION NEAR COLD STRAP.

display cracks and/or chips. Fifth, a great deal of misalignment of both N and P-legs was seen both visually and with radiographs.

Although no definite conclusions can be made at this time concerning the cause for the rapid degradation of performance, several of the observed conditions within the module listed in Table 1 could possibly contribute to that fact. They are:⁷

- Cracks in N-legs (increased resistance).
- Deposits on edges of BeO discs (shorting of thermoelectric circuit).
- Bullet nosing of P-legs (increased resistance).

It remains to be shown if any of these effects or the follower hangup described earlier contributed to the poor performance of GDS-1 or if another effect as yet unknown was the important factor.

7. No measurements to date have shown that the listed observed conditions contributed to the degradation.