2 P
MIX

POLY-SCIENTIFIC
DIVISION OF LITTON INDUSTRIES

POLY-SCIENTIFIC DIVISION OF LITTON PRECISION PRODUCTS, INC. • 1111 NORTH MAIN STREET • BLACKSBURG, VIRGINIA 24060

TELEPHONE (703) 552-3011 • TWX 710-875-3692

POLY-SCIENTIFIC
DIVISION OF LITTON INDUSTRIES

POLY-SCIENTIFIC DIVISION OF LITTON PRECISION PRODUCTS, INC. • 1111 NORTH MAIN STREET • BLACKSBURG, VIRGINIA 24060

TELEPHONE (703) 552-3011 • TWX 710-875-3692

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.

ENGINEERING DIVISION

DESIGN INVESTIGATION AND DEVELOPMENT OF DESIGN IMPROVEMENTS FOR ST124-M STABILIZED PLATFORM SLIP RING CAPSULES

FINAL REPORT
NASA CONTRACT NO. NAS 8-20578
OCTOBER 23, 1969

BY
E. W. Glossbrenner
S. R. Cole

APPROVED BY

Wm. Mader

W. M. Mader, Vice-President
Engineering, Program Director

PREPARED FOR
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

On March 31, 1966, a program was initiated to eliminate and/or reduce reliability hazards resulting from insulating deposits that form on precious metal contacts. The program was a two-phased study, the first of which consisted of analytical and design studies, material and process reviews, concept development, and fabrication and evaluation of concepts necessary to eliminate or minimize the effects of organic contamination of slip ring capsule assemblies. The second phase was the design, manufacture and evaluation of hardware of minimum organic content based upon the studies of Phase I.

The second phase is now complete. This report briefly reviews the work conducted during the first phase, describes the second phase investigation and contains conclusions and recommendations based upon the program as a whole.

The manufacture of totally inorganic capsules (exclusive of lead insulation) was successfully accomplished, and much was learned about design and methods of substituting inorganic materials in place of more easily used plastics and other organics. Some units have passed all mechanical and electrical tests with the exception of lifetime noise. The method of contact lubrication did not allow the capsules to operate at low levels of noise for long periods of time. Design and process improvements are suggested for future inorganic capsules.

Further investigation is needed in the area of inorganic contact lubricants; however, the fabrication of totally inorganic capsules is definitely feasible and could be done on a production basis.

2.0 REVIEW OF PHASE I

2.1 Summary of Activities

The work conducted during Phase I was organized into four principal areas of investigation:

The fabrication of totally inorganic assemblies;

The fabrication of assemblies of reduced organic material;

The fabrication of inorganically lubricated contact surfaces; and

The testing of bearings with inorganic lubricants and low contamination organic lubricants.

In addition, testing was done on prototype capsules of inorganic and low organic materials. One parallel control test series was conducted to evaluate the performance of inorganically lubricated electrodeposited gold

Three concepts were investigated for the fabrication of totally inorganic assemblies. These concepts were:

1. Stacked Assembly - Convertible glass-ceramics were stacked and fired to form both slip ring rotors and brush assemblies. The glass phase was Fotoform B[1] which converted to a ceramic, Fotoceram[2], as the

---

[1] Corning Glass Works

[2] Corning Glass Works

stacked wafers were fused to each other. As the program progressed, the stacked assembly process showed greatest possibilities for further consideration and was selected for the second phase design.

2. <u>Tube and Spline Assembly</u> - The tube and spline concept involved heat shrinking a glass tube over a ceramic or glass spline containing axial leads in the grooves. The ceramic spline was extruded from aluminum oxide and fired; a vitreous frit glass was used to fire the spline onto the centershaft. The glass tube was fitted over the spline and mated to the front face of the flange. The tube was attached to the flange and spline with the use of heat and vacuum.

   The brush assembly for use with the spline and tube concept was made from aluminum oxide. It was a composite substrate assembly having the internal leads spaced between thin layers of alumina. Theleads were metallized onto these thin layers and brought to the surface. The individual layers were then fired and fused into a dense composite.

   As a result of delays in obtaining exact matches of material properties, only sample quantities of the subassemblies were produced, but the structural concept was proven feasible.

3. <u>Cast and Sintered Assembly</u> - The cast and sintered concept involved the casting of glass "slip" (or slurry) in plaster molds, which was dried and finally sintered to a homogenous glass. The ring subassembly was made by loading the Kovar metal ring and lead assemblies, along with a center shaft, into a plaster mold cavity and filling the cavity with glass slip. After drying, the part was removed and sintered. The same principle of loading a plaster mold with leads was used for the brush subassembly.

   There was no success with this concept which would indicate feasibility.

A highly successful method of fabricating a low organic assembly was to drill lead exit holes in the glass tube and load the tube with leads. A specially formulated low expansion plastic was cast into the bore, encapsulating the leads. Other low organic concepts were discarded early in the program because of the success with the drilled glass tube method.

Gas pressure bonding, plasma spraying and electrodeposition were investigated as methods of forming gold-niobium diselenide composites. It was not feasible to form a Au-$NbSe_2$ composite by plasma spraying of a fine powder blend of contact material. Dense, sound composites of gold and niobium diselenide were formed by gas pressure.

bonding techniques. The powder metallurgy technique was concluded to be a quite satisfactory one if the composites were formed on metal rings which were in turn bonded to the slip ring leads. The bonding of leads directly to pressed composites was not considered to be satisfactory.

An extensive survey of possible inorganic and organic bearing lubricants led to the selection of the following materials for testing:

Inorganic/Organic	Trade Name (type)	Manufacturer
Inorganic[3]	Hi T (electrodeposited)	General Magnaplate
Inorganic	CLD 5940 (vapor deposited)	CBS Laboratories
Inorganic	Everlube 811 (sodium silicate bonded MoS_2 and graphite)	Haward Corporation
Organic	Versilube F-50 (silicone fluid)	General Electric
Organic	Fluorolube S-30 (fluorinated liquid)	Hooker Chemical
Organic	Nujol (mineral oil)	Plough Inc.

The sodium silicate bonded molybdenum disulfide provided the most consistent torque in excess of 500 hours (except under moist conditions) and was selected for use in the

---

[3] Hi T was subsequently found to have an organic bonding agent of a phenolic base.

Phase II study. Satisfactory performance could also be expected with mineral oil and fluorinated lubricants of viscosity similar to Nujol and Fluorolube S-30.

2.2 Conclusions of Phase I

Slip ring capsule assemblies can be feasibly manufactured from totally inorganic materials. The most successful process to date for both slip ring and brush assemblies has been the fusion of the glass ceramic disks (or wafers) under pressure.

Slip ring capsules of the low organic type can be feasibly produced in the same size packages as conventional units. Glass barrier slip rings and very low organic content brush blocks would be used.

Manufacture of the contacts with a composite of gold and niobium diselenide self-lubricating surface is feasible for applications where noise levels in the range of 20 to 60 milliohms can be tolerated for periods up to 500 hours.

Sodium silicate bonded molybdenum disulfide and graphite is a satisfactory inorganic bearing lubricant. Nujol and Fluorolube S-30 are satisfactory organic bearing lubricants when applied in prescribed quantities and operated at 50°C.

2.3 Recommendations for Phase II units were that Poly-Scientific:

1. Fabricate slip rings and brush blocks from stacked and fused Fotoceram.
2. Electroform rings of 24 K gold and lubricate them with a gold-niobium diselenide electrodeposit.
3. Lubricate bearings with Everlube 811.
4. Seal the entire capsule to the maximum extent possible.

3.0 PHASE II - PROGRAM AND ACTIVITIES

During Phase II, a total of five units (DP1766) were fabricated by the stacking and firing of Fotoceram brush blocks and slip rings. The contacts were lubricated with electrodeposited niobium diselenide and the bearings with Everlube 811. The capsule housings were designed to close with graphite seals so that the contacts were partially sealed from external contamination. Appendix IV contains detailed engineering drawings of the capsules and components. Records of fabrication difficulties and methods of solution were kept during the building of the units. The details of problems in fabrication are discussed later, along with action taken for improvement. Three of the completed capsules were performance tested during vibration, and acceleration and after shock tests; two capsules were life tested for 5000 hours. All units were evaluated after testing in order to determine what improvements could be incorporated in future designs and processes.

4.0 FABRICATION OF INORGANIC CAPSULE

4.1 Concepts

All five slip rings were fabricated by the stacked assembly techniques, and the only organic components used were Teflon insulated leads.

Internal slip ring and brush block conductors were fired in place as the Fotoform was being fused and converted into Fotoceram.

The rings-to-slip ring-lead conductors and the brush-to-brush block conductors were electroplated copper. Silver was painted and used as a ring starting conductor. After the slip ring was plated with approximately 0.5 mil of copper, the silver and copper over the lead ends were picked away so that there would be direct electrical contact between the internal slip ring leads and the copper rings which served as substrates for electroformed 24 karat gold. The electroformed gold was grooved and overplated with a composite of nickel hardened gold and dispersed niobium diselenide. A copper reduction coat allowed the electroforming of copper pads to which brushes could be attached by soldering.

Sauereisen #31[1] was used for potting over the external to

---

[1] Sauereisen Cement Company

internal slip ring lead joints and for bonding the nameplate to the capsule. A one-piece end cap and housing was fitted to a spring loaded graphite seal.

4.2 Details of Problems and Solutions

There were a number of design and manufacturing problems resulting from using only inorganic materials. One of the first difficulties was that the unfired glass (Fotoform B) was quite fragile and had to be handled with care. We found that glass could be very easily cracked or chipped when a technician was inserting relatively stiff wires through holes in the slip ring wafers or slots in the brush block wafers. The solution to this problem was to preform the conductors so that very little stress would be applied to the Fotoform during the stacking of the unfired assemblies.

Eight units were started for the Phase II program, but three were damaged beyond repair during the firing operation. A redesign of the firing fixture allowed the remaining five units to be completed. Complete wafer-to-wafer bonding was still not obtained between either the slip ring wafers or between the brush block ones. The wafers were held slightly apart by the internal leads which were present in the assemblies at the firing stages. Good wafer fusion was found away from the leads, but there were some non-bonded areas between leads which later resulted in electrical shorts.

The voids between wafers were first patched with solder glass which unfortunately was attacked by the plating baths We learned that Sauereisen #31 was not damaged by plating electrolytes and it was subsequently used in place of the solder glass. Future units should be designed so that there will be little or no interference between stacked wafers and conductors. Also, attention must be given to applying uniform pressure to all fired surfaces so that the wafers will be uniformly forced together while they are in the plastic state. We have discovered that part of the fusion problem was caused by rough Fotoform wafers. Rough wafers, as were used during Phase II, do not fuse nearly as well as smooth ones. We now require that all Fotoform have a 25 microinch (CLA) finish and the problem of incomplete fusion has been essentially eliminated on the Fotoceram units currently being manufactured at Poly-Scientific.

As a result of this study, we learned that external protrusions or bosses that can be broken or ground away after firing can assist in the stacking of Fotoform wafers. Designers of Fotoform wafers should remember that the photoetch process does not necessitate the use of straight lines, round holes, absence of sharp undercuts, and uniform radii that are so desirable for machined components. For instance, future rotor wafers should be designed, as shown in Figure 1, so that the tabs can be used for positioning during firing and then ground or broken away after firing is completed. Future designs should not require depth etching of Fotoform. If a depth etch is required, it should not be done on a wafer that is also to be through-etched. For example, the DP1766 brush block wafer which contained leads can be designed so that depth etching is not necessary, if breakaway fixturing material is included in the Fotoform design.

Some difficulties in drilling holes to internal leads were encountered. The problem of locating internal leads was intensified by the fact that the shrinkage of the Fotoceram during firing could not be determined accurately beforehand. We now have learned more about the dimensional changes which occur when Fotoform is converted to Fotoceram. However, a test assembly should be fired before positioning fixtures are designed for subsequent grinding and drilling operations, since the dimensional changes upon firing depend on applied load, height of stack, Fotoform surface finish, shape of wafer and method of fixturing.

The P-S E.S. 56 leads oxidized during firing so that unsupported leads were so brittle that they broke when attempts were made to braze external leads to them. (Figure 2). It was therefore necessary to grind ceramic

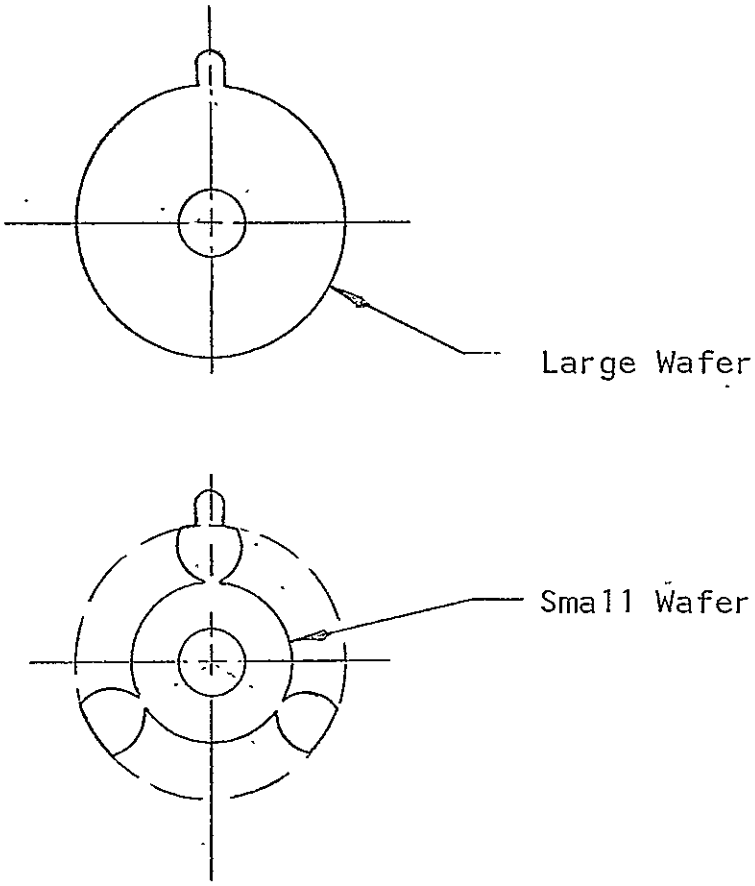


Figure 1

Design of rotor wafers with removal tabs that could be used to assist in positioning wafers during firing operation.

away from a remaining part of the leads and soda blast them to remove surface oxidation. The leads were then too confined to allow brazing so it was necessary to solder the external to internal leads together and to insulate over the joints with Sauereisen #31 (Figure 3). Future Fotoceram units which are fired with leads in place should be fired in an inert or slightly reducing atmosphere so that lead oxidation will be reduced to a minimum.

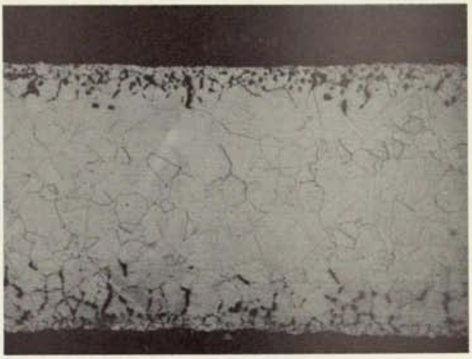


Figure 2

Etched cross section of P-S E.S. 56 internal lead. Note intergranular corrosion caused by approximately 4 hours exposure to air at 1500°F. (285X)

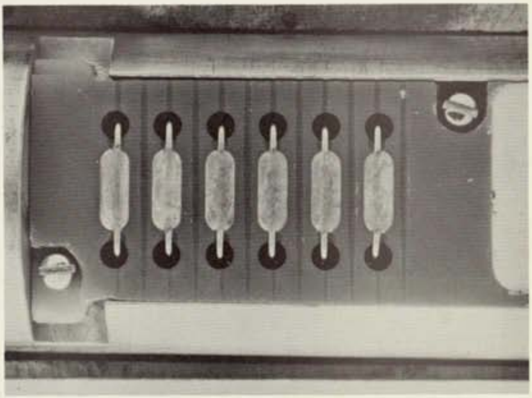


Figure 3

Back of ceramic brush block. White area at the right is Sauereisen #31 which has been potted over internal to external lead joints. (2.5X)

5.0 TESTING OF CAPSULES

5.1 Test Procedures

Three units were tested for d.c. resistance, contact resistance variation (noise), torque, and insulation resistance before and after acceleration, vibration, shock, and load tests. The details of the test procedures are described in Appendix II. Two units were life tested as described in paragraph 4.10 of Appendix II. The life test units were also tested for d.c. resistance, contact resistance, noise, and insulation resistance as descriged in paragraphs 4.1 through 4.4 of the Test Procedure. The detailed test results are recorded in Appendix III.

5.2 Results

5.2.1 Qualification Test Units (three) - The initial noise levels of all circuits on all three capsules were less than 10 milliohms after acceleration, vibration and shock tests. Two qualification units showed a significant increase in noise after the load test, but noise on the third capsule decreased slightly after load testing. The highest noise on a single circuit after qualification testing was 22 milliohms. The maximum noise experienced during acceleration testing was 7 milliohms and there were no significant changes in d.c. resistances. Noise reached as high as 50 milliohms during vibration testing, but we believe this was partly because the test drive shaft reached resonant frequency. Maximum noise, exclusive of that probably caused by resonance of the test fixture, was approximately 20 milliohms.

One unit had two high potential shorts and another had five at the beginning of the testing program. The insulation resistances did not change appreciably during acceleration, vibration or shock testing, but dropped by approximately three orders of magnitude after load tests. Not considering the initially shorted circuits, the minimum insulation resistance after load testing was four megohms. DC resistance did not change significantly during any of the qualification tests. Maximum capacitance between circuits was 68 picofarads - maximum capacitance to ground was 37 picofarads.

The initial torque of the qualification units varied appreciably (see Table I). In general, the torque decreased as the units were tested.

The differences in bearing torques were the dominant reason for the differences in torque needed to turn slip ring capsules. Even though brush formation was checked after brush block assembly, the variation in measured brush force was great.

TABLE 1: TORQUE AND BRUSH FORCE DATA FROM QUALIFICATION UNITS

S/N	Initial Torque (gm-cm)	Torque During Post Test Evaluation (gm-cm)	Bearing Torque After Test	Brush Force After Test (gm-cm) (average)	Brush Force Range
3	35	25	13	3.5	2-6.5
4	18	13	9	5.0	4-5.5
5	45	38	29	4.7	2-6.2

5.2.2 Life Test Units - The initial maximum noise on the two life test units was 13 milliohms and 32 milliohms respectively. At the end of 500 hours, the maximum noise levels were 80 and 1100 milliohms. Figures 4 and 5 indicate the lowest, highest, and median circuit noise levels for capsules S/N 1 and S/N 2. S/N 1 performed similarly to the test capsules that were lubricated with a gold-niobium diselenide composite during Phase I, and were tested for only 500 hours. The second capsule exceeded comparable Phase I noise test results after 168 hours. Sometime after 500 hours, noise on all circuits of both capsules exceeded 1 ohm.

S/N. #1

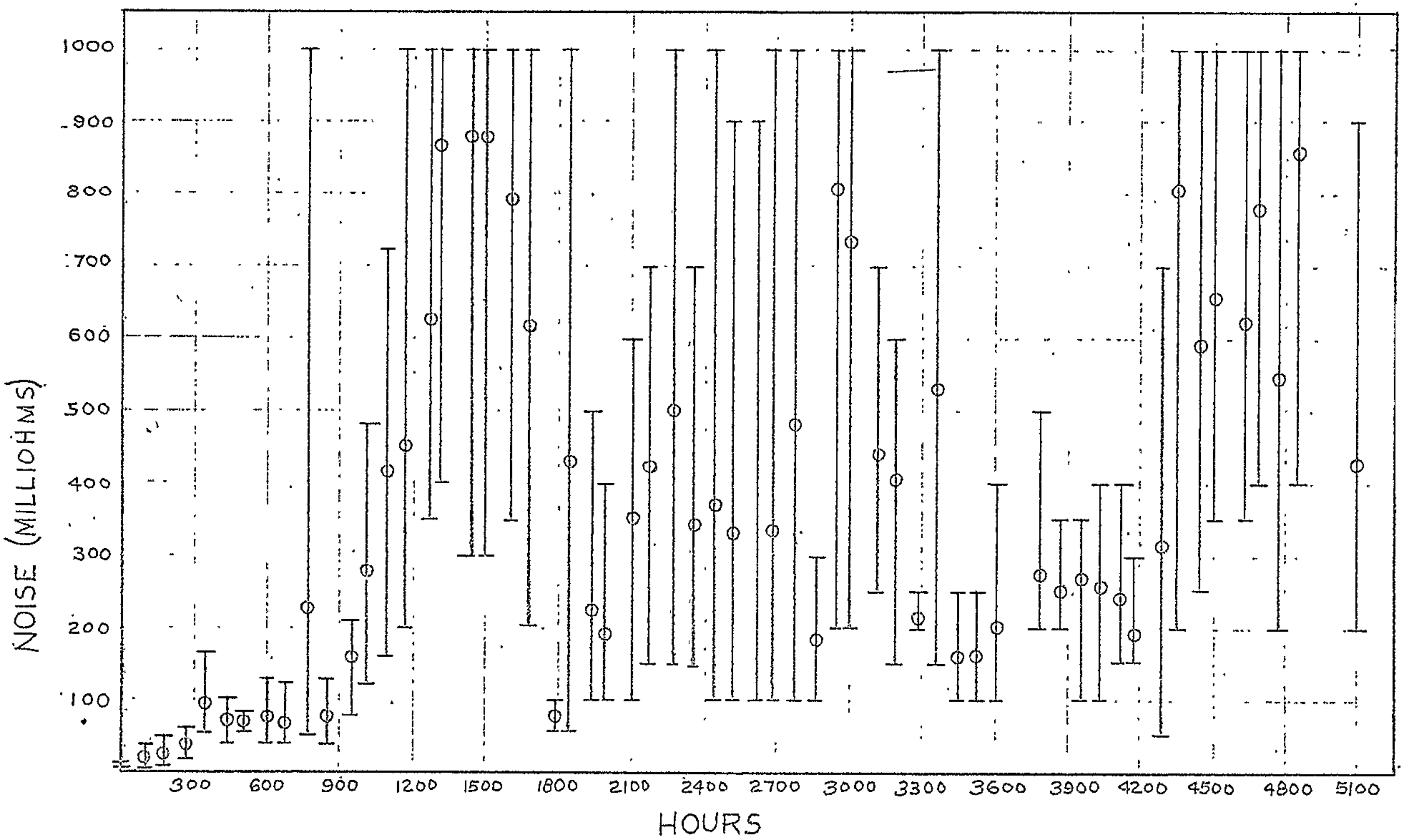


FIGURE 4: MINIMUM, MAXIMUM AND MEAN NOISE LEVELS OF CIRCUIT PAIRS ON SN1 LIFE TEST CAPSULE.

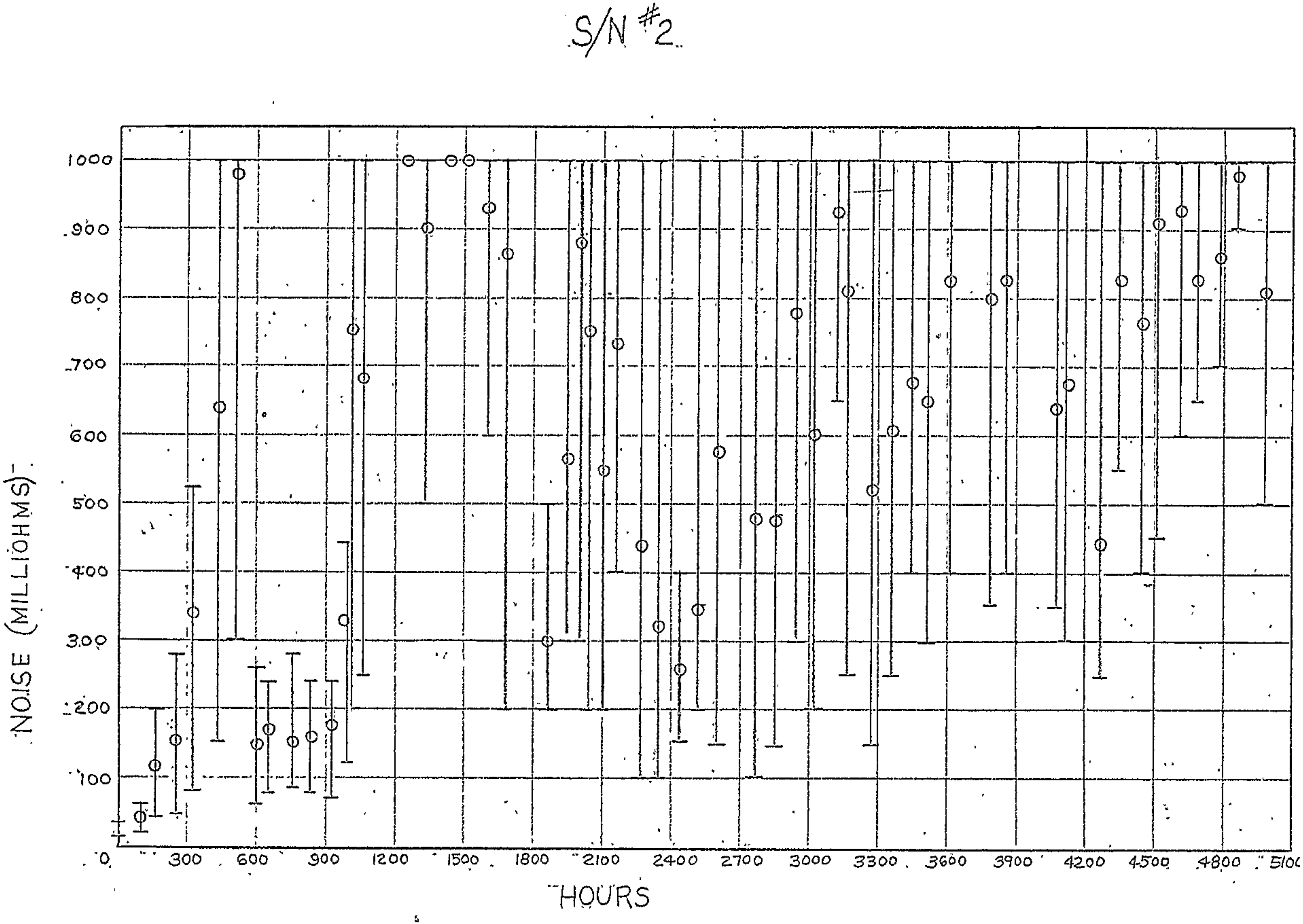


FIGURE 5: MINIMUM, MAXIMUM AND MEAN NOISE LEVELS OF CIRCUIT PAIRS ON SN2 LIFE TEST CAPSULE.

6.0 EVALUATION OF PARTS

6.1 Structural

The capsules were not structurally or functionally damaged by the acceleration, vibration and shock tests. The Sauereisen used as a nut locking compound on the slip ring front shaft appeared to have been slightly cracked, but the cracking was not sufficient to allow the cement to break from the part. The ceramics were in no way damaged by the mechanical tests and there were no joint failures. The internal to external lead joints were sound even though the internal leads had been oxidized (Figure 6). Some of the plated jumpers between internal leads and rings or brush pads contained large voids (Figure 7). These voids were probably caused by entrapped air during plating. Future units should be vacuum impregnated with plating solution and then the jumpers electrodeposited while the plating bath is being ultrasonically agitated.

There was discoloration of the Fotoceram in areas which adjoined the oxidized P-S E.S. 56 internal leads. The discoloration was probably caused by oxides of the E.S. 56 material and not by the alloy itself. Thus, the firing of the Fotoform internal lead assemblies in an inert or slightly reducing atmosphere may reduce the

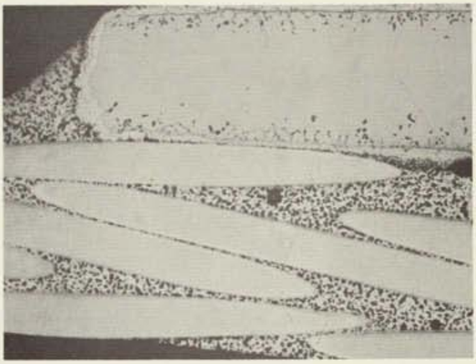


Figure 6

Solder joint between internal and external leads. Note that the residual oxidation of the internal lead did not prevent it being wetted by the solder. (138X)

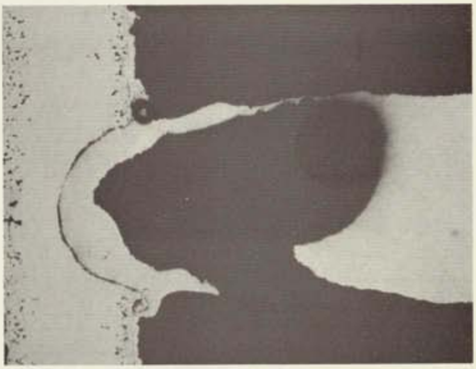


Figure 7

Cross section of copper jumper plated between internal brush block lead and brush pad. Large void was probably caused by trapped air. (138X) amount of discoloration. The discoloration does not represent a structural problem, but the subassemblies would have a more pleasing appearance if they were uniform in color. There will be some slight differences in color from one wafer to another if the wafers are not flooded (exposed to high intensity light) and otherwise processed in exactly the same manner during the manufacture of the Fotoform.

There was very little wear of the graphite seal (Figure 8). No loose graphite particles were seen and the amount of graphite transferred to the rotor flange surface was slight (Figures 8 and 9).

Brush alignment was quite good (Figure 10).

6.2 Electrical

Dielectric failures which were a result of incomplete wafer fusion (Figure 11) can be corrected by further refinement of Fotoceram firing techniques. We are presently stacking five wafers to form an eight segment switch without problem of high potential shorts between segments, or between segments and ground. An increase in relative humidity is believed to be the cause of the drop in insulation resistance after the load test was performed. The insulation resistance before load testing was on May 1, 1969 (≈ 37% RH). The after load tests were performed on July 14, 1969 (≈ 48% RH). The

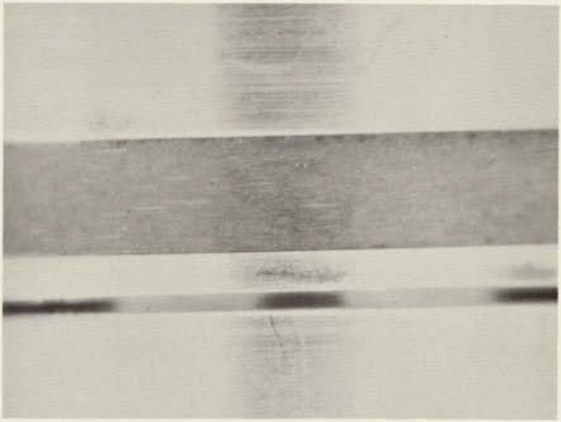


Figure 8

Side view of graphite seal. Note absence of graphitic wear debris. (14X)

Figure 9

The dark area on the slip ring base was caused by burnishing of the graphite seal. There are very few loose particles of graphite. (11X)

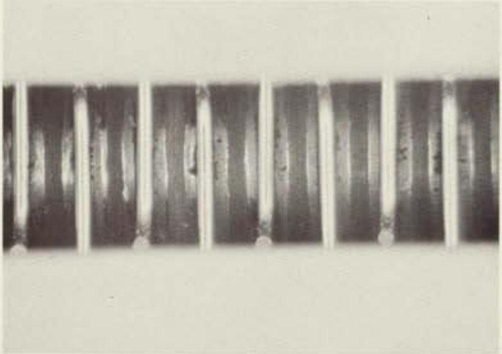


Figure 10

Capsule as viewed through slot in housing after 5000 hour life test. Even though the slip ring is rotated so that the wear debris is at a maximum, there is only a small amount of it on the ring shoulders and barriers. (14X)

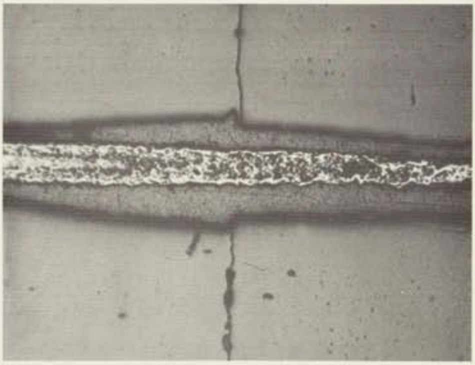


Figure 11

Photomicrograph showing extreme case of voided areas between ceramic wafers in the area of an internal lead. Note also the poor fusion between wafers. (69X) months of June and July were, in general, humid and probably caused the capsules to adsorb some water.

6.3 Contacts

Initial noise levels were low (e.g., 10 milliohms), but they increased to approximately 1 ohm after about 500 hours of testing. The amount of wear debris appeared to be quite small when one looked through the windows of the life test capsules (Figure 10). Removal of the brush blocks on one of the life tests units revealed the presence of black adherent debris which was concentrated in the area of the wear spots (Figures 12 and 13). The black part of the debris dissolved in a solution of concentrated H_2SO_4 saturated with CrO_3. There were a few gold particles (<5 volume percent) in the wear debris which did not dissolve in the H_2SO_4-CrO_3 solution. Most polymers will dissolve in H_2SO_4-CrO_3 solutions, and tests at Poly-Scientific showed that $NbSe_2$ is not soluble in the acid mixutre. Thus, we feel that the black debris was an organic polymer and that it was probably the cause of the high noise. The source of carbon for the polymer is not certain. The units were tested in a nitrogen atmosphere and the dielectric materials were ceramics. It has been reported[1] that hard gold plates of the type used can co-deposit organic

---

[1] Munier, G. B. - "A Study of Polymer Co-Deposition with Gold during Electroplating", presented at American Electroplater's Society Meeting, Boston, Massachusetts, February 1969.

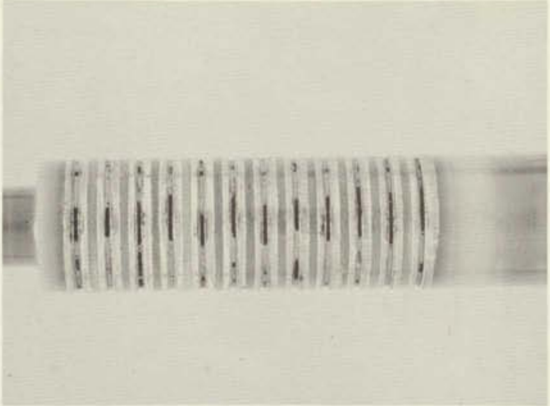


Figure 12

Overall view of rotor after 5000 hours of testing. The areas which contacted the brushes during oscillation are at the top, but as the slip ring was rotated during noise testing, wear debris was transferred and redeposited along the bottom of the slip ring grooves. (7X)

Figure 13

Grooves of slip ring (S/N 1) after 5000 hours of testing at 5 - 6 cps, 6° double amplitude. Note that most of the wear debris remained in the grooves and that it is as high as the bottom of the wear areas on the rings. (20X) materials. The lower the cathode efficiency of the plating bath, the greater the likelihood of polymeric material being co-deposited with the gold. Cathode efficiency decreases in the acid gold bath[1] from approximately 35% to approximately 27% as the current density is decreased from 7.5 ASF (the current density normally used) to 2.5 ASF (the current density used during deposition of the Au-$NbSe_2$ composite). Some organic material could have been in the nitrogen or counter diffused (with respect to the N_2 flow) into the test chambers. However, the quantity of debris was on the order of that expected to form on a similar unit with conventional lubrication and organic insulators when tested in air. The black debris was in contrast to the fluffy, loose type polymer found in conventional slip ring capsules in that it was more adherent and appeared to contain "oil". Oil is used as a descriptive term only, for the unit was definitely not lubricated with a liquid material.

The black debris was situated in the grooves in such a manner that we feel sure that it was the cause of the high electrical noise.

There was appreciable wear of both the rings and the brushes (Figures 13, 14, 15 and 16). A typical brush

---

[1] Technic, Inc.

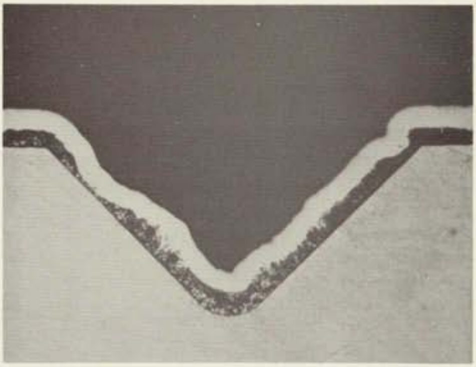


Figure 14

Cross section of slip ring groove in area worn by oscillation. The gold-niobium diselenide composite appears dark because of etching. It was over-plated with nickel to more clearly delineate the wear area which does not extend through the composite to the gold substrate. (285X)

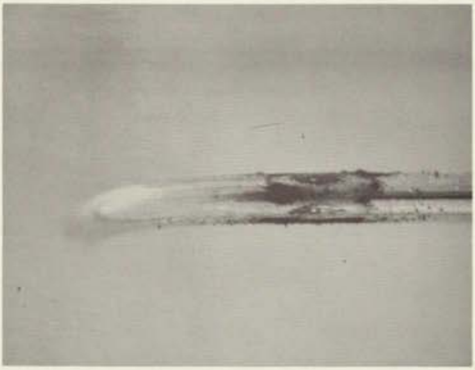


Figure 15

Wear spot on a brush taken from a life test capsule (S/N 1). Note the black wear debris and the absence of prow formation. (40X) was worn to a maximum depth of 0.0003 inch. The gold-niobium diselenide composite plates were in some cases worn approximately two thirds the way to the substrate gold electroform (Figure 14). In no case was the composite worn through to base metal. The wear rate was approximately 10^{-10} in./in. The composite was harder than expected (169 HK_{10}). In comparison, the 24 karat electrodeposit had a hardness of 87 HK_{10}.

We found that even though the brushes were formed correctly before assembly, they did not have the correct force after assembly. The differences in force could have been caused, in part, by the fact that only two of the three frame surfaces to which the block was designed to mate could be used. Thus, the brush blocks may have been slightly twisted. The brush block "ears" (shown in Figure 3) were designed to fit snugly in the slot of the frame; however, to obtain correct brush alignment, the ears had to be ground so that they did not contact the inner side of the frame slot. The correct mating can be obtained, on future units, by a slight redesign of the brush block wafers. We will check the brush force of future units immediately after assembly, rather than rely on correct brush formation and torque as measurement indicators of correct brush force.

6.4 Bearings

There were no bearing failures and the wear of the sodium silicate bonded MoS_2 and graphite (Everlube 811) was slight. There were a few loose particles of lubricant inside the bearings, but none of them appeared outside of the bearing shields. In fact, fewer than six particles were observed on the internal surfaces of four shields removed from two bearings. The quantity of loose particles in these bearings (Figure 17) which were operated for 5000 hours did not appear any greater than the quantity found in the bearings which were tested for 500 hours during Phase I. Both inner and outer races (Figure 18) were uniformly burnished and there was no sign of Brinelling; also, the lubricating film remained continuous and smooth on all surfaces. The balls of the bearing did not appear (30X) to be worn as a result of being operated in an oscillating mode for 5000 hours at 5 - 6 cps (Figure 19). We feel that future inorganic units should contain bearings lubricated with sodium silicate bonded MoS_2 and graphite. Also, this lubricant appears to be an excellent candidate for vacuum applications.

We found that running reduced the friction torque of the qualification units. Future bearings lubricated with sodium-silicate bonded molybdenum disulfide and graphite should be run-in so that a smooth burnished finish is obtained before use.

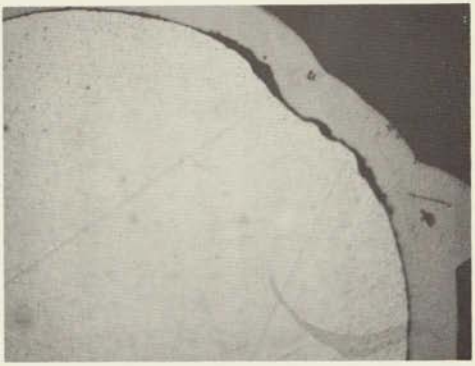


Figure 16

Cross section of brush showing wear area. The wear extends approximately 0.0003 inch along a radius from the original circumference of the brush. The black areas are wear debris sandwiched between a nickel overplate and the brush. (550X)

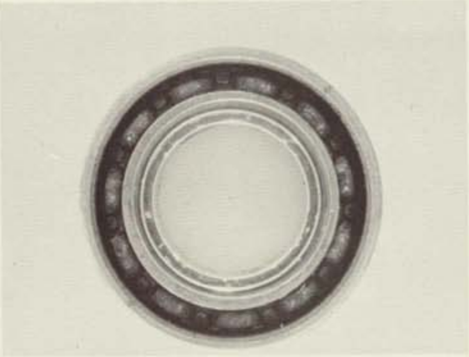


Figure 17

SR155 bearing after 5000 hours of operation at 5 - 6 cps, 6° double amplitude. (7.5X)

Figure 18

Inner bearing race after life test. The lubricating film is burnished, but not chipped, flaked, or worn to the stainless steel. (18X)

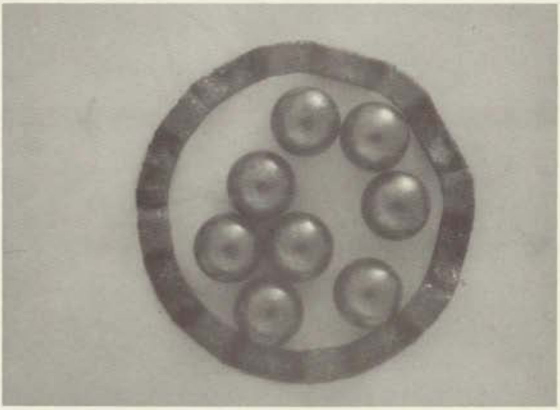


Figure 19

Balls and one retainer ribbon from bearing of a life test unit. Notice that balls are coated with lubricant and that lubricant on the sides of the retainers has been only slightly burnished. (18X)

7.0 CONCLUSIONS OF PROGRAM

The following program conclusions are advanced:

Slip ring assemblies can be feasibly manufactured from totally inorganic materials. The most successful process for both slip ring and brush assemblies has been the glass ceramic disks (or wafers) fused under pressure. To the best of our knowledge, this is the first time that a totally inorganic slip ring capsule has been fabricated.

Sodium silicate bonded molybdenum disulfide and graphite serves as an excellent inorganic bearing lubricant when operated in a N_2 atmosphere at 50°C.

Composite rings are not yet satisfactory sliding electrical contacts for operation in excess of 500 hours at 5 - 6 cps. Noise levels are too high and wear too severe. The composite could be used approximately 200 hours if noise levels in the range of 20 to 60 milliohms could be tolerated. The performance of the electrodeposited gold-$NbSe_2$ is equivalent to similar rings produced by pressing techniques.

Slip ring capsules of the low organic type can be feasibly produced in the same size packages as conventional units. Glass barrier slip rings and very low organic content brush blocks would be used. Changes would be required for specification GC125355 to permit such a modification.

The experience gained by virtue of this study has allowed Poly-Scientific to manufacture, in production quantities, two types of completely inorganic switches which can be operated at temperatures in excess of those which would destroy conventional organic dielectrics.

More investigation is needed in the area of totally inorganic contact lubricants.

Design and process improvement recommendations for future inorganic units are listed in Appendix I.

The specific technical accomplishments of the program were:

1) A technique was applied for fusing Fotoform wafers to build ceramic bodies for electrical integrity.
2) A method was developed for introducing electrical conducting elements in the Fotoceramic bodies with continuity and electrical separation.
3) A method of applying solid lubricant by co-electrodeposition was developed.
4.) A satisfactory inorganic bearing lubricant was demonstrated for N_2 environment which probably would be satisfactory in vacuum.
5) The glass surface slip ring concept was shown to be reducible to practice with the enclosure as conventional slip rings.
6.) Ultrasonic drilling of ceramic and glass bodies was made practical.

7) Plastic formulations were developed with coefficients of thermal expansion so low as to nearly match soda-lime glass.

8) Techniques were developed for grinding ceramic and glass to good surfaces without breaking.

9) Laser welding was proven feasible where permanent mechanical support for the components is designed into the unit.

0) A spline and tube method of inorganic slip ring manufacture was shown to be feasible for low cost, low precision slip rings.

Poly-Scientific gained considerable general information about various glasses, ceramics and lubricants. This knowledge has already been applied to a number of other programs, and has ben of particular benefit during the design and development of assemblies which are to operate in space environment, or at high temperatures.

APPENDIX I

DESIGN AND PROCESS IMPROVEMENTS RECOMMENDED FOR FUTURE INORGANIC CAPSULES

DESIGN AND PROCESS IMPROVEMENTS RECOMMENDED FOR FUTURE INORGANIC CAPSULES

As a result of this study, we recommend that:

1. External bosses and tabs of Fotoform be used to assist in positioning wafers during firing or assembly.
2. Depth etched wafers be avoided in preference to through etch ones. A 20 to 1 etch rate should be assumed.
3. Fotoform wafers comply with P-S E.S. 344 which requires a smoother surface finish than that on the Phase II wafers.
4. Fotoform containing internal leads be fired in an inert or slightly reducing atmosphere.
5. Firing fixtures be designed to provide uniform pressure over entire horizonal surfaces of Fotoform.
6. Internal to external jumpers be plated via processes of vacuum impregnation of electrolyte and ultrasonic agitation of electrolyte during electrodeposition.
7. Brush block Fotoform wafers be slightly redimensioned so that all three brush block aligning surfaces can be used.
8. Brush forces be checked immediately after assembly.
9. Sodium silicate bonded MoS_2 and graphite lubricated bearings be run-in before brush blocks are placed on the capsule.
10. A matrix gold electrodeposit that does not contain polymer (e.g., BDT 200)[1] be used in the formation of gold-niobium diselenide composites.

---

[1] Sel Rex

11. If there is allowable space, Au-$NbSe_2$ composite brushes be used in conjunction with hard gold rings.

APPENDIX II

QUALIFICATION TEST PROCEDURE
FOR
DP1766 CAPSULE SLIP RING ASSEMBLY

QUALIFICATION TEST PROCEDURE

FOR

DP1766 CAPSULE SLIP RING ASSEMBLY

Procedure No. RLT - 91
Date 27 February 1969
Revised
Approved

1. SCOPE

This procedure describes the testing required for qualification of the 12 circuit capsule slip ring assembly in accordance with Marshall Space Flight Center Drawing No. GC-125355 Rev. H, dated 2-17-67 and the Military Standards referred to in the drawing.

2. TEST UNITS

Five prototype assemblies shall be used as the qualification units.

3. TEST EQUIPMENT REQUIRED

General Radio Megohmmeter Model 1862C
General Radio Precision Decade Resistor Box type 510-AA in .010 steps
Hewlett Packard Power Supplies, Model 721A
Cimron Digital Voltmeter Model 6200A DVM
Cimron Preamplifier Model 6801A
Sanborn Model 150 Recorder with AC-DC Preamplifier Model 150-1000
Sanborn Low Level Amplifier Model 850-1500A
Sanborn Medium Gain Amplifier, 8 Channel, Model 658-3400 with Optical Recorder Model 650.
Bruel and Kjaer Exciter Control Preamplifier type 1608
Bruel and Kjaer Accelerometer
Bruel and Kjaer Automatic Vibration Exciter Control Model 1018
Unholtz-Dickie Shaker system No. 52
AVCO Shock Machine Model SM-005
Tektronix L-C Meter type 130
Tektronix Oscilloscope Model 533 or equivalent
Tektronix Preamplifier type "E" or "1A7"
Tektronix Preamplifier type "CA"
Waters 0-42 Gram/Centimeter Torque Watch Gauge
Radio Frequency Laboratories Variable Frequency Power Supply Model 150
Poly-Scientific Shock, Vibration and Acceleration Test Fixture
Poly-Scientific Centrifuge
Poly-Scientific Noise Test Drive Fixture
Poly-Scientific Current Control System
Poly-Scientific Run-In Fixture
Poly-Scientific Life Test Fixture

TEST EQUIPMENT REQUIRED (...Continued)

Rotational Drive Motors for Vibration and Acceleration Tests.
Wire Wound Resistor.
Assorted Cables, Hardware and Other Required Incidental Hook-Up Equipment

4. OPERATION SEQUENCE

4.1 D.C. Resistance

4.1.1 Adjust the power supply and current control system to 10 VDC open circuit voltage with 0.010 ampere current.

4.1.2 Using the digital voltemeter, measure and record each circuit of the capsule assembly.

Contact Resistance Variation (Noise)

4.2.1 Install the capsule assembly on the noise test drive fixture.

4.2.2 Adjust the power supply to 10 VDC open circuit voltage and the current control to 0.100 ampere.

4.2.3 Rotate the capsule assembly rotor at 2 RPM with superimposed oscillation of $5^{\circ} \pm 1^{\circ}$ DA @ 6-8 Hz.

4.2.4 Test the capsule assembly and record the noise level of each circuit pair.

4.3 TORQUE

4.3.1 Using the torque watch gauge, take six random torque measurements of the capsule slip ring rotor with the housing static.

4.3.2 Record both the maximum and the minimum torque readings on the data sheet.

4.3.3 The torque test shall be performed within 15 minutes from completion of the noise test.

4.4 Insulation Resistance

4.4.1 Using the 500 volts setting on the megohmmeter, measure and record on the dats sheet each circuit to all other circuits and all circuits to the frame.

4.4.2 Apply the voltage to the circuit until the meter has stabilized, then take the reading.

4.4.3 Testing shall be performed at $22 \pm 5^{\circ}$ C. with 50% Relative Humidity.

4.5 Capacitance

4.5.1 Connect the L-C Meter to Circuits 1-2.

4.5.2 Measure and record the capacity of the circuit pair, then measure and record the capacity of circuit 1 to frame and circuit 2 to frame.

4.5.3 Measure the remaining circuits in the same manner and record each reading on the data sheet.

4.6 Acceleration

4.6.1 Install the capsule assembly in the test fixture and attach the fixture to the centrifuge arm.

4.6.2 Install the rotational drive motor on the centrifuge arm and connect to the capsule assembly.

4.6.3 Make the required electrical connections.

4.6.4 Adjust the centrifuge speed to attain 20 ±2 G's for 30 minutes in each of the three mutually perpendicular axes.

4.6.5 The DC Resistance and Noise shall be monitored during the test.

4.6.6 Upon completion of acceleration testing, perform DC Resistance, Noise, Torque and Insulation Resistance tests per Paragraph 4.1, 4.2, 4.3 and 4.4 of this procedure.

4.7 Vibration

4.7.1 Install the capsule assembly in the vibration test fixture.

4.7.2 Connect the rotational dirve motor to the capsule assembly rotor.

4.7.3 Program the vibration exciter control to sweep from 20 to 2000 and return to 20 Hz in 20 minutes.

4.7.4 Set the amplitude at 0.06 inches displacement, use 55 Hz as the crossover, and set the acceleration to 15 G's peak

4.7.5 Vibrate each of the three mutually perpendicular axes for one hour.

4.7.6 The noise level shall be monitored during the vibration.

4.7.7 When the vibration testing is completed, perform DC Resistance, Noise, Torque and Insulation Resistance tests per Para. 4.1, 4.2, 4.3 and 4.4 of this procedure.

4.8 Shock

4.8.1 Install the capsule assembly in the shock test fixture and secure to the shock machine, taking care to secure all lead wire.

4.8.2 Apply 20 G's acceleration with 7 to 11 milliseconds duration half sine pulse, one blow in each direction, to each of the three mutually perpendicular axes.

4.8.3 A total of six blows is required.

4.8.4 Using the oscilloscope, monitor the acceleration level and the pulse duration of each blow.

4.8.5 When the shock testing is completed, perform DC Resistance, Noise, Torque and a visual examination for workmanship, per Para. 4.1, 4.2, 4.3 of this procedure and Para. 3.4.16 of drawing no. GC-125355 Rev. H from MSFC.

4.9 Load Test

4.9.1 Connect fifty percent of the circuits is series and apply 115 volts AC @ 400 Hz.

4.9.2 Using the wire wound resistor, limit the current through the series circuit to one ampere for 500 continuous hours.

4.9.3 At the end of 500 hours, connect the remaining fifty percent of the circuits in series and apply the same voltage and current for an additional 500 hours.

4.9.4 When the load test is completed, perform DC Resistance, Noise, Torque and Insulation Resistance per Para. 4.1, 4.2, 4.3 and 4.4 of this procedure.

4.10 Life

4.10.1 Install the capsule assembly in the life test fixture.

4.10.2 Adjust the power supply to 10 VDC open circuit voltage and adjust the load applied to 0.010 ampere to all circuits in series.

4.10.3 Oscillate the rotor 2 ±1 degrees @ 6-8 Hz.

4.10.4 At intervals of 100 -10 hours during the test, the rotor shall be rotated one revolution for noise test of all six circuit pairs simultaneously.

4.10.5 With the 8 channel optical recorder, monitor and record the noise level on the data sheet.

4.10.6 When the noise test is completed, return the rotor to the original oscillation position ±1 degree, using the mechanical locator on the fixture.

4.10.7 5000 hours is the required duration of the life test.

4.10.8 The entire life test shall be performed in a nitrogen atmosphere.

4.11 Final Testing and Examination

4.11.1 Upon completion of the life test, the capsule assembly shall be given the following tests:

DC Resistance
Noise
Torque
Insulation Resistance per Para. 4.1, 4.2, 4.3 and 4.4 of this procedure
... and in addition a thorough visual examination

4.11.2 The visual examination shall include workmanship, contamination and seizure, per para. 3.4.16 and 4.4.4.1c, (1) and (2) of MSFC Drawing No. GC-125355 Rev. H.

APPENDIX III

TEST DATA

LIFE TEST FOR P/N DP1766 . S/N 1　　ROTATION 1RPM (DURING NOISE TEST) OSCILLATION 6° D.A. @ 5-6 HZ

Date Ckt. Pair	6 FEB 69	10 FEB 69	13 FEB 69	17 FEB 69	20 FEB 69	24 FEB 69	27 FEB 69	3 MAR 69	6 MAR 69	10 MAR 69	13 MAR 69	17 MAR 69	20 MAR 69	24 MAR 69	27 MAR 69	31 MAR 69	3 APR 69	7 APR 69	10 APR 69	14 APR 69	17 APR 69	21 APR 69	24 APR 69	28 APR 69
1-2	9	16	12	28	56	80	60	70	60	80	40	180	120	720	400	400	1000+	300	1000	1000	300	100	100	100
3-4	13	32	22	42	160	100	60	120	120	100	80	210	400	440	350	400	400	1000+	1000+	350	200	100	200	200
5-6	11	12	40	56	96	60	80	125	120	90	80	180	480	470	1000+	1000+	1000+	1000+	1000+	700	1000	100	1000+	500
7-8	3	8	14	40	128	60	60	60	60	1000	125	120	120	160	200	600+	1000	1000+	1000+	700	800	80	150	150
9-10	3	16	26	20	80	70	70	45	40	60	60	200	320	400	400	1000+	1000+	1000+	1000+	1000+	800	80	150	300
11-12	10	8	12	32	72	40	60	40	40	50	60	80	180	360	350	350	800	1000+	360	1000+	600	60	60	160
~~13-14~~																								
15-16	13	32	40	56	168	100	80	125	120	1000	125	210	480	720	1000	1000	1000	1000	1000	1000	1000	100	1000	500
~~17-18~~																								
19-20	3	8	12	20	56	40	30	40	40	50	40	80	120	160	200	350	400	300	320	350	200	60	50	100
~~21-22~~																								
~~23-24~~																								
25-26	8	15	21	36	99	68	65	77	73	230	74	162	233	417	450	625	867	883	833	792	517	87	421	245
27-28																								
29-30						1																		
31-32																								
33-34																								
35-36																								
37-38																								
39-40																								
41-42																								
43-44																								
45-46																								
47-48																								
49-50																								
51-52																								
53-54																								
55-56																								
57-58																								
59-60																								
61-62																								
63-64																								
65-66																								
67-68																								
69-70																								
71-72																								
HOURS	0	96	168	264	336	432	504	600	672	768	840	936	1008	1104	1176	1272	1344	1440	1512	1608	1680	1776	1848	1944

LIFE TEST FOR P/N DP1766 S/N 1 ROTATION 1 RPM (DURNING NOISE TEST) OSCILLATION 6°D.A. @ 5-6 HZ

Ckt. Pair / Date	1 MAY 69	5 MAY 69	8 MAY 69	12 MAY 69	15 MAY 69	19 MAY 69	22 MAY 69	26 MAY 69	29 MAY 69	2 JUNE 69	5 JUNE 69	9 June 69	12 JUNE 69	16 JUNE 69	19 JUNE 69	23 JUNE 69	26 JUNE 69	30 June 69	3 JULY 69	7 JULY 69	14 JULY 69	17 JULY 69	21 JULY 67	24 JULY 67
1-2	150	150	150	150	154	200	100	100	100	100	100	650	200	250	250	200	250	200	200	150	350	300	400	400
3-4	200	600	200	250	200	450	200	200	600	600	200	1000+	1000+	450	400	250	1000+	100	100	400	250	250	350	350
5-6	200	450	600	700	250	1000+	900	600	250	250	300	1000+	1000+	600	600	750	1000+	250	250	150	700	700	100	100
7-8	100	300	700	800	700	300	200	600	300	300	150	1000+	1000+	700	550	250	200	100	100	100	150	700	300	350
9-10	400	500	650	1000+	400	350	300	900	1000+	1000+	250	1000+	1000+	300	150	700	150	150	150	150	200	700	350	350
11-12	100	100	300	150	150	800	300	150	200	200	100	200	200	350	500	200	600	150	150	250	500	350	150	150
13-14																								
15-16	400	600	750	1000	700	1000	900	900	200	1000	300	1000	1000	700	600	250	1000	250	250	400	500	250	400	450
17-18																								
19-20	100	100	150	150	150	100	100	100	200	100	100	200	200	250	150	200	150	100	100	100	200	200	100	100
21-22																								
23-24	192	350	433	508	342	367	333	425	408	408	183	508	733	742	408	212	533	158	158	200	275	250	267	258
25-26																								
27-28																								
29-30																								
31-32																								
33-34																								
35-36																								
37-38																								
39-40																								
41-42																								
43-44																								
45-46																								
47-48																								
49-50																								
51-52																								
53-54																								
55-56																								
57-58																								
59-60																								
61-62																								
63-64																								
65-66																								
67-68																								
69-70																								
71-72																								
HOURS	2016	2112	2184	2280	2352	2448	2520	2616	2688	2784	2856	2952	3024	3120	3192	3288	3360	3456	3528	3624	3792	3864	3960	4032

NOT REPRODUCIBLE

page 2

LIFE TEST FOR P/N DA766 S/N 1 ROTATION 4 RPM During Noise Test OSCILLATION 6° PA c̄ 5-6N

Ckt. Pair \ Date	28 July 69	31 July 69	4 AUG 69	7 AUG 69	11 AUG	14 AUG	18 AUG	21 AUG	25 AUG	28 AUG	3 SEPT
1-2	250	300	1000	200	350	350	400	500	450	1000	300
3-4	200	200	700	900	1000+	1000+	1000+	850	1000	1000	250
5-6	150	150	150	750	600	850	650	1000	600	1000+	800
7-8	250	150	350	1000+	250	350	350	1000	200	900	200
9-10	200	150	200	1000+	1000+	1000+	900	400	300	800	300
11-12	400	200	50	1000+	350	400	400	800	700	1000	900
13-14											
15-16	400	300	700	1000	1000	1500	1000	1500	1500	1000	900
17-18											
19-20	150	150	50	200	250	350	350	400	200	400	200
21-22											
23-24	242	193	308	505	592	655	617	775	552	857	425
25-26											
27-28											
29-30											
31-32											
33-34											
35-36											
37-38											
39-40											
41-42											
43-44											
45-46											
47-48											
49-50											
51-52											
53-54											
55-56											
57-58											
59-60											
61-62											
63-64											
65-66											
67-68											
69-70											
71-72											
Hours	4118	4190	4286	4358	4454	4526	4622	4694	4790	4862	5000

NOT REPRODUCIBLE

LIFE TEST FOR P/N DP1766 S/N 2 ROTATION 1RPM (DURING NOISE TEST) OSCILLATION 6°P-P @ .5-6 HZ

Ckt. Pair / Date	6 FEB 69	10 FEB 69	13 FEB 69	17 FEB 69	20 FEB 69	24 FEB 69	27 FEB 69	3 MAR 69	6 MAR 69	10 MAR 69	13 MAR 69	17 MAR 69	20 MARCH 69	24 MARCH 69	27 MARCH 69	31 MARCH 69	3 APR 69	7 APR 69	10 APR 69	14 APR 69	17 APR 69	21 APR 69	24 APR 69	28 APR 69
1-2	20	56	120	70	280	1400	1200	240	240	140	240	320	440	1100	900	1200	1000+	1000+	1000+	1000+	1000+	200	500	1000+
3-4	32	26	40	50	80	150	300	60	80	90	80	70	120	300	300	1200	1000+	1000+	1000+	600	200	300	300	600
5-6	32	52	85	280	360	800	1200	100	240	280	160	160	240	1100	950	1000+	900	1000+	1000+	1000+	1000+	300	300	200
7-8	23	40	70	260	460	300	1000	100	80	100	100	240	400	800	800	1000+	1000+	1000+	1000+	1000+	1000+	[illegible]	300	700
9-10	26	48	180	160	350	1100	1100	260	200	150	200	320	440	300	250	1000+	500	1000+	1000	1000+	1000+	300	1000	1000+
11-12	18	28	200	120	520	900	1100	140	180	160	200	200	400	1000	1000+	1000+	1000+	1000+	1000+	1000+	1000+	500	1000	1000+
13-14																								
15-16																								
17-18	32	56	200	380	520	1400	1200	210	240	280	270	290	440	1100	1000	1205	1010	1000	1000	1000	1100	500	1000	1000
19-20																								
21-22	18	21	40	50	80	150	300	60	80	90	80	70	120	200	250	1000	500	1500	1000	550	200	200	300	300
23-24																								
25-26	25	42	116	157	343	640	983	150	170	153	163	185	333	750	683	1017	900	1020	1000	833	867	300	517	750
27-28																								
29-30																								
31-32																								
33-34																								
35-36																								
37-38																								
39-40																								
41-42																								
43-44																								
45-46																								
47-48																								
49-50																								
51-52																								
53-54																								
55-56																								
57-58																								
59-60																								
61-62																								
63-64																								
65-66																								
67-68																								
69-70																								
71-72																								
Hours	0	96	168	264	336	432	504	600	672	768	840	936	1008	1104	1200	1272	1344	1440	1512	1608	1680	1776	1848	2040

page 1

LIFE TEST FOR P/N DP1766 S/N 2 ROTATION 1 RPM (During Noise Test) OSCILLATION 6° DA. @ 5-6 Hz

Ckt. Pair / Date	1 MAY 69	5 MAY 69	8 MAY	12 MAY	15 MAY	19 MAY	22 MAY	26 MAY	29 MAY 69	2 JUNE 69	5 JUNE 69	9 JUNE 69	12 JUNE 69	16 JUNE 69	19 JUNE 69	23 June 69	26 June 69	30 June 69	3 July 69	7 JULY 69	14 JULY 69	17 JULY 69	21 JULY 69	24 JULY 69
1-2	1000+	300	1100	150	100	150	200	1000+	400	400	350	1000+	650	1000+	1000+	400	950	1000+	1000+	1000+	1000	1000+	650	400
3-4	300	200	400	100	150	150	200	200	100	100	150	300	500	950	250	250	250	400	300	400	600	600	150	560
5-6	1000+	400	400	200	200	250	300	900	200	100	150	1000+	200	1000+	800	150	300	500	900	1000+	350	400	300	600
7-8	1000+	400	500	200	350	300	200	260	200	200	200	1000+	500	1000+	1000	500	650	550	300	1000+	850	1000+	700	500
9-10	1000+	1000+	1000+	1000+	150	400	200	150	1000+	1000+	1000+	400	700	650	800	800	500	650	400	550	1000	1000	1000	1000
11-12	1000+	1000+	1000+	1000+	1000+	300	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000+	1000	1000	600	1000+
~~13-14~~																								
15-16	1000	1000	400	1000	1000	700	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
~~17-18~~																								
19-20	300	200	400	100	100	150	200	150	100	100	150	300	200	650	250	150	250	400	300	400	350	400	300	350
~~21-22~~																								
23-24	583	550	733	712	325	255	350	585	483	433	475	783	592	437	808	517	608	683	350	525	500	833	517	642
25-26																								
27-28																								
29-30																								
31-32																								
33-34																								
35-36																								
37-38																								
39-40																								
41-42																								
43-44																								
45-46																								
47-48																								
49-50																								
51-52																								
53-54																								
55-56																								
57-58																								
59-60																								
61-62																								
63-64																								
65-66																								
67-68																								
69-70																								
71-72																								
HOURS	2016	2112	2184	2280	2352	2448	2520	2616	2688	2784	2856	2952	3024	3120	3192	3288	3360	3456	3528	3624	3792	3864	3960	4032

DURING NOISE TES

Ckt. Pair / Date	28 July 69	31 July 69	4 AUG 69	7 AUG 69	11 AUG 69	14 AUG 69	18 AUG	21 AUG	25 AUG	28 AUG	3 SEPT
1-2	700	950	300	1000+	1000+	1000+	1000+	1000+	1000+	1000+	550
3-4	650	850	300	1000+	1000+	1000+	600	650	700	900	1000+
5-6	1000	450	450	700	400	450	1000+	700	750	1000+	1000+
7-8	400	250	350	1000+	650	1000	1000+	1000+	1000+	1000+	500
9-10	300	300	250	550	1000	1000	1000+	650	800	1000+	800
11-12	1000+	1000+	1000+	700	800	1000+	1000+	1000+	900	1000+	1000+
~~13-14~~											
~~15-16~~	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
~~17-18~~											
~~19-20~~	300	150	250	550	400	450	600	650	700	900	500
~~21-22~~											
~~23-24~~	675	542	442	625	758	908	733	833	858	983	808
25-26											
27-28											
29-30											
31-32											
33-34											
35-36											
37-38											
39-40											
41-42											
43-44											
45-46											
47-48											
49-50											
51-52											
53-54											
55-56											
57-58											
59-60											
61-62											
63-64											
65-66											
67-68											
69-70											
71-72											
Hours	4118	4190	4286	4358	4454	4526	4622	4694	4790	4862	5000

NOT REPRODUCIBLE

QUALIFICATION

INSULATION RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. 3 Date 2-28-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	50 000
2	2 000
3	100 000
4	2 000
5	100 000
6	20 000
7	HIPOT SHORT
8	20 000
9	50 000
10	HIPOT SHORT
11	50 000
12	40 000

F. AKERS
Technician

QUALIFICATION

D.C. RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. 3 Date 14 APR 69

Specification: .030 Ohms ± .015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.681
2	.679
3	.685
4	.686
5	.678
6	.685
7	.699
8	.677
9	.671
10	.683
11	.673
12	.675

H.

Technician

QUALIFICATION

NOISE and TORQUE TEST

INITIAL

P/S Part No. DP-1766 Serial No. 3 Date 14 APR 69

Noise Spec: Milliohms

Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 Rpm Oscillation: 6Hz5°

Ckt. Pairs	Reading
1-2	3
3-4	6
5-6	6
7-8	5
9-10	6
11-12	5

Starting Torque: 18 35 G/C

H. Irwin
Technician

QUALIFICATION

CAPACITANCE

INITIAL

P/S Part No. DP-1766 Serial No. 3 Date 14 APR 69

Specification: PFD Maximum

Mounted in handling fixture with readings taken through plugs.

Circuit	Ckt Pair	Ground
1	43	28
2		28
3	44	27
4		27
5	42	27
6		27
7	64	33
8		27
9	57	28
10		33
11	42	28
12		28

H. Irwin

Technician

QUALIFICATION

ACCELERATION

P/S Part No. DP-1766 Serial No. 3 Date 15 & 16 APR 69

Specification: 20 ± 2G's for 30 Minutes each a

No. Axes: 3

DC Resistance				Noise			
Ckt Pair	Axis I	Axis II	Axis III		Axis I	Axis II	Axis III
1-2	1.315Ω	1.325Ω	1.305Ω		5 mΩ	4 mΩ	4 mΩ
3-4	1.325	1.335	1.325		7	5	7
5-6	1.320	1.325	1.315		7	6	7
7-8	1.345	1.335	1.335		6	5	5
9-10	1.315	1.305	1.295		6	7	7
11-12	1.320	1.300	1.300		6	7	7

REMARKS

Note: Axis I - Axial direction
Axis II - Radial I (Brushes Horizontal)
Axis III- Radial II (Brushes Vertical)

H. Drumm
Technician

QUALIFICATION

D.C. RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 3 Date 17 APR 69

Specification: .030 Ohms ± .015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.685
2	.692
3	.696
4	.692
5	.682
6	.688
7	.707
8	.682
9	.678
10	.683
11	.679
12	.680

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 3 Date 18 APR 69

Noise Spec: Milliohms

Torque Spec: ____ G/C Max.

____ G/C Min

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6HZ 5°DA

Ckt. Pairs	Reading
1-2	5
3-4	8
5-6	8
7-8	6
9-10	8
11-12	8

Starting Torque: 15 MIN 19 MAX G/C

H. Frumin
Technician

QUALIFICATION

INSULATION RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 3 Date 4-22-69

Test Voltage: 500V DC Specification: ____ Megohms Minimum

Circuit	Megohms
1	20000
2	600
3	30000
4	600
5	40000
6	5000
7	SHORT
8	10000
9	10000
10	SHORT
11	20000
12	20000

Fred Akers
Technician

QUALIFICATION

VIBRATION TEST

P/S Part No. DP-1766 Serial No. 3 Date 23 APR 69

Amplitude Limits: 0.06" Disp. 15G's Accel.

Frequency Limits: 20 to 2000 Hz

Axis I 1013E BEGAN
1113E STOPPED

Maximum Noise: 30 Milliohms @ 20-750 Hz

Axis II 0856E BEGAN
0956E STOPPED

Maximum Noise: 40* Milliohms @ 700-800 Hz

Axis III 0752E BEGAN
0852E STOPPED

Maximum Noise: 18 Milliohms @ 50-200 Hz

REMARKS: * FIXTURE SHAFT RESONANT AT THE FREQ. OF HIGHEST NOISE, DO NOT BELIEVE RESONANT SPIKES ARE FROM BRUSHES ALONE.

Note: Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H. Irwin
Technician

QUALIFICATION

D.C. RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. 3 Date 24 APR 69

Specification: +.030 Ohms ±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.686
2	.681
3	.703
4	.691
5	.679
6	.683
7	.708
8	.681
9	.675
10	.684
11	.678
12	.677

Technician

QUALIFICATION

NOISE and TORQUE TEST

POST VIBRATION

P/S Part No. DP-1766 Serial No. 3 Date 24 APR 69

Noise Spec: Milliohms

Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6HZ 5°DA.

Ckt. Pairs	Reading
1-2	6
3-4	9
5-6	6
7-8	7
9-10	7
11-12	6

Starting Torque: 16 MIN 19 MAX G/C

H. [illegible]

Technician

QUALIFICATION

INSULATION RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. 3 Date 4-25-69

Test Voltage: 500 VDC Specification: Megohms Minimum

Circuit	Megohms
1	40000
2	1000
3	60000
4	900
5	90000
6	7000
7	SHORT
8	20000
9	30000
10	SHORT
11	10000
12	40000

Fred Ohern
Technician

QUALIFICATION

SHOCK TEST

P/S Part No. DP-1766 Serial No. 3 Date 30 APR 69

Specification: 20 G's No. Blows: 6 (1 blow each direction on each of 3 axes)

Axis I
/ 1 Blow Down
/ 1 Blow Up

Axis II
/ 1 Blow Down
/ 1 Blow Up

Axis III
_ 1 Blow Down
/ 1 Blow Up

REMARKS 1.35V @ 9 MS DU[illegible] 1/2 SINE

Note: Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

POST SHOCK

P/S Part No. DP-1766 Serial No. 3 Date 30 APR 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6Hz 5°D.

Ckt. Pairs	Reading
1-2	6
3-4	10
5-6	6
7-8	8
9-10	10
11-12	6

Starting Torque: 19 MIN 22 MAX G/C

H. Irwin
Technician

QUALIFICATION

D.C. RESISTANCE

POST SHOCK

P/S Part No. DP-I766 Serial No. 3 Date 1 MAY 69

Specification: +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.688
2	.683
3	.692
4	.690
5	.681
6	.686
7	.705
8	.684
9	.676
10	.684
11	.678
12	.679

Technician

QUALIFICATION

INSULATION RESISTANCE

POST SHOCK

P/S Part No. DP-1766 Serial No. 3 Date 5-1-69

Test Voltage: 500 VDC Specification: : Megohms Minimum

Circuit	Megohms
1	30000
2	950
3	40000
4	850
5	70000
6	8000
7	Short
8	20000
9	20000
10	Short
11	30000
12	30000

Fred Akers
Technician

QUALIFICATION

D.C. RESISTANCE

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 3 Date 8 JUL 69

Specification: ______ +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.686
2	.686
3	.687
4	.691
5	.679
6	.684
7	.677
8	.680
9	.672
10	.678
11	.677
12	.680

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 3 Date 8 JUL 69

Noise Spec: Milliohms

Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6 HZ

Ckt. Pairs	Reading
1-2	11
3-4	14
5-6	18
7-8	22
9-10	11
11-12	12

Starting Torque: 25 G/C

H. Irwin

Technician

QUALIFICATION

INSULATION RESISTANCE

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 3 Date 7-14-69

Test Voltage: 500 V DC Specification: Megohms Minimum

Circuit	Megohms
1	10
2	10
3	50
4	10
5	5
6	5
7	HI-POT SHORT
8	5
9	10
10	HI-POT SHORT
11	10
12	10

Fred Ohern PSC 23 INSP

Technician

QUALIFICATION

INSULATION RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. 4 Date 3-11-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	400
2	10 000
3	100
4	30 000
5	60
6	10 000
7	100
8	10 000
9	200
10	5 000
11	400
12	2000

F. L. A.
Technician

QUALIFICATION

D.C. RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. 4 Date 31 MAR 69

Specification: ____________________ +.030 Ohms ± .015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.698
2	.702
3	.711
4	.698
5	.705
6	.691
7	.695
8	.686
9	.690
10	.690
11	.689
12	.683

H. Irwin

Technician

QUALIFICATION

NOISE and TORQUE TEST

INITIAL

P/S Part No. DP-1766 Serial No. *4* Date *14 APR 69*

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: *2RPM* Oscillation: *6HZ 5°DA*

Ckt. Pairs	Reading
1-2	9
3-4	5
5-6	6
7-8	5
9-10	4
11-12	4

Starting Torque: *18* G/C

H. Irwin
Technician

QUALIFICATION

CAPACITANCE

INITIAL

P/S Part No. DP-1766 Serial No. 4 Date 14 APR 69

Specification: PFD Maximum Mounted in handling fixture with readings taken through plugs

Circuit	Ckt Pair	Ground
1	43	28
2		28
3	43	27
4		28
5	47	27
6		28
7	45	28
8		28
9	44	27
10		27
11	42	28
12		28

H. Irwin
Technician

QUALIFICATION

ACCELERATION

P/S Part No. DP-1766 Serial No. 4 Date 15 & 16 APR 69

Specification: 20 ± 2G's for 30 Minutes each axis.

No. Axes: 3

DC Resistance				Noise			
Ckt Pair	Axis I	Axis II	Axis III		Axis I	Axis II	Axis III
1-2	1.385Ω	1.345Ω	1.355Ω		6 mΩ	4 mΩ	4 mΩ
3-4	1.395	1.355	1.355Ω		5	5	4
5-6	1.390	1.340	1.360		6	5	6
7-8	1.395	1.345	1.345		5	4	3
9-10	1.395	1.345	1.345		5	4	4
11-12	1.385	1.330	1.340		5	5	6

REMARKS

Note: Axis I - Axial direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H. Frumi
Technician

QUALIFICATION

D.C. RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 4 Date 17 APR 69

Specification: +.030 Ohms ± .015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.704
2	.706
3	.717
4	.704
5	.708
6	.698
7	.701
8	.693
9	.703
10	.700
11	.697
12	.690

H. Irwin

Technician

QUALIFICATION

NOISE and TORQUE TEST

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 4 Date 10 APR 69

Noise Spec: Milliohms

Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2RPM Oscillation: 6HZ 5°D

Ckt. Pairs	Reading
1-2	7
3-4	5
5-6	5
7-8	4
9-10	4
11-12	4

Starting Torque: 13 MIN 22 MAX G/C

H. Irwin

Technician

QUALIFICATION

INSULATION RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. 4 4-22-67

Test Voltage: 500V DC Specification: Megohms Minimum

Circuit	Megohms
1	1000
2	20000
3	450
4	30000
5	400
6	30000
7	450
8	10000
9	1000
10	10000
11	2000
12	6000

Technician

QUALIFICATION

VIBRATION TEST

P/S Part No. DP-1766 Serial No. 4 Date 23 APR 69

Amplitude Limits: 0.06" Disp. 15G's Accel

Frequency Limits: 20 to 2000 Hz

Axis I 1136E BEGAN
1236E STOPPED

Maximum Noise: 20* Milliohms @ 650-750 Hz

Axis II 1310E BEGAN
1410E STOPPED

Maximum Noise: 30* Milliohms @ 650-750 Hz

Axis III 1433E BEGAN
1533E STOPPED

Maximum Noise: 50* Milliohms @ 650-750 Hz

REMARKS: * RESONANT SPIKES OCCURRED AT FIXTURE RESONANCE FREQUENCY. AT OTHER FREQ. NOISE WAS 18 MΩ PEAK. ALL CIRCUITS IN SERIES WITH 100 MA CURRENT.

Note:
Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H. Irwin
Technician

QUALIFICATION

D.C. RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. 4 Date 24 APR 69

Specification: +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.705
2	.707
3	.719
4	.706
5	.711
6	.701
7	.702
8	.690
9	.697
10	.689
11	.706
12	.691

Technician

QUALIFICATION

NOISE and TORQUE TEST

POST VIBRATION

P/S Part No. DP-1766 Serial No. 4 Date 24 APR 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6Hz 5° DA

Ckt. Pairs	Reading
1-2	5
3-4	5
5-6	6
7-8	5
9-10	5
11-12	7

Starting Torque: 16 MIN 22 MAX G/C

H.

Technician

QUALIFICATION

INSULATION RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. 4 Date 4-25-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	2000
2	20000
3	900
4	40000
5	700
6	50000
7	1000
8	20000
9	1500
10	20000
11	1500
12	7000

Fred Okerson

Technician

QUALIFICATION

SHOCK TEST

P/S Part No. DP-1766   Serial No. 4   Date 30 APR 69

Specification: 20 G's   No. Blows: 6 (1 blow each direction on each of 3 axes)

Axis I	/	1 Blow Down
	/	1 Blow Up
Axis II	/	1 Blow Down
	/	1 Blow Up
Axis III	/	1 Blow Down
	/	1 Blow Up

REMARKS 1.35V @ 9MS DURATION ½ SINE

Note: Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H.
Technician

QUALIFICATION

NOISE and TORQUE TEST

POST SHOCK

P/S Part No. DP-1766 Serial No. 4 Date 30 APR 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2RPM Oscillation: 6Hz5°DA

Ckt. Pairs	Reading
1-2	5
3-4	4
5-6	5
7-8	4
9-10	6
11-12	7

Starting Torque: 16 MIN
19 MAX G/C

H. Drunn
Technician

QUALIFICATION

D.C. RESISTANCE

POST SHOCK

P/S Part No. DP-1766 Serial No. 4 Date 1 MAY

Specification: +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.705
2	.708
3	.716
4	.706
5	.709
6	.696
7	.702
8	.689
9	.696
10	.688
11	.682
12	.689

H. [illegible]

Technician

QUALIFICATION

INSULATION RESISTANCE

POST SHOCK

P/S Part No. DP-1766 Serial No. 4 Date 5-1-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	1500
2	20000
3	900
4	50000
5	900
6	40000
7	900
8	20000
9	30
10	20000
11	50
12	10000

Fred. Oberas
Technicia

QUALIFICATION

D.C. RESISTANCE

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 4 Date 8 JUL. 69

Specification: +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.700
2	.693
3	.714
4	.702
5	.702
6	.692
7	.699
8	.686
9	.690
10	.685
11	.689
12	.685

H.

Technician

QUALIFICATION

NOISE and TORQUE TEST

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 4 Date 8 JUL 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6 Hz

Ckt. Pairs	Reading
1-2	4
3-4	4
5-6	3
7-8	2
9-10	2
11-12	3

Starting Torque: 22 G/C

H. Irwin
Technician

QUALIFICATION

INSULATION RESISTANCE

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. 4 Date 7-14-69

Test Voltage: 500V DC Specification: Megohms Minimum

Circuit	Megohms
1	10
2	40
3	5
4	50
5	4
6	50
7	5
8	40
9	8
10	20
11	5
12	40

Fred Okers PSC 23 INSP.
Technician

QUALIFICATION

NSULATION RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 3-31-69

Test Voltage: 500 VDC Specification: Megohms Minimum

Circuit	Megohms
1	2500
2	250
3	1500
4	HIPOT SHORT
5	HIPOT SHORT
6	500
7	40
8	2000
9	HIPOT SHORT
10	5000
11	HIPOT SHORT
12	HIPOT SHORT

F. L. A.
Technician

QUALIFICATION

D.C. RESISTANCE

INITIAL

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 14 APR 69

Specification: +.030 Ohms ±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.620
2	.637
3	.634
4	.768
5	.630
6	.628
7	.632
8	.624
9	.629
10	.628
11	.625
12	.690

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

INITIAL

P/S Part No. DP-1766   Serial No. NONE (S/1/5)   Date 14 APR. 69

Noise Spec: Milliohms   Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC   Rotation: 2RPM   Oscillation: 6Hz @ 5°

Ckt. Pairs	Reading
~~1-2~~ 1-4	8
~~3-4~~ 2-5	4
~~5-6~~ 3-9	9
~~7-8~~ 6-11	3
~~9-10~~ 8-12	8
~~11-12~~ 7-10	5

Starting Torque: 35 45 G/C

H. [illegible]
Technician

QUALIFICATION

CAPACITANCE

INITIAL

P/S Part No. DP-1766 Serial No. NONE (S/N5) Date 14 APR 69

Specification: PFD Maximum Mounted in handling fixture with readings taken through plugs.

Circuit	Ckt Pair	Ground
1	39	27
2		27
3	60	28
4		37
5	68	37
6		28
7	41	27
8		27
9	40	27
10		27
11	58	27
12		37

H. Irwin
Technician

QUALIFICATION

ACCELERATION

P/S Part No. DP-1766 Serial No. NONE (S/N5) Date 15&16 APR 69.

Specification: 20 ± 2G's for 30 Minutes each axis.

No. Axes: 3

DC Resistance				Noise			
Ckt Pair	Axis I	Axis II	Axis III		Axis I	Axis II	Axis III
1-4 ~~1-2~~	1.335Ω	1.335Ω	1.325Ω		6 mΩ	5 mΩ	4 mΩ
2-5 ~~3-4~~	1.195Ω	1.215Ω	1.205Ω		7	4	4
3-9 ~~5-6~~	1.220Ω	1.210Ω	1.210Ω		5	5	6
6-11 ~~7-8~~	1.195Ω	1.195Ω	1.205Ω		5	4	4
8-12 ~~9-10~~	1.245Ω	1.245Ω	1.235Ω		6	6	5
7-10 ~~11-12~~	1.220Ω	1.205Ω	1.220Ω		5	6	6

REMARKS

Note: Axis I - Axial direction
Axis II - Radial I (Brushes Horizontal)
Axis III- Radial II (Brushes Vertical)

H. Irwin
Technician

QUALIFICATION

D.C. RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 17 APR 69

Specification: +.030 Ohms ±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.625
2	.641
3	.637
4	.771
5	.645
6	.638
7	.640
8	.630
9	.633
10	.640
11	.628
12	.677

Technician

QUALIFICATION

NOISE and TORQUE TEST

POST ACCELERATION

P/S Part No. DP-1766 Serial No. NONE (S/N5) Date 18 APR 69

Noise Spec. Milliohms

Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6HZ 5°DA

Ckt. Pairs	Reading
1-2	6
3-4	3
5-6	4
7-8	3
9-10	0
11-12	3

Starting Torque: 22 MIN 35 MAX G/C

H. Fruin
Technician

QUALIFICATION

INSULATION RESISTANCE

POST ACCELERATION

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 4-22-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	2000
2	100
3	2000
4	Short
5	Short
6	150
7	20
8	700
9	Short
10	800
11	Short
12	Short

Technician

QUALIFICATION

VIBRATION TEST

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 22 APR 69

Amplitude Limits: 0.06" Disp. 15 G's Accel.

Frequency Limits: 20 to 2000 Hz

Axis I 1115E BEGAN
1215E STOPPED

Maximum Noise: 10 - 14 Milliohms @ 1000 - 1250 Hz

Axis II 1252E BEGAN
1352E STOPPED

Maximum Noise: 11 Milliohms @ 700 - 1000 Hz

Axis III 1355E BEGAN
1455E STOPPED

Maximum Noise: 10 Milliohms @ 700 - 800 Hz

REMARKS: PEAK NOISE OCCURRED AT RESONANT FREQ. OF FIXTURE DRIVE SHAFT.

Note: Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H.
Technician

QUALIFICATION

D.C. RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 24 APR 69

Specification: 30 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.620
2	.640
3	.636
4	.757
5	.675
6	.632
7	.634
8	.627
9	.628
10	.679
11	.675
12	.675

Technician

QUALIFICATION

NOISE and TORQUE TEST

POST VIBRATION

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 24 APR 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2RPM Oscillation: 6HZ 5°DA

Ckt. Pairs	Reading
~~1-2~~ 1-4	5
~~3-4~~ 2-5	5
~~5-6~~ 3-9	7
~~7-8~~ 6-11	4
9-10 7-10	7
11-12 8-12	6

Starting Torque: 25 MIN 38 MAX G/C

H. Irwin
Technician

QUALIFICATION

INSULATION RESISTANCE

POST VIBRATION

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 4-25-69

Test Voltage: 500 VDC Specification: ______ Megohms Minimum

Circuit	Megohms
1	7000
2	200
3	5000
4	Short
5	Short
6	300
7	40
8	1500
9	Short
10	2500
11	Short
12	Short

Fred Okerson
Technician

QUALIFICATION

SHOCK TEST

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 30. APR 69

Specification: 20 G's No. Blows: 6 (1 blow each direction on each of 3 axes)

Axis I	/	1 Blow Down
	/	1 Blow Up
Axis II	/	1 Blow Down
	/	1 Blow Up
Axis III	/	1 Blow Down
	/	1 Blow Up

REMARKS 1.35V @ 9 MS DURATION ½ SINE.

Note: Axis I - Axial Direction
Axis II - Radial I (Brushes Horizontal)
Axis III - Radial II (Brushes Vertical)

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

POST SHOCK

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 30 APR 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 ma @ 10 VDC Rotation: 2 RPM Oscillation: 6 HZ 5°DA

Ckt. Pairs	Reading
~~1-2~~ 1-4	5
~~3-4~~ 2-5	7
~~5-6~~ 3-9	9
~~7-8~~ 7-10	5
~~9-10~~ 6-11	6
~~11-12~~ 8-12	6

Starting Torque: 19 MIN 38 MAX G/C

H. Drum

Technician

QUALIFICATION

D.C. RESISTANCE

POST SHOCK

P/S Part No. DP-1766 Serial No. NONE (S/N5) Date 1 MAY 69

Specification: .030 Ohms ± .015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.620
2	.639
3	.634
4	.768
5	.626
6	.630
7	.634
8	.630
9	.629
10	.631
11	.623
12	.674

H.
Technician

QUALIFICATION

INSULATION RESISTANCE

POST SHOCK

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 5-1-69

Test Voltage: 500 VDC Specification: Megohms Minimum

Circuit	Megohms
1	4000
2	150
3	4000
4	Short
5	Short
6	250
7	30
8	1000
9	Short
10	2000
11	Short
12	Short

Fred Akers
Technician

QUALIFICATION

D.C. RESISTANCE

AFTER LOAD TES.

P/S Part No. DP-1766 Serial No. NONE (S/N5) Date 8 JUL 69

Specification: +.030 Ohms±.015 Ohms Maximum

Test Current: 10 MA @ 10 VDC

Circuit	Ohms
1	.620
2	.638
3	.635
4	.768
5	.625
6	.627
7	.631
8	.623
9	.629
10	.630
11	.623
12	.670

H. Irwin
Technician

QUALIFICATION

NOISE and TORQUE TEST

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 8 JUL 69

Noise Spec: Milliohms Torque Spec: G/C Max.

G/C Min.

Test Current: 100 MA @ 10 VDC Rotation: 2 RPM Oscillation: 6 Hz

Ckt. Pairs	Reading
~~1-2~~ 1-4	11
~~3-4~~ 2-5	11
~~5-6~~ 3-9	11
~~7-8~~ 6-11	6
~~9-10~~ 7-10	6
~~11-12~~ 8-12	7

Starting Torque: 44 G/C

H. Irwin

Technician

QUALIFICATION

INSULATION RESISTANCE

AFTER LOAD TEST

P/S Part No. DP-1766 Serial No. NONE (S/N 5) Date 7-14-69

Test Voltage: 500 V DC Specification: ______ Megohms Minimum

Circuit	Megohms
1	4
2	5
3	Hi-Pot Short
4	Hi-Pot Short
5	Hi-Pot Short
6	20
7	10
8	20
9	Hi-Pot Short
10	20
11	Hi-Pot Short
12	Hi-Pot Short

Fred [illegible] 23

Technician

APPENDIX IV

ENGINEERING DRAWINGS

Litton Precision Products, Inc.
BLACKSBURG, VIRGINIA 24060

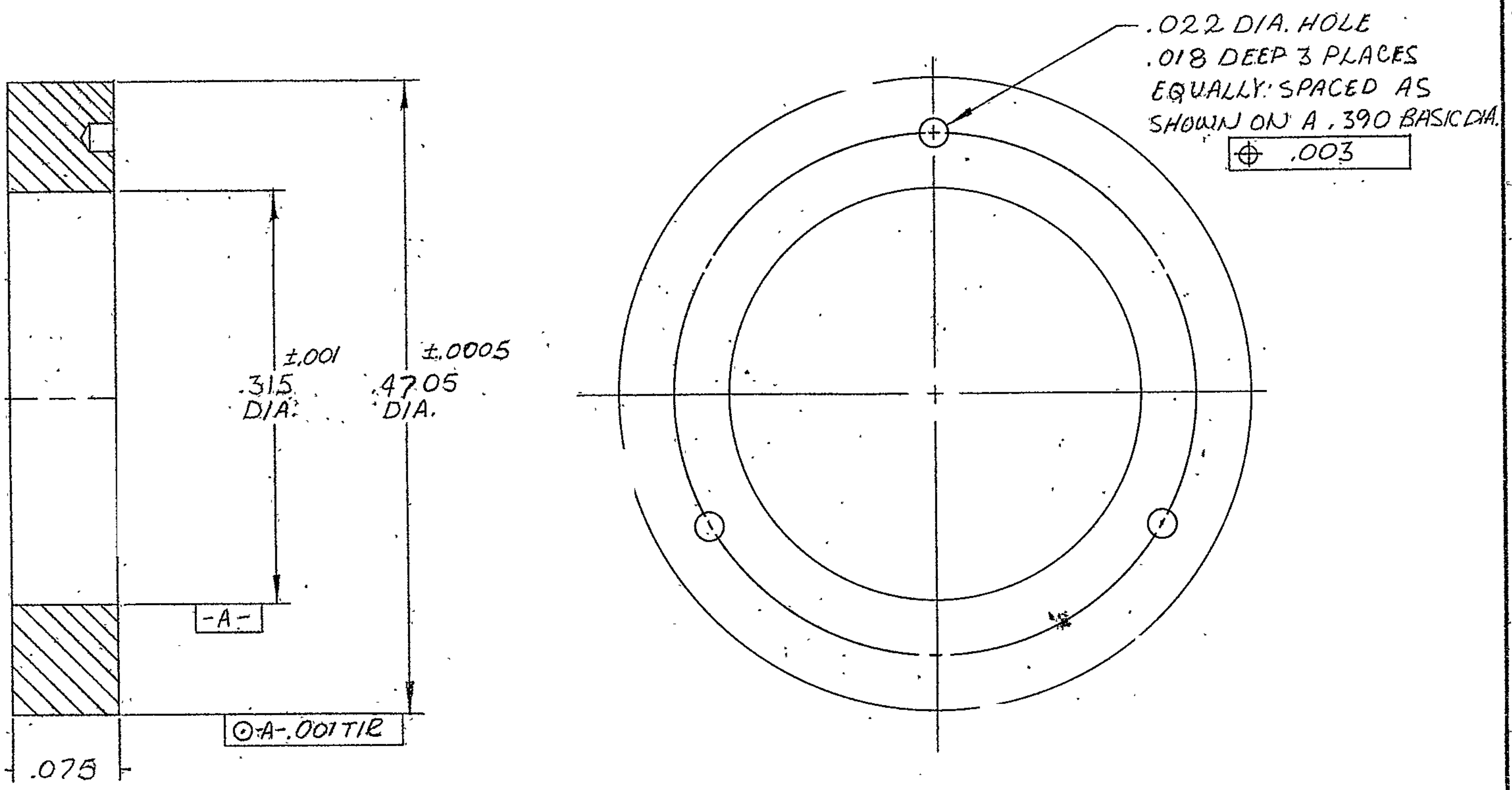
NOTICE: WHEN GOVERNMENT DRAWINGS. SPECIFICATIONS. OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION. THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED. FURNISHED. OR IN ANY WAY SUPPLIED THE SAID DRAWINGS. SPECIFICATIONS, OR OTHER DATA. IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE. USE. OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC., MAY OTHERWISE AGREE IN WRITING.

FILE: DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
A	ADD MATERIAL PER ECO 10544	9/15/67	



FOLDOUT FRAME 2

NOTE

Ⓐ 1. MAT'L - GRAPHITE: NON-ORGANIC CARBON/GRAPHITE (STACKPOLE CARBON GRADE 331 OR EQUIVALENT)

FOLDOUT FRAME

176629	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES.

		FRACTIONS
±	1/16	
		DECIMALS
.X	±	.030
.XX	±	.010
.XXX	±	.005
		ANGLES
X°	±	.5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE	DATE 3-17-67
CHECKED	DATE
ENGINEER	DATE 4-5-67
APPROVED	DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

SEAL RING

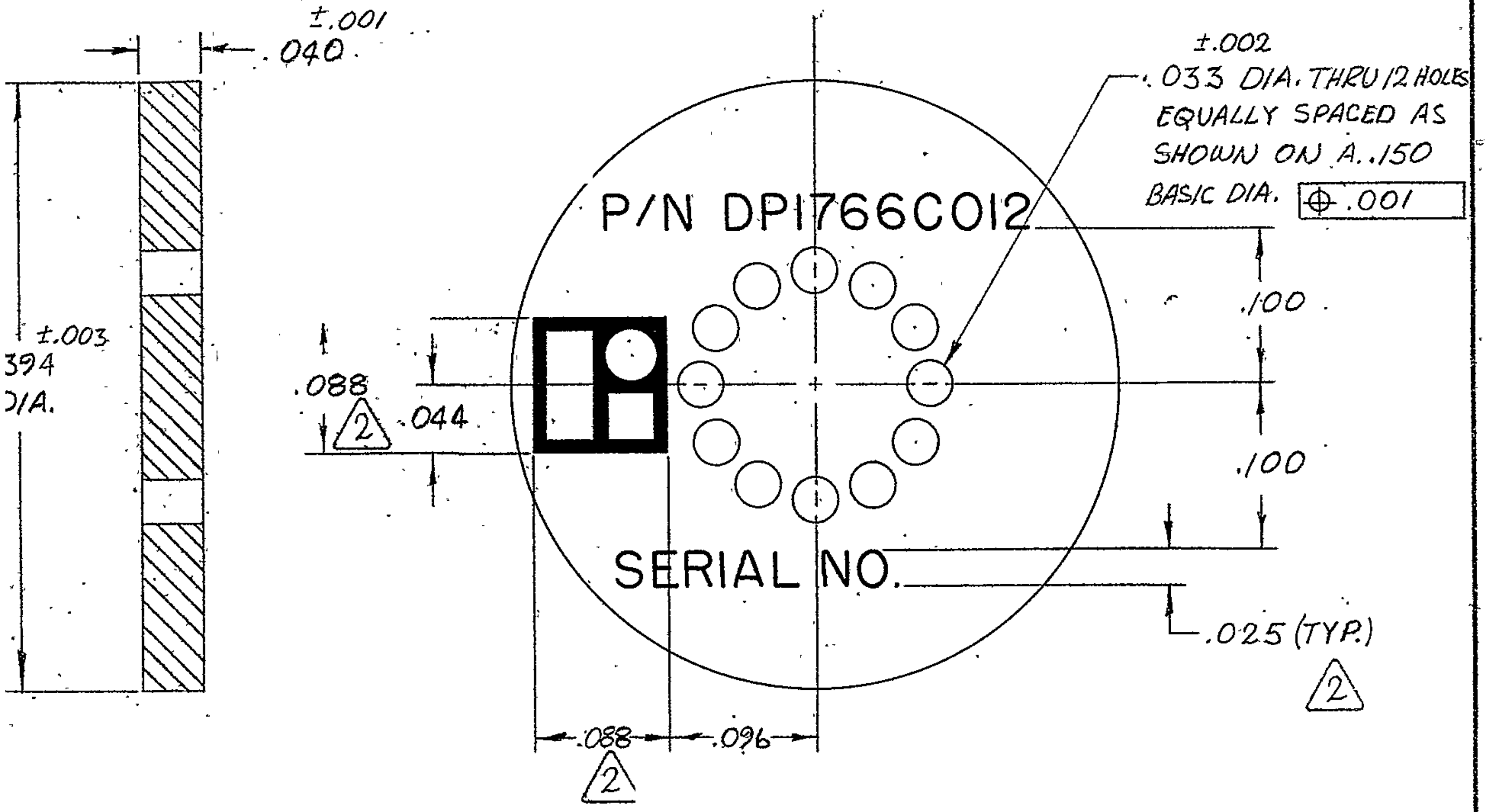
SIZE	CODE IDENT. NO.	DRAWING NUMBER
B	99932	176630 A

SCALE: 10:1 WEIGHT: SHEET 1 OF 1

FILE: DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED



NOTES:
1. MAT'L - FOTOFORM B.
2 DEPTH OF CHARACTERS MUST BE .010.

FOLDOUT FRAME 2

FOLDOUT FRAME

176602	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES:		FRACTIONS
±	1/16	
		DECIMALS
X	±	.030
.XX	±	.010
.XXX	±	.005
		ANGLES
X°	±	.5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

	DATE
DRAWN F. WOOLDRIDGE	2-28-67
CHECKED	
ENGINEER	3-22-67
APPROVED	

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

DISK (STYLE 5)

SIZE	CODE IDENT. NO.	DRAWING NUMBER
B	99932	176615

SCALE 10:1 WEIGHT: SHEET 1 OF 1

DP1766

LIST OF DRAWINGS

ENGR. REF.	PART NUMBER	QTY.	DESCRIPTION
DP 1766	176601 A		CAPSULE ASSY
	176602 D(E)	1	SLIP RING ASSY
	176603 C	1	SLIP RING SUB-ASSY
	176605 A	3	DISK (STYLE 1)
	176606 A	2	DISK (STYLE 2)
	176607 A	14	DISK (STYLE 3)
	176608 A	2	DISK (STYLE 4)
	[illegible]	[illegible]	[illegible]
	176612 B	12	LEAD (SLIP RING INTERNAL)
	176640	1	SHAFT
	176604 C	1	SLIP RING BASE
	176613	24	LEAD (EXTERNAL)
	176615	1	DISK (STYLE 5)
	176616 B(E)	1	BRUSH BLOCK ASSY (ODD)
	176617 B(E)	1	BRUSH BLOCK SUB-ASSY (ODD)
	176619-1 A	1	WAFER (ODD)
	176619-2 A	1	WAFER (ODD)
	176619-3 B(E)	1	WAFER (ODD)
	176619-4 B(E)	1	WAFER (ODD)
	176619-5 B(E)	1	WAFER (ODD)
	176619-6 B(E)	1	WAFER (ODD)
	176621-1 A thru 176621-3 A	4 ea	LEAD (B.B. INTERNAL)
	[illegible] (E)	[illegible]	
	176624	2	INSULATOR
	176625 B(E)	1	BRUSH BLOCK ASSY (EVEN)
	176626 B(E)	1	BRUSH BLOCK SUB-ASSY (EVEN)
	(E)	[illegible]	
	176630 A	1	SEAL RING
DP 1766	176631	1	SUPPORT RING ASSY

PREPARED	DATE
L GRAY	6-12-67
CHECKED	DATE
APPROVED	DATE

POLY-SCIENTIFIC
DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

PAGE 1 OF 2

LIST OF DRAWINGS
CAPSULE ASSY

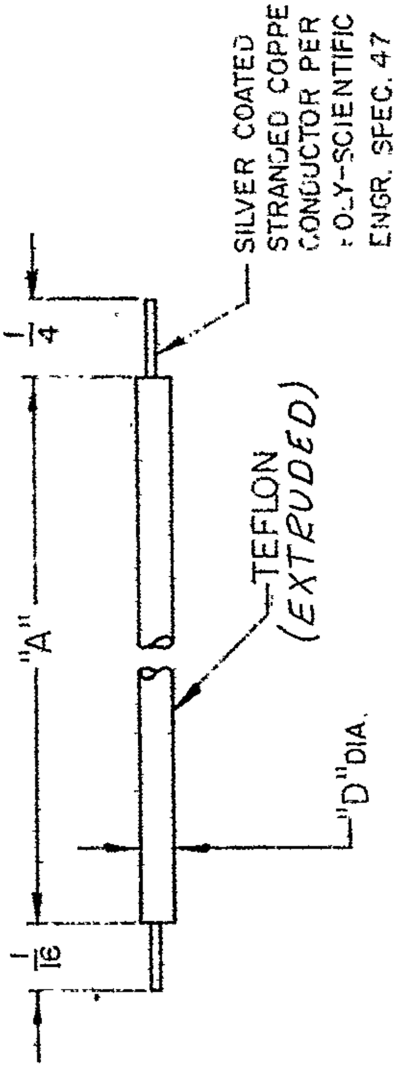
LD-DP1766C012

REV. E

176613 _

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVED

FILE. DP1766



35					
34					
33					
32					
31					
30					
29					
28					
27					
26					
25					
24					
23					
22					
21					
21					
19					
18					
17					
16					
15					
14					
13					
12					
11					
10					
9					
8					
7					
6					
5					
4					
3					
2					
1	CLEAR	32"	±.002 .028	30(19/42)	176613 _
	COLOR CODE	"A"	"D"	AWG	PART NO.

176625	DP1766	6
176616	DP1766	6
176602	DP1766	12
NEXT ASSY	PS FILE	QTY, REQD.
APPLICATION		

TOLERANCES [illegible]	DESIGNED	DATE	LEAD (EXTERNAL)
DECIMALS ± .005	DRAWN F. WOOLDRIDGE	DATE 3-2-67	
FRACTIONS ± 1/64	CHECKED	DATE 1-5-67	
[illegible]	APPROVED	DATE	SCALE NONE

POLY - SCIENTIFIC

DIVISION
LITTON PRECISION
PRODUCTS INC

BLACKSBURG, VIRGINIA

DWG NO. 176613 _

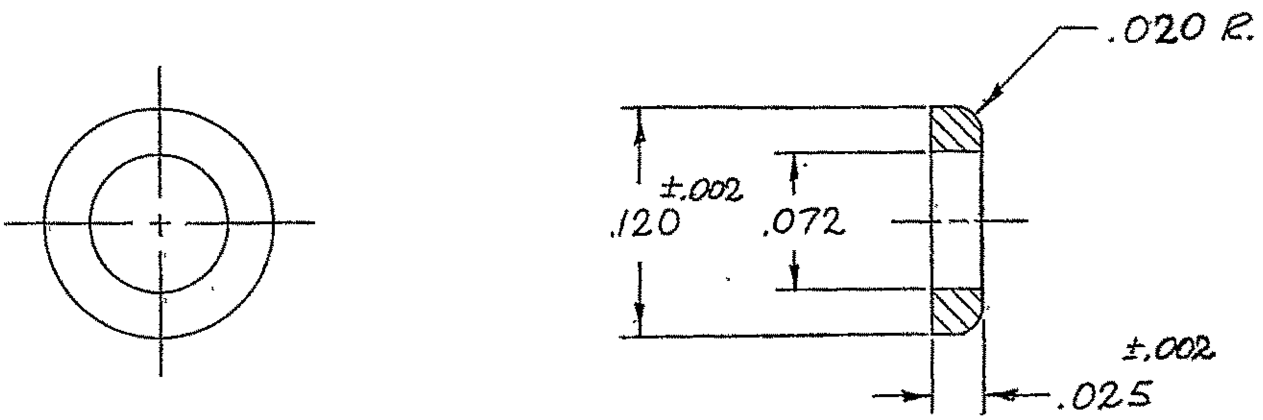
176636 —

REV.

FILE: DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED



NOTES

1. MAT'L - ST. STL. PER QQ-S-763b, TYPE 303, COND. A.

2. ALL OUTSIDE CORNERS MUST BE BROKEN .002-.006 R. OR CHAM.

3. MUST BE BURR FREE PER P-S E.S. 49, CLASS B.

4. MUST BE PASSIVATED PER P-S E.S. 19.

NEXT ASS'Y	P.S. FILE	QTY. REQ'D.
176601	DP1766	1

APPLICATION

TOLERANCES Unless Otherwise Specified		
DECIMALS ± .005	DESIGNED	DATE
FRACTIONS ± 1/64	DRAWN F. WOOLDRIDGE	DATE 3-18-67
ANGLES ± 1/2°	CHECKED	DATE 4-5-67
FED. SUPPLY CODE NO. 99932	APPROVED	DATE

COLLAR

POLY - SCIENTIFIC

DIVISION OF
LITTON PRECISION
PRODUCTS, INC.

BLACKSBURG, VIRGINIA

SCALE:

DWG. SIZE A

176636 —

SHEET 1 OF 1

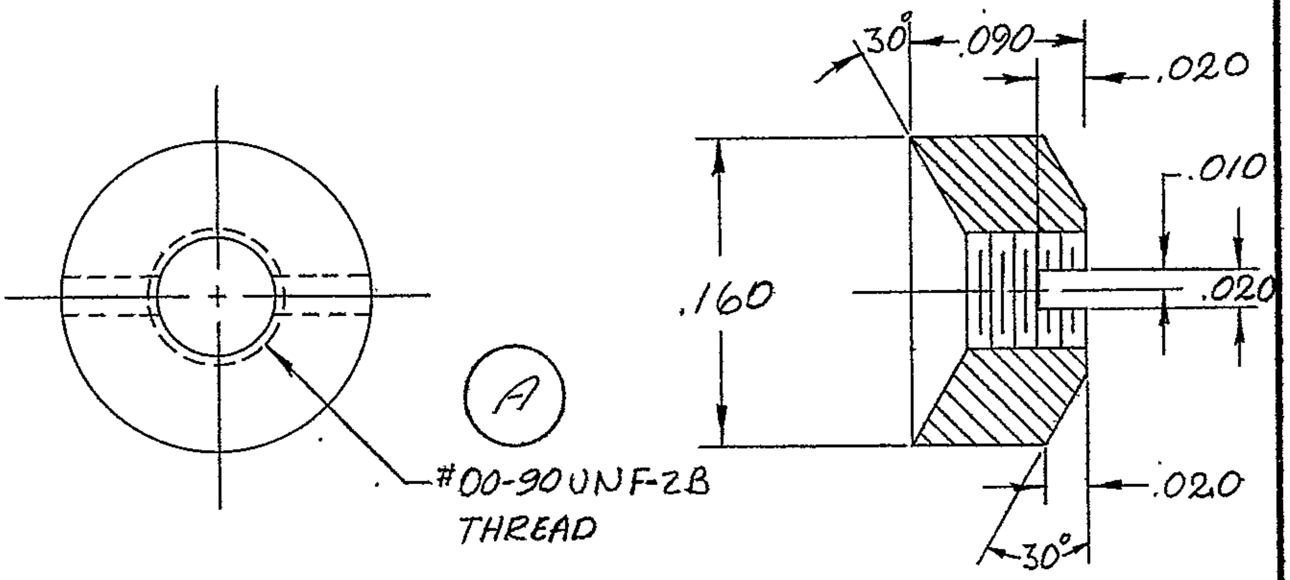
176637A

REV.

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
A	INC PER ECO #11526	2/17/68	D.H.

FILE: DP1766



NOTES

1. MAT'L – ST. ST'L PER QQ-S-763b, CLASS 303, COND. A.
2. ALL OUTSIDE CORNERS MUST BE BROKEN .002-.006 R. OR CHAM.
3. MUST BE BURR FREE PER PS E.S. 47, CLASS B.
4. MUST BE PASSIVATED PER P-S E.S. 19.

176601	DP1766	1
NEXT ASS'Y	P.S. FILE	QTY. REQ'D.

APPLICATION

TOLERANCES UNLESS OTHERWISE SPECIFIED		
DECIMALS ± .005	DESIGNED	DATE
FRACTIONS ± 1/64	DRAWN F. WOOLDRIDGE	DATE 4-18-67
ANGLES ± 1/2°	CHECKED	DATE 4-5-67
FED. SUPPLY CODE No. 99932	APPROVED	DATE

NUT

POLY - SCIENTIFIC
DIVISION OF
LITTON PRECISION
PRODUCTS, INC.
BLACKSBURG, VIRGINIA

SCALE:

DWG. SIZE A

176637A

SHEET 1 OF 1

LIST OF DRAWINGS

ENGR. REF.	PART NUMBER	QTY.	DESCRIPTION
DP 1766	176632 A	1	FRAME
	176633 A	1	HOUSING
	176634 —	1	GASKET
	176635 —	3	SPRING
	176636 —	1	COLLAR
DP 1766	176637 A	1	NUT
DP 1766	176641 —	12	BRUSH
		1	BEARING (BARDEN #SR133SSWX17K25)
		1	BEARING (BARDEN #SR156SSWX13)
		2	SCREW (J. I. MORRIS 0-80 X .125 LG, ST. STL. FIL. HD.)
		4	SCREW (J. I. MORRIS 000-120 X .094 LG. ST. STL. FIL. HD.)
	(E)	AR	SAUEREISEN CEMENT NO. 31
	176628-1 A	1	WAFER (EVEN)
	176628-2 A	1	WAFER (EVEN)
	176628-3 B(E)	1	WAFER (EVEN)
	176628-4 B(E)	1	WAFER (EVEN)
	176628-5 B(E)	1	WAFER (EVEN)
	176628-6 B(E)	1	WAFER (EVEN)

PREPARED F. W. DATE 3/31/67

CHECKED DATE

APPROVED DATE 4/6/67

POLY-SCIENTIFIC
DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

PAGE 2 OF 2

LIST OF DRAWINGS

CAPSULE ASSY

LD-DP1766C012

REV. E

176641 —

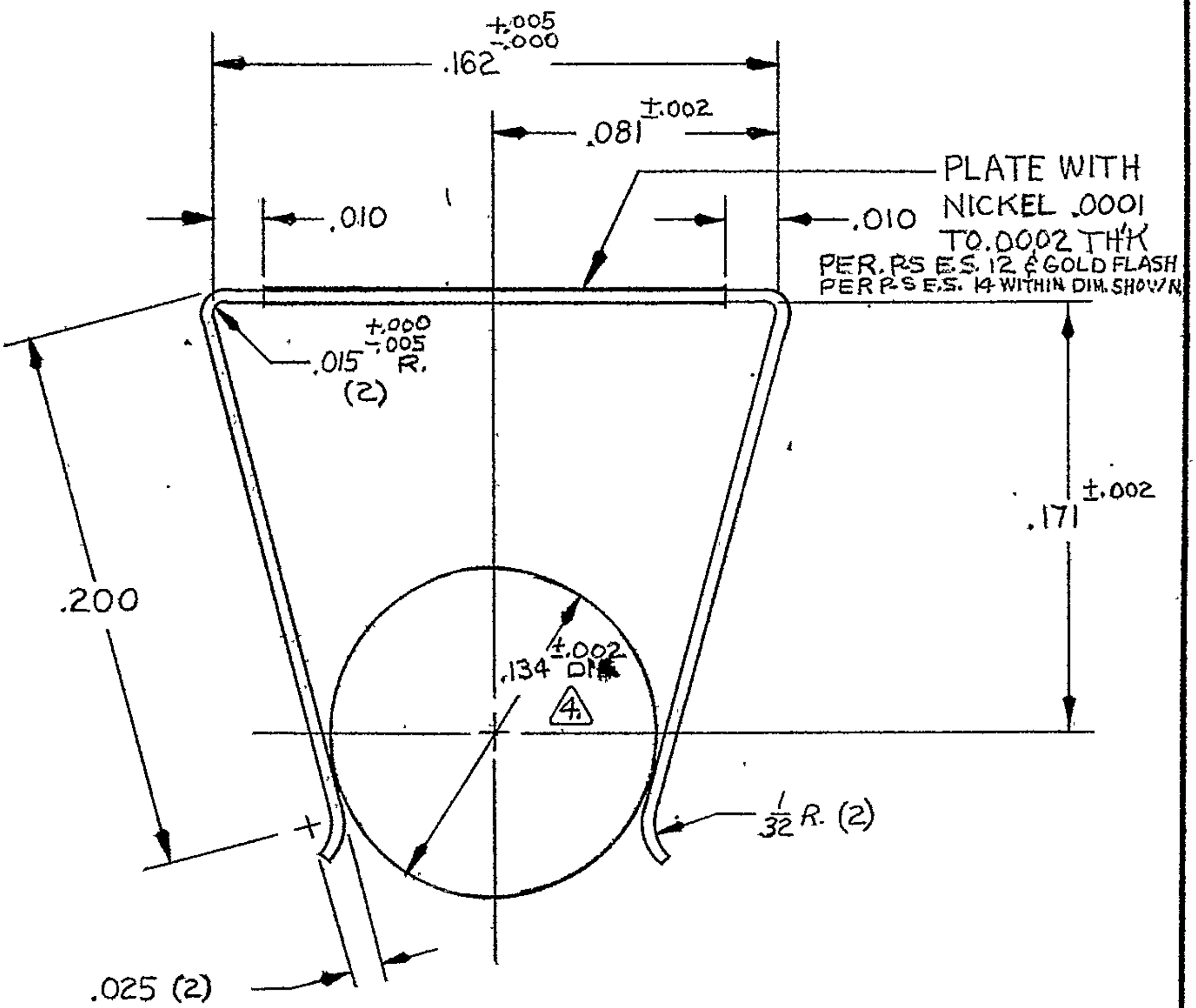
REV.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC., MAY OTHERWISE AGREE IN WRITING.

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
—	CREATED PER ECO 12136 D.H.	10-6-69	RH.

FILE: DP1766



NOTES:

1. MAT'L; .009 DIA. WIRE PER E.S. 57 COND. CWZ.
2. DEBURR PER E.S. 49 CLASS B..
3. DESIGNED FOR 2 3/4 GRAMS FORCE ON .148 DIA (REF.)
4. FREE DIA. AFTER SOLDERING SHALL BE .139 ±.002 DIA. REF.

176601	DP 1766	12
NEXT ASS'Y	**P.S. FILE**	**QTY. REQ'D.**

APPLICATION

TOLERANCES UNLESS OTHERWISE SPECIFIED
DECIMALS ± .005
FRACTIONS ± 1/64
ANGLES ± 1/2°
FED. SUPPLY CODE NO. 99932

DESIGNED DATE
DRAWN R. DUNCAN DATE 10-6-69
CHECKED RH DATE 10-6-69
APPROVED DATE

BRUSH

POLY - SCIENTIFIC
DIVISION OF
LITTON PRECISION
PRODUCTS, INC.
BLACKSBURG, VIRGINIA

SCALE: NONE
DWG. SIZE A
176641 —
SHEET 1 OF 1

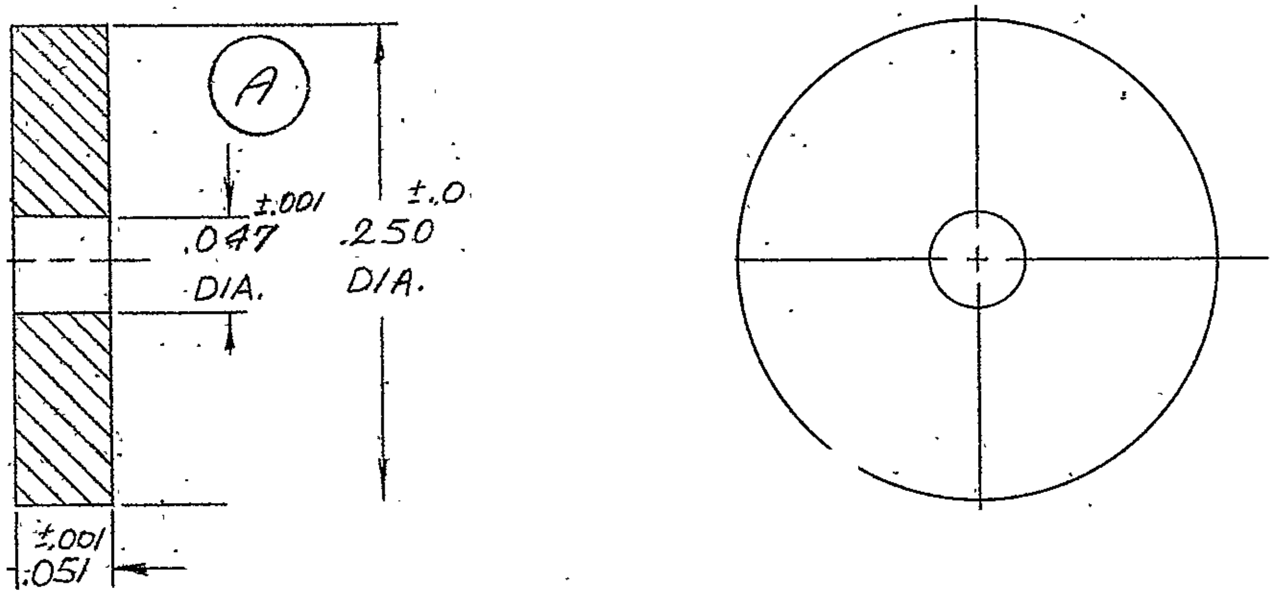
NOTICE: WHEN GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. MAY OTHERWISE AGREE IN WRITING.

FILE DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
A	INC PER ECO # 11526 CHA	2/17/68	D.H.
B	INC PER ECO # 11814 CHA	3/26/68	D.H.



NOTE
1. MAT'L - FOTOFORM B.

Ⓑ
Ⓐ

FOLDOUT FRAME 2

FOLDOUT FRAME 1

176603	DP1766	3
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONS ± 1/16
DECIMALS
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± 5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE DATE 2-24-67
CHECKED DATE
ENGINEER DATE 3-22-67
APPROVED DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

DISK (STYLE 4)

SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176608 B

SCALE: WEIGHT: SHEET OF

DP1766

5 4 3 2 1

FILE: DP1766

REVISIONS

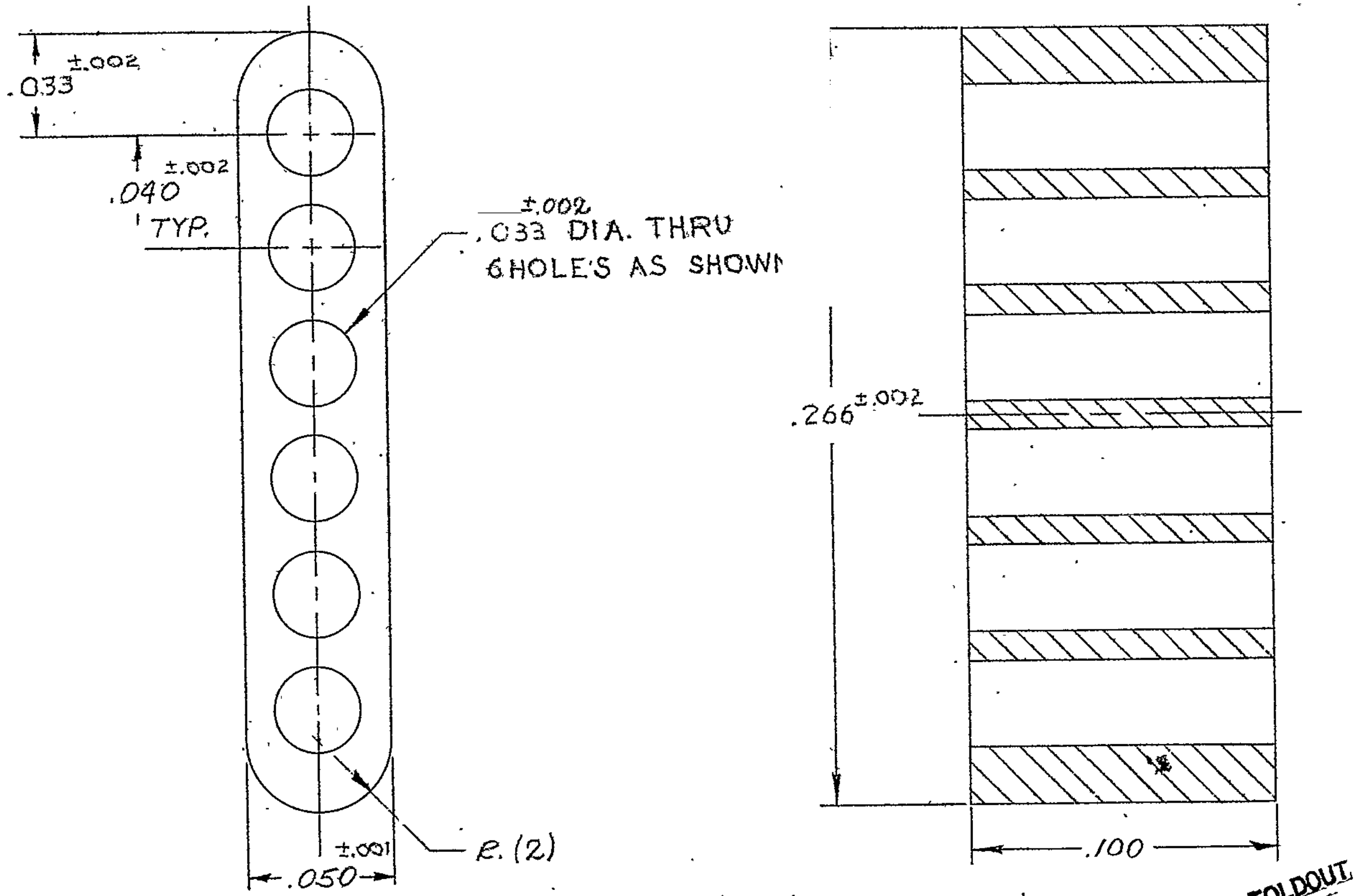
SYM.	DESCRIPTION	DATE	APPROVED

D

C

B

A



NOTES:
1. MAT'L - FOTOFORM B.

FOLDOUT FRAME

FOLDOUT FRAME 2

176625	DP1766	1
176616	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:

		FRACTIONS
±	1/16	
		DECIMALS
.x	±	.030
.xx	±	.010
.xxx	±	.005
		ANGLES
x°	±	5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

DRAWN F. WOOLDRIDGE	DATE 3-9-67
CHECKED	DATE
ENGINEER	DATE 4-5-67
APPROVED	DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

INSULATOR

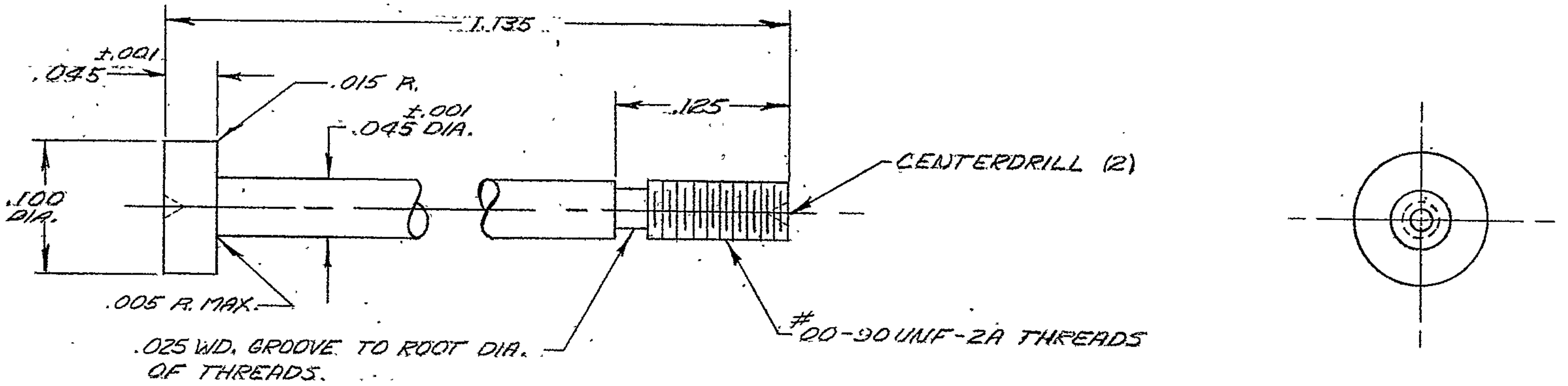
SIZE	CODE IDENT. NO.	DRAWING NUMBER
B	99932	176624 —

SCALE: 20:1 WEIGHT: SHEET 1 OF 1

DP1766

File: DP1766

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVED
-	CREATED PER ECO# 11814	3/22/68	D.H.



Notes:
1. MAT'L - ST. STL. 416 PER QQ-S-763, COND. H.
2. ALL SHARP EDGES SHALL BE .003-.005 R. OR CHAM. EXCEPT ON THREADS.
3. MUST BE BURR FREE PER P-S. E.S. 49, CLASS "C".
4. CENTERDRILL PERMISSIBLE, BOTH ENDS.
5. PASSIVATE PER P-S E.S. 19.

FOLDOUT FRAME 2

FOLDOUT FRAME 1

176602	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONS ± 1/16
DECIMALS
X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± 5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN D. COVEY — DATE 3-20-68
CHECKED D. HYLTON — DATE 3-29-68
ENGINEER — DATE 4/3/68
APPROVED — DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

SHAFT

SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176640
SCALE: 10:1
WEIGHT:
SHEET 1 OF 1

5 4 3 2 1

NOTICE WHEN GOVERNMENT DRAWINGS SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS INC. ANY REPRODUCTION DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION LITTON PRECISION PRODUCTS, INC. MAY OTHERWISE AGREE IN WRITING

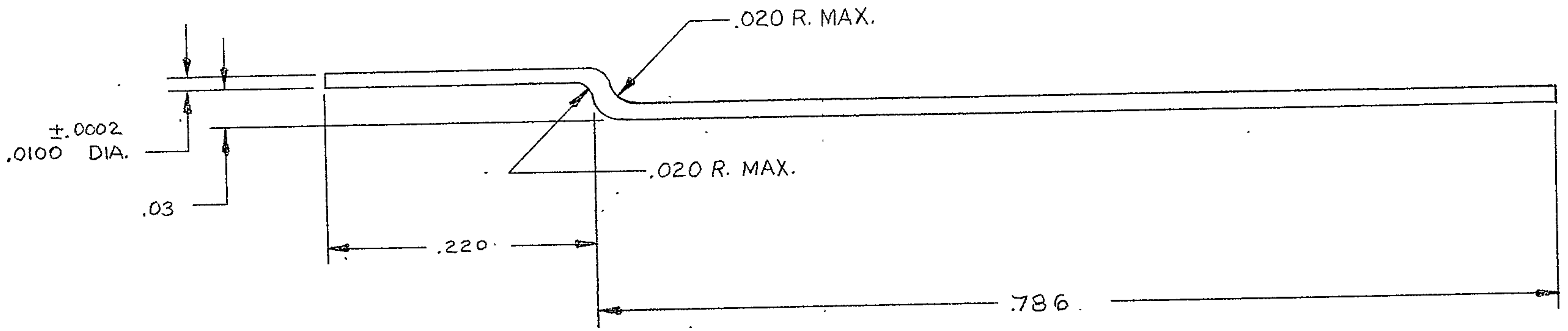
"THIS DOCUMENTARY MATERIAL IS SUBMITTED WITH THE UNDERSTANDING THAT IT WILL BE RETAINED ON A PRIVILEGED OR CONFIDENTIAL BASIS PURSUANT TO SECTION 3 (E) (4) OF PUBLIC LAW 89-487."

FILE: DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
B	REDRAWN INC. ECO 12336 RED	10-3-69	

D



C

B

NOTES:

1. MAT'L - PER P-S E.S. 56, COND. A.
2. DEBURR PER P-S E.S. 49, CLASS C.

FOLDOUT FRAME 2

FOLDOUT FRAME 1

176603	DP1766	12
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES.

FRACTIONS	±	1/16
DECIMALS		
X	±	030
XX	±	010
.XXX	±	005
ANGLES		
X°	±	.5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE	DATE 2-27-67
CHECKED	DATE
ENGINEER	DATE 3-22-67
APPROVED	DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

LEAD
(SLIP RING INTERNAL)

SIZE	CODE IDENT. NO.	DRAWING NUMBER
B	99932	176612 B

SCALE: 10:1 WEIGHT: SHEET 1 OF 1

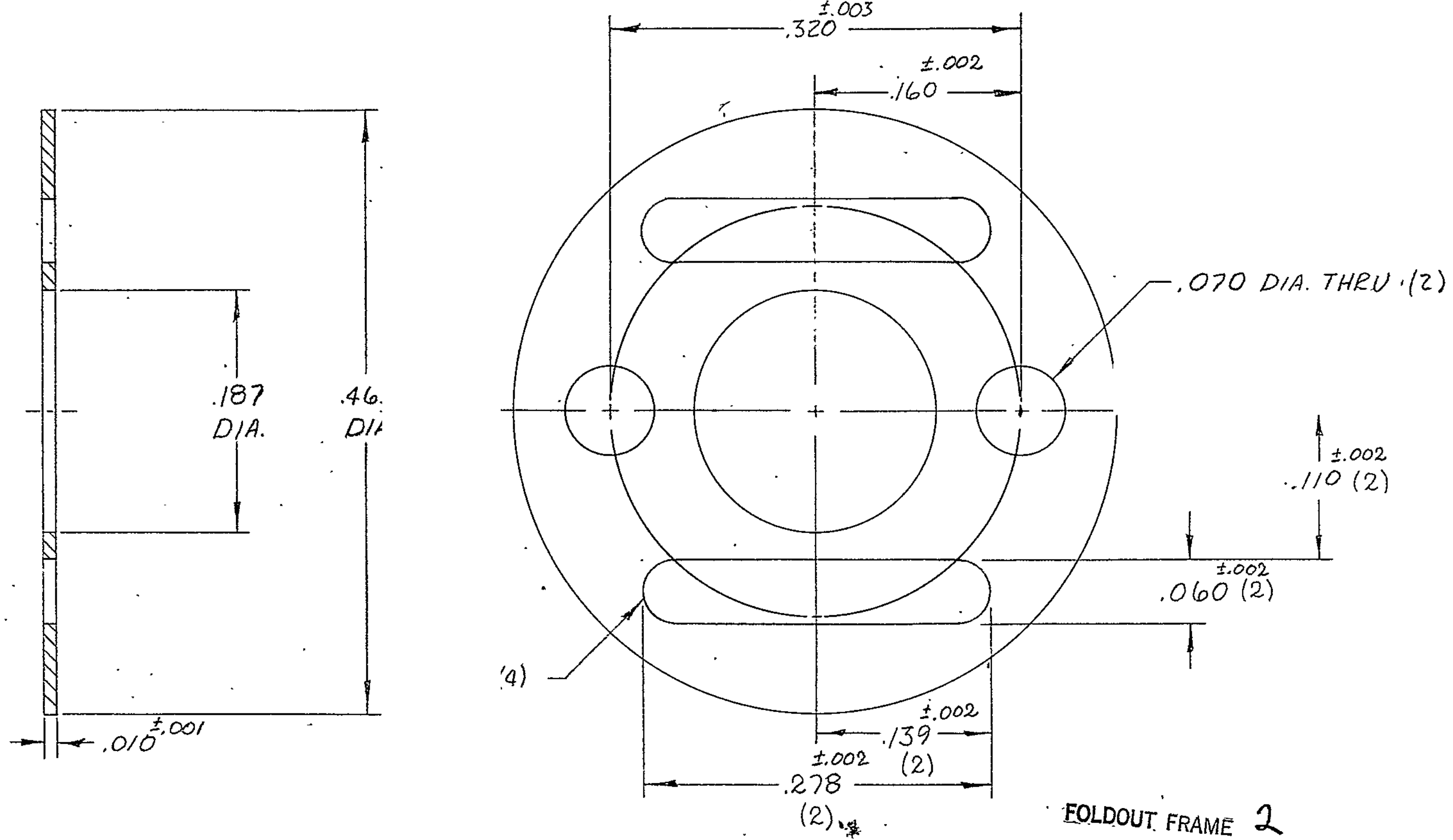
A

NOTICE: WHEN GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS INC ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC., MAY OTHERWISE AGREE IN WRITING

FILE DP1766

SYM.	DESCRIPTION	DATE	APPROVED



NOTE

1. MAT'L – GOLD PER P-S ES. 118.

FOLDOUT FRAME 2

FOLDOUT FRAME 1

176601	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES, FRACTIONS
± 1/16
DECIMALS
.X ± 030
XX ± .010
.XXX ± .005
ANGLES
X° ± 5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE DATE 3-17-67
CHECKED DATE
ENGINEER DATE 4-5-67
APPROVED DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

GASKET

SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176634
SCALE. 10:1
WEIGHT:
SHEET 1 OF 1

DP17

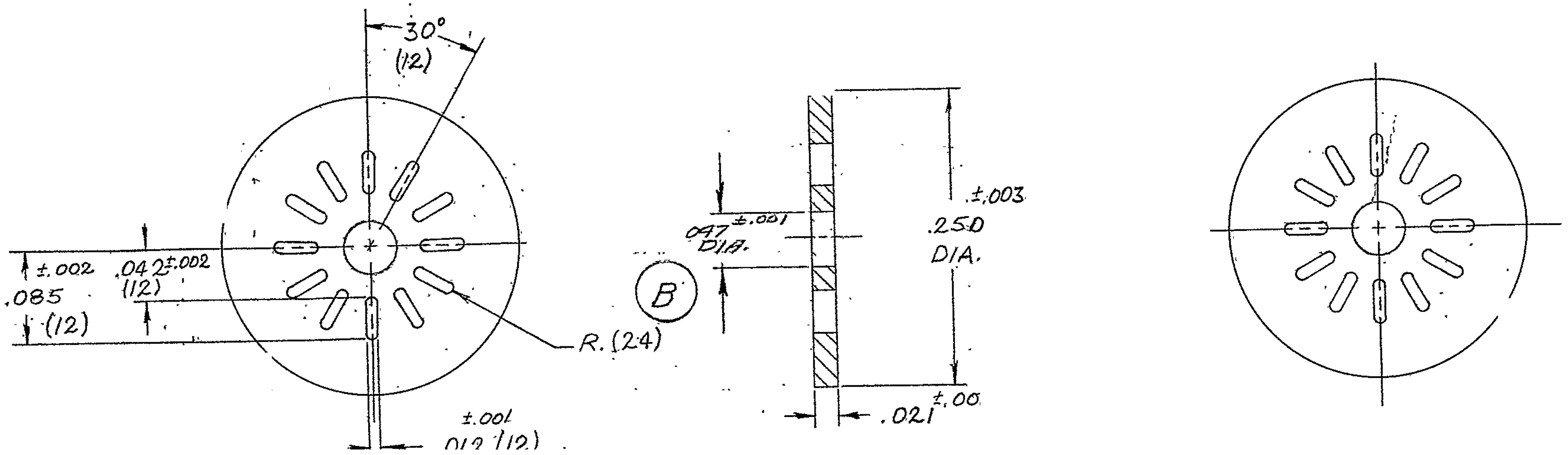
NOTICE: WHEN GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. MAY OTHERWISE AGREE IN WRITING.

FILE: DP 1766

REVISIONS

SYM.	DESCRIPTION		DATE	APPROVED
A	INC PETR ECO # 11526	CHA	2/17/68	D.H.
B	INC PETR ECO # 11814	CHA	3/26/68	D.H.



NOTE

1. MAT'L – FOTOFORM B.

A

FOLDOUT FRAME 2

176603	DP 1766	2
NEXT ASS'Y.	PS FILE	QTY/ REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONS ± 1/16
DECIMALS
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± .5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE DATE 2-24-67
CHECKED DATE
ENGINEER DATE 3-22-67
APPROVED DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

DISK (STYLE 2)

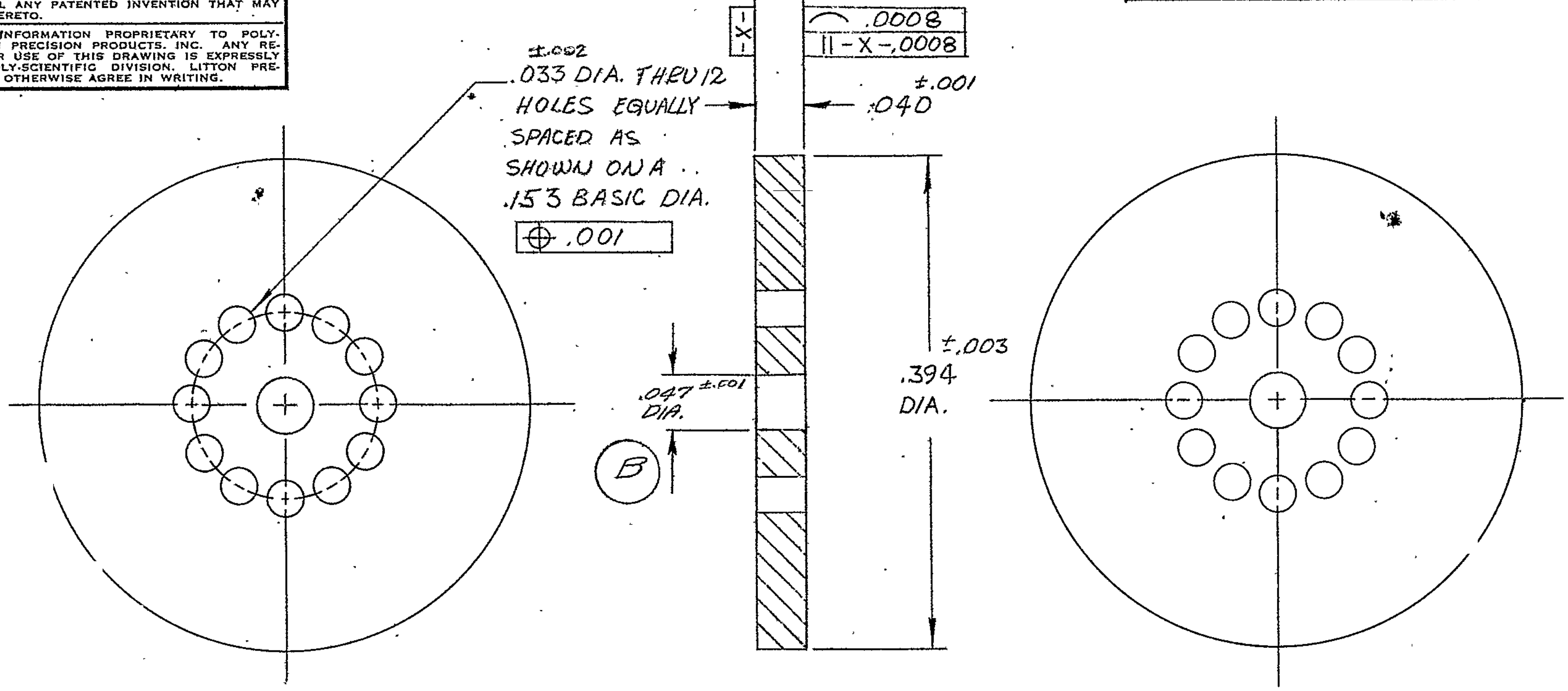
SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176606 B
SCALE: 10:1
WEIGHT:
SHEET 1 OF 1

FOLDOUT FRAME 1

FILE: DP1766.

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
A	INC PER ECO # 11526 CWJ.	3/17/65	D.H.
B	INC PER ECO # 11814 CHA	3/[illegible]	D.H.



NOTE
1. MAT'L - FOTOFORM B.

A B

FOLDOUT FRAME 2

176603	DP1766	2
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/16
DECIMALS
X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± 5

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE	DATE 2-22-67
CHECKED	DATE
ENGINEER	DATE 3-22-67
APPROVED	DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

DISK (STYLE I)

SIZE	CODE IDENT. NO	DRAWING NUMBER
B	99932	176605 B

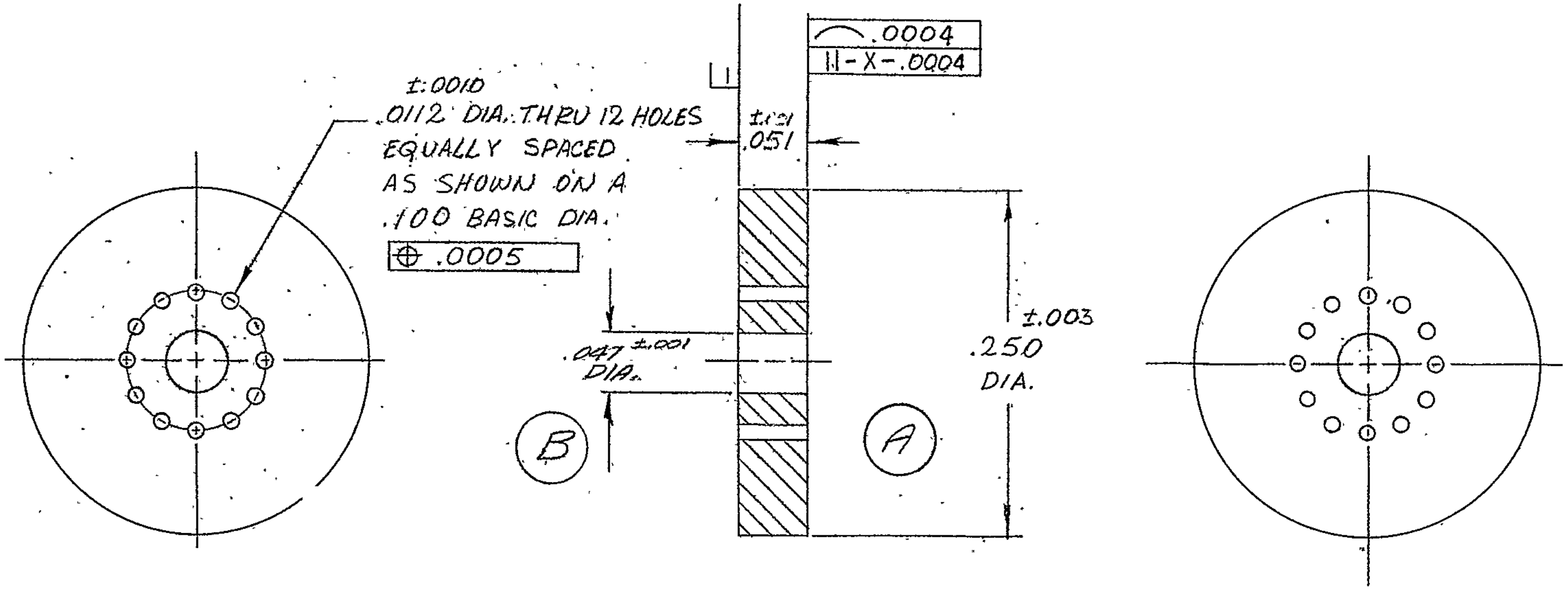
SCALE: 10/1 WEIGHT SHEET 1 OF 1

FOLDOUT FRAME 1

FILE DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED
A	INC PER ECO # 11526 CHA	2/17/68	D.H.
B	INC PER ECO # 11814 CHA	3/26/68	D.H.



NOTE
1. MAT'L - FOTOFORM B.

B

FOLDOUT FRAME 2

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

176603	DP1766	15
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONS ± 1/16
DECIMALS
.X ± .030
.XX ± .010
XXX ± .005
ANGLES
X° ± 5

DO NOT SCALE DRAWING

MATERIAL

FINISH

		DATE
DRAWN	F. WOOLDRIDGE	2-22-67
CHECKED		DATE
ENGINEER		DATE 3-22-67
APPROVED		DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

DISK (STYLE 3)

SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176607 B
SCALE: 10:1
WEIGHT:
SHEET 1 OF 1

FOLDOUT FRAME 1

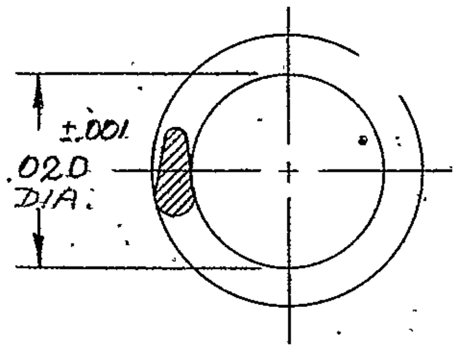
5 4 3 2 1

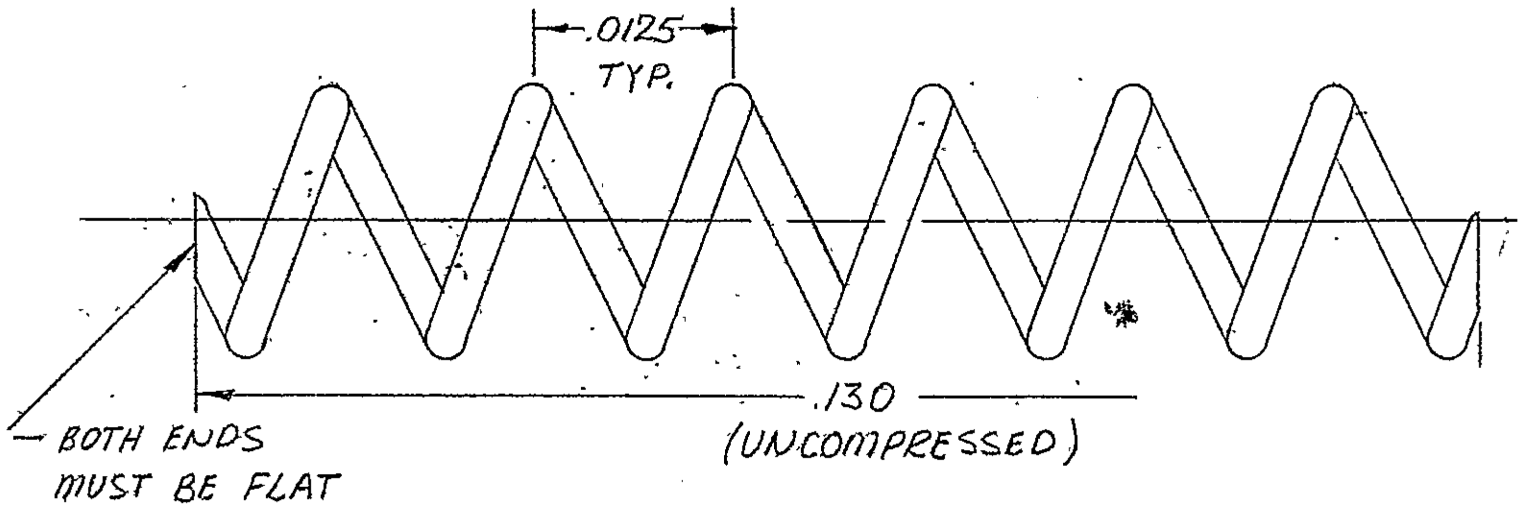
NOTICE: WHEN GOVERNMENT DRAWINGS, SPECIFICATIONS, OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE UNITED STATES GOVERNMENT THEREBY INCURS NO RESPONSIBILITY NOR ANY OBLIGATION WHATSOEVER, AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA, IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE, OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

THIS DRAWING CONTAINS INFORMATION PROPRIETARY TO POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC. ANY REPRODUCTION, DISCLOSURE OR USE OF THIS DRAWING IS EXPRESSLY PROHIBITED EXCEPT AS POLY-SCIENTIFIC DIVISION, LITTON PRECISION PRODUCTS, INC., MAY OTHERWISE AGREE IN WRITING.

FILE DP1766

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVED





NOTE

1. MAT'L - .005 DIA. E.S. 55. FORM FROM COND. A, THEN HEAT TREAT TO COND. HT.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

176601	DP1766	3
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONS ± 1/16
DECIMALS
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± 5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

ITEM	REQ'D	PART NO.	DESCRIPTION

LIST OF MATERIAL

DRAWN F. WOOLDRIDGE DATE 3-18-6
CHECKED DATE
ENGINEER DATE 4-5-67
APPROVED DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

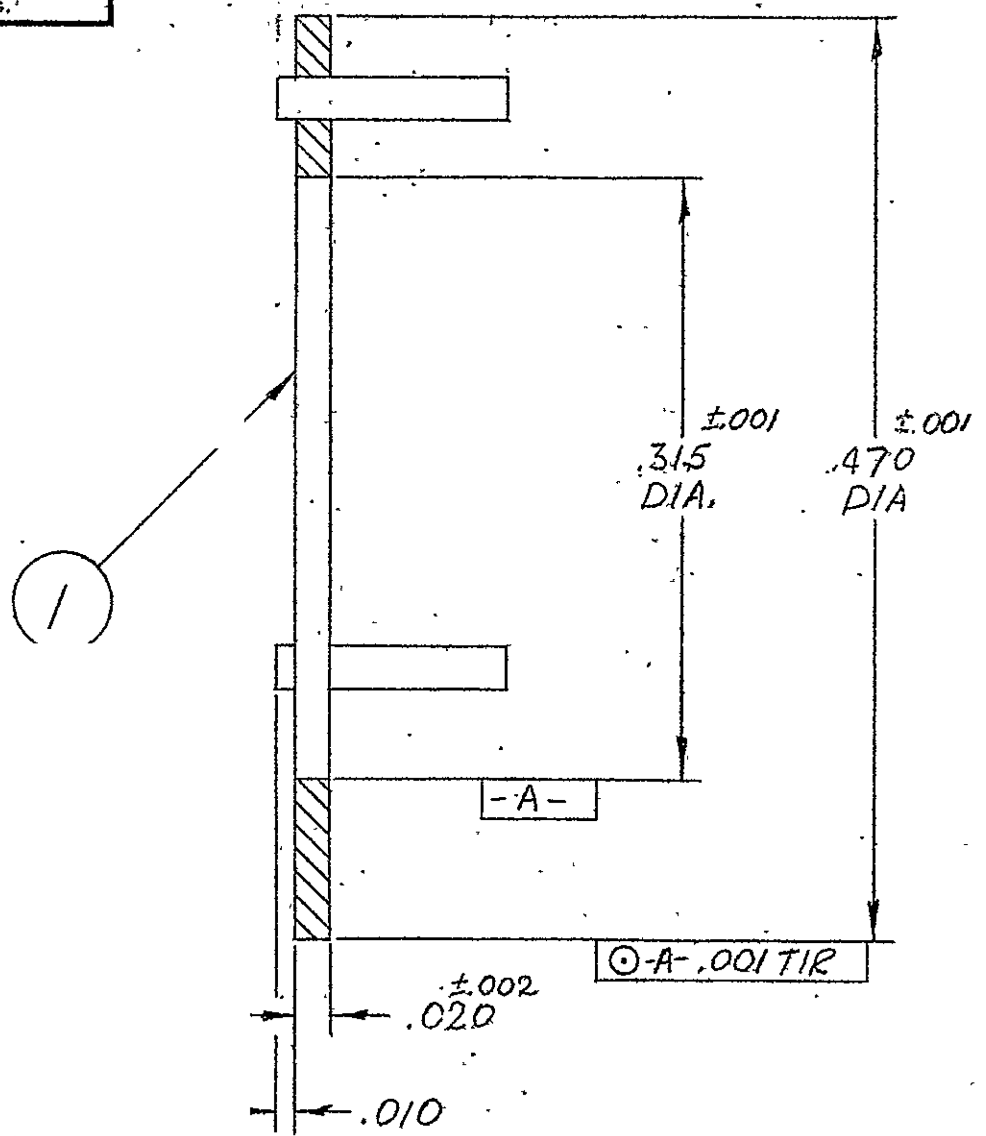
SPRING

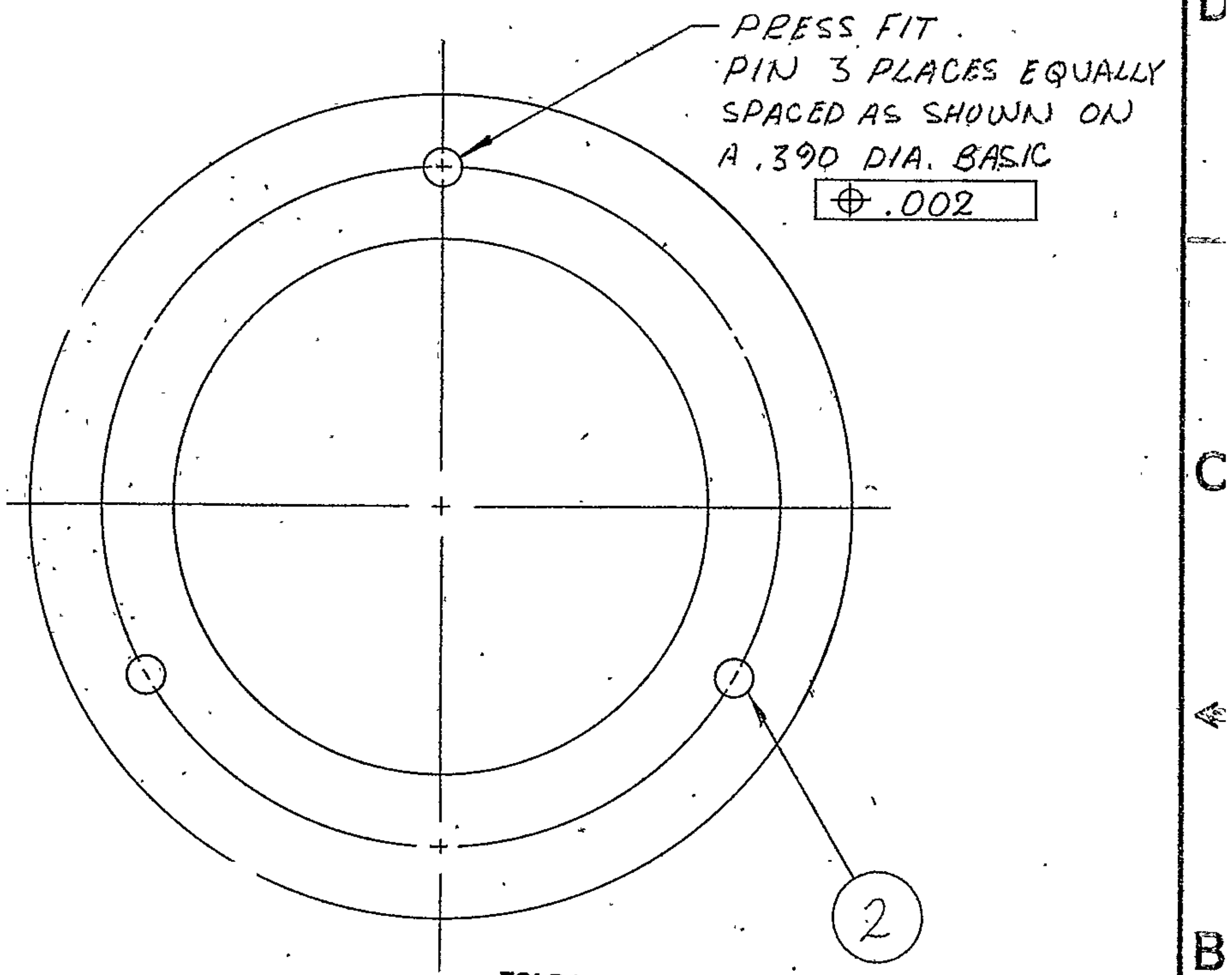
SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176635
SCALE 50:1
WEIGHT:
SHEET 1 OF 1

FILE: DP1766

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVED





FOLDOUT FRAME 2

NOTES

1. MAT'L - ST. STL TYPE 303 PER QQ-S-763b, COND. A.
2. ALL OUTSIDE CORNERS MUST BE BROKEN .002-.008 R. OR CHAM.
3. MUST BE BURR FREE PER P-S E.S. 49, CLASS B.
4. MUST BE PASSIVATED PER P-S E.S. 19.

FOLDOUT FRAME 1

176629	DP1766	1
NEXT ASS'Y.	PS FILE	QTY. REQ'D.

APPLICATION

ITEM	REQ'D	PART NO.	DESCRIPTION
2	3	————	.018$^{\pm.001}$ DIA. (#25AWG) ST. STL. PIN X .120 LONG
1	1	————	AS SHOWN

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONS ± 1/16
DECIMALS
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES
X° ± .5°

DO NOT SCALE DRAWING

MATERIAL

FINISH

DRAWN F. WOOLDRIDGE DATE 3-17-67
CHECKED DATE
ENGINEER S. Bonelan DATE 1-5-67
APPROVED DATE

POLY-SCIENTIFIC DIVISION
LITTON PRECISION PRODUCTS, INC.
BLACKSBURG, VIRGINIA

SUPPORT RING ASSY

SIZE B
CODE IDENT. NO. 99932
DRAWING NUMBER 176631
SCALE: 10:1
WEIGHT:
SHEET 1 OF 1

DP1766

POLY-SCIENTIFIC DIVISION
Litton Precision Products, Inc.
BLACKSBURG, VIRGINIA 24060

POLYSCIENTIFIC DIVISION
Litton Precision Products, Inc.
BLACKSBURG, VIRGINIA 24060