NASA CR 143794

FABRICATION AND EVALUATION OF AN OSO-I TYPE BASEPLATE

To

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

May 6, 1975

Contract Number NAS5-11411

by

C. W. Marschall

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BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

FINAL REPORT

on

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FOREWORD

This report was prepared by Battelle's Columbus Laboratories under National Aeronautics and Space Administration Contract No. NAS5-11411. The work was administered under the direction of the Goddard Space Flight Center with Mr. Frank J. Cepollina (Code 410) as Technical Officer.

SUMMARY

A program was conducted to prepare a demonstration OSO-I type baseplate of a low thermal-expansion material--Owens-Illinois Cer-Vit C-126--and to evaluate its dimensional stability after exposure to thermal cycling and mechanical vibration. The results indicate that Cer-Vit C-126 baseplates of relatively simple design can be successfully cast and machined, although the demonstration article produced in this program deviated somewhat from design specifications. Furthermore, it is likely that baseplates of more sophisticated designs and improved structural efficiency can be prepared from Cer-Vit C-126.

Some uncertainty exists relative to the dimensional stability of the baseplate. Thermal cycling 30 times from -46 to +38 C (-50 to +100 F) caused an apparent uniform growth of about 5 to 8 x 10^{-6} inch/inch. Exposure to mechanical vibration was not attempted due to deviations of the plate from design tolerances and to the fact that the plate was not designed to withstand a typical vibration spectrum for launch into earth orbit. Instead, the baseplate was subjected to five vacuum thermal cycles from -100 to +100 C (-150 to +210 F). The effect of this latter treatment on dimensional stability is uncertain because of possible detrimental effects of this treatment on the measuring instrumentation.

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FABRICATION AND EVALUATION OF AN OSO-I TYPE BASEPLATE

by

C. W. Marschall

INTRODUCTION

Spectrometers in an orbiting solar observatory (OSO) require a dimensionally stable baseplate in order to function properly. Thus, the material from which the baseplate is made (1) must not distort permanently under its own weight and the weight of instruments over long periods of time prior to launch, (2) must neither distort permanently, nor fracture, under the relatively high, short-duration stresses and the mechanical vibrations encountered during launch, (3) once in orbit, must not undergo excessive reversible dimensional changes associated with thermal expansion and temperature variations, and (4) must not distort permanently over long periods of time under the influence of temperature cycling associated with light/dark cycles of the observatory.

In 1970, at the time that NASA-Goddard Space Flight Center issued RFP No. 17251-103 for fabrication and evaluation of an OSO-I type baseplate, three main candidate materials were considered: beryllium, TZM molybdenum, and a glass-ceramic material, Owens-Illinois Cer-Vit C-126. Several properties of importance in dimensionally stable design are compared for these three materials in Table 1. Although beryllium has the lowest density and highest modulus and TZM has the highest microyield strength, NASA selected Cer-Vit C-126 as the baseplate material on the basis of its near-zero thermal expansivity and its relatively low density.

TABLE 1. COMPARISON OF PROPERTIES OF CANDIDATE MATERIALS FOR OSO BASEPLATE

Material	Density,		Young's Modulus		Thermal Expansivity,	Microyield Strength	
	kg/m^3	lb/in^3	GPa	psi	$10^{-6}/°K$	MPa	ksi
S-200 Beryllium	1855	0.067	293	42.5×10^6	11.5	$\sim$14	$\sim$2
TZM Molybdenum, Stress relieved at 2200 F	10240	0.37	295	42.8×10^6	5.4	360	52
Owens-Illinois Cer-Vit C-126	2510	0.091	85	12.3×10^6	-0.35	>83	>12

Accordingly, early in 1971 NASA issued a contract to Battelle's Columbus Laboratories for preparation and evaluation of an OSO-I type baseplate. The plate was to be fabricated from Cer-Vit C-126 under a subcontract to Owens-Illinois, Incorporated, at their Development Center in Toledo, Ohio.

PROGRAM OBJECTIVES

The program had two primary objectives:

(1) Fabrication of a Cer-Vit C-126 baseplate having nominal outside dimensions of 54 x 13.5 x 2 inches.

(2) Evaluation of the dimensional stability of the baseplate after thermal cycling 30 times between -46 and +38 C (-50 and +100 F) and after mechanical vibration.

The vibration was to be accomplished at NASA-Goddard and was originally intended to simulate a typical launch spectrum. However, during the plate design stage of the program, it was agreed that the vibration severity would be lessened because the baseplate was to be a demonstration unit of unsophisticated design. Late in the program, NASA personnel decided against vibrating the baseplate and elected instead to expose it to thermal vacuum testing (5 cycles, +100 to -100, 10^{-7} mm Hg).

MATERIAL

Cer-Vit C-126 is a structural grade of low-expansion glass ceramic developed by Owens-Illinois, Incorporated. Although its composition is proprietary, it consists of various oxides -- Li_2O, Al_2O_3, SiO_2, for example -- and nucleating agents. It is originally cast as a glassy product that exhibits positive thermal expansivity. The glass is subsequently heat treated to cause partial crystallization. As crystallization proceeds, the thermal expansion coefficient gradually declines, reaching zero or even slightly negative values. The mixed microstructure of ceramic crystals in a glass matrix gives rise to the name glass-ceramic.

Because of their potential usefulness in high-precision optical systems, Cer-Vit C-126 and other glass and glass-ceramic materials have come under careful scrutiny from the standpoint of micromechanical behavior and dimensional stability. Each of these materials can be classified as brittle and, hence, incapable of supporting large stresses in tension without fracturing. The usual maximum design stress for brittle materials is 10 to 15 percent of the modulus of rupture of abraded bend specimens. This means that the maximum design stress for Cer-Vit C-126 is likely to be about 14 to 20 MPa (2 to 3 ksi). For this reason, most studies of micromechanical behavior have been limited to relatively low stresses.

Evidence currently available indicates that Cer-Vit C-126 experiences little or no permanent plastic strain when exposed to short-duration external loading and, hence, has a microyield strength that equals or exceeds the fracture strength.(1) Its behavior is not perfectly elastic, however; anelastic effects are often observed. Upon removal of an applied stress of sufficient magnitude, some residual strain will be present but this will gradually disappear with time. The greater the applied stress, the larger will be this anelastic strain. Paquin and Goggin,(2) who tested mirror disks with a centrally applied load and uniform edge support at a reported strain sensitivity of 4×10^{-8}, found that at an applied stress of 20MPa (3 ksi), the anelastic strain was 0.9×10^{-6}. Approximately 5 hours were required for this strain to disappear.

These anelastic effects are undoubtedly responsible for the reported reduction in apparent modulus with increasing stress for

Cer-Vit C-126.(1) As shown in Table 2, Young's modulus measured over a stress range of 0 to 70 MPa (0 to 10 ksi) is approximately 2 percent less than that measured over a stress range of 0 to 14 MPa (0 to 2 ksi).

TABLE 2. YOUNG'S MODULUS VALUES OBTAINED IN COMPRESSION TESTS ON CER-VIT C-126.(1)

	Young's Modulus (10^6 psi) for Indicated Stress Range			
	0 to 2 ksi	0 to 4 ksi	0 to 6 ksi	0 to 10 ksi
	12.19	12.17	12.08	11.98
	12.16	12.04	11.98	11.90
	12.16	12.08	12.02	11.92
Average	12.17	12.10	12.03	11.93

Exposure to stress over long periods of time produces little microcreep if the stresses are maintained at a relatively low level. Paquin and Goggin,(2) employing centrally loaded edge-supported mirror disks, reported that the permanent strain is no greater than about 0.1×10^{-6} when the maximum fiber stress does not exceed 35 MPa (5 ksi) and when sufficient time has elapsed after removal of the load to allow recovery of anelastic strains to occur. At higher stresses, significantly greater amounts of microcreep have been reported. For example, in compression tests at 70 MPa (10 ksi), Cer-Vit C-126 exhibited creep strains of nearly 20×10^{-6}.(1) These measurements were made while the specimens were under load. After the load was removed, the creep strain was observed to recover gradually with time.

In view of the above observations, it appears that stress-induced dimensional instabilities in Cer-Vit C-126 are extremely small, so long as the stresses are kept at low levels. Assuming design stresses no greater than about 20 MPa (3 ksi) to avoid brittle fracture, this material may be assumed to exhibit nearly ideal elasticity.

Somewhat less is known about the dimensional stability of Cer-Vit C-126 in the absence of external loading. A mirror sample subjected to 100 thermal cycles between -46 and +38 C (-50 to +100 F) exhibited a figure change of only $\lambda/25$ (0.08×10^{-6} strain), where λ is the wavelength of the light employed in the test.[2] These observations do not preclude the possibility that dimensional changes may have accompanied thermal cycling. If small dimensional changes did occur and if they occurred uniformly in all directions, they would not produce a shape change. Other types of tests would be required to reveal small dimensional changes.

Based on the available experimental evidence, low expansion Cer-Vit C-126 appears to possess attractive properties for use as a baseplate in an orbiting solar observatory. This program was undertaken to further assess the potential of this material.

BASEPLATE FABRICATION

Fabrication of the Cer-Vit C-126 baseplate was subcontracted to Owens-Illinois, Incorporated, under Battelle Purchase Order C-9905, dated 1 April, 1971. At that time, the exact configuration of the baseplate had not been finalized. The contract stated that the baseplate configuration would be nominally the same as a typical OSO-I experimental optical bench employed with a 1000 mm Ebert Spectrometer, with outside dimensions of approximately 54 x 13.5 x 2 inches. Drawing ER47R216224 for an S-200 beryllium baseplate was to be used as a guide after revision to the above dimensions. The desired weight was 55 pounds or less.

In attempting to design a Cer-Vit C-126 baseplate within the above framework, Owens-Illinois personnel became concerned with the conditions that such a baseplate would experience during a launch into earth-orbit. Their analysis, based on information supplied by NASA-Goddard, indicated that the vibration and acceleration envelope might induce dangerously high tensile stresses in certain regions of the baseplate. Accordingly, they took the position that optimum performance could be obtained only by designing an integrated system including the baseplate, dust cover, support structure, and the method for attaching instruments to the baseplate. A major design effort of this nature was not possible within the cost framework of the program. Thus, compromises were reached, based on the understanding that the Cer-Vit C-126 baseplate was to be a demonstration article that would not be launched into orbit and that would be tested only within the limitations recommended by Owens-Illinois.

The final design submitted by Owens-Illinois and approved by the NASA Project Officer was a simple flat plate measuring 54 x 13.5 x 1 inch (Owens-Illinois Drawing No. E-340-15-6). As shown in Figure 1, the design specified 42 through-the-thickness holes for mounting instruments. In addition, 53 holes were to be drilled through the plate in the width direction at mid-thickness to reduce the overall weight of the plate to less than 55 pounds.

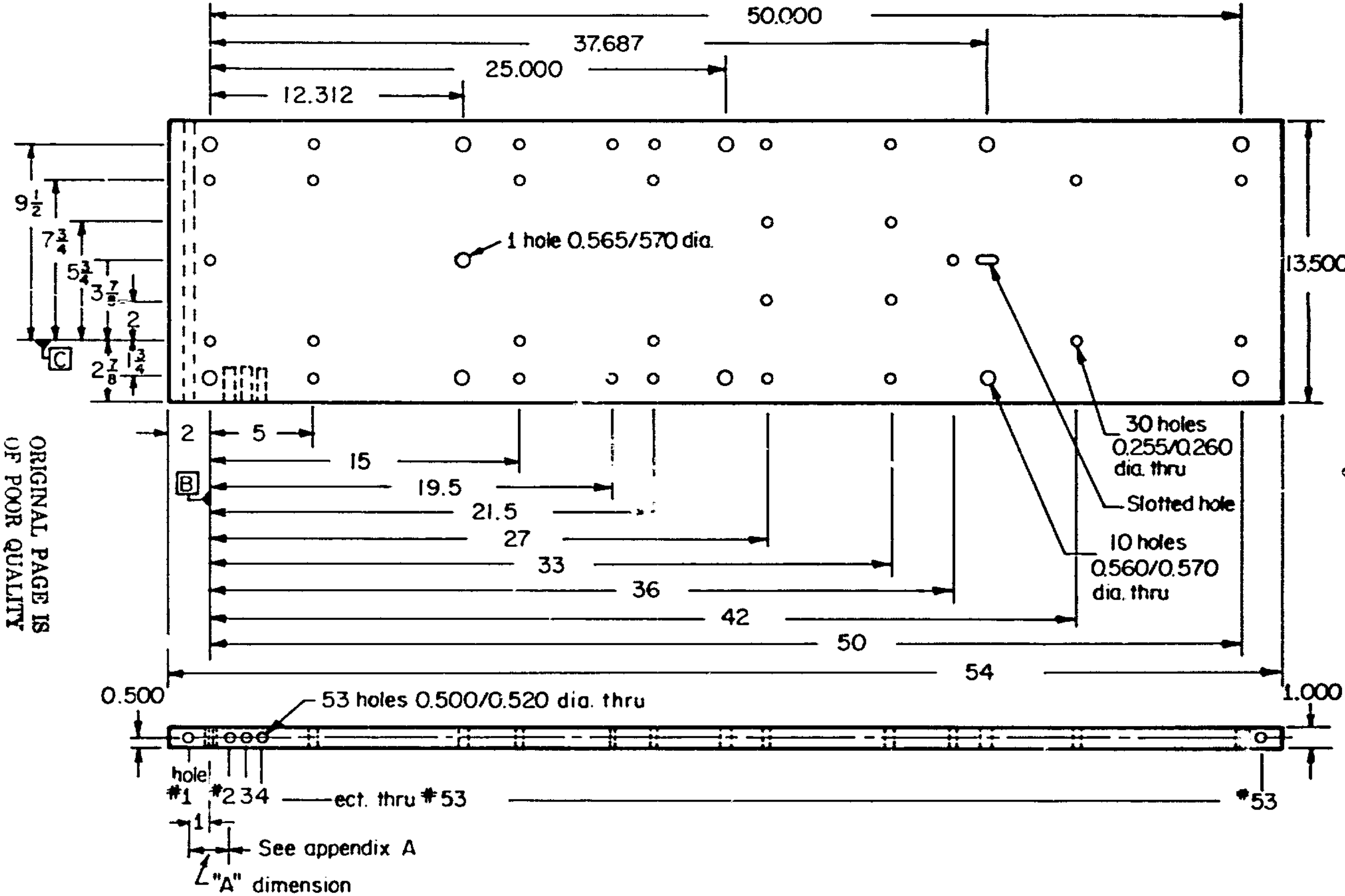

FIGURE 1. DRAWING OF OSO-I TYPE BASEPLATE TO SHOW DIMENSIONS AND HOLE LOCATIONS

A Cer-Vit C-126 baseplate blank was cast at Owens-Illinois and subsequently given a proprietary heat treatment to develop the degree of crystallization necessary to achieve near-zero thermal expansivity. Machining of the configuration shown in Figure 1 was then carried out and the baseplate was delivered to Battelle. Figure 2 is a photograph of the finished plate. A copy of the inspection report furnished by Owens-Illinois is included as Appendix A of this report.

Examination of the inspection report reveals that design tolerances were met in most, but not all, cases. Where deivations occurred, they were generally small. However, two deviations of a somewhat more serious nature are not evident from the inspection report. First, due to improper positioning of a hole-drilling template, the 42 through-the-thickness holes were improperly located relative to the long edges of the plate. This deviation was of the order of 0.5 inch and is evident in Figure 2. Second, many of the machined holes, which were to have had a 1/64-inch radius where they met the plate surface, were chipped. The template was returned to Owens-Illinois for further inspection and reworking of these chipped areas. The Owens-Illinois inspection report of chipped holes is included as Appendix B. It shows that most of the holes contained chipped edges, many of them severe. The hole edges were subsequently hand-chamfered at Owens-Illinois to minimize the likelihood that cracks would be present in these regions. The reworked plate was then returned to Battelle. A photograph of several hand-chamfered holes is shown in Figure 3. Inasmuch as neither of the above-described defects appears to jeopardize the subsequent evaluation of the baseplate, the NASA Project Officer recommended Battelle's acceptance of the reworked baseplate from Owens-Illinois.

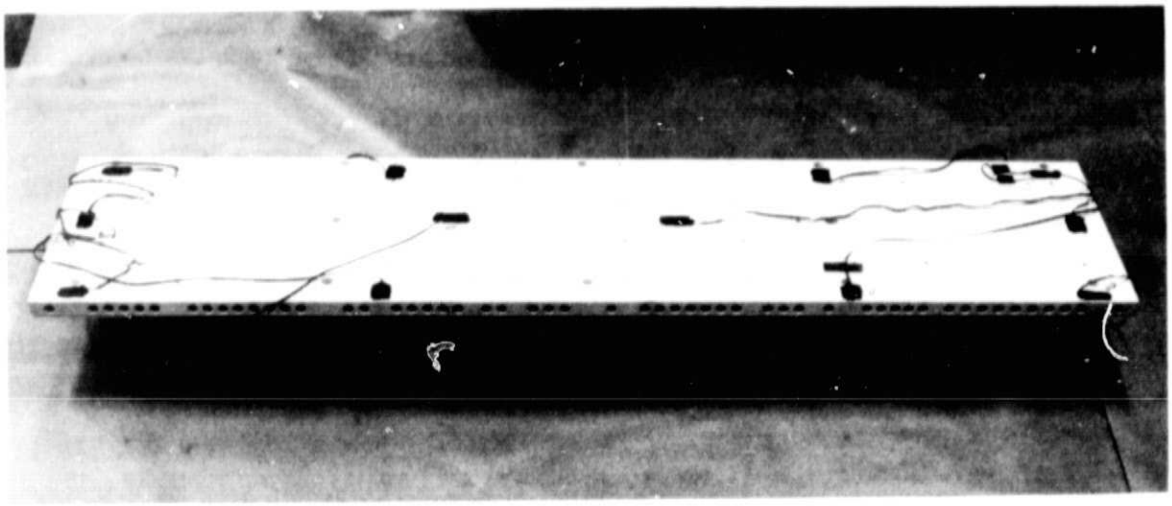

FIGURE 2. PHOTOGRAPH OF DEMONSTRATION OSO-I TYPE BASEPLATE PREPARED FROM OWENS-ILLINOIS CER-VIT C-126

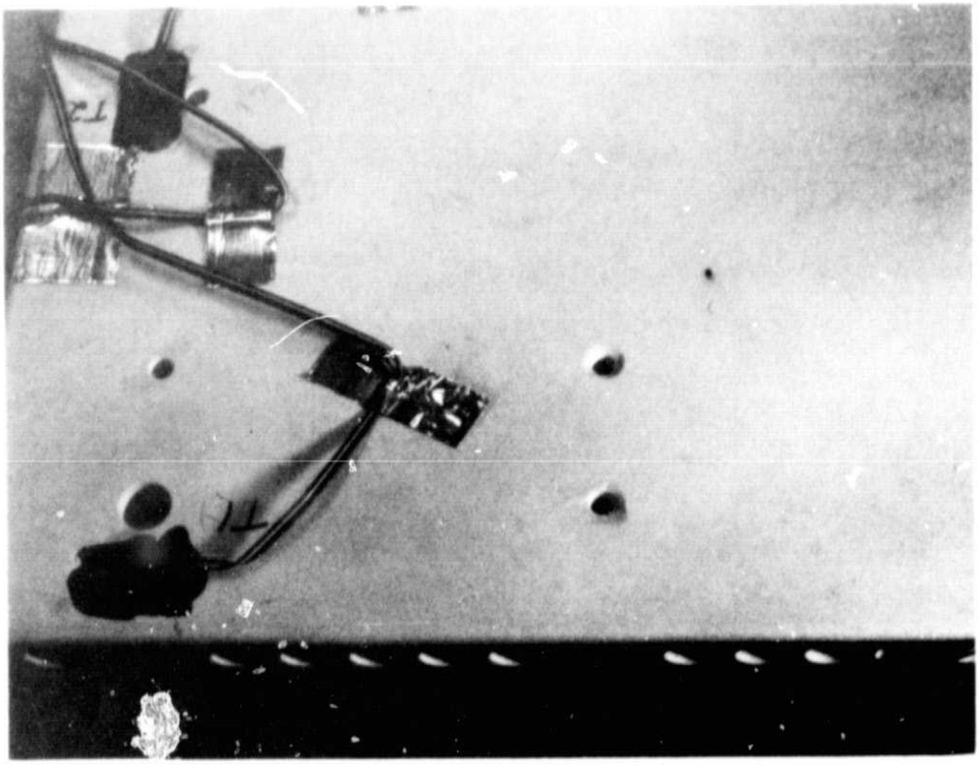

FIGURE 3. PHOTOGRAPH OF SEVERAL HAND-CHAMFERED HOLES IN CER-VIT C-126 BASEPLATE

BASEPLATE EVALUATION

A precision strain-gage technique was selected for monitoring the dimensional stability of the Cer-Vit C-126 baseplate. Previous experience on low-thermal-expansion materials had indicated that similar strain-gage techniques for monitoring dimensional stability are reliable within about $\pm 2 \times 10^{-6}$ for observation times of up to ten months.

Twenty-four (24) electrical resistance foil strain gages (12 per side) were cemented to the plate in the locations shown in Figure 4. This arrangement of gages was designed to indicate changes in length, changes in width, and changes in flatness of the plate.

Procedures for Applying Strain Gages to Baseplate

Procedures for employing strain gages to measure dimensional stability were developed through consultation with specialists at Micromeasurements, Incorporated, in Romulus, Michigan. These procedures were used to minimize errors arising from instrument drift, gradual changes in gage resistance, gradual changes in lead-wire resistance, change in contact resistance, and moisture effects.

Materials developed in gaging and wiring were obtained from Micromeasurements. They included:

WK-00-250BG-350 strain gages with option B-100

Terminal strips--Type CTF-50C

M Bond AE-10 Epoxy (room temperature setting)

Neutralizer (water, detergent and ammonia)

Conditioner (a weak acid solution)

Gauze pads

Cellophane tape (old fashioned)

Rosin solvent

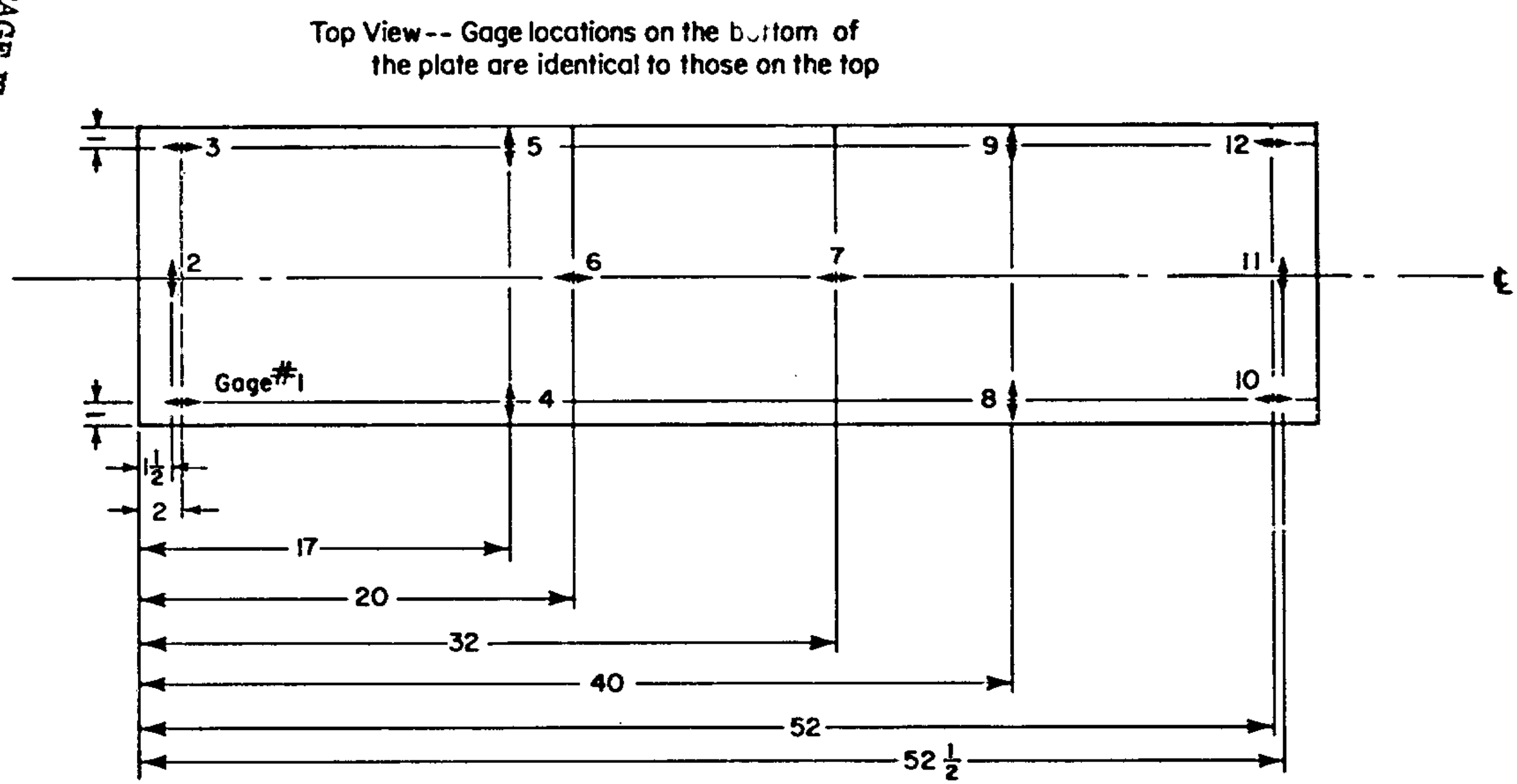

FIGURE 4. LOCATION OF ELECTRICAL RESISTANCE STRAIN GAGES ON BASEPLATE

Solder--Type 360-20R

Wire--Type 426-DFV (flat, vinyl, four conductor cable)

GT-14 Pressure Pads (3/32" x 1" by 1/2" Silicone Gum and 1/8" x 1" x 1/2" Aluminum)

Gagekote No. 2 (W. T. Bean)

Gagekote No. 5 (W. T. Bean).

The location for each strain gage was thoroughly degreased and cleaned using conditioner and neutralizer. The gages and terminal strips were positioned with cellophane tape. AE-10 cement was applied to the plate surface as well as to the back of both gages and terminal strips. The gage assemblies were pressed into place with thumb pressure and a small silicone pad and aluminum plate were placed over each gage. These were then weighted to apply the necessary 10-15 psi pressure overnight.

Each of the four wires from the gage was soldered onto a terminal strip with a slight strain-relief loop left in the wire. A length of four-conductor flat cable was then soldered to the terminal strips. This configuration provided two leads from each side of the strain gage. The need for this is explained later. The cable was then tacked down with a drop of Duco cement about two inches from the gage, to prevent movement of the wire.

Each gage was then encapsulated with Gagekote No. 5 over a precoat of Gagekote No. 2.

Readings were taken with a BLH C-120 strain indicator factory modified to read to 0.2-microinches per inch. The fourth wire from each gage allowed switching of the leads so that two different quarter-bridge readings could be taken. The average of these two readings produced a value not affected by contact resistance.

Effect of Thermal Cycling and Vacuum Thermal Cycling on Plate Dimensions

Initial strain gage readings were taken in a room controlled at 20 ± 0.15 C (68 ± 1/4 F), with the baseplate laying flat upon a 1-inch felt pad. The baseplate was then placed in an insulated chamber and thermal cycled in air thirty (30) times from -46 to +38 C (-50 to +100 F). Both heating and cooling were done at relatively low rates to avoid thermal shock. Each complete cycle was accomplished in about 6 hours. Cycling of the plate was done only during normal working hours. The total elapsed time to complete thirty cycles of heating and cooling was about 40 days.

Following thermal cycling, the baseplate was returned to the 20 C room for additional strain gage readings. Changes in individual gage readings are shown in Table 3. The data indicate that thermal cycling caused the baseplate to expand by approximately 5 to 8 x 10^{-6} in/in in both the width and length dimensions. The fact that growth indications were similar on both sides of the plate suggests that little bending or warpage occurred as a result of thermal cycling.

Following the thermal cycling tests, the baseplate was carefully packaged and sent to NASA-Goddard for exposure to mechanical vibrations. However, for various reaons, the Project Officer decided against subjecting the baseplate to mechanical vibrations. Instead, the plate was subjected to five cycles of thermal-vacuum testing.

In the thermal vacuum tests, the plate was instrumented with 12 thermocouples and placed in a vacuum chamber. A vacuum of about 10^{-7}mm

TABLE 3. CHANGES IN STRAIN GAGE READINGS FOLLOWING THERMAL CYCLING AND VACUUM THERMAL CYCLING OF CER-VIT C-126 BASEPLATE

Gage Position		Gage Orientation[a]	Change in Gage Reading (10^{-6} in/in) Following Treatment Indicated: 30 Cycles From -46 to +38 C (-50 to +100 F)	Change in Gage Reading (10^{-6} in/in) Following Treatment Indicated: 5 Thermal Vacuum Cycles from -100 to +100 C (-150 to +210 F)
Top-side	1	L	(b)	(b)
	2	T	+5.8	+29.1
	3	L	+5.4	(b)
	4	T	+8.4	+30.9
	5	T	+6.3	+21.5
	6	L	-1.2	+40.8
	7	L	+7.2	+33.8
	8	T	+9.1	+22.0
	9	T	+7.8	+32.6
	10	L	+7.0	+25.5
	11	T	+8.4	+16.0
	12	L	+6.6	(b)
	Average change (L-orient.)		+5.0	+33.4
	Average change (T-orient.)		+7.6	+25.4
Bottom-side	1	L	+7.2	+129.6
	2	T	+9.0	+71.5
	3	L	+5.8	+46.3
	4	T	+4.6	+59.9
	5	T	+3.5	+43.6
	6	L	+9.9	+48.5
	7	L	+12.9	+31.6
	8	T	+5.0	+45.2
	9	T	(b)	(b)
	10	L	+4.6	+34.1
	11	T	+15.6	+49.8
	12	L	+6.0	+23.5
	Average change (L-orient.)		+7.7	+52.3
	Average change (T-orient.)		+7.5	+54.0

(a)
(b)

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of mercury was drawn in the chamber and the plate was gradually heated to about 100 C (210 F) and then gradually cooled to room temperature. This half-cycle of testing required an entire working day (about 8 hours) for completion. On the next working day, the plate was gradually cooled to about -100 C (-150 F) under vacuum and then gradually warmed to room temperature. Again, this half-cycle of testing was accomplished in about 8 hours. A total of 12 days was required to complete five complete cycles from +100 to -100 C (+210 to -150 F).

Following the thermal vacuum tests, the plate was again carefully packaged and returned to Battelle for additional strain-gage readings. In a letter accompanying the baseplate, NASA personnel pointed out that the protective coatings over several strain gages had cracked as a result of the thermal-vacuum cycling. In addition, inspection at Battelle revealed that many of the electrical connectors at the ends of the strain-gage lead wires were loose and required retightening.

Strain-gage readings were again taken in a 20 C room with the baseplate resting flat upon a 1-inch felt pad. Changes in gage readings relative to the original readings are shown in Table 3. The data indicate that the plate underwent additional growth in both the length and width directions and that the bottom side of the plate had grown somewhat more than the top side. The latter observation implies that the flatness of the plate had changed, assuming a slightly concave-up shape.

DISCUSSION AND CONCLUSIONS

One of the program objectives was to determine whether a baseplate could be successfully cast and machined from Cer-Vit C-126. This objective was realized only in part. A plate was prepared at Owens-Illinois, Incorporated, that had the desired outside dimensions of 54 x 13.5 x 1 inch and a weight less than 55 pounds. However, the plate deviated from design tolerances in several ways: (1) the 42 through-the-thickness holes were improperly located relative to the long edges of the plate, and (2) many of the machined holes were seriously chipped where they intersected the plate surface. Discussions with Owen-Illinois personnel indicated that these shortcomings could be easily overcome in manufacture of additional Cer-Vit C-126 articles.

Evaluation of the dimensional stability of the plate was also only partially successful. The deviations from design tolerances described above, along with the fact that the baseplate was not designed as part of an integrated system, led NASA personnel to eliminate mechanical vibration exposure and to substitute vacuum thermal exposure. This, in turn, gave rise to uncertainties in the dimensional stability measurements, as described in subsequent paragraphs.

As noted in an earlier section of this report, work at Perkin-Elmer Corporation has shown that Cer-Vit C-126 mirror blanks undergo virtually no figure change after 100 thermal cycles between -46 and +38 C (-50 to +100 F). It was also noted that this observation did not preclude the possibility of dimensional changes, if such changes occurred uniformly in all directions.

The current investigation on a Cer-Vit C-126 baseplate indicated that 30 thermal cycles over the same temperature range as employed at Perkin-Elmer did, in fact, cause ne material to grow uniformly by about 5 to 8 x 10^{-6} inch/inch. B-ause these observations are based on strain-gage measurements with no independently verifiable standard for comparison, they are subject to question. However, based on Battelle's experience in an earlier program in which identical gage installations were employed with a verifiable standard to measure the dimensional changes in low-thermal-expansion materials, it appears that gages can be read with a confidence of about $\pm$ 2 x 10^{-6} over a period of at least 10 months. Since the time interval between initial readings on the baseplate and those taken after 30 thermal cycles was only about 1-1/2 months, the measured growth of 5 to 8 x 10^{-6} would appear to be real.

Considerably greater doubt must be raised about the gage readings obtained after the vacuum thermal cycling at NASA-Goddard. Both the total elapsed time--about 18 months between initial and final readings--and the fact that vacuum thermal cycling caused visible damage to the coatings protecting the gages act to decrease confidence in the results. On the other hand, with only a few exceptions, the gage readings are reasonably uniform on a particular side of the plate and do not show a great deal of scatter.

The following conclusions may be drawn from this investigation:

(1) Cer-Vit C-126 baseplates of relatively simple design can be successfully cast and machined. It is likely that more sophisticated designs can be prepared, employing conventional

diamond-machining techniques, that will permit improved structural efficiency.

(2) Thermal cycling 30 times from -46 to +38 C (-50 to +100 F) caused an apparent uniform growth of about 5 to 8 x 10^{-6} inch/inch. Vacuum thermal cycling 5 times from -100 to +100 C (-150 to +210 F) appeared to cause additional growth as well as warpage. However, this latter observation is subject to question because of possible damage to the measuring instrumentation associated with the vacuum thermal cycling.

REFERENCES

(1) Marschall, C. W., "Micromechanical Properties and Dimensional Stability of Materials for Use in Orbiting Observatories", Battelle-Columbus Laboratories, Final Report, Contract No. NAS5-11351, June 16, 1972.

(2) Paquin, R. A. and Goggin, W. R., "Micromechanical and Environmental Tests of Mirror Materials", Perkin-Elmer Corporation, Final Report, Contract No. NAS5-11327, 1971.

APPENDIX A

OWENS-ILLINOIS INSPECTION REPORT
ON CER-VIT C-126 BASEPLATE

BATTELLE MEMORIAL INSTITUTE
54 x 13.5 x 1 BASEPLATE
P/N E-340-51-6

7/19/72

DRAWING OR CONTRACT REQUIREMENT	ACTUAL READING	TYPE OF INSP.	COMMENTS	INSP. STAMP
54.000±0.015	54.007" / 54.010"			
Width 13.500±0.015	13.502" / 13.503"			
Thickness 1.000± 0.020 / 0.000	1.010"			
1-Slotted Hole See Attached	See Attachment #3			
10 Holes .560/.570 Dia. Thru.	See Attachment #3			
30 Holes .255/.260 Dia. Thru.	See Attachment #2			
53 Holes Drill Thru. .500/.520 Dia.	See Attachment #1			
G/N #1 All Surfaces to be 250 ✓ Unless Otherwise Noted	125 OR BETTER			
G/N #2 Total Weight After Finish Machining Approx. 50 lbs.	53.50 LBS.			
Side to be parallel to C Datum within .005 (long side) Side to be 2.875 ± .005 From C Datum	READING R to L 2.249 2.236 2.238 2.241 —||— .005 2.244 IS .013 2.245			
	ORIGINAL PAGE IS OF POOR QUALITY			

BATTELLE MEMORIAL INSTITUTE
54 x 13.5 x 1 BASEPLATE
P/N E-340-51-6

7/19/72

DRAWING OR CONTRACT REQUIREMENT	ACTUAL READING	TYPE OF INSP.	COMMENTS	INSP. STAMP
Edge to be Parallel to B Datum within .005 (short side) Edge to be 2.000 ± .005 from B Datum	READING R to L 2.008 2.004 -||- .005 2.000 2.002 is .008 2.007			OIF 7 QA
Surface A to be Flat within .002	.0045			OIF 7 QA
125 Finish on Surface A	BETTER THAN 125			OIF 7 QA
Center Line of 53 Hole to be Parallel to B Datum w/.012	52.000 / 52.002 -||- .002		SOME OTHER HOLES ARE OUT OF SPEC. SEE ATTACH #1 PAGE 1.	OIF 7 QA
Center Line of 53 Holes to be Parallel to Surface A w/.012	CENTER LINE DEVIATES A MAXIUM OF .034		SEE ATTACH. #1 PAGE 2.	OIF 7 QA
Surface to be Flat w/.002 125 Finish on Surface	.0045" BETTER THAN 125			OIF 7 QA
Surface to be Parallel to A w/.005	.0042"			OIF 7 QA
Surface A to be Flat w/.002	?			OIF 7 QA
3/8" Radius on Corner 4 Places	OK			OIF 7 QA
1/8" Radius on Edges 8 Places	OK			OIF 7 QA

BATTELLE MEMORIAL INSTITUTE
54 x 13.5 x 1 BASEPLATE
P/N E-340-51-6

7/19/72

DRAWING OR CONTRACT REQUIREMENT	ACTUAL READING	TYPE OF INSP.	COMMENTS	INSP. STAMP
1/64" Radius Top and Bottom All Holes	OK		SOME CHIPPING	
Marking Along Edge & Side Indicating Datum Hole India Ink Over-coated with Shellac	O.K			7/24/72 [illegible]

BATTELLE MEMORIAL INSTITUTE
54 x 13.5 x 1 BASEPLATE
P/N E-340-51-6
.500" DIA. HOLES THRU SIDE OF
PLATE. TOLERANCE ± 0.005

7

7/19/72

HOLE NO.	DIM. "A"	ACTUAL	HOLE NO.	DIM. "A"	ACTUAL	HOLE NO.	DIM. "A"	ACTUAL
2	2.063	2.058 / 2.064	21	19.750	19.751 / 19.749	40	40.250	40.258 * / * 40.257
3	2.813	2.811 * / 2.807	22	21.125	21.125 / 21.128	41	40.938	40.943 / 40.942
4	3.563	3.562 / 3.564	23	21.875	22.874 / 22.874	42	41.625	41.630 / 41.628
5	4.313	4.313 / 4.314	24	23.375	23.374 / 23.375	43	42.313	42.318 / 42.313
6	5.063	5.065 / 5.061	25	24.125	24.126 * / 24.119	44	43.625	43.631 / * 43.626
7	6.938	6.938 / 6.941	26	24.875	24.875 / 24.875	45	44.438	44.442 / 44.440
8	7.688	7.690 / 7.689	27	27.125	27.124 / 27.126	46	45.250	45.254 / 45.251
9	8.438	8.439 / 8.438	28	28.750	28.750 / 28.750	47	46.063	46.068 / 46.064
10	9.188	9.188 / 9.187	29	29.500	29.502 / 29.500	48	46.875	46.881 / * 46.871
11	9.938	9.938 / 9.938	30	30.250	30.251 / 30.245	49	47.688	47.691 / 47.691
12	10.688	10.687 / 10.688	31	31.000	31.000 * / 30.991	50	48.500	48.503 / 48.502
13	11.438	11.436 / 11.436	32	31.750	31.750 * / 31.741	51	49.313	49.316 / 49.317
14	12.188	12.189 / 12.188	33	32.500	32.502 * / 32.485	52	50.125	50.126 / 50.124
15	14.438	14.434 / 14.438	34	33.250	33.252 / 33.245	53	52.000	52.002 / 52.000
16	15.188	15.186 / 15.185	35	34.750	34.753 * / 34.744			
17	16.750	16.749 / 16.750	36	35.500	35.503 * / 35.493			
18	17.500	17.501 / 17.500	37	36.250	36.254 * / 36.243			
19	18.250	18.252 / 18.251	38	37.688	37.694 / * 37.692			
20	19.000	19.000 / 19.000	39	39.563	39.570 / * 39.567			

* = OUT OF TOL. DIMENSION.

BATTELLE MEMORIAL INSTITUTE
54" x 13.5" x 1" BASEPLATE
P/N E-340-51-6
HOLE NO. 1 1.000 ± .005 DIMENSION
ACTUAL 1.003" / 1.009"

7 QA

7/19/72

HOLE NO.	HOLE SIZE	ACTUAL	DIM. FROM "A" NEAR	FAR	HOLE NO.	HOLE SIZE	ACTUAL	DIM. FROM "A" NEAR	FAR
1.	.500 $^{+.020}_{-.000}$	.519	[illegible]	.5205	28.	.500 $^{+.020}_{-.000}$	.518	.491	.5255
2.		.519	.492	.523	29.		.518	.500	.5255
3.		.518	.4945	.519	30.		.517	.498	.522
4.		.518	.494	.5215	31.		.517	.498	.5275
5.		.518	.4945	.519	32.		.517	.4965	.5265
6.		.518	.498	.5245	33.		.516	.4995	.524
7.		.517	.486	.523	34.		.516	.500	.5255
8.		.517	.4945	.522	35.		.516	.4965	.522
9.		.519	.495	.522	36.		.516	.500	.5285
10.		.519	.499	.523	37.		.516	.500	.530
11.		.519	.497	.5225	38.		.515	.537	.5255
12.		.518	[illegible]	.5235	39.		.515	.5385	.5275
13.		.518	.498	.524	40.		.515	.5345	[illegible]
14.		.518	.4955	.525	41.		.516	.533	.529
15.		.518	.498	.5255	42.		.517	.5185	.5245
16.		.518	.502	.525	43.		.516	.532	.5265
17.		.518	.500	.526	44.		.516	.536	.526
18.		.517	.503	.526	45.		.516	.535	.5255
19.		.518	.4945	.5275	46.		.516	.5385	[illegible]
20.		.517	.503	.528	47.		.516	.531	.5255
21.		.517	.497	.5285	48.		.517	.5265	.525
22.		.517	.495	.5265	49.		* .515	.533	.525
23.		.516	.503	.5275	50.		.517	.5335	.5235
24.		.517	.502	.5285	51.		* .516 / .521	.5365	.5235
25.		.516	.501	.5285	52.		* .515 / .521	.5325	.5245
26.		.516	.500	.5285	53.		.514	.532	.520
27.		.518	.499	.529					

* #1 UNDERCUT .002" APPROX. 1/8" DEEP.

* #s 2 & 3 SMALLER DIMENSION HOLDS THROUGH EXCEPT THE FINAL 1/8" WHICH TAPERS TO THE LARGER OVERSIZE DIMENSION.

NOTE: INDICATOR TIP IN 3/8" FROM EDGE OF HOLES.
HOLE PARALLISM TO SURFACE "A" ACROSS 13" DIMENSION DEVIATES A MAXIMUM OF .033".

HOLE PARALLISM TO SURFACE "A"
ACROSS 13" DIMENSION.

Attachment # 1
Page 2"A" of 2
7/24/72

7

DIMENSION FROM "A"				DIMENSION FROM "A"			
HOLE #	NEAR SIDE	FAR SIDE	-11- ERROR	HOLE #	NEAR SIDE	FAR SIDE	-11- ERROR
1	.4875	.5205	+ .033	28	.491	.5255	+ .0345
2	.492	.523	" .031	29	.500	.5285	" .0285
3	.4945	.519	" .0145	30	.498	.528	" .030
4	.494	.5215	" .0275	31	.498	.5275	" .0295
5	.4945	.519	" .0146	32	.4965	.5265	" .030
6	.498	.5245	" .0255	33	.4995	.524	" .0245
7	.486	.523	" .037	34	.500	.5255	" .0255
8	.4945	.522	" .0275	35	.4965	.528	" .0315
9	.495	.522	" .027	36	.500	.5285	" .0285
10	.494	.523	" .029	37	.500	.530	" .030
11	.497	.5225	" .0255	38	.537	.5255	- .0115
12	.497	.5235	" .0265	39	.5385	.5235	" .015
13	.498	.524	" .026	40	.5345	.528	" .0065
14	.4955	.525	" .0295	41	.533	.529	" .004
15	.498	.5255	" .0275	42	.5185	.5295	+ .011
16	.502	.525	" .023	43	.532	.5265	- .0055
17	.500	.526	" .026	44	.536	.526	" .010
18	.503	.526	" .023	45	.535	.5255	" .0095
19	.4945	.5275	" .033	46	.5385	.524	" .0145
20	.503	.528	" .025	47	.531	.5255	" .0055
21	.497	.5285	" .0315	48	.5265	.525	" .0015
22	.495	.5265	" .0215	49	.533	.525	" .008
23	.503	.5275	" .0245	50	.5335	.5235	" .010
24	.502	.5285	" .0265	51	.5365	.5235	" .013
25	.501	.5285	" .0275	52	.5325	.5245	" .008
26	.500	.5285	" .0285	53	.532	.520	" .012
27	.499	.529	" .030				

MAXIUM PLUS ERROR - HOLE # 7 .037"
MAXIUM MINUS ERROR - HOLE # 39 .015"

.255/.260 DIA.
HOLE LOCATION, SIZE AND ⊥
30 HOLES

7/19/72

HOLE NO.	ACTUAL	LOCATION FROM B DRAWING	LOCATION FROM B ACTUAL	LOCATION FROM C DRAWING	LOCATION FROM C ACTUAL	⊥ TO A .005	COMMENTS	INSP STA…
1		Datum	N/A	Datum	N/A			
2	.260	5.000±.005	5.000	1.750±.005	1.748	.003		
3	"	15.000±.005	14.996	1.750±.005	1.747	"		
4	"	19.500±.005	19.495	1.750±.005	* 1.742	"		
5	"	21.500±.005	21.498	1.750±.005	* 1.744	"		
6	"	27.000±.005	27.496	1.750±.005	1.752	"		
7	"	33.000±.005	32.496	1.750±.005	1.745	"		
8	"	5.000±.005	5.003	0.000±.005		"		
9	"	15.000±.005	14.999	0.000±.005		"		
10	"	21.500±.005	21.496	0.000±.005		"		
11	"	42.000±.005	42.002	0.000±.005		"		
12	"	50.000±.005	50.000	0.000±.005		"		
13	"	27.000±.005	27.001	2.000±.005	1.999	"		
14	"	33.000±.005	32.499	2.000±.005	2.000	"		
15	"	0.000±.005		3.875±.005	3.875	"		
16	"	36.000±.005	36.002	3.875±.005	3.878	"		
17	"	27.000±.005	27.001	5.750±.005	5.745	"		
18	"	33.000±.005	32.498	5.750±.005	5.748	"		
19	"	0.000±.005		7.750±.005	7.750	"		
20	"	5.000±.005	5.002	7.750±.005	7.753	"		
21	"	15.000±.005	14.998	7.750±.005	7.751	"		
22	"	21.500±.005	21.502	7.750±.005	7.753	"		
23	"	42.000±.005	* 42.006	7.750±.005	7.755	"		
24	"	50.000±.005	50.003	7.750±.005	* 7.741	"		

* = DIMENSION OUT OF SPEC.

ORIGINAL PAGE IS
OF POOR QUALITY

.255/.260 DIA.
HOLE LOCATION, SIZE AND ⊥
30 HOLES

7/19/72

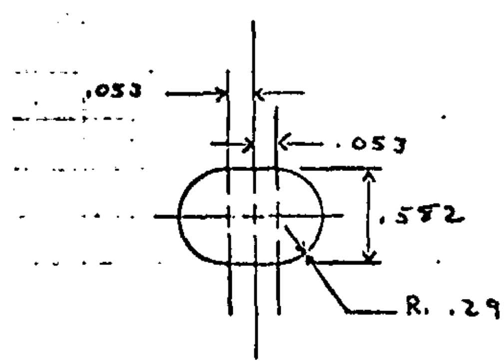
HOLE NO.	ACTUAL DIA.	LOCATION FROM B		LOCATION FROM C		⊥ TO A .005	COMMENTS	[illegible]
		DRAWING	ACTUAL	DRAWING	ACTUAL			
25	.260	5.000±.005	4.996	9.500±.005	9.501	.003		
26	"	15.000±.005	* 15.006	9.500±.005	9.500	"		
27	"	19.500±.005	19.504	9.500±.005	9.503	"		
28	"	21.500±.005	21.503	9.500±.005	9.503	"		
29	"	27.000±.005	* 27.006	9.500±.005	9.496	"		
30	"	33.000±.005	* 33.006	9.500±.005	9.498	"		

* = DIMENSION OUT OF SPEC.

.560/.570 DIA.
HOLE LOCATION, SIZE AND
10 HOLES

7/19/72

HOLE NO.	ACTUAL DIA.	LOCATION FROM B DRAWING	LOCATION FROM B ACTUAL	LOCATION FROM C DRAWING	LOCATION FROM C ACTUAL		COMMENTS	I'S…
1	.569	0.000±.005		1.750±.005	1.749			
2	"	12.312±.005	12.315	1.750±.005	1.746			
3	"	25.000±.005	25.000	1.750±.005	1.752			7
4	"	37.687±.005	37.684	1.750±.005	1.752			
5	"	50.000±.005	50.003	1.750±.005	1.750			
6	"	0.000±.005		9.500±.005	9.500			
7	"	12.312±.005	* 12.306	9.500±.005	* 9.508			
8	"	25.000±.005	25.003	9.500±.005	9.497			
9	"	37.687±.005	37.690	9.500±.005	* 9.492			
10	"	50.000±.005	50.003	9.500±.005	* 9.487			
		1 HOLE .565/.570						7
1	"	12.312±.005	12.316	3.875±.005	3.878			7
		1 SLOTTED HOLE						7
1	See Diagram	37.687±.005	37.688	3.875±.005	3.878			



* = DIMENSION OUT OF SPEC.

APPENDIX B

OWENS-ILLINOIS INSPECTION REPORT
OF CHIPPPED HOLES IN CER-VIT C-126 BASEPLATE

[illegible] ILLINOIS, INC.

[illegible]CKER SY[illegible]TEMS DIVISION

[illegible] (I) [illegible] Pittsburgh Pa 15213

|M|E|O| 9291

INSPECTION REPORT

1. Part No.	2. Ser. No.	3. Oper. No.	4. Part Name	5. S.O. Number
[illegible]			Base Plate, Instrument.	OLD- 415

6. Lot [illegible]	7. Qty. Insp.	8. Qty. Def.	9. Insp. By	10. Date Rec.	11. Date Insp.	12. P. O. Number
1	1	1	A.O. [illegible]		9/28/72	

13. Re[illegible]: T[illegible]

14. Type of Inspection			15. Disposition	4 RTV
1. Incoming	✓	4. Assembly	1. Accept	5. Use as is
2. In-process		5. Acceptance	2. Reject	6. Rework
3. Final		6. Rework	3. QRB	7. Scrap

16. [illegible] 17. [illegible] 18. Description

EXAMINATION OF CORED HOLES TO DETERMINE THOSE WHICH ARE IN NEED OF LARGER LEVELS.

FOUR PAGES ATTACHED LIST ALL HOLES AND THEIR CONDITION.

ORIGINAL PAGE IS OF POOR QUALITY

[illegible] for Rework

20. Corr[illegible]

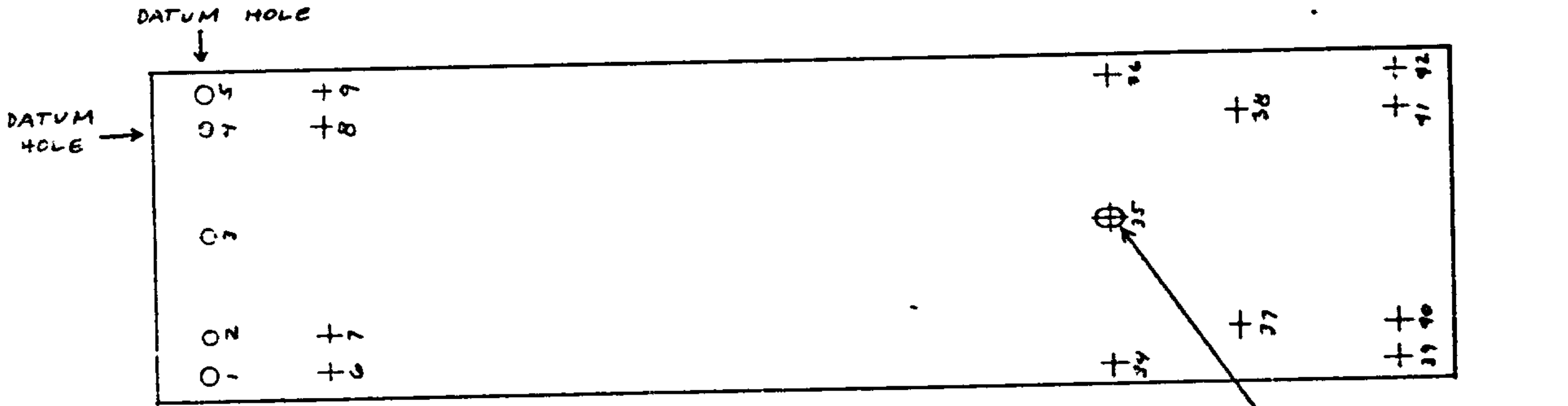
Accept as is Condition Borderline will not affect. ~~~ LI ~~~ [illegible] 10-[illegible]-72

21. QRB Approval

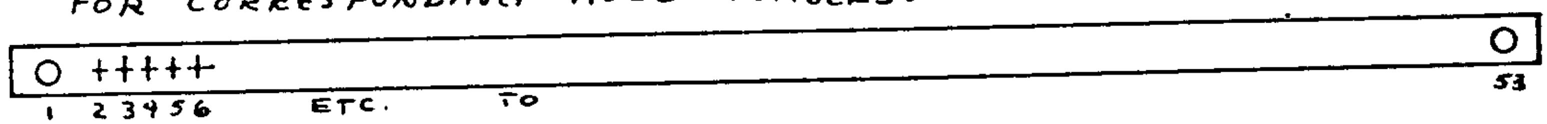
Eng. ____ Prod. Eng. ____ Q.A. [signature] Date ____ Customer [illegible]

INSTRUMENT BASE PLATE

SIDE # 1



HOLE NUMBER SEQUENCE AS SHOWN:
REFERENCE ATTACHMENT SHEETS 1, 2, 3 of ATTCH. # 2
FOR CORRESPONDING HOLE NUMBERS.



NUMBERS OF SIDE HOLES CORRESPOND TO THE SAME NUMBERS FOUND ON ORIGIONAL INSPECTION REPORT.

SUBMITTED 10/6/72

9/27

Cer-Vit Plate Side # 1

Subject: Chipped holes

Holes with No chips:

# 1	# 18
2	19
4	22
5	24
9	30
11	35
15	36
16	39
17	41
	42

Holes with minor chips (under .020")

# 3	# 21
8	25
10	31
12	32
20	33
	34
	38

Holes with major chips (over .020")

# 6 *	# 26 *
7 *	27 *
13	29
14	37
23	40 *
28 *	

* EXTREME chipping and deep. Approx. AVG. [illegible]

ORIGINAL PAGE IS
OF POOR QUALITY

9/27/72

Cer-Vit Plate Side #2
subject: Chipped holes

Holes with no chips:

# 1	# 22
5	24
7	27
8	29
9	30
12	31
15	32
16	33
17	36
18	38
20	40
21	41

Holes with minor chips (under .020")

# 2	# 23
3	25
4	26
10	28
11	34
13	37
14	39
19	42

Holes with major chips (over .020")

#6
35

CER-VIT PLATE Edge "A"

subject : chipped holes

Holes with no chips

# 1	# 37
3	38
8	40
14	41
27	46

Holes with one or two small chips or chips under .010

# 2	# 24
4	25
5	26
9	28
13	30
15	43
16	50

Holes with many chips or chips over .010"

# 6	# 21	# 39
7	22	42
10	23	44
11	29	45
12	31	47
17	32	48
18	33	49
19	34	51
20	35	52
	36	53

ORIGINAL PAGE IS
OF POOR QUALITY

Gentlemen;

To expedite measuring chips, the piece was observed as it lay upon opening. Later it was found that the numbers used for this inspection did not correspond to the drawing hole numbers. The attached sheets correlate these numbers.

D. L. Ott.

HOLE MATCH ONLY 10/6/72

.255/.260 DIA.
HOLE LOCATION, SIZE AND ⊥
30 HOLES

HOLE NO.	ACTUAL	LOCATION FROM B DRAWING	LOCATION FROM B ACTUAL	LOCATION FROM C DRAWING	LOCATION FROM C ACTUAL	⊥ TO A .005	COMMENTS	INS STA
1	4	Datum	N/A	Datum	N/A			
2	9	[illegible]00±.005		1.750±.005				
3	16	15.000±.005		1.750±.005				
4	18	19.500±.005		1.750±.005				
5	22	21.500±.005		1.750±.005				
6	28	27.000±.005		1.750±.005				
7	32	33.000±.005		1.750±.005				
8	5	5.000±.005		0.000±.005				
9	15	15.000±.005		0.000±.005				
10	21	21.500±.005		0.000±.005				
11	38	42.000±.005		0.000±.005				
12	41	50.000±.005		0.000±.005				
13	27	27.000±.005		2.000±.005				
14	31	33.000±.005		2.000±.005				
15	3	0.000 ±.005		3.875±.005				
16	33	36.000±.005		3.875±.005				
17	26	27.000±.005		5.750±.005				
18	30	35.000±.005		5.750±.005				
19	2	0.000±.005		7.750±.005				
20	7	5.000±.005		7.750±.005				
21	14	15.000±.005		7.750±.005				
22	20	21.500±.005		7.750±.005				
23	37	42.000±.005		7.750±.005				
24	40	50.000±.005		7.750±.005				

HOLE MATCH ONLY 10/6/72.

.255/.260 DIA.
HOLE LOCATION, SIZE AND ⊥
30 HOLES

HOLE NO.	ACTUAL DIA.	LOCATION FROM B		LOCATION FROM C		⊥ TO A .005	COMMENTS	IN[illegible] STA[illegible]
		DRAWING	ACTUAL	DRAWING	ACTUAL			
25	6	5.000±.005		9.[illegible]00±.005				
[illegible]	13	15.0[illegible]±.005		9.50[illegible]005				
27	17	1[illegible].500±.005		9.5[illegible]±.005				
2[illegible]	19	21.[illegible]00±.005		9.500[illegible].005				
29	25	27.00[illegible].005		9.500[illegible]05				
30	29	33.00[illegible]±.005		9.50[illegible].005				

HOLE MATCH ONLY 10/6/72

Attachment No. 3
Page 1 of 1

.560/.570 DIA.
HOLE LOCATION, SIZE AND
10 HOLES

HOLE NO.	ACTUAL DIA.	LOCATION FROM B. DRAWING	LOCATION FROM B. ACTUAL	LOCATION FROM C DRAWING	LOCATION FROM C ACTUAL		COMMENTS	IN[illegible] ST[illegible]
1	5	0.000±.005		1.750±.005				
2	12	12.312±.005		1.750±.005				
3	24	25.000±.005		1.750±.005				
4	36	37.687±.005		1.750±.005				
5	42	50.000±.005		1.750±.005				
6	1	0.000±.005		9.500±.005				
7	10	12.312±.005		9.500±.005				
8	23	25.000±.005		9.500±.005				
9	34	37.687±.005		9.500±.005				
10	39	50.000±.005		9.500±.005				
		1 HOLE .565/.570						
1	11	12.312±.005		3.[illegible]5±.005				
	35	1 SLOTTED HOLE						
1	See Diagram	37.687±.005		3.8[illegible]5±.005