Header Design Evaluation

Kansas City Division

R. L. Stubenhofer

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Final Report

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R. L. Stubenhofer

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Abstract

An evaluation was conducted of two new six-pin header designs. This evaluation consisted of designing, evaluating, procuring, and building contact module subassemblies with each of the two designs. The study was initiated as a result of the high scrap costs associated with the current product design. Two new designs were found to be feasible alternatives to the current design.

Summary

Two new six-pin header designs were developed jointly between Sandia National Laboratories in Albuquerque and AlliedSignal Inc., Kansas City Division (KCD), to evaluate changes in configuration and metallization of the ceramic-to-metal interface. Initially, five designs were under consideration. The driver for this project was the excessive amount of scrap produced during the assembly, cleaning, and testing of the assemblies. The prevalent failure indication was exceeding the allowable helium leak rate of 1×10^{-8} cm³/s. During the first three quarters of fiscal year 1990, scrap cost from components not meeting the leak test requirements was excessive. Using the FY 1990 production requirements, future nonconformance was projected to be an unacceptable amount.

Three changes were proposed to improve the performance of the header assembly. First was a change to a denser metallization, or the bond between the ceramic and the metal counterpart. The second change required the denser metallization and the redesign of the braze joint between the ceramic and metal interface. The design currently in production contained a very narrow area

where the braze and metallization could form a bond capable of withstanding the environmental requirements imposed on the final mechanism. The third change was increasing the tub thickness in the area containing the alumina ceramic pieces. This would reduce flexing during assembly, welding, and handling. The final evaluation was conducted using two proposed design options, one from Sandia National Laboratories and one from KCD.

As a preliminary step, four pieces of three different designs were built and brazed. Metallurgical examination of the parts was done to evaluate the braze joint and the metallization. The units were welded into contact module housings and then put through a series of tests.

Final design analysis determined that the Mod B and the Mod C would be the configurations chosen for further study.

Pieceparts in both designs were built by a supplier and shipped to Kansas City for testing. The testing included push tests on the headers themselves, cross-sectional evaluations for braze length and metallization density, and repeated exposure to assembly operations such as

welding, cleaning, and temperature cycling. History had indicated that the current design of the header assembly had a high probability of failing during one of these operations. Both designs were fully functional, from a hermetic and an electrical standpoint, at the conclusion of the evaluation.

The final design chosen would be incorporated on all new product for the assembly, approximately half of the FY90 schedules or 450 units. Additionally, it is anticipated that the design would be extended to include a 14-pin header on the an intent stronglink switch; incorporation on the switch would be based on future schedules. At this time the current design has been procured for life of build.

Product redesign was discontinued when changes in the world situation reduced future weapons production. However, should the product ever be resurrected, the results indicate that the redesigned product would be a vast improvement over the current design.

Discussion

Scope and Purpose

This work was performed to evaluate two replacement designs for a six-pin header. The replacement design analytically appears to be a significant improvement from a durability standpoint and would reduce the amount of nonconformance currently generated. The design configuration would be extended to another unit if production schedules require additional procurement. The two stronglink switches are used on multiple programs.

Activity

Product History

The driver for this study was the 16.4% scrap rate seen on one switch during FY 1990. For the other switch, the rate for the same period was 24.9%. The problems had been inherent in the design of both mechanisms, and the scrap rates for previous years track along the same lines. The six-pin and 14-pin headers on the two switches must each pass a 1×10^{-8} cm³/s helium leak test after being welded into a housing and then again after the final assembly of the mechanism has been completed.

The final product containing the six-pin header must withstand a linear acceleration of 210 g's, and temperature extremes of -55°C to +65°C. In addition, the unit must withstand a 2800-volt direct current high pot test through the pins of the six-pin header. The unit cannot leak after

any of these tests. Destructively tested units must also pass a 3500-g shock and a simulation of a transportation vibration test sequence.

The six-pin header is currently designed to be built using a hydroformed Kovar tub, 0.010-inch thick, and alumina ceramic feed-thrus which are machined to their final dimensions before firing to the final hardness. The ceramics are painted with a metallization paint, a silver nickel braze is applied to the ceramic-to-metal interface, and the resulting assembly is cured at high temperature to flow the braze. This design yields an assembly that is relatively easy to manufacture and assemble.

The product has been procured over the years from three different vendors. All three vendors have supplied parts which fail at some point during the assembly process. This appears to indicate that it is the design of the product and not the manufacturer.

Documentation

This evaluation will show the effect of increased surface area and denser metallization between the ceramic and metal pieceparts. Cross-sectional samples were made of the current design and the proposed designs. Pictures were taken and the material composition was analyzed in the joint area. These photographs give a visual history of the changes in the product and design.

Design Definition

Initial failures on the six-pin header and 14-pin header are indicated by leak paths in the area between the alumina ceramic bodies and the Kovar tub. Leak paths are detected at various levels of assembly, in the case of the six-pin headers, at three different assembly points. The method of detecting leaks is backfilling the product or a bell jar with helium and testing the product to meet a 1×10^{-8} cm³/s requirement.

The feed-thru form or "tub" of the header is made from Kovar. Kovar is a sealing alloy made from 53% iron, 29% nickel, and 17% copper. It is widely used for bonding with alumina ceramic. The tub is hydroformed from 0.010-inch stock of the Kovar to meet the definition shown in Figure 1.

The feed-thru or ceramic piece is made from alumina ceramic for electrical and electronics applications. The ceramic is machined in the green or unfired state and then fired to meet the final hardness requirements. The definition is shown in Figure 2.

The material properties of the components in question are included in Table 1 for reference.

The six-pin header design has two sharp corners, a butt joint, and the interface which is filled with a silver nickel braze material, as shown in Figure 3. A metallization paint is applied to the ceramic to improve the bond with the braze material. A cooperative effort between KCD Materials Engineering and a vendor determined that the metallization layer was not dense enough to efficiently bond the braze material with the ceramic. The

sharp corners between the two pieces create an interface of 0.0045 square inch at worst case. This is exacerbated by the thickness of the tub which warps during temperature extremes such as welding, handling, and product-required temperature testing. The other design is similar and is shown in Figure 4.

Independently funded efforts by the vendor and KCD Purchased Products Engineering provided an improved metallization paint. The paint was denser than what was previously used on either product. Samples of the product with this paint were requested and analyzed. The metallization product is a proprietary process and the actual content was not available. The result was a more uniform layer of metallization on the ceramic and an improved braze line. This is discussed in more detail in the section on the Metallization Study.

The SNL/New Mexico design engineer developed a design that incorporated a conical interface between the ceramic and the Kovar tub, thereby increasing the surface area interface between the two parts. This design required that the Kovar tub be machined from a solid piece of material. This increased the overall thickness and the extra material would help prevent warping. The final requirement was that the conical section of the ceramic be machined after firing to maintain concentricity. This eliminates high spots in the braze interface that are detrimental to the bonding strength. The first design, or "Mod A," is shown in Figures 5, 6, 7, and 8.

The Mod A design was analyzed at KCD by assembly and welding engineers. The objective was to determine if the amount of material added to the tub and the changes in the configuration would improve the

Figure 1. Feed-Thru Form

Table 1. Material Data

Properties	Kovar	Silver	Ceramic
Young's Modulus (psi)	20 x 10 ⁶	11 x 10 ⁶	4 x 10 ⁶
Poisson's Ratio	0.34	0.33	0.22
Initial Yield Stress (psi)	45,000	9,200	NA
Plastic Hardening Modulus (psi)	5 x 10 ⁵	2 x 10 ⁵	NA

overall design enough to virtually eliminate the leak problem. One area evaluated was whether the thicker wall design would trap and retain a significantly greater amount of heat than the metallization and braze material could withstand without generating a leak path. A second area evaluated was the thickness-to-depth ratio on the tub. The conclusion was that this design would require a longer or hotter weld to generate the same weld penetration currently being generated. This change could substantially increase the probability of cracks in the braze area. These factors caused Sandia to reevaluate the design and develop a Mod B, shown in Figures 7, 9, 10, and 11. The Mod B reduces the wall thickness and increases the depth to provide a 1:2 ratio of width to depth for welding purposes.

Two suppliers with experience building the headers were asked to review both the Mod A and Mod B designs for manufacturability and durability. Their design review suggested modifications to the Mod B design, generating a Mod C, shown in Figures 7, 12, 13, and 14. Both suppliers suggested very similar changes to the Mod B.

The Finite Element Analysis group was asked to review the three designs: the current design, Mod B, and Mod C. The

objective of the study was to determine their abilities to withstand the extreme temperature shocks which welding would introduce into the product. The results from this analysis will be discussed later in more detail; however, the outcome was that no design appeared to be suited to withstanding the temperature extremes without plastic deformation. The engineer performing the work developed two additional designs, which completed the design package with Mod D and Mod E. The tub design cross sections are shown in Figures 15, 16, and 17. They were designed in an effort to find a configuration that produced lower stresses in the ceramic than those obtained from the current design. The radius between the floor and side wall of the current design was considered a critical feature to retain in order to ensure elastic bending. Efforts were made to incorporate the countersink feature of Mod B and Mod C to provide a greater bond area between the header and feed-thru.

On the basis of the finite element analysis, the inputs from the vendors, and the recommendation of the SNL/New Mexico engineer, the decision was made to produce Mod B and Mod C. A purchase order was placed with one vendor to produce 20 pieces of each design. These would then be tested in the piecepart state

ALL DIMENSIONS
ARE IN INCHES

Figure 3. Contact Module Subassembly

Figure 5. Mod A Assembly

and in the final design configuration and welded into a contact module housing. Over-testing would be performed, and the final results would be analyzed. The sample size was chosen using statistical probability and a 95% confidence level that a leaker would occur. An engineering

decision was made to accept a maximum of a 4% leak rate in next assembly usage.

Metallization Study

In addition to the mechanical redesign, a large amount of effort was directed at the

Figure 6. Mod A Ceramic Feed-Thru

area between the alumina ceramic and the Kovar tub to determine the weak link in the bonding process. Cross-sectional photographs, scanning electron microscopy (SEM), and dye penetrant were used to evaluate the various interfaces between the alumina ceramic and Kovar tub. They indicated that the ceramic and tub were not damaged when a leak occurred. The dye penetrant evaluations found leak paths in the metallized layer. This was usually due to cracks or separations in the metallized layer.

Examination by SEM of the metallized layer indicated excessively thin metallizing, characterized as zero to 200 microinches, and discontinuities ranging from zero to 60%.

Metallization is a proprietary solution which each manufacturer develops independently. In this case both vendors preferred to use a solution composed primarily of two elements, molybdenum and manganese. The actual composition and carriers were not disclosed to KCD. Both

Figure 7. Modified Feed-Thru Form

suppliers did guarantee that they would not cause adverse effects to the product. The primary concern in the hermetically sealed unit is outgassing.

A study was conducted to determine how the bonding layer could be contributing to the leak paths. This study used headers which had leaks and those which passed the product requirements. Samples were taken from different manufacturing lots and manufacturers. The samples from both current suppliers exhibited similar problems: the metallization layer was not

uniform and was too thin to provide adequate bonding.

All samples exhibited common problems in the glassy manganese phase which bonds sintered molybdenum to the ceramic: insufficiency or absence of the phase. If either compound is absent or insufficient, the bond is weak. This can be driven by two things: one, the application process or two, the manganese glassy phase migrating away from the interface into the bulk of the ceramic. The metallizing layer is applied with a small brush to the ceramic in a slurry and subsequently fired

Figure 8. Mod A Feed-Thru Cross-Sectional View

at 1300°C to sinter and bond it to the ceramic. It appears that the brushed-on slurry layer is too thin. This is especially apparent in the corner where the slurry has migrated towards the edges of the

ceramic. Migration could be a result of excessive firing or excessive porosity of the ceramic. Excessive firing is a result of either firing for too long or at too high a temperature. The resulting migration takes

Figure 9. Mod B Assembly

the glassy manganese bonding agent away from where it is needed most at the ceramic interface. An example of a well-defined layer is shown in Figure 18.

Examples of the worst cases are shown in Figures 19 and 20. Both pictures are taken at 500 power magnification. Figure 19

has a metallization layer thickness of 146 microinches; Figure 20 has a thickness of 168 microinches. Slight improvements in the thickness are shown in Figure 21. This sample is 372 microinches thick but contains 50 percent discontinuities. An adequate metallization layer for this type of bonding

Figure 10. Mod B Ceramic Feed-Thru

should be a uniform thickness of 300 microinches, that is, with no discontinuities.

One vendor was commissioned to develop a better metallization paint. The paint that they developed was described as being denser than the previous paint. Twenty-eight samples were built and sent to KCD for evaluation. These parts were cleaned, leak tested, and welded into contact module housings. The subassemblies

were then high-potted at 2800 volts direct current, cleaned, baked, and exposed to three cycles of thermal shock. Some of the assemblies were then re-welded. All assemblies passed the final leak test. A sample of the headers were then cross-sectioned and evaluated. Finally, a portion of the remaining samples were pull-tested. Three pins each on two headers were push-tested to failure. The product samples had separation values from 39.1 to 51.9 pounds. Current product typically

VIEW AA

Figure 11. Mod B Feed-Thru Cross-Sectional View

separates around 31 pounds. The metallization layer in these parts was a significant improvement over the previous product. Examples of the braze joint with the new metallization paint are shown in Figures 22 and 23.

Finite Element Analysis

A finite element analysis was performed on the Mod B and Mod C designs to determine the best choice for continued study. The analysis centered on the

Figure 12. Mod C Assembly

welding aspect of the process only. This process was chosen based on all processing associated with the assembly. It was determined that welding would be the highest potential cause of defects. Inherently, welding imparts high heat into

a concentrated area for a short period of time followed by rapid cooling.

Figure 13. Mod C Ceramic Feed-Thru

Two-Dimensional Analysis

The welding operation was initially investigated using simple two-dimensional models of the Kovar header (Figure 24). For comparison purposes, each header was assumed to be welded to a steel block.

A two-step methodology was followed in carrying out the analyses. First, a transient heat transfer analysis was conducted to predict an entire temperature history as a

result of the welding process. This was done by applying energy to the header and block interface over a short duration (0.125 seconds). The model was then allowed to cool via convection and radiation losses over the next 100 seconds. Finally, all nodes were brought back to room temperature over the last 100 seconds. The energy application was carried out iteratively, to match the approximate size and shape of the melt zone in the current design.

Figure 14. Mod C Feed-Thru Cross-Sectional View

The entire temperature history predicted by the heat transfer analysis was used as the loading mechanism for the subsequent stress analysis. Both the Kovar and steel were considered as thermo-elastic-plastic materials that generally soften and lose

strength as they are heated. The right side of the steel block was restrained against any displacement throughout the analysis; this simulated the restraint imposed by the stiffness of the actual housing and header assembly. In addition, a symmetry

Text continued on page 29.

Figure 15. Mod D Feed-Thru Cross-Sectional View

Figure 16. Mod E Feed-Thru Cross-Sectional View

Figure 17. Mod E Feed-Thru Form

Figure 18. Acceptable Metallization Study, 400X

Figure 19. Poor Metallization--146 Microinches, 60% Discontinuous, 500X

Figure 20. Poor Metallization--168 Microinches, 30% Discontinuous, 500X

Figure 21. Poor Metallization--372 Microinches, 50% Discontinuous, 500X

Figure 22. Improved Metallization--375 Microinches, 500X

Figure 23. Improved Metallization--500 Microinches, 500X

condition was imposed along the centerline of the header, allowing vertical displacement, but prohibiting horizontal displacement. The header and block were connected to a depth corresponding to the weld penetration, with a contact interface specified between the two bodies for an appropriate depth below that.

Temperature results from the heat transfer analysis for the current design are shown in Figure 25. These are plotted for the point in time immediately following the application of energy to the header and block interface. The contours delineate the solid and liquid phases of the metals, as indicated. The size and shape of the melt zone approximately match those of the current weld penetration area. A second temperature plot is depicted in Figure 26. In this plot, the contours are set up to delineate the heat-affected zone in the steel, greater than 950°F. This region

shows up clearly on etched cross sections of experimental weld samples. The radius of the heat-affected zone predicted by the analysis is 0.040 inch, while the weld sample measurement is approximately 0.030 inch. Temperature histories at three points in the model are shown in Figure 27. While the predicted temperatures appear to be higher than those measured experimentally, this can be accounted for by noting that the actual housing into which the header is welded provides significantly more mass to dissipate the heat generated by the laser than the block used in the analysis.

Using the predicted temperature histories at all nodes in the model, a thermal stress analysis was then carried out. Two plots of magnified distortions predicted by this analysis are depicted in Figure 28. The first is immediately following the energy application to the header-to-block interface.

Figure 24. Two-Dimensional Models

Figure 25. Weld Temperatures (°F)-Current Design (Example A)

Figure 26. Weld Temperatures (°F)—Current Design (Example B)

Figure 27. Weld Temperature History

At this point, material in close proximity to the weld is at its greatest temperature and wants to expand both vertically and horizontally due to its thermal expansion characteristics. Vertical expansion is, for the most part, unrestrained. However, horizontal expansion is inhibited by the restraints on the right and left edges of the model. To accommodate this expansion, the header bends at the radius between its floor and side wall, thus forcing the center of the header downward, as indicated. The second plot in this figure depicts the deformed configuration once the entire node has cooled back down to the initial

room temperature. It can be noted that this configuration is nearly identical to the original, before-weld configuration. Thus, little permanent deformation is predicted for the current header design as a result of the laser welding process.

Stress histories at selected points in the header are plotted in Figure 29. Normal stresses in the x-direction along the symmetry plane and through the floor thickness are plotted as a function of time. Corresponding to the displacement results shown in the first plot of Figure 11, the top and bottom surface of the floor go into

Figure 28. Weld Distortions—Current Design (Example A)

Figure 29. Weld Stress History--Current Design

compression and tension, respectively, during and immediately following the generation of the weld. This is denoted by the spikes in the history near $t = 0$. However, as the model cools and returns closely to its original configuration at $t = 200$, these stresses relax significantly to a state of low residual tensile stress through the thickness.

The same analysis procedure was then carried out for Mod B. Applying the identical energy profile as for the current design model results in the weld temperature profiles depicted in Figure 30.

As the side wall thickness for Mod B is 50% greater than for the current design, the smaller melt zone predicted by this analysis can be expected.

Predicted displacements from the thermal stress analysis of Mod B are shown in Figure 31. Similar to the current design, the corner between the side wall and floor bends to accommodate the thermal expansion. However, as the model cools, the floor of the header displaces to a position above the original configuration. This final equilibrium position significantly affects the final state of stress in the

Figure 30. Weld Temperatures (°F)-Mod B

Figure 31. Weld Distortions-Mod B (Example A)

header, as shown in Figure 32. As a result, the top surface ends up in a relatively high state of tensile stress as compared to the current design.

Plastic deformation in the header appears to be the primary cause of these high residual stresses. Figure 33 shows a comparison of equivalent plastic strain, a measure of permanent deformation, in the current header design and Mod B immediately following the generation of the weld. The plot indicates plastic strain levels are somewhat greater in the Mod B model than in the current design model.

The difference in the final stress states between the two models is accounted for as follows. In the current design, the radius corner between the floor and side wall is relatively flexible. It is capable of bending elastically to accommodate the thermal expansion of the heated material near the weld, as indicated by the low or nonexistent levels of plastic strain in this region. As the welded bodies cool, the lack of permanent deformation in the corner allows the header to return to its original position and a relatively low residual stress state. In Mod B, the corner is not capable of any significant elastic bending. As it bends to accommodate the thermal expansion, the deformation induced is permanent, as indicated by the higher levels of plastic strain. As cooling is initiated, the thermal expansion reverses, and the associated internal forces begin to pull on the header side wall. Because the corner has deformed plastically, it will not readily return to its original configuration. Rather, these internal forces cause the header floor to displace above its pre-weld position, resulting in relatively large residual tensile stresses across the top surface of the floor.

Analyses of Mod C indicate the same type of results, although to a lesser degree. Geometrically, Mod C is more flexible than Mod B, thus generating less plastic strain near the corner, as shown in Figure 34. However, the residual stress state is still relatively high, as indicated by the stress history plot in Figure 35.

Three-Dimensional Analysis

The previous two-dimensional analyses considered only a tub with no internal components, such as the ceramic feed-thru. It was assumed that the stresses in the header floor were transmitted to the braze joint and feed-thru. Three-dimensional analyses were conducted to verify that the predicted characteristic behavior of each header configuration is not significantly altered by the internal components.

Figure 36 illustrates the three-dimensional finite element models that were generated for the current design, Mod B, and Mod C. The steel block to which each header was welded was identical to that used in the previous analyses. The right face of the block was fully restrained, and symmetry conditions were specified along the centerline of each header. In addition, two more symmetry planes were specified along the front and back face of each model.

Figure 37 depicts temperatures in the model of the current design immediately following the generation of the weld. As before, the contours delineate the solid and liquid phases. The predicted melt zone in this case is similar to that for the two-dimensional analysis.

Results from the stress analysis are also similar to those previously obtained.

Figure 32. Weld Stress History--Mod B

Predicted displacements are shown in Figure 38. The header bends elastically as the heated material expands, then returns to its original position after cool-down to room temperature. Maximum principal stress in the ceramic after cool-down is illustrated in Figure 39. The largest tensile stress develops along the front symmetry plane, at the braze joint.

Displacement results from the analysis of Mod B are shown in Figure 40. As before, upon cooling to room temperature, the header does not return to its original position. As indicated in Figure 41, this

causes much larger tensile stresses to develop in the ceramic, compared to the model of the current design. Although not plotted, results from the Mod C analysis also indicate relatively large tensile stresses in the ceramic.

Mod D and Mod E Analysis

Finally, the two Mods suggested by the finite element engineer were analyzed. The resulting configurations are shown in Figures 15, 16, and 17. The corresponding

Figure 33. Equivalent Plastic Strain—Current Design and Mod B

Figure 34. Equivalent Plastic Strain--Mod B and Mod C

Figure 35. Weld Stress History--Mod C

finite element models are depicted in Figure 42.

Stresses in the ceramic from each model are plotted in Figures 43 and 44. In each case, the location of largest tensile stress has rotated 90 degrees, compared to the previous models. However, in the Mod E analysis, predicted stresses in the ceramic are significantly lower than from any of the previous analyses.

Table 2 summarizes the results obtained from all the three-dimensional analyses.

Finite Element Conclusions

Analyses of the welding operation for the six-pin header assembly indicate that the bending in the corner between the floor and side wall accommodates the thermal expansion. This is of primary importance in the final state of stress that develops in the ceramic feed-thru. Elastic bending allows the header to return to its pre-weld configuration. This allows relatively low residual tensile stresses to be transmitted to the feed-thru. Plastic bending inhibits the corner from returning to its pre-weld

Text continued on page 52.

Figure 36. Three-Dimensional Models (Example A)

Figure 37. Weld Temperatures (°F)-Current Design (Example C)

Figure 38. Weld Distortions--Current Design (Example B)

Figure 39. Maximum Principal Stress in Feed-Thru-Current Design

Figure 40. Weld Distortions—Mod B (Example B)

Figure 41. Maximum Principal Stress in Feed-Thru-Mod B

Figure 42. Three-Dimensional Models (Example B)

Figure 43. Maximum Principal Stress in Feed-Thru-Mod D

Figure 4A. Maximum Principal Stress in Feed-Thru-Mod E

Table 2. Tensile Strength in Ceramic Feed-Thru

Model	After Weld (psi)	After Cool-Down (psi)
Current Design	12,600	15,000
Mod B	6,100	74,400
Mod C	7,200	51,000
Mod D	1,800	11,400
Mod E	1,100	3,100

configuration, thus forcing the header floor to displace upward, above its pre-weld position. These conditions generate significant tensile stress across the top surface of the floor, which is transmitted to the feed-thru.

Both Mod B and Mod C exhibit plastic bending of their respective corners during the welding simulation, and thus relatively large tensile stresses are generated in the feed-thru upon cool-down. Mod D and Mod E both incorporate the same radius between the floor and side wall as the current design. This flexibility allows the bending to occur elastically and minimizes the final stress state. Mod E particularly indicates a potential to reduce stresses significantly over the current design.

Test Plan

The test plan developed included building a limited number of prototype units at SNL/New Mexico and the balance at the supplier. Initially Mod A, Mod B, and Mod C were built and analyzed metallurgically to determine the best combination of design and braze flow. Four units of the Mod A and Mod B were built at SNL New Mexico and four Mod C units were built at the supplier. All three

designs increased the braze area and eliminated the butt joint of the two sharp corners, as previously stated. The prototype assemblies were subjected to the tests listed in Table 3.

These tests fairly well indicated what had been suspected originally, that a sample of four parts would not provide enough data to make a complete design change. It did, however, provide enough information to eliminate Mod A as one of the design choices.

Twenty pieces of each of the final sets of Mod B and Mod C were ordered. The test plan for these parts was similar to the initial test but contained more steps and doubled the amount of leak-testing involved. The parts were leak-tested in the loose state, and four of each mod were push-tested to determine a minimum strength. The 16 remaining pieces of each configuration were welded into contact module housings and subjected to a series of assembly operations similar to those a unit might experience during the production cycle. The test plan is summarized in Table 4.

Table 3. Prototype Test Plan

Condition	Test	Parameter/Limit
Loose Headers	Helium Leak Test	$1 \times 10^{-8} \text{ cm}^3/\text{s}$
Header and Housing	Weld Product	Standard Schedule
Welded Assembly	Helium Leak Test	$1 \times 10^{-8} \text{ cm}^3/\text{s}$
Welded Assembly	Weld Ball Cleaning	Standard Operation
Welded Assembly	Helium Leak Test	$1 \times 10^{-8} \text{ cm}^3/\text{s}$
Welded Assembly	Hi-Pot	2800 VDC, 2-s maximum, 5X
Welded Assembly	Helium Leak Test	$1 \times 10^{-8} \text{ cm}^3/\text{s}$
Welded Assembly	Vapor Degrease Cleaning	Standard Operation
Welded Assembly	Vacuum Bake	Standard Operation
Welded Assembly	Push Test Pins	Compare to WR Product
Welded Assembly	Cross-Section Weld and Braze	Compare to WR Product

Test Results

Push-Test Results

The results of the push-testing performed on the Mod B and Mod C units are summarized in Table 5. The push-test was performed on the large diameter of two pins per header. One end pin and one pin near the middle of the six-pin header were chosen for each header in the test. The selected pins were pulled to failure or fifty pounds; as stated previously, current product fails or separates around 31 pounds.

The test report indicates that none of the units failed the fifty-pound requirement, although the majority of the values are below this level. The grip slid off the parts at the level recorded.

Assembly Test Results

All 16 of the Mod B and 16 of the Mod C were completed without any leak indications. The weld duration and intensity were not changed from the schedule of the current design in the WR definition. This indicates that both designs are more durable than the current definition.

Conclusion

The two designs, Mod B and Mod C, are improvements over the current design definition of the Contact Module Subassembly, or the six-pin header. The product appears to be more stable than the predecessor in terms of the braze joint and the susceptibility to handling damage. If either assembly is reactivated, this design

Table 4. Mod B and Mod C Qualification Plan

Condition	Test	Parameter/Limit
Loose Headers	Soda Blast	Standard Operation
Loose Headers	Demagnetize	Standard Operation
Loose Headers	Clean	Standard Operation
Loose Headers	Clean	Standard Operation
Loose Headers	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Loose Headers	Form Wires	Standard Operation
Loose Headers	Assemble	Standard Operation
Assembled Header and Housing	Laser Weld	Standard Operation
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Weld Ball Clean	Standard Operation
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Hi-Pot	2800 VDC, 2-s maximum, 5X
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Two-Stage Alcohol Clean	Standard Operation
Welded Assembly	Vacuum Bake	Standard Operation
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Hi-Pot	2800 VDC, 2-s maximum, 5X
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Thermal Shock	See Below*
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s
Welded Assembly	Re-weld 4 of Each Mod	Standard Operation
Welded Assembly	Helium Leak Test	1 x 10 ⁻⁸ cm ³ /s

*The thermal shock cycle consisted of three cycles. The temperatures were cycled between -55°C and +65°C with a soak of one hour at each extreme.

Table 5. Mod B and Mod C Push-Test Data

Sample Number	Pin 1 (lbs)	Pin 2 (lbs)	Mean (lbs)
MODC1P	49.4	49.3	49.4
MODC2P	50.3	47.6	49.0
MODB1P	47.4	45.2	46.3
MODB2P	47.2	47.6	47.4

should be considered a major component for new or continued production.

Accomplishments

The accomplishments of this project are as follows.

- An improved alternative to the current design product was designed and built.
- An improved metallization layer in the alumina ceramic and Kovar interface was developed.
- A process was developed to perform precision machining on fired ceramics.
- Design agency, supplier, and production agency personnel worked concurrently to design an improved product.

END

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