176
27 cyp
5 to WT 15
MLM-22

MLM-2280

**MC2990 - Development of a Helium
Leak Tight Header**

Frank W. Weyler and Alvan C. Taulbee

July 30, 1976

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Abstract

All of the development efforts expended on establishing a fabrication process for the MC2990 sealed header are described. Effects of molding pressure and temperature are discussed. Helium leak test data are presented for various header configurations.

The header molding process as developed in this effort has resulted in an acceptance rate greater than 90%.

EQUIPMENT

LEAK DETECTOR

All helium leak tests were performed using a Consolidated Electrodynamics Corporation (CEC) leak detector (24-120B), which incorporates a No. 24-038 test port and roughing station. A special bell jar fixture was fabricated to accommodate the MC2990 header for leak testing.

The housing (connector side of detonator) is submerged in helium at a pressure of one atmosphere while header surface F (See Figure 1) is being pumped by the leak detector. The two parts of the header are isolated by an o-ring seal around the insert so that the only leak path for the helium is through the header.

FIGURE 1 - Cross-sectional view of MC2990 header.

MOLDING PRESS

A Drabert Press, Model DS-25, was used to mold the MC2990 headers for this development effort. This press is a horizontal, hydraulic transfer press, which has automatic, semiautomatic, and manual modes of operation. A modification was made to the press that incorporates a timer and control valve, thereby providing the

capability of filling the component with plastic at a low pressure and then automatically raising the pressure to its maximum. The press has a shot capacity of approximately one ounce and a maximum ram pressure of 3000 psig. The platens are electrically heated and thermostatically controlled.

INTRODUCTION

The MC2990 is an exploding bridgewire (EBW) detonator undergoing development for incorporation in the W 76 and W 78 weapons. In order to prevent possible deterioration of the explosives from outside environments, the detonator header (Figure 1) must be fabricated in such a way that no gaseous atmospheres can penetrate. The specification requires that the seal between the DAP (diallyl phthalate) and contact wires-housing/insert interfaces must not leak more than 1×10^{-5} cc/sec of helium at a pressure differential of one atmosphere. Sandia purchase order 64-8046 was placed with Mound Laboratory to develop a process capable of producing MC2990 headers meeting this leak rate specification. The work described herein is a chronological description of all activities performed on Sandia purchase orders that relate to the development of a sealed MC2990 header.

DEVELOPMENT EFFORTS

In the early development of the MC2990, the molding operations were performed on the basis of past experience gained from molding the MC2318 detonator which has the same helium leak rate requirement.

Basically, this involved molding at higher pressures than were normally used. The first few headers, molded at approximately 2400 psig ram pressure, failed the high potential test between contacts and housing.

Upon sectioning these parts, it was observed that the contact wires had been deformed and were touching the inside wall of the housing. This deformation was caused by the DAP flowing into the part at a relatively high velocity, which was a direct result of the higher molding pressures being used. To overcome this situation, the molding process was changed to fill the part with DAP at low pressure/velocity and then raise the pressure while the DAP is still fluid (approximately 30 sec depending on the plastic batch). It became readily apparent, that the techniques used previously would not accomplish the desired results in the MC2990. New

methods, processing, and/or design were required. Although the geometry of the MC2318 and MC2990 detonator is similar, their size and housing/insert materials are different. See Table 1 for comparative data.

Table 1

COMPARISON OF MC2318/MC2990

	MC2318	MC2990
Housing/Insert	Brass	Aluminum
Molding Compound	DAP	DAP
Housing (i.d.)	0.135 in.	0.304 in.
Insert (i.d.)	0.123 in.	0.125 and 0.146 in.

Leak rates were large enough in the early phases of development that the leak detector would not read on scale or a vacuum could not be achieved on the header to start the test. These excessive leak rates allowed pressure testing with argon and Leaktec (soap solution). Pressurizing the header with 15 psig of argon while applying Leaktec to the connector and sprue areas of the housing indicated that the leak path was along the inside walls of the insert and housing. Leakage was observed at the sprue and the inside diameter of the housing. No leakage was evident around the contact pins.

Since the molding pressure had already reached the limits of the press, and no higher pressures could be achieved, three potential solutions were pursued: (1) apply a primer coating to the inside of the housing/insert . . . this concept would provide a filler material in the gap as the DAP shrinks away from the housing/insert . . . additionally it would provide an adhesive surface to which the DAP might adhere, (2) incorporate grooves in the walls of the housing/insert so that the helium would encounter a more torturous path . . . also, a groove should be incorporated to take advantage of the fact that the plastic shrinks away from the housing and in so shrinking would seal against the inside edge of the groove, (3) use different configurations of vent slots to achieve a better seal between the housing/insert and the mold that will facilitate higher molding pressures.

Three types of primers were used:

- (a) Epon 828 - Versamid 140
- (b) Alumina
- (c) Urethane

None of the primers provided molded headers that met the helium leak test requirements.

Four types of grooves were used:

- (a) Square
- (b) Vee
- (c) Spiral
- (d) Undercut Grooves

Incorporation of grooves was also unsuccessful in achieving the desired results.

Combination grooves and primers were tried with the thought that the primer in the groove would be compressed during molding and would expand during cure. None of these experiments provided leak tight headers consistently.

The best vent configuration proved to be that of the original design (slots, 0.050 in. wide by 0.002 in. deep). The purpose of vents is to allow air to escape as the molding compound is flowing into the part. After the part is filled, the DAP in the vent areas will cure and seal the plastic in the part allowing a higher molding pressure to be applied. If this seal is lost, the DAP in the header is cured under very little or no pressure. It was learned that successful sealing was accomplished by controlling the fill/cure cycles within the range of time that the plastic is fluid. Attention was again directed to the molding parameters of pressure, temperature, cure and fill cycles.

Evaluation of data (See Table 2) obtained during the course of these experiments indicated the following trends:

- (a) Molding pressures in excess of 2400 psig are required.
- (b) Temperatures above 150°C yielded more headers meeting the helium leak rate requirement.
- (c) Whenever the seal was lost during molding, the header did not pass the helium leak test.
- (d) The physical properties of the DAP batch greatly affect the mold seal.

Table 2

INITIAL RESULTS OF LEAK TESTS

DAP Batch	Serial No.	Pressure	Temperature (°C)	Leak Rate	Remarks
1	416	1000/2400	152	$<1.0 \times 10^{-9}$	
1	417	1000/2400	162	2.5×10^{-7}	
1	418	1000/2600	152	8.0×10^{-5}	Reject
1	419	1000/2600	152	3.3×10^{-8}	
1	426	1000/2900	150	3.3×10^{-8}	
1	429	1000/2900	150	$<1.0 \times 10^{-9}$	
1	431	1000/2900	148	1.3×10^{-4}	Reject/ Lost Seal
2	415	1000/2600	150	1.7×10^{-5}	Reject
2	421	1000/2600	150	3.5×10^{-5}	Reject/ Lost Seal
2	428	1000/2400	150	4.6×10^{-9}	Reject
2	432	1000/2400	~150	3.4×10^{-5}	Reject/ Lost Seal
2	435	1000/2400	150	3.5×10^{-5}	Reject/ Lost Seal

Comparison of physical properties of the DAP and housing/insert assembly provided additional insight into the problems of achieving a helium leak tight header. It was necessary to determine if the aluminum housing/insert assembly was remaining in the elastic range during the molding process. This determination was made for both the connector end of the housing and the insert, using the following equations for stress:

$$S_A = \text{Axial Stress} = P \left(\frac{ID^2}{OD^2 - ID^2} \right)$$

$$S_H = \text{Hoop Stress} = P \left(\frac{OD^2 + ID^2}{OD^2 - ID^2} \right),$$

where: P = Molding Pressure - 2900 psi

ID = Inside Diameter

OD = Outside Diameter

The results of these calculations are tabulated in Table 3 along with the published yield stress. In reviewing these data, it is apparent that both the housing and insert are well within the elastic range and therefore need not be a consideration in the leak problem.

To determine how much the DAP shrinks in comparison to the housing/insert, it was necessary to consider the thermal expansion of the housing/insert during molding. Starting with the equation of linear expansion:

$$L_1 = L_0 (1 + \alpha \Delta t),$$

where L = length

α = temperature coefficient of linear expansion for aluminum = $24 \times 10^{-6} \text{ in./in./}^\circ\text{C}$

Δt = temperature difference $\approx 125^\circ\text{C}$

let, L = inside circumference =

πID ; substituting

$$\pi D_1 = \pi D_0 (1 + \alpha \Delta t)$$

$$\text{or } D_1 = D_0 (1 + \alpha \Delta t)$$

Thus, this equation will provide the thermal expansion and subsequent contraction of the diameters of the housing/insert which can be compared with the DAP shrinkage after molding. Results of these calculations are tabulated in Table 4.

Table 3

COMPONENT STRESS

Stress (psi)	Yield Stress ^a
Insert S_A = 5394	27 000 psi @ 300°F
S_H = 13 688	
Housing S_A = 3965	
S_H = 10 830	

^a ASME Section VIII Division 2 Table AWF 2.1.

Table 4

COMPONENT SHRINK RATES

	Molding Temperature (°C)	Aluminum ΔD (in.)	DAP ΔD (in.)
Housing	150	0.00091	0.00122 ^a
Insert	150	0.00037	0.00050 ^a
Housing	160	0.00098	
Insert	160	0.00042	

^aBased on shrink rate of 0.004 in./in.
(Allied Chemical Data Sheet DIAL 52-1
lists shrinkage as 0.002-0.005 in./in.)

Judging from these rudimentary calculations, it would appear that the physical characteristics of the materials involved would prevent the fabrication of a helium leak tight component. Or, at best, it would result in borderline leak rates. However, there is also a small housing/insert shrinkage from its elastic expansion caused by molding pressure; the calculations for which are beyond the scope of this development effort. Additionally, the DAP shrink rates may vary anywhere from 0.002 to 0.005 in./in. depending on the molding parameters and plastic batch being used.

In order to overcome the inequities caused by the physical properties of the materials involved, the following process parameters were established:

Molding Pressure:

1. Must be relatively low (1000 psi) during fill to avoid deformation of contact wires.
2. Must be as high as possible (2900 psi - maximum attainable with present equipment) when plastic is in fluid state to decrease the amount of shrinkage during cure.

Molding Temperature:

1. Must be relatively high (160-170°C) to obtain maximum expansion and subsequent contraction of aluminum housing/insert.
2. Must not be too high to avoid blistering of the DAP.

Mold Seal:

1. Must not lose seal.
2. So high pressure can be maintained, control fill/cure cycle to first seal vents.

Test data for components molded using these parameters are listed in Table 5. Evaluating these data substantiate the earlier conclusions that the materials involved provide only a marginal capability of producing a helium leak tight header. The reject rate of 40%, determined from Table 5, is unacceptable for production.

In order to obtain an acceptable reject rate, a vacuum impregnation process has been devised to seal the headers after molding. A low viscosity epoxy compound (Epon 815 and Versamid 140) is applied to the molded component at the bridgewire end (datum feature - F in Figure 1). The component, having the liquid epoxy covering the DAP, contacts and insert, is placed in a vacuum (20-29 in. Hg) for 1 to 2 min. during which time the air is evacuated from the small gaps between the plastic and metal surfaces. Upon bringing the component back to atmospheric pressure, the epoxy is forced into the gaps. The excess epoxy is then wiped off, the component is sprayed clean with alcohol, inspected to ensure all traces of epoxy are removed, and then allowed to cure. This process has yielded a better than 90% acceptance rate. Leak rate results before and after vacuum impregnation are tabulated in Tables 5 and 6, respectively.

TESTING

In order to determine if the headers would maintain an acceptable helium leak rate after thermal environments, 29 headers were subjected to the 190°F, 30-hr environment as specified in PS315395 paragraph 4.3.3. Of the headers subjected to this test, only two had the seal broken during thermal storage. See Table 6 for a tabulation of these data.

CONCLUSIONS

It has been determined that it is possible to fabricate MC2990 headers having an acceptable helium leak. However, it is necessary to use a separate sealing process in addition to controlling the molding parameters to achieve this condition.

Table 5

LEAK TESTS - RESULTS BEFORE EPOXY IMPREGNATION

Serial No.	Temperature (°C)	Low Pressure (psi - sec)	High Pressure (psi - sec)	Leak Rate (cc/sec Helium)	Remarks
885	160	1000-18	2900-12	5.3×10^{-6}	
890	164	1000-16	2900-14	No Reading	Seal Lost (Rej)
891	162	1000-18	2900-12	No Reading	Seal Lost (Rej)
898	162	1000-16	2900-14	3.4×10^{-8}	
899	164	1000-16	2900-14	1.1×10^{-8}	
900	162	1000-16	2900-14	1.4×10^{-6}	
901	163	1000-16	2900-14	No Reading	Seal Lost (Rej)
902	162	1000-16	2900-14	1.6×10^{-6}	
903	168	1000-16	2900-14	8.1×10^{-6}	
904	164	1000-16	2900-14	2.6×10^{-6}	
905	162	1000-16	2900-14	8.1×10^{-6}	Seal Lost (Rej)
906	162	1000-16	2900-14	3.8×10^{-6}	
907	160	1000-16	2900-14	3.0×10^{-6}	
908	160	1000-16	2900-14	3.0×10^{-6}	
909	162	1000-16	2900-14	2.4×10^{-6}	
910	166	1200-17	2900-13	2.7×10^{-5}	Reject
911	158	1200-17	2900-13	7.8×10^{-6}	
912	162	1200-17	2900-13	6.5×10^{-6}	
913	162	1200-17	2900-13	No Reading	Seal Lost (Rej)
914	164	1200-17	2900-13	2.1×10^{-5}	Reject
915	164	1200-18	2900-12	7.7×10^{-6}	
916	166	1000-16	2900-14	7.8×10^{-6}	
917	164	1000-16	2900-14	No Reading	Seal Lost (Rej)
918	164	1000-16	2900-14	1.2×10^{-6}	
919	162	1000-16	2900-14	3.8×10^{-6}	Seal Lost (Rej)
920	166	1000-16	2900-14	3.0×10^{-6}	
921	163	1000-16	2900-14	8.4×10^{-6}	
922	166	1000-16	2900-14	1.2×10^{-5}	Reject
923	162	1000-16	2900-14	1.2×10^{-5}	Reject
924	166	1000-18	2900-12	4.0×10^{-5}	Reject
925	162	1000-18	2900-12	1.7×10^{-5}	Reject
926	166	1000-18	2900-12	4.1×10^{-5}	Reject
927	164	1000-18	2900-12	3.2×10^{-6}	
928	164	1000-18	2900-12	4.4×10^{-6}	
929	164	1000-18	2900-12	5.7×10^{-6}	
930	164	1000-18	2900-12	4.6×10^{-6}	
931	164	1000-18	2900-12	5.7×10^{-6}	
932	162	1000-18	2900-12	3.8×10^{-6}	
933	162	1000-18	2900-12	3.7×10^{-6}	
934	162	1000-18	2900-12	5.5×10^{-6}	
935	162	1000-18	2900-12	2.1×10^{-6}	
939	164	1000-16	2900-14	6.5×10^{-6}	
940	162	1000-16	2900-14	5.5×10^{-5}	Seal Lost (Rej)
941	164	1000-16	2900-14	1.2×10^{-5}	Seal Lost (Rej)
943	162	1000-16	2900-14	9.1×10^{-6}	
957	167	1000-16	2900-14	1.1×10^{-5}	Reject
958	162	1000-16	2900-14	1.2×10^{-5}	Reject
959	164	1000-16	2900-14	5.5×10^{-5}	Seal Lost (Rej)
960	162	1000-16	2900-14	1.0×10^{-5}	
961	166	1000-16	2900-14	1.4×10^{-5}	Reject
962	162	1000-16	2900-14	1.1×10^{-5}	Reject
963	162	1000-16	2900-14	7.5×10^{-6}	
964	162	1000-16	2900-14	1.2×10^{-5}	Reject
965	162	1000-16	2900-14	4.3×10^{-6}	
966	162	1000-16	2900-14	No Reading	Seal Lost (Rej)

Table 6

LEAK TESTS - RESULTS AFTER EPOXY IMPREGNATION

Serial No.	Leak Rate (cc/sec of helium)	Leak Rate After Epoxy Impregnation (cc/sec of helium)	Leak Rate After Thermal Storage (cc/sec helium)
880	Unmeasurable	3.7×10^{-6}	6.3×10^{-9}
881	2.8×10^{-6}	2.0×10^{-9}	3.1×10^{-7}
882	Unmeasurable	2.7×10^{-9}	8.9×10^{-8}
883	1.5×10^{-5}	1.9×10^{-6}	1.9×10^{-6}
884	2.1×10^{-6}	1.6×10^{-9}	1.5×10^{-6}
885	5.3×10^{-6}	1.9×10^{-10}	1.3×10^{-6}
886	Unmeasurable	6.1×10^{-10}	4.3×10^{-5} Rej
888	Unmeasurable	6.3×10^{-6}	2.5×10^{-5} Rej
889	8.2×10^{-6}	1.8×10^{-9}	9.6×10^{-7}
898	3.4×10^{-8}	2.5×10^{-9}	1.1×10^{-7}
903	8.1×10^{-6}	2.0×10^{-8}	2.0×10^{-6}
904	2.6×10^{-6}	6.9×10^{-7}	4.3×10^{-7}
905	8.1×10^{-6}	3.0×10^{-7}	1.9×10^{-6}
906	3.8×10^{-6}	3.3×10^{-6}	4.5×10^{-8}
907	3.0×10^{-6}	1.7×10^{-8}	1.6×10^{-6}
908	3.0×10^{-6}	4.2×10^{-9}	Not Tested
909	2.4×10^{-6}	7.2×10^{-9}	1.4×10^{-6}
910	2.7×10^{-5}	3.3×10^{-6}	4.6×10^{-6}
911	7.8×10^{-6}	2.3×10^{-8}	1.9×10^{-8}
912	6.5×10^{-6}	1.1×10^{-7}	2.4×10^{-7}
913	No Reading	2.7×10^{-9}	Not Tested
914	2.1×10^{-5}	9.9×10^{-7}	4.7×10^{-6}
915	7.7×10^{-6}	2.9×10^{-7}	6.0×10^{-7}
916	7.8×10^{-6}	1.6×10^{-9}	Not tested
917	Unmeasurable	1.2×10^{-7}	Not tested
918	1.2×10^{-6}	1.3×10^{-9}	Not tested
919	3.8×10^{-6}	2.2×10^{-9}	Not tested
920	3.0×10^{-6}	2.9×10^{-7}	Not tested
921	8.4×10^{-6}	3.0×10^{-8}	Not tested

FURTHER STUDY AREAS

At the end of the scheduled development effort, two additional methods for molding helium leak tight headers were briefly investigated. Both of the following techniques warrant additional study:

1. Use Epiall 1914 as a substitute for DAP. Epiall 1914 is an epoxy molding compound reinforced with short glass fibers and has a smaller shrink rate than the DAP. Helium leak rates of the four parts molded with 1914 are listed in Table 7.
2. A primer coating (M & T Primer 227-P; manufactured by M & T Chemicals Inc.) was applied to the inside diameter of the insert and cured for 15 to 30 min at 365-400°F. The leak rate data for these parts, both before and after thermal storage, were very encouraging and are listed in Table 8.

There is no compatibility data for the M & T Primer 227-P and the Epiall 1914 with explosives at the present time. Additional work in this area is needed before these materials can be considered for use in the MC2990.

Table 7

LEAK TEST RESULTS OF HEADERS
MOLDED WITH EPIALL 1914

Serial No.	Mold Press (psi)	Leak Rate (cc/sec helium)
951	~1100	2.6×10^{-5}
953	1100	Unmeasurable
954	1900	7.3×10^{-8}
955	1100	2.1×10^{-5}

Table 8

LEAK TEST RESULTS AFTER
APPLICATION OF M & T PRIMER 227-P

Serial No.	Leak Rate (cc/sec helium)	Leak Rate After Thermal Storage (cc/sec helium)
967	$<1.0 \times 10^{-9}$	1.9×10^{-9}
968	1.7×10^{-7}	9.7×10^{-10}
969	3.1×10^{-8}	6.8×10^{-9}
970	1.7×10^{-9}	5.7×10^{-9}
971	9.3×10^{-7}	3.9×10^{-9}
972	1.1×10^{-7}	1.9×10^{-9}
973	7.4×10^{-10}	5.8×10^{-9}

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