Attention: Procurement and Production Directorate
SMIPA - PBI

Subject: Contract No. DA-04-200-AMC-477 (A)
Development and Evaluation of a Lightweight Aluminum Honeycomb Case
Monthly Progress Report No. 9

Gentlemen:

Enclosed is the report describing the work done on the subject contract during the months of September and October, 1964. The report was prepared by the Advanced Structures Group, Research Division, Hexcel Products Inc., Berkeley 10, California.

Included as attachments are (1) Statement of Man Hours Expended - September and October, 1964, (2) Schedule showing Current Progress - September and October, 1964, and (3) Schedule showing Program of Ensuing Activities - November and December, 1964.

Yours very truly,

E. C. Vicars
Research Director

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Cases 9 and 10 were fabricated and tested during the months of September and October, 1964. A summary of design changes and test results is given below.

**Design Modifications**

1. **Case HXL-9-477**: The amount of the energy absorption core was increased from 17" to 27-1/2" along the length of the case. In addition, 16 longitudinal slots were cut out of the core as shown in Figures 1 and 3.

   As part of the work that constituted Case 9, several rings of honeycomb were manufactured and tested for the purpose of determining the dimensions of slots that would give the best impact response for the entire case. These are shown in Figure 3.

2. **Case HXL-10-477**: The size of the slots in the energy absorption core was increased slightly over that of Case 9, as shown in Figure 2.

   In all other respects, Cases 9 and 10 were identical with Case HXL-8-477.
Movies

Motion pictures were taken to provide a visual record of the environmental tests performed on Cases 8 and 10. The record includes pictures of the equipment used and the conduct of the following tests:

1. Case HXL-8-477
   a) temperature shock
   b) transportation vibration

2. Case HXL-10-477
   a) hydrostatic pressure
   b) impact

High speed (200 frames/second) pictures were taken of the impact tests to better illustrate the crashing action of the honeycomb core.

Test Results

1. Hydrostatic Pressure Test:

   The pressure test was not performed on Case 9. Case 10 was twice subjected to an external pressure for a duration of five (5) minutes. At the completion of pressure cycles, the case was filled with approximately one (1) foot of water. By visual inspection, it was determined that the leaks were caused by poor sealing at the electrical connector and the locking device on the front cap. Design changes are being made on Case 11 to correct these deficiencies.
2. Impact Tests - General Comments:

The results of tests on Cases 6, 6a, 7 and 8 indicated the need for design changes to reduce the payload response to impact from side drops. In addition, the problem of payload vibration within the case structure has made it necessary to clarify the methods being used for data acquisition and analysis.

When the payload is decelerated during impact, the total acceleration consists of the sum of the response to the forcing function and the transient free vibration. Since the payload-case system is continuous (as opposed to a lumped parameter system), the free vibration component is composed of an infinite sequence of mode shapes and frequencies. This means that the total acceleration experienced by the payload will be different at every point even though the response to the forcing function is approximately the same everywhere.

To cope with this situation, the project engineers at Picatinny Arsenal and Hexcel have agreed that the following criteria will be used in evaluating the case design:

1. The acceleration of the payload will be measured at the mounting ring and at the free end of the payload (see Figure 4).

2. The case design will be considered satisfactory with regard to impact response if the faired value of the acceleration-time
relationship, measured at the mounting ring, is less than the contract specification (27 g's laterally, 40 g's axially).

For side drops, the average peak value of the fairied a-t curve (measured at the mounting ring) on Cases 6 through 8 was 33.3 g's.

In an effort to reduce this value to 27 g's, impact tests were performed on several rings of honeycomb core as shown in Figure 3. Tests on ring segments are simpler to perform and yield more accurate measurements than tests on the entire case. The results of tests on the rings led to the conclusion that the acceleration response of the payload could be decreased by increasing the amount of core along the length of the cylinder providing there was a means to reduce the crushing strength of the honeycomb at large deflections. Drop tests on Cases 9 and 10 demonstrated that this conclusion was correct.

The reasoning behind this is as follows. The best energy absorber (for this application) would be one that absorbs energy at a constant rate. This requires a honeycomb configuration that crushes with a constant force, a condition that is difficult to achieve with the increasing area that results from crushing a cylindrically shaped object.

Without modification, i.e. no slots, honeycomb of this configuration yields a force-deflection curve where the force increases almost linearly with deflection until the total kinetic energy is absorbed. To approach the ideal more closely, an additional 10 lineal inches of honeycomb were added to the case. The additional honeycomb increased
the total crushing force at small deflections, while the slots weaken the core, resulting in a more nearly constant force at larger deflections. These relations are shown below in Figures a, b and c.

**Figure a.**

**Figure b.**

**Figure c.**
Case HX1-9-47:

Typical results for Case 9 are shown in Figures 5, 6, 7, 8 and 9. For all drop tests, the accelerometers were mounted as shown on Figure 4. The acceleration response of the honeycomb ring shown in Figure 5 came close to yielding a constant force-deflection relationship than any of the other rings tested. The unit loading of this ring was the equivalent of 27-1/2 inches of honeycomb on the full-length case.

Figure 6 shows the acceleration response for Case 9, drop 3 (9-3). Case 9 was tested without skin and end caps so that the payload response could be more easily correlated with the impact tests on the honeycomb rings.

Figure 7 shows the acceleration, velocity and displacement responses for both the fixed and free ends of the payload during drop 9-3. These were obtained by double integration of the faired acceleration-time curve. The force-deflection relationship at each end of the payload is obtained by eliminating the parameter time from the a-t relationship and the displacement-time relationship. The force-deflection relationships for 9-3 are shown on Figure 8.

Figure 9 is a comparison of various force-deflection relationships. The curve labeled "Parson's Ring" was supposed to give the same response as the "Best Ring" (from Figure 5). The difference in response was attributed to manufacturing variations in the shape of the slots.
Also shown are drops 1 and 3 for Case 9. Complete results of the drop tests on Case 9 are shown in Table 1. The average peak value of faired a-t curve, measured at the mounting ring, was 26.0 g's for 4 drops.

There were no end drops or edge drops performed on Case 9.

**Case II-I-10-47:**

The accelerometers were mounted as shown on Figure 4.

**Side Drops:** The average peak value (for 3 drops) of the faired a-t curve was 28.4 g's at the mounting ring and 29.4 g's at the free end of the payload.

**End Drops:** The peak value of the faired a-t curve was 24.2 g's, average for 2 drops.

**Edge Drops:** One edge drop was performed, yielding a maximum value of 16.5 g's on faired a-t curve.

The results of all drops are shown on Table 2.

**Attachments:**

2. Program of activities during September and October, 1964.
DROP TEST FIXTURE
NOT TO SCALE
PROJECT 6065 10/13/64

HEXCEL RESEARCH
BERKELEY, CALIFORNIA
FIGURE 5, ACCELERATION RESPONSE OF HONEYCOMB RING

Vertical Calibration: 14.6 g/s/cm
Horizontal Calibration: 5 msec/cm

FIGURE 6, ACCELERATION RESPONSE FOR CASE 9, FLAT DROP 3

Upper Trace: Fixed End of Payload
Calibration - 17.7 g/s/cm and 5 msec/cm
Lower Trace: Free End of Payload
Calibration - 14.6 g/s/cm and 5 msec/cm
FORCE - DEFLECTION CURVES

CASE 3 - DROP 5

DEFLECTION - INCHES

FIGURE 8
VARIOUS FORCE-DEFLECTION CURVES.

CASE A DROP #2
PARSON'S RING
CASE B DROP #1
BETT RING

UNIT LOAD LBS/IN.

DEFLECTION - INCHES

FIGURE 9
Fixed end than at the free end.

The average maximum value is 1% higher at the fixed end.

Acceleration is 8% higher at the free end than at the fixed end.

For the free curve, the average value of peak

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Results of flat drop tests - Case 4

Table 1
### Table 2

Results of Drop Tests for Case ~ 10

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**See Figure 4 for location of accelerometers.**

Values of acceleration are $g$ units.
ATTACHMENT NO. 1

STATEMENT OF MAN HOURS EXPENDED
SEPTEMBER AND OCTOBER, 1964

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