AD-A065 092 AIR FORCE PACKAGING EVALUATION AGENCY WRIGHT-PATTERSO--ETC F/G 13/4
ANALYSIS OF PACKAGING FOR THE LN-15S INERTIAL MEASUREMENT UNIT.(U)
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AFPEA PROJECT NO. 77-27-42

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Final rept.,

ABSTRACT

The evaluation of the LN-15S Inertial Measurement Unit (IMU) packaging revealed that impacts on the bottom surface of the shipping container generated shock levels on the IMU which were 67% greater than the specified fragility of this item. The problem was caused by a combination of a cushion "grip effect" of the side cushion pads and a temporary set of the cushioning material.

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INTRODUCTION

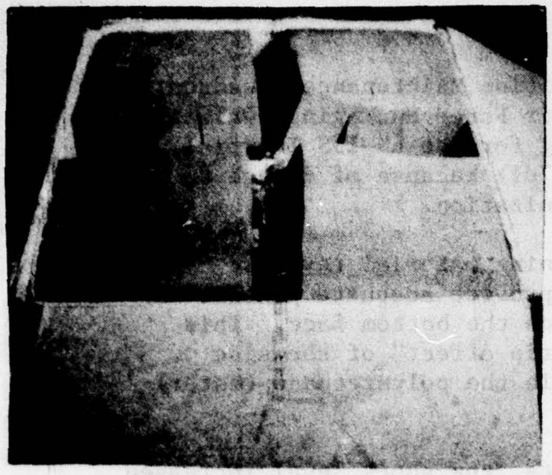
In August 1977, the 320th Bomb Wing Munition Maintenance Squadron, Mather AFB, California, requested the Air Force Packaging Evaluation Agency (AFPEA) to evaluate the packaging for the LN-15S Inertial Measurement Unit (IMU-NSN 1430-00-184-4701) because of damage to serviceable IMUs received by their organization.

Testing of the container and the cushioning material revealed that the cushioning material would not provide adequate protection for the IMU when the pack was impacted on the bottom face. This was attributed to a combination of a "grip effect" of the side cushion pads and a temporary set noted in the polyurethane (ester) cushioning material.

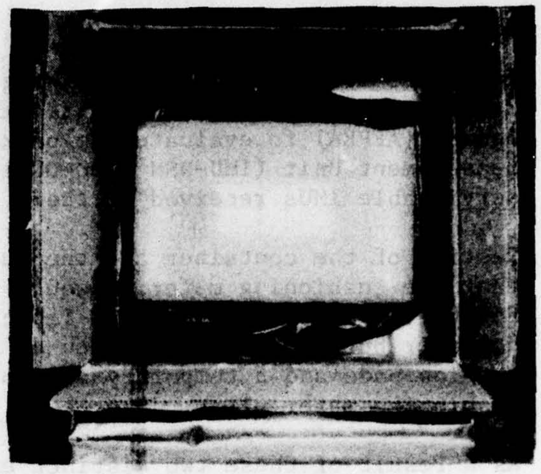
As a result of these two distinct effects, the shock level increased from 15 Gs to 25 Gs (67% increase) when the pack was dropped on its bottom face from a height of 21 inches. The manufacturers fragility rating for the LN-15 is 15 Gs.

DESCRIPTION OF TEST PACK

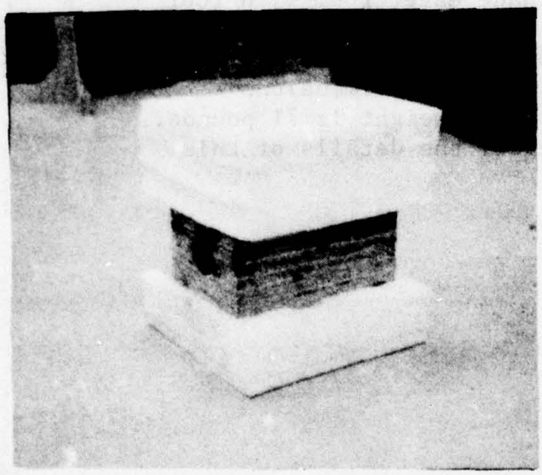
The outer shipping container and the inner carton are fabricated from triple wall corrugated fiberboard material. The cushion inserts are 2 pcf, 4 inch thick polyurethane ester foam with four 6 x 6 inch pads for each of the bearing surfaces. The 2 pcf polyethylene inserts for the inner carton are cut and bonded together to fit the contour of the IMU. The pack dimensions are 23 1/4 x 22 x 24 3/8 inches and the gross weight is 71 pounds. The series of photographs in Figure 1 reveal the details of this pack.



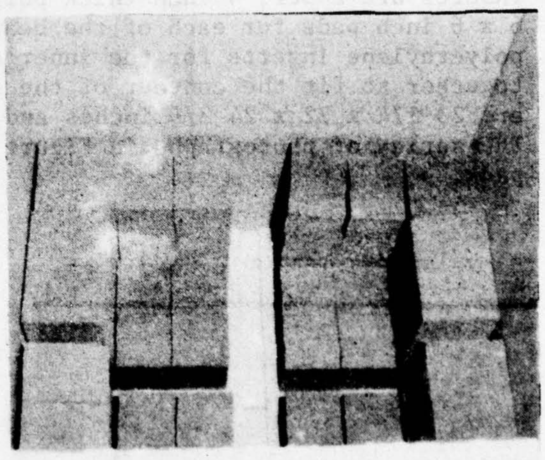
(a) Complete Pack



(b) Inner Carton and IMU



(c) Polyethylene Inserts



(d) Bottom Corner Pads

Figure 1. Photographs of Test Pack

Test Equipment and Instrumentation

The following equipment and instrumentation were used to evaluate this test pack:

1. Gaynes Drop Tester, Model 125

2. Oscilloscope, 4 channel storage, Tektronix, Model 564 B

3. Accelerometer, tri-axial, Endevco, Model 2233E

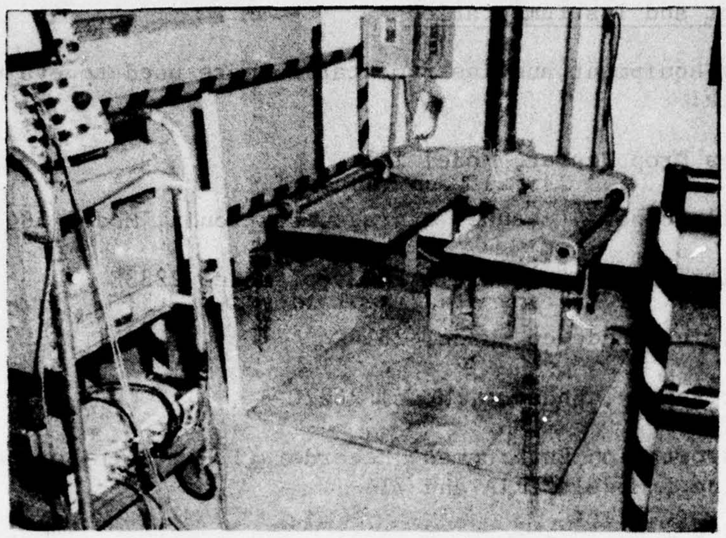
4. Amplifier, Endevco, Model 2614C

5. Power Supply, Endevco, Model 2622C

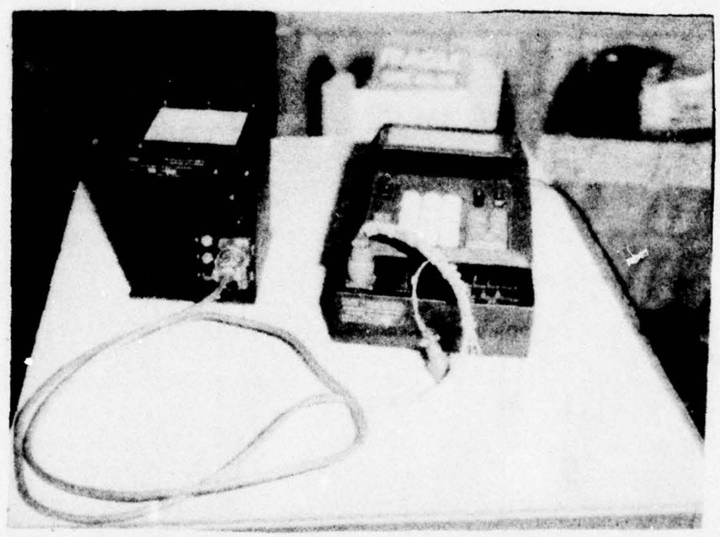
6. Transportation Environment Recorder (TER), Bolt-Beranek and Newman, Inc., Models 711A and 714

7. Digital Readout for transportation environment recorder, Bolt-Beranek and Newman, Inc., Model 615

Photographs of the drop test apparatus, the transportation environment recorder and the recorder readout are shown in Figure 2.



(a) Drop Test Apparatus



(b) TER Recorder and Readout

Figure 2. Photographs of Test Equipment and Instrumentation

Pre-Test Inspection of Pack

Immediately after the arrival of the test pack from Mather AFB, the container and its contents were carefully examined for possible deficiencies. Prior to removing the top corner pad assemblies, it was noted that some of the cushion pads had separated at the bonded edges or had been torn at the shear stress joint. It appeared that these loose segments had been placed at random on the top and sides of the pack. Some of these loose pieces are shown in the photograph of Figure 3.

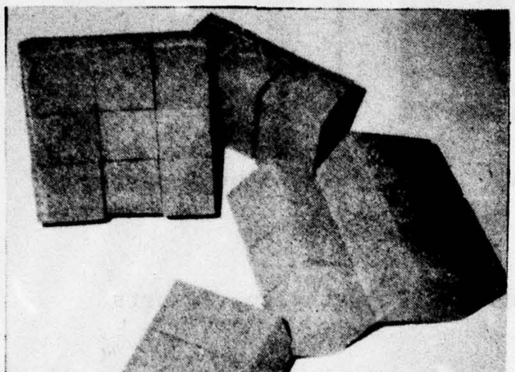
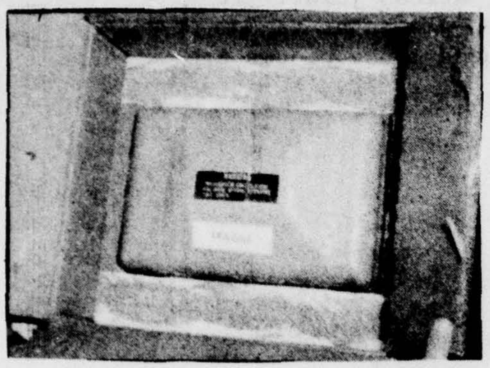
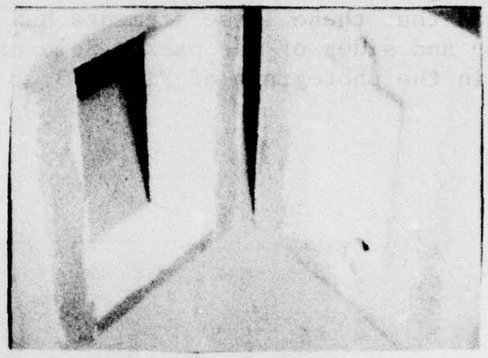


Figure 3. Loose Cushion Segments

While attempting to remove the IMU from the inner carton, it was also noted that the top section of the polyethylene insert had separated at the bonded joint as can be seen in the photographs of Figure 4.



(a) Insert Wedged between IMU and carton



(b) Bond Separation

Figure 4. Photographs of Polyethylene Inserts

Because of the improper bond, the item was difficult to remove and the carton had to be turned on its side while trying to force the dislodged insert from around the IMU. As a result of this awkward maneuver it was recognized that damage to the IMU could occur if it came in contact with a hard surface, such as the floor. This prompted the implementation of the "Out of Container" handling tests of the LN-15 as described in AFPEA Report No. 78-6, dated March 1978.

Prior to the removal of the inner carton from the test pack, the clearance between the bottom surfaces of the inner and outer container was measured at 2 1/4 inches. After removal of the inner carton, the compressed pad assembly was compared to a non-compressed pad assembly as shown in Figure 5. The recovery rate of its return to the original thickness (4 inches) was extremely slow.

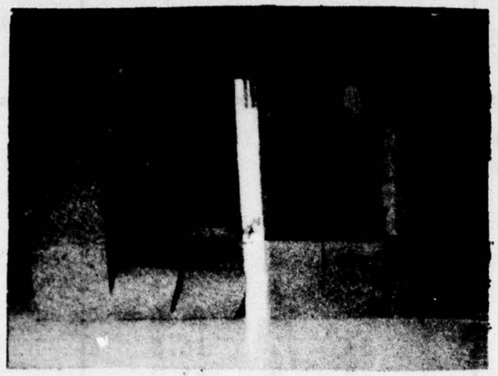


Figure 5. Photograph of Compressed Corner Pad Assembly

Test Procedures/Results

Free Fall Drop: A tri-axial accelerometer was located at the center of gravity of the wood simulated model of the LN-15 IMU as shown in Figure 6.
This test load was packaged identical to the actual item and dropped from a height of 21 inches as specified in Federal Test Method Standard 101B, Method 5007, Level A, Procedure A. The results are presented in Table 1. Note that the bottom (Face 3) surface impact generated the highest shock level.

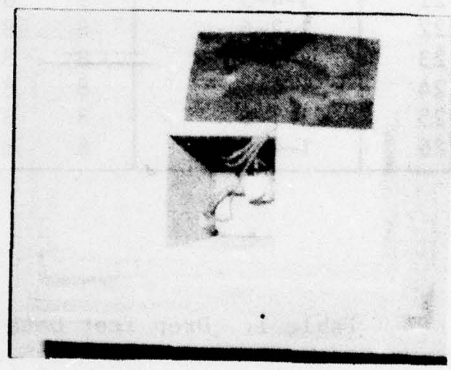


Figure 6. Simulated Model LN-15 IMU

Drop NR	Container Impact Surface	Acceleration (G's) Components X	Y	Z	Resultant	Duration of Shock Pulse (msec)
1	3 (bot)	3	4	24	24.8	35
2	1 (top)	1	2	14	14.2	54
3	2	2	14	3	14.5	48
4	4	4	14	1	14.6	52
5	5	12	4	0	12.6	48
6	6	13	1	1	13.1	52
7	1-2	0	11	11	15.6	50
8	3-4	4	11	12	16.8	52
9	2-3	1	12	12	17.0	50
10	1-4	1	12	11	16.3	50
11	2-5	10	10	5	15.0	60
12	4-6	12	12	0	17.0	50
13	4-5	10	11	4	15.4	55
14	2-6	11	10	3	15.2	50
15	1-5	11	3	12	16.6	50
16	3-6	11	4	10	15.4	55
17	3-5	12	2	12	17.1	50
18	1-6	11	2	10	15.0	55
19	1-2-5	8	7	10	14.6	55
20	3-4-6	9	8	10	15.7	55
21	3-4-5	9	8	10	15.7	55
22	1-2-6	8	8	9	14.6	55
23	2-3-5	8	8	8	13.9	55
24	1-4-6	8	8	8	13.9	55
25	2-3-6	8	8	9	14.6	55
26	1-4-5	8	8	9	14.6	55

Table 1. Drop Test Data (21 inch drop height)

The oscilloscope trace of a typical flat face drop is shown in Figure 7.

10 G's/cm (vert.)
20 msec/cm (horiz.)

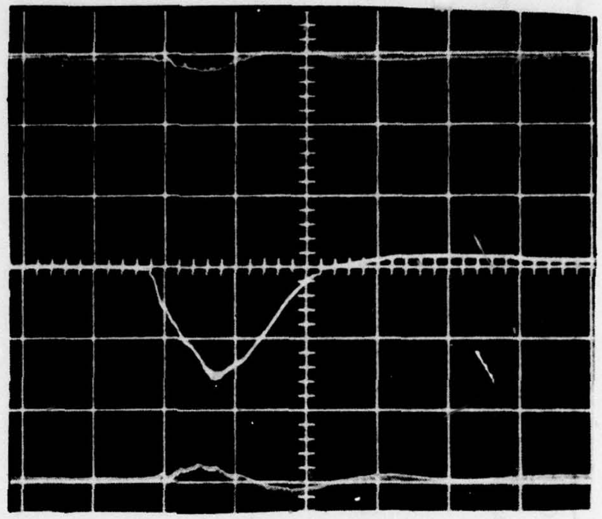


Figure 7. Oscilloscope Trace of a Typical Flat Face Drop

To provide information on accidental drops from two and three high stacks and from truck beds, each impact surface received two consecutive shocks as shown in Table 2.

Container Impact Surface	PEAK ACCELERATION - G's (Resultant)							
	21" D.H.	AV	30" D.H.	AV	36" D.H.	AV	42" D.H.	AV
3 (bot)	22.3		20.2		32.2		33.0	
3 (bot)	26.1	19.8	34.1	24.2	42.9	32.5	50.5	35.3
1 (top)	13.6		14.3		20.3		20.0	
1 (top)	17.1		28.2		34.4		37.8	
2-3 (edge)	17.1		16.3		18.1		21.8	
2-3 (edge)	17.7	16.7	20.4	19.1	21.4	20.0	22.1	21.7
1-4 (edge)	15.0		18.7		18.5		20.0	
1-4 (edge)	17.1		20.9		21.8		22.7	

Table 2. Supplemental Drop Test Data

Field Test: Two independent field tests were conducted with this test pack using a self-contained Transportation Environment Recorder (TER) as shown in Figure 8. The first shipment was sent to Mather AFB via Logair with stops at Tinker, Hill and McClellan Air Force bases. Data for the return trip to WPAFB was also recorded. A resultant type recorder was used to collect the test data for this test shipment. This instrument records the x, y and z components of each impact and immediately computes and records the resultant force.

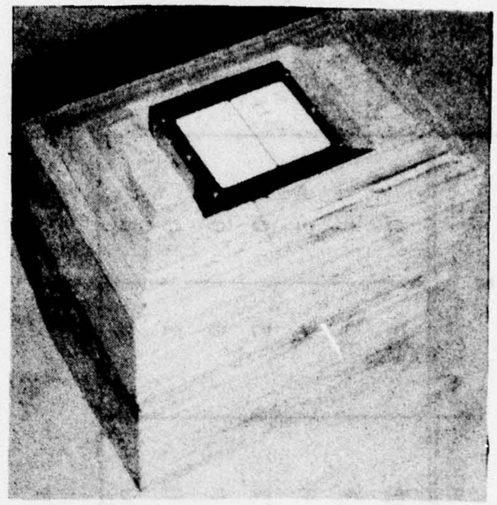


Figure 8. Test Load with Recorder

This data is presented in Table 3. The majority of the low level shocks are caused by transportation vibration. The bottom and top surfaces received 62 of the 123 total shocks recorded. Only the resultant values are shown in the table.

Shock Level Range (Peak Acceleration - G's)	Number of Recorded Shocks
2.5 to 5.0	63
5.0 to 7.5	16
7.5 to 10.0	4
10.0 to 12.5	2
12.5 to 15.0	3
15.0 to 17.5	1
27.5 to 30.0	1

Table 3. Field Test Data (Test No. 1)

The second field test was conducted between WPAFB and Nellis AFB, Nevada. This Logair route included stops at Dover, Robins, Kelly and Hill Air Force bases. For this test, a non-resultant type recorder was used; the individual recorded shocks are listed in Table 4.

Shock Level Range (Gs)	Number of Recorded Shocks — Pack Orientation: X + (Front)	X - (Back)	Y + (L. Side)	Y - (R. Side)	Z + (Top)	Z - (Bot.)
1 to 2.5	24	30	45	18	*47	10
2.5 to 5	5	5	4	4	14	4
5 to 7.5	1	2	3	0	4	2
7.5 to 10	1	0	0	2	3	0
10 to 12.5	1	0	0	0	0	0
12.5 to 15	0	0	0	0	1	0
15 to 17.5	1	0	0	0	0	0

Environment Temperature Range: 50 to 80°F
Environment Humidity Range: Inoperative
Total elasped time of field test: 12.1 days

*Possibility of pack stored upside down

Table 4. Field Test Data (Test No. 2)

After the arrival of the test pack at WPAFB, the contents of the container was removed and one of the four compressed bottom pads was compared to a non-compressed assembly as shown in Figure 9. The thickness of the compressed section measured 2 3/4 inches.

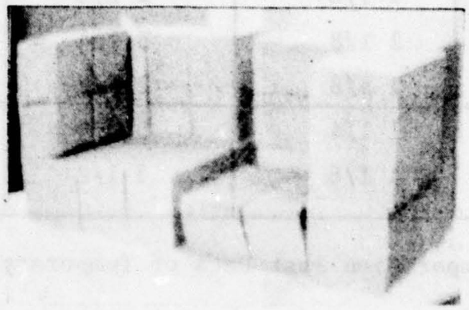


Figure 9. Photograph of Compressed Corner Pad After Field Test No. 2

Cushioning Material Evaluation: To verify the visual observations related to the temporary set of the cushioning material, a comparision test was conducted using a sample of the LN-15 polyurethane (ester) and reference samples of an ether and ester base urethane. The four inch thick samples were compressed with a 30 pound load for a period of 24 hours. This weight was selected to reproduce the condition caused by the combination of the "grip effect" and the dynamic forces when impacts occur. Each sample was identical in size and included the shear stress relief cuts. The results are presented in Table 5.

Type Sample	Density (pcf)	Th'k Before Wt. Removal (Inches)	Th'k After Wt. Removal (Inches)	Time Req'd to Return to Initial Th'k (Hours)
Ester (LN-15)	2.02	1 7/8	2 5/8	24
Ester (Ref.)	2.44	2 1/8	3 1/4	24+
Ester (Ref.)	1.66	1 3/8	2 5/8	21
Ether (Ref.)	1.80	1 1/4	3 3/4	3
Ether (Ref.)	1.30	1 1/8	3 1/2	1 3/4

Table 5. Comparision Test Data of Temporary Set

These results indicate that the ester base materials are more susceptible to taking a temporary set than the ether base materials.

DISCUSSION

During the evaluation of the test pack, the dimensions of the outer container, the inner carton and the cushioning material were compared to the dimensions as specified in the Transportation Packaging Order (TPO) No. 00-184-4701. The dimensions were correct for proper mating of these components; however, the bulge of the side walls of the inner container reduced the clearance between the two containers and compressed the cushioning material and prevented free movement of the inner container. This is referred to as a cushion "grip effect". Also, the overlap and bulge of the cover flaps of the inner container caused the top cushion assemblies to protrude beyond the opening of the outer container as shown in the photograph of Figure 1a.

A performance analysis of the TPO pack design using this Agency's computer program for package cushion design indicated that the four inch thickness of polyurethane (ester) corner pads are adequate for protecting the LN-15 from a drop height up to 21 inches.

The examination of the corner pad assembly bonding revealed that a 3/8 inch wide adhesive surface was used instead of the 3/4 inch wide area as specified in the TPO. This together with the shear stress cuts and the improper removal procedures of the top corner pad assemblies caused the separation of the bond and the tearing of the material. The proper method for removing the top assemblies is to reach under the material and lift up. If the assembly is pulled up by grasping the top edges, the tight side wall sections will tear loose from the upper section.

The shear stress relief cuts in the polyurethane cushioning pads contributed to the problem of the loose segments of the pad assembly. Previous tests of a similar pack (LN-12) revealed that the shear stress relief cuts did not significantly affect the cushioning characteristics of the pack. Tearing did occur with the non-cut design but not enough to justify the use of the stress relief design. A design, without shear stress relief cuts, will help to reduce the amount of the temporary set experienced with the LN-15 pack. Comparison tests between a cut and a non-cut sample revealed a 13% reduction in the amount of set for the 2.66 pcf sample and a 7% reduction for the 1.66 pcf sample.

Personnel at Mather AFB expressed concern about the proper orientation (upright position) of the LN-15 during storage, transportation and handling. The manufacturer, item manager, equipment specialist and the repair depot (AGMC) were queried to determine if orientation was critical. There is no evidence to indicate that improper orientation would affect the calibration or cause damage to this unit. However, to supplement this information, a serviceable LN-15, packaged in a new container, was dropped from a height of 21 inches on the bottom, top and one side and returned to the repair depot (AGMC) for inspection and calibration. No misalignment or damage occurred. The maximum impact shock measured was 13.2 G's.

CONCLUSIONS

1. The combination of the "grip effect" and the temporary set of the cushioning material currently used in this pack can reduce the effectiveness of the pack resulting in 67% greater shock levels on the bottom surface when the pack is dropped from a height of 21 inches. If the pack is inadvertently stored on its other surfaces, similar results can occur.

2. The ester base polyurethane will take a temporary set more readily than the ether base material. However, changing the pack design to an ether base material is not recommended because of the additional costs involved. The thickness would have to be increased to approximately six inches and the bearing surface would have to be increased approximately 35%.

3. Orientation of the pack during storage, transportation and handling is not critical; however, proper orientation (upright position) is desirable and recommended.

RECOMMENDATIONS

1. To eliminate the "grip effect of the side cushion pack, increase the dimensions of the outer container from 23 1/4 x 22 x 24 3/8 to 24 x 22 3/4 x 25 1/4 inches.

2. Include an Indent Load Deflection (ILD) value for the cushioning material to control the degree of temporary set.

3. Eliminate the shear stress relief cuts in the polyurethane cushioning material to reduce temporary set.

4. Inspect new packs for proper bonding of the cushion assemblies and the polyethylene inserts.

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15 AF/LGWA March AFB CA 92508	1
32 DBMW/MAWS Mather AFB CA 95655	1
32 DBMW/MAQ Mather AFB CA 95655	1
HQ SAC/LGWS Offutt AFB NE 68113	1

OC-ALC/MMH Tinker AFB OK 73145	1
OC-ALC/MMS Tinker AFB OK 73145	1
8 AF/LGW Barksdale AFB LA 71110	1
323 FTW/LGSSM Mather AFB CA 95655	1

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LN-15S Packaging, shock levels, drop tests, field tests

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The evaluation of the LN-15S Inertial Measurement Unit (IMU) packaging revealed that impacts on the bottom surface of the shipping container generated shock levels on the IMU which were 67% greater than the specified fragility of this item. The problem was caused by a combination of a cushion "grip effect" of the side cushion pads and a temporary set of the cushioning material.

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