FOR FURTHER TRAN

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LOCKHEED ELECTRONICS COMPANY, INC.

A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

LEC

Lockheed Electronics Company, Inc.
Products and Systems Division
Plainfield, N.J. 07061

Report of Impact Fuze Tester Improvement Study

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Prepared by: R. Wass

Approved by: T. Affatigato

D. Lev

J. Iervolino

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SUMMARY

Lockheed Electronics Company's investigation, analysis and testing of the Drop Test Fixture #8879484 (Ref 1), used to test the M1139 Impact Fuze #9232991 (Ref 2), resulted in improvements to the Drop Test Fixture. These improvements increased the accuracy, consistency and speed with which tests of production fuzes could be performed.

This report contains an analysis of the effect of test variables on test results including: (1) fuze weight; (2) drop height; (3) impairment of free fall conditions; (4) securing of Fuze to test fixture and (5) impact surface area.

As a result of LEC's analysis, the following improvements to the Drop Test Fixture were made: (1) modification of the cabling from the Impact Fuze to the amplifier circuits; (2) improvement of finishes for the sliding surfaces of the fixture and (3) modification of calibration (dummy) fuze to simulate the production configuration to a greater degree.

These improvements have reduced test time by providing a higher degree of "g" load accuracy and repeatability making it possible to obtain the proper test "g" loading without requiring constant re-adjusting of the test parameters. In addition, the number of tests to be performed on each fuze was reduced thereby resulting in a reduction of testing wear and tear on the fuzes, as well as improvement of fuze reliability.

IMPACT FUZE TEST FIXTURE MODIFICATION

1.0 BACKGROUND

Problems associated with the testing of Impact Fuzes, P/N 8879484, Ref 1, during production of Lance Adaption Kits M238, dictated a need for improvement of drop fixture, P/N 9232991, Ref 2, used to measure the voltage output of the fuzes. The purpose of the drop fixture is to apply a specified deceleration force on the impact fuze under test and concurrently measure the voltage generated by the fuze. The deceleration provided by the fixture is monitored by an accelerometer mounted on the platform which houses the impact fuze under test. The output signals from both the accelerometer and from the impact fuze itself are amplified and displayed on an oscilloscope.

The test requires subjecting the fuze to 450 ± 25 g's and monitoring the fuze output at this "g" level. The testing of impact fuzes P/N 8879484 using drop fixture P/N 9232991 with its ancillary amplification circuitry, oscilloscope display and calibration components proved to be a time consuming and unpredictable test due to the lack of repeatability of the deceleration forces generated by the fixture. The excursions experienced beyond the permissible tolerance on the "g" level necessitated improvement of the fixture. The improvements included modification of the cabling from the impact fuze to the amplifier circuits, improvement of the finish of the fixture's moving parts which provide the means of generating the high deceleration forces, and modification of the calibration fuze to more closely simulate production fuze configuration.

The results of these improvements reduced test time by providing a higher degree of "g" load repeatability to the fuzes under test. In addition, the ability to maintain consistent "g" forces minimized the number of tests performed on each fuze in accordance with test procedures thereby improving fuze reliability. The test fixture improvements reduced the tolerance of the "g" reading which were attributable to the fixture itself, thereby enhancing the accuracy of the data obtained from these tests. The evaluation and modification of the test fixture was an effective method for improvement of the testing of a critical Lance Adaption Kit component.

2.0 TEST VARIABLES

Engineering evaluation and analyses of the equipment and procedures used in conjunction with testing impact fuzes revealed a number of variables which entered into the attainment of repeatable deceleration forces. Among these variables are: (1) weight of impact fuzes; (2) height of drop of the impact fuze and associated mounting platform; (3) impairment of free fall conditions of the mounting platform due to: forces induced by cabling to the impact fuzes and accelerometers, condition of the contacting surfaces, and levelness of the structure; (4) tightness of fit of the impact fuze under test within the mounting platform; (5) surface area of impact surfaces; (6) proper calibration and operation of the ancillary equipment used with the drop fixture. Figure 1 shows the major components associated with this fixture. A brief description of the operation of the fixture is provided below to aid in the understanding of the variables previously listed and in the discussion of each of the variables which follows the operational description.

2.1 FUNCTIONAL DESCRIPTION

Referring to Figure 1, the fuze under test, item 1, is mounted into the sliding platform of the fixture, item 2. Likewise, the accelerometer, item 3 which monitors the deceleration forces imposed on the test fuze is mounted into item 2. A notch in item 2 provides for the raising of this part by a ramp which is part of item 4. Item 4 is rotated by a "V" belt drive attached to a motor. As rotation occurs, the beginning of the ramp catches the notch and raises the sliding platform until the ramp end is reached and a sharp drop off of item 2 occurs. The drop off allows item 2 to "free fall" until a hardened button, item 5, at the base of the sliding platform impacts a hardened platform, item 6, mounted in the fixture base, item 7. This impacting of hardened surfaces causes the generation of the high deceleration forces. Continued rotation of item 4 permits automatic repetition of the test cycle as required by the acceptance test procedure. A discussion of the critical factors which effect proper function of the test fixture follows.

2.2 FUZE WEIGHT

Consideration of variations in weight of the impact fuzes tested indicated that no appreciable effect on deceleration forces could result from the variations in fuze weight. The nominal weight of the sliding platform is 20.0 ounces. The weight of impact fuzes measured on more than 1000 fuzes ranged from 8.5 to 8.8 ozs. The variation in fuze weight with regard to the sum of the platform and nominal fuze weight represents approximately $\pm$.5% change, maximum. This, when compared to the allowable variation in deceleration force of 5.5%, does not constitute a significant factor in the variation of deceleration forces.

IMPACT FUZE
(DROP FIXTURE)

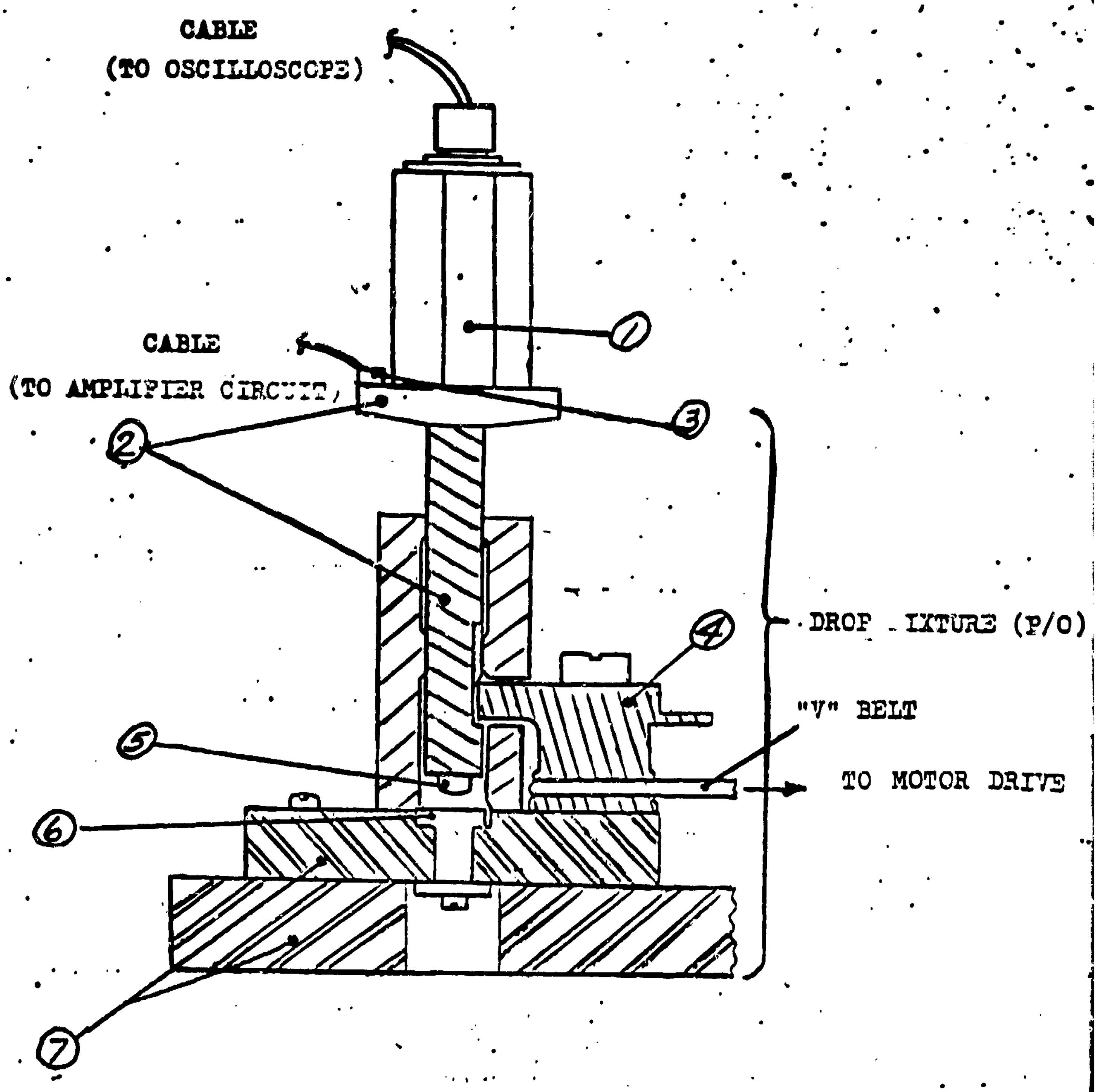

FIGURE 1

2.3 DROP HEIGHT

The second factor considered was the drop height of the platform/fuze assembly. This height is adjusted during calibration of the fixture by shiming the hardened impact button at the base of the sliding platform (if necessary) to meet deceleration force requirements. The nominal drop distance was calculated from the physical construction of the fixture to be .258 inches. Analysis of the drop distance required to generate 450 g's deceleration was calculated to be approximately .242 (see Appendix I) inches, thereby allowing ample shiming tolerance from the nominal dimension in the fixture. Inasmuch as the drop height undergoes adjustment only during calibration, this factor should not effect test repeatability within a calibration period and hence is not a factor in this investigation.

2.4 FREE FALL

A critical aspect of the drop fixture is the need to maintain "free fall" conditions for the sliding platform. A level indicator is included in the fixture design along with leveling bolts to assure the sliding platform is normal to the fixture base. This is adequate to provide plumbness of the drop fixture. Side loading is imposed upon the sliding platform by cabling which connects the impact fuze to the oscilloscope displays and accelerometer to the amplifier circuit, (See Fig. 1). These cables, as specified by the technical data package for test of the M1139 impact fuze, are RG 58/U and Endevco Corp. cable No. 3030. A bracket for supporting the cables is provided on the fixture. Due to the mass and rigidity of the RG 58/U cable connecting the impact fuze to the oscilloscope, slight changes in the position of this cable were found to appreciably alter the deceleration forces at impact, causing them to exceed their allowable tolerances. This was found to occur without handling the cable, but merely as a result of repeated testing of the same fuze. As the cable was disconnected and reconnected for testing other fuzes, the problem of repeating deceleration forces within tolerance was increased. Tedious adjustment of cable position was required to meet the tight deceleration level tolerances.

This situation was corrected by adding to the RG 58/U impact fuze/cable a short length of lightweight flexible coaxial cable similar to that used with the accelerometer. This lightweight cable exerts virtually no load on the sliding platform. The new cable was routed with a generous service loop which extends to the cable bracket on the fixture. At this point the new cable connects to the existing RG 58/U cable which is affixed to the cable bracket. The new cable contains a copper plated steel conductor with a polyethylene dielectric and a polyvinyl chloride outer jacket. A capacitor change in the circuitry was made to compensate for the additional capacitance of the new cable. Success of this cable modification was demonstrated by a series of tests involving 20 fuzes. The accelerometer output was recorded when testing these fuzes for two successive drops. Between each drop, the fuze cable was disconnected and reconnected to further demonstrate the repeatability of the deceleration forces as a result of the new cable design. The results of these tests are shown in Appendix II. The consistency of the two readings taken of each fuze and even between fuzes shows a marked improvement over previous readings taken with the original RG 58/U cable.

To assure that "free fall" conditions exist for the sliding platform, friction between the sliding platform and the stationary column into which it slides must be minimized. The finishes of the sliding surfaces were each designed to have a four micron surface finish; however, the material used for these parts was carbon steel with no exterior protective finish. During normal storage and operation, the unprotected surfaces became corroded and rusted causing the action of the sliding surfaces to become erratic and rough. This condition effected the attainment of the required deceleration forces and prevented consistency in these deceleration forces from drop to drop. To correct this situation, all sliding surfaces of parts which are involved in the free fall operation of the fixture, including the sliding platform, the stationary column and the ramp surface of the rotating lift component, were hard chrome plated and refinished to 4 microns to the dimensions specified on the drawings. This protective finish is durable, non-corrosive and offers minimal friction between the interacting surfaces. The resulting action of the fixture was improved and, after approximately two years of operation, the protected surfaces showed no signs of corrosion, pitting or other deterioration.

2.5 TIGHTNESS OF ASSEMBLY

A factor which appreciably affects the deceleration forces at impact is the tightness with which the fuze under test is secured into the sliding platform. With the threads of the fuze loosely engaged in the sliding platform, very high deceleration loads can be observed. These forces vary greatly as the fuze is tightened into the fixture. Consistency of deceleration forces is impossible to achieve unless the effects of the tightness factor can be minimized. This was accomplished by instructions added to the operating procedures for the fixture to "hand tighten" the fuze within the platform. Although "hand tighten" infers a qualitative rather than a quantitative value for the tightening of fuzes into

the fixture, it was found that based upon the results of observing several operators, a torque of 25-30 in-lbs. resulted from this instruction. The effects of "hand tightened" versus various other measured levels of torque are shown in Appendix III for one particular fuze with regard to deceleration forces measured on the fixture. It should be noted that no fuze cable connections were made during this series of tests to better isolate the effects of fuze tightening on the fixture operation. As can be seen, no noticeable change in deceleration output occurred until the fuze was torqued to 60 in lbs at which point the deceleration forces increased about 2%. This new value was maintained through 120 in-lbs.
As a result of these findings, it was concluded that instruction to secure the test fuze "hand tight" in the sliding platform was sufficient to assure consistency of deceleration readings from fuze to fuze under test. Successful testing of fuzes using this technique confirmed the adequacy of this approach.

2.6 IMPACT AREA

The surface area of contact at impact between the sliding platform and the base impact surface affects the spring constant of the interacting parts and in turn affects the deceleration forces generated. (See Appendix IV). As can be seen from the calculations, the surface area of the sliding platform button would have to increase significantly before its effect would be seen in the generation of deceleration forces. This area is controlled in the calibration procedure where the button contact area is monitored and the button replaced if the surface area increases to an established value. Inasmuch as changes in contact area are very slight from drop to drop, this factor does not affect the consistency of the deceleration forces appreciably under normal operations.

2.7 CALIBRATION & ANCILLARY EQUIPMENT

The final factor which could substantially effect the proper and consistent operation of the fixture is the calibration of the fixture and operation of fixture ancillary equipment, e.g. the dummy fuze. The calibration of the fixture utilizes a "dummy" fuze for purposes of determining drop height and other fixture variables. The dummy fuze, as specified in the technical data package, was 0.8 oz (`%) lighter than the nominal weight of a test fuze and did not contain a connector for attaching the fuze cable as is done in normal operation. The lack of a cable connected to the dummy fuze greatly changed the deceleration forces generated by the fixture. This, together with the slightly lighter dummy fuze, caused the calibration to deviate from normal test conditions. Additional adjustments were required when production fuzes were tested. To correct this situation, the dummy fuze was modified by mounting a connector, identical to the connector on the production fuzes, to it. Although this connector was not electrically wired to the fuze, it increased the weight of the dummy to the production fuze weight and it provided a connection for the fuze cable so that the calibration set-up was physically identical to the normal test set-up. This resulted in calibration of the fixture which was consistent with the normal operation of the fixture and required no additional adjustment when normal fuzes were under test. The resulting data obtained from fuzes tested on a properly calibrated fixture was reliable and consistent with production units.

3.0 CONCLUSIONS

The corrective actions taken in the areas described in the preceding paragraphs, have yielded a test fixture which provides proper, reliable and repeatable test results when testing the M1139 impact fuze. An acceptance inspection engineering change proposal was submitted to P.A. and approved. It described in detail the recommended changes to the cabling arrangement for the impact fuze, the chrome finishing of critical moving parts, the modification to the calibration "dummy" fuze and the tightening requirements of the fuze in the test fixture. The incorporation of these changes has been cost effective in that the non-recurring cost of evaluating and implementing the changes has been offset by the time saved in testing the fuze on a recurring basis. In addition, the fuze data obtained from the improved fixture has been more reliable and can be repeated more accurately than in the past, thereby adding a high degree of confidence to the results.

APPENDIX I

Calculation of Impact Fuze Drop Distance

Assuming free falling body:

$$d = \sqrt{\frac{2kh}{mg}} \; *$$

where
d- deceleration force (g's)
k- spring constant of system
h- height of drop
mg- weight of impact fuze + holder

$$h = \frac{d^2}{2k/mg}$$

mg = 28.8 oz $\approx$ 1.8 lbs (for holder and nominal wt. impact fuze)

k = $.754 \times 10^{+6}$ #/in (see Appendix IV for calculation)

d = 450 g's (nominal required force)

$$h = \frac{(450)^2}{2(.754 \times 10^{+6})/1.8} = \frac{20.25(10^4)(1.8)}{1.508(10^6)} = \frac{36.45(10^4)}{1.508(10^6)}$$

h = $2.417(10^{-1})$ = .242 inches = (drop distance to achieve 450 g's deceleration force)

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* Shock and Vibration Technical Design Guide
U.S. Army Electronics Command
Fort Monmouth, N.J.
SCL-7851A

APPENDIX II

Date: 9/23/78 Location: LEC Lance Area
Time: 10:00 a.m.

Accelerometer and Impact Fuze Outputs

	1st Run		2nd Run (Reconnected Fuze End of Microdot Cable)	
I/F S/N	Acceler. Output	I/F Output	Acceler. Output	I/F Output
Dummy (S/N1)	2.2 cm	N/A	2.2 cm	N/A
880107	2.25 cm	1.65 cm	2.30 cm	1.65 cm
495001	2.2 cm(-)	2.00 cm	2.2 cm(-)	2.00 cm(+)
494016	2.2 cm	2.10 cm	2.2 cm	2.10 cm
495006	2.15 cm	1.60 cm	2.15 cm(-)	1.70 cm
495014	2.15 cm	1.70 cm	2.15 cm	1.70 cm
495013	2.25 cm	1.60 cm	2.25 cm	1.60 cm
495002	2.15 cm(-)	1.80 cm	2.15 cm(-)	1.80 cm
495007	2.15 cm(+)	1.80 cm	2.15 cm(+)	1.80 cm
495003	*2.10 cm	1.70 cm	*2.10 cm	1.70 cm
495008	*2.10 cm	1.60 cm	*2.10 cm	1.60 cm
495015	2.20 cm(+)	1.60 cm	2.20 cm(+)	1.65 cm
495005	2.25 cm	1.80 cm	2.25 cm	1.85 cm
485250	2.20 cm	2.10 cm	2.20 cm	2.10 cm
495249	2.20 cm(-)	2.00 cm	2.20 cm(-)	2.00 cm
495244	2.20 cm(-)	2.00 cm	2.20 cm(-)	2.00 cm
495010	2.20 cm	1.60 cm	2.20 cm	1.60 cm
495243	2.20 cm	2.20 cm	2.20 cm	2.20 cm
495248	*2.10 cm	2.25 cm	*2.10 cm	2.30 cm
495242	*2.05 cm	2.00 cm	*2.05 cm	2.00 cm
489110	2.25 cm	1.65 cm	2.25 cm	1.65 cm

1st Article "A" Section

218006	2.20 cm	1.60 cm	2.20 cm	1.60 cm
218004	2.20 cm	1.65 cm	2.20 cm	1.65 cm

APPENDIX II (cont'd)

NOTES:

1. Drop fixture level checked at start of test.

2. Accelerometer "Zero Reference" checked every third fuze.

3. Drop fixture sliding and moving parts were chrome plated.

4. Fuzes torqued hand-tight to fixture (25-30 lb-in).

5. Symbols:

   * = Denotes out-of-tolerance output reading. Acceptable range is $2.13 \leq R \leq 2.38$.

   (+) = Reading slightly greater than numerical value shown.

   (-) = Reading slightly less than numerical value shown.

APPENDIX III

Sequence of Torque/Output Tests

Fuze	Torque (lb-in)	Accelerometer Output (cm)
Dummy	Hand Tight	2.2
Dummy	36	2.2
Dummy	48	2.2+
Dummy	60	2.25
Dummy	72	2.25+
Dummy	120	2.25
Dummy	180	2.3
Dummy	240	2.3

APPENDIX IV

Impact Fuze Drop Fixture Deceleration Calculation

Assume free falling body:

$$d = \sqrt{\frac{2kh}{mg}} \;*$$

d - deceleration force (g's)
k - springconstant
h - height of drop
mg - weight of impact fuze and holder

h = .258" nominal as determined from dwg. 9232991

mg = 20 ounces + 8 ounces = 28 ounces (for holder and calibration dummy fuze)

or 28.8 ounces (for holder and nominal impact fuze)

Determination of $k_{Total} = \dfrac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \frac{1}{K_4} + \frac{1}{K_5}}$ (for stress members in series)
(see Fig. A)

$$k = \frac{W}{\delta} = \frac{AE}{L}$$

where W - load (lbs)
δ - deflection (in)
A - area under stress (in^2)
L - length of stress member (in)
E - modules of elasticity

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* Shock and Vibration Technical Design Guide
U.S. Army Electronics Command, Fort Monmouth, N.J.
SCL-7851A

IMPACT FUZE
(DROP FIXTURE)

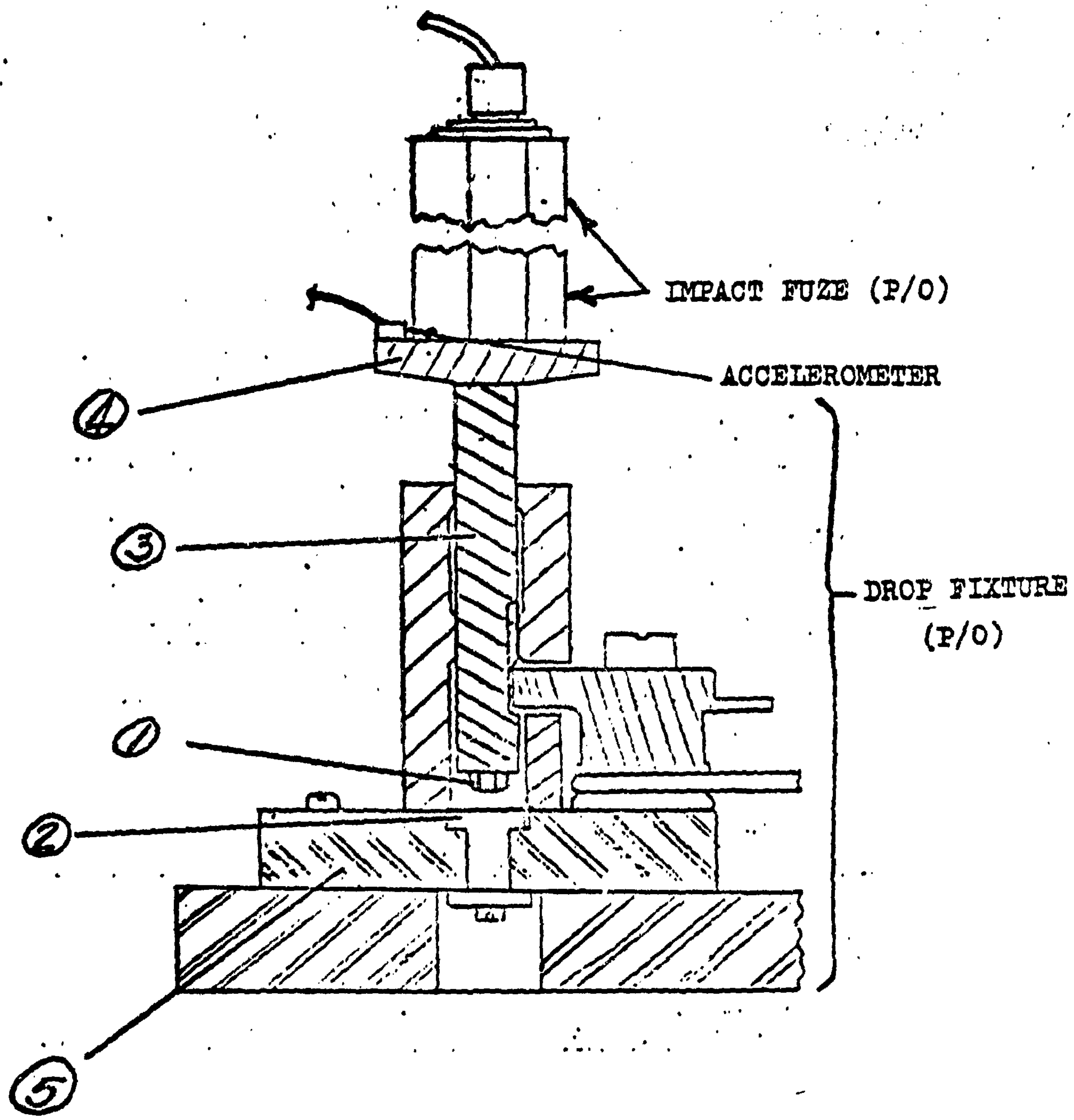
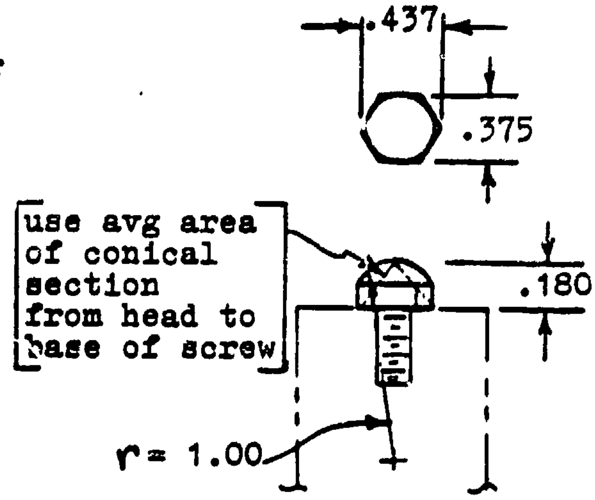


FIGURE A

1. BUTTON

$k_1 = \frac{AE}{L}$

A = avg area (cross sectional)
E = $30(10^6)$ - steel
L = length of member



$$A_{\substack{Avg \\ cone}} = \frac{vol.}{ht.} = \frac{1/3\ Bh}{h} = \frac{\left(\frac{.375}{2}\right)^2 \pi}{3}$$

$$= .037 \text{ sq.in.}$$

(where B = base area)

$$k_1 = \frac{.037(30)(10^5)}{.180}$$

$$k_1 = \underline{6.13(10^6)\#/in}$$

2. PAD

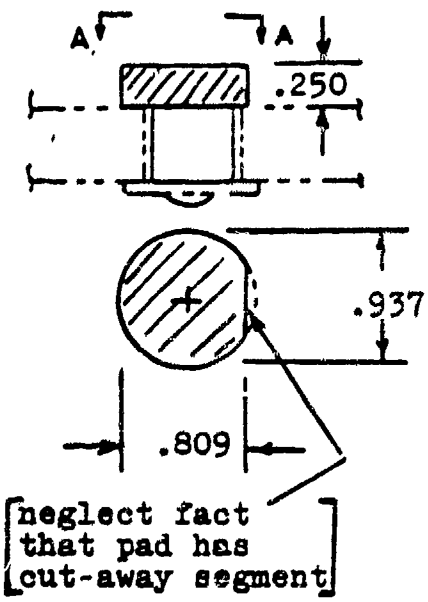
k_2 - assume simply supported plate with load at its center (lined area) (ignore remainder of pad)

$$k_2 = \frac{P}{\delta} = \frac{16\pi(1+\nu)D}{(3+\nu)\ a^2} {}^{*} = \frac{16\pi(1+\nu)\ Eh^3}{(3+\nu)\ a^2(12[1-\nu^2])}$$

$a = .465$, $\nu = .30$(steel)
$h = .248$, $E = 30(10^6)$ (steel)

$$k_2 = \frac{16\pi(1.3)(30)(10^6)(.248)^3}{(3.3)(.465)^2(12\ [.91]\ )}$$

$$k_2 = \frac{2.99\text{x}10^7}{7.79} = \underline{3.84(10^6)\#/in}$$



View A-A

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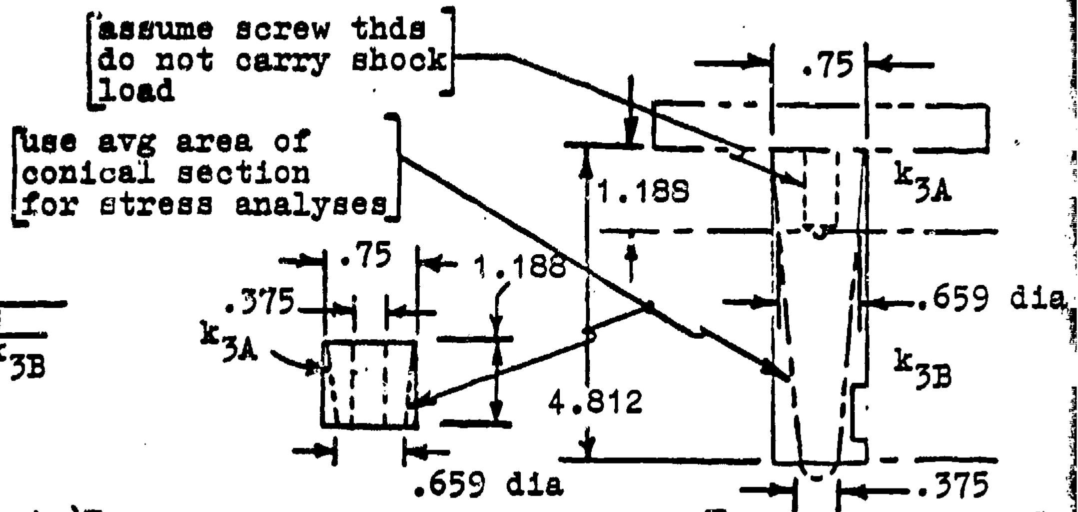
* Theory of Plates and Shells, S. Timoshenko and S. Woinclosky-Kreter, McGraw Hill, N.Y., 1959, P.68

3. SHAFT



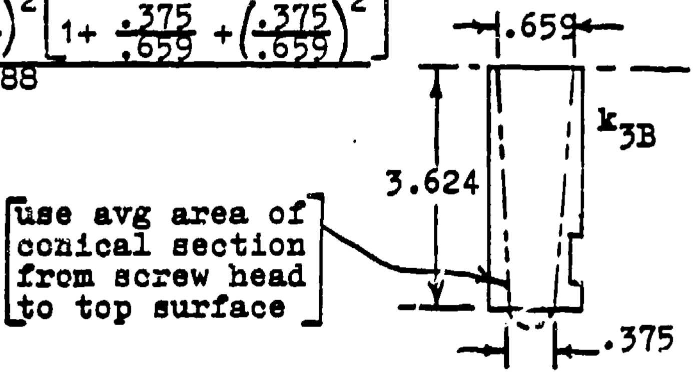
$$k_3 = \frac{1}{\frac{1}{k_{3A}} + \frac{1}{k_{3B}}}$$

$$k_{3A} = \frac{AE}{L} = \frac{(A_C - A_H)E}{L} \; ; \quad A_{\substack{avg\\ frustum\\ cone}} = \frac{V}{h} = \frac{1}{3}\pi\left(\frac{.75}{2}\right)^2\left[1 + \left(\frac{.659}{.75}\right) + \left(\frac{.659}{.75}\right)^2\right]$$

$$= .39$$

$$k_{3A} = \frac{\left[.039 - \left(\frac{.375}{2}\right)^2 \pi\right] 30(10^6)}{1.188} = 7.06(10^6)$$

$$k_{3B} = \frac{AE}{L} = \frac{30(10^6)\ 1/3\,\pi\left(\frac{.659}{2}\right)^2\left[1 + \frac{.375}{.659} + \left(\frac{.375}{.659}\right)^2\right]}{4.812 - 1.188}$$



$$k_{3B} = 1.78\ (10^6)\ \#/in$$

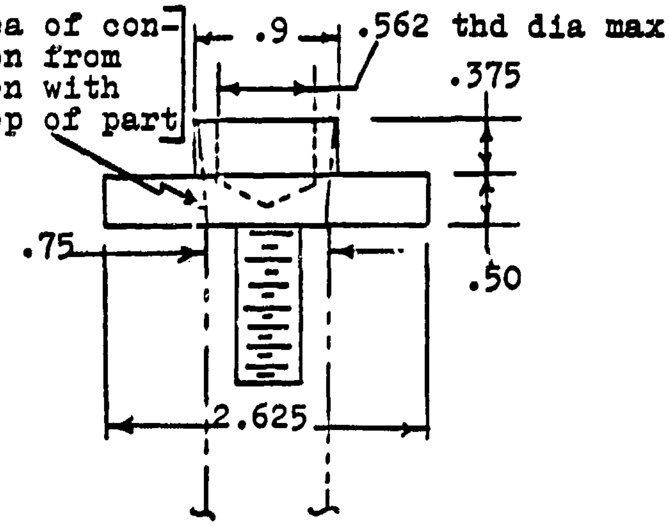
$$k_3 = \frac{1}{\frac{1}{7.06(10^6)} + \frac{1}{1.78(10^6)}}$$

$$k_3 = \frac{1}{1.42(10^{-7}) + 5.62(10^{-7})} = \frac{1}{7.04(10^{-7})} = \underline{1.42(10^6)\#/in}$$

4. FUZE PLATE

$$k_4 = \frac{AE}{L} = \frac{\left(\left[\dfrac{\left(\frac{.90}{2}\right)^2 + \left(\frac{.75}{2}\right)^2}{2}\right]\pi - \left(\frac{.562}{2}\right)^2\pi\right)30(10^6)}{.875}$$

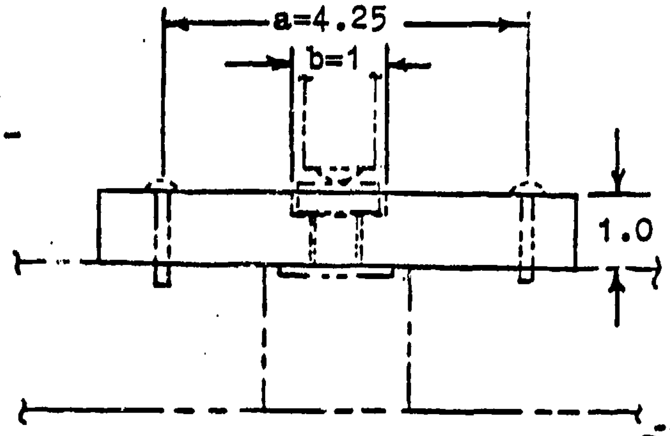
[use avg area of conical section from intersection with shaft to top of part]



$$= \underline{10.09\ (10^6)\#/in}$$

5. PAD PLATE

k_5 = assume plate acts like it is clamped at mounting screw positions and load is at hole dia.



$$k_5 = \frac{{}^{*}4\pi E t^3}{3\nu^2\left(\frac{1}{\nu^2}-1\right)}\left\{(4.25)^2 - 1^2 + \frac{(2)\frac{1}{\nu}(1)^2\left[(4.25)^2-1\right] - \frac{8}{\nu}(4.25)^2\log\frac{4.25}{1} + 4(4.25)^2\left(1+\frac{1}{\nu}\right)\left(\log\frac{4.25}{1}\right)^2}{(4.25)^2\left(\frac{1}{\nu}-1\right) + 1\left(\frac{1}{\nu}+1\right)}\right\}^{-1}$$

$$k_5 = \frac{4\ (30(10^6)}{.27(10.11)}\left\{17.06 + \frac{113.75-302.67+38}{42.15+4.33}\right\}^{-1}$$

$$= 1.38\ (10^8)(17.06 - 3.25)^{-1} = \underline{9.99(10^6)\#/in}$$

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* Forumulas for Stress and Strain, R. J. Roarke, McGraw Hill, N.Y., 1965, P221, Formula #18

$$k_T = \frac{1}{\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{1}{k_4} + \frac{1}{k_5}}$$

$$k_T = \frac{1}{\frac{1}{6.13\ (10^6)} + \frac{1}{3.84(10^6)} + \frac{1}{1.42(10^6)} + \frac{1}{10.09(10^6)} + \frac{1}{9.99(10^6)}}$$

$$k_T = \frac{1}{1.63(10^{-7})+2.60(10^{-7})+7.04(10^{-7})+1.0(10^{-7})+1.0(10^{-7})}$$

$$k_T = \frac{1}{13.27(10^{-7})} = .754(10^6)$$

$$d = \sqrt{\frac{2k_T h}{mg}} = \sqrt{\frac{2(.754)(10^6)(.258)}{28/16}} = \sqrt{.222}\ (10^3) = .472(10^3)$$

$$= 472\ g's$$

Actual "g" output is 450 ± 25 g's however consideration of intangible factors existing in analysis as well as hardware configuration yields the conclusion that a more detailed analysis would not realistically provide a more reliable result.

Value of "d" for weight of 28.8 ounces:

$$d = \sqrt{\frac{2(.754)(10^6)(.258)}{28.8/16}} = 465 \text{ g's}$$

Change of "calibration dummy fuze" weight reflecting nominal fuze weight changes "g" output by 7 g's. A percent change in weight reflects ~ ½ percent change in g's.

REFERENCES

1. Picatinny Arsenal Drawing 8879484, Fuze, Impact, Atomic Weapon: M1139.

2. Picatinny Arsenal Drawing 9232991, Fixture.

3. Picatinny Arsenal Drawing 8880000, Lance Adaption Kit: M238.