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Report No. ZRC-8216-69-19

PRODUCTION ENGINEERING OF SAFETY AND ARMING DEVICE, GM, XM114

Final Summary Report

By
J. Hilliard
Mechanical Fuze Group

February 1970

PICATINNY ARSENAL
DOVER, NEW JERSEY 07801

ZENITH RADIO CORPORATION
Chicago, Illinois

Contract No. DAAA21-68-C-0145

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Under

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Government Engineering Department
ZENITH RADIO CORPORATION
6501 West Grand Avenue
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SUMMARY

This report describes the implementation and results of a program of production-engineering performed on the XM114 Safety and Arming Device. The object was to minimize costs, simplify the design, and improve reliability and producibility. This was to have been accomplished through study and analysis of the drawing package, specifications, and tooling and inspection components and processes. In performing the program, all goals applicable to the end item were achieved: the design was simplified, material usage was revised, production was facilitated, etc.

FOREWORD

The effort described in this report was performed under Contract DAAA21-68-C-0145, titled "Production Engineering of Safety and Arming Device GM, XM114".

The findings in this report are not to be construed as an official Department of the Army position.

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1. INTRODUCTION

Under Contract DAAA21-68-C-0145, Zenith Radio Corporation conducted a production engineering study of Safety and Arming Device, GM, XM114. The results of the study were to be implemented by fabrication and testing of a specified quantity of production engineering units. The object of the effort was to simplify and/or modify the device and its parts; change dimensions, tolerances, concentricities and finishes, and develop new or improved acceptance inspection and test methods, in order to:

1. Minimize item cost (including Government acceptance costs).
2. Reduce production lead time.
3. Assure efficient materials utilization.
4. Broaden supply base.
5. Assure item mass producibility.
6. Assure ease of loading, assembly, and inspection.
7. Maintain high assurance of safety and conformance to design, while minimizing acceptance inspection cost.
8. Assure maximum use of approved specifications and standards.
9. Assure ease of maintenance and minimize frequency of maintenance operations.
10. Effect standardization and interchangeability of parts and components.
11. Assure durability and reliability of the components and/or system.
12. Provide data pertinent to maintaining item in the field.
13. Analyze abilities and limitations of human operator to ensure that the resulting man-equipment combination will permit safe, least time-consuming and, in general, efficient operator performance.

14. Eliminate (to the maximum possible extent) use of proprietary items, or items requiring use of proprietary manufacturing techniques.

The objectives listed above were to have been achieved through the following:

1. Conduct engineering study of the drawings and specifications.

2. Analyze machine tool and manufacturing methods capable of achieving the objectives of the specified production rate. This was to include comparative ability of machine tools and "know how" connected with the above, and detailed estimate of capital outlay involved.

3. Develop inspection for inclusion in specifications to assure the Government of obtaining satisfactory end items at minimum cost for inspection labor and material destroyed in testing. Emphasis was to have been placed on developing the optimum combination of examination and functional testing that will, with minimum cost, assure that the product manufactured conforms to the design. A preliminary specification and supporting inspection equipment design was to have been prepared, submitted for approval by the Contract Project Officer, and made available for application to the production-type quantity.

4. Estimate cost to mass-produce the item if this production engineering study were not conducted. This cost was to have been compared component by component with the production-engineered item on a continuing basis. The final estimate is submitted as part of this Final Summary Report. Inspection costs were to be segregated.

Contract DAAA21-68-C-0145 was issued to Zenith on 8 September 1967, and was to have been completed 8 September 1968. Changes to the direction of the effort, and revised unit quantities resulted in extension of the effort to the present date.

2. END ITEM DESCRIPTION

The XM114 S&A consists of a single assembly containing a leaf system, escapement, and electrical contacts and connectors. The S&A is housed in an aluminum cylinder, with the connecting wires and screws encased in a plastic cover attached to the aluminum housing. The entire S&A is 1.75 in diameter by 2.06 high, and weighs approximately 0.20 pounds.

The function of the S&A is as follows. The S&A device has a rotor delay time of 344 msec ± 52 msec. The leaves are positively locked until the missile has left its launcher and the flight motor ignition signal has been transmitted The acceleration sensing leaf is then unlocked by the miniature piston actuator. This leaf prevents the rotor latching leaf from releasing the spring-driven rotor until missile acceleration exceeds the acceleration sensing leaf's preset bias level of between 10 and 19g. The leaf is then caused to set back, releasing the rotor latching leaf at the same moment. A mechanical escapement prevents the spring-driven rotor from arming until 0.344 seconds ± 0.052 seconds have elapsed. This delay provides for fuze arming within the system requirements.

The XM114 S&A device is physically mounted to the boattail of the TOW missile warhead. A flanged end on the housing assembly (9231497) is provided for this purpose. Lead wires are provided on the S&A device for connecting it to the warhead, and the electronic section of the missile.

In its "safe" or unarmed condition, the S&A device is mechanically locked with the detonator (7549133) in the out-of-line position. In this position, the detonator is disconnected from the firing circuit, and is shorted out. The impulse to the flight motor is also used to ignite the miniature piston actuator (9231434) in the S&A device. When fired, the actuator piston extends itself, moving the detent spring (9231513) out of engagement with a slot in the g-sensing leaf (9231470).

This action unlocks the g-sensing leaf, and allows it to move when subjected to acceleration forces of no less than 10g nor more than 19g. When missile acceleration reaches the minimum level and the g-sensing leaf drops, it clears the way for the latching leaf (9231469) to drop. This releases the rotor. The rotor assembly is biased to rotate via the rotor spring (9231492), but is delayed by a two-stage gear train driving a starwheel (9231490) against a pallet (9231450), both part of the escapement assembly (9231438). As the rotor assembly reaches the in-line, or armed position, its insulated detonator contact (9231461) makes contact with the armed contact (9231491). This electrical path is completed to the missile firing circuit by way of the contact stud (9231433), which is part of the terminal board assembly (9231502). Also, the miniature piston actuator mentioned earlier is part of this assembly.

Two wires (brown-black) from the assembly are connected to the warhead, and three (black-red-yellow) are connected to the missile electronics. The piston actuator is connected to the yellow and black pair, and the red and brown wires form the detonator firing circuit.

A self-destruct function called the graze system will function in case of an electrical failure in the system upon sensing a negative acceleration of 100g's after arming cycle has been completed. A graze lever (9231482) restrains the locking shaft (9231493), which in turn restrains the spring-loaded firing pin (9231431). Upon impact with the target or ground (and only after the rotor has been rotated to the armed position), the graze lever is caused to trip when deceleration forces reach 100g, allowing the primer (8796462) to be exploded by the firing pin. This initiates the explosive train to propagate the warhead.

3. DESCRIPTION OF DEVELOPMENT

3.1 Engineering Study

3.1.1 General. Zenith conducted an engineering study which encompassed all documentation included in the contract as reference material (drawings and specifications). The experience gained through the XM114 R&D contract (DA-28-017-AMC-1059(A)) was utilized in this study. As a result, the following changes were incorporated into the drawings and specification developed under the Production Engineering contract.

The upper arming time limit at -25°F was raised from 396 milliseconds to 450 milliseconds. This change increased the manufacturability of the unit with no loss of performance. This was possible because the missile never achieves maximum acceleration at -25°F, and therefore, the shortest time to reach minimum target distance is longer at -25°F than at ambient temperatures.

The arming level was raised from 10g to 19g because the output of the latest design flight motors would allow this higher arming level. This change also increased unit manufacturability, because at this higher g-level, the friction effect on arming level variation is smaller.

The basic dimensioning system was incorporated into the drawing package.

Wire insulation was changed from polyvinyl chloride to teflon to insure compatibility at the warhead-missile interface stage of assembly.

Changes were made in the housing assembly, terminal board base, arming contact terminal board, electrical receptacle contact and fuze base to insure that the electrical receptacle contact could not become shorted to ground when the cover was assembled on a unit. This problem had been encountered during the R&D contract. These changes increased reliability, because the short would render the detonator inoperative. This, in turn, would cause a failure in explosive function, the ultimate function of the missile.

Material for the rear support, setback support, and escapement plate was changed from brass to steel. This was done to reduce the amount of critical material used in the unit. A minimal cost savings was also achieved.

The graze shaft was redesigned for more economical production. The cost of this part was reduced from $0. 254 to $0. 082 each.

The following escapement parts were teflon-coated to improve cold temperature performance: pinion No. 1, pinion No. 2 and starwheel. This change also improved manufacturability by decreasing the arming time spread between ambient and cold temperature functioning.

In order to reduce the frictional effects on arming level in the leaf system, teflon coated latching leaves were tested. The frictional effect was drastically reduced. Ambient test results indicated that manufacturability could be greatly increased, because the teflon coating eliminated almost all in-process arming level rejects. However, teflon-coated latching leaves had to be scrapped because of problems encountered during cold testing (see leaf system section for details).

As a result of problems encountered in reliability testing, the detent plunger assembly (9231477) was replaced with a spring wire detent (9231513). This change resulted in both improved safety and reliability, and reduced cost.

During the course of the contract, the slotted washer (9231479) became disengaged from the detent plunger, causing a safety hazard. Also during reliability testing, it was found that the piston actuator drove the detent plunger assembly into the rotor, possibly causing long arming times. Both of these problems were cured by using the spring wire detent. The spring wire detent also resulted in a cost savings of \$0. 13 for material and \$0. 05 for labor. This resulted in a total savings per unit of \$0. 18.

During reliability testing, it was also found that with existing tolerances the escapement plate could interfere with the housing assembly. When the housing was assembled to the unit, the escapement plate was forced out of proper alignment with the rear support plate (the second bearing plate for the escapement). This condition caused long arming times. The escapement plate was redimensioned to correct the problem, and improved reliability was achieved.

3.1.2 Escapement Functional Study. A study of the escapement gearing was made and AGMA standards for specifying gear tolerance were changed to incorporate the latest issues. The results of the study showed all gearing used in this assembly to be satisfactory.

A study was made to determine the effect of tolerance variation on escapement time. Using the formula,

$$t = 2Nf \sqrt{\frac{2I\theta\ (16\ \text{oz/lb})}{T\ (\omega_w/\omega_p)}}$$

where: t = rotor delay time, msec

N = number of pallet oscillations = 75 (constant)

I = pallet moment of inertia, in-lb-sec^2

θ = pallet arc of movement, radians

T = average torque of starwheel, in-oz

ω_w/ω_p = angular velocity of starwheel/angular velocity of pallet = 1.23

f = friction factor = 1.75

From these calculations, the following values were derived:

t_{max} = 390.6 msec

t_{avg} = 342.8 msec

t_{min} = 298.7 msec

The details of these calculations are given in Appendix 1.

Tests were conducted to determine escapement performance at -25°F and to determine the effect of solid-film lubrication on low temperature performance. Table 1 shows results at room temperature and -25°F, both with and without solid-film lubrication. The averages obtained from room temperature testing were 327.3 msec without and 314.9 msec with lubrication. These tests indicate that, on the average, the lubricated assemblies run faster and with less variation in time. The averages from cold testing were as follows: first run without lubrication: 407.9 msec, second run without lubrication: 438.3 msec, first run with lubrication: 381.4 msec, second run with lubrication: 356.1 msec. The results obtained indicated that solid-film lubrication of the starwheel and pinion assembly would contribute greatly to escapement function at low temperature.

Table 1. Rotor Delay Times at Various Temperatures, msec

Serial No.	Room Temperature without Lubrication	Room Temperature with Lubrication
390	309.6, 308.8, 311.7	311.0, 318.3, 318.2
392	327.7, 335.8, 344.7	318.3, 322.0, 326.5
393	335.1, 332.2, 326.7	318.0, 314.9, 311.7
377	322.3, 334.8, 338.0	303.7, 308.0, 308.8
Serial No.	-25 °F without Lubrication	-25 °F with Lubrication
390	429.3, 554.4	495.0, 368.1
392	474.3, 465.5	--
393	360.2, 357.8	301.6, 278.7
377	367.8, 375.8	347.5, 345.8

Empirical verification of these tests showed a variation of time of ±16%; previous studies had predicted ±10% variation. Subsequent additional ambient and cold temperature testing utilizing various types of solid lubrication were performed. The results were then compared with previous R&D Reliability testing, and the two were found to compare favorably in that the P-E results were improved over the R&D results. Differences between static rotor delay time, rotor delay time under 25g, and combined leaf drop and rotor delay time at 25g were derived from testing analysis, and arming time was found to be capable of being held to within the required ±2δ standard deviation.

At that time, it was decided to use teflon-coated escapement parts (pinion No. 1, pinion No. 2, and starwheel) in the 75 preliminary design samples. The units were to be split into two groups, one group coated with "straight" teflon and one group with teflon-S, in order to further evaluate the properties of each material.

3.1.3 Leaf System Functional Study. The functional study of the R&D safety and arming devices had occasionally revealed a problem of latching leaf hang-up. Four methods of eliminating this problem by reducing friction were tried:

1. Solid-film lubricated latching leaf (electrofilm)
2. Teflon-S coated latching leaf
3. Latching leaf with redesigned cams
4. Rotor pins with smoother surfaces.

Test were run (see Table 2) to determine friction for the various modifications to the leaf system. This was done by removing the g-sensing spring and measuring the g's required to function the leaf system. The resulting readings would therefore be the g's required to overcome friction.

Table 2. Redesigned Leaf Drop Test in g's

Sample Leaf	Test Run					
	1	2	3	4	5	6
Solid-film Lubricated	5.56	4.80	6.39	4.80	4.80	5.56
Teflon-coated	≤1	≤1	≤1	≤1	≤1	≤1
Redesigned Cam Profile	6.39	7.27	10.25	6.39	5.56	7.27

The tests indicated the teflon-S coated leaves to be optimum, because they had the least, and also the most consistent, friction. (NOTE: Because of delay in receiving smoother rotor pins, method No. 4 above had to be dropped.) The units incorporating the modifications were then stored for one month in the armed position to detect any tendency to hang up after storage (the R&D units had previously displayed this tendency.) Of the three units, only the solid-film lubricated (electrofilm) unit showed a slight tendency to hang up. The teflon-S coated unit was considered optimum, and this type was to have been used in the 75 preliminary design fuzes.

However, difficulty was experienced in applying teflon-S uniformly to the latching leaf on a production basis. Therefore, leaves coated with straight teflon were compared with those having a teflon-S coating.

Twenty S&A's were tested, ten with each type of coating. Each S&A was tested with and without rotor load on the leaf system. The reading with rotor load minus the reading without gave us the g-force required to overcome friction for each unit (see Table 3).

Table 3. Teflon-Coated Latching Leaf Tests

Unit No.	Type of Coating	Leaf Drop, No Rotor Load, g's	Leaf Drop, With Rotor Load, g's	Difference, g's
1	'Straight' Teflon	10.2 g's	13.5	+3.3
2		15.0	16.3	+1.3
3		19.2	18.9	-0.3
4		6.0	6.0	0.0
5		23.1	26.4	+3.3
6		5.2	3.8	-1.4
7		6.8	8.2	+1.4
8		6.0	7.3	+1.3
9		6.4	6.4	0.0
10		7.3	6.8	-0.5
			Average	+0.84

Table 3. Teflon-Coated Latching Leaf Tests (Cont'd)

Unit No.	Type of Coating	Leaf Drop, No Rotor Load, g's	Leaf Drop, With Rotor Load, g's	Difference, g's
11		11.2	12.8	+1.6
12		6.0	5.4	-0.6
13		6.8	10.8	+4.0
14		7.3	8.9	+1.6
15		6.4	7.7	+1.3
16		6.4	6.6	+0.2
17		6.4	9.2	+2.8
18		6.4	8.7	+2.3
19		6.8	6.5	-0.3
20		6.0	6.0	0.0
			Average	+1.35

The straight teflon coated leaves displayed slightly less g's to overcome friction. An average of 0.84g was required to overcome friction with straight teflon leaves, and 1.35g for the teflon-S leaves. Standard deviations for the two types were 1.72g for the straight teflon and 1.91g for the teflon-S.

Further tests to determine if straight teflon or teflon-S was best for use on the latching leaf were run using new design springs. In addition to proving out the new springs, the test indicated leaves coated (tested at an average g-level of 14.5) with straight teflon yielded a standard deviation of 2.28g, and teflon-S 1.95g. Test results are shown in Tables 4 and 5. σ was obtained from the formula:

$$\sigma = \sqrt{\frac{\Sigma \ Fx^2 - \Sigma \ (Fx)^2}{N-1}}$$

This friction load is considered to be the difference (in g-levels) between test results with and without rotor load.

Table 4. Teflon Latching Leaf Tests

Unit No.	With Rotor Load		No Rotor Load		Average Friction Load, g's
	1st Test, g's	2nd Test, g's	1st Test, g's	2nd Test, g's	
1	15.0	15.0	14.4	15.6	0
2	11.4	11.9	11.9	11.9	-0.15
3	16.3	16.3	15.0	15.0	+1.30
4	13.1	15.0	14.4	13.8	-0.05
5	17.0	18.5	13.1	13.1	+4.65
6	10.2	10.2	11.4	11.4	-1.20
7	15.0	15.0	14.4	15.0	+0.30
8	12.5	13.8	13.1	13.8	-0.30
9	16.3	17.0	17.8	18.5	-1.50
10	14.4	14.4	17.8	18.5	-3.75
Avg.	14.42g with σ = 2.28g		14.50g		-0.08g
	Avg. friction load = 0.08g with σ = 2.12g				

Table 5. Teflon-S Latching Leaf Tests

Unit No.	With Rotor Load		No Rotor Load		Average Friction Load, g's
	1st Test, g's	2nd Test, g's	1st Test, g's	2nd Test, g's	
11	13.8	14.5	15.0	15.0	-0.85
12	12.5	11.9	11.9	12.5	0
13	17.8	17.8	14.4	14.4	+3.4
14	15.0	15.0	13.1	15.0	+.85
15	13.1	13.8	13.8	13.8	-2.5
16	17.8	15.6	15.0	17.0	+0.70
17	17.0	16.3	13.8	17.0	+1.25
18	12.5	13.1	13.1	11.9	+0.30
19	13.8	13.1	13.1	12.5	+0.65
20	12.5	12.5	12.5	12.5	0
Avg.	14.47g with σ = 1.95g		13.87g		+0.60g
Avg. friction load = +0.60g with σ = 1.40g					

These results indicated teflon-S to show less variation. Some of each type of coated leaves were used in the Reliability Test Program for evaluation. It was anticipated that straight teflon, because of its ease of application, would be used in production. However, tests showed the use of teflon caused long arming times at -25°F (see paragraph 3.2.7), and therefore the use of teflon was discontinued in favor of chromium-plated leaves.

3.1.4 Graze System Functional Study. The graze shaft was redesigned for more economical fabrication. Prices for the redesigned graze shaft in quantities of 12K are $18.00 per thousand plus a progressive die charge of $1250.00. This compares favorably with the previous graze shaft price of $254.00 per thousand plus $1700.00 for original tooling.

A tolerance study was made on the graze lever and no problems were uncovered.

Paragraph 3.2 contains information on graze system in-process controls necessitated by results obtained during reliability testing.

3.2 Reliability Testing

On May 20th, 1968, Zenith was to perform reliability tests on the 75 preliminary design fuzes. The reliability test was to have been performed by Picatinny Arsenal, but test facilities would not be available at that time.

During the month of July 1968, Picatinny Arsenal requested that Zenith perform the reliability test per MIL-S-14799, the present purchase description. Zenith's proposal stated that only R&D test equipment would be used. Production test equipment was to have been designed, but not fabricated under this contract. Because Zenith's present test equipment is not capable of all the tests as specified in MIL-S-14799, the test plan had to be somewhat modified from that described in MIL-S-14799. The decision to modify the test plan was made only after a determination that the extensive test equipment modification necessary would be prohibitive in terms of both time and funds.

On August 14, 1968, Picatinny Arsenal submitted the preliminary test plan to Zenith (see Figure 1).

3.2.1 Preliminary Functional Tests. The preliminary functional tests (non-arm and arm at ambient temperature, and graze function) were completed on September 3rd, 1968. Table 6 shows the results of these tests. Cited references in the table indicate that the unit was reworked before acceptable readings were obtained.

3.2.2 Missile Vibration. The missile vibration tests were performed on September 12th and 13th, 1968, using the vibration levels specified in MIL-S-14799. The fuzes were vibrated along the rotor axis in a nose-down attitude. All units passed the test, that is, no switch chatter was observed, and no graze function was observed.

The units were then vibrated perpendicular to the rotor axis in a nose-down attitude. Two of the first three units tested exhibited graze function, and

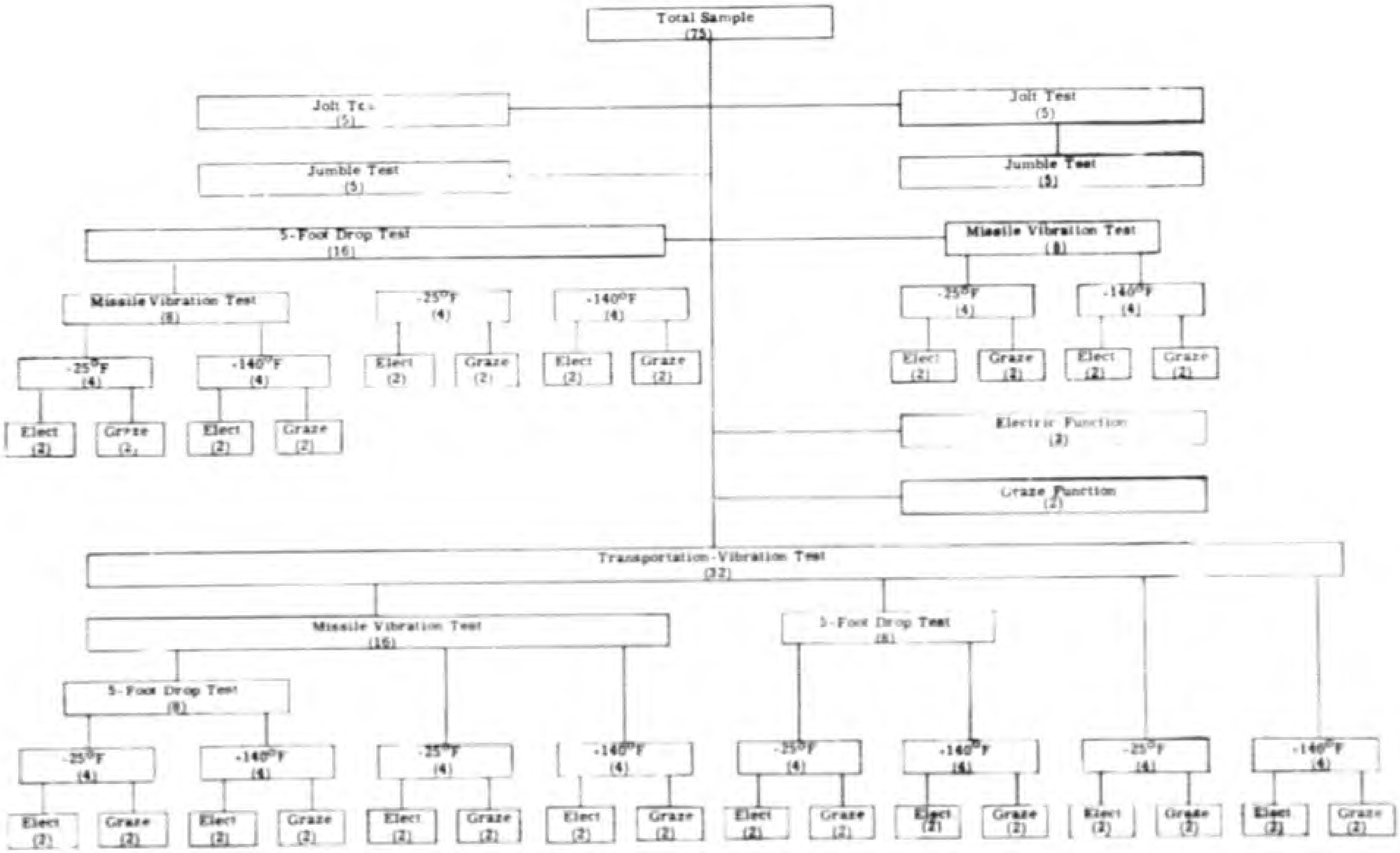

Figure 1. Sampling Plan for Reliability Testing

one of the graze-functioning units showed 160 μsec chatter. At this point, the tests were halted and the fixture changed to orient the longitudinal axis of the fuze parallel to the ground, simulating missile flight. It was felt that the previous orientation (nose down) placed a constant 1g load on the graze leaf, trying to arm it. This force, plus the vibration force, allowed the graze lever to "walk" and release the graze. The new orientation also provides that the key slot in the housing is downward simulating the normal missile mounting.

The tests were re-run on September 13th. In vibration along the rotor axis with the key slot down, seven of the eight units passed. Six showed no chatter or graze, and one showed three discontinuties of 20 to 30 μsec length but no graze. The failed unit showed discontinuities at greater than 105 μsec and no graze. In vibration along the longitudinal axis of the unit with the key slot down, five units passed, exhibiting no chatter or graze, and three showed chatter at greater than 105 μsec and no graze. Testing was again halted, and the test conditions examined. It was found that of the total of four failed units encountered thus far, all had improperly seated escapement plates. Upon correction of this condition, three of the four units passed the vibration test.

The last axis test, run on September 23rd, was perpendicular to the rotor axis with the key slot down. Two units passed of eight tested. Two units showed chatter at greater than 105 μsec plus graze function, two showed only chatter, and two showed only graze function. The units were re-tested per the HAC Missile Interim Specification No. MIL 13645, dated April 1967. This test required lower power levels than MIL-S-14799.
The re-tests still indicated problems; however, it was found that the results obtained depended upon where the accelerometer sensor was placed on the test equipment. Further tests were run to provide optimum simulation of missile conditions, i. e., without the vibration amplification induced by remote placement of the accelerometer. The extreme sensitivity condition, being ascribed to the remote placement of the acceleration sensor, led to placement of the accelerometer on the warhead mounting ring, where it was felt that vibration amplification induced by remote mounting would be eliminated. This proved correct, and the extreme sensitivity condition was no longer encountered.

Of the 32 units tested for missile vibration arming contact (switch chatter) and graze function in all three planes, 31 evidenced no chatter or graze function. The graze functioned on one unit (No. 26) in the longitudinal plane. Upon re-testing, the graze did not function, and it was felt that the graze lever was not reset properly for the first run.

Zenith was subsequently informed by Picatinny Arsenal that of the 20 units submitted to Picatinny Arsenal for missile vibration tests on warhead, all passed satisfactorily.

Table 6. Preliminary Functional Test Results

S & A No.	Non Arm Test (10g)	Arming Time Test (19g), msec	Graze Function Level Test, g's
26	ok	360.3, 350.9	34.8
27	ok	333.2, 325.1	43.2
28	ok	343.1, 348.7	38.9
29	ok	320.2, 322.9	41.0
30	ok	a 303.0, 308.3	38.9
31	ok	b 363.4, 349.3	43.2
32	ok	348.1, 338.6	36.8
33	ok	341.3, 323.1	34.8
34	ok	333.6, 329.2	34.8
35	ok	321.1, 316.5	38.9
36	ok	c 294.0, 299.0	45.5
37	ok	318.1, 317.5	32.8
38	ok	340.1, 334.6	34.8
39	ok	324.5, 319.7	45.5
40	ok	320.1, 320.5	43.2
41	ok	328.0, 326.3	38.9
42	ok	311.8, 308.8	38.9
43	ok	327.8, 320.4	45.5
44	ok	329.3, 319.9	46.5
45	ok	333.2, 359.3	38.9
46	ok	342.9, 337.7	36.8
47	ok	321.3, 314.4	34.8
48	ok	339.9, 339.9	38.9
49	ok	332.2, 337.8	50.1
50	ok	317.6, 317.5	30.1
51	ok	d 315.2, 312.5	43.2
52	e ok	f 313.4, 316.1	50.1
53	ok	311.6, 310.3	34.8
54	ok	g 317.5, 322.8	38.9
55	ok	318.7, 324.0	47.7

Table 6. Preliminary Functional Test Results (Cont'd)

S & A No.	Non Arm Test (10g)	Arming Time Test (19g), msec	Graze Function Level Test, g's
56	ok	345.8, 340.2	47.7
57	ok	307.4, 312.1	41.0
58	ok	305.5, 308.3	50.1
59	ok	[h] 387.9, 378.3	36.8
61	ok	[i] 314.6, 311.5	43.2
62	ok	366.4, 337.6	47.7
63	ok	329.1, 333.5	36.8
64	ok	339.6, 336.8	43.2
65	ok	323.9, 314.4	43.2
66	ok	338.8, 333.7	41.0
67	ok	315.3, 321.3	36.8
68	ok	329.1, 330.7	36.8
72	ok	314.7, 299.0	38.9
73	ok	340.9, 326.6	41.0
74	ok	336.5, 334.8	38.9
75	ok	317.4, 314.5	34.8
76	ok	[j] 293.6, 299.8	41.0
77	ok	328.8, 331.6	36.8
78	ok	309.4, 314.8	43.2
79	ok	380.3, 376.0	41.0
80	ok	314.1, 300.6	43.2
81	ok	314.5, 312.9	43.2
82	ok	[k] 369.2, 336.9	45.5
83	ok	295.9, 292.7	52.5
84	ok	321.8, 322.8	45.5
85	ok	313.4, 312.0	38.9
86	ok	300.4, 300.0	41.0
87	ok	[l] 323.8, 328.8	43.2
88	ok	[m] 338.1, 335.8	34.8
89	ok	311.8, 309.1	45.5

Table 6. Preliminary Functional Test Results (Cont'd)

S & A No.	Non Arm Test (10g)	Arming Time Test (19g), msec	Graze Function Level Test, g's
90	ok	300.2 298.4	45.5
91	ok	n 354.9, 361.6	38.9
92	ok	o 337.7, 337.1	38.9
93	ok	321.1, 329.5	36.8
94	ok	p 318.3, 324.5	41.0
95	ok	332.2, 330.5	38.9
96	ok	q 318.4, 325.9	32.5
97	ok	292.9, 295.7	45.5
98	ok	342.0, 337.0	52.5
99	ok	328.8, 333.5	43.2
100	ok	317.5, 315.7	36.8
101	ok	359.4, 355.1	47.7
102	ok	301.9, 302.6	45.5
103	ok	322.3, 330.4	43.5
104	ok	331.3, 334.6	52.5
		Avg. 327.2, 325.2	Avg. 41.3

NOTES: Units with reference citations required rework. The following is a list of problems and corrective action taken on those units.

a. Unit 30 did not arm at 19g. The main shaft shoulder was too short for the pallet and gear No. 2 to clear each other. The condition was corrected by replacing the main shaft.

b. Unit 31 did not arm because the rotor was binding. Examination showed that the rotor had no end play. The condition was corrected by straightening the plate to provide end clearance for the rotor.

c. Unit No. 36 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

d. Unit No. 51 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

e. Unit No. 52 armed at 10g. The condition was corrected by replacing the g-sensing leaf spring.

f. Unit No. 52 had a rotor delay time under the minimum. A change in rotor spring did not correct the condition, but a new escapement assembly did.

g. Unit No. 54 did not arm at 19g because the g-sensing leaf was hanging up on the detent plunger. The condition was corrected by straightening the detent plunger.

h. Unit No. 59 did not arm at 19g because the g-sensing leaf was staked too tightly. The condition was corrected by replacing the setback support assembly.

i. Unit No. 61 did not arm because of poor teflon coating on the latch leaf. The condition was corrected by replacing the setback support assembly.

j. Unit No. 76 did not arm because of interference between the g-sensing leaf and the detent plunger. This condition was corrected by straightening the detent plunger. Unit No. 76 also had an arming time less than the minimum. This condition was corrected by replacing the rotor spring.

k. Unit No. 82 had an arming time greater than the maximum because of a faulty starwheel and pinion assembly. The condition was corrected by replacing the starwheel and pinion assembly.

l. Unit No. 87 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

m. Unit No. 88 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

n. Unit No. 91 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

o. Unit No. 92 did not arm because of leaf hang-up. The condition was corrected by running in the unit.

p. Unit No. 94 did not arm because the rotor was binding. The condition was corrected by straightening the setback to provide clearance for the rotor.

q. Unit No. 96 escapement did not function because the pallet was hanging up on gear No. 2. The condition was corrected by replacing the main shaft. This provided clearance between the pallet and gear. A new leaf spring was also required for the unit to arm at 19g.

3.2.3 Five-Foot Drop. Five-foot drop tests were performed September 26, 1968, on 16 of the required 32 units. Two of the 16 units failed because the leg of the g-sensing leaf spring popped out of its retaining slot on the fuze base, a condition that had never been encountered before. As a result, the leg will be made 0.060" longer and the slot will be 0.040" deeper. New springs were ordered, but until they were received, reliability tests continued to be run using present springs, which should have no effect on any other tests. The two failed units and any additional failures results from the 16 units remaining to be tested were to have new springs installed and, if necessary, bases reworked, after which they were re-tested. Subsequent testing with redesigned springs and reworked bases provided satisfactory results.

3.2.4 Transportation-Vibration. Transportation-vibration tests were begun September 30, 1968, and completed October 3rd. All units remained safe.

3.2.5 Low Temperature Tests. When low temperature functional tests were conducted, problems arose in the form of excessively long arming times experienced in testing. Analysis showed that the rotor delay portion of the arming time was not excessively long at cold temperature. Because rotor delay time is measured in a different fixture than arming time, there were two possible causes of the extremely long arming times. The first was that the arming time fixture was not operating properly; the second that the leaf drop portion of the arming delay was excessively long.

Checking out the fixture indicated that it was operating properly. When leaf drop times were checked, they proved excessively long. The first attempt to correct this condition was to ultrasonically clean the entire unit. One preliminary test showed this to solve the problem. However, five more units were cleaned and only one of these functioned within limits. Also, the cleaning procedure was found to be detrimental to the graze function. On four of the five units tested, the graze functioned above the upper limit. These units showed acceptable graze function before cleaning.

At this point, it was decided to continue the cold test. Static rotor delay and arming time at 35g were to be checked, in addition to non-arm and arming time at 19g and graze function level. Information from these tests was to have been used to determine a solution to the problem. In addition, Zenith tested several R&D type fuzes to see if they exhibited the same problem. Also, several g-sensing leaves were "dimpled" in an effort to reduce possible friction between the leaf and support plate.

Of the 32 units tested for arming time at low temperature, 7 functioned within limits (see Table 7). The others all had longer than allowable arming times. Table 8 summarizes the cold test data in Table 7, and shows 19g ambient and cold, 35g cold, static rotor cold, and static rotor ambient (after cold test). Rotor times are shown to be within limits and 35g times are considerably faster than 19g times, proving that the long arming times at cold temperature are primarily due to excessively long leaf system functioning times.

Curves of leaf drop versus g-level at ambient and low temperatures were prepared. Of nine units chosen, three were of the production-engineered design, three were production-engineering designs with "dimpled" g-sensing leaves, and three were R&D models. All nine showed acceptable leaf drop at ambient temperature (less than 20 msec at 19g; less than 10 msec at 35g). At cold temperature, P-E units with dimpled leaves all remained acceptable, only one standard P-E unit remained acceptable and no R&D models remained acceptable. The three standard P-E units were disassembled and their g-sensing leaves dimpled. Upon re-testing at cold temperature, the performance of the single unit previously acceptable had degraded to unacceptable, and the other two units, while showing improved performance, remained outside the acceptable limits.

The possibility of erroneous test readings caused a plan to be evolved for checking the equipment. Arming time had been measured from mechanical release of the g-sensing leaf until the rotor reaches the armed position. This meant there was a possibility of poor contact release, so that counting may have commenced before the leaf was released. A new fixture that would release the leaf by initiating the piston actuator and thereby

Table 7. Reliability Test Results

(In first column, (T) - teflon, (TS) - teflon-S for latching leaf)

Unit No.	No Arm at 10g, Ambient	Arming Time at 19g Ambient	Graze Level (30-100g), Ambient	Five-Foot Drop	Transportation Vibration	Missile Vibration	No Arm at at 10g, -25 F	Arming Time at 19g, -25 F	Graze Level (30-100g) -25 F	No Arm at 10g, -140 F	Arming Time at 19g, -140 F	Graze Level (30-100g), -140 F
26 (T)	OK	360.3	34.8	X		X[d]	OK	1832.2	50.1			
27 (T)	OK	333.2	43.2	X		X	OK	2486.3	50.1			
28 (T)	OK	343.1	38.9	X		X	OK	1218.0	47.7			
29 (T)	OK	330.2	41.0	X		X				OK	344.9	45.5
30 (T)	OK	303.0	38.9	X		X				OK	314.5	38.9
31 (T)	OK	363.4	43.2	X[a]		X				OK[e]	342.0	36.8
32 (T)	OK	348.1	36.8	X			OK	678.6	36.8			
33 (T)	OK	341.3	34.8	X			OK	575.7	50.1			
34 (T)	OK	333.6	34.8	X			OK	568.4	38.9			
35 (T)	OK	321.1	38.9	X						OK	495.0 332.0[f]	43.2
36 (T)	OK	294.0	45.5	X						OK	321.3	45.5
37 (T)	OK	318.1	32.8	X[b]						OK[g]	333.4	38.9
38 (T)	OK	340.1	34.8			X	OK	433.5	71.0			
39 (T)	OK	324.5	45.5			X	OK	1502.6	41.0			
40 (T)	OK	320.1	43.2			X	OK	695.2				
41 (T)	OK	328.0	38.9			X				OK	321.3	45.5
42 (T)	OK	311.8	38.9			X				OK	328.9	29.6[h]
43 (T)	OK	327.8	45.5			X				OK	319.2	32.8
44 (T)	OK	329.3	46.5	X	X	X	OK	444.4	47.7			
45 (T)	OK	333.2	38.9	X	X	X	OK	1496.4	36.8			
46 (T)	OK	342.7	36.8	X[c]	X	X	OK	1606.8	41.0			
47 (T)	OK	321.3	34.8	X	X	X				OK	327.7	34.8
48 (T)	OK	339.9	38.9	X	X	X				OK	327.2	47.0
49 (T)	OK	332.2	50.1	X	X	X				OK	335.3	41.0
50 (T)	OK	317.6	30.1		X	X	OK	411.3	41.0			
51 (T)	OK	309.1	43.2		X	X	OK	899.8	45.5			
52 (T)	OK	316.1	50.1		X	X	OK	370.4	50.1			
53 (T)	OK	311.6	34.8		X	X				NG[i]	315.9	41.0
54 (T)	OK	317.5	38.9		X	X				OK	317.4	36.8
55 (T)	OK	318.7	47.7		X	X				OK	356.8	j

Table 7. Reliability Test Results (Cont'd)
(In first column, (T) = teflon, (TS) = teflon-S for latching leaf)

Unit No.	No Arm at 10g, Ambient	Arming Time at 19g Ambient	Graze Level (30-100g), Ambient	Five-Foot Drop	Transportation Vibration	Missile Vibration	No Arm at 10g, -25 F	Arming Time at 19g, -25 F	Graze Level (30-100g) -25 F	No Arm at 10g, +140 F	Arming Time at 19g, +140 F	Graze Level (30-100g), +140 F
56 (T)	OK	345.8	47.7	X	X		OK	760.9	52.5			
57 (T)	OK	307.4	41.0	X	X		OK	2890.2	45.5			
58 (T)	OK	305.8	50.1	X	X		OK	609.1	43.2			
59 (T(	OK	387.9	36.8	X	X					OK	339.0	36.8
61 (T)	OK	314.6	43.2	X	X					OK	310.8	38.9
62 (T)	OK	366.4	47.7	X	X					OK	318.9	34.8[k]
63 (T)	OK	329.1	36.8		X		OK	406.6	52.5			
64 (T)	OK	339.6	43.2		X		OK	1356.5	50.1			
65 (T)	OK	323.9	43.2		X		OK	373.8	55.0			
66 (T)	OK	338.8	41.0		X					OK	339.8	32.8
67 (T)	OK	315.3	36.8		X					OK	309.9	36.8
68 (T)	OK	329.1	36.8		X					OK	321.9	38.9
87 (TS)	OK	323.8	43.2	X		X	OK	No Arm[m]	43.2			
88 (TS)	OK	338.1	34.8	X		X				OK	342.0	41.0
89 (TS)	OK	311.8	45.5	X			OK	530.4	45.5			
90 (TS)	OK	300.2	45.5	X						OK	297.0	38.9
91 (TS)	OK	354.9	38.9			X	OK	2053.1	47.7			
92 (TS)	OK	337.7	38.9			X				OK	323.1	38.9
93 (TS)	OK	321.1	36.8	X	X	X	OK	860.0	36.8			
94 (TS)	OK	318.3	41.0	X	X	X				OK	333.3	38.9
95 (TS)	OK	332.2	38.9		X	X	OK	No Arm	38.9			
96 (TS)	OK	318.4		X	X					OK	307.7	60.1
97 (TS)	OK	292.9	45.5	X	X		OK	7230.6	45.5			
98 (TS)	OK	342.0	52.5	X[1]	X					OK[n]	332.7	65.4
99 (TS)	OK	328.8	43.2		X		OK	No Arm	60.1			
100 (TS)	OK	317.5	36.8		X					OK	310.9	38.9
101 (TS)	OK	359.4	47.7									
102 (TS)	OK	301.9	45.5									
103 (TS)	OK	322.3	43.5									
104 (TS)	OK	331.3	52.5									

Table 7. Reliability Test Results (Cont'd)
(In first column, (T) - teflon, (TS) - teflon-S for latching leaf)

Unit No.	No Arm at 10g, Ambient	Arming Time at 19g Ambient	Graze Level (30-100g), Ambient	Five-Foot Drop	Transportation Vibration	Missile Vibration	No Arm at at 10g, -25 F	Arming Time at 19g, -25 F	Graze Level (30-100g) -25 F	No Arm at 10g, +140 F	Arming Time at 19g, +140°F	Graze Level (30-100g), -140 F
105 (TS)	OK	343.4	36.8			X				OK	357.4	41.0
106 (TS)	OK	323.4	38.9			X				OK	303.2	34.8
107 (TS)	OK	316.0	36.8			X	OK	2777.2	47.7			
108 (TS)	OK	327.8	45.5			X	OK	381.2	47.7			
109 (TS)	OK	304.7	38.9			X	OK	No Arm°	50.1			
110 (TS)	OK	299.9	32.8			X	OK	530.6	43.2			
111 (TS)	OK	297.4	41.0			X				OK	298.0	43.2
112 (TS)	OK	311.3	38.9			X				OK	309.6	36.8
				Jolt	Jumble	Jolt and Jumble			Avg. 43.8		Avg. 324.7 σ 15.4	Avg. 40.5
72 (TS)	OK	314.7	38.9	X							Avg. +2σ 355.5	
73 (TS)	OK	340.9	41.0	X							Avg. -2σ 293.9	
74 (TS)	OK	336.5	38.9	X								
75 (TS)	OK	317.4	34.8	X								
76 (TS)	OK	293.6	41.0	X								
77 (TS)	OK	328.8	36.8		X							
78 (TS)	OK	309.4	43.2		X							
79 (TS)	OK	380.3	41.0		X							
80 (TS)	OK	314.1	43.2		X							
81 (TS)	OK	314.5	43.2		X							
82 (TS)	OK	369.2	45.5			X						
83 (TS)	OK	295.9	52.5			X						
84 (TS)	OK	321.8	45.5			X						
85 (TS)	OK	313.4	38.9			X						
86 (TS)	OK	300.4	41.0			X						
		Avg. 327.2										

Table 7. Reliability Test Results (Cont'd)

NOTES

a. Leaf spring leg was out of retaining slot in base after 5-foot drop test. This condition will be corrected by a leg length change from .250-.015 inches to .312-.015 inches. Base slot will be changed to accommodate longer slot.

b. Same as a.

c. Escapement plate had slipped over head of one of its mounting screws. This condition was caused by use of an improper screw.

d. Graze functioned during missile vibration along longitudinal axis. Test was repeated and graze did not function.

e. Fuze armed at 10g because leaf spring leg was out of its retaining slot in base. With spring correctly mounted, fuze did not arm at 10g.

f. 495.0 msec arming time was considered a result of test equipment malfunction.

g. Same as e.

h. Graze functioned slightly below limits.

i. Armed at 10g.

j. Graze functioned above 100g. Condition was due to improperly dressed detonator lead. Lead was dressed and unit was re-tested. Unit failed re-test due to small burr which caused the firing pin and graze locking shaft to hang up on each other.

k. Graze functioned above 100g. Condition was due to improperly dressed detonator lead. Re-test after lead was dressed is given.

l. Same as a.

m. Unit did not arm because rotor locking pin hung up on latch leaf.

n. Same as e.

o. Unit was washed in freon before test. It is believed that washing is the reason for non-arming.

Table 8. Cold Test Results

Unit No.	Five-Foot Drop	Transportation Vibration	Missile Vibration	Graze, Ambient	Graze, Cold	19g, Ambient	19g, Cold	35g, Cold	Static Rotor Cold	Static Rotor, Ambient (after) Cold and Env.
26 (T)	X		X	34.8	50.1	360.3	1832.2	971.9	338.2	316.8
27 (T)	X		X	43.2	50.1	333.2	2486.3	600.5	307.9	
28 (T)	X		X	38.9	47.7	343.1	1218.0	434.3	332.1	307.3
32 (T)	X			36.8	36.8	348.1	678.6	408.2	332.4	289.5
33 (T)	X			34.8	50.1	341.3	575.7	419.6	337.0	321.8
34 (T)	X			34.8	38.9	333.6	568.4	423.0	332.6	312.5
38 (T)			X	34.8	71.0	340.1	433.1	491.8	365.7	304.4
39 (T)			X	45.5	41.0	324.5	1502.6	418.2	342.0	294.9
40 (T)			X	43.2		320.1	695.2		*	416.5
44 (T)		X		45.5	47.7	329.3	444.4	388.8	339.9	
45 (T)		X	X	38.9	36.8	333.2	1496.4	533.1	338.4	
46 (T)		X	X	36.8	41.0	342.7	1606.8	435.8	302.0	312.7
50 (T)		X	X	30.1	41.0	317.6	411.3	396.0	302.0	287.3
51 (T)		X	X	43.2	45.5	309.1	899.8	456.3	329.6	293.1
52 (T)		X	X	50.1	50.1	316.1	370.4	396.7	326.4	295.2
56 (T)	X	X		47.7	52.5	345.8	760.9	405.4	306.9	
57 (T)	X	X		41.0	45.5	307.4	2896.2	546.5	301.5	
58 (T)	X	X		50.1	43.2	305.8	609.1	456.2	302.8	285.6
63 (T)		X		36.8	52.5	329.1	406.6	424.9	343.9	
64 (T)		X		43.2	50.1	339.6	1356.5	513.1	315.1	288.7
65 (T)		X		43.2	55.0	323.9	373.8	407.8	324.9	295.9
87 (TS)	X		X	43.2		327.5	No Arm	67270.0		305.3
89 (TS)	X		X	45.5	48.9	311.8	530.4			296.1
91 (TS)			X	38.9	47.7	345.5	2053.1	402.3	354.6	295.4
93 (TS)		X	X	36.8	38.9	332.1	860.0	1655.0	331.3	294.9
95 (TS)		X	X	38.9	47.7	332.3	No Arm	497.5	528.7*	393.3
97 (TS)	X	X		45.5	47.7	292.9	7230.6	382.5		289.2
99 (TS)		X		43.2	60.1	328.8	No Arm	15179.1	360.1*	383.8
107 (TS)			X	36.8	47.7	316.0	2777.2	414.1	305.2	
108 (TS)			X	45.5	47.7	327.8	381.2	385.2	301.5	286.1
109 (TS)			X	38.9	50.1				*	323.4
110 (TS)			X	32.8	43.2	299.9	530.5		*	362.5

* - washed (ultrasonically cleaned) in freon.

measure time from the point where voltage is applied to the actuator was therefore designed. The new fixture was fabricated and sample units were tested at ambient temperature during this period.

The low temperature tests were re-run using the redesigned test fixture. The results, shown in Table 9, were considerably improved over the previous tests.

Table 9. Low Temperature Re-Test with Redesigned Piston Actuator Nest

Unit No.	Leaf Drop, msec
26	387.4 (a)
28	423.0
33	423.2
34	574.0
39	No Test
50	384.6
51	437.2 (a)
52	No Test
56	401.4
57	812.1
63	397.0
65	378.9
87	612.8
89	418.0
93	435.3 (a)
97	389.3
101	1462.6 (b)
102	394.1 (b)
104	465.8 (b)
107	423.4
110	1674.1 (c)

Original cold test: $\% \text{ good} = \frac{7}{32} \times 100\% = 21.8\%$

Average of good units 407.1 } with new test fixture

$\% \text{ good} = \frac{13}{19} \times 100\% = 68.5\%$ } with new test fixture

(a) Unit had dimpled leaf.
(b) Control units; saw no environments.
(c) Unit washed in freon prior to test.

Following this test run, another problem area was discovered: the g-sensing leaf (9231470) was found to contain burrs, which may have been contributing to cold temperature malfunctions. Twelve units from the cold test lot, six yielding the best results and six the worst, were disassembled and their g-sensing leaves removed for examination. All 12 leaves were found to contain burrs on both sides of the bearing hole and the tip of the ramp on which the latching leaf rides. These leaves were stripped, deburred and reassembled to the same units.

The 12 S&A's were then re-tested. The best units continued to test well, and the bad units improved. Table 10 shows this improvement and the percentage of good units in each test run.

Table 10. Low Temperature Re-Test with Deburred Leaves

Unit No.	1st Run, msec	2nd Run, msec
26	390.8	393.5
34	522.1	542.4
45	394.3	483.6
50	423.4	433.3
56	Rotor hang-up (a)	382.1 (a)
57	449.1	430.6
63	407.3	429.2
65	386.1	380.9
87	553.9	455.5
101	No Test	357.9 (b)
102	357.6	370.3 (c)
104	414.7	414.3

Avg. of good units 402.9 — Avg. of good units 399.1

$\% \text{ good} = \frac{8}{10} \times 100\% = 80\%$ — $\% \text{ good} = \frac{9}{12} \times 100\% = 75.0\%$

(a) Hang-up caused by burr on rotor; burr removed for second run.

(b) (c) Switched setback support plates for second run.

The examination for burrs also revealed that the g-sensing and latching leaf studs (9231471 and 9231472) were being impressed into the setback support plate (9231468) when staked. This reduces axial leaf clearance and may impede leaf movement, causing long arming times. The studs were therefore redesigned to have 0.005" longer bearing surface to prevent leaf hang-up between the support plate and leaf stud head.

The examination also indicated that the detent plunger (9231478) was hitting the rotor (9231456) after the piston actuator (9231434) fired, another possible cause of excessive arming time. The detent plunger was found to hit the rotor because the force applied by the actuator bends the retaining plate (9231484). It was felt that this condition occurred on these units because of their subjection to multiple actuator firings during testing. The plates were tested to withstand one actuator firing, the normal function. The plate proved too weak, and its thickness was increased.

Cold tests were re-run January 15th and 16th, 1969, two using 30 of the 32 units previously subjected to hot tests. The remaining units were unavailable for testing. The test utilized the following improved factors: new test fixture, deburred leaves, and leaf studs with 0.005" longer bearing shoulders. The results of the test are shown in Table 11. A total of 93.4% of the units passed, and the average arming time of the good units was 378.6 milliseconds. The average ± 2σ is 420 and 336. If unit 105 is included in the calculations, the average is 381.2 and the average ± 2σ is 435 and 327. When unit 35 is included in the calculations, the average becomes 386, and the average ± 2σ is only 8 milliseconds over the limit.

The results obtained were considered an excellent improvement, and similar results were expected from the next cold test. This was to have been part of the complete Reliability Test Program to be run with the 75 inert production-engineered units in March, 1969.

Results from arctic test firings of telemetry S&A's built under the R&D contract were examined to determine the reason for their long arming times. In the telemetry traces examined at White Sands Proving Ground, the R&D type units tested showed long arming times. The leaf drop portion of the arming times were all under 50 msec, and since the rotor arming times ranged from 400 to 460 msec, the problem area appeared to be rotor delay rather than leaf drop.

Table 11. Arming Time Cold Test

Unit No.	Cold Arming Time, msec	Ambient Arming Time, msec	
		Run 1	Run 2
29	394.1	334.9	335.1
31	368.8	349.1	340.6
35	531.3	366.6	375.4
36	374.3	301.5	309.7
37	367.1	344.1	329.0
41	380.5	340.9	336.7
42	353.3	329.7	328.4
47	374.6	350.0	334.0
48	393.3	345.2	349.9
49	427.2		
53	378.7	329.8	327.2
54	417.1	348.6	349.0
55	364.0	322.3	341.8
59	408.7	303.4	307.4
61	361.5	307.7	316.5
62	351.8	309.5	315.3
66	396.3	326.0	327.6
67	358.2	314.1	306.9
68	375.1	305.1	307.1
88	405.9	363.2	360.8
90	360.0	297.2	277.6
92	389.8	318.7	310.7
94	394.2	308.8	311.5
96	349.7	*	*
98	391.1	337.1	326.6
100	379.6	321.7	317.1
105	456.7	350.2	335.2
106	374.1	321.3	318.7
111	349.0	297.6	298.5
112	361.8	311.0	302.7
	Avg. 386.3	Avg. 326.9	Avg. 324.9

*Units did not arm at 19g ambient when tested in the old fixture.

3.2.6 Jolt and Jumble. Jolt and jumble testing was completed as indicated in Table 7. All units remained safe.

Units 77 through 81, which underwent jumble only, had been assembled with incorrect screws. Unit No. 80's escapement plate "pulled" over one screw head, and unit No. 81 did the same over two screw heads. On the latter, the plate fell off when the cover was removed. It should be noted that this condition does not affect safety, and would not have occurred had the proper screws been used. This is shown by the five units tested for both jolt and jumble; none evidenced any irregularity with the escapement plate.

3.2.7 Reliability Test Program Re-run. Picatinny Arsenal and Zenith agreed that the 75 inert units from the production-engineering quantity would be used to re-run the Reliability Test Program. (In the inert units, a detonator simulator is used, and an aluminum plug replaces the primer.)

The 100 tactical units were to be shipped to Picatinny Arsenal, and the results of the reliability tests were to be the basis for acceptance of the tactical units. Twenty-five telemetry units were to be tested at Zenith; these would be the basis for acceptance of the remaining 100 units.

Zenith submitted a test plan showing the proposed functional tests on all units, and the lot acceptance tests on lot acceptance samples. The Test Plan was formulated in accordance with MIL-S-14799 requirements, and included with it were the following:

1. Supporting test equipment designs (equipment and fixture drawings and schematics)

2. Marked-up prints indicating Zenith's recommendations for changes to the XM114 drawing package.

These changes were based on Zenith's efforts in the areas of cold testing, improved manufacturability, and S&A producibility. The changes requested were as follows:

a. Drawing No. 9231468 Support, Setback

    1. Edge break of 0.007 maximum on stamped holes cannot be held.

    2. 63-microinch finish in rotor hole cannot be held by stamping. To obtain this finish, hole would have to be reamed after stamping.
    3. Dimension 0.151 - 0.004 should be removed from drawing.

b. Drawing No. 9231448 Support, Rear
    1. Same as 1 and 2 above.
    2. Flatness tolerance should be changed from 0.004 to 0.007.

c. Drawing No. 9231451 Plate, Escapement
    1. Same as 1 above.
    2. Flatness tolerance should be changed from 0.004 to 0.007.

d. Drawing No. 9231469 Leaf, Latching
    1. Allow 1/32 radius at corners of part, instead of 0.005 radius maximum specified.
    2. 32-microinch finish specified cannot be held by stamping.

e. Drawing No. 9231470 Leaf, G-Sensing
    1. Change 0.005 maximum edge break to 0.010 maximum edge break.
    2. Note should be added that 32-microinch finish applies to shaved surface of part only (not on die break surface).

f. Drawing No. 9231450 Pallet
    1. Change edge break from 0.005 maximum to 0.010 maximum.

To insure optimum performance at -25°F, it was decided that the following parts would be ultrasonically cleaned prior to subassembly fabrication.

1. Support, Setback (9231468)
2. Leaf, Latching (9231469)
3. Leaf, G-Sensing (9231470)
4. Shaft, Shouldered-Latching Leaf (9231471)
5. Shaft, Shouldered-G-Leaf (9231472)

Because of delays in receiving acceptable parts, the re-run of the Reliability Test was not started until early May 1969. On May 8, 1969, it was discovered that on some units, the escapement plate (9231451) was interfering with the housing assembly (9231497). When the housings were assembled to these units, the escapement plate was forced out of proper alignment with the rear support plate (9231448), thereby causing excessively long arming times. The escapement plate was redimensioned and the parts reworked to eliminate this problem. The Reliability Test was then run and completed during the week of May 19th (see Table 12).

Because of difficulties encountered in the arming time test at -25°F, only 12 units were tested for arming time at +140°F. Twenty-four units were to have been tested at +140°F, but 12 of these were used for additional testing at -25°F. For the +140°F arming time test, the average -2σ (283.3 msec) was less than the low limit (292.0 msec). This indicates that effort should be made to raise the average arming time. For these 12 units, the average arming time was 313.5 msec. The average in-process arming time for all 60 units tested at ambient temperature was 312.9 msec. Raising the in-process average to 330 msec or more should eliminate this problem. The nominal arming time for this unit is 344 msec. If the average in-process arming time is monitored and maintained between 330 and 360 msec, no problems should be encountered with ambient or +140°F arming times.

One unit was below the low limit in the +140°F arming test. This problem can be corrected by better in-process control. In the future, units falling below 300 msec or above 370 ms in in-process testing will be removed from the lot.

The -25°F arming time test was not passed. Twenty-two of 35 units were tested within the allowable range. One result was considered a "no test". The average arming time of the 22 good units was 356.4 milliseconds. The test was re-run and 25 of 35 units passed with an average time of 365.2 milliseconds. Comparison, unit by unit, of the two tests show some units to vary greatly. Analysis of these results, and those of a third cold test led Zenith to suspect a problem with the teflon coating on the latching leaf. Zenith theorized that the pressure between the rotor locking pin (9231457)

Table 12. Reliability Test Program Re-run Results

Unit No.	Leaf Function Level, g's	10g Non-Arm	19g Arming Time, msed	Graze Function Level, g's	Transp. Vib.	5-Foot Drop	19g Run 1	Arming Time Run 2	-25 F, msec Run 3	19g Arming Time, -140 F, msec	Graze Function Level, g's
711	12.5	OK	294.1	38.9					341.7		
712	13.1	OK	318.7	38.9			750.4	19000.0			
713	11.9	OK	343.5	50.1			380.7	441.6			
714	13.7	OK	307.1	41.0					339.0		
715	12.5	OK	292.9	43.2			347.2	343.3			
716	11.9	OK	312.0	43.2			861.7	446.0	No Arm		
717	13.1	OK	312.6	34.8			350.6	3547.9			
718	12.5	OK	315.9	38.9					359.2		
719		OK	347.2	32.8			No Arm	385.6	380.6		
720		OK	302.5	36.8			340.2	346.5			
721	12.5	OK	320.8	43.2					No Arm Det. Lead		
722	13.1	OK	306.4	36.8						295.0	37.7
723	14.3	OK	292.1	41.0						290.3	46.6
724		OK	359.7	43.2			501.0	512.9	1051.3		
725		OK	317.0	41.0			347.0	347.6			
726	13.1	OK	322.9	41.0						304.9	39.8
727		OK	311.7	38.9			355.9	352.3			
728	13.1	OK	314.6	45.5					325.0		
729	15.6	OK	314.5	44.4						301.1	61.5
730		OK	314.8	36.8			No Test	349.5	346.6		
731		OK	340.8	34.8			379.3	No Test			
732		OK	331.0	36.8			No Arm	399.6			
733	14.3	OK	310.1	41.0			No Arm	5830.2			
734	11.9	OK	296.2	32.8			No Arm	705.6	362.2		
735	13.1	OK	305.7	43.2			345.5	536.9			
736	13.7	OK	320.5	41.0			365.5	364.7			
737	14.3	OK	309.3	39.9			348.1	363.2			
738	11.3	OK	292.4	32.8			354.6	343.2			
739	11.9	OK	324.8	43.2			367.7	370.7			
740										306.7	48.9

Table 12. Reliability Test Program Re-run Results (Cont'd)

Unit No.	Leaf Function Level, g's	10g Non-Arm	19g Arming Time, msec	Graze Function Level, g's	Transp-Vib.	5-Foot Drop	19g Run 1	Arming Time Run 2	-25 F, msec Run 3	19g Arming Time, -140 F, msec	Graze Function Level, g's
741	12.5	OK	306.9	34.8			362.1	338.8	367.8		
742	11.3	OK	301.6	38.9			350.8	349.2			
743	11.9	OK	298.8	38.9			No Arm	519.7	No Arm		
744	13.7	OK	325.5	45.5			341.4	349.9			
745	13.7	OK	314.1	38.9			351.3	354.5			
746	11.9	OK	311.2	34.8					347.1		
747	16.3	OK	311.4	45.5			336.9	443.6			
748	13.1	OK	311.7	47.7			2985.9	380.5			
749	14.3	OK	317.1	57.5			1645.5	4420.3			
750	11.9	OK	301.6	47.7			333.2	324.6			
751	13.7	OK	305.2	41.0						351.3	44.3
752	13.7	OK	293.6	38.9						295.9	33.6
753										327.7	53.8
754	13.1	OK	292.9	47.7			347.5	346.1			
755	13.7	OK	294.5	47.7			No Arm	349.1			
756	14.3	OK	315.7	45.5			450.0	347.5			
757	15.0	OK	301.9	36.8			4047.6	2334.9			
758	14.3	OK	305.4	36.8			330.9	325.4			
759	13.7	OK	298.3	38.9			583.7	366.0			
760	11.9	OK	357.5	45.5			355.4	4443.7			
761	12.5	OK	319.2	47.7					351.1		
762	16.3	OK	296.2	41.0						306.8	
763	13.7	OK	308.1	38.9						328.5	
764	11.9	OK	293.4	41.0					336.9		
765	13.7	OK	325.5	30.1					No Arm Det. Lead		
766	14.4	OK	301.1	55.0					497.7		
767	17.0	OK	332.8	34.8						329.0	
768	17.8	OK	344.7	38.9						325.6	
769	13.1	OK	299.4	32.8					344.2		
770	14.4	OK	312.9	41.0					341.8		
			(Avg. 312.9)				(62.9% good)	(71.5% good)	(68.5% good)	(Avg. 313.5)	
							(Avg. of 22 good - 356.4)	(Avg. of 25 good - 365.2)	(Avg. of 13 good - 352.3)	(σ 15.1)	
										(Avg. + 2σ 343.7)	
										(Avg. - 2σ 283.3)	

and the latching leaf (9231469) caused the pin to sink into the teflon coating. Apparently, at ambient temperatures the teflon flowed and allowed the latching leaf to drop. At -25°F, the teflon would not flow readily, and the latching leaf hung up. Picatinny Arsenal agreed to allow the -25°F arming time test to be re-run using chromium-plated latching leaves (finish 1.2.1.1 of MIL-STD-171).

It was also noted that the explosive piston actuator (9231434) was still forcing the detent plunger assembly (9231477) to hit the rotor on some units. This was another possible reason for long arming times. The detent plunger assembly was replaced by a spring wire detent (9231513) to solve this problem.

Units were assembled with the chromium-plated latching leaves and spring wire detents. On June 9, 1969, 20 units were tested for arming time at -25°F (see Table 13). All 20 units tested were within allowable limits. The average arming time was 353.3 milliseconds with a standard deviation of 11.0 milliseconds. Prior in-process tests at ambient temperature showed the units to have an average time of 309.0 milliseconds with a standard deviation of 10.7 milliseconds. Eight units with teflon-coated latching leaves were also run. One of these units displayed a long arming time of 473.6 milliseconds. The leaf drop portion of arming time on this unit was 130 milliseconds. From the above results, it can be concluded that rejects for long arming time at -25°F were caused by the teflon coating on the latching leaves.

In view of the above findings, Picatinny Arsenal agreed to allow the -25°F arming time portion of the Reliability Test to be re-run. It was agreed that 39 units would be tested. These units would have chrome-plated latching leaves and the new spring wire detent. The test was successfully passed, as shown in Table 14.

3.3 S&A Deliveries

According to the original contract, Zenith was to deliver 75 preliminary samples and 300 production-engineered units to Picatinny Arsenal. Contract modification P009, dated 6 January 1969, instructed Zenith to use the 75 preliminary samples to conduct a reliability test. Contract modification P008, dated 25 November 1968, specified that the 300 production-engineered units were to consist of 200 tactical and 100 telemetry units. Delivery destinations for these units were given to Zenith on 6 May 1969.

Twenty telemetry units were shipped to Hughes Aircraft Company, Culver City, California on 23 May 1969. The balance of 80 telemetry units were shipped to the same destination on 16 June 1969.

Table 13. Latching Leaf Test Results

Chromium-Plated Latching Leaves				Teflon-Coated Latching Leaves			
Sample No.	In-Process Leaf Drop Level, g's	In-Process Arming Time, msec Ambient	Acceptance Arming Time, -25 °F, msec	Sample No.	In-Process Leaf Drop Level, g's	In-Process Arming Time msec Ambient	Acceptance Arming Time -25 °F, msec
1	18.4	295.0	340.2	21	15.6	317.9	377.9
2	15.0	307.3	343.8	22	13.1	342.3	370.7
3	15.0	303.8	349.0	23	15.0	303.2	361.7
4	16.3	305.0	343.5	24	13.7	305.1	355.0
5	19.9	320.0	372.5	25	13.7	312.7	473.6*
6	14.3	322.5	360.6	26	12.5	302.3	354.4
7	13.7	302.0	348.7	27	15.0	319.1	347.8
8	17.0	318.4	351.3	28	13.7	301.4	338.2
9	15.0	308.4	349.5				
10	15.0	313.0	351.8				
11	18.4	312.1	355.2				
12	15.6	325.8	365.1				
13	15.6	303.2	350.3				
14	19.2	302.5	350.0				
15	13.1	302.0	352.2				
16	16.3	325.2	378.0				
17	15.0	311.1	361.6				
18	14.3	301.6	350.0				
19	15.0	282.9	331.2				
20	17.0	318.7	362.4				
	Avg.	309.0	353.3				
	σ	10.7	11.0				
	Avg. $+2\sigma$	330.4	375.3				
	Avg. -2σ	287.7	331.3				

*Long arming time because 130 milliseconds were required for leaf drop portion of arming time (10 to 20 msec leaf drop time is normal).

Note: All 28 units had the new spring wire detent incorporated.

Table 14. Chrome-Plated Latching Leaf Test Results

Sample No.	In-Process Leaf Drop Level, g's	In-Process Arming Time, msec Ambient	Acceptance Arming Time, -25° F, msec	Sample No.	In-Process Leaf Drop Level, g's	In-Process Arming Time, msec	Acceptance Arming Time, -25° F, msec
1	16.3	305.7	383.4	21	16.3	315.2	352.1
2	15.0	315.1	359.6	22	16.3	306.7	336.1
3	16.3	310.8	363.6	23	15.6	304.6	390.0
4	15.6	328.1	368.6	24	16.3	339.9	404.6
5	14.4	309.3	362.6	25	15.6	301.5	360.9
6	15.0	308.4	370.0	26	14.4	323.9	360.0
7	16.3	320.7	355.3	27	15.6	311.9	377.8
8	14.4	317.4	357.8	28	12.5	314.0	376.5
9	13.7	317.4	390.0	29	14.4	320.8	364.6
10	15.0	322.6	377.5	30	14.4	315.0	367.8
11	15.6	335.2	385.1	31	12.5	325.5	364.5
12	15.6	315.6	378.1	32	16.3	318.6	378.0
13	14.4	303.4	359.1	33	16.3	302.7	355.9
14	15.0	338.1	391.6	34	15.6	301.2	349.8
15	14.4	300.5	342.7	35	13.1	325.2	361.7
16	16.3	317.1	370.0	36	15.0	311.7	355.4
17	15.6	336.9	418.0	37	13.7	313.7	349.3
18	13.7	313.8	375.2	38	14.4	324.7	370.0
19	13.7	322.8	335.6	39	15.0	304.6	368.4
20	15.0	339.3	404.0				
					Avg.	316.9	369.0
					σ	10.4	17.8
					Avg. -2σ	296.1	333.4
					Avg. $+2\sigma$	337.1	404.6

Twenty-five tactical units were shipped to the Iowa Army Ammunition Plant, West Burlington, Iowa on 6 June 1969. Picatinny Arsenal waived the remaining tactical unit requirements to allow Zenith to concentrate on producing units under the limited production contract DAAA21-69-0385.

The first 20 telemetry units shipped utilized the old detent plunger assembly (9231477). The 25 tactical units and the remaining 80 telemetry units contained the spring wire detent (9231513) which replaced the detent plunger assembly.

All units shipped had teflon-coated latching leaves, and the redesigned escapement plates described in paragraph 3. 2. 7.

3.4 Documentation Requirements

The following documentation was submitted to Picatinny Arsenal under the requirements of this contract.

The unit drawing package was submitted during June 1968.

The preliminary specification draft was submitted in October 1968. A final copy incorporating the changes required by Picatinny Arsenal was submitted in January 1969.

Special Test Equipment drawings (STE hardware) were submitted October 1969. These drawings depict the complete design of the environmental centrifuge used to check coded defects 23011 through 23020 of MIL-S-14799A, dated 10 February 1969.

Two draft copies of Description of Manufacture were submitted 1969. Final copies were distributed in February 1970.

A Government Bill of Material (Form DD346 & DD347) were submitted 3 December 1969.

4. MASS PRODUCTION COSTS

This section contains the following estimates of mass production costs for the XM114 S&A:

a. Table 15 details the various components of the S&A, with part numbers and costs for both the R&D and production-engineered designs, and the part cost saving.

b. Table 16 provides a material summary based on the desired quantity of 12,000 units at a production rate of 1,000 units per month.

c. Table 17 enumerates all costs associated with the production quantity and rate in b above.

Table 15. Component Cost Savings

PE Part No.	R&D Part No.	Description	Cost After PE Study	Cost Before PE Study	Cost Savings
7549133	7549133	Detonator	$1.050	$1.050	-
8796462	8796462	Primer	0.250	0.250	-
9231429	9207762	Terminal Strip-Base	0.121	0.121	-
9231431	8887429	Pin, Firing	0.100	0.100	-
9231432	8887386	Setscrew, Hexagon Socket	0.045	0.045	-
9231433	8887435	Contact, Electrical, Stud	-	-	-
9231434	8887406	Actuator, Piston, Miniature	3.000	3.000	-
9231435	8887417	Terminal Board-Base	*	-	-
9231437	8887352	"G" Sensing & Graze Mechanism Assembly	*	-	-
9231438	8887342	Escapement Assembly	*	-	-
9231439	8887345	Starwheel & Pinion Assembly	*	-	-
9231440	8887358	Starwheel	0.060	0.060	-
9231441	8887359	Pinion, Spur-No. 2	0.018	0.018	-
9231442	8887346	Gear and Shaft Assembly	-	-	-
9231443	8887356	Shaft, Shouldered-Rotor	0.022	0.022	-
9231444	8887357	Gear, Spur-Rotor	0.110	0.330	0.220
9231445	8887350	Escapement Assembly-Gear	-	-	-
9231446	8887363	Pinion, Spur-No. 1	0.018	0.018	-
9231447	8887364	Gear, Spur-No. 2	0.090	0.200	0.110
9231448	8887365	Support, Rear	0.015	0.017	0.002
9231450	8887360	Pallet	0.180	0.180	-
9231451	8887361	Plate, Escapement	0.070	0.081	0.011
9231452	8887410	Screw, Machine, Pan Head-Escapement	0.008	0.008	-

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*The production process flow for this device does not consider separate major assemblies; as such, these are not inventoried and figures are not available at this time.

Table 15. Component Cost Savings (Cont'd)

PE Part No.	R&D Part No.	Description	Cost After PE Study	Cost Before PE Study	Cost Savings
9231453	8887343	Rotor and Detonator Assembly	*	-	-
9231454	8887353	Rotor Assembly-Terminal	*	-	-
9231455	8887354	Rotor Assembly-Pins	*	-	-
9231456	8887388	Rotor	0.940	3.000	2.060
9231457	8887389	Pin, Grooved, Headless	0.005	0.005	
9231459	8887355	Terminal Board and Contact Assembly-Rotor	*	-	-
9231460	8887394	Terminal Board-Rotor	0.020	0.020	-
9231461	8887395	Contact, Electrical-Rotor	0.062	0.062	-
9231462	8887396, 7409	Rivet, Plate	0.003	0.003	-
9231463	8887387	Insulator, Plate	0.003	0.003	-
9231464	8887411	Screw, Machine, Round Head-Rotor Contact	0.024	0.024	-
9231465	8887416	Washer, Nonmetallic	0.001	0.001	-
9231466	8887344	Fuze Base and Setback Assembly	*	-	-
9231467	8887341	Setback Assembly	*	-	-
9231468	8887377	Support, Setback	0.305	0.325	0.020
9231469	8887378	Leaf, Latching	0.235	0.235	-
9231470	8887379	Leaf, "G" Sensing	0.145	0.145	-
9231471	8887380	Shaft, Shouldered-Latching Leaf	0.055	0.055	-
9231472	8887381	Shaft, Shouldered-"G" Leaf	0.018	0.018	-
9231473	8887382	Washer, Flat-Retaining	0.097	0.097	-
9231474	8887383	Contact, Electrical, Grounding	0.016	0.016	-
9231475	8887384	Rivet, Tubular-Grounding	0.004	0.004	-
9231476	8887385	Spring, Helical, Torsion- "G" Leaf	0.018	0.018	-

Table 15. Component Cost Savings (Cont'd)

PE Part No.	R&D Part No.	Description	Cost After PE Study	Cost Before PE Study	Cost Savings
9231477	8887349	Plunger Assembly	-	-	-
9231478	8887373	Plunger, Detent	-	0.100	0.100
9231479	8887375	Washer, Slotted	-	0.005	0.005
9231480	8887376	Spring, Helical, Compression-Plunger	-	0.004	0.004
9231481	8887370	Base, Fuze	0.990	3.000	2.010
9231482	8887371	Lever, Graze	0.221	0.221	-
9231483	8887372	Screw, Shouldered, Graze	0.043	0.043	-
9231484	8887374	Plate, Retaining, Plunger	-	0.026	0.026
9231485	8887402	Screw, Machine, Round Head	0.032	0.040	0.008
9231486	8887428	Spring, Helical, Compression-Firing Pin	0.012	0.012	-
9231487					
9231488	8887391	Terminal Board & Contact Assembly	*	-	-
9231489	8887392	Terminal Board	0.066	0.066	
9231490	8887393	Contact, Electrical, Receptacle	-	-	-
9231491	8887393	Contact, Electrical, Receptacle (Modified)	0.024	0.024	-
9231492	8887368	Spring, Helical, Torsion-Rotor	0.008	0.008	-
9231493	8887369	Shaft, Locking	0.082	0.254	0.172
9231494	8887415	Screw, Machine, Clutch Head	0.016	0.016	-
9231495	9207260	Washer, Lock	0.001	0.001	-
9231496	9207263	Spacer, Actuator-Piston	-	-	-
9231497	8887347	Housing Assembly	1.390	0.500	.890
9231498	8887397	Housing, Tubular	-	0.980	0.980
9231499	8887398	Cover, Housing	-	0.620	0.620

Table 15. Component Cost Savings (Cont'd)

PE Part No.	R&D Part No.	Description	Cost After PE Study	Cost Before PE Study	Cost Savings
9231500	8887338	Safety and Arming Device, GM: XM114	*	-	-
9231501	8887340	Safety and Arming Mechanism Assembly	*	-	-
9231502	8887348	Terminal Board Assembly, Electrical-Base	*	-	-
9231503	8887418	Terminal Strip Assembly	*	-	-
9231504	8887403	Terminal Strip and Lug Assembly-Base	*	-	-
9231505	8887404	Terminal, Lug	-	-	-
9231506	8887404	Terminal, Lug (Modified)	0.005	0.005	-
9231507	8887401	Cover, Terminal Board	0.006	0.006	-
9231508	8887399	Bracket, Angle	-	0.029	0.029
9231509	8887427	Plug, Base	0.028	0.028	-
9231510	8887405	Terminal, Lug-Grounding	-	-	-
9231511	8887405	Terminal, Lug-Grounding (Modified)	0.005	0.005	-
9231512	-	Screw, Detent	0.043	-	.043
9231513	-	Spring, Detent	0.010	-	.010
MS9486	8887390	Pin, Straight, Headless	0.005	0.005	-
		Totals	$10.100	$15.534	$5.434

Table 16. Material Summary
(Based on Quantity of 12,000, in 24 Lots of 500, at Production Rate of 1,000 per Month)

Item	Cost After PE			Cost Before PE	
Base Quantity	12,000				
Lot Acceptance Tests [24 Lots (64 Lot Acceptance Qty + 20 Missile Vibration Qty)]	2,016				
Production Requirement	240				
Engineering Requirement	120				
	14,376	At $10.32 ea.	$148,370.38	At $15.53 ea.	$223,259.28
		Purch. Lot Charges	200.00		200.00
		Purch. Set-up	670.00		670.00
		Purch. as Required	475.00		475.00
			149,715.38		224,604.28
Base Quantity Packaging	12,000	At $55.30/M	$ 663.60		
		Purch. Lot Charges	100.50		
			764.10		764.10
Totals			150,479.48		225,368.38
Scrap (3.95%)			5,944.10		8,902.05
Total Material Costs			156,423.58		234,270.43
Cost Per Unit			$13.0353		$ 19.52

Table 17. Total Production Costs

Item	After PE		Before PE
	Total	Each	
Material	$156,480.00	$13.04	$19.52
Material OH (7.8%)	14,640.00	1.22	1.52
Total Engineering Labor	36,000.00	3.00	3.00
Total Production Labor		17.98	17.98
Travel, Telephone & Telegraph	720.00	.06	.06
In Cost		35.30	42.08
G&A (10.5%)		3.71	4.42
Total Cost		39.01	46.50
Profit (10% of Selling Price)		4.33	5.17
Selling Price		$43.34	$51.67

5. CONCLUSIONS

This section provides conclusions as to how well the various tasks of the production engineering program were accomplished, that is, the extent of simplification and/or modification of the device and its parts. The numbered items below correspond to the tasks delineated in Section 1 of this report.

1. Item Cost. As shown in Section 4, the end item cost of the XM114 S&A has been reduced from $51.67 to $43.34.

2. Production Lead Time. Production lead time has been minimized through redesign to provide a simpler can (housing) and simpler spring detent.

3. Materials utilization. The only parts previously fabricated of a potentially critical material—brass—have been redesigned for steel construction.

4. Supply Base. In addition to current production-ready suppliers, Zenith has prepared a process for minimum difficulty in apprising new suppliers of production requirements. This consists of a package containing applicable drawings, specifications and other documentation relating to the part and/or assembly under consideration. Where applicable, this information has been conveyed to Zenith suppliers.

5. Mass Producibility. The production-engineering study has shown all parts and assemblies employed in the current design to be highly mass-producible. No special or unique materials, techniques or processes are required in the fabrication, assembly, testing or packaging of the XM114 S&A.

6. Ease of Loading, Assembly and Inspection. Process sheets and inspection plans have been evolved to assure compliance to this task (see Description of Manufacture).

7. Assurance of Safety and Conformance to Design. MIL-STD-331 testing has been employed wherever possible. As a result of further study, the system requirements were revised to increase the cold temperature arming time limits and the operational g-level was raised. These changes were incorporated in the S&A requirements. Equipment and fixtures for safe, economical environmental testing were designed and fabricated.

8. Approved Specifications and Standards. In addition to maximum incorporation of military, federal, and industrial specifications and standards, Zenith, in cooperation with Picatinny Arsenal, developed MIL-S-14799, the basic spec for the XM114. The drawing package was reviewed and Government specifications were replaced by industry specs wherever cost-effectiveness considerations dictated.

9. Ease and Frequency of Maintenance. This section is not applicable to the XM114 S&A.

10. Standardization and Parts Interchangeability. Standard hardware and wiring was incorporated where possible. The tolerance study performed assured the interchangeability of all parts between similar assemblies and units.

11. Durability and Reliability. The units manufactured to the design resulting from this program passed all environmental tests as part of the Reliability Test Program. The reliability of the end item, based on the results of the test program, meets the requirements of MIL-S-14799. The present estimate of shelf life is that the present design meets the 5-year requirement.

12. Maintenance Data. This item is not applicable to the XM114 S&A.

13. Human Engineering Study. This item is not applicable to the XM114 S&A.

14. Proprietary Items or Techniques. With the sole exception of the 1MT11 actuator piston, no proprietary items or items requiring the use of proprietary manufacturing techniques, are used in the fabrication of the XM114 S&A.

APPENDIX

ESCAPEMENT TIME CALCULATIONS

$$t = 2nf \frac{2I\theta}{T} \frac{(16\ \text{oz/lb})}{(T_p/T_w)}$$

where: n = number of pallet oscillations = 75

f = friction loss correction factor = 1.75*

I = pallet moment of inertia

T = torque at the starwheel

(T_p/T_w) = ratio of pallet torque to starwheel torque = 1.23

$$t_{max} = 2nf\sqrt{\frac{2\ I_{max}\ \theta_{max}\ (16\ \text{oz/lb})}{T_{min}\ (T_p/T_w)}}$$

$n = 75$
$(T_p/T_w) = 1.23$
$I_{max} = 7.53 \times 10^{-8}$ in-lb-sec^2
$\theta_{max} = 6.61° = 0.1154$ rad
$T_{min} = 0.102$ in-oz

$$= 2(75)f\sqrt{\frac{2\ (7.53 \times 10^{-8}\ \text{in-lb-sec}^2)(0.1154)\ (16\ \text{oz/lb})}{(0.102\ \text{in-oz})\ (1.23)}}$$

$$= 150f\sqrt{221.6 \times 10^{-8}} = 150\ (14.88 \times 10^{-4})\ f\ \text{sec}$$

t_{max} = 223.2f milliseconds for $f = 1.75$; $t_{max} = 390.6$ ms

---

*f was determined experimentally by matching calculated times to actual times.

$$t_{nom} = 2nf \sqrt{\frac{2\ I_{nom}\ \theta_{nom}\ (16\ oz/lb)}{(0.107)\ (1.23)}}$$

$I_{nom} = 7.02 \times 10^{-8}$ in-lb-sec^2

$\theta_{nom} = 5.73° = 0.1000$ rad

$T_{nom} = 0.107$

$$= 2\ (75)\ f \sqrt{\frac{2\ (7.02 \times 10^{-8}\ \text{in-lb-sec}^2)\ (0.1000)\ (16\ oz/lb)}{(0.107)\ (1.23)}}$$

$$= 150f \sqrt{170.6 \times 10^{-8}\ \text{sec}^2} = 150\ (13.06 \times 10^{-4})\ f\ \text{sec}$$

t_{nom} = 195.9 milliseconds for f = 1.75; t_{nom} = 342.8 ms

$$t_{min} = 2nf \sqrt{\frac{2\ I_{min}\ \theta_{min}\ (16\ oz/lb)}{T_{max}\ (T_p/T_w)}}$$

$I_{min} = 6.70 \times 10^{-8}$ in-lb-sec^2

$\theta_{min} = 4.78° = 0.0834$ rad

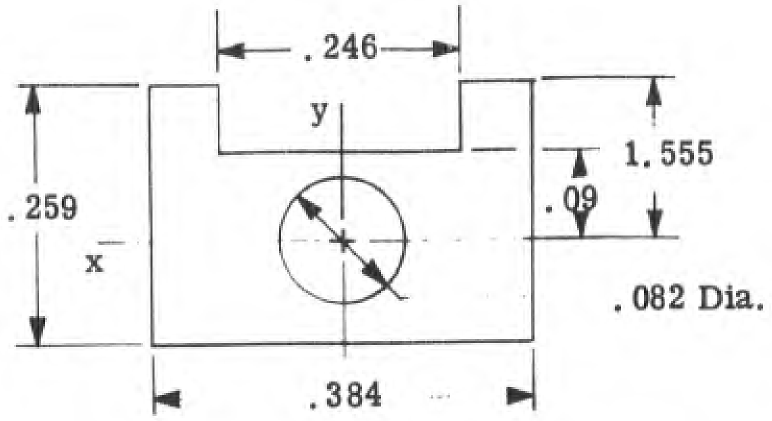
$T_{max} = 0.112$ in-oz

$$= 2(75)f \sqrt{\frac{2\ (6.70 \times 10^{-8}\ \text{in-lb-sec}^2)\ (0.0834)\ (16\ oz/lb)}{(0.112\ \text{in-oz})\ (1.23)}}$$

$$= 150f \sqrt{129.7 \times 10^{-8}\ \text{sec}^2} = 150\ (11.38 \times 10^{-4})\ f\ \text{sec}$$

t_{min} = 170.7f milliseconds for f = 1.75; t_{min} 298.7 ms

I_{max}:



$$I_y = 1/12\ (2.59 \times 10^{-1})\ (3.84 \times 10^{-1})^3 - 1/12\ (.655 \times 10^{-1})(2.46 \times 10^{-1})^3$$

$$= \qquad 12.23 \times 10^{-4} \qquad - \ 0.81 \times 10^{-4}$$

$$I_y = \qquad 11.42 \times 10^{-4}\ \text{in}^4$$

$$I_x = 1/3\ (3.84 \times 10^{-1})\ (1.035 \times 10^{-1})^3 + 1/3\ (3.84 \times 10^{-1})\ (1.555 \times 10^{-1})^3$$

$$-1/12\ (2.46 \times 10^{-1})\ (.655 \times 10^{-1})^3 - (2.46 \times 10^{-1})\ (.655 \times 10^{-1})$$

$$(1.227 \times 10^{-1})^2 \quad 1.418 \times 10^{-4} + 4.80 \times 10^{-4} - 0.06 \times 10^{-4}$$

$$-2.43 \times 10^{-4}$$

$$I_x = 3.73 \times 10^{-4}\ \text{in}^4$$

$$I_{p\text{-hole}} = \frac{\pi d^2}{32} = \frac{3.14\ (.82 \times 10^{-1})^4}{32} = 0.044 \times 10^{-4}\ \text{in}^4$$

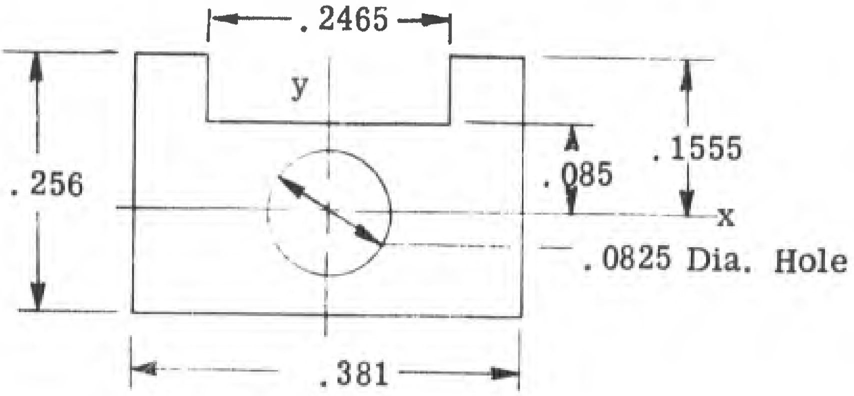
$$I_p = I_x + I_y - I_{p\text{-hole}} = (11.42 \times 10^{-4}) + (3.73 \times 10^{-4}) - (0.04 \times 10^{-4})$$

$$I_p = 15.11 \times 10^{-4}\ \text{in}^4$$

$$I_p = \frac{(15.11 \times 10^{-4}\ \text{in}^4)(\ 0.064\ \text{in})\ (0.3\ \text{lb/in}^3)}{386.4\ \text{in/sec}^2} = \text{in-lb-sec}^2$$

$I_{p_{max}} = 7.53 \times 10^{-8}$ in-lb-sec^2

I_{nom}:



$$I_y = 1/12(2.56 \times 10^{-1})(3.81 \times 10^{-1})^3 - 1/12\,(.705 \times 10^{-1})\,(2.465 \times 10^{-1})^3$$

$$= \quad 11.80 \times 10^{-4} \quad - 0.88 \times 10^{-4}$$

$$I_y = \quad 10.92 \times 10^{-4} \text{ in}^4$$

$$I_x = 1/3\,(3.81 \times 10^{-1})\,(1.005 \times 10^{-1})^3 + 1/3\,(3.81 \times 10^{-1})\,(1.555 \times 10^{-1})^3$$

$$- 1/12\,(2.465 \times 10^{-1})(.705 \times 10^{-1})^3 - (2.465 \times 10^{-1})\,(.705 \times 10^{-1})$$

$$(1.202 \times 10^{-1})^2$$

$$= 1.29 \times 10^{-4} + 4.77 \times 10^{-4} - 0.07 - 2.51 \times 10^{-4}$$

$$I_x = 3.48 \times 10^{-4} \text{ in}^4$$

$$I_{p\text{-hole}} = \frac{\pi d^2}{32} \doteq \frac{3.14\,(.825 \times 10^{-1})^4}{32} = .045 \times 10^{-4} \text{ in}^4 = .05 \times 10^{-4} \text{ in}^4$$

$$I_p = I_y + I_x - I_p$$

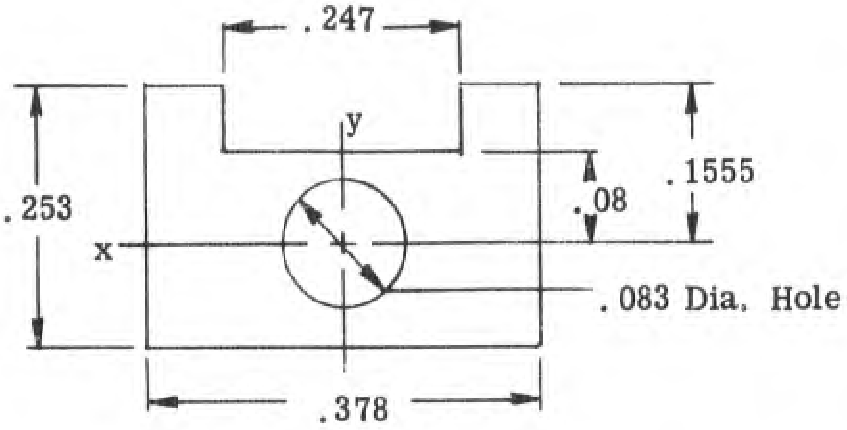
$$= (10.92 + 3.48 - 0.05) \times 10^{-4}$$

$$I_p = 14.35 \times 10^{-4} \text{ in}^4$$

$$I_p = \frac{(14.35 \times 10^{-4} \text{ in}^4)\,(0.063 \text{ in})\,(0.3 \text{ lb/in}^3)}{386.4 \text{ in/sec}^2} = \text{in-lb-sec}^2$$

$$I_p = 7.02 \times 10^{-8} \text{ in-lb-sec}^2$$

I_{min}:



$$I_y = 1/12\ (2.53 \times 10^{-1})\ (3.78 \times 10^{-1})^3 - 1/12\ (.755 \times 10^{-1})\ (2.47 \times 10^{-1})^3$$

$$= \quad 11.39 \times 10^{-4} \quad - \quad 0.95 \times 10^{-4}$$

$$I_y = \quad 10.44 \times 10^{-4}\ \text{in}^4$$

$$I_x = 1/3\ (3.78 \times 10^{-1})\ (0.975 \times 10^{-1})^3 + 1/3\ (3.78 \times 10^{-1})\ (1.555 \times 10^{-1})^3$$

$$- \ 1/12\ (2.47 \times 10^{-1})\ (.755 \times 10^{-1})^3$$

$$- \ (2.47 \times 10^{-1})\ (.755 \times 10^{-1})\ (1.177 \times 10^{-1})^2$$

$$= \quad 1.168 \times 10^{-4} + 4.74 \times 10^{-4} - 0.07 \times 10^{-4} - 2.32 \times 10^{-4}$$

$$I_x = 3.52 \times 10^{-4}\ \text{in}^4$$

$$I_{p\text{-hole}} = \frac{\pi d^2}{32} = \frac{3.14\ (.83 \times 10^{-1})^4}{32} = 0.046 \times 10^{-4}$$

$$I_p = I_x + I_y - I_{p\text{-hole}} = 3.52 \times 10^{-4} + 10.44 \times 10^{-4} - 0.05 \times 10^{-4}$$

$$I_p = 13.91 \times 10^{-4}\ \text{in}^4$$

$$I_p = \frac{(13.91 \times 10^{-4}\ \text{in}^4)\ (0.062\ \text{in})\ (.3 \quad /\text{in}^3)}{386.4\ \text{in/sec}^2} = \text{in-lb-sec}^2$$

$$I_{p_{min}} = 6.70 \times 10^{-8}\ \text{in-lb-sec}^2$$

Figure 2 is a calculation of the pallet to starwheel center distance considering bearing clearance and assuming that the starwheel and pallet will always be forced as far apart as possible.

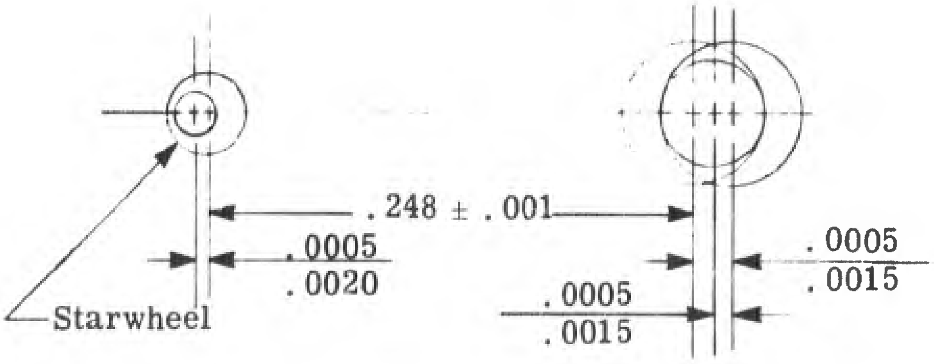


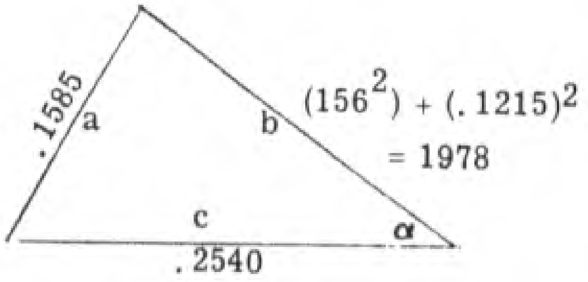
Figure 2. Starwheel to Pallet Center Distances

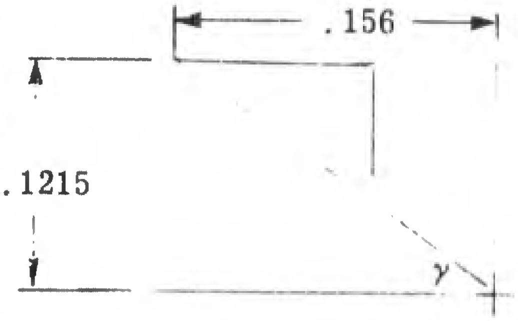
Minimum center distance = 0.2470 + 0.0005 + 0.0005 + 0.0005 = 0.2485

Nominal center distance = 0.2480 + 0.0010 + 0.0010 + 0.0012 = 0.2512

Maximum center distance = 0.2490 + 0.0015 + 0.0015 + 0.0020 = 0.2540

This error resulted in an error in the calculation of ϕ. A corrected calculation follows.





$$\cos\alpha = \frac{.1975^2 + .2540^2 - .1585^2}{2\,(.1975)\,(.2540)}$$

$$= \frac{.7851859}{1.0033}$$

$$\gamma = \arctan \frac{.1215}{.156}$$

$$= .77885$$

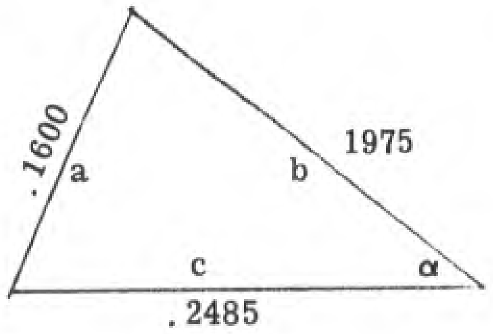
$$\gamma = 37.92^\circ$$

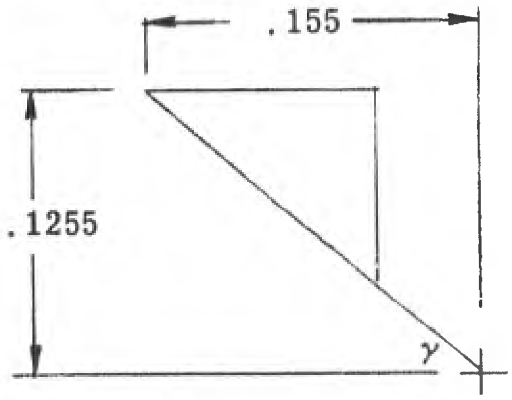
$\cos\alpha = .7814213$

$= 38° \, 36'$

$= 38.60°$

$\phi_{min} = \alpha - \gamma = 0.28°$





$$\cos\alpha = \frac{.1975^2 + .2485^2 - .1600^2}{2\,(.1975)\,(.2485)}$$

$$= \frac{751585}{9815750}$$

$\cos\alpha = .76567$

$\alpha = 40.03°$

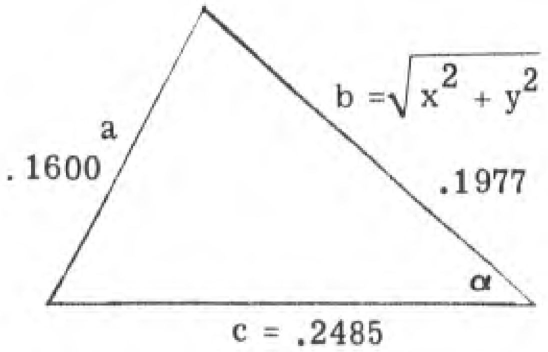
$\phi_{max} = \alpha - \gamma = 2.11°$

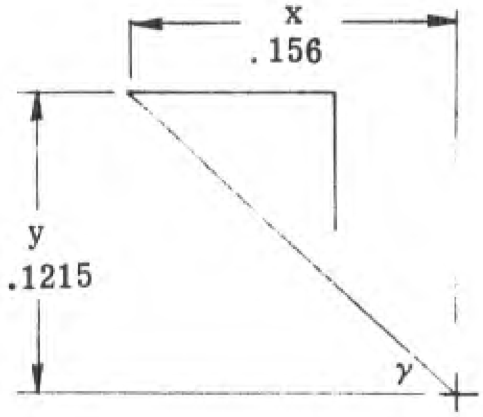
$$\tan\gamma = \frac{.1225}{.155}$$

$= .79032$

$\gamma = 38.32°$

θ_{max}





a = starwheel radius
b = pallet working radius
c = starwheel to pallet center distance

$$\cos \alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

$$= \frac{(.1977)^2 + (.2485)^2 - (.1600)^2}{2\,(.1977)\,(.2485)}$$

$$\gamma = \tan^{-1}\ y/x$$

$$= \tan^{-1}\ (.1215/.156)$$

$$\gamma = 37.92^\circ$$

$$\cos \alpha = .76572$$

$$\alpha = 40.03^\circ$$

$\phi = \alpha = \gamma$ = angle pallet must move from centered position to clear one starwheel tooth.

θ = side to side angle of pallet oscillation.

$= 2\,\phi$ + allowance for overtravel

We assume

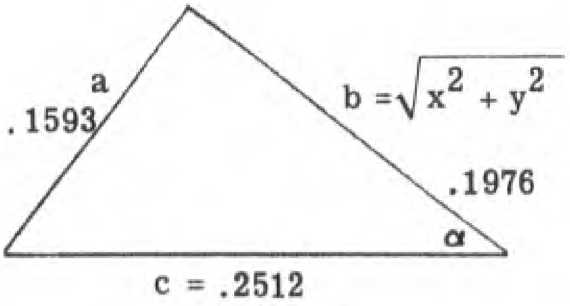
$$\theta = 2\phi + 1/2\ (9^\circ - 2\phi) \quad \text{where } 9^\circ = \text{max. possible travel}$$

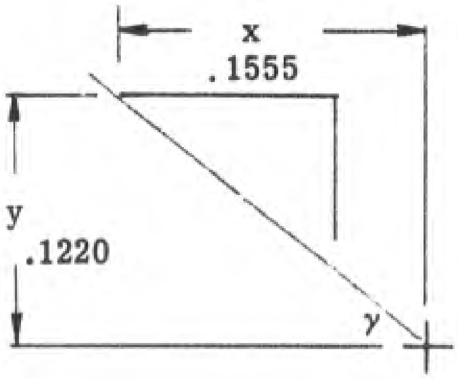
$$\theta_{max} = \phi + 4.5^\circ$$

$$\theta_{max} = 40.03^\circ - 37.92^\circ + 4.50^\circ$$

$$\theta_{max} = 6.61^\circ$$

$\underline{\theta_{nom}}$





a = starwheel radius
b = pallet working radius
c = starwheel to pallet center distance

$$\cos\ \alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

$$= \frac{(.1976)^2 + (.2512)^2 - (.1593)^2}{2(.1976)(.2512)}$$

$$\gamma = \tan^{-1} y/x$$

$$= \tan^{-1} (.1220/.1555)$$

$$\gamma = 38.12^\circ$$

$$\cos \alpha = .77331$$

$$\alpha = 39.35^\circ$$

$\alpha - \gamma = \phi$ = angle pallet must move from centered position to clear one starwheel tooth.

θ = side to side angle of pallet oscillation

= 2 ϕ + allowance for overtravel

We assume

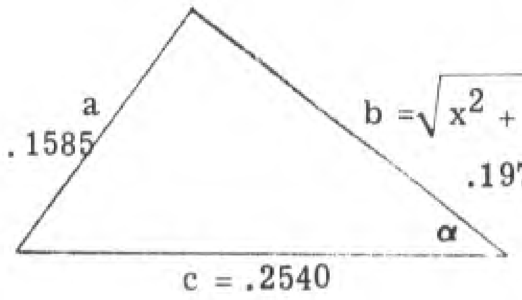
$$\theta = 2\phi + 1/2\,(9^\circ - 2\phi) \quad \text{where } 9^\circ = \text{max. possible travel}$$

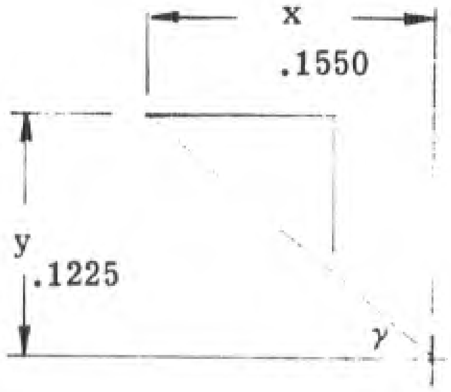
$$\theta_{nom} = \phi + 4.5^\circ$$

$$\theta_{nom} = 39.35^\circ - 38.12^\circ + 4.50^\circ$$

$$\theta_{nom} = 5.73^\circ$$

θ_{min}





a = starwheel radius
b = pallet working radius
c = starwheel to pallet center distance

$$\cos\alpha = \frac{b^2 + c^2 - a^2}{2bc}$$

$$= \frac{(.1975)^2 + (.2540)^2 - (.1585)^2}{2(.1975)(.2540)}$$

$$\gamma = \tan^{-1} y/x$$

$$= \tan^{-1}(.1225/.155)$$

$$\gamma = 38.32^\circ$$

$$\cos\alpha = .78142$$

$$\alpha = 38.60^\circ$$

$\alpha - \gamma = \phi$ = angle pallet must move from centered position to clear one starwheel tooth.

θ = side to side angle of pallet oscillation

$= 2\phi$ + allowance for overtravel

We assume

$\theta = 2\phi + 1/2\,(9^\circ - 2\ \ )$ where 9° = max. possible travel

$$\theta_{min} = \phi + 4.5^\circ$$

$$\theta_{min} = 38.60^\circ - 38.32^\circ + 4.50^\circ$$

$$\theta_{min} = 4.78^\circ$$

T = average spring torque × torque reduction of gear train

$$T_{min} = 1.47 \text{ in-oz} \left[\frac{12}{58}\right]\left[\frac{12}{36}\right] = 0.102 \text{ in-oz}$$

$$T_{nom} = 1.51 \text{ in-oz} \left[\frac{12}{58}\right]\left[\frac{12}{36}\right] = 0.107 \text{ in-oz}$$

$$T_{max} = 1.58 \text{ in-oz} \left[\frac{12}{58}\right]\left[\frac{12}{36}\right] = 0.112 \text{ in-oz}$$

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13. ABSTRACT

This report describes the implementation and results of a program of production-engineering performed on the XM114 Safety and Arming Device. The object was to minimize costs, simplify the design, and improve reliability and producibility. This was to have been accomplished through study and analysis of the drawing package, specifications, and tooling and inspection components and processes. In performing the program, all goals applicable to the end item were achieved: the design was simplified, material usage was revised, production was facilitated, etc.

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Missile Fuzes						
Production Engineering						
Safety and Arming (ordnance)						