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SIMULATOR, TACTICAL USE, FLARE (STUF) PROJECT FINAL REPORT

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Large numbers of infrared (IR) decoy flares, which are used to counter IR missile threats, have been expended during past training exercises of Naval combat pilots. In an effort to maintain a current level of training using the most cost-effective manner, a low cost training simulator was desired. The deployment of relatively low cost simulators in place of decoy flares during training exercises will be a savings of nearly 50% of the cost of the expendable used.

Simulator, Tactical Use, Flare (STUF) has been developed by Crane Division, Naval Surface Warfare Center (NAVSURFWARCENDIV Crane) for use as a training substitution for decoy flares. The purpose of this round is complete visual simulation of an expendable decoy flare.

A complete review of the design phase, design optimization, and engineering tests of the STUF round at NAVSURFWARCENDIV Crane will be presented.

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SUMMARY

Background.

Large numbers of infrared (IR) decoy flares, which are used to counter IR missile threats, have been expended during past training exercises of Naval combat pilots. In an effort to maintain a current level of training using the most cost-effective manner, a low cost training simulator was desired. The deployment of relatively low cost simulators in place of decoy flares during training exercises will be a savings of nearly 50% of the cost of the expendable used.

Simulator, Tactical Use, Flare (STUF) has been developed by Crane Division, Naval Surface Warfare Center (NAVSURFWARCENDIV), Crane, IN, for use as a training substitution for IR decoy flares.

Purpose.

This report presents a review of the design phase, design optimization and engineering tests of the STUF round at NAVSURFWARCENDIV Crane. The purpose of the STUF round is complete visual simulation of an expendable decoy flare.

Principal Results.

Preliminary concept testing identified that the basic design needed to include the cartridge retainer, obturator, foam spacer, candle (magnesium/sodium nitrate composition - pressed into a fishpaper tube), end cap, aluminum tubular case, and the appropriate O-rings for proper sealing.

The most important design consideration was that the unit be safe to handle, even if it sustained damage from rough handling. Employing a simple parasitic ignition and a tough polycarbonate engineering plastic, the unit is lightweight and extremely durable.

Functionality was tested statically while design changes were being made. After establishing a baseline design, function tests (windstream, altitude chamber, leak, dispenser compatibility) were run on prototype units. Minimal changes were made after the "baseline design" was reached; however, these changes were held to slight dimensional and tolerance changes. Durability series tests included aircraft vibration, temperature and humidity, and the five-foot drop. A test lot was also assembled and tested for a flight test at a relative speed of Mach 0.7 and Mach 0.85 at altitudes of five-thousand and fifteen-thousand feet.

Performance optimization efforts were directed at problems of delayed ignition, the case swelling upon ejection, "split stars" (or double display), and candle curing parameters. Different curing processes were examined and it was decided that quality was optimized when the candles were cured at room temperature.

Conclusions.

STUF meets the primary requirement of an inexpensive item which can be used instead of decoy flares for training purposes. Current projected costs are only fifty percent that of current Navy decoy flares. Simple components molded or cut from stock materials, a pressed candle composition made from inexpensive materials, common assembly procedures, and minimal acceptance testing helped minimize development as well as production costs.

A secondary requirement on the program was to minimize development time to get something to the Fleet quickly. In spite of the difficulties encountered, the time required to go from the initial concept to flight testing was less than fourteen months. This can be attributed in great part to the knowledge available at NAVSURFWARCENDIV Crane in the field of pyrotechnics. Of equal importance perhaps was the capability to do the work in-house in order to make quick changes when problems arose. The ability to do pyrotechnic pressing, injection molding of plastics, and assembly within the Ordnance Engineering Directorate at Crane allowed the project personnel to respond to problems quickly.

INTRODUCTION

Currently, large numbers of infrared (IR) decoy flares need to be expended during training of Naval combat pilots to familiarize them with timing, maneuvers, and switch positions on the countermeasures dispensing system (CMDS). In an effort to increase the proficiency of operational pilots with the CMDS on their aircraft, a low cost training expendable was needed. This training round will not only be less expensive to manufacture, but will also require less stringent acceptance testing; thus, significantly reducing the cost of training.

Simulator, Tactical Use, Flare (STUF) has been developed by Crane Division, Naval Surface Warfare Center (NAVSURFWARCENDIV Crane) for use as a low cost training substitute for IR decoy flares. The development process has been done to design a unit which is inexpensive, yet simulates the visual characteristics of a decoy flare.

To minimize costs, three criteria were established: 1) low cost materials would be used (i.e. molded plastic instead of machined metal parts); 2) mixing and manufacturing processes available throughout the pyrotechnic industry would be utilized; and 3) a minimal amount of acceptance testing would be done. The resulting design consists of a pressed candle of magnesium/sodium nitrate illuminating composition and ignition mix, three molded plastic parts, a foam spacer, and a metal tube case. The design uses a parasitic ignition which is slower, but safer and less expensive, than that used in conventional Navy decoy flares. The current design would allow several companies to produce the item, making it more cost-competitive and allowing higher production rates using multiple manufacturers.

Although the high reliability necessary for decoy flare acceptance is desired, it is not necessary for a training round. A minimal number of tests were included in the specification to assure functional, safety, and environmental requirements are met. These included: functional testing in a simulated altitude and windstream, a drop test and vibration test to assure safe handling, temperature and humidity, and sealing tests to meet the environmental requirements of the item. Flight testing of the STUF was done during developmental and evaluation testing, and will be done with the first article acceptance lot from a low rate initial production (LRIP).

Physical Description.

The STUF round is functional from the AN/ALE-29, AN/ALE-39, and AN/ALE-47 dispenser systems. The physical configuration of the STUF (see Figure 1 below) consists of a cylindrical aluminum case 3.828 inches long and 1.42 inches in diameter. One end of the training round is closed with a plastic end cap. Internally, the STUF consists of the pyrotechnic composition or candle grain (magnesium/sodium nitrate), the ignition composition (red lead) which is pressed on the end of the grain, a foam spacer, and an obturator to absorb the shock of the impulse cartridge. The impulse cartridge is housed in a plastic cartridge retainer crimped into the base end of the aluminum case. The cartridge retainer is flanged to a maximum diameter of 1.495 inches to restrain the unit on the counterbore in the chamber of the dispenser. Each unit weighs seventy-nine (79) grams and has the center of gravity two inches from the flanged end.

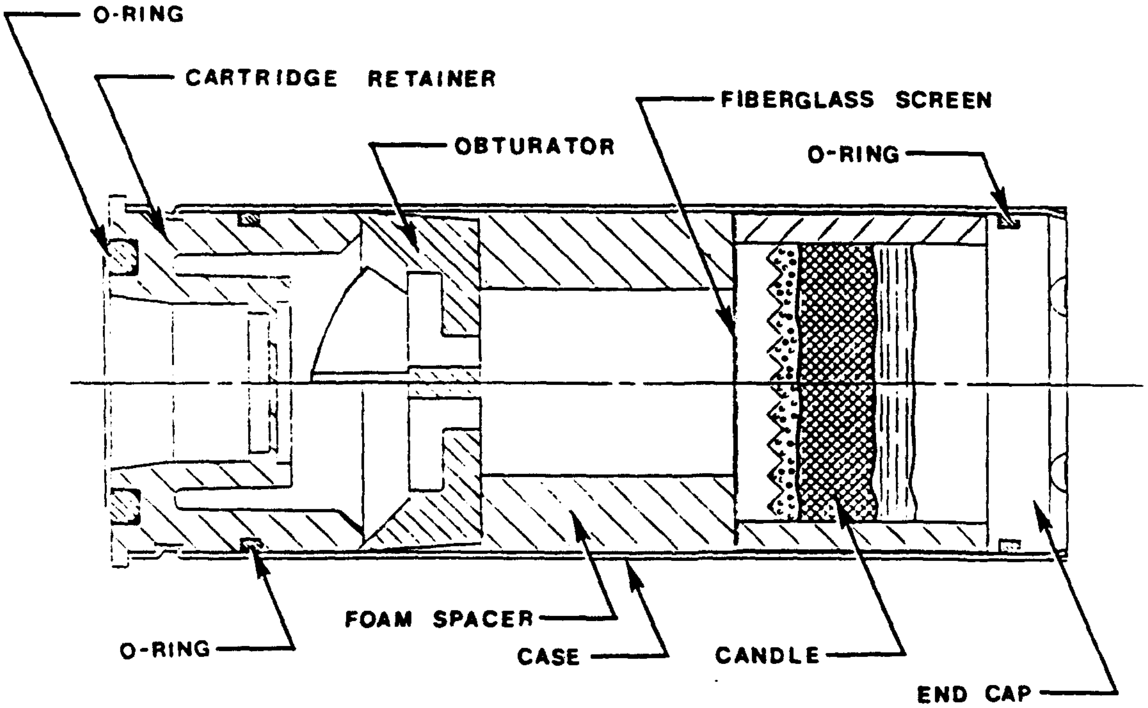

FIGURE 1. PHYSICAL CONFIGURATION OF STUF ROUND

In the final configuration, the STUF round carries a DOT hazard classification of "Class C Explosives." This classification is less stringent than that of decoy flares because of the lack of any type of internal ignition system.

DEVELOPMENTAL METHODOLOGY

Concept Design.

The STUF round was developed through a progressive design building process from initial concept models to fully operational units. As each test was completed any undesirable traits were studied for possible elimination through design. This process of significant changes continued until the design team had arrived at a design which performed as desired. The design was tested for reliability in harsh functional tests, then only small dimensional and tolerance changes were made after establishing a baseline.

The unit was designed with the intention of meeting certain criteria which would make the unit more desirable for the end users. All of these design goals have been met or exceeded.

The unit must:

- Be safe to handle;
- Be compatible with the CCU-41 and CCU-63/B impulse cartridges;
- Have visible signature within 250 milliseconds after ejection;
- Produce visible signature for approximately five seconds;
- Eject at a velocity of 100-200 feet/second;
- Be functional out of ALE-29, ALE-39 and ALE-47 dispenser systems;
- Be constructed from components which are easily manufactured; and
- Be designed and released for Fleet use in the most timely manner.

The most important design consideration was that the unit be safe to handle, even if it sustained damage from rough handling. This was accomplished by designing the unit to ignite parasitically from the impulse cartridge instead of an internal ignition mechanism. The unit incorporates the use of Lexan 500,®[1] a 10% glass-filled polycarbonate engineering plastic, for the three larger parts. Because of the use of this high strength plastic in the design, it is very lightweight and suffers minimal damage if dropped during handling.

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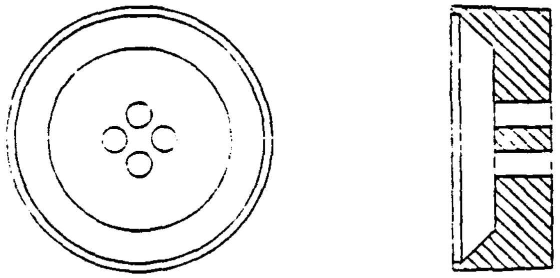
[1] Lexan 500 ® is a registered trademark of DuPont Industries.

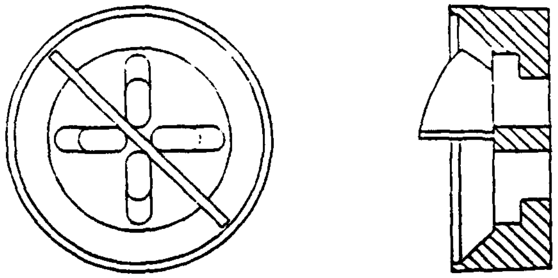
To make the unit compatible with different types of impulse cartridges, an expansion chamber was created from pressure absorbing material within the unit to keep the shock wave of the CCU-63/B cartridge from destroying the ignition portion of the flare grain. The CCU-63/B impulse cartridge has an extremely high initial shock wave, compared to the CCU-41 impulse cartridge. This is related to the speed of the powder igniting. In the CCU-63/B, the powder burns quickly, producing the high shock wave and little flash. In the CCU-41, the powder burns slower, giving a slower pressure rise, but also causing a large flash (due to the residual powder). The shock wave of the CCU-63/B impulse cartridge was found to be the overpowering factor of compatibility with both types of cartridges. By reducing the amount of the shock wave which is allowed to hit the candle, the unit is functional with both CCU-41 and CCU-63/B impulse cartridges.

Obtaining a fast ignition has always been a problem while using either illumination or smoke composition flare grains. The slow ignition characteristics inherently present in these types of compositions make it somewhat difficult to ignite quickly by using a parasitic ignition off an impulse cartridge. If the candle is too far from the cartridge, the cartridge's initial flash doesn't contact the ignition composition long enough for the flame front to spread over the complete face of the grain. If the candle is placed closer to the impulse cartridge, the shock wave from the cartridge is strong enough to actually degrade the physical form of the composition. In either case, the effective speed and/or intensity of the ignition process is depreciated to the point that the final outcome is a delayed or failed ignition.

Contributing to the slow ignition was the disk from the cartridge retainer, which was able to almost completely cover the holes in the obturator. In order to increase the speed of ignition, the holes in the obturator were widened into slots, the slots were stepped to reduce blockage, and a thin web was bridged across the obturator. This web folds the disk from the cartridge retainer and impulse cartridge to allow gases to pass through to the candle. (See Figure 2.) The slots allow more of the hot burning gases from the impulse cartridge to pass through to the ignition composition, while retaining most of the pressure from the initial shock wave. Above the obturator, the fiberglass screen wire allows gases to pass through to the candle while retaining any ignition material near the composition which may break off due to the force of the initial shock wave. The screen wire will hold the larger pieces of ignition composition, while it burns, close to the candle.



ORIGINAL OBTURATOR DESIGN
STRAIGHT IGNITION HOLES



IMPROVED OBTURATOR DESIGN
SLOTTED IGNITION HOLES
WEB BRIDGE

FIGURE 2. IMPROVED DESIGN OF OBTURATOR

The original goal was to ignite the STUF round within 250 milliseconds after ejection. Although ignition was completed in less than 250 milliseconds, during an evaluation flight test it was determined that at high air speeds this time frame allows the unit to separate too far from the aircraft before ignition. Attempts were made to increase the speed of ignition with notable improvements. These efforts succeeded in a notable increase, but more emphasis needs to be placed on this in future improvement efforts.

The STUF round is intended to produce a visual signature with a duration long enough to be picked out by the human eye. The intended operational range assumed that for training purposes an altitude "floor" was placed at least 500 feet above ground level. By balancing the ratio of ejection velocity and burn time, it was theoretically possible to target a trajectory which will keep a unit from contacting the ground while it is still burning.

After determining the appropriate burn time and exit velocity (by using the above consideration) design of the candle was started. In attempting to produce a visual signature for a given length of time and an approximate ejection velocity, it was recognized that both aspects were related to the mass of the candle grain. Given the required burn time, an approximate quantity of candle composition was determined experimentally. After determining the appropriate mass for the candle, all variance in burn time was accomplished by varying the granular size and the amount of magnesium in the composition. The appropriate ejection velocity was achieved by varying the amount of cushioning material, and adding to the amount of internal expansion volume available to the gases from the impulse cartridge.

The STUF round is relatively inexpensive to manufacture with parts either cut to length from stock materials or injection molded. The cartridge retainer, which has the most complex geometry of all of the parts, is cored to allow for uniform wall thickness and to remove all thick sections which may cause a shrinkage deformation problem after molding.

RESULTS

The following section of this report is a sequential summary of the engineering design and testing which took place throughout the course of the project. This is a summary of design aspects tested and the results found. Where applicable, several small specific steps which were taken in the design process are included together as one phase.

Initial Concept Testing.

Testing of the initial concept took place with fully inert candles in order to safely explore hardware designs. The design team agreed that the cartridge retainer was the first component design desired. Then, other components would be designed accordingly.

Using wooden plugs for "candles" and a somewhat "funneled" design on the cartridge retainer (see Figure 3) the early concept units were functioned using CCU-63/B impulse cartridges. The results of this test revealed that the "funneled" design did not work favorably with the CCU-63/B cartridge. The CCU-41 opens in a flower petal arrangement, whereas the CCU-63/B breaks the end cap disk out in one whole piece. Although the retainer did not perform as desired when shot with the CCU-63/B, the candles showed significant amount of burn marks indicating that at ambient conditions the impulse cartridge had sufficient flash to ignite the units.

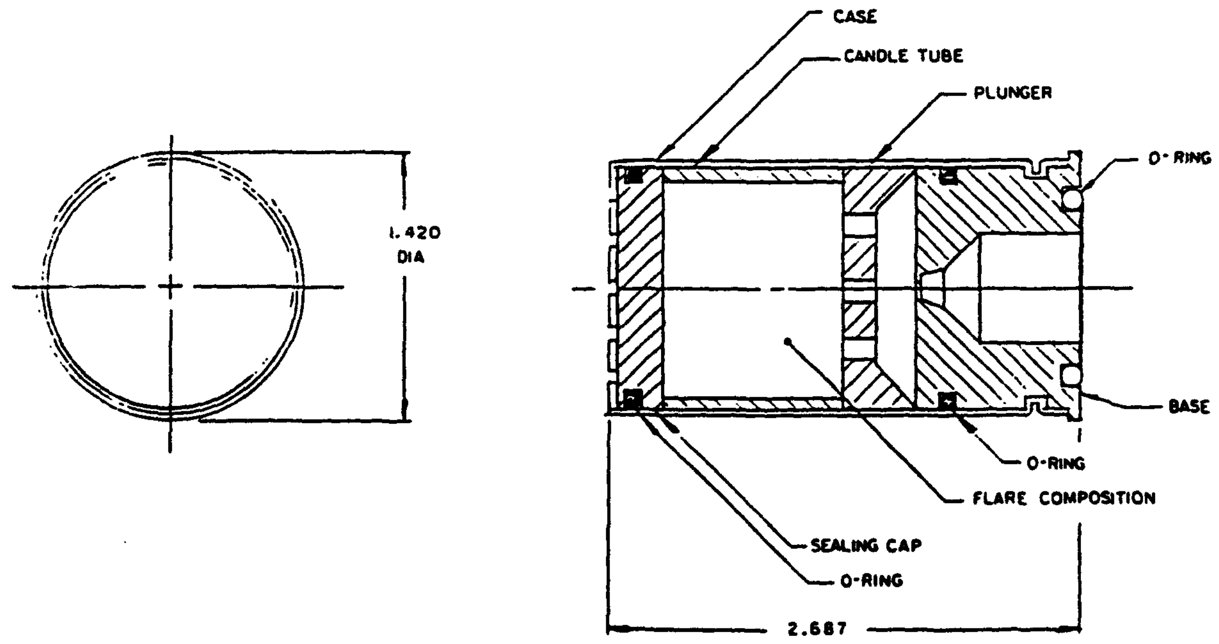


FIGURE 3. EARLY CONCEPT MODELS

The cartridge retainer was changed so that the "funneled" design allowed for the shear area to be a slightly larger diameter than the end cap of the CCU-63/B. This allowed for the frangible disk and the end cap to pass through the retainer without breaking excess material from the retainer body, which could block the ignition process. These early tests incorporated only subtle changes in the aspects of the retainer in order to more fully understand the performance consequences of slight changes in design.

Tests of early prototype units defined the basic design of the retainer. The retainer was then targeted for a wide variation in the test matrix on subsequent tests. Details which were changed were:

- The expansion volume;
- Cored/not cored for thinner wall sections which added to the expansion volume;
- Staking groove angle and location; and
- Thin/thick web in the shear area.

Performance during early concept testing of the STUF was hampered by damage caused by the impulse cartridge impact on the ignition composition. This impact caused the ignition composition to break off the end of the candle and not heat the surface of the candle with enough intensity to light. This problem proved to consist of many complex contributing factors. The main factors were that the impulse cartridge was hitting the unprotected candle with enough force to physically break up the ignition composition and these broken pieces were separating from the candle, thus causing poor transfer between the ignition and candle portions of the grain.

A felt pad was added as a shock absorber in the second stage of tests. It was noted that the felt did not sufficiently absorb the shock from the CCU-63/B impulse cartridge but showed improvements over designs without it. Therefore, the felt pad was replaced by a piece of semi-rigid polyethylene foam. A test matrix was defined to test combinations of the retainers (felt and foam) with and without a paper disk on the candle, assembled in both one- and two-piece cases. It was concluded from this data that the specific cartridge retainer design did not effect the functionality nor the exit velocity of the unit in any appreciable manner. Therefore, production considerations (ease of molding, time requirements, etc.) dictated the retainer configuration.

Many types of plastics were examined before choosing Lexan 500 resin (with 10% glass filled) as the material for injection molding and deciding upon the retainer configuration. This material was chosen for its strength and its flow abilities to mold the .040" frangible disk in the cartridge retainer, while retaining its shape in the rest of the part's configuration.

This choice of material was not without compromise to the original design due to the production requirements which the material has. The use of Lexan 500 also included a light blowing agent added during the molding process. The original design required very thick and thin sections in the same molded part. By adding "cores" to the part and using a glass-filled material with minimal sinking characteristics, the part was molded with enough accuracy and consistency to not require secondary machining of the main sealing O-ring groove.

Lexan 500 resin's chemical structure will not withstand long exposure to hydrocarbons such as fuels and oils. Because the unit is a "one shot" training item, it will not be required to resist such harsh chemical attacks. The concept of using this material to mold the entire unit was explored with a limited success, but not fully pursued.

The decision to proceed with further development of the two-piece instead of the one-piece case (even though it is more expensive to produce) was based on the performance of the one-piece case design during its initial test. These units were assembled using the same molded obturator as the two piece units. Because of it's size, this obturator jammed in the unit after ejection thus it effectively functioned as a nozzle to the burning gases. The resulting rocket motor effect made the units appear slow to light and have erratic flight. The cause of this performance was not fully understood until somewhat later in the project, therefore, this design was not tested further. However, prototype hardware for this design was produced which suggested that this design might be less complicated and less expensive to manufacture.

The above mentioned preliminary testing identified the basic design concept needed to include the cartridge retainer, obturator, foam spacer, candle (composition - pressed into a fishpaper tube), end cap, aluminum tube, and the appropriate O-rings for proper sealing. After arriving at the design of these parts, the design team set baseline performance criteria based on performance of these "rough" parts.

Performance Optimization.

The design team then set out to optimize the performance of the unit. The first undesirable trait which was targeted for elimination was the swelling of the case upon ejection. This was seen in some of the earlier tests to be so severe that the unit had to be driven from the dispenser block with a long shaft and a hammer. By reducing the clearances between the obturator and the cartridge retainer, and enhancing the mating surface seal between these parts, the initial shock loading forces were held by the rigid plastic parts instead of the very thin aluminum case. It was also found that by reducing the "wiping" angle of the edge of the obturator, from four degrees to one-half of a degree, the length/diameter ratio of the contact surface could be maximized without sacrificing the draft required in order to injection mold the part. The combination of the two above mentioned design aspects and increasing the "effective" expansion volume by slotting the holes in the obturator and allowing the expanding gases to expand more quickly through the obturator into the foam section, virtually eliminated case expansion. (See Figure 2.) After these changes were made, it was discovered that these changes actually made it possible for the part to release from the mold easier, thus reducing the molding time and cost by a very significant amount.

A problem of "split stars" or double display has persisted throughout the project and has only been partially alleviated. This occurs when a portion of the candle breaks off (for any number of reasons) and the display is two smaller stars instead of a single display. This undesirable trait still gives a visual signal, but not with optimum intensity and duration. Many design changes have been tried but without total success. The most effective ones have been the addition of the screen wire, recessing the top of the candle slightly into the fishpaper candle tube, and changing the curing process of the candles in order to produce higher quality candles.

The candle composition incorporates an epoxy binder system which requires at least a 24-hour cure time at room temperature. It was desired to shorten this time in an effort to reduce the amount of material in process during manufacturing. Therefore the curing was accomplished in an oven at approximately 120 degrees Fahrenheit. This shortened the curing time of the candles but also added adverse affects on the performance of the units. By curing the candles at elevated temperatures, moisture in the fishpaper tube was driven off causing the tube to shrink away from the candle, with the possibility of cracks in or around the candles. Changing the requirements to specify that the candles are cured at room temperature has eliminated the majority of the problems associated with cracks *forming* in the candle.

Function Tests.

Windstream Tests -

After reaching a point where the units were reliable statically, it was desired that they be tested in the windstream facility. Units were fired in a "Blow Down Profile," which simulates firing from an aircraft at Mach 0.85 and slowing down in relative air speed due to drag. A flare test was set up with a large number of units with combinations of the following variations:

- Temperature conditioned to -65° F, +120° F, or ambient temperature;
- CCU-41 and CCU-63/B impulse cartridges;
- Candle pressing load of 5000 lbs or 8000 lbs; and
- Candle cured in an oven or ambient cured.

A small sample of these units had a plastic perforated disk over the end of the candle to keep the foam spacer from forming down across the end of the candle. These few units with the perforated plastic disk did not function. The units which were pressed on the high and low sides of the acceptable pressing pressure functioned without any appreciable difference between them. The units with different curing methods did not exhibit a noticeable difference as might have been expected since in previous tests the oven-cured candles appeared to be brittle and broke apart during burning. The units which were temperature conditioned to -65° F lit somewhat slower than the ambient and the hot-conditioned units as was expected, but were still acceptable. Units were modified for mounting purposes during production. (See Figure 4).

Altitude Chamber Tests -

The other function test which could be performed at the NAVSURFWARCENDIV Crane facilities was functioning within the altitude chamber. In performing this test it was discovered that the existing test setup, which is routinely used in testing decoy flares, was invalid for the STUF round. The problem occurred when attempting to measure the time to light within the chamber. Unlike the decoy flares which are ignited by a pull-wire, the STUF round depends on parasitic ignition from the impulse cartridge, which is slower than the pull-wire ignition. This natural delay of ignition is long enough for the unit to travel the length of the altitude chamber before ignition occurs. The impact of the candle on the wall of the chamber can be of sufficient force to knock out any flame which may be present if it is not fully developed.

In order to circumvent this problem it was necessary to restructure the test. The units were assembled in the same manner which were used for the windstream units. (See Figure 4.) A mounting block was included in the assembly and allowed to protrude through the end cap of the unit. This mounting block was fastened to a test fixture and the case was fired off of the candle assembly.

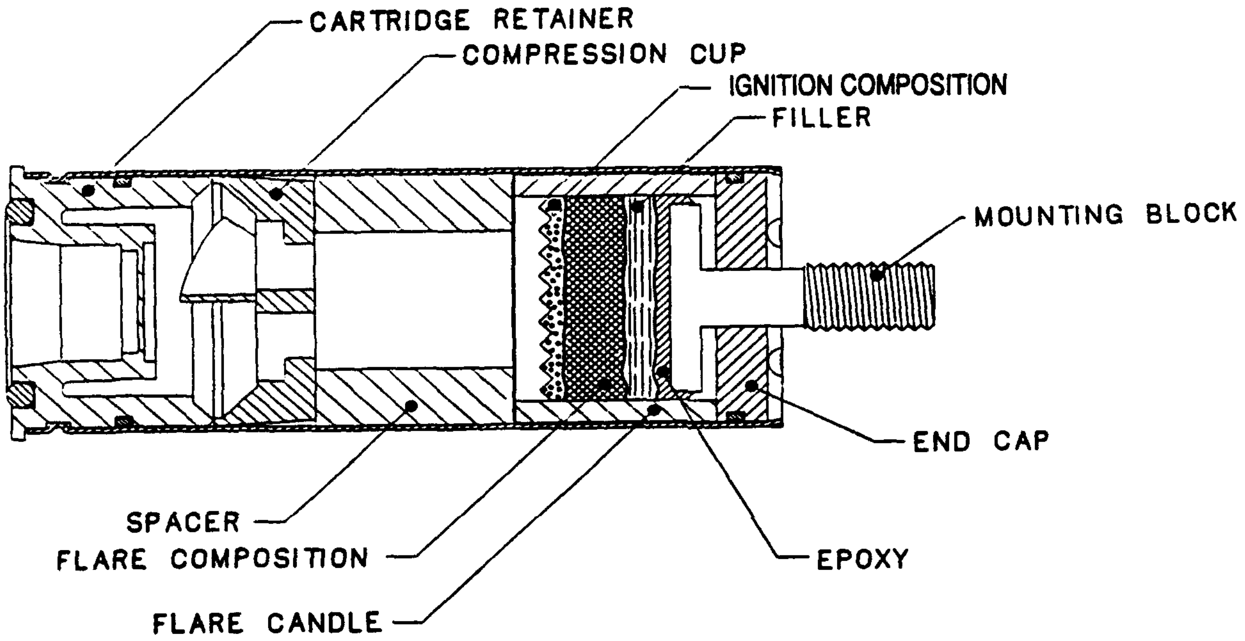


FIGURE 4. WINDSTREAM AND ALTITUDE TEST UNIT ASSEMBLY

The units were temperature conditioned to -65° F and functioned up to a simulated altitude of 40,000 feet with the CCU-63/B cartridge. Units which had a perforated paper disk over the end of the candle to retain any of the ignition composition, which might get damaged upon functioning, were tested with mediocre results. This paper was replaced by a piece of plastic screen cloth, to allow more hot gases to come into contact with the candle. Because of this change to screen cloth, a few units were shot in the windstream to verify the validity of previous testing in the windstream. Only a few units with screen were tested this way due to test restraints on the windstream. After this modification, a limited number of units were cold conditioned and functioned at altitudes up to 40,000 using the CCU-63/B cartridge. These were the conditions at which the previous test samples had failed. This limited test showed the units to have complete success.

Leak Tests -

An initial leak test of the STUF round resulted in twenty (20) of twenty units failing to hold a six inches of mercury vacuum load. Engineering investigation led to the conclusion that the assembly process of "stake crimping" the case to the plastic cartridge retainer is what jeopardized the integrity of the sealing of the unit. Because of the distance between the crimping stakes, this crimping style allowed for the case to deform. This deformation raised the case from the O-ring, thus allowing minor leaks between the stakes. As an alternative to the traditional "stake crimp," a continuous roll crimp was perceived as a possible solution. Measurement tests were conducted to determine the integrity of a continuous roll crimp on a thin aluminum case. The results of the test indicated that the roll crimp held 140% of the staked crimp strength. By changing the process to a continuous roll crimp the quality of the seal was greatly improved, without any noticeable effect on performance. This change in the style of crimping also eliminated the need for each unit to be placed in a re-sizing die to insure proper configuration of the final product.

Sealing tests have shown 100% leak-free units (even units that withstood catapult launches and arrested landings on an F-18 aircraft appeared to be leak-free). One drawback to the roll crimp is that it is labor-intensive to roll crimp the units without some type of automated device. Efforts are being made to obtain the technical knowledge to economically crimp a 360-degree roll crimp without damaging the unit. A faster method of crimping has been utilized by Crane Army Ammunition Activity (CAAA) at NAVSURFWARCENDIV Crane, who are manufacturing an LRIP test lot of 5000 units. CAAA employs a Magna Form machine which uses a strong electro-magnetic force to crimp the retainers. Initial testing by CAAA has shown that this is an acceptable alternative, but extremely large quantities may be time prohibitive.

Dispenser Compatibility -

It was also desirable for the STUF round to be compatible with any future dispenser system which may be used for expendables. Because the STUF round is the same caliber as standard decoy flares and uses the same impulse cartridge, it is reasonable to assume that it will physically fit into other dispenser blocks. However, one problem was foreseen with the D-47/ALE-29 "Long Dispenser Block," in that the long block could possibly cause the parasitic ignition to react differently than when functioned out of the standard length dispenser block. A test lot of 120 units was statically fired using both CCU-41 and CCU-63/B impulse cartridges from a long block. All of the units functioned as designed. In earlier tests using the short block, it was noted that the use of the CCU-63/B impulse cartridge caused a portion of the ignition composition to split out during functioning. During this test it was noted that the ignition was quick and no "split stars" occurred. The fact that "split stars" were not present suggests that the longer block allows for a more fully developed ignition. The exit velocities were close to what would be expected using a short block. No adverse effects to the normal function of the STUF rounds were noted during the test, nor was damage noted on the block from the ignition flash. It was demonstrated successfully that the STUF round can be fired from the long block in addition to the standard block.

Durability Series Tests.

Aircraft Vibration -

A group of units were tested through the appropriate safety series of tests. A sample of units were subjected to aircraft vibration simulation only and then fired statically. Of thirty (30) units fired, one unit fired with a CCU-63/B impulse cartridge failed to ignite. Upon examination of the unit it was thought to have been an assembly error. The unit which failed had the paper disk instead of the screen wire and it appeared to have two pieces of paper instead of one. This did not allow enough fire through to ignite the candle. All other units functioned as designed.

Temperature and Humidity Tests -

A group of units were subjected to the standard fourteen-day temperature and humidity (T&H) cycle, then subjected to the standard aircraft vibration cycle. When the X-ray of these units was examined, it was noted that the ignition composition had degraded to some extent. This damage was not present after the T&H cycle. Also there was not any damage noted on the above units which saw only aircraft vibration. The combination of the two did, however, moderately affect the integrity of the ignition surface. These units were then statically fired. All of the units fired and functioned without incident even though the majority of the units had moderate damage to the ignition composition from the pretest conditioning. These units were subjected to the T&H cycle out of their protective packaging. It is considered that this particular test data is at an extremely harsh condition. Future testing and specifications will require the units be tested at realistic conditions and within the packaging.

Five-Foot Drop Test -

A sample of ten (10) units were pulled from the group of STUF which had seen both T&H and aircraft vibration. These units were subjected to a five-foot drop onto a steel witness plate in a variety of orientations. All units were safe to handle and functioned as designed.

Flight Tests.

After doing the durability tests, a test lot was assembled for a flight test at Naval Air Warfare Center Weapons Division, Point Mugu, California. Units were flown on an F-4 aircraft at a relative speed of Mach 0.7 and Mach 0.85 at altitudes of five-thousand and fifteen-thousand feet. The video coverage showed safe separation of the units using both the CCU-63/B and the CCU-41 impulse cartridge. Because of the extremely bright background provided by a dense layer of lower clouds, the burning units were extremely hard to distinguish. Although the units functioned properly, this test raised the desire for a faster ignition system because of the apparent distance which the unit traveled from the aircraft in the 200-250 milliseconds before ignition.

Since the time of the above mentioned tests, units have been flown at Naval Air Warfare Center, Aircraft Division, Patuxent River, Maryland, and again at Point Mugu. All indications are that the units will function and perform desired duty as they are currently configured.

CONCLUSIONS

STUF meets the primary requirement of an inexpensive item which can be used instead of decoy flares for training purposes. Current projected costs are only one-half that of current Navy flares. Simple components molded or cut from stock materials, a pressed candle composition made from inexpensive materials, common assembly procedures and minimal acceptance testing helped minimize development as well as production costs.

A second requirement on the program was to minimize development time to get something to the Fleet quickly. Development of even a simple design can be an arduous task (as was proven by the STUF program). In spite of all the difficulties, the time required to go from the initial concept to flight testing was less than fourteen months. This can be attributed in great part to the knowledge available at NAVSURFWARCENDIV Crane in the field of pyrotechnics. Of equal importance perhaps is the capability to do the work in-house in order to make quick changes when problems arise. The ability to do pyrotechnic pressing, injection molding of plastics, and assembly within the Ordnance Engineering Directorate at Crane allowed the project personnel to respond to problems quickly.

The ability to respond quickly when a problem surfaced does not mean that all problems were unconditionally resolved. As in any R & D effort, compromises were made to continue progress. An example of this is the decision to use the slower parasitic ignition from the impulse cartridge to minimize costs. During static testing most units were observed to light within twelve to eighteen feet of the dispenser; not impressive, but certainly acceptable for a training round. Tested from an aircraft at Mach 0.8 and an altitude of 25,000 feet however, this translates to observed ignition at 200 to 250 feet behind the aircraft which no longer approximates the characteristics of current decoy flares. The units will be provided to the operational Fleet in this configuration to determine their usefulness. Preliminary feedback from test pilots is that the display is easily picked up by the human eye and visually appears to be a typical decoy flare, although it was noted that STUF "didn't have as much smoke as a decoy flare."

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