THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Aeronautical and Astronautical Engineering
High Altitude Engineering Laboratory

Quarterly Progress Report
UPPER AIR RESEARCH AT HIGH LATITUDES

(Covering period from 1 January 1962
through 31 March 1962)

Submitted for the project by
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ORA Projects 03433 and 04926

Under contract with:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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1. INTRODUCTION

On 27 December 1961, as reported in the preceding progress report, the University of Michigan had been informed by the NASA that the research effort authorized by contract NASw-115 would be continued under contract NASr-54(02). On 2 January 1962, the NASA was requested to extend contract NASw-115 to 1 March 1962, with no increase in funds, in order to permit closing out of subcontracts, etc. On 8 January 1962 project account 04926 was established by the U. of M. business office in advance of execution of a written agreement, with expenditures limited to $5,000 for the period from 8 January through 31 January 1962. This was not sufficient to cover payroll plus travel incident to grenade vibration tests and scheduled rocket firings. Accordingly, the project director initiated a request for the authorization of additional expenditures. On 18 January 1962, a telephone call (P. A. Brooks, U. of M. — Frank Giroux, NASA) confirmed that contract NASr-54(02) was under preparation, with a total authorization of $100,000 and an expiration date of 1 December 1962. Accordingly, the project director's request for additional authorization on account number 04926 was forwarded to the business office. On 23 January 1962, account number 04926 was extended in advance of execution, with expenditures limited to a total of $25,000 through 28 February 1962. On 14 February 1962, the sixth amendment to contract NASw-115 was received for acceptance processing by the U. of M. This amendment extended the completion date to 28 February 1962, with no increase in funds. On 26 February 1962, contract NASr-54(02) was in acceptance processing within the U. of M., and accordingly, a further extension of account no. 04926 was requested. On 28 February 1962, the account was extended through 31 March 1962, with expenditures limited to the $25,000 previously authorized. On 12 March 1962, the project director was notified that amendment no. 6 to contract NASw-115 had been received, extending the time of the agreement through 28 February 1962, with no increase in funds. On 16 March 1962, the project director was informed by information copy that a fifth amendment to the Superior Engineering Co. subcontract had been executed, which extends the completion date to 1 February 1962 at no additional cost. On 23 March 1962, contract NASr-54(02) had been accepted by the U. of M. and returned to the NASA for final execution. On 30 March 1962, the U. of M. business office was requested to extend account no. 04926 through 30 April 1962, in advance of execution of a written agreement. It is anticipated that after 1 April 1962, this further extension will be granted.

2. SHEAR TESTS OF SOFT RIVETS

The variation in grenade ejection velocity measured during the Fall of 1961 has not been satisfactorily explained. The dummy test grenades used were rebuilt and fired repeatedly, and this may have affected the force required to shear the soft rivets. Accordingly on 5 January 1962 a series of shear tests was carried out using five sets of new lanyard tubes and grenade tubes. The rivets were sheared in a Riehle testing machine and replaced five times. The loads required to shear the rivets remained within less than ±3% of the mean value, with no systematic relationship between the load and the number of times the rivets had been replaced. The holes were then enlarged by very roughly reaming the holes with a scriber, an instrument sometimes used to remove sheared rivets. The resulting damage to the holes was much more severe than was permitted during the grenade velocity tests. The shear loads then increased 12% to 14%, which is not sufficient to explain the variation in observed ejection velocities.

Further investigation of the problem of ejection velocity will be carried out at a later date, as time permits.

3. VIBRATION TESTS OF HIGH-EXPLOSIVE GRENADES

Following the extensive series of grenade vibration tests carried out during November and December 1961, a minor redesign of the explosive grenades was carried out. The redesign included the following changes:

1. RDX booster pellets were cast integral with the HE.
2. A rubber o-ring was incorporated in the middle bulkhead.
3. A felt pad was placed on the detonator holder between the metal shelf and the RDX.
4. The detonator was cemented in place with weatherstrip cement.

The first batch of 60 production grenades was procured from National Northern Division of Atlantic Research Corporation by Superior Engineering Co. under contract with the NASA. These grenades were completed by 30 January 1962, and on 31 January and 1 February 1962, vibration tests were carried out at West Hanover, Mass. of four 1 lb. and two 2 lb. grenades selected from this batch. All grenades were x-rayed in two positions 90^{o} apart, and the test grenades were selected after inspection of the x-ray photographs.

The test grenades were subjected to axial vibration with 0.4" total amplitude at the following frequencies and durations:

Frequency	Duration
600 cpm	1^m
800	1^m
1000	1^m
1200	1^m
1400	1^m
1600	30^s
1800	30^s
2000	30^s
2200	30^s
2400	30^s
2600	1^m
2400	30^s
2200	30^s
2000	30^s
1800	30^s
1600	30^s
1400	1^m
1200	1^m
1000	1^m
800	1^m
600	1^m

The total time of vibration of each grenade was 16 min. All grenades were x-rayed following vibration, and none showed any evidence of damage. The grenades were then taken to the Halifax range and test fired. All detonated at normal height.

The remaining grenades were then dispatched to Wallops Island by truck, as scheduled firing dates in early February did not leave sufficient time for shipment by rail freight. The vibration jig was returned to Ann Arbor and rebuilt with better vertical balance.

4. ELEVATED TEMPERATURE TEST OF HIGH EXPLOSIVE GRENADES

During the vibration tests of live grenades which were carried out in November and December 1961, a heater jig had been hastily constructed and shipped to West Hanover, Mass. for the purpose of carrying out an elevated temperature ground firing of a complete nose cone at Otis Air Force Base. This test was not carried out, as the difficulties then being encountered appeared to be related to vibration rather than elevated temperature.

The elevated temperature nose cone test carried out on 15 December 1961, and reported in the preceding progress report, indicated that the asbestos covering on the nose cone might be weakened by aerodynamic heating, and if the styrofoam plugs were melted out, the asbestos might be caved in by aerodynamic forces. If this were to occur early in the flight, significant heating of grenades might occur, at least near the forward end. Therefore there was still a requirement for further investigation of the effect of elevated temperature on live grenades.

Accordingly, the heater jig was modified for firing single grenades, and taken to Wallops Island. A single test mortar base was mounted on a block of transite (asbestos board) above a gas burner. A short mortar tube was used, so that thermocouples could be conveniently applied to the grenade near the middle and forward end of a 1 lb. grenade. The mortar tube was then insulated with fibreglas so that more heat is applied to the upper portion of the grenade than to the lower portion. The test setup is shown in figure 1 with a dummy grenade in place. The upper thermocouple is visible about 2" below the top of the grenade, held against the grenade by light wires, which rupture easily when the grenade is fired. The firing lines extend out of the jig near the bottom of the picture. Figure 2 shows the test setup with the insulated casing in place and a piece of light transite over the top for a cover.

Two grenades were tested at Wallops Island on 1 March 1962. The first grenade was heated for 10 minutes, at which time the temperature of the upper thermocouple was 100°C (melting temperature of HBX-6 is 95°C) and the lower thermocouple, just inside the mortar tube, was 85°C. At this point the gas was turned off. Approximately two minutes later the thermocouples read 80°C and 75°C, respectively. About 45^{s} later the grenade was fired by means of a 12 v. automobile battery, and detonated at normal height.

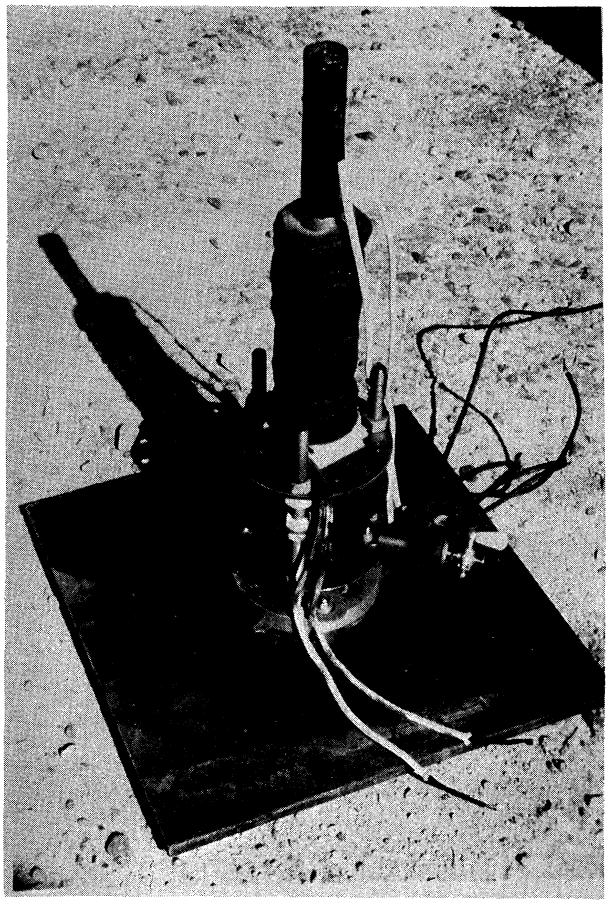

Figure 1.

Apparatus for Firing High-Explosive Grenades at Elevated Temperatures.

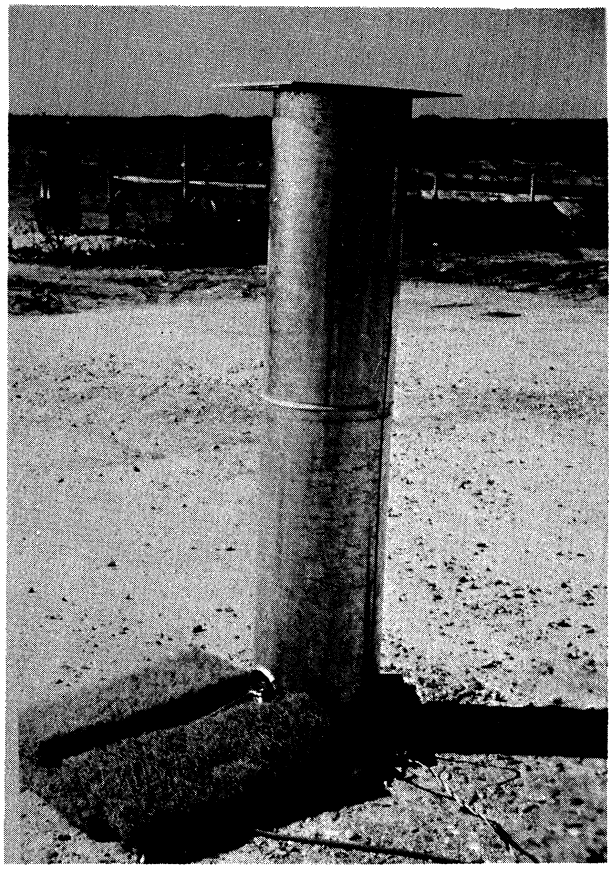

Figure 2.

Grenade Heater with Insulated Casing in Place.

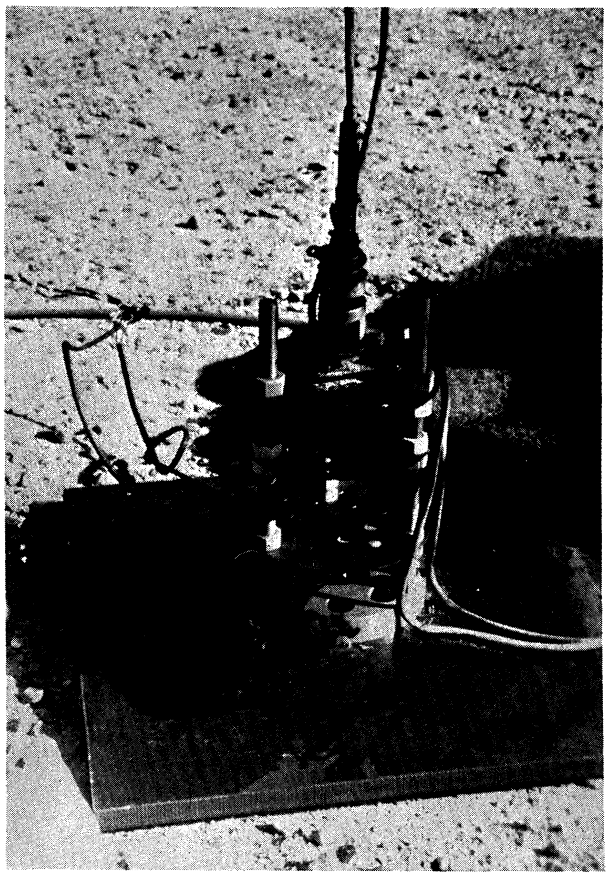

Figure 3. Burned Lanyard Coils and Damaged Mortar Tubes After Spontaneous Grenade Ejection at Elevated Temperature.

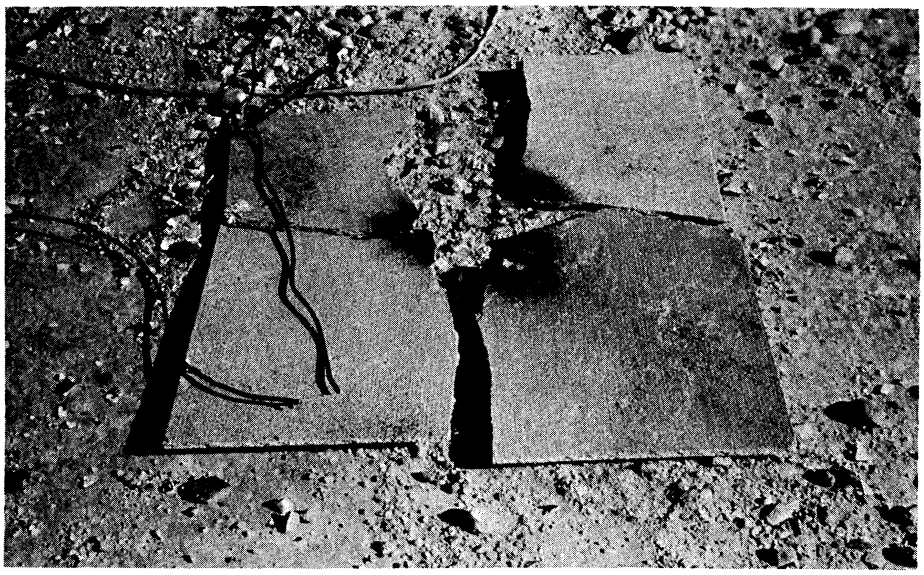

Figure 4. Pieces of Transite Cover after Spontaneous Grenade Ejection.

The second grenade was heated for 25 minutes at which time the upper thermocouple read 160°C and the lower read 150°C. About 45^{s} after the last reading, the ejection charge fired spontaneously, ejecting the grenade, which was apparently detonated in a normal manner by lanyard pull on the firing pin. The event was not expected, so only one observer was watching the heater, and his impression was that the explosion was lower than normal. However, there was no damage to the heater casing, so the explosion could not have been significantly lower than normal.

The explosion of the ejection charge was probably more violent than at normal temperatures as the mortar tube was ruptured at the bottom and blown upward. This action is somewhat similar to that observed occasionally during vibration tests, when the ejection charge was reinforced by pulverized RDX from the booster charge.

The portion of the lanyard outside the oven casing after the test appeared normal, but after the casing was removed, several coils of burned lanyard were found wrapped around the capsule cage (fig. 3). It is probable that these coils dropped back in place after the firing pin had been pulled (a normal occurrence during ground tests) and were burned by the gas heat before the gas was turned off, being unprotected by the insulated mortar tube.

The transite cover over the heater was broken by the departing grenade, and the four major pieces are shown in figure 4. The stains visible near the center are yellowish or brownish in color and appear to be splashes of a liquid. The National Northern representative stated that these were melted explosive, principally TNT, as the aluminum powder in the HBX-6 would tend to settle out, leaving largely TNT at the upper end of the grenade. It is possible that some damage to the grenade occurred on impact with the transite, permitting some of the liquid to spray out. The explosive in the lower part of the grenade must have retained sufficient plasticity so that the RDX pellets were held in place around the detonator, as the grenade exploded normally, even though the explosive must have been largely liquid at the instant of ejection.

If the nose cone covering remains intact during flight of the rocket through the atmosphere, it is very unlikely that grenade temperatures will reach values approaching those encountered during this test. The maximum temperature recorded on a grenade during the nose cone elevated temperature test was 180°F (82°C)at the forward end of the 2 lb. grenades. If the nose cone covering is ruptured early in the flight, the stagnation temperature will be applied directly to the grenade. However, in the absence of any information regarding the airflow around the grenade within the mortar tube, there is

some doubt that enough heat can be transferred into the material of the nose cone and grenades to result in critical temperatures within the short time available. In any case, it appears that the ejection charge will "cook off" before the HE, so that there is little likelihood of a heat-induced premature explosion within the nose cone. However, eventually a better nose cone covering would be desirable, or at least a more heat-resistant binder than the glue currently used.

5. NIKE-CAJUN ROCKET FIRING

The first four rocket firings with the modified grenades had been scheduled for early February 1962. Five timers, two transistor amplifiers, and several vacuum tube amplifiers were completed and taken to GSFC for environmental tests on 29 January 1962. Three of the timers were standard, but one (no. 17) had been modified to fire the 11th grenade at 95^{s} and a balloon at 109^{s}, and one (no. 14) was the last of the old style timers with the 24 step ledex solidly mounted instead of shock mounted.

During vibration tests there was considerable noise on the telemeter records. This appears to be motor noise, is more evident on some timers than others, and is intensified by the transistor amplifiers. It is probably not too severe for actual firings. One lower ledex wafer-mounting screw was broken during vibration, but the test was completed in spite of this. The timer was returned to Ann Arbor on the week end, and the screw was replaced, after which the timer was taken to Wallops Island on 5 February 1962.

Cajun rockets nos. 10.38, 10.39, and 10.40 were prepared for firing, and horizontal tests were carried out during the week of 5 February. Vertical tests were conducted on 6 February on all three rockets but firings were delayed by bad weather. Heavy rains penetrated the covering of the armored cable connecting the arming and monitoring panels in blockhouse 2 to the I-beam launcher, reducing the insulation resistance and causing a drain on the internal B batteries whenever the pullaway cable was plugged into the payload. This situation was aggravated by frequent instrumentation checks necessitated by delays and schedule changes. The B batteries had to be replaced frequently, usually under conditions of extreme cold and darkness.

Cajun no. 10.38 was finally fired on 1 March 1962, with the transistor amplifier TR-1 and standard timer no. 21. All 12 grenades were ejected and detonated. No. 10.39 was fired on 2 March 1962, with a standard vacuum tube amplifier and the old style timer #14. All 12 grenades were ejected, but apparently only 11 detonated.

Cajun no. 10.41 had been scheduled for 6 March 1962, but was postponed for a week due to schedule difficulties and weather conditions, and all personnel returned to Ann Arbor. On 6-8 March 1962, high tides and strong NE gales flooded the preparation area, and a special trip was made to Wallops Island on 8-9 March to determine the condition of timers, amplifiers, grenades, and other equipment stored in Bay 3 and the explosives bunker. This was found to be undamaged and in good order for the next firings. Accordingly, Cajuns 10.40 and 10.41 were scheduled for the week of 19 March 1962.

On Wednesday, 21 March 1962, horizontal tests were carried out on Cajuns 10.41 and 10.42. Vertical tests were attempted on 22 March, but difficulties were encountered with the cable from the blockhouse to the I-beam launcher. This had been further damaged by a bulldozer during clean-up operations following the storm. Surface breaks in the armor were sprayed with freon, which dried out the insulation sufficiently, and a vertical check was run on no. 10.40 about 2 a.m. on Friday in preparation for an early morning shot. However, trouble developed in the elevation system of the tubular launcher, on which the coordinated sodium rocket was mounted, so the shots were cancelled. During the day, vertical checks were carried out on both 10.40 and 10.41. No. 10.40 was fired at 6:54 p.m., following the sodium rocket which was fired at 6:44. The balloon timer (#17) was installed in this rocket, along with a standard vacuum tube amplifier, and a one meter diameter corner reflector balloon was installed in place of the 12th grenade. All eleven grenades were ejected and detonated, and the balloon was ejected, as indicated by the telemeter record, but it was not picked up by radar. The most probable reason appears to be failure to inflate. However, a damaged or partially inflated (from trapped air) balloon should present as large a radar cross section as a dud grenade, and these have been clearly observed at slant ranges as great as 80% of the slant range at balloon ejection. The scope films exhibit considerable noise at this time, but careful examination failed to show the slightest indication of a target other than the Cajun. Further investigations of sphere ejection and inflation are obviously indicated before any further firings are attempted.

Cajun 10.41 was mounted for firing on Saturday morning, 24 March. However, the shots were cancelled at T-10 min. on account of clouds at two of the photographic sites required by the sodium rocket. During the period between grenade loading and the final cancellation, the insulation on the armored cable began to deteriorate again. Following the earlier difficulties, the arming panel had been modified so that a large station battery could be

connected in parallel with the internal B battery, and the use of this station battery kept up the voltage on the internal battery during the period of cable leakage. However, a permanent underground cable, leading from the block-house to the I-beam launcher, which was not in use, was appropriated, and no further insulation difficulties were encountered.

Bad weather caused postponements on Saturday, Sunday, Monday,and on Tuesday morning. The rocket was finally fired Tuesday evening, 27 March at 7:05 p. m. following the sodium rocket. Standard timer #19 and a vacuum tube amplifier were installed. All 12 grenades were ejected and detonated, and 12 sound returns were received.

These four rockets appear to establish the soundness of the present grenade design, as only one grenade failed to detonate, while all ejections were satisfactory, and all timers operated through the complete cycle to shut-off. The next rocket will be scheduled in mid-April, to check the timers and amplifiers constructed by Superior Engineering Co. using the U. of M. design. The decision was made at this time to employ only transistor amplifiers henceforth, except that there are several vacuum tube amplifiers on hand which may be used as spares.

6. MISCELLANEOUS NOTES

During the first week in January 1962, 12 dummy grenades were fired through the nose cone which had been used for the elevated temperature test on 15 December 1961. As anticipated, all ejections were clean and without difficulty. The nose cone was only slightly damaged by heat, so it was repaired, recovered, repainted, and furnished to the GSFC to serve as a demonstration model, along with the timer, amplifier, battery pack, grenade bulkhead, and instrument can which had been previously furnished.

Development of a miniaturized, transistorized, plug-in type amplifier, a solid state timer, and a mechanical timer are continuing at low priority. Additional investigations of balloon ejection and inflation will be carried out at a later date.

Very little has been accomplished on the new task specified in contract NASr-54(02), namely investigation of the efficient production of low frequency sound. Such library search as has been carried out to date has turned up nothing directly bearing on the subject although there is considerable background material on atmospheric sound transmission and refraction. Further reading and consultation will be carried out during the next quarter.