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Combustion of Velcro in Low Gravity

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COMBUSTION OF VELCRO IN LOW GRAVITY

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SUMMARY

An experimental program was conducted to investigate the low-gravity burning characteristics of nylon and Nomex Velcro fastening tapes in an atmosphere of 30-percent oxygen, 70-percent nitrogen at a 70-kPa pressure. The tests were conducted using the NASA Lewis Research Center Zero Gravity Facility. The test results, as documented by high-speed cameras, indicate that both nylon and Nomex burn in low gravity for the full 5.18-sec test time but that Nomex burns less vigorously than nylon. Nylon melts as it burns, whereas Nomex forms a solid char. Nylon also sputters burning droplets as it burns. Thus, from these limited tests, it appears that Nomex Velcro is less hazardous than nylon Velcro for spacecraft applications. The results also show that residual gas velocities, and by analogy spacecraft air circulation, can enhance the low-gravity combustion.

INTRODUCTION

Fire safety on spacecraft has always been a major concern to NASA. The criteria for selecting and evaluating materials for use in spacecraft are very strict. The current test methods are described in NASA Document NHB 8060.1B, "Flammability, Odor, And Offgassing Requirements And Test Procedures For Materials In Environments That Support Combustion" (ref. 1). These tests are performed at normal Earth gravity. It is not possible to conduct routine acceptance testing at low gravity. However, normal-gravity testing of materials for spacecraft is justified, in part, by the early studies (refs. 2 to 8) that compared normal- and low-gravity combustion processes. These studies showed that in each case the normal-gravity combustion presented the more severe fire hazard. In low gravity, flame propagation was slow, and in some cases flames would self extinguish. These few test results have been generalized to the extent that there is, perhaps, a tendency to assume routinely that a low-gravity fire hazard can be satisfactorily assessed with the use of normal-gravity tests.

However, there is concern now that low-gravity fires may be more hazardous than was previously estimated. In special instances, the lack of gravity may actually assist in fire propagation rather than inhibiting it. An example is the case where a burning liquid or molten material ejects particles of burning material which would then float freely in the low-gravity environment. These burning particles could be carried by momentum or by air circulation to other materials far from the source of the fire. To look anew at fires in low gravity, NASA Lewis has begun a low-gravity experimental program to study the combustion of solid materials.

Nylon and Nomex Velcro were chosen for study in order to compare results to the Skylab experiment studying the burning of a piece of nylon in 65-percent oxygen at 36 kPa (ref. 8). The material burned for 10 minutes, 43 seconds, and motion pictures of the combustion showed an agitated pulsating flame that became more agitated as time passed. During the extinguishment by venting the atmosphere to vacuum, the burning intensified because of the gas movements. This was in contrast to the steady and self-extinguishing low-gravity combustion of other nonmetallic specimens. Because of this strange flame behavior and because the Velcro material presently used on the shuttle is an invaluable asset to the astronauts in space, the Johnson Space Center requested NASA Lewis to conduct a test program to evaluate the relative fire hazards of nylon and Nomex Velcro in an actual low-gravity environment. Nylon Velcro has a much longer wear life but Nomex Velcro is the less flammable material as determined from normal-gravity tests.

This paper presents the results of experiments conducted in the NASA Lewis Zero Gravity Facility on the burning of nylon and Nomex Velcro in low gravity. The goal of these experiments was to determine whether Velcro burning in low gravity would sputter burning droplets that could ignite surrounding materials. This report is organized into five sections. The first section describes the test conditions and experiment configuration, the second describes the test materials used, and the third details the sequencing of the tests and the test matrix. The fourth and fifth sections present and discuss the test results.

ACKNOWLEDGEMENTS

The authors would like to thank Ms. Janice Margle of the Pennsylvania State University - Ogontz Campus for her assistance in designing the ignition system for these tests.

EXPERIMENTAL COMBUSTION APPARATUS

The NASA Lewis Zero Gravity Facility is illustrated in figure 1. A complete description of the facility can be found in the appendix of reference 5. The 5.18 sec of reduced gravity is obtained by allowing the experiment to free-fall in a vacuum through a distance of 131.7 m. The estimated net gravity level experienced by the experiment package is 10^{-6} times that of normal Earth gravity. The combustion package in which the experiments were performed is shown in figure 2. Within the drop frame is a stainless-steel bell-shaped experiment chamber with an internal volume of approximately 0.1 m^3 (100 liters). A motion picture camera operating at 100 frames/sec was used to photograph the burning sample contained in the experiment chamber. A timing light generator recorded calibration marks on the film at 0.1-sec intervals.

Within the combustion chamber, the sample holder shown in figure 3 was designed to support the Velcro sample and the two mirrors that provide multiple views of the flame with a single camera. The side mirror was present in all tests, but the bottom mirror was added after the fourth test in order to view the observed flames below the sample. The light mounted to the right of the sample in the photograph illuminated the chamber to record the holder on film prior to ignition.

The test samples were mounted on a fibrous ceramic substrate which supported the sample and provided an insulating backing to minimize heat losses.

The substrate was clamped to the rectangular metallic holder through four extension tabs. This design permitted a maximum gas flow around all sides of the sample. The ignition source was a heated 0.8-mm-diameter Nichrome wire with a 1.1-Ω resistance. The ignitor wire covered the entire surface of the sample in multiple loops. This was to insure that the sample would be quickly and uniformly ignited over the entire surface. The ignitor was powered by 28 V for 5 sec in all tests.

The test atmosphere was 30-percent oxygen, 70-percent nitrogen at a 70-kPa pressure. From a fire safety perspective, this atmosphere is the most hazardous atmosphere regularly used on the shuttle. It is the atmosphere established for preconditioning prior to extravehicular activities to reduce the time astronauts must prebreath in their spacesuits. The test configuration described herein represents an attempt to maximize the material flammability characteristics in order to evaluate the worst-case fire hazard of the material. This is in accordance with the approach used in NHB 8060.1B (ref. 1), although no standard test configuration or method is described in that document for low-gravity tests.

TEST MATERIALS

The materials used in these tests were Velcro hook and pile fastener tapes (fig. 4) made of nylon and Nomex. The only chemical difference between nylon and Nomex is that the Nomex monomer has a chlorine atom replacing a hydrogen atom in the nylon monomer. Because the chlorine atom reacts with important intermediate ions produced during combustion, the chlorine acts as a fire inhibitor and thus Nomex is considered a fire retardant material.

The Velcro is produced by the manufacturer (ref. 9) in 5.08-cm- (2-in.-) wide tape with an adhesive-coated backing. Samples for testing were cut to be 5.08 cm (2 in.) square. The Velcro tapes were woven with a 0.16-cm (1/16-in.) selvage on each edge. Both the nylon and Nomex hook tapes were made of 0.017-mm- (6.5-mil-) diameter nylon monofilaments. The nylon hook tape used nylon hooks with over 62 hooks/cm^2 (400 hooks/in.^{2}) on a nylon base. The Nomex hook tape also used nylon hooks spaced about 50 hooks/cm^2 (340 hooks/in.^{2}) but on a Nomex base. Nylon was used by the manufacturer to make the actual hooks for the Nomex hook tape because Nomex hooks do not wear well under repeated use. The nylon and Nomex pile tapes consisted of uniformly distributed loops in nylon and Nomex, respectively. The adhesive backing used for the nylon Velcro was a permanent or pressure-sensitive adhesive. The adhesive backing used for the Nomex Velcro was a fire-retardant adhesive.

The important difference in the two materials is their wear lifetime. Nylon Velcro has a lifetime of over 10,000 uses whereas Nomex Velcro has a lifetime of only about 1200 uses because of faster breakage of the loops in the Nomex pile tape. For durability, nylon is the more desirable material.

TEST PROCEDURES

Prior to each test the sample and ignitor wire were mounted on the holder and placed within the experiment chamber. The experiment chamber was then evacuated and finally filled with the test atmosphere. The experiment package was loaded into the drop position, and the facility vacuum chamber was sealed and evacuated. In all tests the ignition was initiated in normal Earth gravity. This was done to establish uniform burning of the entire sample and to accumulate enough melted material to maximize the probability of observing sputtering of molten material during the low-gravity test time (5.18 sec). After a specified normal-gravity delay time, the package was released to create a low-gravity environment.

A delay time of 10 sec was chosen for the first four tests, each with a different material. Prior normal-gravity tests indicated that within 10 sec each material would ignite and establish uniform burning over the entire sample long enough to accumulate a substantial amount of molten material. However, the low-gravity flames observed with the four materials were difficult to analyze because they were strongly distorted by residual normal-gravity buoyancy-induced flows. In an attempt to reduce these residual gas movements, the delay time was decreased to 5 sec so that the experiment package was released just after the igniter wire was turned off. The subsequent two tests with this delay time showed even more drastic flame disturbances. For the remaining tests the delay time was shortened to 3 sec, which was determined to be the minimum delay time based on the normal-gravity tests. For each material in normal gravity, it took 3 sec to achieve a uniform combustion of the sample even though the igniter remained on for 5 sec. The tests performed with this delay time did show greatly reduced flame disturbances from residual gas flows.

Ten low-gravity experiments were performed with the four materials and the three normal-gravity ignition delay times. The test conditions for the ten tests are listed in table I. Eight of the ten tests were successful; the remaining two tests extinguished on entering low gravity because the ignitor wire lifted off the surface of the sample.

The only data recorded during these tests were color motion pictures of the flames from ignition to just after impact of the experiment package. While the results are therefore qualitative in nature, some important conclusions may be derived from the tests. A composite film of the test results is available from the NASA Lewis Research Center (Film Serial MPD 1678).

RESULTS

All the materials burned for the full 5.18 sec of low-gravity test time. Of the four materials tested with the 10-sec delay, the Nomex pile (test 1) had the least vigorous burning characteristics. Near the end of the 5 sec of low-gravity the Nomex pile flame had dimmed to a very faint small blue flame with intermittent flashes of yellow. Since this demonstrated that the Nomex pile is the slowest burning and potentially the least hazardous of the four materials, the remaining tests were confined to the other materials. The Nomex hook flames (test 2) were roughly twice as large and much sootier than the Nomex pile flames and also appeared to be growing brighter and larger near the end of the test time.

Both of the nylon materials showed much more energetic burning characteristics than the Nomex materials. The nylon pile (test 3) had large bright flamelets emerging from the flame zone, and the flames were strongly affected by eddy gas motions resulting from the normal-gravity ignition. The nylon hook combustion (test 4) behaved in a similar way, and two burning droplets of molten material were observed being ejected from the flame zone as a result of these flamelets. The nylon hook combustion was much sootier than the nylon pile, an observation also made for the Nomex materials.

Because the nylon materials were very disturbed by eddy gas motions caused by the normal-gravity ignition, these materials were tested again with a delay time of 5 sec in an attempt to reduce the buoyancy-induced gas flows (tests 5 and 6). Reducing the delay time, instead of subduing the flow, had the opposite affect. A greater quantity of fuel vapor was seen to flow from the fuel surface, causing the flame to swell to a much larger size than in the previous tests. It appeared that the increased flame size was caused by the elimination of 5 sec of normal-gravity convective cooling of the igniter wire after it was de-energized. The very hot ignitor wire caused much of the sample to vaporize during the early part of the experiment. The flamelets, however, did not appear until late in the test time, and they were not as large or as frequent as they were with the 10-sec delay time. It is thought that the shorter normal-gravity burn time reduced the amount of molten material available as the flames went into low gravity. Again, the hook was much sootier than the pile.

The remaining tests were performed with a 3-sec delay. This delay time showed some flame size increase but to a much smaller degree than was the case for the 5-sec delay because the flame was only present in normal gravity for a very short time. Thus, most of the ignitor wire heating went into the preheating and ignition of the sample. The test of nylon pile was performed twice (tests 9a and 9b) but in both instances the igniter wire lifted off the sample surface on entering low gravity and caused the sample to quench. For the nylon hook test 7 the wire partially lifted off the surface, carrying a small piece of sample with it. That small burning bit of material drifted slowly away from the wire and broke into smaller fragments before burning completely.

The test of nylon hook tape with a 3-sec delay was much less disturbed by gas flows around the sample than the previous tests. The flames were sporadic; that is, fuel vapors coming from the fuel surface would diffuse away from the surface and then ignite into a moving flame front. Each flame front lasted approximately 0.5 sec and propagated 2 or 3 cm before extinguishing. A short time later another flame front would propagate in a different direction.

Test 7 of the Nomex hook tape was of particular interest because in this test no residual gas movements were observed. The flame propagated above the sample as a single hemispherical front. This test thus best represents a zero-gravity flame in a completely quiescent environment. The flame propagated for almost 3 sec at approximately 1.5 cm/sec. The flame front then faded from orange to red and then disappeared from view. There was, however, a continued low level of combustion at the fuel surface generating fuel vapors. When the concentration of fuel and oxidizer at the last visible position of the hemispherical flame front reached the flammability limit, a thin flame front outlined that hemisphere again. Thus, it appeared that the rate of flame front propagation was controlled by the rate of diffusion of fuel and/or oxidizer to that region.

DISCUSSION

The flame intensity and shape at any time during these tests was most strongly influenced by the direction and strength of the residual buoyancy-induced gas movements. The development of the hemispherical flame front in the absence of residual gas movements is shown in figure 5 from test 8 with Nomex hook tape. In this series of still photographs the direct view of the sample edge-on is at the center, with two mirror views at the left and bottom. In contrast, figure 6 shows the same Nomex hook material in test 2, where the longer ignition delay time in normal-gravity promoted residual gas movements. Again the direct edge-on view is in the center and the single mirror view is at the left. The flow past the sample caused the flame to intensify at the point where the flow first contacted the burning sample. The residual gas velocities were estimated where possible by tracking glowing soot particles being carried along in the flow. The measured velocities were from 5 to 12 cm/sec.

For the tests with nylon, boiling the nylon sample was stimulated by the residual gas flow. The gaseous nylon bubbles ignited as they left the surface and appeared as flamelets, which would spurt out from the flame zone. In a few instances these eruptions broke off a small droplet of the liquid fuel, which then separated from the flame zone at high velocities. Figure 7 from test 4 shows a series of photographs of nylon hook burning in low gravity under the influence of strong residual gas flows. A liquid droplet is shown ejecting from the fuel surface in figure 7(c). Although the velocities were difficult to measure because of the three-dimensional trajectories of the droplets, all velocities were higher than 30 cm/sec. These droplets continued to burn vigorously until the fuel was completely consumed. It is possible, because of the high ejection velocities observed, that larger droplets could travel very far from their source before being consumed.

The boiling phenomenon observed with the nylon materials is similar to that observed by Kashiwagi (ref. 10) in PMMA and PE samples. In his experiments he noted that bubbles burst through the highly viscous melted polymer very violently and frequently caused vapor jets to extend a few centimeters out from the melt surface. These jets of gaseous fuel also threw molten material into the gas phase. He concluded that the bubbles comprised a substantial mechanism of mass transport from the solid into the gas phase. Additionally, he noted that increasing the oxygen concentration of the surrounding atmosphere significantly reduced the melt viscosity near the surface, which enhanced the bubble transport.

The nylon pile material burned less vigorously than the nylon hook material and formed less soot. These tendencies are most likely due to the different configurations of the two materials. The pile is in the form of very fine fibers which are packed very tightly together, whereas the hook is in the form of much thicker and more widely spaced bristles. It can be speculated that the less homogenous fuel and oxidant environment in the hook configuration promotes more rapid mixing while creating nonuniform fuel-rich and fuel-lean zones. This can allow increased mixing and more vigorous burning while at the same time promoting soot production in the fuel-rich zones.

Only the nylon-based materials showed a tendency to boil and to eject material. The Nomex pile, which is the only one of the four materials tested made completely of Nomex, did not show any flamelets at its leading edge. The Nomex material formed a char as it burned rather than a melt, a further indication that the flamelets observed with the nylon are caused by boiling the melted nylon. The Nomex hook did have flamelets at the leading edge of the material, because the hooks of the Nomex hook sample were actually made of nylon, but these flamelets were smaller than those observed with the materials made completely of nylon. This may be due to the combustion-inhibiting effect of the Nomex base.

These studies indicated that the Nomex material is clearly superior to nylon with respect to fire safety. Furthermore, the studies also showed that the relatively slow flame propagation in low gravity does not necessarily provide a safety factor for flammability hazard assessments made from normal-gravity tests. First, air circulation in inhabited spacecraft modules can supply fresh oxidizer to the flame as well as remove the products of combustion. The velocities of the air motions on the inhabited spacecraft are typically 8 to 20 cm/sec (ref. 11). These air currents are as great or greater than the residual gas movements in these tests which were observed to intensify and spread the flames. Second, flame propagation by mass transfer of burning material, as evidenced by the nylon tests, poses a distinct hazard in low gravity.

CONCLUDING REMARKS

An experimental program was conducted to investigate the low-gravity burning characteristics of nylon and Nomex Velcro fastening tape in an atmosphere of 30-percent oxygen, 70-percent nitrogen at a 70-kPa pressure using the NASA Lewis Research Center Zero Gravity Facility. The four material sample types were Nomex hook and pile and nylon hook and pile. The other parameter varied was the length of the ignition induction period before the low-gravity test was initiated.

It was observed that all the materials tested burned for the full 5 sec of low gravity. Nomex pile appeared to be the least flammable material because the flames were weakening near the end of the test. The Nomex hook, although partially constructed of nylon, also showed a reduced flammability. The nylon materials in three of seven tests were observed to eject burning material away from the fuel source. In two instances these burning droplets had a substantial velocity which, had they not been small and thus short-lived, would have carried them far from the fuel source.

Gas flow around the burning material very strongly influenced the nature of the combustion. For those tests where gas flow was very weak, the flames were correspondingly weaker. The gas flows were the primary source of the very vigorous combustion at the leading edge of the flame from which the burning droplets originated.

Thus, the tests indicated that, qualitatively, Nomex Velcro is a less hazardous material than nylon Velcro for use in spacecraft. The tests also showed that the generally slow low-gravity flame propagation can be enhanced by residual gas flows and by mass transfer from the burning materials. Further research on the effect of spacecraft air circulation on solid material flammability is needed.

REFERENCES

1. Flammability, Odor, and Offgassing Requirements and Test Procedures For Materials In Environments That Support Combustion. NASA NHB 80.60.1B, NASA TM-84066, 1981.

2. Kimzey, J.H., et al.: Flammability in Zero-Gravity Environment. NASA TR R-246, 1966.

3. Neustein, R.A., et al.: The Effect of Atmosphere Selection and Gravity on Burning Rate and Ignition Temperature. (DAC-62431. McDonnell Douglas Astronautics Co.; NASA Contract NASW-1539.) NASA CR-106652, 1968.

4. Andracchio, C.R.; and Aydelott, J.C.: Comparison of Flame Spreading Over Thin Flat Surfaces in Normal Gravity and Weightlessness in an Oxygen Environment. NASA TM X-1992, 1970.

5. Cochran, T.H., et al.: Burning of Teflon-Insulated Wires in Supercritical Oxygen At Normal and Zero Gravities. NASA TM X-2174, 1971.

6. Andracchio, C.R., and Cochran, T.H.: Burning of Solids in Oxygen-Rich Environments in Normal and Reduced Gravity. NASA TM X-3055, 1974.

7. Andracchio, C.R.; and Cochran, T.H.: Gravity Effects on Flame Spreading Over Solid Surfaces. NASA TN D-8228, 1976.

8. Kimzey, J.H.: Skylab Experiment M-479, Zero Gravity Flammability. NASA JSC-22293, Aug. 1986.

9. The VELCRO Circle of Fastening Knowledge, #181050 M, VELCRO, USA, Inc., 1981.

10. Kashiwagi, T.; and Ohlemiller, T.J.: A Study of Oxygen Effects on Non-flaming Transient Gasification of PMMA and PE During Thermal Irradiation. 19th Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, 1982, pp. 815-823.

11. Roth, E.M.: Space-Cabin Atmospheres: Part II - Fire and Blast Hazards. NASA SP-48, 1964.

TABLE I. - SUMMARY OF LOW-GRAVITY COMBUSTION TESTS

Test	Material	Delay time, sec
1	Nomex pile	10
2	Nomex hook	10
3	Nylon pile	10
4	Nylon hook	10
5	Nylon pile	5
6	Nylon hook	5
7	Nylon hook	3
8	Nomex hook	3
[a]9a	Nylon pile	3
[a]9b	Nylon pile	3

[a]Unsuccessful.

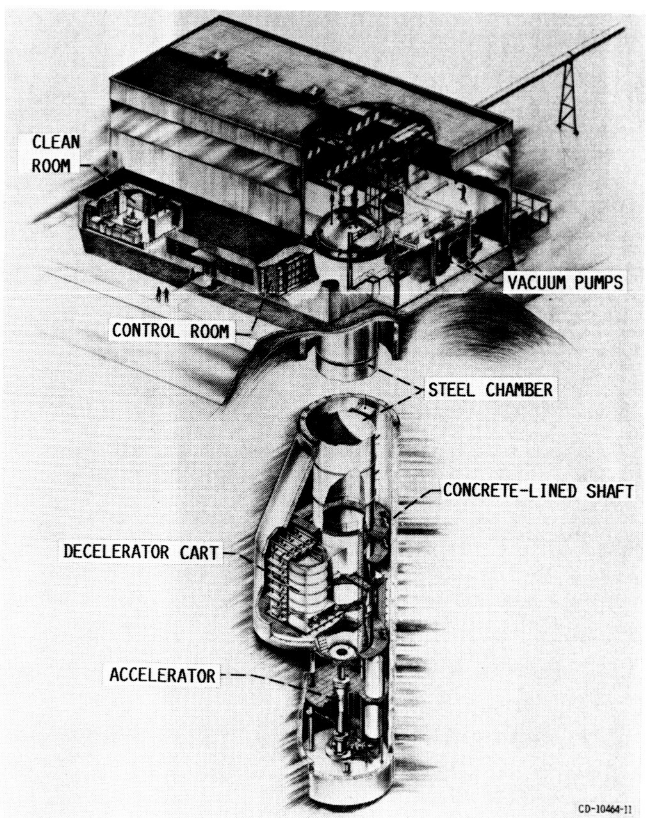

FIGURE 1. - CUTAWAY OF NASA LEWIS RESEARCH CENTER ZERO GRAVITY FACILITY.

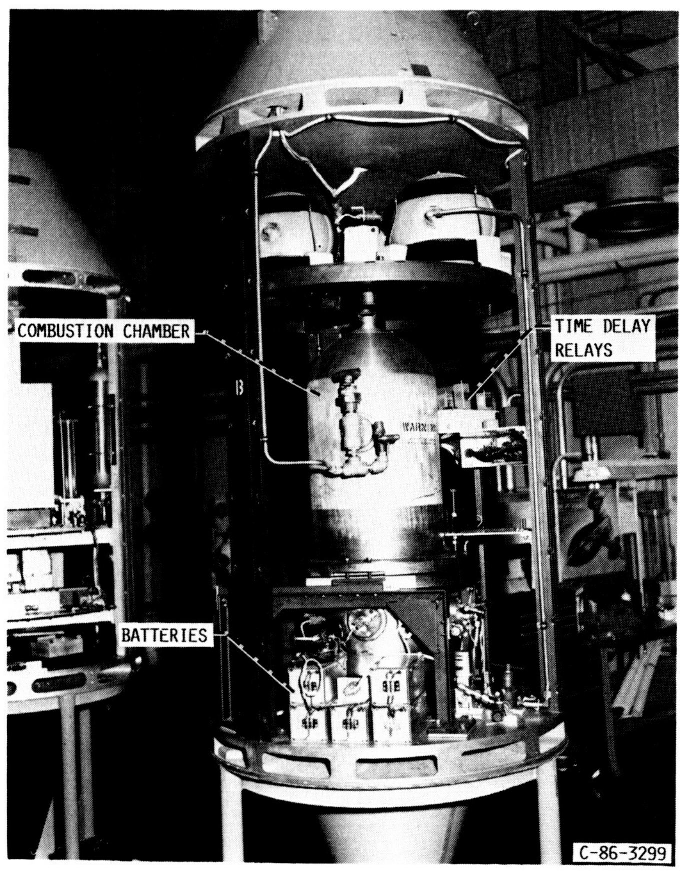

FIGURE 2. - DROP PACKAGE WITH EXPERIMENT CHAMBER.

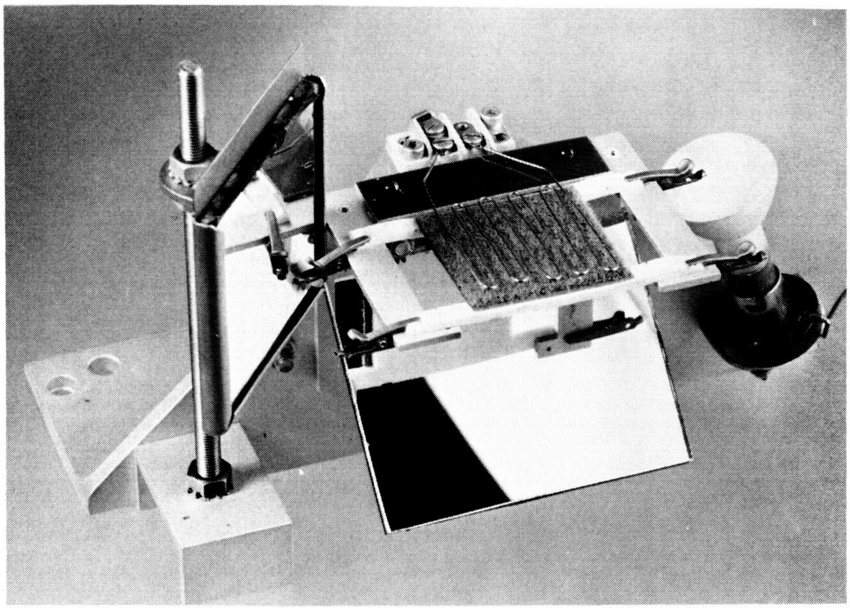

FIGURE 3. - VELCRO SAMPLE HOLDER.

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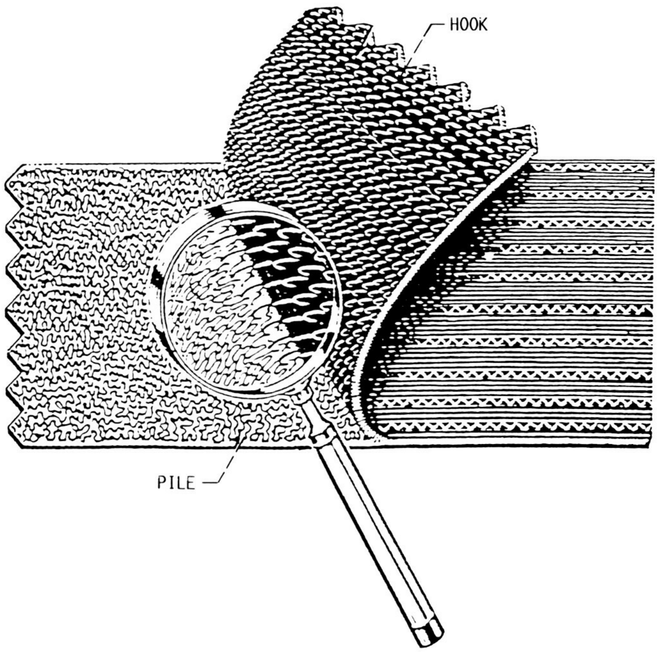
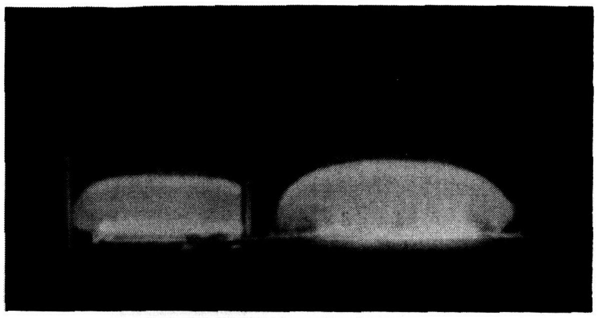


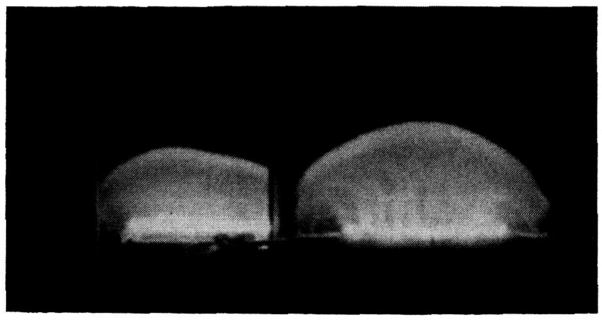
FIGURE 4. - VELCRO TAPE COMPONETS.



(A) TIME, t, 0.66 SEC.

(B) TIME, t, 0.86 SEC.

(C) TIME, t, 1.06 SEC.

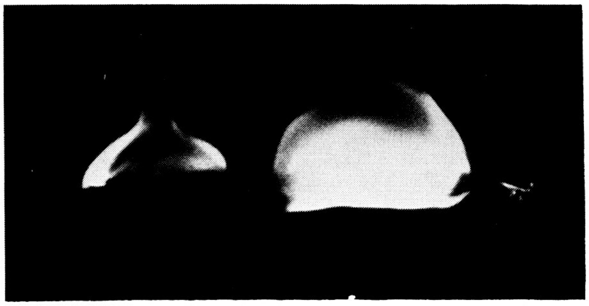


(D) TIME, t, 1.26 SEC.

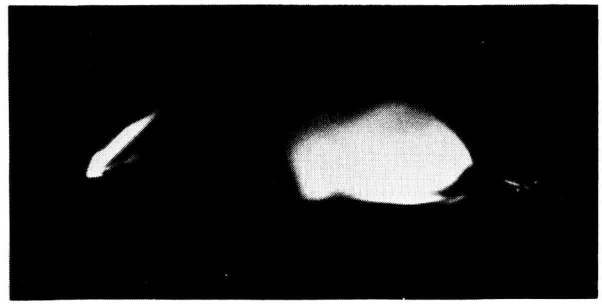
(E) TIME, t, 1.46 SEC.

(F) TIME, t, 1.66 SEC.

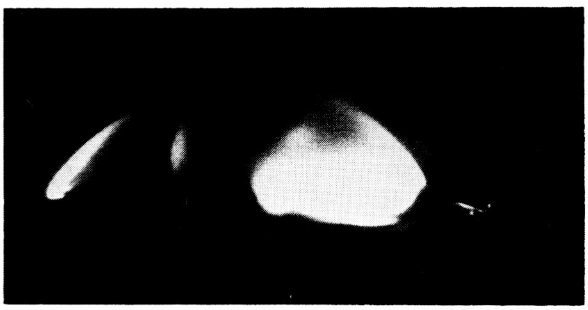
FIGURE 5. - NOMEX HOOK DURING TEST 8 DEVELOPING AS HEMISPHERICAL FLAME IN ABSENCE OF RESIDUAL GAS.



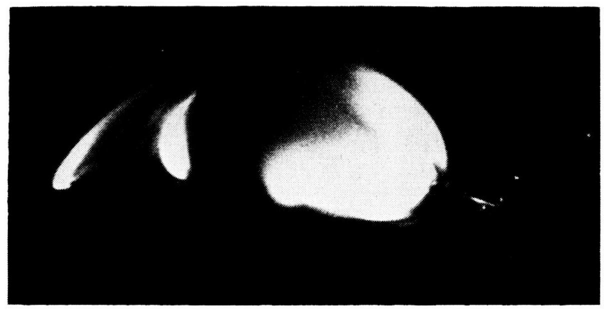
(A) TIME, t, 0.56 SEC.



(B) TIME, t, 0.93 SEC.



(C) TIME, t, 1.60 SEC.

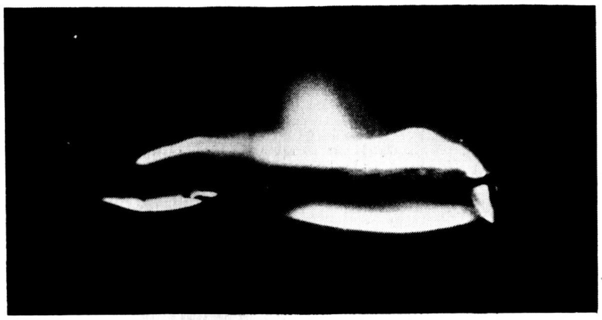


(D) TIME, t, 1.84 SEC.

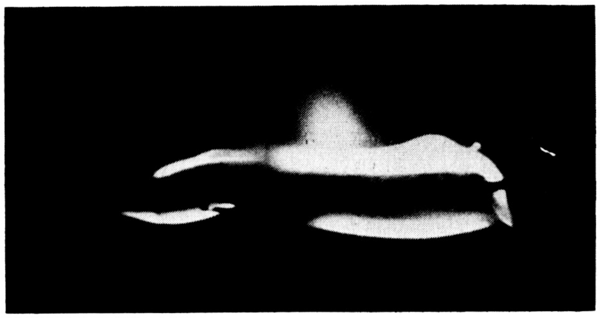
(E) TIME, t, 2.29 SEC.

(F) TIME, t, 3.01 SEC.

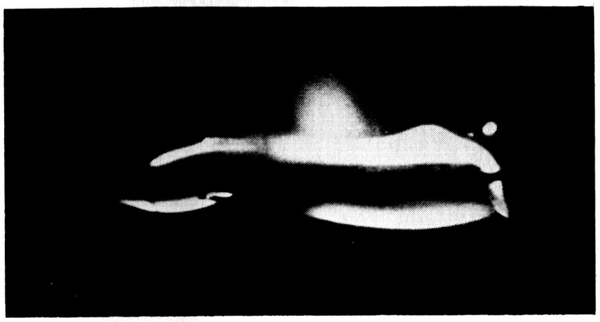
FIGURE 6. - NOMEX HOOK DURING TEST 2 DEVELOPING NONSYMMETRICALLY DUE TO RESIDUAL GAS FLOWS AROUND THE SAMPLE.



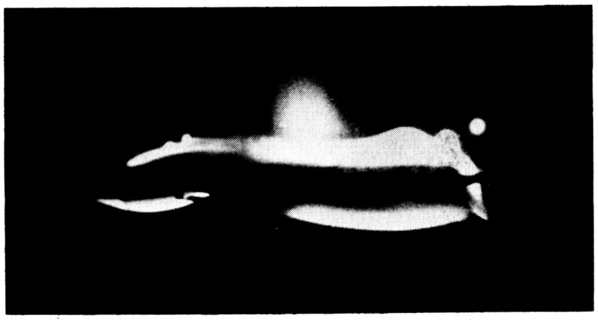
(A) TIME, t, 4.99 SEC.



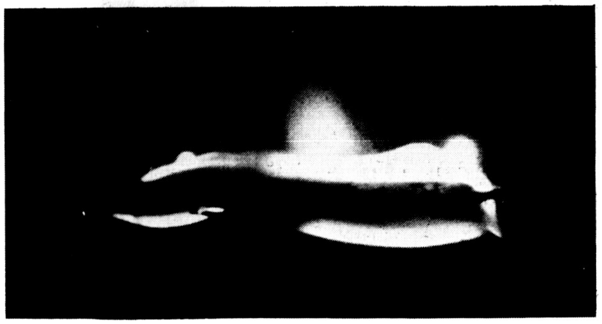
(B) TIME, t, 5.00 SEC.



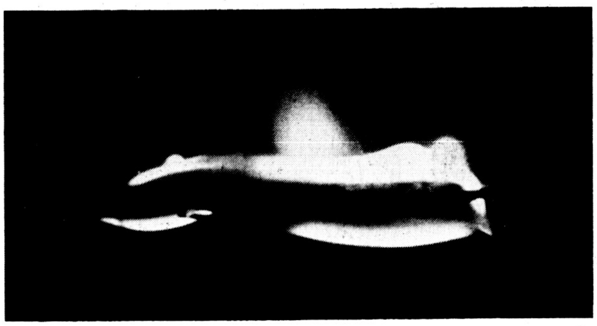
(C) TIME, t, 5.01 SEC.



(D) TIME, t, 5.02 SEC.



(E) TIME, t, 5.03 SEC.



(F) TIME, t, 5.04 SEC.

FIGURE 7. - NYLON HOOK DURING TEST 4 EJECTING A BURNING DROPLET OF MOLTEN NYLON.

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15. Supplementary Notes

16. Abstract

An experimental program was conducted to investigate the low-gravity burning characteristics of nylon and Nomex Velcro fastening tapes in an atmosphere of 30-percent oxygen, 70-percent nitrogen at a 70-kPa pressure. The tests were conducted using the NASA Lewis Research Center Zero Gravity Facility. The test results, as documented by high-speed cameras, indicate that both nylon and Nomex burn in low gravity for the full 5.18-sec test time but that Nomex burns less vigorously than nylon. Nylon melts as it burns, whereas Nomex forms a solid char. Nylon also sputters burning droplets as it burns. Thus, from these limited tests, it appears that Nomex Velcro is less hazardous than nylon Velcro for spacecraft applications. The results also show that residual gas velocities, and by analogy spacecraft air circulation, can en- hance the low-gravity combustion.

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