AVCO

APOLLO HEAT SHIELD NEWS

AVCO

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FOR IMMEDIATE RELEASE

AVCO HEAT SHIELD PROTECTS APOLLO 11 CREW

LOWELL, MASS. --- Schirra, Eisele, Cunningham, Borman, Lovell, Anders, McDivitt, Scott, Schweickart, Stafford, Young, Cernan -- the crews of Apollo missions that have successfully brought the United States to the threshold of a lunar landing.

They have circled the globe, circumnavigated the Moon, and returned safely to earth.

When astronauts Armstrong, Collins, and Aldrin, the Apollo 11 crew, return from their lunar landing mission, they, too, will be subjected to the perilous and breathtaking moments of entry into the earth's atmosphere.

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As with all previous Apollo missions, the success of the last fifteen minutes of the return journey from the Moon, will depend upon the ability of a thin layer of plastic-type material to counteract heat generated by the rapid entry into the earth's atmosphere.

The thermal protection system of the Apollo Command Module (CM), devised and fabricated by Avco Applied Technology Division (Avco/ATD), Lowell, Mass., will do battle with surface heat that will rise to approximately 5,000^{o}F. During the period of entry, the three-man crew will remain comfortable and untouched by the heat in a cabin having a temperature range of between 70^{o} and 80^{o}F (usually closer to 70^{o}).

The heat shield will provide the protection after having traveled through temperatures in outer space that, at the surface of the CM, could drop to minus 150^{o}F. The final jump during the period of entry of from 150^{o} below zero to over 5,000^{o} above zero will take place while the craft is traveling at a speed of nearly 25,000 m.p.h.

The development of the ablative heat shield material -- a phenolic epoxy resin, or type of reinforced plastic -- was the result of three years research by Avco/ATD. Working with NASA and the North American Rockwell Corporation, Avco research centered around two primary aims: (1) the production of a material able to cope with the unique environments of a lunar mission while taking into account stringent weight restrictions, and (2) the development of innovative techniques for the application of the material -- in varying thicknesses -- across the stainless steel substructure of the CM. The thickness of the material when fabrication is completed averages two inches.

Because of the dramatic difference in entry speeds, the Apollo heat shield has been designed to weather twice as much heat as that encountered by Gemini and Mercury spacecraft.

During entry the heat shield will undergo a rise in temperature true in any burning cycle: charring, followed by combustion and/or melting. The job of the heat shield is to control the rate of absorption.

It does this by ablating, or dissipating the heat away from the vehicle's metal structure by a combination of vaporizing and charring, allowing the burning action to consume the ablative material (some 300 pounds over a fifteen minute period) rather than the structure itself. In this fashion, the burning cycle produced by excessive heating is controlled before it spreads back to the steel surface of the vehicle, at which point rapid melting and destruction would be unavoidable.

The Avco ablative heat shield underwent several qualifying tests before NASA certified it for manned missions. Heat shield performance tests were among the primary objectives of four unmanned flights (AS 201, AS 202, Apollo 4, Apollo 6).

Ablator performance in the four flights met all test objectives. There was no structural damage to the spacecraft, nor were there any areas of undue burning on the heat shield. Results from the manned missions have been as equally impressive.

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AVCO/ATD UTILIZES SPECIAL MANUFACTURING TECHNIQUES FOR THE APOLLO HEAT SHIELD

The Apollo ablative heat shield developed by Avco Applied Technology Division (formerly Space Systems Division), Lowell, Mass., is a low-density composite material based on an epoxy resin, reinforced with a fiberglass honeycomb structure, and containing reinforcing fibers. Because of rigorous mission requirements and the particular nature of the ablative material, Avco had to develop unique fabrication techniques.

Two factors are paramount: (1) Weight must be kept to a minimum; (2) Contour requirements are complex. The heat shield's thickness varies greatly around the spacecraft, aligned with the amount of reentry heat to which each area of the vehicle is exposed.

Throughout the entire mission, the metal out of which the Command Module is constructed and its ablative material with which it is covered must shrink and expand together so as not to cause damage to either surface.

Avco/ATD fabricates the ablative heat shield on the aft section, crew compartment and forward section, which comprise the spacecraft's so-called Block II, or lunar-type Command Module. (On spacecraft designed for orbiting the moon, the nose cap on Block I, earth orbiting vehicles, is eliminated to permit docking with the Lunar Module (LM) in which two members of the crew descend to the moon's surface.)

After delivery to Lowell from North American Rockwell's Space Division in Downey, California, prime contractor for the Apollo Command and Service Modules, weight and center of gravity determinations are made of the Command Module's metal substructure. Fiberglass honeycomb

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panels are prefitted then fixed to the substructure with a special adhesive tape, and oven-cured at about 350°F. Ultrasonic inspection of the bonding is made after cure.

The ablative material can be prepared ahead of time. Dry and liquid ingredients are weighed and mixed separately, then mixed as a composite, after which catalysts and hardeners are added. Mixing sequence and temperature are critical to obtaining the correct density. Batches of finished ablator are stored in a deep freeze, and dielectrically heated before being injected into each of the 350,000 fiberglass honeycomb cells which now comprise the Command Module's surface.

After all cells are filled, the ablator-covered vehicle is oven-cured at about 250°F, for periods of from one hour to four days, depending on the section.

Since conventional injection equipment could not handle the fibrous ablative material, guns were designed for this task, containing a heating element to allow temperature control of the ablation material during injection. All gunners must complete a training program before being certified to work on actual hardware.

The surface of the substructure has various panels and hatches for crew access, maintenance, and windows. These joints are sealed by a silicone rubber compound cured at room temperature.

Heat shield panels which fit in abort tower wells and rendezvous windows are bonded in place separately, using a low-temperature oven cure.

The entire structure is now machined on a computer-controlled vertical axis turret lathe, with tolerances up to 50,000ths of an inch.

In order to keep weight to a minimum, much of the material in areas of less-severe heating is machined off. The thickness differs by a factor of approximately three inches from thickest to the thinnest areas. A final x-ray inspection is made, and the thickness of the heat shield checked. A pore sealer is applied, and the Command Module given a final coating of white paint.

Weight and center of gravity determinations are again made and the Module is recrated and returned to North American Rockwell to be fitted over the inner crew compartment and mated with the rest of the spacecraft. The heat shield is ready to do its job of helping bring the NASA astronauts safely back to earth.

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BACKGROUNDER

THE DEVELOPMENT OF REENTRY THERMAL PROTECTION MATERIALS BY AVCO

Behind the selection of Avco's Applied Technology Division (formerly Space Systems Division) for the critical task of developing, designing, and fabricating the ablative heat shield of the Apollo Command Module lies ten years of pioneering research in the development of materials to survive reentry into the earth's atmosphere.

For the Apollo lunar mission, at earth reentry, heat shield temperatures of the Command Module can go as high as 5,500°F. Other crucial factors will be involved. First, the heat shield will be protecting human lives -- the three NASA astronauts. Secondly, the lunar vehicle will be subjected to temperatures as low as minus -150 degrees in the vicinity of the moon. Thirdly, the heat shield must perform under these and other exacting conditions within stringent weight restrictions.

The first two of these conditions are unique in the development of manned spacecraft. The protective heat shield must cover the complete return spacecraft because of the Apollo's higher velocity of return (about 36,000 ft. per sec.) as compared to the lesser return velocities of the Mercury and Gemini -- about 25,000 feet per second. And, even during the period of peak heating, the interior of the Apollo spacecraft must be maintained at "room temperature" for the safety and performance efficiency of the astronauts.

The beginning of Avco's involvement in the development of materials was imposed by the necessity of devising materials which could survive reentry into the atmosphere as the delivery package for the warhead of an Air Force intercontinental ballistic missile (1955 - 1956).

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At first, the problem seemed unsolvable . . . even to some of the nation's leading scientists.

The initial answer was a heat-sink reentry vehicle basically composed of copper and stainless steel, nickel-plated to assist in absorbing the heat of reentry. While it could perform satisfactorily, the vehicle's dense construction meant a "heavyweight" payload package.

Because of the desirability of reducing weight, always an important factor of consideration in the development of ICBM's, the next objective was to develop materials of lower density which used a different thermal protection mechanism principle. Ceramics and plastic composites which ablate or vaporize in order to dissipate heat away from the payload seemed to offer the best possibilities. The Division's continuing program of materials research and development met this requirement for lower weight thermal protection with AVCOITE I, a ceramic composite reinforced with a metal honeycomb. The success of AVCOITE I and the ablation theory was flight-proven in a historic launch from Cape Kennedy at ICBM range and velocities in April, 1959.

Eventually, and continuing to the present, Avco-designed reentry vehicles protected by Avco-developed materials have been flown successfully on all of the U. S. Air Force ICBM's, from the Atlas and Titan to the Minuteman I and the advanced-design Minuteman II.

The transition from missile reentry materials technology to spacecraft materials requirements followed as a logical consequence. From 1959 and the demonstrated success of AVCOITE to the present, Avco research and development continued to produce a family of new materials specifically to solve high temperature problems. These included a phenolic resin with silica fibers, a low thermal conductivity tape-wound material, and epoxy materials reinforced with various forms of silica.

Actually, even before the Applied Technology Division received the initial contract for the development and fabrication of the Apollo ablative heat-shielding system (from North American Rockwell Corp. in 1962), Avco's materials scientists had been working on development of suitable materials for the Apollo spacecraft. This was a company-funded research and development program.

In 1961, Division scientists and engineers designed and built three nose caps for materials test flight on a Scout advanced research vehicle. The work was performed under contract to the NASA Langley Research Center.

It was during this pre-contract period that the eventual configuration of the Apollo heat shield began to evolve. As in all previous materials developments, the effort was supported by the Division's outstanding testing facilities. These, among the finest in the nation, include electric arc devices ranging from 30 kw. models up to 10 megawatt giant (10 million watts) which can simulate the complete profile of reentry from a lunar mission; numerous shock tubes up to 100 feet in length, and ballistic ranges where light gas guns fire aerodynamic test projectiles at velocities exceeding 25,000 feet per second.

In addition, the Division's non-destructive test laboratories created unique techniques to evaluate Avco's ablative material. For example, the contrast amplification of X-rays had to be improved over those available by standard methods. New ultrasonic testing techniques were also developed because previous procedures were not adequate for evaluating the bonding of Apollo material to the spacecraft. Also, special dielectric probes were designed to sense moisture in both raw materials and the final ablative material.

The materials development stages for the Apollo heat shield followed a planned cycle of screening and optimization which has resulted in the final product . . . the ablative heat shield (based on an epoxy resin reinforced with a fiberglass honeycomb structure) which will protect the lives of the NASA astronauts assigned to the lunar mission.

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APOLLO MISSION
Launch and Entry Data Sheet

Apollo Mission AS 201
CSM 009, Saturn 1B-201

February 26, 1966
Launch: 11:12 a.m. (EST)
Landing: 11:52 a.m.
Supercircular Entry with High Heat Rate
Entry Speed: 18,000 mph
Maximum Entry Surface Temperature: 4000°F

Apollo Mission AS 202
CSM 011, Saturn 1B-202

August 25, 1966
Launch: 12:16 p.m. (EST)
Landing: 1:49 p.m.
Supercircular Entry with High Heat Load
Entry Speed: 19,400 mph
Maximum Entry Surface Temperature: 3000°F

Apollo 4
CSM 017, Saturn V-501

November 9, 1967
Launch: 7:00 a.m. (EST)
Landing: 3:37 p.m.
Supercircular Entry at Lunar Return Velocity
Entry Speed: 24,916 1/3 mph
Maximum Entry Surface Temperature: 4200°F

Apollo 5
LM-1, Saturn 1B-204

January 22, 1968 - January 23, 1968
Launch: 5:48 p.m. (EST)
First Lunar Module Flight, Earth Orbital
CSM Not Flown
Duration of Mission: 7 hrs., 52 minutes

Apollo 6
CSM 020, Saturn V-502

April 4, 1968
Launch: 7:00 a.m. (EST)
Landing: 4:57 p.m.
Entry Speed: 22,300 mph
Maximum Entry Surface Temperature: 3000°F

Apollo 7
CSM 101, Saturn 1B-205

October 11, 1968 - October 22, 1968
Launch: 11:03 a.m. (EDT)
Landing: 7:11 a.m.
First Manned Apollo Saturn V Earth Orbital Flight
Entry Speed: 17,500 mph
Maximum Entry Surface Temperature: 2700°F

Apollo 8
CSM 103, Saturn V-503

December 21, 1968 - December 27, 1968
Launch: 7:51 a.m. (EST)
Landing: 10:51 a.m.
First Manned Circum Lunar Flight
Entry Speed: 24,751 1/3 mph
Maximum Entry Surface Temperature: 4200°F

Apollo 9
CSM 104, Saturn V-504

March 3, 1969 - March 13, 1969
Launch: 11:00 a.m. (EST)
Landing: 12:01 p.m.
First Lunar Module Test Flight, Earth Orbital
Entry Speed: 17,500 mph
Maximum Entry Surface Temperature: 2700°F

Apollo 10
CSM 105, Saturn V-505

May 18, 1969 - May 26, 1969
Launch: 12:49 p.m. (EDT)
Landing: 12:52 p.m.
Full Dress Rehearsal for Apollo 11 Mission
Entry Speed: 24,759 1/3 mph
Maximum Entry Surface Temperature: 4200°F

Apollo 11
CSM 106, Saturn V-506

Scheduled Launch Date: July 16, 1969
Scheduled Moon Landing: July 20, 1969
Scheduled Splashdown: July 24, 1969
First Manned Lunar Landing
Expected Entry Speed: 24,760 mph
Expected Maximum Entry Surface Temp: 4200°F

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