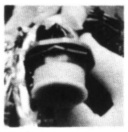
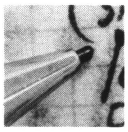




North American Rockwell
Aerospace & Systems Group

SKYLINE VOL. 27 No. 3, 1969

Published quarterly by the Aerospace and Systems Group of North American Rockwell Corporation for employees. Contents copyrighted 1969 but may be reprinted with credit.

Printed in the U.S.A.

John J. Oswald
Group Director of Public Relations
A. R. Sorrells, Publications Manager
L. B. Taylor, Jr., Editor

Despite a determined effort, young Marie Machuszek, bucking wind currents and the forces of Earth's gravity, cannot blow a perfect sphere with her bubble pipe. Perfect spheres can be made out of many kinds of metals in space, however, promising exciting future manufacturing dividends. See page 26.

Cover photo by Bill James. Pages 4 and 9 (right), NASA photos. Pages 12 and 13 (bottom), FBI photos.

Art and Production, Executive Offices Services.

Is it good enough for Charlie?

For Homeward-Bound Moon Explorers, the Lunar Module Ascent Engine HAS to Fire.

There comes a time on every major manned space flight when the outcome — the degree of success or failure — of the entire mission hinges on one critical maneuver. In the purest sense, of course, every step in a complicated sequence of events can be considered critical. Booster engines must fire on time and with just the right amount of thrust. Upper stages have to separate at a precise moment. Rocket engines must build to exacting levels of acceleration. Complex spacecraft systems must perform to perfection. All this is true and cannot be understated or taken for granted.

Still, there is one heart-stopping instant on every flight that is remembered above all others. Seven years ago, as John Glenn circled Earth in Friendship Seven, it occurred when he fired the retro-rockets, slowing his orbital speed for re-entry. Last December, pulses quickened and breaths shortened when Apollo 8 crew members sailed behind the dark side of the moon for the final time, and, there, out of sight and reach of communication or help they triggered the vital spacecraft service propulsion system engine which kicked them free of lunar orbit and toward their home planet.

There will come such a time, too, on the first manned lunar landing expedition. To be sure, there will be hundreds of interlocking functions, each of paramount importance, that must fall flawlessly into place to assure mission success. However, perhaps none of these singly will exceed for sheer dramatic impact the moment when the two moon-exploring astronauts, their work complete, will fire the 3,500-pound thrust ascent engine of the lunar module (LM) and lift off the moon's surface.

It is hard to imagine one individual action of more overpowering significance. For should there be a misfire then, the consequences could be, in a word, catastrophic. The astronauts would likely be marooned forever on an alien world, with but a few days supply of life-supporting oxygen.

For the past two years, a small group of engineers, technicians and craftsmen at North American Rockwell's Rocketdyne Division has devoted virtually every waking hour and then some to assure that this four-foot-tall, 200-pound engine, which fits in the guts of the LM, is the finest operating piece of machinery man can produce. Specifically, NASA awarded a contract in August 1967 that has evolved into dual responsibilities. Under it, Rocketdyne designs and builds the engine injector, and also assembles, inspects, tests and qualifies the overall engine.

"The injector serves roughly the same function on the lunar module as a carburetor does on a car," says project engineer Cliff Hauenstein. Actually, it is a round piece of aluminum which weighs about 10 pounds and looks like an oversized shower head. There are 515 finely machined holes in it, through which exacting proportions of hypergolic fuel and oxidizer flow, in fine mist fashion, to mix and ignite on contact in the engine's thrust chamber.

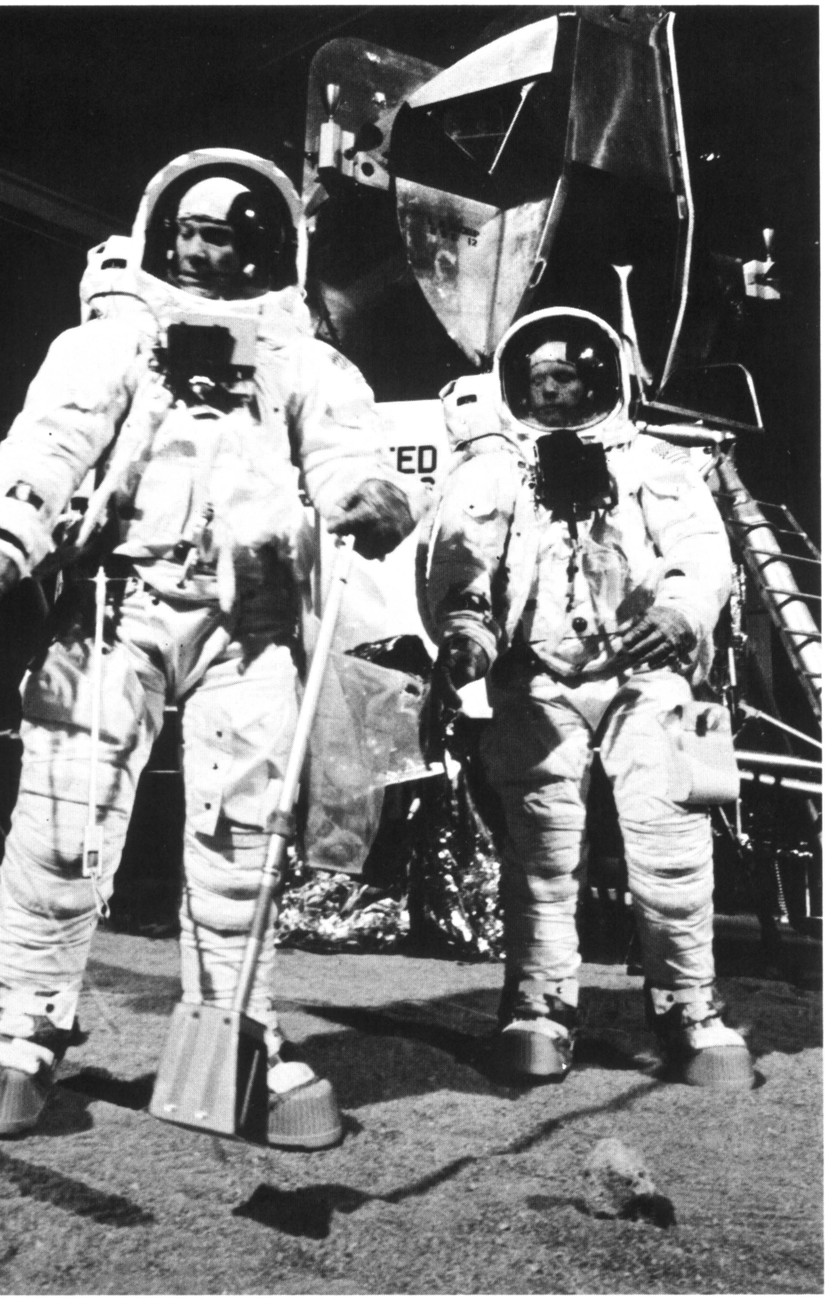
Before Rocketdyne received the contract, there had been severe injector development problems. Principally, if the fuel and oxidizer are not mixed with utmost precision they can cause combustion instability in the thrust chamber. Uncontrolled burning could raise temperature levels well above the normal 4,800 degrees, and literally burn out the hardware.

"The combustion process can resonate like an organ pipe," Hauenstein explains, "and this can disrupt the streams of propellant and promote instability. We had to come up with a design that prevents this."

Acoustic Cavities

Under project engineer Mike Yost and lead designer Jerry Hillman, the Rocketdyne team set to work, three shifts a day, seven days a week. They relied heavily upon the division's past experience in developing the Saturn V's F-1 engines, and in work done on the LM's descent engine. To the basic injector design a sequence of "acoustic cavities," (special slots) was made, tuned to the mode of instability anticipated. The pattern of holes was also changed somewhat so as not to interfere with a Y-shaped baffle that runs across the injector.

"One of our major problems," Hillman says, "was to standardize the injectors so they would all perform exactly alike." To do this, the latest manufacturing techniques were used. For instance, the holes, which measure from 14 to 35 thousandths of an inch in diameter, were not drilled, but made by electrical discharge machining. In this process, electrodes cleanly pierce the aluminum with uniform precision, leaving no chips or burrs in the metal. Also electron beam welding was used throughout



Stepping surely on simulated lunar terrain, Apollo 11 astronauts Edwin Aldrin and Neil Armstrong, above, practice for actual walk they are scheduled to make on the moon's surface later this month.

Brainstorm session: Key Rocketdyne lunar module ascent engine team members, right above, include Jerry Hillman, Cliff Hauenstein, Mike Yost, Ed Schuster, Max Honigsbert, Terry Treinan and Bob Kiningham. Steve Domohos, not present, is program manager.

Experimental manifold is fitted onto test model LM injector, right.

production, whereby a highly concentrated beam of electrons zeroes in only on the specific area to be welded and thus does not disrupt anything else, as a normal weld torch might.

Thirty days after award of contract, the first field test of the new injector and engine was made at Test Stand Bravo 3 in the Santa Susana hills. "It ran for two and a half seconds and we stopped it while we were ahead," Hauenstein recalls with a smile. "That was good enough for a first demonstration."

Flight qualification testing of the complete engine was completed 11 months after Rocketdyne started work, an unprecedented feat. It did not come easy. Hillman didn't get a solid night's sleep for months. Whenever a problem arose in the shop, day or night, he was called. But it was imperative to get every injector built to identical standards. Otherwise, combustion action on the ablative material in the thrust chamber would vary and could cause a hardware failure.

"Designing and verifying the injector was only part of it," Hauenstein points out. "We had to marry it with the rest of the engine — the valves and thrust chamber, which had already been developed. We also had final responsibility for the entire engine system — all the documents, the specifications, the maintenance manuals, design reviews. Ram Martinez was project engineer for this phase of the work, and his people had stacks of drawings and prints this high," he said, raising his arm straight out, shoulder level.

Test figures alone almost defied belief. The engine will fire for less than 460 seconds (under eight minutes) as it lifts the LM ascent stage off the surface of the moon. "We've had more than 93 *thousand* seconds of testing," Hauenstein emphasizes. There have been 140 separate tests running the full 460 second duration, with no major adverse after-effects.

Shaken and Jolted

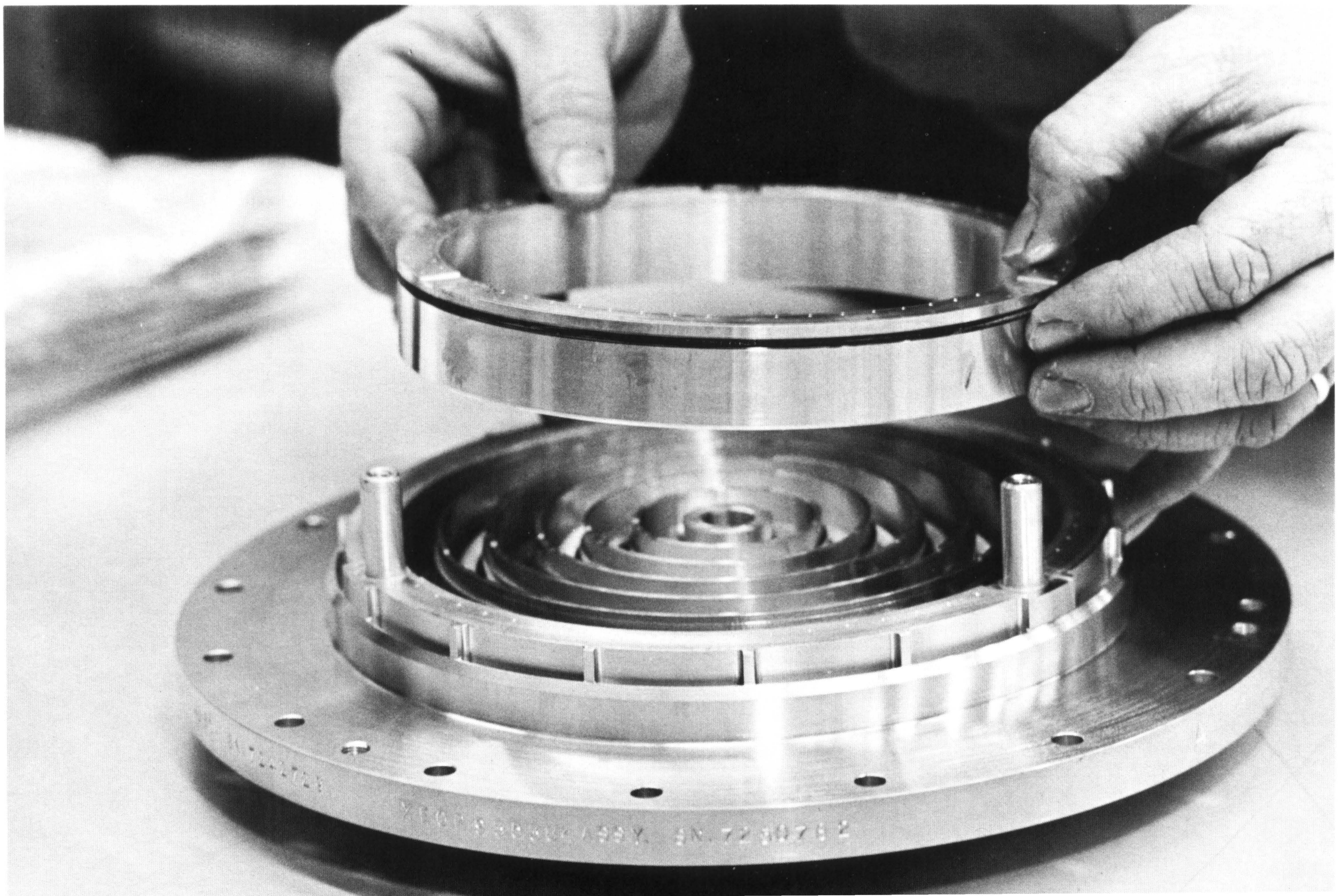
Everything was tried to disrupt the engine. It was shaken and jolted to simulate the lunar landing, and then test fired. It was wrung through a set of vibration tests, and run at operational extremes. Normal temperature of propellants involved is about 60 degrees F. This was driven up to 110 and down to 40 degrees. Performance held up. The regular inlet pressure on the injector is 170 pounds per square inch (psi). To simulate all conceivable type leaks and malfunctions, pressures ranging from 155 to 220 were run. Even bomb tests, where an explosive charge is set off in the chamber to force a high wave of propellant across the face of the injector, could not cause loss of stabilization. And this was tried 468 times!

In all, more than 3,000 tests were run in a little over 18 months, at Santa Susana and in an altitude chamber near Reno, Nev. As Hauenstein put it, "Man, that's a lot of testing. It proved the design's inherent stability."

Verification that the engines could perform as well in space as on land came in March and May when they fired on time, successfully, during the Apollo 9 and 10 missions.

Hauenstein credits a sincere, dedicated effort on the part


LUNAR MODULE ASCENT ENGINE
TEST ACTIVITY
PRODUCTION
VALVE STATUS
IN-HOUSE

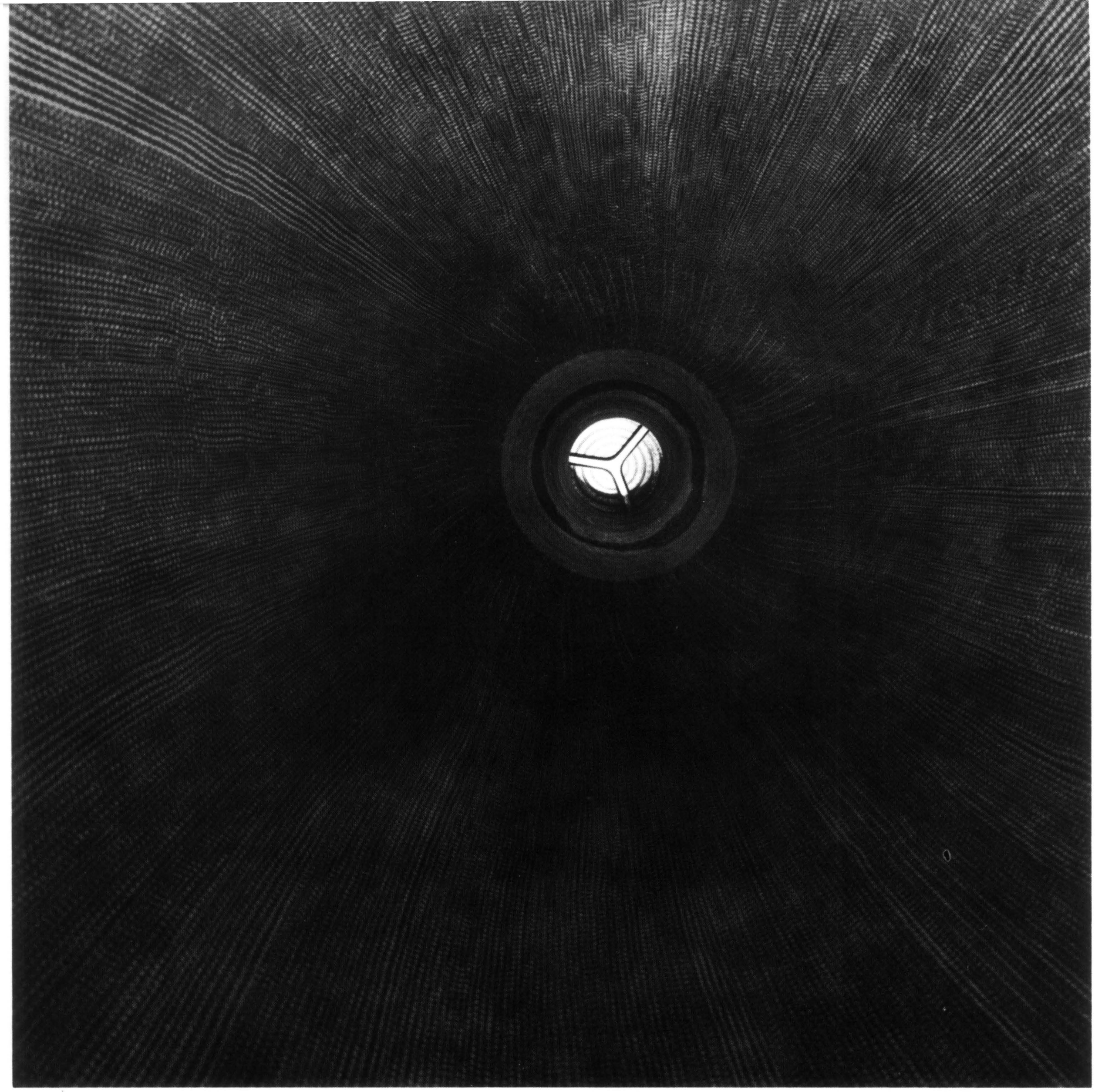

ASSY.

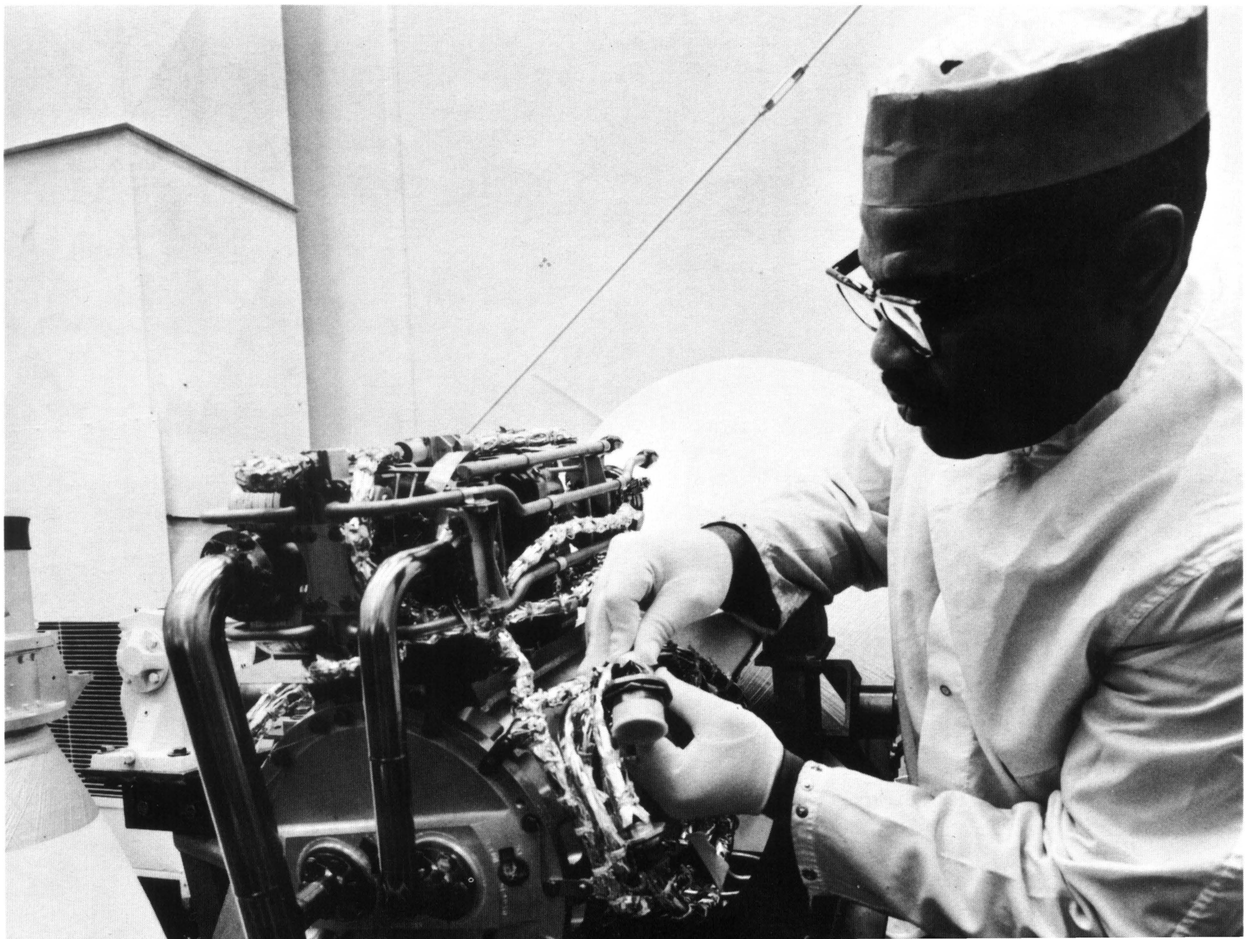
Modern manufacturing techniques, including electrical discharge machining, above, are used on engine injectors.

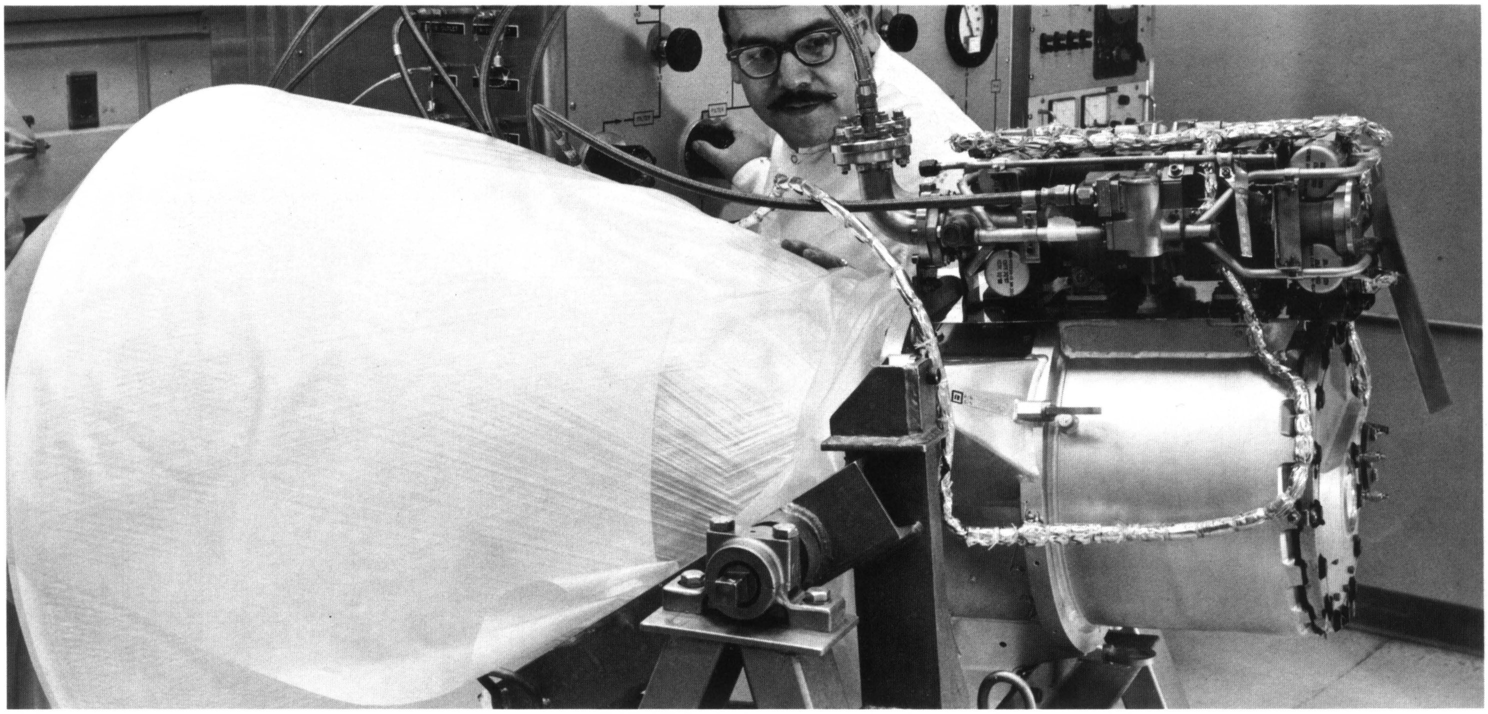
With super-fine precision, size of baffle propellant injector holes, left, are quality control checked for uniformity.

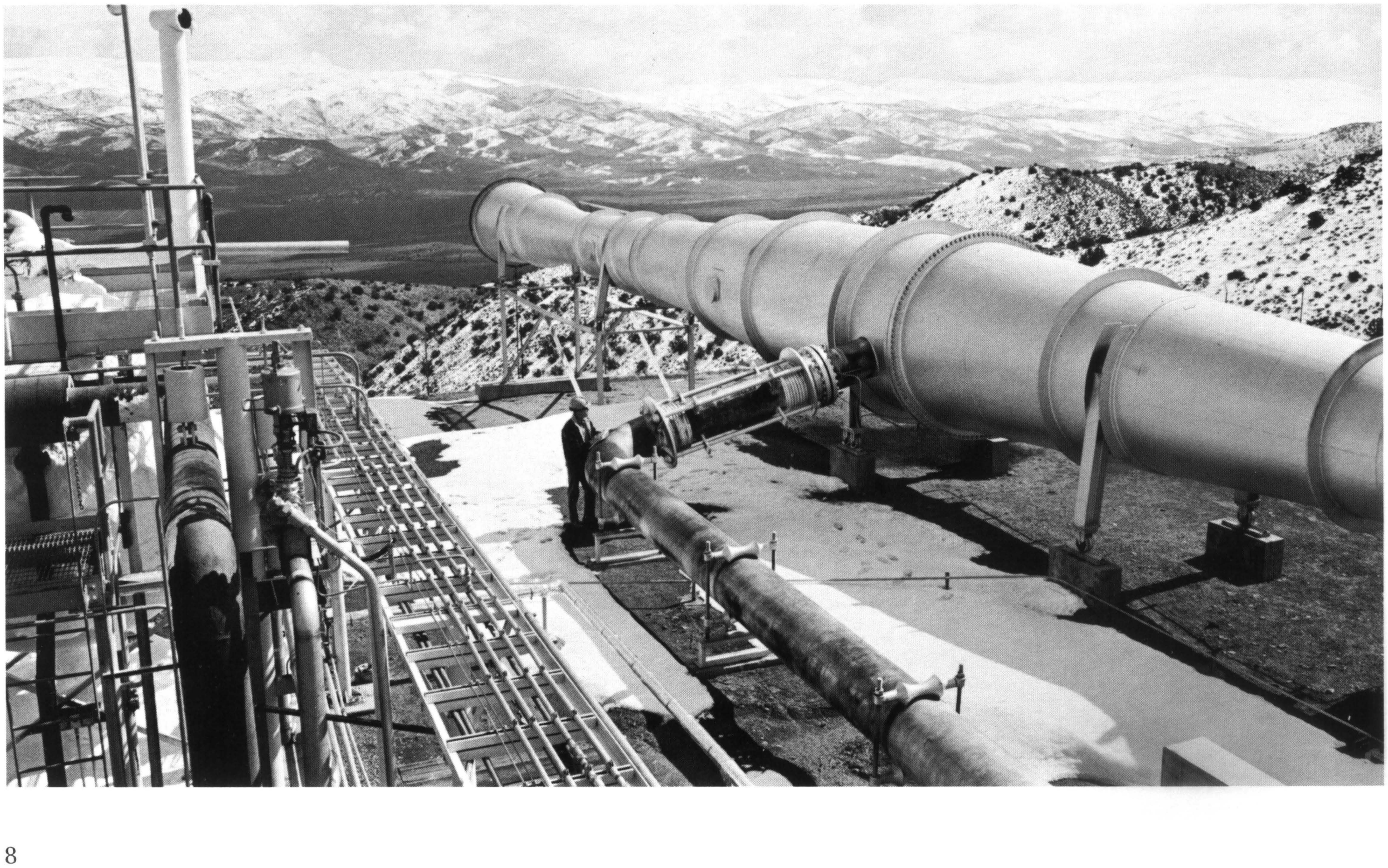
Y-shaped baffle is artistic highlight, above right, when viewed up engine thrust chamber, lined with ablative cloth material.

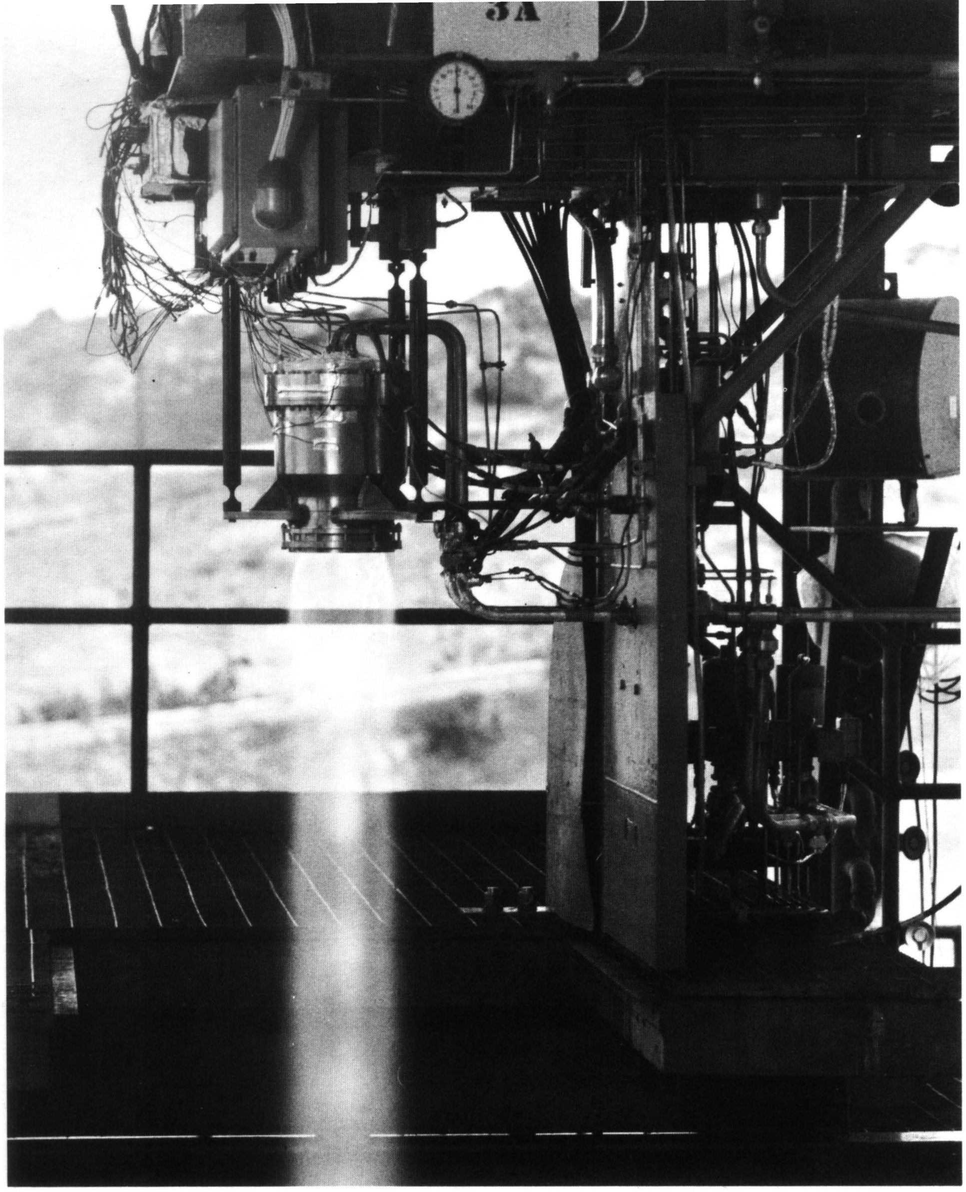
Protective plastic sheathing is applied to engine's electrical wiring following assembly, right, by technician Jim Smith.











Final checkout of fully assembled engine is effected, left above, by technician Enrique Delgado in super-clean Rocketdyne work area.

Against snowcapped backdrop of Sierra Nevada mountains, ascent engines are test fired in special altitude test facility near Reno.

Emitting incandescent flame, an engine is tested at Santa Susana, above. For lunar liftoff, 3,500 pounds thrust will be generated.

Personable astronaut Charles Duke, right, worked with Rocketdyne people during engine development period; inspired quality control.

of everyone involved, and a quality control consciousness with an unusual twist as being key factors in qualifying the engine under some of the most demanding deadlines ever imposed in the space program.

"I'm pretty proud of this operation," he says frankly. "We were really up against it, but everyone here knew what this meant to the Apollo schedule and they really pitched in. It's been a heartening experience."

During much of the time, astronaut Charles M. Duke, Jr., a major in the U.S. Air Force, was assigned to work with the Rocketdyne team, and the personable North Carolinian made friends quickly.

"We spent less time on worrying about meeting the legalized requirements of specifications than we did on the fact that Charlie might be one of the men on the moon who would someday depend on this engine to get back home," Hauenstein said. "So everytime we had something ready to check, the first thing we'd ask would be 'is it good enough for Charlie?' And believe me, with this attitude we far exceeded what the book called for."

Rocketdyne is responsible for about 20 production engines and four or five more that will be used for other than space flight purposes. Each is being assembled, tested and okayed with the thought that it will be the one which will blast off the lunar surface, sending astronauts on the crucial first leg of the long route back to Earth. There is a very real knowledge that this phase of a manned mission is for keeps, that there is no backup, no margin for error.

That is why extra efforts are taken to make every engine on the line "good enough for Charlie."