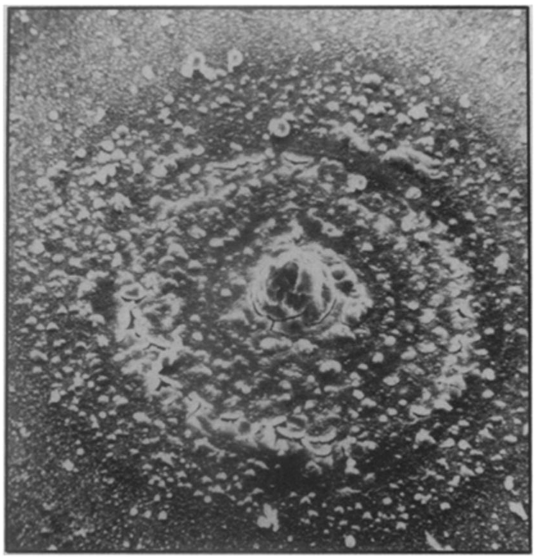
# Scanning Into the Future

Observations using a scanning electron microscope are trying to anticipate the effects on earth's atmosphere of the space shuttle's exhaust

BY JONATHAN EBERHART



*Shuttle exhaust droplet collected on copper plate reveals size in electron microphoto enlarged 425×.*

*Quest for the core: The electron microscope's beam had to probe crevices like these within the droplet residue to find the aluminum oxide particle at the center, around which droplet condensed.*

Photos: USAF-AECD

*''Broken eggshell'' remains of larger nucleus show some droplets may be more buoyant.*

During the development of the Apollo lunar module, one of its mentors' concerns was that its voluminous exhaust—estimated by some to total as much as 20 percent of the then-unmeasured lunar atmosphere—might contaminate rock samples being brought back for analysis. The LM's potent propellants, unsymmetrical dimethylhydrazine and hydrazine with an oxidizer of nitrogen tetroxide, were studied and found to form more than 100 different by-products during their reaction. These had to be known so that they would not confuse scientists analyzing the lunar material.

A similar propellant study is part of the National Aeronautics and Space Administration's probe into the possible environmental effects of the space shuttle, which is scheduled to make the first of its up-and-down, earth-orbiting flights in 1979. The shuttle will never go to the moon, but it will leave much of its 1,875 tons of propellant in the earth's atmosphere, and NASA anticipates shuttle flights as often as once every two weeks.

The space agency predicts only minimal effects, but just to be on the safe side, the shuttle program has its own environmental officer, and a wide range of tests are being made. These range from studies of exhaust-atmosphere interaction to downwind concentrations and atmospheric dispersion.

Some of the most basic work is being done for NASA by the U.S. Air Force in a 12-foot-diameter test chamber at Arnold Engineering Development Center in Tennessee. Researchers from ARO, Inc., which operates the facility for the Air Force, first had to verify that the firing of the shuttle's huge engines could even be accurately simulated with scale models in a closed chamber. A larger task was to invent ways of preserving traces of the exhaust so that their physical and chemical structure could be studied.

The three engines of the shuttle orbiter itself—the spacecraft part—are of little concern, since they consume only liquid hydrogen and liquid oxygen. The two powerful solid-propellant ''strap-on'' engines that help kick it into orbit, however, use a combination of ammonium perchlorate and aluminum powder, held together by a synthetic rubber binder, totalling about 2.2 million pounds.

One exhaust product of concern was hydrogen chloride. In a water solution it forms hydrochloric acid. To capture representative exhaust samples, ARO engineers surrounded their engine model with copper-coated glass plates at varying distances, so that the acid, if any, would react with the copper, leaving a residue that could be studied at leisure. Using the scanning electron microscope at Georgia Institute of Technology, they found that the diameter of each acid ''splash'' would indicate the size of the droplet that produced it, which could affect how it would be carried by the wind. Further magnification enabled calculation of the volume of material in the droplet. Crystallographic analysis showed that the material was indeed the product of an acid reaction, copper chloride. Simple chemical arithmetic was then able to reveal the amount of hydrogen chloride required to create it, and from that, the concentration of acid in the droplet can be determined. Tests were run in varying relative humidities from 20 to 100 percent (water produced by the burning propellant formed at a constant rate), enabling engineers to work out preliminary correlations between weather conditions and possible formation of a mist containing exhaust products.

X-ray and electron-microscope techniques showed that the nuclei on which the droplets condensed were the aluminum particles from the propellant, oxidized by the combustion process. Most of the particles were about the size of those in cigarette smoke, but some were much smaller or larger. The researchers noticed that some of the larger ones seemed to be rather ''pearlescent,'' suggesting that perhaps they were hollow. Scanning plate after plate under the electron microscope, the team finally found one that indeed resembled a broken eggshell, the wreckage of a hollow sphere. This could mean that these larger particles would stay aloft longer in the atmosphere.

There remain many questions about other exhaust products, freak weather effects and long-term reactions in the atmosphere. Some of these issues, in fact, may not be answerable until after the first space shuttle takes to the skies. ☐