PESCO PROGRESS

SEPTEMBER/OCTOBER, 1968

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Baby, it's cold in there...

PESCO PUMPS HAVE BEEN IN "SPACE" BEFORE THEY LEAVE THE GROUND

About 30 miles northeast of Cleveland, on a 51-acre tract near Perry, Ohio, "space trips" are made every day right on the ground.

There, in Pesco Products Cryogenics Laboratory, the cryogenic system components manufactured by Pesco to propel space craft, are "space" tested long before they're installed in a space vehicle.

Before initial flight the design encounters conditions on the ground tougher than it will meet in outer space.

In an elaborate testing program, every production pump is put through a long, grueling ordeal. Complete testing systems are built for each individual pump. The unit being tested is operated by the same type of power that will be used on the space craft.

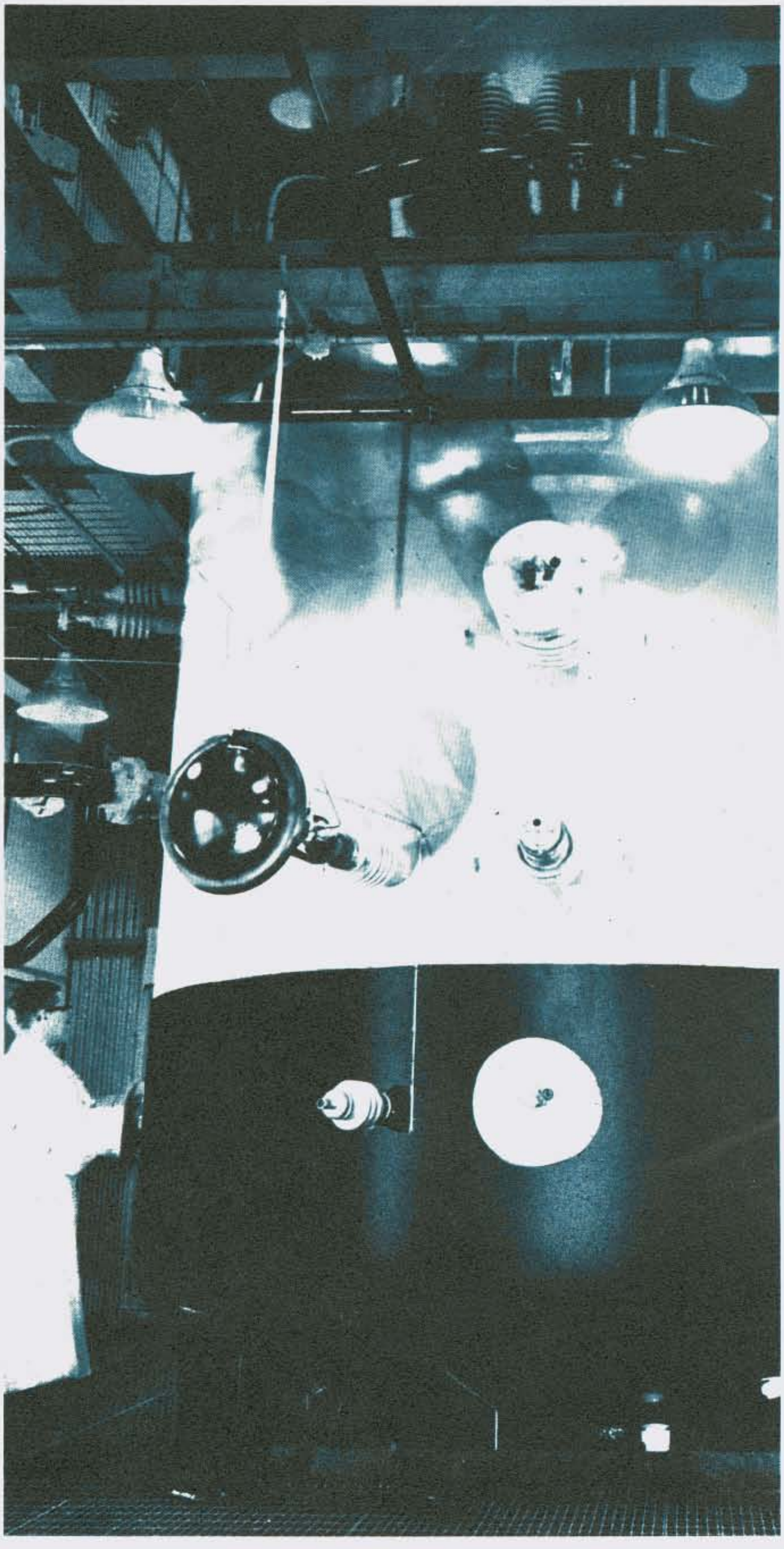
Pressure, flow rate, rpm, the installation . . . even the conditions of fuel propellant . . . are as close to the actual flight situation as the finest in modern cryogenics engineering techniques can make them.

The working life of each pump is tested far beyond its normal work cycle. The chilldown pumps used on the Saturn vehicle, for instance, are required to function for 20 minutes in actual operation, but they're run for as long as 50 hours in Pesco's tests.

Under the direction of Dudley Rose, manager of Pesco's Cryogenics Laboratory, the center tests pumps regularly. But, testing is not limited to pumps alone. Development programs are conducted on electric motors, cryogenic mixing fans, valves, and vapor liquid separators.

Units may be tested in LOX, LH_2 and LN_2, and can be driven by hot gas turbines, electric or hydraulic motors in dewars from 100 to 7000-gallon capacities.

Since the laboratory was founded in 1956, Pesco engineers and technicians have made substantial contri-



The Laboratory's 7000-gallon dewar. Test dewars from 100 to 7000-gallons can handle liquid hydrogen, liquid oxygen and liquid nitrogen with flows up to 20,000 gpm.

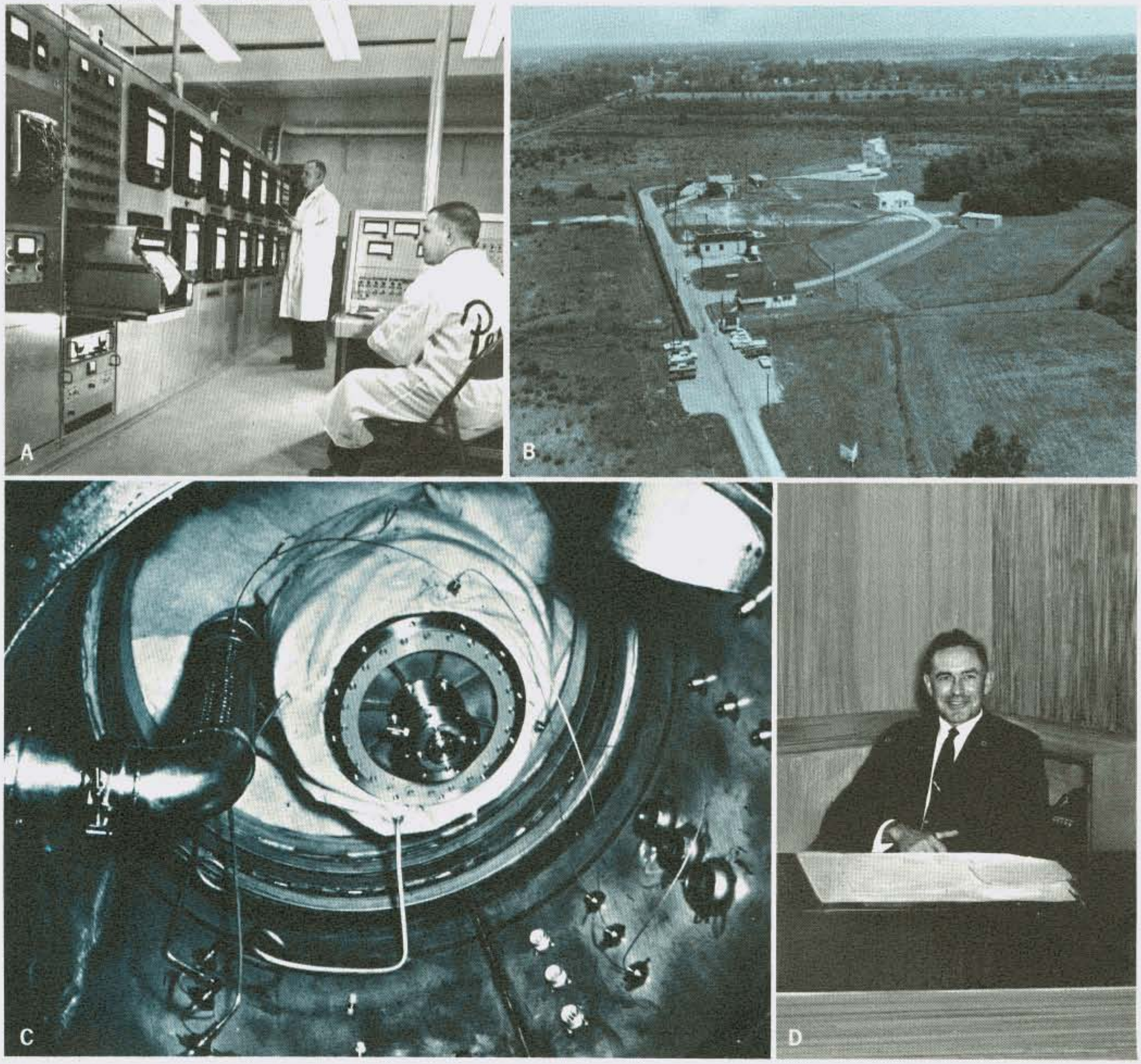
butions to the aerospace use of cryogenic fuels and oxidizers, solving complex problems of pumping liquid hydrogen and liquid oxygen.

From Pesco cryogenic research and engineering have come single and multi-stage centrifugal pumps, cryogenic electric motors and generators, vapor-liquid separators and vent valves, and liquid and gas turbines, torque converters, and destratification fans.

The laboratory's facilities contain 7 test areas, each of which is connected with a remote control building. The control building contains banks of instrumentation, capable of recording 75 pieces of information at the same time. Strip charts, oscillograph recorders, closed circuit TV and vibration analyzing equipment are all used.

At the Pesco Cryogenics Laboratory, major cryogenic projects can be researched and developed and special studies, systems engineering, production, cleaning and pre-launch testing can all be conducted. The laboratory's skilled staff and sophisticated equipment they use are two more reasons why Pesco leads the way in the application of cryogenics techniques to space technology.

(A) Remote control center is connected to self-contained test cells. This equipment can record 75 separate pieces of information at the same time. **(B)** The Pesco Cryogenics Laboratory in Perry, Ohio. **(C)** A hydrogen booster pump installed for testing in Pesco's 7000-gallon dewar. **(D)** Dudley Rose, Pesco Cryogenics Laboratory manager.



For improved air filtration

PESCO FANS ARE IMPORTANT BUILDING BLOCKS IN THE DONALDSON MODULAR SYSTEM

There *is* an escape from air pollution. Join the army and be assigned to a vehicle or command post with a "collective protection system."

Under contract by the Edgewood Arsenal, Edgewood, Maryland, the Donaldson Company of Minneapolis, Minnesota, is building these systems for installation in all types of military vehicles and command posts. They are designed to cleanse the interior atmosphere of toxic gases and contaminated materials.

The Donaldson design calls for airflow ranges of from 100 to 600 cfm, and, according to need, employs one of four Pesco fans with airflow capacities or sizes of 100, 400 or 600 cfm to circulate the contaminated air through the filtering system.

The modular system enables assemblies such as filters, fans, control panels and other components to be replaced as units. Standardization of interchangeable components enables the protection system to handle a wide variety of filtration jobs with a minimum number of parts.

Components in the system, called the "Gas Particulate Filter Unit" (GPFU), include the air supply, dust collector, particulate filter, gas filter, filter housing, air inlet and control panel.

The air supply, which includes the fan and housing, is equipped with an airflow valve and, when applicable, a transformer-rectifier in some of the six concepts Donaldson has studied. The main fans are designed to use 208 V ac, either 400 and 60 cycle, and 28 v dc motors. They have one impeller speed of 11,200 rpm.

The dust collector mechanically separates most of the dust particles from the air, expelling it through an exhaust blower. The virtually dust-free air is then circulated through a particulate filter which extracts all other foreign solid matter. Finally, the partially cleansed air is forced through activiated charcoal where any gases are filtered out by absorption and adsorption.

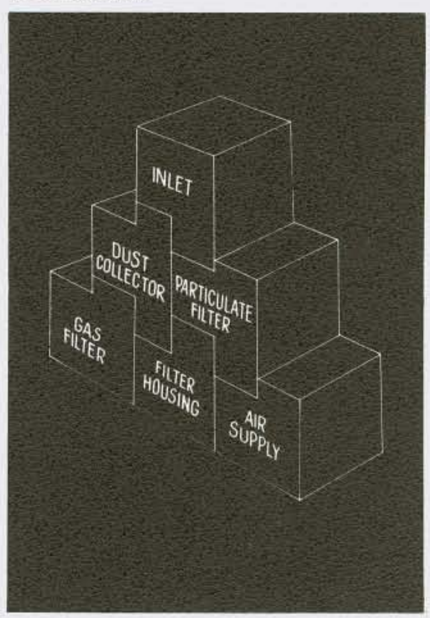
Pesco's major role in the GPFU's development was to engineer single stage fans of optimum size, efficiency and quietness. Donaldson required a fan that was stall-and oscillation-free and relatively quiet.

There is a tendency for fans previously available to stall out at surge flow and fail to provide a stable pressure within the protected area. The fans developed for Donaldson are of the centrifugal or mixed flow type and successfully damp out surges and oscillations in the system.

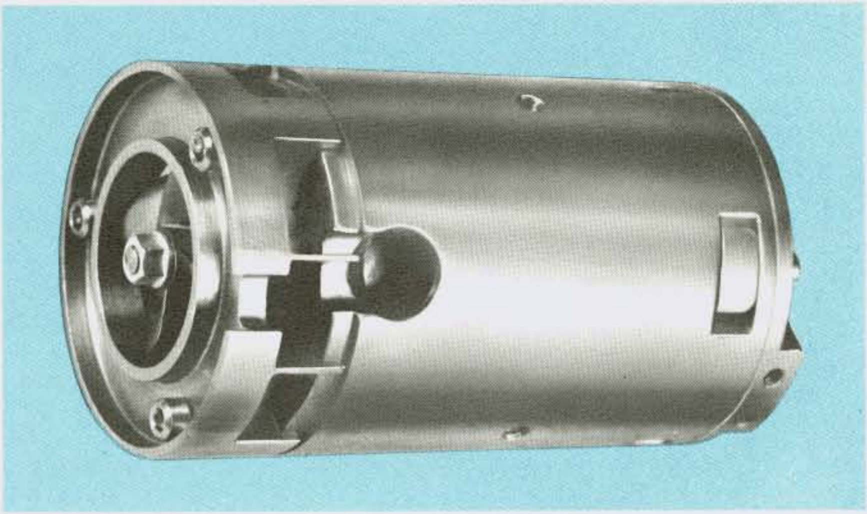
In order to fit in the modular system, the fans also had to be relatively compact yet still deliver a high volume of air. Pesco conducted a series of optimization studies to establish minimum size, weight and minimum noise level.

The result is four efficient, quiet, low-power-consuming units that meet the GPFU's air supply needs within the system's total concept, have a service life expectancy of several thousand hours of continuous running and are easy to replace or relocate in the system.

Drawing illustrates how Pesco fans fit in one of the six Gas Particulate Filter Units being studied by the Donaldson Company of Minneapolis.



PESCO SUBMERGED "FLUID BLENDER" FAN DESTRATIFIES LIQUID HYDROGEN



Heat and liquid hydrogen are not compatible. All cryogenic tanks have some heat leak which eventually produces a stratified or "layered" temperature condition in the fluid. The stratification problem exists both at the earth's surface and in space. Fluid temperature, vapor pressure and density within the tank vary widely between the stratified areas.

In a gravitational field stratification occurs when the surface of the fluid or the side walls of the tank are subject to heat leak.

The liquid at the surface turns to gas. Temperature goes up while density goes down. The heat is not transferred to the bulk of the liquid in the tank because the gaseous hydrogen "floats." When the side walls of the tank take in heat, bubbles rise along the walls without conducting much heat to the liquid. (Convection carries the heat through the fluid when the heat leak is in the bottom of the tank, so there's little stratification in such a case.)

Under weightless conditions, the stratification problem is intensified, because the specific gravity difference between liquid and gas is negligible. There is no circulation of heat so the hydrogen stays stratified.

Some of the fluid boils off. Tank pressures rises, and venting is required to control the gas while the bulk of the fluid remains unaffected.

If the heat were generally circulated throughout the enclosure, frequent, wasteful venting would be unnecessary, and more of the liquid hydrogen would be available when required.

Some controlled heat input is necessary to raise and maintain tank pressures for transferring the liquid, and some kind of convection inducing device is required to control stratification.

That's where Pesco Products comes in.

General Dynamics called on Pesco's broad experience in cryogenics to help solve a stratification problem.

The design requirements for the pump or fan they needed were: 1) effective fluid circulation, 2) a high degree of reliability and a long operating life without the need of frequent inspection, repair, or replacement, 3) use of a convenient power source, 4) lightweight and minimum bulk, 5) a high degree of efficiency with a minimum power input for general mixing effectiveness.

Pesco designed and built a low speed axial flow fan-motor assembly that could operate in the −421° F temperature of liquid hydrogen moving approximately 5.0 cubic feet per minute of the gas-liquid combination.

Bearings in the fan are glass impregnated Teflon to withstand the extreme cold. The fan is powered by a 7 watt, a.c. motor. A similar but more sophisticated unit is now being supplied to the Manned Space Flight Center in Houston.

PESCO DC MOTOR WORKS SUBMERGED IN LOX

The cruel lesson of the tragic Apollo flash oxygen holocaust brought home clearly some of the dangers inherent in working with pure oxygen.

One spark can spell disaster.

Drawing on its knowledge of the cryogenic field and utilizing experience gained in developing booster pumps for the Centaur and Saturn space vehicles, Pesco has developed a new DC motor that can operate completely submerged in liquid oxygen. DC motor drives for aerospace cryogenic pumps cut system weight and reduce costs by eliminating the heavy and costly static inverter needed when an induction motor drive is used.

DC motor driven pump designed to be used submerged in liquid oxygen.

Pesco eliminated the fire danger in LOX by developing a motor that can be pressurized with inert gaseous helium. The inert motor atmosphere could be maintained only after successful development of almost completely pressure tight, dynamic shaft seals. Brush material also had to be researched to provide long life in a dry, non-oxidizing, helium atmosphere.

Pesco has a long history of success in pumping liquid gases. They started pumping liquid hydrogen in 1956. Recent successes in the field include LH_2 pumps on Saturn S-II, Saturn S-IV-B and Centaur, and LOX pumps on S-IV-B and Centaur.

Pesco People

PESCO PIONEERED IN CRYOGENIC PUMPS

"Bearings to work at −421° F? Someone must have misplaced a decimal point!"

That was the reaction of a leading bearings manufacturer when Gerard Caine, a Pesco product development engineer, contacted him for assistance back in 1956.

The problem . . . or problems, for there were literally hundreds of them . . . started when the Air Force was considering using liquid hydrogen as aircraft and rocket fuel.

There were advantages, plenty of them, if it could be done. A gallon of liquid hydrogen weighs only about half a pound. Conventional jet fuel, about eight. Liquid hydrogen generates about six times the energy per pound and is so oxygen hungry it can keep an air-breathing engine running at extremely high altitudes.

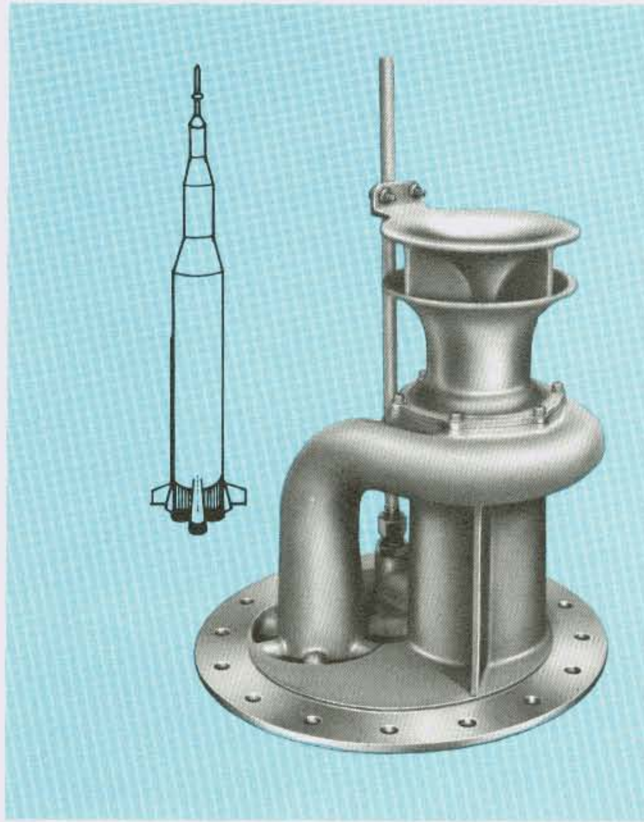
But in order to get the fuel to the engine, some way of pumping it had to be devised. How do you pump a fluid that has the viscosity of a bagful of smoke, is a potential bomb, and boils away at the slightest introduction of heat? It boils continuously from the time it is liquefied, and the usual materials wear about 1000 times as fast in liquid hydrogen as they do in air.

It fell to Caine, who had been with Pesco only two years at the time after a career in aviation components and pump manufacture, and a team of Pesco engineers to find out how.

First, there was the pump's electric drive. Should it be run "hot" outside the tank, sealed off from the liquid hydrogen, or was it possible to submerge it in the fluid and run it inside the tank?

Then, there was the matter of bearings both for the motor and the pump. All known lubricants are frozen to brittle solids at the near absolute zero temperature of liquid hydrogen. So, Caine and his crew decided to forget lubrication and run the motor and pump dry. The fluid to be pumped was not viscous enough to lubricate anything, and, without oxygen, pump and motor components didn't even have the protection of oxidized surfaces.

Rolling contact bearings were adopted to reduce surface friction. "There wasn't a bearing or lubricant manufacturer around who could give us the answers," said Caine. "No one knew much about anything.



The submerged centrifugal chill down pump with inducer inlets used in the Saturn space vehicle.

We had to develop our own materials and contraptions, and then learn something about high vacuum techniques so we could try them out in the big 'thermos bottles' we built to test them."

To avoid the sealing problem, it was decided to submerge the pump and motor assembly in the hydrogen.

The cost of liquid hydrogen at that time was very high, so miniature versions of the pump were built and tested. There was so much to learn that Caine and his crew groped their way along, but finally succeeded in producing a unit that worked.

What makes hydrogen dangerous is air. Without it, it's inert and harmless.

About the time Pesco built their first successful cyrogenic hydrogen pumps, NASA was working with liquid hydrogen as a possible rocket fuel.

Pesco was called upon to solve the problem of pumping it, and NASA was pleasantly surprised when they discovered Pesco had already developed techniques for handling the tricky fuel.

Liquid oxygen presented its problems too. Materials compatibility was one of them. Unless it is already

Gerard Caine, Pesco cryogenics engineer

burned, anything you put into liquid oxygen could cause an inferno with a rise in temperature or the slightest spark. Work in this area also lead to the use of a submerged electric motor driven pump. In this case, however, the motor is double sealed in a hermetic housing that is filled with inert helium.

From the work pioneered by Caine came the Saturn's submerged cen-

PESCO DEVELOPS FUEL-POWERED BOOSTER PUMP FOR FUTURE AIRCRAFT

In the never-ending struggle to simplify operation and reduce the weight of aircraft components, Pesco Products is helping lead the way with a new fuel-powered fuel booster pump designed for the next generation of aircraft such as the VSX, VFX and the VFAX.

The new unit eliminates the need for an electrically driven pump or ejectors, affects an important weight reduction, reduces the drain on the aircraft's electrical system, and provides optimum reliability.

Propelling force for the booster is gained by diverting a small portion of the engine system's fuel supply after it has passed through the main fuel pump and returning it to the aircraft's fuel tank where it drives a turbine-driven booster pump.

As an alternative to using fuel from the main fuel pump, a lower pressure, engine-driven pump may be used.

Immediately apparent advantages over ejector systems are greater efficiency, simplification of the fuel supply system, weight reduction, and lower cost especially where higher flow and higher performance are required.

Frequently, in multiple-engine aircraft, multi-stage or a series of ejectors must be used to assure an adequate fuel supply. The use of multi-stage or multiple units increases both cost and weight and complicates the fuel system, tankage and plumbing.

Pesco's new booster pump, however, may draw its energizing force from the excess flow in the aircraft's fuel system. Fuel forced back to the tank drives a turbine wheel and a pump impeller that are combined into a single rotating unit which greatly simplifies design.

Further simplification is achieved through the use of fuel lubricated, carbon sleeve bearings. Since the fluid which operates the turbine is the same as that being pumped, only labyrinth seals are required.

The hydraulic turbine-driven booster pump is capable of sustained operation from sea level to 60,000 feet. Turbine booster pumps of this type have a flow range up to 130,000 lbs. per hr. or more and will satisfy any known fuel system pressure requirements.

Thirty years of experience and development in fuel booster pumps by Pesco lies behind the design of this latest fuel-powered unit. Pesco fuel booster pumps . . . primarily electrically driven . . . have more than proved that they perform well under a wide variety of adverse conditions.

Pumping boiling fuels from non-pressurized tanks at 60,000 feet above sea level, as well as contaminated fuels, is just run-of-the-mill work for these pumps. Their fuel lubricated carbon sleeve bearings have enabled them to attain mean-time-between failure in excess of 40,000 hours.

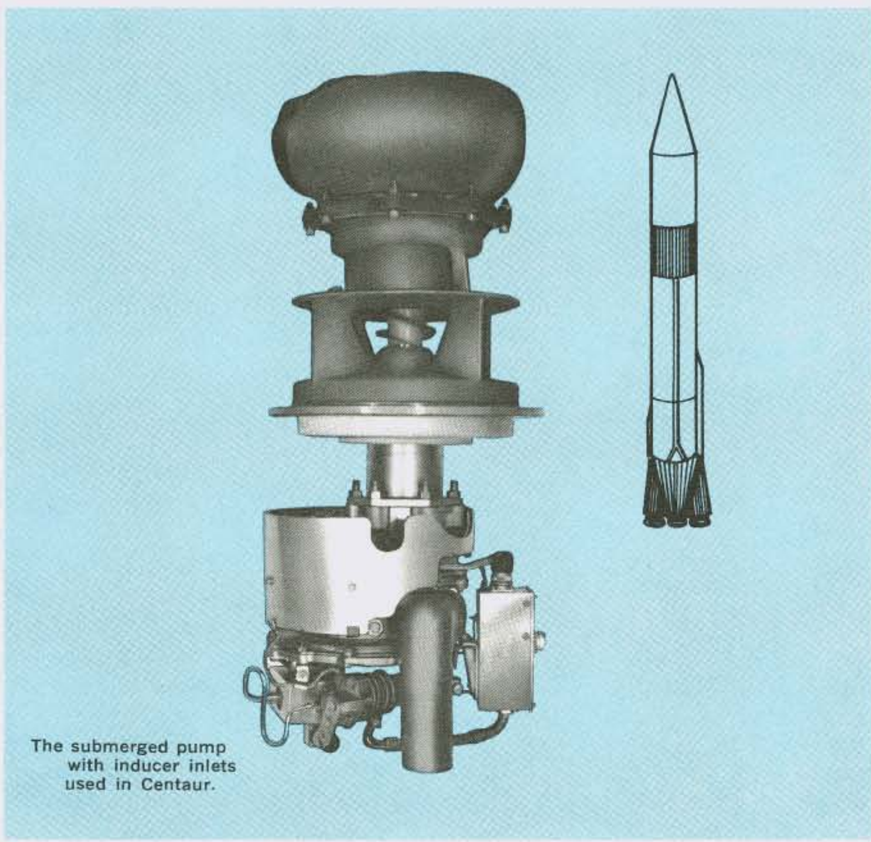
"Experience we've already had developing a special hydraulic, turbine-driven booster section of the afterburner pump used on one of the most advanced jet engines in production today," said Jack Murray, Pesco's vice president in charge of engineering, "helped us a great deal in developing this new turbine driven booster pump. We look forward to exploring further the use of hydraulic turbine driven fuel booster pumps for advanced, high-performance aircraft requirements."

trifugal chill-down pumps with inducer inlets that pump both liquid hydgrogen and oxygen to cool propellant supply lines to the engines and provide vapor-free liquid propellants to start the engine. Operating at 11,000 rpm, the liquid oxygen pump delivers 135 gpm at seven psi, and the liquid oxygen pump, 31 gpm at 25 psi.

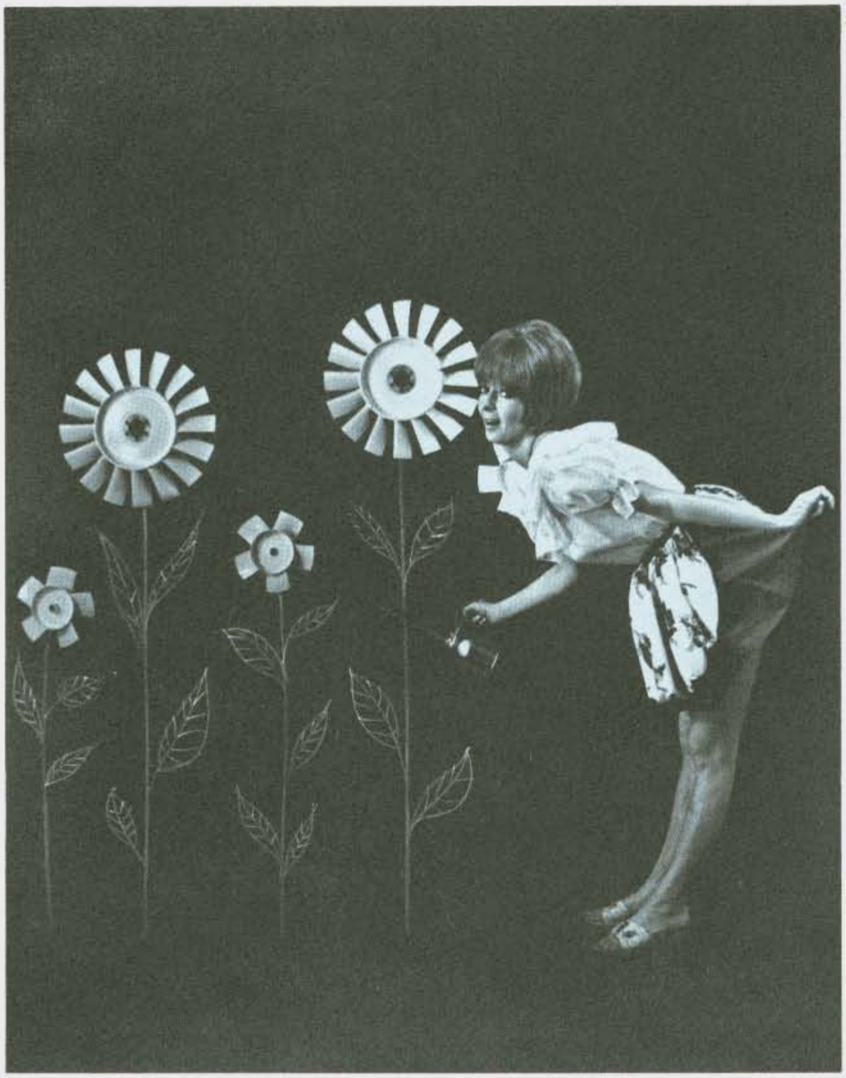
The submerged turbine-driven Pesco pumps in the Centaur deliver liquid oxygen and hydrogen to the main rocket engine pumps throughout its flight. The hydrogen pump has an operating range of 1270 gpm, 19.5 psi at 8458 rpm, and the LOX pump, 397 gpm, 30 psi at 3650 rpm.

"The cryogenics industry has come a long way since we first started to pump liquid hydrogen, Gerard Caine said, "With greatly improved and recently discovered materials, the pumps we're designing and building today are far superior to the first ones we built."

But, no matter how much cryogenic pumps improve it was Pesco that got them off the ground, and Gerard Caine who gave them the first boost.



The submerged pump with inducer inlets used in Centaur.



Flower Power?

Actually they aren't flowers and they don't need the water. They're fan blades used to cool the Army Track Vehicle M 109. Manufactured by Pesco Products, a division of Borg-Warner Corporation, Bedford, Ohio, the large blades cool the radiator in the tank; the small ones ventilate the crew compartment.

Export Offices
Borg-Warner International

36 S. Wabash Avenue
Chicago, Illinois 60603
Telephone DE-2-2050

in this corner, weighing 185...

Another vital message from Pesco The Great, conqueror of things!

If you think it's tough to design something, you ought to try writing about it. For instance, why can't you engineering types give simple names to things? Like here on this one-third page, Pesco wants to impress you with its capability and experience in the field of designing and producing hydraulic power packages. So...

"Which one should we emphasize?" the writer asked innocently. "Well," said the Pesco engineer, "for Lockheed's helicopter we developed an engine driven, high performance variable delivery piston pump power package with bootstrap reservoir."

"Fine, what do you call it?"

"That *is* what we call it."

"Swell, there goes the whole ad. You wouldn't settle for something like 'Ultragoodo' or 'Tiger-tuff' or anything like that?"

"Cut that out! If you don't like that package, we have plenty others. For the Minuteman we made submerged variable displacement hydraulic piston pump power packages with bootstrap reservoirs. Or try the 1.7 pound pressure compensated variable displacement hydraulic piston pumps we made for the Polaris. Or pick from the packages we did for the Phoenix and the Titan III and Start. They're all Pesco electric motor driven, of course."

"Spare me the details. It looks like we'll have to do the best we can without mentioning the full name of the product."

"Oh, can you do that?"

"Sure. How does this grab you? 'Let a Pesco Puma Package do your pushing around!'"

That's when the fight started.

pesco

The current issue of Pesco Progress, our colorful and informatively prepared technical publication, contains detailed data on Pesco pump capability. Send for your free copy.

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