m/r SEPTEMBER, 1957

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

AN AMERICAN AVIATION PUBLICATION

This Issue:

LIQUID ROCKET PROPELLANTS AND EXOTIC FUELS

Friendly Foe
When a new air defense missile is produced, its "kill accuracy" is theoretical until it is tested against a realistic target under operational conditions. The new, supersonic missile target, USAF XQ-4, is one of many "friendly foes" developed by Radioplane to simulate various air enemy threats.
Duplicating the performance and radar appearance of a supersonic, high-altitude bomber, the radar-controlled XQ-4 is designed to test the seek-and-kill ability of air defense systems and their missiles.
As major advancements have been made in U.S. Armed Forces air defense weapon systems, Radioplane has designed and developed targets compatible with the missions of these weapons. The XQ-4, for example, not only imitates invading bombers, but tallies up the score of hits and misses when fired upon.
Radioplane, the first to produce remotely controlled target aircraft, maintains dynamic research programs to seek low-cost solutions for tomorrow's defense problems.
Radioplane
A Division of Northrop Aircraft, Inc.
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USAF

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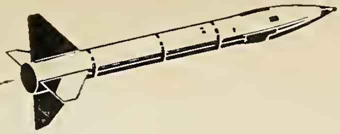
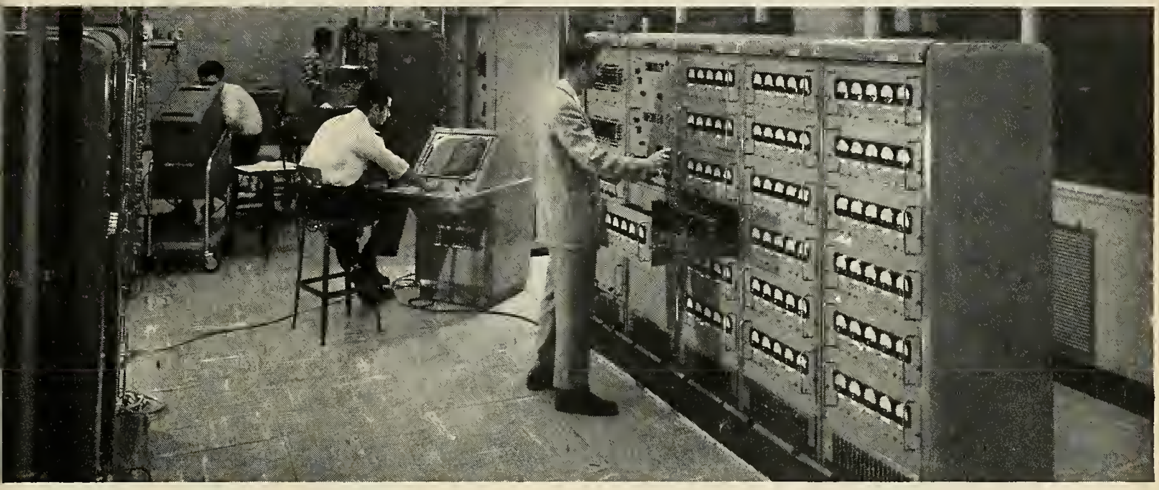


records missile "history" at giant new DATA CENTER



ASCOP M Series Ground Station at General Electric's Data Reduction Center

GENERAL ELECTRIC's new multi-million dollar Missile Data Processing Center — one of the nation's largest — is now engaged in advanced scientific computation and evaluation of missile flight tests.

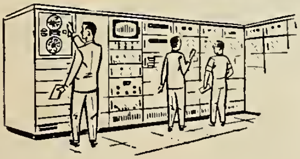
This giant Philadelphia center contains the most advanced automatic data processing and handling equipment in use today. A completely integrated operation, it greatly facilitates the speed with which vital data can be made available for analysis.

Playing an important role in this strategic operation is the ASCOP PW Data Reduction System which includes monitoring facilities. An ASCOP Ground Station handles many channels of low frequency data . . . simultaneously reduces eighty-six data channels, held to a system accuracy well within 1%. This data is originally gathered in the missile by ASCOP airborne telemetering units.

The linearity and reliability of this ASCOP system is a major factor in the advanced performance of the entire installation. And, significantly, the modular-unit flexibility of ASCOP equipment made possible delivery of the system **months in advance** of the opening of the GE Data Center . . . one more reason why it will pay you to investigate ASCOP for your present and projected programs.

ASCOP M SERIES GROUND STATION

PLAYBACK AND MONITOR GROUP • DECOMMUTATOR AND TRANSLATOR GROUP



This ASCOP PW Ground Station is a complete "packaged" system for data processing. Eighty-six Channels may be reduced in real time from tape records. Utilization of zero and full scale sensitivity reference channels affords continuous automatic system calibration, avoiding frequent manual adjustment and the need for critical components. All channels may be visually monitored simultaneously. Easy access to slide mounted chassis is featured even during operation.

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missiles and rockets

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September, 1957 Volume II, No. 9

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that's the word, sir...

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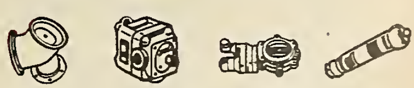

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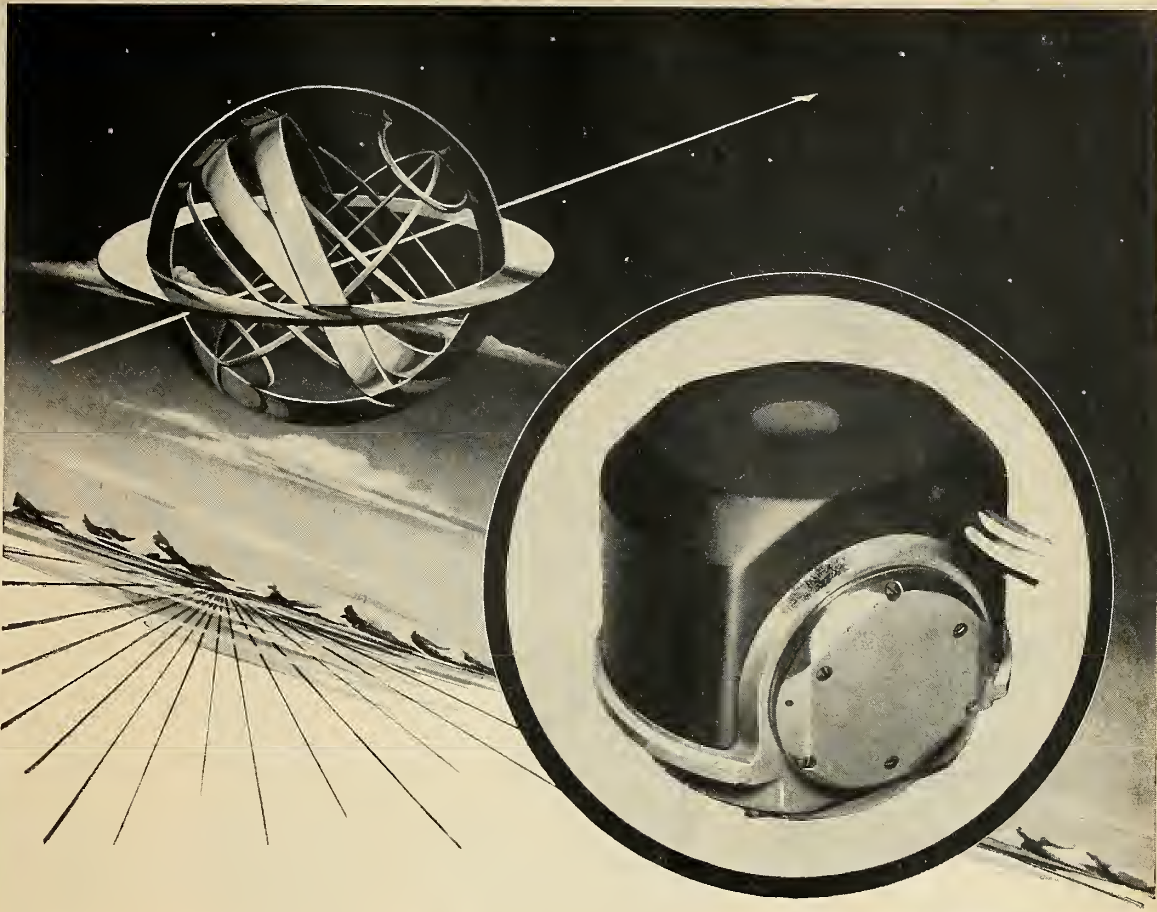
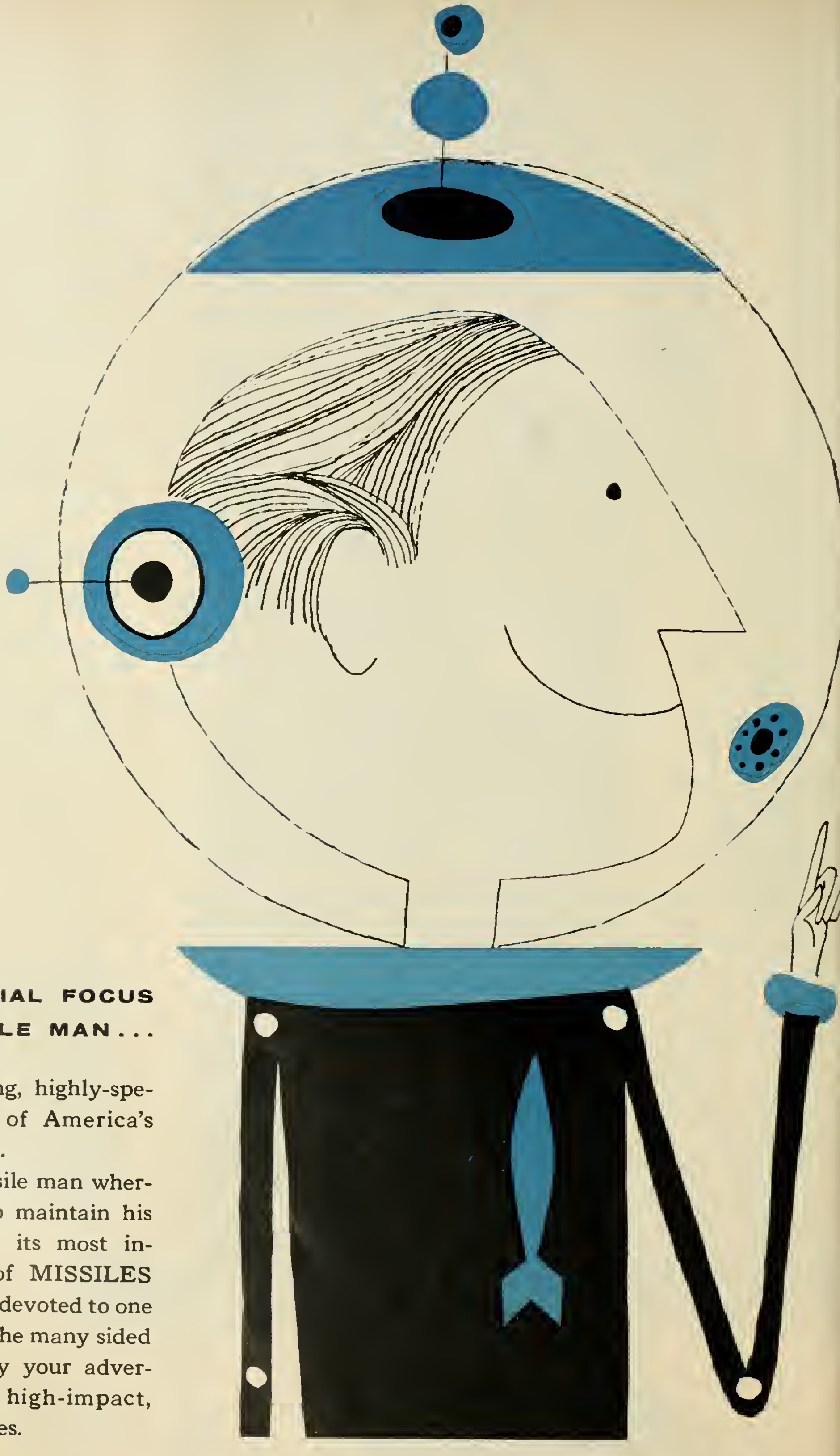


Model II B Accelerometer



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to meet the growing, highly-specialized demands of America's newest marketplace.

To serve the missile man wherever he may be, to maintain his "reader-interest" at its most intense, each issue of MISSILES AND ROCKETS is devoted to one specific segment of the many sided missile market. Key your advertising into these high-impact, reader-oriented issues.

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FROM NOSE TO NOZZLE, FROM FIN TO FIN, CONTOUR TURNED PARTS—WITH PRECISION BUILT IN

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Let's Call In General Yates!

Cutbacks in military buying and manpower are under way, with more coming. Arms cuts of major size are already in effect. Defense spending will be cut from $40.2 billion to $38 billion or less. Actually, this may be interpreted as an avalanche-type cutback, and it will be felt. The Army will feel it in terms of less manpower; the Navy must mothball 60 major combat ships; the Air Force will stretch out and cut orders for planes.

Businesswise, our missile programs will not suffer much, in spite of such drastic cancellations as the death of the *Navaho*. Those 12,000 or more people weren't all working on the *Navaho*, were they? Furthermore, North American's facilities and engineering capabilities represent such an asset to the nation's missile knowhow, that North American already is back in business. However, current defense cutbacks will mean a streamlining of the missile program. This isn't to say that there will be a cutback in terms of ultimate missile striking powers. But the White House expects more and better missiles for less money. This makes sense. We are beginning to learn.

Nevertheless, it remains a fact that the missile business is still in quite a messy state. It is rather disorganized. Very few people know very much about where we're going, nor the best way to go about getting there. That's why the White House asked for action. Reportedly, important decisions will be made next month when the policy makers sit down and discuss where we're headed, what should be cut and what should be done, in general, to eliminate wasteful spending. In other words, decisions vital to our current and future defense will be made.

In this connection, the spotlight will be on our new Secretary of Defense. Neil H. McElroy is known as a man who wants facts, not theories, from subordinates and associates. His approach probably will be much like Charlie Wilson's, viewing the job as a business rather than a political or technical problem. He is known to be digging hard for facts. He makes up his mind quickly, and only new facts can make him change a decision.

There's nothing wrong with that approach, so long as fact can be sorted from fiction. This hasn't always happened. Many people lay claim to the role, but few are missile experts. Very few. When McElroy starts digging for facts he most certainly will have to turn to some of those few who know something about missiles, those who have built and flown missiles successfully. And they are not always where you expect to find them.

To arrive at the optimum of overall missile producibility and operational effectiveness, the new defense secretary ought to call in the man who knows more about Army, Navy and Air Force missiles than anyone else . . . AF Maj. Gen. Donald N. Yates. He is Patrick AFB's energetic, eager commander. He is the only top military man who has had the opportunity—for several years—to watch all the birds all the time, who has had daily contact with the missile industry's researchers, designers and military brass—even the push-button personnel—and who has built up a truly vast scientific knowhow of our entire missile arsenal.

Gen. Yates is known as an efficient, hard-working military man—working in the interest of this country's military strength. He is a scientist as well. He is admired by his associates. He wears the Air Force blue, yet he is popular with Army, Navy and Air Force missile men alike. Call him in. Listen to him. It will pay.

Erik Bergaust

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MI

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RECORD SPEED RANGE	0.0812 to—129.9 inches per second
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WRITING SPEED	Above 30,000 inches per second
OPTICAL ARM	11 inches—
POWER REQUIREMENTS	115 Volts—60 cps
TIMING LINES	0.01 and/or 0.10 second interval
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WEIGHT	130 pounds


Honest John, Redstone, Asroc, Corporal, Little John, Sergeant, La Crosse, Wag Tail...
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One big reason so many missiles carry warheads made by Honeywell is that the Honeywell Ordnance Division has the development and production experience and facilities necessary to handle warhead projects through their complete evolution—from feasibility studies to volume production.
Honeywell Ordnance is equipped for, and has extensive experience in aerodynamic and lethality studies and structure design. Also helping to make Honeywell Ordnance a leading supplier of warheads is the fact that all types of fuzing, safing and arming devices can be developed and produced under the same roof.
If you require development work in the areas of missile equipment, fuzing, fire control, underwater ordnance or special products, Honeywell Ordnance Division would welcome your inquiry. Phone, wire or write to Honeywell Ordnance Division, Dept. MI-9-225, Hopkins, Minnesota.
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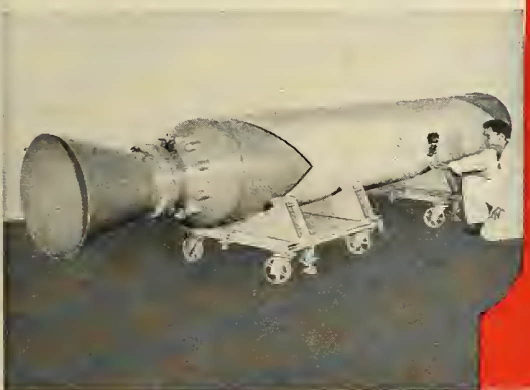
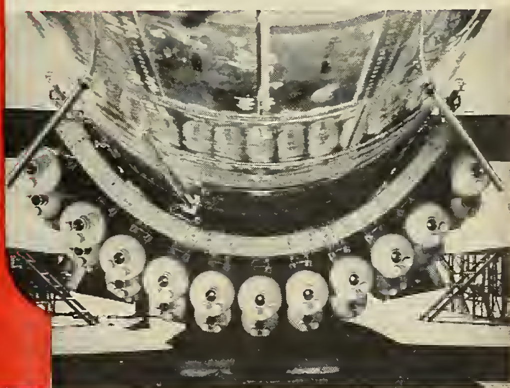


Giant PUSHER rocket made from low cost, petroleum-derived materials gives tremendous thrust for short durations.



The M15 JATO loaded on Boeing B-47. The first JATO to meet rigid Air Force performance tests. (Boeing Airplane Company photo.)

Rocket Fuels Division

PHILLIPS PETROLEUM COMPANY
McGregor, Texas

Phillips 66

Simmonds

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GUIDED MISSILES AND ROCKETS AROUND THE GLOBE

cover picture:

Symbol of the US position in the field of liquid propellant rocket engine development is the flame and smoke of the Titan ICBM engine undergoing static test at Aerojet-General. The Titan engine, developed by Aerojet, is one of the highest impulse engines in the free world. It is our responsibility to push the Titan and Atlas ICBMs to completion to counter the threat of Russian supremacy in the arsenal of 'ultimate' weapons.

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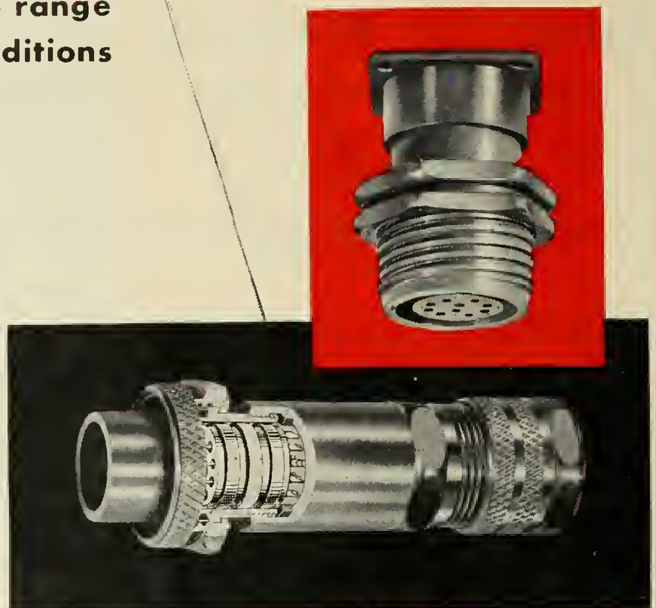

Currently establishing itself as a performance leader in the missile systems field, Pyle-Star-Line connectors offer engineers an entirely new line of electrical connectors for universal military and industrial use.

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FEATURES

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Chemical Resistance	Most acids, most alkalis, oil
Corrosion Resistance	Salt Spray: 300 days without failure
Dust Resistance	Exceed requirements of MIL C-5015C
Shock Resistance	50G Minimum
Vibration	Exceed 20G to Method II of Mil C-5015C
Humidity & Moisture Resistance	Exceed Class E. Spec. of Mil C-5015C
Air Leakage	Meet Class E Spec. of Mil C-5015C

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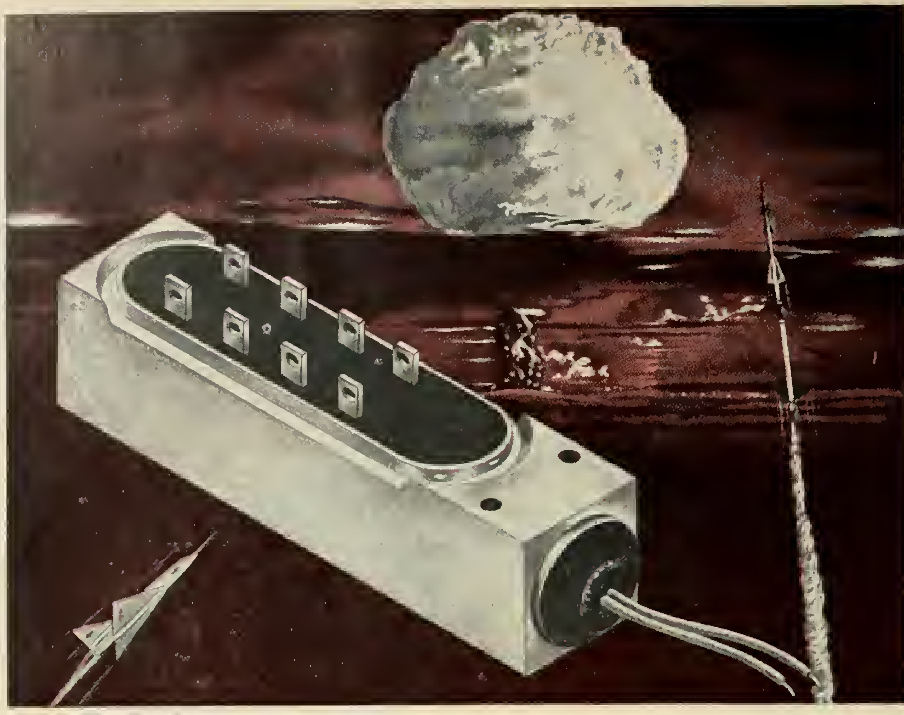


letters

Solid-fuel Issue is Challenge

To the Editor:

Your magazine serves extremely useful purposes. Not only does it keep the layman up to date on a common sense basis but it also provides information in well co-ordinated comprehensive form a businessman can understand.

But most important of all, the statements in your magazine must be appreciated for their authoritative value at a time when advertising writers and customers' men in brokerage offices have suddenly become experts on missiles, rockets and jets and, with the help of a few chemical terms, dispense so glibly an appalling amount of hogwash that at best represents 25 per cent half-baked knowledge, 25 per cent imagination and 50 per cent stupidity.

Your article on the solid fuel industry is excellent in every respect and I am looking forward with much pleasure to your next issue which will discuss the exotic fuels and their values, about which there is so much controversy.

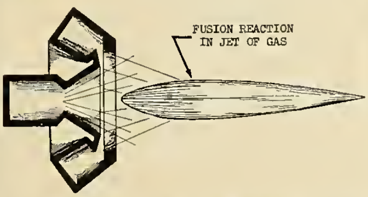
A. Swoboda
Securities Cycle Research Corp.
60 East 42nd St.
New York 17, N. Y.

A New Road To Controlled Fusion?

To the Editor:

Here is an idea I thought of three years ago. I have tried to make it several times, but haven't succeeded yet.

The rocket works on the "hollow charge" principle.



I thought that this engine would increase the rocket exhaust velocity and could be throttled. The directional control is similar to the air nozzle in the Ator VTOL. Most important about this is that you might be able to have a nuclear fusion reaction in the jet of the rocket.

This could be done by having a plasma jet of tritium and deuterium focused so that the molecules collide similar to a "hollow charge" which would form tremendous heat to start the fusion reaction.

The heat problem would be solved because the fusion reaction is away from the walls of the rocket chamber.

Russell H. Jones, Jr.
112 N. Abington St.
Arlington, Va.

To the Editor:

Our Society, the Asociacion Argentina Interplanetaria, is a member of the International Astronautical Federation and has nearly 500 members of which about 30% are university graduates, 35% are university students and the rest are amateurs. We are organizing a big exposition to be held in Buenos Aires, December 1957-February 1958 and expect to get some material to be exhibited from foreign countries. We will also exhibit some small rocket motors built in this country and some models of different satellites as well as designs, graphs and photographs of rockets.

We ask you to consider the possibility of sending us on a loan basis some of the material you have exhibited at the Sheraton Park exhibition hall. We are sure you have many, very interesting things to be exhibited in this great Latin American city.

Teofilo M. Tabanera, President,
Asociacion Argentina
Interplanetaria
Buenos Aires
Argentina

We feel the best sources for you to contact would be the American Rocket Society, 500 Fifth Avenue, New York, N. Y., and the State Department, Argentine Desk, Washington 25, D.C.—Ed.

SRO at m/r

To the Editor:

I have just received a two year subscription to your magazine and would just like to say the first copy exceeded my expectations. Keep up the good work.

I would like to know if the back issues of m/r are available. My subscription started with the July, 1957 issue.

Gene A. Lewis
15718 Mandalay Rd.
Cleveland 10, Ohio

Sorry. No back issues available. All gone.—Ed.

Our Ed Gets New Look

To the Editor:

I am an engineering student and enjoy your excellent magazine very much.

A group of my classmates and myself were discussing MISSILES AND ROCKETS the other day. We agreed that one of the best things about it is the column, Missile Business (formerly Aerophysics), written by Seabrook Hull. He is an extremely colorful writer. However, we

Ed Hull: New Look

Ed Hull: Old Look

were curious about what he was thinking when his picture, which appears at the top of the column, was snapped. We made the following conjectures:

1) His wife had just run off with another man.
2) She came back.
3) He had just given up smoking.
4) You are not paying him what he thinks he's worth.
5) He had just been told by his doctor he has to give up drinking.
6) He had been drinking too much the night before.
7) He lost $200 on a horse.
8) Aviation Week scooped him.
9) The photographer reminded him of his father whom he hates.
10) He hates everybody.

Tom Monahan
369 Bleeker Street
New York City, New York

Thanks for those kind words on Seabrook (Ed) Hull's column. He's not quite as mean as he looks. However, Ed is such a busy man around here, we never got around to having his picture taken, so an old passport photo was used over the column. But your letter did it.—Ed.

Future Lady Missileer Wants Advice

To the Editor:

I am a junior in high school and am very interested in astronomy, missiles and rockets. I make A's in school and am taking physics, chemistry, and algebra as well as other required subjects. I think I would like to major in physics, since I am more interested in rockets and missiles and actually going into outer space than I am in just studying the stars. Could you tell me what subjects I will need, how to select a college for this, and any other information I might need?

Miss Marsha Meador
625 9th St. N.
Columbus, Miss.

There are three basic subjects that should be included in your high school curriculum—Chemistry, physics and mathematics. There are many excellent colleges throughout the country that can supply the required courses. We suggest you contact your high school counselor for individual guidance. If you are 18 years of age you can and should join *the American Rocket Society as a student member. Good luck!—Ed.*

m/r Encyclopedia for National War College

To the Editor:

The National War College has selected the following item, among others, as required reading during a five-week course beginning Oct. 11, 1957:

First Annual Guided Missile Encyclopedia, MISSILES AND ROCKETS, July 1957.

Your advice is solicited with regard to securing a minimum of 160 copies for distribution to the students and faculty.

F. E. Fitzgerald
Faculty Service Consultant
The National War College
Washington 25, D. C.

Reprints are in the mail.—Ed.

A Question of Semantics

To the Editor:

There has been a rapid evolution in the aviation industry which has affected many fields. The latest to be affected appears to be semantics. Several times recently I have seen the word "sophisticated" used in aviation literature with a new meaning quite at variance with its original meaning. The latest such usage that I have noted was in your June editorial: "This Is Not the Time to Cut," where you refer to the "more *sophisticated Titan*." Would you please enlighten me as to your definition of this ubiquitous adjective, and the authority for such a definition.

R. B. Wall
6401 Lander Lane
Dayton, Ohio

Webster's states that one of the definitions of sophisticated is "deprived of original simplicity, made artificial, or, more narrowly, highly complicated, refined, subtilized, etc." Use of the word "sophisticated" in reference to the Titan was simply to say that the Titan is considered to be more advanced and a more complex missile, which is in accordance with Webster's definition. Who started using the word "sophisticated" in aviation and missile circles isn't known, but usage has spread.—Ed.

Not That Young

To the Editor:

The fifth paragraph in the July Astrionics column is resented. Please be informed that the average age of most licensed, transmitting radio amateurs is approximately 30 years. This makes your reference to "high school kids and other amateur hams" misleading to the reader. I have enjoyed amateur radio as a hobby since 1915 and have been licensed by our federal government since 1927. My resentment comes only from unfavorable publicity the radio amateurs unjustifiably receive. Let's hear more of the many favorable things.

F. C. South W3AIR
Electronics Engr.
APL/JHU

We seriously respect the fine traditions of amateur radio operators and are sorry if Mr. South mistook our intentions. However, there are always some irresponsible persons in every field. It is because of this that the audio tones to be used are secret.—Ed.

Here G. D. Schott (right), Flight Controls Department head, discusses computer solutions of control and guidance problems with E. V. Stearns (center), Inertial Guidance Department head, and J. E. Sherman, Analog Computer Section head.

Lockheed Missile Systems announces new positions in

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SEPTEMBER

Society of British Aircraft Constructors, Ltd., 18th Flying exhibition Royal Aircraft Establishment, Farnborough, Hampshire, England, Sept. 2-8.

International Union of Geodesy and Geophysics. General Assembly, (IUGG), Toronto, Sept. 3-14.

American Physical Society Mtg., Boulder. Colo., Sept. 5-7.

American Chemical Society Mtg., Hotels Commodore, Statler, Park Sheraton, New York, N. Y., Sept. 8-13.

Second Annual Course on Investment Castings, Massachusetts Institute of Technology Cambridge, Mass., Sept. 8-13.

Twelfth Annual Instrument-Automation Conference & Exhibit, Cleveland Auditorium, Cleveland, Ohio, Sept. 9-13.

Damage Criteria for Shock and Vibration Conference, Cambridge, Mass., sponsors: AFOSR/SRD (HOST) Interservice Technical Committee on Shock & Vibration, Sept. 12-13.

OCTOBER

National Electronics Conference and forum on electrical research, development and application, Chicago, Ill., Oct. 7-9.

NACA Lewis Propulsion Lab. Triennial Inspection, Cleveland, Ohio., Oct. 7-9.

International Astronautical Federation, 8th Annual Congress, Barcelona, Spain. Oct. 7-12.

ARDO Fifth Annual Science Symposium, Interdepartmental Auditorium (across street from AFOSR hqs). Host Center: AFOSR, Washington, D. C., Oct. 8-9.

Society for Experimental Stress Analysis Nat'l Fall Convention, El Cortez Hotel, San Diego, Calif., Oct. 9-11.

Canadia Institute of Radio Engineers Convention-Exposition, Automotive Bldg., Exhibition Park, Toronto, Canada. Oct. 16-18.

ASME Conference on New Developments in the Field of Power, Americus Hotel, Allentown, Pa., Oct. 21-23.

Aeronautical and Navigational Electronics 4th Annual East Coast Conf., sponsored by Baltimore Section. IRE and the Professional Group on Aeronautical and Navigational Electronics. Fifth Regiment Armory, Baltimore, Md., Oct. 28-30.

Association of the U.S. Army Third Annual Mtg., Sheraton-Park Hotel. Washington, D. C., Oct. 28-30.

American Nuclear Society, Henry Hudson Hotel, N. Y., Oct. 28-31.

NOVEMBER

Military-Industry Guided Missile Reliability Symposium, Naval Air Missile Test Center, Pt. Mgu. Calif., Nov. 5-7.

Third Aeronautical-Communications Symposium, Utica, New York, sponsored by IRE-PGCS, Nov. 6-8.

IAS Weapons System Management Mtg., Statler-Hilton Hotel, Dallas, Tex., Nov. 7-8.

DECEMBER

ASME, Annual Mtg., Hotel Statler, New York, N. Y., Dec. 1-6.

American Rocket Society Annual Mtg., Hotel Statler, New York City, Dec. 2-6.

ARS 1957 Eastern Regional Student Conf., sponsored by the Polytechnic Institute of Brooklyn Chapter, Hotel Statler, New York, Dec. 6-7.

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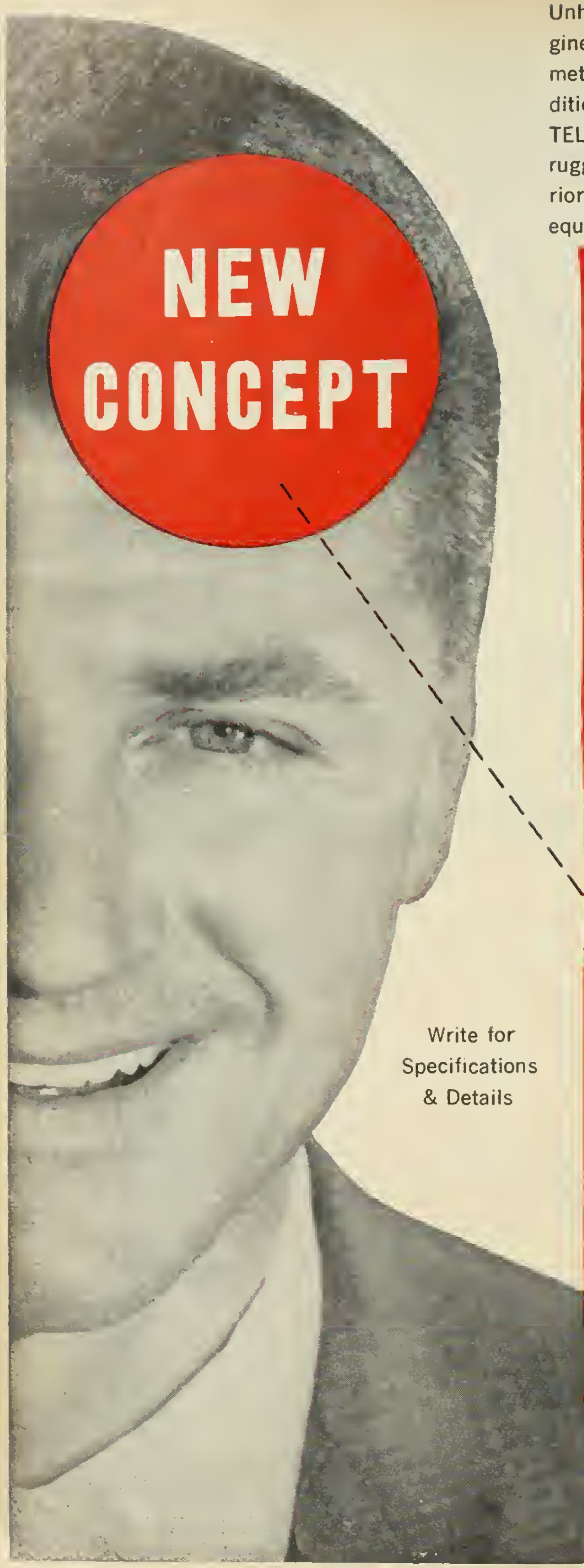

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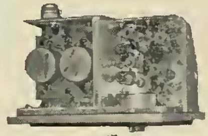

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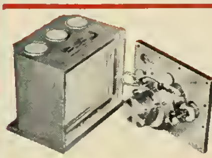

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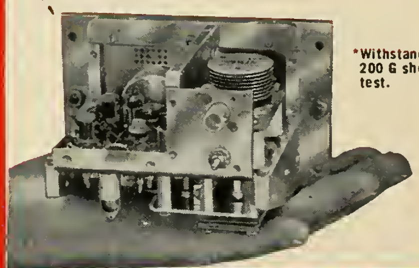

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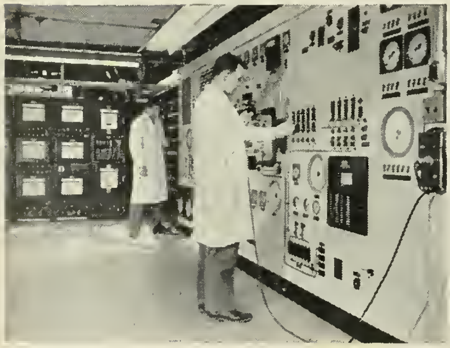

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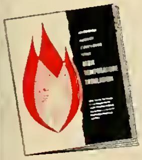

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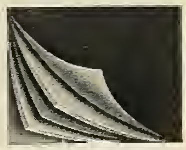

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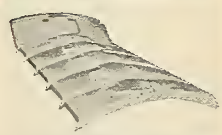

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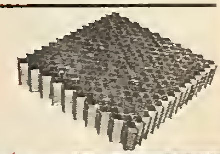

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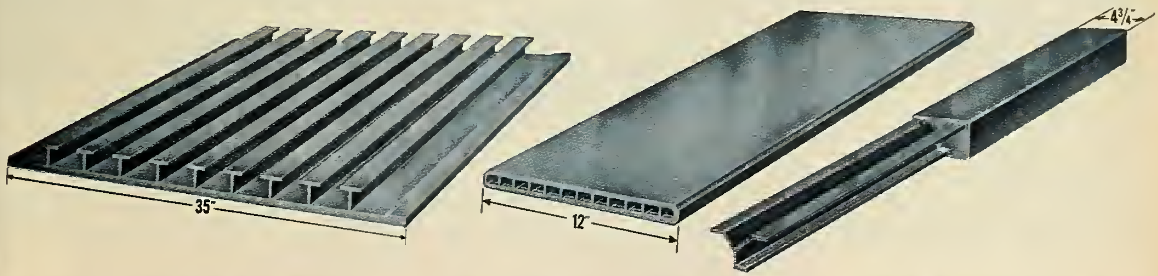

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MISSILE ELECTRONICS
Another AAP First

Sums up to one half of this nation's missile expenditures are invested in the *electronics* part of the business. With new, sophisticated guidance, tracking and computing systems under way, missiles will become more efficient, yet more complex. Thousands of engineers today—and many more thousands tomorrow—will put their efforts into *missile electronics* for the sake of advancing missile guidance, tracking, telemetry, data reduction, computing.

These thousands of engineers—comprising the *missile electronics* business—have not been adequately served. After an extensive survey American Aviation Publications, Inc. has decided to meet this challenge. It has decided to cover the missile electronics market and its engineers and management personnel with an up-to-date exclusive and extensive monthly presentation titled MISSILE ELECTRONICS, starting October 1957.

This "magazine"—a supplement to MISSILES & ROCKETS—will be published as a separate section within MISSILES & ROCKETS—at no additional cost to our subscribers. The two-magazine-in-one approach to the vast missile and astronautics field will enable us to serve our readers better, in that we will cover the entire field to the very utmost extent.

For this important expansion program American Aviation Publications, Inc., the world's largest aviation and astronautics publishers, will again increase its staff of top-notch editors. Needless to say, MISSILE ELECTRONICS and its readers will benefit from our worldwide staff facilities.

Your comments and suggestions as to how we can make MISSILE ELECTRONICS useful to you would be welcomed and appreciated.

Watch for the first issue, next month—October.

WAYNE W. PARRISH,
President and Publisher,
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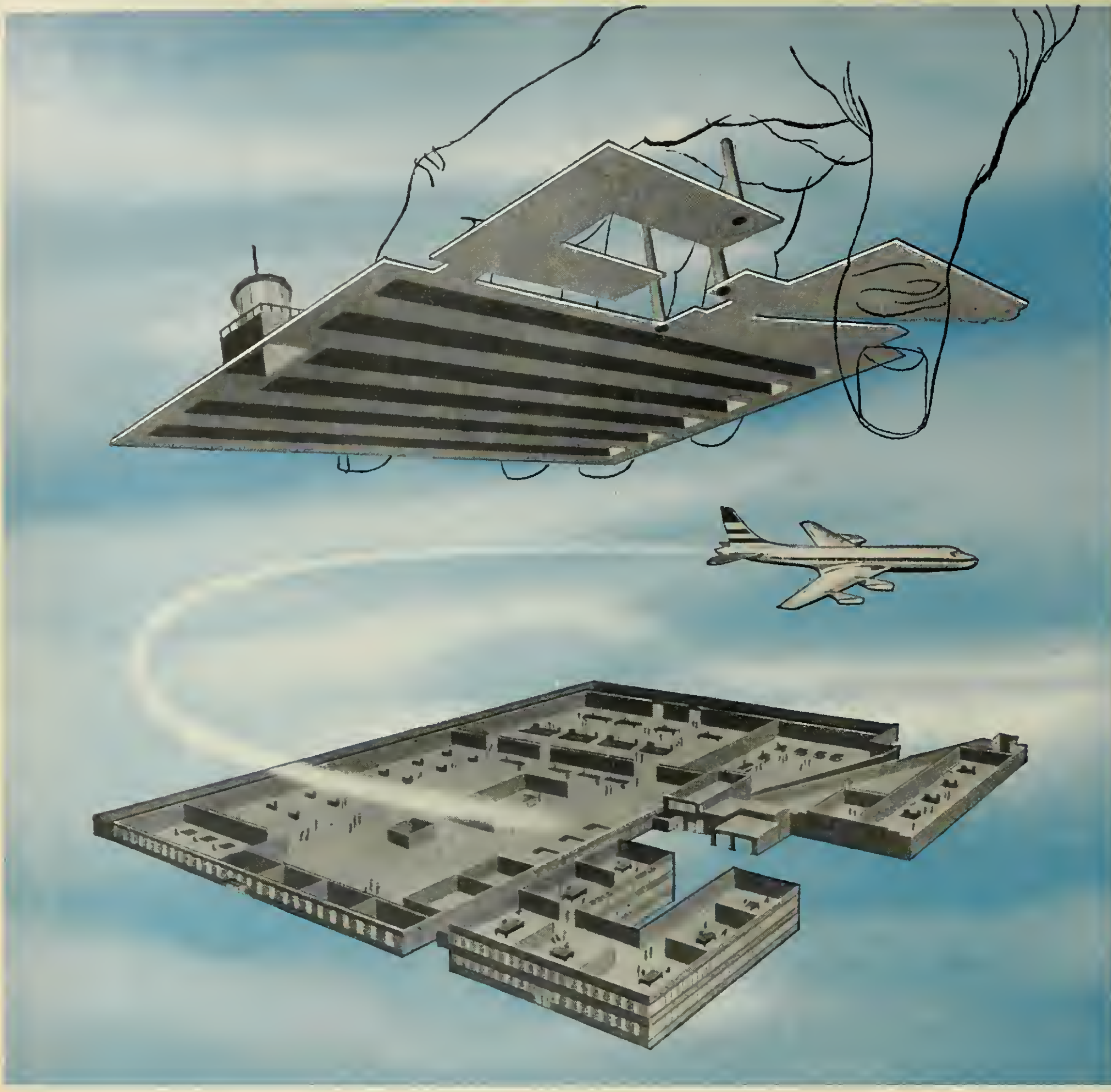


Soviet IRBMs, ICBMs Jolt U.S.

A Soviet count-downer recently pusbed a button that fired a ballistic missile probably between the small missile-launching island of Kolguev in the Arctic near Novaya Zemlya, and the Northwest Pacific Sea of Okhotsk—apparently tbe first intercontinental ballistic weapon anywbere in tbe world to go the distance (over 3000 miles). Furthermore m/r learns from reliable Norwegian sources tbat the Reds have been launcbing intermediate range ballistic missiles from naval sbips in arctic waters for some months and continue to do so. And while the Reds were impressing their missile prowess on the world, a group of top U.S. missile producers met in Washington and formed the National Guided Missile Industry Conference with an avowed purpose "of putting the U.S. missile effort on a more rational basis."

On that Monday evening when the first banner headlines of Russia's ICBM capability blared across tbe nation's front pages, none of tbe missile businessmen had forecast Soviet ascendancy in long-range missiles, but frustration and premonition were common to everyone present—"We need missiles, not politics and false economy."

On what indeed may be a fateful evening in world history, these representatives of American competitive free enterprise decided that they, if nobody else, would try to put order and efficiency into the U.S. missile effort. They are convinced missiles require a different approach from aircraft.

Those in at the founding represent some of the most successful names in missiles today—boast contracts on such important projects as *Titan, Polaris,* the *Nike* series, *Lacrosse, Talos, Falcon,* and *Hawk.*

Their organization will work, within the limits of security, to air basic guided missile problems and their solution before Congress and the American public; and to spread vital missile knowhow throughout the guided missile industry. A secondary, but still important emphasis of the group will be to push producibility (low cost) as well as availability and reliability of "in-service" missiles.

In recent history, the record shows, the Russians have never made an announcement such as this on the ICBM, without there being a sound basis of fact. Announcements of Soviet A-bomb and H-bomb achievements are good examples of this. Besides, the ICBM is not a big step from the IRBM—and they have been firing these with alarming regularity.

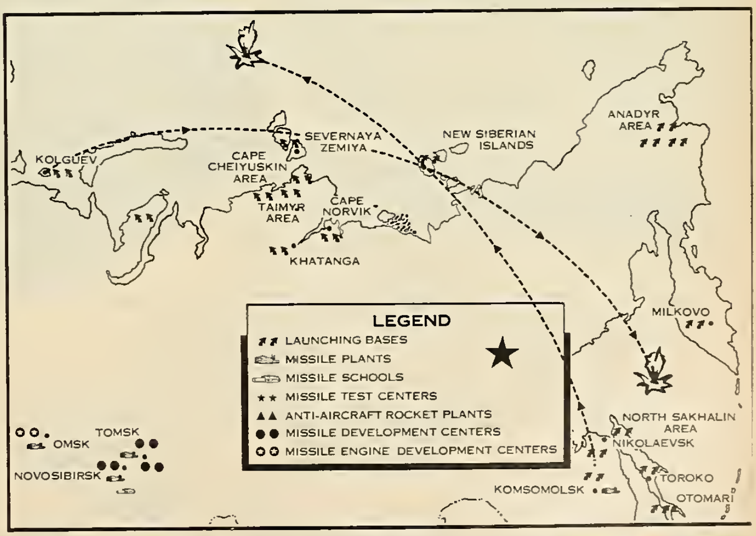
The official TASS ICBM announcement, as quoted in a Radio Moscow news broadcast monitored by m/r describing the missile as an "over-continental ballistic missile, capable of delivering a nuclear warhead anywhere in the world." The difference between "inter-continental" and "over-continental" isn't clear, but it could imply a range over the standard U.S. ICBM figure of 5000 miles or could merely have been a way of stating that the missile was tested over the Russian land mass. A tip-off to Western intelligence sources that something big was brewing could have been the Soviet warning a short while back for all foreign shipping to stay clear of the Sea of Okhotsk, north of Vladivostok.

Furthermore, a U.S. missile engineer just returned from Russia within the last few days insists that the Reds will launch an artificial earth satellite before the end of September—probably on Sept. 17, the 100th anniversary of Tsiolkovsky's birth. Konstantin Tsiolkovsky is generaly recognized as "the father of space flight" for his proposals on reaction-powered space flight before the turn of the century.

Meanwhile, Scandinavian fishermen report having witnessed several Soviet shipboard IRBM launchings this summer. First reports of such firings over a year ago suggested that the missiles involved were Russia's 700-mile ballistic missile, the *Comet.* More recent reports indicate the missiles may now have a much greater range—could possibly be the 1800-mile T-2 (M-103).

Norwegian sources told m/r the firings take place at night under bright midnight-sun conditions when visibility and optical tracking are perfect. In addition, Russia is known to have missile-launching sites on the Kolski peninsula as well as near Novaya Zemlya. Reports have not been confirmed whether Russia has launched any big missiles from these land sites. Sea launching is considered, however, to be much more difficult. The U.S. has still not launched any ballistic weapons from shipboard.

As reported in previous issues of m/r Russia's long-range ballistic missile knowhow probably is on a par with ours. Their guidance systems might be cruder, but their production output is in high gear. Ours is not. Apparently, the Reds believe in a vast amount of crude missiles rather than a few with pin-point accuracy.



Possible flight paths of the Russian ICBM firing is depicted by dotted lines. The more probable impact point is the Sea of Okhotsk (lower right) recently closed to shipping.

Spectre: First Throttleable Production Rocket

LONDON—(JAMES HAY STEVENS) In offering the *Spectre* as a production HTP/kerosene rocket, The de Havilland Engine Co. claims seven special advantages for the propellant choice: (1) automatic thermal ignition—but *not* spontaneous combustion; (2) catalytic decomposition of all HTP entering engine—i.e. avoidance of liquid injection with its explosion risk; (3) low-loss turbine drive for propellant pumps—its exhaust is used as part of oxidant; (4) controlled variable output over wide thrust range—idling less than 5% of max.; (5) ability to stop and re-start indefinitely; (6) foolproof—designed as an airplane engine with safety and long life; and (7) self-contained—propellant pumps and starting system are in the engine and it uses turbojet fuel.

Although the first practical airplane rocket—the *Walter* 509 in the WW-II Me 163 intercepter—was controllable, the *Spectre* is the first modern rocket to be throttle-operated, as distinct from multi-barrel thrust controlled.

Development by DH has continued for about ten years, starting with the *Sprite* ATO unit for the *Comet* 1. This was a 'cold' HTP unit, using solely the energy released by catalytic decomposition into oxygen and superheated steam at 1,100°F (600°C), publicly demonstrated at the 1952 SBAC Display. Next step was the *Super Sprite* 4000 lbs. x 40 sec. ATO pack for the Vickers *Valiant*, which burns the decomposition products with kerosene.

Design and prototype construction of the *Spectre* took about two years, with the first bench run in July 1953. This run was "cold"; the first "hot" run not being made until the early fall, an acceptance test being made within a month. Design rating of the *Spectre* D.Spe.1 was reached in July 1954. A water-cooled reaction chamber and nozzle were used for these early runs, but in November 1954 this was discarded and the engine was run continuously for more than one hour, using only the integral HTP cooling system.

Initial flight trials in the belly of an English Electric *Canberra* (B-57) started cold last December, with the first hot firings in January. Ground firings in the tail unit of a Saro S.R.53 were carried out in a rig at Hatfield before the airplane itself flew on May 16.

The advantages of being able to use the same fuel as a turbojet are obvious in terms of flight plan flexibility and tactical supply in the field. HTP is, at present, expensive to manufacture, but the method lends itself to mass production as economical as other oxidants. A practical design feature is that the flame temperature of HTP/kerosene not only peaks at the Stoichiometric ratio, which means cold running in the event of control valve failure, but its value of around 3600°F (2000°C) is about the limit for present materials.

The *Spectre* is now on British Security's Initial Publication List, which means only externally obvious features are revealed—dimensions but neither weights nor performance.

It is a compact, completely self-contained engine 56.5 in. long, 26.5 in. in diameter. The installation diameter over the three-point thrust mounting is 32 in. The reaction-chamber/expansion-nozzle assembly scales 44 in. long, with an overall diameter of about 13 in. and a nozzle lip diameter of some 10 in. The HTP supply pipe is nearly 2 in. in diameter, that for the fuel, over 1 in.

The cylindrical reaction-chamber-/expansion-nozzle assembly is bolted together from three sub-units—a forward end, ribbed central body and the rear casing, which is almost half the engine length. In order to achieve efficient combustion over a wide thrust range, it is necessary to use a high pressure, around 500 lb/sq. in., hence the ribbing.

The front of the *Spectre* is a gearbox casing with a large oil sump having a filler and sight level glass on the left side. The position of the gearbox suggests a turbine drive in the head of the reaction chamber, probably of impulse type and energized by a portion of the catalyzed HTP.

At the front of the gearbox is a vane-type, high rpm centrifugal pump, which delivers HTP into a pipe running along the top of the nozzle casing. Beneath the fore part of the casing, there is a smaller external pipe leading to the head of the reaction chamber.

Kerosene is delivered by a centrifugal vane pump on the left side of the gearbox to a cylindrical fuel-cooled oil cooler on the right side, after which it again traverses the engine to a valve unit on the left side of the reaction chamber.

Most of the control cranks and the various sequencing valves are on the left side of the engine. On the right, is a spherical accumulator mounted atop a pump/valve unit with a manual actuating unit. Pipes lead from the inlet side of the HTP pump to the valve, thence to the top of the sphere and from there to the reaction-chamber casing.

Although performance and weight data are classified, it is known that the *Spectre* was made to the same specification as the Armstrong Siddeley *Screamer*. The latter is unclassified because it was axed when the Ministry of Supply decided to abandon LOX for manned aircraft rockets. A full development story on the *Screamer* was given by S. Allen, chief engineer of Armstrong Siddeley's Rocket Division to *The Royal Aeronautical Society* on October 11, 1956.

The *Screamer* had a design sea level static thrust range from 1000 lbs to 8000 lbs; maximum thrust at 40,000 ft of 9500 lbs.

Army to Supply Navy *Polaris* Test Motor

The U.S. Navy's *Polaris* Fleet Ballistic Missile program is still a joint Army-Navy operation—in part at least. Thiokol Chemical Corp. holds a contract from Army Ordnance to supply engines for *Polaris* test vehicles. This is in cooperation with Lockheed Aircraft Co., prime *Polaris* systems contractor. These are full-scale missiles. The firing schedule has all the earmarks of a crash program, with actual flight tests to begin this fall. This means Navy's already well ahead of previously announced targets for getting an operational FBM.

Navy, apparently, is taking full advantage of the knowhow that has been accumulated by ABMA at Huntsville, Ala. Though Aerojet-General Corp. is officially designated as the *Polaris* rocket motor contractor, it is not beyond the realm of possibility that Navy is running a competitive development program as between Thiokol and Aerojet to see who comes up with the best solution to *Polaris* propulsion problems. If so, look for a later determination between the two, as to just which one gets the final production contract.

Little information is available as to the exact nature of the *Polaris* missile, except that it is to be a 1500-nautical-mile ballistic missile, capable of being fired from either surface ship or a submerged submarine. It will be powered by a solid-propellant motor and be about eight feet in diameter and 40-to-45 feet long. Every effort will be made to keep its length down, including such devices as the use of multiple exhaust nozzles, say, four instead of one. This configuration offers other advantages as well, such as: imparting spin by canting the nozzles; enabling any number of nozzles to be fired as desired; and a possible gain in efficiency as more complete burning is achieved in the plenum chamber.

Stromberg-Carlson Opens New Facility

Stromberg-Carlson, a division of General Dynamics Corp., has opened its new administration building and recently purchased electronics center at Rochester, N. Y. The facilities provide an additional million sq. ft. to the company's expanding telecommunication and electronics business.

X-17 Nose Cone Has Mirror Finish

A ballistic missile test nose cone, with one of the smoothest surfaces created by man, has super buffing and polishing prior to flight into the ionosphere on the Air Force's X-17 re-entry rocket. The AF said the X-17 has brought many ballistic missile test nose cones past the extreme re-entry temperatures.

Underground Factory In the Works?

HUNTSVILLE, Ala.—A series of obscure real estate transactions is now nearing completion here. Execution of the final deed to some remote mountain property on the big bend of the Tennessee River is expected to clear the way for start of a much-discussed but little publicized project believed to involve American Machine & Foundry Co., Redstone Arsenal and the Army Ballistic Missile Agency. (See m/r, May '57).

For almost two years now, a group of citizens who work to bring new industries into this area has been quietly buying up, in their own names or through proxies, various parcels of land scattered about nearby Green Mountain. This is a big ridge, about 1500 feet high and five miles long, a part of the Blue Ridge-Smoky range that cuts across Northeast Alabama to Birmingham. Green Mountain lies across U.S. Highways 231-431 from Redstone Arsenal and stops at the very edge of the Tennessee River.

The men who have been buying up the tracts of land on Green Mountain are all members of the Huntsville Industrial Expansion Committee. The city being what it is—a rapidly-expanding missile and rocket center—it has been impossible to conduct such operations in secrecy.

There have been persistent reports that AMF is planning some kind of

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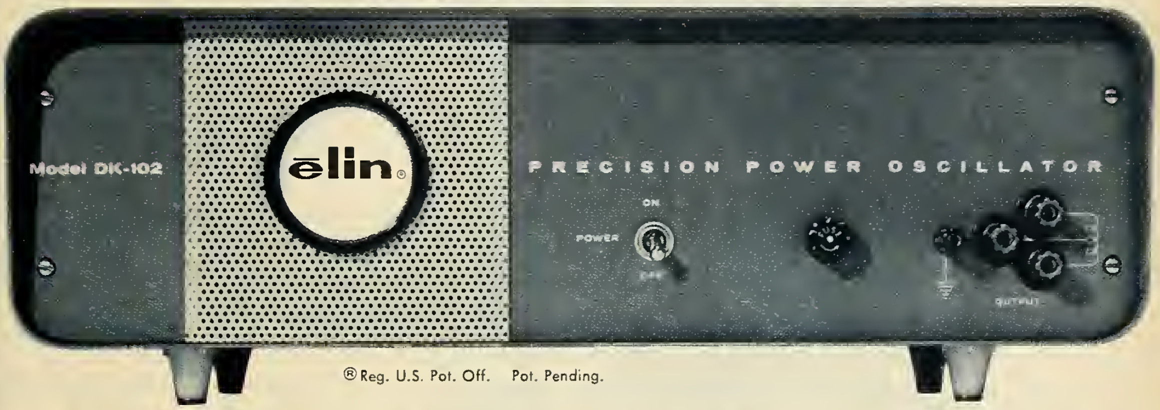

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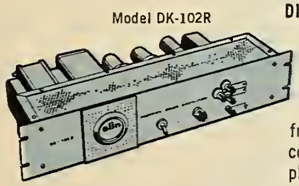

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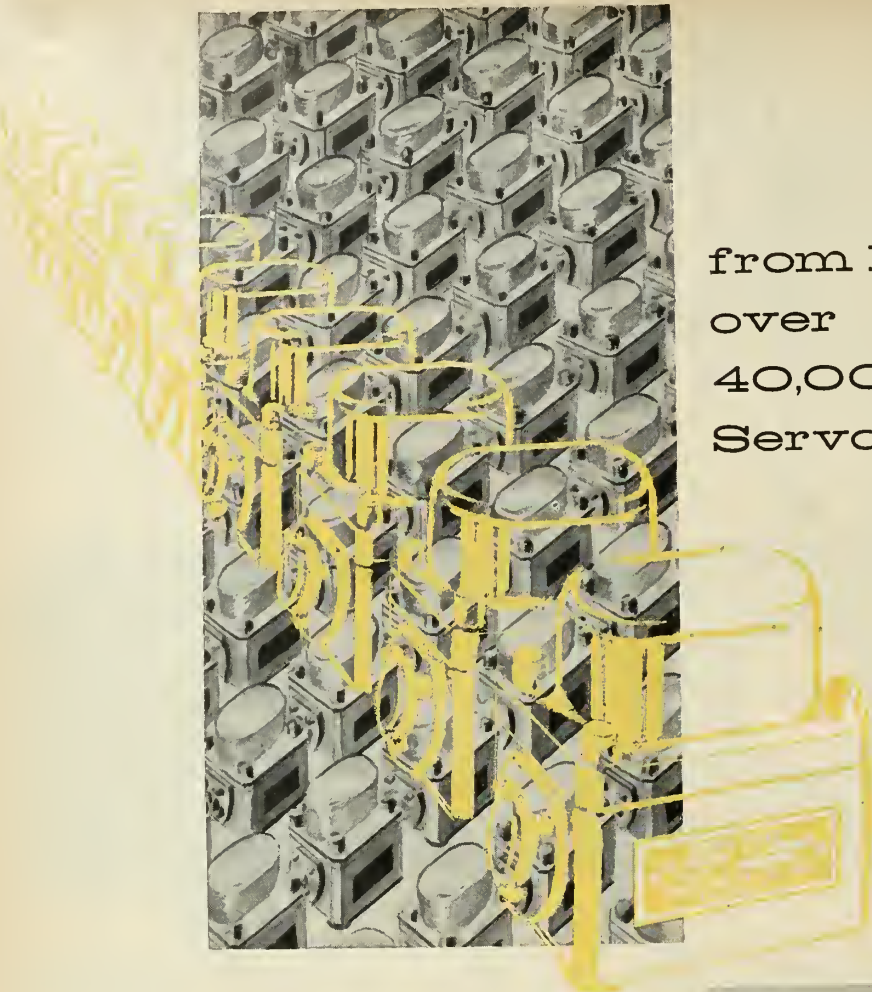

underground factory in the mountain, perhaps for the manufacture of missiles, rockets and components. AMF officials are here periodically for closed sessions with officers at Redstone and ABMA and the Industrial Expansion Committee. None will say anything publicly about the Green Mountain reports; neither has anyone denied them.

The latest acquisition of some 35-40 tracts is said to clear the big promontory for whatever purposes are in mind, although there is another report that one more tract remains to be purchased—one that is legally complicated because it involves property that passed to the Alabama State Board of Education under a will. This transaction, however, is said to be virtually completed.

Earlier this year the same group negotiated the purchase of some 200 acres on the river at the very end of Green Mountain. This is now to become the site of new state docks, presumably to serve the new installation and also to help cart away the vast quantities of limestone that must be excavated if the factory is to be built.

Informed sources say that some explanation of all the mysterious moves in and around the mountain may come within six months.

Missile Submarine Launched at Mare Island

The Navy's first submarine built primarily as a guided-missile sub was launched in June at the Mare Island Naval Shipyard. Capable of handling the *Regulus* missiles, the *Grayback* (SSG 574) is scheduled to join the fleet in July, 1958.

The two submarines now operating with the fleet as guided-missile subs, *Barbero* and *Tunny,* were converted to missile-carrying subs after first operating as conventional submarines. Two others being constructed are the *Growler,* a conventional powered submarine and the *Halibut,* the Navy's first guided-missile, nuclear powered submarine, and the first ever designed from the keel up as a guided-missile carrier.

Funds for three additional nuclear-powered guided-missile submarines have been requested in the fiscal 1958 budget.

Gilfillan Receives *Corporal* Contract

Gilfillan Brothers, Inc. has received a $695,000 contract for *Corporal* ground guidance improvement, it has been announced by the Department of Commerce.

Big B Rocket May be Major Breakthrough

Primarily Army's *Big-B* and *Big-B Junior* programs involve major developments in solid rocket propulsion. Whether the knowhow is applied to a 2000-mile missile, a 750-mile missile or a 12,000-mile missile is, for the moment, academic.

The most important point is that by the application of wholly new techniques to conventional solid propellants, considerable gains in mass ratio as well as thrust, and possibly specific impulse, are expected. Details of just what these techniques are, is a closely guarded secret. It is known, however, that from a manufacturing point of view, there are no really thorny problems in the way of rapid progress. Static tests of the first motors are expected to take place within a few weeks.

Once the new state of the art has been proved out, solid propellants for large-missile applications will hold a much more competitive position with the liquid rocket engines that are now doing the big jobs. Doing this work is Thiokol Chemical Corp. at Huntsville, Ala. This solid propellant breakthrough is believed to involve several simultaneous approaches to different problems. One is believed to be concerned with a new appreciation of the old principle of several smaller nozzles replacing one and firing out of a high-pressure plenum chamber—such as Thiokol is supplying on its *Polaris* test vehicle motors.

Electronics Spending Predicted at $3.5 Billion

Military spending for electronics may reach the $3.5 billion level by the end of the current fiscal year, according to an estimate made by the Radio-Electronics-Television Manufacturers Association. This will top by $700 million fiscal 1956's $2.8 billion expenditures.

The estimate is based on the premise that fourth quarter government spending often approaches 60% of the total of the three preceding quarters. Through the first three quarters this fiscal year military spent $2,492 million.

New Building Spurs Payroll at Redstone

HUNTSVILLE, Ala.—July's new construction contracts awarded at Redstone Arsenal, Army Ballistic Missile Agency and Ordnance Guided Missile School bring the value of the building program now under way at this huge Army rocket and missile center to more than $24 million.

Temporary employment of some 1500 persons on the new projects has boosted the work force at the three installations to almost 16,000, the highest total in its history. More than 14,500 people are working permanently at the three agencies.

Largest of the new projects involves five buildings for the Missile School—three classroom and laboratory structures and two shop buildings costing nearly $4 million. Blount Bros. Construction Co. of Montgomery, Ala., contracted to complete this project by June 1958 in time for the slated expansion of the Missile School from its present 1750 students to 3500 in 1958.

Other new structures at ABMA include: a missile surface treatment facility, an acceptance test and qualification building and an engineering mission support building.

In varying stages of construction now are: three static testing service buildings, a $4,280,000 four-building complex for structures and mechanics use, a guided missile test shop, a missile assembly and inspection hangar, an addition to a structural fabrication laboratory and 270 family housing units.

400 Days to Reach Mars Army Scientist Says

HUNTSVILLE, Ala.—The first projected time table for travel to and from Mars has been set by Dr. Gilford G. Quarles, scientific consultant at Army Ballistic Missile Agency here.

An ionic propulsion ship, using an earth satellite platform, would require 400 days to reach Mars, he says while the return trip would take 300 days.

"Although interstellar travel must await the development of more efficient propulsion systems, such as the photonic system, interplanetary travel is definitely within the scope of present technological feasibility," he declared.

"Daffynitions" Amuse Redstone

In the wake of Dave Morrah's *Saturday Evening Post* comic series on the mixture of German and English terms invented by his fictitious Herr Schnibbel, it was inevitable that the close co-operation between former German scientists and U.S. missile men at Redstone Arsenal should result in their own glossary of terms. Here are some "daffynitions" concocted by bi-lingual jokesters:

guided missile—das skientifiker geshutenwerke firenkrakker
rocket engine—firesphitter mit schmoken-und-schnorten
nuclear warhead—das eargeschplitten loundenboomer
celestial guidance—das skrewbalische schtargazen peepenglasser mit komputenrattacen schteerenwerke
engineering department—das aufguefen grupe
project engineer—das schwettenouder
structural test engineers—das pullenapardten grupe
security detail—das schnoopen bunche
hydrogen device—das eargeschplitten laudenboomer mit ein grosse hollengraund und alles kaput.

Amoco Solid Rocket Plant Nears Completion

Amoco Chemical Corp.'s new factory at Seymour, Ind., for the manufacture of solid-propellant starters for jet engines, is expected to be finished this November. Standard Oil Co. of Indiana, a pioneer in ammonia-based propellants, did the original research work leading to development of the solid propellant starters. The $3.5-million Air Force production contract for 300,000 of the units is handled by Standard's subsidiary, Amoco Chemical Corp.

Meanwhile, Standard's Research Laboratories at Whiting, Ind., and Seymour are continuing work under Air Force contracts on solid-propellant grain sizes for various purposes.

Martin Announces Missile Cooling System

Baltimore, Md.—At a press conference last week the Martin Co. disclosed the development of an advanced missile cooling system. System was designed to combat heating from aerodynamic friction in high-speed flight and electronic components.

Main feature of the system is the use of water as a cooling medium instead of the frequently used ammonia systems. Martin announced that the system has undergone one year of ground testing with an excellent performance record. Advantages over present cooling systems is its compact size, low cost and ease of manufacture.


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Jupiter Guidance Hits 99.98% Accuracy

A *Jupiter-C* test vehicle, consisting of a *Redstone* first stage, cluster of *Recruits* second stage and another cluster of *Recruits* third stage, recently flew 1200 miles and landed within 400 yards of its target. That works out to about a 0.02 per cent miss error—or 99.98 per cent accuracy.

This was the Army rocket flight that also achieved a 400-mile altitude and a reentry velocity of 12,000 miles per hour. Just prior to the warhead hitting the Atlantic, a capsule was ejected containing a letter addressed to Maj. Gen. John B. Medaris, Commanding, Army Ballistic Missile Agency. This was recovered.

The reentry velocity was in the same ballpark as that which will be faced by ICBM and IRBM warheads. It is significant that the nose cone made the reentry flight down to the ocean's surface intact. It is also significant that this nose cone is reported to have been a nonmetallic structure.

No statement, official or otherwise, has been made as to the guidance system used in this *Jupiter-C* flight. However, it seems virtually certain that it was the radio-inertial system developed under ABMA direction jointly by Jet Propulsion Laboratory and Motorola's Western Electronics Division.

More *Vanguard* Details Given to Congress

Incrementally, version by version, the story on the Project *Vanguard* satellite creeps out. With the recent request to Congress for an additional $34.2 million "to complete the project", some additional facts were put on the public record by Office of Naval Research Chief, Rear Admiral Rawson Bennett and others of his staff, including Dr. John P. Hagen, Project *Vanguard* Director, Naval Research Laboratory. Amplification and additional details, however, were placed off the record.

In what for a Capitol Hill committee hearing was a mild session on the record, Adm. Bennett placed the blame for rocketing *Vanguard* costs on the General Electric first-stage engine, the Aerojet-General second-stage and "some structural troubles with the vehicle itself."

Near the end of the brief hearing, Rep. George H. Mahon (D., Texas), Chairman of the House Appropriations Subcommittee on Defense Department Appropriations, asked Adm. Bennett about reports that the Army had the capability for launching an artificial earth satellite, and at considerably less cost than *Vanguard*. Adm. Bennett replied:

"I would like to answer that on the record. The Navy Department was selected by the Department of Defense on the basis of the considered recommendation of the Stewart committee, a committee of nationally known experts, to do the job. This assignment was made with complete knowledge of the work which was going on in all agencies. Therefore, we are proceeding with it as best we can. (Discussion off the record.) We were asked to do a job to further science and we are trying to do that. On that basis, we have no comment on the rumors."

Clarification on the troubles with the first-stage engine only serves to muddy the waters. Again, quoting Adm. Bennett from the hearings: "In the case of the first-stage G.E. engine, it seemed to burn out. A lot of work was required to find out why, and then to correct it. Briefly, the real answer was that quality control: the nozzles, the injectors, and other items were not accurately enough made so that unusual heats, that is, local heat spots in the engine, would be prevented. Once that was realized and corrected, the first-stage engine was on the beam."

This conflicts with other stories of what happened to General Electric's engine. GE engineers suggest that the trouble with the first three engines delivered to the prime contractor and rejected was as follows: In subjecting the delivered engines to hydrostatic test prior to static test firing, water of insufficient purity was used, and afterwards the engines were not properly cleaned. A period of time elapsed prior to test firing. During that period, rust spots developed which in turn resulted in hot spots and burnout.

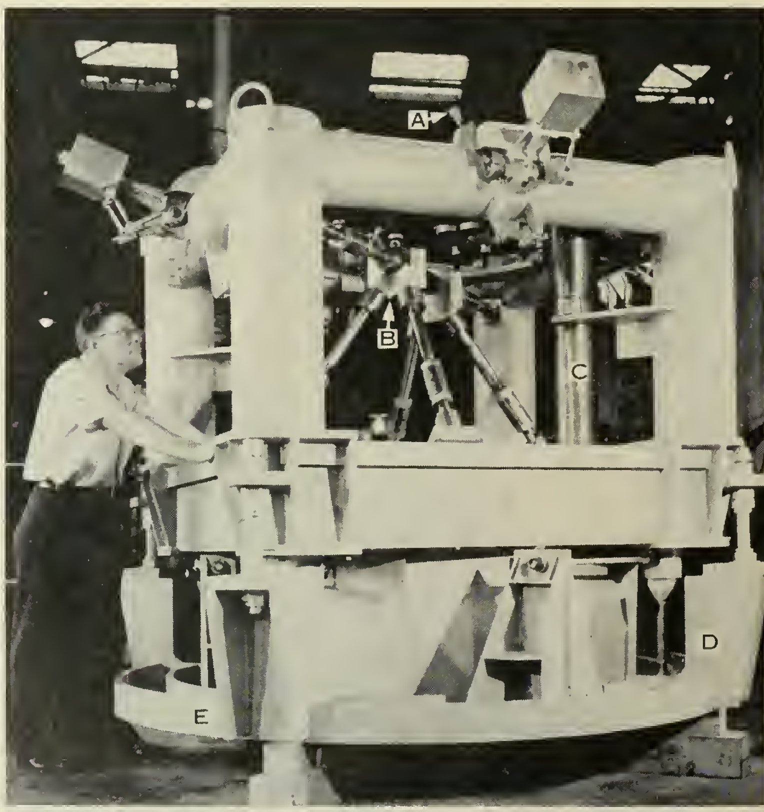
Second-stage engine experienced a similar sort of trouble which was eventually corrected. He pinned down structural problems with the vehicle as a "computational suspicion that vibration, etc., would set in within the vehicle frame."

As a result of these and other problems, as well as an initial inability to estimate costs properly in advance on such an unfamiliar project, "to date, The Martin Co. estimates its committed costs to be $47,581,000. This figure has built up from an original estimate of $28,649,000, made in March 1956."

The total estimated cost of the satellite program now stands at $110 million. These are directly chargeable or traceable costs. Of this, the Navy is responsible for supplying all but $13,874,000. The latter amount is being supplied by the Defense Department and National Science Foundation.

Adm. Bennett does not anticipate any further major costly problems, but doesn't rule them out either.

Vanguard Launching Platform Displayed



VANGUARD launching and static test platform, manufactured by Loewy-Hydropress, as it awaited shipment to Patrick AFB, where it has been installed for some weeks. (A) Pullaway pickup points on which the rocket rests, (B) the tripod which supports the engine, (C) pipe to carry exhaust to flame deflector, (D) one of four load cells to weigh rocket, fuel, measure thrust and similar functions, and (E) weighing ring for the entire unit.

Rocket Trends

by Erik Bergaust

WASHINGTON IS WHISPERING ABOUT A POSSIBLE MERGER of the *Atlas* and *Titan* programs. This comes sooner than expected and may be nothing but a rumor. It is conceivable that *Titan* will be taken off the super-priority list. In line with current streamlining and cutbacks, Air Force might want to save some money on expensive overtime work etc.

LOOK TO TWO LARGE CHEMICAL FIRMS to enter the missile picture. One is about to receive a dollar-per-year information contract. (Chose the Air Force because of its open-minded attitude about proprietary rights.) The other company has already spent considerable money in R&D on new solid propellants for industrial uses.

THROTTLEABLE, INFINITE TIME, ON-OFF SOLID PROPELLANT SYSTEM is under test. The system does not employ an auxiliary liquid system for throttling. Standard motor configuration is used for on-off operation. The system is being written into several drawing-board missiles.

JUPITER PROGRAM IS STILL HANGING FIRE. Ford's missile subsidiary is trying to get this IRBM to keep its Chicago (near Midway Airport) plant going. An alternate Ford site may be the Navy reserve engine plant at Romulus, Mich. Meanwhile, Chrysler has lined up 180 potential large vendors for *Jupiter* and is considering a solid-propellant back-up version (to meet increasing solid demands from *Redstone* and to compete with Aerojet's solid *Polaris*).

PHILLIPS PETROLEUM IS REPORTED AS NOT BEING TOO INTERESTED in such high energy oxidants as ammonium perchlorate. Because Phillips' process uses extrusion equipment, grain scale-up is probably now at its peak. From publicly shown pictures, it looks like Phillips is not likely to exceed ¼-million lb/sec for single grains.

AMERICAN POTASH & CHEMICAL HAS TAKEN ANOTHER STEP nearer getting into the rocket picture. National Northern of West Hanover, Mass. has been acquired by AmPot and will work on squibs, igniters, gas generators, and solid rocket propellants. AmPot is a leading producer of potassium perchlorate and the new lithium oxidants—the nitrate and perchlorate. AmPot also is the nation's only large-scale producer of ammonium perchlorate—which forms the basis for virtually all of our present high-energy composites.

SOVIET MISSILE SPIES IN THE US must have an easy time. All one has to do is drive down US Highway 70 toward Alamogordo, N.M. The *Dart* anti-tank test range is clearly labeled and visible from the road. In addition, all targets are numbered (you can easily determine the distances with your speedometer and take a jim-dandy picture with your camera), so that width of traverse and range can be estimated.

DEATH OF *LOKI* HAS LEFT AMERICA OPEN TO ATTACK by low-flying, enemy cruise missiles. Even effectiveness of *Hawk* (which will not be operational for several years), is questionable against modern low-altitude jet planes or even sonic cruise missiles. A barrage flak rocket is still needed in the defense picture and *Hawk* is designed for a fleet of large bombers and not one single hostile airplane.

REACTION MOTORS INC. HAS DEVELOPED A PACKAGE liquid propellant rocket system. The Navy has expressed considerable interest in the system as a competitor for solid propellant systems. Major feature of the system is its capability of providing a constant total impulse.

DIMETHYL ETHER COMPLEX OF BORON TRIFLUORIDE has been found useful in a process of separating the isotopes of boron. The dimethyl ether complex of boron trifluoride is converted to potassium fluoborate by introducing the complex into an aqueous ethanol solution containing potassium fluoride, expelling ether liberated from the complex and recovering the potassium fluoborate formed.

Space Medicine

By Hubertus Strughold, MD., PhD.

In a paper given at a symposium on astronautics in Cranfield, England, in July, Dr. Hans G. Clamann from the School of Aviation Medicine at Randolph Air Force Base, Texas, dealt with the importance of metabolic water production in the human body, for a closed cabin system in space flight. In such a system, green algae could be used to convert carbon dioxide and water into oxygen, and into food for the occupants. But over a long period of time, through biological oxidation which reconverts oxygen and food into carbon dioxide and water, an excess of water is continuously produced in the human body and would eventually accumulate in the cabin. This throws cold water on the plans of those space enthusiasts who hope to go into interstellar space, which takes much more than the time necessary to complete this chemical transformation. Thus, in space travel of long duration, the astronaut is faced with a new type of barrier—a "water barrier"—within the closed ecological system of the cabin, which can only be overcome by returning to the paleological stage of an amphibian like the crocodile or by finding some method of dealing with this excess water.

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Two books have been published in the Soviet Union by Astronomy Professor G. Tikhov under the titles ASTROBIOLOGY and ASTROBOTANY. They deal essentially with the botanical aspect of life on Mars. The greater part of Tikhov's discussion is devoted to the optical properties (reflective and absorptive) of the blue-green areas on Mars, as compared with those of terrestrial plants in the subarctic regions. Studies of this kind are closely related to the work of the Institute of Aerophotography in Leningrad.

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The books report that a special institute, known as the Department of Astrobotany, has been founded in Alma-Ata, Russia. It also includes a description of an astrobotanical garden, in which hardy cold-resistant plants from the Antarctic which may be possible on Mars, are cultivated.

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At the School of Aviation Medicine, Maj. Gen. Otis O. Benson, Jr. has expanded the Department of Space Medicine considerably, so that it can cope with all conceivable problems in missile and space operations.

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Several space medical papers will be presented at the annual Congress of the International Astronautical Federation in Barcelona, Spain, Oct. 7-12. Maj. David G. Simons of Holloman Air Force Base, N. M., will discuss Medical Problems Involved in Sealed Gondolas; Dr. Siegfried J. Gerathewohl will give a paper on producing the Weightless State in Jet Aircraft; and Dr. Ingeborg Schmidt of the University of Indiana at Bloomington, will present research on the Visibility of Artificial Satellites.

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The writer will attend the Barcelona meeting, representing the Space Medicine Branch of the Aero Medical Association by request of the president, Alfred M. Mayo of the Douglas Aircraft Co., who cannot be present because of other commitments.

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1000 TO 1 GEAR RATIO UNIT USED IN BOEING'S BOMARC

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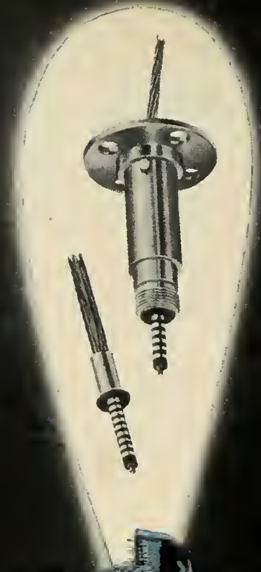

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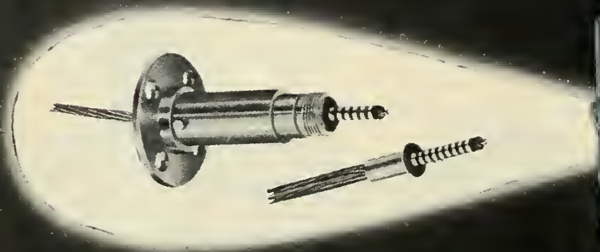

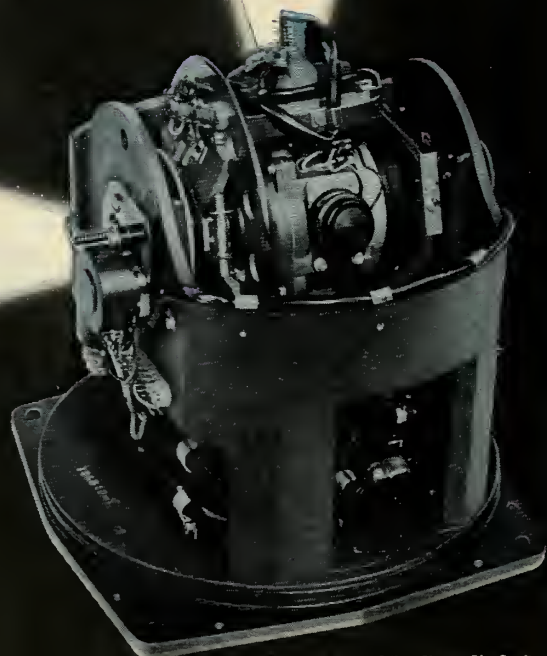

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Photo courtesy of Eclipse-Pioneer Div. Bendix

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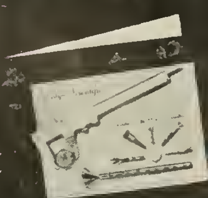

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INTERNATIONAL NEWS

By Anthony Vandyk

Trainer Role for Britain's *Fireflash* Resented

The Fairey Aviation Co. is very bitter at the British administration's relegation of the RAF's first production missile, the *Fireflash,* to a training role. The Weapon Division's Executive Director, C. H. Chichester Smith, says the *Fireflash* WS met all its specification requirements—exceeding several—and points out that it is fully tested, tropicalized, winterized and in production *now*, whereas delivery of the early operational models of the D.H. *Firestreak* will only start eighteen months from now.

Although tailored to the now abandoned Supermarine *Swift,* the *Fireflash* has been successfully adapted as a two-missile installation on the Hawker *Hunter* 6. The beam-riding guidance of the *Fireflash* is an all-weather all-altitude system, in contrast to the infrared homer, which can be foiled by thick cloud.

It seems likely, however, that RAF Air Staff policy has changed on the basis of two factors in beam-riding guidance; (a) human error possibility during period between launch and hit, during which pilot must keep narrow pencil beam aligned on target and (b) the fact that pilot must continue to head toward the possible explosion of a nuclear bomb load.

It is also apparent that the external boost system used to accelerate the *Fireflash* dart must have considerably higher drag than an internal rocket motor.

Description

The *Fireflash* WS consists of a fighter plane fitted with a radar beam, a gunsight, a simple "permission-to-fire" computer, with aircraft-to-missile services and a battery of missiles.

The missile itself is a cruciform unpowered dart which is boosted to maximum speed by two solid-propellant rockets externally mounted on its forward end. During the boost phase the unguided missile is spun by offset venturi nozzles to minimize dispersion due to asymmetric thrust.

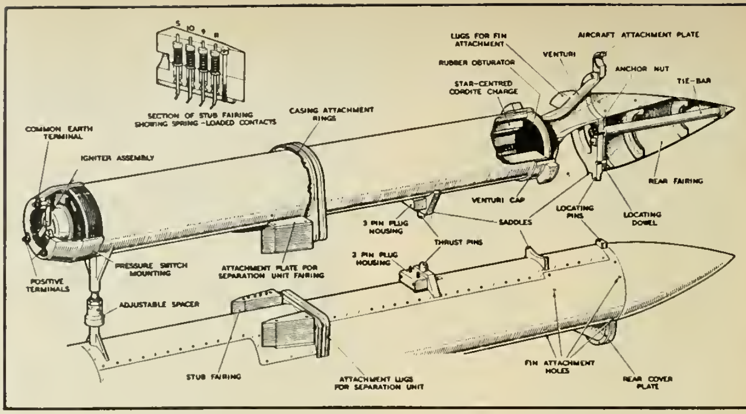
At burnout, an explosive separation device throws off the spent rocket cases laterally, leaving the dart to coast supersonically toward the target. The rudders, indexed at 45° to the wings, unlock at separation and the missile is roll stabilized by aileron-type (differential) rudder action to a datum established at launch.

As soon as roll error is reduced to specified limits, guidance commands are switched to the control blocks. The missile's position relative to the axis of the radar beam, measurable in polar co-ordinates, is interpreted as Cartesian linear errors resolved in the two control planes, pitch and yaw.

The pneumatic actuator, served by electro-pneumatic relay valves, applies rudder deflection which reduces linear errors and returns the missile toward the beam-axis. During this gathering phase, clamping diodes limit maximum lateral acceleration. The missile then rides along the beam axis, following any beam motion which may occur.

Thus accuracy of *Fireflash* is dependent upon the accuracy with which the beam is laid on the target. In daylight the fighter pilot simply tracks the target by keeping the image at the center of his gunsight graticule. The radar beam axis is accurately harmonized relative to the gunsight axis, so that the only significant guidance error introduced is that due to the aim-wander of the pilot airplane combination in tracking the target.

Development trials were carried out by Fairey on suitably modified



Cut-away view of FIREFLASH booster rocket and attachment fittings.

Meteor 7 and *Meteor* NF 11. Successful beam-riding has also been demonstrated from a two-weapon installation in a *Hunter*. A third installation, in a RAF squadron of *Swift* F 7 fighters, is currently operating as a missile training unit. Installations in other planes are practicable and simple.

Construction

The *Fireflash* breaks down conveniently for ground handling into the rear cylindrical portion of the dart, which contains all the control, guidance and power supply equipment, mounting wings and rudders and an explosive assembly comprising the warhead and its fuse, the two boosters and their separation gear. This assembly is simply attached to the main body of the dart, after it has been fully pre-flight tested on a Fairey O.A.T.S. (Operational Airfield Test Set).

Structurally, the rear body of the dart is a magnesium-zirconium alloy extruded and forged tube, into which slides a two-rail chassis carrying the internal equipment. The wings and rudders are aluminum alloy precision forgings machined only over their attachment bosses.

The boosts are attached to each other by a U-shaped separation unit and fittings on the motors mate with holes in the warhead case. The fuse is attached to the warhead, and a spacer device forward of the fuse tip pre-tensions the assembly to make it adequately rigid.

The separation gear comprises a twin piston-cylinder breech block containing 0.06 lb of cordite. The pistons, attached to one motor, are held by shear pins in the cylinders attached to the other motor. A single igniter in the base of the unit flashes to the two separate charges in the two cylinders.

A pressure switch, which arms on build-up of pressure in the boost rocket case and fires when the pressure subsequently falls to 250 lbs/sq in., is located in the nose of each rocket. These are series-connected, so that when both boosts are all-burnt, a firing pulse is passed to the igniter.

The pressure in the cylinders builds up until the shear pins fail and the boosts then separate relative to each other and to the dart. The boosts are fitted with stabilizing fins to prevent toppling after separation, which could cause deceleration fast enough to endanger the firing airplane.

Control and guidance components mounted on the chassis, from front to rear, list as follows:

- Forged light-alloy 3,000 lb/sq in. air bottle, internal reducing valve, electro-pneumatic stopcock.
- Lateral accelerometers measuring in the two control planes.
- Air-blown gyro assembly: roll displacement gyro, two rate gyros for the two control planes. These are con-

A FIREFLASH is examined after it has been exposed to a simulated dust-and-sand storm for an hour.

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tinuously blown while the missile is attached to the airplane, but coast during missile flight—the rate gyros have speed monitors.

- "Receiver": electronic component blocks predominantly interpreting received guidance signals, plus control system electronic components.
- Electric power supply assembly.
- Servo motor comprising actuator, four pairs of piston-cylinder units and four electro-pneumatic relay valves.

Russians Design Burner Devices for Rock Boring

Russia claims to be pioneering in the development of non-military uses for "rocket" engines.

Scientists at Moscow's Bauman Institute—an aviation research center—have designed burner devices for boring granite and other hard rock with a gaseous stream obtained by combustion of kerosene. Sections of rock at which the incandescent streams of gas are directed are heated rapidly and unevenly. This causes the rock to break up instantly into scales that are blown out of the bore hole.

According to the Russians, this method allows holes of various diameters to be bored in the hardest rock "many times faster" than by mechanical methods. By reducing the exhaust velocity of the gas, it is possible to make a pocket for explosives.

Soviet reports say that this form of heat boring is cheaper than any other process and is being introduced at quarries and pits. Portable "rocket borers" are planned for mineral prospectors.

Red Meteorite Probe In Progress for IGY

The Soviets report that their IGY study of meteorites is being concentrated in four observatories: at Kharkov in the Ukraine, Kazan on the Volga, Tomsk in Siberia, and Stalinabad in Tadjikistan (Central Asia). Accounts of this work are being made public by Professor V. V. Fedynsky.

At Stalinabad, Pulat Babajanov, a young Tajik scientist, is in charge of meteorite work. He guides the "meteorite patrol," as the Russians call their meteorite-photographing camera. As the result of the camera's continuous performance, the Stalinabad observatory now owns hundreds of photographs of meteorites in flight. With the aid of these photos, Babajanov and his associates are calculating the meteorites' trajectories and speed.

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World Astronautics

By Frederick C. Durant III

The orbits planned for the Russian IGY satellite vehicles have been reported to be "at a small angle to the meridian." Reliable information just received indicates that the orbit will be about 60°. The U.S. orbit selected will be about 35°. This choice by the Russians will permit viewing of their satellites by a much wider portion of the earth than those of the U.S. Areas which will be able to view the U.S.S.R. satellites include Great Britain and all of Europe from Madrid to Oslo, the northern half of the U.S. and most of the U.S.S.R.

•

Astronautical personalities from all over: Photon rocket pioneer Dr. Eugen Sänger, Director of the Forschungsinstitut für Physik der Strahlantriebe e.V. Stuttgart, has been hospitalized for a cardiac condition. First President of the International Astronautical Federation and a rocket scientist for more than 20 years, Dr. Sänger's many friends wish him a speedy recovery.

Len Carter, Secretary of The British Interplanetary Society, and editor of the excellent JOURNAL OF THE BRITISH INTERPLANETARY SOCIETY for more than 10 years, is stepping down from his post because of press of other Society duties. Carter rates a real expression of thanks.

Two recent birthdays are noted in Germany. Dipl. Ing. Leo Zanssen, former Major General at Peenemünde, celebrated his 60th. WELTRAUMFAHRT editor and ex-BMW rocket engineer and author, Dipl. Ing. Heinz Gartmann celebrated his 40th. British physicist and top science fiction writer Arthur C. Clarke writes from Colombo, Ceylon, where he has been aqua-lunging, that he'll attend the IAF Congress at Barcelona in October. His latest work, THE MAKING OF A MOON (Harpers), has just been released. Former German rocket expert Dipl. Ing. Rolf Engel, Technical Director of C.E.R.V.A., Heliopolis, for the past five years, has left Egypt with combustion specialist Dr. U. T. Bödewadt. Engel is now in Rome acting as a consultant to the Italian Ministry of Defense.

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From Japan comes word that Mitsubishi Shipbuilding Co. is concentrating on liquid propellant research for rockets. Japan Oil Co., Asahi Trans. Co. and Japan Carlit Co. are working on solid propellants.

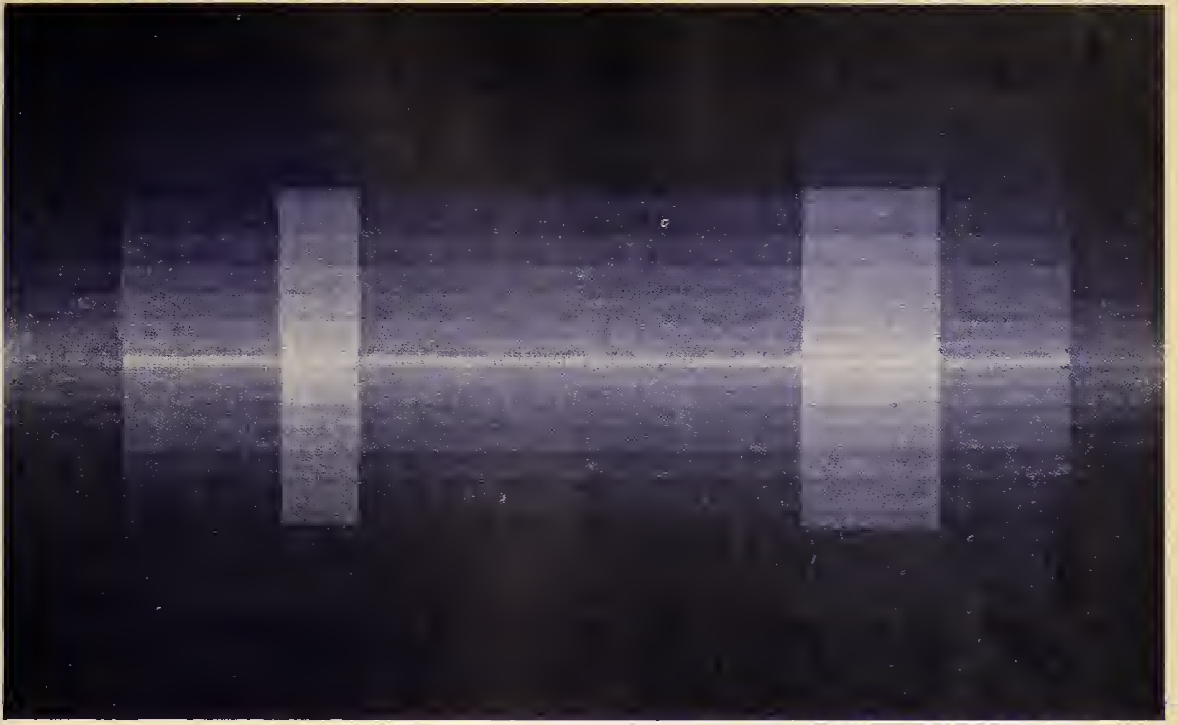
•

The West German government has purchased 1000 jeep-launched SS-10 anti-tank missiles from France. The similar anti-tank rocket development of Bölkow Luftfahrtenwicklungen, Stuttgart, is in the latter stages of development.

Rocket motor tests of increasing size at the Deutschen Arbeitsgemeinschaft für Raketentechnik, Bremen, had to be shut down recently because of "noise and danger" at the local airfield. This is an old story to amateur rocketeers. New test facilities have been completed near Oldenburg, about 30 miles west. Tests on the oil-spray rocket (m/r April, p. 88) will be conducted on the nearby Zwischenahner Meer during the DAFRA meeting this month.

•

Artemis Press, London, has recently published the fascinating SPACE ENCYCLOPEDIA. Eight well known authorities (including NRL's Homer Newell and space medicine man Dr. Hubertus Strughold) have written an excellent reference work. Details of guided missiles and upper atmosphere research are uniquely combined with a survey of all branches of astronomy.



"STUDY FOR ECLIPSE," a preliminary development by the creative team of Simpson-Middleman, artists whose work is a penetrating expression of the forces and phenomena of the natural sciences. This painting is one of the steps—ground structure—in which the ultimate action will take place. Courtesy of John Heller Gallery, Inc.

ORDNANCE

The design, development and testing of advanced ordnance products and systems is one of the principal activities of the Research and Development group at Rheem Aircraft Division. The technical capabilities of Rheem in this field are evident in the extensive list of projects currently being conducted for the military and their suppliers:

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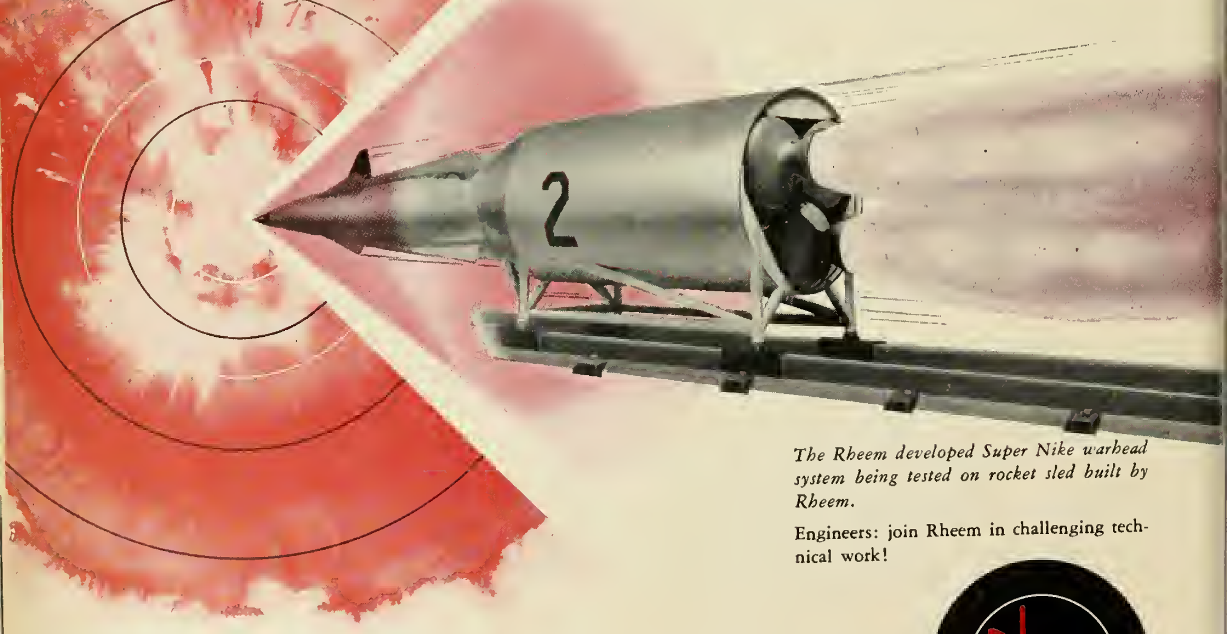

The Rheem developed Super Nike warhead system being tested on rocket sled built by Rheem.

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29-57

Behind the Curtain

By Dr. Albert Parry

"Our bombs and rockets are no worse than yours," said Nikita Khrushchev to a group of American tourists in the Kremlin on July 24.

Note that Khrushchev did not claim their rockets are superior to ours. Could be that he didn't then want to alarm the U.S. into a redoubled effort to catch up with the Soviet Union. Only a week before, an alarming report was published in the U.S. press that the Soviets had been firing intermediate-range ballistic missiles for at least 18 months at a rate of more than five a month—this against our successful testing of just one non-operational IRBM, the Army's *Jupiter*.

Soviet policy is highly opportunist, however, attempting to soothe or panic the world according to the political dictates of the moment. Thus, the recent ICBM announcement comes at a time when Russia wants no interference from the West in its efforts to grab off Syria; just three weeks prior to the opening of United Nations debate on Hungary; and near the end of deadlocked London disarmament talks.

Red policy is also contradictory sometimes, as witness the peace-loving protestations of Russian scientists Anatoly Blagonravov and Yu. Khlebtsevich on "soon-to-be-fired" Red moon rockets.

Contrary to certain American fears, they said in TRUD, the Soviets do not plan to appropriate the moon. Says Khlebtsevich, Chairman of Moscow's Scientific-Technical Committee on Radio-Tele-Guidance in Astronautics: "The aim of the Soviet scientists is not at all to establish military bases on the moon so as to threaten the U.S. from there. Our efforts in astronautics are to penetrate the secrets of cosmic space the soonest; to comprehend the measureless universe the deepest."

According to Professor A. A. Blagonravov, head of the Technical Sciences Division of the Soviet Academy of Sciences, the construction of war bases on the moon "is an absurdity to any sober-thinking military expert in any country." The Soviets feel, declares Blagonravov, that "the unfurling of any national flag on the moon should not at all be the basic goal" of the world's astronauts.

To prove the peacefulness of the Red rocket-to-the-moon plans, both Moscow scientists suggest that Americans join with the Soviets in all research and rocket-building, not only with our brains but also with our dollars.

The economy-minded among us are tempted by Khlebtsevich when he insists that the Russian blueprints of such rockets and their flights "will be far less expensive than American projects" of similar enterprise. Let's start right away, Blagonravov urges. "We would be glad to inaugurate a steady, firm contact with the scientists of the U.S. working in astronautics; also with American interplanetary rocket societies."

•

The official Soviet telegraphic agency TASS gives prominence to unofficial information from Bonn that West Germany and Great Britain have prepared a "secret" plan of collaboration in developing and producing certain "modern types of weapons," including "guided missiles and rockets with a distant radius of action."

The plan, says TASS, was slated for early discussion in London by "military experts of both nations." The report adds that the West German government has a similar cooperative plan with France.

With this report as Moscow's excuse, we may now expect more of a Red admission that missile-and-rocket work is being carried on by the Soviets in East Germany.

Washington Spotlight

By Henry T. Simmons

Appointment of the Holaday-Schriever-Medaris committee to determine the final configuration of the Air Force's 1,500-mile IRBM was calculated to raise the decision from an interservice to a "national" level, according to one Pentagon insider. He believes it may be the first of a series of high-level actions aimed at eliminating sources of interservice wrangling over missile assignments. Though no decision has been made at this writing, the odds apparently favor selection of the *Thor* engine-airframe combination, with the decision as to guidance and control left open until a later date.

•

North American is scheduled to fire four more XSM-64 *Navaho* test vehicles during the remainder of the research program authorized by the Air Force. Landing gear will be removed and no attempt will be made to recover the birds. Ironically, NAA's launching attempt last month worked perfectly, following four successive failures. The test vehicle reached design speed and altitude and covered a distance of 350 miles. The success came almost exactly one month after cancellation of the project.

•

The Air Force's new "multiple-source" development policy will have a greater impact on the missile industry than any other group of defense contractors. As outlined by Assistant Air Force Secretary Richard Horner (R&D), the policy calls for joint development undertakings by two or more companies in order to restrict outlays for new facilities. This means a company proposing a technically superior solution cannot expect USAF facilities support as in the past, but will have to enter into licensing arrangements with another firm which does have the necessary facilities. "We recognize our deficiencies in officiating at such a marriage," Horner said, but declared there is "increasing evidence" that the aeronautical industry will accept the new arrangements.

•

Most disconcerting exhibit on display at the D.C. Armory during last month's Air Force Association convention here dealt with aviation medicine. It showed a cutaway section of a rocket nose cone with chambers containing models of two disconsolate monkeys. The simians appeared to be making unearthly cries, but it was later discovered that the noise came from a squeaking bearing in an exhibit in the next booth.

•

Rocket propulsion appears to be losing its monopoly in the USAF's arsenal of airborne missile systems. The new WS-131B air-to-surface missile, awarded to North American, will use turbojet propulsion. Fairchild J83, General Electric J85 and other new engines have been suggested. USAF weapon system planners believe that turbojet propulsion offers more room for growth in certain missiles than rocket power.

•

A high-level civilian committee may be created in the Pentagon in the near future to coordinate the release of missile technical data to NATO countries interested in building U.S. missiles under license. The committee would presumably control the types of missiles cleared for use by the nation's foreign allies. The Navy's *Sidewinder* has been mentioned as one possibility for the NATO countries, and there have been suggestions that Britain will build the Air Force's intermediate-range ballistic missile when it is fully developed.

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VOL. 2 NO. 9

SEPTEMBER, 1957

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

m/r exclusive:

Report on Our Booming Missile Communities

a special service for m/r readers

During the last ten years a fabulous chapter in the book of American industrial expansion has been written. This is the story of our booming missile and rocket communities, the mushrooming test, research and development centers in the South, the West and the East. This is the story of the migration of scientists, engineers and military men to arsenals and bases that are sometimes hidden in a desert or on a tropical island. Sometimes they have sprung up out of nowhere: sometimes old war bases have been reactivated and small towns and communities have been completely re-erected and re-organized to keep up with the Klondike-type economic boom that has always followed.

The missile industry is coming of age. It appears to be separating itself from the aircraft industry and is about to outgrow it. In this respect, names like Patrick, White Sands, Redstone, Point Mugu, Palo Alto have become significant. In a period when we witness cutbacks in manpower and arms, when our aircraft and navel ship-building programs are being streamlined, missiles are zooming ahead. Because missiles form the backbone of tomorrow's defense, the missile industrial boom will continue. It probably will continue indefinitely, for it is our key to space flight and offers limitless possibilities.

A phenomenon of the missile and rocket industrial expansion in progress throughout the U.S. is the trend of many national nonmissile companies to establish plants in the new missile communities. Private contractors paving the way for small and large businesses, homes, schools, churches, follow in the wake of Army and Air Force bulldozers.

MISSILES & ROCKETS has followed this industrial boom closely, its editors having traveled thousands of miles to compile facts and figures on every major missile industrial expansion area, such as the areas around Patrick, Huntsville and others.

As a special service to our readers who might be considering moving across the country to any one of these missile Klondike areas, m/r introduces in this issue (next page) the first in a series of *complete analyses* of our missile communities. Our editors selected Patrick AFB and Cape Canaveral Auxiliary AFB as the first of this series because of their current importance as test sites for all three services and because the Air Force has just let new housing contracts in the area representing many millions of dollars.

U.S. Department of Commerce figures show that in the 10 years 1946-55 Florida led the seven Southeastern states in the amounts spent for new industries, with a jump of 110% from more than $50 million to upward of $105 million. Georgia came next with almost 100%, followed by Tennessee, 82%; Mississippi 72% and Alabama, 15.3%. The Florida Development Commission, in a recent report, lists 163 industries which, during the first half of the year, announced plans for new plants or expansion of existing plants, and this list does not include some of the more recent acquisitions such as Pratt & Whitney Aircraft Division of United Aircraft, The Martin Co., and others. Projected new plants and expansions run to $200 million or more.

In forthcoming issues m/r will present roundups on other missile communities. This *special service* is in accordance with m/r's editorial policy and is possible because m/r editors make it a point to travel extensively and get on-the-spot news and first-hand reports from the experts in the field.

The editors of m/r express their thanks to the U.S. Air Force and the Florida Chamber of Commerce, without whose assistance, this first roundup on Patrick AFB would not have been possible.

The Editors

m/r exclusive

PATRICK AIR FORCE BASE
today and tomorrow

By Erik Bergaust

PATRICK AFB—Stretching along more than 4 miles of highway A1A in Florida, Patrick Air Force Base occupies the beautiful land area between the Atlantic Ocean and the Banana River. The long, narrow installation is one of 13 Air Force missile test center activities and serves as headquarters for the group.

Originally built as the Banana River Naval Air Station, the post was deactivated after World War II, turned over to the Air Force in 1949, and renamed after Major General Mason Patrick, first chief of Army Air Services. The base covers 1822 acres and houses much of the administrative and logistical functions of the test center. Two runways are in operation at the field, one of 4000 feet and one of 10,000 feet.

Organization

Maj. Gen. Donald N. Yates, who probably knows more about missiles than any other military man in the country, assumed command of AFMTC in July 1954, after four years of research and development duty at Air Force headquarters. General Yates, a rated command pilot, has won the Distinguished Service Medal, Legion of Merit, and the Air Medal. His foreign decorations include the Degree of Chevalier in the French National Order of the Legion of Honor, the French Croix de guerre with Palm, the Degree of Honorary Officer in the Most Excellent Order in the British Empire, and the Ordem Militar de Christo of Portugal.

The General is a former president of the American Meteorological Society and a member of the Institute of Aeronautical Sciences and the American Rocket Society. He and his wife live on the base.

The deputy chief of staff for operations directs the center's programming. He makes policy, and provides program guidance and information for budget preparation. He is the watch dog of the center's activities when it comes to reprogramming and establishment of priorities. He decides what should be done and when. He also sets up liaison with foreign governments on down-range matters, directs staff intelligence activities and conducts the manpower and organizational programs.

The deputy commander for tests has charge of guided missile test planning. He controls engineering evaluation, data reduction, and photo lab facilities through the test engineering directorate. Official contact with the missile contractors is maintained through the project offices of the deputy commander for tests. He keeps in close touch with testing agencies' activities while at AFMTC.

Major General Donald Yates, USAF, Patrick AFB, Commander.

The deputy commander for range directs use of the AFMTC range. He makes policy on its use and on safety and sees that it is carried out. He assists the commander in supervising the activities of the range contractor and supervises the directorate of range operations and range development.

The deputy commander for support acts for the commander in administrative and logistical support operations of AFMTC. He commands the air base group and is designated base commander.

The director of range operations heads up communications, instrumentation, aircraft and range facilities in direct support of tests.

The director of range development controls all nonstandard range communications and instrumentation systems development for AFMTC. He supports and watches over the range contractor's development efforts.

The commanding officer of the 6550th Air Base Group is head man at Patrick Air Force Base and provides staff, administrative and logistical support to the command.

Missiles received at the center are handled by the 6555th Guided Missiles Squadron, which inspects, assembles and launches missiles. It also introduces military cadres to new guided missile programs and implements and evaluates firing procedures.

Logistical support for down-range stations and aircraft and crew support for the testing program is provided by the 6550th Operations Squadron.

Actual operation and management

of the various stations along the test range, including the launching site at busy Cape Canaveral, are the responsibility of Pan American World Airways and RCA. They maintain facilities and equipment and plan range operations to support missile test data. Various missile contractors have set up field stations for missile testing.

Other operating units at the base include Detachment 11, 4th Weather Group, responsible for forecasting and observing weather conditions in connection with missile launchings; the Patrick AFB detachment of the 7th district, Office of Special Investigations; the 2026 Airways and Air Communications Squadron; the Army Ballistic Missile Agency; and the Naval Ordnance Test Unit.

Down-Range Station

The AFMTC neither builds missiles nor fires armed missiles. It acts as a test facility and evaluation center for missiles of the three services. AFMTC provides the test range, assures the safety of the range area, and gathers information on missiles in flight. It then analyzes the data and determines whether missiles meet established requirements.

For several years, the AFMTC has been firing missiles from Cape Canaveral to the first island station on Grand Bahama, some 180 miles to the southeast. At about the center of the island is the Auxiliary Air Force Base, containing radio facilities, range clearance, inflight safety, weather reporting, telemetry reception, and radar and optical tracking equipment. Beyond Grand Bahama, other island stations are Eleuthera, San Salvador, Mayaquana, Grand Turk, Dominican Republic, Puerto Rico, St. Lucia, Fernando de Noronha and Ascension Island. Each station has both a military base commander and a civilian commander.

The Cape

Cape Canaveral Auxiliary Air Force Base consists of 12,160 acres of government-owned land, 18 miles north of Patrick AFB. The area is cut off from the mainland by the Banana River and until recently, its only landmark was a lighthouse. Today, the site is as busy as any big air base.

Actual launching of missiles takes place at the Cape. The first launching from Canaveral was that of a V-2 on July 24, 1950. The operation of Cape Canaveral became the responsibility of PAA in March 1954.

Facilities at the Cape include launching areas with blockhouses, radio transmitter and receiver sites, telemetry receiver sites, radar, missile assembly

buildings, guidance laboratories, LOX plant, photo-theodolite and camera sites, power supply buildings, motor pool, dining hall and fire station.

All activities at the Cape are coordinated at the central control building, three miles from the launching sites. It houses the range clearing and in-flight safety sections and the contacting center for all down-range stations. While in-flight safety functions are located at the Cape, this function may be transferred to any down-range station. There is a skid strip on the base for the recovery of missiles when possible. Normally, the missiles are impacted into the sea.

A submarine cable connects Cape Canaveral to the down-range stations as far as Puerto Rico and serves as a key factor in transmission of technical data during missile tests.

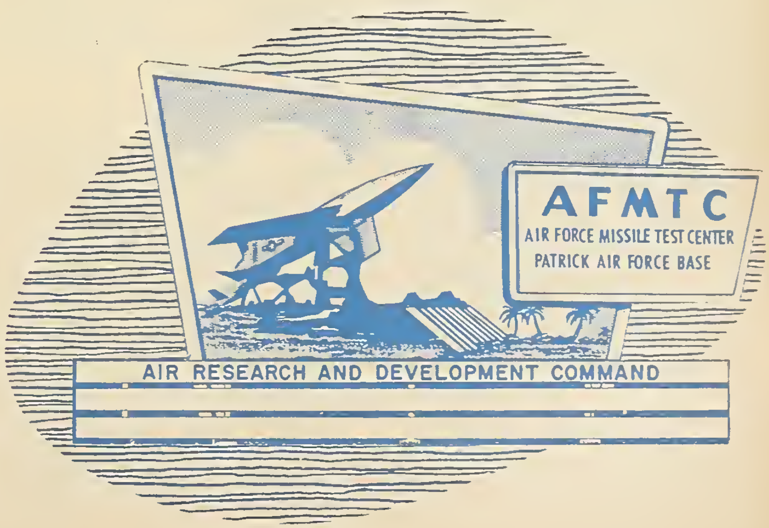
Housing

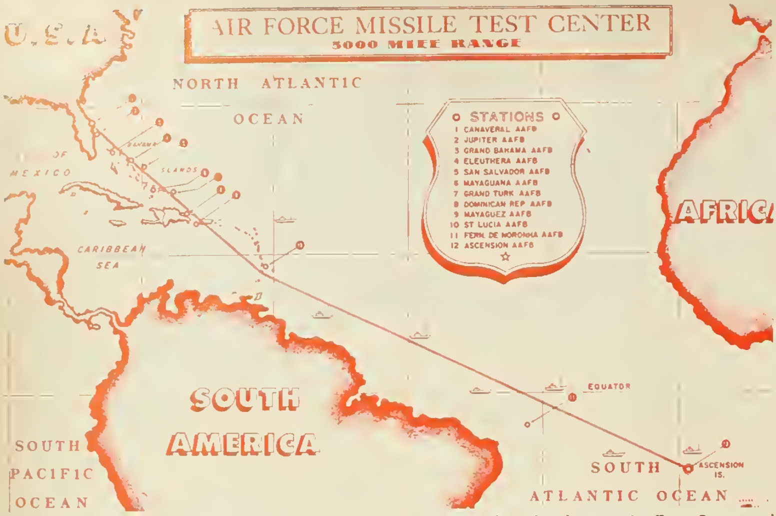
In addition to a few government quarters, there are 680 Wherry housing units (built and rented by a private concern) on the base. In the south Wherry area is a new primary school for the first through sixth grade for children whose parents live on the base. Congress has already approved 999 Capehart housing units for the base, and the Air Force has requested an additional 1000 units, bringing the total to 2679 housing units.

Construction of the 999 authorized units is expected to start soon. Bids have been submitted by various contractors and details of the arrangements are being worked out. In requesting more housing, the Air Force certified to the Federal Housing Administration that the base would be in operation for a longer period of time than that required for amortization of loans made in connection for the Wherry housing project. This means that the base will have to be utilized for at least the next 20 years. One Air Force Colonel put it this way, "The base is here to stay."

Air Force officials expect that about 150 houses will be ready within six months. These will be occupied as they become available. An additional 400 are scheduled for completion within a year, and the entire number within 18 months. The proposed housing area of about 300 acres will be connected to the base by an access road. Included in the plans, are a commissary, a chapel, and several recreation areas. The entire project is under AF supervision.

The individual houses will be constructed of concrete block and brick masonry, with terrazo floors and plastered walls and ceilings. Heating and air conditioning will be included in all





RANGE: The Air Force Missile Test Center operates the Florida Missile Test Range, the world's longest range for testing guided missiles. Bases are in operation or under construction along 5,000 miles of range from Cape Canaveral, Florida, southeast over the Atlantic to Ascension Island. Picket ships gather data between St. Lucia and Ascension.

units and each will have a garage. Many of the houses, and perhaps all, will have screened terraces.

The Capehart housing units will be for military personnel, who will be charged their quarters' allowance for use of the house with all utilities furnished. The housing quarters are being constructed under the government's policy of aiding free enterprise by contracting civilian companies for construction whenever possible.

Approval and guarantee of the construction mortgages will be processed through FHA channels from the Tampa field office. The contractor for the Capehart units will finance the project, while the AF will be tenants, making monthly payments until the mortgages are paid. The Air Force will then be sole owner of the housing.

In addition to the Capehart projects, the AF will buy the 680 Wherry units from their civilian owner. Patrick's Installations Office will begin a renovation process on the Wherry units and they will become quarters for military and civilian personnel at AFMTC.

Except during the peak of the winter season, small furnished apartments and rooms are in fair supply. The bulk of sale housing is newly built and attractively planned, mostly concrete block stuccoed, modern ranch-type units. Of the many housing projects under way in the area, most contain their own shopping centers. A list of real estate firms active in the area is available from the local chamber of commerce.

Present employment at AFMTC is about 15,500, compared to 1955's 8500 and 1950's 1500. By the end of 1958, the AF expects to have more than 18,000 employed at the base.

Of the 18 contractors at the base, about 12 are considered "major". The range contractors are Pan American World Airways and Radio Corporation of America. Others include Boeing Convair, Douglas, General Electric, Martin, Lockheed, North American, Northrop, and Ramo-Wooldridge.

Over 9500 of the base personnel are contractor personnel. Almost half of the total expenditures at the base in 1956 was spent in Florida, with 33 per cent being spent in surrounding Brevard County. The present AF payroll at Patrick amounts to about $6 million monthly.

The 225 separate parcels of real estate along the test range are the responsibility of the Air Force. Extending from the Florida coast to Ascension Island in the south Atlantic, the easements and right-of-way making up the 5000-mile range have been valued at a net worth of $335 million.

Schools

Public schools in surrounding Brevard County are operated on a full nine-month term. Approximately 5000 children from the Cocoa area are enrolled in eight local schools, and school bus service is available in all outlying areas. No tuition and all text-books are free. However, automobile owners are required to purchase Florida license plates if their children are enrolled in the state's schools.

The high school is fully accredited and offers courses in commerce, vocational home economics and industrial arts in addition to the regular academic courses. The county adult education program is one of the most progressive in the state and offers a variety of evening courses. It's enrollment is the fourth largest in the state.

Churches

The twenty-two churches in the Greater Cocoa area represent many denominations. Assembly of God, Baptist, Catholic, Christian, Christian Science, Church of Christ, Church of God, Episcopal, Lutheran, Methodist, Presbyterian and Seventh Day Adventist. Services for Jewish, Protestant and Catholic faiths are held at Patrick AFB. A complete list of churches is available from the local chamber of commerce.

Climate

Florida weather lives up to its billing: clear sunny days and pleasant cool nights. The area has never experienced sustained winds of hurricane force. A constant breeze blows from either the Banana or Indian rivers or the ocean. Elevation ranges from sea level to 81 feet. Almost all types of soil are found in the area although sandy loam is predominant and is suitable for the growing of many varieties of fruits and vegetables.

Here are some attractive figures from the U.S. Weather Bureau:

	Normal Temperature	Normal Rainfall
January	62.2	2.72
February	63.7	2.83
March	67.0	2.81
April	71.4	2.25
May	76.2	4.00
June	79.5	6.20
July	81.2	6.37
August	81.5	5.43
September	80.0	7.30
October	75.5	6.59
November	68.4	2.17
December	63.2	2.52

Health

Wuesthoff Memorial Hospital, a nonprofit community hospital located at Rockledge, is a modern, well-equipped fifty-bed hospital. In addition to facilities at Patrick AFB for base personnel, the Cocoa area has fourteen medical doctors, two chiropractors, four dentists, two optometrists, and one chiropodist. The Brevard County Health Department has offices in Cocoa with a resident medical doctor and a staff of nurses. A doctor is on call at the hospital at all times for emergencies, and a list of local doctors available for emergency calls, may be obtained from the chamber of commerce.

Water Supply

Water for Cocoa and Rockledge is secured from a clear lake through waterworks owned by the city of Cocoa. Water is filtered, fluoridated and chlorinated. Capacity of the $485,000 plant is 2,115,000 gallons per day. Average consumption is 900,000 gallons per day. Water rates for Cocoa are: 5000 gallons or less, $2.50; over 5000 to 10,000 @ 30¢ per thousand; over 15,000 to 20,000 @ 25¢ per thousand; over 25,000 @ 20¢ per thousand. Water is inclined to be hard, but water softener is available.

Electric Power

The area around Patrick AFB and Cape Canaveral is served by the Florida Power and Light Co., which owns and operates the generating and distribution systems. The minimum electric bill in incorporated areas is $1.25, and in unincorporated areas, $1.50. Rates scale down to 1½¢ per kilowatt hour. Rate sheets will be furnished by the local office. The electric power is adequate and dependable.

Economy

Extensive citrus groves produce famous Indian River premium fruit, and the Cocoa-Rockledge area is the largest shipper of citrus gift packages in Florida. There are six commercial packing houses that pack carloads of fruit daily during the fruit season.

Vegetables are grown during the fall and spring and such sub-tropical fruits as mangoes, avocadoes, guavas, papayas, and bananas grow well here. Production of these on a commercial basis is increasing.

There is extensive beef cattle farming in the area and thousands of acres of land have been converted to improved pasture. Other agricultural activities include forestry, poultry, dairying, commercial gladiolus and gladiolus bulb raising, honey production, etc.

There is an abundance of sea food in commercial quantities, obtained from both the ocean and two nearby rivers. Fishing is a major industry, primarily shrimp.

Fishing and Hunting

Fishing is probably the most popular sport of the area. The ocean, salt waterways, rivers and fresh water lakes in the vicinity attract fishermen from all over the country. Fishing licenses are not required for fishing in salt water. This includes the ocean, Banana River, Indian River, and Sykes Creek. The best fishing spots in the rivers are from banks or bridges and the most popular equipment is casting rod with level-winding reel or fly rod. Fish caught in the rivers are usually large.

Trout, drum, bass and snook are found in great quantities in the local rivers, while the ocean surf yields channel bass, blue fish, snook, flounder, weakfish (salt-water trout), pompano, drum, whiting, tarpon, sea bream, triple tail, sheephead and mangrove snapper.

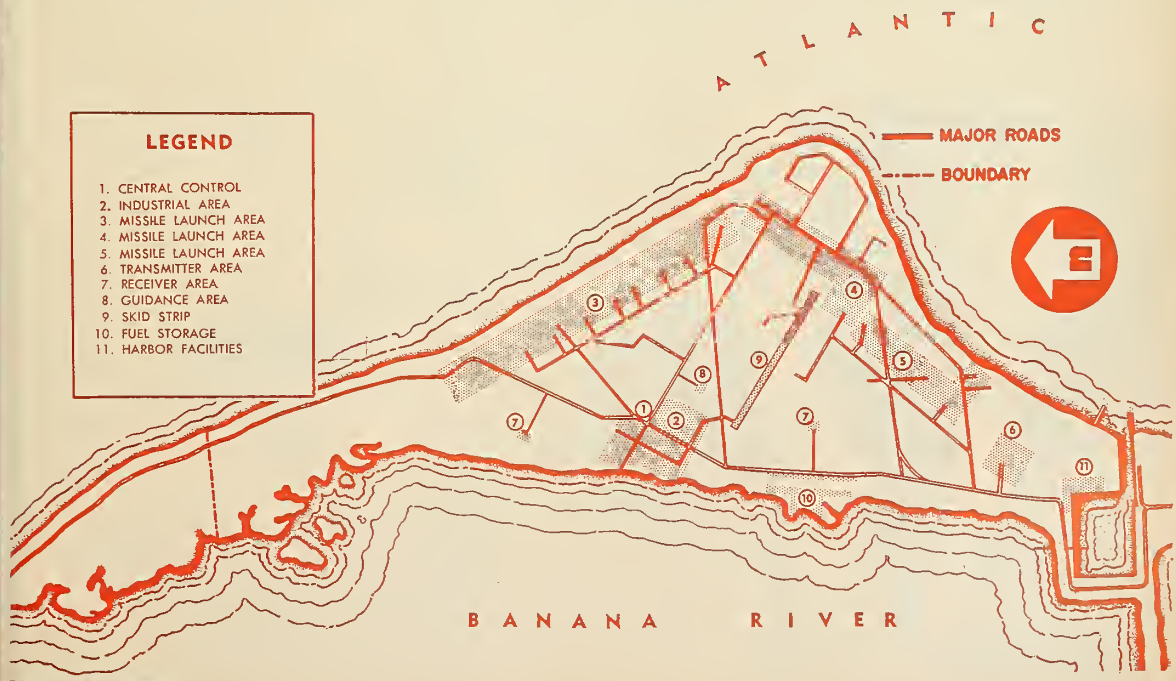
A fishing license, costing $2.25 and obtainable at most boat rental and bait houses, is required for fishing in fresh water. Fishing for large-mouthed black bass is very popular in nearby fresh water bodies, such as Lake Poinsett, St. John's River, Lake Washington, and Lake Winder.

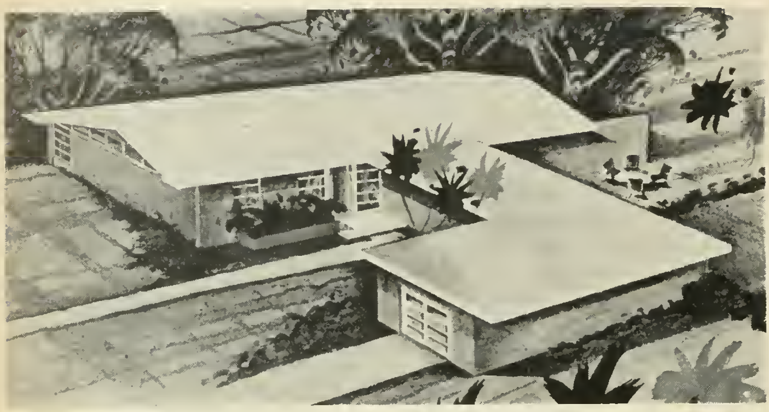
Duck and quail hunting is popular in this part of the state during the season, which lasts from about mid-November to the end of January. Deer and turkey hunting may be done on hunting preserves with a license obtainable from the State Game Commission. Local hunting requires a city hunting license.

Taxes and Citizenship

Insofar as the state is concerned, a new resident of Florida is a citizen of Florida (a resident being a person domiciled in the state). One is not eligible to vote, however, until he has resided in the state one year and in the county and precinct six months. Declaration of intention to become a citizen may be filed in person by a new resident in any courthouse. Florida has no poll tax.

Florida has none of the penalizing taxes now common to most states. Its constitution prohibits the state from imposing taxes on incomes (either individual or corporate) and on real property and permits no state inheritance tax, although sharing in that which is federally imposed. The state's finances originate solely from excise and sales taxes, occupational and other licenses of the usual character. The state sales and use tax is similar to that in effect in the majority of other states. Exempt from sales tax are: food,





Beautiful, modern Capehart housing units for Patrick AFB airmen.

medicine and some farm supplies.

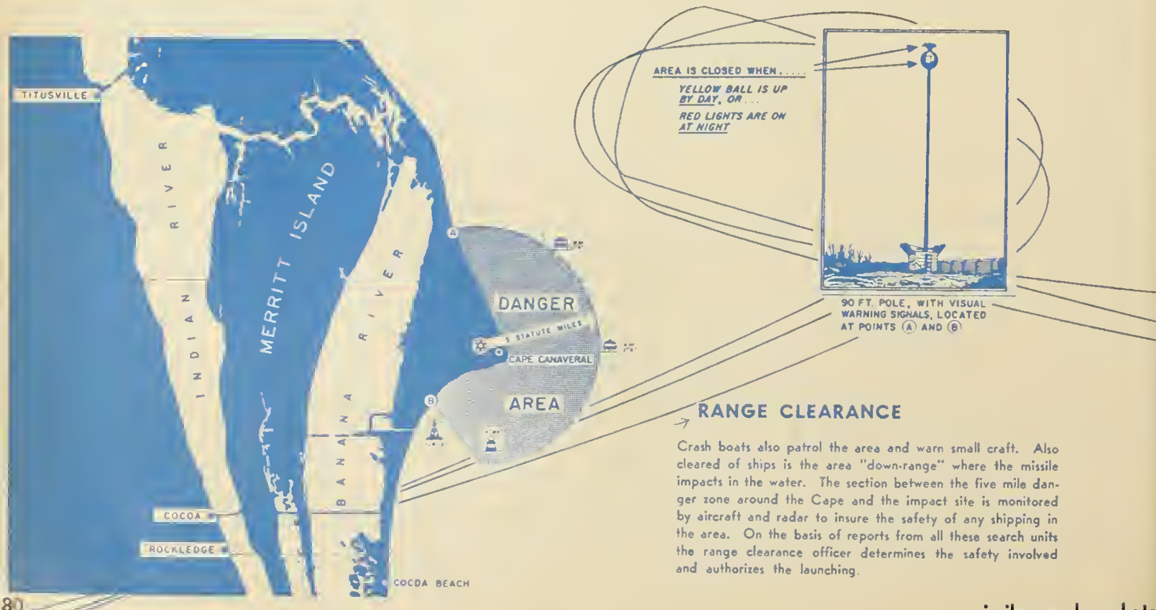
There is no property (ad valorem) tax in Florida on automobiles, but the state imposes a license fee as follows: weight up to 2000 lbs., $5.00; to 2500 lbs., $10.00; to 3500 lbs., $15.00; to 4500 lbs., $20.00; above 4500 lbs., $25.00. House trailer tags are $10.00 when it is used on the highway; when used as a home, it is taxed as personal property (see below). Nonresidents, entering children in public schools, are required to purchase Florida tags for automobiles used in the state.

Florida has a negligible tax on intangible property. The tax is assessed at full value and is 10¢ per $1000 on money and $2.00 per $1000 on stocks, bonds, notes and mortgages. This tax does not cover savings bonds.

Occupational and business licenses are required by the state, counties and cities. Other city and county taxes are difficult to compile because of the variety of conditions, localities, etc. To secure information on these various local taxes, the Florida Chamber of Commerce suggests writing to the tax assessor in both the city and county in which you are interested, regarding the following subjects: Real Property: Counties and cities levy property (ad valorem) taxes, but may not tax a homestead except where the assessed value is over $5000, and then only on that part exceeding this minimum. Personal Property: These are city and county taxes and there is a $1000 exemption for the heads of families.

Taxation in the Patrick AFB locality are approximately as follows: Taxes on nonhomestead-exempt property in Cocoa, 10 mills; state and county 61.85; in Rockledge, 9 mills; state and county, 70.35. On homestead-exempt property in Cocoa, 2.7 mills; Rockledge, none; state and county, none. Property is evaluated at about half its sales value.★

Facts, figures and illustrations in this article have been compiled and digested by m/r from material and statistics furnished by the Air Research and Development Command, Office of Public Information, HQ, Patrick AFB; The Florida Chamber of Commerce, Jacksonville, and the Greater Cocoa Chamber of Commerce, Cocoa, Fla.



RANGE CLEARANCE

Crash boats also patrol the area and warn small craft. Also cleared of ships is the area "down-range" where the missile impacts in the water. The section between the five mile danger zone around the Cape and the impact site is monitored by aircraft and radar to insure the safety of any shipping in the area. On the basis of reports from all these search units the range clearance officer determines the safety involved and authorizes the launching.

WHY ASTROPHYSICS?

Astrophysics applies the laws of physics to the study of the universe, according to the dictionary. But only the history book reveals that it was the study of the universe which gave impetus to the development of physics. The basis of all science is precision measurement. However, without the universe around us such concepts as precise time and precise position may never have evolved.

The ancients observed the regular motion of stars, caused by the earth turning on its axis—uniformly, with hardly any variation in the 24-hour period. Nowhere on earth do we have an example of such uniformity.

If we look at the history of astrophysics, we find a number of breakthroughs. Some are related to the development of new instruments, others are theoretical in origin. Our ideas about the nature of the universe are based on what we see and the better we see, the greater our understanding.

The first and most important breakthrough was the invention of the telescope which, in the hands of Galileo, led to the first real discoveries in astronomy. In his "Sidereal Message" Galileo describes very excitedly the "many great wondrous spectacles" which he saw when he first picked up his telescope.

His first discovery—the mountains of the moon whose height he measured very crudely; his next discoveries—the moons of Jupiter and the phases of Venus, which proved that otber planets have satellites and also give great impetus to the Keplerian solar system theories.

Galileo was tbe first man to view the Milky Way and recognize that it is made up of countless stars. Larger and larger telescopes have evolved up to the 200-inch Mount Palomar instrument which now looks far out into space. Here in 1610. physics. for the first time. advanced astronomy.

The stimulating effect of the astronomical discoveries on physics itself must not be overlooked. Nowhere on earth are there phenomena as regular and therefore as simple as in the workings of the universe, especially in the solar system. Objects on earth never move under gravity alone. There are always winds, air friction and other disturbing elements.

It is no wonder that Newton formulated the simple law of gravitation (in 1666) through astronomical observations and only later applied it to phenomena on the earth. Now we use it to describe the motion of earth satellites, and ballistic rockets moving freely outside the atmosphere under the influence of the earth's gravitational field alone.

The next great advance was the invention of the spectroscope, the instrument which can analyze the light from celestial objects after it has been collected by a telescope. It is the instrument which tells us what kinds of atoms contribute to the light.

The spectroscope, first in the hands of Kirchhoff who in 1862 applied it to the sun, has been and still is the most important tool of the astrophysicist. It has been used to deduce the composition of stellar atmospheres and of interstellar gas.

It can tell us the temperature of the earth's atmosphere and the nature of the surface of Mars and Venus. Spectroscopy, however, really became valuable only after the development of modern atomic physics, which provided the key to why atoms emit light of particular colors and with particular intensities.

Nuclear physics has also found its application to astronomy, and a very important one. It has given us a means of understanding the ultimate energy sources for the stars. We now know what the interior of the stars consists of, the relative abundances of hydrogen and helium and of the heavier elements and we can calculate how rapidly these materials are burnt up in order to provide the energy.

We can even calculate the evolution of stars, their past behavior and past energy output and we can predict their future behavior and their eventual death. As a result of our increasing knowledge of nuclear physics we now know more about the internal constitution of stars than we do about the internal constitution of the earth itself.

The development of radio astronomy was a major breakthrough closely tied to the technological developments of electronics. We can now "see" objects in space through radio waves.

They are not subject to absorption by interstellar dust which limits the visible light radiation. We can, therefore, look much farther into the region of the galactic center than we can with optical telescopes. And we can get new data on celestial objects by studying their emission of radio waves.

There have been discoveries of new objects, such as the radio stars which are slowly being identified. There has also been much activity in tbe science of magnetohydrodynamics, one task of which is to explain the production of radio noise in the universe as well as cosmic ray origins.

But these advances are only the beginning. A new tool of technology has arrived which will push astrophysics on to greater horizons—the rocket. Already high-altitude rockets have made pioneer explorations above the ocean of atmosphere which screens up from most of the radiation coming from outer space.

We have already been able to "see" the sun in its ultraviolet light but only for short periods. The artificial satellite will eventually allow long-term observations of solar ultraviolet and X-rays. The *Vanguard* project will be of major importance for astrophysics. So will extensions of the vertical rocket techniques to extremely high altitudes.

The recently announced Project *Far Side* will carry instruments to unbelievable altitudes, measured in earth radii, and eventually to the limits of the earth's gravitational field. To begin with, these observations will be crude and rather simple, but as larger rockets are developed the vehicles will become heavier and more intricate and the instrumentation carried out into space will become more elaborate.

In the meantime, the study of the universe may give us another insight into physics. Cosmology may solve the most fundamental problems of all; gravity and the ultimate nature of matter. The steady-state model of cosmology which assumes that matter is created spontaneously and uniformly throughout space may in the end allow us to glimpse the properties of subnuclear matter and of antimatter.

Already theoretical speculation is rife on whether antimatter obeys the same laws of gravity as ordinary matter. But this is a hypothesis which we may never be able to test in the laboratory. For confirmation we must look to the cosmos itself.

1957 Liquid Propellant Round-up

By the Editors of m/r

BY THE TIME our GALCIT Project had formed and actually got under way, the Germans had a head start in liquid propellant rockets. By 1931 a 660-lb. thrust liquid engine had been developed in Germany, and by 1934 a rocket using this engine was successfully launched. Peenemuende had developed a 3300-lb. thrust engine by 1939.

It was not until 1939 that the Jet Propulsion Laboratory undertook the development of liquid propellants. On July 1, 1940, JPL started work on nitric acid systems. The aim: develop a liquid propellant rocket to deliver 1000 pounds of thrust for one minute. Starting with gasoline as fuel, ignition problems and combustion instability were encountered (the engine worked properly about 80% of the time).

At about the same time, a group of researchers at the Naval Experiment Station (Annapolis, Md.) also had the same combustion trouble with a nitric acid-gasoline combination. It was found that aniline was spontaneously combustible (hypergolic) with red fuming nitric acid.

In April, 1942, an A-20A attack bomber was equipped with a 1000-lb. thrust acid-aniline rocket. During the tests some 44 successive runs were made without any misfires or explosions. This marked the first liquid propellant rocket assist takeoff (RATO) in the U.S.

After the successful RATO, Aerojet Engineering Corp. (now Aerojet-General) took over to manufacture liquid units. However, liquid engine use was dwarfed by the efforts devoted to solid RATO and artillery rockets.

A Signal Corps assignment in 1944 required a rocket to carry 25 pounds of meteorological instruments to an altitude of at least 100,000 feet. JPL started to work on this project by first firing a missile booster *(Baby WAC)* in July, 1945. Test of the *WAC Corporal* was made in autumn 1945. The engine, delivering 1500 lbs. thrust for 45 seconds was an acid-aniline engine built by Aerojet.

One of the world's more highly developed liquid rocket engines—Reaction Motor's power plant for the North American Aviation X-15 rocket research plane undergoing static test.

On the East Coast the scene was somewhat different. A number of ardent American Rocket Society members (Lovell Lawrence, Jr., James H. Wyld, John Shesta, and Franklin Pierce) had been conducting Sunday afternoon rocket shots. They formed Reaction Motors, Inc. in 1941 and by November, 1942 successful runs were made at over 1000-lb. thrust. They upped this to 3400 pounds by May, 1943.

The end of the war, however, showed that the U.S. was lagging far behind in development and production of large liquid rockets. The V-2 was immediately accepted as the workhorse around which additional developments nucleated. There then followed a growing number of government, industry, and research groups (Tables 2, 3 and 7). A rundown on the latest activities follows:

AEROJET-GENERAL CORP. Working on the *Titan* (LOX), second-stage *Vanguard* (acid) liquid rockets. Also *Aerobee-Hi* (acid) and liquid underwater units (lithium). Now building three acid-JP rocket sleds.

AMERICAN MACHINE & FOUNDRY CO. Working with ethylene oxide and alkyl nitrates for ICBM APUs at its Pacoima, Calif., facility.

AMERICAN ROCKET CO. Recently entered the liquid rocket field with a new monopropellant combination. Also working on new high energy fuels.

ARMOUR RESEARCH FOUNDATION. Extensive research work on stabilization of liquid ozone. Also: chemistry of the boron exotic fuels.

BELL AIRCRAFT CORP. Developed powerplant for *Nike Ajax* (acid) and liquid rocket for *Rascal.*

CALIFORNIA RESEARCH CORP. Working toward improvement of properties of nitric acid systems.

CURTISS-WRIGHT CORP. Developed a LOX-gasoline ATO and a throttleable motor for Bell X-2. Thrust is 12,000 pounds. Major propellant emphasis: LOX.

ETHYL CORP. Doing research in development of monopropellants and fuels. Products: alkyl nitrates and alum-

TABLE 1

ON THE SHELF LIQUID ENGINES

Model	Length (Overall) (in.)	Diameter (Maximum) (in.)	Weight (Dry) (lb.)	Thrust (lb.)	Burning Time (sec.)	Mfr.	Oxidizer	Fuel	Notes
Aerobee-Hi				4,100	53	A	NA	XY	Niafrak nozzle, ceramic lined.
AJ24-1 (YLR45)	74	30			45	A	NA	JP	B-47 RATO (2 retractable chambers on each side of fuselage).
AJ-10-24	130	15				A	NA		*Aerobee* liquid booster.
LR63AJ-1	144	12				A	NA	JP	F-84 RATO & Auxiliary Thrust (1 permanent chamber in tail).
1500N4C	56	19	210	6,000		RMI	LOX	ALC	Used on X-1, D-558-2, and XF-91. 4 cylinders.
XLR10-RM2			250	20,000	60	RMI	LOX	ALC	*Viking* engine.
ESM				50,000	8	NAA	LOX	ALC	Edwards Sled engine.
Atlas				135,000	180	NAA	LOX	JP?	Uses two tandem boosters.
				100,000			LOX	JP?	Sustainer.
Corporal						R	NA	XY	
	132	32	60	4,000		C-W	LOX	JP	ATO.
XLR-25CW-1				12,000		C-W			Bell X-2 engine, stop, start, throttles.
A1				13,000		GE	LOX	ALC	*Hermes* 1 engine.
Nike				2,600	35	B	NA		*Nike* A sustainer.
Redstone				75,000		NAA	LOX	ALC	*Redstone* engine.
X405				27,000	150	GE	LOX	JP	Stage 1 *Vanguard.*
AJ10-37				7,500	100	A	NA	UDMH	Stage 2 *Vanguard.*
Jupiter				135,000		NAA	LOX		*Jupiter* engine.
Titan				300,000 60,000		A	LOX		Booster. Sustainer. *Titan.*
TPM			4,250	50,000 150,000	8	RMI	HP	JP-4	Transonic pusher engine for Edwards track, uses 3.
SPM			14,300	62,000 500,000	9	RMI	HP	JP-4	Supersonic pusher engine for Edwards track, uses 8.
AJ10-28	160			35,000		A	RFNA	JP-X	SNORT engine, uses 1.
AJ10-36	196			35,000		A	RFNA	JP-X	SNORT engine, uses 1.
AJ10-33	233			35,000 105,000		A	RFNA	JP-X	SNORT engine, uses 3.
X-15				60,000	60-180	RMI			Motor for NAA X-15.

A: Aerojet-General.
RMI: Reaction Motors, Inc.
NAA: North American Aviation.
R: Ryan.
C-W: Curtiss-Wright.
B: Bell Aircraft.
GE: General Electric.
UDMH: Unsymmetrical dimethyl hydrazine.
RFNA: Red fuming nitric acid.
HP: Hydrogen peroxide.
JP-4: Kerosene.
ALC: Alcohol (ethyl).
XY: Xylidine.
NA: Nitric acid.
LOX: Liquid oxygen.
JP-X: 40% UDMH, 60% JP-4 with aniline-furfuryl alcohol starter fuel.

inum organics.

EXPERIMENT, INC. Engaged in research on liquid propellants.

FOOD MACHINERY. Its Becco Div. is a major supplier of high strength hydrogen peroxide while Chlor-Alkali Div. supplies UDMH fuel.

GARRETT CORP. Has specialized in liquid APUs (viz. alkyl nitrates).

GENERAL ELECTRIC CORP. With research in all phases of propulsion, GE's major propulsion task is to develop and produce first-stage *Vanguard* engine (X405). Operates large static test stand at Ballston Spa, N. Y. Major propellant emphasis: LOX.

LOCKHEED AIRCRAFT CORP. Now developing its own central California research facility and construction of large-scale static test facilities.

NORTH AMERICAN AVIATION, INC. Big gun in liquid rocket field, has liquid powerplants for *Atlas, Navaho, Redstone,* and *Thor*. Operates huge stands in Santa Susana Mountains. Building *Atlas* engine plant at Neosho, Mo. Major propellant emphasis: LOX.

OLIN MATHIESON CHEMICAL CORP. Now aligned with RMI under OMAR program. Major propellant tasks: production of hydrazine and derivatives, and Zip fuels.

PENNSALT CHEMICALS. Pushing development of fluorine and fluorine chemicals for liquid rockets.

REACTION MOTORS, INC. Active in liquids for aircraft propulsion, ATOs, and launching systems. Also working on two large rocket sleds for Edwards AFB track.

RYAN AERONAUTICAL CO. Producing *Corporal* rocket engines.

WYANDOTTE CHEMICAL CORP. This producer of ethylene oxide is now entering production of auxiliary propulsion systems using this material.

Liquid Status

During the twenties, thirties, and early forties of this century, the basis for all our liquid rocket systems was established. There was Goddard and the VfR with liquid oxygen, Walther, BMW, and JPL with hydrogen peroxide and nitric acid. With the exception of hydrogen peroxide, the LOX and acid systems power all our present "modern" liquid rockets. Of these combinations, LOX has emerged as the liquid king.

It may seem incredible that our *modern* missiles are powered by *ancient* propellants. Modern solid systems, a scant ten years old, are competing hard and heavy with these liquids in performance, scale-up, and reliability. The difficulty has been not so much in the inadequate liquids themselves but in finding better replacements. Thus, because of the lead time required for new systems, these present liquids, as bad as they are, simply could not be dropped.

The properties of the liquid twins (LOX and nitric acid) have been known for some time (and this includes performance characteristics). Continuing efforts have gone into improving and enhancing properties. However, most of the efforts have gone into time-and dollar-consuming engineering—that is, translating an expanding propellant system into an expanding missile system.

LOX is now the undisputed liquid king. Its realm is the IRBM, ICBM and the first-stage *Vanguard*. Although performances have been increased some 50 seconds since World War II, the greatest triumph has come in the evolution of mighty engines.

Both government and industry feel that these large engines will probably form the propulsion basis for man's first real trip into space—at least for establishing the manned satellite and the first rocket to the moon. However, it has cost us ten years to do this. It may be another ten years before liquid ozone or fluorine systems start displacing LOX.

The hot-tempered nitric acid systems have not been so regal. Nitric acid has had early favor. For example, the *Nike* (now *Nike Ajax*) liquid system was ready about ten years before the overall system (including guidance) caught up with it and was ready for operation. This overall systems difficulty has been responsible for the slow liquid progress.

Although the bugs in the acid systems had been pretty well worked out by the Germans, it remained for us to inherit two major difficulties. One, the matter of scale-up, is now near solution. The other—storage and handling—is about to put nitric acid systems into the "use as soon as possible" category.

One major lag in the advancement of liquid systems has been the failure to evolve a *practical* monopropellant suitable for primary propulsion of large missiles. All present monopropellants, hydrogen peroxide, alkyl nitrates, tetranitromethane, and ethylene oxide have failed for big unit consideration. Only one, hydrogen peroxide (as a bipropellant system), is now going into a medium-thrust engine. The rest of the monopropellant lot have turned to the gas generator realm for their continued existence. Thus, a major breakthrough is needed to stimulate the monopropellant picture.

Hardware developments have come as a result of slow-plodding rather than breakthroughs. Thus, the thrust levels have gradually crept up. Ten years ago, the 35,000-lb. thrust V-2 engine was a monster. Today's ICBM engines produce thrust at about four times this level. However, the average liquid rocket (viz., the IRBM and the two liquid *Vanguard* engines) operate at much lower levels. Thus, by grouping or modifying existing engines using existing liquids, our hardware needs may be solved for future applications.

As the newer propellants come along they can be evaluated and applied in available engines with or without modification. Liquids have established a good growth pattern that has not been duplicated in solid engines.

Although liquid rockets have established a scale-up technology and have also provided for performance increases, the handling and reliability problems will continue to plague liquids.

The handling problem of liquids, bad as they now are, may tend to worsen with the two potential oxidizer contenders—ozone and fluorine. Both can be handled safely but require extreme care. Whether these two can be engineered to a "GI-proof" status is difficult to say. However, improvement of the handling characteristics may already be under way in classified work.

Despite handling improvements, it is doubtful if ready-to-go, long-storage capabilities comparable to the new solids can ever be expected. The liquids have only been favored where the highest performance is the most important parameter.

It is in the reliability department that even the best possible liquid systems can be considerably improved. Present reliabilities are on the order of 95-97% with the hope that 98-99% can eventually be achieved. For manned craft even this may not be enough. It should be noted that the U. S. still is only in the research vehicle stage in its liquid propellant rocket aircraft.

What of the ultra-energy liquid systems such as free radicals? Although research in this field is still embryonic, it is unlikely that handling will be materially improved. As a matter of fact, it looks like the solid and liquid fields will merge here—solid storage and liquid or gaseous use.

The applications picture for liquids is such that they will continue to grow but are lagging somewhat in the specialized race with solids. Of course, the future applications for all rocket power are expanding at such a rate so that it would be hard to say whether solids or liquids would be winning sales-wise ten years from now.

The liquid rocket industry has accomplished a herculean task—translating the hot laboratory combinations into workable systems. Now that the pattern is established, liquids will continue to push toward the limits of chemical propellants.

Liquids Growing

During World War II and the bustling period immediately afterward, about $1 billion went into liquid propellant rockets. In the ten years since the war another billion has been spent. At the present time, the liquid rocket business is worth about a billion per year, and it may double in another two to five years. Unofficial estimates break down the annual liquid rocket industry as follows:

	Millions
Nose cone, payload, and guidance	$650
Airframe	100
Powerplants	100
Propellant chemicals	100
Other chemicals and materials	25
Miscellaneous	25

This includes research, development, production, training and testing, and maintenance.

In addition to the industry lineup

TABLE 2
GOVERNMENT LIQUID ACTIVITY

Group	Location	Activity
Air Force		
Flight Test Center	Edwards AFB, Calif.	Rocket aircraft and test stand work.
Holloman AFB	Alamogordo, N. M.	Flight tests.
Missile Test Center	Cocoa, Fla.	Static & flight tests.
Wright ADC	Dayton, Ohio	Propellant evaluation & static testing.
Army		
Redstone Arsenal	Huntsville, Ala.	Propellant evaluation & static testing.
White Sands Proving Ground	White Sands, N. M.	Flight & static tests.
NACA		
Lewis Flight Propulsion Lab.	Cleveland, O.	Propellant evaluation.
Navy		
Air Rocket Test Station	Dover, N. J.	Large test stand.
Missile Test Station	Point Mugu, Calif.	Flight tests.
Ordnance Test Station	Inyokern, Calif.	Research & development.

TABLE 3
INDUSTRIAL ACTIVITY IN LIQUIDS

Company	HQ	R	D	P	T
Aerojet General Corp.					
Azusa, Calif.	x	x	x	x	x
Sacramento, Calif.		x	x	x	x
American Machine & Foundry Co.					
New York, N. Y.	x				
Pacoima, Calif.		x	x	x	x
American Rocket Co.					
Wyandotte, Mich.	x	x	x		
Ypsilanti, Mich.					x
Armour Research Foundation					
Chicago, Ill.	x	x	x		
Bell Aircraft Corp.					
Buffalo, N. Y.	x	x	x	x	x
Wheatfield, N. Y.					x
California Research Corp.					
Richmond, Calif.	x	x	x		
Continental Aviation & Eng. Corp.					
Detroit, Mich.	x	x	x		
Curtiss-Wright Corp.					
Woodridge, N. J.	x	x	x	x	x
Ethyl Corp.					
Detroit, Mich.	x	x	x		
Experiment, Inc.					
Richmond, Va.	x	x	x		x
Food Machinery & Chemical Corp.					
New York, N. Y.	x				
Becco Chemical Div., Buffalo, N. Y.		x	x	x	
Westvaco Chlor-Alkali Div., S. Charleston, W. Va.				x	
Garrett Corp.					
Los Angeles, Calif.	x	x	x	x	x
General Electric Co.					
Schenectady, N. Y.	x	x	x	x	
Ballston Spa, N. Y.		x	x		x
M. W. Kellogg Co.					
Jersey City, N. J.	x	x	x		
North American Aviation, Inc.					
Los Angeles, Calif.	x				
Rocketdyne Div.,					
Canoga Park, Calif.	x	x	x	x	
Santa Susana, Calif.			x		x
Neosho, Mo.				x	
Olin Mathieson Chemical Corp.					
New York, N. Y.	x				
Lake Charles, La.				x	
Niagara Falls, N. Y.				x	
Pennsalt Chemicals Corp.					
Philadelphia, Pa.	x	x	x		
Propulsion Research Corp.					
Santa Monica, Calif.	x	x	x		x
Reaction Motors, Inc.					
Denville, N. J.	x	x	x	x	
Dover, N. J.			x		x
Ryan Aeronautical Co.					
San Diego, Calif.	x	x	x	x	
Wyandotte Chemical Corp.					
Wyandotte, Mich.	x	x	x	x	x

HQ: Headquarters *R: Research* *D: Development* *P: Production* *T: Testing*

TABLE 4
DEMAND VERSUS SUPPLY
LIQUID OXIDIZERS & FUELS

Material	U.S. Production 1956 (est.) (short tons)	Rocket & Missiles Use, 1956 (est.) (short tons)
Oxidizers:		
Alkyl nitrates	100	10
Ethylene oxide	500,000	100
Liquid fluorine (capy)	40,000	25
Hydrogen peroxide (100%)	24,000	1,000
Liquid oxygen (95%)	742,000	10,000
Liquid ozone	1	1
Nitric acid (100%)	2,500,000	15,000
Tetranitromethane	10	10
Fuels:		
Ammonia (100%)	2,800,000	10
Ethanol (100%)	1,000,000	1,000
HEF (alkylated boranes)	10	10
Hydrogen (100%)	900	1
Hydrazine	100	15
Hydrazines, alkylated	2,000	1,500
JP (4&6), USAF only	7,000,000	1,000
RJ-1 (petroleum ramjet fuel)	1,750	1,750
RP-1 (petroleum rocket fuel)	1,750	1,750

TABLE 5
CALCULATED PERFORMANCES OF LIQUID PROPELLANTS

Oxidant	Fuel	Oxidizer/Fuel Ratio	Specific Impulse (sec)
LOX-LOZ (70-30)	JP-4	2.3	253
LOZ (100%)	JP-4	1.9	266
LOZ (100%)	Hydrogen	3.2	369
Fluorine	JP-4	2.6	265
Fluorine	Diborane	5.0	291
Fluorine	Hydrogen	4.5	352

TABLE 6
BEYOND CHEMICAL COMBINATIONS: THE FREE RADICALS

Combination (on a mol volume basis)	Theoretical Specific Impulse (sec)
2.8H+1NH	410
2.2H+1BH	420
5.0H+1CH	492
0.5H+1H	1040
H (alone)	1280

The tables on this page present the U.S. liquid rocket industry in a statistical nutshell. Listed in Table (3) above are 21 companies in the liquid propellant rocket business. Alltold they have offices and facilities at 34 locations around the United States. Their activities range from work on gas generators with a few pounds thrust to ICBM motors whose thrust runs into the hundreds of thousands of pounds. If any doubt still remains that the chemical industry has a big stake in the business of missiles and rockets, Table (4) should dispel it. The other two tables give an idea of what's in store for the future.

shown in Table 3, most aircraft firms are engaged in various rocket activities. This trend has recently spread to the automotive and chemical industries. The employment force for liquids, therefore, is much larger than for the solid rocket industry.

When all supporting personnel (including administration and research) are included, an estimated 100,000 to 200,000 people are working on liquid missiles and rockets. In two years the figure may increase by another 25,000 and in five years the total force may be near 500,000. Most of the new personnel will be coming from colleges and universities and from the aircraft, automotive, and chemical industries.

Table 4 lists some of the major liquid oxidizers and fuels going into rockets. Major efforts are now going into LOX expansion since all the ICBMs and IRBMs will use this oxidizer. Production of liquid fluorine and ozone is still very small. Nitric acid capacity is still far ahead of use (as is the case for liquid ammonia); however, use of nitric acid seems on the downgrade. Other oxidizers are being made and used only in very small amounts. Petroleum-based fuels are still far out in front over others and still increasing in use despite the new HEF entries.

Hardware Heavy

Since the war a large amount of hardware has become available (Table 5). Thrust levels range from the early 4000-lb. ATO units to the 135,000 ballistic missile booster engines. Burning time ranges from 8 to 180 seconds. It is thus probable that the designer now need not look for completely new engines for future applications.

On the shelf rocket engines are available even for the beginnings of space flight. Tried and proven engines may be clustered or staged to give almost any desired thrust program. Not only will today's liquid rocket engines help to establish the first earth satellite, but it is predicted that they will:

1) establish a manned satellite,
2) impact the moon,
3) make an unmanned circumlunar flight.

Limit Near

Despite the many possible liquid oxidants, only LOX, peroxide, and nitric acid systems have large-scale application. Of these, only LOX systems give the highest performance, at the price of non-storability and messy handling.

Nitric acid, though manageable, gives rise to a host of handling and storing problems. It now looks like acid systems are on the way out. Peroxide, costly and heretofore relegated to auxiliary propulsion, is hanging in the balance. Present liquid systems are now at the 220-240 sec level. And solids are already nipping at liquids in this range.

What of the new line? There does not appear to be any breakthrough in storage and handling of the new high-energy combinations. Therefore, the big push will be for performance. The liquid people are hanging their hats on two techniques for raising specific impulse.

By using hotter burning fuels and building hardware which can take care of higher temperatures and pressures, an upping of some 25-50 seconds may result. A more promising technique will be to switch to new oxidizers.

Research is now under way with the two most promising prospects—fluorine and ozone. Both may put the liquid rocket near the limits of chemical propellants. Thus, an increase of some 50 seconds may be in the offing (Table 6). This push will be a long and costly one. It won't come in a year but may be with us in ten years.

Liquids have managed to keep ahead of solids by virtue of only two major parameters—scale and performance. Solids are now scaling up fast. Liquids can thus keep ahead only by keeping ahead in performance. With this stimulus the picture should prove very interesting.

In the future the greatest hope for a propulsion breakthrough lies in free radicals or nuclear processes. In free radical propulsion, fragments of chemical molecules recombine to form the original molecules, with heat releases much greater than conventional combustion processes (Table 6). For example, combining atomic hydrogen to give molecular hydrogen could give some 90,000 BTU/lb.

The big problem in free radical propulsion schemes seems to be twofold: storage in large amounts (present technique is to cool to near absolute zero) and the high temperatures of recombination (up to 12,000°F). Then, fission one pound of uranium ^{235} gives off about 1 billion BTUs and in expanding hydrogen could give a theoretical I_{sp} of about 900 seconds.★

TABLE 7

LITERATE LIQUIDS AT THE UNIVERSITIES

University	Activity
California Institute of Technology Pasadena, Calif.	With the Jet Propulsion Laboratory, the student has an opportunity to work in the missile field while learning. JPL also carries out an extensive program in all areas of liquid propellants—research, development, and testing.
University of Detroit Detroit, Mich.	Operates Missile and Rocket Section. Offers student training and conducts research projects in liquid propellants.
Johns Hopkins University Baltimore, Md.	Operates the Applied Physics Lab. at Silver Spring, Md. APL is active in research, development and testing of liquid rockets.
Massachusetts Institute of Technology Cambridge, Mass.	Has available a static test facility operated by MIT Rocket Research Society.
University of Michigan Ann Arbor, Mich.	Operates a propulsion laboratory for liquid rockets.
Ohio State University Columbus, O.	Research and development of premixed propellants and liquid hydrogen rockets.
Princeton University Princeton, N. J.	Its Forrestal Research Center administers Project Squid. Has static test stands and is doing work on liquid ozone.
Purdue University West Lafayette, Ind.	Rocket laboratory conducts research in liquids—mainly nitric acid systems.

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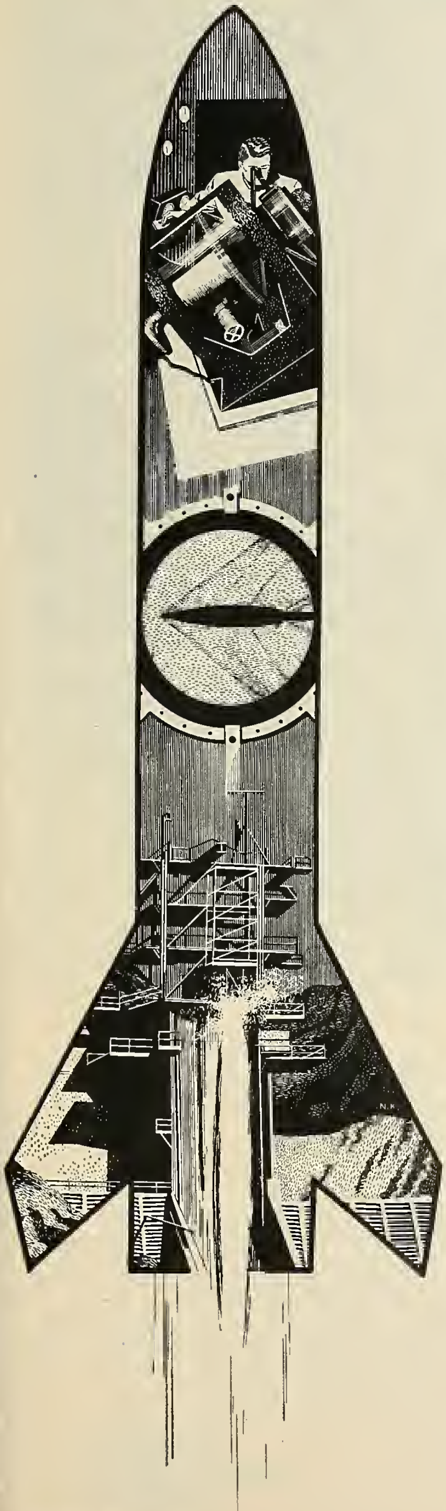

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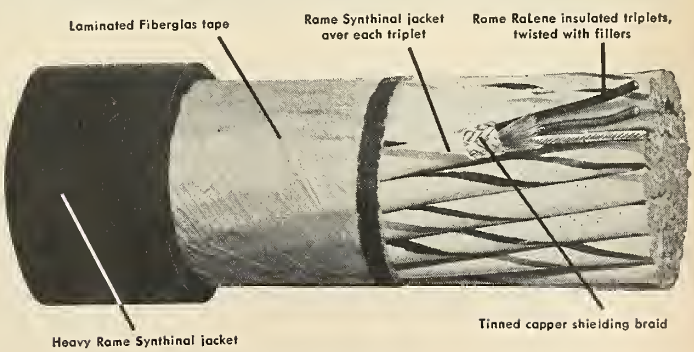

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Propulsion Engineering

By Alfred J. Zaehringer

BORON FUELS: A BILLION DOLLAR MARKET in ten years is the prediction by Olin Mathieson. OM's $5.5 million pilot plant is now delivering high energy fuels to USAF. Second plant, three times present size, will be "on stream" this year. Third plant ($36 million) will start operating by end of 1959. OM is said to be shooting for a fuel price of $1/gal. in ten years. Meanwhile, there is talk that Olin and U.S. Borax will get together and form a company for research and production of boron and lithium compounds.

NEWEST BORON COMPOUND is trimethyloxyboroxine. Anderson Chemical offers the liquid—containing 18.7% boron—in carload quantities. Suggested applications include: jet fuel additive, neutron detector.

ATOMIC OXYGEN, found at high altitudes, could be used as a super "fuel" by jets or ramjets, says USAF. Cambridge Research Center has found a catalyst which kicks atomic oxygen into molecular oxygen with a large energy release.

CHLORYL FLUORIDE has been prepared and studied by chemists in Argentina. The compound, $C10_2F$, is a powerful oxidant. A similar oxidant, perchloryl fluoride ($C10_3F$) is available in pilot plant quantities from Pennsalt.

DIRECT MEASUREMENT OF ROCKET EXHAUST VELOCITY has been developed at Ohio State University. Seven optical probes are used with a 10 meg. 6-channel chronograph to measure time (in steps of 0.1 microsecond) for a luminous wave to pass between probes. The system is calibrated by means of a gaseous mixture of known detonation velocity. Good checks have been made when compared to other measuring systems.

NOW A ROCKET ENGINE FOR STUDENTS. A group of Aerojet-General engineers have built the "Spark I," LOX-watered alcohol rocket engine of 400 lb. thrust. The regeneratively-cooled motor has an I_{sp} of about 227 sec. and is designed primarily as a training tool.

CARTRIDGE ACTUATED DEVICES using solid propellants are in for study and test by Microloc Corp. of Los Angeles. The Army Ordnance contract comes from Frankford Arsenal. The Conax Corp., Beckman-Whitley, et al. have long been producing explosive actuated valves for missiles. Now a new entry: Atlas Powder Co. is producing a squib-actuated missile switch.

MORE SOLID PROPELLANT ACTIVITY in the Midwest. Standard Oil Co. (Ind.) is expanding lab facilities at its Seymour, Ind. (USAF Freeman Field) plant; completion date is this fall. Olin Mathieson is adding to its high-energy solids facility (Ordhill Works) at Marion, Ill. Propellex Chemical Corp. has moved to a 100-acre site at Edwardsville, Ill. The facility will permit preparation of ammonium nitrate and cast double base propellants to grain sizes of up to 250 lbs.

SHIELDING OF PROPULSION REACTORS is still a big problem. While boral or the boron stainless steels do cut off neutrons, they are still transparent to gamma rays. Even the lead plastic compounds, effective gamma shields, are not the optimum for airborne use because of the very high density. There are now indications that metal-organics or complex organics in combination with light metal carriers may prove effective gamma-ray shielders.

RESEARCH ON FROZEN FUELS has been reported. The technique is to freeze a gas (such as hydrogen) and to use solar energy to melt and evaporate it into a combination chamber. Such frozen fuels might be conveniently stored in space (near absolute zero) and used for space rockets. Work is also underway in determining the physical properties (tensile and compressive strength) of such "iced" materials at these very low temperatures.

ANTI-MATTER may be possible. Just as anti-particles exist for electrical matter, some scientists have theorized that a negative gravitational matter concept may explain several analomies in existing theories.

m/r's personal report from . . .

Rocketeer Sam Hoffman

For Big Jobs Re-use or Controlled Flight Liquid Rocket Engines Now Lead the Field

Manager of North American Aviation's Rocketdyne Division and a member of the American Rocket Society's National Board of Directors, Samuel K. Hoffman oversees design and production of Atlas, Thor, Jupiter and Redstone liquid rocket engines.

Q. *Mr. Hoffman, can you give us an indication of the measure of effort Rocketdyne is putting into liquid propellant engines?*

A. We employ about 10,000 people. Of these, roughly 4000 are in our Engineering Department.

In facilities, we have about 600,000 square feet of floor space in the San Fernando Valley, 130,000 of our Slauson facility in East Los Angeles and 220,000 in our plant in Neosho, Mo. Our test areas include the 1700-acre propulsion Field Laboratory in the Santa Susana mountains and a 200-acre complex in Neosho.

Our purchases are running at slightly better than $70 million a year and the weekly payroll is about $1,250,000.

Q. Mr. Hoffman, will you please outline the role of liquid propellants in the field of missiles today?

A. Liquids today are the predominant type of propulsion in large missiles where their unlimited thrust, relatively small size, precision cutoff, high specific impulse, variable thrust and gimballing ability are particularly suited.

Liquids are also being used in some small missiles where a need for one of their unique characteristics outweighs the simpler structure of solid propellant motors.

I think there is no question in anyone's mind that present liquid propellant engines are capable of putting us into the space flight business. Certainly, the refinement of our present power plants is making a large contribution toward that future. The question of when is largely one of money.

Another application for the liquids is in the field of manned aircraft where the characteristics of long duration operation, safety, repeated on-off operation, thrust control and re-use are vital.

Q. Is this the X-15 sort of thing you're talking about in manned rockets?

A. Yes, the X-15, glide or skip bombers, rocket boost takeoff for some future ramjet airliner maybe—any use where the rocket motors are recovered or brought back for re-use.

Q. The Cook rocket test sled used a Rocketdyne engine. Isn't this a good example of a re-usable engine?

A. Yes. The best information we have is that it made over 100 runs with only routine maintenance—no major replacements. And in 130-to-140 runs the only failures were a couple of valves.

Q. This is quite a testimonial on the re-usability of liquid rocket engines, isn't it?

A. Yes. When we delivered the engine, we predicted 300 runs before it would wear out, and it could well be a lot more than that.

Q. What about the cost of liquid propellant engines compared to solids?

A. For present one-shot applications, it depends largely on how the engine is to be used, which is cheaper. However, when the day comes that you can recover or desire to recover a missile powered by a rocket engine, the liquids will really come into their own. Then they'll be quite cheap. Like your automobile, you put fuel into it and run it; you make one trip and come back, fill it up with fuel again and then get on your way.

Q. Doesn't this seem to indicate that insofar as any possible potential commercial application of the chemical rocket propulsion is concerned, liquids are well in the lead?

A. I believe so, and I believe there'd be general agreement on that.

Q. Do you have any trouble turning a liquid rocket on and off?

A. When you say you have no trouble doing any of these things, it's a relative thing. The engines we work with today are sort of in the Model T stage. There are still troubles, but they are a lot different today than they were two years ago. And progress will be much faster because we have more engines to work with, more experience. Progress, insofar as reliability is concerned, is going along at a tremendous rate.

Q. Within the limits of security, for which missiles is Rocketdyne making engines?

A. We are building liquid propellant engines for the Convair *Atlas*, Douglas *Thor*, Army-Chrysler *Redstone*, Army *Jupiter* and until recently, the Air Force *Navaho*.

Q. Well, doesn't Rocketdyne supply the entire power package—engine, pumps, fuel tanks, valves, etc?

A. No. We supply the engine itself and its immediate supporting equipment. Somebody else supplies the tanks, lines leading to them, valves, etc.

Q. Does Rocketdyne have any licensing or exchange know-how agreements with any companies abroad?

A. We have a license agreement with Rolls-Royce. They have a license from us to build our engines.

Q. You are restricted by security on just what plans and specifications you can supply under such an agreement, aren't you?

A. Yes.

Q. What is the largest liquid propellant engine NAA has fired—in terms of straight thrust—in terms of specific impulse?

A. We are not in a position to give you the highest thrust or specific impulse figures that we have reached, but we can tell you we have produced an engine with the highest thrust rating that we know of to date—and by a considerable margin.

Q. Can you comment on the cost of liquid propellant motors?

A. Costs today, even in small quantities, are something on the order of one third of what they were when production first started. They may go down still more. Basically, cost is associated with quantity. If Ford were making 1000 cars a year instead of in the millions, we couldn't afford to buy one. And that's about the same situation here. Quantities are so small that high production techniques are just not applicable.

Q. Is Rocketdyne doing any research and development on solid propellant rocket motors?

A. Yes, during the past five years we have engaged in several developmental projects and subsequent pilot production programs.

Q. Can you give us some estimate of the measure of improvement in specific impulse and mass ratio in liquid propellant engines by the use of additives?

A. The first thing I think we should do is define the term "additive". We will assume that an additive will constitute no more than 20 per cent to 30 per cent of the propellant into which it is placed. With this definition in mind, performance gains, in the order of 3 per cent to 5 per cent, may be realized through the use of additives in certain fuels and/or oxidizers. This gain in specific impulse performance would correspond roughly to 10 per cent in mass ratio for missiles of the intermediate and intercontinental ballistic type.

Q. What are some of the more promising additives?

A. The probable future trend in rocket fuels and oxidizers will be toward increased hydrogen content in fuels and increased fluorine content in oxidizers. On that basis, promising additives would include hydrazine and other compounds with concentrations of either of those two elements.

Q. What's the general consensus on the future role of fluorine, boranes, etc?

A. It is probable that the trend in oxidizers will be toward increased fluorine content. With boron, a great deal of experimental and analytical work faces us before we can be certain of the gains to be had.

Generally speaking, there are inherent problems in the future use of high-energy propellants, but we certainly can't rule them out on chemical grounds. The engineering problem of adapting them to reliable powerplants, or powerplants to the propellants, is not insurmountable.

Q. We understand that the temperature limitations of materials place an absolute limit on improvement of specific impulse of 40 per cent compared to current levels. Is there any known device by which this ceiling may be breached with liquid propellant motors?

A. The energy limit which has been quoted widely recently—and we refer to it as being a possible improvement of 50 per cent rather than the 40 per cent you mentioned—deals with molecular species and the energy derived from their normal chemical, or valence, bonds. The limit is one of propulsive energy rather than temperature. For instance, the combustion temperature of the highest specific impulse theoretically available—that of 373 theoretically possible through the combination of fluorine and hydrogen—burns with a temperature of about 5100°F. The second highest, in these theoretical tables, is specific impulse of 364 by oxygen and hydrogen, with combustion temperature even lower—that of 4500°. In contrast to this, the lower specific impulse of 316 from fluorine and hydrazine would develop combustion temperatures of nearly 8000°. The key to the limit of propulsive energy is not temperature but the best combination of high combustion temperature and low molecular weight of products.

It is true, of course, that more energetic fuels and oxidizers, because of their weak bonds and relatively high vapor pressures, will be progressively less capable of handling the high thermal loads which will be impressed upon them in the regenerative cooling passages of future engines.

The ability of the engine materials to withstand the high combustion temperatures associated with the highest performance chemical propellants is not fundamental by limitation in liquid rocket engines since cooling methods are characteristic of this type.

If energy sources other than chemicals are employed, material temperature limitations are a major problem.

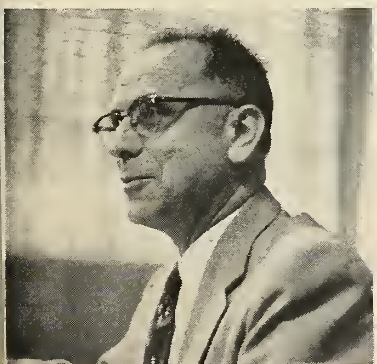
Q. Is any consideration being given to development of electromagnetic thrust chambers and nozzles—along the principles of the "pinch" effect that's being worked on for controlled thermo-nuclear rockets? Could this principle be successfully applied to chemical rockets and would it be worth while in terms of mass ratio (considering need for high wattage electric power source, etc.) for large, long-range space vehicles—or do other systems promise more efficiency?

A. It is conceivable that the principle of an electromagnetic thrust chamber based on the "pinch" effect could, someday in the future, be used for propulsive purposes in conjunction with a liquid propellant rocket. I wouldn't want to rule it out.

Other systems of electromagnetic motors are also possible. We, for instance, are working for the USAF on a feasibility study of an ion propulsion system using charged ions accelerated by high voltage electrodes to very high velocities.

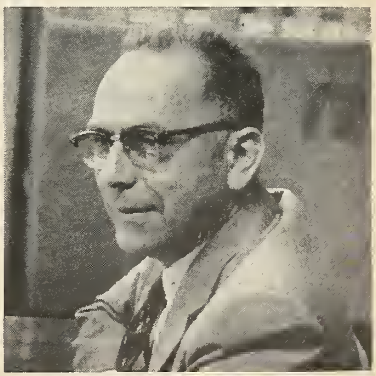
Q. What effect will the Navaho *cancellation have on Rocketdyne?*

A. This cancellation has had a relatively light effect on Rocketdyne, due to the fact that we are currently engaged in four other major rocket engine programs. Less than 500 persons, or roughly 5 per cent of our work force, were layed off as a direct result of the cancellation.★



We have a license with Rolls-Royce.

On solid-propellant rocket motors.



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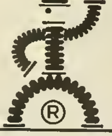

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What's all this talk about EXOTIC PROPELLANTS?

By John F. Tormey
Chief, Research, Rocketdyne

IT IS ALMOST impossible to trace the time when the words exotic propellant first rose full-blown from the brow of a mesmerized rocket engineer. American rocketry has no historian and little recorded history after Goddard.

One recollection of the birth of exotic propellants goes back eleven years to 1946. It was customary then to assign an advanced study unit the task of creating, almost out of nothing, a list of all the liquid propellant fuels and oxidizers that could be purchased, found in handbooks, or conceived of by stretching molecular structural norms to their conceivable limits.

When the lists were prepared, well over half of the chemicals were known and available—alcohol, aniline, 70 per cent hydrogen-peroxide, ammonium nitrate, etc. The rest appeared to be new, unfamiliar compounds, products of uninhibited and sometimes inspired thinking. Such compounds as polyatomic oxygen (O_4), hydrogen molecules containing several atoms, and assorted halogen complexes were typical. Liquid ozone was a regular. Rather than list these things—of which he was generally a little self-conscious in 1946—along with the more regular and familiar chemicals, the rocket propellant researcher invariably made a second list which he titled "exotic," primarily because the testing fitted so well Webster's definition of exotic—"introduced from a foreign land." It was as if by labelling them exotic he had freed himself from any technical responsibility to defend or deliver them.

As is usually the case with the wrong word (exotic is no adjective for a chemical) it found immediate and ready acceptance, appearing in numerous reports.

Examples of exotic chemical compounds outside of rocketry abound everywhere. The application of silicon in the solar battery is a case where physical structure alone brought about something new and exotic. The successful formation of the first synthetic diamonds was an application of a chemical innovation and belief in principles in the face of difficulty.

The free radical particles produced under the Bureau of Standards' current program of fundamental research in that field have brought to light materials which might be defined as exotic both because of irregularity of formation, and also because of the magnitude of energy possible through the recombination of the freed particles. Tetraethyl lead, liquid helium, the boron hydrides, the classic freons, the bubble-forming isocyanates, now rather standard items of chemical commerce, were once exotic by definition.

And so it was also with many of the exotic propellants listed so lightheadly in 1946. They, too, were once exotic. The now familiar 90 per cent hydrogen peroxide was exotic in 1941, when 81.5 per cent produced in Germany was regarded as the highest concentration possible. Liquid flourine met the exotic definition until 1951. These and other exotic propellants are passing from a state of seemingly wondrous alchemy to practical chemical and rocket engineering.

But what of these exotic fuels? Are they above our ordinary considerations in every respect? Hardly. Rocket propulsion principle gives no reason to assume that because a material has been labelled exotic it need no longer obey the thermodynamic principles of rocket combustion and expansion in a nozzle. Like their less sensational brothers—oxygen, hydrogen, peroxide, jet fuel, alcohol and the rest of the other familiar liquid rocket propellants—the exotic species must square with the law which says that performance is a function of the square root of combustion temperature divided by the molecular weight of the products of the reaction. The theory says that the rocket propellants, exotic or otherwise, convert their internal energy into kinetic energy through the formation of energetic exhaust gases. The theory states that this energy will be derived primarily from the exchange of reactant bond energies for the bond energies of the reaction products. The rocket theory states that the molecular weight of the exhaust products is a factor in determining performance. Rocket theory also says that most rocket propellants will be formed from the first two periods of the periodic table.

Here, then are our ground rules. Regardless of the bizarre nature of the exotic propellant, regardless of any incredible property it may have, regardless of the persuasiveness of its advocates, when the exotic substance goes to work in a rocket combustion chamber, it has it no better nor worse than any other propellant because, exotic or not, each must follow the same physical laws, make generally similar exhaust products, and be bounded by the same temperature and molecular weight conditions.

The exotic propellant has no special license to run up a high molecular weight in its exhaust products. It cannot generate exhaust products whose molecular weight is higher than 20 and it had better generate exhaust products whose molecular weight is less than 10, if it wants to keep its reputation.

On the matter of combustion chamber temperature, the exotic propellant must generate high temperatures at least equal to those generated by conventional propellants (5500°F) and yet its exhaust products must either resist dissociation or be of such chemical composition that a maximum of energy can be withdrawn from them prior to the atmosphere.

Each exotic propellant must be judged strictly on its merit. Now this is a pitifully obvious remark, but the exotic has been known to dim man's reason and blunt his judgment. It is well to keep in mind that there is no easy street in liquid rocket chemical propulsion. No matter how exotic the material may appear on paper, it still has two jobs to perform, to live in our environment and generate thrust on demand.

Exotic propellants can be thought of in the same way one considers exotic foods. To some, *escargots ala Francais* is a most exotic entree, particularly to the eye and the palate. To stomach acids the once exotic escargots are now a collection of mixed polypeptides ready for energy release and tissue building.

During the past two years there has been a renewed interest in exotic propellants. Where does all this interest come from? Its primary source is faith, a faith which the majority of us have in the propellant chemists and the chemical industry to create rocket miracles. This faith can be touching (H_2O_4), futile (C_2H_2), or profitable (UIMH), as the case may be, both for the exotic propellant named and the chemical manufacturer in question.

Exotic propellants are probably our best path for substantial increase in power delivery. All manner of rocket power plants exist today, but if today's liquid rocket power plants are designed much beyond their present power level, we must go to higher performance propellants. The surest path for maximum increase will lie in the application of exotic propellants.

The same reasoning holds in the solid propellant field. If solid propellant power packages are to shake themselves loose from their present base at the impulse of 225 to 240, incorporation of new materials in the solid propellant matrix is probably the only solution to this problem.

Although there is no real and present reason to bring skepticism to bear on the field of exotic propellants, a few precautions are necessary. Any propellant can have hidden disadvantages which are not apparent to the over-enthusiastic. In the case of exotic plants, exotic furniture, exotic drinks and exotic places, what is irresistible at first glance proves later to be mundane and even dangerous.

Each new exotic rocket propellant, either solid or liquid, which appears on the scene should be probed cautiously by the conscientious. The exotic material must be subject to unimpeachable thermodynamic calculation to determine if it will deliver the promised power. It then should be subjected to unbiased laboratory tests to determine thermal stability, toxicity, resistance to decomposition, and the character of its combustion products.

It should be subjected to small scale motor firings to assay its general feasibility in real rocket applications. It should be thoroughly discussed with practical, down-to-earth, profit-motivated chemical firms. Can they make it? Do they want to make it? Do they have the plant to make it in? When could they make it? At what cost?

An exotic propellant must be shaken down before it can take its place with our other regular rocket propellants.★

Individual Initiative in Research and Engineering

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A recent survey of this staff indicated that the most important reason for their preference of JPL as a work center is the high degree of responsibility and freedom given the individual to pursue his own assignments. The intriguing nature of the work, challenging problems, professional association, fine residential location, pay scales and opportunities for career development were also important considerations.

. This appreciation, from within, of the Laboratory's principle of recognizing ability and talent and allowing it to operate with freedom and confidence under its own initiative is a gratifying tribute in itself.

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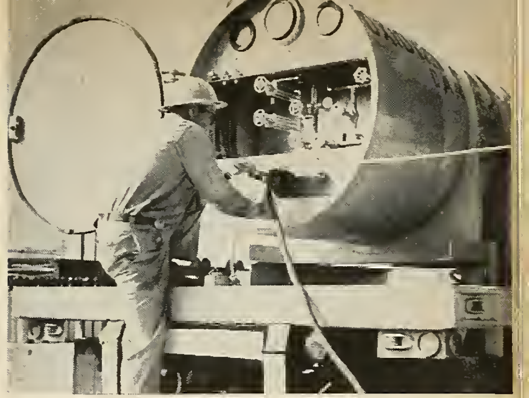
FLUORINE . . .
Tamed for Rockets



By Dr. H. R. Neumark and Dr. F. L. Holloway
General Chemical Division,
Allied Chemical and Dye Corp.

THE POTENTIALLY high performance characteristics of elemental luorine as an oxidizer in rocket propulion systems have generated a great deal of interest.

However, until the beginning of Vorld War II elemental fluorine was prepared solely on a research scale. Then the development of atomic energy led to large scale production of luorine for the manufacture of uranium hexafluoride.

Private industry recently entered he field of large scale fluorine producion with the announcement by General Chemical Division, Allied Chemcal & Dye Corp. of a contract with the Atomic Energy Commission to produce 5000 tons per year of uranium hexaluoride. This will require production acilities for about 1000 tons per year of elemental fluorine.

Further expansion is simply a unction of demand. The plants would require no more lead time than other ypes of industrial facilities given similar priorities. Fluorine is no longer a aboratory curiosity. Today it is a commercial chemical which can be produced by industry in large tonnages just as liquid oxygen, hydrogen peroxide, nitric acid, or other oxidizers.

Until this year, the shipping regulations for fluorine limited its use. ICC regulations formerly restricted shipment of the gas to six pounds of fluorine in a 200-pound cylinder under 400 pounds pressure. The uneconomical weight ratio of 1 pound of gas to 33 pounds of container virtually ruled out shipment and use in large tonnage applications. Now, however, General Chemical's development and practical demonstration of an ICC licensed tank system, which permits bulk storage and shipment of liquid fluorine, has materially changed the picture.

The U.S., Canada and Mexico have ample reserves of fluorspar to take care of any emergency military requirement, in addition to an expanding civilian market for flourine-based products. To quote from the testimony of Mr. Josephson, Chief of Construction and Chemical Materials Branch of the U.S. Bureau of Mines, before the Senate Committee on Strategic Minerals, February, 1954:

"Fluorspar reserves containing 35% or more calcium fluoride would include nearly all the known deposits that are workable under present economic and technological conditions. Reserves of domestic ore containing more than 35% calcium fluoride are estimated by the U.S. Geological Survey to total 15,000,000 net tons, not considering development of latent reserves.

"If reserves of Mexico and Canada are added to those of U.S., the total ore containing 35% CaF_2 is estimated to be 23,000,000 N. T. An additional 500,000 N. T. are estimated for other known Western Hemisphere deposits on a like basis. U.S. reserves of material containing 15-35% CaF_2 are estimated to be 20,000,000 N. T."

This means about 12 million tons reserves equivalent to acid-grade spar are equivalent to 6 million tons of fluorine. An emergency need for 100 tons of fluorine per day over a period of two years equals 70,000 tons of fluorine, or only 1.15% of our total reserves.

Selected Physical Properties of Fluorine

Chemical symbol	F_2
Molecular weight	38.00
Melting Point	−219.62°C. (−363.32°F)
Boiling Point	−188.14°C. (−306.55°F)
Heat of Vaporization at normal b.p.	1564 ± 3 cal/mol
Vapor Pressure Range:	
Melting point	53.54°K to 90°K
$\text{Log } P = 7.08718 - \frac{357.258}{T} - \frac{1.3155 \times 10^{33}}{T^{8}}$	
P= mm of Hg, T = °K	
Entropy of Vaporization at boiling point and 1 atm	18.38 cal/mol °C
Critical Temperature	−129°C
Critical Pressure	55 atm
Liquid Density (g/cc at 81.0°K)	1.539 − 0.002
Gas Density (0°C and 760mm)	1.696g/1
Viscosity of Liquid (80.9°K)	2.75 centipoises
Viscosity of Vapor (°C and 1 atm)	218 micropoises
Thermal Conductivity (gas, 0°C and 1 atm)	5.92×10^{-5} cal/cm degree sec
Surface Tension (liq. at 81.0°K)	14.6 dynes/cm

Chemical Properties

Fluorine is the most powerful oxidizing agent known, reacting with practically all organic and inorganic substances. The heats of reaction are always high and most reactions take place with ignition.

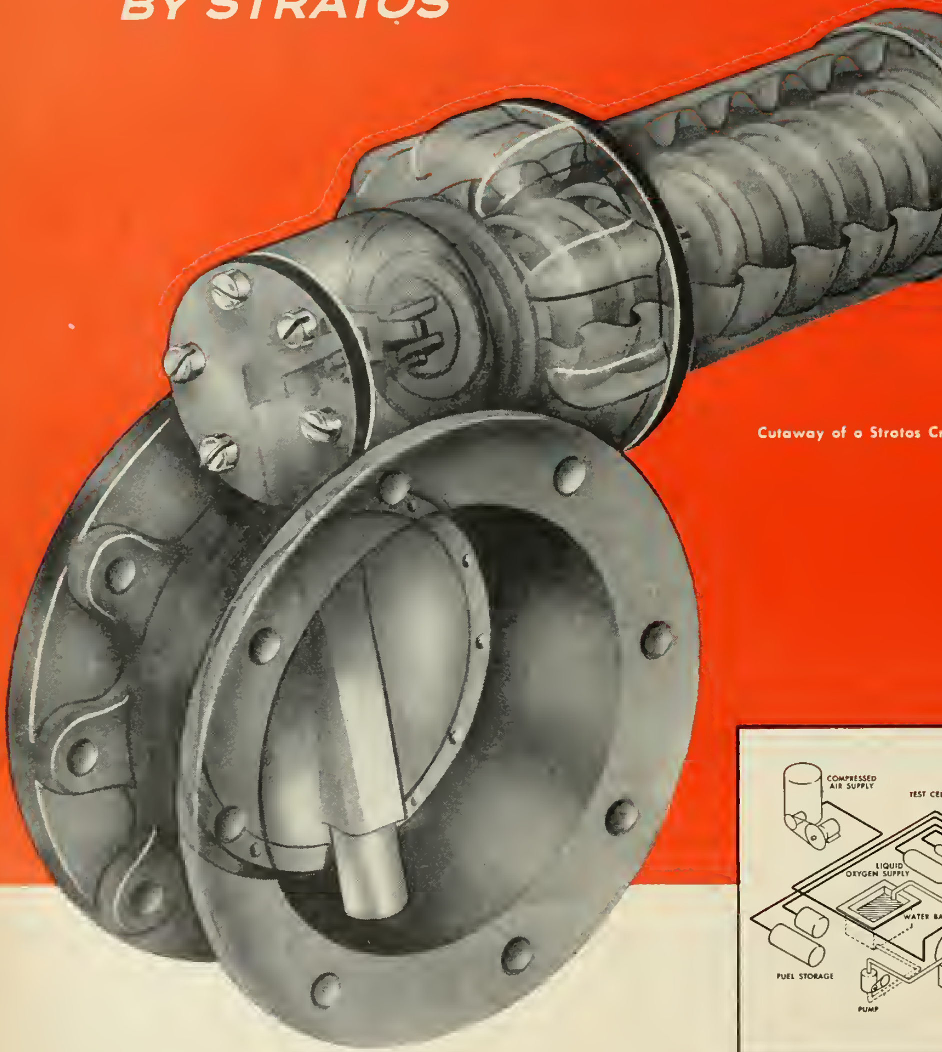
The few exceptions are the inert gases, metal fluorides in their highest valence state, and highly-fluorinated organic compounds such as Teflon, Genetron* Plastic H-L, or Kel-F. Even the latter may ignite in a fluorine atmosphere if contaminated with a combustible material or if subjected to high flow velocities of fluorine.

The reaction of fluorine with most metals of construction is slow at room temperature and often results in the formation of a metal fluoride film on the surface of the metal. The characteristics and adherence of this metal fluoride film determines the resistance of the metal to fluorine.

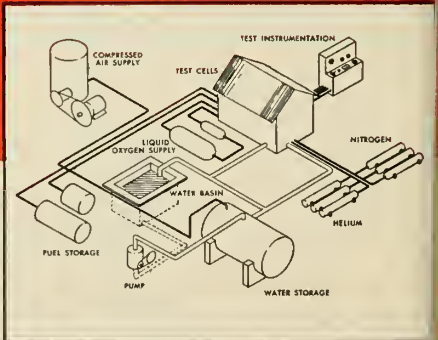
Fluorine reacts with water, forming a mixture containing principally oxygen and hydrogen fluoride plus small amounts of ozone, hydrogen peroxide and oxygen fluoride. Fluorides exhibit abnormal solubilities and high complexing power and, of all the halogens, the fluoride ion has the highest heat of hydration.

Fluorine and oxygen, gaseous or liquid, are miscible in all proportions, with no reaction taking place between

* *Reg. Trade Mark Allied Chemical & Dye Corp.*



Cutaway of a Stratos Cryogenics Valve



Schematic of the new Cryogenics Test Facility at Stratos Western Branch them either at ordinary or very low temperatures.

Materials for Handling Gaseous and Liquid Fluorine

Most common metals and alloys such as nickel monel, steel, stainless steel, brass, copper, aluminum and magnesium are quite satisfactory for handling fluorine at room temperature. At elevated temperatures, the use of nickel and its alloys and stainless steel is preferable. Monel proves to be the most satisfactory metal for all-around applications at low and high temperatures.

Safe Handling of Fluorine

Fluorine can be handled without undue hazards if proper precautions are taken. In order to minimize the risks involved, the following measures should be observed:

1) In handling fluorine under pressure, remote-controlled valves should be used, preferably those operated by manually actuated extension handles passing through suitable barricades.

2) Double valving should be employed in all cases where large quantities of fluorine are being handled such as with manifold cylinders or liquid fluorine tanks. Double valving is also recommended for pressure reduction of high pressure fluorine cylinders.

3) Any equipment to be used for fluorine service should first be thoroughly cleaned, degreased and dried, then treated with fluorine gas so that any impurities may be reacted without the simultaneous ignition of the equipment.

4) Clean Neoprene gloves must be worn when handling equipment containing or contaminated with fluorine. This precaution not only affords protection against fluorine but also against hydrofluoric acid which may be formed by escaping fluorine reacting with moisture in the air. Neoprene coats and boots may be worn to afford overall body protection for short intervals of contact with low-pressure fluorine or splashes of liquid fluorine. All such protective clothing should be designed and used, however, in such a way that it can be shed easily and quickly.

5) Safety glasses should be worn at all times. Metal frames are preferable to plastic which are a fire hazard. Face shields should be equipped with clear Kel-F or Genetron Hl Plastic.

In addition to these special safety measures important for the safe handling of fluorine, common sense safety precautions necessary for the handling of any toxic or reactive material should be followed.

Barricade, Remote Control Systems

Barricade systems will vary widely depending on the buildings available. In general, the function of the barricade wall is to dissipate and prevent the breakthrough of any flame and/or flow of molten metal which could issue from any part of a system containing fluorine under pressure. Quarter-inch steel plate, brick or concrete walls are adequate for cylinder amounts of fluorine (nominally six pounds).

Remote control can be achieved by a wide variety of conventional devices. A common means of opening and closing cylinders is through a right-angled transmission of torque along supported rods by means of a beveled gear arrangement. Devices using universal joints can frequently be used to advantage. Needle valves can usually be positioned so that single straight rod manipulators can be used.

Decontamination Procedures

Any equipment that has contained fluorine must be thoroughly purged with a dry inert gas such as nitrogen and evacuated prior to opening or refilling unless the system is used exclusively for fluorine service. A soda lime tower followed by a drier should be included in the vacuum line to remove trace amounts of fluorine in order to protect the vacuum pump.

If large quantities of fluorine are to be purged, the disposal system should include a fluorine-hydrocarbon-air burner, scrubber and stack to prevent any exit hazards.

Liquid fluorine spillages should be neutralized with sodium bicarbonate. Dry chemical type fire extinguishers employing bicarbonate well-suited for this purpose. This material not only neutralizes the fluorine, but also assists in extinguishing any secondary fires caused by the reaction of fluorine with combustible material.

Packaging and Shipping

Gaseous fluorine is packaged and shipped in returnable ICC seamless high pressure cylinders #3AA-2400; these are 10 5/8" outside diameter and 55½" long without the valves. They are equipped with Chlorine Institute Valves having a ¾" male pipe thread cylinder connection and a left hand

Materials for Fluorine Service

	Gaseous Service	*Liquid Service*
(1) Lines and Fittings	Nickel, Monel, Copper Brass Stainless steel 304, 347 Aluminum 17, 24, 52, 61 Mild steel (low pressure)	Monel Stainless steel 304, 347 Copper Aluminum 17, 24, 52
(2) Storage Tanks	Stainless steel 304, 347 Aluminum 61 Mild steel (low pressure)	Monel Stainless steel 304, 347 Aluminum 61
(3) Valve Bodies	Stainless steel 304 Bronze, brass	Monel Stainless steel 304 Bronze
(4) Valve Seats	Copper Aluminum 2S Brass	Copper Aluminum 2S
(5) Valve Plugs	Stainless steel 304, 347 Monel	Stainless steel 304, 347 Monel
(6) Valve Packing	Copper braid backed with Tetrafluoroethylene polymer	Tetrafluoroethylene polymer
(7) Valve Bellows	Stainless steel 347 Monel	Stainless steel 347 Monel
(8) Gaskets	Aluminum 2S, Tin, Copper Tetrafluoroethylene polymer Lead Red rubber (< 5 psig)	Aluminum 2S Copper

Possible Fluorine Oxidizers

CHLORINE TRIFLUORIDE—ClF_3

Molecular Weight	92.46
Melting Point	−76.32°C
Boiling Point	11.75°C
Critical Temp.	153.5°C
Liq. Dens. (8/cc at 0°C)	1.885

BROMINE PENTAFLUORIDE—BrF_5

Molecular Weight	174.92
Melting Point	−62.5°C
Boiling Point	40.3°C
Critical Temp.	ca. 197°C
Liq. Dens. (g/cc at 1°C)	2.547

OXYGEN FLUORIDE—OF_2

Molecular Weight	54
Boiling Point	−144.8°C
Critical Temp.	−55.6°C
Liq. Dens. (g/cc at B. P.)	1.496

These compounds, like fluorine itself, are thermodynamically stable and exhibit an indefinitely long storage life.

outlet thread with a nominal diameter of 1.030". The cylinder tare weight is approximately 195 lbs.; net weight is six lbs. The gas is shipped under 400 psig pressure.

Tonnage quantities of liquid fluorine are available in tank trucks, under a special ICC permit issued to General Chemical Division, Allied Chemical & Dye Corp., authorizing shipment of the product in cargo tanks designed in accordance with company specifications.

The tank system developed for storage and shipment of liquid fluorine is basically very simple. However, it required more than two years of research and development to perfect a system which did not involve any moving parts or mechanical refrigeration.

The tank system consists of three horizontal tanks, one inside the other. The innermost tank contains fluorine, which is kept in a liquid state by liquid nitrogen in the second tank. The space between the second and third tank serves as an insulating shield for the nitrogen. It is filled with pearlite or santocel and evacuated.

The workability of this design principle is based on the low boiling point of liquid nitrogen (–320°F) which is 14° below the boiling point of liquid fluorine (—306°F). This relatively small temperature difference permits keeping the fluorine liquid under a slight vacuum in an entirely loss-free system.

As long as there is liquid nitrogen in the second tank, there is no possibility of a pressure build-up in the fluorine tank. The insulation of the liquid nitrogen tank is so efficient that nitrogen losses are maintained at a very low level. No replacement of the coolant is required for a period of several weeks. The tank system is designed to be used either as stationary storage or as a bulk shipping container when mounted on a trailer transport chassis. It is also designed to be mounted on a railroad car.

Every conceivable safeguard has been provided to assure safe filling, storage, transportation and discharge of the tank system. In order to prevent discharging liquid fluorine in the case of accidental rupture of a fluorine line each entry into the product tank i made through the top.

Double valving is provided fo both gas and liquid fluorine service in order to prevent leakage into or from the tank. The discharge of the liqui fluorine can be either carried out b standard practice of pressurizing th tank with helium or through a pressur build-up coil which would pass warr nitrogen through a vaporizing coil im mersed in liquid fluorine. The heliur pressure discharge method is consic ered simpler and considerably faster.

Liquid Rocket Engine Control

By Rudolf H. Reichel
Bell Aircraft Corp.

IN RECENT YEARS the development of large liquid rocket powerplants has followed a path similar to that of reciprocating engines, turbojets, and ramjets. Problems that were at first rather limited have increased in number and complexity leading to a more complicated engine configuration. The improvement of performance has led from simple adjustment and calibration methods to the application of control engineering philosophy. This trend has been primarily influenced by the following:

(1) Maintaining or varying the thrust vector and the combustion chamber pressure, according to a predetermined characteristic.
(2) Maintaining the propellant mixture ratio (oxidizer weight/-fuel weight).
(3) Maintaining the dynamic stability of the propellant feed system as well as the stability of the combustion process.
(4) Maintaining or varying major parameters according to a program such as combustion chamber pressure and mixture ratio for static firing test purposes.
(5) Compensation of transient or steady state errors resulting from manufacturing tolerances.
(6) Simplification of operation of the powerplant.

For airborne purposes, two basic parameters, mixture ratio and thrust can be automatically controlled.

Mixture Ratio Control

Automatic control of the mixture ratio is required in order to obtain a maximum cut-off velocity as the criterion for rocket performance. Its exact observance during the burning time will guarantee maintaining the optimum specific impulse and the complete emptying of both propellant tanks. With this a decrease of burning time as well as an increase of the total rocket mass at cut-off, is avoided.

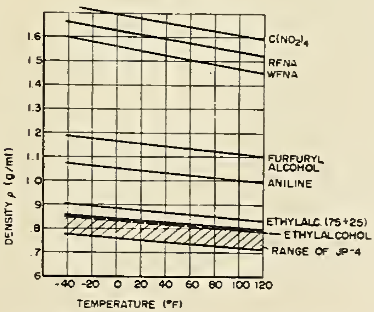
The mixture ratio can be affected by several influences. Considering some different rocket propellant combinations as presented in Fig. 1, the density characteristics of fuels run approximately parallel to each other within a usual operational temperature range between —40°F and +120°F, as do the characteristics of oxidizers. However, the slopes of the two propellant groups are different. Therefore, a change in temperatures can lead to a noticeable deviation from the design point. Further alteration of the mixture ratio is possible by incorrect propellant weight flow rates due to incorrect pump characteristics or manufacturing tolerances of the various components. Finally, because of the effect of the missile acceleration on the propellant columns of different height and density, a deviation from the mixture ratio set point may also be expected.

A suitable control system which will consider these influences is represented in Fig. 2. The basic method is to measure oxidizer and fuel flow rates and to compare their ratio with the set value. Any deviation causes a control command by which the control valve will be operated until this deviation becomes a minimum. The control valve can be installed either in the oxidizer or the fuel side. For automatic control purposes, continuous or discontinuous control systems can be used.

For the *Viking* high altitude rocket which has a vertical trajectory during the burning time, an automatic mixture ratio control system was developed with the differential pressure measurement of the propellant columns in the tanks, Fig. 3.

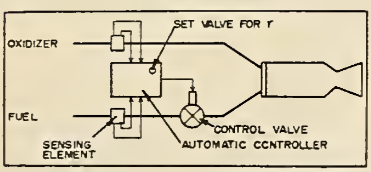
In order to demonstrate the importance of the mixture ratio control with respect to rocket performance, the ballistic single-stage rocket corresponding to Table 1 may be taken for comparison purposes. The cut-off velocity value is based upon a vertical and drag free trajectory. It is obvious that design parameters can be maintained only

Figure 1



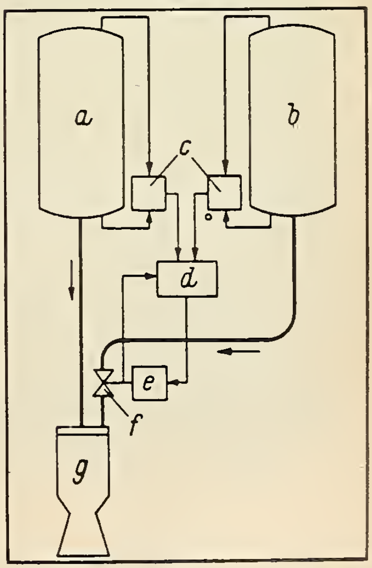
Specific gravity of some typical rocket propellant components vs. temperature

Figure 2



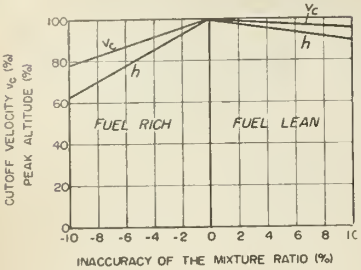
Arrangement of an automatic liquid rocket mixture ratio control system.

Figure 3



Mixture ratio control system or the sounding rocket VIKING. (a) oxidizer tank (b) fuel tank (c) differential pressure sensor (d) mixture radio controller (e) actuator (f) control valve (g) combustion chamber.

Figure 4



Loss of cut-off velocity and peak altitude, respectively, due to the inaccuracy of the mixture ratio using the propellant combination $C(NO_2)_4$/JP-4.

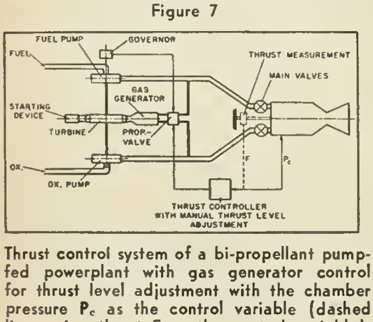
when the powerplant is accurately controlled. Fig. 4 shows the variation of the cut-off velocity v_c and the obtained peak altitude h, with deviation from the mixture ratio design value. The predominating influence for fuel rich combustion is easily explained by the high weight portion of the oxidizer. With respect to the cut-off velocity we find a diminution of about 5 per cent if the mixture ratio is only 2 per cent fuel rich which corresponds to a loss of 8 per cent of peak altitude.

In order to get a better idea of how missile acceleration affects the mixture ratio, the above-mentioned rocket can be taken as an example. In this case the predetermined mixture ratio varies from 4.52 to 4.9 under launching conditions, attaining 4.2 at cut-off. This corresponds to 9 per cent fuel lean and 7 per cent fuel rich, respectively. Such alterations of the mixture ratio cannot be accepted for large vehicles.

Thrust Control

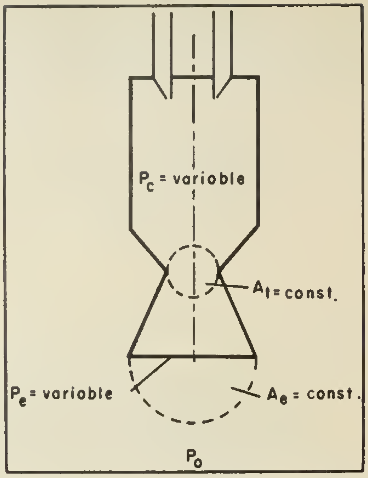
The importance of automatic thrust control depends on the required performance output characteristic of the rocket engine. In ballistic rockets, thrust will either be controlled to meet a specified acceleration requirement, or a constant thrust output will be maintained. However, the latter operating technique gives the best possible conversion of the propellants into rocket energy only if a drag free flight path

Figure 7



Thrust control system of a bi-propellant pump-fed powerplant with gas generator control for thrust level adjustment with the chamber pressure P_c as the control variable (dashed line: using thrust F as the control variable).

Figure 5

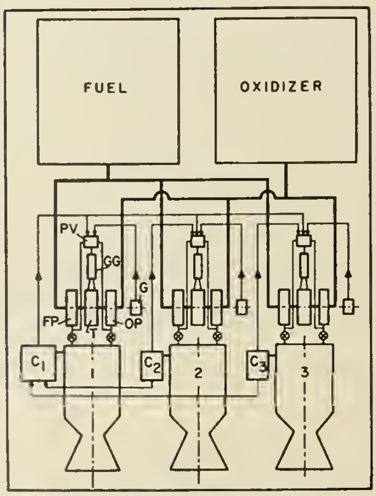


Parameters of a fixed expansion nozzle.

is assumed. Therefore, this operating restriction can be applied only for the upper stages of multiple-stage rockets. For all other cases the aerodynamic drag requires an optimum thrust programming in order to get highest possible cut-off velocity.

With respect to supersonic winged missile applications, the requirements of optimum thrust programing are similar. In many cases the propellant-wasting climbing phase will also be eliminated by launching from another ship. After release, the missile will then be propelled either by a quasi-

Figure 8



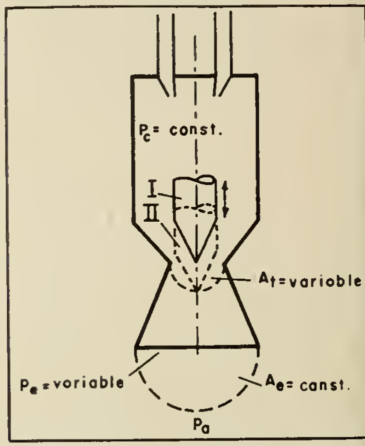
High thrust powerplant applying three combined rocket units. The master controller C_1 of unit 1 mixes the signals received from the other controllers C_2 and C_3 and compensates for the deviation according to the thrust set valve. Separate governor control loops are required to maintain stable conditions during starting transient. (PV = prop. valve; GG = gas generator; T = turbine; FP = fuel pump; OP = oxidizer pump; G = governor.)

constant thrust or the flight path will consist of a primary high thrust booth phase followed by an optimized lower thrust level cruising phase.

If a fixed expansion nozzle is used, Fig. 5, any off-design operation means a decrease of the specific impulse. For control purposes, the nozzle has to be designed so that with decreasing chamber pressure due to the throttling of the flow rate, shock conditions do not develop in the operating range. This occurs when the exit pressure becomes less than about 0.4 of the ambient pressure.

With a common injector, a decrease in injection differential pressure tends toward decreasing system stability even at a constant mixture ratio. This

Figure 6



Parameters of a variable expansion nozzle.

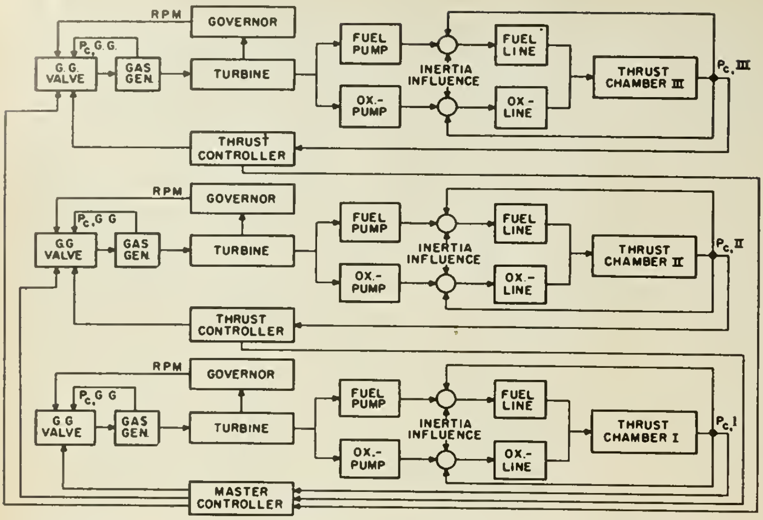
is due to the alteration of the injection flow pattern and the efficiency loss in propellant preparation for combustion. The use of several independently controlled injector groups may solve this.

With a variable throat area, Fig. 6, the operating conditions correspond to the fixed nozzle design at full thrust, i.e., when the throat plug is in position 1. For maximum throttling position 2, the limitation of the expansion nozzle area ratio is similarly affected by the critical pressure ratio due to the shock criterion. In order to control the engine, the throat plug position must be varied to maintain constant combustion chamber pressure with corresponding charge in the propellant flow rate.

The major design problem involved here is the high rate of heat transfer to this complex throat area control device. Similar to the fixed expansion nozzle design, heat transfer problems for the combustion chamber walls may also arise due to the decreasing propellant flow rate at lower thrust level.

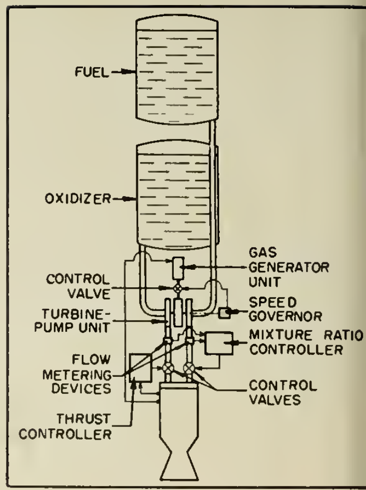
The control procedure for a pres-

Figure 9



Block-diagram of the high thrust powerplant according to Fig. 8 with several "internal" loop actions and cross-connections. Probable mixture ratio control is disregarded.

Figure 10



Rocket powerplant with turbine/-pump-unit including automatic thrust and mixture ratio control.

surized system using a fixed expansion nozzle motor can be performed by control valves arranged in the main propellant line. In case of more complex powerplants like those using a turbine-pump system, the propellant flow rate variation can also be achieved by automatic control of the turbine speed and the pump head, respectively, Fig. 7. In this case the combustion chamber pressure is the control variable. This method has this advantage: Any alteration of the mixture ratio will be limited due to the mutual dependance of both pump characteristics on speed. To compensate for the thrust increase due to the decreasing ambient pressure with altitude, the atmospheric pressure can be applied as an auxiliary control variable. This can be considered directly when the thrust force itself is used as a control variable (dashed line). For special requirements, it is possible to take the magnitude of missile acceleration as a control variable.

The automatic control system has to avoid any excess of turbine speed overshoot, say more than 5 per cent, and has to stabilize the engine operation at any dictated thrust level. It is obvious that these requirements need a close knowledge of the various parameters involved.

For high performance requirements multiple engine powerplants can be expected. Here, the thrust chambers will be arranged around a center line. Exact thrust control of any one chamber with respect to the others is required to avoid unsymmetrical thrust forces. In Fig. 8 such a high thrust engine unit applying three rocket motors is presented schematically. The extreme complexity of such a propulsion system can be seen by its block diagram, Fig. 9, disregarding the automatic control of the mixture ratio.

Mixture Ratio and Thrust Control

Considering a powerplant, Fig. 10, from the control engineering standpoint, several closed loops can be recognized which represent a dynamically complex system with correlative influences due to the cross-connections, Fig. 11. The thrust here is controlled by the chamber pressure, the mixture ratio by the fuel flow variation, and the gas generator system which is supposed to drive the gas turbine, by the turbine speed. Together with the feedback action of the chamber pressure, six closed loops result. The various pressure controllers, as usually arranged within the engine system, represent minor control loops which in case of instability act as disturbances on the major loops.

Combustion Stability Control

One of the major problems o[f] rocket development is the dynami[c] stability of the combustion process eve[n] when an automatic control system i[s] applied. Several investigators hav[e] pointed out that not only the configur[a]

Figure 11

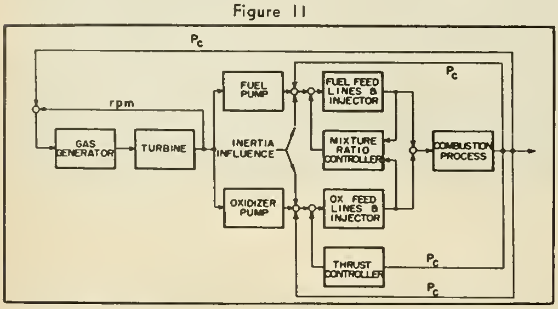


Figure 12

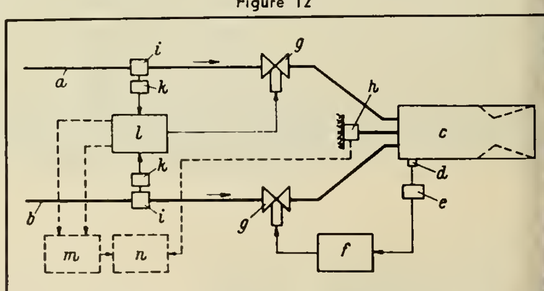


Fig. 11. Block-diagram of the rocket powerplant according to Fig. 10 with six closed-loop actions. Fig. 12. Experimental arrangement f[or] automatic control of combustion chamber pressure P_c and mixture ratio. (a) oxidizer (b) fuel (c) combustion chamber (d) pressure pick[up] (e) transmitter (f) pressure control unit (g) control valves (h) thrust measurement device (i) sensing elements (k) transmitter (l) mixtu[re] ratio controller (m) computer for the determination of the mass flow rate (n) computer for the determination of the exhaust veloci[ty]

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Further technical data, prices and delivery information — on the 5490/5495 Console Recording Systems and two- to eight-channel 5475/5480 Systems are available on request from your Sanborn Sales-Engineering Representative or the Industrial Division in Waltham.

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Mass ratio	5.64
Propellant weight	44,100 lb
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Thrust	132,500 lb
Specific impulse	210 lb-sec/lb
Cut-off velocity	9,460 ft/sec
Peak altitude	303 miles
Burning time	73 sec

Table I—Data for a single-stage ballistic rocket using tetranitromethane as the oxidizer and JP-4 as the fuel.

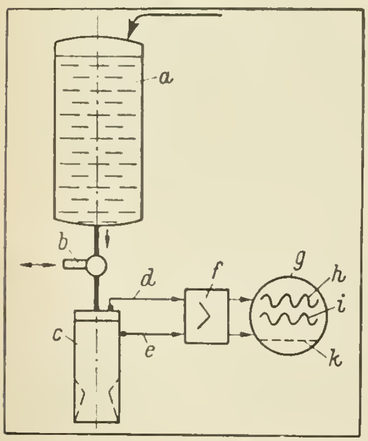
tion of the combustion chamber and the injector, the chemical and physical properties of the propellants, but also the effect of dead time and non-linearity within the process, the stiffness of the structure including propellant tanks and lines, the propellant compressibility and aerodynamic forces, represent a complex system affecting the combustion stability.

Up to the present, the low and high frequency combustion instability problem must be handled more or less in an empirical manner although there are several theoretical papers which propose methods for the automatic control of low-frequency combustion instability. These control methods are not yet of any practical use.

Automatic Control Methods for Static Firing Test Purposes

It is an essential task of the static firing test to check design parameters and to examine propellant combinations. Common methods to determine the plot of specific impulse I_{sp} vs. mixture ratio step by step within a test series using manual control procedure, include some difficulties, especially when optimum conditions (e.g., constant chamber pressure) should be maintained. By application of automatic control methods, the function $I_{sp}=f$ (mixture ratio) can be determined within only one run. This method results in saving of time and propellant expense, and improves the accuracy especially when oxidizers with a corrosive effect are used.

Figure 14



Test arrangement for the stability investigation of a mono-propellant pressurized system. (a) propellant tank (b) piston pulser to generate a harmonic disturbance (c) combustion chamber (d) injection pressure P_i (e) chamber pressure P_c (f) amplifier (g) oscillograph (h) P_i as the input variable (i) P_c as the output variable (k) time mark.

Using an automatically controlled arrangement according to Fig. 12, the following problems can be solved:

(1) I_{sp} vs. mixture ratio with the chamber pressure as the parameter, Fig. 13, solid lines.

(2) I_{sp} vs. combustion chamber pressure with the mixture ratio as the parameter, Fig. 13, dashed lines.

(3) Combustion chamber pressure and mixture ratio are held constant. This method corresponds to an acceptance test.

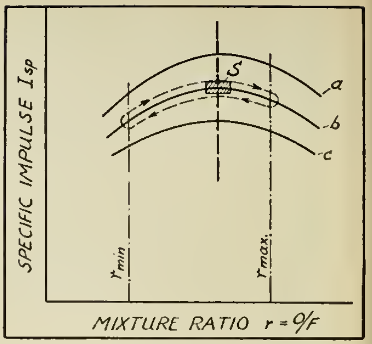
The last step would be to evaluate the test values by means of computers and to record the results even as the test run is being carried out. Besides the usual data such as tank pressures, thrust, propellant flow rates, and combustion chamber pressure, other values can then also be evaluated immediately after the run. To perform all required calculations computers are needed as plotted by dashed lines, Fig. 12.

The Experimental Investigation of The Dynamic Stability

Theoretical papers try to represent the dynamic system, e.g., Figs. 10 and 11, by means of linear differential equations of the closed-loop or by the transfer function. However, for practical purposes there are limitations since the theoretical representation of the dynamic system and therefore the information on coefficients and disturbances, is hard to realize at the design stage.

Besides the experimental dynamic stability investigation of pressure regulators, turbine-RPM-governors, or any other control arrangements known in common control engineering, the investigation of the complete propulsion system is of a special interest. To consider a simple example of overall stability, a mono-propellant pressurized system is represented in Fig. 14. The investigation has to be performed under actual conditions with installed combustion chamber, lines, values, propellant tank, etc. Because there is an "internal" feedback action here due to the combustion chamber pressure, it is not possible to get open-loop conditions for investigation purposes. The only possibility is to feed the propellant feed system or even the combustion chamber with a harmonic disturbance. As an example we can disturb the propellant flow rate by means of a piston pulser (input variable) and record the chamber pressure response (output variable) depending on the frequency, in order to get the stability margin. Unfortunately, up to the present time it is very difficult to measure flow rate fluctuations reliably. For that reason we only can measure the injection pressure and determine whether there is any critical amplitude ratio (chamber pressure injection pressure ratio) within the required operating range.

Figure 13

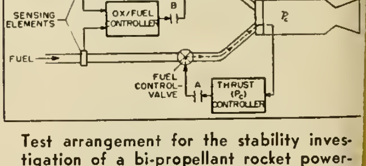


Automatic control of P_c = constant and mixture ratio = constant. a to c are curves of three different P_c values as parameters. S = area covers the tolerance for an acceptance test.

In the case of a bi-propellant rocket, this method has to be applied accordingly, however, the harmonic disturbances are to feed in such a way that any alteration of the mixture ratio will not influence the overall stability.

As another example a thrust and mixture ratio control is considered. The dynamic overall stability can be determined when the thrust control loop as well as the mixture ratio control loop are to be cut and considered as open loops, points A and B, Fig. 15. The investigation then can be accomplished subsequently by feeding the loops with harmonic disturbances according to the operating conditions. ✦

Figure 15



Test arrangement for the stability investigation of a bi-propellant rocket powerplant with a thrust and mixture ratio control loop. At A and B the loops can be cut for investigation purposes.

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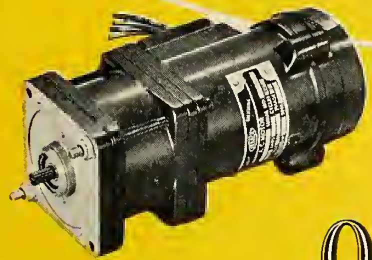
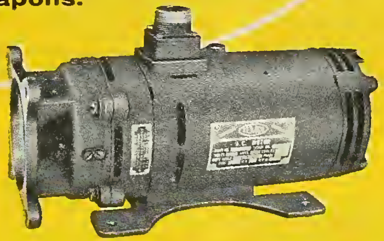


Type: C-1874 400 cycle 3 phase AC Motor and Clutch. **Weight:** 4.5 lbs. **Voltage:** 200 volts. **Output:** 650 watts. **Intermittent duty:** 12,000 rpm. Meets Military Specification MIL-M-7969A (ASG).



Type: D-638 400 cycle AC Motor. **Weight:** 17.5 lbs. **Voltage:** 200 AC, 20 amps at 6.5 hp. **Duty cycle:** 3.0 seconds at 6.5 hp, 15.0 seconds at 1.5 hp. **Maximum capacity:** 6.5 hp. **Continuous rating:** 5 hp at 2300 rpm, 15.8 amps, 200 volts. Meets Military Spec. MIL-M-7969A (ASG).

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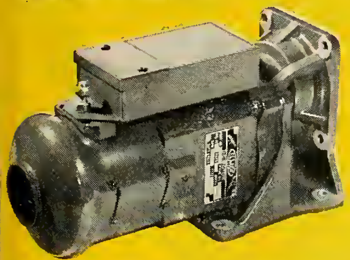
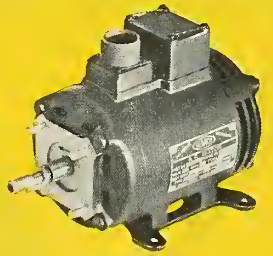
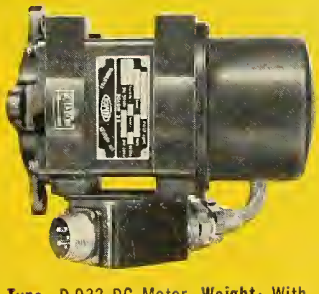


Type: D-751 DC Motor. **Weight:** 20 lbs. **Duty Cycle:** 5.2 hp at 2100 rpm (intermittent) on 26 volts DC; 3.5 hp at 2200 rpm (continuous) on 26 volts DC. **Meets Military Specification** MIL-M-8609.

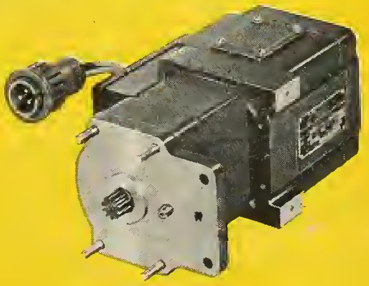


Type: D-800 400 cycle 3 phase AC Motor. **Weight:** 8.75 lbs. **Voltage:** 208 volts. **Horsepower:** 2.5 hp. **Continuous Duty:** 11,300 rpm; Equipped with thermal protector. **Meets Military Specification** MIL-M-7969A (ASG).

Type: D-899 400 cycle 3 phase AC Motor. **Weight:** 11.25 lbs. **Volts:** 200 volts. **Load:** 2.75 hp continuous output. **RPM:** 3140 rpm output at gear box. **Power factor:** 83%. **Overall efficiency:** 76% for entire unit. **Meets Military Specification** MIL-M-7969A (ASG).



Type: D-932 DC Motor. **Weight:** With radio noise filter—13 lbs., without same—12.4 lbs. **Terminal voltage:** 27.5 DC plus or minus 1.5 volts. **Load:** From .5 hp minimum to 2.6 hp maximum. **Speed:** Continuous at 12,000 rpm, plus or minus .005%. **Speed Control:** By frequency regulator supplying control field. **Meets Military Specification** MIL-M-8609 (ASG).



Type: D-927 DC Motor. **Weight:** 7.25 lbs. with 2-circuit noise filter for ungrounded systems. **Weight of filter:** 1 lb. **Terminal voltage:** 27 volts, 18 amps. **Load:** 0.5 hp. **Speed:** Continuous at 9900 rpm. **Meets Military Specification** MIL-8609.

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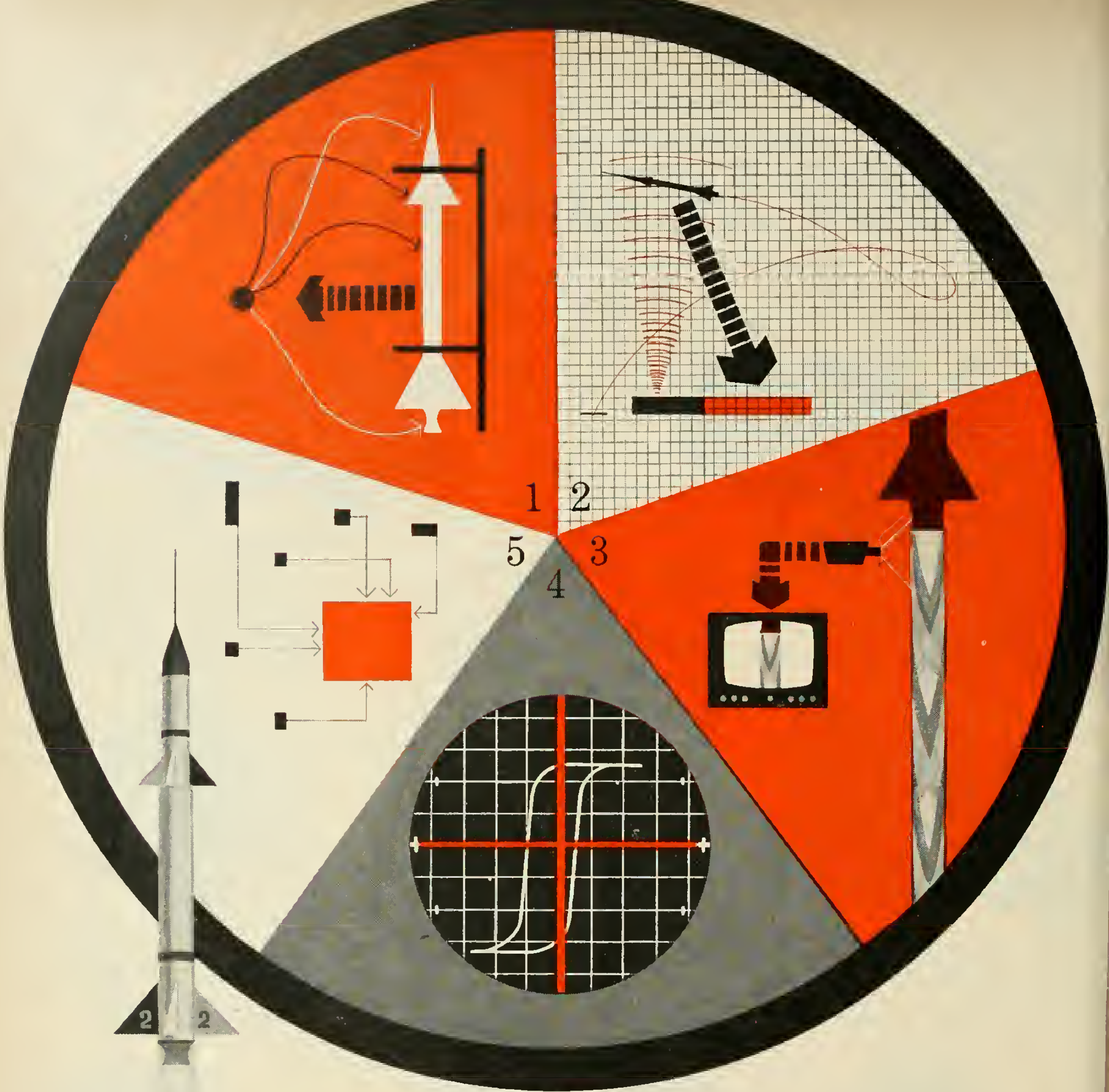

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Liquid Propellants for Manned Rocket Aircraft

By **William Mitchell**
Reaction Motors Inc.

THERE IS A MILITARY NEED for manned rockets. Guidance lone may never measure up to the job f bringing in the shot on a pinpointed ırget. At 150 lbs. a pilot represents ertain guidance functions that all the ectronic gear in the world couldn't uplicate. The pilot could act as ver- ier guidance to rain a whole fleet of her guided missiles on particularly ɔscure targets.

There is also the most exciting ɔle of all, the passenger and cargo ırrying rocket. It does not seem likely ıat a chemical rocket will ever propel an over interplanetary distances, nor ven to the moon. That seems to be a b for the nuclear rocket.

North American has announced eir forthcoming X-15 with speeds omised in excess of those achieved to- ıy. The propellants for the X-15 are ıannounced but the others employ quid oxygen and ethyl alcohol. This ɔmbination has done yeoman service the early missiles such as the V-2 ıd the *Viking*. While LOX and ethyl cohol fulfill today's needs, they will not do for tomorrow's job.

The manned rocket of the future will fall into one of the three classes already mentioned: the military rocket, the commercial rocket, the research rocket.

Propellant Requirements

The propellant requirements for each of these will in some ways vary from each other and from guided missiles. In most qualities the requirements of manned and unmanned rockets will be the same. The major difference between a manned and unmanned rocket is the need to return the pilot. This means some form of airfoil device to permit a glide return which results in a drag increase for a manned rocket greater than that of an equivalent impulse guided rocket.

The pilot must be protected from aerodynamic heating, so an additional cooling problem is impressed on the manned rocket. In addition, the pilot cannot withstand the same accelerations that can be tolerated by instruments, airframe and warhead. He must have oxygen, be protected from toxic leaks, and some sort of atmospheric pressure must be supplied. The hardware weight in a manned rocket will tend to be higher than is necessary for a guided rocket.

On the plus side, however, the manned rocket will require little or no guidance, although the pilot may depend to a large degree on data and instructions from electronic gear. The pilot is a reliability promoter and can correct some failures if they occur. In general, his ship should be less complicated in system concept than a guided missile.

For any rocket, manned or guided, high boiling point and low vapor pressure are desirable propellant characteristics: the propellant can act as a heat sink without boiling or requiring very high propellant pressures to remain liquid. Liquid temperatures can easily approach 300°F in supersonic dashes as a result of aerodynamic heating. On top of this—the regenerative cooling requirement of heat flux in excess of 10 BTU/sec-ft^2

—°F—the temperature requirements of the propellants can easily be raised to 500°F. It is a natural desire on the part of the designer to reject to the propellants the heat liberated in cooling the passenger of the manned rocket. So still another heat load is added to the propellants.

The ideal property of high boiling point is even more desirable for the manned rocket than for the guided missile. In all of today's manned rockets the liquid oxygen oxidizer is a totally worthless propellant in view of the high boiling point requirement. The other half of the propellant team, ethyl alcohol, is more noted for its cooling properties and thermal stability than as an energetic fuel.

Low Freezing Point

Propellants that do not meet freezing point requirements can sometimes be rendered usable by the use of additives such as ammonium thiocyanate added to hydrazine or water to hydrogen peroxide. Usually, the use of an additive to improve one property, such as freezing point, will result in the deterioration of another desirable property. For example, while the freezing point of hydrogen peroxide can be improved by adding water, the resultant solution does not have the oxidizing power that neat peroxide enjoys. Mechanical aids can be used to overcome high freezing point such as heating blankets, blowing warm air around a propellant tank, or storage of propellants in heated areas. All of these add to the complexity of handling equipment.

The desirable property of low freezing point can be somewhat sacrificed by limiting launching operations to tailor-made installations or temperate climates. While this may be tolerated for research vehicles, it would hardly be a worth while sacrifice for fleets of military rockets and it would exact a severe logistic penalty for future commercial operations.

A low value of viscosity plus a flat viscosity vs temperature curve is desired. Low values of viscosity are necessary for the small, superspeed pumps that are being designed into missiles. Lacking temperature independence of viscosity, the rocketeer must then accept engine performance variations or else build in a complicated compensation system.

As in the case of freezing point the designer of a manned rocket may accept a relaxation of this requirement because in the pilot he has a guidance computer that can readjust to compensate for temperature variation. The pilot may be able to adjust the trajectory or the rate of propellant flo

to maintain the planned mission for the vehicle.

The missile designer is constantly faced with a choice between high density or high impulse, rarely does he enjoy the advantage of both. Fuels usually run to densities less than 1.0 gm/cc—more often than not around 0.8 gm/cc. Oxidizers are heavier, running from around 1.14 gm/cc for liquid oxygen to 1.55 gm/cc for red fuming nitric acid and fluorine. Practically all rocket propellant systems use more pounds of oxidizer than pounds of fuel, and this is a distinct advantage in lowering tankage weight.

In the past most of the rocket chemist's attention has been devoted to rocket fuels, but in the past few years there has been a switch to more research in oxidizers. Fuels still command the lion's share of propellant R&D. Oxidizers offer a promising field for research, since most oxidizer molecules are dense, and rocket engines always operate most efficiently on the fuel rich side. It is through oxidizer research that the present bulk densities of propellant systems can be raised from the prevailing range of 1.0-1.2 gm/cc to the 1.5 gm/cc range.

High density for the manned rocket is a must or else the rocket is forever chained to sub-space flight. The silhouette must be kept small so that the rocket can be launched from a mother vehicle. Ground-launched, manned rockets require a glide vehicle for the pilot's return. The added drag of the return vehicle must be compensated by high propellant density and a subsequent lowering of drag area through compact tankage.

Present-day manned rockets utilizing LOX and ethyl alcohol are in violation of the high density principle. These rockets are very limited in flight capacity.

Nontoxic Requirements

Aviation gasoline, jet fuel, and liquid oxygen must be considered toxic, or at least dangerous propellants, by the usual methods used to determine toxicity. Beryllium, now labeled dangerously toxic from its history in the fluorescence field, is practically ignored as a fuel atom.

Meanwhile boron is the subject of a great deal of experimentation, although beryllium has at least as bright a theoretical future. Such taboos can be overcome as indicated by the rise in liquid fluorine and liquid interhalogen research as rocket oxidizers. With materials research and handling techniques constantly lessening the danger of accidents, it is not unlikely that dangerously toxic materials will be tolerated for manned rockets of the future.

Toxic propellants can be controlled through adequate containment and toxic exhaust products can be vitiated by treatment or firing in remote places.

Noncorrosive Factor

There are no "ordinary" materials capable of containing some of today's corrosive propellants. Today's rocketeer talks of stainless, inconel, aluminum, silver, nickel, monel, teflon, Kel-f, fluorlub, etc. These are now "common" materials. The program leading to the synthesis of a new propellant quite often touches off an equally large program in the synthesis of a new alloy compatible with the propellant or its combustion products.

Liquids that can propagate explosions in the liquid phase are considered unsatisfactory for any kind of rocket, since involvement of the entire propellant supply in the tanks is possible.

The field of shock sensitivity is still far too much in the realm of clairvoyance. There are many propellants moderately labelled shock sensitive that await standardization and interpretation of tests. This is one facet of propellant chemistry that is receiving a great deal of attention today. The very nature of the molecular instability is an advantage when one considers the propellant from the viewpoint of wanting high specific impulse. A definition of tolerable limits is needed.

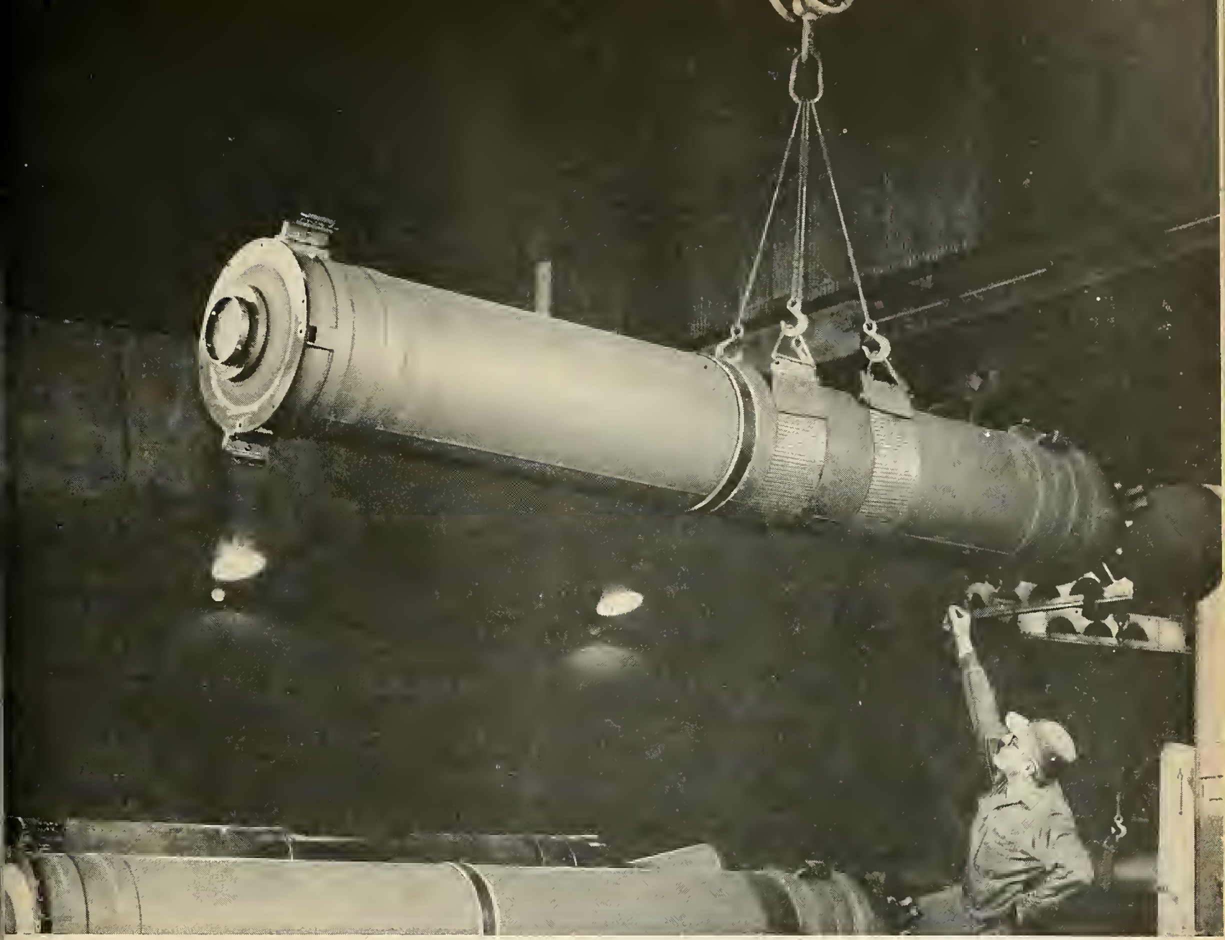
The requirements for a manned rocket are no different in this respect than for a guided rocket, unless, as in the case of corrosivity, a little extra is required.

Ease of Ignition

There is probably no area which has been more of a headache to the combustion chemist, the thrust chamber designer, and the test engineer than accomplishing safe, positive, repetitive starts and maintaining smooth combustion. Since it is impossible to predict combustion kinetics, propellants are evaluated and chambers are designed on equilibrium conditions and a number of ignorance factors commonly called "experience."

The size of the combustion chamber and the injection arrangement is usually finalized after hundreds of hot tests, some of which result in harder starts than the test chamber can stand. There are spark igniters, glow plugs, pyrotechnic squibs, hypergolic leads sequenced operations, injector face shutoff valves, splash plates, and other sundry rocket engine tricks to overcome our lack of knowledge of combustion kinetics and droplet burning. Since these problems are not likely to be solved soon, we must fall back on "experience."

A rocket industry innovation is



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the hypergolic pair, in which the fuel and oxidizer ignite on mutual liquid contact. Hydrazine and red fuming nitric acid (RFNA) are such a typical pair. Fluorine and nearly any fuel is another pair, while hydrogen peroxide can accomplish ignition with many fuels because the exothermic decomposition of the peroxide provides temperature as well as free oxygen.

The ignition delay of a hypergolic pair must be short enough (less than 50 milliseconds, preferably less than 20) so that propellant cannot accumulate in the chamber to create an explosion.

Good ignition and combustion is a must for manned rockets.

High Specific Impulse

This is the most important property of all, for it is in the bond energies of the molecule and in the resultant combustion product that the chemical energy is converted to kinetic energy. The parameter specific impulse is usually defined as the pounds of thrust per pound per second of propellant flow or $I_{sp} = F/W = \frac{\text{lb.}}{\text{lb. 1/sec.}} = \text{sec.}$

The propellants react in the chamber to produce heat and gaseous products. The products expand through a nozzle, converting part of their heat energy to kinetic energy, and are exhausted. The specific impulse of a rocket motor depends only on the nature of the propellant, the chamber pressure and the exhaust pressure. The only properties of a propellant that affect specific impulse are empirical formula and heat of formation.

There appears to be a limit of about 400 seconds to specific impulse for chemical rockets. It is unlikely that a manned rocket will ever achieve this since this high a value will probably require high heat of formation propellants which lowers sensitivity and thermal stability.

Specific impulse is a measure of impulse per unit weight. The term density impulse has been created to represent a measure of impulse per unit volume.

$$I_{sp} = \frac{\text{impulse}}{\text{unit weight}}$$

$$\text{bulk density} = \frac{\text{unit weight}}{\text{unit volume}}$$

Therefore,

$$(I_{sp})(\text{bulk density}) = \frac{\text{impulse}}{\text{unit volume}}$$

A high density impulse is desirable in reducing silhouette for manned rockets, but not at the expense of low specific impulse coupled to a high density propellant combination. The weight of the pilot plus the special hardware and glider requirements represent a fairly heavy payload and high value of specific impulse is a must if the rocket is to be propelled very far. Therefore, the manned rocket has the same requirements as the long-range, heavy payload guided missiles, namely high specific impulse. On top of this it has the further requirement of high density to trim silhouette, so that it will fit in the mother ship necessary for launch, or, barring that, will present a low drag area for ground launched vehicles.

High Thermal Stability

If any rocket motor is to survive for very long with combustion gas temperatures of 4000 to 10,000°F, it must be cooled, or else the burning time is restricted to seconds, not minutes. The heat is usually rejected to one or both of the propellants. In a manned rocket, the extra cooling required dictates a need for thermally stable propellants.

To be thermally stable, a propellant should not decompose exothermically, or become excessively shock sensitive as temperature increases. To maintain satisfactory cooling of the rocket chamber, the propellant must stay below the critical temperature, and remain a liquid in the cooling passages without resorting to extremely high fluid pressures.

High impulse fuel usually dictates materials that are inherently sensitive due to high heats of formation, and this basic sensitivity cannot be overcome by additives. A compromise must be made between performance and sensitivity. One such compromise is the case of unsymmetrical dimethylhydrazine (ULMH) over hydrazine. Another is liquid oxygen over liquid ozone.

The requirement of high thermal stability is more necessary for the manned rocket then the unmanned rocket; however, some degree of instability must be tolerated to gain performance. There is a great need for propellant research in producing thermally stable propellants that pack performance. If none are found, manned rockets will never be much more than a dangerous research tool.

The accompanying list and table gives an approximation of the qualities of some of today's propellants.

Jet Fuel and LOX

Combustion difficulties and hard starts are known. Specific impulse is better than average but not good. Bulk densities are low. Thermal stability of the jet fuel is good and may be used as a regenerative coolant. This propellant combination would support today's manned rockets, but density, specific impulse, and combination qualities are not up to tomorrow's needs. Availability and cost will always make this combination attractive.

Ammonia and LOX

These are readily available; cost only slightly greater than jet fuel and LOX. Specific impulse is about the same. The low density of ammonia is even more of a penalty than is jet fuel. While ammonia ignition is difficult, combustion is smooth and hard starts are rare. Ammonia is a good regenerative coolant and endothermic decomposition is an advantage. Satisfactory for current needs only.

Hydrogen Peroxide and Boron Fuel

Boron fuels have been announced as a future jet fuel. Therefore, it is a reasonable assumption that they will also be among future rocket fuels. Specific impulse is moderately high. Bulk densities are good. Cooling may be a problem, but both materials may be used as coolant. Costs are apt to be moderately high. No cryogenic fluids in this system.

RFNA and Amine

Acid density is very high. Hypergolic starts and smooth combustion prevail. Cost presently is fair, and may be relatively good in the future. Specific impulse is on the low side. Availability is good. Cooling can be achieved by both fuel and oxidizer. Low impulse will limit lifetime.

Hydrazine Liquid Fluorine

This is the ultimate in today's propellants for density and impulse. It employs hypergolic ignition. Very high flame temperatures and the uselessness of fluorine as a coolant plus the marginal thermal stability of hydrazine will probably mean a third fluid as a coolant. Cost will be high, and handling will be dangerous. This is one of the few materials that measure up to tomorrow's needs from the impulse and density view.

Liquid hydrogen appears to have no place in the manned rocket field due to extremely low density. Liquid ozone is far too unstable. Normal propyl nitrate and nitromethane lack impulse and present sensitivity problems for manned rockets. Ethylene oxide also lacks impulse, but may be used as a gas generator for turbopumps and auxiliary power units.

The field of propellant chemistry must produce the high specific impulse, high density and thermally stable materials that tomorrow's manned rockets need. If not, the answer must be sought in nuclear rockets or space particle rockets, or else man will have to be content with flying up to a few hundred thousand feet and then gliding back to earth.★

DIMAZINE . . .

comes of age as rocket fuel

By William G. Strunk
Westvaco-Chlor-Alkalai Div.
Food Machinery and Chemical Corp.

UNLIKE THE physically refined, naturally occurring hydrocarbon fuels, Dimazine is a specific synthetic chemical compound. Because it is a pure compound, produced under controlled conditions, its physical and chemical properties are constant. It is a clear, colorless, hygroscopic liquid with a rather sharp ammoniacal or fishy odor, generally characteristic of organic amines.

Its structural formula is $(CH_3)_2NNH_2$, and its molecular weight is 60. It has a specific gravity of 0.795 at 60°F/60°F and weighs about 6.64 pounds per gallon. It boils at 146°F and freezes at —71°F. The material is reasonably volatile, having a vapor pressure at 70°F of about 120 mm, or one-sixth atmosphere.

It is miscible in all proportions with water, ethanol and most petroleum fuels.

Dimazine has a flash point of 34°F and flammability limits in air from 2.5 to 95 per cent by volume. The autoignition temperature in air is 482°F.

Dimazine reacts with carbon dioxide to form a salt. Extended exposure of it to air or other carbon dioxide-containing gases could lead to eventual precipitation of the material. Dimazine reacts slowly with oxygen or oxygen-containing gases at ambient temperatures to form several products.

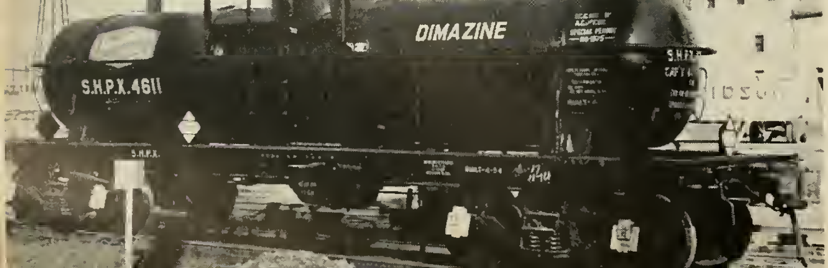
For flammability safety considerations, Dimazine is stored under nitrogen and under these conditions we have observed no formation of gums or other solids, even after sustained storage.

Range-forming work on high temperature stability has been carried out by heating small quantities of Dimazine in glass capillaries to successively higher temperatures. Essentially no decomposition was observed below the critical temperature of 482°F, or during thirty minutes at 550°F.

Some carbonization appeared at 700-800°F accompanied by a decrease in liquid volume upon cooling at ambient temperatures. Inclusion of nickel and stainless steel specimens in the capillary containers had no obvious effects. Further work investigating the high-temperature characteristics of Dimazine is under way. Dimazine mixtures have been used as regenerative coolants in rocket motors.

Dimazine is not shock sensitive. Work by the Bureau of Mines has demonstrated that Dimazine could not be detonated even after deliberate contamination with classical sensitizers, such as rust, copper and magnesium turnings and aluminum powder.

Dimazine is shipped in special tank cars to eliminate hazards of this sensitive fuel.



Materials of Construction

METALS. No known limitation exists on the use of nickel, Monel or Types 303, 304, 316, 321 and 347 stainless steel in contact with Dimazine. Aluminum and its alloys and magnesium (Dow metal 302) are good. Commercial Dimazine does not attack aluminum even with several per cent added water; however, some attack of aluminum has been observed by dilute aqueous solutions of Dimazine.

It should be noted that Dimazine typically contains about 0.1 per cent water. Easy Flow #45[1] silver solder appears satisfactory for use in brazing applications associated with Dimazine. Copper and high-copper alloys should be tested under proposed use conditions because we have observed corrosion of copper by refluxing Dimazine, although brass was essentially inert under these conditions.

Elastomers

Compatibility of Dimazine with a large number of non-metallic material of construction has been checked. Th best materials include Teflon[2], unplasticized Kel-F[3], polyethylene, Garlock gasket 900[4], Hydropol rubber[5], and graphite, but even less resistant elastomers are being used successfully in certain applications. Promising result are being obtained in a program developing fuel cells and bladders fc Dimazine and Dimazine blends.

O-RINGS. Westvaco manufactu ing facilities have used Garlock 90 gaskets with very good service. Polyethylene and Teflon have proven excellent as gaskets for shipping container

HOSE. The type of hose recom mended will depend on the specif service intended. Flexible stainless ste and polyethylene hoses have been use for some applications. In view of th inertness of Teflon and unplasticize Kel-F, hoses properly fabricated o these materials would be serviceable

Pumps and Packing. Conventional centrifugal pumps with graphite impregnated asbestos or braided Teflon packing is used in most instances. Chempumps[6] (sealless, centrifugal pumps) can also be recommended.

Sealants and Lubricants. Xpando[7] and Q-seal[8] have given satisfactory service as pipe dopes in production facilities. Because of Dimazine's excellent solvent properties, no completely satisfactory lubricant has been found. The current best recommendation is a mixture of Apiezon L[9] and graphite.

Drums. No unusual practices are indicated for the unloading and handling of sound sealed drums of Dimazine. If a leak results from damage of a drum in transit, the spilled material should be washed away with water before salvaging the remaining Dimazine.

It is recommended that drums of Dimazine be left sealed, just as received, pending need for transfer of their contents. Before unloading, the drums are conveniently emptied by either pump or gravity flow.

If the drum is to be emptied in a single operation, it can be vented during withdrawal by loosening or removing the plug from the opening not used for the liquid discharge. It is normally unnecessary either to maintain a nitrogen atmosphere or to dry the air that is drawn into the drum as the liquid contents flow out. It should be pointed out, however, that an explosive mixture may be present in the vapor space of the drum if air is allowed to displace the contents.

Neither oxidation nor moisture pick-up should be significant under these conditions. Before discarding, the empty drum should be flushed thoroughly with water to remove any small amount of Dimazine remaining. For drums being only partially emptied, the most conservative method requires that an atmosphere of inert gas be maintained within the vapor space as the contents are withdrawn.

Storage

There appear to be no critical limitations on storage environment. Mild steel tankage is satisfactory. Tests have shown Dimazine to be thermally stable at temperatures well above those normally encountered in the atmosphere. It freezes at a very low temperature.

From a practical viewpoint, storage should be maintained comportably below the boiling point of the material (146°F). A limit of 120°F as the peak temperature for sustained period is recommended. Large quantities should be stored in comparatively isolated areas, and oxidants such as nitric acid, hydrogen peroxide and halogens should be kept out of the immediate storage area.

Large quantities of Dimazine must be stored in isolated areas, and away from oxidants.

Studies suggest the use of horizontal cylindrical tanks, maintained under a slight pressure. Mild pressurization under an inert gas, rather than atmospheric breathing, is favored for reduction of Dimazine losses from periodic fills and withdrawals and from daily changes in ambient temperature.

Fire Hazards

As noted earlier, Dimazine is flammable. Open fires, sources of sparking etc., should be avoided and all equipment in which it is handled should be electrically grounded. Explosion-proof wiring, lighting and motors are indicated for areas in which it is to be handled.

A flammable mixture is present in the vapor space whenever Dimazine is handled under air. This is not unique to Dimazine, but is characteristic of a number of other chemicals and fuels frequently handled under air. Some of these materials that form flammable vapors with air at ambient temperatures are ethanol, methanol, acetone, ether and JP-4 jet fuel. As a safety consideration, the use of a nitrogen atmosphere is recommended over Dimazine.

Dimazine fires should be combatted with large volumes of water. This achieves both dilution and cooling effects. Liquid Dimazine burns smoothly and cleanly, and is readily extinguished on dilution with two or more volumes of water per volume of Dimazine. Much higher concentrations in water will support combustion, although flame intensity is progressively weakened as the Dimazine concentration of the solution is lowered.

Carbon dioxide and water fog are also effective in extinguishing Dimazine fires. Chemical foams are not recommended since Dimazine tends to deactivate the foam-forming surfactant and to destabilize the foam.

Toxicity

The acute toxicity characteristics of Dimazine are similar to those of hydrazine, and moderate care must be exercised in its handling. Westvaco has been producing substantial amounts of this chemical for several years, and has had no case of acute poisoning or evidence of chronic poisoning.

Our medical surveillance program

	MIL-F-25604 Specification	Typical Dimazine
Assay	98 wt. % minimum	99.2
Specific Gravity @ 25/4°C	0.783-0.786	0.7845
Distillation Range		
10% Temperature	143°F minimum	145°F
90% Temperature	148°F maximum	147°F
Melting Point	−70°F maximum	−73°F
Color (light transmittance)	90% minimum	96%
Water Content, wt. %	0.3% maximum	0.1%

includes a pre-exposure physical examination. Personnel exhibiting anemia or evidence of liver disease are not used on the operation. Hemoglobin and white blood cell counts are made at intervals of six weeks.

The safety precautions recommended for our plant operators are as follows: (1) If the odor of Dimazine is apparent, use a respirator equipped with an ammonia canister. (2) Wear splash-proof goggles and vinyl-coated gloves. If possibility of gross splashes exists, suitable splash-proof garments are recommended. (3) If splashes do occur, wash thoroughly with water and launder clothing and other protective equipment before re-use.

The most complete studies on the acute toxicity of Dimazine have been made at or under contract to the Army Chemical Center where they are currently studying the effects of chronic exposure.

Propellant Applications

One of the outstanding propellant characteristics of Dimazine is its hypergolicity with fuming nitric acids and the very low ignition delay when used with this oxidizer. The ignition delay of this system is the shortest of any known —only a few milliseconds. It also has been satisfactorily used as a fuel with liquid oxygen. This system is not hypergolic but smooth burning results once ignition has been initiated.

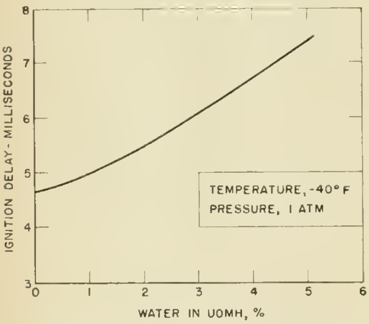
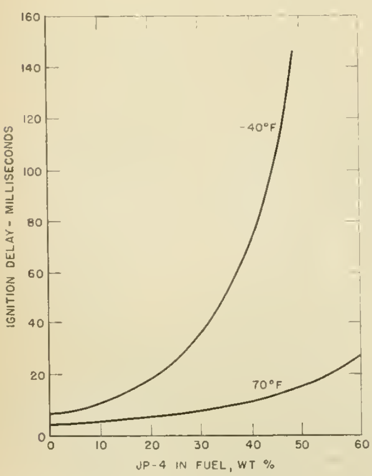


Table showing overall effect of water in UDMH on ignition delay with IRFNA.



Ignition delay of JP-4/UDMH mixtures with IRFNA showing delay in milliseconds.

The hypergolic character of Dimazine is utilized in a variety of ways. Propellant systems using only Dimazine and fuming nitric acid have been used very successfully. In other systems, a "lead slug" of Dimazine has been used to give reliable ignition to another nonhypergolic fuel system.

Dimazine has been used in blends with other fuels such as hydrocarbons to promote smooth burning. Rocket systems using Dimazine include the Army's *Nike Ajax*, the Air Force's *Rascal* and the Navy's *Vanguard*.

The results of a study of the hypergolicity of UDMH with IRFNA was reported by Potter and Byington at a meeting of the American Rocket Society in September, in 1956. They reported the following conclusions: (1) At atmospheric pressure, the ignition delay of UDMH in fuming nitric acid is very short, i.e., of the order of a few milliseconds. (2) Dilution of UDMH by up to 5 wt. per cent of water increases the ignition delay a small amount at −40°F. (3) Temperature, over a range of −65°F to 100°F, has little effect on the ignition delay of the UDMH-IRFNA system. Dilution with jet fuel (JP-4) increases the ignition delay only modestly at 70°F with a value of 30 milliseconds observed for a blend containing 40 wt. per cent UDMH. At −40°F the ignition delay of these blends rises rather sharply as the UDMH concentration is reduced.

Specifications and Analysis

A military specification, MIL-F-25604 (USAF), has been issued by WADC for unsym-dimethylhydrazine. We collaborated with WADC in development of this specification. Its key requirements are compared with typical Dimazine as shown in table.

Dimazine consistently complies with this specification and we see no economic penalty in maintaining this standard as opposed to turning out a material of lower quality.

We have proven the precision and accuracy of analytical methods for determining the properties listed in the above tabulation and will be pleased to supply copies of both the methods and the technical reports supporting them to those interested.

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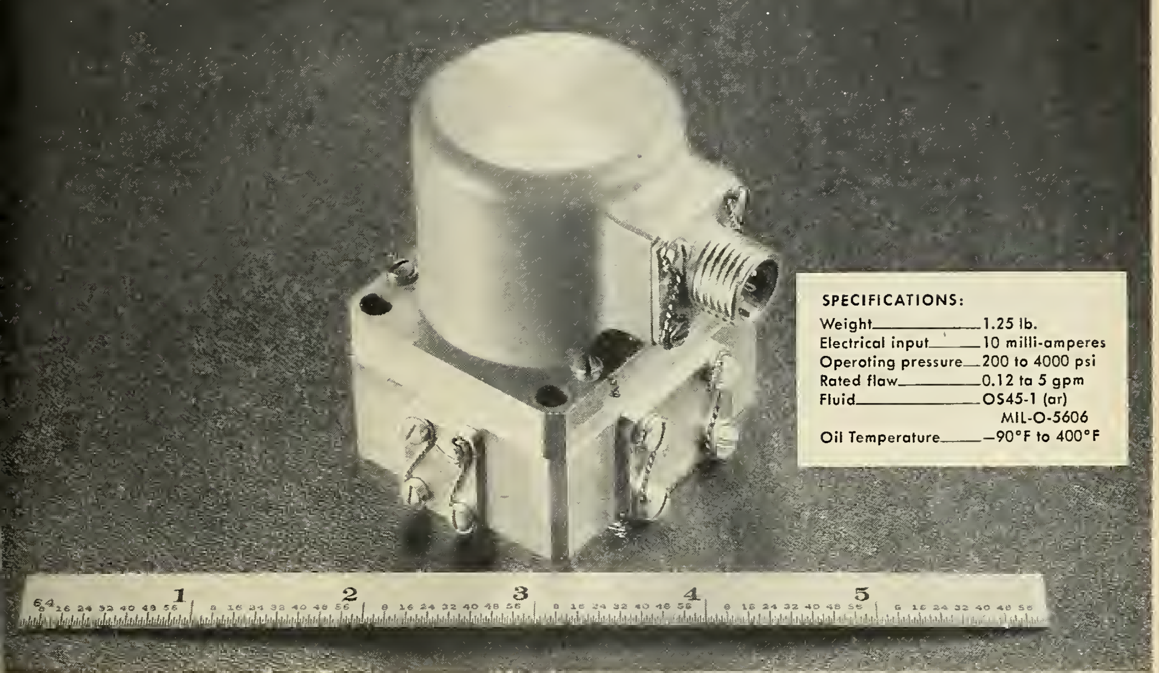

SPECIFICATIONS:

Weight	1.25 lb.
Electrical input	10 milli-amperes
Operoting pressure	200 to 4000 psi
Rated flaw	0.12 ta 5 gpm
Fluid	OS45-1 (ar) MIL-O-5606
Oil Temperature	−90°F to 400°F

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UDMH are coal or natural gas, wate and air. Salt must also be included as source of chlorine if a modified Ras chig synthesis is used. Dimethylamine one of the building blocks for UDMH is made from methanol and ammoni and the second nitrogen in UDMH is also fundamentally derived fron ammonia.

The equivalent of two moles o each of these chemicals appears i each mole of UDMH. When proceed ing through the nitroso route, hydroge is required to convert the nitroso t Dimazine. In the modified Raschi process, the ammonia is oxidized b chlorine. Chlorine and hydrogen ar cheap, readily available chemicals whic present no serious limitations to pro duction.

Less than one per cent of ammonia-methanol capacity would be required to make 50-million pounds o UDMH annually. The processes involved in the manufacture of UDMH are of a type that are readily adaptabl to large volume production.

It has been Westvaco's policy t maintain capacity substantially in ex cess of demand. Engineering studie have been completed which will per mit prompt expansion of our facilitie if and when increased demand appear

The price of UDMH has bee steadily decreasing during the relative ly short time it has been in commerci production. Prior to 1954, the price c UDMH was about $15.00 to $30.0 per pound. In 1954 and 1956, this w reduced to less than $4.00 and le than $3.00 per pound, respectivel Current price for tankcar quantities under $2.00 per pound.

Our engineering studies indica that a selling price of about $.50 p pound should be possible if large-scal sustained production is achieved. Th includes amortization of the investme and a modest profit.★

Footnotes

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2) *Registered trademark of du Pont C Wilmington, Del.*
3) *Registered trademark of Minnes Mining and Manufacturing C St. Paul, Minn.*
4) *Registered trademark of Garlock Pa ing Co., Palmyra, N. Y.*
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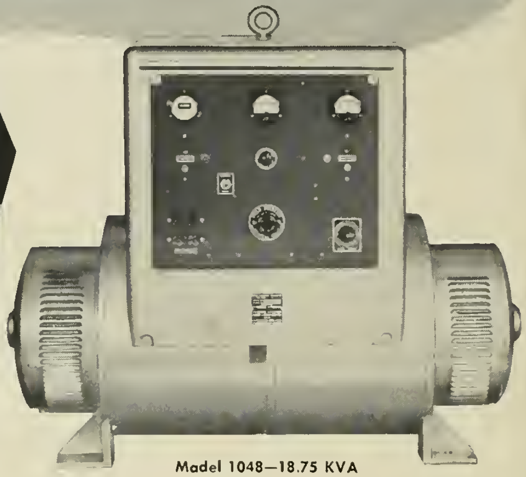

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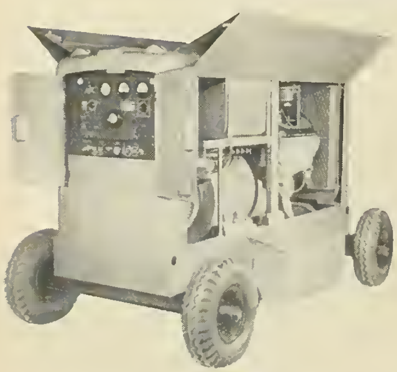

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Propulsion Systems Evaluation

By George P. Sutton
Chief, Preliminary Design Section
Rocketdyne

AN EVALUATION of future propulsion systems for space travel is, at best, highly speculative at this time. The technology of some of the more advanced propulsion systems needs considerable research and development. Some of them may prove to be fundamentally restrictive.

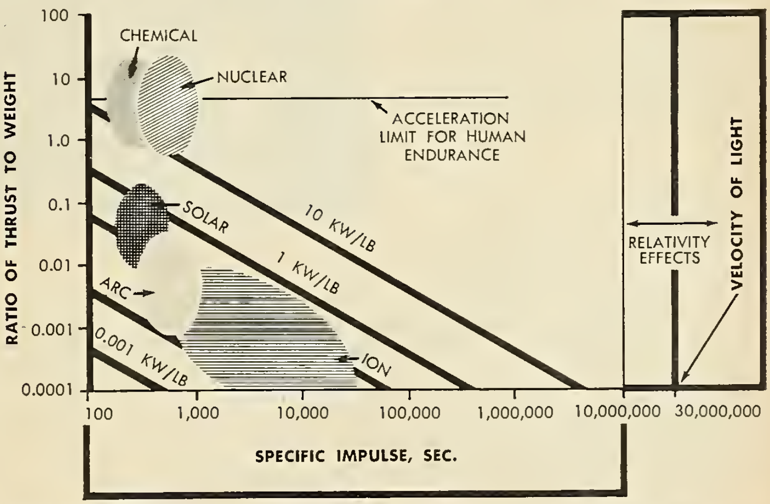
Analytical studies indicate that a number of propulsion devices, which will permit space travel, are theoretically possible. Those giving high performances will require a larger amount of energy expenditure per unit thrust. This implies that the problems of some of the more advanced propulsion systems will be more intimately associated with the energy source, rather than the thrust-producing device.

Many of the propulsion problems become more difficult when the mission requires a pilot or a passenger. Safety provisions, acceleration limits, hazard of radiation, or check-out procedures become more involved. From the propulsion standpoint, therefore, unmanned space flight will be easier to achieve at an early date.

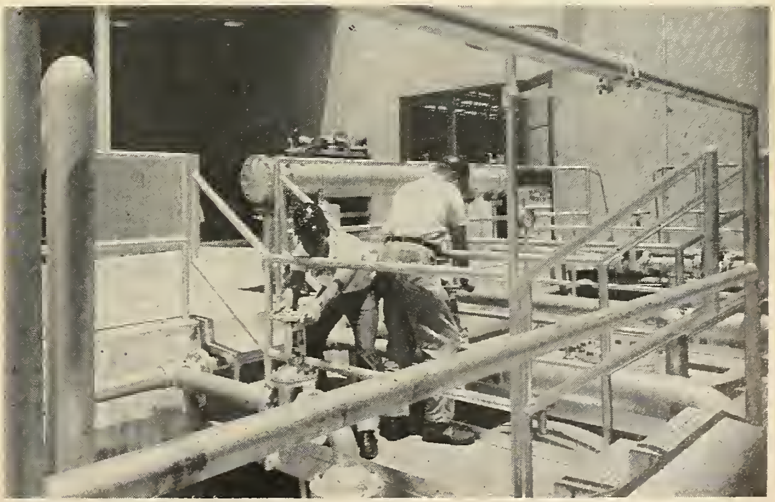
The evaluation of the relative merits of one propulsion system over another and the selection of optimum propulsion system parameters will require the examination of many factors, some of them still unknown. Therefore, it is not possible at this time to make a general statement as to the optimum powerplant for space flight. Very likely the vehicle will be a multiple-stage space ship and carry more than one type of powerplant, each to be utilized for a specific portion of the flight. A relative evaluation of the optimum powerplant, therefore, will require an evaluation of specific missions.

For takeoff from the earth and other large heavenly bodies, and in many cases for landing also, a relatively high acceleration is required. For these functions, a liquid propellant rocket may well be adequate. A notable contribution to space flight can be made by improving and refining existing chemical rocket engines.

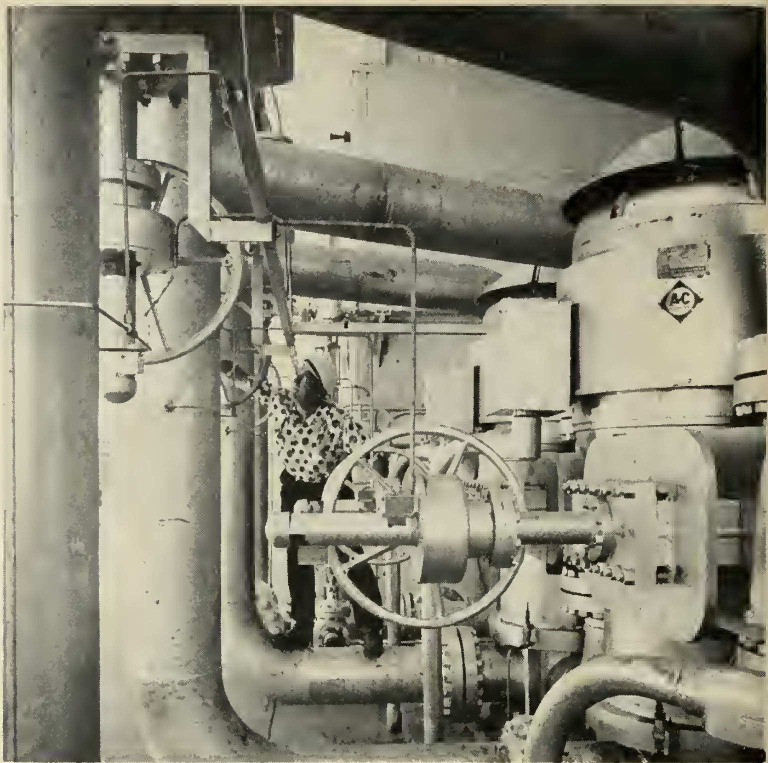
Presently known devices appear to make flights around and to the Moon, Mercury, Venus, and Mars theoretically feasible. Multiple-stage devices being



Ratio of thrust to weight versus specific impulse, sec., of different propulsion systems.



Mechanics Walter Pressir and J. W. Stewart set water-flow control valves on Rocketdyne's high flow bench used to test fuel control components in large liquid fuel rocket engines.



Pipe lines from three multi-stage centrifugal pumps on Rocketdyne's test unit. Harold Hupp sets one of the valves on the equipment, the largest of its kind in the free world.

conceived can, with reasonable flight times, make it theoretically possible to fly missions to Jupiter and Saturn. There is no known powerplant today which would permit trips to Neptune or Pluto, or which would permit escape from the solar system in any reasonable length of time.

Several different propulsion systems will be considered here in very general terms.

Liquid Propellant

The liquid-propellant rocket today is well developed and relatively well understood. It uses a chemical fluid and a chemical liquid oxidizing agent to create thermal energy which, in turn, is converted into a kinetic energy in a nozzle. Apparently there are no fundamental limitations as to size of this propulsion device. Many different forms and types have been produced.

Rockets which produce only a few pounds of thrust, as well as those producing many tons of thrust, are entirely feasible. The operating duration is generally short (less than 5 minutes) and the accelerations are relatively high, yet adequate, for giving good maneuverability in space flight. Takeoff and landing accelerations of 0.12 to 2.0 g's and space flight accelerations of less than 0.25 g are considered practical.

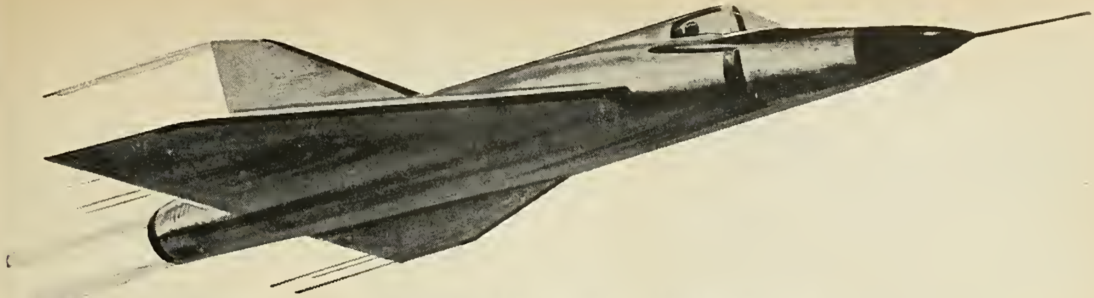
The liquid-propellant rocket is excellent for take-off from a body of large mass, such as the earth, moon, or the planets. A vehicle designed for these takeoff and return missions and for limited space travel to nearby planets will very likely require multiple stages.

The high-energy liquid-propellant rockets are very similar except they give a somewhat higher performance. These rockets permit fewer stages or an improved vehicle mass ratio for a given mission, but they do present problems in logistics and engine design.

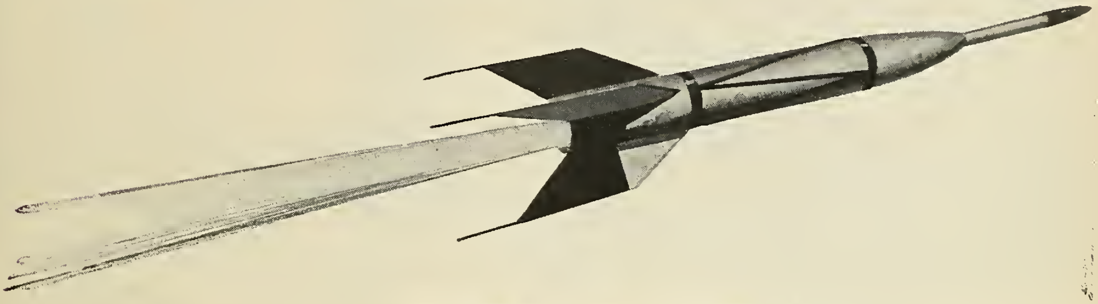
Nuclear Energy

A nuclear energy device achieves its reaction by ejecting a heated working fluid such as ammonia, helium or hydrogen. The energy released by the fission of uranium in a reactor is transferred to the working fluid which is vaporized by heating. The performance is limited by the maximum temperature that the nuclear reactor material can stand.

The radiation hazards inherent in this device from gamma rays, neutrons and alpha particles require special shielding provisions, particularly for applications where people are to be transported. Nuclear reactor heating offers a potential specific impulse improvement over the chemical propellant rocket by a factor of two or three. I

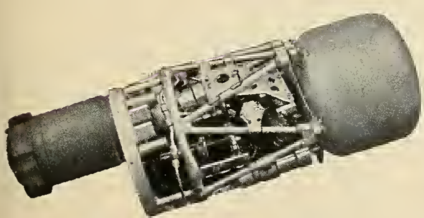


WHEN YOU WANT IT...



WHERE YOU WANT IT...

A DEPENDABLE SOURCE OF AUXILIARY POWER



A leader in the development of reliable, light-weight, self-contained monofuel auxiliary power systems for guided missiles and piloted high performance aircraft, Kidde now offers its combined engineering talents and precision manufacturing resources to firms interested in advanced applications of auxiliary power systems.

At present, Kidde has available turbine-driven units with horsepower of up to 200. These high speed units are designed to supply accurately regulated power at mean altitudes of 40,000 feet and up. However, they may easily be made environment-free, permitting airframe builders extremely wide latitude in systems design.

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general, the nuclear rocket appears to offer the same areas of application as the chemical rocket, except that the improved performance would permit a lower vehicle mass ratio and a smaller takeoff weight.

Free Radicals

If it becomes possible to store activated species of propellant, such as nitrogen or hydrogen, then it may be possible to attain a further improvement in performance by augmenting the energy release and reducing the molecular weight.

Solar Heating

The solar heating device collects radiation from the sun by means of a large optical system and converts this radiation to thermal energy. This energy is then permitted to heat a working fluid, such as hydrogen, to a temperature high enough to produce a reaction thrust.

This device has very low acceleration potential and a relatively low thrust output per unit of propulsion system hardware weight. They are not suitable for flight propulsion in the proximity of the earth or the planets. Acceleration will last over long periods of time and the thrust magnitude will probably always be relatively small. This fact limits the solar heating device to interplanetary space missions, and possibly to satellite sustaining missions.

Arc Heating

Electrical energy is discharged in an electrical arc which heats a working fluid, which is then expanded through a nozzle. The energy for the arc could emanate from various sources, such as captured solar radiation, a nuclear reactor, or batteries. Its thrust per unit engine weight is believed to be lower than that of the solar heating rocket.

Ion Rocket

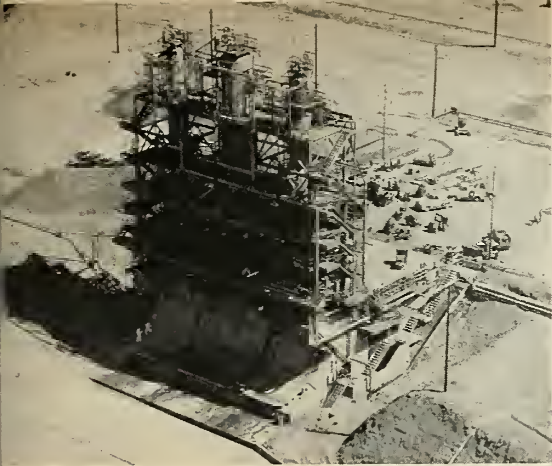
Charged atoms (ions) are accelerated by electric fields to very high velocities. The electric energy is obtained from a nuclear reactor, batteries or a solar radiation system. The thrust-to-weight ratio is probably even smaller than that of the arc heating or solar heating device and the rocket is again limited to space missions.

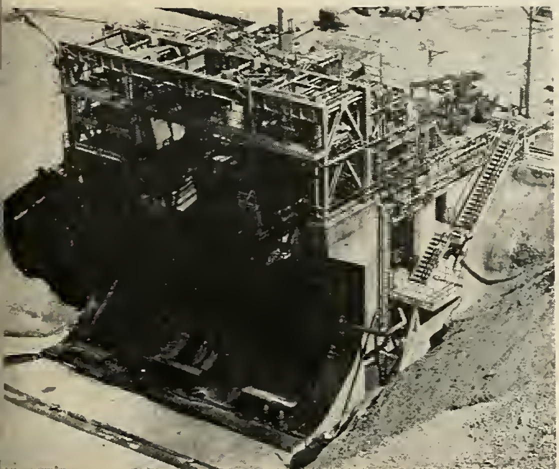
Should the specific outputs of the powerplants mentioned be limited to perhaps twice their present value, then it follows there are no existing powerplants which would make possible travel to another star or even travel to the outer planets within the lifetime of a man in a space ship. The crew would die before the journey was even half completed. It will be necessary to devise new, more powerful, rockets to achieve flight to the stars.★

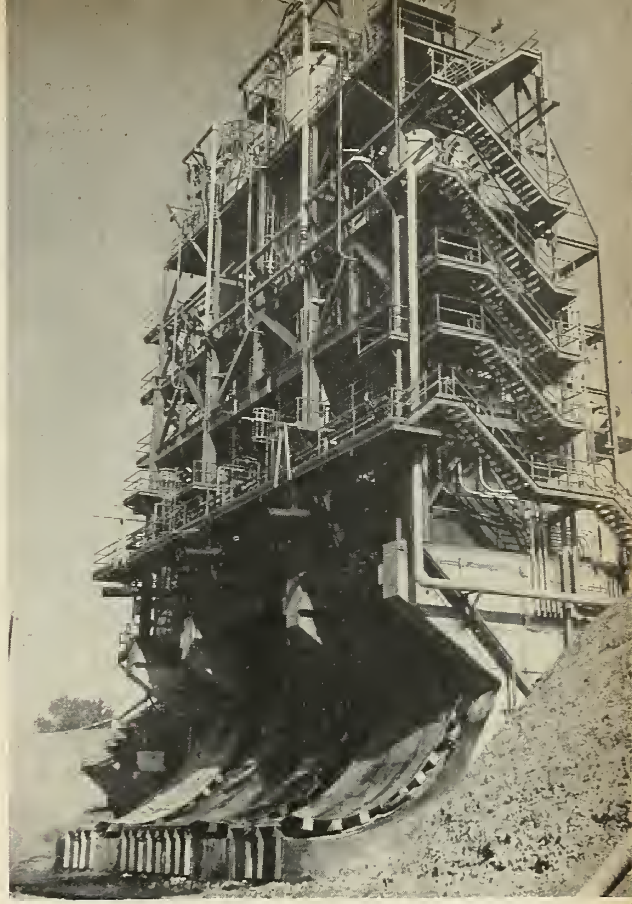

·M93:
·A71:
·C33

POWER UNLIMITED . . .

Big missiles mean big engines. And big engines mean big tes facilities. TITAN is a big missile—an ICBM designed to carry 300 pounds or more of thermonuclear warhead some 5000 miles. Aerojet General Corporation, TITAN prime propulsion contractor, has buil eight giant static test stands like those shown here at Sacramento Calif. Immediately above is the simulated high altitude test chambe Other views on this page show actual tests under way. Aero jet is not allowed to comment on whether any are TITAN engine







t doesn't take much examination of these ictures to see that rockets are an expensive usiness. The tons of concrete and close-olerance, high strength structure, water sup-lies for cooling the blast deflectors and all he measuring and calibration equipment nake these multi-million dollar monsters. The est stand to the right, shown both by day nd night, can take engines of over one mil-ion-pounds thrust. It cost $3 million to build. hough no one-million-pound thrust engines ave yet been fired, it may not be too long efore this is done. Unofficially, it's been tated that liquid engines of over 300,000-ounds thrust have already been tested. nd elsewhere in this magazine, it is stated hat engines of virtually any thrust that may e required can be constructed. From a tate-of-the-art viewpoint, there's no limit.

LOX . . . Mainstay Oxidizer for the Missile Age

By **William H. Thomas,** *Assistant General Manager Process Equipment Division, Air Products, Inc.*

TOMORROW'S DEFENSE depends on a wide variety of highbrow systems. With scientific and industrial tools accompanying advanced military units in so many ways, cryogenic liquids such as oxygen and nitrogen have become as familiar in today's armed forces as ham and eggs.

LOX occupies a position of leadership mainly because it does one job supremely well. As missiles continue to influence our major defense efforts, only those systems with the highest performance capabilities may be considered for certain key jobs.

For packing energy into small volume with minimum mass, nothing yet developed can successfully challenge liquid propellant rocket systems. High specific impulse and ease of storing liquids in irregularly shaped spaces provide a very potent missile combination.

Why should one oxidizer stand out among the wide number of available liquids? The answer is practicability. In addition to high performance, LOX answers more of the cost, storage, handling, safety and logistics requirements than perhaps any other material contemplated for volume application.

More for Less

Available for pennies per pound, LOX costs less than coal in many areas. Few oxidizers are equally available for purification and refrigeration (atmospheric air is available everywhere), hence more reasonable in their cost than LOX.

Insulated storage facilities are available for LOX which limit losses to ½ to 1 per cent per daily use both for hauling and stationary storage. Storage aloft is not a serious problem as the rate of consumption in most missile equipment is so rapid that vaporization losses are inconsequential.

Handling LOX is similar to handling other fluids of high vapor pressure. As in any other such liquid system, for example, gasoline, absolute sealing can invite dangerous pressure buildup. Simple venting is the rule. LOX may be pumped, valved, filtered, vented and even spilled like most other warm or cold liquids. LOX has been handled commercially and profitably for a long time. Techniques developed over long years in the commercial oxygen industry are successfully practiced today throughout the military.

Safety is a critical factor in selection of materials and methods for defense. Systems so hazardous to personnel as to include high risks of nonperformance could be catastrophic in a time of real emergency.

LOX has a proven record of safe storage and handling. Warm vapors emanating from LOX are breathable and noncorrosive. Oxygen is used as a therapeutic agent in hospitals and is assuredly not poisonous. Combustion products of LOX with most fuels are also generally nontoxic and safe for breathing, so that personnel need not be restricted from access to a launching site because of atmospheric contamination.

No fuel-oxidizer combination is of any value unless available when and where it's needed. Success of any military operation depends on the effectiveness of supply lines and freedom from dependence upon questionable supply sources.

Today, LOX is available wherever standard highway trailers can be put down on a firm footing. Portable LOX plants, currently in production, are available for generating LOX from diesel fuel and atmospheric air anywhere on the face of the globe.

The efficiency of LOX production facilities today is such that one pound of diesel fuel may produce two pounds of LOX. Once a portable LOX facility is installed at an advance base, further problems of supply amount to the effective delivery of standard diesel fuel.

In summary, LOX is available at very low cost, may be handled and stored effectively by routinely trained personnel, and may be produced anywhere in the world where a supply of fuel is available for an internal combustion engine.

On-Site LOX Generation

For many years, most oxygen was manufactured in central generating plants, compressed as a gas and distributed in heavy cylinders. Later, liquid LOX became commercialized because it afforded more efficient distribution. However, despite handling economy, delivery costs still soared as a result of extensive manpower needs and high labor costs.

Improvements in manufacture and the development of advanced types of on-site oxygen generating equipment brought a significant change in the shipping and storing of oxygen. Today, most large industrial consumers prefer to establish oxygen generators within the boundary limits of their own plants, saving transportation costs and utilizing free local air.

LOX requirements, dating back to Goddard's experiments on rocket engines and missiles in the early '20s, were supplied in relatively small quantities from commercial sources. As the U.S. military missile program gained momentum, it soon became apparent that vast quantities of LOX would be required at areas remote from existing large oxygen producing locations. Thus, the on-site generator, born of industry's needs for cost reduction, came to serve military requirements.

Military 75 Ton/Day LOX Generators

These units are designed for meeting the following basic requirements:

1) Low cost and high operating efficiency.

2) Minimum of utilities.

3) Reliability for continuous operation.

4) Transportability.

Large LOX producing facilities which meet the above requirements are currently "on-stream." Each facility is made up of individual LOX generating units which are considered to be a maximum size compatible with railroad and highway transportability or packaged components. Each LOX generating unit produces 75 tons per day of liquid oxygen simultaneously with 7.5 tons per day of liquid nitrogen, each at 99.5 per cent purity.

Multiple LOX generating unit facilities are currently in operation and under construction at stations in California, Florida and Colorado.

The 75 ton/day LOX generator employs a high pressure cycle, with certain process and equipment innovations designed to combine lowest initial investment with highest operating efficiency.

Filtered air is compressed in a multi-stage compressor to 2000-3000 psig. Between the second and third stages of compression, the air is passed through a caustic scrubbing system to remove carbon dioxide from the air stream.

Air leaving the fifth stage of the compressor passes through a desiccant-type drier system to remove moisture from the air. After the air drier, the air stream is split. One stream passes through the main heat exchangers, being cooled by effluent gases from the distillation column and is expanded through a valve in the high pressure column.

The other portion of the air stream is expanded from compressor discharge pressure to an intermediate pressure through a reciprocating expander, warmed through coils in the main heat exchanger and expanded into the high pressure column through a centrifugal expander.

A double rectification column is used. Crude liquid oxygen from the high pressure column is passed through hydrocarbon absorbers before being expanded to the low pressure column. Liquid nitrogen product is withdrawn from the stream which also provides liquid nitrogen reflux to the low pressure column.

Liquid oxygen is withdrawn from the bottom of the low pressure column. Effluent nitrogen-rich gas from the low pressure column is warmed in the main heat exchangers against incoming air and discharged to atmosphere.

A portion of the warm, effluent gas is used to load the centrifugal expander and is then used for reactivating the air driers, hydrocarbon absorbers and reciprocating expander oil filters.

Actual operation of 75 T/D LOX generators have resulted in an over-all cycle efficiency (power cost) of approximately 780 Kwh/ton of LOX plus liquid nitrogen. Actual operating costs for large quantity production rates have been reduced to approximately 0.7 cents per pound of delivered LOX and liquid nitrogen.

The 75 T/D LOX generator is designed to operate with electrical power as its only essential utility.

It is required that these LOX generators operate in remote areas, often where no cooling water is available. Therefore, the air compressor is equipped with large air-to-air inter- and after-coolers. It is important that the generator have a high reliability factor.

Several units have been in operation for over a year with very high "on-stream" factors. Actual production has been about 10 per cent over the rated capacity.

Because the use of the LOX may be cyclic with high peak requirements and also periods of full storage, it is very important that the generators can be taken "off-stream" and put back "on-stream" with a minimum delay in production.

Experience has shown that approximately five hours are required for a single warm generating unit to be placed in full production. Approximately one-half is required to re-establish production from a "cold" start.

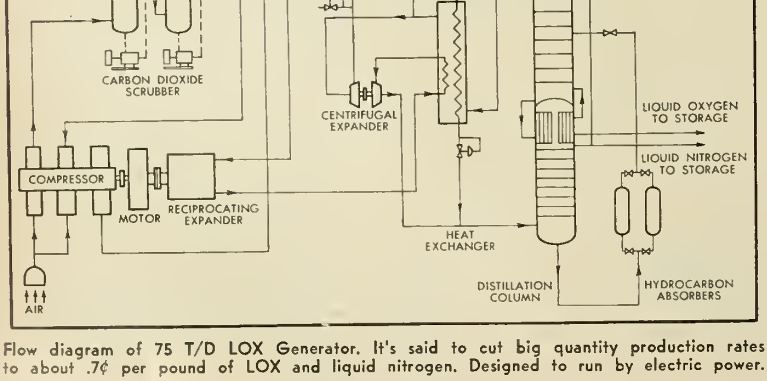
Occasionally, any high pressure cycle LOX generating unit requires defrost of the main heat exchangers. This unit is designed so that the heat exchangers can be defrosted independently of the main cold equipment. The total time required to defrost the main heat exchangers, and cool down again to normal LOX production, is five hours.

The size of the LOX generators developed for the Air Force missile program was dictated by the transportability factor. Even though the generator is large, the components including "factory packaged" cold boxes are all capable of transport by rail or low-bed trailer which permits a minimum of erection time and reduces erection costs. It is estimated that the cost of a factory packaged cold box of this size is about 75 per cent of the cost of a field assembled cold box.

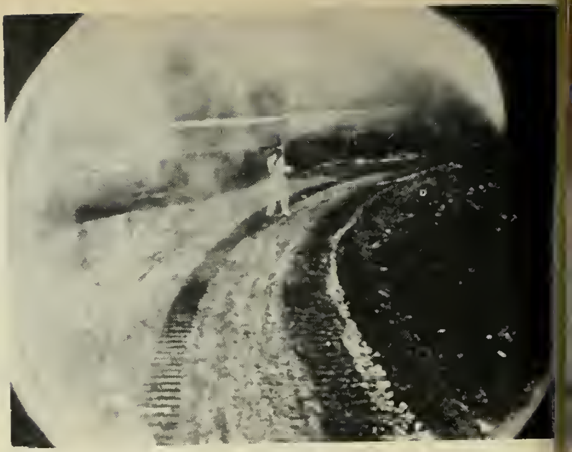
The importance of LOX in this country's missile program is firmly established. It is already being produced in large volume for the missile program by the most modern and efficient type of equipment available and at a cost which assures its expanded use.

Vast improvements have been made in rockets and missiles since Germany, in military desperation, launched its first V-2 rocket against England. The efficiency of a missile depends on many things. Not the least of these is the fuel oxidizer. It must fulfill many exacting requirements.

Technological advances in low temperature processing have brought LOX production to a high point of safety and efficiency. It can be produced anywhere and transported safely in large volume. We at Air Products are proud to be a part of our country's missile program—and look forward to new developments in the field of applied cryogenics as it affects this vital defense effort.★

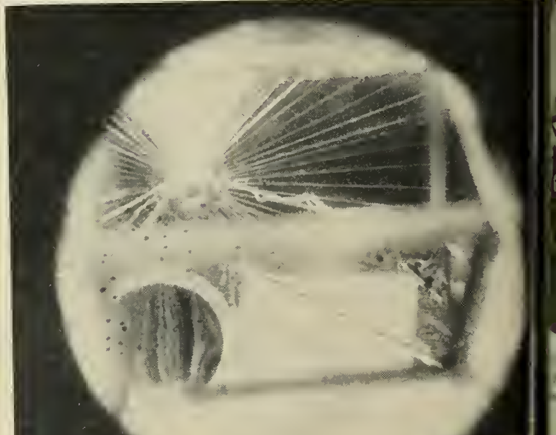


Flow diagram of 75 T/D LOX Generator. It's said to cut big quantity production rates to about .7¢ per pound of LOX and liquid nitrogen. Designed to run by electric power.



LEFT—The huge Winzen polyethelene balloon, with Major Simons suspended in capsule, rises out of open pit iron mine in Minn. ABOVE—Porthole view at instant of launch. Crewmen are Winzen Research technicians. Man in center is holding capsule antenna.

PRELUDE to SPACE



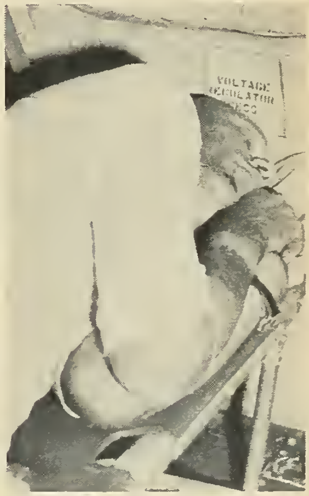
Mirrow mounted outside porthole afforded Major Simons a vi balloon and chute shroud lines (upper) and ballast can (lo

An infrared view of the earth between Wadena and Fergus, M taken on the first day. Temperature device is seen at lower r Temperature within the capsule was held near constant by flective insulation, an air circulator and an electric he

akes of uppper Minnesota seem small in this photo, shot near
ne peak of balloon's ascent. Earth's curvature is discernible.

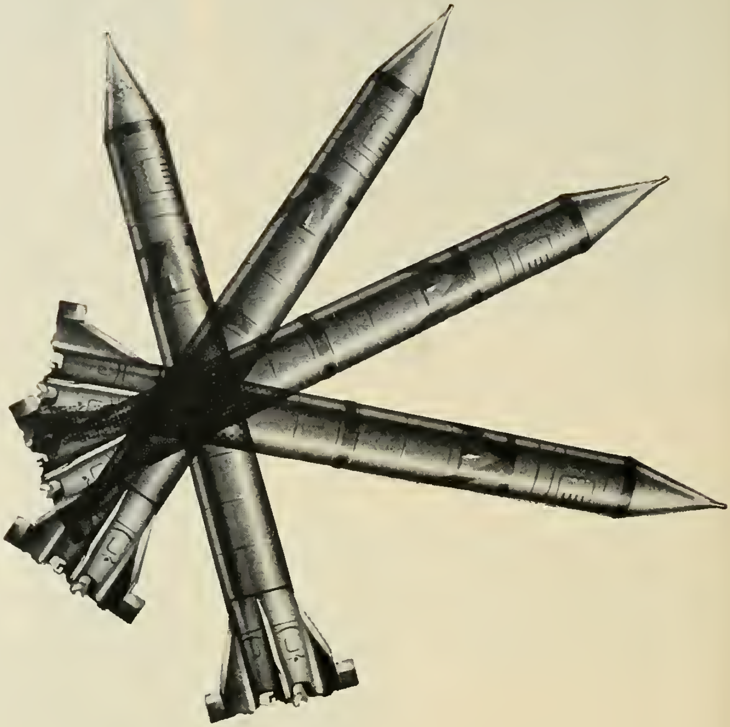
Storm center, reported to ground stations by Major Simons, from approximately 100,000 ft. in the "unfriendly realm of silence."

xhausted and disheveled, Major Simons eceives a blood test from an Air Force urse shortly after landing. The capsule lies n its side where it toppled during land- ng. Shortly after boarding the pickup heli- opter, he succumbed to a much needed leep. Although he had planned to take hort naps during his balloon flight, the nany duties required kept him awake.



-photograph of Major Simons taken near peak of his 102,000-ft. ascent. He was fined to the capsule for 42½ hours.

er a short sleep, Major Simons eats ham- ger while calling his wife in Alamogordo, M. Scott William, 3, sitting by Mrs. ons, holds father's cap. Standing, left ight, are Samuel J., 9, Susan Ann, 10, and y Jo, 8. Major Simons' remark upon en- ng the phone booth: "Another capsule!"



CURE FOR CRAZY MISSILES

Once airborne, "sick" autopilots are a cinch to spot. Even the boys at the roadblocks can spot them. The trick, of course, is to design those bugs out of the guidance system long before the count-down. It's easy to say. And it's easy to do too . . . with the SERVOSCOPE® servosystem analyzer. You "fly" the complete system through the entire performance envelope, and spot all of the weak points in no time flat with Servoscope.

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Non-Metallics for Missiles

Non-Metallics Take over Where Metals Leave Off

By John H. Lux* and Robert L. Noland*

THE RAPID GROWTH of the rocket and missile field has placed a great emphasis on production. Severe environmental conditions have resulted in a heavy emphasis on non-metallic parts as construction material. These can stand higher temperatures, are lighter in weight, better insulators, easier to fabricate, and have a wider variety of properties than metals. Among the missile non-metals are a family of proprietary materials made by Haveg Industries, Inc., and its wholly owned subsidiary Reinhold Engineering and Plastic Co. These are now used for components in 17 different types of missiles.

Proprietary materials such as Rocketon and Missileon are fabricated in pieces from ¼-inch in dimension, weighing only a fraction of an ounce, up to single pieces weighing as much as 50,000 pounds each. They may be finished by standard metal machining procedures and, in general, tolerances are fairly close to those encountered in the metals machining field.

Properties of these materials at temperatures about 14,000°F are still undisclosed, but in tests conducted, performance was considerably better than for magnesium oxide. During a 20-second run at temperatures ranging from 9,000°F up to 12,000°F, a half-inch thick disc of this material showed very little erosion and no cracking. This suggests the material could play a major role in the solution of severe reentry problems.

Haveg compounds are not metals, plastics nor ceramics, but a combination developed for high temperature operation. At high temperatures, the organic binder is pyrolyzed or reacts slowly with the high melting inorganic silicates, giving a surface which has the ability to resist erosion and the conductance of heat while most of the energy is reflected from the surface and subsurface back into the flowing stream of gases.

Among the items made on production schedules at the present time are blast tubes for use at temperatures approaching 6000°F., insulators, insulator adapters, motor cases, rupture discs, throats, jet vanes, jetevators, combustion chambers and nose cones.

Production techniques already enable nose cones up to 108 inches in diameter to be fabricated on regular plant equipment. Several of these can be made daily and at very low cost.

Production Techniques

There are at least ten different methods of handling the materials; extrusion, internal spinning, external spinning, indenting, casting, pressure molding, transfilling, hand lay-up, bag molding and filament winding. In addition, there are the same finishing operations used for metals, such as cutting, turning, threading, drilling, tapping, planing, milling, grinding, and coating.

While extruding is familiar to everyone in the metals and thermoplastic industry, it also works with thermosetting materials such as Rocketon and Missileon. The compound is forced through a cold or heated die or mandrel to form the shape desired, and the material cures on, or shortly after, emerging from the die. This is used, for example, in making blast tube insulation.

Units up to 12 inches in diameter and up to 20 feet in length may be produced in this manner either batchwise or continuously. In instances where post curing or post forming is desirable, this type of operation may be followed by pressure molding, indenting or other processes.

For large insulation systems or blast tubes up to 12 feet in diameter, extrusions are not feasible. Internal spinning is necessary. Here high temperature compounds are "spun" to an outside mold surface and compacted by centrifugal force or by pressure.

Pieces may be used in the steel structure in which they are spun, or may be removed by means of mold release and utilized unsupported. An example of process was in the coating with Missileon of the interior of a steel missile tube six feet long and six

*President, Haveg Industries, Inc. *Exec.-Vice President, Reinhold Engineering and Plastic Co.

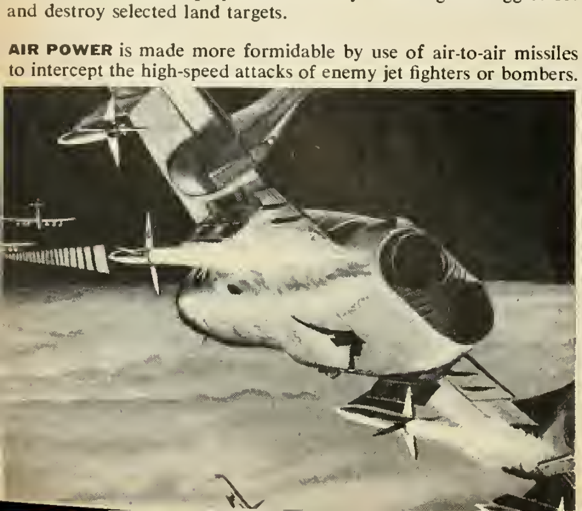
Left, Rocketon liner for solid propellant motor nozzle. Right, equipment now in place as it may be used for mass producing high temperature reenty nose cones for ICBMS.

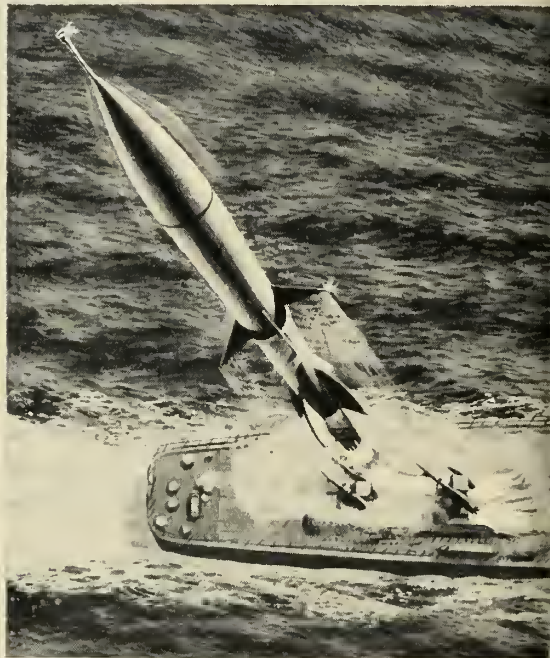
MATERIAL TYPES

TYPE	USES	CONDITIONS
Rocketon	Missile Insulation Insulator Adapters Blast Tubes Nozzles Flame Deflectors	Up to 6000°F., several minutes, up to 3000°F., for one hour. Mach 0.1 to Mach 1
Missileon	Same as Rocketon Protective Insulation	Capable of standing *much* higher temperatures than Rocketon at low gas flow
Planeton	Jet Vanes Jetevators	Up to Mach 3 with temperatures in range of 5000°F., permanent operation at 550°F
Satellon	Same as above	Higher temperatures operations than Planeton but for lower gas velocities
Orbiton	Missileon reinforced with glass cloth	Same as Missileon
Mercuron	High temperature electrical insulation, Jet insulation	Designed for permanent operation at 700°F
Terran	Adhesive for assembly of insulating materials to steel	In conjunction with insulating materials has withstood the same conditions of the above insulations
Reinhold Epoxies	Structural parts in missile and aircraft applications	Environment temperatures under 300°F
Reinhold Polyesters	Same	Environment temperatures under 200°F
Reinhold Diallyl Plthalate	Electronic parts where low dielectric constant and low water absorption are required	Temperature under 200°F
Reinhold Phenolic Glass	Same as Rocketon	Up to Mach 3 with temperatures in range of 4000 to 5500°F, Continuous operation at 450°F
Reinhold Filament Wound	High strength of structural parts in missile and aircraft applications	

inches in diameter with a closed end. The spun interior was cured and machined right in place and then forwarded for loading with propellant. In both internal and external spinning, an outstanding resistance to erosion is developed by virtue of the fact that the filler structure is oriented circumferentially to the direction of gas flow through the tubes. Erosion resistance is improved up to ten times previous best values.

In contrast to internal spinning, there is no limit in size to external spun pieces. For example, the whole 8-foot length of a rocket unit was coated with Missileon ½ inch thick (including the nose cone), followed by a polishing operation which provided a brilliant marble-like highly reflective surface. Rolls, 12 feet in diameter, have also been coated. Venturi sections up to 20 feet in length have also been made, and shapes such as elbows are





easily converted by spinning first in one direction and then changing the axis and completing the job. External spinning also allows one to build up the strength by adding additional wall thicknesses or by inclusion of reinforcing materials such as glass cloth or other fibrous materials.

Indenting is a general process where a clay-like high temperature compound is forced, under low pressure, to conform to an irregular shape. Using these techniques, such peculiar devices as angular exhausts, angular tail cones, reversing chambers, auxiliary tubes and igniters may be installed in rocket motor systems.

Casting techniques are useful for filling a shape for either protection from heat to provide electrical insulation or to provide extra strength or rigidity.

A large amount of engineering and technical effort has been directed toward the development of high pressure molded parts containing large percentages of inert fillers, such as glass and asbestos. In the fabrication of these parts, hardened chromium-plate match-metal steel dies are employed.

These dies are usually designed to yield parts that conform to the drawing requirements without subsequent machining operations. By proper control of the die design it is possible to mold satisfactory parts having very close dimensional tolerances. For example, with high pressure molding, Planeton has replaced a molybdenum-tipped graphite jet vane. The molded vane is not only more economical to produce but also has superior performance characteristics in the jet stream.

Many other rocket and missile parts are being produced by high pressure molding operations, such as nozzle and throat sections, exit cones, heat insulators and various other motor internal components. Molding requires high temperatures and pressures varying from 100 to 15,000 psi. The actual molding pressure, temperature and cycle is a function of the parts design as well as the type of molding material utilized. This method is particularly valuable for mass production. The size can vary from a few grams to as high as 450 pounds.

Great strides have been made recently in the molding of close-toleranced parts for the electronics industry. For example, in one large electronic molding there are approximately 100 rare-metal plated inserts positioned relative to each other by close (less than .001 inch per inch) dimensional and angular tolerances. The tolerances are such that it is necessary to maintain tolerances of less than .001 inch per inch. This part was put in production at a cost far less than that of the hand-fabricated part.

In areas where a moderate number of parts are needed (normally 50-100), it is too costly to buy a complete match metal die mold and to set up on a production basis. These units may be made by buying an inexpensive steel mold which is then filled by transferring the proper amount of compound by means of a hydraulic ram. Once the mold has been filled under pressure, it may be moved to curing ovens for final completion.

When it is impossible to utilize the existing mechanical techniques because of the size and shape of a unit or for the fabrication of a single model unit, hand lay-up is often the simplest. Skilled operators, using melamine, epoxy, phenolic or polyester resin, impregnated upon glass or other fibrous materials, actually make the compound conform to the shape of a surface or mold, and put on as many thicknesses as desired to build up the desired surface. Shapes 250 feet long and 20 feet in diameter are common. In such a process it is easy to install honeycomb and other inserts.

Bag molding is a process of pressing a previously prepared lay-up between a fixed form and a flexible bag by application of vacuum to the area between the mold and the bag or by use of steam or other fluid pressure. Both wet and "prepreg" type lay-ups may be used. In contrast to match metal die moldings, where both sides are finished to good surfaces, only one side is in the finished state. Heat exchanger ducts, for example, can be manufactured this way.

Filament winding consists of feeding resin-impregnated continuous glass filaments to a rotating mandrel, with the external dimensions of the mandrel conforming to the requisite internal dimensions of the desired part. By use of the continuous glass filaments it is possible to realize structural strengths considerably higher than those obtained by other fabrication methods where glass filaments are utilized. It is possible to realize tensile strength as high as 150,000 psi under ideal conditions where the filaments are all aligned in the same direction.

By varying the alignment of the filament in the fabricated structure, it is possible to alter its structural characteristics. For example, the 150,000 psi strength condition is achieved in a cylindrical vessel where the fibers are oriented to resist only hoop loads. For a closed end pressure vessel, it is possible to align the fibers in the direction of the principal stress and thus obtain the ultimate structural use of the glass filaments. The resulting pressure vessel can have a hoop-burst strength as high as 80,000 psi, the limiting design feature being the method by which the end closures are attached to the cylindrical section of the vessel.

Since the glass filament wound structures have a low density, approximately .067 pounds per cubic inch, and relatively high strength characteristics, they can be utilized to great advantage in missile and aircraft applications. For example, Reinhold designed, developed and put into pilot production, an all-plastic, small caliber ordnance rocket. Its performance characteristics were far superior to those obtained with a similarly designed all-metal round. The effectiveness of the all-plastic round is demonstrated by its reaching a burnout velocity of 3800 fps as compared to 2300 fps for the metal round.

This method of fabrication makes it possible to obtain excellent productivity. Of 8000 four-inch diameter couplings currently no units have failed the 100 per cent hydrostatic pressure test. This unit will satisfactorily withstand an external pressure in excess of 5000 psi.

Production methods and costs often depend on quantity. For example, a prototype might me made for $100 by an indenting process using a cheap wood mold. Following the success of such a unit, 50 might be made for $50 each, using a low cost metal mold. Finally, production of 5000 units would be carried out at $20 each using a match metal die mold in a large automatic press. Haveg's large stock of over 30,000 different molds enables them to make almost half their new items with an insignificant mold charge.

For machine finishing, cemented carbide tools of the harder grades and coarse abrasive wheels are preferred. Common tool steel may be used, but it dulls rapidly. Another technique is to finish each part independently, assemble in the plant and then perform a second finishing operation. Blast tubes can be cemented into the steel chambers by means of Terran flexible cement. The joint between the two insulation materials is then made by indenting with Rocketon cement which is of the same composition as the insulation and will withstand operation up to 6000°F., at sonic velocities.

These materials have many advantages over graphite as a material of construction. Probably their most important property is their high degree of reflectance at high temperatures. Since a major portion of the heat transfer at temperatures above 2500°F. is by radiation (note the high value of the T^4 factor in the Stefans-Boltzman equation), the degree of whiteness or blackness is extremely critical. While

the reflectivity of most materials ranges from 40 to 70 per cent, Rocketon and Missileon have reflectivities of 95 per cent or above at 3000° to 5000°F. This compares with a factor of 50 per cent to 52 per cent for graphite under the same conditions.

A further advantage is that Haveg's insulating value is many thousand times better than graphite so that in addition to not absorbing the heat, any heat which is absorbed is not passed on to cause deterioration to other parts.

Other advantages over graphite include: Brinell hardness of about 42 where graphite is so soft that it does not even appear on the scale; fabrication into an unlimited number of shapes and sizes; thermal shock resistance—pieces of Haveg have gone from room temperature to 5000°F., in a period of a few seconds, in many hundreds of tests without failure.

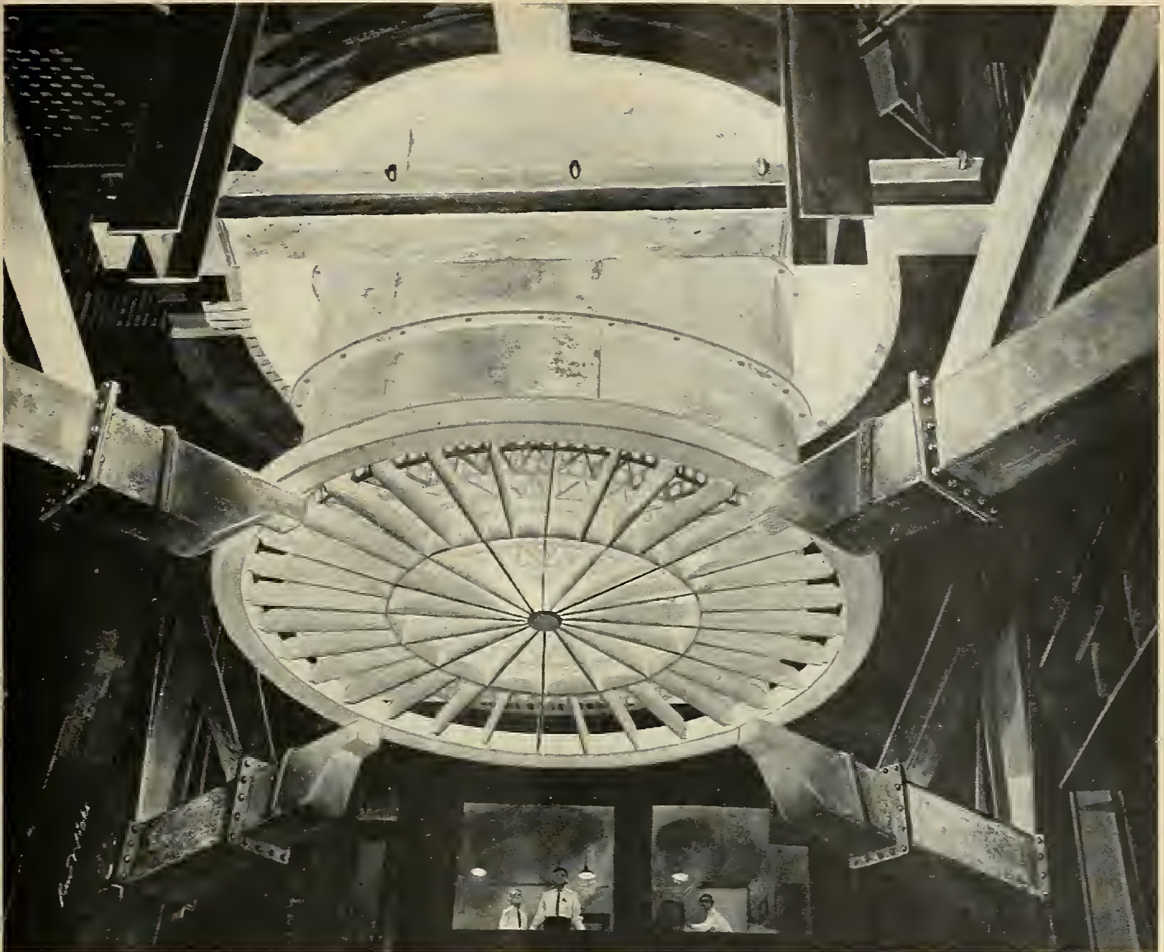
Molded pieces of Haveg may be joined to other pieces or have igniters or other units cemented in after formation. For example, where it was desired to place an igniter in an afthead insulator of Rocketon, all that was necessary was to drill a hole in the Haveg of the proper size, insert a small 2-inch Haveg tube and then apply Haveg Rocketon cement. In one hour the job was complete and ready for use. With most other construction materials, this is an impossible feat.

Another limitation of graphite is its use with chemicals. Haveg is completely resistant to most of the chemicals used in both liquid and solid propellants. Its silicate structure is chemically inert to everything except hydrogen fluoride. And, in instances where HF is encountered, there is a grade of Haveg which will also give satisfactory performance here.

Finally, it is well-known tha graphite, in an oxidizing atmosphere reacts to form CO^2 or CO and thi reaction begins at 500°F., in air—700°F., in steam and 900°F., in carbo dioxide. Rocketon and Missileon ar unaffected by either oxidizing or reduc ing atmospheres up to 5000°F. Beyon that temperature, little is known.

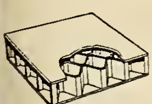
Rocketon for nuclear applicatior has been tested at 10^9 roentgens for period of several months. Examinatio of the test samples showed no a preciable change in chemical or physic properties. Oak Ridge National Labor tories predict that Haveg Rocketon wi withstand higher levels of radiation. I equipment exposed to low level radi tion, the strength approximate doubles.

A big advantage of working wi a family of materials is the fact th properties can be varied over a wi range to suit requirements.★



Solar Advanced Technology

All-metal honeycomb sandwiches solve aircraft heat, weight problems



Aircraft and missile designers continually increase their demands for lighter, heat-resistant materials. Solar technology is helping to solve this heat-weight problem with all-metal honeycomb sandwiches. The new product—called Solite®—is a strong, fatigue-resistant structure of foil-thin ribbons bonded between metal skins.

Large new electric furnaces were designed by Solar to braze these sandwich structures. Capable of operating at high temperatures with extreme purity of atmosphere, the furnaces incorporate many features which make them virtually unique.

Tailor-made for use in advanced aircraft and missiles, Solite offers a practical solution for exacting heat and weight requirements. For 30 years Solar has pioneered in welding and brazing high alloy steels that will stand up under extreme service conditions. Perhaps Solar can bring a fresh viewpoint to your difficult metal-working problems. Write Dept. D-78, Solar Aircraft Company, San Diego 12, California.

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Missile Business

By Seabrook Hull

A DECISION ON WHO GETS WHAT in the way of big missiles is due within weeks—by the end of September in fact. Announcing the results of the evaluation now under way will be the first major missile action of the new Secretary of Defense, Neil McElroy. The currently appointed evaluation committee consists of Defense Department missile czar Wm. H. Holaday, AF ARDC Ballistic Missile Division chief, Maj. Gen. Bernard A. Schriever, and Maj. Gen. John B. Medaris, head of Army Ballistic Missile Agency. The latter two officers and their respective panels of experts are currently studying each other's knowhow and achievements. The original date for settlement was, until recently, October 15, but a variety of factors—deteriorating interservice politics; the international need for the West to have operational ballistic weapons at the earliest possible date—have forced a decision to be made sooner. As a result, a crash program has been instituted. Congress, the Defense Department and General Schriever & Co. have paid extensive visits to ABMA in an attempt to find out just exactly what is going on in the missile field.

FACTORS AFFECTING *JUPITER-THOR* DECISION are many and sometimes conflicting. On the record to date, *Jupiter* is the superior system: it has flown its design distance three times; its guidance has demonstrated a suprisingly high degree of accuracy. Despite its troubles, AF has consistently called *Thor* a production missile and has expended considerable funds on tooling, etc. If the decision is for *Jupiter*, as it appears it must be, *Thor* production facilities can be turned over to other projects—or Douglas might be appointed "second source," though it's doubtful if the volume of the order would justify this.

ONE OR THE OTHER MUST BE CHOSEN. This is certain. A combination is impracticable. The only part of the two systems that is common to both is the NAA liquid-propellant motor, and in each case this is completely trouble-free. Aerodynamic configuration, guidance, control, warhead, etc., are all different for *Thor* and *Jupiter*. A missile is a highly integrated system. This comes only with the expenditure of money and time. Starting anew, for example, to work *Jupiter* guidance in with *Thor's* control system, would dangerously delay operational IRBM.

THE NOD WILL GO TO *JUPITER*. At least this will be the case for this country's earliest IRBM. Later versions may combine both *Thor* and *Jupiter*, but any effort to combine the two systems now will only serve to delay the time when this country will have an IRBM by many months, if not years. Whichever way the decision goes, somebody will be embarrassed—either AF or Army. The basic national need for a usable weapon in this category is so great that politics, etc., will be laid aside.

BRITAIN WILL BUILD ITS OWN LONG-RANGE MISSILES. Tip-off is licensing agreement between NAA Rocketdyne and Rolls-Royce for RR to build large liquid-propellant engines. In fact, this could have been guessed. Britain cannot afford (politically) not to build big weapons.

CLEAN-UP OF CONTRACT PROCEDURES continues as Congress questions recent military service practice of terminating contracts "at the convenience of the contracting authority." Between Jan. 1, 1954 and April 30, 1956, of the 13,711 contracts terminated, 91 per cent were terminated under the convenience authority. Of the 13,711 contracts (worth nearly $4 billion) terminated, 12,502 employed the special authority. House Military Operations Subcommittee considers that this special termination authority has been overused by Army, Navy and Air Force.

PROGRESS PAYMENT ALLOWANCES HAVE BEEN CUT on all price-type contracts. These are being cut back in an effort to minimize the effects of military spending program reductions. Defense Department directive, detailing new formulas for progress payments, is No. 7800.5. It applies primarily to new contracts, though those in force now with optional clauses will be adjusted downward accordingly.

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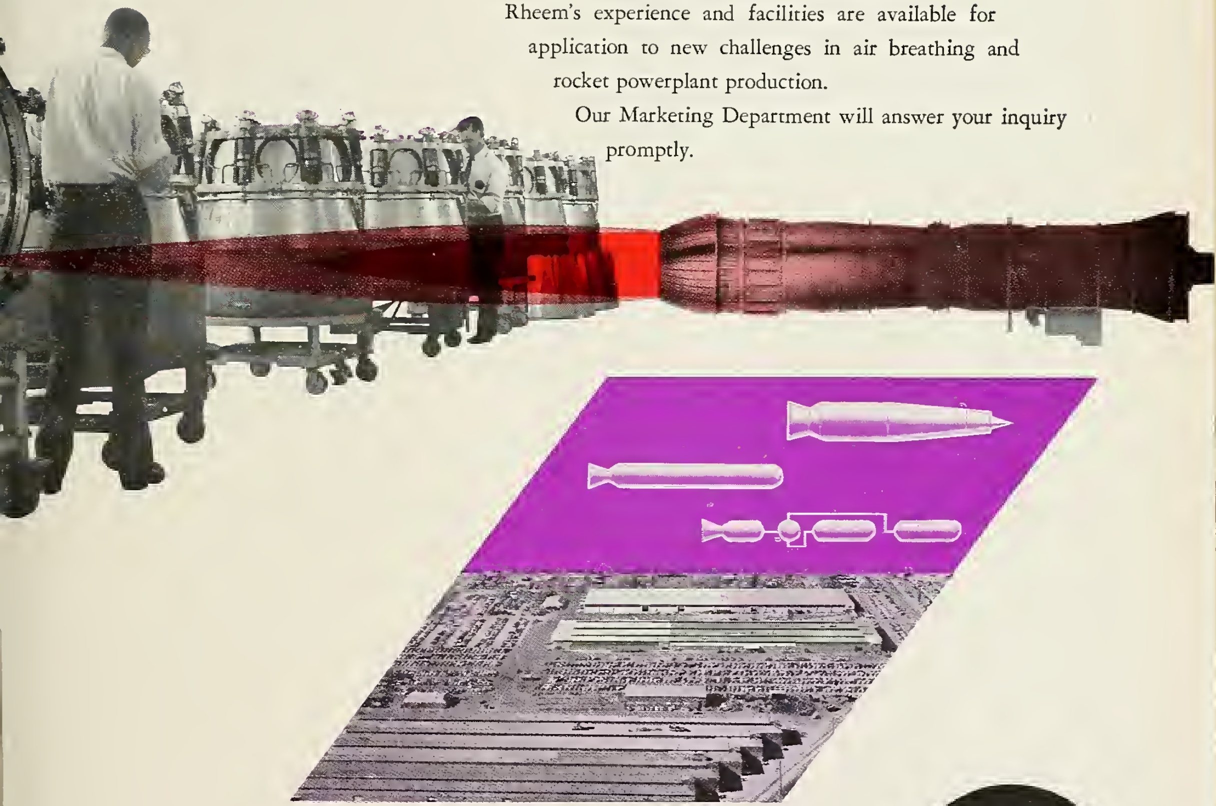

View of Rheem Downey facility showing the area now devoted to jet engine production

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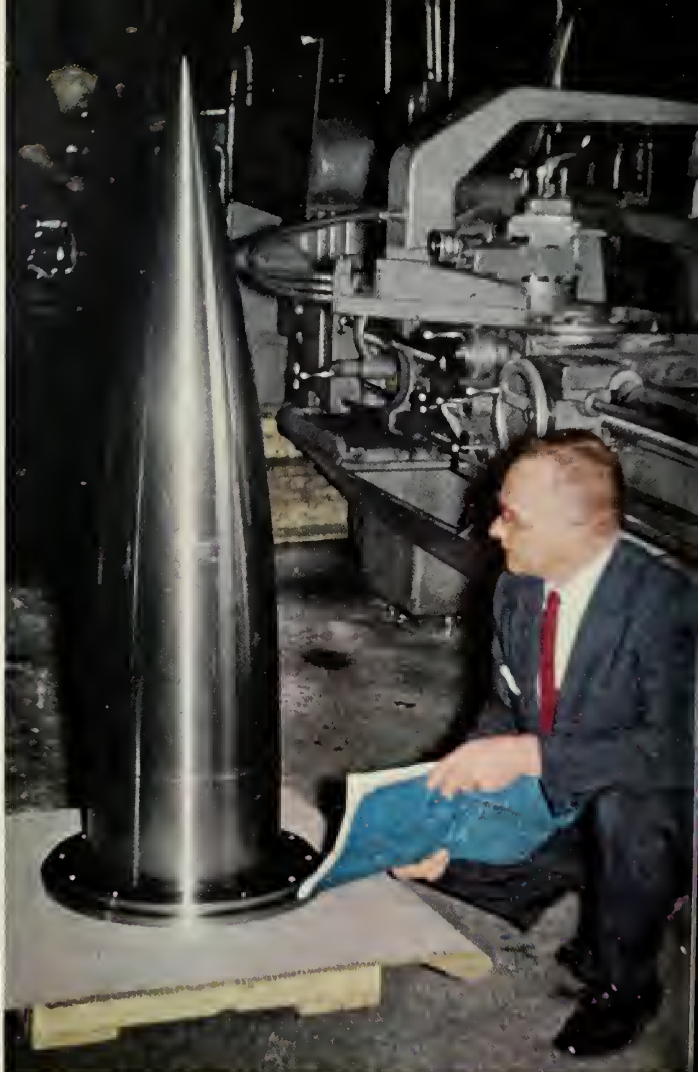
28-57

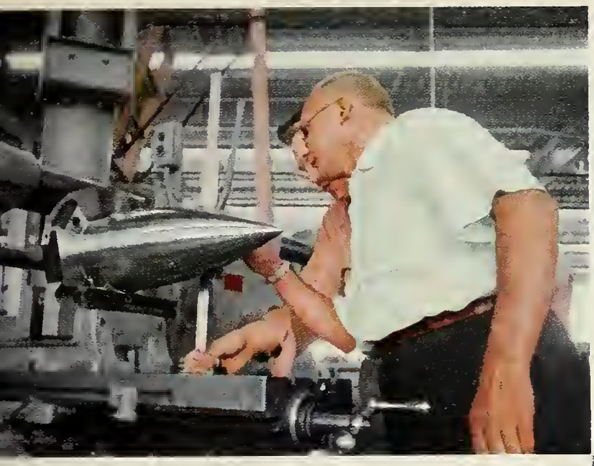
missile production

Photography by
Art Papke and E. Hull

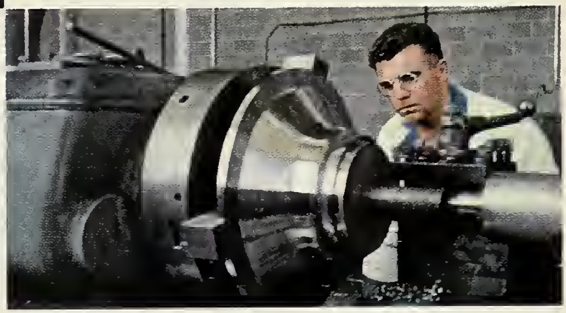


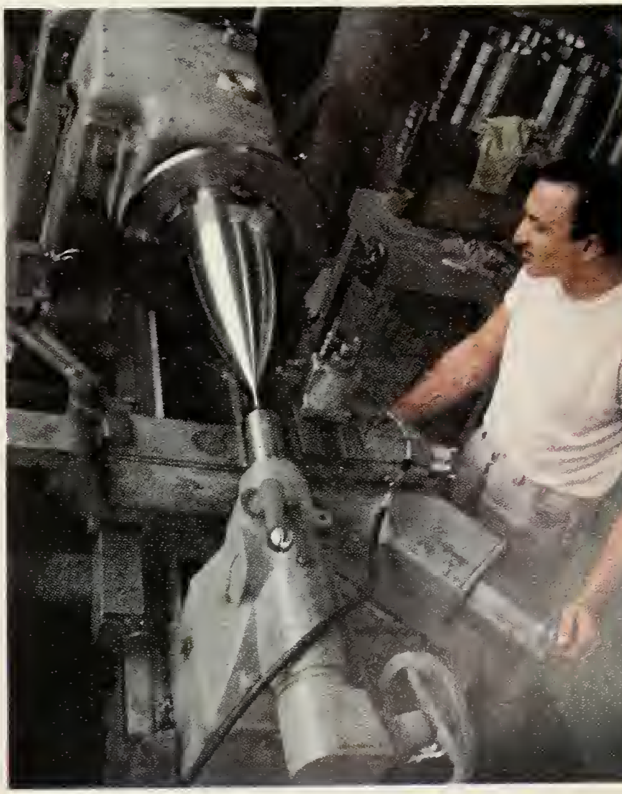
Machining for Missiles

The greatest single need in missiles today i producibility, repetitive-but-reliable mass pro- duction of complex close-tolerance parts. A curse and a beauty of missiles and rockets i that they are not like airplanes—a curse be cause we now try to build them as though the were; a beauty because, we start to realize, w don't have to. Once the first design tangle are out of the way, missiles are susceptible t the same kind of production knowhow tha works so well for highly competitive consume products. This means: The expensive, exotic sophisticated, often preposterous missile c today is subject to cost-cutting technique never yet available to military aircraft. I takes some getting used to, but is begin ning to be applied at the bits, parts an pieces level. And what the vendors and sub contractors have begun will become commo to the whole industry—for they now figur on trying for some missile systems contract



To the left, J. H. Kauffmann, President, Diversey Engineering Company, Franklin Park, Ill., admires the dye mold for a HAWK nose cone. . . . Beyond, a solid propellant rocket nozzle is checked for surface finish—16 microinches on production items is not unusual, attained in the regular machining operation without additional polishing. . . . The smaller dye mold in this series is for the SPARROW. Immediately below, the core mold for a solid propellant rocket motor requires intricate close-tolerance tapered contours . . . while above right, Monarch air tracer lathes, a mainstay of missile metal machining, cut missile adapter rings out of solid stock. Plus-or-minus one thousandth of an inch over a 24 inch diameter, is a standard missile tolerance. Missile metals range through the temperature series from aluminum to molybdenum. Repetitive near-automatic machining is a must. New tools are being devised, as often by the machine tool user as by the manufacturer. Missile machining is highly competitive. New methods are being perfected, and certain aspects of missile production begin to take on the air of a Detroit assembly line. Of the 15 missile machining companies in the country, Diversey, which also does rocket motor assembly, is largest.





Astrionics

By Henry P. Steier

The Army has done it again! Recent "mail delivery" flight of *Jupiter* missile points up delivery accuracies achievable with Army's basic guidance system technical philosophy. The flight "delivered" a letter to Maj. Gen. Medaris, Commander, Army Ballistic Missile Agency.

After a flight to a couple of hundred miles altitude, and covering a range of about 1200 miles, the missile reportedly fell within a predicted 400-yard circle and the letter was easily recovered.

Not bad! And, it brings to mind the undercover war that has been waged between Army and Air Force guidance experts on relative merits of air-bearing versus hermetic-integrating gyros (liquid-floated to cause rotor weightlessness) as sensing elements in inertial guidance systems for Army's *Redstone, Jupiter* missiles and AF's *Atlas, Thor, Titan,* missiles.

Army's marriage to air-bearing gyros probably reflects strong influence of gyro philosophy held by German scientists in Army's employ. The philosophy began with design of German V2 during World War II. V2 used air-bearing gyros. Basic idea of using air for a bearing is to reduce friction at the bearings supporting the gyro rotor and thus remove error induced by unwanted friction torque.

On AF side Ramo-Wooldridge Corp. is reportedly pushing use of HIGs as the answer. However, rumors state R-W believes HIG gyros supplied by Minneapolis-Honeywell are "too good". They *are* good, and apparently are the mainstay of inertial navigation systems for aircraft where problems are somewhat different than in missiles.

Some indication of reliance the AF is placing on its gyro philosophy is indicated by recent reports of a switch from radio-inertial to pure inertial for the *Atlas. Titan* reportedly also uses pure inertial, although the *Thor* is radio-inertial.

Attack on the basic parameters of bearing friction was begun by Sir Isaac Newton near the end of the 17th Century. Newton learned some basic facts when he experimented with resistance to motion of two concentric cylinders turned relative to each other while submerged in a liquid. He observed that for a constant temperature, the frictional force was proportional to the speed of rotation and to the swept area, and inversely proportional to the radial clearance between the cylinders, providing this clearance was small. The equation Newton got from this theory was demonstrated to be accurate when applied to air-lubricated bearings by Albert Kingsbury, an American, in 1897.

Surprisingly, top-quality air-lubricated bearings can be purchased at the local drug store. Dry hypodermic syringes are excellent journal bearings that run very well with air as a lubricant under ordinary hydrodynamic conditions. When air is introduced into bearings hydrostatically at elevated pressures, load carrying ability is very good.

Some basic papers on air and water bearings in the 1941-1945 period work of the Institute for Technical Physics at the Technical Higher Institute, Darmstadt, Germany indicate intense German interest in such bearings for gyros during the war. These probably influenced V2 design and seem to be still influencing U.S. designs. Sperry-Gyroscope was a major early producer of air-bearing gyros in the U.S. and still produces them through its Ford Instrument Co. division for the *Jupiter*. Just recently, Sperry began production of HIG type gyros of latest design for AF navigation systems.

Whatever comes out of the "gyro-war", the Army has established a very handy standard of reference with its recent *Jupiter* flight and the results should be interesting to watch.

Missile Miscellany

How miscellaneous can you get! Defense Department learns of Army's year-old ability to launch a satellite with off-the-shelf hardware and issues direct order to ABMA's Gen. J. B. Medaris not to do so; dispatches auditors to Huntsville to see how Army missile money's being spent—and likes $29-million Vanguard to an admitted $110 million. AF telephones in cancellation of Navaho—cost to date, $690 million—and "dead" bird makes perfect Mach 2-plus flight. ARDC officially defines space flight as dirty word; orders its Office of Scientific Research to deny any-and-all contemplation of moon rockets—then puts on gala show for AF Ass'n meeting that's all space flight, including spacemen spielers in passionate pink uniforms and star-gazing quotes galore from AF generals. And now a $139-million production contract for Bomarc even though missile's yet to meet design requirements for operational reliability at range. Your turn, Mr. McElroy!

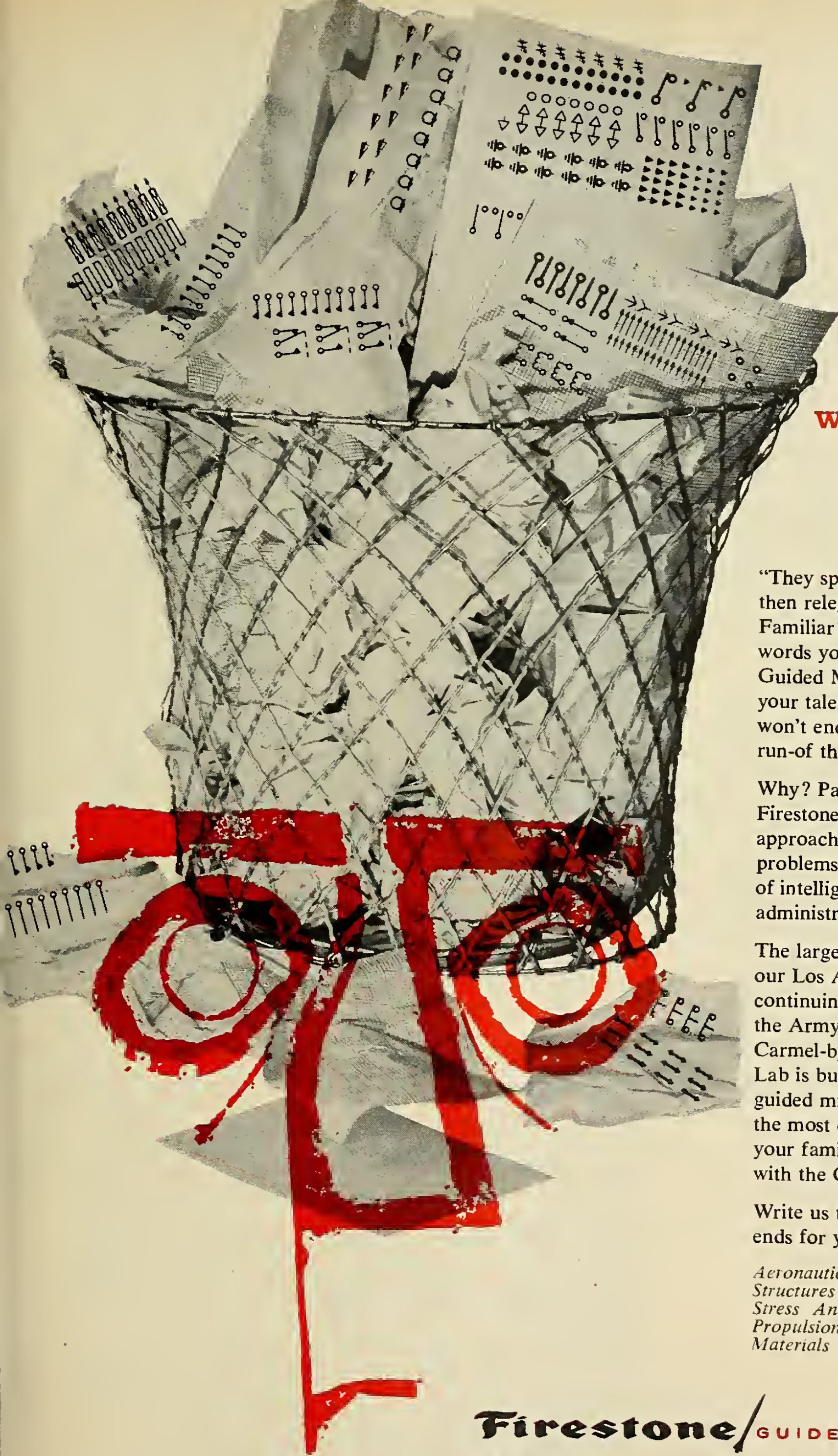
And who popped up the other day but a friend asking m/r: "Why don't you glaze your articles a little bit, like other magazines do?" In reply: We roam, report and reflect and where the chips fall, we leave them. m/r's life and primary interest is the missile industry and for this reason we must serve as conscience, executioner and number one salesman. Footsy, glazing and other connivery remain the privilege of the old, established and subsidized. We don't want missile business to rust prematurely . . .

CX—This page heard wrong (it's human): Army, not AF, worked out anti-slosh devices that took teeter out of Jupiter. Even so, AF argues any combination IRBM be called Thorpiter instead of Thupiter, as suggested, because "we think we deserve more credit . . ." And further proof that there's still humor (and hope) in the missile business, a quip from Redstone Arsenal: "Retreat, Hell! Those are our rockets."

A hint to the "Surfcasting, Long-Lens and Birdwatchers League" at Cape Canaveral: Thiokol's Polaris motor has been dubbed an octopus with the bends. More on propulsion: Advances in solid thrust, mass ratio and specific impulse now under static test may result in giving current Far Side configuration moon impact capability. NACA has proposed afterburning as a way to give ramjets thrust control over a wider range. Despite all the talk, zip fueled ramjets still haven't been flown because of lack of knowledge because of lack of boranes. New production methods should hike supply; cut costs.

Any industry is made up of companies, and there, trends reveal the future: A hotshot management team's being dispatched from Ford Aircraft Engine Division to already competent Aeronutronics. And just a few miles south, NAA's de-Navahoed Missile Systems Division wins AF long-range WS-131B air-to-surface missile contract, but continues to peptalk its salesmen on fact that Army and Navy also have some missile money to spend. Meanwhile, OMAR the first of the missile "groups" lingers in a kind of suspended animation. And from an old Chinese rocketeer, vendors will become primes if they're careful and sharp; primes will become vendors if they're not. More philosophy: Reliability and producibility go hand in hand. They do. They do.

For a Full House we now have several companies working on an anti-anti-missile-missile missile . . . hyper-muzzle velocity bullets may be the best answer yet for bomber anti-missile defense . . . Polaris won't get Bob Truax (or vice-versa) after all—Gen. Schriever talked Navy into extending his AF ballistic missile tour . . . Motorola's tube rejection rate in Terrier black box assembly line was ½% compared to 10% national average and has achieved Ivory soap in-flight reliability for its units . . . careful tests by some guidance system manufacturers show contract specifications may exceed actual operational environments by 1000%—know what this costs? . . .



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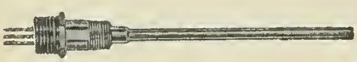

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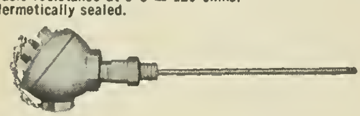
A general purpose Detector for temperature measurement and control in industrial processes.
SPECIFICATIONS:
Stem-sensitive.
Basic resistance at 0°C = 120 ohms.
Hermetically sealed.



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INDUSTRY SPOTLIGHT

By Norman L. Baker

Boron Plays Lead Role in HEF Development

Niagara Falls, N. Y.—Olin athieson predicts that the production high energy fuels, demanding boron mpounds as the basic ingredient, will ach the $1-billion figure within ten ears. For a field in such short existnce, its present rate of growth is markable. This expensive infant, ruggling for recognition in an instry dominated exclusively by hydrorbons, is emphasizing "performance fore cost." Officials in the industry e very optimistic about its future.

t Age Provides Impetus

The emphasis on boron was a rect outgrowth of the search for an eal fuel for high performance jet gines. Requirements for this ideal el are:

1) high energy content per unit eight
2) high energy content per unit lume
3) easy handling
4) low in cost

The long standing hydrocarbons, rfoming efficiently as aviation fuels, uld not meet all these requirements. e HEFs that have been developed d recently placed in limited producn will encompass all these requirents. The most important requirement is the BTU/lb. value, which is the characteristic that separates the high energy fuels from the hydrocarbons. Aviation gasolines have a heating value of about 18,500 BTU/lb. while HEFs are in the range of 25,000 BTU/lb. It has long been known that hydrogen-carrier compounds possessed the highest heats of combustion. Liquid hydrogen, when considered for its heat content, would be an ideal fuel. This element was quickly eliminated due to its low density and the extreme difficulty in handling. Beryllium, the next element to be considered, has a heat content of 29,000 BTU/lb. This element was not very promising because it is rare and expensive to process.

Boron, with 26,000 BTU/lb., presented a much different picture. Here was an element that was very plentiful and would fit into a mass production processing operation. This nonmetallic element exists only in combination with other elements. Boron, next to lithium, is the lightest element to combine with hydrogen.

Borax Basic Ingredient

The principal source of boron was available in unlimited quantities in the compound borax ($Na_2B_4O_7$). For many years a household item, this crystalline salt is mined extensively in the U.S. and South America. The use of borax for production of HEF commands only a small percentage of the borax industry but in a few years this market could easily be the most important.

A Big Three in borax production supply the free world's needs:

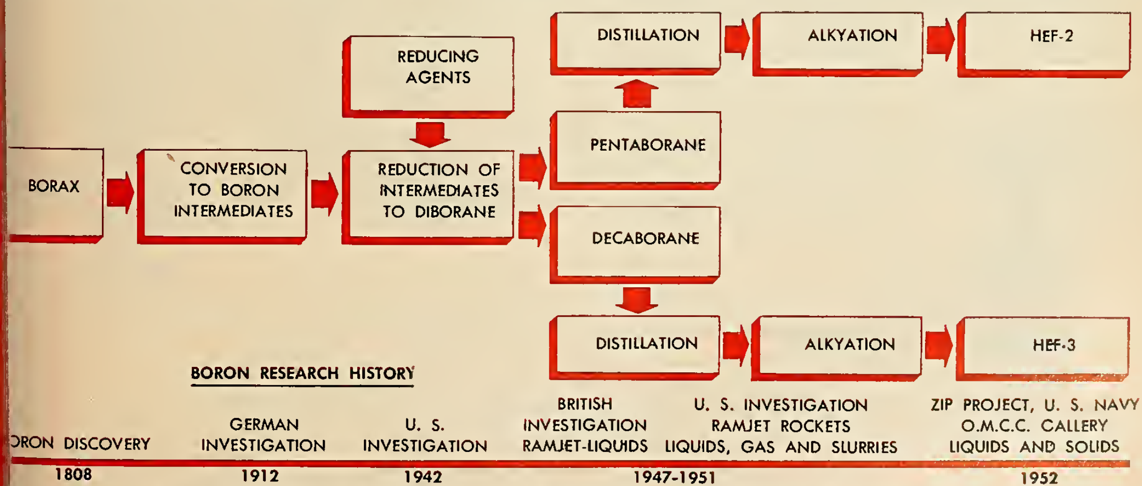
U.S. Borax and Chemical Corp. (also Pacific Coast Borax): Supplies 70% of domestic borax production. World's largest mines at Boron, Calif., contain finest deposits of boron compounds. Originally underground, mines are now open pit.

American Potash and Chemical Corp.: Supplies 20% of domestic borax production. Borax is recovered from brine deposits of Searles Lake near Death Valley.

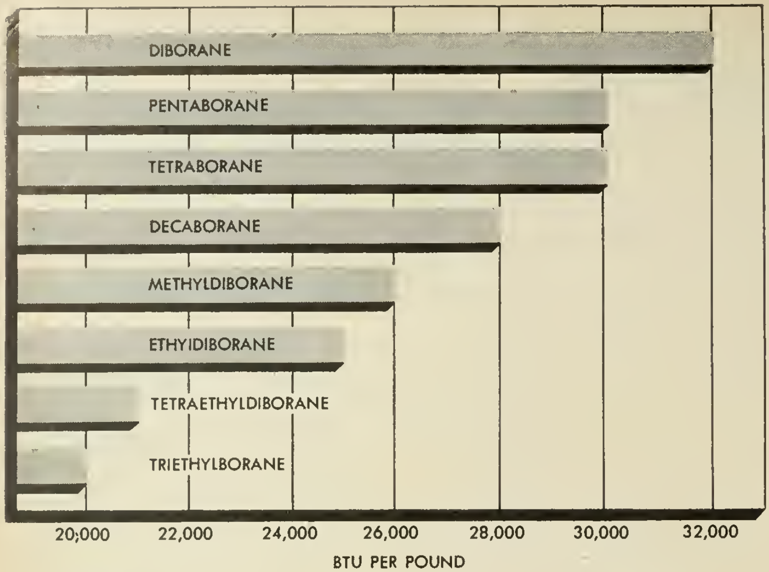
Stauffer Chemical Corp., West End Chemical Div.: Supplies 10% of borax requirements. Recovers borax from brine deposits of Searles Lake.

Intermediates Expensive

Once the basic boron-carrier compound had been found, the next step was to "alloy" the boron with hydrogen. In this way the optimum



Breakdown of boron production steps and the history behind the element's rise to prominence.



Comparison of heat output from various types of borane used as rocket propellants.

could be obtained in heat content, handling characteristics and manufacturing economy. The borax was first converted to a useful boron compound known as an intermediate. The preparation of the intermediates apparently is the more complex and expensive of the operations.

HEF producers are currently using outside purchased intermediates. Boron trifluoride, boron tribromide, and boron trichloride are the three outstanding intermediates now being used for HEF production. Leaders in the production of intermediates a Stauffer, Metal Hydrides, Americ Potash, Chemecon, Delta, Gener Harshaw, K & K Labs., Ohio Chen cal, and Pilot Engineering.

Propellant Processing

The intermediate is reduced either sodium borohydride or lithiu hydride to obtain diborane, the k borane propellant. Diborane, a gas, unsuitable as a propellant due to s bility and logistical involvements.

The processing from this stage can follow more than one route. the application of heat the dibora can be converted to either pentabora or decaborane. When deriving pen borane it first goes to the unstal form (B_2H_{11}) which then reverts the stable pentaborane (B_5H_9).

Although pentaborane has reaso able physical properties (BP 140° sp. gr. 0.61) it is possible that it w be limited to moderate speed rang due to aerodynamic heating. The so state decaborane ($B_{10}H_{14}$), on the oth hand, has a melting point of 211 and a boiling point of 415°F. The on problem here is to get it into suspe sion in the fuel.

Performance figures released Olin Mathieson, indicating a reducti of 10-20% in aircraft or missile ran

Getting Talos Off to a Good Start

For its initial flight, the XX*-ton Talos ram-jet missile is pushed skyward by a powerful booster rocket. In a split second from launching, internal pressures are up to XXXX* psi . . . nozzle temperatures to XXXX* F. To design and produce a unit to endure such sudden torture called for an unusual combination of specialized engineering and fabricating skills. A major responsibility for the Talos rocket case was assigned to The M. W. Kellogg Company

Since 1951, M. W. Kellogg has been closely associated with the development and production of propulsion units for a wide range of missiles. Kellogg's most recent contribution is the development of reinforced plastic for rocket cases, using a unique filament winding method which produces structures of unparalleled accuracy and light weight.

DESIGN
ENGINEERING
DEVELOPMENT
PRODUCTION

*Actual figures classified

FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY

711 THIRD AVENUE, NEW YORK 17, N. Y.

A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corporation, London
Companhia Kellogg Brasileira, Rio de Janeiro • Compania Kellogg de Venezuela, Caracas
Kellogg Pan American Corporation, New York • Societe Kellogg, Paris

M KELLOGG W

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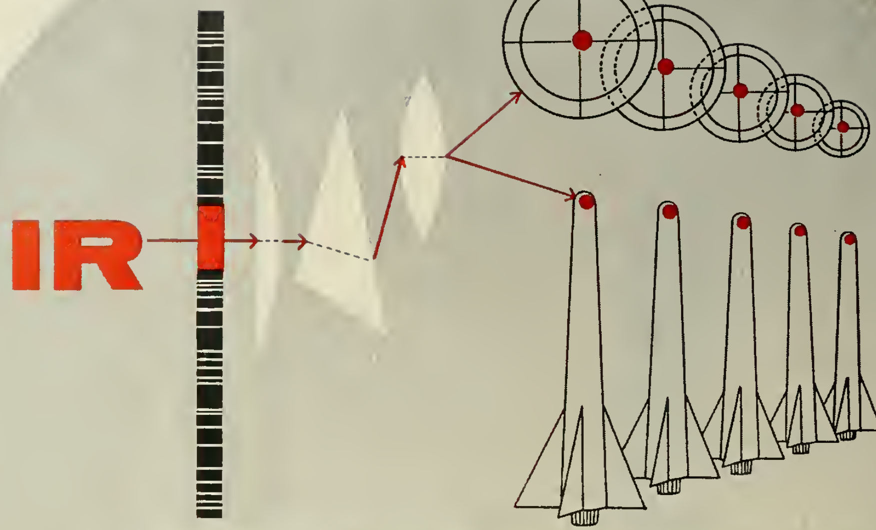

IR

when using HEF instead of pentaborane, could mean that their HEF is an alkylated pentaborane or decoborane. The addition of an ethyl alkyl group to the propellant would improve stability with the resultant loss in heat content.

OMCC identifies their borane propellants as HEF-2 and HEF-3. Informed sources refer to HEF-2 as ethyl alkylated pentaborane and HEF-3 as ethyl alkylated decaborane. Meanwhile, the successor to HEF-3 is ready to be phased into production.

Development History

The first synthesized HEF was submitted to the Air Force two years after initiation of a concentrated effort by industry research teams. Preliminary studies of boron began many years earlier.

Boron chemistry was first investigated in Germany in 1912. Early work in the boron hydrides was not followed up in this country until 1942. It was the Royal Aircraft Establishment in England which first initiated studies of boron as a propellant. The U.S. was soon experimenting with boron compounds for rocket and ramjet fuels. These experiments were extremely limited by a shortage of available materials.

Major impetus was supplied by the Navy in 1952. Research and development contracts to Callery Chemical and Olin Mathieson for Project ZIP, gave birth to the present borane propellant industry. The project was under the Navy's Bureau of Aeronautics until 1956, when it was placed under the Air Force.

The pioneer work by Callery and Olin Mathieson has given them a lead that has not been challenged to date. American Potash & Chemical Co., classed as an intermediate producer for HEF, is also turning out the decaborane propellant. AP&C's price tag of $600-800/lb. for the propellant indicates a small scale operation at the present time. Their predicted commercial price of $100/lb. will still be too high for extended USAF consideration.

Progam Expands

Olin Mathieson's $5.5-million company-owned pilot plant at Niagara Falls, N. Y., first to produce borane propellants on a semi-commercial basis, is now making deliveries to the Air Force. A $4.5 million interim plant, under construction for the Navy, will soon go into operation. Output of this plant is expected to triple present production of borane propellants. The USAF's $36-million Model City in Niagara Falls is scheduled to be completed by early 1959.

Estimates on the capacity of the

Model City facility vary but most sources feel that 2-3 million lb/year is conservative. Olin Mathieson officials are quick to point out that Model City is not intended as a production facility to meet completely the needs of an Air Force traveling entirely on HEF. The "limited production" plant, with 13-14 times the present borane propellant processing capability, is expected to meet the requirements of engine development. Although present fuels are being produced solely for jet aircraft development, such as the WS-110 project, officials confirm rocket engine development work utilizing HEF. Reaction Motors is Olin Mathieson's complimentary partner in the rocket research field.

The role of HEF in the liquid propellant rocket field is questionable. This, according to officials of Reaction Motors, is the conclusion reached after many years of research. Main objection is the high weight of combustion products. Although the HEF heat of combustion is an attractive feature, the heavy combustion exhaust lowers performance until it is only slightly above that of "conventional" propellants. Added to this is the high cost, toxicity, handling and availability problems of HEF.

HEF for rockets seems destined for the solid propellant role. An indication of this is the recent Air Force contract to Olin Mathieson and Reaction Motors for development of high energy solid propellants. Reaction Motors is prime contractor with a sub-contract to OMCC. Olin Mathieson will develop the propellant at its East Alton, Ill. plant while Reaction will package and test the final product.

Callery Chemical's present HEF plant facilities expansion program is on a comparative basis with Olin Mathieson, except it is under Navy sponsorship. In addition to their headquarters and operating pilot plant at Callery, Penn., Callery is building two plants for HEF output. Largest "chemical" plant, located at Muskogee, Okla., will be a $38-million Navy facility. Plant at Lawrence, Kan. will be a $5-million company financed project. Olin Mathieson's plants will devote entire output to HEF while Callery's production will be more diversified and flexible.

In 1952, when the Navy was looking around for takers of the ZIP project the petroleum people apparently were not interested. Perhaps a gauge to the future of the boron industry has been exhibited by the recent Gulf Oil Co. merger with Callery Chemical.

One thing is certain. The present cost of HEF is apparently much too high. Olin Mathieson, although not quoting exact figures, stated that their present fuel is priced considerably less than $30/lb.

OMCC's goal of $1/lb within ten years, where reducing agent is recovered and recycled, should place borane propellants firmly and permanently in the propellant picture. A stable continued growth of boron depends upon the extent and urgency of the military's need for a better propellant.

Era Engineering Winds Up Van Test

Era Engineering, Inc., Santa Monica, Calif., has completed initial field tests on an instrumentation van constructed for Grand Central Rocket Co., Mentone, Calif.

Especially designed for use at remote static rocket motor firing areas, the unit contains electronic recording and pickup instruments, a master fire control panel, and can act as a central communication center for the test area.

The master fire control panel, a feature of the van, was developed by Era expressly for static testing of rocket motors. The panel functions to turn on recorders, cameras, calibratior signals, the rocket motor, and then to successively turn off the same pieces of equipment.

If the test should be interrupted for any reason, it is possible to stop the sequence operation and to automatically instigate calibration checks before turning off the equipment.

The panel is also designed so that the switching schedule can be revised in the field in just a few minutes.

RMI Completes Huge Test Stand

Reaction Motors Inc. has completed, and is operating, a huge new rocket engine test stand at its Lake Denmark, N.J. facility. The stand is claimed to be the largest of its kind in the country and is believed to be the only stand in the world capable of testing engines of over one-million-pounds thrust in any flight attitude.

The stand uses retractable roof and front and side curtains, representing the latest design for test purposes. The stand was designed by RMI engineers and incorporates test and measurements equipment and closed circuit television. The control room, containing instrumentation, recording and monitoring equipment, is located several hundred feet from the test stand.

The large rotating beam, on which an entire engine assembly (including thrust chamber, pumps, regulators, tankage, propellant lines, etc.), can be mounted, is raised and lowered by a huge hydraulic cylinder.

During vertical firings, the rocket engine exhaust is deflected horizontally by a blast plate so that the energy is expended in open air. A two-stage water spray ring system has been installed between the engine nozzle and the deflector plate to cool the exhaust gases and prevent erosion.

80,000-lb. Mica Melt Announced by Synthetic

Synthetic Mica Corp. has produced the largest commercial melt of synthetic mica yet attempted. The company says it used 80,000 lbs. of raw material in the process. After approximately three weeks of cooling, the company broke up the mass of crystalline Mica and will grind or split it into usable form.

The company is conducting research toward producing larger area crystals in great volume. Crystals as large as 4" x 4" have been produced consistently.

Developments are being watched with interest by government agencies and manufacturers of high-temperature electrical and electronic equipment.

Servicing Rocket Engines

Part I: Know-How

by Fred Barker

Supervisor of the Product Service Department at Reaction Motors, Inc., Mr. Barker coordinates the activities which keep rocket engines on their good behavior. A graduate of New York University, with a B.S. in M.E., he has had diverse experience in engineering—including test, manufacturing liaison and customer service liaison. Mr. Barker joined RMI in 1949.

"Know-how" in any business is the result of thorough training and experience on specific products. RMI Product Service Department personnel get a complete grounding on their products right from the development stages through field installation and operation. The know-how thus attained is turned into a direct benefit for all RMI customers.

Key service engineers and service representatives join a project during early development, work actively with Engineering, Component Development, Assembly, Test and Inspection Departments. Mock-ups are reviewed from the standpoint of service—i.e., whether proper consideration has been given installation, accessibility and serviceability of components and the overall powerplants.

When a project is ready to move into the field, these same key men act as instructors, conducting training programs to impart their accumulated knowledge to customer personnel and other service representatives. With our ROR powerplant (rocket-on-rotor for helicopters), for instance, Sikorsky, Navy and Marine Corps personnel attended training programs at RMI and in the field. Scope of these programs covered the rocket powerplant, its installation and operation in the Sikorsky HRS helicopter, and the use, transfer and storage of the hydrogen peroxide propellant. Once ROR settled into operations at the Marine Corps Air Station, Quantico, Virginia, the service representative's know-how assumed a stand-by character. Training programs were repeated or amplified only as required by personnel changes or powerplant modifications.

Safety is a major item in each RMI representative's assignment, because safe use of the powerplant and safe handling of propellants are of paramount importance. Safety is improved by service representatives through on-the-spot lectures and training programs, whereby procedures and policies are outlined and integrated into the activities routine. Again, at Quantico, an admirable safety record has been achieved and maintained in just this fashion. There, over the past few years, our service representative has assisted the Marines in safely utilizing the ROR powerplant and the hydrogen peroxide fuel for their HRS helicopters. The result is found in the simplicity of powerplant operations, peroxide handling and storage area procedures, and in the attainment of a "no personnel injured" safety record.

Obviously, know-how is of importance in a clutch situation. Wisely applied, it leads to the right decision and the proper corrective action on the scene of a problem. The recently launched Glenn L. Martin No. 13 Viking missile provides a case in point. Pre-static firing inspection revealed discrepancies in some components of our 20,000-pound thrust rocket engine. Normal field maintenance sufficed for all but one difficulty: a valve seat and poppet, scored by foreign material, required lapping to meet leakage specifications—but no lapping compound was on hand. Our service representative used common household cleanser, lapped the poppet and seat to within leakage specifications, and the program moved on with only minor delay. This difficulty remained minor only because prompt and proper handling prevented development of a major program obstacle. Immediate action was required; immediate action was taken.

In Part II, we shall examine the function of the service engineer and service representative in various areas of Product Improvement.

Major *Bomarc* Contract Awarded Boeing

The first large production contract for the *Bomarc* surface-to-air missile has been awarded to Boeing Airplane Co. Latest contract, from fiscal 1957 funds, totals $139,315,444. Contract will support limited quantity production of the tactical area defense missiles.

The initial production contract of over $7 million, released in May of this year, covered tooling-up operations. *Bomarc* will be assembled ir Seattle while the major portion of manufacturing will be handled by subcontractors.

Reports that the *Bomarc* has beer plagued by design problems may be related to the recent decision to switch boost systems. Later models of the missile will employ a solid propellan booster motor in preference to the Aero jet liquid engine now being used. One outstanding design feature, apparen in the recently displayed *Bomarc* missiles, was the performance-limiting integration of the boost system to the sustainer portion. The solid propellan booster (if droppable) will undoubtedly increase the range, altitude and velocity of the missile.

Missile Spending Exceeding 1957 Estimate

Military spending for missiles a of May 31 has surpassed the fisca 1957 estimate. The services spent $1, 868,000 for missiles—$362,995,00 more than the $1,506,000,000 planne for the period.

Service breakdown for the 11 month period and an estimate of tota spending for fiscal 1957 is:

	11-Month Actual	Total 1957 Estimate
USAF	$1,261,138,000	$860,000,00
Army	374,368,000	425,000,00
Navy	233,489,000	221,000,00

Stavid Earnings Up 13%

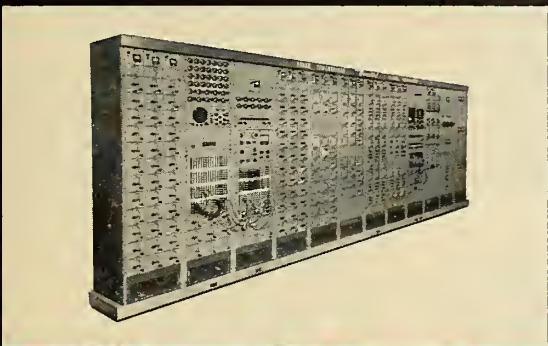
Stavid Engineering Co. earnin for the first six months of this ye showed a 13% increase over the sar period in 1956. The company r ported a total of $110,826 for 195 compared to $86,524 last year.

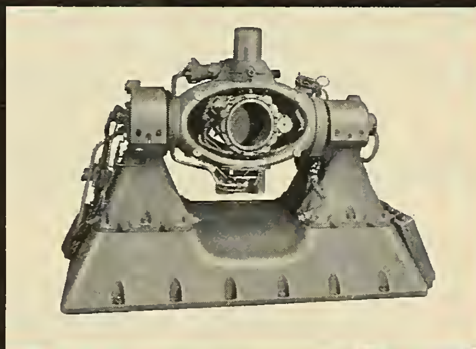
The firm expects their prese backlog of orders to increase from $1 million to $13 million by the end the year.

Page & Rixon Separate

All interest in Rixon Electronic Inc. has been sold by the officers Page Communications Engineers, In All Rixon common stock held by E

Bendix flight simulators reduce the risks





The hazards of missile testing can be materially lowered when performance is checked out on-the-ground with a BENDIX 3-dimensional Flight Systems Simulator, prior to take-off. Comprised of two basic units—a flight table and an electronic analog computer—the BENDIX-built Flight Simulator will foretell complete operating programs from launching pad to target, for rockets, ballistic and guided missiles and jet aircraft. It catches bugs without expensive trial flights, materially reduces guesswork and adds a valuable safety factor at both ends of the test shot. *For complete technical data, mail the coupon.*

Bendix Computer

OFFICES IN WASHINGTON, D.C., DALLAS, LOS ANGELES AND CHICAGO

Export Representatives

Computing Devices of Canada, P.O. Box 508, Ottawa 4, Ontario

Bendix International Division, 205 E. 42nd Street, New York 17, N.Y.

BENDIX COMPUTER DIVISION—BENDIX AVIATION CORPORATION
5630 ARBOR VITAE STREET, LOS ANGELES 45, CALIFORNIA

☐ *Please mail me information on The Flight Systems Simulator.*

NAME____________________

TITLE____________________

COMPANY____________________

ADDRESS____________________

terly C. Page, Joseph A. Waldschmitt and John Creutz was sold to James L. Hollis for an undisclosed amount. Until the time of the sale, Page had been president of Rixon.

Hollis was formerly executive vice-president and general manager of Rixon while it was a wholly-owned research and development subsidiary of PCE, and now owns all the common stock of the company. Completing the separation of the two companies, Hollis sold his stock in PCE and resigned as an officer and director.

Merger Announced By Radioplane & Northrop

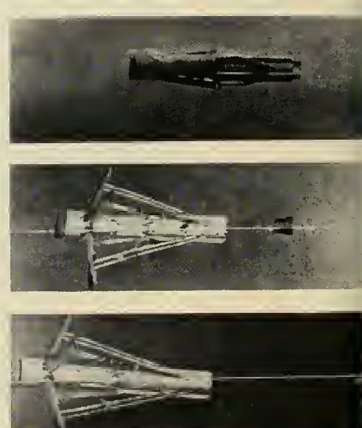
Radioplane Co. has been merged into Northrop Aircraft, Inc. and will be operated as a line division of the parent company. Northrop acquired Radioplane in 1952 and had operated the Van Nuys firm as a wholly-owned subsidiary until now.

Under the realignment, Radioplane will operate under its own group of division officers and will have separate profit-and-loss responsibility. M. W. Tuttle, Radioplane vice-president and general manager, will continue as operating head of the division.

New Firm Cleans LOX Parts

Decontamination, Inc., a new division of Consolidated American Services, Inc., has been formed in Culver City, Calif. The company is a western subcontractor engaged in cleaning liquid oxygen fuel system parts for rocket motors.

Nose Cone Model Tests



Free-flight tests of missile nose cone models are conducted by GE through use of the separation device. Fired from a five-inch gun, the device extends flaps into the air stream, allowing the nose cone model to continue in free flight. This same principle may be applied to large-scale free flight.

Reaction Develops Liquid Package Unit

Missles and Rockets has learned reliably that Reaction Motors Inc. has developed a "package" liquid propellant rocket system. The Navy has expressed considerable interest in the system as a competitor for solid propellant systems.

Essentially, the system will include propellant tanks, pressure system and rocket engine. Operation of the unit will be the ultimate in simplicity. Components common to the present complex liquid systems have been eliminated. There will be no hydraulic lines, pumps, turbos, or valves. A simple flow actuator will be the only moving part. Propellants are hypergolic, eliminating the need for an ignition system.

Major feature of the system is its capability to provide a constant total impulse. Other features include safe handling characteristics, cost competitive with solid propellant systems and a long storage life. In addition the missile design engineer has the option of incorporating the power package either as a fixed or replaceable item.

Reaction Motors initiated the project in 1952. As far as is known RMI is the only company working on this type of project. Apparently the Navy's interest in the program has supplied the necessary incentive for RMI to continue development. Units developing up to 10,000 lbs. thrust have been test fired while a high thrust *Polaris*-type missile system is within the present range of development feasibility studies.

Martin Employes Plan Space Vehicle

A manned space vehicle is being planned by the members of the Martin Astronomical Society. Mainly an educational program, the project is a feasibility study which is expected to involve "some of the engineering areas which will be coming to the fore in this industry during the next 15 years."

The society is composed of Martin personnel who devote their own time to a variety of after-hours programs. Eventually, it is planned to extend the membership beyond company employes.

New Field Office For Lord Mfg. Co.

Lord Manufacturing Co. has opened a new field office in Kansas City, Mo., to provide sales and engineering service on vibration and shock control problems.

GE Says Transistor Sales Might Hit $1 Billion

A General Electric executive has predicted that annual sales of transistors and other semi-conductors could reach $1 billion within the next ten years.

James H. Sweeney, manager of marketing for GE's semi-conductor products department, said that sales of transistors and similar components have risen so fast in the last few years that they have continually outstripped even the most optimistic market projections.

Sweeney noted that the main reason for the great increase in semi-conductor use is the military application of the component. Nevertheless, the GE executive ruled out any complete replacement of electron tubes by transistors, pointing out that electron tubes, transistors and other semi-conductors would probably work side by side in many future pieces of equipment.

Marquardt Delivers First Production Ramjet

Marquardt Aircraft Co., Ogden, Utah, has delivered the first production ramjet for the *Bomarc* missile. Described by the Air Force as the first ramjet engine to be manufactured with production tooling, its delivery was made one month ahead of schedule.

The *Bomarc* uses two of the 28 in. engines to propel the missile to a velocity in excess of Mach 2. Ignition velocity is supplied by an Aerojet liquid propellant rocket engine.

Marquardt has received an additional $12 million Air Force contract for continued production of the *Bomarc* engines. This brings total contract value for the Marquardt Ogden plant to $30 million.

General Dynamics Sales Increase 75% Over 1956

Net sales of General Dynamics Corp. during the first six months of 1957 showed a 75% increase over sales in the same period last year, going from $414,443,947 in the first half of 1956 to $726,081,499 this year.

General Dynamics, which topped the billion-dollar sales mark for the first time in 1956, reported its estimated backlog of unfilled orders as of June 30, at $1,989,000,000. In addition, about $654,000,000 in contracts were under negotiation as of June 30. General Dynamics expects that net sales and net earnings for the entire year of 1957 will substantially exceed those of the record year 1956.

The directors of General Dynamics and the Liquid Carbonic Corp. approved in principle a transaction in which Liquid Carbonic would become a division of General Dynamics. A company spokesman described the chemical field as a "most logical" extension of Dynamic's present activities.

American Lithium Given Study Contract

The American Lithium Institute has been awarded a contract by the Materials Laboratory of ARDC to investigate, analyze and consolidate detailed data on the physical, mechanical and chemical properties of lithium and its compounds.

Martin Sales Top $209 Million

The Martin Co. has reported a six month sales figure of over $209 million for the period ending June 30, showing a considerable increase over the total $138 million in sales during the same six-month period of 1956.

Matador Contract Awarded

Siegler Corp. has received a $1.5-million order for miniaturized magnetic autopilot amplifiers to be used on late-model *Matadors*. The Martin Co. placed the order with Siegler's Hallamore Electronics Div.

Borg-Warner Corp. Opens New Test Lab

Borg-Warner Corp. has placed its new electronic performance and environmental test laboratory into operation at Santa Ana, Calif. The lab will be used to provide environmental conditions for the critical operating examination of electronic and electro-mechanical devices and complete systems.

The new lab includes equipment capable of simulating environmental conditions of 150,000 feet in two minutes, with temperature maintained throughout the range of −135°F to 375°F, 70 g peak vibration from 5 to 2000 cps, and shock tests of 18,000 force lbs. with any desired wave form.

Computer Plant Expanded By Bendix

Computer Division of Bendix Corp. has doubled the size of its manufacturing facilities. The expansion is expected to enable the firm to produce 100 more machines annually.

Cylinder Contracts Awarded Weatherhead

Weatherhead Co. has been awarded two contracts by Consolidated Western division of U.S. Steel for manufacture of missile cylinders. The two contracts, calling for expenditures of over $547,000, are for launching-rail decelerator cylinders and launcher-down latch hydraulic cylinders, to be installed on *Nike-Hercules* launchers. Weatherhead also manufactures accumulators, hydraulic and fluid system components.

Aeroquip Corp. To Produce LP Hose

Aeroquip Corp. has been granted production and sales rights by the Weatherhead Co. for a new permanent type of fitting for hose connections. (See New Missile Products.) The royalty-paying agreement was concluded at the same time as an agreement allowing Weatherhead to produce and sell the "super gem" reusable type teflon hose fitting.

Los Angeles Plant Slated for Technicraft

Technicraft Laboratories Inc. has purchased a ten acre industrial site in the Los Angeles area and plans to begin construction immediately. The company expects the first production shipments to be made from the new plant in January 1958.

RMI Apprentice School Ups Enrollment

Reaction Motors, Inc. has expanded its machinist apprentice program enrollment from the 20 original students to 33 in the class entering last July. The four-year course in extreme-precision machine skills is expected to supply RMI with ". . . highly skilled shop labor, which is just as scarce as—and just as important as—engineering personnel."

The program, which was initiated in July 1956, provides for about 8000 hours of training, of which 6800 hours are on-the-job training and 1200 hours are related classroom instruction. RMI accepts applicants on a competitive basis from outside candidates or from within the company.

After entering the program, students are expected to turn out work that is equal or superior to work of journeymen. Course work is graduated instruction of increasing difficulty.

Although students have no obligation to RMI after graduation, the company expects to retain enough graduates to make the program a worthy one. After receiving certification of Class A Machinist, students may earn an experimental machinist's rating with an additional 9 to 15 months experience.

IBM Computer Aids *Titan* Design

The Martin Co. recently demonstrated its newly-installed IBM 704 computer which will aid in design of the *Titan*. The unit is the same as that installed in the *Vanguard* computing center.

The company's computer, most advanced of the high-speed electronic computers developed by IBM, is not a single-unit machine but a group of electrically-connected units.

Talos "Automat" System To be Developed by GE

General Electric Co. has been awarded a $5-million contract for development of a shipboard handling and launching system for the *Talos* SAM. The "automat" system will work somewhat like "pigeonhole parking" in that the missiles weigh as much as, and are as long as, two automobiles.

The equipment must be able to automatically select whichever type of missile the fire control officer chooses by pushbutton, and deliver it rapidly to the launching station.

The equipment's control system is more complex than that used in area telephone switchboard systems because not only must the system remember which missile is in what rack, but must also remember any changes in the racks themselves.

This is GE's first contract for missile handling systems. The final product is expected to weigh more than 350 tons and require space enough to hold ten freight cars. The first naval vessel to carry the new system will be the cruiser *USS Galveston*. Planned operational date for the ship is 1958.

Narmco Builds New R&D Center

Narmco, Inc. has begun construction on the first phase of a million dollar industrial research and development center in San Diego. Completion of the facility is expected by December, and it will be utilized for work on structural adhesives, reinforced plastics and sandwich-type structures.

Convair Expands European Sales Force

Convair Division of General Dynamics Corp. will expand its European sales office in Geneva, Switzerland. The office will be managed by George C. Prill.

Chance Vought Sales Rise Sharply

Chance Vought Aircraft, Inc. has reported sales of aircraft, missiles, parts and services aggregating more than $86 million, compared with over $51 million in the same period of 1956.

The backlog of the company's unfilled orders stood at $467 million as of June 30. In a statement to stockholders, the firm said that the present economy considerations of the government "should have no appreciable effect on current operations and management believes that its previous estimates of future business activity will not be materially affected."

McLean Names Agents

McLean Engineering Laboratories have appointed several groups of representatives to handle the McLean line of electronic cabinet cooling fans and blowers in the eastern half of the country.

Technical Instruments, Inc., of Waltham, Mass., will represent the firm in the northeastern states: The Kenneth E. Hughes Co., of Union City, N.J., will cover the middle Atlantic states; and W. A. Brown & Associates, Inc., of Indian River City, Fla., will cover the southeastern states.

Cooper Conducts High-Altitude Research

Cooper Development Corp. is engaged in Project Sunflare for investigation of radio propagation interference and is conducting rocket launchings from San Nicolas Island, Calif. The operational phase of the project began on July 1, to coincide with IGY, with the launching of a *Nike-Deacon* two stage rocket. The vehicle, carrying a 30 lb. instrument payload, rose to 80 miles and gathered background spectral data for about two minutes.

CDC is also using a *Nike-ASP* combination to reach altitudes of 150 miles. The initial data obtained will be used to establish baselines for signals recorded during later flights involving flares. A total of 14 rockets are scheduled to be fired during the project.

Since sunflares occur with virtually no warning, and may reach peak brilliance within 5 minutes after an alert, the rocket crews and scientists must be ready to fire at any moment. The CDC crews, alerted by participating observatories, have been getting the rockets off in about 60 seconds.

Military Products Group Set Up By Honeywell

Minneapolis-Honeywell Regulator Co. has made an administrative realignment of its divisions concerned with products for military use. The realignment, executed to meet the management, engineering and manufacturing needs of the military, is said to create "one of the largest sources in the country for research, engineering and production capability."

Packard-Bell To Develop Digital Computer

Packard-Bell Electronics has received a research and development contract from the Army for a high-speed digital computer to work in conjunction with equipment at the computation center at Redstone Arsenal. The digital simulator will compute the behavior of dynamic systems of missile airframes, inertial guidance and fire control devices.

Daystrom Ltd. Formed

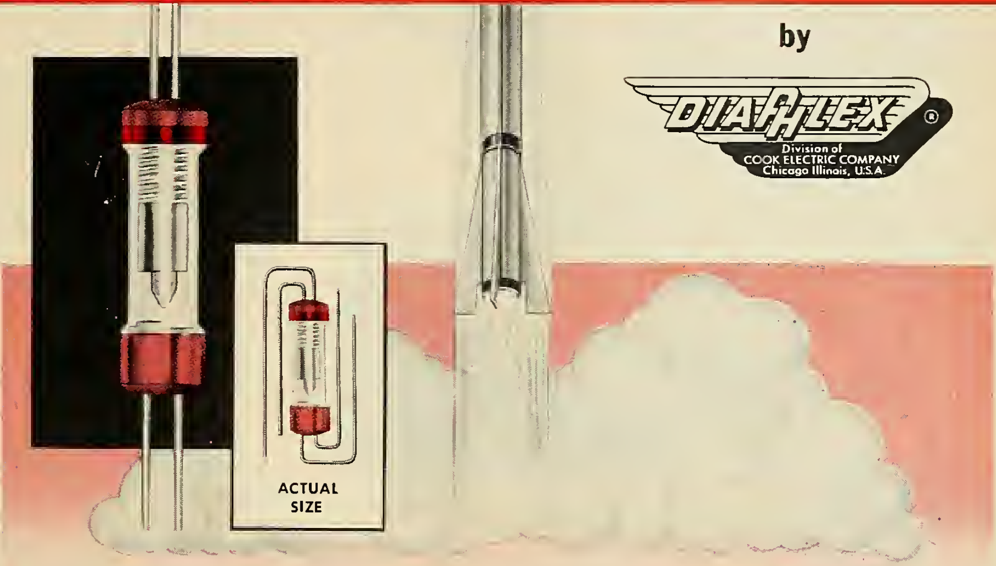
Daystrom, Ltd. has been formed in Canada to handle sales, service assembly and manufacture of Daystrom electronic products. By 1960 the company expects to have a large-scale Canadian manufacturing operation.

Reliability

THERMO-ARMING RELAY

by

DIAPHLEX®
Division of
COOK ELECTRIC COMPANY
Chicago Illinois, U.S.A.



The new Diaphlex Thermo-Arming Relay is designed to close a circuit positively, and with high reliablity, with the application of 3 to 4 volts, AC or DC potential.

The Thermo-Arming Relay has been qualification tested for performance, in accordance with the specifications below, including shock, vibration, acceleration, performance at extreme and varying temperatures and pressure altitude, salt spray, humidity, and storage at varying ambient temperatures. Detailed test reports by Inland Testing Laboratories are available upon request. Cook P/N 666-1960.

Weight	Less than 0.1 ounce
Operating Temp. Range	−55° C. to +85° C.
Altitude	In excess of 75M'
Shock	250 G, 2-4 MS deceleration
Vibration	20-2000 CPS, to 40G
Acceleration	150 G
Operate Time	Less than .3 second with 3-4 VDC applied
Container	Herm. sealed in high thermal-shock resistant glass container
Trigger Ckt. Resistance	1.2 ohms minimum
Contact capacity	5 ma. to 5.0 amperes DC
Insulation Resistance	200 Megohms minimum @ 500 VDC

Cook Electric Company

2700 SOUTHPORT AVE., CHICAGO 14, ILLINOIS

DIAPHLEX—Aircraft Components and Accessories. **COOK RESEARCH LABORATORIES**—Basic & Applied Research. **INLAND TESTING LABORATORIES**—Qualification, Environmental, Reliability and Radiation Testing. **MAGNILASTIC**—Expansion Joints and Large Scale Metal Fabrications. **WIRECOM**—Wire Communication Protection & Distribution Equipment. **ELECTRONICS SYSTEMS DIVISION**—Engineering and Production of Electronic Gear. **AIRMOD CORPORATION**—Modernization, Modification, and Repair of Aircraft. **NUCLEDYNE CORPORATION**—Engineering and Design of Highly Complex Type Facilities. **CANADIAN DIAPHLEX, LTD.**—Aircraft Components and Accessories.

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Litton Industries On Stock Exchange

Litton Industries, organized in November 1953, became one of the youngest firms to be listed on the New York Stock Exchange when its common stock was called for trading on July 30. The company's common stock has been traded on the American Exchange since September 1956.

With recent establishment of an activity in Salt Lake City, Litton now is in operation at 11 locations across the country. The firm is engaged in research, development and manufacture of advanced electronics.

American Aerophysics Adds Fiberglass Division

American Aerophysics Corp. has added a fiberglass division with facilities for development and fabrication of high-strength fiberglass-reinforced laminates for the missiles industry.

The new division will design and produce jet vanes, rocket exhaust nozzles, missile fins and control surfaces, radomes and other equipment.

Callery Chemical Moves Headquarters

Callery Chemical Co. has moved its administrative and sales offices from Callery, Penna., to Pittsburgh. The company recently established new plants at Muskogee, Okla., and Lawrence, Kansas. The Callery, Penna., facilities will remain as R&D division headquarters for the company, which manufactures boron chemical compounds and HEF for missiles.

Laminair Has New Plant

Laminair, Inc., specializing in missile structural and radio frequency fiberglass laminates, has opened its new plant in Gardenia, Calif. The new plant has complete tooling and production facilities for work in polyester, epoxy, phenolic and silicone resins.

Ryan Declares Dividend

Ryan Aeronautical Co. has declared a regular quarterly dividend of 10 cents. This will be Ryan's 28th consecutive quarterly dividend and the 48th since incorporation.

Temco Sales Up

Temco Aircraft Corp.'s sales for the first half of 1957 were at a record high level, rising 56% over a like period in 1956. Backlog of orders at the company's three plants stands at approximately $172 million.

West Coast Industry

By Fred S. Hunter

Lockheed Missile Systems division's new test facility is beginning to take shape near Santa Cruz. Only a few pre-fabricated buildings have been erected, but during the coming year more than $1 million will be spent for site improvement and, if the program is expedited, this figure may go to $2.25 million. First steel test stand is to be ready for rocket firing to begin in February. Four more stands may be erected by the end of 1958 at which time Lockheed expects to have 100 to 150 employes permanently stationed at the Santa Cruz mountain site. Four members of a small-explosive test group comprised the first transfers to the new test center from Newhall recently.

•

Marquardt Aircraft added 300 people to its payroll in one month this summer, highest monthly hiring record since the company's formation. Total is now 3500. Expansion of Marquardt's Van Nuys plant reflects the more realistic view taken by the Air Force toward dispersal. When the late Harold Talbot was secretary and running the show, plans were to move everything to Ogden, including the executive offices. Now research and development stays in Van Nuys with production at Ogden. Marquardt has 450 employes at Ogden where it is now turning out Y ramjet engines for the *Bomarc*.

•

Ryan Aeronautical has completed transfer of all *Firebee* jet drone missile assembly activities to its new Torrance division. Included are final assembly, sub-assembly, electrical shop, painting and engine run-up operations. Fabrication work remains in San Diego. The old *Firebee* final assembly building at the east end of the Ryan Plant at San Diego is now being occupied by Douglas DC-8 pylon main assembly fixtures.

•

Fred H. Rohr, chairman of Rohr Aircraft Corp., says his company expects to participate in missile programs when production manufacturing gets under way. Rohr has been phenomenally successful in the development of aircraft manufacturing techniques, particularly in the field of power packages, and rates very high with old customers like Boeing, Convair and Lockheed. The Chula Vista company undoubtedly will become an important sub-contractor in missile production when the market is ready.

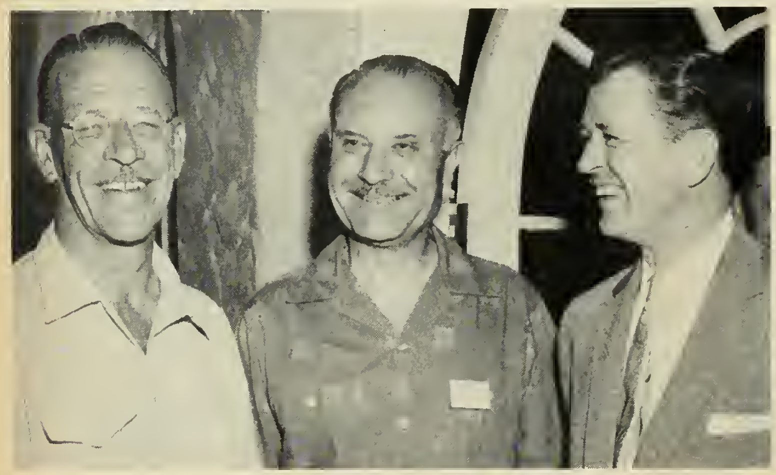
•

Douglas Aircraft's Elizabeth, N. C. division, which started out to be a second source for the *Nike*, is now the sole source, following the Army's transfer of all production on the ground-to-air missile from Santa Monica. But Santa Monica isn't hurt particularly. It can make use of both facilities and manpower on its nuclear tipped air-to-air MB-I *Genie* program. The potential here is very high. This rocket is reported to be so good you might describe it as being "almost as good as they say it is."

•

Air Force cancellation of the *Navajo* was not as abrupt or unexpected as the Los Angeles press made out, but it was a mistake in view of the fact that it came after around $625 million was spent on the program. For that much money the Air Force should have carried it on a little further, or it should have cancelled it before it spent so much. Most people out this way, of course, think the program should not have been cancelled.

Cool as a transistor, JUPITER radio-inertial guidance conferees choose a reliable way to escape 110° Phoenix heat. A young lady whose name for reasons of propriety shall remain anonymous umpires from the shoulder of Mike O'Connor, Motorola's JUPITER contract manager. And swinging around the back arc l. to r. are Lloyd Hershey, Motorola-Phoenix's project manager; Carl Shannon, administrator of Motorola engineers at Jet Propulsion Laboratory; Charles Raudenbush, Motorola-Riverside (Calif.) JUPITER program director; Jerry Landsman, Motorola-Riverside field representative; and Major L. Frankenstein, planning officer, JUPITER project at Army Ballistic Missile Agency, Huntsville, Ala. The three in front are Bob W. Barton, military electronics marketing manager for Motorola; Cliff Cummings, JPL's JUPITER program director; and Daniel H. Murphy, acting legal director for Army's ABMA.

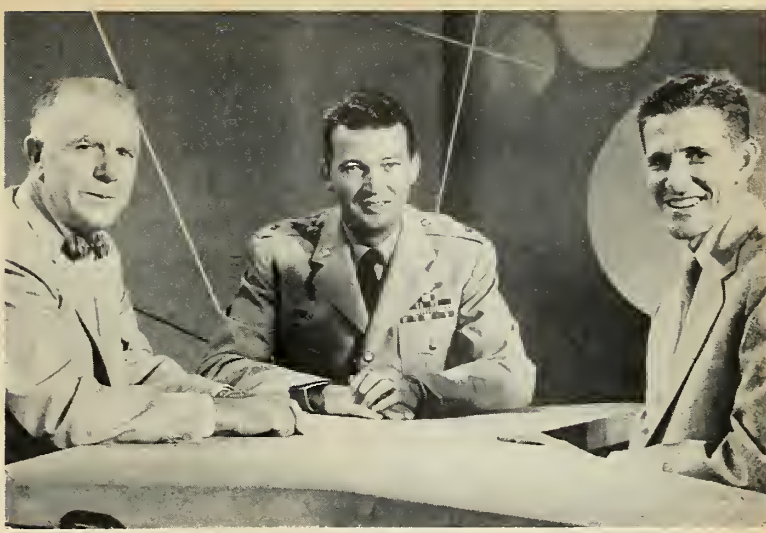


To left, Cal-Tech's rocket pioneer Milliken, AF Deputy Chief of Staff for Development, Lt. Gen. D. L. Putt, and AFOSR chief Brig. Gen. H. F. Gregory at a party at Trade Winds Club Hotel, Melbourne, Fla., during recent meeting of Scientific Advisory Board.

Above, Chrysler Corporation Vice President for Defense and Special Products T. F. Morrow has his problems too, as JUPITER-THOR decision day approaches. Chrysler is prime contractor for REDSTONE & JUPITER.

To the left, Gen. Earle E. Partridge, Commander in Chief, Continental Air Defense Command, and Gen. James E. Doolittle (Ret.), of the Shell Oil Co. at SAB party.

To the right, Dr. Hubertus Strughold (left), Maj. Gen. Bernard A. Schriever and an associate discuss space medicine problems of the future when manned rocket flight is common.



Below, Commander Robert Truax, USN, has had his tour of duty with AF ARDC Ballistic Missile Division extended, which means he will not work on the POLARIS for some time.

To right, Dr. Joseph Kaplan, Professor of Physics, University of California and a member of AF Scientific Advisory Board snapped with missile friends at Trade Winds Club.

C. A. Brady, Operating Manager of Missile Operations, Chrysler Corporation. At stake in current Army-AF squabble over IRBMs is his company's contract for Army's JUPITER.

General Curtis E. LeMay, Vice Chief of Staff, USAF, Lt. General Thomas S. Power, Commanding, USAF Strategic Air Command, and Maj. General Bernard A. Schriever, Chief of the AF Ballistic Missile Division (standing), at recent Scientific Advisory Board party.

people

Anthony Drabicki has been appointed chief application engineer for fluid systems and components for the Waldorf Instrument Co. The company, a division of F. C. Huyck & Sons, also named **John Borah** as southwestern sales manager.

Dr. Martin J. Gould is now director of research at National Electronics Laboratories, a subsidiary of Thiokol Chemical Corp. Dr. Gould recently served as research specialist at the missile test center, Patrick AFB. He will direct guided missile research at NEL with two assistants, **K. W. Hoover** and **H. R. Corbett, Jr.**, both of whom were also at Patrick's missile test center previously.

Willard D. Walker has been appointed chief electronics engineer at Convair-Astronautics.

William H. Shapiro has been appointed manager of engineering services for the rockets division of Bell Aircraft Corp. Shapiro has been with Bell since 1936 and worked on the first jets produced by the company, as well as the X-1 series of rocket-powered planes.

James B. Kendrick has joined the guided missile research division of Ramo-Wooldridge Corp. as chief of preliminary design. Kendrick was formerly instructor of aeronautical engineering at MIT.

Stephen J. Jatras has been appointed to the newly-created post of assistant to the director of Lockheed Missile Systems Division's research and development branch at Palo Alto. Jatras will be succeeded as manager of the R & D coordination division by **Russell L. Reiserer**, formerly assistant chief of the fighter design branch, Navy Bureau of Aeronautics.

Frank S. Wyle has formed a national organization of sales and service engineering specialists in missile testing which will represent independent testing laboratories and test equipment manufacturers.

Dr. Sholom Arzt, research physicist who worked on the *Terrier* and *Talos* missiles, has joined Universal Transistor Products Corp.

Brig. Gen. Romulus W. Puryear has been named Chief of Staff for Headquarters, Air Defense Command. He assumes his post after having served as Commander, 25th Air Division at McChord AFB, Washington.

Lt. Col. Carlo R. Tosti has been named director of information services for ARDC succeeding Col. **Albert A. Arnhym**, who is being reassigned to SAC.

John B. Pearson (RADM, USN, Ret.) has been named director of development planning for North American Aviation. He will head a new corporate office responsible for analysis and coordination of planning for future product developments.

U. Victor Turner is newly-appointed general manager of Vitramon, Inc., producers of electronic components, and will direct all plant operations of the company.

Edwin R. Gamson has joined Telemeter Magnetics computer memory producer, as director of manufacturing. He was formerly reliability coordinator for Autonetics Division of North American Aviation.

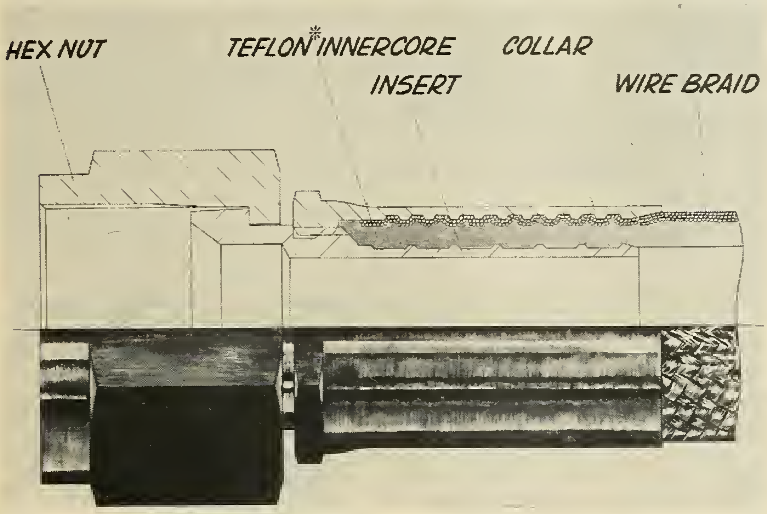
Four appointments to the newly-created Policy Advisory Board of Argonne National Laboratory, the AEC's R & D center, have been made. They are **H. R. Crane**, University of Michigan; **Robert C. Gunness**, vice-president, Standard Oil Company (Indiana); **George A. Hawkins**, Purdue University; and the **Very Rev. Theodore M. Hesburgh**, president of Notre Dame University.

PERMANENT FITTING FOR FLEXIBLE LINES

A new type of permanent fitting, described as optimum in both design and performance, has been developed by Titeflex, Inc. Flexible lines equipped with the fittings have exceeded MIL-H-25579 (USAF) and are applicable to 1500-psi fluid systems in missiles and rockets.

lock between braid and fitting, and between innercore, braid and insert.

The amount and direction of flow of both the plastic and wire braid are carefully controlled to obtain the optimum distribution of forces between the hose and the fitting. The seal does not leak



As shown in the figure, the hose is retained between an insert and a collar. Originally a loose fit over the wire braid, the collar diameter is reduced a predetermined amount by radial pressure applied progressively along its length in a rotary hydroforming machine. The plastic innercore and the braid are worked forward toward the hex nut, resulting in a

in a temperature range from —70°F to 450°F. Titeflex reports that they have never had a fitting blow off a line during their entire test program.

The company has straight fittings, 45° and 90° elbows, and sizes range from 3/16" nominal hose diameter up to 1¼" hose diameter.

Circle No. 220 on Subscriber Service Card.

FLIGHT CONTROL ACCELEROMETER

A remote-control electric actuating device has been made an auxiliary feature

in the Genisco model DDL accelerometer now in production. The new configuration is designated the model DDT and embodies a pair of miniaturized solenoids which permit either pre- or in-flight simulation of full-scale operational accelerations by displacement of the sensory mechanisms.

The device is useful when rapid functional tests are required to insure instrument reliability prior to or during flight. Inclusion of the device does not modify the performance of the standard DDL model.

Complete performance and environmental figures are available from the company.

Circle No. 210 on Subscriber Service Card.

ALL-PURPOSE OSCILLOGRAPH

An improved model of the Hathaway S-25 oscillograph has been introduced by

the company, a division of Hamilton Watch Co. The unit, named the S-25C, is a multi-element, all-purpose oscillograph designed for unlimited application, convenience of operation and high-quality recording. The device is cartridge-loaded and uses 12" wide recording paper capable of recording 18 or 48 channels.

Circle No. 206 on Subscriber Service Card.

ALIGNMENT DEVICE

A device to monitor inertial guidance systems has been developed by Perkins-Elmer Corp. The instrument is designated the Model 169 Auto-Theodolite, and makes it possible to align inertial guidance systems in missiles by detecting angular displacements in the azimuth alignment of the basic monitored equipment.

Functioning of the device is as follows: Two modulated glow lamps in the optical unit of the theodolite direct to the mirror of the monitored system. If the gyro in the guidance system is perfectly squared with the optical axis of the theodolite, the reflected light from the mirror reenters the theodolite objective and is lost back in the light source. If the mirror in the monitored unit is rotated slightly in azimuth, the returning light beams will not be centered on the optical axis and some energy will enter a light-responsive device through a slit. This energy is transduced to an electrical signal which indicates an error in alignment. A corrective signal can then be applied manually or automatically to the drive elements of the monitored system.

The Auto-Theodolite consists of three major components—an optical unit, mount unit and electronic unit. Two distinct and independent systems comprise the optical unit—a supporting base with levelling means and a precision optical limb and reading system for setting off the desired angle between the two optical axes. The theodolite has the electronic control box mounted directly on it to form a compact and readily accessible unit.

Circle No. 228 on Subscriber Service Card.

VARIABLE TIMER

Universal Winding Co. has developed a variable timer for use in missile sys-

tems, programming devices and explosive element initiation. The unit provides for a settable time delay between 0.3 and 10 seconds, with an accuracy of ±5%, and output energy in excess of 35,000 ergs. Temperature ambients from —70°F to 165°F and accelerations up to 100 g's have no effect on the device, which is termed the PM-47.

Transient circuits are used to achieve the delay, which is furnished by components of the weapon approved nonpower-consuming type, i.e., no tube filament power, etc., is required. The selected time delay is obtained by applying between 100 and 400 volts to the device, depending on the delay desired. The delay is initiated by release of a pull wire which allows a spring driven plunger to complete the necessary switching action. At the close of the delay period a pulse of electrical energy is applied to the load.

Circle No. 201 on Subscriber Service Card.

PRECISION STEEL TUBING

Recent order of stainless steel tubing by Carpenter Steel Co. for AEC met tolerances of +.000" —.025" and similar tolerances are available from the company. The tubing is available for missile & rocket applications. It may be covered with insulating material if necessary. Operating temperature on AEC order is said to be 2000°F.

Circle No. 221 on Subscriber Service Card.

SECONDARY PRESSURE STANDARD

A pressure standard for calibration of pressure instruments and for making

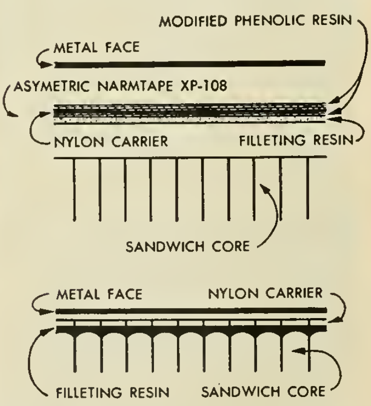
direct pressure measurements is being introduced by Wianco Engineering Co. The portable, compact unit has an overall accuracy of ±0.05% of full-scale ranges of 5 psi to 2500 psi, and ±0.1% for ranges of 3000 psi to 10,000 psi.

The unit weighs 25 lbs., has interchangable pressure heads, and only one secondary standard is necessary for any number of pressure heads. The unit's output may be displayed on a frequency counter or recorded in digital form on standard digital printers. The device is adaptable to measure other parameters, such as force, acceleration and displacement.

Circle No. 204 on Subscriber Service Card.

STRUCTURAL ADHESIVE

An adhesive designed to eliminate the need for core priming in missile sand-



wich component fabrication and also to provide materially improved peel strength, has been developed by Narmco Resins and Coatings Co. Tradenamed "Narmtape XP-108," the new adhesive is said to be the first asymmetric structural adhesive available to the missile industry, and consists of a nylon carrier impregnated with a modified phenolic resin. It is overcoated on one surface with a highly mobile filleting resin.

The addition of this filleting resin, according to Narmco, will eliminate the priming step of bonded sandwich construction operations. The new adhesive is resistent to fuels, salt spray, solvents and corrosive materials.

Circle No. 202 on Subscriber Service Card.

CIRCUIT TESTER

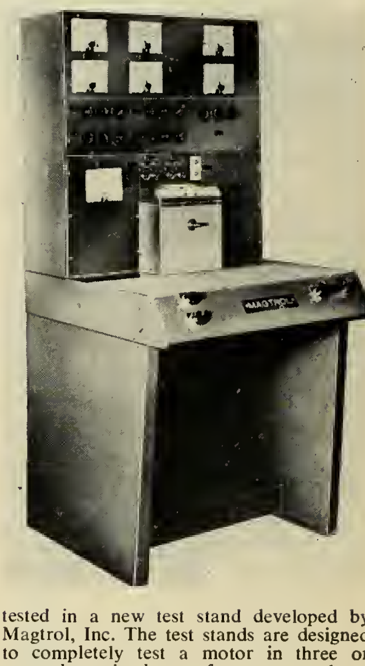
A device capable of testing 1200 electrical circuits in a minute has been introduced by Republic Aviation Corp. The automatic circuit analyzer is simple to operate and can be used on any multiple-circuit assembly. Removable program boards that mate with a receiver mechanism can be employed to reduce costs. The analyzer not only detects reversed, shorted or open circuits, but also determines immediately all those circuits involved.

Five models of the checker have been designed with capacities of 200, 400, 800, and 1200 circuits, in addition to a 100 circuit light-weight portable model for field use. The units can be built to operate from any power source and no modification is necessary to test different types of circuit harnesses, the changeover between types achieved with plug-in, pre-assembled adapters. An automatic megger to detect current leakage through wiring insulation is optional. Other special requirements can be built to customer specifications.

Circle No. 229 on Subscriber Service Card.

AUTOMATIC MOTOR TESTER

Servo-motors of 1/50 to 1 hp capacity, as well as other motor types, may be

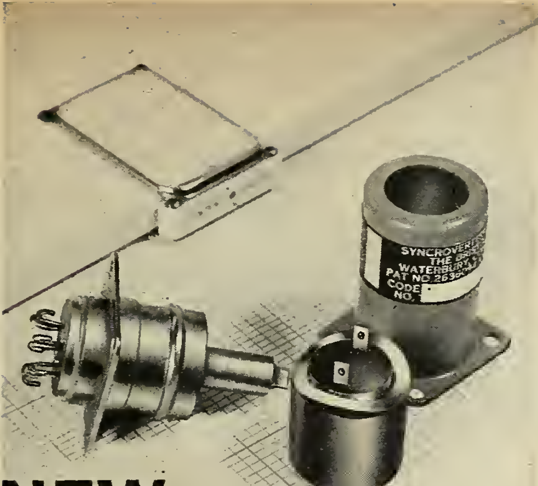


tested in a new test stand developed by Magtrol, Inc. The test stands are designed to completely test a motor in three or more dynamic phases of torque, speed and current characteristics and feature four-digit electronic tachometers to indicate motor speed.

Seven basic dynamometer heads are available, covering the range from 1 oz. in. to 750 oz. in. torque capacity, and capable of checking motors in three phases: no-load check of speed and current; dynamic check of speed, torque and current; second dynamic check of speed, load and current at any point on the curve, of stall current and stall torque check.

The control sequence may be initiated manually by a single start button for each phase, or it may be sequenced automatically.

Circle No. 200 on Subscriber Service Card.



NEW LOW-NOISE CHOPPER

Bristol's Syncroverter† chopper is now available in a low-noise, external-coil model for critical dry circuit applications.

This new external-coil chopper virtually eliminates capacitive coupling between signal-circuit contacts and driving coil leads. Peak-to-peak noise levels are usually *less than 100 microvolts* across a 1 megobm impedance (rms noise, in the order of 10 microvolts).

LONG LIFE and immunity to severe sbock and vibration are outstanding characteristics of the new Syncroverter chopper. Withstands vibration, 5 to 2000 cps, up to 30G, and up to five 30G impacts on any major axis. SPDT switcb action. Nominal contact ratings: up to 10 V, 1 ma.

Write for complete data on this latest addition to the Bristol Syncroverter line. The Bristol Company, 173 Bristol Road, Waterbury 20, Conn. 7.31

†T. M. Reg. U. S. Pat. Off.

TYPICAL CHARACTERISTICS

Driving Frequency Range:	0—1800 cps
Coil Voltage:	6.3 V sine, square, pulse wave
*Coil Current:	70 milliamperes
Coil Resistance:	52 ohms
*Phase Lag:	60° ± 10°
*Dissymmetry:	15° max.
*Switching Time:	15° ± 5°
Temperature Ranges:	—55°C to 100°C or —65°C to 125°C
Operating Position:	Any
Mounting:	Flange; 2-hole or 4-hole Plug-in; fits 7-pin miniature socket

*These characteristics based on sine-wave excitation, 400 cps.

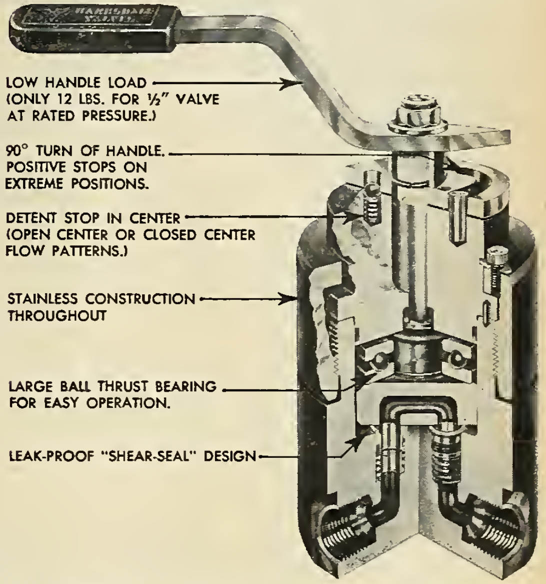
BRISTOL FINE PRECISION INSTRUMENTS FOR OVER 68 YEARS

Circle No. 104 on Subscriber Service Card.

10,000 P.S.I.

4 WAY VALVE

FOR LIQUIDS OR GASES



This new four-way valve series comes in pipe sizes from ¼ to 1 inch, but may be obtained with tube, AND 10050, or any preferred special high pressure connection. It will withstand surges of up to 15,000 P.S.I. without damage to the valve's sealing qualities. It is designed for a burst pressure of 30,000 P.S.I.

No port to port leakage occurs in the detented positions because of the exclusive "Shear-Seal" design.

Long, maintenance-free service is assured because the optically flat metal to metal sealing surfaces of the sealing rings and mating rotor faces are protected by staying in constant intimate contact; flow is always through the center of the "Shear-Seal", never across sealing surfaces (as in conventional valve design). Sealing qualities actually improve as the self aligning "Shear-Seals" lap themselves to a more perfect fit with each valve operation.

Of course, there is no external shaft leakage, because the pressure is confined to the flow passages.

This highly successful principle of extreme pressure control is fully described in "Shear-Seal" bulletin BVM-2.

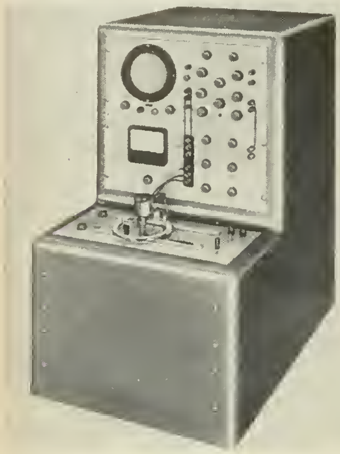
BARKSDALE VALVES

5125 Alcoa Avenue, Los Angeles 58, California

Circle No. 105 on Subscriber Service Card.

LINEARITY TESTER

Linear accuracy in precision potentiometers may be tested with the model TP-800 tester of Technical Products Co.



Use of a long persistent oscilloscope provides display of error signal, and noise due to contact resistance over frequency range of 0 to 100,000 cycles. Individual wire commutation may be shown. Magnetic clamping allows rapid set-up and alignment of test potentiometers.

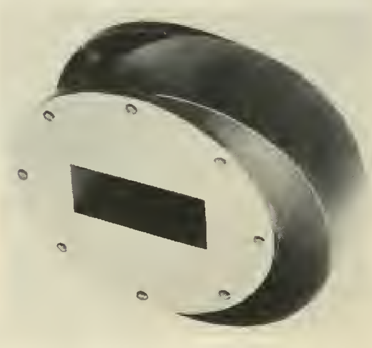
The unit's oscilloscope reads linearity error directly in per cent, in five ranges from .05 to 1.0 per cent of full scale, with accuracies of 0.01%. Terminals provided for recorder operation. A motor-driven precision gear box couples a 40-turn master helipot of .007% linearity to the test potentiometer.

Units of 1, 3, 10, 15, 25, and 40 turns can be accommodated. Test voltages may be selected between 22.5 and 135 volts to give maximum sensitivity for each unit being tested.

Circle No. 222 on Subscriber Service Card.

FERRITE MINIATURE ISOLATOR

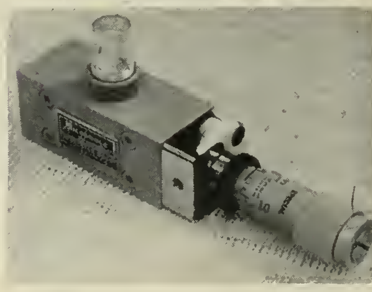
Airtron, Inc. is offering a "C" band 150 kw ferrite miniature isolator designed to operate in the 5000 mc frequency range.



The resonant absorption isolators furnish constant uni-directional magnetron to load isolation and feature a waveguide size of 2.00 x 1.00 O.D. with a weight of less than 3.5 lbs. Electrical characteristics guarantee an isolation of 10 db minimum, insertion loss of 0.5 db maximum, input VSWR 1.10 maximum with matched load and power handling capabilities of 150 kw peak power with 100 watts average into a 2 to 1 mismatch.

Ferrite material is mounted directly on the waveguide wall and full waveguide opening has been used. Heat conduction away from the waveguide is said to be rapid enough to allow operation without forced air cooling. Five units are available to collectively cover the frequency range 5250 to 5750 mc/s.

Circle No. 212 on Subscriber Service Card.



TUNABLE THERMISTOR MOUNT

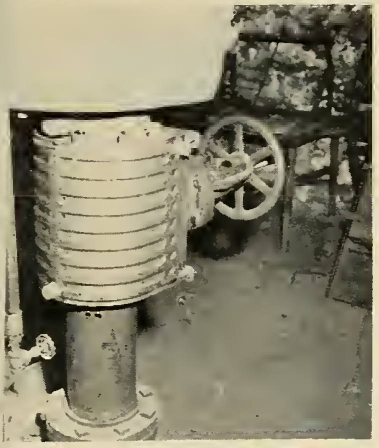
A Ka-band tunable thermistor mount, with thermistor, designed for sensitive measurement of RF power in RG-96/U waveguide transmission systems is available from Microwave Associates, Inc. Frequency coverage of the unit is 34.0—36.0 kmc/s with maximum VSWR of 1.5.

The unit may be used over the complete waveguide range if higher input VSWR's are not a consideration. Nominal operating resistance is 200 ohms and power handling capacity is 10 milliwatts maximum. Insertion loss is determined at 34.86 kmc/s and the value marked permanently on each unit and the accuracy of the measurement is ± ¼ db.

Circle No. 214 on Subscriber Service Card.

VALVE WARMER

A valve warmer incorporating low cost features as well as light weight, easy installation and space saving has been introduced by Dean Products, Inc.



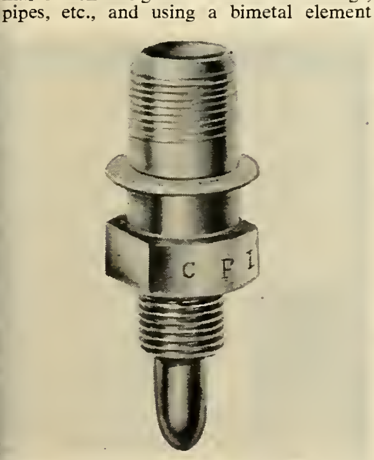
The device is made of two sheets of metal, with the outside sheet embosed to create flow channels. The inside sheet, which is flat, provides greater heat-transmitting contact. The two sheets are welded together and curved to fit the valve.

The unit is said to be easy to install or remove for valve inspection.

Circle No. 227 on Subscriber Service Card.

THERMAL SWITCH

A hermetically-sealed two-wire thermal switch designed for use in bearings, pipes, etc., and using a bimetal element



in a stainless steel body has been introduced by Control Products, Inc. The switch operates in ambient temperatures from —65°F to 700°F, has an electric rating of 2 amps and is resistive at either 28V dc or 115V ac. Length over AN connector is 5/16" and it is designed to meet environmental, shock and vibration requirements of MIL-E-5272A.

Circle No. 215 on Subscriber Service Card.

THREE-WAY VALVE

Designed for highly corrosive materials, this valve features flow through any two selected ports, while automatically shutting off the third port. Valve operation employs a self-wiping and self-lapping action which is free of wear-producing shocks and needs no lubricants that might contaminate fluids.

Also available from the company, Progressive Research and Development Co., are 2- or 4-way valves from ½" to 1½" and operating pressures up to 3500 psi, as well as LOX shut-off valves for line sizes up to 3".

Circle No. 223 on Subscriber Service Card.

DIGITAL FLOW INDICATOR

A digital flow indicator and totalizer, which gives a direct reading in gallons per minute or per hour, can be adjusted to specific gravity changes to give readings in pounds per minute or hour, and will give direct readings of speed in revolutions per unit time has been announced by Potter Aeronautical Corp.

When used with two Pottermeters, the instrument, designated Model 43, will indicate the ratio between two flows. It samples desired information for a controlled sample period, and is adjustable from 1/10 millisecond to 10 seconds in increments of 1/10 millisecond.

The unit is suitable for all types of flow rate measurement and may be used as a short-time totalizer with a four digit readout in ¾" high figures on Burroughs Nixie Tubes.

Circle No. 207 on Subscriber Service Card.

Flight Propulsion—

Some Aspects Pointing Up Engineering Opportunities in Small Aircraft Gas Turbine Engineering

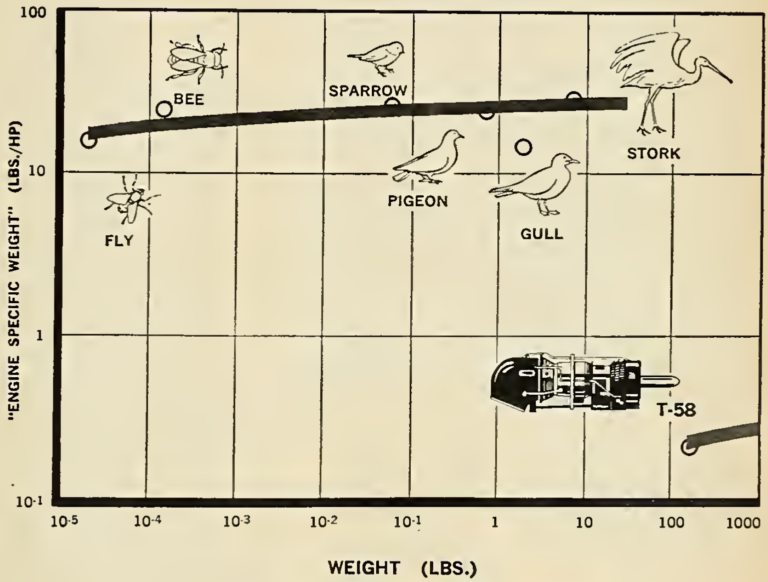
FROM STOKE'S LAW for the very small to Hoyle's work with the very large, the "3/2 power" principle maintains its validity. For an example in the middle range of our immediate experience, note the curves on the chart (1).

The variation of propulsive thrust with the square, and of "engine" weight with the cube of linear dimensions results in the well-known fact that propulsive efficiency increases with decreasing power plant size...whether one studies insects, birds, or aircraft gas turbines.

For the engineer who is curious about the application of engineering principles in nature, we recommend D'Arcy Thompson's "Growth and Form".

For the engineer who is specially curious about the small curve on the plot, we can recommend no better course for *him* than to contact Roger Hawk of General Electric's Small Aircraft Engine Department.

Engineers at SAED are busy extending the 3/2 principle to AGT applications. The success with which they have met in developing *small* highly efficient power plants (2) has created many new openings for engineers with strong backgrounds in AGT work.



"ENGINE SPECIFIC WEIGHT" VS. WEIGHT

Some of the particular components demanding the attention of capable engineers are: combustors, controls, exhaust nozzles, frames, reduction gears, rotors and blading.

If you feel that you would like to put your degree and AGT experience (3) to work in the exacting region of that small lower curve, you can get additional details on these positions from Mr. Hawk.

NOTES AND REFERENCES

1. Values for the "engine specific weight" of the insects and birds were derived from Thompson . . . cf. "Growth and Form," 2nd Ed., 1942, Cambridge University Press; Chapter II on magnitude, especially pp. 45, 47. Birds were assumed to fly at 30 mph, insects at 5 mph.

2. The T58 Turboshaft — 250 lbs. without reduction gear, 1050 HP — now in production. The T64 Convertible — for turboprop or turboshaft use, depending upon gearing — now in development; the J85 Turbojet — details still classified.

3. A degree in engineering or science, plus AGT experience qualifying you for combustor, compressor, turbine and other mechanical design, field and flight test, aerothermodynamics, fluid mechanics, accessories and systems, engineering liaison.

SMALL AIRCRAFT ENGINE DEPARTMENT

GENERAL ELECTRIC

1000 WESTERN AVENUE, WEST LYNN, MASS.

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