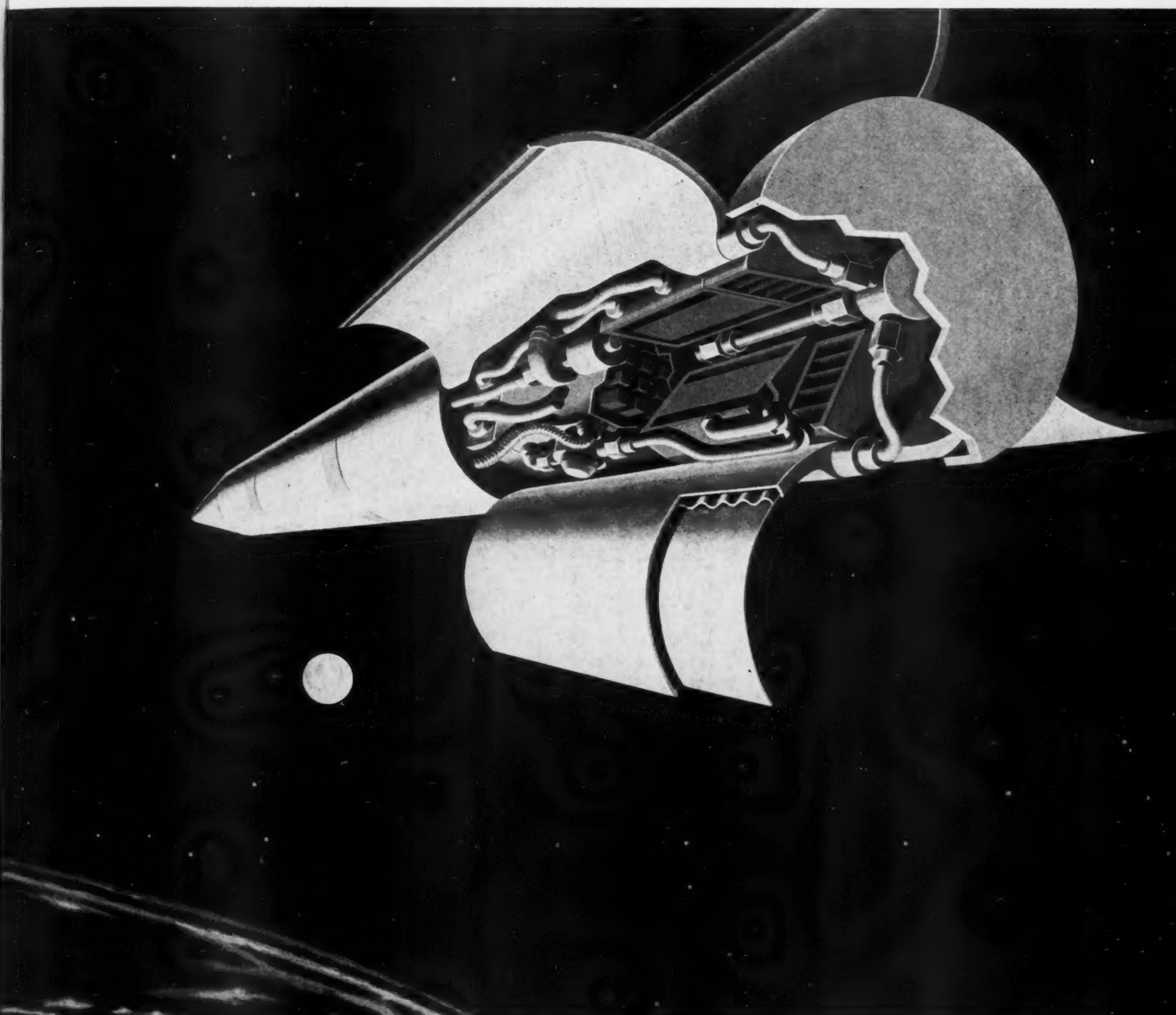
INSTITUTE OF THE AERONAUTICAL SCIENCES

AERO/SPACE ENGINEERING

VIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT



POWER STATIONS FOR SPACE MISSIONS

See Page 30

July / 1958

POWER FOR MISSILE & AIRCRAFT HYDRAULIC SYSTEMS

Eastern Aviation Hydraulic Pumps set new standards for performance, yet are the smallest, most lightweight ever made.

By meeting customer requirements and government specifications with precise detail, Eastern Pumps give reliable long-term service.

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Missile and aircraft system engineers have discovered Eastern Pumps do the same job as units that use greater space and weigh far more. Applications have included circulating coolant in bomber guidance system, providing hydraulic power for ground control of jet, charging accumulator in an in-flight refueling system, furnishing an APU system with power to a missile, and countless others.

For your next project, contact Eastern for creative engineering help that really helps.

Write for NEW Aviation Bulletin 350 describing the above units and larger-capacity pumps.

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13-13

Which Anti-Skid System Will Serve You Best?

Before you decide, read this

Two superbly efficient systems—developments of Wheel and Brake Engineering of the Aviation Products Division of Goodyear—now offer solutions to tire skidding in aircraft landings. Each holds certain definite advantages, both can be depended on to minimize the hazards inherent in today's high-speed landings. Why not look at the facts below, then let us help you decide which system better suits your operating conditions. For complete information, just write: Goodyear, Aviation Products Division S-1711, Akron 16, Ohio, or Los Angeles 54, California.

Skid Warning System*†

A plunger thumps the pilot's foot.

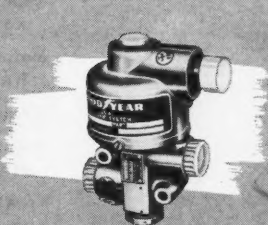
How it works—The moment rotation of any tire begins to drop abnormally, a plunger projecting through the brake pedal involved actually thumps the pilot's foot, warning him to ease up on brake pressure, eliminating skids and tire damage.

Advantages – Lightweight, low cost, completely independent of and simple to install with any braking system, requires minimum certification and flight check-out time, includes simple switch check-out system, pilot retains control.

*Now CAA-approved for Douglas DC-7B series aircraft. Others to follow soon.

†Patents pending

Fully automatic Anti-Skid System



A solenoid valve releases brake pressure.

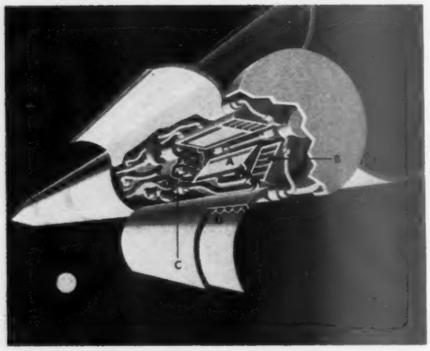
How it works—Automatically releases the brake pressure on the skidding tire through the action of a solenoid valve. When the skid has been stopped, the valve automatically allows braking to recommence.

Advantages—Complete and automatic protection against all skid and wheel lockup conditions. Eliminates flat-spotted or blown tires. Extremely rapid response, resulting in consistently short stopping distances for any given runway condition. Sizable number of field installations have proved years of trouble-free service.

GOODYEAR AVIATION PRODUCTS

60th GOODYEAR ANNIVERSARY

Leading Engineers of Complete Landing Safety—including Tires, Tubes, Wheels, Brakes and Skid Prevention



On our cover

An auxiliary source of energy that may find early use in space—a radioisotope fuel cell power system—is envisioned by artist DiGeorge in an orbiting satellite. This combined nuclear-chemical power station, one of several types discussed in an exclusive report beginning on page 30 of this issue of Aero/Space Engineering, can provide the electrical power requirements for satellite missions over extended periods. Major components, indicated at left, are: (A) Chamber in which water is decomposed into hydrogen and hydrogen peroxide under action of radiation from radioisotopes contained in "fuel" plates. (B) Chamber in which hydrogen peroxide is decomposed into oxygen and water. (C) Hydrogen-oxygen fuel cell. (D) Radiator. (The Editors will fill individual requests on company letterhead for a reproduction of this month's cover suitable for framing, while the limited supply lasts.)

AERO/SPACE ENGINEERING

. . . formerly *Aeronautical Engineering Review*, is published monthly by the Institute of the Aeronautical Sciences, Inc., at 20th and Northampton Streets, Easton, Pa. Headquarters and Editorial Offices: 2 East 64th Street, New York 21, N.Y. (TEmpleton 8-3800). Western Office: 7660 Beverly Blvd., Los Angeles 36, Calif.

Subscription rates: United States and possessions, 1 year, $5.00; single copies, $0.50. Foreign countries including Canada (American currency rates), 1 year, $6.00; single copies, $0.50.

Second-class mail privileges authorized at Easton, Pa. Acceptance for mailing at a special rate of postage as provided for in the Act of August 24, 1912.

Notices of change of address should be sent to the Institute of the Aeronautical Sciences, Inc., 2 East 64th Street, New York 21, N.Y., at least 30 days prior to actual change of address.

formerly
AERONAUTICAL ENGINEERING REVIEW

AERO/SPACE ENGINEERING

VOLUME 17 / NUMBER 7

July 1958

Featured in this issue

Departments

IAS *News*

. . . a record of people and events of interest to Institute Members

Aero-Space Scientists and Engineers to Convene at Congress in Madrid

SCIENTISTS and engineers from 22 nations will meet at Madrid, Spain, for the First International Congress in the Aeronautical Sciences, September 8–13.

Offspring of the International Council of the Aeronautical Sciences, the Congress will be presided over by Theodore von Kármán, ICAS Honorary President. Dr. von Kármán also will deliver the Daniel and Florence Guggenheim Memorial Lecture on September 8.

The same day, delegates will hear the Spanish Aeronautical Society's Juan de la Cierva Memorial Lecture, given by Pedro Blanco, Head, Helicopter Division, Instituto Nacional de Técnica Aeronáutica (INTA).

The program and arrangements have been handled by committees chairmanned by Maurice Roy, Director, l'Office National d'Etudes et de Recherches Aéronautiques (ONERA), and Col. Antonio Pérez-Marín, Secretario General y Técnico, INTA.

IAS members who wish to attend may apply directly to IAS Secretary Robert R. Dexter, in New York.

All general sessions and some of the special sessions will be held at the Instituto Nacional de Prevision, Alfonso XI, #1, and the Conference Room, Palacio de Comunicaciones, Alcala 50. The Instituto Prevision will be meeting headquarters.

A banquet has been scheduled on the evening of Friday, September 12, at the Parque Florida.

Proceedings of the Congress will be published in English, and preprints of papers will be made available at the meeting for a nominal cost.

Nations Participating

The following countries are participating: Australia, Belgium, Canada, Denmark, France, Germany, Hungary, Israel, Italy, Japan, and The Netherlands.

Additional participants include New Zealand, Poland, Rumania, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, and Yugoslavia.

Program Outline

A complete program, listing all technical sessions and papers, was mailed last month. The program in general outline follows:

Tuesday, September 9—General Sessions. "Aerodynamic Design for Supersonic Speeds," Robert T. Jones, NACA (Ames Lab.), U.S.; "Telecommand and Navigation," William H. Stephens, Royal Aircraft Establishment, U.K.; and "Propulsion Supersonique," Maurice Roy, ONERA, France. Special sessions on Hypersonic Flow, and Structures and Aeroelasticity also will be held on September 9.

Wednesday, September 10—Four special sessions on Heat Transfer and the Heat Barrier, Jet Engines and Noise, Navigation and Guidance, and Boundary-Layer Control.

Thursday, September 11—General Session. "Aeroelastic Problems on Aircraft Construction," G. H. Küssner, University of Göttingen, Germany; "A Review of Some Recent Developments in Supersonic Flow," Antonio Ferri, Polytechnic Institute of Brooklyn, U.S.; and "Problèmes de l'Aile Annulaire Résolus par Analogie Rhéoélectrique," L. C. Malavard and G. Hacques, France.

Friday, September 12—Four special sessions on VTOL/STOL, Heat-Resistant Materials, Human Engineering, and Telecommand and Telemetering.

Saturday, September 13—General Session. "Propulsion Methods in Astronautics," Wolfgang E. Moeckel, NACA (Lewis Lab.), U.S.; "Physical Basis of Magneto-Hydrodynamics," W. B. Thompson, Harwell Atomic Energy Research Establishment, U.K.; and "A Comparison of Various Approaches to an Electric Propulsion System," V. H. Blackman, Giannini Research Laboratory, U.S.

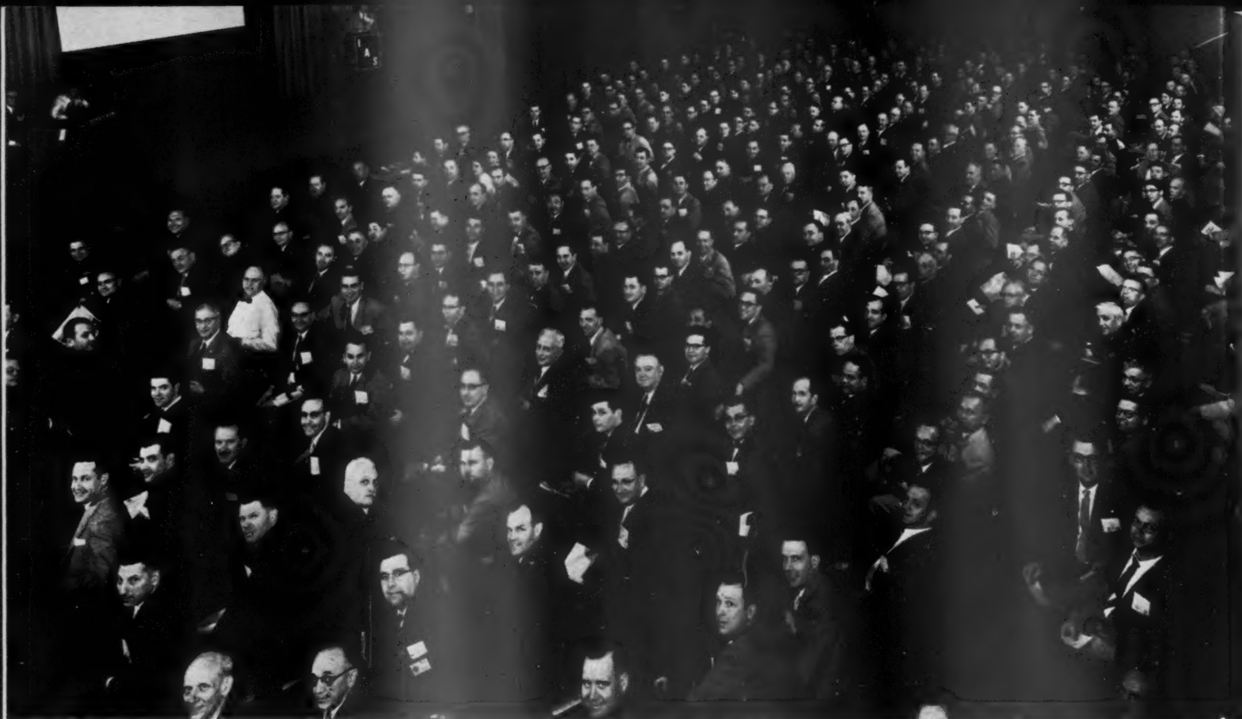
Col. Antonio Pérez-Marín
ICAS host and Secretario General y Técnico, INTA

Heat Session

Five papers have been scheduled for the session on Heat Transfer and Heat Barrier: "Mass Transfer Cooling, A Means to Protect High-Speed Aircraft," Ernst R. G. Eckert, University of Minnesota, U.S.; "The Heat Barrier and Its Influence on Hypersonic Aerodynamics," R. J. Monaghan, Royal Aircraft Establishment, U.K.; "Echanges de Chaleur dans les Ecoulements Presentant des Decollements," R. Siestrunck and Jean-Joseph Bernard, ONERA, France; a paper by E. Schmidt, Technische Hochschule (Munich), Germany; and "Nonadiabatic Flow in a Rotating Duct," J. M. de Sendagorta, INTA, Spain.

Jet-Engine Noise

Four papers scheduled for the session on Jet Engines and Noise include "Progress in Jet-Engine Noise Reduction," F. B. Greatrex and D. M. Brown, Rolls-Royce, Ltd., U.K.; "Noise Research in Canada: Physical and Bioacoustic," H. S. Ribner and B. Etkin, University of Toronto, and K. K. Neely, Defense Research Board, Canada; "Noise in Air Transport," William Littlewood, American Airlines, Inc., U.S.; and "Quelques Etudes sur l'Action Produite par les Jets de Réacteur, sur les Structures," H. J. L. Le Boiteux, ONERA, France.



Second ANNUAL ASTRONAUTICS SYMPOSIUM

The Second Annual Astronautics Symposium drew 861 aero-space scientists and engineers to Denver, Colo., on April 28–30. The meeting was sponsored by the Air Force Office of Scientific Research, ARDC, and the IAS.

The large turnout reflected increased interest in the spatial area of the aero-space industry. Much credit for the success of the meeting goes to Dr. Morton Alperin, AFOSR Director of Advanced Studies, and Col. Paul H. Dane, IAS Rocky Mountain Section Chairman, who were Cochairmen of the symposium.

Credit also is due Brig. Gen. H. F. Gregory, AFOSR Commander, who was host for the Air Force, and the members of the Rocky Mountain Section.

Morton Alperin, AFOSR Director of Advanced Studies, who spoke on "The Far Side Research Concept," also was Cochairman of the symposium.

In his opening remarks General Gregory outlined the AFOSR research program and its objectives in the field of astronautics. (A condensed version of these remarks appeared as the Guest Editorial in the June issue of AERO/SPACE ENGINEERING.)

Technical Papers

The technical papers presented at the various sessions were the backbone of the meeting and stirred up considerable interest. Some of the highlights of these technical sessions are outlined by Dr. Morton Alperin on page 13.

The full discussion plus all of the papers are being published in one volume of proceedings by the Pergamon Press, 122 East 55th Street, New York. (Availability will be announced in this magazine in a few months, at which time the proceedings may be ordered directly from Pergamon.)

Principal speaker at the symposium banquet was Dr. Clifford C. Furnas, Chancellor, University of Buffalo.

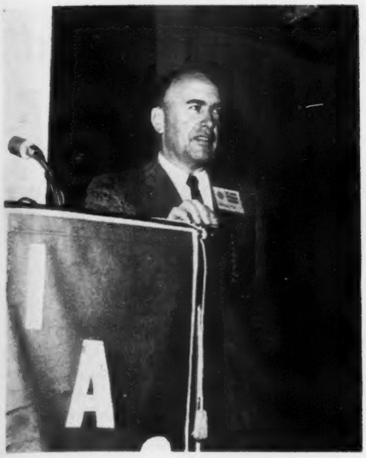
Furnas' Query

Dr. Furnas said the U.S. space program will not only be complicated, but expensive. "Now that we are faced with it, several questions come to mind. Will the public support the program? Is there real justification for that support? How should it be organized? What will be the long-time results?"

To the first question he said the answer today is "perhaps." "The prime impulse back of present public support is fear."

Dr. Furnas advocated establishment of the proposed National Aeronautic and Space Agency as an appropriate way to organize a space program. He

Cochairman of the symposium was Col. Paul H. Dane, Thermodynamics Professor, USAF Academy, and Chairman, IAS Rocky Mountain Section.



IAS President Edward C. Wells

said it should have expanded authority for the support of research by outside agencies to strengthen the program.

"Even though the space program has a very strong military impetus, the greatest yield in the long run may very well be from the indirect results. It will be difficult to predict what the applications may be; whether their greatest impact will be military or civilian."

Far Side Project

At the first day's luncheon Dr. Alperin and Major E. J. Davis, Jr., discussed the "Far Side Research Concept."

Dr. Alperin explained AFOSR thinking that led to the project and Major Davis stated its objectives.

"About March, 1956, AFOSR adopted the opinion that the Air Force would, in the near future, be required to have operational capability at altitudes considerably above the atmosphere," Dr. Alperin said.

The development of ballistic missiles and other related facts indicated the urgent need for more data concerning environmental conditions and their effects in regions remote from the earth.

Such a program had to begin soon, without the use of super rockets not yet developed, at a minimum cost, and with minimum interference with high priority defense programs, he said.

"The conditions under which the Far Side project were undertaken made it possible to construct only six vehicles and to have virtually no component or system tests."

Major Davis, AFOSR Project Engineer, Project Far Side, said the program's rocket test vehicle was evolved as the simplest and cheapest method of accomplishing the research wanted.

"Phase I of Project Far Side was aimed at the development of techniques and equipment to conduct experiments at altitudes up to one earth's radius," he said.

The primary objective of the cosmic ray experiment was to measure the soft component of cosmic rays. A single geiger counter with a transistorized high voltage power supply and an integrating circuit was used.

"In summary, Project Far Side was a program in which the objective was to develop techniques and equipment to conduct scientific investigations at unprecedented altitudes. The aim was to carry out such a program in a period of less than 9 months for less than 1 million dollars. This objective was attained."

Space Environment

Typical of many interesting sessions at the symposium was that on Space

Brig. Gen. H. F. Gregory

Environment and Vacuum Research, chaired by Lt. Col. Charles W. Craven, AFOSR.

His opening remarks, here condensed, set the tone: "In the session today some of the knowledge and research techniques concerning this environment will be discussed. The discussion will include research in the Air Force High Vacuum Laboratory, possible experiments from a lunar vehicle, cosmic debris of interplanetary space, and design and development of high-altitude simulators for human and instrument testing."

Colonel Craven's remark that the solution of problems of space flight depends on knowledge and understanding of space environment was a clue to the underlying thought behind the symposium: This was the exchange of knowledge and understanding of space.

The objective was accomplished.

One of the symposium highlights was a panel discussion on manned space operations with the following speakers: Col. Paul Campbell, AFOSR, Chairman (not pictured); *from left to right*, George Gamow, W. H. Pickering, Paul Rosenberg, A. F. Spilhaus, H. J Stewart, and Fred L. Whipple.

Highlights of Technical Discussions at the Second Annual AFOSR-IAS Astronautics Symposium

*by Morton Alperin**

Six months after the launching of Sputnik I by the U.S.S.R., the U.S. Air Force's Office of Scientific Research and the Institute of the Aeronautical Sciences jointly sponsored the Second Annual AFOSR Astronautics Symposium in Denver, Colo.

In contrast to the first symposium of this series held in February, 1957 (before Sputnik), the second symposium openly and freely discussed the subject of space flight as a distinct possibility for the near future. Problems of a technical nature requiring solution before safe, useful, manned space flight could be achieved were discussed.

It was intended to include a very broad coverage of the field of Astronautics and to include sessions on each of the major areas of scientific endeavor. However, to avoid the necessity of double sessions or an unduly long symposium, it was decided to limit the subject matter of this second symposium by omitting from the agenda any papers on human factors and other major areas. Since these areas (human factors, etc.) had been the subject of separate symposiums during the past year, these omissions were considered justified.

The technical sessions included were:

(1) "Space Environment and Vacuum Research."

(2) "Control and Propulsion of Vehicles Outside the Atmosphere."

(3) Panel Discussion based upon the question: "Assume a Capability for Manned Space Operations—For What Purposes Should This Capability Be Utilized?"

(4) "Departure, Space Navigation, and Re-Entry Problems."

(5) "The Earth's Moon."

In the first of these sessions, "Space Environment and Vacuum Research," some extremely interesting concepts were discussed. Richard Roche of Litton Industries described the Air Force vacuum chamber developed at Litton Industries, as well as some of the interesting research started in this chamber. The large increases in friction coefficient as surfaces become degassed were dramatically shown in a movie. A sliding metallic puck on an inclined plane was shown to become cold-welded to the surface when subjected to high vacuum conditions. This is a very significant phenomenon and may seriously affect the design of space vehicle components. Other talks during this session were given on the subject of experiments to measure the various environmental conditions in space such as cosmic debris, radiations of various wave lengths, and magnetic fields. Dr. Maurice Dubin of the Air Force Cambridge Research Center discussed some of the instrumentation techniques used on the Explorer satellites for measurements of meteoritic particle density outside the earth's atmosphere.

The session on "Control and Propulsion of Vehicles Outside the Atmosphere" contained several very interesting papers on high specific-impulse-type thrust devices. Extremely high specific impulses will be essential for both control and propulsion of vehicles in space since no other form of control is feasible outside of an atmosphere. Also, if controlled flight is to be achieved for long durations, a high specific impulse becomes essential if we are to avoid an excessive fuel or propellant load at launch. Papers discussed the use of ionized fluids accelerated by electric or magnetic fields to extremely high exit velocities. It appears that this is theoretically a convenient way to achieve reasonably large forces with a minimum of utilization of mass. However, the power required to accelerate these fluids to sufficiently high velocities becomes large, and conventional equipment for handling this power is prohibitively heavy. Thus, a need for lightweight electrical machinery looms as one of the major problems to be solved before controlled space flight becomes a reality.

The panel discussion on Tuesday morning produced one of the most surprising and revealing results of the entire symposium. Although the question put to the panelists assumed a capability for manned space flight, it appeared as though the scientists on the panel were not generally convinced that a man was necessary or even desirable as a passenger aboard a space vehicle *for the recovery of scientific information* with the possible exception of space journeys *near solid celestial bodies*. It was generally agreed that man will eventually journey into space; however, his presence in the initial stages of scientific investigation would be disadvantageous due to his inability to observe accurately, if at all, some of the phenomena of space. The weight of the equipment to protect this human would also be prohibitively high, thus reducing the amount of other more useful equipment which could otherwise be carried.

The conclusion of the panel was that man is relatively useless as a scientific observer and should not be used in space vehicles for that purpose unless the vehicle approaches close to a solid celestial body. The audience reaction to this conclusion made it apparent that they believe man will some day venture into space regardless of his utility as an observer of scientific phenomena.

The sessions on "Departure, Space Navigation, and Re-Entry Problems" included some interesting papers on each phase of a round-trip flight from earth to a given point in space. Dr. Ferri of Polytechnic Institute of Brooklyn presented a discussion of an air breathing first stage. This is a very practical consideration since by its nature the first stage is the largest and most expensive part of the vehicle. Using an air breathing propulsive device considerably reduces the fuel weight and makes possible the recovery of this part of the vehicle for reuse.

Other discussions centered around low thrust trajectories recognizing that at least in the next 20 years, if we are to achieve long duration power plants for space flight, they will probably be capable of only small forces.

The re-entry problem received some attention in a paper by Fred Riddell and J. D. Teare of AVCO Research Laboratory. This discussion was restricted to the question of satellite vs. ballistic missile re-entry problems and did not include controlled vehicle re-entry.

"The Earth's Moon" session Tuesday evening was one of the most interesting sessions of the symposium. Hundreds of scientists interested in Astronautics sat until almost midnight to hear the country's most noted astronomers discuss their views regarding the geological structure of the moon's surface.

The session was opened by Dr. John Barnes of Systems Corporation of America who is not an astronomer but who gave an interesting discussion of the engineering problems associated with a lunar exploration.

The session then was continued by three astronomers. Dr. G. P. Kuiper of Yerkes Observatory showed many extremely interesting slides of the lunar surface, and his analysis indicated there were large areas of this surface composed of volcanic material deposited during the time when the lunar volcanoes were active.

This conclusion was refuted by Dr. Thomas Gold, Harvard College Observatory, who showed that analyses of radar reflections from portions of the lunar surface indicated that the surface must be composed of very fine sand many meters thick.

Concluding the session, Dr. Fred Whipple, Director of Smithsonian Astrophysical Observatory, showed that his analysis of the evidence led him to the conclusion that the lunar surface was largely volcanic material covered by a very thin layer of fine dust.

Thus, it appears as though considerably more effort should be expended in learning more about the lunar surface. If landings of either instrumental or manned vehicles are to be attempted, it appears necessary to increase emphasis on this area of investigation.

The symposium was concluded by a third day during which no technical papers were presented but a considerable number of attendees visited the new site of the USAF Academy near Colorado Springs and the new Martin ICBM facility at Littleton.

* Dr. Alperin is Director of Advanced Studies, USAFOSR.

TEXAS REGIONAL STUDENT CONFERENCE

Draws 13 Colleges, 22 Competitors

The Texas Regional Student Conference took place in Dallas, April 24–26, with 13 colleges and universities throughout the south, southwest, and midwest participating.

The conference was sponsored by the Texas Section with help from four aircraft firms: Bell Helicopter Corp.; Chance Vought Aircraft, Inc.; Convair Division, General Dynamics Corp.; and Temco Aircraft Corp.

Luncheon speakers on both days were Bartram Kelley, Vice-President, Engineering, Bell; J. R. Clark, Chief Engineer, Aircraft, Chance Vought; F. W. Davis, Chief Engineer, Convair; and R. E. Galer, Programs Control Manager, Temco. Each speaker centered his talk on company activities.

Featured speaker at the awards dinner was J. B. Montgomery, General Manager, Aircraft Gas Turbine Division, General Electric Co. His topic was "The Jet Age, Its Present and Future Outlook."

Undergraduate first prize went to Robert M. Nerem, University of Oklahoma, for his paper "An Investigation of Barium as an Ionic Fuel."

Second prize was a tie between K. Lawrence De Vries, University of Utah, and Peter A. Sells, University of Wichita. Mr. De Vries' paper was "Possible Applications of High Pressure Research to the Aircraft Industries." Mr. Sells read a paper on "Helicopter Circulation Control."

Graduate division first prize was awarded to Joseph Tsu Chieh Liu, University of Michigan, for his paper "The Laminar Boundary Layer Flow on an Axi-Symmetric Body with Transverse Curvature Effect."

Second prize was won by David L. Clingman, Purdue University, for "An Electric Analog to Determine the Temperature Gradient Across a Gas Turbine Wheel." (Mr. Clingman won an undergraduate first prize during last year's Minta Martin conferences.)

Third prize winner was I. Man Moon, Mississippi State College, for a paper on "Investigation of the Effect of Suction Variation on the Efficiency of a Conical Diffuser Having Distributed Suction Boundary Layer Control."

Undergraduate winners at the Texas Regional Student Conference are (*standing, left to right*): Peter A. Sells, University of Wichita, second prize; K. Lawrence De Vries, University of Utah, second prize (tie); and Robert M. Nerem, first prize. Graduate winners are (*seated, left to right*): David L. Clingman, Purdue University, second prize; I. Man Moon, Mississippi State College, third prize; and Joseph T. C. Liu, University of Michigan, first prize. The conference took place in Dallas, April 24–26.

NORTHEASTERN REGIONAL STUDENT CONFERENCE

Held at Stevens Institute of Technology

The Northeastern Regional Student Conference, postponed because of a severe snowstorm on March 22, was held at Stevens Institute of Technology on April 26.

The Institute's New York Section and Stevens Student Branch sponsored the 1-day affair.

After the first session of technical papers was presented, the group visited the Experimental Towing Tank Laboratory. Static and dynamic displays were shown including "free flight" landings and take-offs of a model in a mock sea with controlled wave dimensions.

The awards banquet was opened by a welcome from Frederick T. Helmer, III, Branch Chairman, after a social hour at the Myers Hotel, Hoboken, N.J.

R. L. Gustafson, Vice-Chairman of the New York Section, presented the awards.

First prize was won by A. Richard Seebass, Princeton University, for his paper on "A Potential Flow Study of the Lift on Slender Bodies of Revolution."

Second prize went to Claiborne R. Hicks, Jr., Virginia Polytechnic Institute, for a paper on "Hypersonic Drag Reduction by Blunting."

C. Howard Robins, Jr., Virginia Polytechnic Institute, won third prize for his paper "Minimum-Drag Bodies in the Superaerodynamic Region."

Conference judges were: G. V. Amico, U.S. Naval Training Device Center; Y. Arkus-Duntov, Curtiss-Wright Corp.; R. L. Gustafson, Grumman Aircraft; E. P. Pillsbury, Fairchild Guided Missiles Division; and N. Shapter, Civil Aeronautics Administration. Chairman of the judging committee was T. F. Hammen, Jr., Fairchild Engine Division.

A. T. Gregory, Chief Engineer, Fair-

Tomorrow's scientists and engineers are pictured in this group of students who attended the Institute's Northeastern Regional Student Conference on April 26 at Stevens Institute of Technology.

child Engine Division, was the principal speaker at the banquet. His topic was "Aviation and Your Future."

Professor Donald Ordway, Branch Faculty Adviser, nominated Cornell University as the site for next year's regional conference. His suggestion was adopted during a short business meeting while the judges were convening.

Two Missile Product Firms Join IAS Corporate Members

The Amoco Chemicals Corporation and Janitrol Aircraft Division, Surface Combustion Corporation, have joined the Institute as Corporate Members.

Amoco manufactures and markets petrochemical and chemical products for military, private, and commercial aircraft. Newest product of the firm is a solid propellant jet-engine starter cartridge for the Air Force. The firm's new plant at Seymour, Ind., also is capable of producing high-grade propellant for solid fuel power units in missile systems.

Janitrol dates back to 1942 when it was known as the Aircraft-Automotive Division of Surface Combustion. Its first products were combustion-type aircraft heaters that would ignite and function at all operational altitudes.

Today, nearly every major airline transport and thousands of military and utility planes use Janitrol aircraft heaters. The division's specialized experience with metals, combustion, and controls is being focused on precision engineered and manufactured products for rockets, missiles, ground support equipment, and spacecraft.

Janitrol products include aircraft heaters, portable ground heaters, liquid heaters, heat exchangers, pneumatic controls, high-pressure couplings and duct supports, aircraft combustion systems, hot fuel priming units, and inert gas generators.

Aero/Space Author Honored by Air Force

Arnold I. Beck, author of "Survival at High Altitudes" which appeared in the April issue, has been honored by the Air Force.

The Republic Aviation Design Safety Specialist and USAFR Major was awarded a commendation medal and cited for his 1956 altitude chamber ascent to 198,770 ft. This is the highest altitude achieved by man, according to the citation.

The ascent was made at Wright-Patterson AFB, WADC, and was "far in excess of the normal requirements of his duty assignment. . . ."

In his article, Mr. Beck discussed the problem areas of pressure change, temperature variations, and high speeds and their interrelationships existing in high altitudes.

Institute Member Founds Missile Product Company

J. H. Overholser, an IAS Member who cofounded Hydro-Aire, Inc., in 1943, has established a new firm, The Hydrodyne Corporation. Mr. Overholser, President, and Robert T. Skinner, Executive Vice-President, the founders, said their company will manufacture fluid control products for aircraft and missiles.

Mr. Overholser formerly was Assistant General Manager, Bendix Pacific Division. Mr. Skinner owns the Skinner Seal Company.

The firm has a new 18,000-sq.ft. plant at 5730 Coldwater Canyon, North Hollywood, Calif.

"We are particularly interested in high and low temperature and also high-pressure problems and products involving exotic fuels including cryogenics, atomic energy, and other difficult to control fluids and gases," according to Mr. Overholser.

National Meeting Scheduled on Dynamics, Aeroelasticity

A National Specialist Meeting on Dynamics and Aeroelasticity will be held at the Texas Hotel, Ft. Worth, Tex., November 6 and 7.

The IAS-sponsored meeting will present papers on the following topics: theoretical and experimental flutter analysis, aeroelastic effects in dynamic stability and control, servomechanism design, and dynamic response.

Further information may be obtained by writing to C. L. Turner, Chairman, IAS Texas Section, at 2639 Woodmere Drive, Dallas 33, Tex.

Central Florida Section Organized by Members

The first meeting of the Institute's newest Section, the Central Florida Section, was held at Patrick AFB Officers Club on April 24.

Raymond C. Woodard, Chairman of the Steering Committee, announced plans for the adoption of by-laws and a constitution, and plans were made for the election of Section officers.

T. C. Helvey spoke on "Man in Outer Space," covering various aspects of the problem and possible solutions Dr. Helvey is on the staff of The Martin Company's Orlando facility.

The Section's Advisory Board includes Major Gen. Donald N. Yates, USAF, Commander, Air Force Missile Test Center; Edward G. Uhl, Vice-President and General Manager, Martin-Orlando; B. G. McNabb, Convair Operations Manager; K. K. McDaniel, Boeing Field Test Director; W. S. Roden, Avco RAD Representative, Field Test Facility; and Lt. Col. E. G. Wodrich, USAF, Chief, Range Control Division.

The IAS now has 29 Sections throughout the nation.

Three IAS Members Serve on CAA Birthday Committee

Three IAS members served on a national committee for the observance of the Twentieth Anniversary of the Civil Aeronautics Act which was celebrated last month.

On the committee were Leslie A. Bryan (M), Chairman, General Aviation Facilities Group; James R. Durfee (HM), Chairman, CAB; and James T. Pyle (HM), Administrator, CAA.

Other committee members included Gen. Orval R. Cook, President, AIA; Representative Oren Harris, Chairman, House Committee on Interstate and Foreign Commerce; Senator Warren G. Magnuson, Chairman, Senate Committee on Interstate and Foreign Commerce; Postmaster General Arthur E. Summerfield; and Stuart G. Tipton, President, ATA.

Necrology

James H. Doolittle, Jr.

The Institute has received word of the death of Major James H. Doolittle, Jr., USAF (A), on April 9. He was 38.

Major Doolittle, the son of NACA Chairman and famed aviator James H. Doolittle, was an Air Force veteran of 17 years and a command pilot. He served overseas during World War II for 39 months and completed 50 combat missions. He held the Distinguished Flying Cross and Air Medal with five oak leaf clusters.

He was an engineering graduate of Purdue University and also attended Massachusetts Institute of Technology while in the Air Force. From 1945 to 1949 he was a Test Pilot, Flight-Test Division, Cargo Section, Wright-Patterson AFB. Major Doolittle also held a commercial pilot's license.

Harland A. Gray, Jr.

The IAS has received news of the death of Lt. Harland A. Gray, Jr., USN (A), on December 30, 1957. The 32-year-old naval officer was killed in an aircraft accident.

Lieutenant Gray received a Bachelor's degree in aeronautical engineering from Massachusetts Institute of Technology in 1946. He was a Project Engineer at the NAMC Aeronautical Engines Laboratory, Philadelphia, Pa., for 1 year and later became a Naval Aviator. He flew in Photographic Squadron 61, Miramar NAS, San Diego, Calif.

Robert K. Hughson

The Institute has learned of the death of Lt. Robert K. Hughson, USAF (A), killed in a T-33 jet crash at Laredo AFB on February 24. He was 22.

Lieutenant Hughson was a 1956 graduate of the University of Kansas and an aeronautical engineer. Prior to service in the Air Force, he was a Data Analyst for the Cessna Aircraft Company.

A resident of Belle Plaine, Kan., he also held a private pilot's license.

Raymond T. Lewis

Word has been received of the death of Raymond T. Lewis (M), 49, Manager of Commercial Engine Sales, General Electric Company's Aircraft Gas Turbine Division. He died on March 31.

Born in Lima, Peru, Mr. Lewis was educated in England, where he received a degree in mechanical engineering from the Manchester Institute of Technology in 1930. He came to the United States in 1936 to study the oil business and in 1937 joined the Hercules Motors Corporation as a sales engineer.

He was an engineering officer in the Naval Air Transport Service during World War II and later was Manager of Service Engineering for American Airlines, Inc.

Mr. Lewis joined G-E in 1951, working on aircraft generator marketing at Lynn, Mass. He transferred to the firm's Aviation Division as a commercial applications engineer and in 1955 was named Manager—Systems Engineering.

Bernhard A. Rose

The Institute has received word of the death of Bernhard A. Rose (M) on November 4, 1957. He was 50.

Dr. Rose had been Manager, Physics Research Department, Lockheed Aircraft Corporation. He was a specialist in physics, mathematics, and chemistry.

A 1929 graduate of Ripon College (Wis.), he completed his graduate studies on a fellowship at Brown University. Dr. Rose was an automotive engineer for the Chrysler Corporation from 1934 to 1939 and taught physics, mathematics, and mechanical engineering at the Chrysler Institute of Engineering at night during this same period.

He joined Lockheed in 1939 as a Mechanical Research Group Engineer. From 1946 to 1948 he was an instructor in mathematics at the University of California, University Extension. Dr. Rose was named Department Engineer, Mechanical Research, at Lockheed in 1949. In this position he was in charge of all mechanical research activity, functional development, and mock-ups, including landing gear, controls, heating and ventilation, pressurization, and extreme temperatures.

Besides the IAS, he was a member of the American Ordnance Association.

Floyd A. Shannon

The Institute has received news of the death of Floyd A. Shannon (A) on April 3, after an extended illness. He was 52.

Mr. Shannon had been Assistant to the President and Secretary of Rotor-Craft Corporation, Glendale, Calif., since 1952. He played an important part in the development of the Pinwheel rocket-powered one-man helicopter developed to fly infantrymen about battle areas.

Formerly an inspector with the USAF, he also was Industrial Relations Director, Kinney Aluminum Company, and a foreman for the U.S. Government, Department of Engineers, in the West Indies and South America.

Mr. Shannon was educated at U.C.L.A. and Bradley College, Peoria, Ill., his home town.

Besides the IAS, he was a member of the American Helicopter Society, the American Rocket Society, and the Society of American Military Engineers.

E. Clinton Wilcox

The Institute has learned of the death on April 9 of E. Clinton Wilcox, 38, an IAS Associate Fellow and Powerplant Research Engineer at the NACA Lewis. Flight Propulsion Laboratory.

Mr. Wilcox joined the NACA in January, 1943, 1 month after receiving a Bachelor's degree in metallurgical engineering at Case Institute of Technology.

From 1943–1946, he was engaged in the acceptance tests for the Air Force and Navy of the earliest turbojet engines. He also ran tests on various methods of thrust augmentation on these engines.

From 1946 to the time of Mr. Wilcox's demise, he was responsible for conducting theoretical analyses of the performance of various propulsion systems and their evaluation in terms of aircraft performance.

He also was a Professional Member of the Cleveland Engineering Society.

News of Members

Milton U. Clauser (F) has been elected Vice-President and Director, Physical Research Laboratory, The Ramo-Wooldrige Corporation. He formerly was Director of the firm's Aero Research Laboratory. Dr. Clauser also is a member of this magazine's Space Technology Editorial Advisory Committee.

Don K. Covington, Jr. (M), General Sales Manager, The Harbor Sales Company, Inc., has been elected President of the Sales Executives Council of the Baltimore Association of Commerce.

Lt. Gen. Laurence C. Craigie, USAF (Ret.), a Fellow of the Institute, has been named Deputy of Defense Products, American Machine & Foundry Company. Also an AMF Vice-President, he will supervise the firm's Ballistics Missiles Program. General Craigie also is a Director of Associated Missile Products Company (an AMF division), the Giannini Research Corporation, Hydro-Aire, Inc., and G. M. Giannini & Co., Inc.

Edward C. Wells (F), 1958 President of the Institute, has been named Vice-President—General Manager, Systems Management Office, Boeing Airplane Company. His former title was Vice-President—Engineering.

Allen F. Donovan (AF) has been elected Vice-President and Director, Aeronautics Laboratory, The Ramo-Wooldridge Corporation. He formerly was Director of the firm's Aero Research and Development Staff, Guided Missile Research Division.

Hugh L. Dryden (HF), NACA Director and a member of the Editorial Committee, JOURNAL OF THE AERO/SPACE SCIENCES, has been chosen by the National Civil Service League as one of the ten outstanding career men in Government work. He was elected from nearly 100 nominees from 31 federal agencies for "competence, efficiency, character, and continuity of service."

William M. Duke (AF) has been elected Vice-President and Associate Director, Systems Engineering Division, The Ramo-Wooldridge Corporation. He formerly was a Program Director for his company.

Krafft A. Ehricke (M), Assistant to the Technical Director, Convair-Astronautics, has been presented the Arnold Air Society's Air Power Award for 1957. The award is given annually to outstanding civilian contributors to air power. He also is a member of this magazine's Space Technology Editorial Advisory Committee.

Donald P. Frankel (M) has joined Chicago Aerial Industries, Inc., as Director of Customer Relations. Mr. Frankel had been Assistant Director, Customer Relations, Marquardt Aircraft Company.

J. E. Froehlich (M), head of the Design and Power Plant Department and Satellite Project Director, California Institute of Technology Jet Propulsion Laboratory, is an official observer at an AGARD meeting at the University of Freiburg, Germany. Dr. Froehlich also presented a technical paper before AGARD's Wind Tunnel and Model Testing Panel.

Frank E. Goddard, Jr. (AF), head of the Aerodynamics and Propellants Department, California Institute of Technology

(*Continued on page 102*)

DATELINE world

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

"Thermonuclear Reaction: Basis of the Future Power" From *Pravda*, Feb. 28, 1958

◆ Academician I. V. Kurchatov predicts that the second half of the twentieth century will be the era of thermonuclear energy. Thermonuclear reactors will use heavy hydrogen. In the next 50 years, the yearly consumption of coal and petroleum will be about a billion tons or 400 tons of deuterium.

Before the war, workers at Leningrad cyclotron found it extremely difficult to obtain even a gram of deuterium from the Institute of Physical Chemistry of the Academy of Sciences of the Ukrainian S.S.R. in Dnepropetrovsk. Now deuterium is being produced industrially by several methods. One method, conducted at temperatures as low as −250°C., was developed in the Institute of Physical Problems, the Academy of Sciences, U.S.S.R.

Building controllable thermonuclear reactors began at about the same time in the U.S.S.R., England, and the United States. It is possible to obtain electrical energy directly from the thermonuclear reactor, as was demonstrated in 1954 by G. I. Budker in the Institute of Atomic Energy, the Academy of Sciences, U.S.S.R. In 1950 Academicians I. Ye. Tamm and A. D. Sakharov built the first model of a magnetic thermonuclear reactor which opened the door to investigations in that field in the U.S.S.R. In 1956 papers were published describing experiments conducted at the Institute of Atomic Energy under the direction of Academicians L. A. Artsimovich, M. A. Leontovich, A. M. Andrianov, O. I. Bazilevskaya, S. I. Braginskiy, I. M. Golovin, S. Yu. Luk'yanov, S. M. Osovets, I. N. Podgornyy, V. I. Sinitsyn, N. V. Filippov, N. A. Yavlinskiy, and others. In these experiments rarefied deuterium was heated by electric current up to temperatures over a million degrees, and the emission of neutrons was observed.

Physicists and engineers of all countries have many problems to solve before they conquer the industrial use of thermonuclear reaction. The principle of the ZETA reactor, built to study the conditions for slowing down ionized hydrogen by magnetic field, was developed in England. Its theory was developed in 1953 by the young Soviet scientist V. D. Shafranov. Investigation of the discharges from toroidal chambers is being done in the U.S.S.R., but somewhat differently than in England. The U.S.S.R. will present its works during the next Geneva conference.

American publications do not reflect the scope of work in the U.S., where investigations on controlling thermonuclear reactions are done in at least five important centers, in which more than 500 persons participate—including E. Teller, creator of the American hydrogen bomb.

Because thermonuclear reactors can be used for military purposes, it is difficult to expect complete cooperation among scientists of different countries until atomic and hydrogen weapons are outlawed.

U.S.S.R. Book on Cosmic Rays Is Lauded by U.S. Authority

◆ A United States authority has called the attention of Western scientists to a book published in the U.S.S.R. in 1957 which, in his opinion, is a timely and unprecedented treatise on cosmic rays. Reviewing *Cosmic Ray Variations*, by Soviet author L. I. Dorman, the U.S. cosmic-ray expert states that this is the first book written anywhere in the world giving complete coverage to the subject of cosmic-ray intensity variations. It convincingly shows, he adds, that the Soviets are aware of the many implications for fundamental research in this new field of physics, especially with respect to astrophysics, solar physics, plasma physics, and possible future applications to the theory of thermonuclear reactions.

The U.S. reviewer is able to give some indication of the reception accorded the book in the U.S.S.R. He relates a conversation among U.S. and Soviet scientists in which the Soviets expressed confidence that the book would provide a basis for their young scientists to learn what has been done in the field, what the current problems are, and what importance this research has for fundamental physics.

The U.S. reviewer believes that L. I. Dorman has admirably fulfilled the requirements laid down for this book, shows excellent comprehension of world knowledge on the subject, and gives a surprising amount of credit to U.S. scientists for their early and current work. He believes the book represents the most comprehensive review of the field yet achieved, although it tends to be somewhat overbalanced in the discussion of meteorological effects and special theories, some of which have now been shown to be no longer acceptable. The reviewer finds that the book contains a remarkable collection of data already published in scattered journals throughout the world, as well as graphs useful for cosmic-ray research work. He feels that the volume is not only a survey of cosmic-ray research up to the present time, but also a basic compendium for current research.

Further Refinement of Yak-12 Reduces Costs

◆ The new model of the Yak-12, Soviet single-engine propeller-driven transport, has reportedly passed its tests and been recommended for production. Its designation is Yak-12A, and, apparently, it is a refinement of the Yak-12M, the third of the Yak-12 series.

Characteristics and performance reported for the Yak-12A are given in Table 1. It is said that the operating cost of the Yak-12A is about 6 per cent less than that of the Yak-12M.

TABLE 1

Take-off weight	3,500 lbs.
Empty weight	2,330 lbs.
Useful load	965 lbs.
(Crew plus 660 lbs. cargo and 305 lbs. fuel, or 3 passengers and 90 lbs. of baggage plus unspecified fuel)	
Maximum speed	115 knots
Cruise speed	80 knots
Landing speed	
(With 40 deg. flap angle)	50 knots

EDITORIAL

Madrid in September

A year and a half ago when an informal group representing the aeronautical sciences in ten countries sat around a dinner table in the Hotel Astor to discuss the possible formation of an international organization in the aeronautical and allied sciences, the outline of how to go about it and where and when the first meeting might be held was not entirely clear. The proposal to form a world-wide forum for the discussion of common problems in aeronautics and in space technology had come originally from Harry Guggenheim. To back up his suggestion, he wholeheartedly approved the use of the income from the Daniel and Florence Guggenheim Fund (which had come to the Institute from the sale of the family estate at Sands Point, L.I., to the U.S. Navy) to provide the necessary financial assistance. With such support we looked to Dr. Theodore von Kármán, with his profound knowledge of the needs of the scientific community all over the world, to steer the thinking of the group in proper directions. He seized the idea with the well-known "Kármánian" enthusiasm.

In subsequent discussions in Paris, London, and Madrid, he played a leading and decisive role. His participation has been far beyond the usual implications of an "Honorary" President. Backed up by the able and energetic Chairman of the Executive Committee, Maurice Roy, Director of L'Office National d'Etudes et de Recherches Aéronautiques of France, he has labored continuously to attract the interests of aeronautical and space scientists from all over the world to participate in the project. Between them they have put together a program of technical papers and discussions for the first meeting that sets a high standard for those that will follow. With the help of Col. Antonio Pérez-Marín—Secretario General y Técnico, Instituto Nacional de Técnica Aeronáutica Esteban Terradas—as Arrangements Chairman, the business of providing suitable meeting places, translation services, and housing for delegates has been in good hands.

By now most IAS members are familiar with the basic facts. The First International Congress in the aeronautical and space sciences will be held in Madrid, Spain, during the week of September 8–13, this year. The preliminary program was published in "IAS News Notes" in the March, 1958, REVIEW. A number of U.S. applications for appointment as a delegate have already been received and processed by the Secretariat. Many more have come in via the aeronautical secretaries from countries all over the world. An educated guess as to total number of attendees now stands at plus or minus 500. Interest everywhere appears to be high. The idea seems to have been a good one.

We realize that it is difficult in these times to make definite plans too far ahead, but, as of the date of this publication, only 2 months stand between us and the Opening Session in Madrid. Travel and hotel accommodations are limited, and, in view of the great interest that has been evidenced in the First Congress, we urge any IAS member who plans to go, and who has not already done so, to communicate at once with the IAS Secretary, Robert R. Dexter, who is handling applications for the Institute.

See you in Madrid?

S.P.J.

Harry F. Guggenheim

Theodore von Kármán

Maurice Roy

The effect of altitude and exit area on the pressures developed in gun bays due to burning of entrapped gun gases is discussed and correlated with flight-test data.

Gun Gas Purging in Combat Aircraft

HOW MUCH IS ENOUGH?

Joseph S. Mount and Elden R. Geib
North American Aviation, Inc.

DURING GUNFIRING in combat aircraft, gas formed in the gun chamber by the powder explosion leaks into the gun bay. The amount of leakage depends upon the type, number, and condition of the guns. A typical analysis by volume of gun gas is as follows[1]:

Hydrogen	19 per cent
Carbon Monoxide	52 per cent
Methane	1 per cent
Nitrogen	14 per cent
Carbon Dioxide	14 per cent

Such a mixture is a reasonably potent fuel with a chemical heat of combustion which compares with those of several more common gaseous fuels (stoichiometric mixtures, gaseous products) as shown in Table 1.

When a combustible gas accumulates in a quantity greater than the lower explosive limit (LEL) but less than the upper explosive limit (UEL), any suitable ignition source may initiate combustion. In the case of a gun bay, the ignition source in the form of tongues of flame from the breech and of hot metal surfaces is generally always present.

This situation is viewed with alarm by purchasers and builders of military aircraft since in-flight explosions from other causes have resulted in much loss of life and equipment over the years. Of the several methods that have been advanced for preventing gun gas combustion,[1] the most commonly used because of its relative simplicity and reliability is that of forced air ventilation or "purging" during, and for a short while after, each gunfiring burst. The authors will not explore at this time the other possible methods of combustion suppression (controlled burning, quenching, etc.) but will devote their attention to what they believe to be the important factors in development of an adequate air purging system for present-day guns and aircraft. To this end, use is made of laboratory experiments with fuels similar in character to gun gas. Also a 7-year background of flight experience and development testing on F-86 and F-100 series aircraft is drawn upon to provide substantiating data. The net result is to show that it is not necessary, or even desirable, to provide purging in such amounts that only incombustible mixtures are present under all flight conditions.

Mr. Mount is Supervisor, Thermodynamics Section, and Mr. Geib is Supervisor, Material and Process Section.

Design Factors

An air purging system should, of course, be as light, inexpensive, and uncomplicated as possible. It should be positive acting and should contribute a minimum to airplane drag. Fundamentally, it should be adequate to prevent damage to the aircraft and gun installation. The other factors can be compromised to obtain this last objective but should not be compromised beyond this.

Fresh air may be introduced by either an external scoop or an internal one located in the engine intake duct. In the F-86 and F-100 series of aircraft, the location of the guns alongside the engine duct favored the latter arrangement. Exits are overboard since combustion gases are apt to give jet-engine compressors indigestion. To minimize drag during other than actual firing conditions, the inlet scoop is retractable, opening just prior to firing and closing several seconds after firing. The exits, however, are left open.

Effect of Altitude on Combustion

As altitude increases, the fuel concentration required to reach the LEL increases. Above a certain critical

TABLE 1

Reaction	B.tu./cu.ft. mixture (60°F., 1 atm.)
Hydrogen & Air	78.7
JP-4 Vapor & Air	70.0
Gun Gas & Air	79.5
Propane & Air	91.0

altitude peculiar to each fuel, combustion cannot occur at all. These effects are demonstrated in Fig. 1 for propane (unpublished data) and JP-4 vapor.[2] A curve which should be approximately correct for gun gas has been added to this figure. Although experimental data on gun gas are not available, qualitative consideration of the probable combustion characteristics of the mixture of primary fuels present leads to the conclusion that the LEL line shown for gun gas will vary in the manner shown relative to the other fuels. Note that the fuel required to reach the LEL increases by about a factor of 2 between sea level and 50,000 ft.

In addition, the combustion process becomes increasingly nonviolent as altitude is increased. "At the lowest pressures, in general, the combustion takes place with little or no pressure rise and appears as a blue, green, or blue-green slowly moving flame front."[2] We can therefore conclude that not only is it unnecessary at high altitudes to purge to as low concentrations as at sea level to prevent combustion but also that burnable concentrations at altitude can probably themselves be tolerated, given a reasonably beefy compartment design.

By happy coincidence these effects fall nicely into line with two physical characteristics of simple, nonmodulated, ram-type ventilation systems. These are: first, that the amount of air available for purging decreases as altitude increases and, second, that low-altitude, maximum air-load conditions dictate the structural design of the rammed compartment. Thus, a ram-type system, designed structurally in the usual manner, will not purge as well at high altitudes and does not need to because combustion, if it does occur, probably can be tolerated by structure designed for low-altitude, high-velocity dynamic pressures.

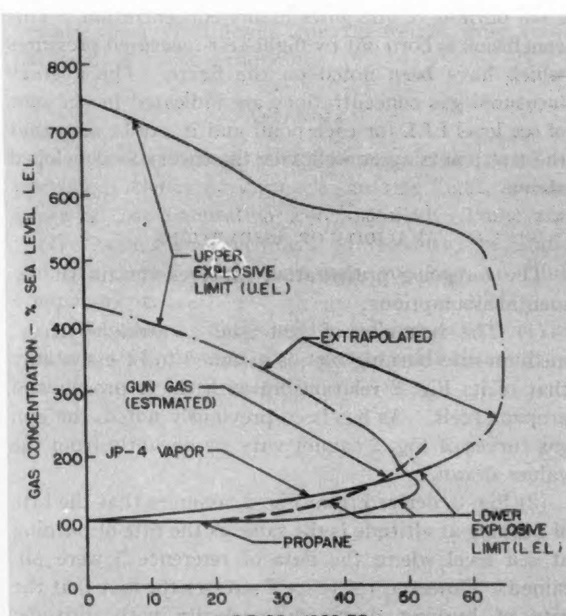


FIG. 1. Explosive limits for medium-rate-burning fuels (propane, JP-4 vapor, and gun gas).

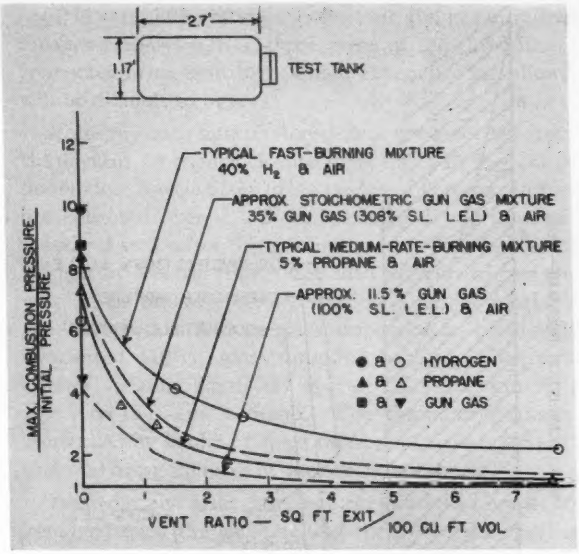


FIG. 2. Variation in combustion pressure ratio with vent ratio. Solid symbols calculated from heats of combustion, open symbols from experiments of reference 3.

EFFECT OF CONSTITUENTS, VENT RATIO, AND ALTITUDE ON EXPLOSIVE PRESSURE

It is pertinent at this point to calculate the maximum pressures that could theoretically be developed in closed containers by burning various gas mixtures, starting at a given pressure (altitude). This may be done by considering complete burning of the mixture in the available oxygen with the constituent heats of combustion applied to raising the pressure in a thermally insulated container. The results of such calculations for certain propane, hydrogen, and gun gas mixtures are plotted (solid points) on the vertical axis of Fig. 2, the combustion pressure being expressed as a per cent of the initial pressure.

Of further interest is the effect of openings in the container on these maximum pressures. For this, test data are available from reference 3 for hydrogen and propane in rigid cylindrical tanks. These test data are also plotted (open points) in Fig. 2. The abscissa is the "vent ratio" of the container defined as the sq.ft. exit area per 100 cu.ft. of volume.

Curves have been faired through the test points, and, using these curves and the calculated zero vent ratio points as a guide, representative curves have been added for the two gun gas concentrations considered—100 per cent sea level LEL and stoichiometric (308 per cent sea level LEL). It will be seen that these latter curves, while admittedly not precise, cannot be far in error due to the rather narrow limits imposed by the hydrogen and propane curves. The curves show the significant effect of vent ratio on the pressure that can be reached during combustion.

Choosing a vent ratio of 5 (it being evident that greater values are relatively ineffective in lowering the chamber pressure) and using the Fig. 2 intersections for 100 per cent sea level LEL and stoichiometric

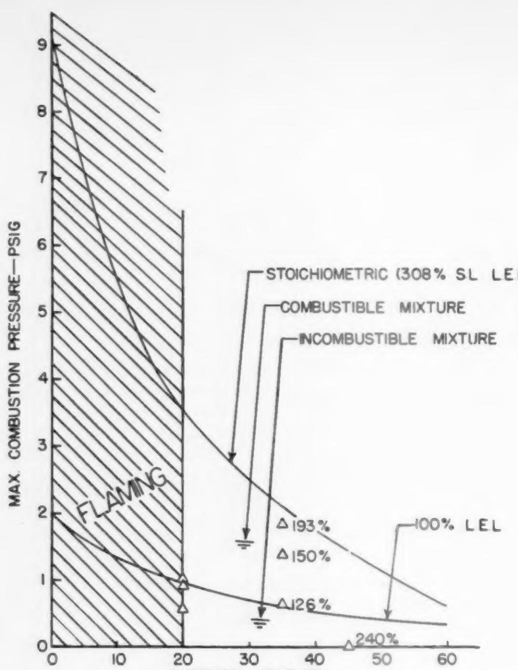


FIG. 3. Effect of altitude on combustion pressure for gun gas in a chamber with a vent ratio of 5. Concentrations of flight-test data points (Δ) are given in per cent of sea level LEL where measured.

concentrations of gun gas, Fig. 3 was prepared to show how the maximum obtainable pressure will vary with altitude. It may be seen that a chamber designed to withstand 2.5 psi bursting pressure would not be damaged by an explosion at sea level of gun gas in the 100 per cent sea level LEL concentration and that a chamber designed to 10 psi would withstand an explosion at sea level of gun gas in stoichiometric mixture with air. It should be noted further that fuel-rich mixtures (greater than stoichiometric) will produce pressures less than the stoichiometric curve—i.e., the stoichiometric curve represents a maximum limit. The effect of increasing altitude is to greatly reduce the maximum combustion pressure for a given mixture.

Effect of Altitude on Purging Effectiveness

During the past 7 years North American Aviation, Inc., has lived with the gun gas purging "problem" as it applied to the 20-mm. gun installations on the F-86H and F-100 series aircraft. Literally hundreds of gunfiring flights have been made during which much qualitative information has been obtained. In addition to this, some 100 hours of test flying have been logged for the specific purpose of obtaining quantitative data relating to gun gas purging. Samples of gas-air mixtures collected in the gun bay during firing were analyzed, pressure rises in the gun bay were measured, and flame detectors mounted on the gun bay wall were used to reveal the presence of combustion. This instrumentation is described in some detail in the Appendix.

The flight-test program showed that average gun gas concentrations of well over 100 per cent sea level LEL existed in the gun bay first of the F-86H and later of F-100A airplanes. For a given flight Mach Number, the concentrations increased with altitude. While fixes were being developed to reduce the concentrations, a good deal of firing was done with the high concentrations and no damage was sustained. Further, the data indicated that ignition did not occur above 45,000 ft. altitude.

The gun bays of these airplanes had a vent ratio of about 5 and had been designed to withstand the pressure (approximately 5 psig) that would result if the purging air inlet scoops were opened in a maximum-velocity dive. From Fig. 3 it can be seen that gun gas combustion pressures cannot exceed this figure above 12,000 ft. altitude. On the basis of structural design alone then, it would appear that given uniformly mixed, near-stoichiometric concentrations there would be no danger of structure damage at altitudes above 12,000 ft. However, the flight tests showed that an additional factor is present which affords complete relief from this danger. At 20,000 ft. altitude and below the gases burned as they escaped from the gun breech and the resulting concentrations in the bay were almost invariably below the lower explosive limit. While this phenomenon called "flaming" is a property of the particular gun and propellant being considered, in the F-86 and F-100 installations it has consistently afforded complete relief from what otherwise might have proved to be a condition requiring more design attention. For this reason, the shaded area marked "flaming" is added to Fig. 3 to indicate its effect on the combustion pressure picture.

Considering, then, the area from 20,000 ft. up, the data show that destructive pressures cannot result from burning of gun gases in any concentration. This conclusion is born out by flight-test-measured pressures which have been noted on the figure. The average measured gas concentrations are indicated in per cent of sea level LEL for each point and it can be seen that the test points agree well with the theory as developed above.

Validity of Assumptions

The foregoing presentation involves certain fundamental assumptions:

(1) The behavior of gun gas, a variable-energy, medium-rate-burning fuel, is assumed to be essentially that of its Fig. 2 relationship with the hydrogen and propane fuels. As has been previously noted, the gun gas curves of Fig. 2 cannot vary significantly from the values shown.

(2) Fig. 3, derived from Fig. 2, assumes that the rate of burning at altitude is the same as the rate of burning at sea level where the data of reference 3 were obtained. However, reference 2 stresses the fact that the rate of burning decreases markedly with altitude. Qualitatively, this fact would tend to lower the pressures shown in Figs. 2 and 3.

(3) Further, the data from references 2 and 3 were obtained on uniformly mixed specimens. Mixing in a gun bay is anything but uniform. A flame front progressing through a gun bay runs the risk of being quenched by either too lean or too rich adjacent mixtures.

(4) The vessels of reference 3 were not exact replicas of gun compartments. However, an actual gun bay should be a less effective combustion chamber for the following reasons: (a) cold walls (except for sustained flight Mach Numbers above 1.2); (b) irregular design, with many natural "fire breaks" in the form of frames, ammunition tracks, guns, etc.; and (c) less dependable ignition—pressure rises often did not occur during the flight tests even when a flammable mixture was present.

Concluding Remarks

It appears evident that the explosion hazard in gun bays is not difficult to eliminate with a ram-air purging system once the design requirements are pinned down. Of primary importance is an adequate vent ratio, at least 5. Next, the flaming characteristics of the gun-ammunition combination should be known. The gun compartment structural design can then proceed and it will probably be found that if the compartment can stand the ram pressures encountered in limit Mach Number flight no additional structural beef-up should be necessary to allow for combustion pressures.

If the above design procedure is followed, it is not necessary to provide purging in sufficient amounts to ensure that none but incombustible mixtures exist in the gun compartments. The philosophy of purging to below 100 per cent of sea level LEL (as expressed a priori in reference 1 and accepted generally as a criterion wherever the subject is discussed) can unduly compromise the aircraft design from the weight, drag, complication, and cost standpoints.

Appendix

In order to obtain the maximum information on purging efficiency during each gunfiring flight, several types of instrumentation were installed. These are:

(1) Oscillograph recorders to measure the static pressure in the ammunition bay, gun bay, and link compartment.

(2) Recording photosensitive cells mounted on the fore and aft bulkheads of the gun bay to indicate gross flaming on the oscillograph.

(3) A sampling system to collect air-gun gas mixtures for Orsat analysis from those areas of the three interconnected armament bays which experience has shown will be difficult to purge.

Static pressure and photocell data are recorded from the instant of trigger closure until the gun bay purge doors close 5 secs. after firing ceases. The gas samples are collected over a 1/2 sec. period starting approximately 2 secs. after firing is initiated. This is accomplished by electric timers tied into the gun trigger circuit. The timers control actuation of rotary solenoids used to open and close glass stopcocks on previously evacuated 440 cc. glass sampling bombs. Aluminum tubing (1/4-in. diameter) is run from the sampling point to the sample bomb. The total firing time is controlled by loading a fixed number of rounds for each gun and firing them all in one continuous burst.

Immediately after landing, the sample bombs are removed from the airplane and their contents checked by Orsat analysis for carbon dioxide, carbon monoxide, and hydrogen. The per cent of the sea level LEL (lower explosive limit) represented by the hydrogen and carbon monoxide in the sample according to the law of Le Chatelier can be calculated using the following equation:

$$(n_1/N_1) + (n_2/N_2) = L/100$$

$$(\%H_2/4.1) + (\%CO/12.5) = \%LEL/100$$

where N_1 and N_2 are the LEL (volume per cent) for each gas, n_1 and n_2 are the volume per cent of each gas actually present, and L is the per cent of the LEL represented by the mixture. Prior to using the above equation, the Orsat analysis must be corrected for dilution by air left in the sample bombs due to incomplete evacuation, and for the quantity (at sampling altitude) of air in the 1/4-in. sample lines connecting the sample bombs with the fixed sample points.

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This article considers power plants utilizing three energy sources —chemical, solar, and nuclear— capable of an electric power output in the range of 100 to 1,000 watts.

Small Power Plants for Use in SPACE

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STANDING on the threshold of the space era we can glimpse some of the many problems that will challenge us as we attempt to move into the unknown. One of the most immediate problems requiring a solution is that of developing compact, lightweight, long-lived power systems. Such systems are needed now to power equipment for data recording and transmission on satellite and other unmanned space vehicles. Later on, as space travel develops, low-power systems will be needed to power space suits, small auxiliary space vessels, and emergency equipment on large spacecraft. However, we may reasonably expect that at some future time when large power plants are developed for the propulsion of spacecraft the need for small power systems will decline; the auxiliary power requirements then could be met by tapping power from the large power plant.

In view of this immediate need it will be of interest to survey power systems, now in use or that can be developed in the near future, capable of an electric power output in the range of 100 to 1,000 watts. This article describes several possible power systems in this power range and compares broadly the relative worth of these systems for the space mission.

Space Environment

The character or nature of a power system will be determined (as in the analogous case of the character of a human being) by two factors: the environment and the parentage. The first factor, environment, can be described as follows: (1) very low gravity, (2) no atmosphere, (3) temperature, −460°F. (in shade) to 300°F. (in sun), (4) meteoroids, and (5) cosmic and solar spectrum radiation.

How do these environmental conditions affect the nature of a power plant? The first condition, very low gravity, demands that pumps be used to move all fluids or that artificial gravity fields be set up by rotation of part or all of the system. Also, comparable provisions must be made to achieve phase separation of working fluids where required.

The second condition, no atmosphere, demands that any heat rejected from the system be rejected exclusively by radiation. Since the systems to be discussed have overall efficiencies of about 10 per cent or less, there will be appreciable quantities of heat to reject. Therefore, the radiator will be a dominant feature of these systems.

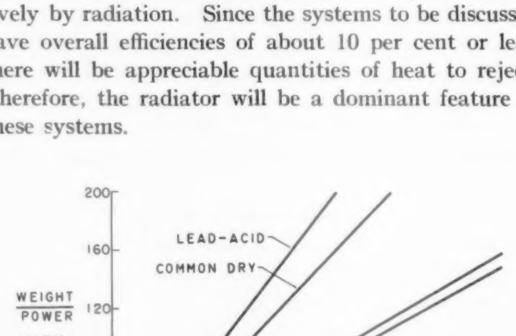

FIG. 1. Comparison of weight-power ratios (for commercial chemical batteries at various load times).

This article has been updated and condensed exclusively for *Aero/Space Engineering* from the paper, "Auxiliary Power Supply for Space Vehicles," presented by the author at the Space Propulsion Session, IAS 26th-Annual Meeting, N.Y., January 27–30, 1958.

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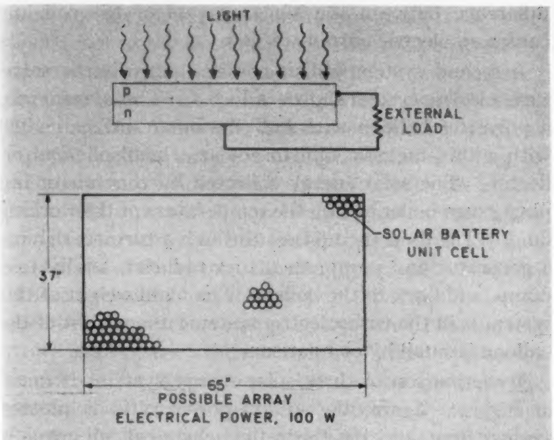

FIG. 2. Solar battery.

Condition (3), the wide temperature range due to the presence or absence of solar radiation, should not seriously affect most systems while in operation. Systems such as nuclear systems utilizing liquid-metal coolants which may be shut down periodically would experience difficulties in start-up. Auxiliary heating would be needed in this case. It also is conceivable that systems requiring radiators might be able to reduce radiator area and weight by properly shielding the system from solar radiation or by suitable orientation of the radiator with respect to the sun.

The fourth condition, meteoroids and cosmic dust, will impose a service time limitation on the power systems. Meteoroids can be expected eventually to puncture radiators and other vital components of the power plant which would vitiate the system. The probability for penetration will depend mainly on exposed area, thickness of material, and density of material. Cosmic dust or micrometeoroids by a process of erosion may reduce the effectiveness of those systems that require the transmission of solar radiation. In view of the uncertainty in the number of meteoroids of any given kinetic energy, the probability of puncture and the extent of micrometeoroid damage cannot be accurately evaluated at this time.

Condition (5), cosmic and other radiation, is not expected to have any detrimental effects on the operation of the power systems and can be neglected.

ENERGY SOURCES

After examining how the environment shapes the character of the power plant, the role that the parentage plays should now be considered. Parentage in this case refers to the particular energy source that powers the system. There are three main hereditary lines, or energy sources, we shall consider: (1) chemical, (2) solar, and (3) nuclear.

Chemical Energy Sources

Chemical energy sources impose a very marked characteristic on power systems utilizing them; this is high weight-to-energy ratio. The chemical system of most interest for space use is the chemical battery. Some of the batteries of interest are shown in Fig. 1 where the weight-to-power ratio is plotted against time. It can be seen that even for the two best cells, the mercury and the silver-zinc-alkaline cells, the weights are very high for times over several days.

It would be instructive to see what the theoretical limit of the chemical cell might be. This can be found from the following equation:

$$\Delta F = \Delta H - T\,\Delta S = \text{maximum electrical energy}$$

where

ΔF = change in free energy
ΔH = change in enthalpy
ΔS = change in entropy

Since the $T\,\Delta S$ term is usually much smaller than ΔH, it may be neglected as a rough approximation. The ΔH term is the heat of the chemical reaction that would result if the chemical changes occurred in an open beaker rather than in a chemical cell. The ultimate in ΔH (B.t.u./lb.) for chemical reactions is approached by the reaction of hydrogen with oxygen. In view of the above approximation, the hydrogen-oxygen chemical cell will therefore approach the theoretical limit for chemical cells. The curve of the ratio of weight to power against time is plotted in Fig. 1 for a hydrogen-oxygen chemical cell (chemical cell theoretical limit). It should be noted that the weights are for a cell plus fuel only and do not include weight of tankage needed to contain the gases.

Solar-Energy Sources

The next energy source, solar energy, also shapes the nature of the systems powered by it. The main features of these systems are that they must be spatially oriented so as to intercept a maximum of solar radiation and that they have small weight-to-power ratios since the "fuel" is supplied from without the system.

The simplest of the solar-energy systems is the solar battery shown schematically in Fig. 2. The cross section of a silicon solar cell shows the *p*-type and *n*-type silicon that is separated by an extremely thin barrier layer which becomes a built-in, permanent electric field. When light is absorbed by the silicon crystal, it causes the displacement of electrons and holes. This together with the action of the *p-n* junction results in a voltage

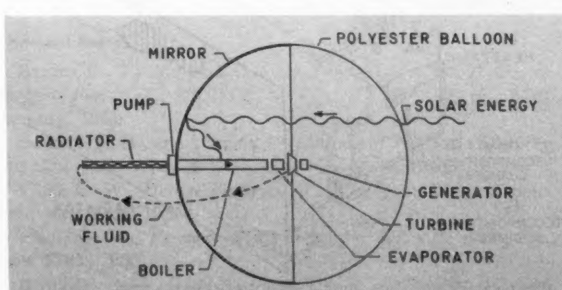

FIG. 3. Solar-turboelectric power system. Electrical power, 1 kw.; balloon diameter, 13 ft.

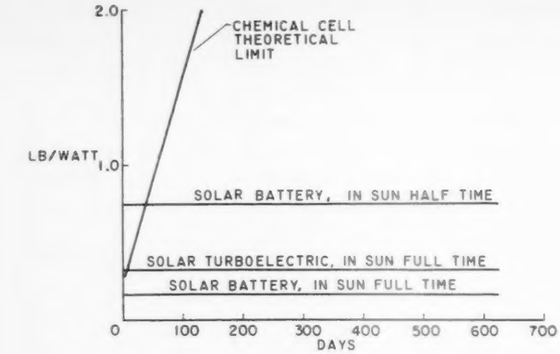

FIG. 4. Solar power plants.

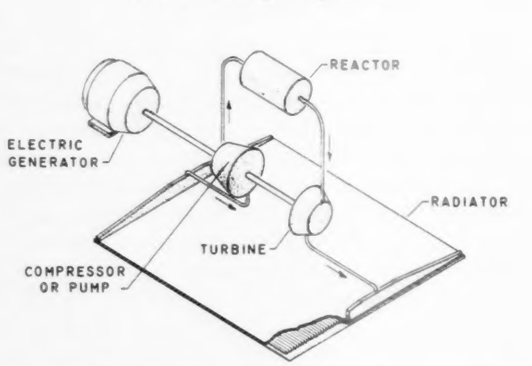

FIG. 5. Nuclear-reactor turboelectric system (single loop).

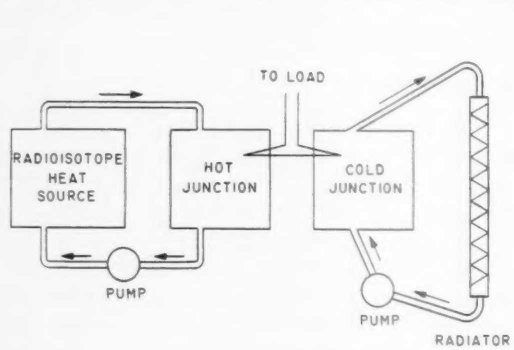

FIG. 6. Nuclear-thermopile system.

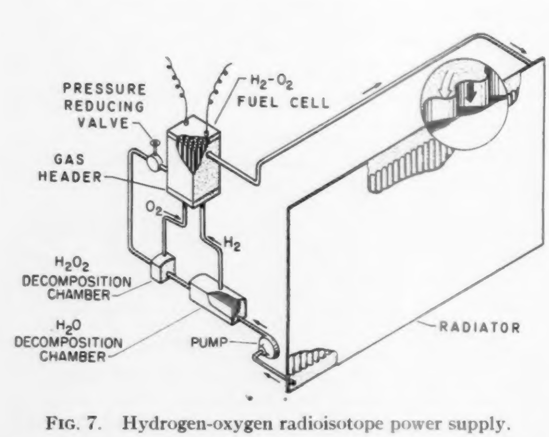

FIG. 7. Hydrogen-oxygen radioisotope power supply.

difference between the silicon layers of the cell and causes an electric current to flow.

A second system utilizing solar energy is the solar-turboelectric system shown in Fig. 3. This system uses a polyester balloon with half the inner surface coated with a thin metallic film to act as a hemispherical reflector. The solar energy collected by this mirror impinges on a boiler raising the temperature of the working fluid. The fluid then passes through a turbine, driving a generator and pump, then to a radiator, finally to a pump, and back to the boiler. The main weight of this system is in the turboelectric system; the weight of the balloon is small by comparison.

A comparison of three solar-energy systems is made in Fig. 4. Again, the weight-power ratio is plotted against time, and the theoretical chemical cell curve is included for comparison of energy sources. The orientation effect is quite noticeable when the curve for the solar battery in the sun full time is compared with that in the sun half time. The solar battery in the sun half time needs twice the collection area of the solar battery in the sun full time, as well as storage batteries to permit continuous electric power output. Another interesting feature of solar-energy sources should be mentioned: the decrease in light intensity with increasing distance from the sun. The values listed in Fig. 4 are for solar-energy systems at earth distance. At Mars distance the sunlight intensity and, therefore, power output would be 0.43 times that at earth distance. On the other hand, at Venus distance the value increases to 1.90 times that at earth distance. This factor will have to be taken into consideration when using solar-energy systems for interplanetary missions.

Nuclear-Energy Sources

The last energy source we shall consider is the nuclear. This source may be logically divided into two types: reactor sources and radioisotope sources. The main feature of nuclear systems is their small weight-to-power ratios due to the compactness and high specific power of the nuclear "fuel." Another characteristic of nuclear systems is the concomitant radiation. This makes heavy shielding mandatory if humans are to be near the power systems. However, for other applications, the level of radiation with light shielding would be tolerable to mechanical and electronic systems. Characteristically, the power output of nuclear reactors is relatively constant over long periods of time. By contrast, radioisotope sources have a decreasing power output with time. The following equation shows the factors determining the specific power of radioisotopes:

$$\text{Specific power, } P_w = C\,(E/AT_{1/2})e^{-(0.693t/T_{1/2})}$$

where

C = constant
E = average energy of radioisotope decay
A = atomic mass of radioisotope
$T_{1/2}$ = half life of radioisotope
t = decay time

The specific power at zero decay time is directly proportional to the average decay energy and inversely proportional to the half life. At other times, the specific power decreases exponentially with increasing time.

The method of choosing a radioisotope for a particular power system can be quite complex. A listing of the important considerations that enter into the choice of a radioisotope will illustrate this point. The determining factors are: (1) availability, (2) cost, (3) half life, (4) type of decay particle, and (5) radiation hazards.

There are many possible systems that can be envisioned utilizing nuclear-energy sources, but, for the present, we shall restrict the examples to a few representative cases. Fig. 5 shows a nuclear-reactor turboelectric system. This type of system may involve a single loop, as shown, or have a double loop with a heat exchanger between. The two-loop system is used mainly to reduce the radiation level in parts of the system external to the reactor when a working fluid is used that becomes radioactive in the reactor.

A second nuclear system employing a radioisotope power source can be pictured similar to the first in which the reactor (Fig. 5) is replaced by the radioisotope source.

A third system is shown in Fig. 6. This is a radioisotope-thermopile system. When alternate junctions of a thermocouple are subject to different temperatures, the Thompson and Peltier effects produce an electromotive force. If the thermocouple circuit is closed, a current will flow. The magnitude of the electromotive force depends on the thermoelectric power of the couples, the number of couples, and the temperature difference between the junctions.

The final nuclear system to be considered makes a unique use of radioisotope decay energy (Fig. 7). Particles from a radioisotope dissociate water into hydrogen and hydrogen peroxide. Hydrogen being a gas of low solubility is separated from the water stream at this point. The hydrogen peroxide is carried by the stream to a second chamber where it passes over a catalyst promoting its decomposition into oxygen and water. The oxygen is removed at this point. The two gases, hydrogen and oxygen, are fed into a chemical fuel cell. In this cell, the gases combine to give water and electric energy. The water stream then passes through a radiator and is pumped back to the decomposition chamber.

Plots of the weight-power ratio against time for the various nuclear systems considered are shown in Fig. 8. For comparison, the curves for the chemical cell theoretical limit and the solar battery in the sun full time are included. The differing characteristics of the reactor and radioisotope energy sources (in this case for Po^{210}, an alpha emitter, $T_{1/2} = 138$ days) are evident from the curves. The weight increases in the radioisotope systems come both from the additional "fuel" needed to maintain a given power level as the "fuel" decays and from the increased radiator size needed to reject the surplus heat from the excess of "fuel." The use of a radioisotope with a longer half life than Po^{210} would give

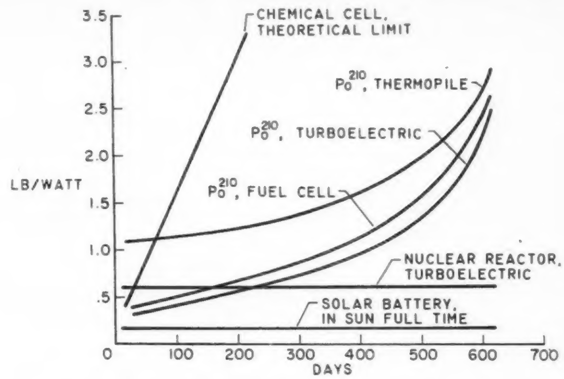

FIG. 8. Nuclear-fueled power plants.

curves with less steep slopes and a smaller variation in the weight-power ratio with time.

Conclusion

In conclusion, the characteristics and potentialities of the small power plants for space applications can be summarized as follows:

Chemical energy systems: These systems are characterized by high weights, but, in spite of this, they will continue to find use for some time because of their ready availability, low cost, and reliability of operation.

Solar-energy systems: These systems are lightweight and require proper orientation for maximum effectiveness. They are potentially the best of the systems considered and among the simplest. Micrometeoroids might restrict the effectiveness of these systems.

Nuclear-energy systems: These systems are in the same lightweight class as solar-energy systems. Radiation will restrict the use of these systems to unmanned applications unless weight penalties for shielding can be accepted.

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(*Continued on page 51*)

"AND NOW the metal used by Robur in the construction of the aeronef—a name which can be exactly applied to the Albatross. What was this material, so hard that the bowie-knife of Phil Evans could not scratch it, and Uncle Prudent could not explain its nature? Simply paper!"

So wrote Jules Verne in *The Clipper of the Clouds*, and, from the more elaborate details given in his work, it is possible to interpret the information as a prediction of "the plastics aircraft." There is no doubt, however, that he visualized paper suitably impregnated being developed to great advantage as a structural material.

There is probably no other medium commercially available with such versatility of application as a sheet of paper. Except for mechanization, the process of manufacture differs little from the original method so ably demonstrated by the paper wasp in building its

The de Havilland Mosquito showing 100-gal. capacity paper petrol tanks fitted to each wing.

nest. Vegetable fibers are moistened, chewed, and rearranged in the pulped state to take the desired form which is ready for use after drying. If the structural properties of paper have been too readily despised in the past, it has been mainly due to high moisture pickup but even so, it is the material to which the aircraft manufacturer has turned for a great variety of purposes which range from model making to the production of such parts as fairings, wing tips, and elaborate curvature work.

Many thousands of components have been made by the simple technique of accumulating layers of adhesive-treated paper on simple plaster formers. But while the results have been admirable and the various shapes economical to produce, they have had little real structural value and very low wet strength.

As paper manufacturers turn to the possibilities of using more inert fibers such as asbestos or glass, and with new improved impregnating media now available, the author reviews his experiences over a period of progressive practical development work.

During World War II, shortage of preferred materials in the United Kingdom made improvisation necessary and, in 1942, the author had succeeded in making paper containers acceptable to the Services for carrying oil—by the use of cellulose-acetate coated liners. As a result he was invited by The de Havilland Aircraft Co., Ltd., to concentrate on the possibility of constructing from paper an auxiliary aircraft fuel tank of 50 gal.

Paper, Plastics, and Weight-Saving Construction

in Aircraft

George May
Dufaylite Developments, Limited

capacity. It had become highly important to extend the flying range of the Mosquito, and the tanks, which normally would have been of metal, could not be produced in sufficient quantity owing to shortage of material and skilled labor.

Experimental work on the 50-gal. paper tank was completed, prototypes flown and approved, and production started within a few weeks. Reinforced-plaster formers made by film studio craftsmen were employed. Probably one of the most important features was the specially developed adhesive, a casein glue with the unusual characteristics of having a very high solids content in a very low viscosity solution. As a result, it was possible for the paper to be glue-coated and impregnated in one operation.

When paper is coated with an aqueous solution, it becomes extended dimensionally by the absorption of moisture. After application to a curved male former, the paper contracts on drying, thus bringing into action a considerable pressure. With the new glue, the impregnated laminate was compressed so efficiently that tank shells could be sawed, planed, drilled, and screwed as readily as plywood. A layer-by-layer diagram shows the way in which sheets of treated paper were applied to the mold for a 50-gal. tank. In production, the work was successfully executed by unskilled labor, the average time taken to complete the hand-made shell being 4 hours.

After many thousands of 50-gal. paper tanks had been in service, a 100-gal. prototype was approved which replaced the smaller one. Eventually, the 100-gal. tank was superseded by the 200-gal. design, which meant that the Mosquito was able to carry up to 400 extra gal. of fuel.

When a paper shell had been reinforced by fitting a wooden chassis, the completed assembly was slushed out with a fuel-proof shellac compound. It was then pressure tested and finished externally with a cotton scrim and cellulose-acetate dope treatment.

It is unlikely that there is a more outstanding single example of paper being used for double-curvature aircraft moldings than in the manufacture of Mosquito fuel tanks. The total war output of these was: 50-gal. capacity, 25,000; 100-gal., 75,000; 200-gal., 2,000—giving a total of 102,000.

Sandwich Construction

One of the most impressive forms of low-density sandwich construction was that used in the production of the Mosquito. This comprised a balsa wood core glued between two skins of thin plywood and the resulting lightweight laminate had a very high resistance to bending.

Toward the end of 1943, as proposed by scientific officers of the Telecommunications Research Establishment, the author undertook to make a series of experimental radomes in a similar type of construction with a view to improving their general characteristics. The radomes were required to be, as nearly as practically possible, electrically transparent; and as spacing of skins had a relation to the operational wavelength, it was necessary to find a core material which could be controlled in double curvature to within ±0.005 in. Balsa wood had too high a moisture pickup and the foamed plastics then available were found to be either inconsistent in density or difficult to manipulate.

In constructing a honeycomb, the bee uses a minimum of substance to maximum advantage, and, bearing this in mind, most encouraging results in double-skin radome construction were obtained by applying hand-made honeycombs as the core materials. These were made from a variety of substances including paper, fabrics, and glass-fiber cloth. They were molded and stabilized by impregnation with synthetic resins.

Visualizing the scope of such low-density cores and influenced by theoretical proposals made by scientific officers in government research establishments, the author then concentrated on the perfection of a practical process for manufacturing structural honeycombs. Patent rights have since been granted in Great Britain, the United States, and in many other countries in the world.

This system, which employed for the first time the expansion method of making low-density cores, was found suitable for producing materials having advantages over those previously known, as follows: (1) higher strength/weight ratios, (2) greater control over consistency of thickness (±0.005 in.), (3) suitability for contact laminating, (4) adaptability to simple and complex curvature-molding, (5) acceptance of cutting,

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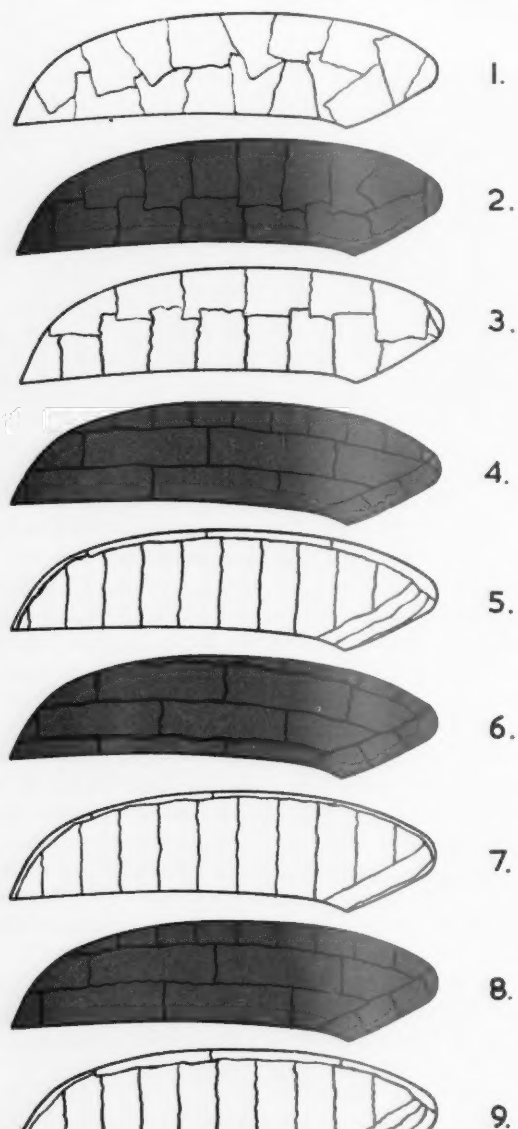
The author is Technical Director.

shaping, and profiling before expansion, and (6) fewer limitations on size of structures.

The process was originally demonstrated to J. E. Gordon, Senior Principal Officer of the Royal Aircraft Establishment's Plastics Structures Section in 1944. As a result, a new low-density material credited with possession of the highest strength/weight ratio ever developed was made available to the aircraft industry. This product, comprising a combination of all-wood kraft paper and thermosetting phenol-formaldehyde resin in honeycomb form, was marketed under the registered trade name of "Dufaylite."

In addition, many other types of honeycomb have been produced by the same process and it is important to record that their successful development has only been possible by applying materials made available by the plastics industry.

For example, the combination of paper and phenolic resin, converted to cellular form, gives a structure of great stability principally because of the synthetic product contributing desirable physical properties lacking in the natural fiber. Honeycomb made from woven-cotton fabric is stiffened by impregnation with selected thermosetting-resins while cold-setting grades of polyester resin are preferred for the treatment of converted glass-fiber cloth. Metal honeycomb is constructed by using adhesive plastics.



Nine-ply arrangement of paper lamination used to make 50-gal. fuel tanks for the Mosquito. This system allowed for equal distribution of stresses, and different colors of paper for alternate layers controlled consistency of thickness. The tanks were made in the upside-down position.

Application of Honeycomb Cores

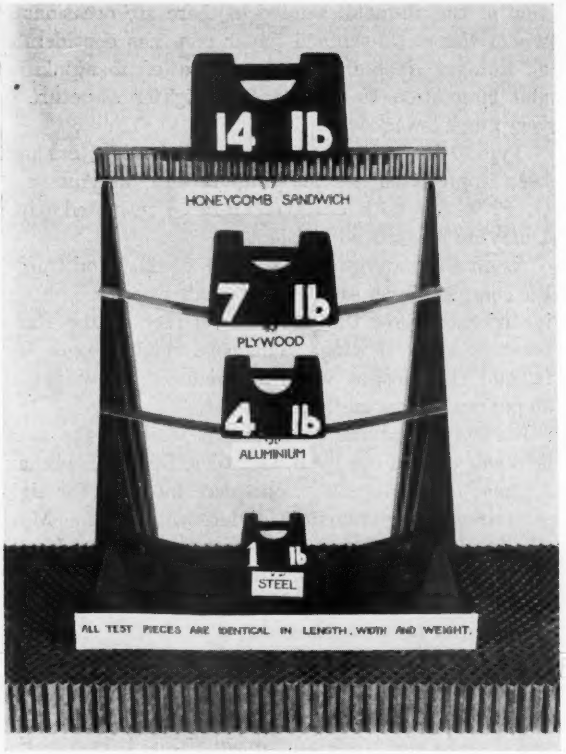
In civil aviation it has been estimated that each ounce of weight reduction can effect a saving of up to $2.80 per annum on operational costs. It is not surprising, therefore, that lightweight honeycomb sandwich, applied in the form of bulkheads, partitions, floors, doors, furniture, and fittings, is greatly favored by designers.

After elaborate tests had been carried out by the R.A.E., the first large-scale practical application of Dufaylite weight-saving construction in aircraft was in Vikings of the Royal Flight. This example set by Vickers-Armstrongs, Ltd. has since been followed by many other aircraft manufacturers, both in Britain, the United States, and other countries.

Honeycomb ranging from 15 oz. to 30 oz./cu.ft. is technically and economically satisfactory for general-purpose weight-saving in aircraft. These materials are used as low-density cores and are sandwiched between thin skins of higher-density materials which may be of plywood, metal, or plastics. In practice it is essential that the laminating operation should result in a fully satisfactory type of bond.

For this purpose, plastics adhesives are without equal and several grades allow excellent capillary attraction to the hexagonal cell edges as soon as the coated skins are brought in contact with the honeycomb core. Special attention has been given by the R.A.E. Plastics Section to wetting-out agents which improve this condition and also to the development of highly efficient synthetic glues for honeycomb laminates in order to provide a satisfactory performance under conditions in tropical heat and arctic cold.

Being accurately cut before expansion, Dufaylite honeycombs are consistent in thickness, and, in laminating, no greater pressure is required than is necessary to bring the adhesive-coated skins into contact with the cellular-core material. In many cases, stack pressing of flat panels is employed and the accumulated piles of laminates are usually left in this state overnight, allowing the glue to harden under cold-setting conditions. Where hot presses are available, the curing-cycle may be reduced to as low as 15 min. When curved laminates are required, such as doors for the Vickers Viscount, the directional properties of both



Demonstrating the stiffness of weight-saving honeycomb sandwich construction. The steel strip is loaded with 1 lb., aluminum 4 lbs., plywood 7 lbs., and honeycomb sandwich 14 lbs.

skins and core must be taken into consideration. Dufaylite, normally supplied in convenient panels of 36 in. by 12 in. and ready cut to any specified thickness, has least resistance to bending in the lengthwise direction and should be manipulated accordingly.

While simple, curved sandwiches are often laminated in one operation, another system—originated by the author—is to glue the core to the outside skin of the panel only, in the first instance. This is done in the flat state, and, when the adhesive has hardened, the combination is bent, core inwards, then applied to the second skin which has been prepared with wet glue. The assembly is held in a suitable jig until set.

Reversed-curvature laminates such as S bends are dealt with by gluing part of the core to each skin, according to design, before setting to final shape. An example is illustrated in accompanying figures.

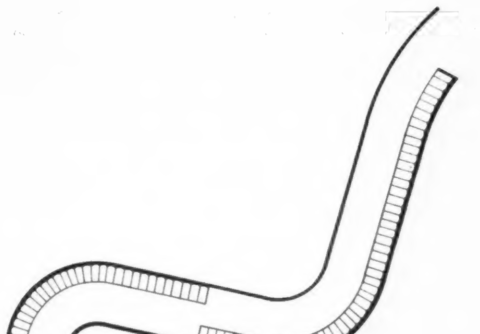
It would not be advisable to suggest a single method of laminating which would be acceptable for all structures curved in more than one direction as the designer has almost unlimited scope. Elaborate experimental work concerned with the fabrication of doubleskin double-curvature structures has shown that resinated-paper, resin-treated woven fabrics (including glass-fiber cloth), and resin-impregnated asbestos-felts are particularly well suited for application as skin materials.

With core it is an advantage to be able to manipulate resinated honeycombs to curvatures while the resin is in the uncured state. In this way, complicated tailoring necessary when using rigid material is avoided.

Aircraft structures such as radomes require the use of glass-fiber honeycomb surfaced with skins of woven glass cloth, all impregnated and laminated with polyester resins. For such purposes, glass-fiber Dufaylite is available in extra large sections and skilled craftsmen prefer this in the unresinated form so that the material may be dipped in liquid cold-setting resin and draped over a waxed former to provide, when set, a complete preformed double-curvature honeycomb core ready for the laminating process.

Examples of radomes made in this way are those produced by the Bristol Aeroplane Co. for the Britannia, the Brigand, and the Meteor; and by A. V. Roe and Co., Ltd., for the Vulcan.

While glass-fiber Dufaylite impregnated with resin in the wetted-out state is suitable for the draping technique, more recently developed honeycombs with entirely different characteristics in the fully cured form have emerged from experimental work carried out by the author in order to provide a specially curved core



Honeycomb cores glued in the first instance to a single skin are manipulated to curves by bending inwards. Some designs make it advisable to glue part of the core to each skin in the flat state, and details of bending are given in this example showing both formation and final assembly.

Jindivik Mk. I, pilotless jet aircraft, used as high-speed targets in guided-weapon development. The mainplanes and tailplanes are stabilized with Dufaylite, resin-treated paper honeycomb.

material for use in the Comet III. These employ an ingenious and patented method of applying interrupted glue joints of predetermined design which results in a variety of effects from sections taking the curved shape on expansion to flat panels which will yield readily to both simple and reversed curvature. The new curved and curvable honeycombs can be produced from a variety of materials including paper, resinated paper, and metal foils.

In the aircraft wing development carried out at the R.A.E., the advantages offered by Dufaylite were particularly acceptable to the requirement for a ready tailored filler suitable for stabilizing the molded shell of the wing. Sections of the unexpanded and uncured honeycomb were cut to predetermined shape by bandsaw so that when stretched and cured they assumed the correct airfoil profile.

The Mark I wing employed a honeycomb core weighing only 15 oz./cu.ft. and consideration was also given to the filled wing being used as a fuel tank. In order to make this possible, the Dufaylite was notched before expansion so that the liquid could enter and flow between all cells in the expanded material. Immersion tests proved that resin-treated paper honeycomb was unaffected by the fuel and it was considered that a further possible advantage to be gained from the cellular construction was a tank which would prevent a surge of liquid when the aircraft banked steeply.

A typical example of production resulting from the Farnborough Mark I wing development is in the manufacture of Jindivik Mark I and Jindivik Mark II, the pilotless jet aircraft used as high-speed targets in guided-weapon development. The mainplanes and tailplanes, many hundreds of which have now been made, comprise resinated paper Dufaylite in profiled section skinned with alloy sheet.

Slabs of honeycomb core are manufactured in Britain and flown to Australia in the unexpanded form. They are then shaped, expanded, cured, and laminated in the Government Aircraft Factory at Fishermens Bend, Melbourne. The grade of honeycomb used has a density of only 30 oz./cu.ft.

With the demand for metal Dufaylite in aircraft steadily increasing, it would appear strange for the paper-cored metal laminate to be used so extensively. It must be realized, however, that with due appreciation of the all-metal sandwich, there are occasions in which the metal-skinned paper core has considerable advantages—including greater ease of manipulation and lamination together with a lighter structure at very much lower cost.

Typical examples of craft in which these factors have been appreciated are the Jindivik and the Auster A. O. P. 9. In both cases, metal-faced resinated paper Dufaylite has proved satisfactory.

As an alternative to the solid profiled section Dufaylite core, a thinner sandwich of smaller honeycomb was incorporated into the compression face of the Farnborough Mark II wing. This core weighed 42 oz./cu. ft. and the plastics wing was reduced in weight to 85 per cent of the metal equivalent.

Further important development work in the same field was carried out by F. G. Miles, Ltd. at Shoreham Airport, in making 30-ft. one-piece moldings for high-performance experimental glider wings. The Miles effort employed Durestos resinated asbestos felt stabilized with tapered Dufaylite and in this instance the wedge-shaped sections of honeycomb were cut to shape by guillotine before expansion.

As radar equipment improves, it has become necessary to produce larger reflectors with a much higher standard of efficiency. These reflectors continue to be scaled up in size while at the same time it is essential to maintain greater control over weight, dimensional stability, and accuracy of profile.

The Cossor Airfield Control Radar Mk. VI installed at London Airport demonstrates a 14-ft. paraboloidal honeycomb reflector which owes its successful stabilization to the application of a 3-in. Dufaylite core.

Using a technique originated at the R.A.E., these large moldings comprise a specially processed honeycomb core laminated between skins of resin-treated asbestos-fiber felts. The process is one in which the felts are laid up on a prepared mold followed by a layer of furane-treated Dufaylite 3 in. thick tapering to nothing at the outside edge, so that when a further layer of resinated asbestos is applied over the core, both the face and backing skins of the structure are united at the rim.

Pressure is applied by vacuum bag, the molding is heated until the thermosetting resin in the felts has cured, and furane-treated Dufaylite is designed specially to withstand the forces applied in such hot, wet layup techniques.

A further type of large radar mirror, while of different design, employs a similar combination of materials. These structures, used for the aerial defense of Britain, have proved to be more efficient and half the weight of their metal equivalents. Radar scanners are an outstanding development of laminated honeycomb cores, combining both technical and economic advantages.

As an alternative to asbestos felt, glass-fiber mat and woven fabric may also be applied to the Dufaylite as skins with the added advantage that a cold setting process may be used for bonding.

While the core materials most extensively applied in aircraft so far have been those made from resinated paper, metal foil, and glass-fiber cloth, a very considerable amount of development work has been carried out by the author in order to establish a wide variety of new honeycombs with most interesting characteristics. They include cellular products made from dissimilar materials such as combinations of paper coated or impregnated with thermosetting and thermoplastic resins together with metallic foils. These can be distributed in predetermined arrangements either as alternative or composite layers in many ways to provide unique core materials by uniting fibers, plastics, and metals to best advantage.

In some cases, the honeycombs can be microporous or ventilated while in others the structural elements may be airtight and watertight where impervious cellular construction is required.

Honeycomb construction associated with aircraft has been so impressive that other industries have been very considerably influenced, and the modern trend is to abandon dead-weight principles in favor of weight-saving technique. It is now possible to produce a factory-made dwelling in sections and pack it, complete with furniture, in a single freight-carrying aircraft for delivery to inaccessible places. Erection can be accomplished within 48 hours and such a structure weighs only one twenty-fifth of that using traditional building materials.

A further example is in huts used as living accommodations by the French Polar Expedition during their recently completed 6-year stay on the Greenland Ice Cap. These huts, comprising laminated sections of paper Dufaylite and Duralumin sheets, filled with Vermiculite for thermal insulation are light enough to be parachuted to the ground. They can be erected quickly and similar huts are now popular quarters for troops stationed in the Arctic regions.

Conclusion

In his 12 years' practical experience of developing, producing, and applying precision honeycombs, the author has become more and more impressed with the truly amazing characteristics of paper used both as cellular core and skin materials.

Recently, it has been realized that the longer an aircraft is in service, the greater its increase in weight. The condition is due to a variety of causes including oxidation and corrosion. The added weight on a single machine can be as much as 300 lbs. This means that the aircraft designer would do well to give even greater attention to weight-saving and also to the use of noncorrosive materials. With paper makers keenly interested in the application of more inert fibers and plastics manufacturers producing resins with improved characteristics, the Jules Verne specification would now appear to be worthy of further consideration. After all, are we not approaching forms of construction equal to or even more promising than that used in *Clipper of the Clouds*?

This seems to be quite apparent if we think in terms of paperweight webs of such materials as glass or asbestos impregnated with suitable plastics and linked with metal foils in ultra lightweight cellular construction. The honeycomb core has provided the highest strength-to-weight ratio so far achieved, and future developments now demand multilayer sandwich construction with greatly improved characteristics in strength, thermal and sound insulation, and resistance to elements.

IAS Twenty-Seventh Annual Meeting

Hotel Astor, New York City, January 26–29, 1959

The scope of the meeting will be broad to cover the many fields of interest to IAS members. The meetings committee plans to schedule papers on aerodynamics, hypersonics, aeroelasticity, missiles and rockets, missile propulsion, space propulsion, satellites and spacecraft, space medicine, VTOL/STOL aircraft, rotary-wing aircraft, meteorology, etc.

Members or organizations wishing to have papers considered for presentation at this meeting should submit outlines or short abstracts to the Meetings Committee, 2 East 64th St., New York 21, N.Y., no later than August 1, 1958.

The factors which constitute an engineering/economic profile are discussed as practical considerations which may profoundly influence the design of both the vehicle and the propulsion system.

Booster Propulsion for Space Vehicles

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THE SUCCESSFUL launchings of satellite vehicles in connection with the International Geophysical Year have greatly stimulated interest in the conquest of space. The unexpectedly sharp impact of the first Sputnik on world political opinion indicates that we have found ourselves, however reluctantly, in the midst of a race for space. To remain a successful competitor, it will be necessary to provide solutions to problems in many different engineering and scientific fields such as guidance, aeromedicine, and propulsion. The subsequent discussion will be confined to the problems of the propulsion system.

To aid in formulating the propulsion system problem, let us review the methods of achieving space flight which have been proposed by the scientists and engineers actively concerned with the problem. The consensus is that all space journeys originating in the near future would be conducted in at least two steps or phases. The first phase would be the flight from earth to a permanent satellite space station located in an orbit from about 300 to 1,000 miles above the earth. There the space voyagers would debark from the first phase or "booster" vehicle and leave the satellite space station in a second vehicle which would take them to their destination. The second vehicle might proceed directly to the final destination or, alternatively, make an additional stop to refuel at another station deeper in space.

After delivering its cargo and passengers, and perhaps embarking members of the crew of the space station or of second phase vehicles returning from other flights, the "booster" vehicle would return to earth using aerodynamic friction to decelerate the vehicle. In the construction period of the space station, this type of vehicle also would be used to transport the personnel and material used to fabricate the station.

Thus all space flights in the near future will probably have one thing in common— they will begin in a "booster" vehicle whose function is to shuttle back and forth between the earth and the satellite space station.

The immediate problem is to evaluate our capability of providing a propulsion system for the "booster" vehicle. (The second phase or "deep" space vehicle propulsion system is treated in detail in reference 1.) To perform this evaluation, it is necessary to investigate and answer the following questions:

(1) Is it possible to provide a propulsion system for a "booster" vehicle at the present state-of-the-art?

(2) If so, what would be the general features of this system?

(3) If not, what additional scientific breakthroughs are required?

Discussion of Investigation

The investigation will be developed in the following general steps:

(1) The "mission profile" or statement of the task to be accomplished by the booster vehicle will be formulated.

(2) This will be analyzed to yield the explicit and implied requirements.

(3) The "engineering/economic profile" will be discussed. This is a group of engineering and economic factors which, strictly speaking, are not requirements but are practical considerations which may profoundly influence the design of both the vehicle and the propulsion system.

(4) Finally, the requirements of the mission profile will be compared with the current state-of-the-art capabilities to determine what additional breakthroughs are required, if any.

Updated, revised, and condensed especially for this issue of *Aero/Space Engineering* from the paper of the same title presented at the Space Propulsion Session, IAS 26th Annual Meeting, New York, Jan. 27-30, 1958.

Mr. Wentink is Assistant Research Group Engineer in the Aerophysics Group.

Statement of Mission Profile

This mission profile is, by definition:

(1) Manned passenger- and cargo-carrying ballistic vehicle.

(2) Vehicle to be launched from earth and intercept satellite space station at altitude of about 500 miles.

(3) After discharge of passengers and cargo, it will return to earth, using friction with atmosphere to provide most of deceleration.

(4) Vehicle will be capable of return flight without resupply at space station.

Analysis of Mission Profile

The principal requirements established by item 1 concern the safety of the crew and passengers. For this safety it must be possible to abort the mission for any reason, including a propulsion system failure any time after launch, and return the manned stage to earth. The most critical period is immediately after launch when the altitude for maneuvering and the time available to start the engines of the manned stage are at a minimum. This consideration leads to the first two requirements—namely,

(1) The first-stage propulsion system shall consist of more than one independent unit—i.e., it shall be multi-engined so that altitude can be maintained with loss of one unit long enough for manned stage to escape.

(2) The vehicle must be controllable with loss of one engine unit. The physiological safety of the occupants also must be considered. This limits the choice of mass ratio and initial acceleration.

(3) The maximum vehicle acceleration must not exceed the human endurance limit.

Item 2 of the mission profile leads to five additional requirements. The first of these is almost trite but does have significance because it restricts the form of the propulsion system which may be used. It is:

(4) The power plant must provide a thrust to vehicle weight ratio greater than 1.0.

In order to reach a satellite orbit, the vehicle must operate outside of the earth's atmosphere. The necessity for this leads to a fifth requirement—i.e.,

(5) Some form of reaction propulsion system must be provided to accomplish attitude control of the vehicle.

The vehicle must acquire a minimum velocity equal to that of the satellite station. At the assumed altitude of 500 miles, this is approximately 24,500 ft./sec. In addition, gravitational and aerodynamic drag forces must be overcome. An estimate for the extra velocity potential (or velocity gain capability) required to reach a 500-mile orbit is 4,900 ft./sec. Thus:

(6) A velocity potential of 29,400 ft./sec. is required to reach the desired orbit level.

An allowance must also be made for maneuvering the vehicle so that it intercepts the satellite stations with the proper velocity vector and angle between this vector and the local horizontal. The additional velocity potential required to correct the velocity vector angle is about 450 ft./sec. per degree of correction necessary. This is governed by the accuracy of the guidance system. Also normal tolerances and uncertainties in the power-plant thrust and specific impulse and vehicle launch weight can cause appreciable tolerances in the total time of flight which can easily amount to ± 10 sec. This is significant since, for each second of time difference between the actual and intended time of attaining the required velocity vector and altitude, the vehicle will "miss" the space station by 24,500 ft. or about 4.7 miles. (The apparent paradoxes encountered in the final maneuvering of the vehicle to the space station would make interesting grist for the science-fiction writers' mill.) With thrust control available in the power plants of the manned stage, the time uncertainty could be reduced to approximately 1 sec. so that the velocity potential required to compensate for the horizontal "miss" distance would be small compared to that required to correct for the velocity vector angle. A capability for correcting a 2° angle error is a reasonable estimate based on expected guidance system accuracy. Thus two additional requirements are:

(7) An additional velocity potential of 900 ft./sec. is required for final maneuvering of the vehicle to intercept the space station (2° vector angle adjustment at 450 ft./sec. deg.).

(8) Thrust control is required in the manned stage of the vehicle.

The third item of the mission profile leads to other velocity potential requirements of the vehicle—that of separating from the space station and of braking prior to re-entry of the earth's atmosphere.

To ensure a controlled descent to earth, it is necessary to reduce the vehicle velocity to that equal to or below the orbital velocity at the altitude at which the atmosphere will provide braking. The velocity at this latter condition would be equal to that of the space station plus the velocity acquired because of the potential energy level (gravitation) change between the space station and the altitude of the earth's atmosphere.

Two choices are available for the time at which braking is accomplished. It can be accomplished at the time of separation from the space station (which requires 1,050 ft./sec.), or it can be accomplished just prior to re-entry (which requires 950 ft./sec.). However, the latter requires an inflight restart and is not preferred. Assuming the latter altitude is 50 miles, the ninth requirement is:

(9) A velocity potential of 1,050 ft./sec. is required for braking prior to re-entry of the atmosphere to ensure a controlled descent.

This is a modest value compared to a required velocity potential of about 27,000 ft./sec. if the vehicle is retarded by means of propulsion system thrust.

The last item of the profile requires that:

(10) The engines of all stages except the first must be capable of starting in a vacuum and at zero *g* environment.

(11) The propellants required for return to earth and

materials required for starting the engine when leaving the space station must be brought with the vehicle.

Statement of Engineering/Economic Profile

Having completed the analysis of the mission profile, we will discuss some of the basic economic and engineering factors underlying the choice of a propulsion system. These form a profile of the practical or "facts-of-life" type. Although not requirements in the strict sense of the word, they exert a significant influence on many of the engineering decisions and compromises which must be made in the actual choice and design of a propulsion system. For lack of a better term, these factors will be called the "engineering/economic profile" in this discussion. These factors are outlined as follows:

(1) In most engineering problems there is more than one solution which will achieve the desired objective.

(2) The best solution is one which will provide the desired degree of perfection in the specified time available with the least expenditure of money.

(3) The development cost of a propulsion system for the "booster" vehicle will greatly exceed the cost of procurement for use.

(4) The cost of new facilities required to manufacture and test the power plant and propellants, as well as the usual direct manpower costs, must be included in the computation of development cost.

(5) The propulsion system will be the most costly single subsystem of the vehicle to develop.

(6) The propulsion system will probably be the least reliable subsystem of the vehicle at the end of any given time of vehicle development.

(7) The fewer the stages which can be employed to achieve a given objective, the greater will be the overall vehicle reliability (or probability of achieving a successful mission).

(8) The degree of propulsion system reliability which can be developed in a given time period and at a given cost decreases with an increase of thrust level.

(9) The cost of propulsion system development per unit of thrust increases as the thrust level increases.

(10) The greater the margin between the design capability and the actual requirement, the greater will be the probability of achieving the objective.

(11) The propulsion system development time (or lead time) is one of the longest required for any of the vehicle subsystems.

(12) This development time increases with an increase in thrust level.

(13) The cost of providing a propulsion system employing a new propellant combination is greater than the cost of one using a conventional combination.

(14) The fewer the stages which are required (with a given propellant combination), the lower will be the overall vehicle cost.

(15) The greatest vehicle reliability can be obtained within a given time period and dollar cost by using multiple engines to achieve a specified thrust level.

Discussion of Requirements

For convenience, the requirements established by analysis of the mission profile are regrouped and presented below, generally in the order that decisions are required:

(1) Limit values of vehicle thrust to weight ratios:

(a) Minimum value of 1.0 is required to overcome gravitation attraction.

(b) Maximum value is set by human endurance limit and is assumed here to be 9.0.

(2) Velocity potential requirements:

(a) Acquisition of approximate orbit—29,400 ft./sec.

(b) Maneuvering of manned stage to intercept space station—900 ft./sec.

(c) Separating from space station and braking prior to re-entry of atmosphere—1,050 ft./sec.

(3) Vehicle attitude control:

(a) Propulsion system is required to provide control.

(b) At least two engines per stage are required.

(c) Enough control is required to permit safe abort of mission by manned stage if one engine fails.

(4) Propulsion system of upper stages must be capable of starting under a vacuum and at zero *g* condition.

(5) Manned stage must carry with it all materials needed for return to earth.

The most significant requirement is item 1(a)—the requirement of a minimum vehicle thrust to weight ratio of 1.0. This limits the propulsion system of the booster vehicle to a chemical rocket system. It may appear that the possibility of using a thermonuclear rocket has been overlooked. However, this is not the case. When the weight of shielding required to protect the crew is considered, the vehicle thrust to weight is found to be less than 1.0.

A major breakthrough in the science of shielding will be necessary to permit the use of a thermonuclear rocket propulsion system in this application. (This restriction does not necessarily apply to vehicles designed for operation in deep space, however.)

Other considerations enter into the choice of the actual initial thrust to weight ratio. The lowest acceptable value for the first stage is about 1.2 so that the vehicle will clear the launcher area in a reasonable length of time. An arbitrary value of 1.5 appears acceptable and will be assumed here. This would also be compatible with the "abort" requirement (mission profile requirement 1). If, for example, four engines were used in the first stage, the loss of one unit would reduce the thrust to weight ratio to a minimum of 1.12 which would allow enough time to start the propulsion system of the manned stage and abort safely. The use of more than four engines is not desirable because of the adverse affect on overall system reliability. The initial thrust to weight ratio of the second stage can be somewhat lower since the manned stage will have enough altitude to maneuver in the event of an engine failure. A design value of about 1.3 should be an acceptable compromise and will be assumed here.

The requirement of item 1(b) to limit the maximum thrust to weight ratio to 9.0 is not of much practical significance except in the case of a single-stage vehicle design. Since the final thrust to weight ratio value is equal to the initial value multiplied by the stage mass ratio, the value of 9.0 would be exceeded unless a large range of thrust control were available. However, for multistaged vehicles, the limit value of 9.0 does not present a serious problem.

Having established that a chemical rocket propulsion system will be used, the next major decision is the propellant combination required. This has the greatest effect of any single factor in the vehicle design. The launch weight of the first stage required to deliver a pound of payload to the space station, the physical size of the vehicle required for a given payload, and the overall vehicle reliability are all influenced by this decision. In fact, the vehicle and propulsion requirements are so interrelated (how many stages are required, etc.) that they cannot be separated for analysis until the propellant combination has been decided.

The primary parameter in this decision is how much velocity the vehicle must acquire to perform the intended purpose. The velocity values required to accomplish the various phases of the mission are itemized in items 2 (a), (b), and (c).

A few simple equations suffice to evaluate the propellant requirements in a preliminary design manner:

$$M = \exp \{\Delta V_t/[g_e (I_1 + I_2 \ldots I_N)]\} \qquad (1)$$

$$m_0/m_1 = M/[1 - \xi (M - 1)] \qquad (2)$$

$$m_0/m_1 = M \exp (\Delta V_m/g_e) \div \{M - \exp [(\Delta V_m + \Delta V_B)/g_e]\} \qquad (3)$$

Symbols

g_e = gravitational constant at earth's surface
I = propellant specific impulse at earth's surface
M = mass ratio of stage = m_0/m_f
m_e = empty mass excluding payload
m_f = mass after consuming propellant
m_1 = mass of payload
m_0 = initial mass before consuming propellant
m_p = mass of propellant consumed
ΔV_B = velocity change produced during braking
ΔV_M = velocity change produced during manuevering
ΔV_t = total velocity gained (in n stages) in acquiring orbit
ξ = m_e/m_p

Subscripts

1, 2, . . . n refer to number of stages

Eq. (1) relates the individual stage mass ratio of an n stage vehicle to the total velocity acquired and the specific impulse of each stage (1, 2, . . . n). Fig. 1 is a graph of this equation for a range of the variables. (This equation assumes that all of the n stages are of equal mass ratio, which, to a close approximation, is the optimum case.)

Eq. (2), shown on Fig. 2, relates the ratio of the initial mass of an individual stage to the payload of that stage in terms of the overall stage mass ratio and ξ for a stage in which the only change in mass results from consumption of propellant.

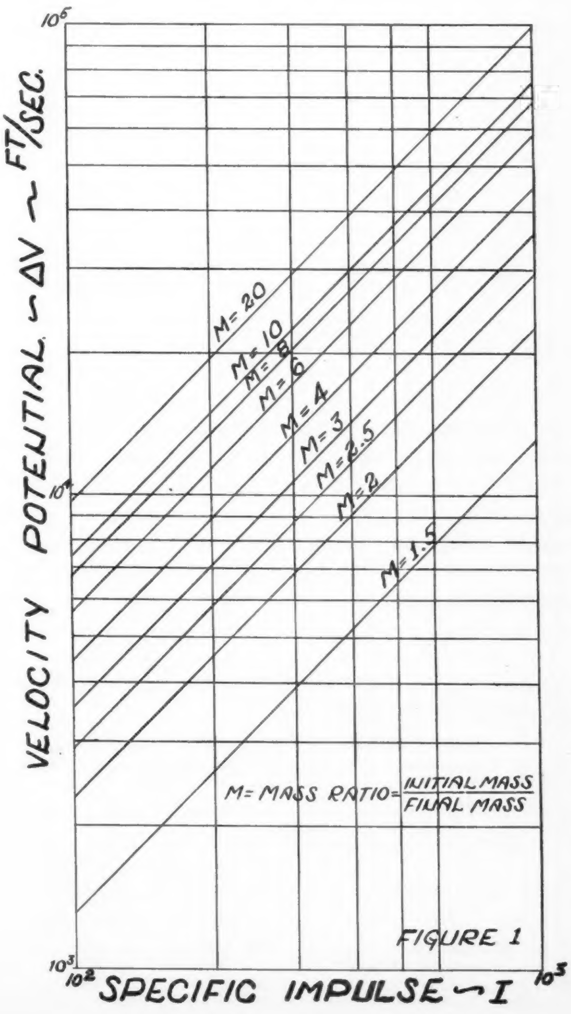
Eq. (3) is a special form of Eq. (2) for the manned stage in which the payload is removed after some propellant has been consumed during manuevering but before the propellant has been consumed for braking. Calculations for the manned stage are considerably more complex than for a simple "booster" stage. However, the following artifice may be employed to evaluate the effects of a change in propellant combination:

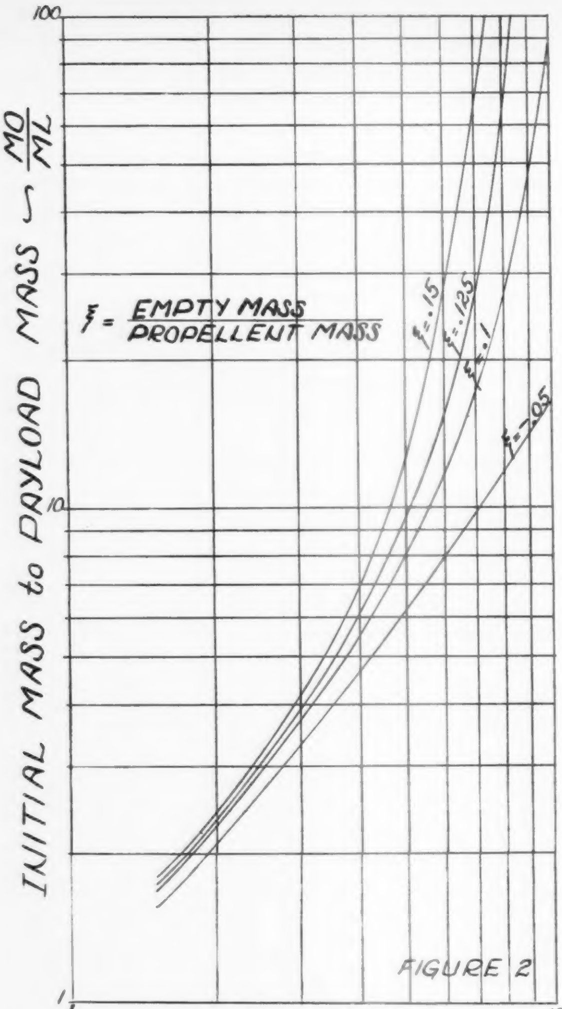
(1) Assume an arbitrary mass ratio and ratio of empty to propellant mass for a reference propellant combination (assumed here to be liquid oxygen-gasoline).

(2) For these values, calculate the ratio of initial to payload mass.

(3) Calculate the ratio of initial to payload mass for a different propellant combination, assuming that the stage mass ratio remains constant—i.e., that the change in propellant mass is equaled by an adjustment of payload mass.

In the following investigation of propellant requirements, two combinations are considered—liquid oxy-





gen-gasoline which is used in most available engines, especially the high thrust ones, and liquid oxygen - liquid hydrogen which is typical of the high energy combinations.

The following list of assumptions completes the groundwork necessary to evaluate the propellant requirements:

(1) Manned stage:

(a) $M = 1.5$.

(b) $\xi = 1.5$ (assumed with liquid oxygen-gasoline propellant combination).

(c) $I = 0.9$ of theoretical in vacuum (assuming 20:1 nozzle expansion ratio and 300 psi chamber pressure).

(2) Intermediate stages operating above atmosphere:

(a) $\xi = 0.1$ with liquid oxygen-gasoline.

$\xi = 0.125$ with liquid oxygen - liquid hydrogen.

(b) $I = 0.9$ of theoretical in vacuum (assuming 20:1 nozzle expansion ratio and 300 psi chamber pressure).

(3) First stage:

(a) $\xi = 0.1$ with liquid oxygen-gasoline.

$\xi = 0.125$ liquid oxygen - liquid hydrogen.

(b) $I = 0.85$ of theoretical in vacuum (assuming 8:1 nozzle expansion ratio and 500 psi chamber pressure).

The assumptions concerning the values of specific impulse, nozzle expansion ratio, and chamber pressure result in the values shown in Table 1.

The expansion ratios and chamber pressures were chosen arbitrarily but are representative of current practice.

First, the propellant requirements of the stages required to deliver the manned stage into the approximate orbit will be studied. Referring to Fig. 1, it is evident that a velocity potential of 29,400 ft./sec. could not be accomplished by one stage since, even if the upper stage impulse is assumed, the required mass ratios would result in final acceleration values greater than 9.0 (about 20 and 10 for liquid oxygen-gasoline and liquid oxygen-hydrogen, respectively). However, a two-stage vehicle using either combination will suffice.

The ratios of initial to payload mass were calculated for the two combinations—from Eq. (2)—using the values of empty to propellant mass ratios previously assumed. The results are tabulated in Table 2.

The most significant result from Table 2 is that the liquid oxygen-gasoline propellant combination is capable of fulfilling the velocity potential and maximum acceleration requirements. The engineering-economic considerations become paramount and result in a decision to use the liquid oxygen-gasoline combination for these two stages at least. This is indicated because available large engines which could be used to power these stages use gasoline as fuel. A new propulsion system would have to be developed and propellant manufacturing facilities expanded if hydrogen were to be used in a system of this size. This approach would be much more costly and would require a longer development time than would adaptation of existing propulsion systems (engineering/economic profile items 2, 3, 4, 5, 11, and 13).

The values shown in Table 2 for liquid oxygen - liquid hydrogen are of interest chiefly to indicate the reductions possible in the initial launch weight by the use of higher energy propellants. It is seen that the use of liquid hydrogen would reduce the initial vehicle launch

Table 1

	Liquid Oxygen-Gasoline	Liquid Oxygen-Liquid Hydrogen
Manned stage	295	405
Intermediate stages	295	405
First stage	262	357

Table 2

	Liquid Oxygen-Gasoline	Liquid Oxygen - Liquid Hydrogen
Stage mass ratio	5.1	3.3
m_0/m_1 first stage	8.65	4.63
m_0/m_1 second stage	8.65	4.63
Overall m_0/m_1	75.0	21.3
Maximum acceleration	7.65	4.95

weight from about 75,000 to 21,300 lbs. to deliver a manned stage of 1,000 lbs. weight (at sea level) into the space station orbit.

More latitude is available in the propellant choice for the manned stage because of the smaller thrust level required. At least preliminary development has been accomplished on engines using high energy propellants, and existing propellant manufacturing facilities could meet the requirements.

The value of the initial to payload mass ratio of the manned stage can be calculated for both the liquid oxygen-gasoline and liquid oxygen - liquid hydrogen combinations from Eq. (3); these are found to be about 6.0 and 4.8, respectively. This comparison asumes that the same overall mass ratio of 1.5 is used in each case and that the difference in propellant mass is equaled by an increase in payload—about 25 per cent in this case.

The manned stage initial to payload mass ratio can be combined with that of first and second stage, and calculations can be made to illustrate the magnitude of thrust and weights (referred to launch conditions) required to deliver two values of payload to a space station. These are tabulated in Table 3.

Comparing first the case in which equal payloads are delivered, it is noted that the improvement in the manned stage initial to payload ratio results in a 20 per cent reduction in weight in all of the stages. Thus the extra cost of development of a small upper stage using a high energy propellant probably would result in a lower overall system cost because of the weight and cost reductions which could be realized in the lower, more costly stages. Alternately, the design could be based on the conventional propellant and could then convert to the high energy propellant when the propulsion system development was completed. This would mean a parallel development and adaptation program of a high energy and conventional propellant engine system. The latter is the safer course of action because, if the new system did not meet expectations, the mission could still be accomplished by the conventional system. The converse is not true.

The remainder of the propulsion system requirements—provide attitude control of vehicle (item 3), start under vacuum and zero gravity condition (item 4), and provide thrust control capability (item 5)—do not present any major, unsolved problems.

A choice of different means of providing vehicle attitude control is available—gimballing of the engines, jet vanes, and jetavators. The first is preferred because it is the most developed and reliable system. The requirement of two or more engines per stage is easily met.

The vacuum start requirement is not nearly as formidable as the start at a zero gravity condition. Here, again, a number of alternatives are available. Small solid propellant rockets could be used to provide an extremely low level of acceleration to ensure positive feed of propellants to the engines. Alternatively, the exhaust from a gas generator/turbine unit, used to drive the propellant pumps or electrical generating system, could provide the small force required. In the manned stage, where the propellant mass is small compared with the vehicle mass, the use of low chamber pressure engines which are fed directly from positive expulsion tanks appears advantageous. An additional advantage would be realized with this feature—the starting reliability of a pressurized tank feed system is usually greater than that of the turbopump feed system which would otherwise be employed.

TABLE 3

	Liquid Oxygen-Gasoline	Liquid Oxygen - Liquid Hydrogen	
Assumed payload weight,* lbs.	1,000	1,000	1,250
Manned stage, m_0/m_1	6.0	4.8	6.0
Manned-stage initial weight,* lbs.	6,000	4,800	6,000
Manned-stage thrust, lbs.	7,800	6,250	7,800
Second stage, m_0/m_1	8.65	8.65	8.65
Second-stage initial weight,* lbs.	52,000	41,500	52,000
Second-stage thrust, lbs.	76,500	54,000	67,500
First stage, m_0/m_1	8.65	8.65	8.65
First-stage initial weight,* lbs.	450,000	360,000	450,000
First-stage thrust, lbs.	675,000	525,000	675,000

* Values at g_e = 32.2 ft./sec.^{2}.

The thrust control required to minimize deviations from the desired trajectory caused by thrust and specific impulse tolerances is small, on the order of ±7 per cent. Most engines have a thrust level controller with this range of control available. Although normally set manually on the ground, it could readily be made controllable during flight.

Summary of General Propulsion System Features

In summary, the principal features and parameters of a typical propulsion system which would be capable of propelling a booster vehicle for space flight in the near future are:

(1) A multistaged chemical rocket propulsion system and vehicle will be used.

(2) It will utilize liquid oxygen-gasoline propellants in all stages at first, with eventual replacement in the manned stage by a high energy propellant combination such as liquid oxygen - liquid hydrogen.

(3) The engine thrust level will be such as to provide an initial thrust to weight ratio of about 1.5 in the first stage and 1.3 in the upper stages.

(4) It will have at least two gimballed engines per stage providing attitude control, with possibly as many as four in the first stage.

(5) A moderate amount of thrust control, approximately ±7 per cent, will be provided to correct for normal thrust and specific impulse tolerances.

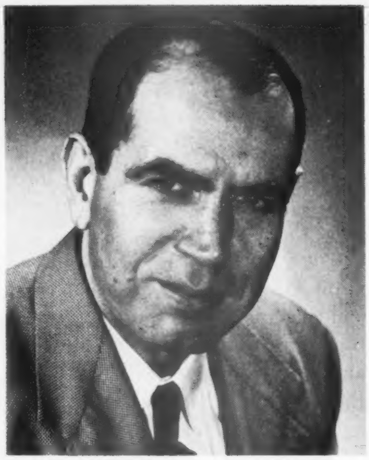
(6) The upper stage engines will be characterized by higher nozzle expansion ratios than are found on the first stage, with values of 20:1 or greater used in the manned stage.

(7) A positive expulsion pressurized tank feed system will provide propellants directly to thrust chambers operating at low chamber pressure in the manned stage.

(*Continued on page 51*)

Realistic evaluation can be accomplished by qualified personnel through the use of suitably directed conversations, which are readily combined with normal day-to-day activities.

How to Evaluate Engineers



Frederick L. Ryder
Research Engineer

Stephen X., the chief engineer of a medium-sized engineering staff, has chosen the various department heads under him largely on the basis of their education and experience. He occasionally gets the impression that, though of comparable background, these men seem to demonstrate strong differences of ability, both in the technical execution of their work and in their handling of subordinate personnel; however, he is reluctant to accept this fact, because it conflicts with his unconscious assumption that men of similar background have roughly similar abilities. Thus, when disagreements arise among the department heads in the normal course of the work he tends to attach equal weight to their different opinions, so that his decisions reflect the *average* rather than the *best* thinking of the group—with mediocrity of achievement as the inevitable consequence. Gradually the better men who are impatient with poor achievement leave for other positions, and the staff settles into mediocrity.

The above example is all too representative of the consequences of inadequate evaluation of engineers. The difficulty usually lies in a naive approach to the problem of evaluation in which reliance is placed on the following two methods:

(1) The engineer's experience and background is assessed.

(2) His actual contributions over a period of time are evaluated.

As to (1) it is a matter of common experience, and has been concluded in at least one systematic study,[1] that there is poor correlation between an engineer's actual ability and readily identifiable factors in his experience and background such as grades in school, type of work previously done, level of positions previously held, etc. This fact must be faced squarely if engineer evaluation is to improve.

Turning to (2), we might expect that it would be easy to achieve reliable evaluation by simply noting the degree of success of each engineer's work as time goes on. However, consider the following practical difficulties:

Engineering projects generally go on for relatively long periods of time, so that it is usually impractical to defer the evaluation of an engineer until his work is fully consummated and can therefore be evaluated in a relatively objective manner.

Most engineering projects involve relatively complicated problems whose solution represents the cooperative effort of various persons, so that it requires considerable judgment and technical insight to identify and isolate the contributions of different individuals.

The fact that a project is or is not satisfactorily completed within a given time estimate has only superficial significance in an evaluation of the engineering effort. One must be able to judge how difficult of achievement the project was and how reasonable the time estimate in view of difficulties (or lack of them) encountered in the course of the work. Also, how does the final solution of the problem compare to the best which can reasonably be expected?

Therefore, the evaluation of the work of an individual by noting his actual contributions is not at all straightforward and, in particular, requires considerable judgment and technical insight. The fact that much evaluation is being done by administrators without adequate technical background, ability, and interest constitutes a serious limitation on engineering progress.

Dr. Ryder is a Member, Scientific Research Staff, Republic Aviation Corporation; however, the opinions expressed in this paper are his own and do not necessarily reflect the principles and practices of Republic.

The author wishes to thank Dr. Paul C. Buchanan, Industrial Psychologist at Republic Aviation Corporation, for helpful criticism during the preparation of this paper.

An incidental result of the difficulty of direct evaluation is to place open to question the evaluation of an engineer by his former associates, unless these are specifically known to have reliable judgment.

A Practical Method of Engineer Evaluation

Since an engineer cannot be evaluated by merely noting his background and experience and since his individual contributions are difficult to isolate and often require a long time for final consummation, a more reliable and practical method of evaluation is necessary. The method to be proposed is one which is followed intuitively by many people, so that it is only necessary to describe explicitly what is already being done unconsciously on a large scale. The method can be stated very generally as follows:

By means of suitably directed day-in and day-out conversations with the engineer in the normal course of business, determine what are his abilities and limitations (not to be confused with his actual contributions); these will normally be indicative of his future achievement.

The remainder of this paper describes in detail how this method can be carried out. We shall deal separately with the three broad categories of technical skill, personal temperament, and practical judgment which have previously been shown[2, 3, 4] to determine overall engineering ability, and we shall give examples of how these can be explored by suitably directed conversation.

Components of Technical Skill and Their Evaluation

It will be found useful to divide technical skill into two major components.

Encyclopedic Knowledge

As its name implies, this consists of information which in general cannot be deduced by reason but must be learned from others and from textbooks. It may be said to consist of two parts:

(1) *Understanding of fundamental physical laws and phenomena* such as Ampere's law of the relationship between electric current and magnetic flux; or the equation of state of a gas relating its pressure, volume, and temperature.

(2) *Knowledge of practical applications* such as conventional television circuitry, or standard practice in structural joint construction.

Problem-Solving Ability

This is the ability to apply encyclopedic knowledge to the successful solution of practical engineering problems. It may be thought of as comprising the following:

(1) *Analytic ability.* This enables the engineer to distinguish between the important and unimportant aspects of a problem; to formulate the desired results in a realistic manner; to idealize the conditions of the problem so that they can be expressed in a manageable form, whether mathematical or verbal; and to interpret the idealized solution in practical physical terms. An important component of analytic ability is the ability to reach technical conclusions by intuition, without the aid of explicit detailed argument. While often lacking reliability, intuitive conclusions are nevertheless useful in that they are very fast, and serve to establish useful directions for systematic analysis.

(2) *Creative ability.* This has to do with ingenuity and inventiveness, without which analytic ability alone, however strong, is rather barren. Most new successful devices and methods in engineering are not "inventions" by Patent Office standards, but they nevertheless represent a creative use of well-known fundamentals and principles to achieve some given result.

Examples of Evaluation of Technical Skill

Consider the case of Henry W., who is devising the circuitry for an electromechanical bombsight computer which will determine the correct aircraft attitude and bomb-release time required for the bomb to strike the target. In conversation with the evaluator, Henry is led to describe the behavior of various components of his circuitry in terms of basic electrical and mechanical fundamentals and to show how the overall circuit meets the various system requirements, as deduced by him in impressive detail from the rather general and somewhat vague wording in which the project needs were originally described. Thus his knowledge of fundamentals and his analytic ability are proven to be excellent. Further probing reveals that his knowledge of conventional design practice in such computers is very limited, which may lead to some difficulty in specifying the various components in such a manner that procurement is convenient and economical. He can, however, remedy this difficulty rather easily by studying appropriate manufacturers' catalogues.

The evaluator then tactfully directs the conversation to show whether or not Henry has been ingenious in achieving design economy within the limitations imposed by the computer requirements. (A typical economy might be to replace a component which generates the trigonometric function $\sin x$ by a function which generates kx, where the maximum magnitude of x is sufficiently small and k is chosen to get the best match between the two functions over the range of operation.) Unfortunately, Henry seems to have overlooked this phase of the work, and is at a loss for ideas which might form the basis for the desired economy. The evaluator explains the importance of design economy, and makes a mental note to check the progress of Henry's thinking in this direction in the future.

As another example consider Martin E., who has a good reputation as a practical engineer who can get things done in the field of control instrumentation. Conversation with Martin reveals that he is in intimate touch with conventional practice and has considerable creative ability in that he is rarely at a loss for an approach to a problem. However, it turns out under tactful probing that he does not adequately comprehend such basic things as simple electrical circuit analysis or the relationships between current and flux and between flux and voltage in a transformer, so that his knowledge of fundamentals is poor. Further, he demonstrates poor analytic ability in distinguishing the particular requirements of a specific job from conventional requirements. Hence he cannot contribute strongly to an unconventional assignment, or to one where critical analysis leading to optimization is important.

Another example of the evaluation of technical skill through conversation, in the form of an actual dialogue between the evaluator and an applicant for an engineering position, has been given in a previous paper.[2]

Personal Temperament and Its Evaluation

Psychologists have made a considerable study of the manner in which an individual's personality traits evolve under the dynamic conditions of his environment and of the ways in which they interact to govern his behavior. For simplicity, however, the present discussion is limited to a brief description of certain traits, considered separately, which are of direct interest in engineering work, together with suggestions as to how they can be recognized in practice. No specific evaluation conversations are given, but it is felt that these can be readily generated as needed to meet particular situations if the general picture of personality traits is reasonably well understood. In fact, such understanding will often permit evaluations to be made by merely listening to and observing the individuals in question, since most people are either unaware of their own personality traits or else find it difficult to conceal them should they desire to do so.

It is generally ineffective and often dangerous to attempt to improve the personality of others under the usual conditions prevailing in an engineering office. This is a long-range job for a psychologist.

Initiative—This determines the degree to which an individual is "self-starting." For example, Fred Y. is a young engineer who has been asked by his superior to study a transformer manufacturer's rather complicated catalog, so that he may relay the information to others in an efficient manner. Although not lacking in purely technical understanding, he is at a loss as to how to proceed and must be guided closely by his superior, even to the point of recognizing the necessity for learning the code system which is used in the catalog to classify the different types of transformers.

Speed—In engineering, as elsewhere, people normally have different rates of speed of accomplishment; some may work naturally and comfortably at a pace which to others seems an agonizing crawl, while some reach useful conclusions by rapid intuitive or analytic processes. In most lines of engineering endeavor, as for example in development or design, progress consists of the execution of a large mass of details, so that speed is just as important an ingredient of productivity as in other fields. However, except in routine work, the measurement of speed cannot be done objectively but requires considerable judgment to take into account the difficulty of the task accomplished.

Thoroughness—Harold Z. is charged with the development of a machine for cutting three-dimensional maps of selected portions of the earth's surface out of plaster. Harold insists on making a very complete theoretical analysis of all aspects of the machine before venturing to recommend an overall layout, in spite of the fact that time limitations do not permit such completeness of analysis. Harold's excessive thoroughness is recognized by his superior, who replaces him by Frank T.

Frank finds the problem of the general layout of the device fascinating and accomplishes it rapidly but loses interest when the time comes for supervising detail design. As a result, unnecessary troubles which are directly traceable to inadequate thoroughness in detail design develop in the working model. Evaluation of Frank's attitude toward detail design could have resulted in a prediction of this difficulty.

Explicitness—Roy W. is discussing the resistance to the passage of wire rope over a pulley in a hoisting block. He speaks in terms of the coefficient of "rolling friction" of different pulleys and feels no need to mention explicitly that this coefficient is a mathematical fiction invented to take into account the total pulley resistance due to all causes including mechanical hysteresis and rubbing in the wire strands due to bending, as well as rubbing between the shaft and journal of the pulley bearing, although he is well acquainted with these phenomena. As a result of the vagueness of his discussion, the possibilities for decrease of the resistance by suitable redesign are not clearly apparent to others who might be able to contribute in this direction. Another result is to force his superior to ask laboriously pointed and detailed questions if he wishes to assure himself that Roy really knows what he is talking about.

Ability to Profit by Criticism—John R., a skillful and experienced designer of complicated automatic machinery, is proud of his ability to the point where he resents discussion of his work by his colleagues and tends to interpret their comments as destructive criticism. Hence he is not in a good position to consider these comments with a view to extracting whatever useful suggestions they may contain and incorporating them in his work.

Another result of John's undue pride or sensitivity is a fear of appearing incompetent by admitting a lack of understanding of ideas which he believes, often erroneously, are clear to others. This deters him from asking those "stupid questions" which are so useful in clarifying engineering discussions.

Open-Mindedness—The most common and important obstacle to open-mindedness among engineers is an exaggerated attachment to the particular concepts and methods with which they have developed a familiarity and a corresponding tendency to derogate unfamiliar practices. For example, in explaining a new electrical analog computer for the direct simulation of statically loaded structures without the explicit derivation of the governing equations, a speaker had considerable difficulty in convincing personnel familiar with conventional analog computers, which solve explicitly derived equations, that the new computer was significantly different.

Two specific forms of the above general type of prejudice are: (1) the feeling by many engineers of limited mathematical ability that the systematic use of mathematics in engineering analysis is "long-hair" and not really practical; and (2) the lack of appreciation on the part of many electrical engineers of the importance and difficulty of good mechanical design.

Self-Interest vs. Group Interest—An engineer's self-interest, involving such things as job satisfaction, friendly surroundings, and advancement in pay and position, is often best served by the same behavior which is best for the interests of the group of which he is a part, namely, by doing his work to the best of his ability, and interpreting his job so that it includes cooperating with others on technical matters as well as maintaining good social relationships with them. There are in general two classes of reasons why people may fail to act in the above manner.

(1) Because of personal temperament some engineers are hostile toward their colleagues or to management and hence cooperate grudgingly, if at all, with their colleagues or do as little on the job as they think management will accept; or they may have feelings of insecurity and try to strengthen their position by not sharing their technical results with others and by jealously guarding whatever authority they have been granted.

(2) Some may deliberately scheme to advance their own interests without regard to the interests of the group. This is usually done by building favorable personal relationships without regard to, and often at the expense of, technical values—in other words, office politics.

Adaptability—No matter how successful management is in distributing the work to suit the various interests and inclinations of individual engineers, it is still often necessary for the latter to work on assignments which may be distasteful to them. For example, those interested primarily in conceiving and executing "hardware" may be called on to do such paper work as system study, or report writing. Those interested mainly in initiating new ideas may become involved in the detailed fulfillment of those ideas. Those desiring to specialize in, say, electronics, may find that they must learn something about mechanical design problems in connection with the packaging of their equipment.

The more limited a management is in the choice of assignments, the more must engineering evaluation concern itself with the greatly varying ability or willingness of individual engineers to adapt their efforts to work requirements which are not in their main line of interest and specialization.

Practical Judgment and Its Evaluation

Certain detailed aspects of engineering are almost exclusively technical in nature—as for example finding the stresses in a structure under given applied loads, or finding the currents in an electrical network subjected to given voltages. However, as problems become less specific and more general, conditions arise where practical judgment, which is the ability to deal with situations not subject to rigorous quantitative analysis, is required. For example, in laying out the instruments and controls in an airplane cockpit one must be able to evaluate different proposed layouts with regard to the complicated and sometimes intangible functions which the pilot must perform.

We shall give two fictitious but representative examples of conversations in which an engineer's practical judgment is evaluated by his superior, together with conclusions drawn from each conversation. Because of the brevity and narrow scope of the examples the conclusions must be regarded as tentative.

John X., an engineering supervisor, has attended a meeting at which an airborne navigational device has been described to himself and to two members of his staff—namely, Charles A. and Walter B. When attached to a conventional navigation system in which the numerical values of latitude and longitude are continuously computed and displayed, the device generates a display in which the aircraft is represented as a red dot which continuously moves across the face of a map, thus giving a pictorial indication of the aircraft's position. John wishes to determine the preliminary opinion of his associates as to the possible use of the device in a future fighter aircraft with whose design they are engaged. He therefore discusses the matter with each of them in turn, taking the opportunity to evaluate the general soundness of their thinking as he does so.

Conversation With Charles A.

John X.—Can we talk a little bit about the pictorial navigation display?

Charles A.—Sure thing. Quite a gadget, isn't it? Should make life a lot easier for the pilot when he has his navigator's hat on.

John X.—What about the additional errors introduced? You know the navigation error even without the device can be pretty sizeable.

Charles A.—Well, it's part of the price you have to pay for improved presentation. Think how much the pilot would appreciate it—provided it doesn't push something else out of the cockpit that he needs more.

John X.—That's exactly the point. We know the pilot will get a better navigation display, but is it *enough* better to justify the extra cost, weight, space, the additional errors, etc.? Suppose we were to investigate this thing very seriously—is there some logical way we can take all these factors into account and come out with the correct decision?

Charles A.—The way I see it, if the errors are not too large and if you can get the thing into the cockpit without knocking something else out, and if the cost is not prohibitively large—why not put it in? After all, it *will* help the pilot.

John X.—O.K., Charlie, we'll go on the basis that we're definitely interested in the device, and we'll prepare a detailed study of how to work the thing into the cockpit. (To himself: I can see Charlie understands that this thing has many disadvantages along with its improved display, but apparently his mind is not sufficiently organized to suggest a systematic method of determining whether the disadvantages outweigh the advantage.)

Conversation With Walter B.

John X.—Well, what do you think of the pictorial navigation display?

Walter B.—It's certainly an interesting device, and leads to many questions. For example, how much will the new display really help under practical conditions? How much of a penalty do we have to accept in relocating other cockpit instruments to make room for this device? What about the weight, cost, and reliability of the thing? Et cetera, et cetera.

John X.—What do you suggest we would have to do to investigate this thing seriously?

Walter B.—I suppose the most logical thing would be to sit down and make a list of all the factors involved and then try to evaluate them. Maybe we can get ideas of the real usefulness of the device by talking to pilots. From the manufacturer I'm sure we can get data on cost, size, weight, accuracy, special installation requirements, and if we are very lucky, reliability. Then we'd have to take a good look at the cockpit and see how badly the overall layout would be affected.

John X.—How do you propose to measure all these different factors? Some of them may be rather intangible.

Walter B.—Well, if necessary we can assign numerical values which denote the net advantage or disadvantage of each of the different factors and then add everything up to see whether positive or negative overall advantage results from putting in the device. But probably this won't be necessary—after we get our data together the correct decision may be clear to the intuition.

John X.—O.K., we'll start getting our data together. (To himself: This fellow is plenty sharp, and practical too. Maybe I should use him more on difficult decisions.)

Factors to Be Ignored in Evaluation

Since true evaluation is difficult, there is a strong tendency to replace it by evaluation based on factors which are obvious but which, unfortunately, are not directly indicative of engineering ability. These factors are often evaluated unconsciously, in which case the evaluation may be affected by attitudes and indoctrinations of which the evaluator is unaware. The following are typical:

General Appearance. There is often an unconscious tendency to favor men of tall and impressive build and Anglo-Saxon appearance.

Facility of Expression. An engineer who can talk skillfully on general matters may impress a naive evaluator favorably even though he lacks the specific qualifications for practical engineering achievement.

Social Category. This includes the engineer's background and schooling (whether "Ivy League" or not), the social position and appearance of his wife, the economic and social acceptability of his residence and neighborhood, and the way he uses his leisure time (for higher positions a golfer or fisherman would be preferred to a chess enthusiast).

Popularity. At the present time many evaluators will unfortunately favor a man who achieves popularity by being careful not to voice a decisive disagreement with others, whereas the man who will agressively seek technical achievement even though it entails clearly stated disagreement with his associates may fail to advance as rapidly as he should.

So long as evaluation is based on such factors as the above, it is inevitable that some engineers should strive to improve their position by deliberately exploiting these factors rather than by straightforward technical achievement.

Conclusion

The lack of systematic evaluation, or, what is perhaps worse, evaluation based on superficial and nonindicative factors, constitutes an important limitation on the effective utilization of engineers. Proper evaluation should rely on the determination of the engineer's abilities and limitations in the areas of technical skill, personal temperament, and practical judgment, for these abilities and limitations will usually furnish the best available indication of his future achievement. This method of evaluation is actually practiced widely at the present time, but quite often without the evaluator's explicit awareness and without an appreciation of the strength and versatility of the method.

The evaluation of abilities can be done within the framework of the numerous conversations which form part of the regular activities of an engineering office. The tactful yet searching direction of these conversations so as to elicit indicative responses by the evaluee places a heavy burden on the evaluator, who must himself have good technical insight and practical judgment, as well as sound personal temperament, plus the ability to express himself with facility on both details and generalities, and the ability to draw different people out and to appreciate their different mental processes and reactions. He must also not be misled by nonpertinent factors such as the popularity of the evaluee and his leisure-time interests.

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Booster Propulsion for Space Vehicles (Continued from page 45)

CONCLUSIONS

(1) It is possible to provide a propulsion system for a "booster" vehicle for space flight, designed for flight between the earth and a permanent satellite space station, at the current state-of-the-art.

(2) A large potential exists for further improvement through research and development activity.

(3) Future research and development effort will probably include the following areas:

(a) Improve the reliability of the propulsion system in general.

(b) Additional development of a high energy propellant propulsion system for the upper stage or stages.

(c) Additional development of positive expulsion pressurized tank feed systems for use with small thrust engines.

(d) Development of larger first-stage engines to permit the design of larger vehicles than now possible, without the necessity of using a number of engines which are excessive from a reliability consideration.

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NOTICE

Consistent with the general trend of Institute coverage, beginning with the July issue, the *Journal of the Aeronautical Sciences* will be known as:

JOURNAL OF THE AERO/SPACE SCIENCES

The human and organizational requirements that have had to be met in preparation for the introduction of the first jet transport into United States scheduled air carrier service.

300 Days to Jet Time

Carl M. Christenson
United Air Lines, Inc.

It appears that each 15 years of scheduled air carrier progress gives us sufficient confidence in the state of the arts, the sciences, and the economics of our business to project the next phase of development into the persistent orbit of reality. The confidence with which we proceed will be the self-sustaining courage of our conviction and the courage of sympathetic men within our system of free enterprise based on the sure and certain record of our accomplishments. As in the past, this new era will be borne on the strong broad shoulders of successful men in business, finance, science, engineering, manufacturing, and operations—the same men who are the keystone of our vast military experience.

The arts and sciences should know no single application in our free world even though the degree and scope be subject to the prudence of national security. We must recognize that the success of our nation's airlines is as much a part of this national security as the ICBM because air commerce is a fundamental part of our social and economic way of life. One day history will further recognize it as the key of the communication which helped to resolve the problems of free men, free trade, and the leveling of the political and religious philosophies which create the uneasy peace in which we live.

Courage of conviction is not always conducive to being first when it comes to developing the products of science and engineering into usable tools of industry, particularly in the public services. As we gain confidence in the state of the arts and sciences to the end that we can find an even balance between safe operation and economic operation of a new airplane, then we in this country must look to free enterprise for the financial support to place the airplane in operation.

The fact remains that the operating companies have supported their statement of conviction by pledging some 2 billions of dollars for new equipment and facilities with which to usher our industry into the turbine-engine era of scheduled transportation. This investment by free men bears with it the prestige of this nation in the competition for domestic and international air commerce. Consequently it is not only a matter of business at home but one of vast national and international importance. Thus the implications of this great decision become clear.

We will soon begin testing the wisdom of our judgment. We are not the least bit interested in introducing the turbine transport as a scientific test of skill, as a "sputnik" to orbit the world of commerce only to lose speed and fall to its destruction through an unfriendly atmosphere of scientific, engineering, and operating uncertainty. On the contrary, we are resolved that, through the logical and orderly solution of the problems associated with the turbine transport, the introduction will be the first smooth step in its safe and economic operation throughout its fleet history.

When the Wright brothers first flew, only two men were directly and vitally concerned with the project. In this phase of aviation history, hardly a person or organization within it can escape a partial responsibility for its success. An airplane and its operation today are so complex in nature that it is difficult to single out the interrelations of responsibility. So this is not a job for a single company or a single person but one for the aviation industry of the United States, including the governments of our many states and territories and the federal Government.

If these thoughts are reasonable, then we may well ask ourselves this question: How best can we as individuals, as an industry, and as responsible government, without stifling the prerogatives of open competition, use these next few days to ensure the success of this, our greatest step in progress?

The Man

As in every business, aviation is severely demanding of leadership and organization. These demands increase with size and complication. They become crucial in the periods of great expansion in the presence of tough competition and tight economic situations. All three of these situations exist today, and there is every evidence that they will continue for the next few years.

Updated and revised exclusively for this issue of *Aero/Space Engineering* from the paper of the same title presented at the Flight Safety Session, IAS 26th Annual Meeting, N.Y., Jan. 27–30, 1958.

The author is Director of Flight Safety.

Where severe demands exist in respect to business, the associated government agencies must, of necessity, recognize these same factors and gear their thinking, planning, and action to them. This dictates that the divergent opinions which may exist in business and government must be brought under severe and critical scrutiny in order that timely solutions may be found.

In this respect we surely should review our organized effort in the critical problem areas to ensure logical and expeditious handling. Within the operating company, or the manufacturing company, or in the government agencies, this means placing the organization on a level and in a frame of mind capable of handling and solving the basic requirements of the turbine-engine era.

Since every organization is composed of individuals, it follows that each individual has a job to do. An organization can plan, train, and provide, but it remains for the individual to do his job in a safe, orderly, and effective manner. This remains one of the great problems of leadership to be completely solved. It appears that the most effective approach is through the many fruitful methods and techniques of indoctrination directed toward creating the desire to exercise the essential personal disciplines necessary to our business. We cannot forget, however, that personal discipline cannot exist under, or within, an organization which has no discipline.

The demands of aviation have placed great demands on individual selection for the job and training. In the past 20 years we have searched diligently through the efforts of the many related human sciences for the ideal solution of these problems. Frankly we do not, as yet, have all the answers to the problems of character, initiative, ingenuity, adaptability, capacity, and perseverance. But we do know that a qualified individual can be led and trained in a manner which will ensure a long and successful career on the job in any phase of this business.

In respect to the man then, we may well direct our efforts toward answering these questions:

(1) Are the key men within our organization equipped through training, indoctrination, and inspiration for the job of planning, leading, and executing the decisions created by the demands of the next 10 years?

(2) Is our organization developed in a clean, clear-cut manner which lends itself to sound leadership, logical decisions, and safe economic operation?

(3) Have we planned and developed our training so that our management can manage, our people can work, and the entire effort can be directed to objectives and success of the operation?

(4) Do we understand the principles of organizational and personal discipline well enough to maintain them at a safe and consistent level?

The answers to these questions will not be found by superficial examination because they are often submerged in those intangible human relations which defy casual observation or thought or personal communication. While answering these questions, we should bear in mind the evolution of our business and the records of our past operations.

The Medium

The medium in which we will operate has been explored and measuredi n terms of the standard atmosphere. We know the approximate deviations from the standard to the extent that we have designed the airplane with reasonable intelligence and are in a position to plan reasonably for the variety of conditions which will exist in normal operation. Through the efforts of the men of science and medicine, dealing with every thing from the psyche to the mechanics of the human animal, we are rather well informed on the problems of the medium and the man with respect to his ability to control the machine intelligently while operating within it.

This does not mean that we have no problems. We still are unable to anticipate the whims of this restless gaseous medium to the extent that we can operate with positive regularity or that we can measure, in flight, certain dimensions necessary to safety and economics. These problem areas are well known but worth repeating. They fall into these categories:

Forecasting

(1) Upper-air forecasts: We are making progress in our ability to forecast those factors necessary to long-range flight planning—particularly the presence, extent, and location of the jet stream.

(2) Weather forecasts: We have made little progress beyond 85 per cent accuracy in relation to upper air, weather, winds, or terminal conditions. The two basic problems still are clear air turbulence and terminal forecasts.

Measurement

(1) The basic problem is the accurate measurement of static pressure which is critically important to altitude separation and to automatic data transfer from the airplane to the ground for the requirements of separation and air traffic control.

(2) Temperature measurement: We probably can determine air temperature to the precision required to fly the jet stream effectively and determine accurate air speed.

(3) We have been unable to measure any form of energy (in a practical way which will inform the pilot) generated by dry air turbulence.

(4) We have not developed the devices necessary to measure the changes occurring in a local area which define the situation with sufficient accuracy for departure or termination.

(5) We have been unable to measure the energy requirements or determine the processes by which we can control the development of fog or low clouds.

Radar has provided a means of avoiding the most insidious of the weather phenomena. The current developments of approach and runway lighting will do much to relieve the low visibility operation.

In respect to the medium, we may well ask these questions:

Characteristics of the Medium

(1) Have we compressed our knowledge of the medium into usable and workable information for the people who have to operate and maintain the airplane?

(2) Are we prepared to provide the basic training of our flight crews in respect to the characteristics of high-altitude flight in regard to perception and decompression?

(3) Are we prepared to forecast on the basis of safe and economic operation?

(4) What are we going to do about accurate terminal forecasting?

Measurement

(1) Will accurate and adequate runway temperature measurement be available?

(2) Will runway visual range equipment be installed on the critical airports?

(3) Will the air data systems installed in the airplanes be reliable and accurate?

(4) Can we depend on the required cooperation between civil operators and the military to ensure accuracy of altimetry, or will it be necessary to make it mandatory by regulation that all aircraft operating in common airspace be equipped with altimetry accurate within ± 100 ft. at all altitudes within which common operations occur through the speed range of the airplane at those altitudes?

(5) How can we obtain agreement within the industry to adopt constant reference or QNE altimetry setting for all cruise altitudes?

These are but a few of the basic questions related to the medium with which we are to be confronted during the next 10 years. It is true that we know a lot about the medium, but our great need is to learn how to anticipate the capricious nature of it and, above all, direct much more time, money, and effort to the science and research necessary for its control.

The Machine and Its Operation

Here we will take a little license with the Flight Safety Foundation's three Big M's and add an O for operation. The vast difference between man and the machine is that man, not God, is responsible for its origin. Consequently, we can expect that, from the time of conception, to birth, on through to maturity of certification and experienced operation, we will find frailties of the man expressed in the frailties of the machine. Never before in our history have we had the benefit of the advances in the state of the arts and sciences—coupled with long military experience—upon which to base the logic of design, manufacture, and preparation for operations.

We are not probing the unknown—we are extending our present operations to a comfortable and conservative design and performance envelope. However, we cannot assume that this is "just another airplane." The jet transport is another breed of cat as far as the scheduled air carriers are concerned. Up to a cer ain point, it can be controlled in flight in much the same way as the more advanced piston-engine aircraft, and perhaps the maintenance is much the same. The important point is that, if we are to operate the jet transport with the degree of efficiency, safety, and regularity necessary to make the operation economically sound, then the similarities cease to exist. Based on the existing average cost, weight, speed, and people, this is so by a factor of approximately twice the cost, twice the weight, twice the speed, and twice the people.

In retrospect, the introduction of previous types of transport aircraft has been marred by technical problems related mostly to detail design—particularly the interrelation of systems and accessory equipment—and our inability to ascertain the end results of these problems. It is essential that the basic philosophies of design and control be carried on through the basic training of all personnel using or maintaining the equipment. In other words, we must learn to fly and maintain the equipment the way in which it is designed and built to be operated. Detailing the important elements of the training program then becomes a major responsibility of the manufacturer and requires an extremely close liaison among the engineering, flight test, certification, and service organizations through which the training curriculums are developed. The operator in turn has the responsibility of maintaining the integrity of these things through flight and maintenance training.

Coupled with a thorough knowledge of the airplane and the ability to control it is the vast area of supporting facilities required to operate this new equipment safely and efficiently. The two outstanding problems confronting us are airports and traffic control. It is going to take a lot of doing on the part of all concerned to solve these problems by 1960 when jet operations will be getting into full swing.

It is important that we make it clear that these problems are recognized by all concerned, but they are going to require that decisions be made promptly and that diverse interests be put aside.

The most fortunate development in the past 3 years is the progress which has been made in both the CAA 5-year program and the recommendations of the Curtis Report. For the first time in over 10 years we now have a well-organized and properly financed program designed to resolve several basic problems related to both airports and traffic control. Close observation of the activities of both the Airways Modernization Board and the CAA cannot help but create a feeling of high confidence, and I would like to congratulate them on aggressive progress based on a practical operations and systems analysis of these problems designed to expedite the recovery from the sad state of affairs which existed 3 years ago. What they need is constructive advice and support from everyone in the industry.

In many cases we tend to ask for many things from responsible government agencies without properly stating the needs and requirements; this is the responsibility of the user agencies of both civil and military aviation. Our greatest need at this time is to end the open controversies and competition for the airspace and traffic control within it by the many segments of this industry. The air carriers, general aviation, and the military all have basic and legitimate claims on this common resource, but we cannot find equitable solutions to these claims by continuing arguments in public press and in public meeting or by boycotting meetings established to resolve them.

Closely associated with the solution of these problems are the costs of them and the desire and willingness to control our operations within the limitations of the system as it exists. This requires a careful balance between the use of the system and the progressive development of it, and it means patience and forbearance on the part of everyone in the business. Perhaps the policy we can follow is to apply a consistent, but moderate, pressure to the system to ensure development, governing the pressure by close liaison with the capability and the capacity of it.

In respect to the machine and its operation, we may well search for the answers to these questions:

(1) Are the Civil Air Regulations which will govern both certification and operations complete and of sufficient clarity that we can properly apply them?

(2) Have we developed the interpretation of the regulations in such a manner that we are clear on the intent, as well as the specific requirements of them?

(3) How many regulations have we developed in the name of safety which are means to other ends or which are created for the pure purpose of regulation and will evolve into simple economic penalties?

(4) Will we have a clear understanding of the characteristics of our airplanes, and will this understanding become an essential part of our training programs?

(5) Will the training manuals and the material contained in them be accurate, pertain to the airplane which will be operated, and be ready in time for the final training courses?

(6) Will we have searched, through a coordinated program, the problems of systems and accessory failures, their effects on the control of the airplane, and, in particular, their effect on other systems?

(7) Are we prepared to state the needs of the airplane in respect to airports and the traffic control system?

(8) Are we clear as to how we will operate the airplane within the limitations of the traffic control system?

(9) Have we organized our flight planning program to the extent that we can provide the crew with the information required for a safe and economic operation?

(10) How are we going to handle alternate operations?

(11) Are we prepared to handle any emergency which will involve up to 150 people and 15,000 gal. of jet fuel?

(12) Have we prepared a check list of those things which experience has taught us will give us trouble, as well as those items required for normal operation?

We have long taught our flight crews to use a check list before take-off and during flight. We can emulate this by the preparation of such a list before the maiden flight into the turbine-engine era. The questions listed here are by no means complete but suggest areas where we might take a long hard look; they are questions which have been before the United Air Lines Turbine Engine Coordinating Committee for over 2 years.

There is no doubt about the tremendous effort which is being made by everyone in the industry to ensure a safe and orderly transition to the turbine-engine era. There are well-organized programs in effect in practically all segments of the industry. This determined interest appears to stem from the realization of the tremendous economic investment, of the pride of accomplishment, and of the great national prestige at stake. The purpose here is to suggest that during the important days ahead we take time to walk out from among the trees to a high hill to take a good thorough look at the forest.

Author's Note: Since these thoughts were originally expressed in New York, 150 days have gone by.

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... current literature of aeronautical engineering and space technology

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Behavior of the Node of an Elastic Beam During Stationary Vibration. Seiichi Higuchi and Kazukiyo Iinuma. *Franklin Inst. J.*, Apr., 1958, pp. 309–315. Presentation of photographs of the movements of the node and its neighboring points in an elastic beam at the time of stationary vibration.

Aeronautics, General

Special Issue: A Review of Canada's Aircraft Industry. *Aircraft* (Canada), Mar., 1958, pp. 15–88, 118–122. *Partial Contents:* A Report on the State of the Canadian Aircraft Industry, R. G. Halford. Canadian Built Aero Engines. A Cross Section View of Canada's Aircraft Industry. Research & Development. A Rare Bird—the Sparrow.

Retour sur les Principaux Avions et Engins Spéciaux Présentés en 1957 à Farnborough. G. Bruner. *Docaéro*, Mar., 1958, pp. 11–28. In French. Survey of aircraft and special propulsion-system types presented at Farnborough in 1957.

Published Reports and Memoranda of the Aeronautical Research Council. *Gt. Brit., ARC R&M 2850* (Nov., 1957) 1958. 6 pp. BIS, New York, $0.45.

L'Astronautica. Glauco Partel. *Riv. Aero.*, Apr., 1958, pp. 491–529. In Italian. Historical survey of astronautical development covering various types of vehicles, propulsion systems, and weapons, as well as satellites, their orbits and instrumentation, and biological problems of interplanetary navigation.

Air Transportation

Luftverkehr mit Überschall. Derek Harvey. *Flug-Revue*, Apr., 1958, pp. 9–11, 32. In German. Discussion of structural, operational, and economic aspects of supersonic air transportation.

Airplanes

Das Mittelstreckenverkehrsflugzeug Boeing 720. F. A. Maxam. *Flugwelt*, Apr., 1958, pp. 228–230. In German. Description of the medium-range Boeing 720 aircraft, including details of structure, power plants, fuel system, electric and hydraulic equipment, navigational aids, air conditioning and pressurization, and deicing systems.

Lockheed F-104 Starfighter. G. W. Heumann. *Flug-Revue*, Apr., 1958, pp. 22–25. In German. Presentation of data on the Lockheed F-104 Starfighter and discussion of its development and military role.

(*Continued on page 82*)

INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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PUBLISHED MONTHLY BY AERO/SPACE ENGINEERING

Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 3, Number 7

July, 1958

ACOUSTICS, SOUND, NOISE

ACOUSTIC RADIATION FROM ISOTROPIC TURBULENCE. W. C. Meecham and G. W. Ford. ASA J., Apr., 1958, pp. 318-322. Army-supported extension of Lighthill's work for low Mach Number turbulence which expresses the acoustic radiation of turbulent fluid in terms of a fourth-order velocity correlation. Through the use of the Navier-Stokes equation the relation is put in terms of the space-time pressure correlation. For very large Reynolds Number turbulence (in the inertial subrange where Kolmogoroff's similarity principles are valid), the pressure correlation is written in terms of a function of a single variable. Using the similarity result and Lighthill's formulation the acoustic self-noise power spectrum is obtained.

ACOUSTIC STREAMING NEAR A BOUNDARY. W. L. Nyborg. ASA J., Apr., 1958, pp. 329-339. 27 refs. OSR-sponsored development of an approximate solution for sonically-induced steady flow near a fluid-solid interface. The result is valid, subject to stated conditions, for the flow near any portion of surface in the vicinity of which the irrotational oscillatory velocity distribution u_a is known. The principal condition of validity is that the acoustic boundary layer parameter $(\nu/\omega)^{\frac{1}{2}}$ (where ω is the angular frequency and ν is the kinematic viscosity coefficient for the fluid) should be small compared to the scale of u_a. The conclusion is reached that small compressible bodies, and especially resonant gas bubbles, resting on boundaries, are likely sites of pronounced microstreaming in a sound field.

AERODYNAMICS

Aerothermodynamics

ON THE CALCULATION OF EDDY VISCOSITY AND OF HEAT TRANSFER IN A TURBULENT BOUNDARY LAYER ON A FLAT SURFACE. D. E. Bourne and D. R. Davies. Quart. J. Mech. & Appl. Math., May, 1958, pp. 223-234. 10 refs. Analysis in which the following is assumed to be known: (a) the main stream velocity and plate temperature, (b) empirical formulas for the distribution of surface shearing stress and temperature in the laminar and transition sublayers, and (c) the mean velocity in the fully turbulent, transition, and laminar layers. A similarity law for the distribution of mean velocity in the fully turbulent layer is calculated from empirical formulas, and is used in an integration of the boundary layer equations of mean flows. This enables the distribution of Reynolds shearing stress and of eddy viscosity to be calculated. The distribution of eddy heat diffusivity is then available, using Reynolds analogy, and the method of calculation developed recently by Davies and Bourne is applied to evaluate rates of heat transfer in the case of air. These calculated values are found to be in reasonable agreement with measured values given by Elias.

HEAT TRANSFER FROM SURFACES OF NON-UNIFORM TEMPERATURE. D. B. Spalding. J. Fluid Mech., May, 1958, pp. 22-32. 18 refs. Calculation of steady heat transfer from a surface of arbitrary temperature distribution to a laminar semi-infinite stream of arbitrary velocity distribution. An alternative correction reducing the error of the Lighthill method to 2.5%, regardless of pressure gradient, is described. A method of integrating the differential equations representing the growth of the thermal and velocity boundary-layer thickness, and the procedure giving the total heat transfer rate, are described. The calculation of the shear force distribution is discussed. The effects of pressure gradient and Prandtl Number on the rate of growth of the thermal boundary layer can be described by a single curvature parameter.

ANALYSIS OF TURBULENT FLOW AND HEAT TRANSFER ON A FLAT PLATE AT HIGH MACH NUMBERS WITH VARIABLE FLUID PROPERTIES.

R. G. Deissler and A. L. Loeffler, Jr. US, NACA TN 4262, Apr., 1958. 61 pp. 33 refs. Extension of a previous analysis on a turbulent heat transfer and flow in smooth passages to the case of flow over a flat plate at high Mach Numbers. Velocity and temperature distributions are calculated for a boundary layer in which the effects of both frictional heating and external heat transfer are appreciable. The viscosity and thermal conductivity are assumed to vary as a power of the temperature, while the Prandtl Number and specific heat are taken as constant. Skin-friction and heat-transfer coefficients are calculated and compared with the incompressible values. The relation between boundary layer thickness and distance along the plate is obtained for various Mach Numbers.

EFFECTS OF MACH NUMBER AND WALL-TEMPERATURE RATIO ON TURBULENT HEAT TRANSFER AT MACH NUMBERS FROM 3 TO 5. Thorval Tendeland. US, NACA TN 4236, Apr., 1958. 46 pp. 19 refs. Evaluation of heat-transfer data from temperature time histories measured on a cooled cylindrical model with a cone-shaped nose and with turbulent flow. The experimental data is compared with calculated values using a modified Reynolds analogy between skin friction and heat transfer. Theoretical skin-friction coefficients are calculated using the method of Van Driest and the method of Sommer and Short. The heat-transfer data obtained from the model is found to correlate when the T' method of Sommer and Short is used. The increase in turbulent heat-transfer rate with a reduction in wall to free-stream temperature ratio is of the same order of magnitude as has been found for the turbulent skin-friction coefficient.

STAGNATION-POINT HEAT TRANSFER TO BLUNT SHAPES IN HYPERSONIC FLIGHT, INCLUDING EFFECTS OF YAW. A. J. Eggers, Jr., Frederick Hansen, and B. E. Cunningham. US, NACA TN 4229, Apr., 1958. 54 pp. 19 refs. Development of an approximate theory for predicting the rate of heat transfer, emphasizing the case where wall temperature is small compared to stagnation temperature. The theoretical heat-transfer rate at the stagnation point of a hemispherical body is found to agree with available experimental data. The effect of yaw on heat transfer to a cylindrical stagnation region is treated at some length, and it is predicted that large yaw should cause sizable reductions in heat-transfer rate.

Boundary Layer

NOUVELLE METHODE APPROCHEE DE CALCUL DES COUCHES LIMITES LAMINAIRE ET TURBULENTE EN ECOULEMENT COMPRESSIBLE; CAS D'UN GRADIENT DE PRESSION; PARTICULARITES - EXEMPLES. Alfred Walz. France, Min. de l'Air PST 336, 1957. 48 pp. 11 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 900. In French. Development of a new approximate method for the calculation of laminar and turbulent boundary layers in compressible flow. The study of the boundary layer in the vicinity of a separation point leads to the derivation of simple relations for the boundary-layer thickness and profile parameters. The relationship between the derived parameters and such values as the thickness and friction coefficient is established. Numerical examples include: (a) verification of criteria for the turbulent separation in the case of an NACA profile; (b) general analysis of the eventual separation of laminar and turbulent boundary layers with pressure gradient due to the interaction of a shock wave; and (c) calculation of the boundary layer and of friction coefficients for a rocket with a given external velocity profile.

APLICAREA METODEI PROFILELOR TIP DE VITEZE ŞI TEMPERATURI LA CALCULUL STRATULUI LIMITĂ DE PE UN CORP DE REVOLUŢIE. St. Săvulescu. Stud. Cerc. Mec. Aplic., No. 4, 1957, pp. 975-982. In Rumanian, with summaries in French and Russian. Extension of the method for calculating the two-dimensional boundary-layer characteristics to the three-dimensional case of bodies of revolution. The case of a laminar compressible boundary layer with mass transfer from a cylinder is also considered.

APPLICAZIONE DEI METODI INTEGRALI ALLO STUDIO DEI MOTI DISSIPATIVI LAMINARI DI MISCELE BINARIE IN ASSENZA DI REAZIONI CHIMICHE. Amilcare Pozzi. (15th Natl. Aerotech. Congr., Cagliari, Sept. 25-29, 1957.) L'Aerotecnica, Dec., 1957, pp. 311-320. 13 refs. In Italian. Presentation of a method for studying the laminar motion of a nonreacting binary gas mixture. The equations determining the boundary layer with fluid injection and the mixing of two nonreacting gases are derived on the basis of an extension of the Prandtl boundary-layer theory. The equations are integrated, introducing polynomial expressions for velocity, mass concentration, and stagnation enthalpy profiles. The investigation covers general boundary conditions.

EFFECTS OF FIXING BOUNDARY-LAYER TRANSITION FOR AN UNSWEPT-WING MODEL AND AN EVALUATION OF POROUS TUNNEL-WALL INTERFERENCE FOR MACH NUMBERS FROM 0.60 TO 1.40. L. S. Stivers, Jr., and G. W. Lippmann. US, NACA TN 4228, Apr., 1958. 37 pp. 10 refs. Investigation showing that the effects of fixing transition are very pronounced on the pitching-moment and lift curve slopes at transonic Mach Numbers, but were small at Mach Numbers above about 1.15. For the fixed-transition condition the variations with Mach Number of the pitching-moment and lift curve slopes are much smoother than for the free-transition condition. Within the range of the test Reynolds Numbers the effects of fixing transition remained qualitatively the same. The results indicate that, for tests at transonic Mach Numbers of scale models with unswept wings, it is important to fix transition at locations corresponding to those expected in flight. An evaluation is also made on the interference of porous walls in a transonic wind tunnel utilizing the fixed-transition data for the different-sized models.

THE SMALLEST HEIGHT OF ROUGHNESS CAPABLE OF AFFECTING BOUNDARY-LAYER TRANSITION IN LOW-SPEED FLOW. A. M. O. Smith and D. W. Clutter. Douglas Rep. ES-26803, Aug. 31, 1957. 116 pp. 31 refs. Determination of the critical roughness height over a large range of Reynolds Numbers, and establishment of a method for correlating the critical roughness heights with flow parameters. Critical heights for three types of roughnesses are found; these are two-dimensional, three-dimensional, and the sandpaper type. A comparison of four experimental methods of locating transition are made, and all are found to be in satisfactory agreement. Results show that the effect of critical roughness on transition is primarily a function of the roughness Reynolds Number, with its value depending greatly on shape. The two-dimensional roughness introduces larger disturbances than the three-dimensional and is, therefore, more critical.

TURBULENT SHEARING STRESS IN THE BOUNDARY LAYER OF YAWED FLAT PLATES. Harry Ashkenas. US, NACA TN 4140, Apr., 1958. 58 pp. 15 refs. Presentation of hot-wire anemometer measurements of the turbulent shearing stress for plates with angles of yaw of 0° and 45°. Measurements of the intensity of turbulence were made simultaneously with the shear measurements. The measured velocity profiles are used to calculate the shear distribution and the result is compared with that of experimental shear measurements. The unyawed flat-plate data agree well with the calculated results, whereas the 45° data are apparently not amenable to calculation.

Control Surfaces

LIMITES D'APPLICATIONS DE LA THEORIE DE LA LIGNE PORTANTE AU CALCUL D'AILES D'AVIONS MUNIES DE SPOILERS. André Fauquet. France, Min. de l'Air BST 120, 1957. 73 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 1,500. In French. Experimental investigation to determine the limits of application of the lifting line theory to the calculation of wings with spoilers. Previously obtained results on lift, drag, and rolling and yawing moment of rectangular wings are extended to cover smaller aspect ratios and spoilers located nearer the leading edge. Aspect ratios of 5, 4, and 3 are used and the distances between the spoiler and the leading edge are 10%, 20%, 30% 40%, 60%, and 80% of the chord. It is shown that the two quantities used in the previous calculation (the ratio of the lift coefficient variation and the profile drag) are modified by the presence of the spoiler and vary with incidence. A comparison of experimental results, including the pitching moment not covered by the theory, with those of theoretical calculations is made.

Flow of Fluids

METHODES THEORIQUES D'ETUDE DES ECOULEMENTS SUPERSONIQUES. P. Carrière. France, Min. de l'Air PST 339, 1957. 236 pp. 28 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 3,000. In French. Development of the theory and methods for the calculation of nonviscous supersonic flows based on the method of characteristics. Includes review of the one-dimensional theory, shock-wave theory, study of plane flows by Busemann's method, general method of characteristics applied to rotating flows, and study of boundary conditions in epicycloid coordinates. Application to plane, conical, and rotating flows (air intakes and nozzles, in particular) is also included. Tables and diagrams are provided for the numerical calculation.

ON THE NON-LINEAR MECHANICS OF HYDRODYNAMIC STABILITY. J. T. Stuart. J. Fluid Mech., May, 1958, pp. 1-21. 19 refs. Study of the mechanics of disturbance growth under supercritical conditions in Poiseuille flow between parallel planes, and in flow between rotating cylinders. The nonlinear terms of the equations of motion are discussed, and the connection between linear and nonlinear instability theories are clarified. Experiments show that, in the case of flow between rotating cylinders, the development of turbulence takes place fairly slowly as the Reynolds Number is raised. The distorted mean flow in the equilibrium state and the torque required to maintain the cylinders in motion can be calculated. The Reynolds stress is the fundamental consequence of nonlinearity. Measurements of the torque for the case when the inner cylinder rotates and the outer cylinder is at rest show good agreement.

CALCULATIONS OF UNSTEADY VISCOUS FLOW PAST A CIRCULAR CYLINDER. R. B. Payne. J. Fluid Mech., May, 1958, pp. 81-86. Method using a step-by-step integration of Helmholtz's vorticity equation to calculate the starting flow past a cylinder for Reynolds Numbers 40 and 100. The vorticity generated at the cylinder is transported towards the rear stagnation point inducing a reversed flow on the cylinder. The general features of the flow, including the formation of the eddies attached to the rear of the cylinder, are determined, and the drag calculated. At the two Reynolds Numbers the starting flow is similar, except that vorticity for $R = 40$ is spread over a larger area than for $R = 100$.

INCOMPRESSIBLE FLOW PAST QUASI-CYLINDRICAL BODIES AND SOME ASSOCIATED PROBLEMS. L. E. Fraenkel. Quart. J. Mech. & Appl. Math., May, 1958, pp. 212-222. Presentation of a method for calculating the incompressible flow past slender bodies of revolution with discontinuous profile slope at zero incidence. The problem is reduced to the study of a cylindrical harmonic $G_1(x, r)$, whose normal derivative on a cylinder of unit radius is $\pm 1/2$. More general boundary conditions are satisfied by superposition. This function is used to derive a first approximation solution for bodies of discontinuous profile slope.

EXPERIMENTAL STUDY OF THE EQUIVALENCE OF TRANSONIC FLOW ABOUT SLENDER CONE-CYLINDERS OF CIRCULAR AND ELLIPTIC CROSS SECTION. Appendix - WIND-TUNNEL INTERFERENCE AT TRANSONIC MACH NUMBERS. W. A. Page. US, NACA TN 4233, Apr., 1958. 45 pp. 21 refs. Experimental evaluation of the transonic slender-body theory for the case of a flat, winglike, elliptic cone-cylinder and of a circular cone-cylinder. It is determined that the flow about the two models is closely related in the manner predicted by the theory, the relationship persisting over a Mach Number range of 0.92 to 1.05. It is shown that the lifting forces on the elliptic cone-cylinder vary linearly only over the small angle-of-attack range of approximately $\pm 1^\circ$, and that the aerodynamic loading at sonic speed compares favorably with Jones' slender-wing theory. Results indicate that at transonic speeds and at small angles of attack the calculation of all aerodynamic characteristics of slender, three-dimensional shapes can be made by use of transonic slender-body theory when the pressures of the equivalent body are known.

THE PARABOLOID OF REVOLUTION IN SUBSONIC FLOW. M. D. Van Dyke. J. Math. & Phys., Apr., 1958, pp. 38-51. 19 refs. Analysis of the flow using three different methods: (1) second-order small-disturbance theory, (2) second-order slender-body theory, and (3) the Janzen-Rayleigh expansion in powers of M^2, including terms of M^2 and $(\gamma + 1)M^4$. Advantage is taken of the interconnections between these three different approximations. Unlike the small disturbance or slender-body series, the Janzen-Rayleigh expansion is uniformly valid throughout the flow field, being in fact most accurate near the stagnation point. It therefore complements the other two approximations. All three methods are believed to converge only for purely subsonic flow.

EXPERIMENTAL INVESTIGATION OF THE DRAG OF FLAT PLATES AND CYLINDERS IN THE SLIPSTREAM OF A HOVERING ROTOR. J. W. McKee and R. L. Naeseth. US, NACA TN 4239, Apr., 1958. 42 pp. Experimental study of the drag of flat plates and cylinders in the slipstream of a rotor for the condition of hovering away from the effect of the ground. Models as large as one with an area equal to 0.212 rotor disk area and a span equal to the rotor diameter were tested in a range of distances from the rotor of 0.10 to 1.33 rotor radii. Models tested and the test procedure used are described. Results indicate that the drag for locations closer than one-quarter rotor radius is dependent on total energy in the slipstream rather than on the dynamic pressure. At distances greater than one-quarter rotor radius, the model drag is mainly determined by the summation of the product of incremental area and dynamic pressure, the higher drag effects shown for wider chord models and for models spanning the rotor disk being unexplained.

SCURGEREA SUPERSONICĂ OMOGENĂ DE ORDIN SUPERIOR ÎN JURUL UNEI ARIPI UNGHIULARE PREVĂZUTĂ CU PLACĂ NORMALĂ. Elie Carafoli and Béatrice Horovitz. Stud. Cerc. Mec. Aplic., No. 4, 1957, pp. 959-974. 10 refs. In Rumanian, with summaries in French and Russian. Study of the supersonic flow around a triangular wing within the limits of the theory of higher order homogeneous motions. The problem is reduced to the derivation of the expression for the axial component of the turbulent velocity on the wing and the plate. The Euler formula is used and the case of second-order homogeneous flow around a cruciform wing is treated to illustrate the application.

FRAGMENTATION OF WATERDROPS IN THE ZONE BEHIND AN AIR SHOCK. Appendix A - LOSS OF WATER PER UNIT TIME FROM THE MOVING BOUNDARY LAYER. Appendix B - FLATTENING OF THE WATERDROP WITH TIME. Appendix C - TOTAL FORCE ACTING ON THE WATERDROP. O. G. Engel. J. Res., Mar., 1958, pp. 245-280. 24 refs. WADC-sponsored investigation made on the fragmentation of two waterdrop sizes after collision with air shocks which are moving at three different supersonic velocities. The results indicate that high-speed-rain-erosion damage should not be observed on spheres having a diameter as large as four feet and moving with a Mach Number in the range of 1.3 to 1.7 in rain that has a drop diameter of 1.4 mm. Waterdrops of this size should be reduced to mist in the zone of separation between the detached shock and the surface of the sphere according to the reported results. A means to extend this protection to spheres of smaller diameter or to rain of larger size is pointed out.

MAGNITNAIA GIDRODINAMIKA. V. M. El'zasser. Uspekhi Fiz. Nauk., Mar., 1958, pp. 529-588. 146 refs. In Russian. Study of magnetohydrodynamics covering the basic magnetic concepts, magnetohydrodynamic waves, turbulence and instability, formation of cosmic magnetic fields, secular variation of the Earth's magnetic field, paleomagnetism, solar and astral magnetism, and fields in the rarefied cosmic gas.

INTERACTION BETWEEN GRAVITATIONAL-CAPILLARY AND MAGNETOHYDRODYNAMIC WAVES. M. F. Shirokov. (Zhurnal Teoret. i Exper. Fiz., July, 1957, pp. 67-71.) Sov. Phys.-JETP, Jan., 1958, pp. 50-54. Translation. Demonstration of the uniqueness theorem for the solutions of the hydrodynamic equations for an incompressible strongly conducting ideal liquid. A procedure to determine the Walen solution for gravitational-capillary and magnetohydrodynamic waves is shown. Relations for the stability conditions and the penetration depth are derived for potential and vortex harmonic waves. It is shown that the strongest effect on the concentration of the potential magnetohydrodynamic waves in the surface layer is that due to the capillary forces, and that the current density for the potential surface waves is exactly zero.

MIXING AND CHEMICAL REACTION IN THE LAMINAR WAKE OF A FLAT PLATE. S. I. Cheng and A. A. Kovitz. J. Fluid Mech., May, 1958, pp. 64-80. 10 refs. OOR-sponsored solution of the problem using the boundary-layer approximation. The mixing without chemical reaction is solved in terms of a "universal solution" for a given initial temperature ratio and Prandtl Number from which the solution for arbitrary temperature ratios can be obtained. The mixing with chemical reaction is solved for the first two terms of an assumed series solution for the temperatures. Arbitrary constants are determined from boundary conditions. The axial distance from the trailing edge to the first local temperature maximum is given in terms of the initial conditions and is shown to be greatly shortened by the presence of the viscous wake as compared with nonviscous mixing.

HEAT TRANSFER TO A GAS-PHASE CHEMICAL REACTION. William Schotte. Ind. & Eng. Chem., Apr., 1958, pp. 683-690. 16 refs. Experimental and theoretical investigation to determine heat-transfer coefficients for flow with gas phase instantaneous reactions. Calculated effective thermal conductivities and effective specific heats are used in conventional heat-transfer correlations, and methods for obtaining these effective physical properties are described. Experimental work on heat transfer to dissociating nitrogen tetroxide shows good agreement between measured and predicted heat-transfer coefficients. Both laminar and turbulent flow regions are covered in the investigation.

ON THE EFFECTIVE FIELD IN A PLASMA. B. B. Kadomtsev. (Zhurnal Teoret. i Exper. Fiz., July, 1957, pp. 151-157.) Sov. Phys.-JETP, Jan., 1958, pp. 117-122. Translation. Computation of the effective field acting on charged particles in a plasma by using Bogoliubov's method. The triple function is expressed approximately in terms of binary ones. An expansion is introduced in establishing the connection between the effective and the average fields; only first order correction is considered. It is concluded that in a plasma the effective field coincides with the average field under the condition $nD^3 \gg 1$, n being the density of particles and D the Debye radius. In the equilibrium state a correlated electron "cloud" is formed near each ion. This "cloud" is displaced with respect to the ion, producing an additional field directed oppositely to the average field, when an electric field is applied.

TRANSPORT PHENOMENA IN A COMPLETELY IONIZED TWO-TEMPERATURE PLASMA. Appendix - CALCULATION OF MATRIX ELEMENTS. S. I. Braginskii. (Zhurnal Teoret. i Exper. Fiz., Aug., 1957, pp. 459-472.) Sov. Phys.-JETP, Feb., 1958, pp. 358-369. Translation. Presentation of a system of transport equations for a plasma consisting of electrons and one kind of positive ions placed in an electric and magnetic field. The system includes the continuity equations, equations of motion, and the equation of heat transport for electrons and ions. The case of arbitrary ratio of the particle collision frequency to the Larmor frequency is considered. The method given by Chapman and Cowling is somewhat modified to obtain a separate system of transport equations for each plasma component.

INTERACTION OF CYLINDRICAL SOUND WAVES WITH A STATIONARY SHOCK WAVE. W. R. Johnson and Otto Laporte. Phys. Fluids, Mar.-Apr., 1958, pp. 82-94. Investigation by a method analogous to that used by Weyl in the treatment of radio waves. The incident cylindrical sound wave is represented as a superposition of plane sound waves of varying direction. Each of the plane waves in this superposition interacts with the shock giving rise to a previously determined distortion of the shock front and a reflected or refracted wave field; the cylindrical wave causes a disturbance which may be written in integral form as a superposition of these plane waves. The resulting interaction integrals are evaluated asymptotically to give explicit formulas for the distortion of the shock, the sound field, and the entropy-vorticity wave.

TRANSITIONAL CORRECTION TO THE DRAG OF A SPHERE IN FREE MOLECULE FLOW. R. M. L. Baker, Jr., and A. F. Charwat. Phys. Fluids, Mar.-Apr., 1958, pp. 73-81. 16 refs. Analysis of the mechanics of collisions between molecules in front of a sphere moving at hypervelocity through a rarefied atmosphere. The study is concerned with the "transitional" regime in which molecules emitted by the surface begin to shield the body from the oncoming Newtonian stream and the net drag decreases from its free-molecular value. It is found that a simplified but physically significant model can be formulated, and that it leads to a dependence of the drag coefficient on two transition parameters. These can be interpreted as the Reynolds Number and the surface-to-free-stream temperature ratio. The predictions of the theory agree qualitatively and in order of magnitude with observations.

OBSERVATIONS OF TURBULENT-BURST GEOMETRY AND GROWTH IN SUPERSONIC FLOW. C. S. James. US, NACA TN 4235, Apr., 1958. 85 pp. 13 refs. Study in which some aspects of the mechanics of boundary-layer transition have been deduced from a shadowgraph study of free-flight models at free stream Mach Numbers between 2.7 and 10. That part of the transition process between the first appearance of turbulence vortices and the end result of continuously turbulent flow is found to occur in supersonic flow in a manner closely similar to its observed occurrence in subsonic flow. Minute spots, or bursts, of turbulence form near the leading edge and are swept aft. The rates at which these bursts form and grow are found to vary gradually with Mach Number, unit Reynolds Number, and surface roughness.

INTERAZIONE TURBOLENTA DI DUE CORRENTI COSTITUITE DA GAS DIVERSI. L. G. Napolitano. (15th Natl. Aerotech. Congr., Cagliari, Sept. 25-29, 1957.) L'Aerotecnica, Dec., 1957, pp. 301-310. 12 refs. In Italian. Determination of the turbulent mixing of two streams of different gases. It is shown that the problem can be reduced to the solution of an ordinary differential equation. Two series solutions are given for the case where the density profile is a quadratic function of the velocity profile. The first three terms of both series are given in analytical and tabulated form. The accuracy of the solution is checked against some exact solutions obtained on an electronic computer.

ON THE DECAY OF HOMOGENEOUS TURBULENCE BEFORE THE FINAL PERIOD. R. G. Deissler. Phys. Fluids, Mar.-Apr., 1958, pp. 111-121. 10 refs. Analysis using a three-point correlation equation to obtain a relation for the triple correlations applicable at times before the final period of decay. In this case the equation is made determinate by neglecting the quadruple correlations. The correlation equations are converted to spectral form by taking their Fourier transforms. Expressions are obtained for the energy transfer function, which describes the transfer of energy from large to small eddies, and for the energy spectrum function which gives the contributions of the various eddy sizes to the total energy. By integrating the energy spectrum over all wave numbers (or eddy sizes) a decay law is obtained. Comparison with experimental data indicates good agreement for times considerably before, as well as during, the final period.

Internal Flow

A THEORY OF THIN AIRFOILS, ISOLATED AND IN CASCADE, YIELDING FINITE PRESSURES AT SMOOTH LEADING EDGES. R. A. Fanti, N. H. Kemp, and E. N. Nilson. J. Aero / Space Sci., July, 1958, pp. 409-424. 20 refs. Description of a method, based on the complex variable approach, for finding a flow past arbitrary airfoils of small but finite thickness and camber. The application of a boundary condition [$v = u\ (dy/dx)$] somewhat different from the classical one [$v = V\ (dy/dx)$] leads to an integral equation for the velocity distribution, which, when solved by iteration, yields results which compare well with exact solutions. In particular, this boundary condition avoids the leading edge singularities which occur when the classical condition is used. It is shown that for a given airfoil the solution of one singular integral equation will give the velocity distribution at all angles of attack with good accuracy, even near the leading edge.

SOME FURTHER RESULTS ON THE BENARD PROBLEM. W. H. Reid and D. L. Harris. Phys. Fluids, Mar.-Apr., 1958, pp. 102-110. 12 refs. Extension of the exact solution of the sixth-order differential equation which governs the stability of a viscous fluid contained between two rigid walls and heated from below to include detailed results on the curve of neutral stability and the cell pattern at the onset of instability. Two approximate methods of solution are then discussed which employ a Fourier or Fourier-type expansion and which require the solution of a fourth- or a second-order differential equation. Comparison with the exact solution indicates the Fourier expansion method has a better accuracy than the Fourier-type expansion.

AN APPROXIMATE METHOD FOR DESIGN OR ANALYSIS OF TWO-DIMENSIONAL SUBSONIC-FLOW PASSAGES. Appendix A, B - DERIVATION OF VELOCITY EQUATION. Appendix C - CONSTRUCTION OF PRECOMPUTED CHART FOR SELECTED UPSTREAM MACH NUMBER. Appendix D - DETERMINATION OF AN AVERAGE RADIUS OF CURVATURE. E. F. Valentine. US, NACA TN 4261, Apr., 1958. 38 pp. Development of a method for the design and analysis of two-dimensional subsonic-flow passages with isentropic nonviscous flow. The method is based on the relation between the pressure change across a stream tube and the centrifugal force resulting from the curvature of the flow. The method is limited by the accuracy with which the radius of curvature of the stream lines can be determined. In an example the method is applied to the design of an expanding elbow at each of two Mach Numbers. Two elbow contours and their surface pressure distribution are obtained.

SPREADING OF SUPERSONIC JETS FROM AXIALLY SYMMETRIC NOZZLES. C. J. Wang and J. B. Peterson. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, May, 1958, pp. 321-328. Formulation of the method of characteristics for computing the flow field, and presentation of the finite-difference characteristic equations, the machine programming, and the equations of the shock wave. Calculations of jets issuing from two types of nozzles at various Mach Numbers into a still or moving medium at a wide range of pressures are given. The numerical computation procedure is briefly described. Results show that an increase in the exit Mach Number, or in the Mach Number of the external stream, tends to decrease the jet divergence. At a fixed point relative to the nozzle, the gas density is maximum when the jet boundary passes through the point.

THE EFFECT OF SHOCK WAVES ON THE ISENTROPIC EFFICIENCY OF CONVERGENT - DIVERGENT NOZZLES. B. W. Martin and F. J. Bayley. RAeS J., May, 1958, pp. 377-382. Derivation of isentropic efficiency and discussion of the factors influencing it. It is shown that the pressure ratio for minimum efficiency increases from 0.528 at unit area ratio to 0.626 at infinite area ratio. The influence of the ratio of specific heats is given by an equation. A correlation with conditions for oblique and normal shock waves is made. The efficiency contour indicating the extent of different types of flow is represented graphically. Conclusions indicate that: (1) a normal shock within the divergent cone can bring about a lower nozzle isentropic efficiency than a normal shock standing at the nozzle outlet; (2) an oblique shock may give rise to a lower nozzle isentropic efficiency than a normal shock at the nozzle outlet.

TRANSONIC DRAG OF SEVERAL JET-NOISE SUPPRESSORS. W. J. North. US, NACA TN 4269, Apr., 1958. 34 pp. Description of tests conducted with one-fifth scale suppressors over a range of Mach Numbers from 0.65 to 1.10 and a range of nozzle pressure ratios from 1.0 to 6.0. Total and component drag coefficients for the various models are presented and the propulsive-thrust losses calculated. Results indicate that the eight-lobe nozzle with ejector caused the greatest drag. The cruise propulsive-thrust loss for the tube nozzle and the eight-lobe nozzle with ejector should be about 6 1/2% of the net thrust of the standard nozzle. The standard nozzle with ejector and the lobe nozzles cause a 3% or 4% loss.

Stability & Control

COMPARAISON DE QUELQUES METHODES D'ETUDES DE LA STABILITE TRANSVERSALE DANS LE CAS PARTICULIER D'UN PLANEUR A AILE DELTA. Michel Scherer and Simone Walden. La Recherche Aéronautique, Jan.-Feb., 1958, pp. 7-13. In French. Comparison of methods for studying transverse stability in the case of a delta wing glider. The response of the model to different degrees of sideslip was measured in a wind tunnel by means of the global method and then calculated from the linearized equations of motion. Includes evaluation of the global method; some extensions are indicated.

THE PRESENT STATUS OF AIRCRAFT STABILITY PROBLEMS IN THE AEROELASTIC DOMAIN. Appendix - ELASTIC-INERTIA COUPLING TERMS IN THE "SEMI-RIGID" EQUATIONS OF LONGITUDINAL MOTION OF A FLEXIBLE AIRCRAFT. A. S. Taylor. Gt. Brit., RAE TN Aero. 2538, Dec., 1957. 29 pp. 22 refs. Discussion of recent developments in the study of the effects of structural flexibility on aircraft stability and control emphasizing dynamic stability. Both theoretical and experimental work is reviewed to assess the importance of these effects and to establish how elaborate a mathematical treatment has to be in order to predict them with reasonable accuracy. The advantages of an integrated approach to this and associated aeroelastic problems, whereby the solutions to several related problems may be obtained as special cases of a more generalized problem, are described.

Wings & Airfoils

MINIMUM DRAG AT SUPERSONIC SPEEDS FOR CYLINDRICAL RING WINGS OF SPECIFIED VOLUME OR BASE AREA AT ZERO LIFT. R. M. Licher. Douglas Rep. SM-22995, Nov., 1957. 19 pp. 13 refs. Calculation of minimum drag of a constant chord wing for a given total volume in two cases: (a) a restricted optimum when no radial force is carried, and (b) the optimum when radial forces are allowed. Since this is a spatial configuration, there can be favorable interference between the thickness and radial force distributions, and it is shown that under some optimum conditions it is possible to have a ring wing with zero drag. The minimum drag for a given base area is also calculated for a ring wing, and it is shown that there is no interference drag between this and the previous cases.

A GEOMETRICAL PROBLEM RELATED TO THE OPTIMUM DISTRIBUTION OF LIFT ON A PLANAR WING IN SUPERSONIC FLOW. Appendix - THE AVAILABILITY OF THE OPTIMUM HAYES' CUTS AND THEIR ANALYTIC CONTINUATION. E. W. Graham. Douglas Rep. SM-23020, Nov., 1957. 18 pp. 19 refs. Analysis considering planar wings in which an explicit expression is derived for a lift or thickness distribution in terms of its known Hayes' projections and their analytic continuation. Emphasis is placed in finding optimum distributions of lift from their known projections.

CALCULATION OF OPTIMUM LIFT DISTRIBUTION FOR THE SONIC-EDGE DIAMOND PLANFORM WING FROM SPANWISE MOMENTS OBTAINED FROM THE CORRESPONDING ARTIFICIAL SINGULARITY DISTRIBUTION. B. J. Beane. Douglas Rep. SM-23017, Dec., 1957. 14 pp. Computation of the spanwise moments, up to the fourth moment, of the optimum lift distribution. The optimum loading is represented by a fourth-order polynomial which gives these known moments at every chordwise station. The lift distribution formed in this way is compared at a few points with that obtained by another method; they both agree. A graphical representation of the optimum local lift distribution and of the span loading obtained from the present method compares favorably with the known exact span loading.

APPROXIMATION OF OPTIMUM LIFT DISTRIBUTIONS FROM THEIR SPANWISE MOMENTS. E. W. Graham. Douglas Rep. SM-23021, Dec., 1957. 11 pp. 10 refs. Presentation of a method for approximating the optimum distribution of lift or volume for a planar wing using information contained in the solution of the potential flow problem. The artificial singularity distribution is employed, utilizing the Hayes' cuts (or projections of the optimum lift distribution) which must be the same as the known artificial distribution. The moments for the lift and the artificial distribution can be found by successive integration and differentiation.

NEUSTANOVIVSHIESIA DVIZHENIIA KRYLA KONECHNOGO RAZMAKHA V SZHIMAEMOI SREDE. E. A. Krasil'shchikova. AN SSSR Otd. Tekh. Nauk Izv., Mar., 1958, pp. 25-32. In Russian. Investigation of the turbulent motion of a compressible fluid due to transient motions of a thin finite-span wing. The solution of boundary problems is obtained by means of a method developed previously for the plane parallel transient case. Includes derivation of a solution for all types of transient wing motions when the basic velocity is supersonic and the end effect, as well as the effect of the eddy system in the region behind the wing, have no influence on its surface.

CALCULATION OF DERIVATIVES FOR A CROPPED DELTA WING WITH AN OSCILLATING CONSTANT-CHORD FLAP IN A SUPERSONIC AIR STREAM. J. Watson. Gt. Brit., ARC R&M 3059, 1958. 34 pp. BIS, New York, $2.16. Derivation of the lift, pitching, and hinge moments for a delta wing with trailing-edge flap of constant chord when the wing is at zero incidence in a supersonic air stream and the flap oscillates harmonically with small amplitude and low frequency. The aerodynamic coefficients for the case of a full-span control are calculated, and the extension to partial-span controls is given. The derivatives for the delta wing of aspect ratio 1.8 and taper ratio 1/7 with inboard or outboard controls are tabulated. The accuracy of the results and the ranges of Mach Number for which they apply are discussed. A graphical representation of the variation of the hinge-moment derivatives with frequency and of the derivatives with Mach Number is made.

REPARTITION DE PRESSION SUR UNE AILE DELTA A SECTIONS TRANSVERSALES ELLIPTIQUES. L. Cabot and J.-P. Guiraud. La Recherche Aéronautique, Jan.-Feb., 1958, pp. 3-5. In French. Comparison between the Jones-Ward theories and experiment covering the pressure distribution on a delta wing with 60° sweep, elliptical cross section, lenticular median profile of 10% relative thickness at $M = 1.1$ without incidence. The comparison includes results of the theory of homogeneous motion as well as the result of a correction rule, using the velocity values from the Jones-Ward theory in order to calculate the pressure coefficient C_p by means of the exact ratio of velocity and pressure in an isentropic flow.

AN EXTENSION OF THE LINEARIZED THEORY OF SUPERSONIC FLOW PAST QUASI-CYLINDRICAL BODIES, WITH APPLICATIONS TO WING-BODY INTERFERENCE. R. C. Lock. J. Fluid Mech., May, 1958, pp. 33-63. 15 refs. Development of a method allowing more rapid and accurate calculations to be made of the overall forces and moments acting on a restricted class of wings mounted on quasi-cylindrical bodies. Two examples applying this method are studied: (1) the effect of an arbitrary body distortion on static stability at supersonic speeds; (2) the effect of wing-body interference on rectangular wings mounted on a cylindrical body. The results for double wedge and biconvex parabolic sections are compared with those of the supersonic area rule. The numerical discrepancy in the total wave drag of the wings for aspect ratios covered by the present method is found to be small.

AEROELASTICITY

PRELIMINARY STUDY OF ATMOSPHERIC GUST CONDITIONS AT LOW ALTITUDE. J. O. Barrett. USAF WADC TR 57-253 [AD 142015], Oct., 1957. 92 pp. 18 refs. Establishment of data reduction techniques and test procedures for statistically evaluating the atmospheric turbulence found at low altitudes; both power spectral and probability analysis techniques were used on the data. Two basic methods for experimentally determining a power spectral density representation of gust vertical velocity are investigated. The first, a transfer function method, involves computing the output power spectrum of an aircraft response parameter and then removing the airplane dynamic response characteristics, using a theoretically computed transfer of frequency response function. The second method, a direct method, involves measuring the motions of the air relative to the aircraft and of the aircraft relative to the ground; gust velocity is the difference between these motions. The conclusions drawn indicate that the direct method, together with certain instrumentation and flight test techniques, can be used for statistically evaluating low altitude atmospheric turbulence.

EFFECT OF RIB FLEXIBILITY ON THE VIBRATION MODES OF A DELTA-WING AIRCRAFT. W. D. Kroll. J. Res., Apr., 1958, pp. 335-341. Study to determine the effect of decreasing the number of ribs or making the ribs more flexible on the vibration modes and frequencies of a delta-wing aircraft. The vibration modes and frequencies of the basic wing and of four modifications are computed. Results indicate that rib stiffness has little effect on the critical flutter speed of the delta-wing, and that modifications similar to those investigated would not appreciably affect the airplane's vibration characteristics.

AIRPLANES

AERODINAMICHESKAIA KOMPONOVKA SVERKHZVUKOVOGO SAMOLETA. R. I. Vinogradov and A. P. Bogdanov. Vestnik Vozdushnogo Flota, Apr., 1958, pp. 55-63. In Russian. Evaluation of various aerodynamic configurations for supersonic aircraft and discussion of the effect of design parameters in different velocity regimes, including the related drag problems. Presented are such types as the delta and arrow shaped wing aircraft, straight and disc shaped wings, jet wing, coleopters, and types with boundary layer control.

FUELS & LUBRICANTS

INFLUENCE DE LA TEMPERATURE ET DE LA PRESSION SUR LES DELAIS D'ALLUMAGE D'HYPERGOLS. H. Moutet, A. Moutet, and M. Barrère. France, ONERA NT 45, 1958. 22 pp. 12 refs. In French. Investigation of temperature and pressure effects on ignition delays of hypergolic fuels. Measurements are performed under conditions similar to those encountered during ignition in rocket combustion chambers at high altitude. Such parameters as pressure and temperature are studied separately and simultaneously on pure substances (xylidine, triethylamine, furfuryl alcohol) and mixtures. The evolution of chemical reactions preceding the ignition is also analyzed for various operating conditions.

INSTRUMENTS

THE DESIGN AND TESTING OF BAROMETRIC TYPE ABSOLUTE ALTIMETER WITH A ATMOSPHERIC TEMPERATURE CORRECTION MECHANISM. Lin Shih-Nge. Scientia Sinica, Jan., 1958, pp. 121-130. Theoretical discussion of the possibility of introducing an atmospheric temperature correcting mechanism into the ordinary altimeter to compensate for the error due to atmospheric temperature variations so that the altimeter can indicate the absolute altitude directly. A typical design for the barometric type absolute altimeter is presented. Flight testing results are given in tabular form. Results indicate that the error due to hysteresis and friction is considerably reduced and that the absolute altimeter readings coincide with the theoretically calculated values within an error of 3%.

NOTE SUR LES DEBITMETRES MASSIQUES ET LES METHODES DE MESURE IDIO ET HETERO-ENERGETIQUES. E. Gaignebet. La Recherche Aéronautique, Jan.-Feb., 1958, pp. 27-36. In French. Discussion covering the operation of mass flowmeters and methods for measuring separate and mixed energies. The advantages of an additional energy content for measuring the flow energy rate are shown, the principles underlying such a system are outlined, and some typical installations using the method are described.

MATERIALS

Nonmetallic Materials

CONSTITUTION DES COLLES ET PROPRIETE DES JOINTS COLLES. L. Doussin. France, ONERA NT 43, 1958. 18 pp. In French. Investigation (a) to determine the relationship between the properties of plastic materials used in the composition of phenolic-resin-based glues and the characteristics of glued joints, and (b) to derive the formulas for phenolic glues which harden at a temperature below 135°C. and under low pressure. Includes description of methods used in static and constant-load tests on metal-metal glued joints.

MECHANICS

TENSOR ANALYSIS OF FINITE ROTATIONS. I - POSITION-TENSOR TRANSFORMATIONS, AND APPLICATIONS TO AIRCRAFT MANOEUVRES. E. H. Bateman. Aircraft Eng., May, 1958, pp. 126-130. Method in which the orientation of a rigid body is described by a position-tensor, composed of three unit vector axes fixed in the body; rotation is effected by tensor transformations in which a rotational operator is a Cartesian matrix, formed from the coordinates of the pivotal axis and components of the angle of rotation; rotational sequences are represented by matrix products. Three practical applications are discussed: (1) sequences of aircraft maneuvers, which include composite rotations of roll and pitch, or roll, pitch, and yaw applied simultaneously; (2) the variation of sweep, incidence and dihedral of a wing moving on any axis fixed in the aircraft; (3) the direction of the pivot axis and the angle of rotation in the motion of a retractable undercarriage between two specified positions.

MISSILES

O RESHENII ODNOI VYROZHDENNOI VARIATSIONNOI ZADACHI I OPTIMAL'NOM POD'EME KOSMICHESKOI RAKETY. V. A. Egorov. Prikl. Mat. i Mekh., Jan.-Feb., 1958, pp. 16-26. In Russian. Derivation of a solution of the Mayer problem for Pfaff's equation used in the selection of a rocket trajectory for a given altitude and maximum speed. Includes formulation and evaluation of the problem, indication of the reducibility of such problems as optimum fuel consumption in the case of rectilinear motion, optimum trajectories in the vertical plane for finned bodies with a given thrust regime, and frictionless motion of a rocket along a specific acceleration path.

UNBEMANNTE FLUGKÖRPER. H. L. Hibbard. (AFZ Meeting, Stuttgart, Nov. 8, 1957.) Luftfahrttechnik, Apr. 15, 1958, pp. 98-103; Discussion, pp. 103, 104. In German. Discussion of problems created by the development of unmanned vehicles, in particular, aerodynamics and propulsion. Includes evaluation of the effect of high temperatures and velocities, trends in the rocket-propulsion development, and analysis of the magnetohydrodynamic theory.

GUIDANCE AND CONTROL PROBLEMS IN THE AIR FORCE BALLISTIC MISSILE PROGRAM. II. J. C. Fletcher. Aero / Space Eng., June, 1958, pp. 65-68, 71. Discussion on initial guidance problems, equipment design, and some future trends. The principal problem in inertial guidance is that of constructing a high-precision electromechanical system to measure on-board acceleration components. The three basic elements of the system are (1) accelerometers, (2) the gyro-stabilized platform, and (3) the computer. The accelerometers are characterized by three sources of error: variation in scale factor, zero drift, and linearity. The gyro stabilized platform can be characterized by its angular drift rate, which can be made primarily that of the stabilizing gyros to which the platform is tightly slaved. By careful consideration of accelerometers and gyros, a specific orientation of the platform can be chosen with respect to the applied average direction of thrust, which minimizes the effect of applied acceleration on the resultant miss distance.

NUCLEAR ENERGY

Propulsion

PERSPEKTIVY ISPOL'ZOVANIIA ATOMNOI ENERGII V GAZOTURBINNYKH SILOVYKH USTANOVKAKH ZAMKNUTOGO TSIKLA. A. I. Mikhailov. AN SSSR Otd. Tekh. Nauk Izv., Jan., 1958, pp. 113-119. 11 refs. In Russian. Discussion of possible applications of nuclear energy to closed-cycle gas-turbine power plants, including results of comparative analyses of a system with sodium cooling for the reactor when using helium, nitrogen, an carbonic acid gas as working fluid.

DIE EIGENSCHAFTEN VON WASSERSTOFF UND WASSER ALS ARBEITSGASE FÜR KERNENERGETISCH BEHEIZTE RAKETENTRIEBWERKE. Irene Sänger-Bredt. Astronautica Acta, Fasc. 4, 1957, pp. 241-280. 33 refs. In German. Experimental investigation of the properties of hydrogen and water vapor in terms of their application as working fluids in rockets. Enthalpy-entropy diagrams are computed for both gases taking into account dissociation, as well as ionization, over the pressure range between 10^{+1} and 10^{-5} atm., and within the temperature range between 500° and 10,000°K. Numerical examples for hydrogen, water, and helium are given in order to show the influence of specific heats of mixtures and mean molecular weights on the attainable exhaust velocities. The applicability of boron(III)-hydride and methane as working fluids is examined, as well as the heat transfer to the combustion chamber walls through a comparison of hydrogen, water, and helium. The influence of nonequilibrium processes on heating and expansion is also discussed and three methods of heating the working fluid are investigated. These include the fission reactors, arcs, and fusion reactors.

POWER PLANTS

APPLICATION OF THE CLOSED-CYCLE PRINCIPLE TO AIRCRAFT PROPULSION SYSTEMS. VII - GASEOUS WORKING MEDIA FOR CLOSED CYCLE POWER PLANTS. W. Spillmann and B. Speckert. **VIII - SIZING OF THE COMPONENTS OF A CLOSED-CYCLE He-NAP SYSTEM.** A. Burgdorfer, R. Tognoni, and W. Spillmann. Escher-Wyss Rep. vol. VII, Sp-AK-57-046; vol. VIII, Sp-AK-57-047 (EOARDC TR 58-31; TR 58-32) [AD 152240; AD 152241], July 21, 1957. 31; 49 pp. Presentation of physical data for gases and gaseous mixtures from which it is concluded that helium is the best suited gas with respect to radiation stability and resulting plant size. Its heat transfer properties are of prime importance for the size of the heat transfer equipment. A comparison of several gases with respect to the critical properties which limit their use in a nuclear power plant is made in tabular form. The various components of a helium closed cycle plant are listed, and their design and efficiency are discussed.

APPLICATION OF THE CLOSED CYCLE PRINCIPLE TO AIRCRAFT AUXILIARY POWER PLANTS. IX-COMPARISON BETWEEN DIRECT AND INDIRECT HEAT ADDITION FROM AN ATOMIC REACTOR TO A CLOSED GAS TURBINE CYCLE. R. Tognoni and W. Spillmann. Escher-Wyss TN 5, vol. IX, Rep. Sp-AK-57-041 (EOARDC TR 58-33) [AD 152242], July 21, 1957. 56 pp. Investigation to compare the losses occurring in the "double circuit" (heat added indirectly) to the losses in the "single circuit." The pressure ratio used for the analysis is that corresponding to maximum efficiency. Analysis of the cycle effectiveness for a cycle without intermediate cooler and with, as well as without, recuperator is made, along with comparison of the different cycle configurations for nitrogen and helium. Results indicate that the primary circuit decreases the thermal efficiency of the cycle. The highest power consumption of the pump occurs with the cycle having a recuperator, and the thermal efficiency of the helium circuit is 2% lower than that of air.

APPLICATION OF THE CLOSED CYCLE PRINCIPLE TO AIRCRAFT AUXILIARY POWER PLANTS. X-HELIUM COMPRESSOR DESIGN. R. Tognoni. Escher-Wyss TN 6, vol. X, Rep. Sp-AK-57-042 (EOARDC TR 58-34) [AD 152243], July 21, 1957. 50 pp. Analysis considering the effect of design parameters on compressor performance where helium is used as the working medium. The blading of a model stage for the same requirements, but with air as the working medium, has been designed in detail. Reaction of approximately 105% has ben found as the best compromise between good stage efficiency and a reasonable number of stages.

THE USE OF PLANETARY ATMOSPHERES FOR PROPULSION. S. T. Demetriades and Carl Kretschmer. (AAS 4th Annual Meeting, Jan. 31, 1958.) Aerojet-Gen. Rep. AGC TN-24 (AFOSR TN 58-229) [AD 154132], Apr. 14, 1958. 19 pp. Presentation of the reaction kinetics of atomic oxygen in the earth's upper atmosphere, and a preliminary analysis of an atomic-oxygen propulsion unit. Estimates of the mechanism and magnitude of the recombination rates for atomic oxygen are presented in the homogeneous phase as well as in the heterogeneous phase - i.e., on a catalytic surface. These estimates are based on the results of collision rate theory, absolute reaction-rate theory, and the interpretation of experimental data available in the literature on other three-body recombination reactions and surface-recombination reactions. Assuming 100% efficiency in recombination energy, a thrust of 40 dynes/cm.^{2} of inlet area is obtained at 100 km. altitude. This thrust is independent of the flight speed and depends only on the altitude. The ideal thrust-to-minimum-drag ratio is generalized for any recombination power plant in any planetary atmosphere; it is shown that, as a first approximation, this ratio is independent of altitude and absolute concentrations.

THERMOPROPULSIVE CHARACTERISTICS OF HIGH-SPEED THRUST GENERATORS. A. F. Charwat. Aero / Space Engrg., June, 1958, pp. 49-55. Discussion of the fundamental propulsive and thermodynamic properties of aircraft power plants with particular emphasis on their high-speed potential. Graphical presentations of thrust characteristics are given. Results indicate that there is an optimum compression ratio for any Mach Number which represents the performance of an optimum nonafterburning engine. The turbofan and the turboprop engines are basically the same. In the turbo-ram-jet the emphasis is on a mechanical rather than a thermodynamic coupling. An exceptionally wide performance range is attainable by switching from one engine type to another. The ducted rocket produces more thrust than the rocket itself over limited ranges of Mach Numbers. The results confirm the established succession of propulsors as the flight speed increases: the propeller, the turbofan, the turbojet without and then with an afterburner. The isovolumic combustor seems to offer advantages worth further developmental effort.

Jet & Turbine

MAXIMUM THEORETICAL TANGENTIAL VELOCITY COMPONENT POSSIBLE FROM STRAIGHT-BACK CONVERGING AND CONVERGING-DIVERGING STATORS AT SUPERCRITICAL PRESSURE RATIOS. T. P. Moffitt. US, NACA TN 4271, Apr., 1958. 21 pp. Analysis using the method of characteristics which shows that converging stators are limited to exit tangential components of critical velocity ratios less than 1.714, while values up to the theoretical limit of 2.449 corresponding to an infinity Mach Number might be realized for converging-diverging stators. The greatest theoretical gains in tangential velocity due to expansion about stator blade trailing edges occur at small blade exit angles as measured from tangential and relatively low velocities at the exit of the guided-channel portion of the flow passage.

KRAFTSTOFFZERSTÄUBUNG IN STRAHLTRIEBWERKEN. O. Lutz, W. Alvermann, and J. Lambrecht. DFL Inst. Strahltriebwerke Bericht 87, Oct., 1957. 4 pp. In German. Discussion of requirements to be met by fuel injection elements in jet engines. Includes investigation of the influence of injection nozzles and fuel quality on the atomization and some characteristics defining the atomization quality. A brief survey of the design of injection nozzles is also presented.

Rocket

LA MESURE DU DELAI D'ALLUMAGE EN ALTITUDE SIMULEE DES MOTEURS FUSEES A HYPERGOLS LIQUIDES. Pierre Sarrat. La Recherche Aéronautique, Jan.-Feb., 1958, pp. 15-25. In French. Measurement of ignition delays in liquid-propellant rockets at simulated altitude conditions by means of the "caisson" method. The results are compared to those obtained by means of a laboratory technique and are in agreement at atmospheric pressures. The discrepancy in the case of low pressure is analyzed. The initial pressure points are also determined in relation to the effect of the ignition delay and the chemical nature of the propellant.

ERGEBNISSE VON PRÜFSTANDSVERSUCHEN MIT HEISSWASSER-MODELLRAKETEN. E. Shäfer and W. Michely. Forschungsinst. Phys. Strahlantriebe Mitteil. 11, Aug., 1957. 47 pp. 20 refs. In German. Presentation of results of test-bed experiments on a steam rocket. Tests were made with (a) enlarged Laval-type nozzles, (b) nonenlarged standard nozzles serving as discharge openings for the steam-water mixture, (c) special retardation of the discharge fluid before it enters the haval nozzle, and (d) addition to the rocket water supply of chemicals influencing surface tensions.

RESEARCH, RESEARCH FACILITIES

Rocket Sleds, Tracks

DIE HEISSWASSERRAKETE - ENTWICKLUNG, BETRIEB UND ANWENDUNGSMÖGLICHKEITEN. Otto Mühlhäuser. Raketentech. & Raumfahrtforsch., Apr., 1958, pp. 45-49. In German. Description of the hot-water rocket development covering the operation and possible applications. These include wind tunnels operating in the sonic range and sleds for aerodynamic model research. The simplicity and safety considerations are analyzed, some experimental installations are described, and graphs are presented for showing the performance and weight characteristics.

Wind Tunnels

CONTRIBUTION A L'ETUDE DE L'INTERFEROMETRE DIFFERENTIEL A BIPRISME DE WOLLASTON. Gérard Gontier. France, Min. de l'Air PST 338, 1957. 110 pp. 44 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,200. In French. Evaluation of the working principle of a polarized light interferometer with Wollaston's biprism. Different optical procedures for visualizing a high-speed two-dimensional flow (the shadow, schlieren, and interferometric methods) are described. The polarized light interferometer designed for a sonic wind tunnel comprises three parts: a support bench, a mirror with a 250 mm. diameter and a 2,500 mm. radius of curvature, and a casing. Includes study of the interferometer operation in the general case where the location of the biprism is not in the center of curvature of the mirror, comparison of the integration process for obtaining the gas density at any location of the test section to the computation process using finite differences, computation of a light ray deviation in an isotropic, heterogeneous, three-dimensional body and a plate with varying thickness and refraction index, as well as the calibrating process.

INTERFEROMETRE DIFFERENTIEL A BIPRISME DE WOLLASTON. G. Gontier. Inst. Méc. Fluides, Lille, Prob. GR/82, Jan. 27, 1958. 37 pp. 13 refs. In French. Study of the operation of a polarized light interferometer for measuring the optical thickness gradient of a transparent isotropic strip and, in particular, the density gradient of a subsonic or supersonic flow of gas. Includes description of the design and installation of the device, as well as presentation of five methods for computing interferometric data and their verification by measuring the thickness of a homogeneous glass plate.

ROTATING WING AIRCRAFT, HELICOPTERS

SULL'ACCERTAMENTO IN VOLO DELLA STABILITA STATICA LONGITUDINALE E DELLA MANOVRABILITA DEGLI ELICOTTERI. Georgio Aldinio. (15th Natl. Aerotech. Congr., Cagliari, Sept. 25-29, 1957.) L'Aerotecnica, Dec., 1957, pp. 296-300. In Italian. Presentation of flight test results on a single-rotor helicopter. Longitudinal stability requirements of helicopters in comparison with fixed-wing aircraft are examined, and the importance of flight test measurements for ascertaining helicopter longitudinal static stability and controllability is pointed out. The analysis covers the necessity of a complete set of plots of stick position against forward speed in different conditions of weight, center-of-gravity position, configuration, and power, as well as for such flight conditions as hovering, climb, cruising, and autorotation.

ANALYSIS OF HARMONIC FORCES PRODUCED AT HUB BY IMBALANCES IN HELICOPTER ROTOR BLADES. M. Morduchow and A. Muzyka. US, NACA TN 4226, Apr., 1958. 37 pp. Derivation of explicit expressions for the harmonic forces produced at the hub by an n-bladed unbalanced helicopter rotor. Imbalances due to property differences among the blades and to nonuniform spacing between the blades are considered. Forces applied to the hub both in and normal to the plane of rotation of the blades are analyzed. Numerical examples indicating the order of magnitude of the results obtained are given. Conclusions show that the effect of imbalances in the rotor blades produces at the hub additional forces in all of the harmonics. The effect of eccentricity imbalances, or nonuniform spacing between the blades, is equivalent to the effect of property imbalances, or property differences among the blades.

SPACE TRAVEL

INTERPLANETARY ORBITS. M. Vertregt. Brit. Interpl. Soc. J., Mar.-Apr., 1958, pp. 326-354. Derivation of the basic equations under simplified conditions for interplanetary flight; some of the problems connected with space navigation are considered. Several assumptions are made in order to simplify the calculations. The general conditions for an orbit that can be used for interplanetary flight are investigated. A diagram is developed from which the approximate energy-requirement, duration, and other particulars of a voyage can be easily found. Alternative routes between the orbits of planets are described.

SYSTEMATIK DER LENKVERFAHREN. I. Ferdinand Müller. Raketentech. & Raumfahrtforsch., Apr., 1958, pp. 38-44. 11 refs. In German. Systematic survey of possible methods for launching moving bodies into orbit, and presentation of related location methods. Examples and problems of space-travel application are also presented. Includes such factors as propellants, velocity, and guidance.

ISSLEDOVANIE KORPUSKULIARNOGO IZLUCHENIIA SOLNTSA S POMOSHCH'IN ISKUSSTVENNOGO SPUTNIKA ZEMLI. V. I. Krasovskii, Iu. M. Kushnir, and G. A. Bordovskii. Uspekhi Fiz. Nauk., Mar., 1958, pp. 425-434. 43 refs. In Russian. Discussion of the possible investigation of solar corpuscular radiation by means of artificial satellites. Includes analysis of previous studies and evaluation of the basic theory, as well as description of two methods for obtaining necessary data and modifications to the design and instrumentation of satellites.

PERTURBATION OF ELLIPTIC ORBITS BY ATMOSPHERIC CONTACT. T. R. F. Nonweiler. Brit. Interpl. Soc. J., Mar.-Apr., 1958, pp. 368-379. Evaluation of the perturbation on a single circuit of an elliptic orbit neglecting the effect of this perturbation on the magnitude of the air resistance. The changes in major axis and eccentricity on the circuit are given. The modified Bessel functions occuring are tabulated and their variation indicated. The relation between eccentricity and the number of circuits, and that between the height at perigee and eccentricity are given. The analysis indicates that the orbit does not become circular before ground impact. The final descent is virtually at a constant speed, rather above the circling speed, with the air resistance determining the angle of descent.

OPTICHESKIE NABLIUDENIIA ISKUSSTVENNYKH SPUTNIKOV ZEMLI. I. S. Shklovskii and P. V. Shcheglov. Uspekhi Fiz. Nauk., Mar., 1958, pp. 417-424. 10 refs. In Russian. Discussion of optical methods applied to the determination of spatial coordinates for calculating satellite trajectories. Their importance in obtaining data on physical characteristics of upper atmosphere, as well as on the characteristic deviation of the atmospheric density distribution from spherical symmetry, is emphasized. Other possible applications, including the study of anomalies in the Earth's gravitational field and verification of the general theory of relativity, are also analyzed. Includes description of American and Soviet installations, their design, and operation; evaluation of the accuracy of obtained results; as well as description of other systems of relatively small diameter which use a cell more sensitive to optical radiation than a film.

STRUCTURES

EFFECT OF A STRINGER ON THE STRESS CONCENTRATION DUE TO A CRACK IN A THIN SHEET. J. L. Sanders, Jr. US, NACA TN 4207, Mar., 1958. 19 pp. The results are presented graphically and in tabular form. Derivation of a coefficient for determining the effect of a reinforcing stringer on the stress concentration factor at the tip of a crack in a thin sheet. The stress concentration factor in the stringer due to the crack and the correction factor for the crack in the case of a broken stringer are also found.

FAIL-SAFE STRUCTURAL DESIGN. N. F. Harpur. RAeS J., May, 1958, pp. 363-376. 23 refs. Discussion of the values of structural inspections, the loads to be used in stressing a cracked structure, the three basic types of fail-safe design, the need for minor modifications to make the parts of an airframe fail-safe, the crack propagation in flat sheets, and the design of fail-safe pressure cabins. A description of tests carried out on fuselages and small and full scale cylinders is made. The critical crack lengths for various materials are presented in graphical form.

THE APPLICATION OF RELAXATION METHODS TO THE SOLUTION OF DIFFERENTIAL EQUATIONS IN THREE DIMENSIONS. III - THREE-DIMENSIONAL STRESS ANALYSIS. D. N. de G. Allen and S. C. R. Dennis. Quart. J. Mech. & Appl. Math., May, 1958, pp. 172-184. Extension of previously developed methods in order to include in their scope the solution of stress problems in three dimensions; from the relaxational point of view this requires the simultaneous satisfaction of four Poisson-type equations in four dependent variables. These four equations are derived with corresponding boundary conditions which express given values of the boundary tractions, and then applied to the solution for a particular example of stress distribution in a cube.

Bars & Rods

ELASTIC-PLASTIC TORSION OF SHARPLY NOTCHED BARS. J. A. H. Hult. J. Mech. & Phys. Solids, No. 1, 1957, pp. 79-82. OSR-supported derivation of the shape of the incipient plastic region at the tip of a sharp notch in a twisted bar. It is shown that the shape of the region of incipient plastic yielding can be found for any shape of the cross section, provided the solution of the corresponding elastic problem is known. The elastic stress field near the tip of a sharp notch in pure shear is to be similar to the elastic stress field near a similar longitudinal notch in torsion. The shape of the plastic region produced at the notch in pure shear is known and the corresponding region in this torsion case is derived by analogy.

Beams & Columns

THEORETICAL AND EXPERIMENTAL ANALYSIS OF MEMBERS LOADED ECCENTRICALLY AND INELASTICALLY. O. M. Sidebottom and M. E. Clark. U. Ill. Eng. Exp. Sta. Bul. 447, Mar., 1958. 48 pp. 16 refs. Development of interaction equations for members subjected to axial load and bending moment. The equations are developed in general terms so that they can be applied to many cross sections made up of one or two rectangular elements at right angles to each other, such as angle- and T-sections. In order to use the interaction curve to determine the load and deflection resulting from a given depth of yielding, it was necessary to construct a theoretical moment-load curve. Verification tests were run on 41 eccentrically-loaded tension members and on 32 eccentrically-loaded columns.

Cylinders & Shells

ON STRESSES AND DEFORMATIONS OF ELLIPSOIDAL SHELLS SUBJECT TO INTERNAL PRESSURE. R. A. Clark and E. Reissner. J. Mech. & Phys. Solids, No. 1, 1957, pp. 63-70. ONR-sponsored analysis of thin elastic shells with the major axis of the elliptic cross section perpendicular to the axis of revolution. A qualitative consideration of the problem indicates that some bending does occur, and effects due to this bending become progressively more important as the elliptical cross section of the shell becomes flatter. The range of validity for the membrane solution is found under this condition, and quantitative corrections for the solution are determined.

SECOND-ORDER EFFECTS IN THE TORSION AND BENDING OF TRANSVERSELY ISOTROPIC INCOMPRESSIBLE ELASTIC BEAMS. W. S. Blackburn. Quart. J. Mech. & Appl. Math., May, 1958, pp. 142-158. 12 refs. Extension of a theory developed by Green and Spratt to the case of a material which is transversely isotropic with respect to a certain constant direction. The results are applied to a homogeneous incompressible cylinder which is transversely isotropic with respect to its generators. Complex variable notation is used. It is shown that the second-order problem of torsion and extension can be reduced to the solution of a single boundary-value problem involving two complex potential functions. Without solving the boundary value problem a formula is obtained for the fractional elongation of the cylinder. The problem of the bending of the cylinder by couples over the end is also examined as far as terms of the second order. The solution again reduces to a boundary-value problem involving two complex potential functions together with the boundary-value problem for the classical torsion function. A formula is obtained in the general case for the angle of twist and fractional elongation of the central line.

ON THE COMBINED BENDING AND TWISTING OF BEAMS OF VARIOUS SECTIONS. F. A. Gaydon and H. Nuttall. J. Mech. & Phys. Solids, No. 1, 1957, pp. 17-26. Derivation of upper and lower approximations to the interaction curve of the bending and twisting couples at yield for the combined bending and twisting of cylinders of ideally plastic-rigid material. Rectangular, box, and I-sections are dealt with in detail. For the box section a comparison is made with the thin tube theory of Hill and Siebel.

RESPONSE OF AN ELASTIC CYLINDRICAL SHELL TO A PRESSURE PULSE. J. H. Haywood. Quart. J. Mech. & Appl. Math., May, 1958, pp. 129-141. Application of a modal method of analysis to determine the response of an elastic cylindrical shell subjected to a pressure pulse propagating through the surrounding acoustic medium. An approximate relation is developed between the fluid pressure and particle velocity of a cylindrical wave. Using this relation, the modal equations of motion are simplified and, in the examples chosen, lead to numerical results in close agreement with the true elastic response.

Elasticity & Plasticity

THE ASSOCIATED FLOW RULE OF PLASTICITY. D. R. Bland. J. Mech. & Phys. Solids, No. 1, 1957, pp. 71-78. 10 refs. Analysis in which the workhardening and linearity hypotheses introduced by Drucker are shown to be logically equivalent to the hypotheses on the existence of the plastic potential and of its identity with the yield function. The flow rule at singular points on a yield surface is found by considering the actual yield surface as the limit of a sequence of regular surfaces. It is shown that the limitations, imposed on the plastic strain increment at a singular point on the yield surface for a workhardening material, are different from those imposed when the material is nonhardening.

PLASTIC FLOW AND FRACTURE IN SOLIDS. T. Y. Thomas. J. Math. & Mech., May, 1958, pp. 291-322. 13 refs. ONR-supported analysis of some problems connected with Lüders bands for which the surface Σ is stationary. It is assumed that this surface is singular relative to the stress components. Such wave surfaces are shown to be identical geometrically with the surfaces of separation of the elastic and plastic region of the Lüders band problem. It is shown that all first and second derivatives of the velocity components are continuous over the surface Σ. Also weak singular surfaces Σ whose normal velocity G is different from zero are examined, and it is found that four cases can arise when the plastic region propagates into an elastic medium in dynamical equilibrium. The points of infinite wave strength called fracture points appear on the surface and generate a crack that will be propagated in the direction of the tension or compression in the plate.

STABILITY OF RIGID-PLASTIC SOLIDS. R. Hill. J. Mech. & Phys. Solids, No. 1, 1957, pp. 1-8. Analysis considering the general problem of stability under dead loading for a body of any shape, the material being workhardening and rigid-plastic. It is shown that when the plastic potential and yield function coincide it is only necessary to examine in detail those neighboring positions which can be reached by strain paths beginning as virtual modes of the yield-point state under the given loading. The least energy dissipated in passing to any such position has to be determined in constructing a sufficient condition of stability. The functional concerned turns out to be identical with that in the uniqueness condition for the typical boundary-value problem.

ON RIGID WORKHARDENING SOLIDS WITH SINGULAR YIELD CONDITIONS. W. E. Boyce and W. Prager. J. Mech. & Phys. Solids, No. 1, 1957, pp. 9-12. ONR-sponsored analysis extending Hill's results to rigid bodies with singular yield conditions. A singular yield condition allows for the possibility that in certain plastic states of stress there may be two or more competing yield mechanisms, each of which makes an independent contribution to the strain rate. In analyzing the time-dependent stresses, displacements, and strains in the body, the following boundary-value problem is discussed: given the strain history and instantaneous stress throughout the body, the rates of surface traction F on the part S_F of its surface, and the surface velocity V on the remainder S_v of S, find the stress rate and the velocity throughout the body.

Fatigue

THE PROPAGATION OF FATIGUE CRACKS IN SHEET SPECIMENS. N. E. Frost and D. S. Dugdale. J. Mech. & Phys. Solids, No. 2, 1958, pp. 92-110. 17 refs. Investigation carried out on mild steel, aluminium alloy, and copper sheet specimens containing a small central slit. In some of the mild steel specimens a plastic zone was visible around the growing crack. Measurements of the plastic zone were made whenever possible and showed that a state of geometrical similarity exists between the crack length and plastic zone dimensions. For low stresses the crack growth was sometimes erratic, but, while the growth was steady and the overall crack length less than about one-eighth of the specimen width, it was found that the rate of growth was proportional to crack length.

FATIGUE CRACK PROPAGATION IN TORSION. J. A. H. Hult. J. Mech. & Phys. Solids, No. 1, 1957, pp. 47-52. OSR-supported derivation of the redistribution of the stress and strain in front of a growing crack in a twisted bar, assuming the material to be ideally plastic. The result is used in connection with a simple fracture criterion to determine the initial rate of growth of a fatigue crack. Experimental results on 75S-T6 aluminium specimens confirm the theory.

Plates

SOME MIXED BOUNDARY VALUE PROBLEMS IN ISOTROPIC THIN PLATE THEORY. G. M. L. Gladwell. Quart. J. Mech. & Appl. Math., May, 1958, pp. 159-171. 10 refs. Analysis of problems in which the plate is clamped along part of the boundary and is either free or subject to specified bending moment and shear along the remainder. Complex variable techniques, as evolved by Muskhelishvili, are used throughout. First, the general boundary conditions for the problems are stated and reduced to a suitable form, and then, using known results for plates with fully clamped boundaries, the boundary conditions are reduced to nonhomogeneous Hilbert problems. Special attention is given to the case of point loading in the interior of the plate and to the case when part of the boundary is subject to constant bending moment and shears.

TRANSVERSE BENDING OF INFINITE AND SEMI-INFINITE THIN ELASTIC PLATES. III. W. A. Bassali and M. Nassif. Cambridge Philos. Soc. Proc., Apr., 1958, pp. 288-299. 12 refs. Application of methods of complex-function theory to the problem of an infinite thin isotropic plate having a free outer boundary and elastically restrained inner circular boundary, the plate being subjected to normal loading over a circular patch. The limiting case of a half-plane clamped along the straight edge and subject to the same normal loading spread over the area of a circle is investigated. The method of derivation is simplified by the use of the complex variable technique. The solutions derived are exact within the framework of the small-deflection plate theory.

PROBLEMS CONCERNING THE BENDING OF ISOTROPIC THIN ELASTIC PLATES SUBJECT TO VARIOUS DISTRIBUTIONS OF NORMAL PRESSURES. W. A. Bassali. Cambridge Philos. Soc. Proc., Apr., 1958, pp. 265-287. 20 refs. Derivation of a solution for the problem when the eccentric circle is subject to another type of normal loading which includes as a special case a linearly varying load. The limiting cases where the circular boundary degenerates to a straight line and the radius of the loaded circle tends to zero are considered. Formulas for the moments, shears, and deflections relating to special examples are given. The theory is simplified by the use of complex combinations of stress components and of complex variable technique.

Rings

MULTI-RING PLATES; A STEP FUNCTION APPROACH. P. M. Quinlan. Natl. U. Ireland TN 2 (AFOSR TN 58-211) [AD 154112], Jan., 1958. 27 pp. Derivation of a single, discontinuous, differential equation for the symmetrical bending of an elastic plate consisting of a number of concentric discs, each of constant thickness. The concentrated uniform ring load is taken as the fundamental load type from which all other loading can be derived by integration. The case of a concentrated ring torque is obtained by applying an appropriate limiting technique to the ring load.

ELASTIC PROBLEM FOR A RING OF UNIFORM FORCE IN AN INFINITE BODY. W. H. Pell. J. Res., Apr., 1958, pp. 365-373. OSR-supported study of the displacements due to a force applied along, and normal to, a circle in an infinite solid by using the Kelvin integrals and spherical coordinates. The displacement integrals for a ring of concentrated force are obtained, and an evaluation of the integrals in terms of complete elliptic integrals is made.

Sandwich Construction

KONECHNYE PROGIBY TREKHSLOINYKH OBOLOCHEK S ZHESTKIM ZAPOLNITELEM. E. I. Grigoliuk. AN SSSR Otd. Tekh. Nauk Izv., Jan., 1958, pp. 26-34. In Russian. Investigation of finite deflections of elastic, slightly curved, sandwich (three-layer) shells with a rigid core. It is assumed that the core is incompressible in the transverse direction and undergoes finite deflections. The supporting layers and the core are orthotropic, of constant thickness, remain elastic under stress, have parallel axes, and different mechanical characteristics. A system of four equations is derived for the case of arbitrary transverse load and temperature distribution. Stability in a linear form is also considered, and an equation similar to the Stein-Mayers relationship is derived for the cylindrical case.

Thermal Stress

CREEP STABILITY OF COLUMNS AND PLATES. G. N. Rabotnov and S. A. Shesterikov. J. Mech. & Phys. Solids, No. 1, 1957, pp. 27-34. Analysis using two forms of the creep theory based on the strain hardening hypothesis. For a uniformly compressed plate a comparison is made between results according to the flow theory and to the strain theory.

A CRITICAL STRAIN APPROACH TO CREEP BUCKLING OF PLATES AND SHELLS. George Gerard and A. C. Gilbert. J. Aero / Space Sci., July, 1958, pp. 429-458. Experimental investigation of aluminum cylinders under compressive and torsional loads. The test techniques and equipment are described. The results of the experiments are correlated with the critical strain approach that has been presented previously, and good agreement is obtained both in terms of critical strain and critical time. Some preliminary data on creep buckling of cylinders under cyclic load conditions are also presented. An examination of test data on creep of long flat plates under compressive loads indicates that the theory may be adequate for plates of small width/thickness ratio. Plates of large width/thickness ratio, which can buckle upon the initial application of load, require an analysis of the post-buckled state under creep conditions.

THE INFLUENCE OF AERODYNAMIC HEATING ON THE FLEXURAL RIGIDITY OF A THIN WING. Appendix I - TEMPERATURES DUE TO AERODYNAMIC HEATING. Appendix II - END EFFECTS IN A WING OF FINITE ASPECT RATIO. Appendix III - ANALYSIS FOR A BUILT-UP WING. Appendix IV - LARGE DEFLECTION SOLUTION FOR A SOLID STRIP OF CONSTANT THICKNESS. Appendix V - TOTAL MOMENT ACTING ON CROSS-SECTION OF STRIP. E. H. Mansfield. Gt. Brit., RAE Rep. Struc. 229, Sept., 1957. 38 pp. 11 refs. Analysis considering flexural behavior of a thin solid wing of infinite aspect ratio with a given chodwise distribution of spanwise middle surface stresses. The strain energy in the middle surface of the wing is determined. Variational methods are used for the chordwise variation of the distortion of the wing. The cross-section distortion of the bending wing is due to Poisson's ratio effect and the radical component of the middle surface stresses. Results indicate that the middle surface stresses tend to be more localized in the region of the leading and trailing edges; their effect on the wing as a whole is less marked. A spanwise wavy form of instability may occur if the middle surface stresses are sufficiently localized in the region of the leading and trailing edges. The loss of flexural rigidity is comparable to the corresponding loss of torsional rigidity.

THERMODYNAMICS

Combustion

FLOW FIELD OF A BUNSEN FLAME. M. S. Uberoi, A. M. Kuethe, and H. R. Menkes. Phys. Fluids, Mar.-Apr., 1958, pp. 150-158. OSR-supported theoretical and experimental investigation of the flow associated with a flame propagating in a confined mixture of combustible gases or when the flame is stabilized at suitable boundaries and the combustible gases stream through it. The flow field of a two-dimensional Bunsen flame is examined by approximating the zone of combustion with a surface of discontinuity across which the density drops and normal velocity increases. Even though the flow of unburned gases is potential, the flow of the burned gases is always rotational and is therefore not amenable to complete analysis. Interaction of flame shape and flow field is obtained analytically and experimentally. The entire flow field is mapped by taking stroboscopic photographs of small particles suspended in the combustion gases.

APPLICATIONS DES CONSTANTES ET DONNEES THERMODYNAMIQUES DES MELANGES GAZEUX AUX TEMPERATURES ELEVEES (FLAMMES, MOTEURS ET PROPULSEURS). G. Ribaud and N. Manson. France, Min. de l'Air PST 341, 1958. 194 pp. 41 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 2,700. In French. Presentation of numerical examples in order to illustrate the application of previously obtained data on gases and gas mixtures at high temperatures. Includes methods, using thermodynamic diagrams, for the calculation of characteristic phases of the evolution of fuels in combustion chambers, thermopropulsive systems (turbojet, ram-jet, rocket), internal combustion engines, and behind the combustion shock waves. Includes evaluation of the theory of continuous high-speed gas flows, performance characteristics of various powerplant types, and comparison of numerical data to experimental results.

COMBUSTION OF MONOPROPELLANT DROPLETS. I - THEORETICAL MODEL OF THE COMBUSTION OF A DROPLET. Appendix - OTHER INTEGRATION METHODS. C. S. Tarifa and J. M. Salas Larrazabal. Inst. Nac. Tec. Aero. Esteban Terradas Rep. (AFOSR TN 57-671) [AD 136660], July 27, 1957. 49 pp. An approximate analytical method is developed for the mathematical solution of the combustion problem of a monopropellant droplet, considering chemical kinetics and diffusion, and admitting several simplifications to the physical model of the process. Results are compared with those obtained through a numerical integration of the system of differential equations used. The expansion in series of the formulas obtained allows the direct calculation of the values for all the typical variables of the process. This simplified method is applicable to almost every case.

ETUDE DES FLAMMES STABILISEES PAR DES OBSTACLES DE REVOLUTION DANS DES ECOULEMENTS SUBSONIQUES A GRANDES VITESSES; STRUCTURE THERMO-CHIMIQUE DU NOYAU DE STABILISATION. J. Rappeneau and H. Grassin. France, ONERA NT 41, 1957. 44 pp. 14 refs. In French. Investigation of flames stabilized by bodies of revolution in high-speed subsonic flows. The method of gas analysis is used to study the flames quantitatively and the qualitative study is performed by means of visualization. The existence of a stabilizing core which contains only the burnt gases in pointed out. Measurements of CO concentration show that fresh gases were introduced into the core by diffusion through the flame front. Measurements of CO_2 and CO concentration lead to the study of flame propagation as function of the air/fuel ratio and the flow velocity. Based on these results, the temperatures of the flame have been computed. The determination of the CO_2 (total) concentration shows the existence of a "selection" of the air-fuel mixture, the local air/fuel ratio of the flame being different from the overall air/fuel ratio provided by the combustion onset.

DC-8 Fail-Safe Construction. *Shell Av. News*, Feb., 1958, pp. 19, 20. Evaluation of the DC-8 construction method which is capable of considerable weight saving and eliminates potential causes of metal fatigue.

Fighter Design Philosophy. R. F. Creasey. *Flight*, Feb. 21, 1958, pp. 239–243. Discussion of target-defense against manned bombers as well as of the variables affecting the fighter design.

The Transformed Herald. *The Aeroplane*, Mar. 21, 1958, pp. 388–392, cutaway drawing. Discussion of the principal structural features and power-plant changes made to the airframe in order to effect the transformation of the Herald.

Yakovlev's Yak-25. G. W. Heumann. *Air Pictorial*, Apr., 1958, pp. 128, 129. Presentation of data covering structural and performance characteristics.

Nacht-Allwetterjäger und leichtes Kampfflugzeug Jakowlew Jak-25 Flashlight. *Flugwelt*, Apr., 1958, pp. 255–258. In German. Design and description of the Soviet all-weather night fighter Yakovlev Yak-25 Flashlight.

Samolet Il-18. I—Silovaia Ustanovka, G. Litvinovich. **II—Shassi,** V. Semenov. **III—Vysotnoe Oborudovanie,** B. Pavlovskii. **IV—Letnaia Ekspluatatsiia.** V. Kokkinaki. *Grazhdanskaia Aviatsiia*, Mar., 1958, pp. 16–22. In Russian. Discussion of the operating characteristics of the Soviet Il-18 turboprop transport, covering power plants, landing gear, and flight performance.

De Toepolef 114 "Rusland." P. de Boer. *Avia Vliegwereld*, Jan. 30, 1958, pp. 62, 63. In Dutch. Description of the Soviet Tupolev 114 transport aircraft.

Caravelle. Roland de Narbonne. *Air Revue*, Mar., 1958, pp. 109–118, cutaway drawing. In French. Survey of the development of the Caravelle, including a list of various design stages, operational data, and applications.

Dassault "Méditerranée." Roland de Narbonne. *Air Revue*, Apr., 1958, pp. 168, 169. In French. Description of structural, power-plant, and performance characteristics of the Dassault transport.

SAAB "Draken"—Ein Beispiel einer "Flugzeug-Waffensystem"-Entwicklung. R. W. Schulz. *Luftfahrttechnik*, Feb., 1958, pp. 22–27. In German. Description of the SAAB Draken aircraft and discussion of its development as a military weapon system.

Design Principles of the Draken Supersonic Fighter. Erik Bratt. *Interavia*, 1958, pp. 239–242. Discussion of methods used in determining minimum frontal area, span loading, landing performance, stability, and c.g. position. Design of the wing for minimum total drag and optimum L/D ratio are also discussed.

I—All-Swedish J35 Aims at Mach 2 Speeds. II—Saab Producing J35 Draken Sub-Assemblies Underground. D. A. Anderton. *Av. Week*, Mar. 24; Mar. 31, 1958, pp. 46, 47, 51, 53, 54, 57, 63, 65; 64, 65, 67. Design characteristics and developmental history of the Saab all-weather fighter.

Air Conditioning, Pressurization

Equipment Cooling Systems for Aircraft. III—Cooling Systems Evaluation. R. H. Zimmerman, W. Robinson, K. G. Hornung, and W. E. Krauss. *USAF WADC TR 54-359, Pt. III*, Sept. 1954. 332 pp.

Fuels Tanks

Plastics for Leakproof Fuel Tanks; Details of a Method of Sealing Integral Tanks. J. R. Spurgeon. *Aircraft Eng.*, Apr., 1958, pp. 112, 113.

Operating Characteristics, Economics

Aircraft for Tomorrow's Airline Fleets. *Interavia*, 1958, pp. 212–217. Comparison of design and performance characteristics of British, American, French, and Soviet jet and turboprop transports.

Earning Power and the Jet v Turboprop Controversy. Stephen Wheatcroft. *Shell Av. News*, Jan., 1958, pp. 6, 7. (Also in *The Aeroplane*, Mar. 14, 1958, pp. 348, 349.) Establishment of the economic significance of earning power as a factor in aircraft evaluation.

I—Electra's Goal Is Short-Medium Market. II—Electra Designed for Production Savings. Irving Stone. *Av. Week*, Mar. 31; Apr. 7, 1958, pp. 46, 47, 51, 53, 57, 59, 60, 63; 79–84. Includes traffic analysis, economy considerations, structural aspects, and service and maintenance criteria.

Piloting

Vertical Separation. Derek Mason. *Shell Av. News*, Jan., 1958, pp. 14–17. (Also in *The Log*, Mar., 1958, pp. 67–76.) Discussion on the need for more accurate altimeters brought forth by the increase in volume and speed of air traffic. Several error reducing methods, such as the automatic pilot equipped with automatic height controls, are discussed.

"T" Effect Flight. J. P. Tracy. *Air Line Pilot*, Mar., 1958, pp. 8, 9, 21–23. Discussion considering the influence of ground effect over the ocean on aircraft performance, and presentation of some flight-test results obtained on an MATS C-54.

Seating

The Monroe "T-34" Seat. James Funderburk. *Project Engr.*, Mar., 1958, pp. 2–4. Description of the "T-34" seating arrangement and evaluation of its safety features.

Airports

Handling the Jet Airliner; Problems of Airport Architecture Summarised. *de Havilland Gazette*, Feb., 1958, pp. 4–6.

Aviation Medicine, Space Medicine

Preventive Medicine Aspects of Flight Feeding. A. A. Taylor. (*28th Aero Medical Assoc. Meeting, Denver, May 8, 1957.*) *J. Av. Med.*, Mar., 1958, pp. 206–211.

Review of the Cone-to-Rod Efficiency Ratio as a Specification for Lighting Systems. J. L. Brown. *USAF WADC TR 57-448 [AD 130927]*, Aug., 1957. 21 pp. 27 refs.

A Miniature, Direct-Plotting Pulse-Frequency Nomogram. K. M. Chapman. *USAF WADC TN 57-371 [AD 142097]*, Nov., 1957. 6 pp.

Estimation of the Mass of Body Segments. J. T. Barter. *USAF WADC TR 57-260 [AD 118222]*, Apr., 1957. 10 pp.

Cutaneous Toxicity Evaluation of Air Force Development Materials. II. M. V. Shelanski and K. L. Gabriel. *USAF WADC TR 57-742 [AD 142220]*, Nov., 1957. 16 pp.

Clothing and Tolerance to Heat. J. H. Veghte and Paul Webb. *USAF WADC TR 57-759 [AD 142248]*, Dec., 1957. 10 pp. 10 refs.

Glove Characteristics Influencing Control Manipulability. J. V. Bradley. *USAF WADC TR 57-389 [AD 130836]*, Aug., 1957. 25 pp.

Height-Weight Sizing and Fit-Test of a Cutaway G-Suit, Type CSU-3/P. Irvin Emanuel and Milton Alexander. *USAF WADC TR 57-432 [AD 130912]*, July, 1957. 22 pp.

Zur Pathogenese und Prophylaxe der Druckfallkrankheit des Höhenfliegers. I—Über den Einfluss der Hyaluronidase auf die Dauer der Sauerstoff-Voratmung. *DVL Bericht No. 45*, Aug., 1957. 21 pp. 16 refs. In German. Discussion of decompression effects in high-altitude flight and description of experimental results obtained during animal tests.

Stresses Affecting the Pilot During Post-Stall Maneuvers of High Performance Aircraft. Ch. O. Miller and J. D. Horgan. (*28th Aero Medical Assoc. Meeting, Denver, May 7, 1957.*) *J. Av. Med.*, Mar., 1958, pp. 180–186.

Human Tolerance to Aircraft Seat Belt Restraint. S. T. Lewis and J. P. Stapp. (*28th Aero Medical Assoc. Meeting, Denver, May 6, 1957.*) *J. Av. Med.*, Mar., 1958, pp. 187–196.

Time Judgments, Acoustic Noise, and Judgment Drift. H. J. Jerison and Jules Arginteanu. *USAF WADC TR 57-454 [AD 130963,]* Jan., 1958. 29 pp. 13 refs.

A Study of Muscle Forces and Fatigue. P. A. Hunsicker. *USAF WADC TR 57-586 [AD 131089]*, Dec., 1957. 47 pp. 15 refs.

The Effects of Stress on Uropepsin Excretion. R. H. Bonner. *USAF WADC TN 57-427 [AD 142256]*, Dec., 1957. 11 pp. 15 refs. Description of a method for analyzing uropepsin changes in simulated flight stress.

Mekhanicheskie Usloviia Vozniknoveniia Nevesomosti. V. S. Pyshkov. *Vestnik Vozdushnogo Flota*, Mar., 1958, pp. 45–49. In Russian. Discussion of mechanical conditions of the gravity-free state, its effect on piloting, and some illustrative examples.

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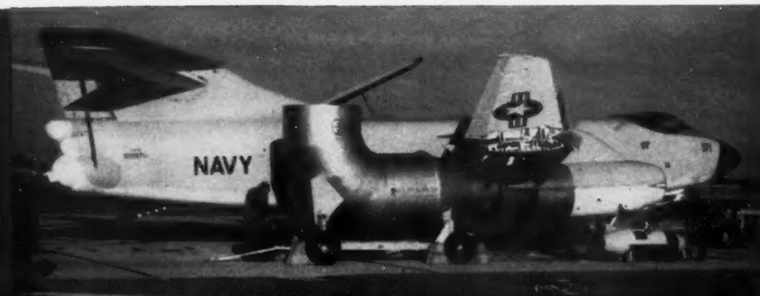

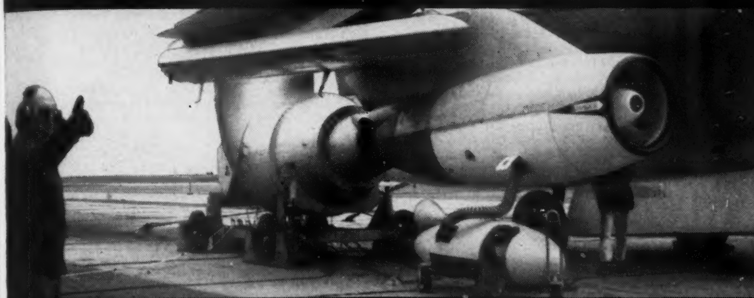

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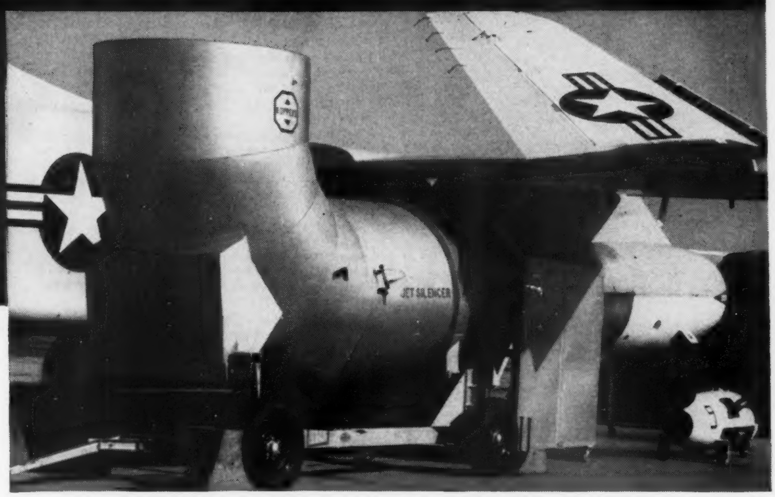

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Testing Methods

Some Developments and Applications of Brittle Lacquers; A Survey of Published Work and Some Original Contributions. J. R. Linge. *Aircraft Eng.*, Apr., 1958, pp. 94–100. 90 refs.

Thermal Stress

Teoria Podobieństwa Zjawisk Termoelastoplastycznych. Jan Madejski. *Rozprawy Inżynierskie*, No. 4, 1957, pp. 479–492. In Polish, with summaries in English and Russian. Derivation of criteria for describing thermoelastoplastic states in bodies of similar shape and load.

One-Dimensional Transient Heat Flow in a Multilayer Slab. W. F. Campbell. *J. Aero. Sci.*, May, 1958, pp. 340, 341. Presentation of a general solution to a problem solved previously by Wassermann. It is pointed out that the solutions given by Wassermann are incomplete for times longer than the duration of the heat input.

Tubes

Coiled Stainless Steel Tubing. I—Test Results. J. J. Chmura, Jr., R. D. Stouffer, and A. N. Winter. *USAF WADC TR 57-507, Pt. I* [*AD 142251*], Dec., 1957. 125 pp.

Wings

Flexion-Torsion de Piezas de Pared Delgada y Seccion Abierta. B. F. Pérez. *Ing. Aero.*, Jan.-Feb., 1958 pp. 11–27. In Spanish. Study of the bending and torsion of thin-walled and open sections under transverse loads.

Experimental Correlation Between the Endurance of a Wing Spar Joint and the Ratio Between 0.1 per cent Proof and Ultimate Tensile Strengths of the Material. W. A. P. Fisher. *Gt. Brit., ARC CP 371* (May, 1956) 1958. 18 pp. BIS, New York, $0.45. Description of fatigue tests of the Vickers Viking outer wing joint. Investigation indicates a correlation between high endurance and low proof/ultimate ratio for a particular design of wing spar joint.

Thermodynamics

Critique on the Analytical Representation of Specific Heat Data. Richard Pawel. *USAF*

WADC TN 57-308 [*AD 142095*], Nov., 1957. 14 pp.

Generalized Thermodynamic Excess Functions for Gases and Liquids. J. O. Hirschfelder, R. J. Buehler, H. A. McGee, Jr., and J. R. Sutton. *Ind. & Eng. Chem.*, Mar., Pt. I, 1958, pp. 386–390. Presentation of concise formulas for the thermodynamic excess functions of gases and liquids in a form suitable for high-speed digital machine computations.

Combustion

The Ignition of Combustible Gases by Flames. *Comb. & Flame*, Mar., 1958, pp. 3–12. ONR-supported discussion of pilot-flame experiments giving values of temperature and energy requirements over a wide range of flame sizes for ignition of stoichiometric methane-nitric oxide mixtures.

Ossidazione Parziale in Fase Gassosa di Miscele Butano Normale–Isobutano. M. Baccaredda and G. Paoletti. (*Chim. & l'Industria*, Apr., 1956.) U. *Pisa, Eng. Fac. Paper No. 770*, 1956. 8 pp. In Italian. Study of the partial oxidation in the gas phase of the *n*-butane–isobutane mixture (at a ratio of approximately 1:2) by air or by oxygen in a Pyrex glass tube at temperatures between 325° and 550°C. at different composition and flow ratios.

The Methyl Nitrite Decomposition Flame. E. A. Arden and J. Powling. *Comb. & Flame*, Mar., 1958, pp. 55–68. 21 refs. Analysis of the changes in temperature and in reaction products and intermediates for the methyl nitrite decomposition flame. Experiments on the propagation of flame in static mixtures are made, and the reactions effecting the reduction of nitric oxide are discussed.

A Review of Some Unusual Stationary Flame Reactions. W. G. Parker. *Comb. & Flame*, Mar., 1958, pp. 69–82. 52 refs. Review indicating that self-propagating flames are not confined to oxidation reactions by oxygen or to oxidation reactions in the broadest sense.

Application of Well-Stirred Reactor Theory to the Prediction of Combustor Performance. H. C. Hottel, G. C. Williams, and A. H. Bonnell. *Comb. & Flame*, Mar., 1958, pp. 13–34. ONR-supported analytical examination of three different models showing the effect of pressure interaction, recirculation interaction, and a nonuniform distribution of fuel/air ratio. Experimental results are also given.

Heat Transfer

Heat Transfer. *Ind. & Eng. Chem.*, Mar., Pt. II, 1958, pp. 543–554. 249 refs. Presentation of a comprehensive bibliography on current heat transfer literature and its application to heat exchangers, aircraft and missiles, and thermal stress and shock.

The Determination of Eigen-Functions of a Certain Sturm-Liouville Equation and Its Application to Problems of Heat-Transfer. S. N. Singh. *Appl. Sci. Res., Sect. A*, No. 4, 1958, pp. 237–250. 10 refs. Presentation of a method in which the eigenfunctions are orthogonal over a finite interval of integration and the Sturm-Liouville system is reduced to an infinite set of linear simultaneous algebraic equations for the coefficients of the series.

Bemerkungen zum Verfahren von Ernst Schmidt zur graphischen Integration der Wärmeleitungsgleichung. H. Heinrich. *ZAMM*, Jan.-Feb., 1958, pp. 70, 71. In German. Evaluation of the Schmidt method for the graphical integration of heat-transfer equations.

Zur Theorie der gesteuerten Anheizvorgänge. H. Jung. *ZAMM*, Jan.-Feb., 1958, pp. 56–69. In German. Simplification of the differential equation $\mathrm{div}\,(\lambda\,\mathrm{grad}\,T) = c\gamma\,(\partial T/\partial t)$ by neglecting the quadratic term in the temperature gradient in order to study the problem of the effect that the temperature dependence of the heat-transfer coefficient has on the transient phenomena.

Nekotorye Voprosy Teorii Teploobmena pri Laminarnom Techenii Zhidkosti v Trubakh. D. A. Labuntsov. *Teplonenergetika*, Mar., 1958, pp. 55–60. In Russian. Study of the heat transfer in hydrodynamically stabilized laminar pipe flows. The effect of axial conductivity on heat transfer is calculated for constant pipe-wall temperature and for constant heat addition.

K Voprosu o Teploobmene pri Turbulentnom Techenii Zhidkosti v Trubakh. B. S. Petukhov and V. V. Kirillov. *Teploenergetika*, Apr., 1958, pp. 63–68. 18 refs. In Russian. Theoretical calculation of the heat exchange in pipes in the case of turbulent flow of liquid with constant physical properties. The effect of alternating viscosity on heat exchange is studied on the basis of experimental data and a formula is suggested.

Wärmedurchgang in waagerechten Flüssigkeitsschichten. P. L. Silverston. *Forschung Gebiete Ing., Ausg. A*, No. 1, 1958, pp. 29–32. Abridged. In German. Representation of measurements of the heat flow across two-dimensional horizontal liquid layers, heated from below and cooled on the upper side, as the ratio of the apparent heat conductivity (including heat transfer) to the true heat conductivity of the stationary liquid depending upon the product of the Grashof and Prandtl Numbers.

Uchet Viiianiia Nestatsionarnosti Rezhima pri Konvektivnom Teploobmene. E. A. Sidorov. *Teploenergetika*, Apr., 1958, pp. 79, 80. In Russian. Development and application of approximate methods for calculating the effect of the nonstationary regime on convective heat exchange.

Fundamental Solutions for Heat Transfer from Nonisothermal Flat Plates. D. C. Baxter and W. C. Reynolds. *J. Aero. Sci.*, June, 1958, pp. 403, 404. Summary of laminar and turbulent analyses of heat transfer, and presentation of special examples which illustrate the effects.

VTOL & STOL

L'Avenir du Vol Vertical. Jean de Lagarde. *Secr. Gén. Av. Civ. & Commerc., Bul. Liaison & Docum. No. 95,* Mar. 15, 1958, pp. 23–26. In French. General discussion of the future development of VTO aircraft.

Maszyny Pionowego Startu i Lądowania. Jan Koźniewski. *Tech. Lotnicza*, Jan.-Feb., 1958, pp. 6–16. 13 refs. In Polish. Discussion of problems of VTOL and STOL aircraft, covering stability, transition from vertical to horizontal flight, and safety.

Ryan X-13 Vertijet. Günter Molter. *Flug-Revue*, Apr., 1958, pp. 12–15. In German. Design, operation, performance, and applications of the Ryan X-13 Vertijet.

Le Fairey Rotodyne—Prolongement Logique de l'Hélicoptère. Guy Roberty. *Air Revue*, Apr., 1958, pp. 173–178. In French. Description of the Fairey Rotodyne including economic aspects and uses.

Rotating-Thrust VTOL Proves Feasible. J. A. O'Malley, Jr. *SAE J.*, Mar., 1958, pp. 41–46. Abridged. Discussion of test results obtained from two different Bell VTOL configurations—one employing rotating engines and the other employing tailpipe manipulation for thrust diversion.

Water-Based Aircraft

Cavitating Flow About a Wedge at Incidence. A. D. Cox and W. A. Clayden. *J. Fluid Mech.*, Mar., 1958, pp. 615–637. 15 refs. Development of a mathematical model having a subsidiary cavity with a re-entrant jet at the vertex. Lift, drag, and moment coefficients are calculated as far as first-order terms in the angle of incidence. It is shown that the effect of the rate of loss in momentum for the re-entrant jet on these force coefficients is negligible to this order.

IAS News *(Continued from page 19)*

Jet Propulsion Laboratory, is an official observer at an AGARD meeting at the University of Freiburg, Germany.

Martin Goland (AF), who was appointed Director of the Southwest Research Institute recently, is *not* Director of Research, Kellert Aircraft Corporation, as incorrectly reported in April. Mr. Goland's brother, Leonard Goland, is Director of Research at Kellert Aircraft.

Brig. Gen. Harold R. Harris, USAF (Ret.) (F), has been elected President of The Wings Club. General Harris is President, Aviation Financial Services, Inc.

Earl R. Hinz (AF), formerly Chief, Dynamics and Computing, Ryan Aeronautical Company, has joined Convair—Astronautics, A Division of General Dynamics Corporation, as Design Specialist, Preliminary Design Group. Mr. Hinz also is a member of the IAS Council, Western Area.

Capt. John J. Ide, USNR (F), President of the Sporting Commission, Fédération Aéronautique Internationale, was elected a Vice-President of the FAI at its meeting in the IAS Building (Los Angeles), April 11–16.

James H. Kindelberger (HF), 1950 IAS President and Board Chairman, North American Aviation, Inc., has been awarded the 1958 Gold Knight Award of the National Management Association. The award is presented each year to the man deemed by the NMA to best exemplify leadership in good industrial management in the Southern California area.

Angelo Miele (M) has been appointed Professor, Aeronautical Engineering, at Purdue University, Lafayette, Ind. He formerly was an Associate Professor at Purdue.

John D. Nisley (M), formerly Supervisor, Power Plant Section, The Hughes Tool Company Aircraft Division, is now with the General Electric Company, Edwards AFB Flight Test Facility as an Aircraft Design Specialist.

Major Robert L. Oakley, USAF (M), recently was awarded the Air Force Commendation Ribbon for establishing courses in the science of parachutes at two leading engineering universities. He also has been awarded the Army's Commendation Ribbon (first Oak Leaf Cluster) for this contribution to the development of airborne troops' parachute assembly. Major Oakley is Assistant Chief, Parachute Branch, Aeronautical Accessories Laboratory, WADC.

Francis E. O'Meara (M), formerly a Staff Member, Weapons System Evaluation Group, at the Pentagon, has been appointed Chief Reactor Engineering Section, Engineering Development Branch, Atomic Energy Commission.

W. A. Pulver (M) has been named Chief Engineer, Georgia Division, Lockheed Aircraft Corporation. He formerly was Assistant Chief Engineer.

Luis A. Sepulveda (AF) has been promoted to the position of Group Leader, Ground Support Equipment (Thor Missile), in the Power Plant Section of Douglas' Missiles Engineering Division.

Arthur V. Sommer (M), Manager, Chicago Division, American Bosch Arma Corporation, has been awarded an Alfred P. Sloan Fellowship in Executive Development by Massachusetts Institute of Technology for the 1958–1959 year.

Harold O. Wendt (M), formerly Manager—Aeronautic R&D, Electronics Division, Curtiss-Wright Corporation, has joined Convair, A Division of General Dynamics Corporation, as Chief—Weapons System Integration Group.

Harper Woodward (A), Associate of Laurance S. Rockefeller, has been elected Chairman of the Board of Governors, Flight Safety Foundation, Inc.

IAS *News* Corporate Member News

• **Aerojet-General Corporation** has announced that the second-stage propulsion system for the Vanguard vehicle provides a nominal thrust of 7,700 lbs. (at altitude) for 120 sec., said to propel the second and third stages and the satellite from 36 to 300 miles altitude. The system consists of a single, gimballed, regeneratively cooled thrust chamber; propellants are inhibited white fuming nitric acid (IWFNA) as the oxidizer and unsymmetrical dimethylhydrazine (UDMH) as the fuel.

• **Aeroquip Corporation** has named Pat Lynch Western Division Administrative Sales Manager and Philip G. Cawrey Aircraft Sales Manager.

• **Aluminum Company of America** has purchased the transformer division of Automation Instruments, Inc., at Boulder, Colo.

• **American Airlines, Inc.,** has named G. Ward Hobbs Assistant Vice-President, Operations Services.

• **Arma, a Division of American Bosch Arma Corporation,** has signed a license agreement with S. G. Brown, Ltd., of Watford, England, for the manufacture and sale of the Arma subminiature gyro compass, the firm has announced.

• **Beech Aircraft Corporation** conducted joint councils for service and parts managers of Beechcraft distributor organizations in five regional locations during April and May. The firm also announced the sale of a new F50 Twin-Bonanza for the personal use of King Hussein of Jordan.

• **Bendix Aviation Corporation,** Pacific Division, reports that production of components and systems for 20 United States missiles will account for more than half of its 1958 sales. . . . Scintilla Division has announced four promotions in its sales department: Donald B. Morse—from Sales Manager to Director—Sales, Service, and Advertising; Donald L. Quinney—from Assistant Sales Manager to Sales Manager; Leonard D. Williams—from Assistant to the Sales Manager to Manager—Sales Office Administration; and William L. Bowler, Jr.—from Product Manager—Aircraft Engine and Burner Ignition Sales, to New Products Manager.

• **Boeing Airplane Company** has announced "expansion of its organization to develop and manage the comprehensive weapon system of tomorrow"; the new group, to be known as the Systems Management Office, will have overall responsibility for the intricate pattern of mission definition, design, materiel procurement, contract and financial control, manufacture, test, and both ground and communications support. Heading the new group is IAS President Edward C. Wells. George Stoner has been named General Manager of the first specific weapon system under development; Clyde Skeen was named Assistant General Manager—Operations; and Harlow J. Longfelder is Systems Engineering Director. The firm also reports successful completion of the Bomarc flight-test program and the start of tests on an improved model. . . . Pilotless Aircraft Division's Chief Engineer Robert H. Jewett has been named to the division's new position of Assistant General Manager—Chief Engineer. Also, George Snyder has been named Engineering Manager in charge of the Engineering Department and John D. Alexander, Advanced Projects Engineer Manager. . . . Robert J. Helberg, Bomarc Project Engineer, has been named Bomarc Weapon System Manager, and E. W. Smith has been named head of the preliminary design organization, Pilotless Aircraft Division.

• **The Bristol Aeroplane Co. (USA) Inc.** reports that its British parent has merged with the Hawker-Siddeley Group on a "fifty-fifty" basis to coordinate aircraft engine activities. Sir Arnold Hall, of Hawker-Siddeley and President of the Royal Aeronautical Society, has been named Chairman, and Air Commodore F. R. Banks, a Director of The Bristol Aeroplane Company, Ltd., has been named Vice-Chairman. The name of the new firm is Bristol-Siddeley Engines, Ltd.

• **Fairchild Engine and Airplane Corporation** reports its twin prop-jet F-27 has successfully completed its first flight. Two Rolls-Royce Dart engines power the aircraft at a cruising speed of 300 m.p.h. and over a range of more than 1,600 miles.

• **General Dynamics Corporation** . . . Convair Division (Fort Worth) reports that its "flying" nuclear reactor has been transferred to Oak Ridge, Tenn., where it will be suspended from four 300-ft. towers for further radiation testing . . . . Stromberg-Carlson Division announced that Douglas W. Anderson, Assistant to the Vice-President and General Manager—Electronics Division, has been awarded an Alfred P. Sloan Fellowship for 1 year's advanced study at the Massachusetts Institute of Technology School of Industrial Management.

NEWS FROM FLEXONICS

DUCTING AND COMPONENTS ENGINEERING BRIEFS

One of a series of reports to help you make more effective use of Flexon products.

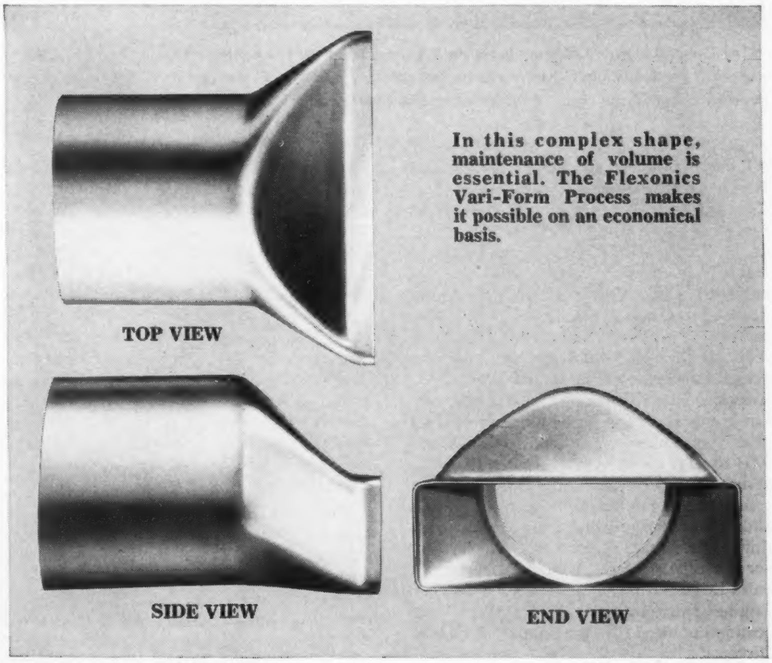
ENVELOPE PROBLEMS? VOLUME CONTROL PROBLEMS?

Solve them with Flexon Vari-Form Ducting Components

As the geometry of ducting becomes increasingly complex, forming problems are compounded. Maintaining equivalent volume becomes difficult through a variety of transitions in shape. These considerations added to the long standing problems of weight, strength, heat resistance, etc. make ducting system design a severe test of ingenuity in fabrication.

Flexonics Corporation's development and advancement of the Vari-Form Process is making the designer's job easier. The Vari-Form method produced from tube is more economical and superior to many half-shell types with burnt down welds.

Vari-Form ducting components are made by redeposition of material to all applicable MIL specs and in small or large quantities.



A representative group of shapes formed by the Vari-Form Process.

According to requirements, wall thicknesses ranging from .010 to .049 are made in daily production routine in such unusual shapes as 1:1 bends in stainless steel thin-wall tubing PLUS unusual shapes, transitions, elliptical, square—anything needed to meet the condition. All are high strength with ultimate yield of approximately 70,000 psi. Metals customarily used in M/R applications and aircraft are easily handled: CRES 302, 304, 316, 321, 347, Inconel X, 19-9DL, Monel and many others, including Titanium.

Advantages to the Designer

By specifying Flexon Vari-Form Ducting Components, the designer frees himself from the severe limitations of conventionally formed components. He is not troubled by limitations in configuration. He is assured of maintaining volume when it is required. He is able to hold weight to a minimum. He need not sacrifice strength for other considerations.

Advantages in Production

Flexon Vari-Form Ducting Components are made to very close tolerances, eliminating bad fit-up. Costs are held in line because Vari-Form Components can be made in any quantity from 1 to many thousands with minimum tooling expense.

Engineering Assistance Available

If you have unusual ducting or piping problems, you can take advantage of Flexonics Corporation's experience. As the nation's most experienced manufacturer of metallic plumbing components for aircraft, rockets and missiles, Flexonics is qualified to help you in the most advanced design problems.

It will pay you to learn more about the Vari-Form Process and how it can serve you. For specific recommendations send an outline of your needs.

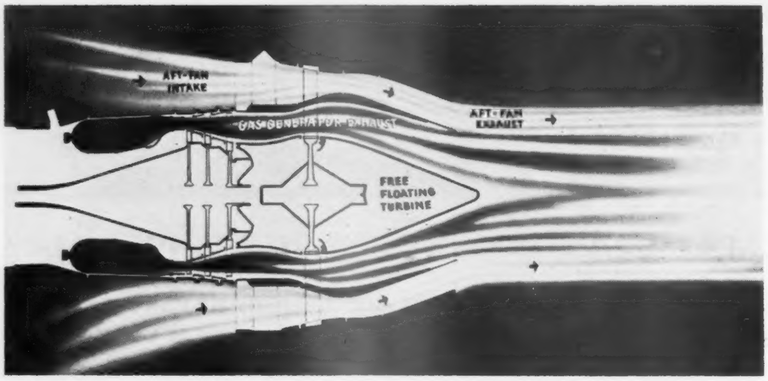
AERONAUTICAL DIVISION
A-39

Flexonics Corporation

1309 S. THIRD AVENUE • MAYWOOD, ILLINOIS

In Canada: Flexonics Corporation of Canada, Limited, Brampton, Ontario

Also Manufacturers of Rubber and Metal Hose Assemblies • Metallic Bellows • Expansion Joints



The General Electric Company is testing this diagramed aft-fan component for its latest production engines. The fan is said to improve cruise fuel economy by about 10 per cent and to increase take-off thrust by about 35 per cent. It will be offered in military and commercial versions.

• **General Electric Company** and the Air Force have activated a new Flight-Test Center to house technical and engineering services of the company's flight-test group at Edwards AFB, Calif. The first flight test of the new CJ-805 commercial jet engine has taken place at the center, the firm also announced . . . . G-E's Research Laboratory has begun operation of its new helium wind tunnel, reaching velocities corresponding to Mach 28 . . . . Aircraft Gas Turbine Division's new aft-fan component for jet engines is said to give them ideal efficiency in the Mach 0.80 to 0.90 speed range. It is a free fan, aerodynamically but not mechanically connected to the main engine rotor, which adds a secondary airflow to the jet exhaust slowing it down. Dallas A. Murphy has been named Spare Parts Procurement Sales Engineer in the division's Production Engine Department. G. H. Ward has been appointed B-58 Engine Program Director.

• **Grumman Aircraft Engineering Corporation** reports that the Japanese Defense Agency has selected the firm's F11F-1F Super Tiger for the Japanese Air Self-Defense Force. Production will begin in 1959, with 300 aircraft scheduled—the majority to be built in Japan. West Germany and Switzerland are also considering the Super Tiger. This same aircraft, flown by Lt. Comdr. George C. Watkins, USN, recently set an unofficial world altitude mark of 76,828 ft. at Edwards AFB.

• **Janitrol Aircraft Division, Surface Combustion Corporation,** has occupied their new offices and factory at 4200 Surface Road, Columbus 4, Ohio. New phone number is BRoadway 6-3561. The 130,000-sq.ft. facility houses the manufacturing, research, development, testing, engineering, marketing, and administrative functions.

• **Lear, Incorporated** has formed a new general division at Santa Monica—Lear Astronics Division—specializing in the development and production of guidance and flight control systems and electronics for airborne vehicles. Division General Manager is James P. Brown; Charles F. Pitts is Assistant Division General Manager. F. Dunstan Graham is Eastern Operations Manager; Donald W. Dressel is Manager—Astronics Manufacturing Division. Astronics Contracts Division staff members are John A. Harper, Manager—Guidance and Control Marketing; Jess Uslan, Head—Contracts Administration; and R. Lynn Eslinger, Assistant Manager—Electronic Marketing. On the Astronics Engineering Division staff are Frank A. Glassow, Manager—Electronics Engineering Department; Ralph Braverman, Manager—Guidance and Flight Control Engineering Department; and Kenneth Kramer, Assistant Manager—Guidance and Flight Control Engineering Department.

• **Lockheed Aircraft Corporation** reports that the Navy will buy Electra turboprop aircraft as an "off-the-shelf" procurement item for antisubmarine warfare. . . . Georgia Division has formed a separate operating branch which is engaged in designing—and is ready to manufacture—nuclear reactors for the generation of industrial heat. Robert W. Middlewood (AF), former division Chief Engineer, has been named Director, Georgia Nuclear Laboratories. . . . Missile Systems Division has named William A. Stevenson to direct the design of the Polaris. He had been Convair's Chief Engineer of Advanced Missile Projects. Gershon R. Makepeace, formerly President and General Manager, Sandshell Corp., has joined the division as Manager of the Polaris propulsion staff. . . . California Division has promoted Harold M. Harrison to the post of Assistant Chief Engineer.

• **Northrop Aircraft, Inc. . . .** Northrop Division Engineering Vice-President George F. Douglas has announced that the division has "developed basic design criteria for a perfectly feasible manned space laboratory." Roger S. Estey has joined the Nortronics staff as a research scientist. Tom J. Venator has been named Chief Applications Engineer, Electronic Systems and Equipment, Nortronics.

• **Pan American World Airways, Inc. . . .** Board of Directors has elected Norman P. Blake Vice-President and Howard M. Blackwell Assistant Vice-President, Services of Supply. John T. Shannon has been appointed Atlantic Division Manager to succeed Mr. Blake.

• **Pesco Products Division, Borg-Warner Corporation,** has formed an Automatic Warehousing Branch to design, develop, fabricate, and install reserve storage warehouse systems featuring semiautomatic or fully automatic operation. It will produce conveyorized production-line systems and a complete line of tooling for service and overhaul of jet engines, as well as custom material-handling equipment of all kinds. D. Wayne Zimmerman is Branch Manager.

• **The Ramo-Wooldridge Corporation . . .** Space Technology Laboratories Division will seek to gain data on the distribution of free electrons in the ionosphere during Atlas ICBM flight tests. . . . Pacific Semiconductors, Inc. (subsidiary), has announced that Simon Prussin and Frank Steinebrey have joined the research and development staff. Dr. Prussin will engage in the study of silicon crystal structure; Mr. Steinebrey has been assigned

Lockheed Missile Systems Division is conducting development tests with a concrete and steel dummy missile to simulate the Navy's Polaris fleet ballistic missile launching system. The tests are being made as a joint effort with Westinghouse Electric Corporation, in charge of launcher development, at the San Francisco Naval Shipyard.

to the firm's high power silicon transistor development group. Three sales engineers have joined the firm: Irwin Samuels, Philip Astra, and Tom Lopker.

• **Republic Aviation Corporation** has retained Antonio Ferri (F), Charles S. Draper (F), Winston Bostick, and John L. Barnes as consultants on space propulsion, inertial navigation, aerodynamics, and thermodynamics. The firm also announced the unveiling of a new transonic-supersonic wind tunnel that will be used to create and evaluate a variety of aerodynamic tests on the F-105 and for explorations of missile design. The transonic section has a speed range of Mach 0.8 to 1.4, and the supersonic capability will be up to Mach 4. Fred G. Draper has been appointed Supervisor, Production and Supply, Helicopter Division.

• **Ryan Aeronautical Company** has sponsored a 2-day symposium on the Firebee drone missile which was followed by a 1-day Air Force closed conference. The firm's "MiniWate" method of fabricating paper-thin, high-strength steel alloy into missile structures has won a national design award, Ryan announced.

• **Solar Aircraft Company** has announced the appointment of Col. William C. Farmer, USA (Ret.), as Weapons System Manager.

• **Thompson Products, Inc.,** has undergone a broad reorganization involving regrouping of several divisions and coordination of their sales efforts. Five divisions—Jet, Accessories, Pneumatics, the Cleveland Operation of the Electronics Division, and the aircraft operations of the West Coast Division—have been combined in a new Tapco Group under managership of Vice-President Edward P. Riley. Stanley C. Pace has been elected a Vice-President of the firm and named Assistant Manager of the group. Pierce T. Angell will direct the central engineering function of the new group, and John H. Shaffer will be in charge of the coordinated sales section. In a companion move, a Customer Requirements Group—consisting of Staff Vice-Presidents Ben W. Chidlaw (also an IAS Vice-President), G. R. Moore, and Len W. Reeves—has been created. Eugene G. Ford, counsel for the company, has been elected Assistant Secretary.

• **United Aircraft Corporation . . .** Sikorsky Aircraft reports the completion of a licensing agreement with Mitsubishi Heavy Industries of Tokyo to build the S-55 helicopter for sale in Japan and adjacent countries under royalty terms.

• **Vertol Aircraft Corporation** has created two new corporate divisions—the International Division and the Government Operations Division—in place of the firm's old Customer Relations Division. Harry S. Peck, Vice-President and former Director—Customer Relations, heads the International Division. James M. Davis, formerly Assistant to the President in charge of the Washington office, has been named Director—Government Operations Division. Other appointments in this division include T. R. Pierpoint, Manager—Military Programs Department; Bruce McKay, Manager—General Products Department; Frank K. MacMahon, Robert G. Barnhart, and Edward B. Wilford—Military Program Administrators; James N. Nutt, Military Products Administrator; and John Hanlon, Industrial Products Administrator. Thomas H. Mullen has been named to the newly created position of Manager—Program Evaluation.

• **Vitro Corporation of America** has announced the appointment of John T. Bailey as Chief Design Engineer, Vitro Engineering Company division.

• **Westinghouse Electric Corporation** has established its Defense Products Headquarters at 1000 Connecticut Avenue, N.W., Washington, D.C. The firm also announced seven appointments in this office: R. M. Wilson, Director, Application Engineering; Patrick Conley, Technical Director; V. W. McMahill, Director, Contract Administration; E. W. Locke, Staff Assistant and Military Liaison; H. E. Dralle, Weapon Systems Coordinator, nondefense divisions; H. A. Gunther, Jr., Director, Customer Requirements; and C. A. Willer, Group Budget Director. T. P. Eldridge has been named Pittsburgh representative for defense products and liaison between the firm's headquarters and the Washington staff. Westinghouse also has established a new microwave center adjacent to Cornell University, Ithaca, N.Y., as a branch of the Electronic Tube Division. The Sunnyvale Manufacturing Division is conducting development work on the Polaris missile launching and handling system.

IAS News — IAS Sections

Boston Section

B-58 Design Features

Edward D. Mathis discussed "**Design Highlights of the B-58**" at the February 6 meeting. He is Manager, B-58 Flight-Test Program, Convair (Fort Worth).

Mr. Mathis covered concept through detail design in his talk. He outlined major design requirements including high altitude and speed, wide speed and temperature range, severe vibration environment due to engine noise, and high structure loads.

As an indication of the "cleanness" of the aircraft, he said that lowering the landing gear approximately doubles the drag.

Honeycomb sandwich construction was used throughout to provide necessary external smoothness and to satisfy the demands of the extreme environmental design conditions. A fiberglass core was used in the area of the wing fuel cells to provide insulation during prolonged supersonic flights.

G. Fallabella, Jr.
Secretary

Dayton-Cincinnati Section

Need for Government Support of Accessory Power Firms

Walter C. O'Connell, General Manager, General Electric's Aircraft Accessory Turbine Department, discussed "**Some Problems of Furnishing Accessory Power Products for Defense and Some Suggested Solutions**" on February 27.

Mr. O'Connell advocated a systems approach to get the best results in terms of equipment performance, cost, and delivery. He illustrated this by tracing the development of an electrical power system from its components to a complete self-contained accessory power system.

Financial risks increase as the complexity of equipment increases, he said. Also, the accessory equipment supplier must constantly search for new and better ways to perform his function to keep pace technically with the needs of industry and with his competitors.

Technical development should be self-starting and should strive for cost reduction through design simplification and efficient operation. Mr. O'Connell also recommended that prime weapons system manufacturers give earlier consideration during their development cycles to accessory power systems. Whenever possible they might subcontract accessory system management, focusing responsibility for subsystem performance.

The Government should encourage industry in military product development and capital investment through better recognition of the price versus value relationship, the allowance of realistic depreciation, and the abolishment of statutory renegotiation. The accessory power manufacturer needs such direct support for state-of-the-art developments, he said.

John S. McCollom
Secretary

Detroit Section

Member Interests Surveyed

A recent survey of members of this Section indicated that programs based on the following topics were most desired: aircraft components or accessories, business aircraft, missiles and high-speed aircraft, and STOL-VTOL aircraft. The annual small gas turbines symposium and the student paper competitions were also very popular.

The Section sponsored a Student Paper Competition on May 6 at the University of Michigan.

Richard Chute
Secretary

Indianapolis Section

Analog Computer Use With Turbine Engines

"The Real Time Simulation of Turbojet and Turboprop Engines and Controls"

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Herbert Kurit (A), an Aerodynamicist for the H. L. Yoh Company, Inc., was one of 27 IAS Niagara Frontier Section members who manned this exhibit during a 4-day Technical Societies Council Science Fair in February. Some 300 visitors obtained information at the Section's exhibit.

was discussed by **D. L. Dresser** before 60 members and guests at the April 14 meeting. Mr. Dresser is Supervisor, Analog Computer Group, Allison Division, General Motors Corporation.

He introduced the analog computer as the most powerful technique for solving the task of the control designer to produce optimum control of a designed engine in a minimum amount of time.

Mr. Dresser also discussed detailed examples of simulation with gas-turbine engines.

R. J. H. Bollard
Secretary

New York Section

160 Members Visit N.Y. International Airport

More than 160 members visited new buildings and the Air Route Traffic Center at New York International Airport on April 10. New York Port Authority and CAA personnel served as guides.

The new International Arrivals Building uses the latest ideas for handling large numbers of passengers and has spacious facilities for public health, inspection, immigration service, and customs checking. Incoming passengers move the shortest possible distance through these facilities and can be met by visitors who may watch their processing from the second floor.

The group also was briefed on future plans for the terminal city including individual airline buildings which will surround an ellipse in which the control tower, parking lots, and other facilities are located. The entire area is landscaped and lighted at night.

The Air Route Traffic Center, located away from the main buildings, is one of the busiest in the world, controlling traffic for some 150 miles west and south of New York and for 500 to 600 miles over the Atlantic. The Center has the latest traffic control and radar equipment and handles all types of aircraft.

R. M. Woodham

Niagara Frontier Section

Stever Discusses Space Technology

H. Guyford Stever delivered a talk on **"Space Technology"** at the April 23 meeting. Dr. Stever is an IAS Vice-President and Chairman, NACA Special Committee on Space Technology.

His talk covered the implications of the space race with Russia, the scientific benefits to be derived from space flight, and the nature of the agency which will administer research in space technology.

Dr. Stever said any grandiose schemes to place a large number of satellites in orbit will be detrimental to the problem of space surveillance. An abundance of information on the nature of space can be obtained from a small number of firings.

Daniel B. Hardie
Secretary

Rocky Mountain Section

Weapons Planning

Major Kemper W. Baker, USAF Air Defense Command, spoke on **"Operational Planning for Future Weapons Systems"** at the March 20 meeting. Major Baker is Chief, Manned Interceptor Branch, Weapons Division, Directorate of Plans.

He described the process for determining future defense weapons systems requirements and showed slides to illustrate his talk.

D. A. Knowlton
Secretary

San Antonio Section

Sources of "Infinite" Energy

John J. Grebe spoke on **"Forms of Energy Available to Man"** at the April 8 meeting. Dr. Grebe is Director, Nuclear and Basic Research, The Dow Chemical Company.

He pointed out the infinite energy potential we have from the "nuclear age" and from the oceans of the earth and drew a comparison between them and what is referred to as dwindling natural resources (oil and water supplies).

Dr. Grebe also discussed how power from nuclear fission and the potential of the seas could be combined to provide "infinite" energy.

M/Sgt. Robert R. Perry, USAF
Secretary

San Francisco Section

Atmosphere Problems in Missile Design

Some 50 members and guests at the April 17 meeting heard **George Taylor** discuss **"Atmosphere in Missile Design."** Dr. Taylor is a Staff Scientist, Lockheed Missile Systems Division.

His talk included an explicit description of the variation of atmospheric properties with underlying explanations. He used slides to illustrate the discussion.

► **"Soaring, the World's Most Beautiful Sport"** was discussed by **Stan Hall** before 60 members and guests at the March 20 meeting. A Staff Engineer, Lockheed Missile Systems Division, Mr. Hall also is Director, the Southern California Soaring Association.

He described the evolution of the high-performance sailplane and episodes in the discovery of soaring techniques in this country.

Mr. Hall also showed a film about the construction and testing of a glider, the Cherokee II, which he designed for those who wish to build an efficient sailplane at home. The film also showed in-flight scenes at Torrey Pines along the ocean cliffs of Southern California.

Daniel Bershader
Secretary

St. Louis Section

Pilot for X-15 Discusses Flight Testing

Captain Iven C. Kincheloe, Jr., spoke on **"X-2 and X-15 Flight Testing"** at the March meeting. An Associate of the Institute, Captain Kincheloe was awarded the Mackay Trophy last year for a 126,200-ft. climb in the Bell X-2 in 1956.

He reviewed his historic flight and explained the different "X" series aircraft. He said the goal of the North American X-15 is to reach the ionosphere, traveling anywhere from 50 to 150 miles into space. This "manned spaceship" will investigate the unknown velocity regions at five, six, or more times the speed of sound.

The X-15 rocket engine will be capable of 60,000 lbs. of thrust. It will fire from 1 to 3 min. Captain Kincheloe said the plane is considered safe. Depending upon circumstances, the pilot, in case of mishap, will have a 90 to 100 per cent survival chance. The aircraft has been carefully designed from the standpoint of human engineering. He illustrated his talk with slides and a movie made by Bell.

The meeting, attended by some 250 members and guests, was classified.

Owen B. McBee
Secretary

Texas Section

Scientists Debate Problem Solving

Sir Richard V. Southwell and **V. G. Szebehely** on April 2 discussed the pros and cons of using **"Relaxation"** methods and electronic computations to solve engineering mathematical problems.

Sir Richard, an Honorary Fellow of the Institute, is Visiting Professor of Mechanical Engineering, The Rice Institute. Dr. Szebehely is associated with the Aeroscience Laboratory, General Electric Company.

Sir Richard said that one school of thinking believed in solving complex problems only through electronic computation while another school believed the best method was to perform all calculations using the human operator. Both men agreed the best course of action was to use both methods in such a way that they complemented each other.

M. V. RICCIUS
Secretary

Tullahoma Section

Spacecraft Fuel and Systems

More than 60 members and guests heard **A. M. Rothrock** lecture on **"The Relation of the Propellant to the Propulsion System for Spacecraft"** on March 31. An IAS Fellow, he is Assistant Director for Research (Propulsion), NACA, Washington, D.C.

Mr. Rothrock discussed liquid, solid, nuclear, ion, magnetic, and other types of propulsion systems.

H. A. REICHMANN, JR.
Secretary

Tulsa Section

Jet Transport Virtues: Speed, Passenger Appeal

Marvin Whitlock, Vice-President, Operations Planning, American Airlines, spoke on the topic **"Why Jet Transports?"** at the April 8 meeting.

He said that, although the airlines could satisfy their needs for increased capacity by buying more piston aircraft, there are several reasons for preferring jets.

The step to jets in the 580-m.p.h. class exceeds greatly the relatively slow average increase of approximately 8 m.p.h. per year for piston aircraft over the past 25 years. Reduced noise and vibration, roomier cabins, and high-altitude weather-free travel are expected to appeal to the passenger even more than the speed advantage.

BRUCE D. OLSON
Recording Secretary

Washington Section

Fundamental Instruments Favored for Space Travel

George E. Valley, USAF Chief Scientist, discussed **"Missile and Spacecraft Electronics"** at the April 8 meeting.

Dr. Valley stressed fundamental electronic aids, the magnetic compass, sextant, theodolite, and directional gyro in lieu of current aids to navigation which have sizable space and power requirements. These, together with a reliable clock and charts of the stars and moons of the universe, could be readily used for space navigation.

He said one electronic device—the radio altimeter—would be required for the terminal phase of the trip to determine accurately the height for firing deceleration rockets.

FLOYD J. SWEET
Secretary

Change of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Aero/Space Engineering.*

Notices should be sent directly to the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

REVIEWS OF *Books*

. . . in the field of aeronautical engineering and space technology

AERONAUTICS, GENERAL

Jane's All the World's Aircraft, 1957–58. Compiled and Edited by Leonard Bridgman; Assistant Compiler, John W. R. Taylor. New York, McGraw-Hill Book Company, Inc., 1957. 488 pp., illus., diagrs. $30.

The seven principal sections of this edition, which has been corrected to September 30, 1957, cover the topics of military aviation, civil aviation, civil airline operators, airplanes, gas-turbine engines, piston engines, and airships. Some 590 new illustrations have been introduced; the Airlines of the World tabulation contains a record of the composition and the 1956 basic traffic figures of 297 scheduled airlines and other operators maintaining scheduled services.

The airplane section comprises 339 pages, 25 more than last year, and contains a total of 761 illustrations, of which 434 are new. Great Britain, Canada, Czechoslovakia, West Germany, Poland, and the United States all show increases in the number of pages compared with last year. The products of 33 countries are dealt with in this section, with the United States occupying 140 pages, Great Britain 65 pages, and France 33 pages. Austria and Bulgaria are represented again after an absence of 20 years, and Eastern Germany and Egypt are appearing for the first time. The Russian section of 14 pages does not contain much new military information, largely because the 1957 military display at Tushino, at which it had been customary for the Soviet Air Force to show off its latest aircraft, was canceled at the last moment.

Although reference is made in the airplane section to the missile work being done by individual manufacturers, more complete tabular information is given in the Guided Missiles and Missile Test Vehicle sections. The engine section contains a total of 94 pages, of which 61 are devoted to gas-turbine power plants and rocket motors. The small airship section gives available details of the airships of the U.S. Navy.

There are four indexes—for aircraft, rotating-wing aircraft, gas-turbine engines, and piston engines. Each index contains, in addition to references to all items in this edition, references to all aircraft and engines described in the ten previous editions of *Jane's*, going back to and including 1947.

Aircraft Year Book, 1957–1958. 39th Ed. Official Publication of the Aircraft Industries Association, Inc. Washington, American Aviation Publications, Inc., 1958. 432 pp., illus., diagrs. $6.00.

Contents: Aviation Events. The Industry: Airframe and Missile Manufacturers, Engine Manufacturers, Systems and Components Manufacturers. Military Aviation. Research and Development. Civil Aviation: The Airlines, Helicopters, General Aircraft. Government and Aviation. Aircraft in Production. Engines in Production. Missiles. United States Chronology. 1957 Day by Day Chronology. Official Records. Bibliography. Index.

AIR CONDITIONING

Into Thin Air. E. W. Still. Yeovil, England, Normalair Ltd., 1957. 215 pp., illus., diagrs., tables. 18*s*. 6*d*.

Written by the Technical Director of Normalair Limited, this volume introduces the aircraft designer and licensed engineer to the complex of equipment and instrumentation involved in the task of pressurizing and air conditioning aircraft cabins. The author has also provided a detailed guide to the various statutory requirements in force in Great Britain, as well as those based upon the recommendations of the SAE.

Contents: (1) Physiological Factors of High Altitude Flight. (2) The General Requirements of Air Conditioning. (3) Pressure Control Systems. (4) Power and Air Supply. (5) Cooling and Heating Systems. (6) Temperature Control. (7) Humidity Control. (8) Air Flow and Ventilation. (9) Oxygen Systems. (10) Mountaineering Oxygen. (11) Testing of Systems and Equipment. (12) Detailed Requirements of Air Conditioning.

Appendixes: (1) Sample Calculations for 100-Seater Civil Transport Aircraft. (2) Duct Loss Data. (3) Temperature Standards. (4) Sub Sonic Flows Through an Orifice. (5) Discharge of Air Through an Orifice into Altitude Conditions. (6) Conversion Data. (7) Standard Atmosphere Tables and Data.

AIRPLANES

Airplane Design Manual. Frederick K. Teichmann. 4th Ed. New York, Pitman Publishing Corporation, 1958. 489 pp., diagrs., tables. $8.50.

The present edition has been rewritten and expanded by more than 100 pages to encompass the developments that have come about in airplane design since the issuance of the 1950 edition. An attempt has been made to amplify the analytical approach to design problems, as well as the purely empirical approach. The objectives of the book are (1) to provide an understanding of the various principles included in aerodynamics, structural design, installation requirements, and application of materials; (2) to afford a basis for stress analysis; (3) to provide some drafting experience; and (4) to enable the student to evaluate various requirements, judge the necessity of compromise, and know the amount of time needed to achieve a given objective.

The author is Professor of Aeronautical Engineering and Assistant Dean, Day Division, College of Engineering, New York University.

An Introduction to the Dynamics of Airplanes. H. Norman Abramson. New York, The Ronald Press Company, 1958. 225 pp., illus., diagrs., tables. $4.50.

The purpose of this book is to acquaint the senior aeronautical engineering student with the various dynamical problems encountered in the design, construction, and operation of aircraft and to furnish the practicing engineer with a useful introduction to more advanced books and to the rapidly increasing number of technical papers dealing with this particular aspect of aeronautical science. Since most of the problems peculiar to airplane and missile dynamics are considered to be principally those of vibration, the first third of the book deals with vibration theory; the balance of the volume is devoted to the main topic, the dynamics of airplanes. A brief treatment of the use of matrix algebra in the literature concerning airplane dynamics is given in Chapter 3, and the subject of flight stability of aircraft is accorded full coverage in Chapter 8. In most instances, the problems which accompany the text constitute amplifications or extensions of the text and should therefore be regarded as as much a part of the theoretical development of the subject as the text itself.

The Observer's Book of Aircraft. William Green and Gerald Pollinger. 6th Ed. London, New York, Frederick Warne & Co., Ltd., 1958. 288 pp., illus., diagrs. $1.25.

This pocket book contains available details, photographs, and three-view silhouettes of 152 of the world's latest military and civil aircraft. From lightweight fighters and supersonic bombers to light touring planes, the aircraft are arranged in alphabetical order by manufacturer's name.

ASTROPHYSICS

Theoretical Astrophysics. E. R. Mustel', A. B. Severnyi, and V. V. Sobolev. Edited by V. A. Ambartsumyan. Translated from the Russian by J. B. Sykes. New York, Pergamon Press, 1958. 645 pp., diagrs., tables. $22.50.

This work by four Soviet astrophysicists, first published in 1952 and revised by the authors for the English translation, gives a comprehensive treatment of the main branches of astrophysics at the graduate level. Two-thirds of the book consists of the work of E. R. Mustel' and deals with the theory of the continuous spectrum; the theory of absorption lines; the physics of the sun; the theory of radiative equilibrium; the structure of the photospheres of stars of various spectral classes; the deviations from thermodynamic equilibrium in stellar photospheres; line contours and their interpretation; curves of growth; sunspots; prominences; the chromosphere; the corona; and solar electrodynamics. Mr. Sobolev's contributions consist of discussions of planetary nebulas, novas, and stars with emission lines in their spectrums, and an elucidation of the physical state of matter in these objects and the mechanism of their radiation. A. B. Severnyi is concerned with the internal structure of the stars; V. A. Ambartsumyan concludes with dissertations on the scattering of light in planetary atmospheres and interstellar matter.

The 183 bibliographical references include Soviet journals, but Soviet textbooks not available in translation have been omitted.

COMPUTERS

Modern Computing Methods. Gt. Brit., National Physical Laboratory, Mathematics Division. New York, Philosophical Library, 1958. 129 pp., diagrs. $8.75.

These notes on computation are based on lectures delivered by various staff members of the Mathematics Division, NPL, and are designed to teach the basic principles of the use of analog machines, high-speed digital computers, and the techniques of numerical mathematics involved in the solution of problems in electrical engineering. Topics discussed include algebraic equations and matrixes, finite difference methods, ordinary and partial differential equations, and the tabulation and computation of mathematical functions.

Appendix 1 contains a fairly comprehensive bibliography of the most useful books and papers on the various topics of numerical analysis. Appendix 2 gives a brief description of DEUCE, the high-speed digital machine in operation in the Mathematics Division, and Appendix 3 describes the basic features of a mechanical differential analyzer also employed at the NPL.

CONTROL THEORY

Control Engineers' Handbook; Servomechanisms, Regulators, and Automatic Feedback Control Systems. Edited by John G. Truxal. New York, McGraw-Hill Book Company, Inc., 1958. 1048 pp., diagrs., tables. $18.50.

This handbook has been written for two primary groups—the engineer recently graduated from college who is anxious to work in the control field, and the control engineer who is experienced in one area but desires an introduction to a different aspect of his chosen science. Some 36 experts have contributed to this volume, in which the chief emphasis is on the components of typical control systems rather than on system design or theory. In line with this emphasis, roughly 80 per cent of the handbook is devoted to components, with the remaining 20 per cent containing digests of basic design and analysis techniques. Linear transistor circuits, magnetic amplifiers, thyratron amplifiers, contactors and relays, power supplies, electromechanical actuators, mechanical components, clutches and brakes, hydraulic components, pneumatic components, and signal transducers are all given a feedback-control-engineering treatment accompanied by physical explanations and mathematical descriptions of their role in typical control systems.

The editor is presently Head, Electrical Engineering Department, Polytechnic Institute of Brooklyn.

DICTIONARIES

Russian-English Glossary of Acoustics and Ultrasonics. Edited by P. Robeson, Jr. New York, Consultants Bureau, Inc., 1958. 193 pp. $10.

The increasing availability and use of Soviet scientific publications has made imperative the prompt publication of a comprehensive and authoritative modern reference for Russian terminology in all fields of modern research physics—both theoretical and applied. To meet this end, Consultants Bureau, Inc., plans the publication within the next 2 years of a Russian-English Physics Dictionary covering the scientific and technical terminology, as well as ordinary Russian expressions and idioms which have special meaning in the various fields of physics.

This interim glossary is one of several that will precede the final, permanently bound volume now scheduled to appear during 1959, and contains over 10,000 terms and expressions taken from numerous articles on various topics in the fields of acoustics, electroacoustics, and ultrasonic theory. These articles appeared in several thousand pages of the most recent issues of Soviet physics and engineering journals, especially the *Journal of Acoustics, Journal of Technical Physics*, and *Radio-Engineering*. Appended is an Index of Russian-English Equivalents of (Personal) Names Commonly Found in Acoustics and Ultrasonics Theory.

ELECTRONICS

Gaseous Conductors; Theory and Engineering Applications. James Dillon Cobine. New York, Dover Publications, Inc., 1958. 606 pp., illus., diagrs., tables. $2.75.

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A reprint of the 1941 edition, with corrections by the author.

GEOPHYSICS

Advances in Geophysics, Vol. 4. Edited by H. E. Landsberg and J. Van Mieghem. New York, Academic Press, Inc., 1958. 456 pp., illus., diagrs., tables. $12.

Contents: Atmospheric Chemistry, Christian E. Junge. Theories of the Aurora, Joseph W. Chamberlain. The Effects of Meteorites Upon the Earth (Including Its Inhabitants, Atmosphere, and Satellites), Lincoln LaPaz. Smoothing and Filtering of Time Series and Space Fields, J. Leith Holloway, Jr. Earth Tides, Paul J. Melchior.

Dr. Landsberg is with the U.S. Weather Bureau, Washington, D.C.; Dr. Van Mieghem is with the Royal Belgian Meteorological Institute, Uccle, Belgium.

GLIDING

Soaring in Poland. W. Humen. Warsaw, Polonia Publishing House, 1957. 105 pp., illus., tables.

Written by the Chairman of the Council for Soaring of the Polish Aero Club, this small volume is divided into two parts, the first of which describes the birth of gliding and soaring in Poland, methods of training and schools, glider designs, and Polish glider records achieved in national and international soaring contests up to the beginning of World War II. Part 2 recounts the postwar development of soaring in Poland and the plans of the Club for increased participation in international contests.

MATERIALS

Rheology, Theory and Applications, Vol. 2. Edited by Frederick R. Eirich. New York, Academic Press, Inc., 1958. 591 pp., illus., diagrs., tables. $18.

In this volume, the second of three devoted to summarizing experimental and theoretical knowledge in the science of deformation and flow, the scope of rheological fields dealt with becomes more specific than the introductory and descriptive material offered in *Volume 1.* The material is presented in the form of independent chapters, written by leading authorities, with the object of providing the reader with specific information of a self-contained nature without making it necessary for him to refer continually to a number of other chapters or volumes.

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1957 Supplement to Book of ASTM Standards, Including Tentatives. *Part 1,* Ferrous Metals. *Part 3,* Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Waterproofing, Soils. *Part 4,* Paint, Naval Stores, Cellulose, Wax Polishes, Wood, Acoustical Materials, Sandwich and Building Constructions, Fire Tests. *Part 5,* Fuels, Petroleum, Aromatic Hydrocarbons, Engine Antifreezes. *Part 7,* Textiles, Soap, Water, Paper, Adhesives, Shipping Containers, Atmospheric Analysis, Leather. Philadelphia, American Society for Testing Materials, 1957. *Part 1,* 512 pp.; *Part 3,* 418 pp.; *Part 4,* 216 pp.; *Part 5,* 345 pp.; *Part 7,* 304 pp.; illus., diagrs., tables.

MECHANICS

Analytical Mechanics for Engineers. Fred B. Seely, Newton E. Ensign, and Paul G. Jones. 5th Ed. New York, John Wiley & Sons, Inc., 1958. 475 pp., diagrs., tables. $7.25.

The new material of the 5th edition includes a chapter on an introduction to vector analysis, a chapter on the equilibrium of bodies which makes use of the concepts of virtual work, new problems involving engineering or physical conditions, an explanation of the use of a general coplanar force system in introducing equilibrium of force systems, a separate chapter for a description of the use of the inertia-force method in kinetics, and discussion of the product of inertia of areas. The book is divided into four parts—statics, kinematics, kinetics, and special topics—with emphasis placed on the use of the general steps or procedure in analyzing problems in equilibrium and in dynamics. The topics covered reflect the modern trends in various fields of engineering practice and education.

The authors are associated with the University of Illinois as Professors of Theoretical and Applied Mechanics.

NATURAL FLIGHT

Insect Flight. J. W. S. Pringle. (Cambridge Monographs in Experimental Biology, No. 9.) Cambridge, England; New York, Cambridge University Press, 1957. 133 pp., illus., diagrs., tables. $3.00.

In this monograph Dr. Pringle brings together the results of the latest investigations of the mechanics of wing motion, the structure and physiology of flight muscle, aerodynamics, sense organs, and nervous coordination and shows how a common structural plan has been perfected during the course of evolution to produce the variety of form and function found in the different insect orders. More than 200 pertinent references follow the text and are accompanied by an Index of Insects whose precision in aerial maneuvers has interested zoologists and biological engineers from the earliest times.

POWER PLANTS

Turbojet Fundamentals. Howard E. Morgan. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1958. 104 pp., diagrs. $3.00.

Originally prepared by Douglas Aircraft, Inc., for training use by their own personnel, this brief introduction to basic theory and operating principles of the turbojet engine is aimed primarily at the aircraft technician. Only a background in high-school mathematics is required.

ROTATING WING AIRCRAFT

Proceedings of the Fourteenth Annual National Forum, April 16–19, 1958, Washington. New York, American Helicopter Society, 1958. 125 pp., illus., diagrs. $6.50.

Contents: Stability and Control of Unducted Stand-On Helicopters, M. William Townsend, Jr., and Edward Seckel. Test Experience on the Vertol 76 Tilt Wing VTOL Research Aircraft, Paul J. Dancik, Frederick R. Mazzitelli, and Walter D. Peck. Ryan Vertiplane Development, Fred Landgraf. Flight Testing of the XV-3 Convertiplane, John R. Mertens and Charles E. Davis. Recent Advances in the Flying Qualities of Tandem Helicopters, Bruce Blake, James M. Clifford, Raymond Kaczynski, and Philip F. Sheridan. Induced Flow Near a Rotor and Its Application to Helicopter Problems, Harry H. Heyson. A Study of Turbine-Powered Helicopter Drive System Instability, John C. Keeling and David L. Kidd. A Mechanical Speed Control for Helicopter Power Plants, Norman C. Olson. Tip Mounted Turbojet Helicopters, Robert A. Wagner. Pressure Jet Helicopters, Friedrich L. von Doblhoff. Hot Cycle Jet Helicopters, Harold Hirsch. The Missions and Future of Army Aviation, Ernest F. Easterbrook.

SPACE MEDICINE

Epitome of Space Medicine. Randolph AFB, Texas, USAF School of Aviation Medicine, Air University, 1957. 408 pp., illus., diagrs.

In recognition of the fact that aeromedical science must concern itself with an anticipation of medical problems related to possible interplanetary travel, the Air University has reprinted in this volume ten research reports from the School of Aviation Medicine and 31 articles that appeared in various scientific journals during the period 1949–1957. The majority of articles contained herein were taken from the *Journal of Aviation Medicine*; other journals represented include the *Aeronautical Engineering Review* (now *Aero/Space Engineering*); *Journal of Astronautics; Jet Propulsion; Astronautica Acta; American Rocket Society, Journal; Scientific American; American Meteorological Society, Bulletin;* and the *Instructors Journal*, a publication of the Air Training Command. The articles and reports contain more than 600 references to the literature.

SPACE TRAVEL

Spacepower; What It Means to You. Donald Cox and Michael Stoiko. Philadelphia, The John C. Winston Company, 1958. 262 pp., illus., diagrs. $4.50.

This is not a technical treatise on rocketry but an analysis of the social, military, and legal aspects of man's extension into the universe in which, by extrapolation from the past and present, the authors attempt to prognosticate where "rocketry tomorrow" will lead us. Space law and space sociology are discussed at length, and the social impact of long-range missiles and earth satellites is considered. In addition, the authors offer a concrete proposal for the control of space through a United Nations force and a "Man in Space" timetable beginning with a research aircraft program in 1958 and ending with the year 2000 when distant planetary probes presumably might begin.

THERMODYNAMICS

Thermodynamics of Engineering Science. S. L. Soo. Englewood Cliffs, N.J., Prentice-Hall, Inc., 1958. 620 pp., diagrs., tables. $9.50.

The aim of this volume is to enable undergraduate students to develop a fundamental understanding of thermodynamics and its application in order to solve problems and develop formulas not listed in any handbook. The book was organized from lecture notes used at Prince-

(*Continued on page 115*)

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to specialists in the aero/space industry. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

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Instructor—Aeronautical Engineering—The University of Southern California has an opening for an instructor in its aviation safety program. Students are U.S. Air Force, Navy, and Army pilots. Instructor should have B.S.A.E. and preferably flying experience and a background in the design or testing of jet power plants. This is a full-time position at base salary of $8,500 for an 11-month year, with usual academic holidays. It involves approximately 12 hours of classroom instruction per week. Time may be made available for study or consultation service in industry. Position to be filled by October 15, 1958. Appointment will be made in September, 1958. Send inquiries to Aviation Safety Division, U.S.C., Los Angeles 7, Calif.

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Engineers—Diversified engineering positions are available involving engine research, design, design and performance analysis, test engineering, compressor and turbine design, controls systems, and other engineering operations associated with the general field of design and development of gas-turbine power plants. Send résumé to Felix Gardner, Fairchild Engine Division, Fairchild Engine and Airplane Corporation, Deer Park, Long Island, N.Y.

Professors—The Air Force Institute of Technology, Wright-Patterson AFB, Ohio, has vacancies in the Department of Mathematics. Most of the work is at advanced undergraduate and graduate levels. Employment will be effected in accordance with Civil Service regulations. Grade levels available are GS-9 ($5,440-$6,250), **Instructor**; GS-11 ($6,390-$7,465), **Assistant Professor**; GS-12 ($7,570-$8,645), **Associate Professor**. Applications should be made on Standard Form 57, available at any post office, or by letter to Dr. Albert B. Carson, Head of Department of Mathematics, ITDSE, Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

Assistant, Associate, or Full Professor—in the Mechanics Department at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio. Applicants should possess an M.S. with industrial or teaching experience or a Ph.D. Teaching assignment may vary from undergraduate mechanics courses through advanced graduate courses in aircraft and missile structures, aeroelasticity, missile ballistics, and advanced dynamics. Employment will be effected under Civil Service regulation at the grades of GS-11, 12, or 13.

Flight Test Engineers, Aeronautical Design Evaluation Engineers—The Civil Aeronautics Administration needs experienced aeronautical engineers in the performance analysis, flight-test, and aerodynamics specialties. Flight-test engineers will be responsible for planning and/or evaluating flight-test programs, test data reduction methods, and flight manual performance and contents on commercial aircraft. Aeronautical design evaluation engineers will be responsible for structural evaluation of commercial aircraft and aircraft component designs in determining compliance with civil air regulations. Salaries range from $6,250 to $10,065 annually. Those interested should submit résumé or contact Robert Barnfather, CAA, Federal Building, New York International Airport, Jamaica, N.Y. (telephone; OLympia 9-7000, Ext. 240).

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869. Engineer—M.S. in Ae.E. Eight years' engineering experience in the aircraft industry. Lecturer in heat transfer at a major southern California university. Engineering experience primarily concerned with analytical design and development of pneumatic systems, cabin and equipment conditioning systems, defog systems, turbine-driven auxiliary power systems, etc. Wide experience in heat-transfer analysis, compressible fluid flow analysis, and research and development testing. Present position involves supervision of group responsible for analytical design and development of conditioning and defog systems on a high-performance aircraft. Desires a position of more scope and responsibility, either technical or technical management. Will consider relocation. Complete résumé on request.

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866. Contract Management—15 years' experience in engineering and management with large and small aircraft and engine manufacturing companies. One year in project engineering, $3^1/_2$ years on general manager's staff, and $3^1/_2$ years on engineering management staff. Last 7 years in contact management areas of program proposals to military services and program planning and management control. Heavy experience in dealing with top engineering, production, accounting, and sales executives. Desires position of greater responsibility with small- or medium-size manufacturer or research center. Prefers eastern Ohio or western New York State location. Now employed by major U.S. corporation. Salary is $7,500 per year. Age 32.

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864. Mechanical Engineer—M.S. in M.E. Age 29. Experience in missile propulsion, turbomachinery research. Teaching experience, graduate level. Strong background in thermodynamics, fluid mechanics. Desires research or advanced development in missile propulsion or aerodynamics. Turbomachinery, related fields.

863. Aeronautical Engineer—Age 38. Seven years in aerodynamic department working on high-speed aircraft design and wind-tunnel testing, the last 4 years as chief aerodynamicist; 3 years of aircraft airfield practice as a qualified maintenance engineer; 2 years of teaching experience in aerodynamics and physics at university level. Holds undergraduate and graduate engineering European university diploma; additionally, for 2 years attended graduate courses at United States and British universities in high-speed aerodynamics, design, stability and control.

Presently teaching and doing experimental supersonic aerodynamic research at an East Coast university. Wants permanent, steady employment, either with aircraft industry or at university or research institution as a teacher in subjects of aerodynamics, stability and control, and aerodynamic design courses—or corresponding advanced research work. Detailed résumé upon request.

BOOKS *(Continued from page 113)*

ton University, where the author is Assistant Professor of Mechanical Engineering. It includes material from several courses on introductory thermodynamics, applied thermodynamics, heat engineering, and power plants.

While there is no intention to cover the wide field of nuclear engineering, the basic implications of thermodynamics are treated in an integral manner—including principles relating to nuclear energy, separation of isotopes, heat source problems, a basic reactive system, aspects of nuclear power, and examples and problems dealing with nuclear engineering. General physics and chemistry, and mathematics through calculus, are prerequisites for an understanding of the text.

Thermodynamics. Enrico Fermi. New York, Dover Publications, Inc., 1956. 160 pp., diagrs. $1.75.

This is a reprint of the 1937 edition which was based upon a course of lectures delivered at Columbia University. The treatment of the subject is elementary and requires no knowledge of advanced mathematics beyond calculus although it is assumed that the reader is familiar with the fundamental facts of thermometry and calorimetry.

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