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QUARTERLY PROGRESS REPORT

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PROJECT SQUID

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A PROGRAM OF FUNDAMENTAL RESEARCH
ON LIQUID ROCKET AND PULSE JET PROPULSION

FOR THE

BUREAU OF AERONAUTICS AND THE OFFICE OF NAVAL RESEARCH

OF THE

NAVY DEPARTMENT

CONTRACT N6ORI-105, TASK ORDER III

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PRINCETON UNIVERSITY
PRINCETON, NEW JERSEY

1 APRIL 1947

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The Office of the Project Organizer, in cooperation with Engineering Research Associates, Incorporated, has been actively engaged in the preparation of the Field Survey Report on Liquid Rockets and Pulse Jets. Approximately eighty agencies were visited during January, February and March, and this virtually completes that part of the program.

Initial rough drafts of each of the following sections of the Survey have been written and are now in the process of final revision.

Aerodynamics
Combustion
Heat Transfer and Cooling
Tabular Data on Contracts, Contractors
and Research Personnel

The following sections are being prepared:

Liquid Rocket Engines
Pulse Jet Engines
Instrumentation
Materials
Fuels

Statement of Phase Assignment

PHASE NO. 1

SPECIFIC PROBLEM

In connection with liquid rockets and pulsating jet engines: to investigate theoretically and experimentally

- (1) the stability of laminar boundary layer,
- (2) the interaction of boundary layer with external flow field at supersonic velocities, as it affects pressure distribution around bodies of revolution, airfoils, etc.,
- (3) interaction of shock waves in channels and diffusers.

PROGRESS

Equipment.—In March, contractors were selected for the major items of equipment for the "blow-down" supersonic tunnel. ONR approval of the contracts and purchase requests is expected shortly.

John H. Carl and Sons, Rockville Centre, New York, will install the motors, compressors, air bottles, and the main regulating valve and control system; furnish and install piping, air filters, coolers, etc., and all quick opening and safety valves, and carry out a hydraulic test of the entire system to 5000 psi, for a fixed price of \$30,500. The completion date is six weeks after receipt of all materials.

The Dravo Corporation, Philadelphia, Pa., will furnish the main reducing-regulator valve and the hydraulically-operated control system for this valve for a fixed price of \$7,120. Substitution of the single 8" Belfield valve and Askania control system for the bank of 14 Foster 2½" regulator valves originally proposed makes possible a considerable simplification in the fabrication and also in the operation of the air supply system. De-

livery of the Askania equipment is 12-14 weeks, but Belfield estimates that approximately six months will be required for the fabrication of the 8" valve. Every effort will be made to reduce this time interval substantially by furnishing material from Navy stores, and by utilizing Navy foundry facilities whenever possible.

With the arrival (1st April) of eighteen 15 cu. ft. air accumulator bottles and one 25-cu. ft. bottle, the supply of storage tanks is complete for the present.

Building Alterations, etc.—ONR approval has been received for the alterations to the old Concrete Testing Laboratory and also for the installation of the concrete foundation blocks for the two Worthington compressors. Matthews Construction Company will begin operations when CPA approval is received.

Optical Apparatus.—A Project Order for approximately \$10,000 has been requested from ONR for the fabrication of the 4" interferometer plates and six 4" and four 9" wind tunnel "windows" and frames at the Naval Gun Factory. The additional 4" "windows" were ordered because the long delivery time of ten months for the 9" windows will necessitate using 4" windows in both the large and small supersonic jets for a time. All the necessary drawings have been forwarded to the Naval Gun Factory and work will commence shortly after the Project Order is obtained.

Rough blanks for the 9" interferometer plates were ordered so that optical glass, which is in short supply, might be available should it become desirable to build the 9" interferometer next year.

Orders have also been placed for the light

source and miscellaneous lenses and optical flats for the pilot tunnel and other apparatus.

Pilot Tunnel.—Design of the pilot supersonic tunnel (test section 2½" x 1") is proceeding. The tunnel will be housed initially in the vertical firing range. A 2" interferometer for studies with this tunnel and other apparatus is under construction.

THEORETICAL STUDIES

(1) *Boundary Layer-Shock Wave Interaction.*

—A technical report is in preparation on the theoretical aspects of the interaction between shock waves and boundary layer in transonic and supersonic flow. The reflection of a shock wave from the laminar boundary layer in transonic flow as an angular or Prandtl-Meyer expansion region is analyzed in terms of the character of the flow in the laminar boundary layer when the static pressure is increasing in the main flow direction, i.e., when the flow is decelerating.

An attempt is made to clarify the interaction between an oblique shock wave and a laminar boundary layer in the case of the plane supersonic flow in a corner. The pressure rise "spreads" upstream in the boundary layer and affects the external flow. A start is made toward relating this "spread" to the behavior of the thin "sub-layer" of the laminar boundary layer adjacent to the

surface, in which inertia forces are negligible and viscous forces dominate.

(2) *Wake Behind Two Dimensional Airfoil in Supersonic Flow.*—It is often assumed that the flow around a cylindrical airfoil moving with supersonic velocity at an angle of attack becomes a uniform parallel stream again on passing through the trailing-edge shock and expansion regions. At low supersonic Mach numbers the departures from this simple picture are insignificant. However, the air passing over the upper surface of an inclined flat-plate airfoil (for example) is accelerated at the leading edge, and therefore the trailing edge shock originating from the upper surface occurs at a higher Mach number than the leading-edge shock on the lower surface. At high supersonic Mach numbers the difference in strengths of these two shocks for the same flow deflection means that the actual flow deflection at the trailing edge must be different than at the leading edge, in order that the pressure shall be continuous and the upper and lower surface streamlines parallel at the rear of airfoil. Calculations are in progress to determine the magnitude of the "downwash" at and immediately behind the airfoil. Previous work by Lighthill (British Reports and Memoranda No. 1933) appears to be in error, since it neglects the difference between the isentropic pressure-density relation and the Rankine-Hugoniot relation in an oblique shock.

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ABSTRACT:

The wind-tunnel equipment for investigating flow characteristics at supersonic speeds is nearly ready for use. A theoretical investigation was conducted on certain aspects of interaction between shock waves and boundary layer in transonic and supersonic flow. Calculations are in progress which may be used to determine characteristics of the wake behind the two-dimensional airfoil in supersonic flow. An attempt is being made to clarify interaction between oblique shock waves and the laminar boundary layer in case of plane supersonic flow in a corner.

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SECTION: Boundary Layer (5)

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AIR TECHNICAL INDEX

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