H. L. Olsen and H. F. Kirk, Jr.

The new Propulsion Research Laboratory has been constructed to provide experimental testing capabilities for advanced air-breathing propulsion systems, including hypersonic ramjets. The PRL is also provided with sufficient built-in flexibility and versatility to serve the bulk of current and future APL propulsion research programs. This paper discusses the principal systems and equipment components in the PRL, giving such details as most clearly define the facility's capabilities and potentialities.

APL Propulsion Research Laboratory

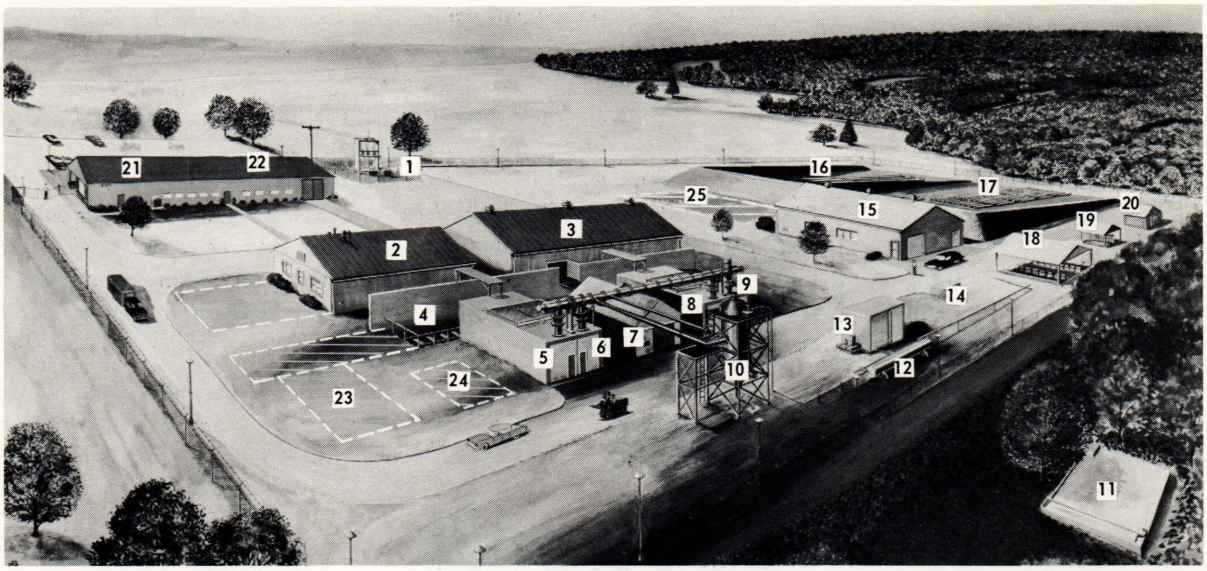
Construction of a new Propulsion Research Laboratory (PRL) on the Howard County site of the Applied Physics Laboratory has recently been completed after several years of intensive planning by the APL Propulsion Group. This extensive facility, designed primarily to provide experimental testing capabilities for advanced air-breathing propulsion systems, contains equipments necessary to implement the bulk of the projected propulsion research program. This includes development of a wide variety of air-breathing propulsion systems—from advanced versions of the Typhon engine to hypersonic ramjets employing supersonic combustion and required to fly within the atmosphere at speeds up to orbital. The PRL is required, in short, to offer testing capabilities neither available elsewhere nor integrated into any other single laboratory.

The guiding principle of the design has been to provide the capacity to meet all known, specific objectives and to insure maximum flexibility and versatility for meeting future requirements. The facility complex will operate on the "blowdown" principle in order to furnish highly advanced capabilities at modest cost. "Blowdown" provides quasi-steady operation at very high temperatures and pressures by drawing all fluids and energy from storage sources at high rates and replenishing them at much lower rates. This type of operation offers no restriction to the planned test programs since satisfactory results, including those of durability testing, can be obtained within the blowdown time which is measured in minutes. Finally, the basic design provides for future growth of the laboratory in a well-ordered pattern to permit integration of expanded capabilities and facilities into the existing plans at minimum cost and effort.

The over-all layout of the PRL is shown in the accompanying artist's sketch in which the basic components and planned expansions are keyed for identification. To indicate the size of the installation, note that the security fence encloses an area of five acres. A brief description of the main systems and equipment components which comprise the PRL will serve to explain its capabilities.

Atmospheric air compressed to 3200 psi by five four-stage reciprocating compressors (15) in parallel is delivered to a receiver tank at a combined mass flow rate of 1.12 pounds per second. (*Note*: Numbers in text are keys to the accompanying illustration.) The air then passes through dryers to the storage tanks (16, 17), of which there are the three types shown in the Table.

The air stored in these tanks is delivered to the heater trench (4) through a 4-inch pipe *via* pre-set pressure reducers, air filters, and flow-



1. ELECTRICAL SUBSTATION
2. CONTROL BUILDING
3. DC POWER SUPPLY BUILDING
4. HEATER TRENCH
5. TEST CELL NO. 4
6. TEST CELL NO. 3
7. SET-UP BUILDING
8. TEST CELL NO. 2
9. TEST CELL NO. 1
10. STEAM EJECTOR SYSTEM
11. SPRAY POND
12. STEAM ACCUMULATOR
13. COOLING TOWER
14. HYDROCARBON FUEL PUMPS
15. COMPRESSOR AND STEAM GENERATING BUILDING
16. 10,000 psi AIR STORAGE AREA
17. 3,000 psi AIR STORAGE AREA
18. DRUM STORAGE
19. GAS BOTTLE STORAGE
20. SPECIAL FUEL STORAGE
21. OFFICES
22. MACHINE SHOP
23. TEST CELL NOS. 5 & 6
24. SET-UP SHOP
25. EQUIPMENT STORAGE

Artist's concept of the Propulsion Research Laboratory, including key to the nomenclature of its components. Ground areas shown in dotted lines indicate positions of planned expansions.

PRL AIR-STORAGE TANKS

	Quantity	*Storage Pressure (psi)*	*Total Vol. (cu. ft.)*	*Max. Air Storage (lbs.)*
Torpedo Flasks	100	2000	2000	20,000
Laminated Tanks	12	3000	336	5000
16″ Rifle Liners	3	3000 10,000	240	3750 7850

measuring orifices at any pressure up to 2500 psi. Three control valves in the heater trench, controlling flows from 0.1 to 70 pounds per second, are electrohydraulically operated and capable of stabilizing flows in less than 15 seconds. From these control valves the air is distributed to four outlets in the heater trench, from which it can be delivered to any one of the test cells (5, 6, 8, 9) *via* an appropriate air heater.

Of the two types of air heaters to be used, the first is of the storage type employing stainless steel as the heat-storage matrix. It will operate at pressures ranging from 200 to 1000 psi and temperatures from ambient to 1900°F. At maximum flow it will heat air at 70 pounds per second to 1000°F at 1000 psi for two minutes. The second type is an electric arc (plasmajet) heater intended primarily for use with the hypersonic propulsion tunnels. It will supply air at temperatures up to 7000°F, at pressures up to 2500 psi. It is intended to deliver 6000 KW to the air, which will require dissipation of 15,000 KW at the electrodes. This heater is currently under development at APL.

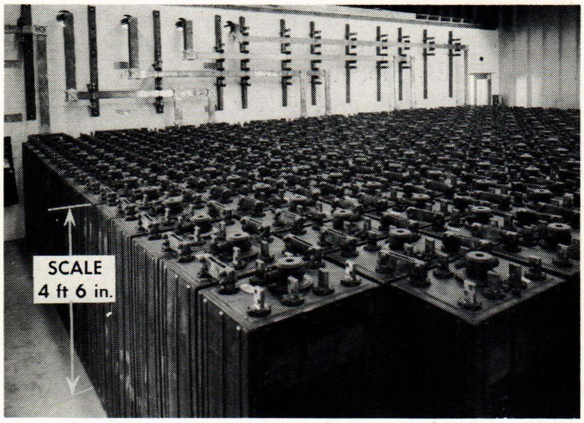
The four test cells are spaced in groups of two along a heater trench equipped with a railway to carry the storage heater from cell to cell. This provides the closest possible coupling between the heater and the test equipment inside each test cell. The four cells are of 12-inch-thick reinforced concrete, with lightweight doors at one end and a frangible panel in the roof; each is 40 feet long, 12 feet wide, and 10 feet high. One cell is capable of handling special fuels and small rocket motors. To provide for personnel protection, the control building and offices are shielded from the cells by reinforced concrete.

The exhauster consists of a two-stage steam ejector (10) driven by steam from an accumulator tank (12). At maximum usage it discharges at the rate of 80,000 pounds of steam per hour and can be operated for five minutes, followed by recharging for one hour. Operating at its minimum air pressure, the system will pump one pound per second of dry air at 0.75 psia, in addition to pumping combustion products and water vapor used for cooling. The ejector is connected to the test cells through a 3-foot-diameter vacuum heater and individual shut-off valves.

There are three water-cooling systems provided in the new facility, of which the first is a 70,000-gallon spray pond (11) that also provides the barometric sump for the vacuum system. This water is used in the condensers of the steam ejector and to cool the exhaust products entering the vacuum piping. The second system furnishes recirculating water to cool piping, wind tunnels, compressors, etc., and is equipped with a cooling tower (13). Third is a high-pressure supply used specifically to cool the arc heaters and the propulsion tunnel throat sections.

The entire testing process is controlled remotely from the control building (2) *via* centralized and integrated control panels. Closed-loop television is permanently installed for visual monitoring of the experimental equipment in the test cells. All test data are transmitted as electrical signals to the control building where they are handled by a data acquisition system designed and constructed by the Minneapolis-Honeywell Company. This system has 100 channels scanned at the rate of 50 per second and recorded on magnetic tape in a form usable by the IBM 7090 Computer located in the APL Computer Building. A Packard-Bell PB-250 Computer providing rapid on-line monitoring of test data as they come from the experiments can also be used in on-site reduction and further analysis of these data.

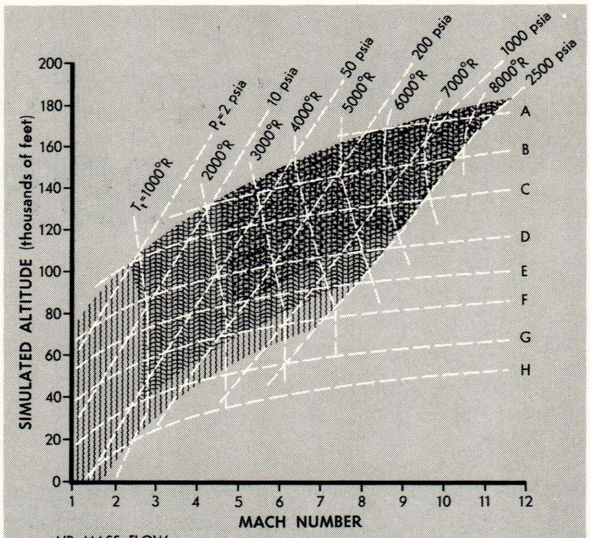
The power supply for the electric arc heater will consist of 1000 lead-acid submarine cells,



View showing some of the 304 submarine cells installed at APL Forest Grove Station as a prototype of the installation at the new Propulsion Research Laboratory.

connected in series, with a no-load voltage of 2000 volts and with a maximum capability of delivering currents up to 30,000 amps. In service it will be used for the present at currents of 13,000 amps through the arc heater. A one-third-size prototype battery has been developed at APL's Forest Grove Station where it has been in operation for ten months.

The test conditions made available by this facility include "connected-pipe" tests for combustor development and "free-jet" tests for over-



AIR MASS FLOW (lb/sec) FOR TEST SECTION AREAS OF:

	A	B	C	D	E	F	G	H
144 IN²	0.5	1.0	2.0	5.0	10.0	20	50	100
72 IN²	0.25	0.50	1.0	2.5	5.0	10	25	50
36 IN²	0.125	0.25	0.50	1.25	2.25	5.0	12.5	25

Initial free-jet testing capabilities that are provided by use of the arc (plasmajet) heater are shown for three test section areas.

all engine development and aerodynamic studies. Either type of testing may be implemented by the storage heater for pressures and temperatures of up to 1000 psi and 1900°F, respectively, and by the arc heater up to 2500 psi and 7000°F. The testing regime made accessible by the arc heater is shown in the accompanying chart for three test section areas. All of these accessible test regimes are for correctly simulated flight conditions with respect to stagnation pressures and temperatures.

The free-jet hypersonic propulsion tunnel and the high-pressure electric arc heater are two major new developments of special interest. Because of their importance to the PRL, both will be discussed at length in future issues of the *APL Technical Digest*.