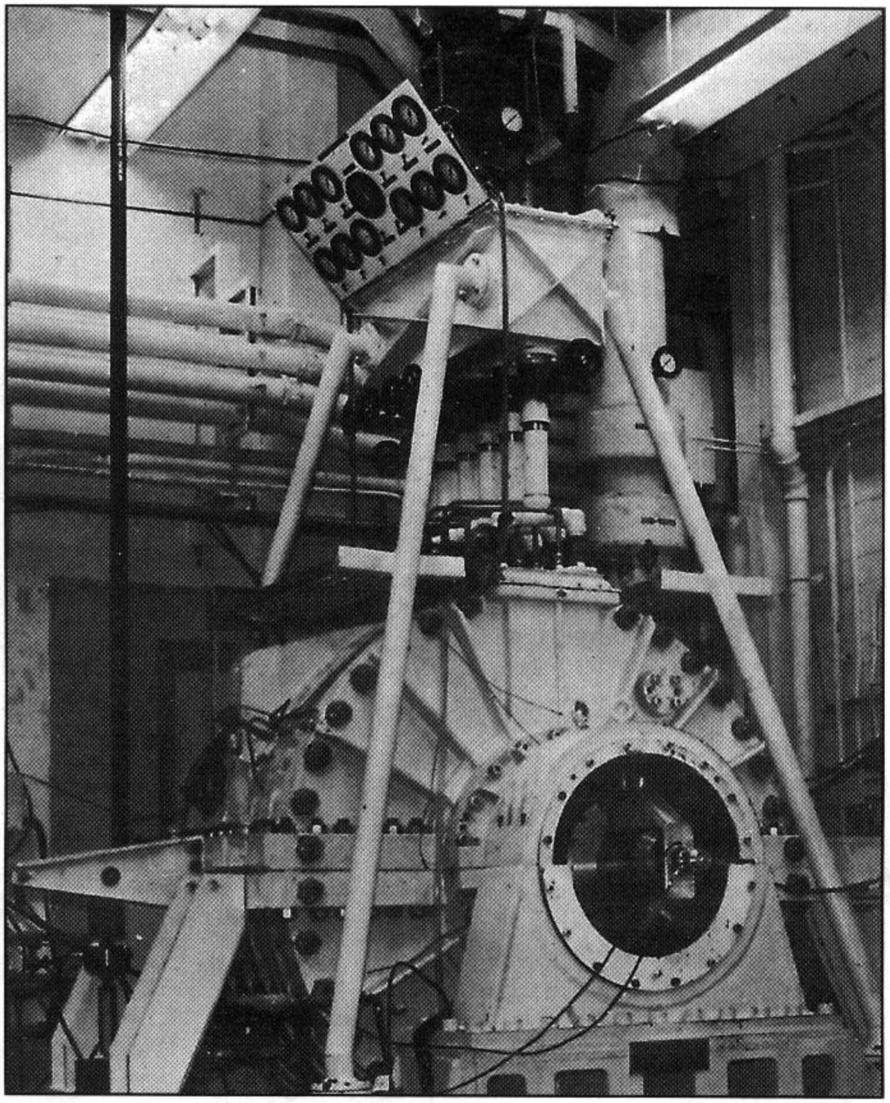


(Left) A feature of the test installation is this Kahn 50,000 hp high-speed, waterbrake dynamometer, one of the largest ever built. It is one of the few types of test equipment that could be economically coupled to the turbine for loading and measurement.

50,000 hp Dynamometer Utilized...

Load Test Facility For GE's LM2500 Engine Module

In 1972 General Electric's Aircraft Engine Group dedicated a multi-million dollar facility at its Evendale, Ohio plant, for testing marine and industrial gas turbine shaft engines. Now, more than three years later, this facility has logged over 3500 hours of operation in testing the 25,000 hp class LM2500 modular powerplant, one of the most technologically advanced lightweight gas turbine engines available.

The Load Test Facility, which was designed and built by the Evendale Test Facilities Engineering section, provides capability to perform full load tests, variable load tests, fuel consumption and endurance tests. In addition, the facility provides test capability for the measurement of smoke, exhaust emissions, structure-born noise, vibration isolation, and airborne noise performance of the gas turbine engine.

The Load Test Facility consists of five major elements: 1) Main Test Cell Reverberant Chamber, 2) Waterbrake Loading Device, 3) Fuel Storage and Conditioning, 4) Water Cooling and Recycling and 5) Instrumentation and Data Recording.

The Test Cell or Reverberant Test Chamber, which is 43 ft. long by 30 ft. wide by 23 ft. high is designed so as to provide a reverberant acoustic field around the engine module enclosure. Sensitive microphones located in this reverberant field "listen" to the very low level noise transmitted through the engine enclosures. Inlet and exhaust noise is isolated from the chamber by the close coupling of the engine enclosure to the facility stacks.

The Test Cell is constructed of 12" thick reinforced concrete, utilizing external pre-stressed arch beam design. This design permits free clear spans in all directions on the cell interior while eliminating the need for a full ring foundation beneath the exterior walls. Each arch beam is supported on concrete piers at grade. The pier connection employs a hinged-key design with lateral ties between opposing piers. This type design results in a stable, economical, high load capacity structure. This structure not only supports itself and the ordinary live loads normally imposed, but also supports roof mounted loads from the intake and exhaust stacks, and the module handling crane with a lift capacity of nearly 250,000 lb.

Concrete was also chosen for the cell structure to provide effective, economical acoustic isolation from the prevailing ambient noise levels in the area which is typical for an industrial area. Since the noise transmitted through the module enclosure is approximately ambient level, it is necessary that the sound level in the Reverberant Chamber from sources other than the module be at least 10 db less so that the acoustic performance of the engine enclosure can be measured and evaluated accurately.

An interesting feature of the test cell is the method by which the engine module is handled and positioned within the chamber. The module, which is approximately 26 ft. long, 9 ft. wide and 10 ft. high, is delivered to the test cell mounted to a structural test base. Over-the-road transportation is provided by a standard low-boy trailer truck. This module and test base assembly (gross weight of 65,000 lb.) is lifted from the trailer truck bed with the module handling crane. The trailer is then driven from beneath and the module is then set on the cell floor. Six (36 in. diameter) air caster bearings which are mounted integrally on the underside of the test base are inflated by 15 PSI air from the cell compressed air supply. The module test base assembly may then be pushed manually by two men laterally across the floor on a thin film of air into the test position. Shafting, stacks, services (fuel, air, water) and instrumentation and controls are connected and the unit is ready to run. The entire setup can be performed in less than four hours.

The control room, which is located adjacent to the test chamber, houses all control, data display and data transmission equipment. All operating data parameters for the engine module and test facility are displayed and controlled from a control panel. Data for recording and computer analysis is transmitted from this area to the test instrumentation data center located in the Evendale test complex. The test cell is equipped to handle 150 channels of display instrumentation, 150 channels of control and 250 channels of recording instrumentation.

Another feature of the test installation is a 50,000 hp high speed waterbrake dynamometer, among the largest ever designed, and built by Kahn Industries. It is one of the few types of test equipment that could be economically coupled to the turbine for loading and measurement. Because of its method of power absorption, the Kahn 406-160 dynamometer does not cavitate, leading to minimum maintenance and a high degree of accuracy. After over 3500 hours of operation, no evidence of cavitation damage has been discovered. The dynamometer also has a relatively low moment of inertia compared to its size, thereby permitting testing of the turbines that could not be easily performed by other types of load absorbing test equipment.

The machine is a smooth disc waterbrake dynamometer with maximum horsepower rating at 50,000 hp at 3,600 rpm and maximum torque, 75,000 ft.lb. Total unit weight is 32 tons with the rotor weighing 15,250 lb.

Much of the design and construction of this dynamometer departs from what might be called standard waterbrake construction. Perhaps the most important feature of the smooth disc waterbrake is the rotor configuration itself. The rotor assembly consists of six smooth tapered uniform stress discs and two forged shaft ends. Each rotor forging has a male and female rabbet and are press-fit to each other. Once the initial stack-up of shaft ends and rotors is completed, there are 16 tie bolts pre-stressed to 50,000 psi that run the length of the rotor assembly. Each rotor is forged into a pancake shape, heat treated and then machined and ultrasonically inspected.

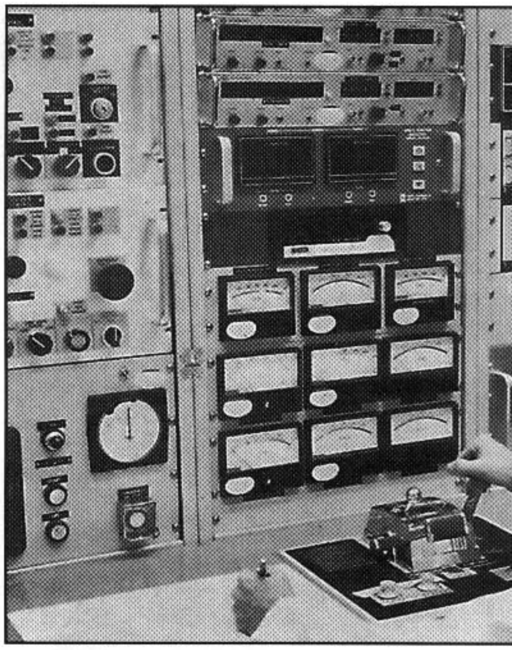
The finished machined rotor is then magnetic particle inspected, flame sprayed with a 420 Series stainless steel and then finally ground to a 32 RMS finish. The completed rotor is then coated with a phenolic sealer. Each part of the rotor, shaft end assembly is individually balanced and then balanced as an assembly with a remaining unbalance of 3 oz. in. The rotor shaft end material is 4340 steel. The reason for the stainless steel flame spraying and phenolic sealer is to prevent any corrosion on the working area of the rotors.

The above method of rotor manufacturing is similar to that method used in the assembly of large gas and steam turbines. Each shaft end is splined to mate with a flexible coupling. The housing consists of five stator castings and two end cap castings, all split on a horizontal centerline and held together with pre-stressed tie bolts. Water passages are integrally cast into the stators and end caps, thus allowing water feed to each side of every rotor at the inner diameter of the stator area. The stator walls are flame sprayed with stainless steel as were the rotor disks. The center of each rotor chamber is vented to atmosphere to prevent any vacuum buildup within the waterbrake housing during the operation.

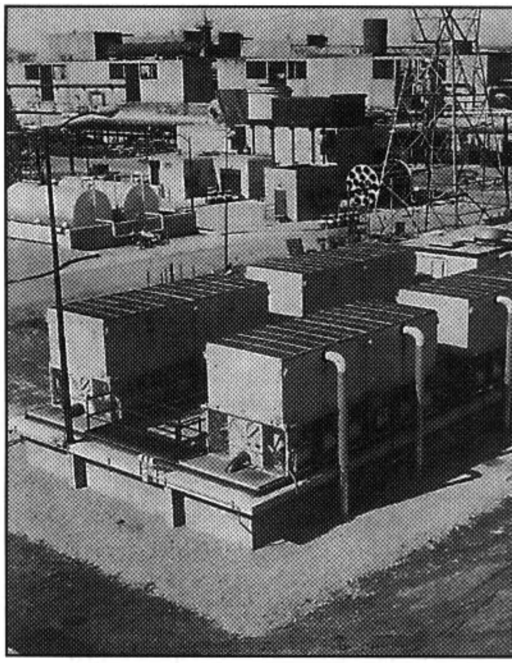
Each rotor chamber is radially divided into two compartments, the working compartment and the discharge compartment, by a bronze discharge ring which allows the high velocity water in the working compartment to discharge on both sides of the rotor at 360 degrees around the rotor, thus allowing for a smooth water discharge and eliminating any turbulence or diversions that are created by a single water outlet port. Each rotor compartment is then separated from the other by means of labyrinth seals.

Cold water enters the waterbrake through an overhead distributor tank which has a manifold arranged above the brake and is rigidly connected to the base. From the manifold there are six spherical flex joints connected to the waterbrake housing that allows freedom of movement of the waterbrake housing within the trunnion bearings. With the individual water feed to each rotor stage, it is possible to run low loads at high speed by only having two or three rotor stages actually operating, thus increasing the rangeability of the waterbrake.

Cold water enters the rotor chambers near the hub of each rotor stage. It is then accelerated by the rotor discs and thrown out by centrifugal force. There it forms a continuous water ring which rotates at approximately one-half of the rotor speed. However, the thin layer of water that is in contact with the rotor runs at approximately the same speed as the rotor while the layer of water in contact with the stator wall is almost at a standstill. It is this action that creates a viscous shear



Part of the well instrumented control room, which is located next to the test chamber at GE's Load Test Facility.



Dynamometer water cooling and recycling area. The four cooling towers built by Havens are double units (eight cooling units total) with a maximum specification input of 4500 gpm capacity at 150˚F inlet temperature and an 85˚F outlet temperature.

and resulting friction which dissipates the energy created by the gas turbine. The water level in the rotor chamber is controlled by valve positions on the outlet side of the waterbrake.

The load absorbed at any given time is a function of the water level in the rotor chamber and the rotor speed. Maximum load is absorbed when all the rotor chambers are nearly filled with water. While a particular water level is maintained for a given operating point, a continuous flow of water is required to carry away the heat generated by the friction of the viscous shear. As a rule of thumb, four gallons per hour per horsepower is required. The main bearings are of tilting pad journal bearing design. Both bearings are split and mounted in spherical sets to allow easy assembly and alignment. The main thrust bearing is of the kingbury tilting pad-type with a load rating of 100,000 pounds.

The facility complex supplies water to the waterbrake, pumped from on site reservoirs with an aggregate storage capacity of a half million gallons. Maximum water flow capacity for the facility is 5,000 gpm, which allows for considerable growth potential. Water flow to the brake for load application is controlled automatically by electronic controlled pneumatic flow control valves. This controller is speed sensing and applies load (varies water flow) so as to maintain the speed setpoint. Speed fluctuations at maximum load (3600 rpm) are within plus or minus 3 rpm's.

Water pressure is controlled and stabilized by an air pressurized level controlled 5,000 gal. surge tank mounted above the brake. Brake inlet pressures are controlled readily with ±3 Psig of set point with the installed system.

Hot water (130°F max.) is recycled from the facility to new cooling towers which have an installed cooling capacity of 125 million Btu/hr. In this way, water resources are conserved and the thermal pollution of the local waterways is prevented.

Fuel for engine operation is provided to the cell from a 50,000 gallon above ground fuel storage area. Fuel is stored in two heated/insulated tanks, and is pumped through heated, insulated stainless steel piping to the engine. The cell fuel package in addition to controlling pressure and flow, is capable of heating and controlling fuel temperature for the maintenance of stable fuel viscosity at the engine inlet controls.

The total facility, as described, was designed and built in one year to meet U.S. Navy requirements for acceptance of marine gas turbines. ★

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