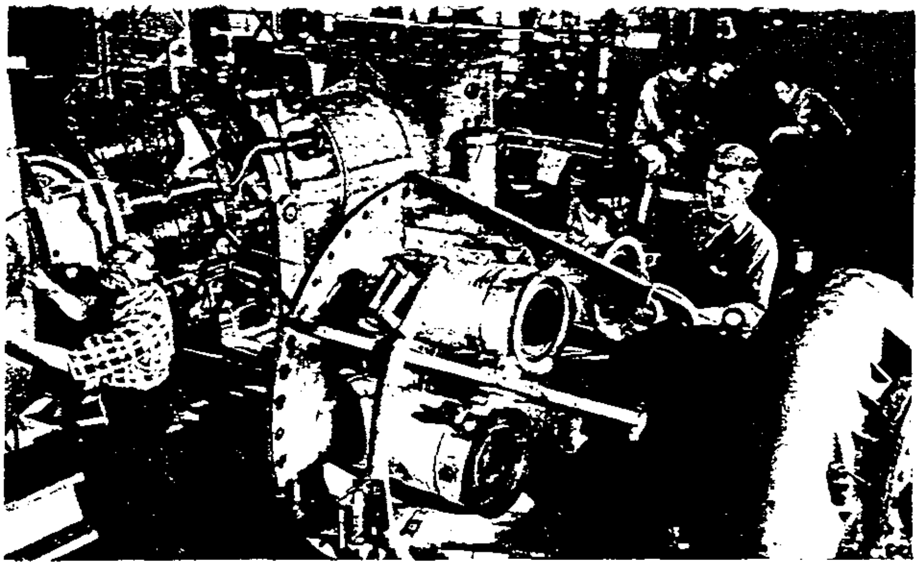

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How G. E. Tests Gas Turbines

Unlike the steam turbine, the gas turbine power plant must be assembled and test operated as a whole, including all accessories. Here is how the General Electric Company solved new problems in developing test facilities for a new product

IN THE DEVELOPMENT and manufacture of a new design of prime mover, such as the combustion gas turbine, one of the important technical problems to be considered is the matter of comprehensive tests before shipment. Consideration must be given to new test techniques, adequate instrumentation to secure complete data for engineering design and performance analysis, and flexibility to cope with new and unexpected problems. Space must be assigned and adequate manpower trained in the special techniques required. Consideration must also be given to expansion to meet increased production requirements, and to provide for new designs.

Unlike ~~the steam~~ turbine, which receives its source of energy in the form of steam at a predetermined pressure and temperature, the combustion gas turbine incorporates within its structure the combustion of fuel, the control and metering of this fuel, and the supply of the necessary primary combustion air and secondary cooling air.

Usually none of these components, with the possible exception of control and certain other accessories, are interchangeable between designs. Therefore again, unlike the steam turbine, each gas turbine power plant must be assembled and operated as a whole, including all its accessories. This imposes a severe problem on the manufacturer, since the assembly time of each unit, together with its required auxiliaries and accessories and piping would become a major problem not commensurate with modern production.

In this article it is assumed that the reader is familiar with, and has access to, descriptions of the commercial types of combustion gas turbines. Commercially, three types are in current production by the authors' company, all of the open-cycle design. The first is the 4800-hp simple cycle gas turbine, Fig. 2, intended for a 4500 traction horsepower gas turbine electric locomotive. (Ref. 1; references at end of article) In this design, a 15-stage axial flow compressor delivers 80,000 cu ft of air per minute at approximately six atmospheres pressure directly to a combustion chamber system. Fuel is burned to raise the temperature of this air to approximately 1400 F, where it is passed into a two-stage impulse-type turbine, exhausting directly to atmosphere. No regenerators or heat exchangers are used in this cycle because of space limitations in the locomotive cab. The turbine is designed to use oil as fuel and the power developed by the gas turbine will drive four d-c traction type generators to power the locomotive. The same gen eral design has also been successfull applied to stationary power plants b the use of standard reduction gear and 3600-rpm a-c generators fo power generation. (2), (3)

Early Test Stands

In the development of the first ga turbine of this type, intended fo locomotive, a test stand was speciall designed to simulate the structure c a locomotive. It consisted essentiall of two 30 in. I beams mounted on trunnions at either end, which represented the support of the locomotive trucks. The stand was purposely made flexible to obtain as nearly as possible any expected reaction or effect on alignment of the gas turbine with its reduction gears and four d-generators. This developmental stan was used for more than 700 hr firing test on the first unit, and wa also used for two subsequent gas tu bines intended for power plant in stallation. However, it was not we suited for production testing.

The first of the new-design con pound-cycle 5000-kw power gener tion unit (4) was also tested on a d velopmental stand, located in th corner of the building near the initi locomotive test stand. This com pound cycle gas turbine incorporat two stages of compression, repr

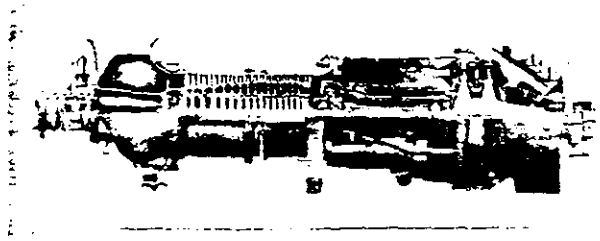


Fig. 2. General Electric 4870-hp turbine for 4800-hp locomotive drive

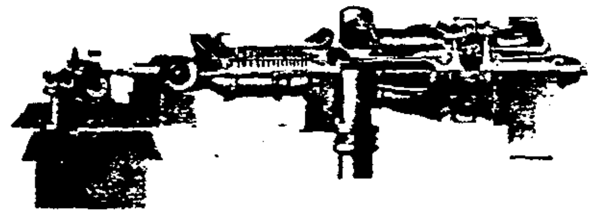


Fig. 3. Regenerative cycle gas turbine with independent shaft load turbine

sented by a low-pressure compressor driven by a low-pressure turbine, and a high-pressure compressor driven by the load turbine.

The intercoolers and the regenerators are mounted in pairs on either side of the gas turbine. It is obvious that the cycle is too complex for mounting in a locomotive cab, as in the case of the simple-cycle turbine previously described.

Test Problems

The necessary pressurized air ducts, piping, lubricating oil and fuel piping and water cooling would render it almost prohibitive to assemble this type of gas turbine, piece by piece, on a factory test stand before shipment. Actually the first three machines of this type were individually assembled and tested on the developmental test stand before the production test area was developed. Because this test stand was mounted partly on a cast iron factory floor, and partly on a reinforced concrete foundation, it was difficult to hold the component parts in alignment and to prevent leaks in the high-pressure air piping.

The General Electric Co. is at present manufacturing three types of gas turbines: The first is the 4800-hp locomotive power plant previously described, redesigned from the developmental model for repetitive quantity production. This simple-cycle gas turbine is identical with the 3500-kw simple-cycle stationary generating unit. The second is a 5000-kw compound cycle gas turbine with regeneration and intercooling, essentially identical to the developmental models, except for minor redesign. The third is a new design of a 5000-hp regenerative cycle gas turbine (5), primarily intended for mechanical drive applications, but equally suitable for power plant installations when driving a geared a-c generator with direct-connected exciter.

This 5000-hp class of gas turbine, Fig. 3, includes a large outdoor-mounted regenerator which forms the base of the exhaust stack, and therefore requires ducting of high-pressure air from the compressor to the regenerator. This same air, after being heated by the waste heat of the exhaust, is ducted back to the six combustion chambers. A large exhaust duct takes the hot waste gases from

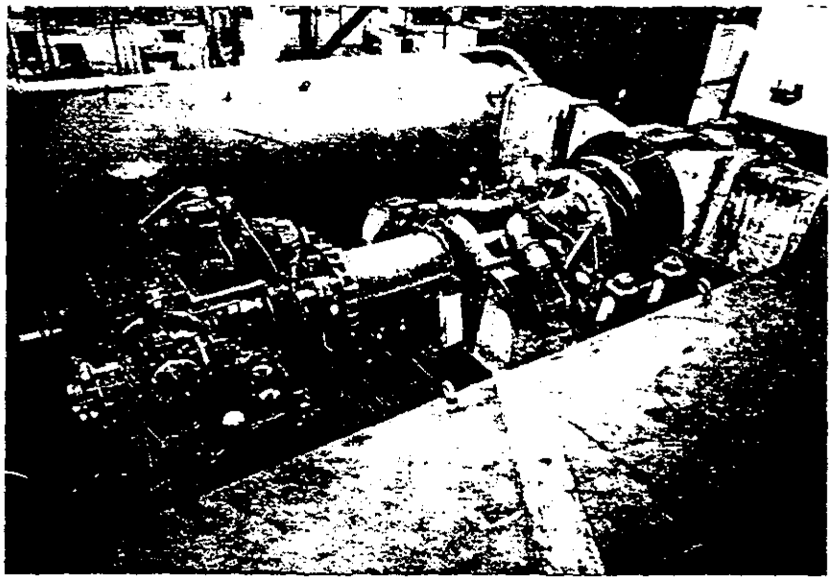


Fig. 4. A General Electric Co. 5000-kw gas turbine power plant on permanent factory test stand showing reduction gear, high-pressure compressor, turbines, and low-pressure compressor, all without lagging

Fig. 5. The first 5000-kw compound cycle gas turbine generator unit on permanent factory test stand

Fig. 6. Permanent factory test stand showing simplicity of mounting arrangement for 4870-hp gas turbine

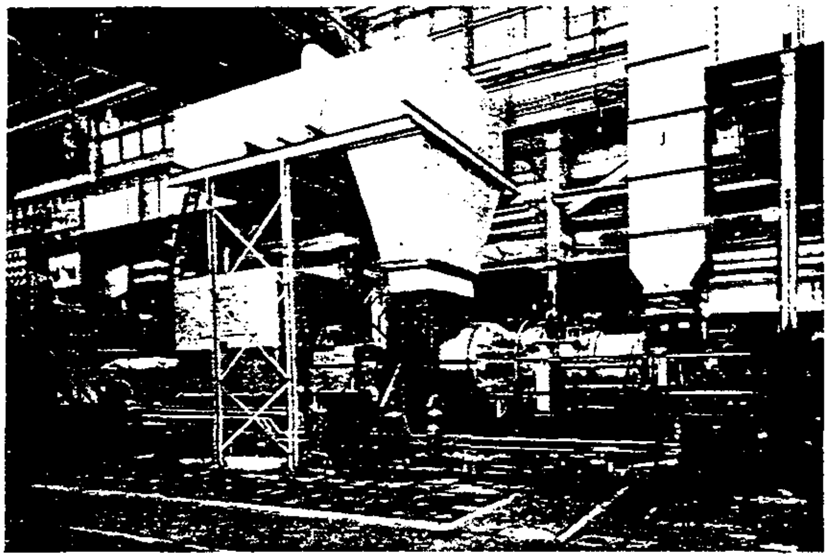
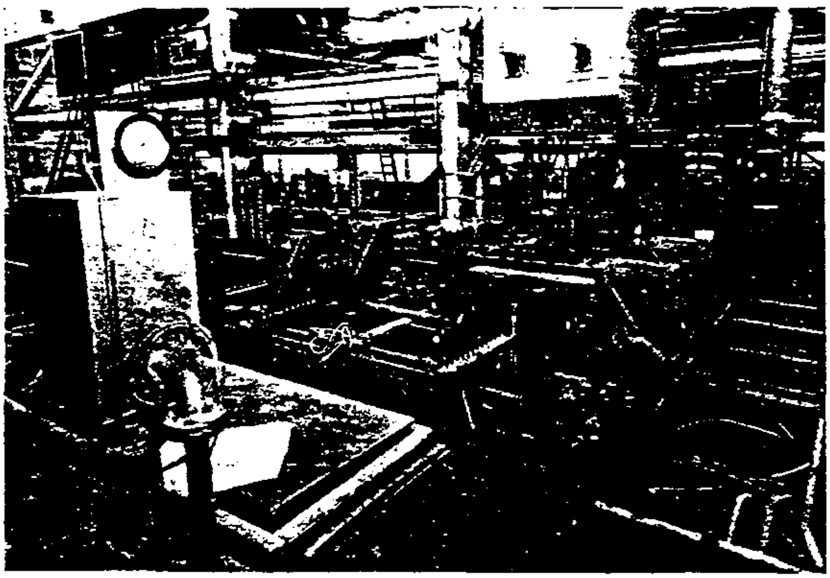


Fig. 7. Production model, 4870-hp gas turbine locomotive power plant on permanent factory test stand

Fig. 8. Test stand for 5000-hp, two-shaft, regenerative cycle gas turbine, just before installation of unit



the exhaust of the gas turbine to the base of the regenerator, where, after heating the compressed air, it is discharged vertically through the stack.

Production Test Area

In entering a planned production program, it was therefore found expedient to abandon the development test stands, and to erect permanent test stands for each class of gas turbine, each stand designed specifically for the cycle intended. Principal details of these are shown in this article.

As the units are factory tested by running them under their own power, it is necessary to have complete starting and supervisory control equipment, Fig. 11, identical to that which will be used in the field installation — on each test stand. In fact, each test stand is essentially a replica of the final installation on customer's foundation, plus the addition of special test equipment, Fig. 9.

For production test purposes, the unit test stands have permanent lubrication systems. This necessitates separate testing of all unit lubrication systems which will be shipped to purchasers, to insure proper piping and operation. These tests are conducted in the main test area adjacent to the test lube oil storage and filtering system.

In addition to testing the complete gas turbine, all accessories must be pre-tested before being assembled with and installed on the gas turbine. To accomplish this, a special enclosed room is provided containing motor driven accessory test stands and all necessary indicating equipment. During this pre-test it is necessary to open parts to make adjustments and settings. To avoid erratic operation which might be caused by dust and dirt normally present in a manufacturing plant, this room is pressurized with filtered air.

Testing of the gas turbines is conducted in the large factory building formerly used in steam turbine manufacture, which has since been converted and equipped with new facilities for gas turbine manufacture.

Unit Test Stands

Each test stand consists of an air filter house, intake and exhaust ducts, foundation blocking, air piping, lubricating system, fuel system, control system, loading system and test instrumentation.

Each filter house contains two calibrated flow nozzles for accurately determining air flow to the unit compressors at existing ambient temperature and pressure conditions. Filters are protected by louvers to prevent clogging from snow during winter months. The inlet ducts and the portion of the filter house back of the flow nozzles are constructed to be as airtight as possible, and are periodically calibrated to determine actual leakage. Filter houses are located on the building roof, Fig. 13, adjacent to the test area.

All ducts are insulated to reduce

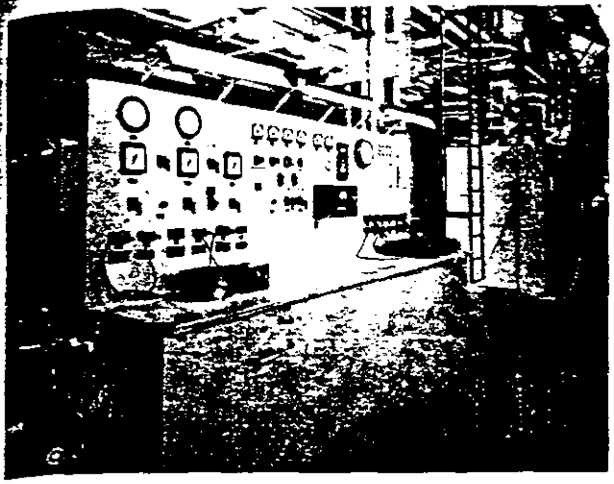


Fig. 9. (Above) 5000-kw gas turbine power plant test stand. Test control area showing load table, panel, auxiliary Cabinetrol and starting resistors

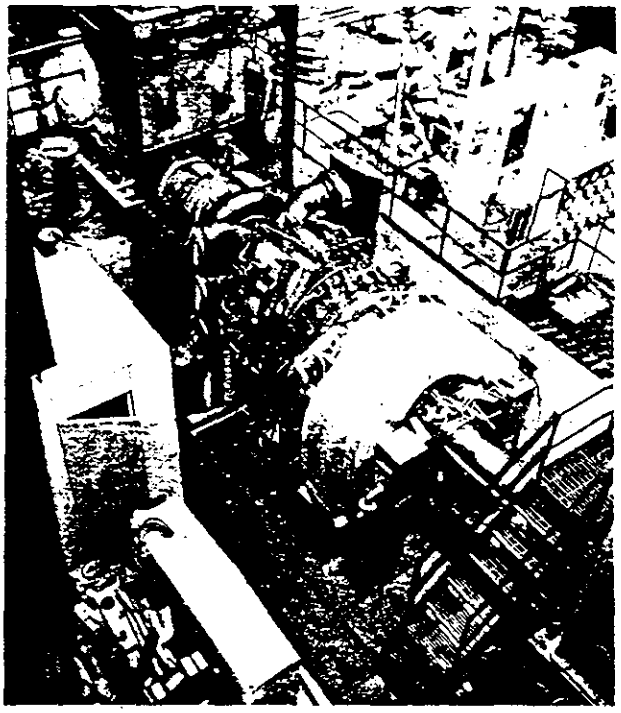


Fig. 10. (At right) First 5000-hp/3500-kw two shaft regenerative cycle gas turbine on test stand without enclosing covers. Note control equipment, top right

the noise level. The exhaust duct for the locomotive test stand is also lagged to keep heat transfer in the test area to a minimum — the locomotive unit exhausts at about 800 F during the summer and the heat given off by about 30 ft of ductwork would make operation rather uncomfortable, as the duct is directly over the control and instrument area.

A transit-leveled cast iron "T" slot section floor is laid in the test area where the stands are located, to simplify anchoring foundation blocks. Foundation blocks are fabricated from steel plate and fastened to the floor with hairpin clamps, doweled in place and grouted in to avoid movement from the forces involved. Every effort possible was made to design the blocking so that natural frequencies would not coincide with running speed of the units.

The 5000-kw compound cycle gas turbine, Fig. 5, consists of two compressors, a turbine, a reduction gear, generator and direct-connected exciter in addition to the stationary intercoolers and regenerators. The test stand for the rotating parts of this unit is made to hold each component, assembled complete with bases. Alignment of components, Fig. 4, with each other and with the reduction gear is done with jack bolts attached to the test stand. Dowel bushings are used when doweling after the line-up is completed. This unit operates at constant speed and varying load as will be encountered in central station service.

The simple cycle locomotive units are assembled on a line-up fixture, and the fully assembled unit is then swung onto the test stand for connecting to the reduction gear and loading generator. Proper footings and foundations are provided on the permanent test stand base, Fig. 6, to permit minimum alignment time with shims, as the locomotive gas turbine does not have its own rigid base, Fig. 7: The stand is equipped with a 4000-kw a-c generator and is practically identical with a stationary power plant installation. The unit is operated at variable speed and load to simulate locomotive operation.

5000-Hp Unit

Because of the number of orders for this new 5000-hp regenerative cycle unit (which also may be rated 3500 kw when used with a power generator), two stands have been provided for this type of unit. One of the test stands, Fig. 8, is complete with reduction gear and 4000-kw a-c

(Continued on page 120)

Fig. 11. Test stand for 5000-hp two shaft regenerative cycle gas turbine. Control panel, load table and temperature recording panel at the rear

Fig. 12. One of the special manometer boards for making pressure measurements which is erected at each of the permanent gas turbine test stands

Fig. 13. (L to R) Filter houses for test stands on roof of building. Exhaust stack stand, filter house and exhaust stack stand in process of erection