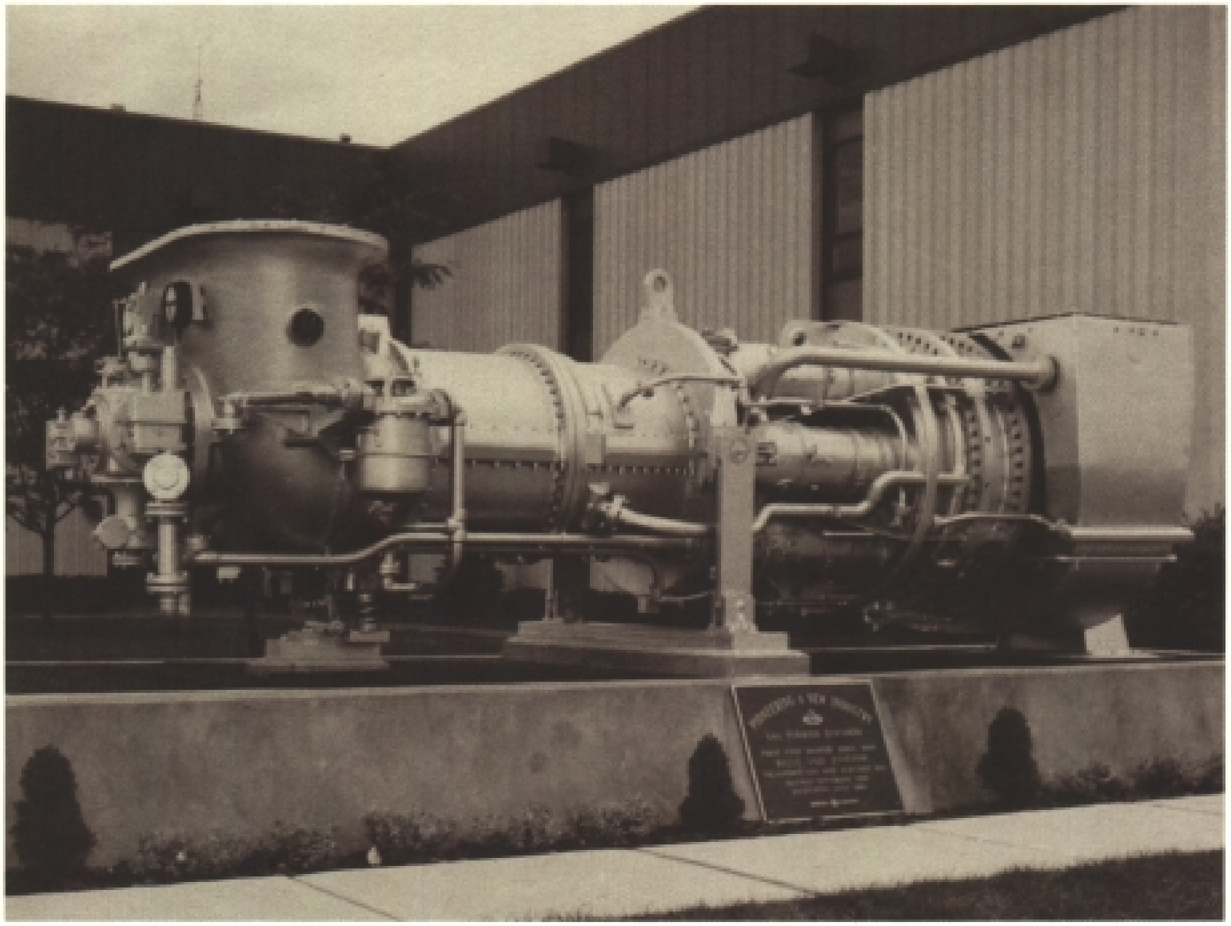
3500 kW Gas Turbine
at
the Schenectady Plant of the General Electric Company



Printed in honor of the occasion of its dedication as a National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers

November 8, 1984

HISTORICAL SIGNIFICANCE OF THE BELLE ISLE GAS TURBINE

The Belle Isle gas turbine (Figure 1), which is being dedicated today as the seventy-third National Historic Mechanical Engineering Landmark, was, when installed in 1949, the first gas turbine built in the United States for the purpose of generating electric power. It represents the transformation of early aircraft gas turbine practice, in which engines seldom ran for more than 10 hours at a stretch into a long life, reliable, electric utility prime mover.

The low-cost, trouble-free service experienced with the landmark turbine by the owners, the Oklahoma Gas and Electric Company, aroused considerable interest in the electric utility industry, both here and abroad. This led ultimately to the wide-scale adoption of the gas turbine by electric utilities, such that in the 10-year period 1966 through 1976, American utilities installed 1429 gas turbine units with outputs over 3500 kW, equivalent to more than 45 million kW of electrical generating capacity, and representing some 9% of the total United States electrical output (see Figure 2). The Landmark gas turbine represents the first point on the curve labeled "Electric Power Generation" in Figure 2, and, as the figure shows, it was the precursor of many more similar applications. The growth shown in Figure 2 is remarkable because the electric utility industry is generally conceded to be conservative in its approach to new technology. A good review of the contributions of the General Electric Company to land-based gas turbine technology will be found in Arne Loft (1981).

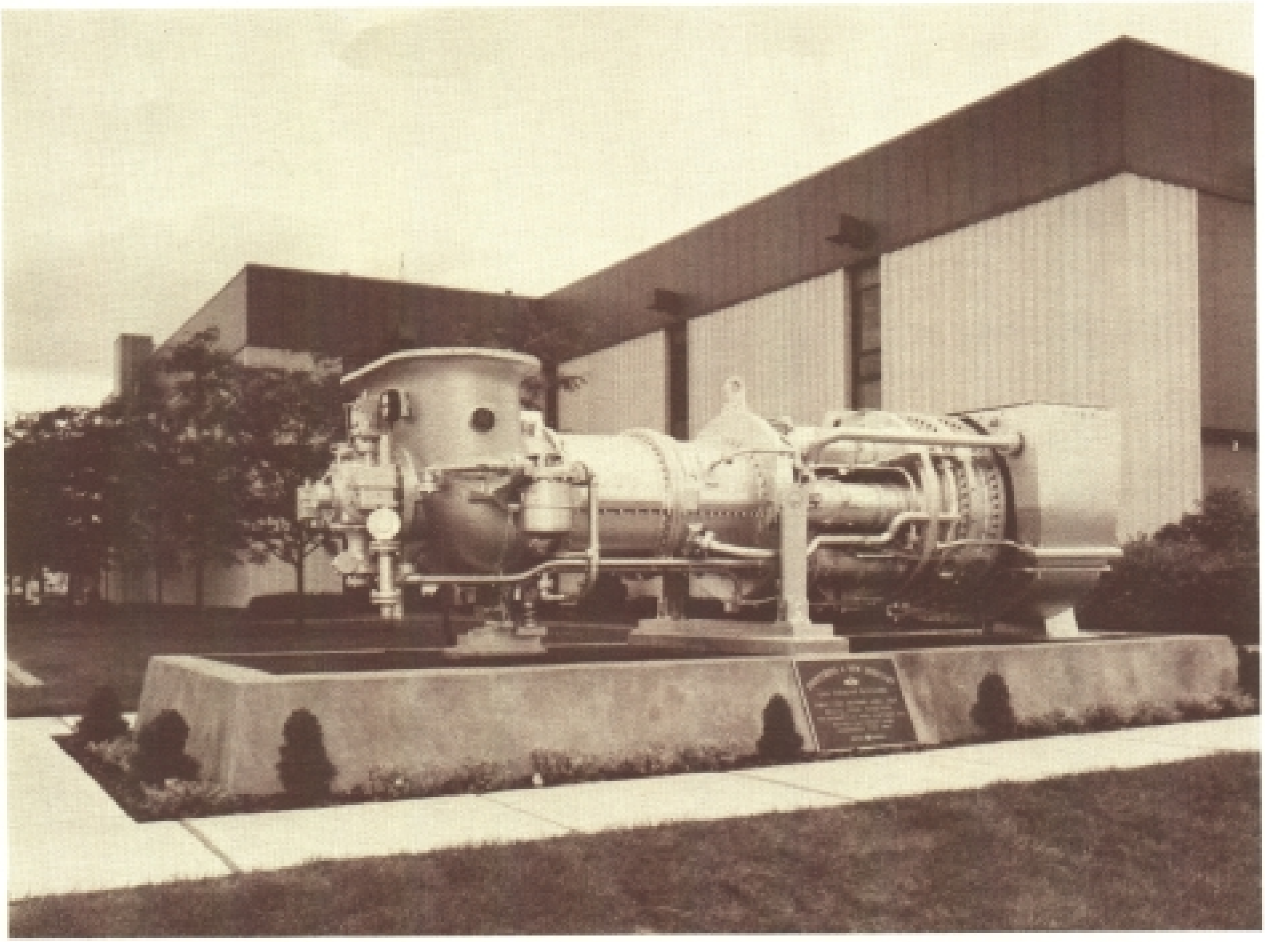


Figure 1. Belle Isle gas turbine on static display in Schenectady, New York

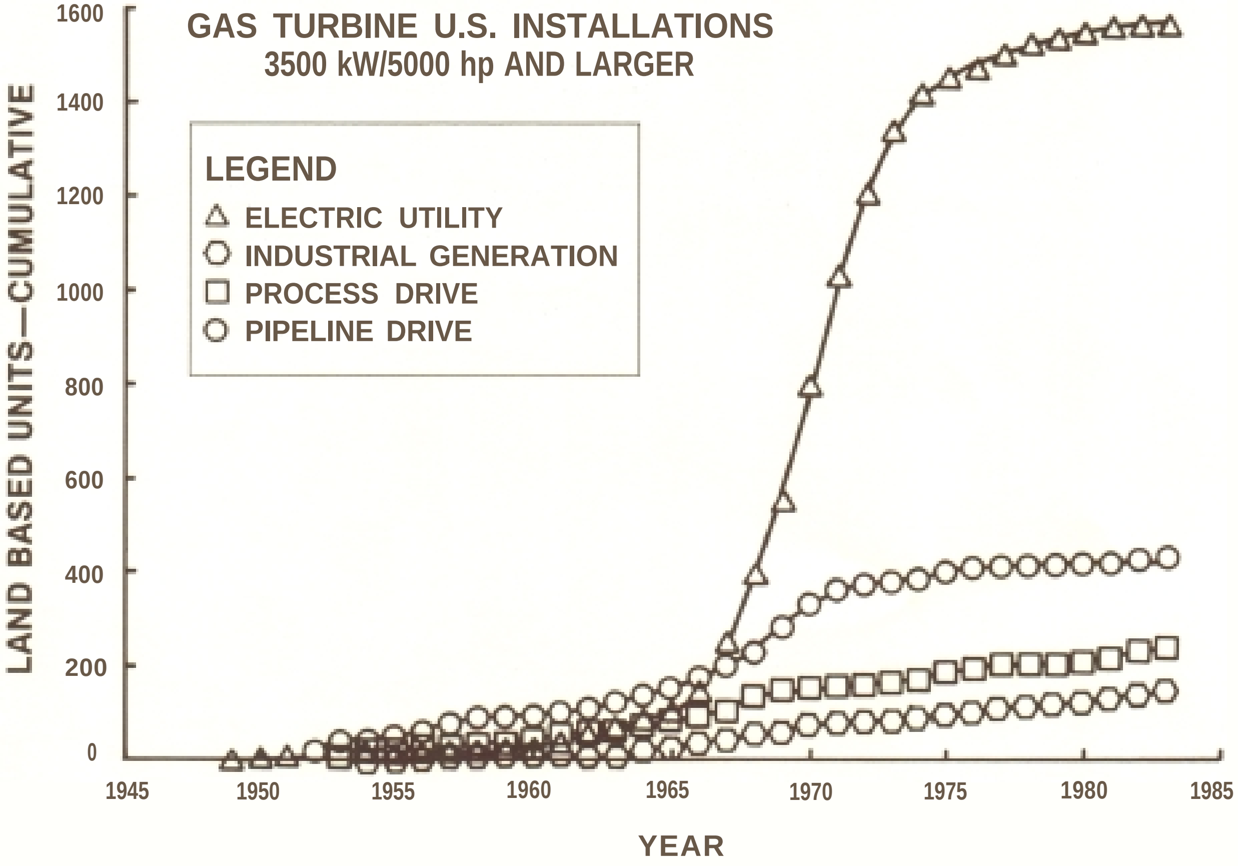


Figure 2. The growth of land-based gas turbine installations in the United States between 1945 and 1983.

Gas turbines have been used in a number of other land-based applications, most particularly for driving gas pipeline compressors, and in process applications such as providing hot, high-pressure gas for use in the Houdry catalytic cracking process. However, as Figure 2 shows, neither of these applications has involved anything like the number of units used in electric power generation. Clearly, the generation of electric power is by far the most important application of the gas turbine in the United States.

The Belle Isle gas turbine has been nominated as a National Historic Mechanical Engineering Landmark in recognition of its working life being spent in the U.S., its American origins, both in design and manufacture, and its technical antecedents in both pre-World War II and wartime research by the General Electric Company on land-based and aircraft gas turbines [Howard (1947, 1949), Driggs and Lancaster (1953)].

HISTORY OF THE BELLE ISLE GAS TURBINE

The Landmark gas turbine was delivered in April 1949 to the Belle Isle Station* of the Oklahoma Gas and Electric Company in Oklahoma City. It was installed (see Figure 3) in a separate building (see Figure 4) attached to the station, which was a 51 MW steam station [Blake and Tumy (1948, 1950)]. On July 29, 1949 at 2:15 p.m. the unit started delivering power to the company's distribution system. By November 1953 the machine had run for a total of 30,000 hours. A thorough inspection at that time showed some deterioration of the turbine inlet nozzles, in the form of wear and cracking of the nozzle partitions. The combustor liner also showed the effects of long exposure to the hot combustion gases. Apart from these two points the unit appeared to be in good condition [Blake (1954)].

The Belle Isle turbine, together with a second, identical unit installed in 1952, served the Oklahoma Gas

* Later named the Arthur S. Huey station.

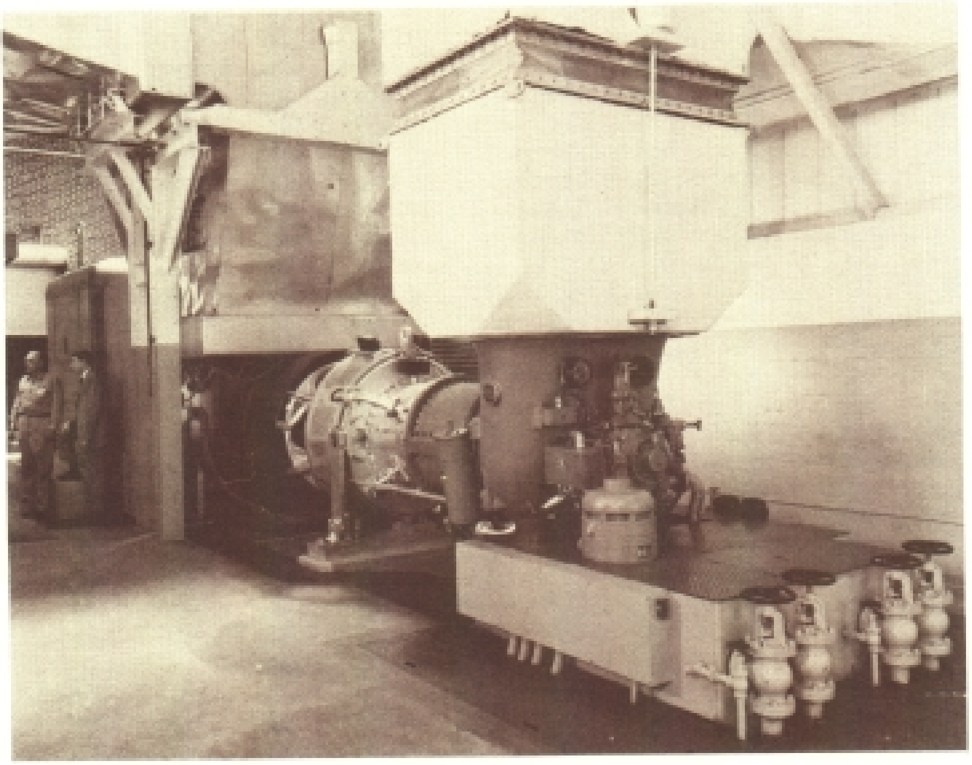


Figure 3. 3500 kW gas turbine-generator in operation at Oklahoma Gas and Electric Co., Belle Isle Station, Oklahoma City, Oklahoma, June 20, 1956.

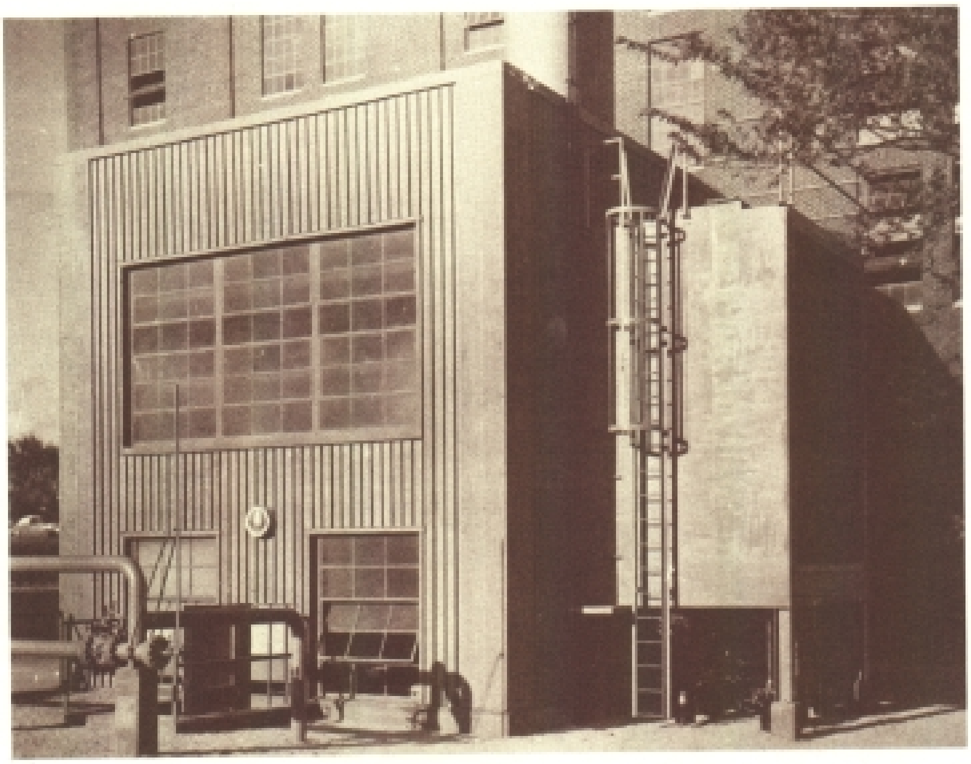


Figure 4. Exterior view of the building housing the 3500 kW gas turbine-generator set at the Belle Isle Station of the Oklahoma Gas and Electric Co., October 14, 1949.

and Electric Company for 31 years. It was withdrawn from service in August 1980 with the closing of the Belle Isle Station which was obsolete. At that time the General Electric Company made arrangements for the turbine to be returned to Schenectady, where it is now on display outside Building 262 of the company's plant, and where it may be inspected.

On June 16, 1982 the turbine was dedicated by H.A. Carlson of the General Electric Company, and at that time a plaque was unveiled which reads:

PIONEERING A NEW INDUSTRY
GAS TURBINE DIVISION
First Unit Shipped April 1949
Belle Isle Station
Oklahoma Gas and Electric Company
Retired September 1980
Dedicated June 1982

The predecessors of the Belle Isle gas turbine, from which it was developed, had their origins sometime in the late 1930s when a group at the General Electric Company's steam turbine manufacturing plant in Schenectady, New York commenced the design of a gas turbine using an axial flow compressor. This engine was intended to drive the propeller of an aircraft; that is, it was a so-called turbo-prop gas turbine. This machine was known as the TG-100. It was plagued with difficulties at first, but the first one flew in December 1949 in a Consolidated Vultee XP81 and another was used in a Ryan XF2R-1 [Hendrickson (1977), Howard and Walker (1947)]

In May 1943, at the request of the Army Air Force, work was commenced on another axial compressor gas turbine known as the TG180 (later the J-35GE). This was not a turbo-prop, but was intended to be a jet engine.* In its first flight it was used to power the Republic XP-84 Thunderjet at Muroc Dry Lake, California, in February 1946.

At the close of World War II, those aircraft gas turbine activities of the General Electric Company that were located in Schenectady, New York were moved to Lynn, Massachusetts. The engineers working on gas turbines in Schenectady under the leadership of Mr. Alan Howard (see "Biographical Sketch of Alan Howard") were provided with an option to transfer to Lynn to continue their involvement with the TG100 or TG180 turbines, or to stay in Schenectady and resume work on a locomotive gas turbine that had been started before the war but laid aside by the need to design and develop aircraft gas turbines.

The prewar activity in gas turbines in Schenectady had been initiated as a result of a study conducted by J.K. Salisbury of the General Electric Company, which had shown that a gas turbine locomotive would be competitive with existing steam locomotives. When, following the war, work was resumed on the locomotive gas turbine the experience gained with the TG100 and TG180 aircraft gas turbines was invaluable, and in 1949 Alco-GE locomotive No. 50 was placed in revenue service on a number of American railroads [Howard (1947)]. One of these locomotive gas turbines was slightly modified for stationary use as a prime mover to drive an electric generator. This machine was the turbine that was shipped to the Belle Isle Station of the Oklahoma Gas and Electric Company in April 1949 and is now the National Historic Mechanical Engineering Landmark that is being dedicated today.

THE GAS TURBINE

Gas turbines are internal combustion engines, just like the automobile engine, except that rotating compressors and expansion turbines† are used instead of a piston reciprocating in a cylinder. In an internal combustion engine air is drawn into the machine and compressed, fuel is added to the compressed air, and the resulting mixture is burned, thereby raising the temperature of the gas; the hot gases are then expanded, i.e., their temperature and pressure are lowered by withdrawing the energy supplied by the burning fuel. This extracted energy is used in the compression process and to provide energy to propel an aeroplane, a locomotive, generate electricity or any other uses. In the reciprocating internal combustion engine, such as that used to drive a car, the various processes take place in a cylinder with a reciprocating piston. This engine operates in a non-flow mode, in the sense that all the processes occur in one component. The same processes can be arranged to be carried out in separate components; namely, a compressor, a combustion chamber, and an expansion machine. If a rotary compressor and a rotary expansion engine, that is, an expansion turbine, are used, then the device is known as a gas turbine. The arrangement of these components is shown in Figure 5.

Gas turbines can have two forms depending on the way in which the combustion process is carried out. The earliest gas turbines heated the air by burning the air/fuel mixture in a chamber closed by inlet and outlet valves. When the combustion process was complete the

* A good technical description of the TG-180 engine will be found in Burgess (1947).

† The terminology expansion turbine is introduced in order to avoid confusion between the gas turbine as an overall term for a particular form of the internal combustion engine, and the expansion turbine which is a component of the gas turbine.

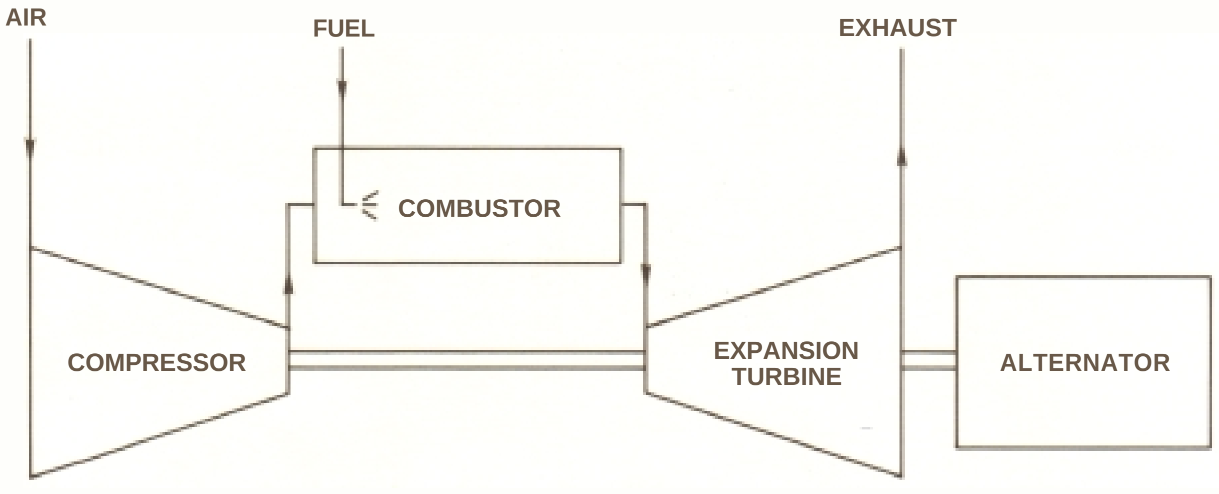


Figure 5. Arrangement of gas turbine-generator.

outlet valve opened and the hot gases were discharged and flowed through the turbine. This intermittent process does not work in harmony with the steady flow characteristics of the rotary compressor and the turbine, and for that reason this type of gas turbine, using constant volume combustion, was quickly abandoned.

An alternative mode of combustion, which is called constant pressure combustion, operates with the air and fuel entering the combustion chamber in a steady stream, and, likewise, the hot products of combustion leave in a steady stream. With this type of combustion the pressure is very nearly the same at all points in the combustion chamber and does not change with time. Modern gas turbines operate with constant pressure combustion because it is well adapted to handling the steady flows of air passing from the rotary compressor to the expansion turbine.

Two topics of importance to the gas turbine, and indeed to any thermodynamic prime mover, are the thermodynamic efficiency and the power output. The thermodynamic efficiency of the ideal gas turbine using a perfect compressor and a perfect expansion turbine, depends only on the pressure ratio in the compressor. In principle, increasing the pressure ratio results in an increase in the thermodynamic efficiency; however, the gas entering the expansion turbine then has a higher temperature. There is a limit to which this temperature can rise that depends on the ability of the materials used in the expansion turbine to work at elevated temperatures. For this reason, a continuing international research effort is underway, with the objective of identifying suitable materials for use in the expansion turbine.

With real, and therefore imperfect, compressors and expansion turbines, the thermodynamic efficiency of the gas turbine also depends on the efficiencies of these components, as well as the pressure rise in the compressor. In particular, the thermodynamic efficiency of the gas turbine is very sensitive to the efficiency of the compressor, such that a modest decrease in the latter can have a disastrous effect on the former. Within the limits set by the metallurgical requirements, the expansion turbine inlet temperature can be raised to offset, to some extent, the effects of losses in the compressor and the expansion turbine.

The power output of the gas turbine, which is a variable of interest to the user, can, once again, within the limits set by the materials used in the expansion turbine, be increased by raising the temperature of the gases entering the expansion turbine. However, this may result in a decrease in the efficiency of this component and, hence, in the thermodynamic efficiency of the gas turbine. Clearly, the successful design of a gas turbine involves an optimization of component parameters, together with very careful attention to detail in their design so as to ensure that they operate at very high efficiencies.

Gas turbines for the production of electric power can be compared with steam power plants on the basis of size and on the basis of thermodynamic efficiency. The gas turbine has the potential for producing large amounts of power in a fraction of the space required by a steam power plant of the same power output. Modern gas turbines operate with efficiencies of 30 to 35%, whereas fossil fuel fired steam power plants can operate with efficiencies in the vicinity of 39%, although the addition of air pollution controls lowers this substantially. Because of the expanding use of equipment to minimize air pollution by the products of combustion, the efficiencies of the two types of power plant are approaching one another. This means that the gas turbine is becoming an increasingly attractive proposition for electric utilities seeking to generate power from the combustion of fossil fuels, particularly when these are in the form of oil and natural gas.

An outstanding feature of the gas turbine is its short start-up time. Where a steam turbine would require several hours to reach its operating temperature in order to prevent warping of the heavy parts forming the casing and rotor, the gas turbine can produce full power within about 15 minutes. This characteristic, together with the low initial investment, has meant that the gas turbine has been used to generate electrical power at times of peak demand rather than carry the baseload of the distribution system.

The idea of the gas turbine is quite old; reputedly it was first proposed by John Barber, who described a gas turbine with constant pressure combustion in a British patent granted in 1791 [Moss (1944)]. However, the necessary materials, manufacturing methods and engineering experience to ensure its successful practical realization were not available until the early part of this century. Turbines using both constant volume and constant pressure combustion have been built, but, as explained earlier, modern gas turbines use constant pressure combustion.

Constant pressure combustion gas turbines were first built independently by Sanford Moss [Moss (1944)] in the United States, and by Armengaud and Lemale in France [Meyer 1939)]. Both of these machines were demonstrated in 1903. Neither was successful because material properties placed limits on the temperature of the gas entering the expansion turbine, so that the thermal efficiency of the gas turbine was not competitive with other available prime movers, such as the steam power plant. In addition, the need for very high efficiency compression required Armengaud and Lemale to use 25 stages of compression arranged in three separate housings, so that the overall length of the compressor, with a 3:1 compression ratio, was probably in excess of 20 feet. Moss did not even attempt to drive his compressor with the expansion turbine, so it is not known if his gas turbine could produce useful work; nevertheless, it was a gallant attempt by a graduate student at Cornell University to overcome engineering problems that would later take teams of the best engineers about 15 years to solve.

In 1936, a gas turbine to supply air to the Houdry catalytic cracking process was installed by the Sun Oil Company at its refinery in Marcus Hook, Pennsylvania [Pew (1945a,b)]. Then in 1939, the first application of a gas turbine to electric power generation was made at Neuchatel in Switzerland [Endres (1979)].

These early gas turbines were characterized by comparatively low temperatures at the inlet to the expansion turbine [Marcus Hook: 468-510 °C (875-950 °F), Neuchatel 549 °C (1020 °F)] and modest compression ratios in the axial flow compressor (Marcus Hook 3:1, Neuchatel 4:1) [Pew (1945a,b), Schneitter (1953)]. In addition, the combustion chambers were large, presumably in order to ensure adequate life by keeping local heat fluxes on the combustion chamber walls at moderate levels compared to current practice.

Significant increases in compression ratios, expansion turbine inlet temperatures, and gas turbine power came as a result of the intense effort in World War II that went into the production of practical aircraft gas turbines for jet propulsion in Germany, Britain, and the United States. The first German aircraft gas turbines used centrifugal compressors, and a machine of this type was first flown in an aircraft in 1939 [Maguire (1948)]. However, the development of this type of compressor was abandoned and efforts were concentrated on the axial flow compressor. Gas turbine engines using the axial flow compressor eventually saw service with the German Air Force in 1944, but they had, by modern standards, a spectacularly short operational life of about 10 hours, because materials that would give a longer life were not available for the construction of the expansion turbine.

The first British gas turbine flew on May 15, 1941. This was one of the gas turbines developed under the leadership of Frank Whittle. They had a longer life than the German engines and eventually went into service with the Royal Air Force in July 1944. The Whittle [Whittle (1945)] turbines used centrifugal compression rather than the axial flow compressors* of the Brown Boveri gas turbines and the German aircraft gas turbines. This,

* The British did develop gas turbines using axial flow compressors, but this effort was not started as soon as the development of the Whittle gas turbine.

no doubt, was motivated by a desire, on Whittle's part, to ensure satisfactory performance of the gas turbine by using known technology. However, such gas turbines have the drawback that the frontal area of the engine for a given volume of air handled is higher than is the case for gas turbines using axial compressors. This means that the frontal area, and hence, aerodynamic drag of the aircraft, in which a gas turbine with a centrifugal compressor is used, is correspondingly larger than would be the case if an axial flow compressor were employed. The axial flow compressor is the accepted standard for all high power gas turbines having maximum outputs in excess of, say, 500 hp, but for lower maximum power outputs the centrifugal compressor is used. This is motivated, no doubt, by the smaller space occupied by the centrifugal compressor and its relative simplicity.

In the United States the General Electric Company started to build Whittle gas turbines in October 1941 at its Lynn, Massachusetts plant [Neal (1966)]. A vigorous development program was applied to the Whittle engine and this eventually led to the production of the General Electric IA gas turbine engine. This was test flown in a Bell XP59A at Muroc Dry Lake, California on October 1, 1942.

A purely American effort to develop an aircraft gas turbine was commenced in 1941 at the request of the U.S. Navy [Diggs and Lancaster (1953)]. This machine had an axial flow compressor and was called a type 19A and had its first trial run on March 19, 1943. A second model was flown as a booster in a Goodyear FG-1 Corsair on January 21, 1944.

A third group located at the General Electric Company's plant in Schenectady, New York had started to study gas turbines in the late 1930s. Their efforts led to the production of the TG100 and TG180 gas turbines, the progenitors of the Belle Isle gas turbine, as has been described in the section entitled "History of the Belle Isle Gas Turbine."

DESCRIPTION OF THE BELLE ISLE GAS TURBINE*

The gas turbine was arranged with its axis horizontal (Figure 6). When installed in the power station, air entered the machine from outside the turbine house through an air cleaner and pre-cooler (necessary because high summer ambient temperatures could result in a reduction of the power output of the turbine). The air stream was turned through 90° at the inlet to the compressor and flowed through the 15-stage axial compressor, which had a 6:1 compression ratio. This consisted of 15 bladed disks connected to stub shafts by multiple through bolts (Figure 7) and enclosed in a casing in which the forward part was machined from aluminum castings (Figure 8), while the after part and the mid-frame were of steel. The first four compressor disks were machined from aluminum forgings, with the remaining wheels made of steel. The compressor blades, which were forged chrome-iron alloy, were attached to the disk rim with dovetails.

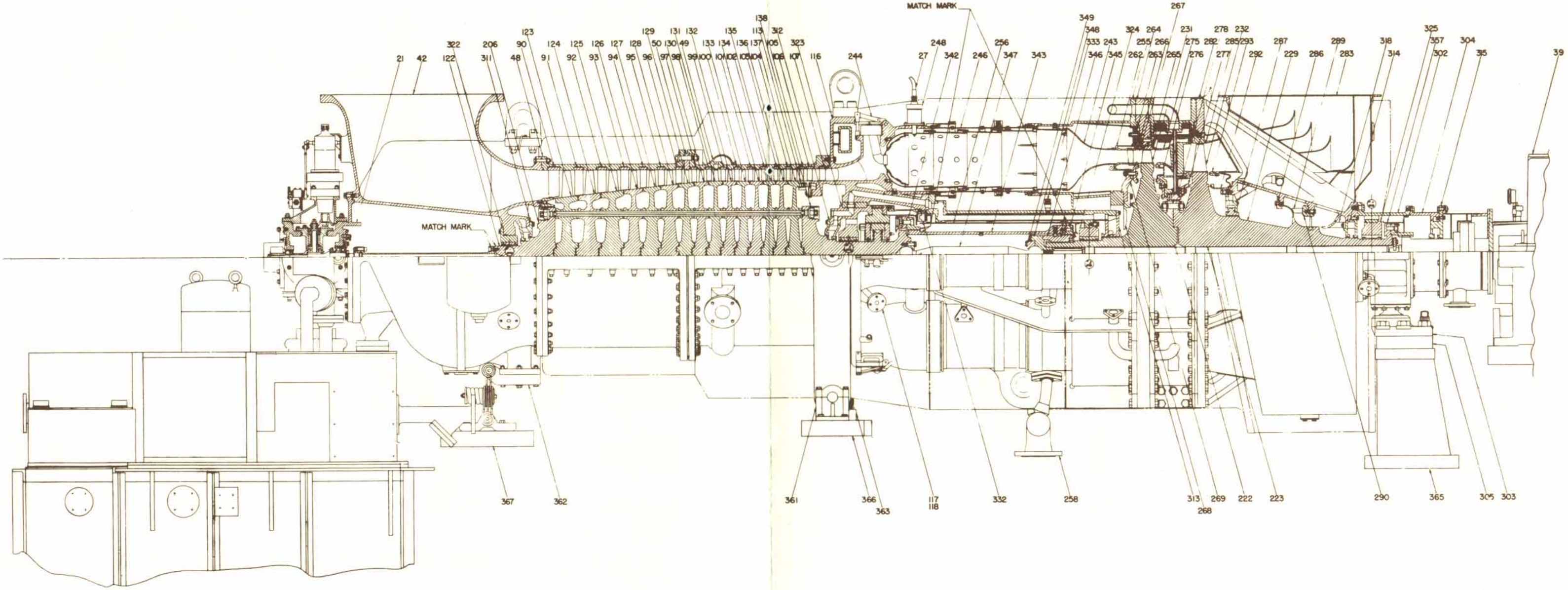
The compressor casing was split horizontally and bolted together so that it enclosed the rotor. The forged compressor stator blades were attached by dovetails to blade rings, which were then inserted into circumferential grooves machined in the casings. Fifteen rows of stator blades were used, and an additional three rows of exit guide vanes were located at the exit from the compressor.

The air from the compressor passed to one of six cylindrical combustion chambers that were arranged circumferentially around the axis of the turbine (Figure 6). The combustion chambers consisted of an outer chamber enclosing a removable liner and fuel nozzle. Igniter plugs were located in two of the six combustion chambers, and crossfire tubes connected the chambers to ensure that ignition took place in all the combustors. Air was introduced into the combustion space inside the liner by holes throughout its length. This cooled the liner and diluted the combustion gases, keeping them at 760 °C (1400 °F), which was the expansion turbine inlet temperature.

The expansion turbine was a two-stage, free vortex design with impulse at the root (see Figure 9). It comprised a nozzle diaphragm, a first-stage wheel, a second-stage diaphragm, and a second stage wheel. The expansion turbine wheels were made from a low alloy, high strength steel for operation at 380 °C (700 °F). Each wheel was forged integrally with its own shaft for maximum strength, and the two shafts were bolted together. The wheel rim was made from stainless steel which can operate at 760 °C (1400 °F), and it was welded to the center portion of the wheel. The turbine wheel was cooled, and the wheel spaces were sealed, by air extracted from the ninth stage of the compressor which was delivered to both sides of the wheel. Air was also extracted from the eleventh stage of the compressor for cooling the first forward wheel spaces, i.e., the space on the upstream side of the first-stage turbine wheel. The turbine buckets were forged from austenitic steel and were fastened to the wheel by dovetails.

The first-stage nozzle diaphragm was made in four pieces, consisting of an inner circular piece of stainless steel, the nozzle guides, and the inner and outer rings

* For additional information see Howard (1948)



21 Accessory drive assembly
27 Spark plug lead
39 Generator, exciter, gear, turning gear and flexible coupling assembly
42 Inlet casing assembly
48 Forward compressor casing
49 Aft compressor casing
50 Centering ring
90 Inlet blade and ring assembly
91 1st stage blade and ring assembly
92 2nd stage blade and ring assembly
93 3rd stage blade and ring assembly
94 4th stage blade and ring assembly
95 5th stage blade and ring assembly
96 6th stage blade and ring assembly
97 7th stage blade and ring assembly
98 8th stage blade and ring assembly
99 9th stage blade and ring assembly
100 10th stage blade and ring assembly
101 11th stage blade and ring assembly
102 12th stage blade and ring assembly
103 13th stage blade and ring assembly
104 14th stage blade and ring assembly
105 15th stage blade and ring assembly
106 Blade and ring assembly exit No. 1
107 Blade and ring assembly exit No. 2
113 High pressure compressor rotor seal
116 Mid frame
117 Oil line for No. 2 bearing (journal & thrust)
122 Stub shaft forward
123 1st stage wheel
124 2nd stage wheel
125 3rd stage wheel
126 4th stage wheel
127 5th stage wheel
128 6th stage wheel
129 7th stage wheel
130 8th stage wheel
131 9th stage wheel
132 10th stage wheel
133 11th stage wheel
134 12th stage wheel
135 13th stage wheel
136 14th stage wheel
137 15th stage wheel
138 Aft stub shaft
206 Compressor rotor assembly and clearance diagram
222 1st stage turbine wheel
223 2nd stage turbine wheel
229 Turbine rotor assembly and clearance diagram
231 1st stage bucket
232 2nd stage bucket
243 Transition piece assembly
244 Assembly of mid frame, fuel nozzle, clamp hinge and clevis
246 Combustion chamber
248 Spark plug assembly
255 Aft frame
256 Oil shield
258 Bearing drain assembly
262 1st stage nozzle assembly
263 Insulation ring assembly
264 Support ring
265 Spacing ring
266 Connecting ring
267 Cover plate
268 Inner nozzle plate
269 Outer nozzle plate
275 2nd stage nozzle and diaphragm assembly
276 Forward cover plate
277 Aft cover plate
278 Packing ring assembly
282 Exhaust casing
283 Exhaust casing assembly
285 Spacing ring
286 Air shield
287 Packing ring assembly
289 Inlet guide vane
290 Inlet guide vane ring
292 Inner exhaust casing cover
293 Outer exhaust casing cover
302 Aft end support
303 Ball support
304 Deflector housing
305 Shim (for ball support)
311 Oil deflector for compressor forward
312 Oil deflector for compressor aft
313 Oil deflector, turbine forward
314 Oil deflector, turbine intermediate
315 Oil deflector, turbine aft
318 Air guide, turbine intermediate oil deflector
322 No. 1 bearing assembly
323 No. 2 bearing and thrust bearing assembly
324 No. 3 bearing assembly
325 No. 4 bearing assembly
332 No. 2 thrust bearing thermocouple
333 No. 3 bearing thermocouple
342 Coupling ring
343 Spline sleeve and ring assembly
345 Spline ring
346 Spline hub
347 Thrust link
348 Thrust link socket
349 Thrust link retainer ring
357 Coupling guard, turbine aft
361 Trunnion support assembly
362 Front end support
363 Mid frame guide support
365 Mounting
366 Foundation plate
367 Sole plate

Figure 6. Cross section of the 3500 kW gas turbine.

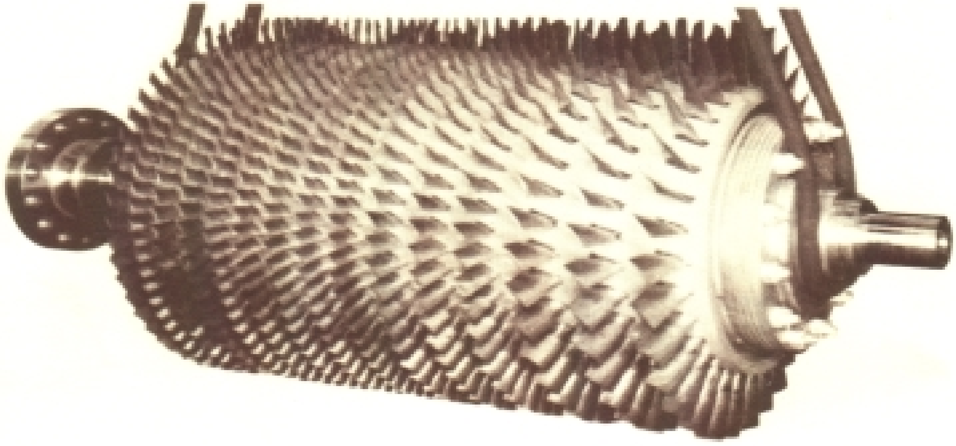


Figure 7. Compressor rotor for 3500 kW gas turbine-generator.

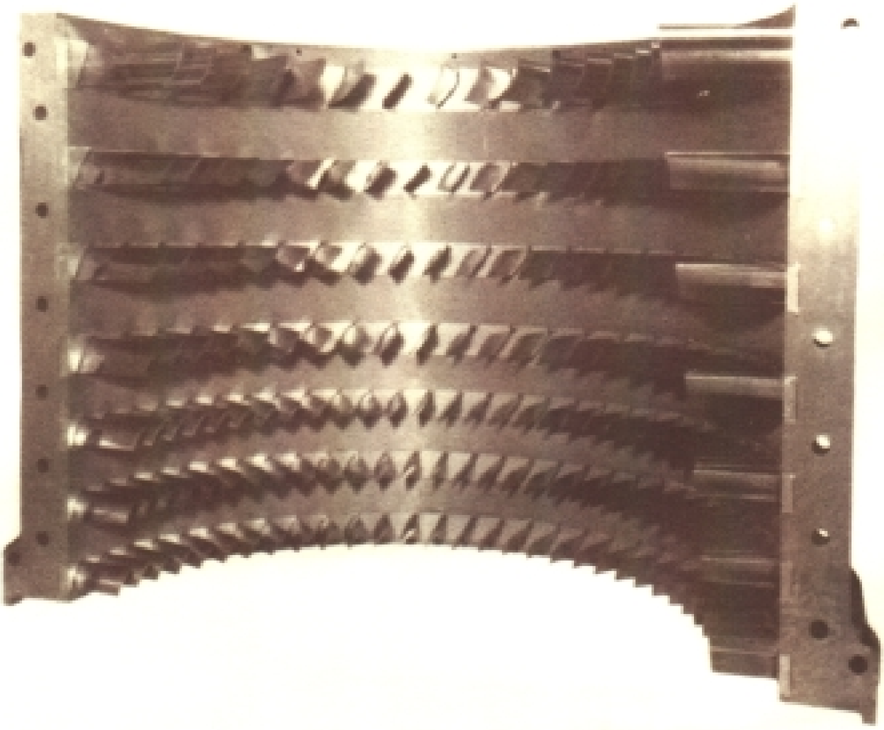


Figure 8. Compressor casing half (aluminum portion) for 3500 kW gas turbine-generator. Inside view showing blades and blade rings in place.

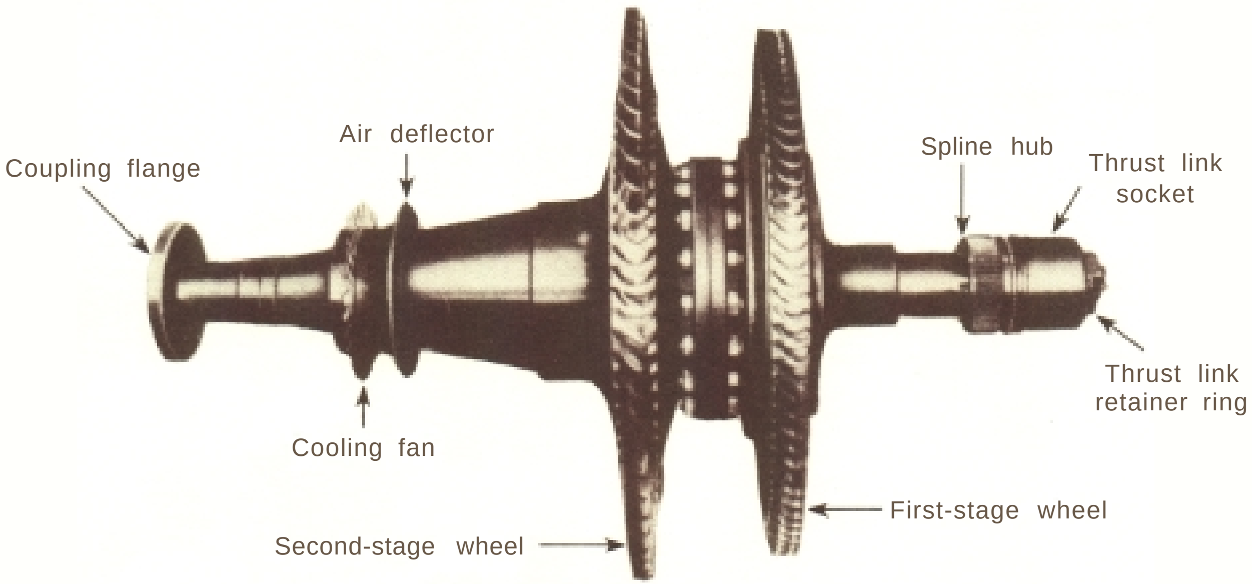


Figure 9. Side view of expansion turbine rotor.

that carry the guides. These last three parts were made from ordinary carbon steel. The second-stage nozzle diaphragm was made in the same way except that it was split on the vertical centerline to allow bucket replacement on the two turbine wheels.

When the machine was installed in the Belle Isle station, the exhaust gases leaving the expansion turbine were directed upward into a recuperator where they flowed over tubes carrying condensate from the condensers of the steam section of the power station. The leaving gases were conveyed from the heat exchanger by an unlined stack and dispersed to the atmosphere.

One very interesting feature of the turbine was that all the rotating parts were carried on plain bearings with pressurized oil lubrication, as was the initial TG100 gas turbine. This was a consequence of the experience with the anti-friction bearings used in the later versions of the TG100 and in all TG180 engines (see the section "History of the Belle Isle Gas Turbine"), which were one of the main sources of failure of the early aircraft gas turbines after only 15 to 100 hours of operation [Hendrickson (1977)].

The turbine was started by a 100 hp electric motor connected to the turbine shaft through a "jaw" clutch.

The gas turbine speed/load governing was accomplished by a mechanical-hydraulic fuel regulator that controlled the fuel flow rate to the combustion system in response to an electrical signal transmitted from the speed sensing governor and the operator's manual setpoint.

Specifications of the Belle Isle gas turbine-generator unit were:

Gas Turbine serial no.:	76393
Generator serial no.:	6784566 (air cooled)
Electrical output:*	5000 kW, 3 phase, 60 Hz at 13,800 V.
Speed:	6700 rpm (to drive the alternator at 3600 rpm a step-down gear was provided with a 1.86:1 ratio).
Compressor:	15-stage, axial with 6:1 compression ratio [air leaves at 600 Pa (87 psia)].
Combustors:	six
Fuel:	natural gas
Expansion turbine:	2-stage Inlet temperature: 760 °C (1400 °F) Exit Temperature: 416 °C (780 °F)

* The gas turbine/generator rating was 3500 kW (see further comments).

Weight:	29,000 kg (64,000 lb)
Length:	5.49 m (18 ft)
Width:	2.74 m (9 ft)

Although this unit was rated at 3500 kW, it actually exceeded this output in service by a wide margin. It often provided an electrical output of 5000 kW, and between July 1949 and July 1952 the average output was 4200 kW [Loft (1984)].

THE PLAQUE

The plaque denoting that the 3500 kW Belle Isle gas turbine has been designated as a National Historic Mechanical Engineering Landmark bears the following words:

NATIONAL HISTORIC
MECHANICAL ENGINEERING LANDMARK
FIRST GAS TURBINE FOR U.S.
UTILITY POWER GENERATION

1949-1980

This unit, retired from the Belle Isle Station, Oklahoma Gas and Electric Company, was the first gas turbine to be used for electric utility power generation in the United States. It represents the transformation of the early aircraft gas turbine in which the engines seldom ran more than ten hours at a stretch, into a long life prime mover. This redesign was based upon creep-rupture tests of S-816 cobalt-base alloys for turbine buckets. The low-cost, trouble-free service led to wide-scale adoption of the gas turbine, over 45 million kW capacity (over 9% of the U.S. output) being installed during the period 1966-1976.

This two-stage expansion turbine has a 15-stage axial compressor. It ran on natural gas. Through a reduction gear, it drove a 3500 kW alternator at 3600 rpm.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

1984

BIOGRAPHICAL SKETCHES

Alan Howard

The success of the Belle Isle gas turbine owed much to the engineering skill and administrative expertise of the late Alan Howard (see Figure 10 for a portrait dating from 1946), who was the leader of the group of engineers responsible for the design and development of this turbine.

Figure 10. Alan Howard (1905-1966) in 1946.

Alan Howard was born on August 19, 1905 in Washington, DC and was educated as an electrical engineer at Purdue University, receiving his bachelor's degree in 1927. Following graduation he joined the General Electric Company in Schenectady, New York. Initially he was employed as an electrical engineer but then became involved with the steam turbine activities of the company. In 1941, while still employed by General Electric, he was asked to join the Subcommittee on Jet and Turbine Power Plants of the National Advisory Committee for Aeronautics. The activities of this committee were part of the general wartime effort in this country to develop gas turbines for military aircraft propulsion.

During the Second World War, Mr. Howard was in charge of the group of engineers responsible for designing and developing the TG100 and TG180 aircraft gas turbines for the Army Air Force. Because of this responsibility he was involved from its inception with work that ultimately led to the development of the gas turbine that was installed in the Belle Isle Station.

With the end of World War II, Alan Howard concentrated his efforts on the development of gas turbines for non-aircraft applications, although he continued as engineering consultant to the Aircraft Gas Turbine Division. Howard's group developed the gas turbine for use in railroad locomotives and the modified version which was installed at Belle Isle. The remarkable operating record of this machine (thousands of hours of continuous service compared to the tens of hours of the TG100 and TG180) is a tribute to the skill of Mr. Howard, and the team* that he directed, in taking experience gained in aircraft applications and turning it to the successful development of a land-based gas turbine.

From September 1951 to March 1952, and again from November 1960 until his untimely death in May 1966, Alan Howard served as general manager of the General Electric Company's Gas Turbine Department in Schenectady, New York.

Mr. Howard was honored by his employers by being given the Charles E. Coffin Award for his accomplishments in connection with the design and development of the TG100 and TG180 aircraft gas turbines. In 1946 he received an honorary Doctor of Engineering degree from Purdue University, his alma mater. The American Society of Mechanical Engineers elected him a Fellow in 1962 and gave him the Engineer's Medal in 1964.

Mr. Howard died suddenly in May 1966. A bronze bust of Alan Howard is mounted in the entrance lobby of Building 53 at the General Electric Company's Schenectady plant.

Joel Blake

The Oklahoma Gas and Electric Company provided the opportunity for the 3500 kW gas turbine-generator to show its capabilities and thereby draw the attention of the U.S. electric utility industry to this important new and practical method of power generation. Joel Blake, who was employed by the Oklahoma Gas and Electric Company at the time of the turbine's installation, was instrumental both in the decision to purchase the turbine and in ensuring its successful operation after it was installed in the Belle Isle Station.

Mr. Blake was born on January 31,1903 in Checotah, Oklahoma and grew up in the community of Wagner in the same state. He graduated in 1924 from the University of Arkansas with a double major in electrical and mechanical engineering.

Following graduation, Joel Blake was employed by a number of companies in engineering and associated fields, and in 1937 he joined the Oklahoma Gas and Electric Company. He had a prominent role during the installation of the gas turbine in the Belle Isle Station, and later when it was in service. The fine operational record of this machine from 1949 until 1980 is a tribute to Mr. Blake's outstanding managerial and technical skills.

In 1968 Mr. Blake retired from his position as Manager of Generation after 31 years with the Oklahoma Gas and Electric Company. He died in January 1975.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The American Society of Mechanical Engineers (ASME) was founded in 1880 as an educational and technical society. ASME has consistently sought to provide an impetus for the continuing professional development of its individual members and advancement of the state-of-the-art of mechanical engineering. The principal goals and objectives of ASME are:

- To provide a forum for the development, exchange and dissemination of technical information, particularly on mechanical engineering.
- To develop mechanical standards, codes, safety procedures and operating principles for industry.
- To encourage the personal and professional development of practicing and student engineers.
- To aid members of the engineering profession in maintaining a high level of ethical conduct.

The Society consists of more than 111,000 members, of whom some 20,000 are engineering students. ASME members are active in private engineering firms, corporations, academic and government service. A ten-member board governs the Society. Its headquarters are in New York City and it has five field offices—Chicago, Dallas, San Francisco, Danbury, CT and Burke, VA, plus a government relations office in Washington, DC.

* The team involved about one hundred engineers including Bruce O. Buckland, Donald C. Berkey, Robert L. Hendrickson, Alva A. Hafer, and Neal E. Starkey (all Fellows of the ASME).

THE HISTORY AND HERITAGE PROGRAM

The History and Heritage Landmark Program of ASME began in September 1971. To implement and achieve the goals of the Landmark Program, ASME formed a History and Heritage Committee, composed of mechanical engineers, historians of technology, and the curator of mechanical engineering of the Smithsonian Institution. The committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements of particular significance.

LANDMARK DESIGNATION

The 3500 kW gas turbine is the 73rd National Historic Mechanical Engineering Landmark to be designated since the ASME program began. In addition, 17 International and eight Regional Landmarks have been recognized. Each represents a progressive step in the evolution of mechanical engineering, and each reflects its influence on society, either in its immediate locale, nationwide, or throughout the world.

The Landmark Program illuminates our technological heritage and serves to encourage the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers and helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

ACKNOWLEDGMENTS

The Hudson-Mohawk section of ASME gratefully acknowledges the efforts of all who participated in the landmark designation of the 3500 kW gas turbine. In particular: D.E. Brandt, H.A. Carlson, R.H. Hubbell, Arne Loft, J.L. Mangan, M.T. McCullough, and J.T. Reilly, all of the General Electric Company; J.R. Feese and R.C. Tobin of the Sun Refining and Marketing Company; E.R. Andersen, Mississippi River Transmission Corporation; C.M. Oakes, National Air and Space Museum; J.B. Hilliard, United States Air Force Museum; W. Armstrong, Historians Office, Naval Air Systems Command.

This publication was prepared by E.F.C. Somerscales and R.L. Hendrickson of the Hudson-Mohawk Section of the American Society of Mechanical Engineers. All illustrations, with the exception of Figure 5, are courtesy of the General Electric Company.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE ASME HUDSON-MOHAWK SECTION

THE ASME NATIONAL HISTORY AND HERITAGE COMMITTEE

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