CHAPTER 6

GAS TURBINE POWER PLANT DESIGN

6-1. General

Gas turbines find only limited application as prime movers for power generation at military facilities. This is because gas turbine generators typically have significantly higher heat rates than steam turbine or diesel power plants; their higher fuel costs quickly outweigh their initial advantages in most applications. Applications to be evaluated include:

a. Supplying relatively large power requirements in a facility where space is at a significant premium—such as hardened structure.

b. Mobile, temporary or difficult access site—such as a troop support or lie of sight station.

c. Peak shaving, in conjunction with a more efficient generating station.

d. Emergency power, where a gas turbine's light weight and relatively vibration-free operation are of greater importance than fuel consumption over short periods of operation. However, the starting time of gas turbines may not be suitable for a given application.

e. Combined cycle or cogeneration power plants where turbine exhaust waste heat can be economically used to generate additional power and thermal energy for process or space heating.

6-2. Turbine-generator selection

a. Packaged plants. Gas turbines are normally purchased as complete, packaged power plants. With few exceptions, only simple cycle turbines are applicable to military installations. Therefore, the remainder of this chapter focuses on the simple cycle configuration. The packaged gas turbine power plant will include the prime mover, combustion system, starting system, generator, auxiliary switchgear and all turbine support equipment required for operation. This equipment is usually "skid" or base mounted. The only "off base" or additional auxiliaries normally required to supplement the package are the fuel oil storage tanks, transfer pumps and oil receiving station, distribution switchgear, step up transformer and switchyard, as required.

(1) Selection of unit size requires establishment of plant loading and the number of units required for reliability y and turndown. Wide gaps in the standard equipment capacity ratings available may force reconsideration of the number of units or the total plant capacity,

(2) Initial selection of the gas turbine unit begins using the International Standards Organization (ISO) rating provided on the manufacturer's data sheets. This is a power rating at design speed and at sea level with an ambient temperature of $59^{\circ}F$ ($15^{\circ}C$). The ISO rating considers inlet and outlet losses to be zero. Initially, ISO ratings will be reduced 15 percent for typical applications, which will further be refined to reflect actual site and installation conditions. The four variables which will be considered in unit rating are:

(a) Elevation.

(b) Ambient temperature.

(c) Inlet losses.

(d) Exhaust losses.

The following subsections define the impact of each of these variables.

b. Elevation. For a specific site, the ISO rating reduction due to site altitude is read directly from an altitude correction curve published by the various manufacturers. There is little difference in such curves. For mobile units, the effect of possible site altitudes will be evaluated. The operating altitude will be used to determine the unit rating.

c. Temperature. Site temperature data will be obtained from TM 5-785. The design temperature selected is normally the 2 1/2 percent dry bulb temperature, although the timing of the load curve peak will also be considered. Unless the choice of equipment is tight, there is usually sufficient overload capability to carry the unit during the 2 1/2 percent time of higher temperature. Another temperature related selection parameter is icing. Icing is caused when the right combination of temperature and humidity levels occurs, and is manifested by ice formation on the downstream side of the inlet filters or at the compressors bell mouth intake. Chunks of ice can be sucked in the compressor with possible blade damage resulting. Icing occurs when ambient temperatures are in the 350 to $42^{\circ}F$. range and relative humidity is high. This problem will be avoided by recirculating hot air from the compressor discharge to the filter inlet, either manually or automatically. This causes some loss of turbine efficiency.

d. Inlet losses. Inlet losses are a critical performance variable, and one over which the designer has considerable control. Increases in the inlet air friction cause a significant reduction in power output. The total inlet pressure loss will not exceed 2 inches of water and will be as close to zero as space limitations and economics will permit. Additional ductwork costs will be quickly amortized by operating fuel savings. Dust, rain, sand and snow will be prevented from entering the combustion air inlet of the engine. Inlet air filter design will preclude entrance of these contaminants with minimal pressure loss. The air inlet will be located to preclude ingestion of combustion products from other turbines or a nearby boiler plant, or hot, humid discharge from any cooling towers.

e. Outlet losses. Outlet friction losses also result in a decrease of turbine-generator output and will be accounted for in the unit design. The major factor in outlet losses is the requirement to attenuate noise. More effective silencers typically have higher pressure losses. Exhaust back pressure has a smaller overall effect on performance than inlet losses but will be kept as low as possible, and will be less than 6 inches of water. Since increasing exhaust silencer size costs considerably more than ductwork design improvements, the return on investment for a low pressure loss exhaust is significantly longer.

6-3. Fuels

Each manufacturer has his own specification on fuel acceptable for his turbine. The high grade liquid fuels such as Diesel No. 1 or 2 and JP-4 or JP-5 will likely be acceptable to all manufacturers. Use of heavier oils is possible with a specially designed turbine. The heavy oil will have to be cleaned up to reduce corrosive salts of sodium, potassium, vanadium, and sulfur–all of which will elevate the cost of the fuel. Storage and handling at the site will also be more costly, particularly if a heavy oil such as No. 6 was involved because of the heating requirement. No. 4 oil will increase transfer pumping costs a bit but, except in extremely cold regions, would not require heating.

6-4. Plant arrangement

a. General. Turbine generator units are frequently sold as complete packages which include all components necessary to operate, ready for connection to the fuel supply and electrical distribution system. This presents the advantages of faster lead time, well matched components and single point of performance responsibility y.

b. Outdoor vs. indoor.

(1) *Outdoor.* Outdoor units can be divided into two sub-types.

(a) The package power plant unit is supplied with the principal components of the unit factory assembled into three or more skid mounted modules, each with its own weatherproof housing the separate modules have wiring splits, piping connections, and housing flanges arranged so that the modules may be quickly assembled into a unit on a reinforced concrete pad in the field. Supplementing these main modules are the inlet and exhaust ducts, inlet silencer and filters, exhaust silencer, fuel tanks, unit fuel skid, and unit auxiliary transformer which are connected by piping and cables to the main assembly after placing on separate foundation as may be required.

(b) The other outdoor sub-type is a similar package unit except that the weatherproof housing is shipped knocked down and is, in effect, a prefabricated building for quick field assembly into a closure for the main power plant components.

(c) Outdoor units to be provided with all components, auxiliaries and controls assembled in all-weather metal enclosures and furnished complete for operation will be specified for Class “B” and “C” power plants having a 5-year anticipated life and requiring not more than four generating units.

(2) *Indoor.* An indoor type unit will have the compressor-turbine-generator mounted at grade floor level of the building on a pad, or possibly raised above or lowered below grade floor level to provide space for installation of ducts, piping and cabling. Inlet and exhaust ducts will be routed to the outside through the side wall or the roof; the side wall is usually preferable for this so that the turbine room crane can have full longitudinal travel in the turbine generator bay. Filters and silencers may be inside or outside. All heat rejection equipment will be mounted outside while fuel oil skids may be inside or outside. Unit and distribution switchgear and motor control centers will be indoors as in a conventional steam power plant. Figure 6-1 shows a typical indoor unit installation with the prime mover mounted below grade floor level.

6-5. Waste heat recovery

Waste heat recovery will be used wherever cost effective. If the turbine unit is to be used only intermittently, the capital cost of heat recovery must be kept down in order to be considered at all. Add-on or sidestream coils might provide a temporary hot water supply for the period of operation—for one example. Care must be exercised due to the high exhaust gas temperature. It may prove feasible to flash steam through the jacket of a small heat exchanger. In the event that a long term operation is indicated, the cost trade off for heat recovery equipment is enchanced, but still must be considered as an auxiliary system. It will take a sizable yearly load to justify an exhaust gas heat recovery boiler.

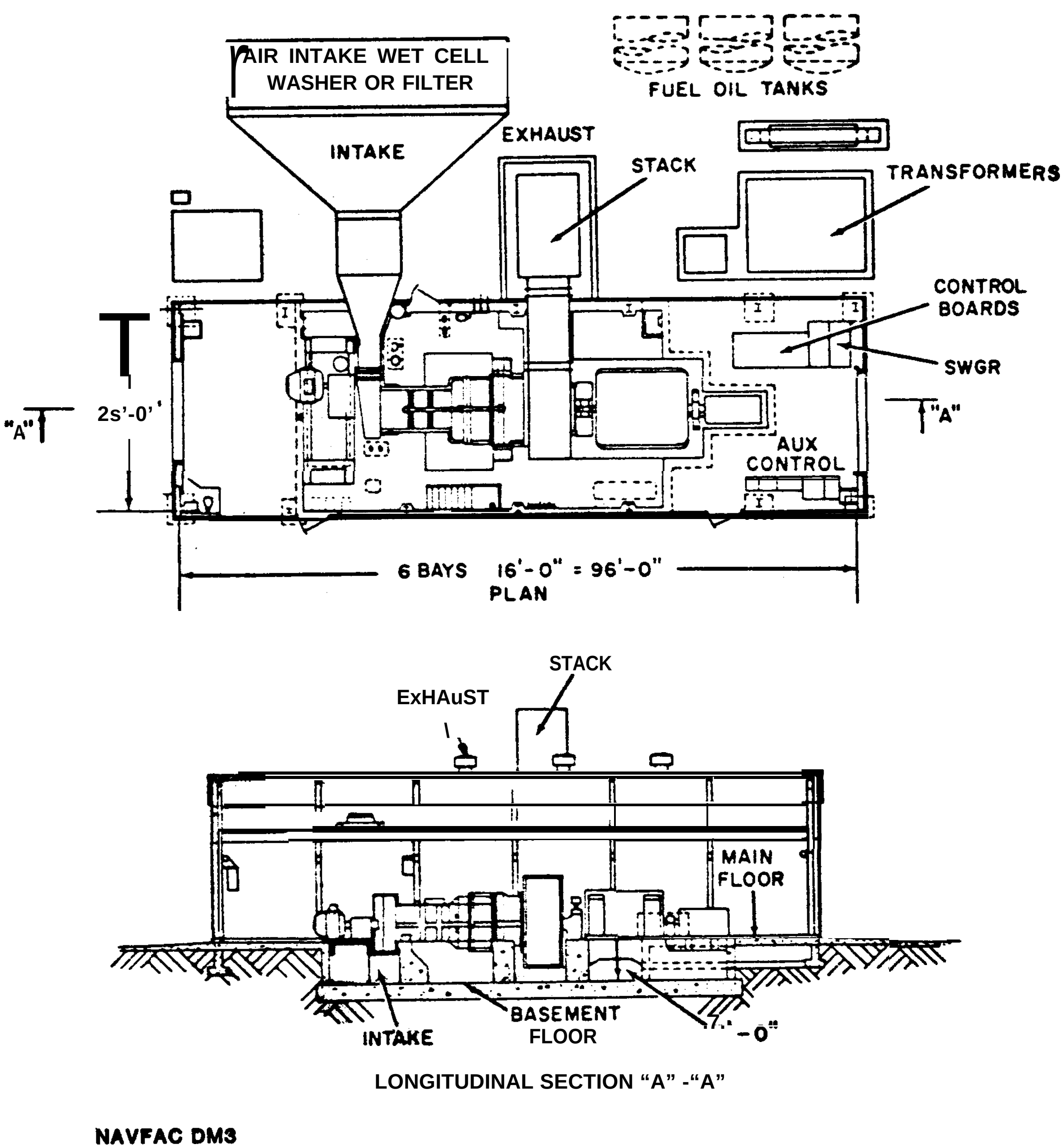

Figure 6-1. Typical indoor simple cycle gas turbine generator power plant.

Turbine efficiency loss due to back pressure is also a factor to be considered.

6-6. Equipment and auxiliary systems

a. General. The gas turbine package is a complete power plant requiring only adequate site preparation, foundations, and support facilities including fuel storage and forwarding system, distribution switchgear, stepup transformer, and switchyard. If the fuel to be fired is a residual oil, a fuel washing and treating plant is also required.

b. References. Chapter 4 sets forth guidelines for the design of the electrical facilities required for a gas turbine power plant, including the generator, switchgear, switchyard, transformers, relays and controls. Chapter 2 describes the pertinent civil facilities.

c. *Scope.* The scope of a package gas turbine generator for purchase from the manufacturer will include the following

(1) Compressor and turbine with fuel and combustion system, lube oil system, turning gear, governor, and other auxiliaries and accessories.

(2) Reduction gear.

(3) Generator and excitation system.

(4) AC auxiliary power system including switchgear and motor controls.

(5) DC power system including battery, charger, and inverter if required.

(6) External heat rejection equipment if required.

(7) All mechanical and electrical controls.

(8) Diesel engine or electric motor starting system.

(9) Unit fuel skid (may be purchased separately if desired).

(10) Intake and exhaust ducts.

(11) Intake air filters.

(12) Acoustical treatment for intake and exhaust ducts and for machinery.

(13) Weatherproof housing option with appropriate lighting, heating, ventilating, air conditioning and fire protection systems.