LARGE STEAM TURBINE LOSS EXPOSURE

INTRODUCTION

Steam turbines, particularly those larger than 1000 hp (750 kW), frequently present significant loss exposure in three ways:

- Loss of the machine itself, including machine repair and replacement costs and the business interruption or extra expense associated with the loss of the electrical or mechanical output.
- Loss of production in the overall facility because of loss of an auxiliary function performed by the machine or the systems that directly serve the machine.
- Loss of use of the machine because of auxiliary equipment failure or the loss of an associated system.

To assist in loss exposure analysis, this section describes possible areas of dependence between:

- Large steam turbines and their auxiliary equipment (together referred to as steam turbine power plants) and
- Steam turbine power plants and the overall facility.

Steam turbine loss prevention is discussed in greater detail in PRC.6.1.1.0.1. Specific steam turbine loss prevention concerns are discussed in other sections in the PRC.6 series. The fire protection recommendations in PRC.17.12.1 apply to all steam turbine power plants. Those power plants which involve process materials have additional requirements. Business interruption and extra expense associated with the turbine power output depends upon the specific application.

Pre-emergency planning for a power plant having more than one product must consider the loss consequences for all the products. Loss of electricity production may cause a loss of revenue; loss of reduced pressure steam supply could completely shut down the facility. While using a steam pressure reducing valve would be inefficient and expensive, it would probably be better than having a prolonged outage or attempting to rent and install backup boilers.

Facilities which use a turbine plant to dispose of waste heat in the form of steam should find another way to dispose of steam so that a turbine failure will not shut down the entire facility.

STEAM TURBINE POWER PLANTS

A steam turbine power plant uses large turbine(s) to generate mechanical or electrical power. Steam turbine power plants in most industrial facilities often drive generators to produce electricity, however, some drive other large and fairly constant loads, such as blast furnace air compressors. Power plant operation is often part of the facility operation in other ways. These include using or supplying process steam or other process materials.

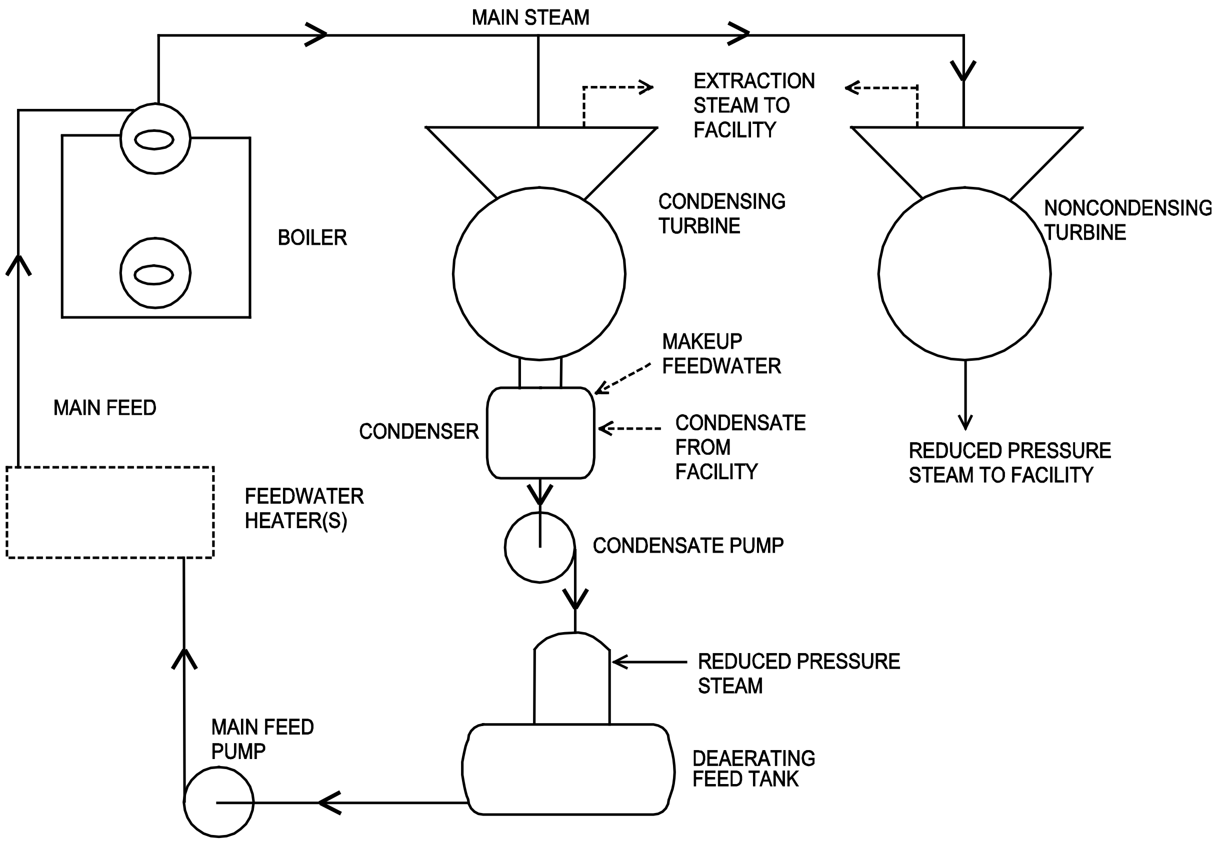

Figure 1. Steam Turbine Power Plant Schematic.

The steam-producing source is usually one or more of the following:

- Fuel-fired boiler(s)
- Boiler(s) fired with process-derived fuel (refinery or coke oven gases, spent pulping liquor, bark, spent solvents, etc.)
- Process waste heat steam generators
- Gas turbine heat recovery steam generators

Most industrial turbine power plants cogenerate. That is, in addition to providing the turbine output, they produce a product, such as reduced pressure steam, or perform a service, such as buffering a variable process steam or gas supply. In addition, some power plants perform processing functions. Examples include power plants with recovery boilers and power plants at refuse burning facilities. In many cases, these plants are functionally identical to an electric utility generating station except for the specialized nature of the boiler. In most electric utility generating stations, the power plant is the facility. Its sole purpose is to drive the generator(s) that produce electric power.

Plant operation is cyclic. The operating fluid (water/steam) is recycled as much as possible for purity and chemical control. Operation is also cyclic in the thermodynamic sense. Figure 1 is a schematic of one arrangement for a steam turbine power plant that provides mechanical or electrical power and reduced-pressure steam to a facility. This particular steam cycle is called a topping cycle because the steam cycle passes heat to a lower temperature and pressure system at the “bottom” of the cycle.

POWER PLANT EQUIPMENT

Steam Turbines

Energy from steam is converted to mechanical energy in the turbine(s). Turbines for most industrial facilities are single-casing machines directly coupled to the driven machine(s). Many industrial turbines use superheated steam. Reheat is seldom used.

Turbines for electric utility generating service are usually three-casing machines having high pressure (HP), intermediate pressure (IP) and low pressure (LP) sections. The HP turbine receives “main steam” from the boiler superheater outlet. In most cases, the exhaust from the HP turbine is conducted by the “cold reheat” piping to a section of the boiler called the reheat superheater or reheater. The steam flows through the “hot reheat” piping to the IP turbine from which it exhausts to the LP turbine.

All turbines have drains at various locations to remove moisture. The energy of the hot water and steam from the drains may be recovered in feedwater heaters or process heat exchangers. Removing the moisture from the turbine minimizes blade erosion.

Extraction Steam

Most large turbines are designed to exhaust significant amounts of steam from one or more interstage extraction points. This allows the turbines to supply steam for plant loads, such as pumps or feedwater heaters, or to operate as “swing producers” for reduced pressure steam systems. The turbine acts as an efficient reducing valve. The turbine throttle controls the steam flow to the system, and the turbine uses the energy associated with the pressure reduction.

If extraction demand increases, more steam leaves the turbine before flowing through all the blading. To maintain turbine power output, the throttle admits more steam to flow through the higher turbine stages and compensates for the loss of flow through the lower stages. If extraction steam demand drops, more steam flows through the whole turbine, and the throttle admits less steam. If other sources of reduced pressure steam exist, the system may be designed to allow reverse extraction flow. If this happens, more steam is supplied to the lower turbine stages, and less steam is required at the throttle for a given load.

Extraction control is an important part of turbine protection. For two-way flow systems, limiting the reverse extraction flow may be necessary to avoid losing turbine speed control. Systems not designed for two-way flow require nonreturn valves. All extraction turbines require positive shutoff of flow from the extraction line to the turbine if the turbine is tripped.

Some facilities have pressure reducing valves that can supply reduced pressure steam systems if the turbine is out of service. This is an inefficient operation that does not replace the turbine power output. In some facilities, however, such a valve may be necessary as a viable way of preventing a facility shutdown because of insufficient reduced pressure steam.

Condensers

After the usable energy has been removed from the steam, it is condensed. Some turbines, known as condensing turbines, exhaust directly to a condenser. The condensate is recycled. Other turbines, known as noncondensing or backpressure turbines, exhaust steam to loads elsewhere in the plant or facility. Steam from extraction turbines also may serve such loads. Whether or not condensate eventually returns to the system depends upon the nature of the loads. If there is any danger of condensate contamination, the condensate should be dumped.

Condensing steam in a condenser wastes considerable “latent heat” that was added in the boiler to convert water to steam. The effort to use the latent heat motivates cogeneration schemes which use noncondensing turbines. Turbine exhaust steam is condensed in district heating systems or process heat exchangers, possibly after driving smaller turbines.

Condensers require a large volume of cooling water. Most plants use a circulating water system cooled by cooling towers. Plants located near a suitable lake or stream may use water from the natural source to cool the condenser. The water is returned to its source after one pass through the condenser. Most condenser cooling water systems require chemical treatment to inhibit corrosion and control biological fouling. All systems are subject to various algae and slimes. Systems using natural sources may be subject to barnacles, zebra mussels and other pests.

Most condensers are tube-and-shell type surface condensers. Turbine exhaust steam passes through an exhaust trunk and is directed by internal baffles to contact the tubes. The tubes are cooled by water from the cooling water system flowing through them. The resulting condensate collects in the bottom portion of the condenser, known as the hotwell.

Because condensers operate at a vacuum, they are convenient for adding makeup water and most treatment chemicals to the system. Condensers may also receive hot water or steam from various low point or condensate drains in the turbine and piping systems. In some plants, especially those with once-through boilers, condensers may receive steam dumped directly from the boiler during startup. Condensers in combined-cycle plants may be designed to receive all the steam from one or more of the heat recovery steam generators for startup and shutdown, or they may be designed to allow emergency gas turbine operation without the steam turbine(s).

A few barometric and jet condensers may still be in service, usually in older industrial plants. These condensers are direct contact heat exchangers that use the turbine exhaust and a pure-water coolant.

Condensate and makeup feedwater may pass through various heat exchangers and treatment devices. The makeup water will require chemical treatment before it is introduced to the system. Although naturally-occurring “soft water” is suitable for most heating boilers, power boilers require extremely pure water. Even very small amounts of impurities can produce internal boiler deposits that may cause boiler damage and formation of particulate materials that may damage the turbine. Although condensate is almost pure, the extreme demands of high pressure and temperature service may require further treatment. This treatment is often called “condensate polishing.”

Deaerating Feed Tanks

All condensate and makeup feedwater is passed through the deaerating feed tank (DFT). The DFT has two sections, the preheater in the upper section and storage in the lower section. DFT's usually operate between 15 and 50 psi (1 and 3.45 bar). The preheater atomizes the incoming condensate and mixes it with low pressure steam from drains and exhaust steam from auxiliary equipment. If the steam and water temperatures, pressures and flows are properly balanced, the steam will condense, rapidly heat the water nearly to its saturation temperature at the tank operating pressure, and drive most air and noncondensable gases out of solution. Therefore, the DFT preheats and deaerates the water and provides a surge volume for the boiler feed system. The DFT is also convenient for adding oxygen-control chemicals, if necessary.

Although they are relatively simple devices, DFT's are required for the safe operation of power boilers. They are almost never duplicated or spared. Therefore, the plant and possibly the entire facility must be shut down if the DFT is out of service for any reason.

The main feed pumps transfer water from the DFT to the boiler(s). With the exception of the main turbine(s), these pumps are usually the largest mechanical equipment in the plant. At least two full capacity pumps with independent power sources are provided. Usually, at least one pump is driven by a noncondensing turbine, whose exhaust steam supplies the DFT.

The feedwater, now treated, preheated and pressurized, may pass through the high pressure feedwater heater(s). These are used when exhaust steam or condensate drain streams are available that are too hot for efficient use at low water pressures. The feedwater, controlled by a boiler level control regulating valve for each boiler, is then fed to the boiler(s).

Boilers produce steam by transferring heat from fuel combustion or a waste heat stream. Power boilers and their maintenance requirements are further discussed in PRC.7.1.0.3 and PRC.7.1.1.0.

COMBINED CYCLE POWER PLANTS

A gas turbine-combined cycle power plant has one or more gas turbine-driven generators or other machines. The gas turbine exhaust is directed to the heat recovery steam generator(s), which produces steam to drive a steam turbine. Although some combined-cycle plants incorporate supplementary firing of the waste heat boilers and possibly a separate fuel-fired auxiliary boiler, the gas turbine exhaust is the major source of heat. Figure 2 illustrates a steam cycle called, in this case, a bottoming cycle, because the steam receives heat from a higher-temperature process at the “top” of the overall cycle.

PLANT OPERATIONS

Power plant operations usually emphasize the following:

- Converting the fuel supply or waste energy source into steam of suitable temperature, pressure and purity.
- Using the steam to produce the required energy output(s).
- Balancing plant operation with all the process and power demands.

Using the most economical fuel mix is important for plants with available options. Selecting the most efficient combination of steam and gas turbines that will provide the needed output is important for combined-cycle plants. Reliably disposing of the fuel at the desired rate is important for waste-to-energy or resource recovery plants.

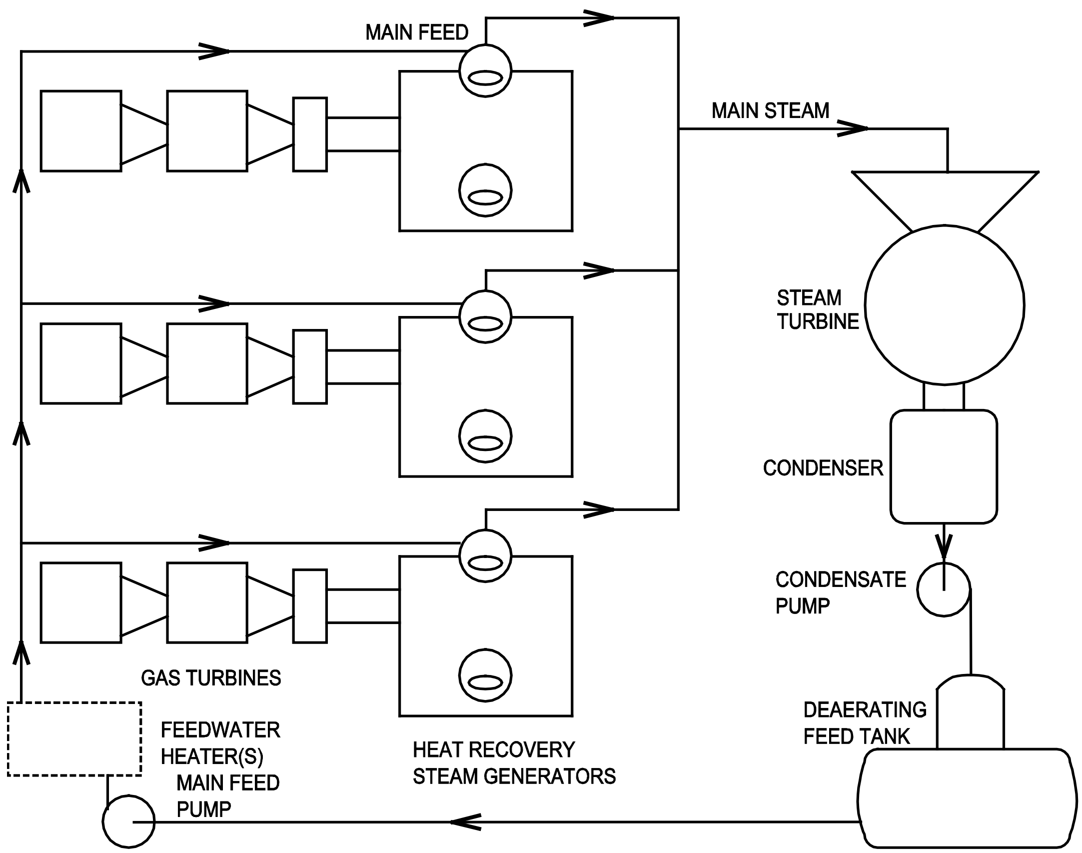

Figure 2. Gas Turbine Combined Cycle Power Plant Schematic.