STEAM TURBINE MECHANICAL PROTECTION

INTRODUCTION

This section discusses several conditions potentially damaging to steam turbines. These include:

- **Overspeed** - This is the most serious mechanical hazard of turbine operation. A slight overspeed can stress the rotating parts sufficiently to distort them. A more serious overspeed can cause the blade ends to rub against the casing. A severe overspeed may break the blades free of the wheel or may rupture the wheel. Resulting blade or wheel fragments can penetrate the casing.
- **Overpressure** - While some turbine casings are designed to contain the maximum pressure of the steam source to which they are connected, most are not. Therefore, protection against overstress or rupture because of overpressure is necessary.
- **Excess vibration** - Mechanical vibration is present in any operating machine. The nature of the vibration depends upon many factors related to machine condition.
- **Rotor axial position out of limit** - The equipment used to monitor vibration may also be used to measure rotor axial position. Rotor axial position is a critical parameter to control, because an out-of-specification reading indicates thrust bearing failure. Thrust bearing failure is followed almost immediately by catastrophic machine failure.
- **Rotor instability** - This is most frequently detected and diagnosed through vibration analysis. Uncorrected instability problems can result in rough operation, nuisance shutdowns and catastrophic failure.

PRC.6.1.1.0.1 describes steam turbine construction and component parts.

POSITION

The following recommendations apply to mechanical protection for steam turbines:

- Provide all turbines with at least two independent overspeed protection devices. The primary protective device should be an overspeed trip that may be combined with the governor. For some applications an independent speed-limiting governor may be substituted.
- Provide backup overspeed protection by an independent mechanical or electronic tripping device that responds solely to turbine rotor speed.
- Examine all possible steam sources to turbine inlet, extraction, extraction and exhaust openings to identify any path which could allow uncontrolled steam admission under any circumstances. Install intercept valves where necessary.

- Provide two overpressure protective devices for turbine casings not designed for the maximum steam supply pressure. One device should be a full-capacity safety valve or rupture disk.
- Provide continuous vibration monitoring for all the following. Also provide an alarm for high vibration and an alarm with an automatic shutdown for rotor axial position out of limit. Automatic shutdown for high vibration is strongly recommended.
    - Critical turbines - turbines driving machines whose continued service is necessary for the safe operation of the process or facility.
    - Turbines rated at 10,000 hp (7460 kW) or more
    - Turbines rated at 10,000 rpm (167 Hz) or more
- Monitor and protect, as recommended previously, all turbines driving machines for which any of the following apply:
    - The daily production of the facility depends on the machine.
    - The machine is rated at 1000 hp (746 kW) or higher.
    - The machine's failure could release a hazardous or flammable substance.

Until continuous vibration monitoring equipment is installed on any such turbine or machine, use portable equipment to take and record vibration readings at least weekly.

- Monitor the vibration of turbines rated at 100 hp (75 kW) or more at least monthly. Monitor all other turbines at least quarterly.
- Annually, connect each turbine rated at 500 hp (373 kW) or more to a vibration analyzer and record a complete vibration signature.

Vibration problems which cannot be corrected by balancing, alignment or correction of faults, particularly those problems which involve significant vibration at any frequency below running speed, may be due to rotor instability. Such problems should be resolved using rotordynamic analysis and making any necessary adjustments of rotor or bearing parameters.

Maintenance and testing of all protective devices must be included in a managed maintenance program. Minimum maintenance requirements include:

- Annually testing turbine overspeed protection by overspeeding the turbine, keeping the machine speed under control at all times. Uncouple the driven equipment if necessary. Allow all valve(s) to trip. For machines that absolutely cannot be removed from service, use stem travel limiting devices. These devices permit partially verifying valve operability without shutting down the machine.
- Quarterly performing tests of tripping devices. Where possible, conduct the test by simulating overspeed using an artificially produced overspeed signal input to the protection system.
- Quarterly performing tests of speed-limiting governors.
- Weekly exercising all block, throttle, extraction and intercept valves associated with turbine protective trip shutdowns.
- Maintaining overpressure protective devices.
- Recalibrating rotor axial position whenever work is done on the thrust bearing or any other component that could affect the rotor axial position.
- Monthly testing and annually calibrating all other protective devices in accordance with the manufacturer's recommendations.

The overspeed trip and the rotor axial position trip are critical protection tests. The associated unit must not be operated if either system is out of service. Therefore, redundant overspeed trip and rotor axial position trip systems should be provided for important machines.

DISCUSSION

Whether a turbine is provided with a preliminary overspeed trip versus a speed limiting governor as a means of overspeed protection depends upon the nature of the connected load. However, overspeed trips are preferred in all cases. They are required for turbines driving devices which can shed load quickly. For example, generators can be unloaded quickly by tripping the output breaker or exciter field breaker.

Speed-limiting governors may be used for turbines driving loads which cannot be quickly unloaded. For example, most pumps are difficult to quickly unload, unless they run dry. Even when such loads are involved, speed-limiting governors should only be used on turbines whose continued operation, even with the primary speed control out of service, is essential for the safety of the facility.

Steam turbines are occasionally destroyed by overspeed conditions resulting from reverse flow of steam in extraction lines or by steam systems depressurizing through the turbine. A careful analysis is necessary to ensure that steam supply from all sources is controlled under all conditions. Intercept valves are often required.

Trip throttle, extraction and intercept valves are all subject to accumulated deposits on the stem or to other conditions which could interfere with their function. If these valves fail to close fully within the proper time interval after a turbine trip, the turbine will overspeed. A maintenance program that includes frequently exercising and regularly testing valves will minimize valve failure.

Valves are exercised by moving them. Most valves can be exercised by partially closing and re-opening them without interfering with the turbine operation. Valves are tested by actuating the trip mechanism and witnessing proper operation. Therefore, valve tests require at least a short turbine outage. When a turbine outage cannot be tolerated, the stem travel limiting devices or “gags” previously described can be used for a partial test.

Since turbine casings are not normally able to withstand the connected steam supply pressure, they must be protected against overpressure. Condensing machines are often protected by an input to the trip valve that responds to condenser overpressure. Backup or alternate overpressure protection may be provided by a relief valve or rupture disk installed on the casing or condenser.

Sentinel valves are sometimes used on older units as alarm devices. A sentinel valve is a relief valve which is too small to actually relieve significant overpressure. Its operation is intended to warn the staff of an unsafe condition.

Noncondensing machines exhaust to system(s) which will normally be protected from overpressure; however, their casings may be subject to overpressure if they are isolated from the exhaust or extraction systems. Therefore, spring-loaded nonreturn or combined exhaust relief valves are often used instead of isolation valves. If a turbine casing which cannot withstand the steam supply pressure has an exhaust valve that shuts tightly, the casing requires a relief valve. If no relief valve is provided, the exhaust valve must be chained and locked open any time steam is available in the plant. If the exhaust valve must be closed for maintenance, the steam supply line to the turbine should be disconnected.

Overpressure protection on extraction lines is normally provided by the downstream system.

Rotor instability is associated with the critical speed(s). Any mass has a characteristic or resonant frequency. It will vibrate at that frequency when struck with a hammer. A speed corresponding to a resonant frequency is called a critical speed. A given rotor may have more than one critical speed; however, the speed corresponding to the main resonance, or “first critical” is usually the most troublesome. Integer multiples of that speed may also be troublesome.

Manufacturers take great pains to keep operating speeds away from critical speeds; however, operational changes or turbine modifications may nullify the manufacturer’s efforts. Also, operating procedures should be designed to provide fast acceleration through critical speeds below the operating speed. Operating a machine in any manner that produces a critical vibration frequency may cause unstable vibration at destructive levels.

Instability problems are usually characterized by vibration peaks at frequencies less than running speed. While such peaks are not necessarily evidence of instability, they indicate that the machine requires attention. Correction of instability problems may involve action such as the following:

- Modifying bearing stiffness, by:
  - Changing bearing type, e.g., journal to rolling element or tilting-pad
  - Changing clearances in journal bearings
  - Adjusting preload in tilting-pad bearings
  - Changing lubricant properties
- Changing bearing locations
- Modifying rotor stiffness or mass distribution

Many of these actions may be included in machine modifications undertaken for other reasons. A complete rotordynamic analysis is required before any such modification is executed.