MECHANICAL EQUIPMENT DESIGN AND INSTALLATION

INTRODUCTION

If facility owners and managers consider loss prevention and control when they design, install and test mechanical equipment, they will reduce the facility's loss exposure and they will:

- Make the completed work more reliable.
- Have more easily and effectively maintainable equipment.
- Minimize time and material during construction and operation.
- Maximize chances for trouble-free startups.

This section describes loss control principles to use while designing, installing or relocating mechanical equipment such as turbines, compressors, pumps, gear sets and mills. Fire and explosion protection and extra safeguards for certain types of equipment are covered in other Property Risk Consulting Guidelines. Section 5 of *OVERVIEW* discusses loss control for the overall construction project.

Facility management and AXA XL Risk Consulting should discuss projects that involve new equipment while the projects are being planned. The designer, the equipment manufacturer and installer, facility management, and insurer must all work together to minimize the potential for equipment damage or failure during installation, startup, testing or subsequent operation. Before work begins, management should provide AXA XL Risk Consulting with a project schedule so that a consultant can plan to witness key activities, such as casing closures, and performance and protective equipment tests. If the schedule changes, AXA XL Risk Consulting should be informed.

POSITION

Perform a preliminary hazard analysis as soon as practical, and use it to eliminate potential hazards when possible. (See Section 13 of *Overview*) Management can often reduce the required amount of loss prevention equipment by making relatively minor adjustments. Also, a facility can most economically incorporate protective devices when they are included in the initial specifications.

Design for reliability and maintainability. The pressure to minimize initial cost when buying equipment is intense, however, small initial investments in these areas provide substantial returns over the life of the equipment by reducing the number of breakdowns, the required length of maintenance outages, and the overall cost of maintenance and repairs. A variety of conflicting goals must be considered. For example:

- Installing single large machines or units may be economical, but two or more smaller machines or units may be more reliable and easier to maintain. Each smaller machine may also have less direct damage and business interruption loss potential.
- Installing fewer valves in a system may reduce its cost and eliminate potential leakage sites, but having too few valves can make the system less flexible and can make maintenance more dangerous and expensive.
- Some types of equipment, such as gas turbines and dynamic compressors, operate most efficiently in conditions that leave very little design margin, but the safety devices needed to operate this way may be sensitive enough to shut the machine down when it is not truly in danger.

Include document requirements in the contracts for the entire installation and for each piece of equipment. The following documents and their time of delivery should be specified by any contract for new machinery. The same documents should also be obtained for a used machine.

- Assembly drawings and instructions for initial assembly and subsequent overhaul. These must include:
  - Weights, weight distributions and dimensions of all major parts and subassemblies.
  - Rigging instructions, including tackle needed, points of attachment and any special precautions or instructions.
  - Specified piping load limitations for all connections.
- Foundation drawings and specifications. These must include any channels, conduits or connections to be located in the foundation. The drawings must also show the location and other requirements for bedplates, anchor bolts and grouting.
- Structural drawings of the machinery room(s). These must show the location and load-bearing ability of areas that may be used to store major components temporarily during overhaul. Room for both an incoming replacement part and the part coming out of service may be useful.
- Machinery manuals, including complete equipment drawings, descriptions and specifications, and instructions for installing, dismantling and reassembling, commissioning, operating and maintaining the equipment.
- Schematic drawings, equipment drawings and specifications, instruction manuals, commissioning requirements and maintenance schedules for all support systems.
- Benchmark inspection data, including “as-built” internal clearances, and all data from bench tests, including balancing runs, alignment tests, vibration signatures and performance curves.

Establish preventive maintenance (see Section 3 of *OVERVIEW*) and operator training programs before equipment startup (see Section 4 of *OVERVIEW*).

Plan for future removal or repair of complete machines or their major pieces. Provide adequate overhead cranes or ensure sufficient head space and accessibility for mobile lifting equipment. Provide suitable and secure laydown areas.

Equipment layout can affect its maintainability. Space units to allow piping arrangements that permit thermal movement with as few expansion joints as possible. Place piping and equipment so that equipment access is not restricted. Review piping and piping support design calculations to ensure that the loadings at connection points will not exceed the loadings allowed by the manufacturer.

Do not receive weather-sensitive equipment before it can be protected from the elements. This applies to projects requiring building or shelter construction. Plan temporary shelter when early receipt cannot be avoided.

Maintain strict quality controls during equipment construction and installation. Tool control is frequently overlooked. Strictly limit access to open machinery casings and account for all tools and parts used so that nothing is left in the machine by mistake.

Control the activities of contractor personnel. Doing so may be difficult when structures are being built or modified and machines are being installed. Nevertheless, contractors must comply with management's loss prevention and control programs. Use a contract inspection and auditing service, if necessary, to ensure compliance with specifications and applicable management loss control programs. Refer to *OVERVIEW* Section 5, Appendix B.

Clearly identify in writing the test criteria and the time and conditions of acceptance for all machinery. Performance tests, inspection witness points, and performance benchmarks should never be waived unless all concerned parties, including the insurance carrier, provide a written agreement. All startup and acceptance procedures specified by the manufacturer should be completed before any equipment is accepted for service.

Complete all of the following that apply before starting up any large rotating machine:

- Inspect the machine thoroughly and review the fabrication and construction records to ensure that all preliminary activities, such as leveling, cold alignment and balancing are complete.
- Install and test all protective devices and systems to whatever degree possible without operating the machine.
- Inspect, flush, reinspect and commission the supply and support systems, such as steam and lubricating oil, before operating the machine.
- Install steam strainers, lubricating oil system fabric filters and any other precautionary devices suggested by the manufacturer or good engineering practice.
- Turn the machine over by hand or use a jacking device before applying power to ensure that gross binding, interference or misalignment are not present.
- Provide sufficient vibration recording and analysis equipment to detect possible flaws and to obtain baseline vibration signatures for maintenance records. The pre-production testing period may be the best time during the life of the machine to collect data under a variety of operating conditions. See PRC.6.0.8.1.1 for additional vibration monitoring recommendations.

Be sure to restore normal conditions before attempting unrestricted operation. Most initial testing of equipment involves abnormal configurations. Examples include:

- Safety valves removed or gagged and piping hanger travel stops installed for pressure equipment hydrostatic tests.
- Flanges blanked and valves removed for fluid system flushing.
- Fine-mesh steam strainers and oil system filters installed for turbine pre-acceptance testing.

Learn as much as possible about used equipment before deciding to purchase or use it. Proceed as follows:

- Arrange a performance test and have a qualified representative witness it on the buyer's behalf.
- Witness a complete overhaul, including nondestructive testing of critical areas.
- Test samples of materials taken from critical areas, such as gas turbine hot gas paths, or use on-site testing methods to ensure that the parts have not been overheated or otherwise damaged.
- Have a third-party inspection and evaluation performed. Use a neutral contractor who specializes in the type of equipment in question.

DISCUSSION

A preliminary hazard analysis may reveal new ways to design a safer and more reliable facility. For example, some compressor applications can be designed with magnetic bearings to eliminate the lubricating oil system and its hazards. Dry shaft seals may eliminate seal oil systems. Applying new technology requires caution, however, and eliminating one hazard may introduce another.

It may be difficult to get documentation for equipment once it has been accepted and paid for. Complete drawings must be delivered on time while the equipment is being planned, built and installed.

During planning, rough drawings are needed to evaluate the overall equipment layout in detail. Rough drawings of the equipment and facility structures permit:

- Arranging equipment for operating efficiency and service accessibility.
- Designing connecting piping and piping support systems.
- Planning the construction sequence.
- Planning safe and efficient rigging.

Once the equipment is installed, detail drawings and specifications are needed for maintenance and repair, to help determine if damaged parts are repairable or to permit the quickest possible manufacture of replacement parts. If the correct drawings are available, either the original manufacturer or another contractor can usually provide these services.