General Electric Advanced Technology Manual

Chapter 4.6

Air System Problems

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4.6 AIR SYSTEM PROBLEMS

Learning Objectives:

1. State two safety related functions performed by plant air systems.

2. List two sources of air system contamination.

3. List two causes (other than contamination) of air system failures.

4.6.1 Introduction

Many U.S. Boiling Water Reactor (BWR) plants rely upon air systems to actuate or control safety-related equipment during normal operation. However, at most BWRs, the air systems are not classified as safety systems. Plant safety analyses typically assume that nonsafety-related air systems become inoperable during abnormal transients and accidents, and that the air-operated equipment which is served fails in known, predictable modes. In addition, air-operated equipment which must function during transients or accidents are provided with a backup air (or nitrogen) supply in the form of safety grade accumulators to aid in continued system operation.

On December 3, 1986, 140,000 gallons of radioactive water drained from the spent fuel pool at Hatch 1 and 2 due to deflated pneumatic seals resulting from a mispositioned air line valve.

On December 24, 1986, Carolina Power and Light Company engineers discovered a potential for a common mode failure of all of the emergency diesel generators at Brunswick 1 and 2. They found that HVAC supply dampers for the diesel generator building would fail closed, due to the loss of air, during a loss of offsite power event. The dampers failing closed, reduces the air flow and causes the diesel generator control system to heat up. It was calculated that within one hour the air temperature in the diesel rooms would exceed the environmental qualification temperature of the control system.

On November 25, 1989, Cooper Nuclear Station experienced a closure of the main steam isolation valves which occurred as a result of a total loss of instrument air pressure. An instrument air dryer prefilter pipe ruptured causing low instrument air pressure, which in turn caused the outboard main steam isolation valves to drift closed and some of the control rods to drift into the core.

Consider the following effects the air system has on the Control Rod Drive System. If instrument air is lost, the control rods drift into the core as a result of the scram outlet valves failing open. Control rod drift can cause peaking problems and possible fuel failure even though the rods are moving in the safe direction. Also, oil contamination of the air system has prevented control rods from scramming by preventing the scram solenoid valves from functioning correctly.

4.6.2 Typical Instrument Air System

A simplified diagram of a typical air system is shown in figure 4.6-1. The air system begins with air compressors that take suction from the room in which they are located, raise the pressure of the air to approximately 100 psi, and discharge the air to storage receivers. There are two or more 100% capacity air compressors which are powered from nonvital 480 Vac electrical busses. The compressors are controlled by pressure switches located on the instrument air receivers. During normal operation, one of the air compressors is in service with the redundant compressor in standby. The running compressor loads (compresses air) when the receiver pressure drops below a predetermined value (approximately 95 psi) and unloads when the receiver pressure reaches its normal operating pressure. If instrument air pressure decreases below 95 psi, the standby compressor(s) is/are started. Typically the standby compressor starts between 70 and 80 psi.

The receivers supply the air to instrument and service air headers. Instrument air passes through air dryers and filters prior to supplying various plant components. Dryers remove moisture from the air supply and filters remove foreign particles. The dryers and filters are necessary components because of the materials and small clearances of the internal moving parts of pneumatic equipment. Clean, dry, and oil free air is required for reliable trouble free operation. The air from the conditioning equipment is distributed throughout the instrument air system.

The instrument air system is subdivided by building location, i.e. turbine building, auxiliary building, fuel building, and containment building. The turbine building instrument air supplies components such as the hotwell level control valves, turbine extraction steam and heater drain system, various valve actuators that control cooling water flow to generator hydrogen and oil systems, condensate system demineralizer valves, building heating and air conditioning, and the steam sealing system for the turbines. The reactor building instrument air loads include the outboard main steam isolation valves, control rod drive hydraulic system and various other components. The drywell air supply is use for the inboard main steam isolation valves, and equipment and floor drain isolation valves. The instrument air supply to the drywell is equipped with an automatic isolation valve that closes on a containment isolation signal. Of course, when an isolation occurs, the air supply header inside the containment will depressurize.

The service air system is used to supply air to components such as the demineralizer backwash and precoat system and hose stations for pneumatic tools. Many boiling water reactor plants utilize separate service air systems to meet this need.

4.6.3 Instrument Air System Problem Areas

4.6.3.1 Water Contamination

Although the instrument air dryers are designed to remove water from the air system, moisture is one of the most frequently observed contaminants in the air system. Water droplets entrained in the air can initiate the formation of rust or other corrosion products which block internal passageways of electric to pneumatic converters resulting in sticking and/or binding of moving parts. In addition, water droplets can obstruct the discharge ports on solenoid air pilot valves (CRD hydraulic system), thus reducing their ability to function properly. Furthermore, moisture can cause corrosion of air system internal surfaces as well as the internal surfaces of equipment connected to the air system. Rust and other oxides have caused the exit orifices of pilot valves and other equipment to be totally blocked, resulting in degraded equipment operation or its complete loss. Additionally, rust particles on the inside of the piping/equipment have the potential to be dislodged during severe vibrations which could lead to simultaneous common mode failures of many downstream components.

4.6.3.2 Particulates

Particulate matter has prevented air from venting through discharge orifices of solenoid air pilot valves and valve operators. A clogged orifice changes the bleeddown rate, which affects the valve opening or closing times and could result in complete failure. Additionally, small particles have prevented electrical to pneumatic converters from functioning properly. Air dryer desiccant has been found in air pilot valve seals, preventing the valve from operating correctly.

4.6.3.3 Hydrocarbons

Hydrocarbon contamination of air systems can cause sluggish valve operations as well as complete loss of valve motion. Compressor oil has been observed to leave a gummy-like residue on valve internal components. This causes the valves to operate sluggishly, erratically, or completely fail to operate. Hydrocarbons have also caused valve seals to become brittle and stick to mating surfaces, thereby preventing valve motion. In some cases, parts of deteriorated seals were found in air discharge orifices of valves thus preventing the valve from operating correctly.

4.6.4 Component Failures

Numerous components make up the plant service and instrument air system. The following paragraphs describe a few common failures and possible ramifications.

4.6.4.1 Air Compressors

In most plants, instrument air systems include redundant air compressors, but generally they are not designed as safety-grade or safety-related systems. As a result, a single failure in the electrical power system or the compressor cooling water supply can result in a complete loss of the air compressors. Because plants have redundant air compressors and automatic switching features, single random compressor failures usually do not result in a total loss of air. Most air system compressors are of the oil-less type. However, some plants do use compressors that require oil as a lubricant, and have experienced oil contamination of their air systems. Similarly, the temporary use of oil lubricated backup or emergency compressors without provisions for adequate filtration and drying can result in significant air system degradation.

4.6.4.2 Distribution System

Since most instrument air systems are not designated safety-grade, or safety-related, they are vulnerable to a single distribution system failure. For example, a single branch line or distribution header break could causing partial or complete depressurization of the air system.

4.6.4.3 Dryers and Filters

Single failures in the instrument air filtration or drying equipment can cause widespread air system contamination, resulting in common failures of safety-related equipment. For example, a plugged or broken air filter, a malfunctioning desiccant tower heater timer or plugged refrigerant dryer drain can cause desiccant, dirt or water to enter the air lines. As discussed in section 4.6.3.1, such contaminants could result in significant degradation, or even failure, of important air system components.

4.6.5 Regulatory Issues

4.6.5.1 Safety Issue Definition

Compressed air degradation has the potential to affect multiple trains of safety-related equipment. Air system degradation includes (1) gradual loss of air pressure and (2) air under pressurization or over pressurization outside the design operating pressure range of the associated equipment dependent on the air system. It is not clear what failure modes could result from these types of events. ACRS feels that although unresolved safety issue A-47 addressed sudden complete loss of air pressure, it did not adequately investigate the effects of air system degradation on safety-related equipment.

4.6.5.2 Regulation and Guidance

While no regulations specifically address degradation of instrument air systems, several general design criteria do provide requirements for safety-related structures, systems, and components. General design criterion (GDC) 1 states that structures, systems, and components important to safety must be designed, fabricated, and tested to quality standards commensurate with the importance of safety functions to be performed. GDC 5 requires that shared systems and components important to safety be capable of performing required safety functions.

Guidance provided in standard review plan (SRP) section 9.3.1 "Compressed Air Systems," states that all safety-related air-operated devices that require a source of air to perform safety-related functions be identified and reviewed. This requirement ensures that failure of an air system component or loss of the air source does not negate functioning of a safety-related system.

Guidance for testing of air systems is provided in Regulatory Guide 1.68.3, "Preoperational Operational Testing of Instrument and Control Air Systems". The guide requires tests to determine the response of air-operated or air-powered equipment to sudden and gradual pressure loss, through and including a complete loss of pressure. In addition, response of equipment to partial reductions in system pressure must be tested. Functional testing of instrument/control air systems important to safety should be performed to ensure that credible failures resulting in an increase in the supply pressure will not cause loss of operability. The system must also be able to meet the quality requirements of ANSI/ISA S7.4-1975, "Quality Standard for Instrument Air," with respect to the allowable amounts of oil, water, and particulate matter. If licensees of operating plants make modifications or repairs to their air systems, then their proposed restart testing program will be evaluated according to RG 1.68.3.

In 1988, the NRC issued Generic Letter 88-14, which requests that licensees perform a design and operations verification of their instrument air systems. The verification includes the following:

- Testing actual instrument air quality to ensure it is consistent with the manufacturer's recommendations for individual components served.
- Maintenance practices, emergency procedures, and training are adequate to ensure that safety-related equipment will function as intended on loss of instrument air.
- The design of the entire instrument air system including accumulators is in accordance with its intended function.

- Testing of air-operated safety-related components to verify that those components will perform as expected in accordance with all design basis events.

Generic Letter 88-14 does not address verification of the operation of safety-related component failure during gradual increasing or decreasing pressure.

4.6.5.3 NRC and Industry Programs

The NRC has issued several IE notices that address compressed air system-related failures that have occurred at several nuclear plants. IE Notice 81-38, "Potential Significant Equipment Failures Resulting From Contamination of Air-Operated Systems," reported the potential for air- operated systems to fail because of oil, water, desiccant, and rust contamination. IE Notice 82-25, "Failures of Hiller Actuators on Gradual Loss of Air Pressure," reported the failure of valves to move to a specified position on loss of air pressure. The actuators were depressurized gradually, rather than suddenly, resulting in the failure of the valves to move to their fail-safe position. IE Notice 88-24, "Failures of Air-Operated Valves Affecting Safety-Related Systems," reported failure of safety-related valves to assume their fail-safe positions upon deenergization of their respective solenoid valves. In this event, the maximum operating pressure differential for the valves was less than the operating pressure for the air system. In addition to the IE notices, the NRC created Generic Issue 43, “Reliability of Air Systems,” and assigned it a high priority for evaluation. In a 1989 letter from ACRS to the NRC, ACRS stated that in light of the requirements of Generic Letter 88-14, they did not consider the resolution of Generic issue 43 adequate. In response, the NRC recommended that air system degradation be addressed as a separate issue.

4.6.5.4 Operating Experience

In 1987, AEOD completed a comprehensive review and evaluation of the potential safety implications associated with air system problems. This report identified the following specific deficiencies:

- The air quality capability of the instrument air filters and dryers does not always match the design requirements of the equipment using the air.

- Maintenance of instrument air systems is not always performed in accordance with manufacturer's recommendations.

- The air quality is usually not periodically monitored.

- Plant personnel frequently do not understand the potential consequences of degraded air systems.

- Operators are not well trained to respond to losses of instrument air, and the EOPs for such events are frequently inadequate.

- At many plants the response of key equipment to a loss of instrument air has not been verified to be consistent with the FSAR.

- Safety-related backup accumulators do not necessarily undergo surveillance testing or monitoring to confirm their readiness.

- The size and the seismic capability of safety-related backup accumulators at several plants have been found to be inadequate.

Design deficiencies were identified as the root causes of most air system problems. With the introduction of Individual Plant Examinations (PRA) and accident management requirements by the commission, these deficiencies can be discovered and corrected.

Shortly after the PRA program (April 1988) was begun at Fermi 2, a question arose concerning the safety impact resulting from operating the non-interruptible air system cross connected (division 1 with division 2). An analysis of the effects on core damage frequency showed that the risk from scenarios involving a transient and a loss of air could be reduced by a factor of 2 if the non-interruptible air system was operated cross connected.

4.6.6 Summary and Conclusion

Losses of instrument air have occurred in the industry. Failure of equipment and systems due to air system degradation discussed above, have not been included in the plant safety analyses. Consequently, some plants with significant instrument air system degradation may be operating or may have operated with a much higher risk than previously estimated. Many plants do not have specific license requirements prohibiting operation with degraded air systems. Therefore, high confidence does not exist that all plants will voluntarily take corrective action to avoid plant operation with degraded air systems.

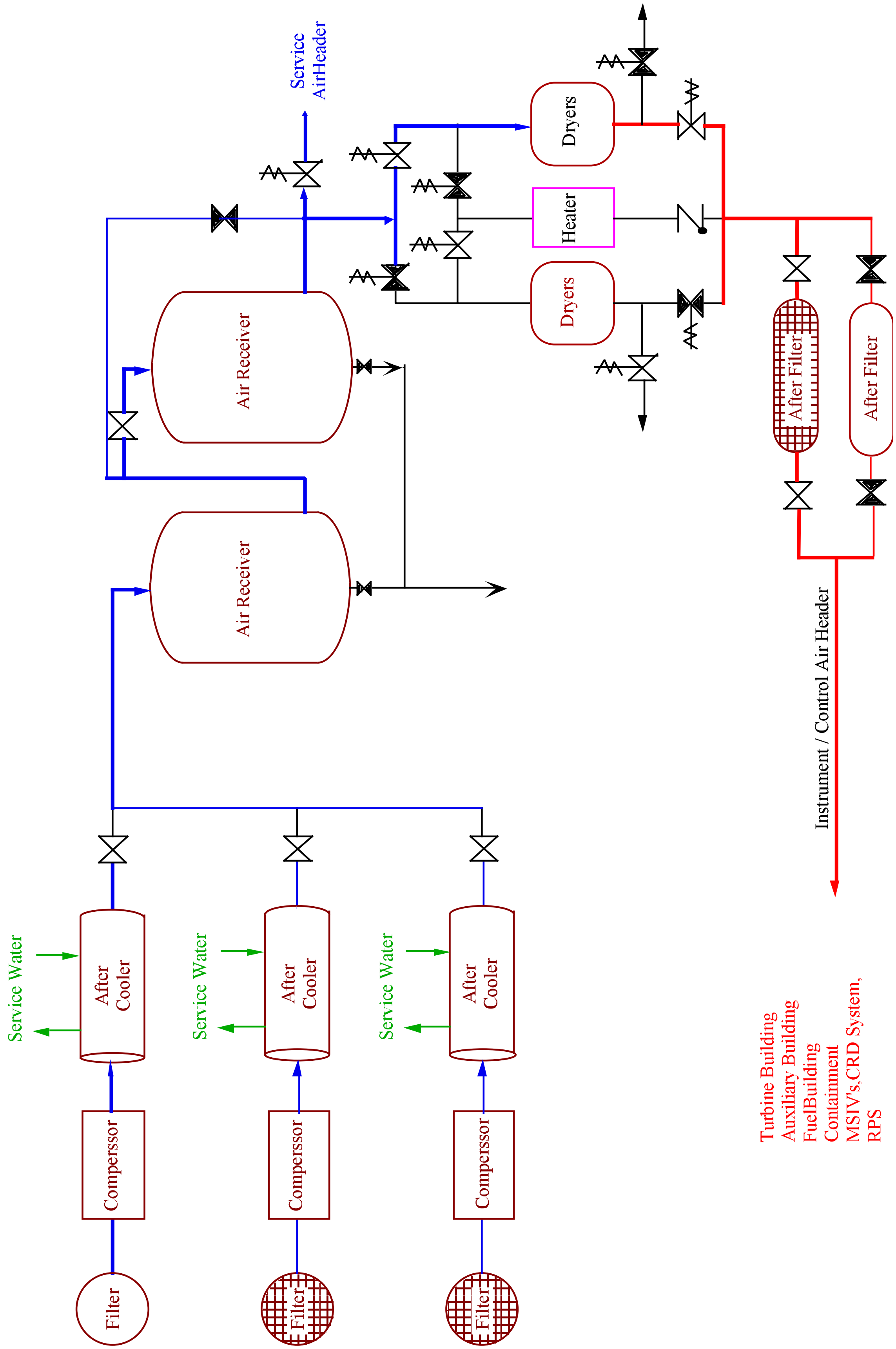

Figure 4.6-1 Typical Air System