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Time is critical when it comes to identifying degrading equipment performance.

Progress Energy's Harris Plant is a 950 MW(e) pressurized water nuclear reactor. In November 2003, operators conducting a surveillance test on a piece of the plant's emergency service water equipment noticed that the differential pressure (dP) was below the minimum required value. During the ensuing investigation, a review of past data showed that the dP had begun decreasing in August 2003—three months earlier—yet had gone undetected. As a result, the site management was interested in improving timeliness in identifying degrading equipment performance. The solution was to use statistical control charts.

Control Chart Rules

1. One data point is beyond the control limit(s).

2. 2 of 3 consecutive data points are within 2-3 sigma.

3. 6 or more points are increasing / decreasing.

4. 8 or more points are above or below the centerline.

Control charts are a statistical trending method used to determine when data variance, or a change in data, is abnormal. They have been used for many years in the manufacturing industry for product or process quality control, but personnel at Harris are now using the method to trend equipment performance and identify degradation in performance at an early stage.

Following the rules
Data varies for many reasons including the repeatability and reproducibility of instruments, differences in test conditions and dependence on other parameters (e.g. temperature).

Equipment performance trending requires an understanding of data variance and when it is due to an abnormal cause. An abnormal cause is a degrading condition in the equipment. For example, a worn bearing in a pump motor or a hardening diaphragm in an air-operated valve are degrading conditions. When these degrading conditions are detected early, they can be scheduled without a need for emergent corrective maintenance. A stable work schedule helps the maintenance organization effectively maintain plant equipment and ultimately results in a more reliable facility.

Control charts help you understand when an abnormal cause is present. When data is measured, it typically has a normal distribution, as shown in Fig. 1. A typical control chart is shown in Fig. 2. It consists of the normally distributed data plotted with time. The centerline (green line) is the mean of the data points and the upper and/or lower control limits (red lines) are typically three standard deviations from the mean. The control chart rules (see Sidebar ) are applied to the data trended on the control chart to determine when an abnormal cause may be present and require further investigation.

Proving effectiveness

The effectiveness of the control chart method was first realized through trending of reactor coolant system (RCS) leakage. The Plant Technical Specifications require periodic monitoring of the system leakage every 72 hours to ensure it does not exceed 1 gpm. To comply with this requirement, the leakage is calculated every 24 hours and trended. In the past, the leakage data was subjectively evaluated against past data. This frequently required re-performance of the surveillance to validate apparent increases in leakage when the data only changed due to normal statistical variance.

Fig. 3 illustrates the application of the control chart to the calculated leakage data. On February 7, 2005, the leakage began to increase. By February 12, the data violated control rules 1 and 3 (refer to Sidebar 1). When the data exceeded the upper control limit of 0.090 gpm, Harris personnel began the process of evaluat-ing several potential leakage paths. The systematic elimination of potential sources culminated in a plant walk-down. During the plant walk-down, a two-inch isolation valve was found with a packing leak. The RCS system uses borated water. The leaking valve shown in Fig. 4 shows the boron deposits on the valve and nearby equipment. The valve packing was tightened to eliminate the leak on March 18. The data then returned to normal. The leak was 0.08 gpm. This is equivalent to approximately one cup of water each minute, illustrating the sensitivity of this trend method.

Numerous other examples have also occurred that demonstrate the effectiveness of using control charts for trending of equipment performance. In the ASME Inservice Test Program

(IST), the condition of air-operated valves is monitored by trending the valve stroke time. The application of control charts has identified erratic performance of solenoid valves, hardening diaphragms and drifting air regulators. These issues were identified well in advance of exceeding an operational limit and permitted scheduling the maintenance rather than the organization responding to an emergent equipment failure.

The payoff

Implementing control charts for data trending not only improves timely identification of equipment degradation, it also standardizes the approach to data trending. Personnel typically will use everything from pencil and paper to computer software to trend data based on their years of experience and comfort with computers.

Common Errors in Data Trending

1. "Head in the Sand" Error – the data being trended indicates an abnormal cause is present, but it is not detected and acted upon.

2. "Wild Goose Chase" Error – the data routinely exceeds the statistical limits due to normal variance of the data and is acted upon with no abnormal cause present.

Control charts are a tool that can help them be proactive in monitoring equipment performance and avoid being reactive to equipment issues. They provide a sound basis for making decisions related to the taking of further action to understand the cause of adverse trend and avoid organizational vulnerability to the common data trending errors (refer to the Sidebar).

The initial reaction by personnel to using statistics can be negative. Many people believe they can subjectively identify abnormal trends in data based on their experience. In some cases this is true. However, experienced personnel are not always available due to vacation, sickness or organizational attrition. Their threshold for identifying and communicating degrading conditions can also vary. Controls charts provide the standard tool without a need for specific component experience to interpret them.

To be successful in implementing this change to your data trending standard, it is important to secure organizational buy-in from the top down. There are key elements to the implementation that are essential. They include:

1. Management Training – Ensure your management team understands the basic statistics involved with control charts. If they are interested in seeing the data trends, it helps them understand what changes in data are significant. It will also help in clarifying their expectations associated with the organization's response to the data when it violates the control rules.

2. Expected Response to Data – Establish with the management team what the organization's standard response should be to data that violates the control chart rules. This should be a graded approach based on the criticality of the equipment and establish the expected timeliness of reporting the issue and scheduling the maintenance.
3. Personnel Training – Ensure that the personnel developing the control charts understand the basic statistics involved and the standard approach when data violates the control chart rules. This should include a basic understanding of what can cause data variance and how the data is expected to change from the potential equipment failure modes/mechanisms.
4. Purchase a Software Tool – To minimize the work involved in the development of control charts, software should be provided to personnel. There are many software tools on the market, each with its pros and cons. Harris utilized a Microsoft EXCEL add-in that proved to be very effective since personnel were familiar with EXCEL.
5. Start Small – The organization can be overwhelmed if control charts are placed on every possible parameter. Understand what the critical equipment is in the plant and what the critical performance parameters are before getting started. Pilot the method on a limited set of equipment to work through the logistics involved with the implementation. Logistics include: how and to whom potential equipment issues are to be reported: how the identified issue should be prioritized in the work scheduling process, etc.
6. Understand the Data Pedigree – To get started, it is important to understand the pedigree of historical data used to create control charts. The data must be under statistical control to start. That means, if there were high or low values due to some equipment problem in the past, that data should be excluded or eliminated from the control chart. The data must also be independent or not subject to other influences (i.e. bearing temperatures that fluctuate with ambient temperature conditions). Additionally, if the equipment is subject to varying loads during operation, it may be necessary to establish consistent test conditions for collecting data.

Statistical control charts are a very effective method for monitoring equipment condition. It provides personnel a trending tool that is sensitive to changes in equipment performance, as well as a method that provides the earliest indication of a degrading equipment condition. Early indications of degrading performance can be investigated to determine the scope of required maintenance and the maintenance scheduled without a need for emergent work.

A stable work schedule has many benefits, including helping the maintenance organization effectively maintain plant equipment, resulting in a more reliable facility. It also improves the plant personnel's quality of life, with less call outs from emergent equipment failures.

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