AVAILABILITY— A TEAM EFFORT

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During the seventies, the electric utility industry came under criticism by the public it serves because of rate increases necessitated by rising fuel costs. Because of all the public criticism, individual state regulatory agencies have been closely scrutinizing the electric utilities to see that they are making every effort to keep their operating costs down. Recently, the Department of Energy (DOE) contracted with the National Regulatory Research Institute (NRRI) to study the industry and make recommendations for regulatory actions in order to promote cost effective power plant productivity improvements, and to prepare a reference document to assist in the evaluation of power plant productivitiy improvement programs. The NRRI established a Working Group on Power Plant Productivity, consisting of individuals from the NRRI itself, Federal agencies and some state regulatory agencies which have already established regulations on productivity.

The Working Group stated that power plant productivity improvements are primarily the responsibility of the utility industry. However, they believe that state regulators must be committed to ensuring the proper discharge of this responsibility. They define power plant productivity improvements as increasing the time a plant is available for operation and reducing the time a plant is not available at rated power. The Working Group recommends that regulatory agencies implement the following actions to promote power plant productivity improvements by the utility industry:

1. Acquire and support the development of power plant performance data and information systems.
2. Acquire the capability to perform independent in-house analysis of performance.
3. Direct the establishment of productivity improvement programs, including explicit performance objectives for existing and planned power plants.
4. Develop a system of performance assurance.
5. Establish a system of incentives, sanctions and/or penalties.
6. Participate in on-going efforts and initiate new actions to promote productivity improvements.

A few state regulatory agencies have started to implement some of these recommendations, and when all are implemented, the efforts of a number of individuals within each utility organization, from corporate officers to maintenance men and clerical help in the individual power plants, will be required to comply with them.

The Working Group found that no single index is sufficient to assess plant performance. Indices such as capacity factor, forced outage rates, equivalent availability and operating availability must all be evaluated in order to form any conclusions.

The definitions that the Working Group used for these indices differed somewhat from the Edison Electric Institute (EEI) definitions.

The Capacity Factor (CF) is a measure of the actual output (MWh) of a unit within a specified time period relative to its potential output.

$$CF = \frac{\text{Total Gross Generation in MWh}}{(PH)\ (MDC)} \times 100$$

Where: PH = Number of hours in the period of measurement

MDC = Maximum Dependable Capacity in MW

The Forced Outage Rate (FOR) is a measure of the full forced outage hours (FOH) relative to the total of the service hours (SH) and the full forced outage hours.

$$FOR = \frac{FOH}{SH + FOH} \times 100$$

The Equivalent Availability (EA) is a measure of the unit's true ability to produce power, since it takes into account partial outages.

$$EA = \frac{AH - (EFOH + ESOH)}{PH} \times 100$$

Where: AH = Service hours plus reserve shutdown hours.

$$EFOH = \frac{\text{Forced Partial Outage Hours x Size of Reduction in MW}}{MDC}$$

$$ESOH = \frac{\text{Scheduled Partial Outage Hours x Size of Reduction in MW}}{MDC}$$

The Operating Availability (OA) is the fraction of time that a unit is available for operation.

$$OA = \frac{AH}{PH} \times 100$$

Of these performance indices, the equivalent availability is probably the best single index of a unit's performance, but the one most commonly available in literature is the operating availability. The EEI had taken the operating availability of over 2,000 power generation units of various types and capacities and analyzed them for the period of 1967 to 1976. The average operating availability was determined for each of the various types of units, then it was determined for different capacity ranges, as shown in Tables 1 and 2.

AVERAGE OPERATING AVAILABILITY BY TYPE OF GENERATING UNIT

TYPES OF ELECTRIC GENERATION UNITS	OPERATING AVAILABILITY
Hydro	95.48%
Diesel	94.96%
Pumped Storage	86.54%
Jet Engine	86.45%
Gas Turbine	86.31%
Fossil (coal, oil and natural gas)	84.57%
Nuclear	72.74%

Table 1

AVERAGE OPERATING AVAILABILITY BY UNIT CAPACITY

CAPACITY RANGE	OPERATING AVAILABILITY
100-199 MW	86.8%
200-299 MW	85.2%
300-399 MW	80.1%
400-599 MW	77.9%
600-799 MW	73.5%
800 MW and above	74.0%

Table 2

From Table 1, it can be seen that the operating availability for fossil units ranks next to last with an average operating availability of 84.57%. This covers units fired by coal, oil and natural gas. Within this group, natural gas fired units have a better operating availability than oil fired units; and coal fired units usually have the worst operating availability of the group. The pumped storage, jet engine and gas turbine units are all grouped together with an operating availability of approximately 86.5%, and hydro and diesel units are around 95% available.

The average operating availability for all types of units grouped in different capacity ranges is given in Table 2. The data indicates that the operating availability decreases as the units get larger. In a June, 1978 report prepared by the Tennsessee Valley Authority (TVA) Power Production Division, it was shown that the historical availability of its nine largest units was 72.9%, which was lower than the industry average and significantly lower than the 87.2% availability of its 54 small units over a 16 year period.

These average operating availability figures are based on the total electric generating units including the steam generator, turbine-generator and the auxiliary plant equipment. Data available on the causes of forced outages indicates that the boiler and its immediate auxiliaries are responsible for about 50% of the outages, the turbine-generators for about 31% and the auxiliary plant equipment for about 19%. Since historically the boiler has been the major cause of forced outages, the boiler and its immediate auxiliaries should be number one on the priority list for power plant productivity improvements.

Where does one start when regulations are implemented which require the utility to start a power plant productivity improvement program? It is our belief that the regulatory requirements will only be met with a concerted team effort. The following steps need to be performed by the team to implement a productivity improvement program.

REVIEW OF PERFORMANCE RECORDS / DETERMINATION OF PAST PERFORMANCE

Historical operating records should be reviewed to determine if they are adequate to calculate the indices previously mentioned. If not, make the necessary changes in record keeping to record the pertinent data. Determine those indices for which adequate historical operating records are available, and compare them to published indices of similar units or performance objectives set by the regulatory agency. Graphically recording the indices as shown in Figure 1 may help show trends which can signal the need for corrective action.

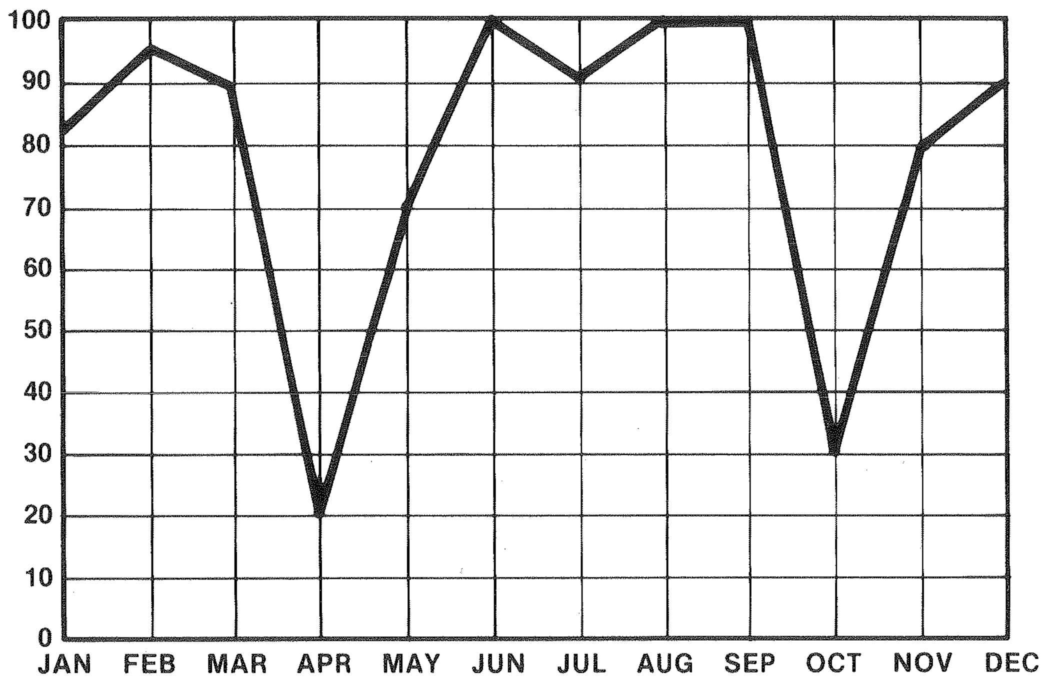

Figure 1 Operating Availability Graph

Review of Maintenance Records

The maintenance records should be reviewed to determine whether there are any specific problem areas or trends in equipment failures. There may not be enough specific data in the past maintenance records to determine trends, and if this is the case, data collection procedures should be implemented for future outages.

Equipment Inspection/Audit

In order to have a benchmark to evaluate any changes in the condition of the equipment, an in-depth inspection along with non-destructive testing and analysis of material samples is required. Particular attention should be paid to those areas where failures have occurred in the past to determine any patterns or trends. The remaining portions of the equipment still need to be thoroughly inspected to determine if there are any signs of potential problems. Non-destructive testing such as magnetic particle and dye penetrant inspection techniques can be used to check for possible cracks or defects in critical components of the equipment. Ultrasonic inspection techniques can be used to determine thicknesses of component sections and sometimes it is also used to locate subsurface defects. There has been some limited success in using ultrasonic testing to define areas of hydrogen embrittlement in boiler waterwall tubing. Analysis of material samples taken from deposits in the equipment and deteriorated equipment components can also give insight into the condition of the equipment.

It is essential to document all observations and findings in writing, as the person(s) who performed the inspection may not be available when later inspections are performed. Color photographs may also be a means of documenting unusual conditions which are difficult to define in writing.

Performance or Capacity Testing

The visual inspection and the non-destructive testing may not be sufficient to totally assess the condition of a piece of equipment. It may be necessary to run tests on a piece of equipment either singly or as a part of the total system. This test may come directly from the ASME Power Test Code or a special test required to obtain the needed data. If a special test is used, it should be well documented so that it can be duplicated at a later date.

Data Evaluation/Formulation of Recommendations

After the performance indices have been calculated, the maintenance records and past failures have been reviewed, and the findings from the equipment inspection and performance test have been evaluated, all possible corrective actions should be listed. Each corrective action should then be evaluated for its advantages, disadvantages, possible side effects, costs and return on investment. After this evaluation is completed, the results would be a recommended plan of action which could be presented to the utility management for any necessary approval or funding.

Implementation of Recommendations

After necessary approvals and funding are received, the recommendations can be implemented. To keep the outage time down to a minimum, detailed plans and schedules must be made including all the outage work so that manpower requirements can be determined. With detailed schedules and manpower requirements, decisions can be made on the number and length of work shifts and if contract labor is necessary.

Monitoring of Improvements and Changes

After the recommendations have been implemented, the improvements or changes must be monitored to see if the desired results have been obtained. This monitoring may take the form of performance testing, periodic inspections, or just continued calculation of the performance indices.

To accomplish all these items, it will take a number of individuals, from the maintenance and clerical personnel at the power plant to the corporate officers at the utility headquarters. These individuals will have to work together as a team, all doing their part in an effort to increase the availability of the units.

Some utilities may find that they need outside help to implement portions of the power plant productivity improvement program. There are many sources of help to the utilities, including the equipment manufacturer. Since the manufacturer has the design details and has been getting feed-back on similar pieces of equipment, a cooperative manufacturer is a natural choice to assist in the team effort.

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