How to Track Machinery Availability.

We are often asked how to best describe equipment performance and how to build suitable indices that reflect machinery reliability for management purposes. Here is an approach that would take the following operational states into account[1]:

- *In Operation*: In service and producing
- *Ready to Start*: Standing by
- *Forced Outage*: Not in operation after a failure during operation that caused the unit to "trip" or be taken off-line; before maintenance
- *Maintenance*: Under preventive or corrective Maintenance, Repair and Overhaul (MR&O)
- *Out of Service*: Not required for operation during a given time period; off

The five operational states are shown in Figure 1. The diagram illustrates the possible changes from one state to the other.

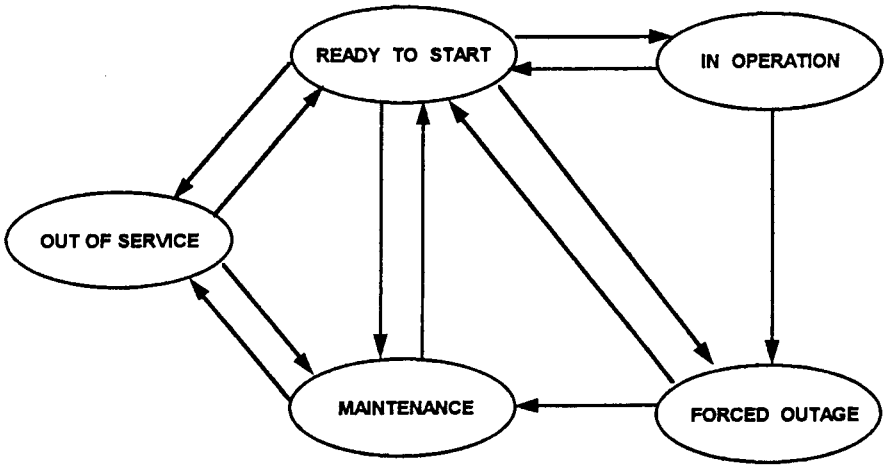

Figure 1.

A machinery availability tracking system should describe operational states and the transition from one state to the other as accurately as possible. This is accomplished by first collecting relevant operational data and then converting them to key machinery performance indicators or management tools. In recent years, this task of data acquisition has been automated in many operations by monitoring equipment run states via DCS[2], SCADA[3] or other control functions.

Table 1 shows a list of required operational data. Key performance indicators are explained in Table 2. It is essential to first define the machinery system to be tracked with all its subsystems and components. Then each data type (Table 1) must be defined

[1] Reference: H. P. Bloch & F. K. Geitner, "*An Introduction to Machinery Reliability Assessment*", 2nd Edition, Gulf Publishing Co., Houston TX, 1994, p.156

[2] Distributed Control System

[3] Supervisory Control and Data Acquisition

by considering the peculiarities of the machinery population such as service mode (i.e., continuous, standby, peak loading) and so on. This is particularly important where company- or industry-wide comparisons of machinery performance indicators are made.

TABLE 1. REQUIRED OPERATING DATA

Available			
Operating time	t	hr	
Ready to start	r	hr	
Unavailable			
Maintenance	M	hr	$M = T_R+T_M$
- Repair	T_R	hr	
- Reliability (predictive, planned)	T_M	hr	
Forced outage	F	hr	
Out of service	O	hr	$O = O_m+O_n+O_d+O_o$
- Modification	O_m	hr	
- Not needed	O_n	hr	
- Time delay	O_d	hr	
- Other	O_o	hr	
Calendar time	C	hr	
Effective calendar time	E	hr	E = C-O
Starts - demand	Sd	#	
Starts - successful	Ss	#	
Total starts	St	#	
Forced outages	n	#	

Definitions:

Operating time (t)

The time unit is operating and producing - automate, obtain from hour meters.

Ready to start time (r)

The unit is ready to run.

Unavailable

The sum of down times caused by maintenance, forced outage and out of service is the total of time not available.

Maintenance time (M)

Time used for the execution of maintenance measures. These measures consist of servicing, i.e. periodic proactive inspection and maintenance, repair and overhaul (MR&O).

- Breakdown maintenance
- Periodic, preventive maintenance
- Condition based maintenance

Forced outage time (F)

Forced outage time commences with the trip of the unit due to a system fault. It lasts until MR&O measures begin.

Out of service time (O)

The unit is defined as being out of service when it is down fore other reasons than MR&O and forced outage.

Modification time (O_m)

This is time for planned improvements etc.

Not needed time (O_n)

Is claimed for keeping the equipment mothballed.

Time delay (O_d)

Accounts for waiting times for spare parts, service personnel etc., i.e. times which are outside the control of the operating/maintenance departments.

Other (O_o)

Also called *miscellaneous*.

Calendar time (C)

The hours within a specified time frame, e.g. annual hours.

Effective calendar time (E)

Actual calendar time is reduced by *out of service time* (O).

Total starts (St)

The sum of all starts, include those after MR&O.

Starts - demand (Sd)

Counting aborted starts. Particularly meaningful if equipment is remotely started.

Starts - successful (Ss)

The unit starts operating after a successful start.

Number of forced outages (n)

Counting forced outages that occur because system components failed while operating.

Table 2. Performance Indicators

Index	Description	Calculation	Units
MTBF	Mean-Time-Between-Failure	t /n	hr
MTTR	Mean-Time-To-Repair	$(F+T_R)/n$	hr
MIR	Maintenance Intensity Ratio	M/(t+r)	-
MTO	Mean-Time-Operating	t /Ss	hr
S	Starting Reliability	100 x Ss/Sd	%
A	Availability	100 x (t+r)/E	%
R	Operating Reliability	$100 \times t /(t+F+T_R)$	%
U	Use Factor	100 x t/C	%

A Brief Discussion of Machinery Performance Indicators

Mean-Time-Between-Failure **(hr)**

MR&O time after a forced outage is not taken into account.

Mean-Time-To-Repair $\frac{(F+T_R)}{n}$ **(hr)**

This index yields valuable information about maintenance performance but also about unit aging trends.

Maintenance Intensity Ratio $\frac{M}{(t+r)}$ **(-)**

Very similar to MTTR

Mean Time Operating

$$\frac{t}{Ss} \quad \textbf{(hr)}$$

Reflects stresses imposed by frequent starts.

Starting Reliability

$$100 \times \frac{Ss}{Sd} \ \textbf{(\%)}$$

Valuable information pertaining to the performance of intermittently operating equipment.

Availability

$$100 \times \frac{(t+r)}{E} \ \textbf{(\%)}$$

Availability as the ratio of the sum of operating and ready to start times and effective calendar time reflects maintenance performance.

Operating Reliability

$$100 \times \frac{t}{(t+F+T_R)} \ \textbf{(\%)}$$

Valuable index to assess equipment aging.

Use Factor

$$100 \times \frac{t}{C} \ \textbf{(\%)}$$

The use factor portrays equipment loading and use.

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