New Reliability Tool for the Millennium: Weibull Analysis of Production Data

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Abstract

The authors will demonstrate how a major Chemical Process company has successfully utilized this new technique to answer questions such as:

1. Do I have a reliability problem or a production problem?
2. What is the demonstrated capacity of my plant?
3. What are efficiency/utilization losses costing me?
4. What is the reliability of my process plant?

The Weibull technique described has helped the company define a strategic course of action based on quantification of process reliability. This tool when added to its reliability improvement arsenal will help any company optimize availability of its products to its customers and maximize profits to its stakeholders.

Introduction To Weibull Plots

Most reliability issues have too much information and too little knowledge. Process plants have vast quantities of data concerning equipment and operating conditions. The problem is trying to make the data speak about reliability in terms that are understandable to the ordinary person. One simple method is to use the daily production output from the process and let the production data "speak". Every production process has daily output data usually organized and studied in time sequence. Few organizations view the data as output from a "black box" to study the results in statistical format to see patterns in the data.

Weibull analysis is one way to organize plant data as described by Abernethy (1998). Weibull plots, the tool of choice for most reliability issues, will be used in this paper in a non-traditional manner. The Weibull plots will define reliability of processes and calculate losses from failure of the process to perform. The production losses in units of output are a precursor for money. When problems are explained in money and time, everyone understands them.

The cost of process failures often exceeds the cost of individual equipment failures by many multiples. We anguish over failure of pumps and heat exchangers—these are the low cost pawns, and what we should worry about are expensive process failures—this is the high priced king. The problem is to decide if you have a reliability problem with equipment or a problem with the production process. Weibull plots help explain and categorize problems in a visual format understandable by engineers, process owners, and management.

Why Use A Weibull Plot?

Definitions for Weibull process details are given below. Weibull probability plots organize many different types of data into straight line X-Y plots. Engineers need data plots, with straight lines, for comprehension at a practical level. For engineers and processes owners the relationship is simple—no cartoon, no comprehension.

Weibull distributions are chosen pragmatically. When data produces a straight line on a Weibull probability plot, the data is considered to be from a Weibull distribution. Weibull distributions are complicated as they are non-linear and usually non-symmetrical distributions.

Traditional Weibull plots utilize age-to-failure data obtained from component failures to make straight-line plots. For components, the slope of the Weibull line tells the failure mode for the component. This is an important feature for letting the data "talk" about what portion of the bathtub curve is best represented, i.e., infant mortality, chance failures, or old age wear out.

Traditional Weibull analysis carefully separates different failure modes to get clean data with suspensions (i.e., the data is censored) so only single modes of failure are represented in each straight line Weibull plot. When mixed failure modes are plotted on a Weibull plot, cusps often appear that give clues to changes and provide evidence for mixed failure modes. Process reliability techniques will take advantage of the cusps to provide information about process reliability.

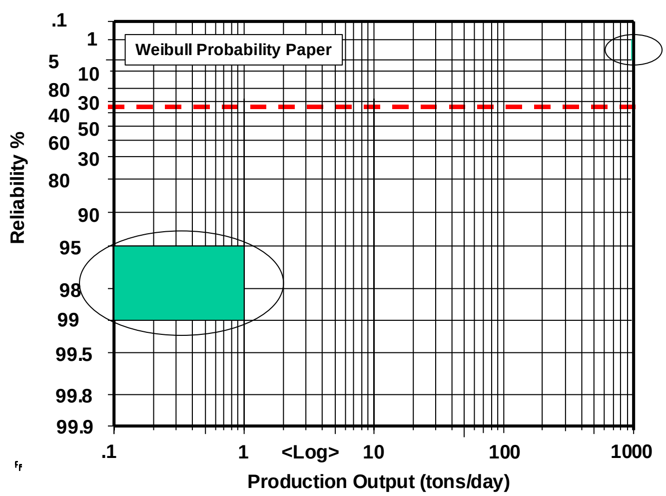

Figure 1: Weibull Probability Paper

Figure 1 shows Weibull probability graph paper. The X-axis is a log scale, and it will be used to plot the daily production from a production unit. The Y-axis is an irregularly divided scale resulting from taking the log of another log. The Y-axis is plotted in a reliability scale rather than the traditional cumulative scale reflecting unreliability.

Notice Weibull plot scales magnify problems in the lower left hand corner so they can easily be observed as shown by the darkened rectangular areas highlighted by the ellipses in Figure 1. Both ellipses are 4%*0.9 units of production.

How Does Scalar Production Data Get Into An X-Y Format?

Production data from a process is usually acquired as daily output. If weekly or monthly data summaries are used, the smoothing of the data hides reliability of the process. The daily output reflects conditions upstream and downstream from the pay-point under measurement. Daily output is a scalar value.

Statisticians have worked out a scheme for handling the conversion of scalar results into a X-Y coordinate system. Data is ranked from low to high to form N pieces of information. The rank of each value is identified with its "i" position for use with Bernard's median rank equation which gives the reliability Y-position as 1 - (i - 0.3)/(N + 0.4). The details are explained in Abernethy.

For a rank column of production data with N = 365 for 365 days of production, suppose the 10th data point (i = 10) was 703. The X-value is 703, and the reliability Y-value is 1- (10 - 0.3)/(365 + 0.4) = 1 - 9.7/365.4 = 100% - 2.65753% = 97.34247% for a Cartesian position (703,97.34247%) on Weibull probability paper.

Notice this scheme does not maintain the typical time position of the data. Instead, the data is randomly (but not haphazardly) occurring information generated by a "black box" device. The "black box" is the process—please note the well-known Weibull modes of failure do not apply to the "black box" data. Thus the information is viewed from a high altitude perspective with Weibull statistical details of β and η. When data from the actual process is compared with Monte Carlo results of the black box details, they have a similar appearance, which adds credibility that the actual data can be represented by a model formed by the Weibull details! (Barringer 1999a).

Production Data From 365 Days—Two Data Sets With Two Points Of View

Consider the Weibull plot in Figure 2 (a). Neither of the curves have reliability problems. Trend line A for a best of class process, with small variation in output, is preferred over trend line B, with its larger variation. Both curves have the same maximum daily output, which is usually fixed by physical restraints in the system. Also note the data plotted in Figure 2 (a) are in rank order. Data is not plotted in a time order.

Shapes of the probability density functions are shown in Figure 2 (b)—these are the shapes you would see if a tally sheet was constructed of daily production quantities—of course, the Figure 2 (b) curves have been normalized so area under the curve is unity and thus the Y-axis represents relative frequency of occurrences. Notice that both curves pass through the same high value for the 365 data point.

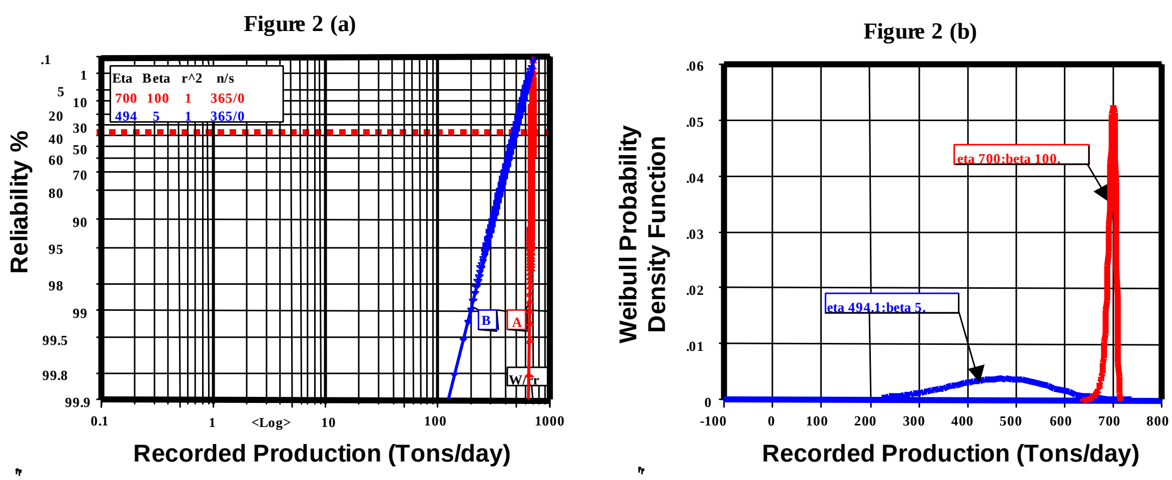

Figure 2: Weibull Plots—No Problems

Straight Weibull lines in Figure 2(a) have curves with tails in Figure 2(b). The flat slope (small beta values), with large variations in output, shows a long tail to the right. The steep slope (large beta values) shows a long tail to the left which says the real opportunities for exceeding the maximum output is very small but the opportunities for having downside production quantities is very large—both conditions are easily recognized by seasoned production personnel.

The interest of six-sigma concepts and Weibull concepts are complementary ideas directed toward reducing variation in the data (Barringer 1999b). The Weibull concept works with non-symmetrical shapes to the curves and the idea of reducing variation in output is considered desirable.

Where Weibull trend lines of production data cut the dashed line in Figure 2 (a), the resulting X-value represents a single characteristic value for demonstrated production output.

This value is represented by eta (η) to show 36.8% of the production will exceed the η value and 63.2% (the complement) will be less than the single point estimate of daily-demonstrated production, η. η is the single point estimates of the demonstrated production value.

The Weibull characteristic value, η, has mathematical properties described by Abernethy. This characteristic value represents a stretch goal for production. The η value is used to best describe the single point estimate of production from non-linear distributions.

Problem Production Data From 365 Days—Two Data Sets With Two Points Of View

In Figure 3, the first cusp in the upper right hand corner of the plot on the Weibull trend line defines a failure point (i.e., the trend line switches to greater variability), which identifies the reliability of the process. The highest cusp defines reliability of the process.

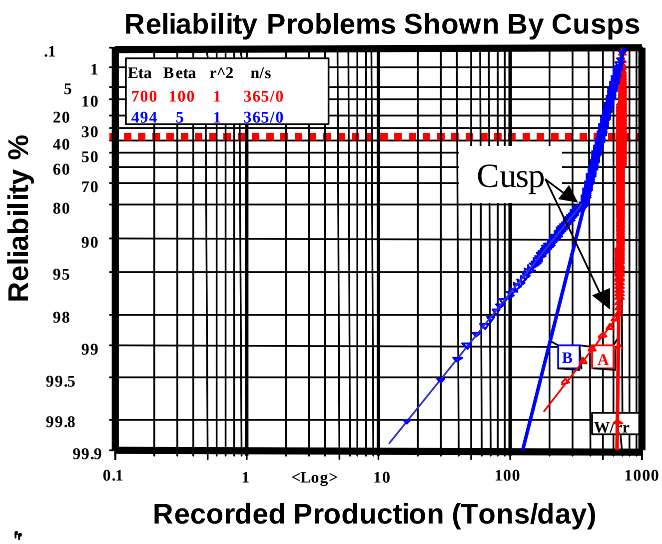

Figure 3: Weibull Plot With Failure Cusps

Reliability problems are shown in Figure 3. The cusp on line A at 98% reliability is more desirable than the cusp on line B at 80% reliability. Notice the cusps, defining reliability of the process, result in larger scatter in the output, which is undesirable and contrary to the concepts of six-sigma efforts because they show a gap between the expected trend line and the actual trend line. The gaps are often characterized as hidden factories—a hidden factory has the cost of the real factory but the hidden factory generates waste and thus lower production.

Reliability losses occur in the gaps between the demonstrated production line (devoid of cusps) and the actual production values which lie to the left of the demonstrated line. Some minor reliability losses are associated with cutbacks. Other reliability losses are associated with significant disasters related to "crash and burn" problems.

Production data scatter to the right of the cusps is the result of common cause variations built into the process and the reasons for the variation are difficult to detect and correct. Scatter in the data to the left of the cusps is caused by special causes identifiable by events related to cause and effects—these conditions are easier to identify and correct.

How much variation is desirable in production output? The answer is naively simple—none, however, in the practical world this naïve simplicity does not exist and some variation in output will occur even in the best of processes. If output variations were extremely small, each variation would be detectable for correction. However, when natural output variation is large, small changes go undetected and thus uncorrected. Furthermore when large natural variations occur, opinions for reasons causing the changes are widely separated which delays corrective action.

Nameplate Ratings For The Process

One criterion for viewing how well the process performs is to define a nameplate rating. The nameplate rating is the maximum production capacity of the factory under theoretically ideal operation and control. The site contractor that designs and constructs the factory usually provides the nameplate rating. It is rarely measurable as it is impossible to achieve the ideal conditions. Some organizations measure their best outputs over a contiguous period of time such as the best 5 days, best 10 days, etc. as judged on a single value to characterize the best nameplate rating.

Comparisons between actual plant results and Weibull analysis have shown the nameplate figure at the characteristic value is steeper than typically obtained by the demonstrated production characteristic values. Figure 4 shows the actual plot of the production line from figure 3 cuts the 38.2% line to give a single point estimate of the demonstrated production, and in a similar fashion the trend line for the nameplate value is established using concepts from statistics relating to the coefficient of variation, which is in proportion to the Weibull shape factor beta.

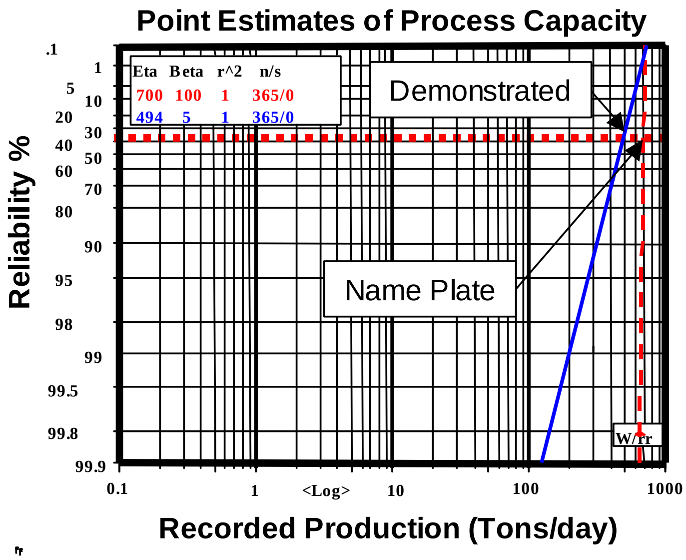

Figure 4: Weibull Plot Single Point Estimates

World-class processes, have a nameplate line with a beta slopes equal to or greater than 100. Not all processes are capable of steep slopes displaying small amounts of common cause variation associated with the nameplate line.

Please note the slope and location of the nameplate line is fixed by the way the process is designed and how it is operated—both issues are under management control. The wedge shape zone between the nameplate line and the demonstrated production line refer to gaps in output best categorized as efficiency and utilization losses.

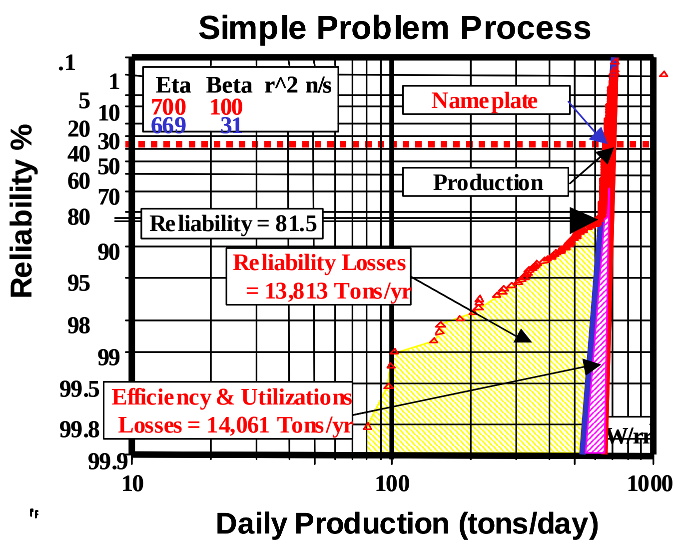

Figure 5: Weibull Plot Losses

Figure 5 shows the production data from a simple process with a problem. The process has demonstrated a reliability of 81.5%

Reliability losses below the cusp are 13,813 tons per year as shown by the cross hatched zone to the left of the demonstrated line.

Efficiency and utilization losses are 14,061 tons per year as shown by the pie shaped zone between the demonstrated line and the nameplate line.

Figure 5 shows the major problem is a production problem followed hard on the heels with a reliability problem.

Failure to identify the nameplate line makes all problems look like a reliability issue. In fact, for the situation in Figure 5, the major problem is due to efficiency and utilization that is directly controlled by management.

Nameplate Ratings For The Process

Using Figure 5, here are the answers to the questions posed earlier:

1. **Do I have a reliability problem or a production problem?** The first problem is due to production and the second problem, of almost the same magnitude, is a reliability issue.
2. **What is the demonstrated capacity of my plant?** Demonstrated plant capacity is 669 tons/day and the nameplate rating is 700 tons/day which says the plant is actually operating (700 – 669)/700 = -4.43% under the nameplate capacity
3. **What are efficiency/utilization losses costing me?** Efficiency/utilization losses are 14,061 tons/year which is equivalent to 14061/669 = 21 days of lost production in a one year time interval
4. **What is the reliability of my process plant?** The reliability of the process is 81.5% and reliability losses are 13,813 tons/year equivalent to 13813/669 = 21 days of lost production.

The situation in Figure 5 shows a hidden factory that has consumed 42 days of actual production that could have been produced and sold for the benefit of the stockholders. Often these losses, when recovered, can more than double returns on assets for investors.

For each problem noted above, a reason for the deficiency must be identified and corrected. You must make a change to get a change. The authors have collectively looked at hundreds of processes and the number of processes requiring improvement exceeds 99%.

The interesting feature of attacking process reliability problems is that most are correctable by teamwork, and the identification/quantification of both production and reliability problems avoids the typical finger pointing and rock throwing which occurs in most plants between departments. In short, correctly quantifying and categorizing the problems shows enough "blame" to go around and neither side is innocent. A clear situation emerges that production, engineering, and maintenance must work together for their common good to eliminate losses.

Competitive environments existing today will quickly eliminate plants that are non-competitive because of losses that could be eliminated, so, if the team does not make the correction, the competition will shut the process and everyone at the plant is the looser. You cannot eliminate problems that you cannot identify and Weibull process reliability provides a new method for ferreting out problems for resolution.

Actual Production Data For Weibull Analysis

Each opportunity described below can have reliability and production problems arising from design, manufacture, equipment/process selection, installation, operation, maintenance, monitoring, equipment/process repair, and operation of the equipment/process in a specified environment for a specified interval of time. The issues at stake are not idealistic perfection but strictly pragmatic commercial—considering complexities of real life operating plants, they must function to make money. It's easy to loose money, and it's difficult to make money—the difficulties of exterior conditions of the market place and interior conditions of plant culture must be considered. You'll never find any plant or any operation devoid of problems—all have situations where problems must be identified and corrected by attacking the roots of the problem.

Weibull analysis of the production data will be examined to show how to attach typical problems—please remember that for competitive reasons the actual remedies will not be disclosed but rather, the details will be generic.

Data From A Real Process

For proprietary reasons, the plant producing this real data is not identified, nor will the product be identified.

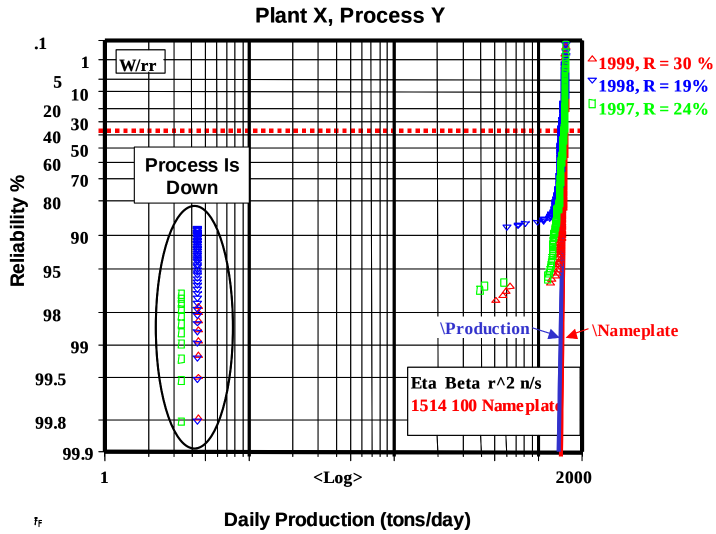

Figure 6: Weibull Plot Of Actual Data

Figure 6 shows actual data during each of three years. The reliability is highly variable and so are the losses. For example, Figure 5 shows the process was idle for ~12% of the time during 1998. Losses are described in the following Table 1.

Table 1 shows the process has low reliability (the cusps in Figure 6 cannot be seen because of the breadth in symbol width for the graphic even though the cusps for the serious deteriorations are observable in the upper 80% in Figure 6. Efficiency and utilization problems are minor in comparison to reliability problems. Notice how closely the nameplate ratings are from year to year based on an analysis of the actual output data.

Data from Table 1 should be viewed as yardstick information--not as micrometers. The turnaround in 1998 was successful and reduced losses in 1999—although the extra losses of ~50,000 tons/year has about a 2 year payback.

Table 1: Summary Of Results From Plant X And Process Y

	1997	1998	1999	3 Yr Average
Actual Results				
Reliability	30%	19%	24%	24%
Production Losses (tons/year)				
Reliability Losses (tons/year)	37,070	76,158	20,370	44,533
Efficiency & Utilization Losses (tons/year)	2,091	15,545	4,376	7,337
Total Losses (tons/year)	39,161	91,703	24,746	51,870
Equivalent Days Lost/yr At Demo. Output	26	62	16	35
Production Losses ($/year) @ 0.10$/lb				
$ Reliability Losses/year @ 0.10$/lb	$ 7,414,000	$ 15,231,600	$ 4,074,000	$ 8,906,533
$ Efficiency/Utilization Losses/year @ 0.10$/lb	$ 418,200	$ 3,109,000	$ 875,200	$ 1,467,467
$ Total Losses	$ 7,832,200	$ 18,340,600	$ 4,949,200	$ 10,374,000
Demonstrated Production Results				
η, demonstrated output (tons/day)	1,511	1,491	1,503	1,502
β, slope of demonstrated line	76.8	53.2	88.3	72.8
Nameplate Results				
η, nameplate output (tons/day)	1,515	1,527	1514	1,519
β, slope of nameplate line	100	100	100	100.0

Using Table 1, here are the answers to the questions posed earlier:

1. **Do I have a reliability problem or a production problem?** The first problem is due to reliability by a factor of ~6:1 over efficiency/utilization problems.
2. **What is the demonstrated capacity of my plant?** Demonstrated plant capacity is 1502 tons/day. Nameplate rating is 1519 tons/day. The plant is operating (1519 – 1502)/1519 = -1.1% under the nameplate capacity.
3. **What are efficiency/utilization losses costing me?** Efficiency/utilization losses average 7,337 tons/year which is equivalent to 7337/1502 = 4.9 days/yr. of lost production.

Efficiency/utilization losses are small compared to reliability losses. Average efficiency/utilization losses are $1,467,467/year.

4. **What is the reliability of my process plant?** The reliability of the process has varied from 19% to 30% over a three year period and the average is 24%. Average reliability losses are 44,533 tons/year which is equivalent to 44533/1502 = 29.6 days/yr lost. Average reliability losses are $8,906,533/year.

Table 1, based on Figure 5, shows a hidden factory that, on the average, consumed 35 days/year of actual production that could have been produced and sold for the benefit of the stockholders.

What Causes Reliability Losses?

Steep beta trend lines for demonstrated production trend lines can deteriorate into less steep beta trend lines as equipment is removed/added to service with accompanying changes in output. When portions of a process (i.e., a train is lost) are added/removed, a cusp forms on the trend line.

Turnarounds result in substantial outages (i.e., a reliability issues of high magnitude) as observed in the 1998 time period for Table 1. Process fouling causes output deterioration and results in a cusp on the demonstrated production line.

Logistic problems causing process starts-stops-cutbacks cause unusual cusps to appear on the trend lines for demonstrated production.

Lack of raw materials and lack of orders (both issues are failures of the business team to provide for successes) are reliability problems with roots for the failure, which are different than traditionally observed for output restrictions. Lack of feedstock to one plant may be due to reliability problems at a supplier plant. Also cutbacks may be required due to utilities such as steam or power being temporarily put on allocation at a site. These “load shedding” requirements will show up as decreased reliability if severe enough.

Short-term process inattention to optimization can result in output cutbacks, which will appear as cusps on the demonstrated production curve—these operation conditions can have a similar appearance on plant output as equipment failures.

Catalyst fouling will show up as reduced reliability also. Downtime to recharge the catalyst will be viewed the same as downtime due to planned turnarounds for equipment maintenance. These scheduled downtimes can be coordinated between operations and maintenance to ensure optimum use of the “window”.

What Causes Flat Slopes In The Demonstrated Production Line?

Changes in set points from shift to shift result in increasing output variation when operators think their shift concepts are superior to prior shifts operational concepts—if they are responding to common cause variation rather than special causes (this concept was repeatedly demonstrated by Dr. Deming’s dropping beads into a funnel to observe their resulting location in an egg crate experiment which showed responding to each common cause change results in more scatter in the results than only responding to special cause).

Speed bursts for records, which are subsequently paid for by many days of substandard performance, result in large variations in process output.

Another cause can be the lack of explaining to operations personnel about location of the process “bulls eye” so that output consistency is obtained rather than use of colorful descriptions such as “give me more”.

Slow deterioration in production output because of equipment fouling does not cause a cusp on the output curve but rather only adds to variability in output. Examples of this are observed in towers, columns, heat exchangers, and high temperature reaction systems where the operations group does not renew the system on frequent or consistent basis. Catalyst fouling will show up like this until it gets severe enough to become a reliability problem.

What Causes Efficiency and Utilization Losses?

Major stresses on the system have large effects such as temperatures, pressures, flow rates, and chemical concentrations. These conditions manifest themselves in displacement of the demonstrated production rates to smaller values from the installed capacities of the system.

Other items have large effects such as mixing efficiencies, late starts and early quits, running plans at continuously reduced outputs, which are failures to use the installed capacity paid for by the investors, inattention to long-term process optimization with inherent inefficient operations, lack of maintaining steady state conditions, use of analog controls rather than rapid response digital controls, use of sub-optimum raw materials, and continuously inefficient scheduling of production facilities. These are the deviations that determine the upper and lower control limits of the process and determine how tight that control is. These are the things that can be worked on to reduce the variation in the statistical control of the process.

How Do You Solve These Practical Problems For Reliability and Efficiency/Utilization?

Look down on the problems from a strategic position rather than treating all details as tactical problems. Keep the big picture in mind and let new ideas lead change. "Organizations need change for three reasons: 1) they are out in front and want to stay there, 2) they are about to be overcome by the competition and have to change in order to stay competitive, and 3) they have already been overcome, and they must change in order to compete and survive." (Clancy 1997) If you can get a clear strategy, the tactics for solving the problem (i.e., making things change) will be clear and this requires: "1) a sense of the objective to focus efforts on achieving the objective and the discipline to stay within the parameters, 2) unity of effort so the organization works toward the same goal, 3) a sense of legitimacy for acceptance [of changes] by the organization, 4) perseverance to reach the objectives." (Clancy)

Don't get tangled-up in the details when working on the high level viewpoint. Understand how and why your operation is performing in the manner it functions. Defer the details for tactical solutions. From your assessment findings, build a Pareto chart to prioritize the efforts for corrective actions.

The big picture concept is described in Table 2 which is an extension of Birchfield's contributions (Birchfield 2000).

Assess where you are and define what your plant is capable of performing. If you don't know where you are and where you're going, how will you know when you've arrived? The assessment must be in terms useful for operations, engineering, maintenance, and management. Use of daily plant output during the assessment, as a precursor for money, is a concept everyone understands without the need for justifying logic for the assessment.

Each operating plant needs an objective assessment based on numbers. The assessment needs to fit on one side of one sheet of paper as can be obtained with the Weibull process reliability technique. The assessment must also show the nameplate rating for the facility. The Weibull slope for well designed and operated processes can have very tight ranges with Weibull beta values greater than 200, and the nice thing about steep betas is you can clearly see a change in the process because changes in output are real and have a special cause demanding immediate corrections.

Problems must be sliced/diced into logical subgroups for understanding roots of the difficulties. Frequently day-to-day problems hide a general trend, which can be observed as results from the "black box" analysis by use of Weibull techniques.

Solve each individual problem by working on roots of the difficulty rather than working on symptoms of problems. Start top down on the root cause, beginning with the effect (the problem) and why it was caused (the conditions which may have caused the event) and recognize the causes are catalyzed by an action (the momentary cause that brings conditions together to cause an effect) (Gano 1999). You don't need to be the best problem solver in the world, but you do need to be better than your most fierce competitor.

Table 2: Reliability--The Same Issue Viewed From Different Organizational Perspectives

	Process	Maintenance	Reliability Engineering	Management
Reliability Issues:				
Definition	Fix When Broken	Fix When Broken	Prevent Failures	Mission times/failure rates
Concept	Tactical	Tactical	Strategic/Tactical	Acceptable cost of unreliability
Mode	Continuous	Discrete	Discrete	Continuous
Involvement	Automated	Manual	Situational	Provide leadership
Provential Interest	Loss of production	Cost of repair	Long term cost of ownership	Short term costs
Methodology	Predictive	Preventive	Avoidance of failure	Strategy first/tactics second
Mental Involvement	Models	Practices	Models	Hold the long term course
Key Issues	Knowledge	Skill	Knowledge & skill	Harmonizing long/short term objectives
Scope of Interest	Contents	Container	System	Business system and accountability
Measurement Scale	Optimization	Effectivemess	Long term cost of ownership	Annual cost of unreliability
Implementation Tools	Control	Inspect	Prevention	Reliability driven engr./mgt./cost tools
Discipline	Chemical	Mechanical	System	Money management
Equipment Family:				
Fixed	Pressure limits Temperature limits Fouling prevention On-stream cleaning Start-up/shut-down trips Corrosion rates/controls TPM issues to reduce failues	Leaks Insulation Painting Strainers & filters TPM, PdM, & PM issues	Corrosion rates Embrittlement Risk-based inspection Infared/ultrasonic testing Failure rates/models Redundancy/trade-off models Root cause failure analysis	Safety & Environmental issues Product yield & cost issues Manning level issues Energy consumption Waste disposal Human errors, good work practices, & avoidance of failure conditons Equipment compatability with feedstock & product changes Process stability & rates of process change on cost & schedules
Rotating	Surge & caviation Over speed BEP control & alternatives Lubrication Start-up/shut-down trips Errosion rates/controls TPM issues to reduce failures	Vibration alignment bearings/seals/gaskets TPM, PdM, & PM issues	Fitness for service Redundancy issues Predictive failure analysis Failure rates/models Redundancy/trade-off models Root cause failure analysis	Safety & Environmental issues Product yield & cost issues Manning level issues Energy consumption Waste disposal Human errors, good work practices, & avoidance of failure conditons Equipment compatability with feedstock & product changes Process stability & rates of process change on cost & schedules
Electrical	Overloads & overload tolerance Trips & shorts Load shedding/switching Energy costs as % of product cost issues TPM issues to reduce failures	Cleaning Transformer Oil Analysis Insulation Hot spots TPM, Pdm, & PM issues	Uniterrruptible supplies Supply swithcing capability Mover overheating Failure rates/models Redundancy/trade-off models Root cause failure analysis	Safety & Environmental issues Product yield & cost issues Manning level issues Energy consumption Waste disposal Human errors, good work practices, & avoidance of failure conditons Equipment compatability with feedstock & product changes Process stability & rates of process change on cost & schedules
Instruments & Controls	Accuracy & repeatability Control loop diagnostics Sample loop conditions Inference vs lab/analyzers Alarms management Control system failures Feed/process interruptions Trip reduction/hazard models & smart/dumb instrumentation Transient vs steady state controls Push vs pull control for productivity issues TPM issues to reduce failures	Calibration Critical checks Sensor fouling/cleaning Standard samples Troubleshooting TPM, PdM, & PM issues	Redundancy Fail-safe modes Housing environment Sensor location Statistical tools Failure rates/models Redundancy/trade-off models Root cause failure analysis	Safety & Environmental issues Product yield & cost issues Manning level issues Energy consumption Waste disposal Human errors, good work practices, & avoidance of failure conditons Equipment compatability with feedstock & product changes Process stability & rates of process change on cost & schedules

Use asset utilization categories for each day where a problem has been identified. Relate the type of problem (i.e., reliability problem or efficiency/utilization problem) to the specific cause listed for problems with asset utilization. Convert the problems into money based on lost production to help justify economic solutions to practical problems.

On reliability issues, separate the losses into production related reasons versus equipment related reasons so the real problem can be solved as a money issue.

On efficiency/utilization issues, separate the issues between efficiency and utilization, as the medicine for solving the problem will be considerably different. Convert the details into money issues to provide motivation for solving economic problems rather than treating the problems emotionally.

Understand that many reliability problems can have people, processes, and procedures as the root of the difficulty. People issues usually cause most equipment problems. People issues involve such items as inferior operating techniques, inferior installation techniques, and inferior maintenance grades for alignment and restoration. The true, inherent equipment problems are less frequently the cause of load-strength issues than people-procedure interferences that choke the equipment into failure. For equipment abnormalities, also consider FRETT (**F**orces, **R**eactive agents, **E**nvironments, **T**emperatures, and **T**ime) as a checklist for what/where to look for improvement opportunities (Bloch 1994). The important concept to grasp is the implementation of resolutions to people, processes and procedures generally require no/little capital and changes can begin in short intervals of time.

Ashbrook (2000) offers good advice for thinking as an entrepreneur to solve problems:

1. Find good models,
2. Learn the right lessons,
3. Make good observations,
4. Prepare for life-long learning and modification

This is the concept of Weibull analysis for process reliability issues to find ways to make improvements.

Definitions

Crash and burn output: A euphemism for seriously deficient production quantities during periods of substantial process upsets or deteriorations.

Cutbacks: A production quantity recorded during a period when output is restricted by partial failures resulting in a slowdown from the intended/scheduled production rate. The zone is often characterized by a cusp at either end of the zone on a Weibull plot.

Demonstrated Weibull production line: A straight-line trend in upper reaches of the Weibull probability plot defining "normal" production when all is well—as quantities deviate from this segment, failures occur (by definition) because the process loses it's predictability.

Demonstrated capacity: A single "talk about" number at 63.2% CDF or 36.2% reliability which best represents a "stretch goal" for production output.

Efficiency/utilization losses: The difference between the nameplate capacity and the demonstrated Weibull line; generally a result of efficiency losses or under-utilization of the facility.

Nameplate capacity: a) For a single piece of equipment, it is the maximum production capacity of the equipment under ideal operation and control as described by process planners or supplier of the equipment. b) For a process comprised of many different components of equipment it is the maximum production capacity of the factory under ideal operation and control as provided by the site contractor that designs and constructs the factory.

Pareto principle: A few contributors are responsible for the bulk of the effects—the 80/20 rule whereby 10% to 20% of the things are responsible for 60% to 80% of the impact. Named for the Italian economist Vilafredo Pareto (1848-1923) who studied the unequal distribution of wealth in the world and by Dr. Juran who described the Pareto concept as separating the vital few issues from the trivial many issues.

Processes: Processes are collections of systems and actions following prescribed procedures for bringing about a result. Using a set of inter-related activities and resources to transform inputs into outputs often uses processes for manufacturing saleable items.

Production losses: The difference between the demonstrated Weibull line and the actual production data point associated with the same % CDF.

Process reliability: The point on a Weibull probability plot where the demonstration production line shows a distinct cusp because of cutbacks and/or crash and burn problems.

Summary

Weibull techniques provide a method, using daily production data, for assessing data to find process reliability, reliability losses, and efficiency/utilization losses. The losses provide enough details to define a Pareto distribution to rank the problem solving priority.

The Weibull process reliability techniques define single point estimates of: process reliability, estimates of the daily demonstrated production, estimates of nameplate capacity, and estimates of losses by category including the size of hidden factories.

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For other issues on process reliability refer to **Problems Of The Month** at **http://www.barringer1.com.**