

Consider using a new reliability tool: Weibull analysis for production data

Using these techniques, companies can distinguish between processing problems and reliability issues

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In this case history, a major chemical company successfully uses the Weibull techniques to answer these questions:

1. Is the problem a reliability problem or a production issue?
2. What is the demonstrated capacity of the plant?
3. What are efficiency/utilization losses costing the facility?
4. What is the reliability of the process plant?

By applying the Weibull technique, this company defines 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. One simple method uses daily-production output from the process and lets the production data “speak.” Every processing unit has daily-output information, which is usually organized and studied in a time sequence. Few organizations view this data as output from a “black box” and study the results in statistical format to generate trends.

Weibull analysis is one way to organize plant data as described by Abernethy.¹ In this example, Weibull plots, the tool of choice for most reliability issues, will be used in a nontraditional manner. These plots will define reliability of processes and calculate losses from failures. Production losses in units of output are a precursor for money. When problems are explained in terms of 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 the failure of pumps and heat exchang-

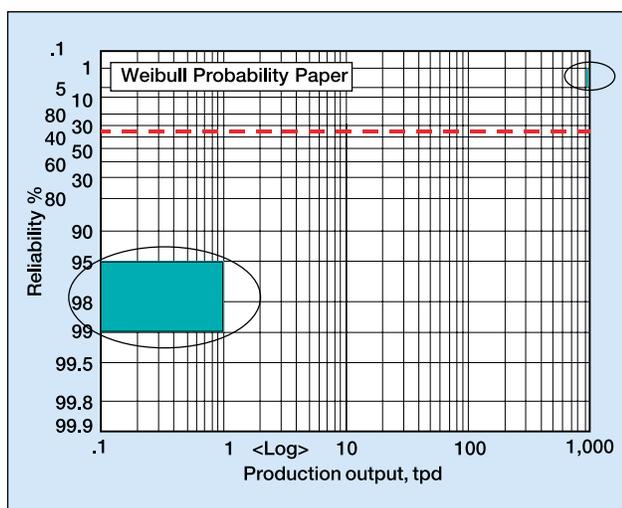


Fig. 1. Weibull probability paper.

ers—these are the low-cost pawns. What we should worry about are expensive process failures. The problem is deciding if you have a reliability problem with equipment or a problem with the process operations. Weibull plots help explain and categorize problems in a visual format that is understandable by engineers, process owners and management.

Why use a Weibull plot? 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 graphed data produces a straight line, it is considered to be from a Weibull distribution. Such distributions are complicated, as they are nonlinear and usually nonsymmetrical distributions.

Traditional Weibull plots use age-to-failure data obtained from component failures to make straight-line plots. For the 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.,

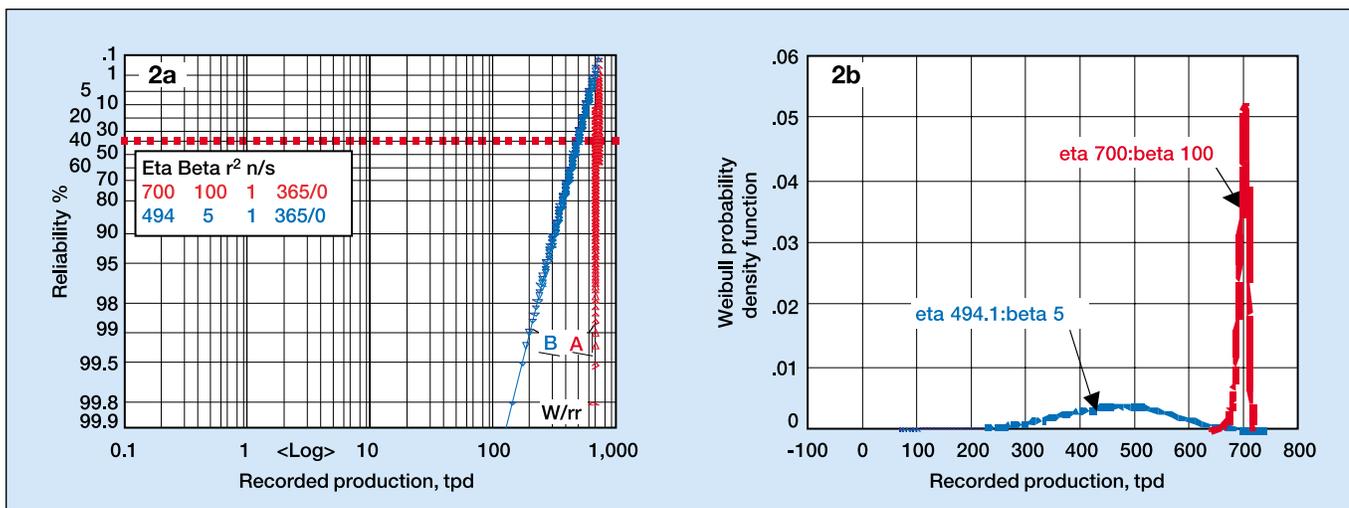


Fig. 2a and 2b. Weibull plots—no problems.

infant mortality, chance failures or old-age wear out.

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. 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.

Fig. 1 shows a Weibull probability graph. The X-axis is a log scale, and it will be used to plot the daily production from a given processing 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 that the Weibull plot scales magnify problems in the lower left hand corner so they can be easily observed as shown by the darkened rectangular areas highlighted by the ellipses in Fig. 1. Both ellipses are $4\% \times 0.9$ 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, then smoothing the data hides reliability of the process. Daily output reflects conditions upstream and downstream from the pay-point under measurement; it is a scalar value.

Statisticians have worked out a scheme for handling the conversion of scalar results into an 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.¹

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.

Note: 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 that 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.²

Production data from 365 days—two data sets with two points of view. Consider the Weibull plot in Fig. 2a. 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 that the data plotted in Fig. 2a are in ranked order; data are not plotted in a time order.

Shapes of the probability density functions are shown in Fig. 2b—these are the shapes you would see if a tally sheet was constructed of daily production quantities. Of course, the Fig. 2b curves have been normalized so the 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.

Straight Weibull lines in Fig. 2a have curves with tails in Fig. 2b. 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.³ The Weibull concept works with nonsymmetrical shapes to the curves, and reducing variation in output is considered desirable.

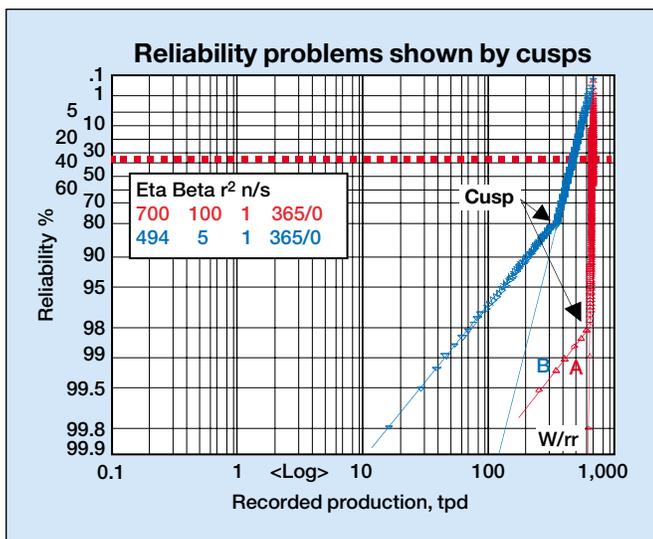


Fig. 3. Weibull plot with failure cusps.

Where Weibull trend lines of production data cut the dashed line in Fig. 2a, 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 . The single-point estimates of the demonstrated production value is η .

The Weibull characteristic value, η , has mathematical properties and this characteristic value represents a stretch goal for production.¹ The η value is used to best describe the single point estimate of production from nonlinear distributions.

Problem production data from 365 days—two data sets with two points of view. In Fig. 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.

Reliability problems are shown in Fig. 3. The cusp on line A at 98% reliability is more desirable than the cusp on line B at 80% reliability. **Note:** 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 and actual trend lines. These 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 lowers production.

Reliability losses occur in the gaps between the demonstrated production line (devoid of cusps) and actual production values, which is 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 results from common-cause variations built into the process, and the reasons for variations are difficult to detect and correct. Scatter in the data to the left of the cusps is caused by special causes identifiable by events

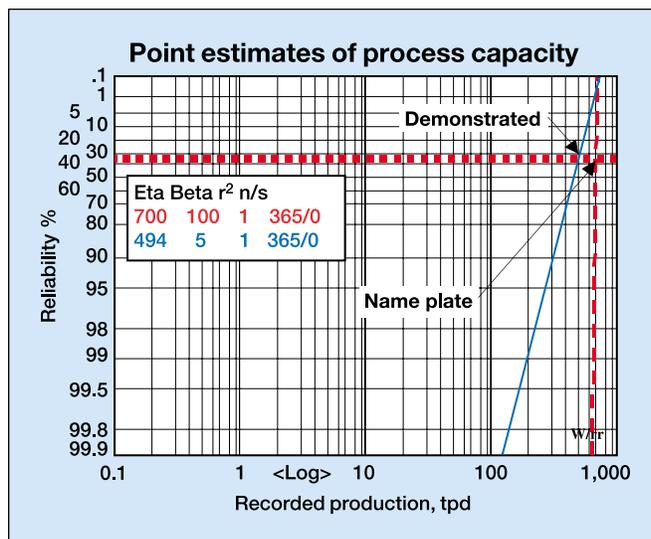


Fig. 4. Weibull plot of single-point estimates.

related to cause and effects—these conditions are easier to identify and correct.

How much variation is desirable in production output? The answer is simple—none. However, in the practical world, this simplicity does not exist, and some variation will occur even in the best of processes. If output variations were extremely small, each variation would be detectable for correction. 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 facility under theoretically ideal operation and control. The site contractor that designs and constructs the facility usually provides the nameplate rating. It is rarely measurable, as it is impossible to achieve 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 that the nameplate figure at the characteristic value is steeper than typically obtained by the demonstrated production characteristic values. Fig. 4 shows how the actual plot of a production line from Fig. 3, which cuts the 38.2% line to give a single-point estimate of the demonstrated production. 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.

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 to display small amounts of common-cause variation associated with the nameplate line.

Please note that the slope and location of the nameplate line is fixed by the way the process is designed and

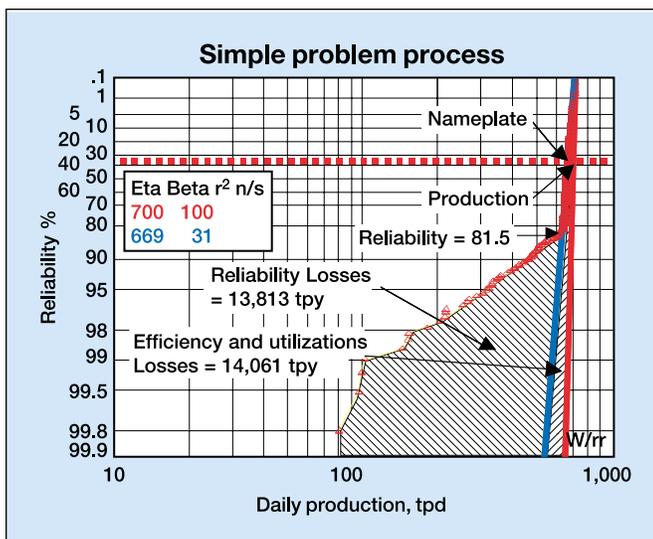


Fig. 5. Weibull plot of losses.

operated—both issues are controlled by management. The wedge-shaped zone between the nameplate line and demonstrated-production line refer to gaps in output best categorized as efficiency and utilization losses.

Fig. 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 tpy as shown by the cross-hatched zone to the left of the demonstrated line. Efficiency and utilization losses are 14,061 tpy as shown by the pie-shaped zone between the demonstrated line and the nameplate line.

Fig. 5 shows that the major problem is a production issue followed hard on the heels with a reliability issue. Failure to identify the nameplate line makes all problems appear as a reliability issue. In fact, for the situation in Fig. 5, the major problem is due to efficiency and utilization that is directly controlled by management.

Nameplate ratings for the process. Using Fig. 5, here are the answers to the questions posed earlier:

1. Is the problem a reliability or a production issue? 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 the plant? Demonstrated plant capacity is 669 tpd and the nameplate rating is 700 tpd. Thus, the plant is actually operating $(700 - 669)/700 = -4.43\%$ under the nameplate capacity.

3. What are efficiency/utilization losses costing the facility? Efficiency/utilization losses are 14,061 tpy, which is equivalent to $14,061/669 = 21$ days of lost production in one year.

4. What is the reliability of the process plant? The reliability of the process is 81.5%, and reliability losses are 13,813 tpy equivalent to $13,813/669 = 21$ days of lost production.

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

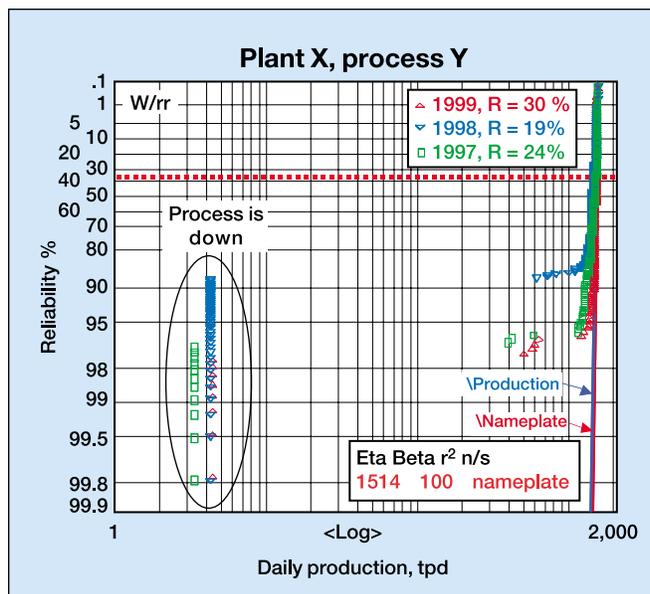


Fig. 6. Weibull plot of actual data.

For each problem noted above, a reason for the deficiency must be identified and corrected. You must make a change to get 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. The identification/quantification of both production and reliability problems avoids the typical finger pointing and rock throwing, which occurs between most facility departments. Correctly quantifying and categorizing the problems shows enough “blame” to go around, and neither side is innocent. Operations, engineering and maintenance must work together for their common good to eliminate losses.

Competitive environments will quickly eliminate those plants that are noncompetitive due to losses that could have been remedied. If the team does not make the correction, then the competition will close the facility, and everyone is the loser. You cannot eliminate problems that you cannot identify. 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. These issues at stake are not idealistic perfection, but rather, strictly pragmatic commercial. Considering complexities of real-life operating plants, they must function to make money. It's easy to lose money, and it's difficult to make money. The difficulties of exterior conditions from 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 situations have problems that must be identified and corrected by attacking the roots of the problem.

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, tpy				
Reliability losses, tpy	37,070	76,158	20,370	44,533
Efficiency and utilization losses, tpy	2,091	15,545	4,376	7,337
Total losses, tpy	39,161	91,703	24,746	51,870
Equivalent days lost/yr at demo. output	26	62	16	35
Production losses, \$/yr @ \$0.10/lb				
Reliability losses/yr @ \$0.10/lb	\$7,414,000	\$15,231,600	\$4,074,000	\$8,906,533
Efficiency/utilization losses/yr @ \$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, tpd	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, tpd	1,515	1,527	1,514	1,519
β , slope of nameplate line	100	100	100	100.0

Weibull analysis of the production data will be examined to show how to attack 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. Fig. 6 shows actual data for three years. The reliability is highly variable and so are the losses. For example, Fig. 5 shows the process was idle for ~12% of the time during 1998. Losses are described in Table 1.

Table 1 shows that the process has low reliability. (The cusps in Fig. 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%.) Efficiency and utilization problems are minor in comparison to reliability problems. Notice how closely the nameplate ratings from year to year are 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 tpy has about a two-year payback. Using Table 1, here are the answers to the questions posed earlier:

1. Is the problem a reliability or operations issue? The *first* problem is due to reliability by a factor of ~6:1 over efficiency/utilization problems.

2. What is the demonstrated capacity of the plant? Demonstrated plant capacity is 1,502 tpd. Nameplate rating is 1,519 tpd. The plant is operating $(1,519 - 1,502)/1,519 = -1.1\%$ under the nameplate capacity.

3. What are efficiency/utilization losses costing the facility? Efficiency/utilization losses average 7,337 tpy, which is equivalent to $7,337/1,502 = 4.9$ d/y of lost production. Efficiency/utilization losses are small compared to reliability losses. Average annual efficiency/utilization losses are \$1,467,467.

4. What is the reliability of the 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 tpy, which is equivalent to $44,533/1,502 = 29.6$ d/y lost. Average annual reliability losses are \$8,906,533.

Table 1, based on Fig. 5, shows a hidden factory that, on the average, consumed 35 d/y 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 the demonstrated production 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 issue of high magnitude) as observed in 1998 from 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/or orders (both are failures by the business team) 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 other 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 “bull’s eye” so that output consistency is obtained rather than using colorful descriptions such as “give me more.”

Slow deterioration in output from 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, flowrates and chemical concentrations. These conditions manifest themselves in displacement of the demonstrated production rates to smaller values of the installed capacities.

Other items have large effects such as:

- Mixing efficiencies
- Late starts and early quits
- Running plants at continuously reduced outputs, which are failures to use the installed capacity paid for by investors
 - Inattention to long-term process optimization with inherent inefficient operations
 - Lack of maintaining steady-state conditions
 - Applying analog controls rather than rapid-response digital controls
 - Use of sub-optimum raw materials
 - 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 to stay competitive
- 3) They have already been overcome and must change to compete and survive.”⁴

If you can get a clear strategy, then the tactics for

solving the problem (i.e., making things change) will be clear and this requires:

- “A sense of the objective to focus efforts on achieving the objective and the discipline to stay within the parameters
- Unity of effort so the organization works toward the same goal
- A sense of legitimacy for acceptance [of changes] by the organization
- Perseverance to reach the objectives.”⁴

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.⁵ 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. Using daily plant output during the assessment, as a precursor for money, is a concept everyone understands.

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. A bonus with steep

betas is that 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 and diced into logical sub-groups to understand *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 the *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 that the causes are catalyzed by an action (the momentary cause that brings conditions together to cause an effect.)⁶ 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.

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

The cost of process failures often exceeds the cost of individual equipment failures by many multiples.

Table 2. Reliability—the same issue viewed from different organizational perspectives

Reliability issues:	Process	Maintenance	Reliability engineering	Management
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	Effectiveness	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 failures	Leaks Insulation Painting Strainers & filters TPM, PDM, & PM issues	Corrosion rates Embrittlement Risk-based inspection Infrared 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 conditions Equipment compatibility with feedstock & product changes Process stability & rates of process change on cost & schedules
Rotating	Surge & cavitation Over speed BEP control & alternatives Lubrication Start-up/shut-down trips Erosion 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 conditions Equipment compatibility 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	Uninterruptible supplies Supply switching 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 conditions Equipment compatibility 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 conditions Equipment compatibility with feedstock & product changes Process stability & rates of process change on cost & schedules

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 the economic problems rather than treating them 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. They involve such items as inferior operating techniques, poor installation techniques and faulty 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 (Forces, Reactive agents, Environments, Temperatures and Time) as a checklist for what/where to look for improvement opportunities.⁷ 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 offers good advice for thinking as an entrepreneur to solve problems:⁸

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 for finding ways to make improvements.

Wrap-up. 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, daily demonstrated production, nameplate capacity and of losses by categories including the size of hidden factories. ■

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 its 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.

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