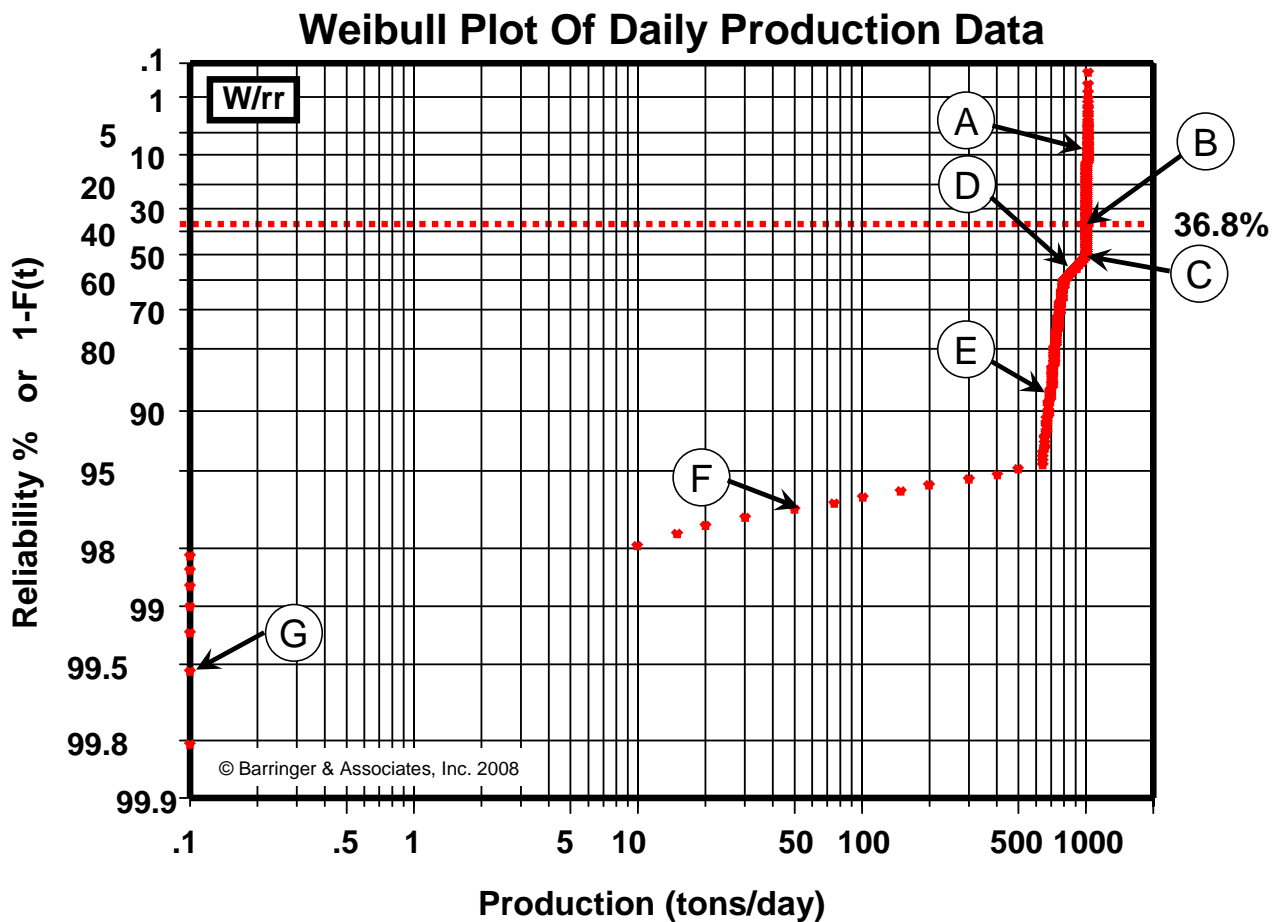


Special Cause Variations, Common Cause Variations, and Process Reliability Plots

Barringer process reliability plots begin with daily output from a production process when output values are plotted in rank order on a Weibull plot. Frequently, process outputs display two or more trend lines when plotted on a Weibull probability plot. The steep trend line displays variation due to **common cause**. The cusp (discontinuity) defines the maximum reliability of the process whereby consistency in output is lost and **special cause variations** prevail. The Weibull plot of daily production is illustrated in Figure 1, which is the foundation of a Barringer process reliability plot. You can download the [data](#) for this figure as an Excel spreadsheet.

Figure 1: A Weibull Process Reliability Plot Without Trend Lines



Zone A - Straight trend line for high production output where **common cause** variations predominate

Zone B - Characteristic value for high production levels in tons/day at 36.8% or 63.2% CDF. This is a single value for describing typical production output

Zone C - The cusp where reliability ceases for continuous high production levels, $R = 50\%$. Common cause variations no longer predominate and **special cause variation** takes over

Zone D - A cutback zone with inferior levels of production, **special cause variations** predominate

Zone E - A reduced output zone where industrial discipline was not maintained in production, **common cause variations** are higher than in Zone A and the production is translated to the left (smaller output) because of **special cause variations**

Zone F - A crash and burn zone of severe production cutbacks, **special cause variations** predominate

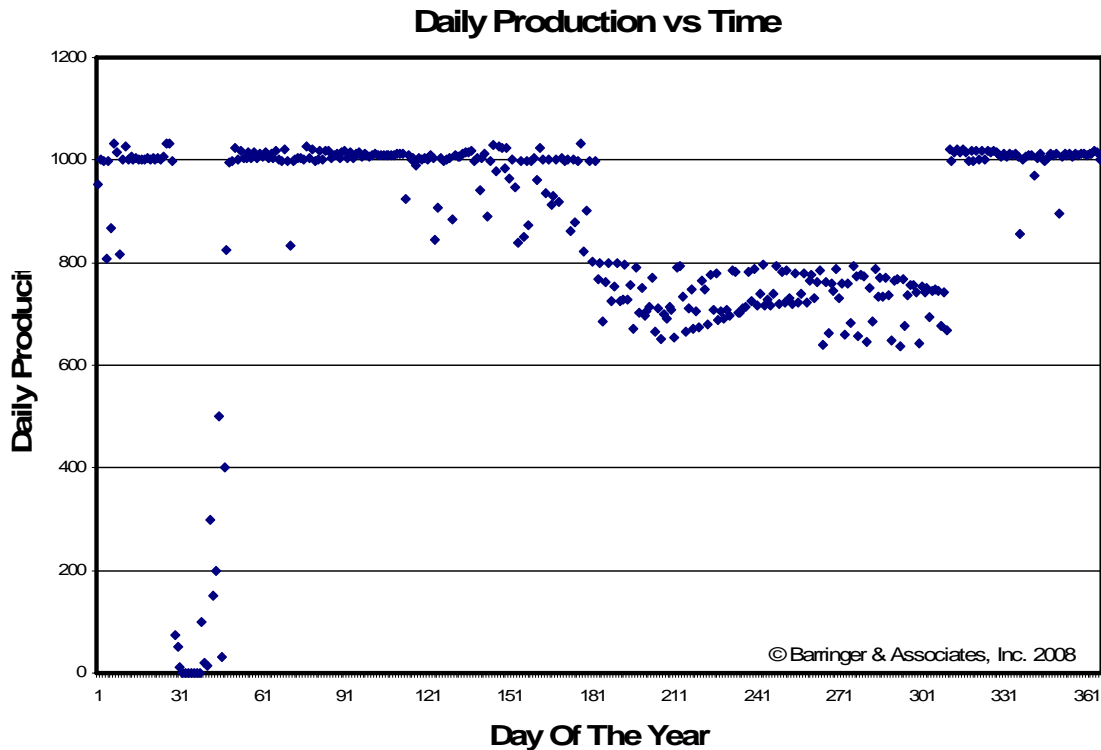
Zone G - Total downtime where zero output is represented by 2-logs lower output value, **special cause variations** predominate

Good processes display steep trendline slopes. Steep trendlines yield large beta values for line slopes, which in turn produce small variability due to common cause variations.

Good processes display consistent output for a high percentage of daily output, which in turn, demonstrates high reliability of the process. This means process output is predictable and variability is small. In Figure 1, production consistency is lost at the cusp, "C", where the reliability is 50%. Figure 1's data is plotted in rank order of output magnitude—in short, Figure 1 disconnects the time influence; and patterns of performance are displayed clearly.

Figure 2 shows production output in traditional time values as a raincloud plot (think of rain clouds seen on the Serengeti Plains at the beginning of the rainy season). Trendlines are not so clear as in Figure 1. One of the reasons you perform the Barringer process control analysis is to provide a clear signal of trends from common cause variability and special cause variability.

Figure 2: Production Output vs Time Plot—A Rain Cloud Plot for 365 days output



Zones A, E, and G from Figure 1 are reasonably clear in the Figure 2 time sequence plot. **Zones B, C, D, and F** from Figure 1 are not so clear in Figure 2. Thus corrective action is often deferred when using Figure 2 because of lack of understanding. Lack of understanding results in lack of a clear cut path for correcting the production disease.

Battle plans for corrective action require clarity for selling the plan! Figure 2's plan lacks clarity.

Variability in output from a process have two broad categories of reasons for the variability:

- 1) **Common cause variability** and
- 2) **Special cause variability.**

Each case requires a different "medicine" for corrective action. Furthermore, the skill level for the correction action is also different. See Table 1 for details.

Table 1: Characteristics Of Common Cause and Special Cause Variability	
Common Cause Attributes	Special Cause Attributes
Generally small variability in each measurement due to “natural” reasons. Common cause issues result in minor fluctuations in the data	Generally larger variability in each measurement due to “unnatural” reasons. A cause can be assigned for the fluctuations in the data.
Repeatable measurements are not the same because of typical variability caused by minute reasons for variability, i.e., you cannot generally and easily point to the reasons for variability however the variability is predictable by use of statistical distributions	Repeatable measurements are not the same because of larger variability caused by special events which you can touch, feel, or see as to the reason for variability, i.e., they are “easier” to observed differences which occur compared to common cause variability
The high values and the low values lack significance for their variability. The data make neat patterns	The high values and the low values have significant reasons for their variability; they do not make such neat patterns.
Common cause = chance cause = statistical control = stable & predictable = natural pattern of variability = variability inside the historical experience base	Special causes = assignable causes = systemic causes = unstable & erratic = unnatural pattern of variability = variability outside the historical experience base
Common cause variability is institutionalized and accepted as “that’s the way things are”	Special cause variability are sore thumbs that standout and are fixable. They are big surprises. They are “exceptions to that’s the way things are”
When the reason for common cause variability is identified, it becomes special causes	Many small special causes are identifiable but may be treated as uneconomical to correct or control
Often many causes are at play with each cause of seeming small importance which contributes to the overall common cause	Special causes have larger impact on variability of the system which result in much cause-effect variability such as failure of a compressor or a pump causing variable output
<p>Wikipedia gives the following 16 item list for common cause variability:</p> <ol style="list-style-type: none"> 1. Inappropriate procedures 2. Poor design 3. Poor maintenance of machines 4. Lack of clearly defined standing operating procedures 5. Poor working conditions, e.g. lighting, noise, dirt, temperature, ventilation 	<p>Wikipedia gives the following 11 item list for special cause variability:</p> <ol style="list-style-type: none"> 1. Poor adjustment of equipment 2. Operator falls asleep 3. Faulty controllers 4. Machine malfunction 5. Computer crashes 6. Poor batch of raw material 7. Power surges 8. High healthcare demand from elderly

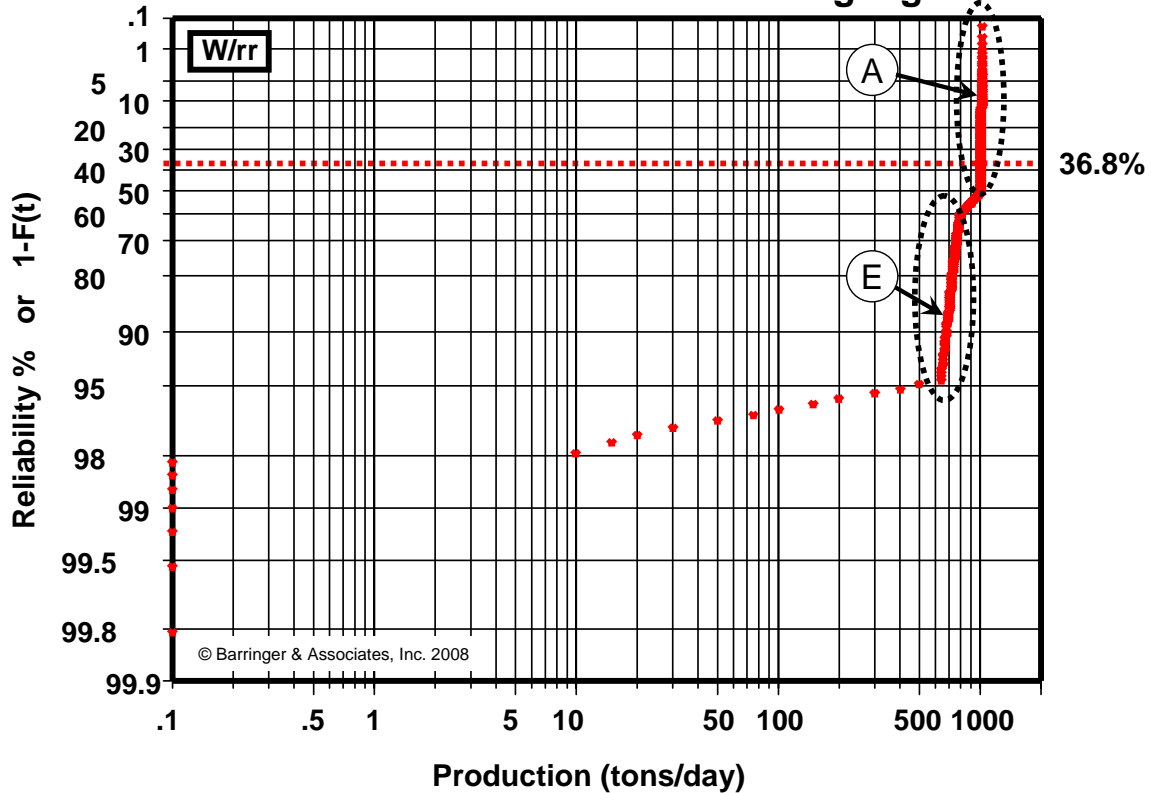
<ul style="list-style-type: none"> 6. Machines not suited to the job 7. Substandard raw materials 8. Assurement Error 9. Quality control error 10. Vibration in industrial processes 11. Ambient temperature and humidity 12. Insufficient training 13. Normal wear and tear 14. Variability in settings 15. Computer response time 16. Incompetent employees 	<ul style="list-style-type: none"> people 9. Abnormal traffic (click-fraud) on web ads 10. Extremely long lab testing turnover time due to switching to a new computer system 11. Operator absent
<p>Common cause variability is solved by management and six-sigma black belts—these problems of variability are difficult to solve because roots of the problems are not obvious</p>	<p>Special cause variability is solved by reliability engineers, maintenance engineers, front line supervision, and the hourly work force</p>

Figure 3 shows zones of common cause variability. Common cause variability is made up of many small reasons for variability, and specific reasons for the common cause variability have not yet been identified.

When an element of common cause variability is identified for corrective action, the variability is then converted to special cause variability. Why the shift? Because, roots for the variability have been identified and we can work to eliminate the specific problems.

Figure 3: Zones Of Smaller Common Cause Variability

Weibull Plot Of Daily Production Data With Common Cause Variations Highlighted



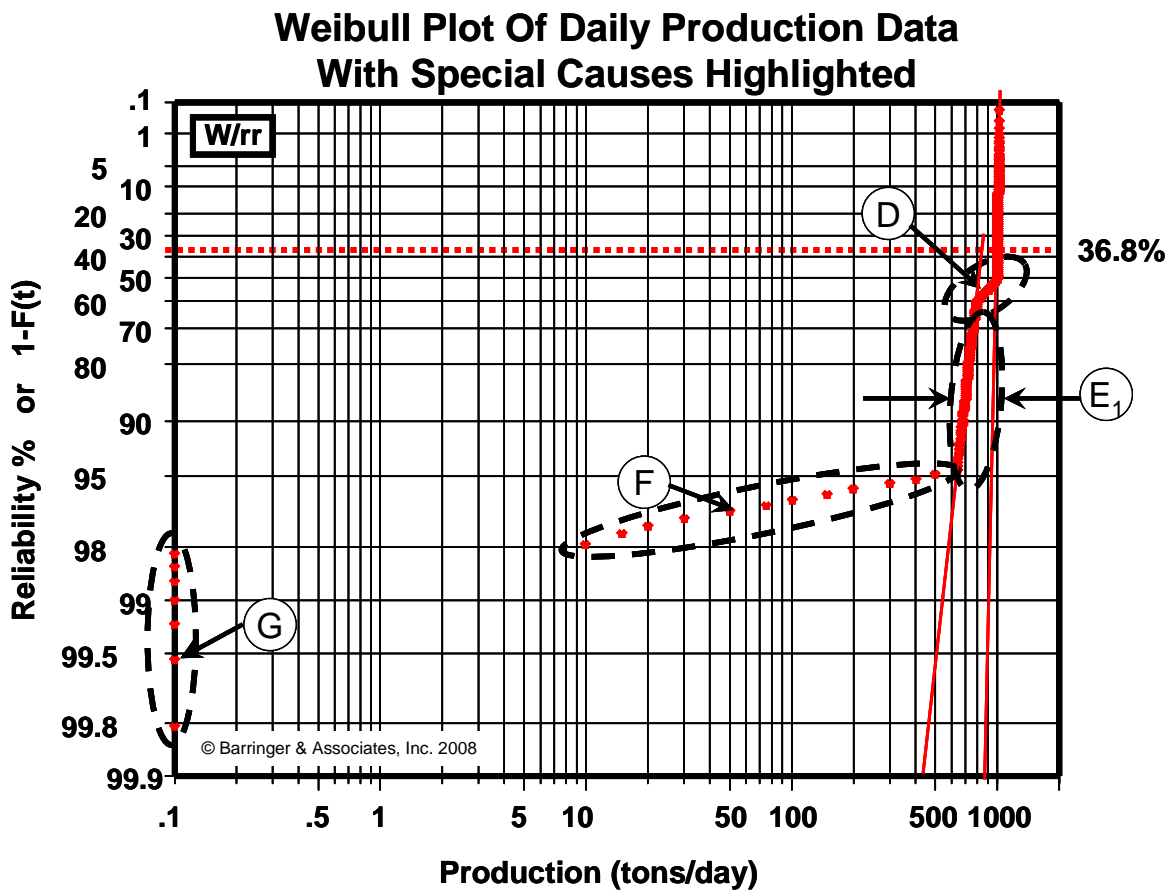
Zone A – Shows the least amount of common cause variability based on line slope, i.e., the beta trend line slope is steep (large beta)

Zone E - Shows a larger amount of common cause variability based on line slope, i.e., the beta trend line slope is less steep (small beta)—of course **Zone E** is translated to lower production output due to special causes.

Figure 4 shows zones of **special cause variability**. Special causes have names and known reasons for the variability. For example, “D” results from cutbacks and transitions from “A” to “E”, F” results from transitions into and out of a shutdown, whereas “G” is a shutdown period. You can put your finger on specific reasons for special causes but you cannot easily put your finger on specific reasons for common cause variations.

The Barringer process reliability plot makes common causes and special causes visible on Weibull production plots of daily production in ways that are difficult with a time series plot in Figure 2

Figure 4: Zones of Special Causes



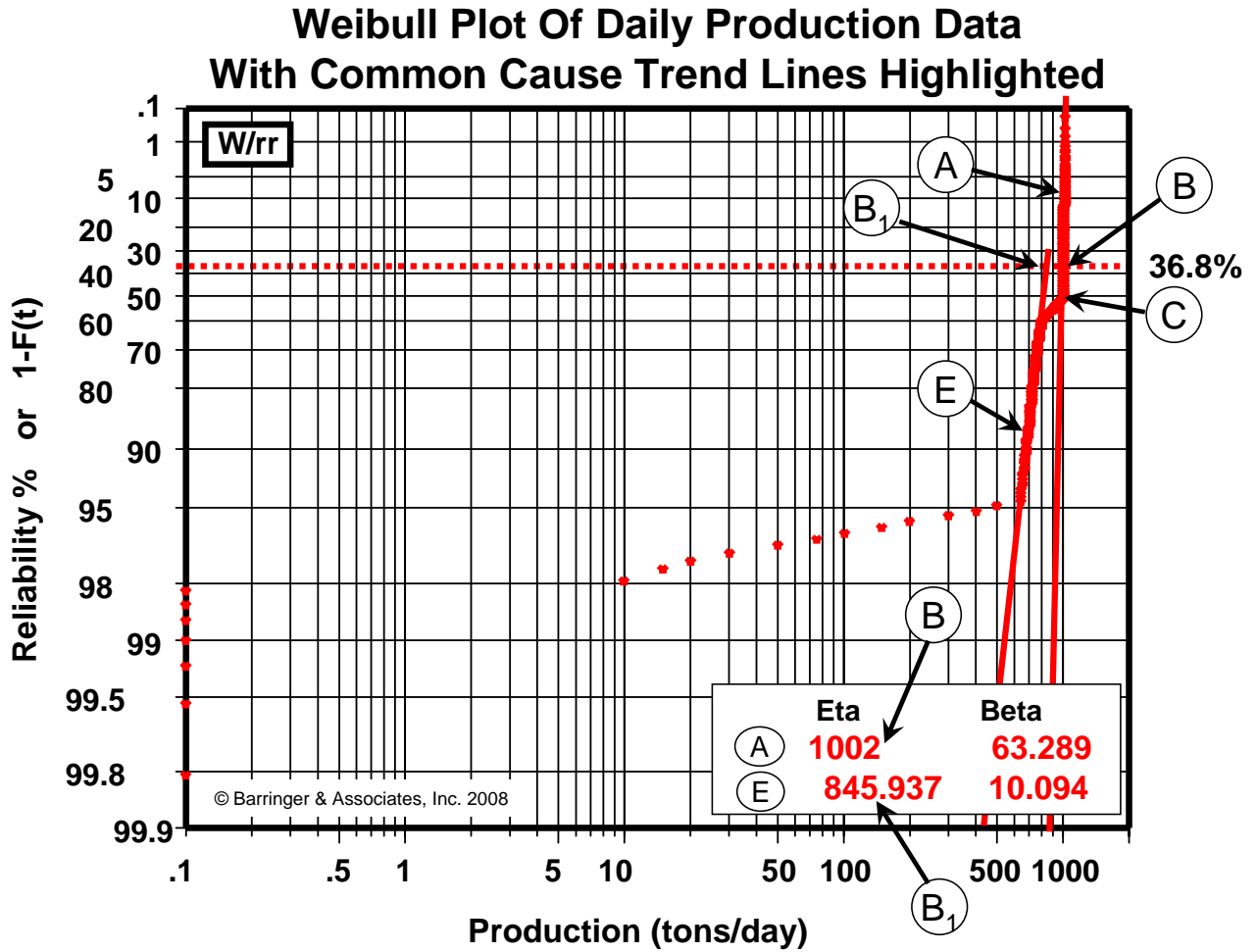
- Zone D** – Shows a transition between Zones A and E as production goes up/down
- Zone E₁** – Shows a translation of common cause variability for Zone E which has a reason for the gap
- Zone F** – Shows a transition between Zones E, and G
- Zone G** – Shows a shutdown zone. The 0.1 value on the log scale represents zero output.

Figure 5 is a Barringer process reliability plot with quantification. The characteristic output, eta, is 1002 tons/day representing the steepest trend line under good statistical control from common cause variability. Eta represents the single best estimate of the typical output. Eta is a descriptor for how much product is produced and measures the “size” of the process capability.

Eta is a mathematical property of the Weibull distribution which occurs at 63.2% CDF or 36.8% reliability where, regardless of the beta values, all trend line slopes will cross through this point when eta is known. The eta value of the demonstrated production line is the single value representing a typical day of output and it is a key performance indicator as described in the [May '98](#) problem. The second line segment “E” represents

a cutback of ~15% and shows eta = 845. In short, the common cause trend lines are quantified.

Figure 5: Quantification Of Common Cause Trend Lines



In Figure 5, the steepest Weibull line slope for common cause variability associated with “A” shows a beta at 63.289, this tells of small scatter around the trend line. The second steepest Weibull line slope for common cause variability is associated with “E” which shows beta at 10.094. Beta = 10.094 describes larger scatter due to common causes and thus lack of industrial discipline compared to data in “A”. The data for “E” is still in a state of statistical control but not as well behaved as for “A” due to common cause variability.

Line slopes for shape factor beta are described in the [February 1998](#) problem of the month concerning coefficient of variation, and in Table 2 of the [May 2001](#) problem of the month concerning flat beta values where Table 2 gives a summary of expected beta values.

Table 2: Typical Values Of Beta For Process Weibull Plots

Typical Beta Values Observed In Various Industries						
	Poor Control	Fair Control	Tighter Control	Excellent Control	World Class Control	Seldom Achieved
Beta→	5	10	25	50	100	200
Quartile Performance	Fourth	Third		Second	First	
Rule of thumb: Every time you double the value of beta, you cut your losses by ½ !!						

When beta is large, variability in the data is small; and when beta is small, large variability occurs in the data. Notice the typical output for segment “A” shows eta = 1002 but for the cutback line of “E” the eta value is cutback ~15% from “A” and is more unruly. In Figure 5, the beta values are benchmarkable and tell how good the process performs.

In Figure 5, point “C” describes reliability of this process as it is a single point on the Y-axis. This represents the maximum value on the Y-axis for consistently high output. Point “C” tell the reliability of the process, so it has single point meaning.

To the left of point “C”, the output is undesirably smaller which means that losses occur. We can calculate losses using [WinSMITH Weibull](#) software which sums the horizontal gaps between the production line and each data point to the left of the production line and south of the reliability point “C”:

Zone “D” (50% to 60%) = 3,417 tons in the transition zone
for 10% of production
Zone “E” (60% to 94.6%) = 31,084 tons in the cutback zone for 34.6% of
production
Zone “F” (94.6% to 97.9%) = 9,877 tons in the transition zone for 3.3% of
production
Zone “G” (97.9% to 98.1%) = 6,501 tons in the shutdown zone for ~2% of
production

50,880 tons lost due to reliability problems

These special causes reliability losses are equivalent to (50,880 tons)/(1002 tons/day) = **50.8 days** of equivalent output. These reliability losses are a portion of the hidden factory.

So what’s a hidden factory? A hidden factory exists in stealth mode creating waste which converts to losses. The hidden factory is fully funded for depreciation, utilities, etc. as we spend money for its existence but get nothing in return. Armand Feigenbaum, the quality guru, estimated the hidden factory may be 15% to 40% of the total effort. Learning-enabled organizations can see their hidden factories. Status quo organizations never can observe the hidden factory and have no plans for destroying the waste.

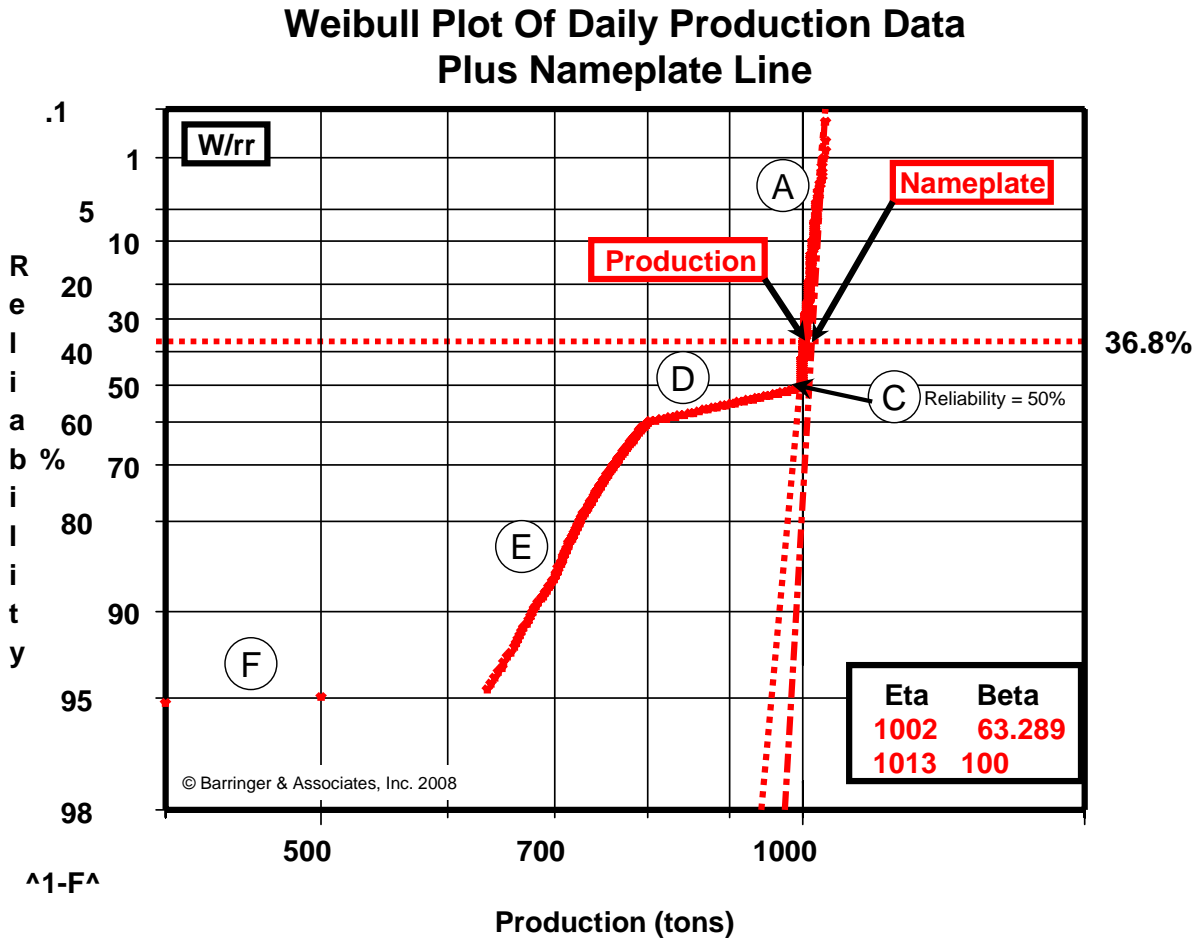
The Barringer process reliability technique quantifies the hidden factory to allow destruction of the waste so as to convert the waste to productive output. Learning organizations find the hidden factory and convert the wasted production into productive output. Status quo organization denies existence of the hidden factory, as the hidden factory is invisible and thus we are not aware of its existence. Hidden factories consume resources but produce no productive output. Destroy hidden factories for competitive advantage, or wasteful hidden factories will consume your profit opportunities and drag you into the mud.

The nameplate line (entitlement line in six-sigma parlance) will lie to the right of the demonstrated production line. In Figure 6 the nameplate line slope with $\beta = 100$ represents a world class performance based on the study of more than 1000 processes.

If you are a theoretical person you would think the line slope should be vertical ($\beta =$ very, very large) however, practical production people will ignore such theoretical ideas. This means nameplate line slopes are chosen so the powerful production “horse” will go after the nameplate “carrot”. When production makes improvements in the β value of the demonstrated production line, then the nameplate β also needs to be changed to a steeper value.

Adding the practical nameplate line allows calculation of the gaps between the nameplate line and the production line for another category of common cause variations. This gap is associated with efficiency and utilization losses. These losses are institutionalized and accepted by management as “this is the way things are in our organization”. Seldom are they clearly identified and seldom are they clearly attacked for elimination. However they are a separate category of hidden factory losses.

Figure 6: Nameplate Line Added To Calculate Efficiency And Utilization Losses



In Figure 6, the sum of the daily efficiency and utilization losses are 5261 tons or **5.3 days** of lost production. Remember again, these losses are common cause losses due to efficiency and utilization. These losses are directly under the control of management because they allow them to happen.

The **system effectiveness** = (production output)/(production output + hidden factory losses.) = $312,695.7 / (312,695.7 + 50,880 + 5,261) = 312,695.7 / 368,836.7 = \mathbf{84.70\%}$.
 The hidden factory losses = $50,880 + 5,261 = 56,141$ tons/year.

Computer output from the process reliability analysis in WinSMITH Weibull shows the following:

- Barringer Process Reliability
- Total Production = 312,695.7 (tons/year)
- Production Line = Eta 1002, Beta 63.289
- Nameplate Line = Eta 1013.243, Beta 100
- Total Reliability (50-100%) Loss = 50,880 (tons)

Process Reliability (%) = **50**

50-60%: Loss = 3,417 (tons)

60-94.6%: Loss = 31,084 (tons)

94.6-98%: Loss = 9,877 (tons)

98-100%: Loss = 6,501 (tons)

Efficiency + Utilization (Production - Nameplate) Loss = 5,261 (tons)

From these details you get:

Hidden Factory Losses = 50,880 + 5,261 = 56,141 (tons)

System Effectiveness = $312,695.7 / (312,695.7 + 56,141) = 84.8\%$

To make these techie facts speak loudly, you must convert them to money issues. Suppose the profit opportunity (gross margin) is \$400/ton. Then the information becomes:

Barringer Process Reliability

Total Production = 312,695.7 (tons/year) → Gross margin produced is
\$125,078,280

Production Line = Eta 1002, Beta 63.289

Nameplate Line = Eta 1013.243, Beta 100

Total Reliability (50-100%) Loss = 50,880 (tons) → Gross margin losses from reliability problems is
\$20,352,000

Process Reliability (%) = **50**

50-60%: Loss = 3,417 (tons) → Gross margin losses are **\$1,366,800 = Zone D**

60-94.6%: Loss = 31,084 (tons) → Gross margin losses are **\$12,433,600 = Zone E**

94.6-98%: Loss = 9,877 (tons) → Gross margin losses are **\$3,950,800 = Zone F**

98-100%: Loss = 6,501 (tons) → Gross margin losses are **\$2,600,400 = Zone G**

Efficiency + Utilization (Production - Nameplate) Loss = 5,261 (tons) → Gross margin losses are **\$2,104,400**

From these details you get:

Hidden Factory Losses = 50,880 + 5,261 = 56,141 (tons) → Gross margin losses from the hidden factory are **\$22,456,400**

System Effectiveness = $312,695.7 / (312,695.7 + 56,141) = 84.8\%$ produces
\$125,078,280
of gross margin
@ 100% effectiveness
would produce
\$147,534,680 of gross margin

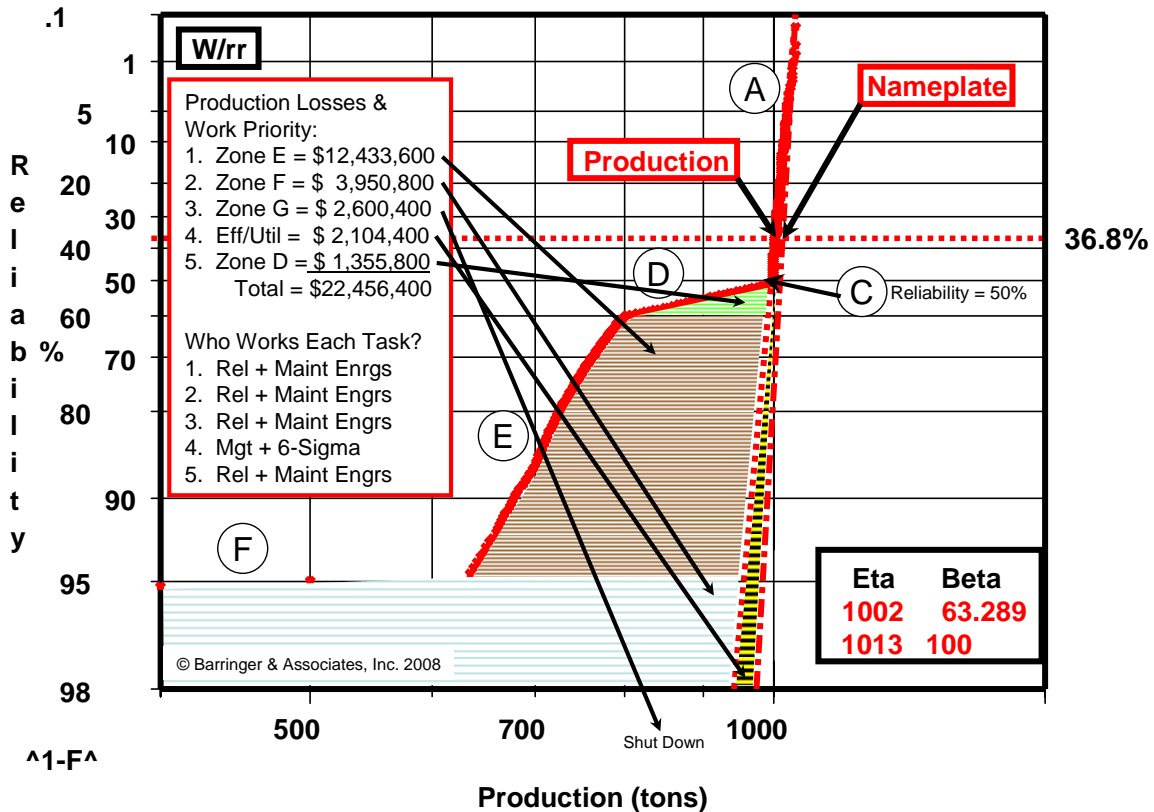
At this point you may say:

1. I know most of this information
[but I did not know all of the details]
2. I have my Pareto list based on failures
[failures only count for the gear-heads—but money counts for the business!
[Build Pareto losses based on money.](#)]
3. I know my production losses
[convert units of production to financial impact]
4. I know my lost profit opportunities
[include the losses from the hidden factory]
5. Most of the issues stay the same each year
[so you really haven't solved anything—you only **talk** about solving problems!]

If you know these details without use of the Barringer process reliability technique, why haven't you solved the problems and moved on to the next most serious problem—conversation doesn't produce profits, finding the problems and resolving them produce profits?

The usual reason for unresolved problems is you have not motivated top management to make these issues THEIR high priority. In short, we have not motivated the team for solving a money issue problem. Generally we continue to present techie issues to management but we need to first present the financial motivation for solving the problems and how the technology is going to help us resolve the issues. Bottom line: we need an effective sales campaign for motivating problem solving efforts. Too often we're like the typical gear-head engineering student who knows 500 detailed sexual positions from the Kama Sutra but can't get a date for Saturday night! Use the KISS principle, and get the sales pitch onto one page for management. Figure 7 is your sales pitch for a \$22,456,400 problem to resolve! It tells you the skill set you need for the problem.

Figure 7: Pareto Distribution and Skill Set For Solving Problems
Weibull Plot Of Daily Production Data
Plus Nameplate Line



Now the task becomes finding what the enemy looks like, where it's hiding, and identify what specific tools will route out the devil in the details. Figure 7 is your battle plan. Now solve it using the skills identified. Report the solution in \$'s saved and when they are saved. Don't give me vague details about good things that could or might happen. Show me the money!

For other Barringer process reliability articles and examples:

- [Summary Of Process Reliability](#)
- [Process Reliability Punch List](#)
- [Production Output/Problems](#)
- [Six Sigma](#)
- [Coefficient of Variation](#)
- [Production Reliability Example With Nameplate Ratings](#)
- [Key Performance Indicators From Weibull Production Plots](#)
- [Production Nameplate Rating](#)
- [Process Reliability Plots With Flat Line Slopes](#)

- [Process Reliability Line Segments](#)
- [Automating Monthly Weibull Production Plots From Excel Spreadsheets](#)
- [Papers On Process Reliability As PDF Files For No-charge Downloads](#)
 - [New Reliability Tool for the Millennium: Weibull Analysis of Production Data](#)
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