Chapter 8: Quality Standards for Failure Prevention

The following three extracts are taken from sources discussing industrial plant and equipment failures.

1. Many managers and engineers believe most failures have a root cause in the equipment. Data from nuclear power plants (which maintain a culture of confessing failures and the roots of failures—this is in opposition to most industries were the culture is to hide the roots of failures) show the following roots for failures:[1]

Early in the life of nuclear power plants:

Design error	35% [people induced problems, not calculation errors]
Random component failures	18% [process/procedure problems]
Operator error	12% [people/procedure problems]
Maintenance error	12% [people/procedure problems]
Unknown	12%
Procedure error & (procedure) unknowns	10%
Fabrication error	1% [people/procedure problems]
	100%

Mature nuclear power plants:

People	38%
Procedures & Processes	34%
Equipment	28%

100%

2. ASME (2002 report) shows a similar root for failures. For 10 years, from 1992–2001, 127 people died from boiler and pressure vessel accidents and 720 people were injured. In the 23,338 accident reports, 83% were a direct result of human oversight or lack of knowledge. The same reasons were listed for 69% of the injuries and 60% of recorded deaths. Data shows that if you concentrate only on the equipment, you miss the best opportunities for making improvements. Another point to seriously consider is little or no capital expenditures are required for improving people, procedures, and processes which can reduce failures. In case you believe that equipment is the biggest root of problems it will be instructive to download (http://www.bpresponse.com) the Final Report of BP's Texas City Refinery explosion and tick off the reasons behind the explosion which took the lives of 15 people and maimed more than 200 additional people—you will see objective evidence for people, procedures, and processes as the major roots for failures. The #1 problem was not equipment[2]!

3. The major challenge to reliability theory was recognized when the theoretical probabilities of failure were compared with actual rates of failure [and the] actual rates exceed the theoretical values by a factor of 10 or 100 or even more. They identified the main reason for the discrepancy to be that the theory of reliability employed did not consider the effect of human error . . . Human error in anticipating failure continues to be the single most important factor in keeping the reliability of engineering designs from achieving the theoretically high levels made possible by modern methods of analysis and materials . . . nine out of ten recent failures [in dams] occurred not because of inadequacies in the state of the art, but because of oversights that could and should have been avoided . . . the problems are essentially non-quantitative and the solutions are essentially non-numerical.[3]

The proportions indicated in the extracts have been consistent for decades. The United States National Board of Boiler and Pressure Vessel Inspectors 2014 Incident Report records 87 deaths from 2002-2009 due to pressure equipment failures—an average rate of 11 deaths a year, much the same as the 1992-2001 period.[4] The 2008 Federal Aviation Administration "Aviation Maintenance Technician Handbook" indicates that the ratio of 80% of aviation accidents being caused by human error and human factors to the 20% due to technical problems has stabilised over recent years.[5]

The foregoing extracts provide evidence that most of the problems we have with our physical assets are not caused by the plant and equipment. Our machines are fine. Most of our problems are caused by ignorance and poor business processes. Poor equipment reliability, poor maintenance, and poor production performance are in the confused minds of those who control our companies, design and manage our business processes, and run and maintain our machines. The conclusion from the evidence presented in the three extracts is that an organization mostly causes equipment failures that are not "acts of God." To make serious improvements to plant and equipment reliability, you first need to focus all efforts and resources on changing your business so that it uses the right beliefs and practices. The business needs to change the way people think about and value quality and reliability.

Recall W. Edwards Deming's famous advice: "Your system is perfectly designed to give you the results that you get!" His admonition explains why an organization gets the results that it does; they were designed into the business system and the bad results were never designed out! If you don't want reliable equipment, simply don't tell your managers, engineers, operators, and maintainers how to deliver reliability. If you don't want a successful business, simply let your capital project people focus on delivering projects for least installed cost and ahead of schedule. The "human factor" will make sure you get a matching level of equipment performance. Moving from a repair-focused organization—one in which failure is seen as inevitable, maintenance is a servant to failure, and reliability is the responsibility of an "elite"—to a reliability-focused organization with a culture of failure elimination that permeates staff at all levels requires a mind-set change.[6] Such change is driven by a passionate management for as long as required until it is embedded in organizational processes and become workplace habits.

You start changing to a reliability culture by first designing the right processes and systems needed in your business. Then you educate your people and teach them to use right thinking and do right practices. Finally, you install the changes in the operation and make them standard practice. Consider this quotation about causing change in organizations: "Changing collective values of adult people in an intended direction is extremely difficult, if not impossible. Values do change, but not according to someone's master plan. Collective practices, however, depend on organizational characteristics like structures and systems, and can be influenced in more or less predictable ways by changing these."[7]

You cannot change peoples' internal values, but what you can change is the practices they must follow so that their cognitive dissonance brings about a change in their values. Cognitive dissonance is the uncertainty and unhappiness you feel when you believe one thing but are forced to do something else. For example, to get your people to do high-quality work, provide a procedure with the quality standards that they must meet. Get them to complete a report sheet confirming that they achieved the required quality so that you train them to do masterly work. If, when a procedure is followed exactly, users produce better results than they ever achieved without it, they will start to change their beliefs. Their old internal values will fade because the external evidence does not support them. This is cognitive dissonance in action. In this way, the quality requirements that are built into your procedures bring about the necessary change in the value that people put on careful observation, quality workmanship, and accurate recording. You use your standard operating procedures to describe and create the "role model" that you want your people to follow.

Unwanted variation produces the defects that cause failure—that was the message in Chapter 3, "Variability in Outcomes." The challenge for a business is to control variation to within the limits that produce good results. If too many outputs are unacceptable, a process produces excessive losses. Such a situation is wasteful, and the process needs to be investigated to understand the causes of the problem so it can be properly corrected. A successful resolution will alter the output spread so that all products are well within the specification. The output range will change from a volatile distribution to a more stable one, as shown in Figure 8.1. Now all output from the process meets specification.

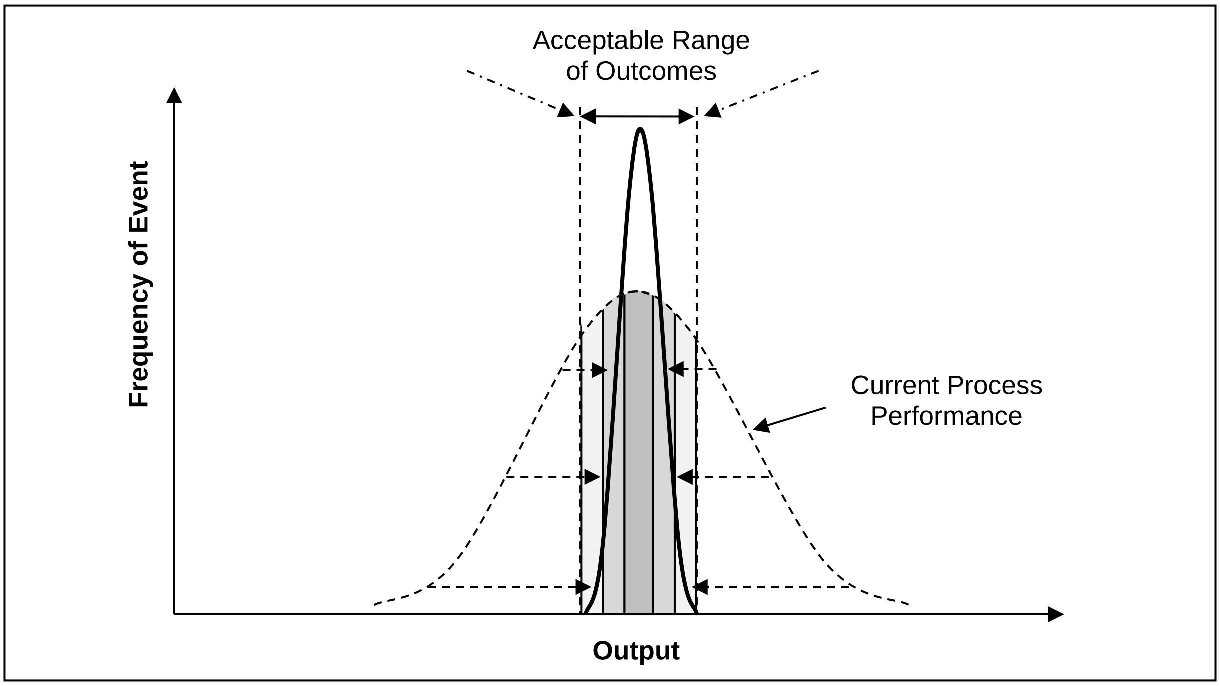

Figure 8.1—The Effect of Removing Volatility from Processes

Weak business processes produce continual problems by allowing new opportunities for unwanted variations to arise and create defects. They compound the size of loss and waste by permitting their transmission throughout the business and into its future. Figure 8.2 indicates that every process in a business can produce variable outcomes, which feed into downstream processes. Any defect created in a process travel through the business, causing quality problems that may require a product or service to be rejected or corrected. If that happens, all the work, money, and resources used to make and provide it are wasted. If that error becomes a future trouble that annoys or hurts customers, you'll need to recall and fix it at your cost.

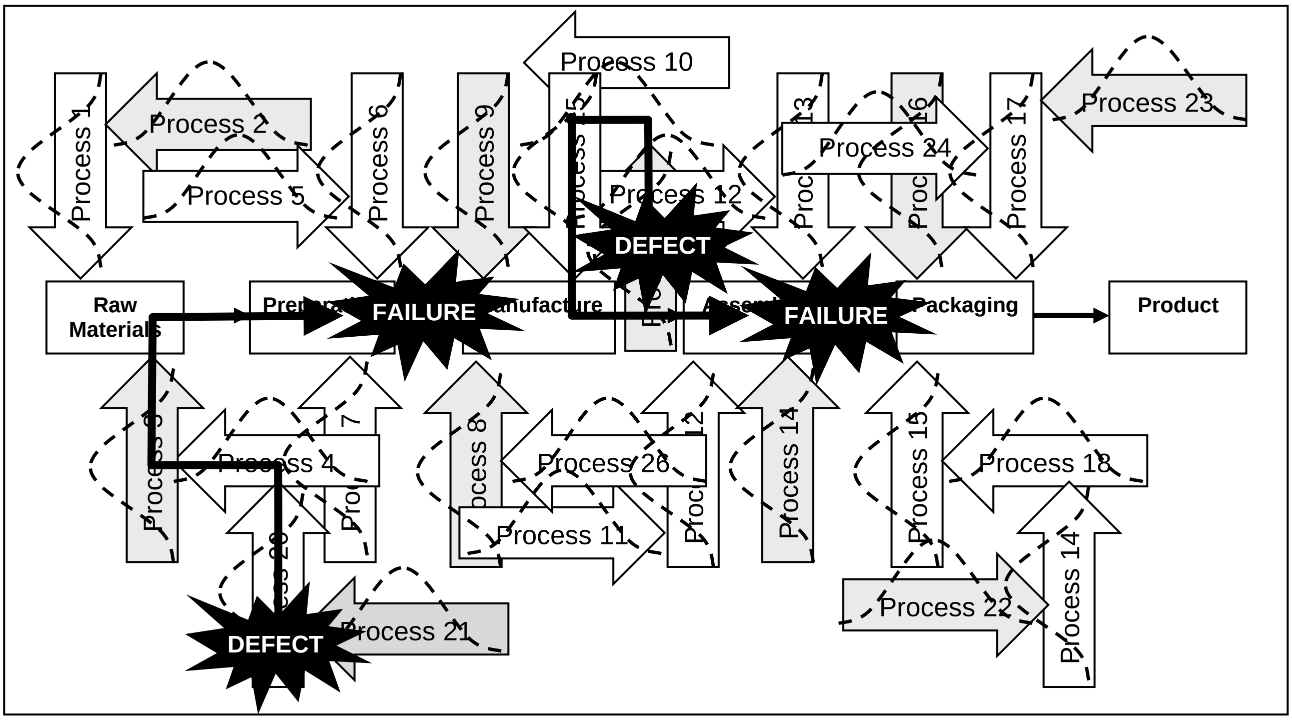

Figure 8.2—Processes That Allow Wide Variation Produce Many Defects

The Need and Purpose of Standardization

In his books, Deming was concerned about the impacts of variability on business. He knew from industrial experience that variability causes great waste, inefficiency, and loss. Starting in 1950, Deming taught industrial statistics to Japanese industry, including the use of process control charts to identify changes in processes so that corrections can be made before production quality deteriorates out of control. The Japanese managers, engineers, and supervisors learned well, and by the 1960s, Japanese product quality was renowned worldwide. The Japanese were gracious and willingly told the world what they had learned. During trade visits to high-quality Japanese companies, the Japanese hosts explained to visitors the factors they believed had made the greatest difference.[8] One factor was regularly identified as the most important: standardizing a process so that there is one way—and only one way—that it is done.

What had the Japanese learned about variation that Western business managers had not? The Japanese saw that output variation is either the natural result of using a particular process (called common cause variation because it is inherent, or common, to a process) or caused by factors external to the process that change performance (called special cause variation because the variability is identifiable as particular to a situation). The Japanese also noticed that the extent of the output spread is dependent on the amount of volatility permitted in a process. If many methods of work are used, each introduces its own effects. Each method causes the final process output to be slightly different from that of the other methods. But when one standard method is used, the outputs are less variable.

The difference in output distribution between a standardized method and the use of many methods is shown in Figure 8.3. Standardization greatly reduces variation. Once a method is standardized, the use of any other way is an external special cause factor, easily identified and corrected by training if it produces volatility, and gladly accepted into standardized practice if it reduces volatility.

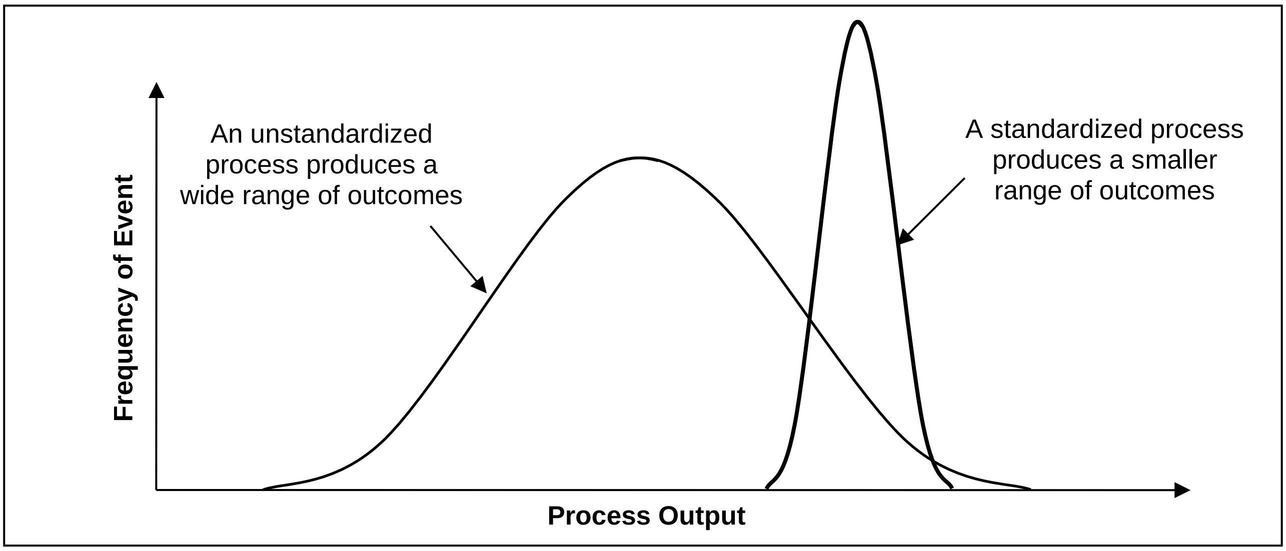

Figure 8.3—The Effect of Applying Standardization on Process Results

However, standardizing does not ensure that the process is the best solution for achieving the requirements. In Figure 8.4, the process produces fewer variations, but its output is not to specification.

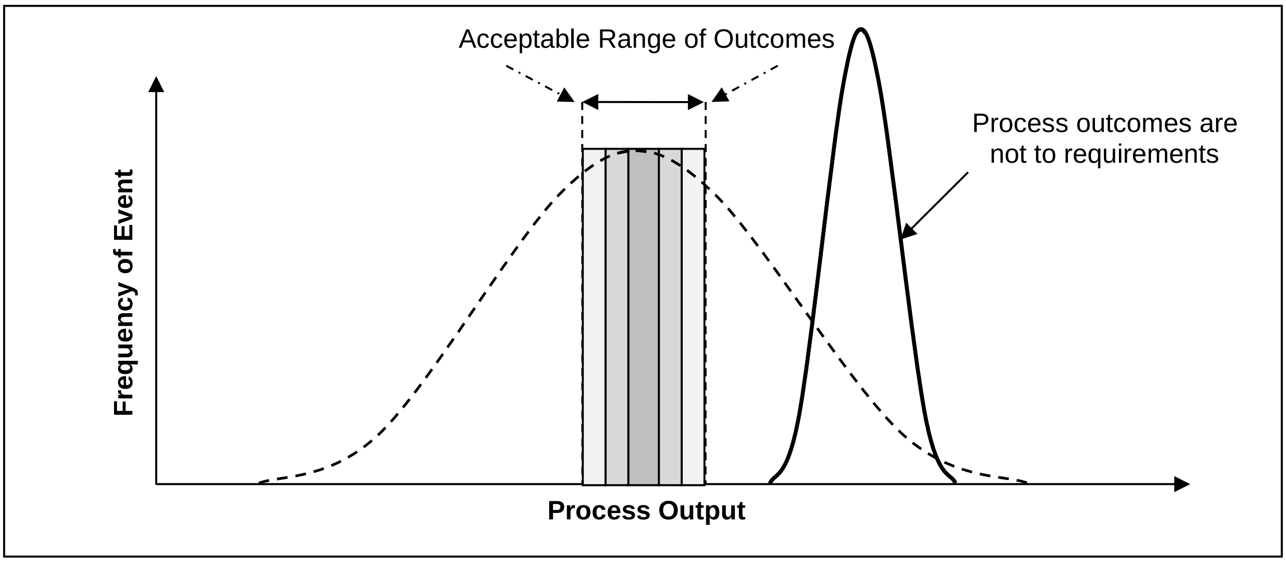

Figure 8.4—Low Variation but Output Is Not to Specification

In such cases, the Japanese repetitively applied the Deming PDCA Cycle (Plan-Do-Check-Act) to test new methods and learn which produced better results. Through experimentation, testing, and learning they continually improved a process until the outputs met the requirements. The approach used by the Japanese[9] to build high-quality processes is shown in Figure 8.5.

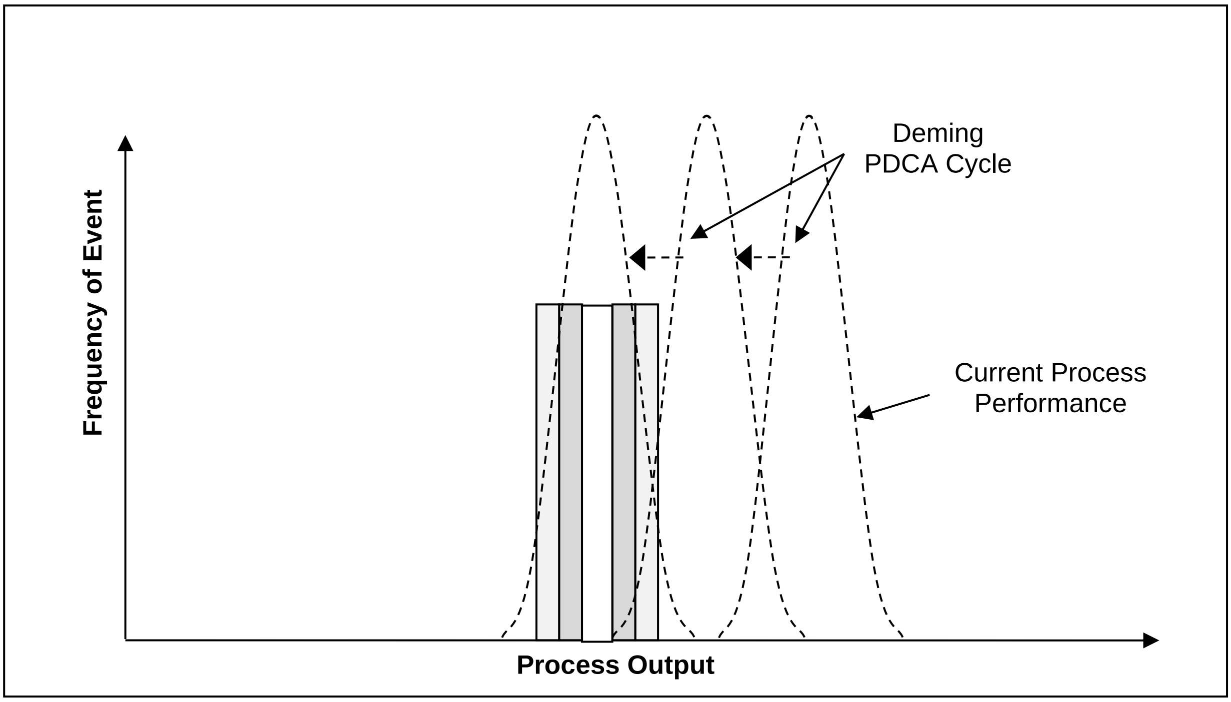

Figure 8.5—Altering Process Performance to Get Desired Results

How to Use Standardization in Your Business

Japanese industry learned that they could change their business processes to produce the results they wanted. It did not matter how much variation existed—if it was attributable to the process, they changed and improved the process. If variation was attributable to external special causes, they found and removed them. Figure 8.6 illustrates how to create a process with excellent outcomes, no matter where you start.

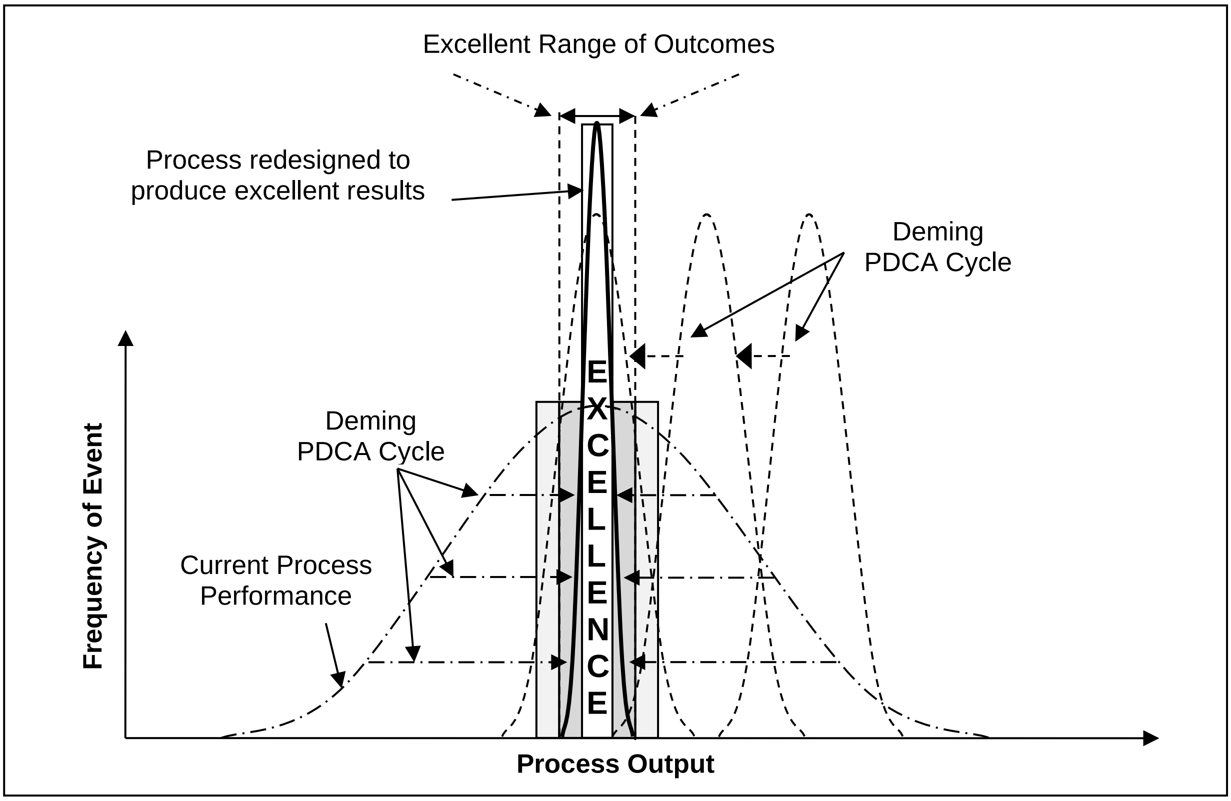

Figure 8.6—Processes Can Be Changed to Deliver Excellence

First, identify what is excellent performance and set limits on its allowable variation. If the current process cannot deliver the required results, then redesign it and standardize it so that there is one way—and only one way—for that process to be done. Use run charts and, if necessary, statistical process control charts to monitor the process and its variables. Process control charts help you find special causes that prevent excellence and remove them. Make the changes and run the new process. If the new standardized process does not meet the requirements after all special causes have been removed, then the process is not capable of doing so. Because it is a process problem preventing achievement of the requirements, the process needs to be redesigned so that it can deliver the necessary quality. With each running of the process, new learning takes place. This learning is used to decide how to change the process to deliver improved performance. The process is again modified and run. This "scientific method" of process development and improvement is repeated until it produces the required results. This is how the Japanese achieved world-class quality and cost performance.

If a business process produces excessive errors—for example, if there is too much rework because of poor quality—it is vital to investigate whether the process failed because of a common cause problem or a special cause problem. In his book *Out of the Crisis*, Deming provided an example of analysing the error rate per 5,000 welds from 11 welders.[10] Figure 8.7 depicts his analysis on a statistical process control chart. Deming calculated the process error limits and put the upper control limit at 19, indicating that process error naturally falls between 0 and 19 errors per 5,000 welds. Any results with fewer than 19 errors per 5,000 welds were within the process variation and considered normal results for the process. Nothing could be done about the variation because that was how the process was designed—it would create anywhere from 0 to 19 errors because of its natural volatility. Those results outside of the process limits were attributable to a special cause that had to be corrected. Only the performance of Welder 6 is unexplainable; all the other welders made no more errors than the system was designed to make. Special causes requiring correction affected the performance of Welder 6.

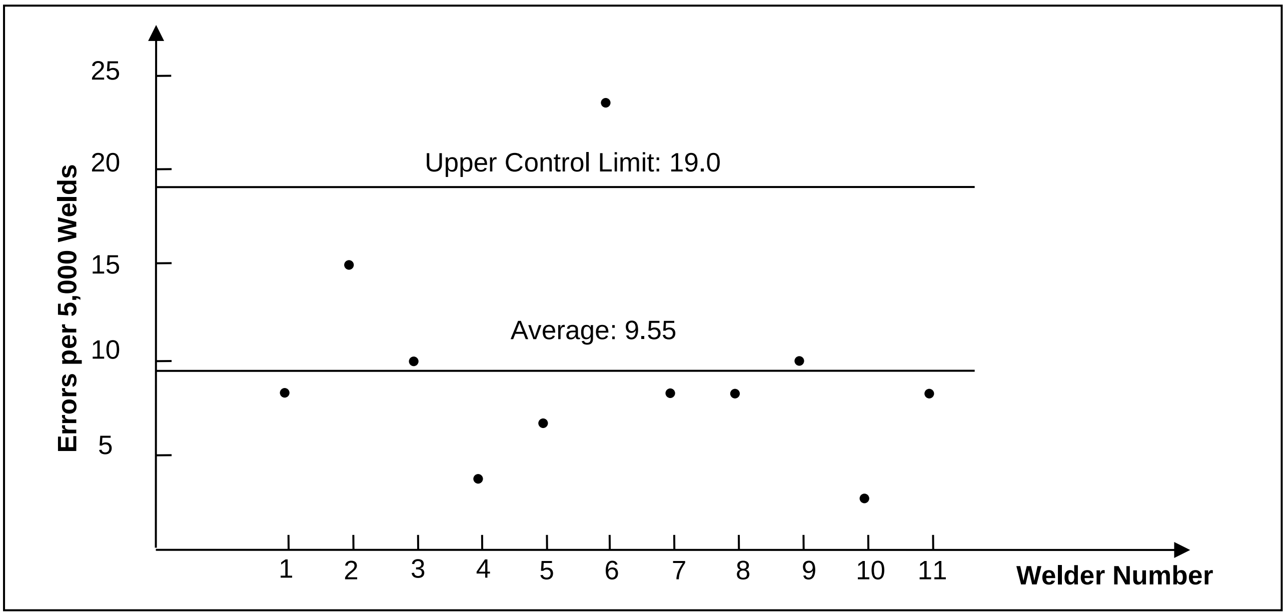

Figure 8.7—Welding Process Control Chart

The control chart is used to show the problems in a process and to understand how it works. Error in a process is a random event, and the probability of errors forms a normal distribution. By showing error on a control chart and defining the three-sigma limits of the distribution of the data, you can immediately see whether the error is likely caused by system volatility or by something outside the system. If it is a system cause, then the data fall within the natural distribution of errors produced by the system—that is, within the number of errors expected when the process is running normally. A system error is no one's fault—it's simply a function of the system design.

Deming did not blame people for poor performance. He knew that the vast majority of faults result from the system design in which the people work (by his estimate, 94% of errors are system caused). Deming suggested that the investigation of Welder 6 consider two issues. The first is to look at the work stream to see whether it is exceptionally difficult material to weld or the welds are in difficult locations. If the job difficulty is the problem, then no more needs to be done because the problem is not with the person, and as soon as the job returns to normal, the welder's performance will, too. The second issue to examine involves factors such as the condition of the equipment being used, the quality of the welder's eyesight, and other personal handicaps, such as problems at home or with the welder's health.

To get fewer weld failures from the whole group of welders, it is necessary to change the design of the process to produce a lower average number of faults. Figure 8.8 shows the measured welding results if the frequency of failures matches a normal distribution. It also shows the new distribution when the process is redesigned to produce an average of 4 faults per 5,000 welds. To move from the current average of 9.55 faults to an average of 4 requires an improved process with much less variation than the existing one. Deming said that "overall improvement . . . will depend entirely on changes in the system, such as equipment, materials, training." He listed possible factors to consider, including getting the eyesight of all welders tested, reducing the variation in material quality, using material that is easier to weld, providing improved welding equipment, developing better welding techniques, and retraining poor performers in highly effective welding techniques.

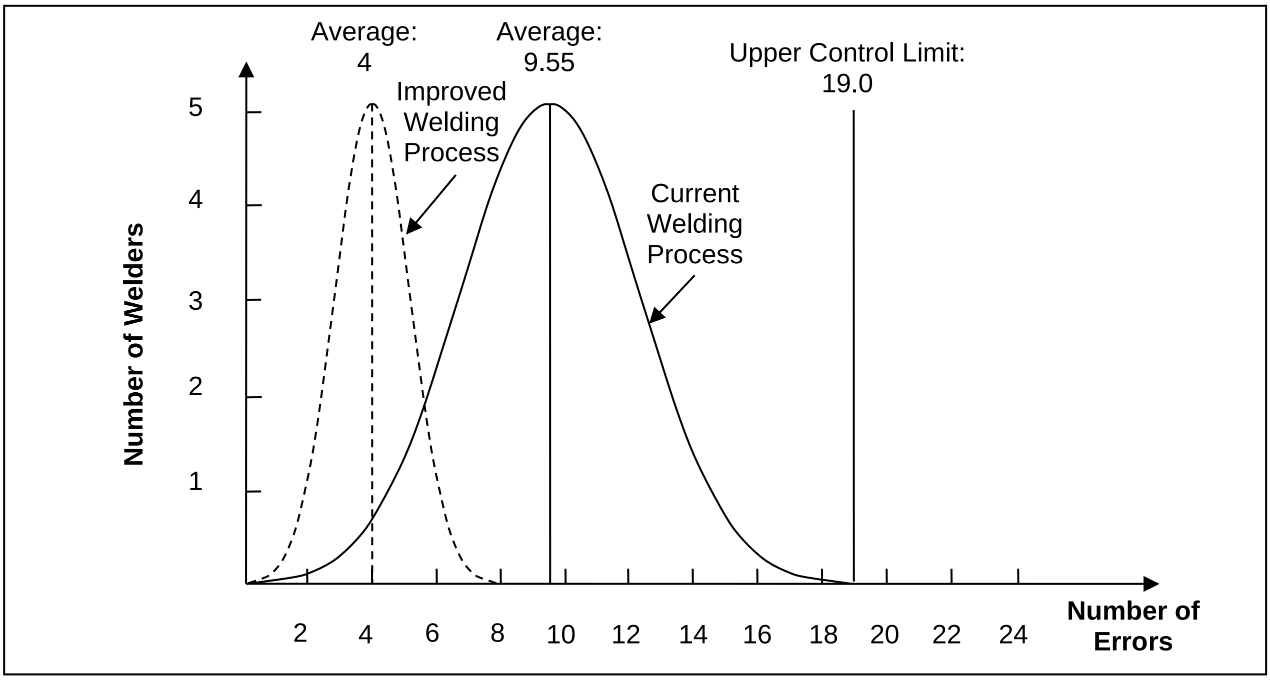

Figure 8.8—Welding Fault Distribution

It was Deming's goal to help businesses learn to control variation in their processes so that their outcomes would always produce top-quality products that customers loved. To have an operation in which great results are natural and excellence abounds, it is necessary to ensure that variation in a process is controlled to within the limits that deliver excellence. Doing so requires that a standardized system of producing excellence is developed and then followed. In a series process, that means accuracy in every step, without which you cannot get excellent process outputs. World-class operations recognize the interconnectivity among processes and work hard to ensure that everything is right at every stage in every process.

Script the Future That You Want

It is our job as asset managers to help our business learn to control life-cycle process variation to the quality results that achieve world-class equipment reliability. Variation is controllable when management sets clear and precise standards. To attack unwanted variation, specify exactly what is required and exactly how to get it; script in detail what must be done to get the desired results. The best practices to achieve those results are then developed by management and workers in collaboration and taught to the people who need them. Those best practices represent the one agreed-upon way to do a job so that variation stays within quality limits. Developing a definitive script of how to do excellent work is the starting point for delivering supreme performance. Achieving success is almost certain once you know what to look for and you have a map of how exactly to get there.

Your planning begins with a description, in words and diagrams, of how your assets will be made highly reliable. It's the same way that movies are made. First the script and storyboard are developed, using words and drawings to explain what the film is about. Only after it is decided what the picture is about and what will happen in the film can the budget be allocated, the sequences shot, the story edited, and the movie released. To create a successful operational future with reliable plant and equipment, you first need a plan with a full set of process maps and procedures to follow so that everyone knows how equipment reliability will happen in your business.

Scripting the future success of an operation starts by setting the required engineering, production, and maintenance quality standards that you will meet. Decide what standards your people, plant, and processes need to achieve and write them into your processes and procedures so that everyone knows what they are. That becomes the level of quality that everyone works toward. Going below those quality standards increases risk to the operation from equipment failure, from wasted production processing, and from poor work task performance. By scripting the quality standards, you apply Series Reliability Property 3 (see Chapter 1) to a business—the series reliability property that delivers the greatest benefits—because setting a quality standard drives improvements in an operation until it is achieved. Without touching a piece of plant or machinery, setting a higher reliability standard decrees the future performance of all equipment and processes. Anything that is not up to the specified standard is changed and improved until the standard is met.

Set the Risk Management, Behaviours and Quality Standards Required

In the end, a library of procedures with standards for all jobs and activities in every department, from board room to shop floor, is needed.[11] Everyone works to quality-controlled procedures. Nothing is left to chance—even the office clothing standard. If variation is acceptable in a job, the procedure will specify the amount of variation permitted. When accuracy and precision are required, the procedure will document and record them and explain task by task exactly how to achieve the required level of excellence. Everyone knows what great performance and world-class results look like because they are described for them exactly. Once there is a script outlining what is a great result, people put plans and actions into place to get there.

Use your organizational policies, process documents, job procedures and work instructions to define and create the workplace culture you want. Include the personal behaviours and etiquette needed when doing a job in its procedure. Include into the work instructions for every task all the applicable workplace management practices to use, such as workspace cleanliness, the return of tools and parts to the store, the correct arrangement of parts for the job, even the way to stand and move when working. In every document used to run the business specify the role model actions and practices and script the right steps to take to get the most successful results. Tell your people exactly what a great job looks like and give them clear, written instructions that take them to total success.

You document and explain the exact details of how all your business processes will be run and the task behaviors to use because it’s the most certain way to get the business outputs you want. The current best method to do every task must be set in writing so you know what it is and the people that do the work use the most effective and efficient practices on each job. The descriptions must be written precisely as things needs to happen. Find people knowledgable and competent in the work to compose these documents and give them the time to sit down, research, and write the standards, work procedures, and checksheets you need. Once the documents are drafted, test them in the workplace and correct them from the experience. Rewrite them and retest them until they consitently produce the correct results. Once the standards are set and the procedures are proven, they will provide the training strategy for the business. Anyone who cannot meet the quality standards must undergo training to achieve the level of mastery needed to do their work excellently. With certain repeatability in meeting standards, you have in-control and capable processes.

Without business excellence documents, and the accurate procedures containing best practices that stem from them, there will be numerous interpretations of what is acceptable performance. Lack of clarity breeds variations, defects, problems, and “firefighting,” as one thing after another goes wrong. By having documented procedures explaining step by step how to do masterly work and get ideal quality, you introduce and apply defect elimination and failure prevention throughout your business. With standardized procedures, variation is controlled, and better methods can be developed to refine and make tasks more effective and efficient. The company documents imbed the culture of excellence that it wants so the right habits become the workplace practices used. You cannot do without world-class procedures if you are to be a world-class operation.

No one will make you design your work processes. No one will make you add the quality controls to get them right every time. Nobody will make you describe the workplace culture you need in your company. Many managers think it is enough to explain things and then let their people sort out the problems. That is how managers create an "also-ran" business—they mistakenly think that defining excellence is not a prequisite for becoming a world-class operation. They are wrong, of course, and their thinking explains why they and their people are average. They will remain "also-rans" until their values and beliefs change and they do the work that is necessary to deliver highest-quality results.

Another mistaken belief is to see detailed documented procedures as the death of creativity. Many people think they know everything they need to know about their job and the best way to do it. They maybe right—they do know one way to do their jobs. Whether it is the best way depends on whether they have kept up with growing knowledge in the fields of research and technology that apply to the job and have regularly introduced better ways to work. A world-class company challenges its people to find better methods. It knows the people doing a job are its resident experts and encourages them to use their creativity to discover superior solutions. Creativity does not die once procedures are introduced; rather, it is funneled into continually improving them toward still better quality, at ever lower cost, at faster production rates, and with higher productivity.

Make Things Visual

To control variability, it is first necessary to see it. This means observing the variables and their effects on process performance. A variable is any factor that influences the outcome of an action, process, or decision. If the effects of a change in a variable are to be observed, the change needs to be presented in ways that can be recognized by the human senses. Graphic and visual displays are preferred, but the use of the other senses such as hearing, or touch is also acceptable. Visual displays "picture" the situation. Comparison tables, graphs, quality control charts, and the like are typical. The simplest means of tracking is best, provided it truly reflects the situation and has the precision to provide control.

Figure 8.9 is an example of a process control chart in a form used to show the performance of a variable. There are numerous types of control charts and other statistical techniques used to monitor process and variable performance.[12] During operation, the process variable is sampled, and performance is monitored by recording measurements and plotting them on the chart. The results are checked against the specification to see whether the degree of control and capability required is present in the process. If the results are within tolerance and repeatable, then the process is in control. When the results show a trend toward loss of control or are outside the tolerance limits, you have accurate information to decide to alter or stop the process or operation.

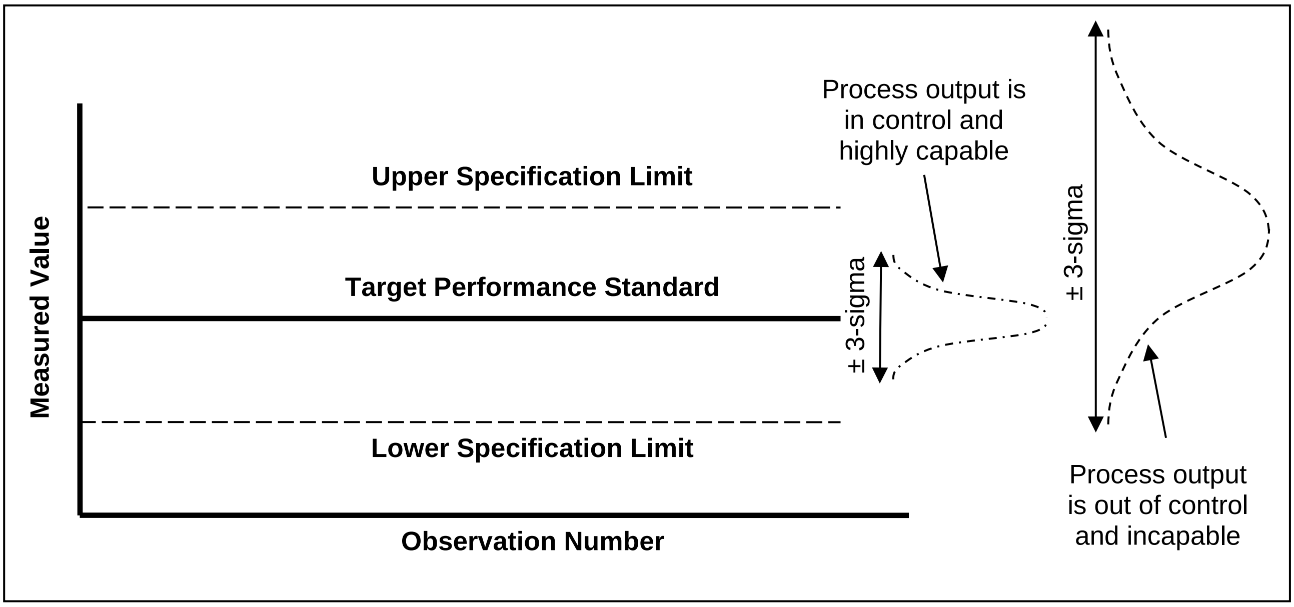

Figure 8.9—A Basic Control Chart

Operator Involvement in Reliability Improvement

Enlist your operators and maintainers in the continual observation for process variation. Give them low-cost diagnostic tools such as those pictured in Figure 8.10 and let them experience process and equipment condition variations for themselves. They will learn to identify changes from normal operation and recognize impending problems. Providing operators and maintainers with simple, hands-on diagnostic tools gives them the opportunity and responsibility to spot problems and to fix them before failure stops the operation. It hands ownership of plant and equipment condition and well-being to the people who are ideally placed to get the best from their plant and equipment.

Automotive Stethoscope

Laser Thermometer

Touch Thermometer

Touch Vibration Pen

Figure 8.10—Low-Cost Condition and Health Monitoring Equipment

The most successful oil refineries in the world, for example, are those that employ production operators to observe their plant and equipment and report back to maintenance any discrepancies they observe.[13]

Defect Creation, Defect Management, and Defect Elimination

Variability crosses borders. It leaves the manufacturer and goes to the user. Every product purchased and every service requested has within it the effects of the manufacturer's process variability. An item or service supplied should be within a range of acceptability specified by the customer and delivered by the manufacturer or provider. The range must be easily achievable within the natural variation of the processes used. If a business has systems that produce a very narrow spread of results, then their products or services will have consistent performance. If instead they "widen the target" and accept large process variations, customers will have problems. The two distribution curves in the control chart of Figure 8.9 show one business with its process in control and easily capable of meeting the specification; the other business allows off-centre quality with wide variation and will have many production problems and warranty claims.

You now know what makes world-class businesses. They use quality-controlled, guaranteed methods in sure processes that deliver the performance standards that their customers want. Then they keep lifting the standards and improving their processes. World-class operations use the scientific method and not accidents of good fortune to get lower-cost, on-time, best-quality production.

FOOTNOTES

1. H. Paul Barringer, “Use Crow-AMSAA Reliability Growth Plots to Forecast Future System Failures,” accessed at http://www.barringer1.com/pdf/Barringer-IMEC-2006-Toronto-Paper.pdf, July 28, 2015.

2. Barringer, “Use Crow-AMSAA Reliability Growth Plots.”

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4. National Board of Boiler and Pressure Vessel Inspectors, “OSHA Incidents by Year”, accessed at http://www.nationalboard.org/Index.aspx?pageID=385, August 5, 2015

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7. Geert Hofstede, *Cultures and Organizations: Software of the Mind*, 2nd ed. (New York: McGraw-Hill, 2005).

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10. Deming, *Out of the Crisis*, 256.

11. “Maximising Operational Efficiency Presentation,” E. I. Du Pont de Nemours and Co, 2004.

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