Chapter 15: The Accuracy-Controlled Enterprise

Variation and risk thrive in processes that allow imprecision. The outliers of life-cycle process variations become the defects and failures that cause plant and equipment breakdowns and necessitate repairs. To get control over variation and stop defect creation, standards of quality must be met. Quality management systems are developed to combat and control variation and risk in business processes.[1] But using a certified quality management system does not give you quality performance. It isn't an International Standards Organization quality accreditation that produces excellent results.

Look carefully at how experts—total masters of their craftwork—do their tasks. There is confidence and certainty in every activity. They know excellent work. Each action meets specific requirements with great accuracy. They continually look for evidence that they are producing the right results. A master craftsman controls variation within a narrow span of quality outcomes. By being precise in every aspect of the job, they do wonderful work. The controlled accuracy of a master craftsman needs to pervade your business if you want world-class equipment reliability. By using the accuracy-controlled methods, skills, and beliefs of the expert in your organization, you can minimize risk, control variation, and slash enterprise-wide costs as failures plummet. The organization becomes an Accuracy-Controlled Enterprise (ACE). The focus in an ACE is not product quality. It is doing a job—every job—masterly by being accurate in every respect.

The Precision Principle

You prevent failure and error by using methods that guarantee precision and accuracy. This is the Precision Principle: set quality standards for every step of a process and measure the outcomes to prove that those standards are being accurately met. If a process step cannot reliably meet the standards, you change its design until it delivers the required result. Figure 15.1 shows what happens when the Precision Principle is applied: first quality standards are set, and then the process is improved until performance meets the standard.

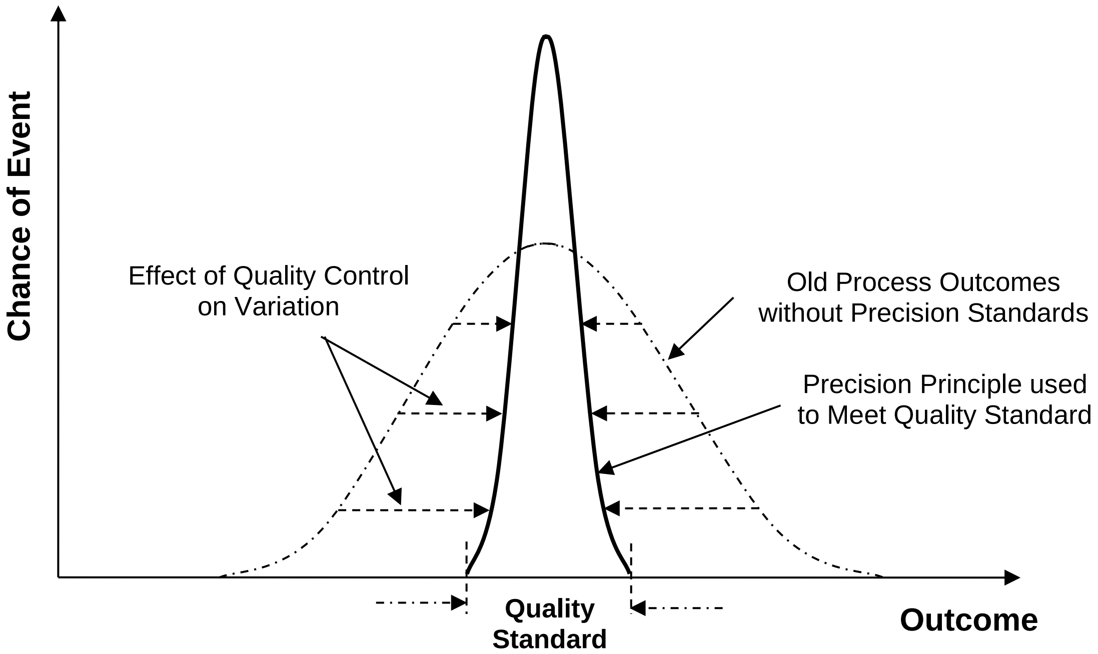

Figure 15.1—The Effect of Controlling Process Step Quality on Variation

The Precision Principle is a rule to help you design successful processes. Having standards is the key; process improvement needs a target to hit. Start by developing appropriate standards with specific targets, tolerances, and measures. Performance and quality will follow because the process is changed until the standards are met. Once variation naturally stays within the standard, quality is consistently achieved because the process is designed to do so. There are far fewer problems and less waste when processes are built to ensure the presence of the methods, skills, equipment, tools, and know-how to produce masterly results.

Highly reliable equipment minimizes production costs and maximizes throughput. Machines require quality manufacture and precision maintenance coupled with precision operating practices to produce the right conditions for high reliability. You get highly reliable equipment when designers make the right choices, installers and maintainers do their work to precision quality, and operators run equipment with least operating stresses under stable production loads. There are no breakdowns when the equipment design is right for the duty, with working parts' microstructure at low stress in healthy contact environments. If an operation's equipment is not performing reliably, then something is very wrong—but not with the equipment! The problem is with the business processes. They are causing wide variation and creating risks. Your challenge is to identify the process failures that are causing defects and stopping equipment from delivering its design performance. Then you must intentionally remove them with effective risk controls and quality assurance.

Often the fault for poor reliability lies with the equipment design. Parts are not suited for the service—the material of construction is not strong enough for the loads, the chosen manufacturing process installed weaknesses, or the material is incompatible with its contacting environment and degrades. Other reasons equipment isn't reliable are that it is wrongly installed, it is poorly assembled or rebuilt, or it is overstressed during operation. Usually these happen because the people involved in the equipment's design, installation, running and care do not know the right ways to minimize and control parts microstructure deformation and degradation. Although designers, fabricators, operators, and maintainers are trained, they can never know enough to handle all situations competently (nor can anyone know it all). In uncertain situations, they use the knowledge they have and decide in hope. If what they do fixes the problem, even if it is the wrong choice, that is how they will solve the same problem in future too. Regrettably, many decisions of this type do not have an immediately negative impact. If the danger were visible, the person would instantly self-correct and get it right. But most errors of choice do not have a negative impact until long after they are made.

When a chosen action has no obvious bad consequences and things are still running fine, people start to believe they've made the right decision. A classic example from industry of falling into an ignorance trap is using the wrong valve to control product flow through a pump. Closing a pump inlet valve will reduce liquid flow, but it will also destroy the pump because of cavitation and vibration. When you control flow with the suction valve, you get a flow rate change, and your aim is achieved. You think what you did was right because it worked. Now a bad practice becomes set in place through ignorance and misunderstanding, and the pump will always have random failures. The only correct valve to adjust for pump flow control is the discharge valve.

There is nothing wrong with making a wrong decision if no harm is done and it is fixed immediately. Bad things happen when wrong actions progress over time to their natural and final sad conclusion. Unfortunately, there are very few decisions that have instant-replay options. If it is important in your company to have highly reliable production equipment with low maintenance costs, then the organization's work processes, and business systems must support and produce that outcome. Your quality management system needs to ensure that all work is done right first time. There is great value in developing a quality system encompassing the standards and instructions that will help everyone deliver masterly results.

Creating Standard Operating Procedures to Become World Class

Human skills, talents, and abilities are typically normally distributed. If we graph the abilities of a wide cross-section of humanity to do a task, we will end up with a normal distribution bell curve. Secondary and higher learning institutions use a normal distribution curve for grading students because it reflects the spread of outcomes on exams. Figure 15.2 shows a normal distribution bell curve, or Gaussian curve, of a talent in a large human population.

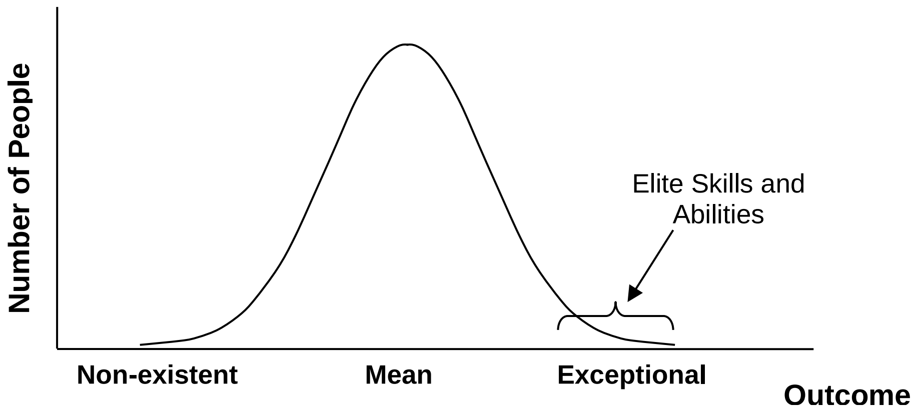

Figure 15.2—Distribution of a Talent in the Human Population

The upshot is that for human skills and talents, there are a few exceptional people, a few with astoundingly poor ability, and many in between clustered around the middle or mean. If a workplace requires highly able people, the distribution curve of human talent warns that it will be hard to get exceptional employees. The talent distribution curve also explains why continuous training of the workforce is so important to a company's long-term success. If the available skill clusters around the mean performance level, then to get better results, additional training and practice are needed to develop higher-quality skills. Training and practice have the effect of moving average performers toward the elite portion of the population,[2] as shown in Figure 15.3.

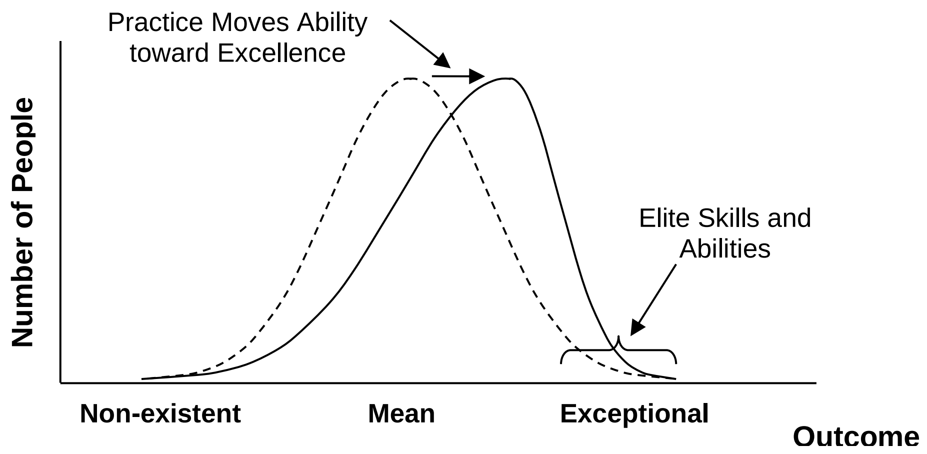

Figure 15.3—The Effect of Higher Skills Training on Developing a Talent

<u>The Best Practices Can Be Done by the Least Skilled People</u>

A job or operating procedure is a written, systematic approach to controlling variations in work performance. Standard operating procedures (SOPs) help people do their work right the first time. Because SOPs control the quality of the work performed by people who are not experts in a task, they are critical to the proper running of a business. Companies have long recognized that getting accurate, reproducible results from the workforce requires proven and endorsed procedures. While SOPs ought to explain and clearly show how to do tasks correctly, it is also vital that SOPs are written to promote high productivity. If you describe in a procedure how to do a task correctly, in the most effective and fastest way, that is how it will be done. Without advice on the proper way to do a task, it will be done ineffectively and at a higher cost.

In the author's workplace experience, very few companies use SOPs to get the best of all possible production outcomes. When SOPs are available, they typically record only what must be done to perform a task; they are not self-checking and do not promote good practices. Better SOPs explain how to do the task, but most offer little practical assistance to the user in controlling job quality through the accuracy of their work. Seldom do they tell the users all the "tricks of the trade" that will make them extremely productive. The SOP is often glanced over when people start a new job and then thrown to the back of the shelf. That is a pity because SOPs are one of the most powerful learning tools ever developed for use in the workplace.

SOPs are a quality and accuracy control device with the capability to deliver a specific level of excellence every time they are used. Few companies understand the true power of SOPs and how they should be employed to set a role model for excellence and teach users to reach that level of quality. Companies use SOPs because their quality system demands it. People mistakenly write SOPs as fast as they can, with the least details and content necessary to get the document approved. SOPs are devices that can save time, money, resources, and effort. They can stop plant and equipment failures and boost productivity if they clearly explain how to do that. If written to their full potential, they can make production outstandingly reliable and highly productive by ensuring the elimination of defects and preventing the loss of time and materials.

In companies that use SOPs, an expert in the job most likely writes the standards. The expert writes the procedure already knowing all the answers. The SOPs describe tasks assuming prior knowledge. You will often see in SOPs statements such as, “Inspect lights, check switch, check fuse, and test circuit” or “Inspect drive linkage for looseness.” In the case of a mobile equipment operator, you might find, “Test the vehicle and report its condition.” The problem with such procedures is that you must be an expert to know whether there is anything wrong with what you are looking at. Procedures that lack quality control and quality assurance details require you to hire trained and qualified people to do what may, in fact, be a very simple job.

Great SOPs ensure work and workmanship quality. They contain all the details and provide sure guidance. They include a target to hit, a tolerance range for accuracy, and proof tests for task compliance that guarantee job quality—in order words, they deliver masterly work performance.

In this way, SOPs stop defects from arising and prevent future failures. With hands-on training and workplace experience, even nonexperts can do the tasks well.

Adding Job Accuracy Controls

Accuracy is the degree of conformity of a measured or calculated value with its actual or specified value. Accuracy first requires setting a target value and a tolerance for outcomes that are acceptably close to the target. Figure 15.4 shows what accuracy means.

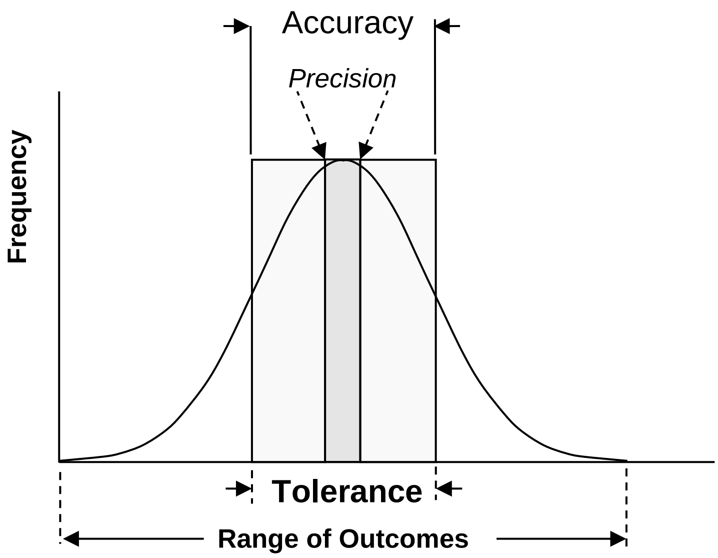

Figure 15.4—Accuracy and Precision

The problem with targets is that they are not easy to hit dead-centre. It is not possible to be perfect. If a task must meet an exact value, that is an unrealistic and virtually impossible outcome. A target requires a range of outcomes that are considered acceptable. There must be upper and lower limits on allowed performance. For example, the bull's-eye on the archery target in Figure 15.5 is not the size of a pin head: it is a circle of sizable diameter. Top marks are possible by hitting within a fair-sized bull's-eye.

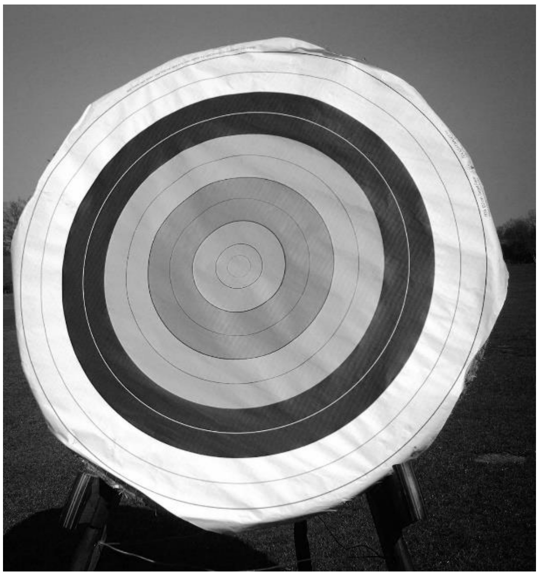

Figure 15.5—Archery Target with Bull's-Eye and Tolerance Bands

"Good, Better, Best" Quality Banding

You can drive continuous improvement in job quality by dividing your tolerance for outcomes into "good," "better," and "best" quality bands. The bands specify degrees of accuracy. Figure 15.6 shows how tolerance banding can be used to challenge people to deliver high-quality work.

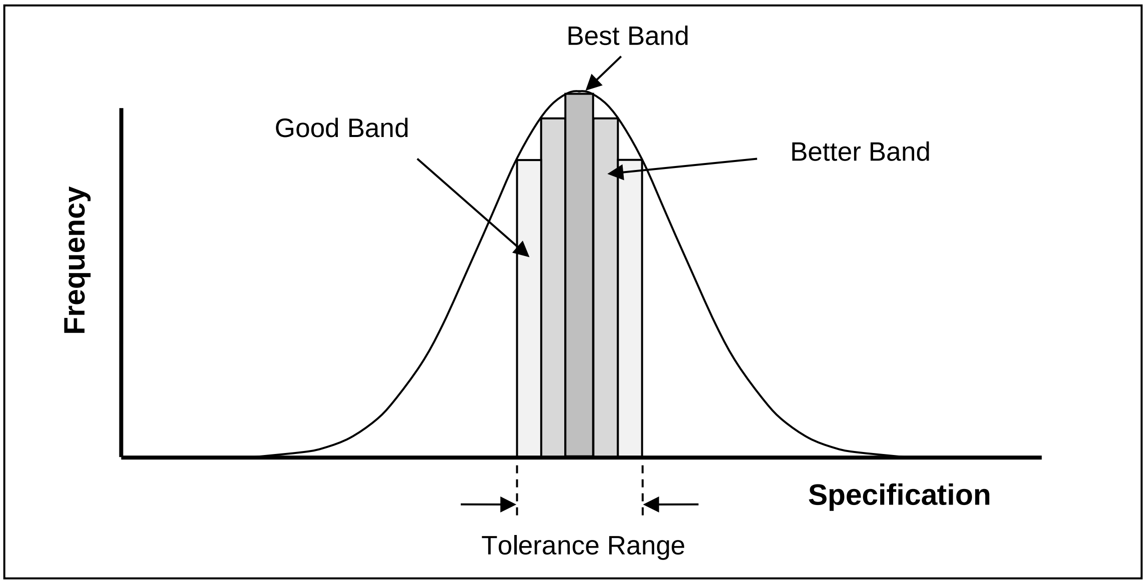

Figure 15.6—Controlling Work Quality with "Good, Better, Best" Tolerance Bands

Experts consistently achieve best-quality results. Competent people do a task to a good degree of accuracy. In between is a level of performance better than that expected of all who do the task. Using tolerance banding provides a clear indication of what is regarded as high-quality work and recognition of its achievement. Application of good, better, and best scales naturally challenges people to try to be the best. It is a simple psychological tool to improve work results.

For an SOP to have a powerful positive effect, it needs to have clear and precise targets, tolerances, and tests—the 3Ts of masterly work—which, if faithfully met, will produce the required outcome. High equipment reliability and production performance naturally follow when work is done according to procedures written to the 3T rule. The 3Ts incorporate Series Reliability Principle 1 and the use of parallel arrangements to make work highly reliable. Tasks are made accurate using masterly specifications and exact descriptions, then a proof-test is put parallel to the task to confirm the outcome is right. Should the activity be done wrong the proof-test double-checks the result and identifies the error. Using the 3T rule creates statistical process control over human activity. They control variation in work quality by focusing on task accuracy and reliability. They standardize expert performance and ensure repeatable quality outcomes from procedures. By using the 3Ts, you limit the range of acceptable results to those you specify. Doing so gives managers and supervisors a sure way to improve workplace practices and create masterly success.

Consider this poorly defined instruction. “Inspect drive linkage for looseness.” If we apply the 3T method, we might revise this instruction to read, “With a sharpened, pointed pencil, mark a straight line on the coupling and shafts of the linkage, as shown in the accompanying drawing/photo. [A sketch or photo would be provided, and if necessary, you also describe how to mark a straight scribe mark.] Grab both sides of the linkage and firmly twist in opposite directions. Observe the scribe marks as you twist. If they go out of alignment more than the thickness of the scribe mark, replace the linkage. [A sketch would be included showing when the movement is out of tolerance.]" The procedure would then list and specify any other necessary proof tests and resulting repairs. With such detail provided, it is no longer necessary to employ highly qualified persons for the inspection. Anyone with mechanical aptitude can do the work reliably once they are trained. Like an automobile manual for novice mechanics, top-class procedures are written with detailed descriptions and plentiful vivid images. When do-it-yourself mechanics have such manuals in hand, they can do a lot of their own work with certainty of job quality. Once procedures contain all the information and measures necessary to rebuild an item of equipment or run a piece of plant accurately, then even people with average skills can do the job well.

The accuracy of a task can be improved by using well-formulated, clearly understood instructions that contain targets to hit, tolerances for an acceptable range of outcomes, and tests to prove that the work has been done to the required level of accuracy. When there are high-cost consequences, the first thing to do is to introduce improved SOPs to control work variability and risk. The inclusion of "target, tolerance, test"—the 3Ts of defect elimination—in all procedural tasks is the first rule of human-error failure prevention. The only solution that is better is to mistake-proof the item's design so that the design prevents mistakes from becoming inherited defects.

Train and Retrain Your People to Your 3T SOPs

Having a procedure full of the best content and excellent explanations for your workforce is not enough to guarantee accuracy. How can you be sure that users comprehend what they read? Not all people are literate, nor will everyone understand the true intent of all the descriptions and words used in a procedure. To be sure that your people know what to do and that they do it right, they need training and practice in the procedure. They need to know how to do the work correctly before they are allowed to do it unsupervised. Later, they will need regular refresher and reinforcement training. The amount and extent of training varies inversely with the frequency which with a procedure is used (tasks done often are fresh in peoples' minds and so they need less retraining), directly with its complexity (more difficult work needs more practice), inversely with the starting skill and knowledge levels of the people involved (the more you know, the less you need to be trained), and inversely with past practical experience in successfully doing the work (once you're competent, you need less retraining because you know how to do the task well).

Human memory rapidly degrades. Procedures that are correctly performed each day by the same people usually do not need retraining unless the method changes. Procedures that are done less often will need refresher training at a frequency commensurate with the risk from an error. If a procedure is dangerous and done infrequently, then retraining and practice are needed before the work is done. Training and retraining may seem like an unnecessary burden on an organization. Managers will say, "If the work is done by qualified people why do I need to train them? They have already been trained." The answer to that question is, "What risks are you willing to carry in your operation—how many defects, errors, mistakes and harm are you willing to pay for?" If an organization's risk management system uses procedures to protect the organization from trouble, then the risk protection barrier must always be working properly. It is a requirement to continuously check and prove the protection layer to ensure that the right knowledge and skills are in place and operating correctly. The training, retraining, and observation of hands-on performance helps keep that protective layer intact.

Assuming that people are "trained once, trained for life" is a serious error in judgment. For example, suppose that a connecting flange in a machine or on a pipe, leaks soon after the job is completed. Flanges that are in good condition, properly rated for the service, and squarely mounted will not leak if they are bolted up right. A leak is a sign that you may need to retrain your people in the correct bolting of flanges. When a repair recurs, often on perfectly good equipment, it warns you that an SOP does not exist, or the SOP that is being used doesn't contain targets, tolerances, and proof tests, or retraining to the right procedures and practices is needed. Or maybe the procedure is sitting at the back of a shelf somewhere because no one knew what it meant.

Making Your Organization an ACE

A classic example of the value that an accuracy-controlled SOP can bring to machinery is the story of a forced draft fan bearing failure. The rear roller bearing on the fan never lasted for more than about two months after a repair. The downtime was expensive and a great inconvenience. To prevent breakdowns, the bearing was replaced every six weeks during a planned outage. It was also put on vibration analysis observation. After several replacements, enough vibration data had been collected to diagnose a pinched outer bearing race. The rear bearing housing had been machined oval when manufactured, and it squeezed the new bearing out of round every time it bolted up. You could say that the vibration analysis did wonderfully well. But the truth is, the repair procedure failed badly. If there had been a task in the procedure to measure the bearing housing roundness and compare the dimensions with the allowable target measurements, the oval-shaped hole would have been found at the very first rebuild. A badly written procedure failed the organization. An accuracy-controlled procedure with targets, tolerances, and proof tests would have found the problem on the first repair, and it would have been fixed permanently.

An accuracy-controlled procedure clearly explains each job task; there is a measurable result that is observable by the user, a range for best quality and a range for minimum quality results, and a test to check and prove the result's accuracy. With each new task allowed to start only once the previous one is within specification; you can be sure of doing a quality job. With targets and tolerances written into the procedure, the user is obliged to perform the work so that the result is within the required tolerance. Having a target and tolerance forces the user to become significantly more accurate than without them. When all the targets have been hit, the job is done right, and the result is high quality work. If tasks are only done within tolerance the result is still acceptable, but you know it's not top quality and will not kid yourself that it is. The 3Ts automatically build defect elimination into any job. Existing procedures can be easily converted to an accuracy-controlled format, requiring only the effort and time to determine, and set standards, and then write clear, complete instructions for each task. The inclusion of a target with tolerances and a proof test to give feedback to confirm that each task is right before the job progresses to the next task makes top-class work quality the designed result that people deliver.

Once a procedure consistently delivers its purpose, you have developed a human-error prevention system. Job steps with target, tolerance, and tested activities are error-proofed to prevent failure and stop the introduction of defects. The work is correctly done when individual tasks are all within their tolerance limits. No longer will unexpected defects happen if work is done accurately to the requirements of the 3T procedure. Using the 3T methodology in procedures results in quality control and training documents of outstandingly high value. An organization that uses sound failure control and defect prevention systems based on proof-tested, accurate work is transformed from a quality-conscious organization to an Accuracy-Controlled Enterprise—an ACE organization. With accuracy in maintenance, operation, and engineering tasks, getting outstanding equipment reliability and consistently high production performance becomes normal.

The Value of Precision Quality

The need for precision and accuracy to control variability dominates asset-intensive industries. Precision quality is the most critical requirement for high plant and equipment reliability. Industries using machines need them to run reliably (no failures or unplanned stoppages) with high availability (ready for immediate use) and high utilization (continuously in use) for their entire working life. Outstanding reliability, availability, and utilization come from being precise and accurate in equipment assembly and operation. Precision and accuracy in equipment design, construction, use, and maintenance is a sure way to achieve a lifetime of high equipment performance and service with low operating costs. But this achievement requires the patience to develop top-class craft and operator skills and the dedication to continually apply accuracy-controlled quality assurance.

Precision is the lifeblood of equipment reliability. It results from controlling accuracy to within high-quality standards. An example of assembly precision is the alignment between the two rotating shafts, shown in Figure 15.7. When two shafts are offset to each other, they run out of true and distort one another, causing massive forces to be loaded onto the bearings and drive coupling. Eventually, the bearings, coupling, shafts, and machine internals are destroyed because of the inaccuracy in the alignment. The two shafts must align with sufficient precision that they generate no destructive forces when they rotate at operating speed. When a 3T accuracy standard is set, a requirement is established that must be confirmed by measurement. An alignment standard for two shafts rotating at 1,500 revolutions per minute (rpm) is to require straight shafts with the axes parallel offset aligned to better than 0.025 mm (0.001 inch) per 100 mm of coupling separation, with angular alignment of better than 0.06 degree.[3] The standard specifies how accurate the shafts need to be in line to meet high reliability requirements. The positions of the shafts can now be measured and adjusted until they are precise. Introducing 3T accuracy into workplace methods ensures everyone knows the precision that prevents defects. When achieved it translates into highly reliable equipment with outstanding availability and performance.

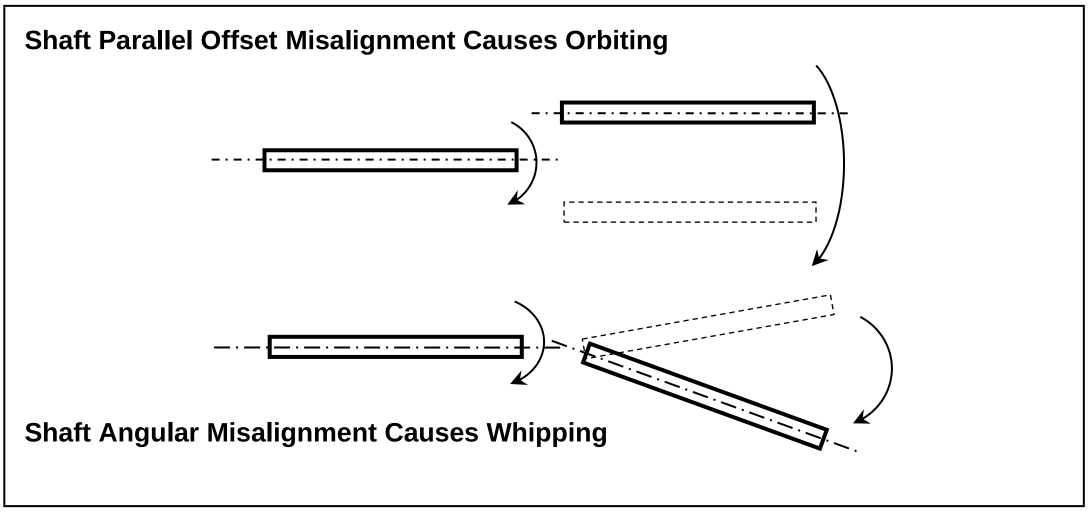

Figure 15.7—Inaccurately Aligned Shafts Destroy Machinery

ACE Is a Business Culture and a Personal Philosophy

An Accuracy-Controlled Enterprise is not the same as an enterprise with a quality management system. Quality management imposes control over the processes, people, and equipment that affect the quality of a product. The ACE concept is subtly different in that it is about instilling excellence into work; it's about helping people be great at what they do. The philosophy requires people to know what an excellent outcome is for every task they do by knowing what expert results look like. From the board room to the shop floor, all roles and jobs throughout an ACE organization follow procedures with clear targets, tolerances, and tests. 3T procedures drive reliability improvement by making each person responsible for the standards of quality they deliver in their performance and guiding them to do top-quality work. An ACE workplace also permits and encourages people to improve their skills and even to change and improve the job design to make it simpler and easier for the work to be done right. Figures 15.8 and 15.9 represent the business aims of using the ACE performance quality assurance system.

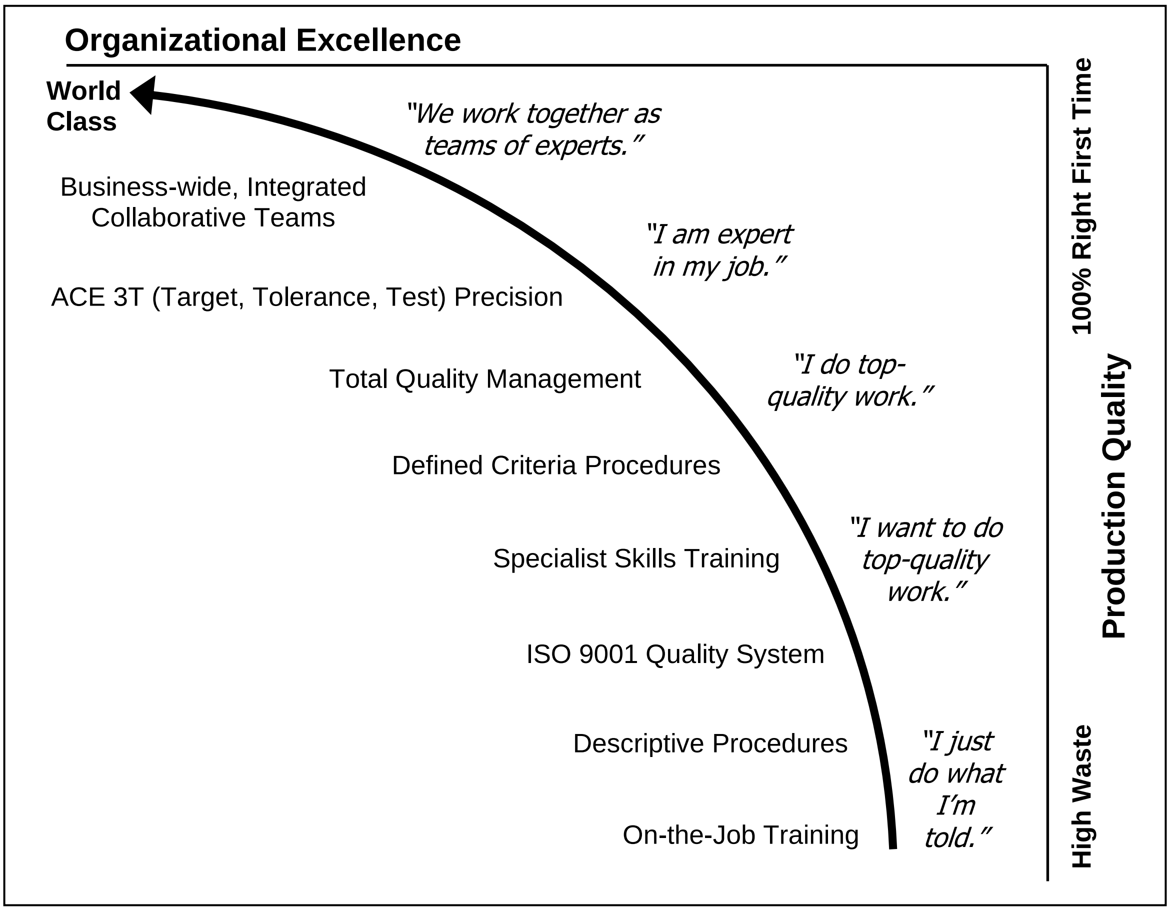

Figure 15.8—The Quality Culture of Plant Wellness Way

Figure 15.9—The People of Plant Wellness Way

<u>Using ACE 3T Standard Operating Procedures</u>

By eliminating human error with robust procedures, you stop equipment problems and deliver immediate positive benefits to your operation. You get lower costs, fewer repairs, fewer operating problems, fewer breakdowns, less time lost, less rework (or even no rework), no wasted materials and parts, higher availability, more throughput, less maintenance, less stock holding, and lower spares inventory levels.

The ACE 3T technique ensures that work is done correctly and accurately time after time by preventing the cause of errors. An ACE focuses on defect elimination and failure prevention. It stops operating risks dead in their tracks by making things go right so that the causes of trouble cannot exist. When you create, build, and use the right systems and techniques, you consistently get the right results by design. It is not good luck, or fate, or the "right people" that gets equipment running reliably and producing at full capacity day after day. Those results happen because the right processes and methods are in place and in use.

The statistical principle of the ACE 3T work process control method is shown in Figure 15.10. The ideal outcome of a process task is to hit its world-class target value. The poorest result allowed is the worst tolerance value. Until the measured result from the test is within tolerance, the task is repeated until it is right. In our minds, the 3Ts challenge us to become world class. It is the way of the expert.

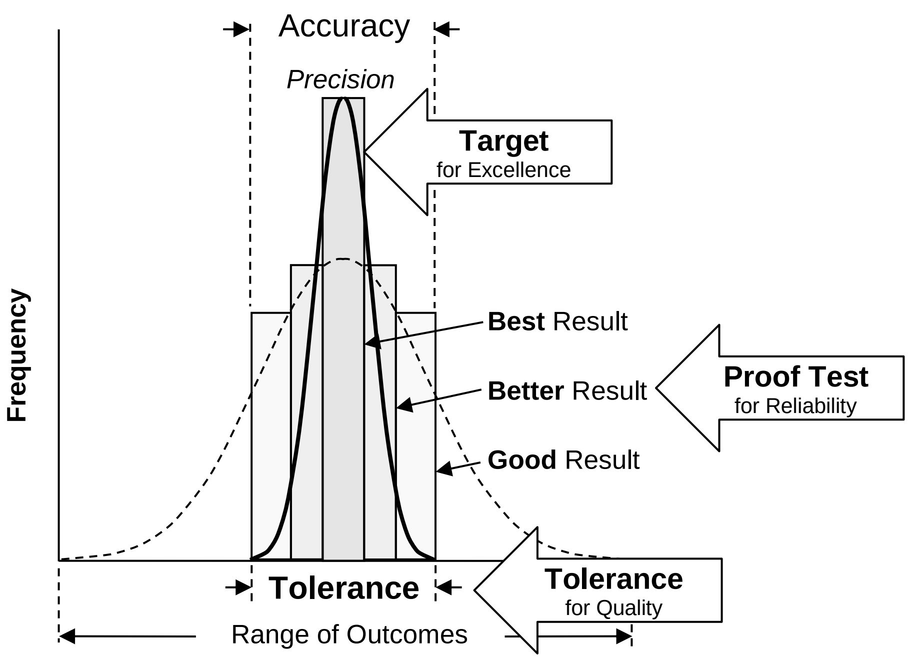

Figure 15.10—Quality Control Principles of ACE 3T Work Quality Assurance

The 3Ts go far beyond the quality control method used in inspection and test plans (ITPs). An ITP only gives you a single-sided limit—it tells you how bad you are allowed to be. With ACE 3T, you have two-sided limits. You have a bull's-eye that tells how good you need to be to deliver world-class results, and you have a tolerance limit on inaccuracy, after which you must correct the defect. Figure 15.11 shows the difference between using 3T and ITP to get top-quality results. Inspection and test plans never tell you what world-class performance really is! They only tell you the worst defect you can get away with in your work. Of course, you have not gotten away with it—poor quality is transferred; it just waits in your machinery and equipment for the next opportunity to fail.

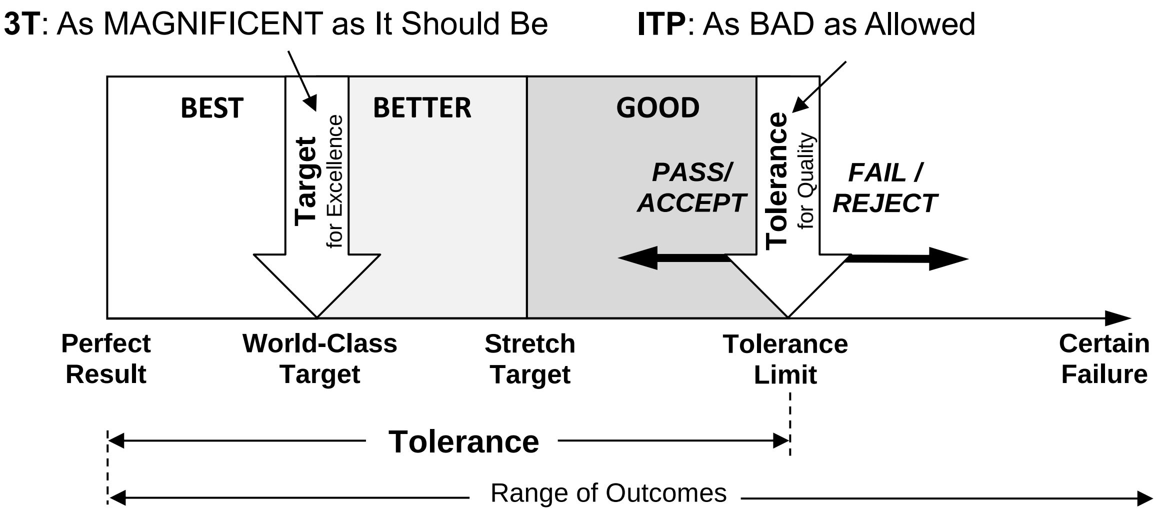

Figure 15.11—ACE 3T Procedure Encourages Masterly Work

The ACE approach to task process control makes work into a game. The work procedures are written to challenge people to lift their skills to the "master craftsman" level of ability. Once all work tasks are done correctly, job success naturally follows, and your people know they have done great work. Human beings will always make mistakes. What the ACE 3Ts add to your standard operating procedures is the protection of both work quality control and quality assurance. More and more world-class outcomes are delivered as your people start hitting 3T bull's-eyes. There is a simple logic to the success of ACE procedures—be exact with your quality requirements, and your people will learn and enjoy delivering great work results.

The king of a country needed a driver for his car. The time came to interview the three short-listed candidates and make his choice. The monarch wanted to make a wise choice, so he asked the first candidate, “How close to the edge of a cliff can you drive my car at 100 kilometres per hour?” The first prospect told him, “Your Majesty, I am sure I can drive the car one meter from the edge of a cliff at 100 kilometres per hour.” The king thought for a second and then told him he would not get the job and waved him away. The king posed the same question to the second prospect, “How close to the edge of a cliff can you drive my car at 100 kilometres per hour?” The second candidate said, “Your Grace, I can drive the car at 100 kilometres per hour just 150 millimetres from the cliff edge.” The king looked at the candidate and told him that the driver’s job would not be his and dismissed him. The last candidate met the king, and he, too, was asked, “How close to the edge of a cliff can you drive my car at 100 kilometres per hour?” The last prospect replied, “Your Royal Highness, when you are in the car, I will drive it as far from the cliff edge as is possible.”[4]

The moral of the story is to not take unnecessary risks. Be smart and stay away from danger. If you aren’t using 3T accuracy-controlled processes and procedures, you’re driving your business too close to the reliability cliffs’ edge.

FOOTNOTES

1. David Hoyle, *ISO 9000 Quality Systems Handbook,* 5th ed. (Burlington, MA: Butterworth-Heinemann, 2006).

2. Malcolm Gladwell, *Outliers: The Story of Success* (New York: Little, Brown, 2008).

3. John Piotrowski, *Shaft Alignment Handbook*, 3rd ed. (Boca Raton, FL: CRC Press, 2007).

4. Thanks to Robert Tillett of OPTIMIZE Consultants, Kampala, Uganda for the use of his story.