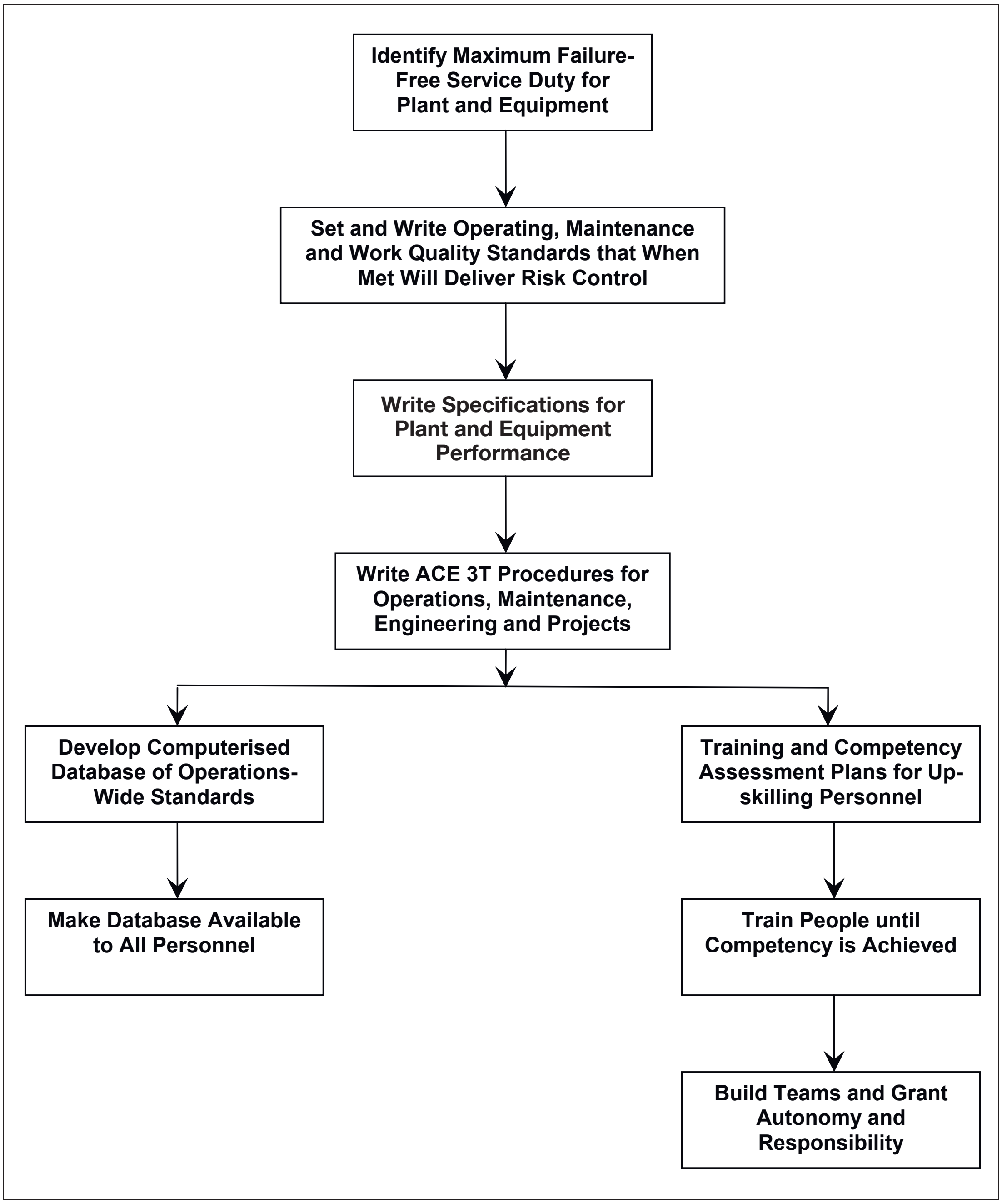
PROCESS 4 – Introducing Risk Control



Description of Process 4 – Introducing Risk Control

Identify Maximum Failure-Free Service:

Indicate in the FMECA Spreadsheet how long the equipment is required to run without unplanned downtime, safety issues, production slowdown, or product quality problems. This allows measurement of the effectiveness of the risk control strategies and provides means to prioritise improvement efforts.

Set and Write Operating, Maintenance and Work Quality Standards:

Set performance standards that deliver the operation specified. Meeting the standards will produce the operating performance needed from an item of equipment. What workplace cleanliness standard will the operators need to meet to reduce shaft seal failures? What lubrication cleanliness will give the failure-free life required from bearings? What materials are to be used for a particular service life? If world-class performance is wanted, you must set and meet world-class standards.

Write Specifications for Plant and Equipment Performance:

Script the future. The performance standards need to become equipment and process specifications. They indicate what function each item of equipment is to deliver and how to achieve that performance. There must be specific targets with measures to prove the performance meets the standard.

Write Accuracy Controlled Enterprise 3T Procedures:

Every activity and job requires high-reliability procedures. Each task quality is made clear to the person responsible so they know the excellence and accuracy they need to deliver.

Develop Computerised Database for all to Use:

The best practice standards, specifications and procedures are in a database that everyone can access. People have the information to run the operation in the best way to ensure least operating risk. These are valuable and important documents that people need to use all the time.

Visual indicators of performance are displayed so everyone knows his or her workplace performance and that of their team.

Training and Competency Assessment Plans:

With performance standards and 3T procedures set, develop training plans to lift managers, engineers, supervisors and workers competency to meet the required performance.

Build Autonomous Cross-Functional Teams:

Establish cross-functional teams of people responsible to run a process. Keep teams smaller than 100 people so comradeship develops. Subdivide large processes into smaller ones if necessary. Whether making a product or providing a service, use series and parallel reliability principles to build teams with the skills and knowledge to competently do the required work. Remove all direct management supervision of the team and instead provide necessary training to team members to develop the knowledge and skills to work as a team. You want to create a community with positive spirit. Let the team profit-share in the additional operating profits they generate above the historical maximum from the process.

13. Organisation Structure and Teams (A Reliability Based Model)

To get high equipment reliability it is necessary to set-up an organisational structure that can deliver it. Reliability reflects the design choices, operating methods and maintenance practices used throughout the life-cycle of equipment. High reliability needs relevant knowledge and skills at each phase of the life-cycle. For example, if the production group run and manage equipment alone they do not usually have the full understanding needed to run it most reliably and profitably. Due to ignorance and mistaken beliefs they cause unnecessary failures and waste. Operations need the support of cross-functional experts with finance, engineering and maintenance knowledge to get their best performance. Figure 13.1 shows the Author's observations during his career of the effect of organisational structures and departmental focus on plant availability.

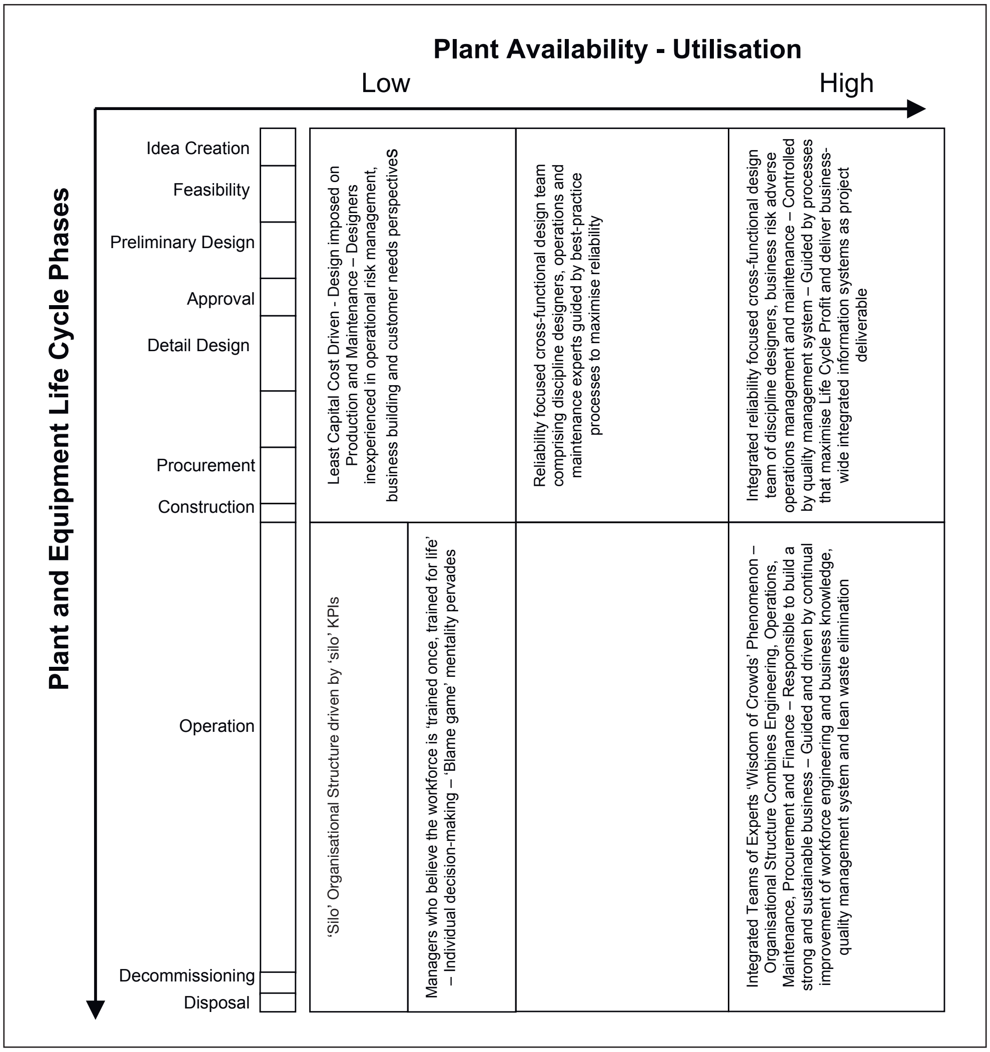


Figure 13.1 – Effects of Organisational Processes and Structure on Plant Availability.

A person working alone and making decisions themselves is at serious risk of causing failure. They are decision-making alone in a series process. One error of judgement in one step of the process will fail the entire outcome. Perhaps not immediately, but eventually. Working alone in any series process is a high risk activity. To protect people making decisions put them into a parallel arrangement where they must get more information and be better informed on their choices. Figure 13.2 shows a decision requiring several parallel activities in order to reduce the risk of conclusion error.

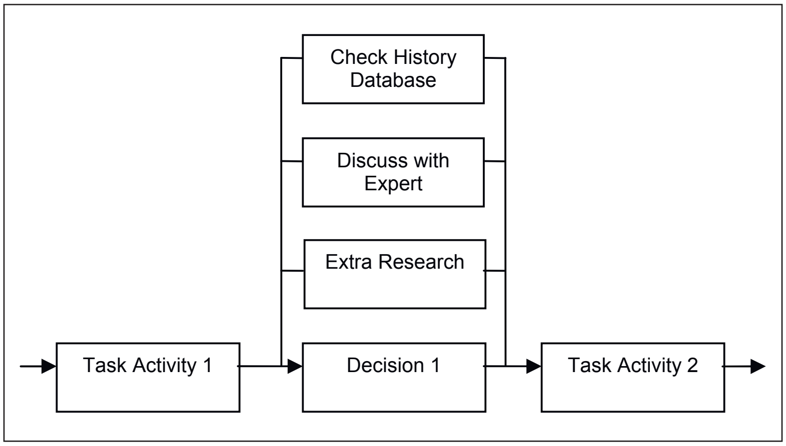


Figure 13.2 – Increase Reliability of Decisions by Making Them a Parallel Activity.

Equipment reliability increases when opportunity is provided for use of more skills and knowledge in the selection, operation and care of the equipment. Setting-up autonomous work teams of people with the right skills and knowledge to increase reliability is a Series System Reliability Property 3 activity. The change to using skilled, cross-functional teams will magnify the reliability of the whole operation because teams combine members knowledge and skills to make better decisions.

The Reliability Improvement Value of Autonomous Teams

Figure 13.3 is a simple process map of a pump delivering water to equipment. To get maximum reliability from the pumping system the mechanical engineering of the equipment has to be correct, the selection correctly done, and the equipment installed correctly, operated correctly and maintained correctly. Similarly, the electrical and control engineering need to be designed correctly, then selected, installed, operated and maintained correctly. A competent operator would typically only know how to do one of those ten activities – operate it correctly. Some operators may dabble in the pump's mechanical maintenance, but few would be experts.

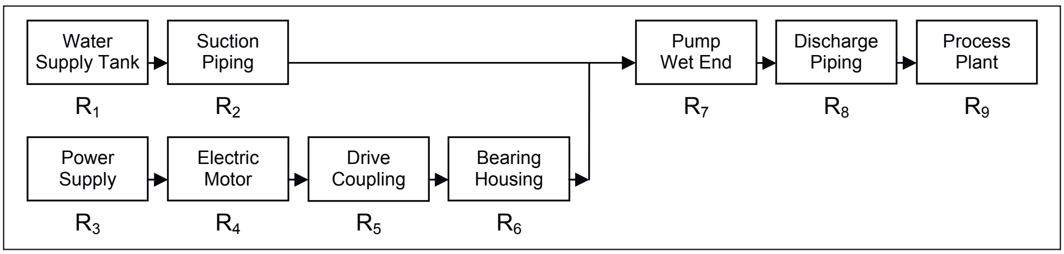


Figure 13.3 – Water Delivery Process Map.

No one is an expert in everything that must be done to have exceptional equipment reliability – there is far too much for one person to know and do expertly themselves. But in a team where each member is proficient in an area of expertise their skills and know-how become available to all the team.

The benefits of a team approach to running business activities become clear when it is realised a team is a parallel arrangement. Figure 13.4 shows the parallel arrangement that teaming-up produces for our pumping system. A mechanical fitter and an electrician are teamed into the operations group. They bring their specialist equipment knowledge and trade skills to the team. Professionally qualified engineers are appointed to work in the team. The engineers bring their added technical knowledge and understanding to the team. The team gains the engineering skills, experience and information needed to achieve high reliability. Each team member learns to call on the situational expert for advice and information before making decisions. This does not mean that people move to new jobs; rather they fill a team function and become team members who work together and develop a team approach in running and caring for plant and equipment. Some people will be in many teams.

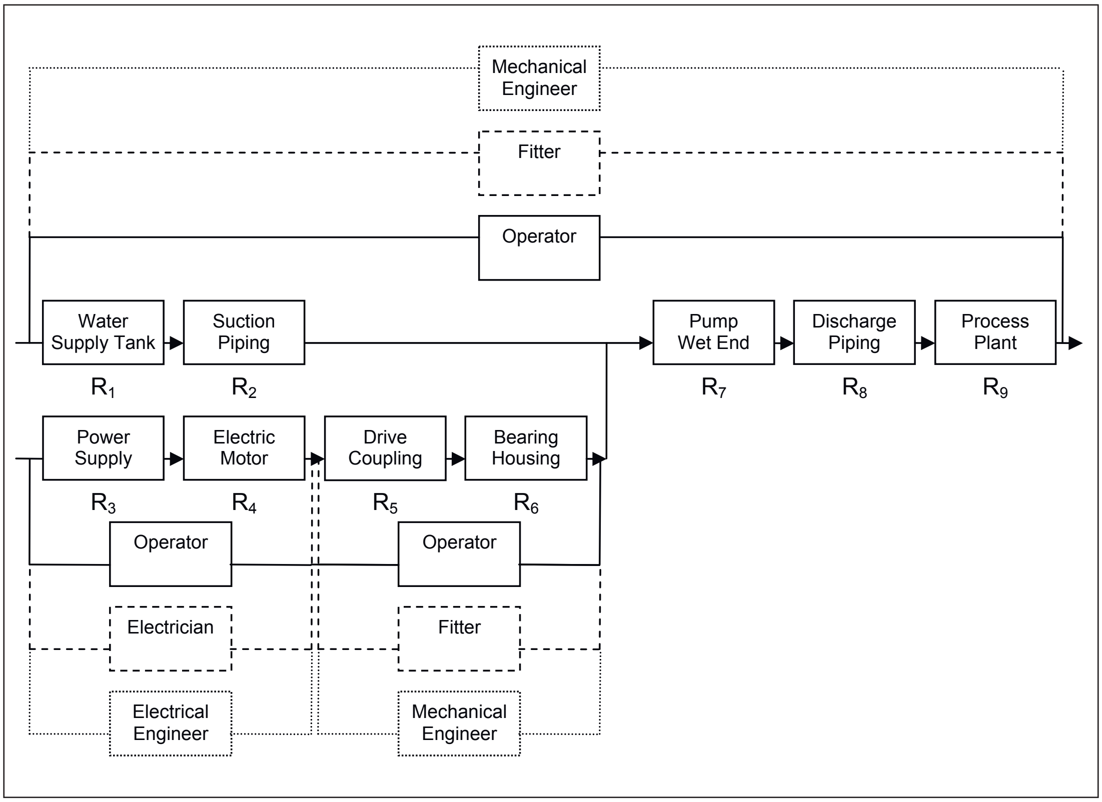


Figure 13.4 – Teams Parallel Skills and Knowledge to Produce Reliability Improvement.

Using Reliability Principles to Create Organisational Structures

There is something very powerful about working in teams. That power comes from the team structure and dynamics. Managers who want higher reliability, top quality production and fewer problems need to understand why teams are so powerful and how to gain that power for themselves.

Reliability concepts can be used to design organisational and business department structures. Teams increase reliability because they parallel the knowledge and skills of its members to produce better performance from plant and equipment. Paralleling people for greater reliability stems from the following two parallel process reliability principles.

1. The more components in parallel, the higher the system reliability.
2. Reliability of a parallel arrangement is higher than that of the most reliable component.

An organisation brings people together to produce an output wanted by its customers and stakeholders. The organisational structure connects people together in their efforts. The quality of the output is dependent on the peoples' skills and the business processes.

The hierarchy structure shown in Figure 13.5 is typical for most organisations. It is an organisation structure that developed from fighting battles and wars. It is a poor structure for helping companies to achieve their goals because it requires managers to the make decisions alone, often hurriedly. It is a high risk design for long-term business success. It encourages managers' egos and ambitions to drive their decisions, rather than making decisions based on careful analysis and understanding of a situation. It promotes human conflict because the person at the top has final authority, yet that person maybe incompetent, ignorant or ill. In those organisations that want top quality products, high equipment reliability and world-class production, such a structure is unsuited to the purpose.

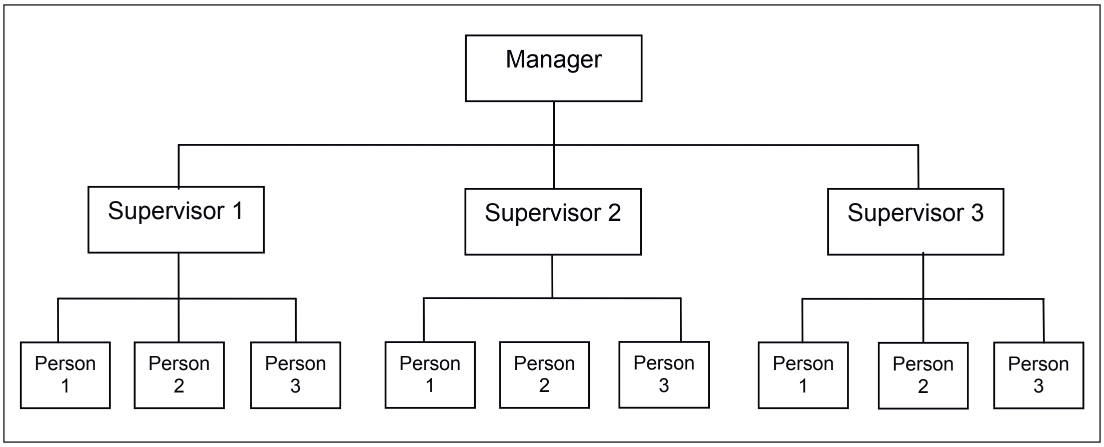


Figure 13.5 – Teams Parallel Skills and Knowledge to Produce Reliability Improvement.

There is a scientific reason why teams improve the chance of success. A team-based decision-cell structure is mathematical a better design for a business then the militaristic hierarchy structure used in most organisations. Group decisions are more likely to be better choices if the conditions are established to promote mutually beneficial interaction [59]. Reliability maths offers deep insights into why and how teams can get better outcomes, and especially why they are a powerful structure for achieving business goals.

To understand the science of how teams and teamwork provide improved quality, reliability and risk control, it is necessary to understand first how work gets done. In Chapter One we identified that all work is a series of actions done one after the other. The sequence of actions makes up tasks. The accumulated tasks make up jobs. This forms a series process, like that in Figure 13.6, which shows a 5-task job that produces a wanted output.

Each task has a probability (P_n) of success between 0 and 1, with 1 being certainty and zero total failure. Figure 13.7 shows that within each task there are many individual activities. These also form a series arrangement. When you have a series of activities following each other, where the next activity builds on the work performed by the previous ones, it only requires one error to happen and the whole job goes wrong. To get this job done right the first time requires each of the 25 activities to be done correctly. If one activity in one task is wrong, the job outcome will be wrong and the job will need redoing, possibly even scrapped.

[59] Surowiecki, James., 'The Wisdom of Crowds', Random House, 2004.

What is the chance that all twenty five activities will be done right, and that the whole job is 100% right? The error rate depends on task difficulty and the stress of the situation [60]. Hard tasks not done often have higher error rates. Add stress to the job and the failure rate gets much worse. The reliability of series processes warns us that unless we have great results at every step the job will go wrong. You need to control the chance of error if you want to stop waste and loss.

What has chance got to do with teams and team work? The people in the team work off each other. When a person is uncertain about a decision, they ask other team members for advice. If the team is a mix of subject matter experts, then each is a knowledgeable resource to help one another work with less chance of making error. An example might be an autonomous work team of operators, maintainers and quality control staff in a production department. The maintainer can advise the other team members on equipment reliability issues, the operator has experience in using the production equipment, and the quality control persons can advise on product performance. Each member contributes their best advice and experience to the decision making processes of the other team members. Instead of having one person working alone a team has several people guiding each other in their work. This interaction improves the chance that things will go right more often for everyone on the team.

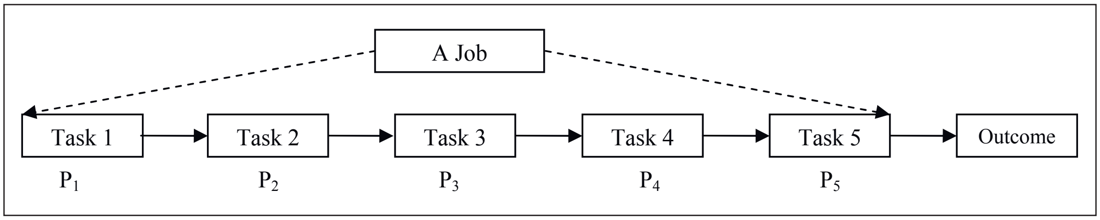


Figure 13.6 – A Series of Tasks are Performed in a Work Process.

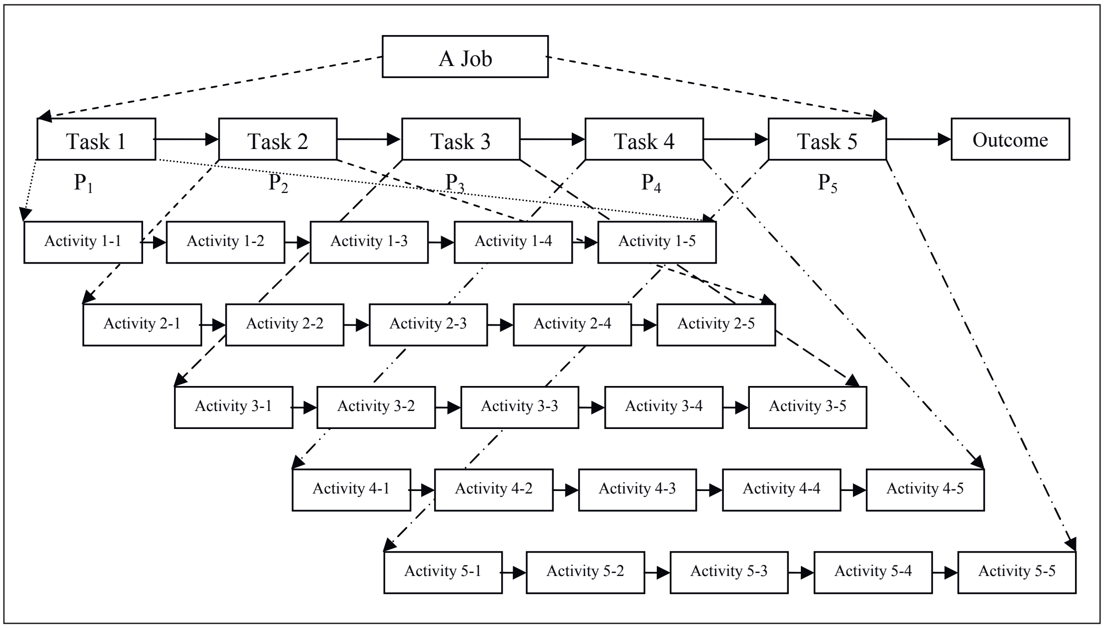


Figure 13.7 – A Series of Activities Occur within Each Task of a Work Process.

60 Smith, Dr, David J., Reliability, Maintainability and Risk, Appendix 6, Seventh Edition, Elsevier, 2005.

How much difference does a well-functioning team make to the chance of a job going right? Figure 13.8 shows the 5-task job as a team might do it, with everyone helping other team members to get the best result. Person 1 is responsible for doing the work and has support from two others on the team. Each person adds his or her useful contribution at each step. The arrangement of each task is now a parallel activity. This arrangement also has a mathematical formula to work-out the chance that a task will be right. The formula is:

$$P_{parallel} = 1 - [(1\text{-}P_1) \times (1\text{-}P_2) \times \ldots.(1\text{-}P_n)]$$

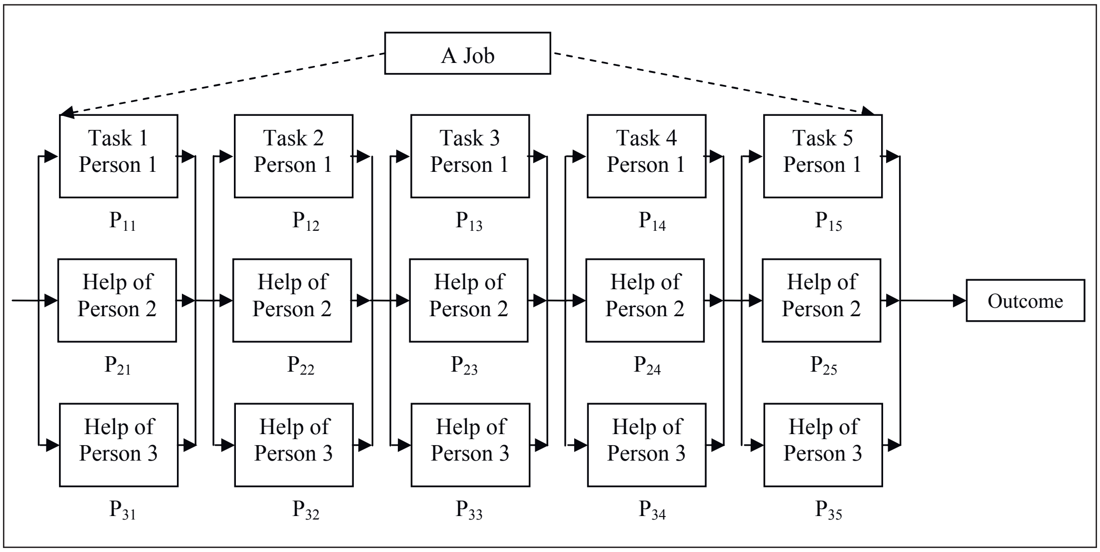


Figure 13.8 – Working as a Team Creates Parallel Teamwork.

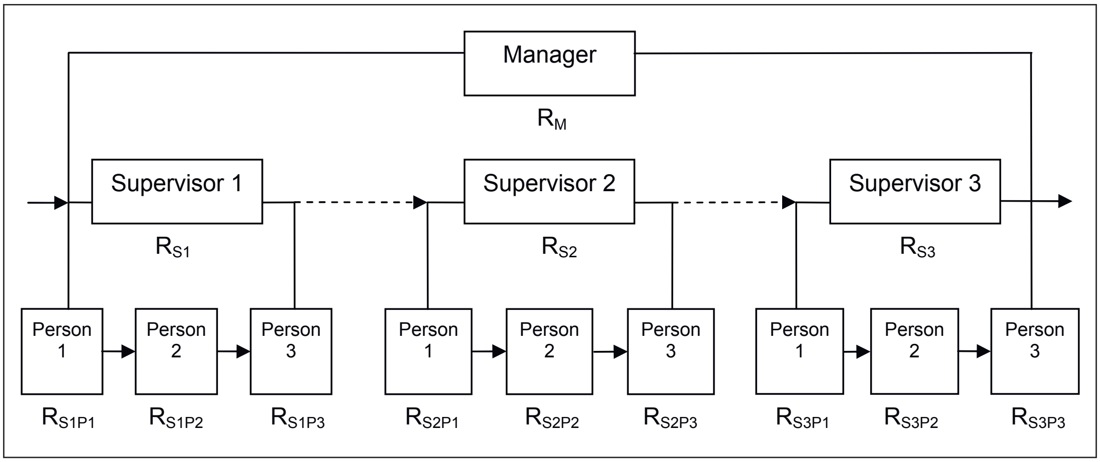


Figure 13.9 – Workplace Silo Groups Formed as Series Structures.

We do not need the formula to see that each task now has three people watching over it. If the person responsible for the work makes an error there are two others helping and checking them. Hopefully one of them will notice any error and correct it. If we were to use the equation, we would find that with three people, each having 90% chance of accuracy, the parallel combination gives us a task that is right 99.9% of the time, and the five task job it is right 99.5% of the time. By paralleling the tasks with a team we have gone from a poor

59% chance of the job being done right with a person working alone, to 99.9% with a team of subject matter experts working together. That is why teams are so powerful. Once people parallel-up in well functioning teams to help each other, the odds of getting better results rises markedly. Teams bring this power to organisations. Teams can help people increase their individual chance of doing outstanding work. They have the ability to greatly improve the odds of delivering right-first-time results. In companies that want high quality, high reliability and fewer risks, a teamwork organisational structure is likely to produce many more favourable outcomes.

How reliable is a cross-functional team structure compared to a silo structure in doing the work? We need to compare the reliability of the silo structure to that of the team structure and see what difference there is. Figure 13.9 is the silo hierarchy drawn as a functional block diagram assuming work is passed from one operator to the next in the work process. For the sake of the example, assume that the people are working in a complicated industrial process without strict quality control making 10 errors in 100 opportunities. This means 90 in every 100 opportunities is done right, a reliability of 0.9. It is about 2.5 sigma quality (3-sigma quality would be 7 errors per 100 opportunities and 4-sigma would be 0.6 errors for 100 opportunities) [61]. The reliability of the silo group process can now be analysed. Starting with the workers doing the series steps, the reliability of the work process is:

$$\underline{R} = \underline{R}_{S1P1} \text{ x } \underline{R}_{S1P2} \text{ x } \underline{R}_{S1P3} = 0.9 \text{ x } 0.9 \text{ x } 0.9 = 0.729$$

With a Supervisor paralleled to overview a group, each group's reliability becomes:

$$\underline{R} = 1 - [(1\text{-}0.729) \text{ x } (1\text{-}0.9)] = 1 - [(0.271) \text{ x } (0.1)] = 1 - [0.0271] = 0.9729$$

The Supervisor's activity paralleled to the workmen lifts their group's performance. The three groups in the department are in series, each feeding work to the other, and have series reliability of:

$$\underline{R} = 0.9729 \text{ x } 0.9729 \text{ x } 0.9729 = 0.921$$

With the Manager placed in parallel to manage the operation, the department reliability is:

$$\underline{R} = 1 - [(1\text{-}0.921) \text{ x } (1\text{-}0.9)] = 1 - [(0.079) \text{ x } (0.1)] = 1 - [0.0079] = 0.992$$

The department has a theoretic reliability of 0.99 or 1 error in every 100 opportunities – nearly 4-sigma quality. Yet organisations that produce 4-sigma performance are rare. Businesses without a quality control system typically rate 2.5-sigma [62]. Those with a working quality system can be 3 to 3.5-sigma. The assumption of 90% reliability for people doing tasks seems to have been too high because the calculated results do not happen in reality. Let us repeat the calculations with a task reliability of 70% for each individual, or 2-sigma quality of 30 errors in every 100 opportunities.

For the workers doing the series steps, the reliability of their process work tasks is:

$$\underline{R} = 0.7 \text{ x } 0.7 \text{ x } 0.7 = 0.343$$

With a Supervisor paralleled to overview the work, each silo group reliability becomes:

$$\underline{R} = 1 - [(1\text{-}0.343) \text{ x } (1\text{-}0.7)] = 1 - [0.197] = 0.803$$

---

[61] George, Mike, et al, 'What is Lean Six Sigma?', McGraw Hill, 2004.
[62] Arthur, J. 'Lean six sigma demystified', McGraw Hill, 2007.

The three work groups are in series and have a series reliability of:

$$\underline{R} = 0.803 \times 0.803 \times 0.803 = 0.518$$

With the Manager placed in parallel to manage the operation the department reliability is:

$$\underline{R} = 1 - [(1\text{-}0.518) \times (1\text{-}0.7)] = 1 - [0.145] = 0.855 \text{ (about 2.5-sigma quality)}$$

The manager improves the silo structure performance by 65%. The manager and supervisor are key to the success of a silo structure and if their error rate is high, the business suffers badly.

Department output is now 2.5-sigma quality, which is what is expected from a typical business without an inspiring quality system. The difference in results between calculations warns us that poor department performance is the accumulated effect of poor individual task performance.

Figure 13.10 shows a block diagram of the same people in a team structure. The team puts people in a parallel arrangement. Each team is responsible for a process and each person works with 0.7 task reliability. The Supervisors disappear and become team players who coach the workers, while the Manager parallels the teams in their department.

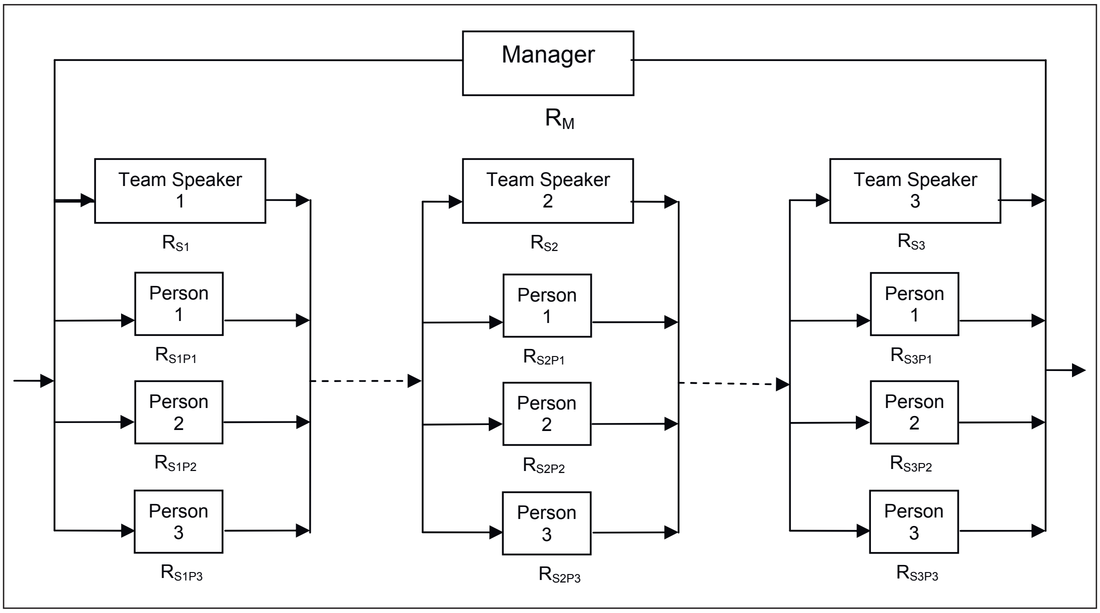


Figure 13.10 – Workplace Groups Teamed in Parallel Structures.

For a team of four people, with each person's reliability at 0.7, the individual team reliability is:

$$\underline{R} = 1 - [(1\text{-}0.7) \times (1\text{-}0.7) \times (1\text{-}0.7) \times (1\text{-}0.7)] = 1 - [(0.008)] = 0.992.$$

The three groups work in series, with one feeding its output to the next; a combined reliability of:

$$\underline{R} = 0.992 \times 0.992 \times 0.992 = 0.976$$

When the manager, also at reliability 0.7, is included with the three teams, the reliability of the structure is:

$$\underline{R} = 1 - [(1\text{-}0.976) \times (1\text{-}0.7)] = 1 - [(0.007)] = 0.993 \text{ (near 4-sigma quality)}$$

Using the same people doing work with 0.7 reliability, the silo structure produced 2.5 sigma quality, while the team structure delivered 4 sigma quality. The manager improved the silo arrangement by 65% for 86% departmental reliability, but in a team structure they improved departmental performance by only by 2% to get 99% departmental reliability. It seems that most of the reliability benefits of a team structure reside with the team and little with the management levels.

The modelling of the silo hierarchical organisation and the cross-functional team structure in the calculations above are not how real organisations actually behave. The examples are constructs for the sake of exploring the effects of each form of structure on the outcomes of an organisation. The investigation indicates that people used in a team arrangement allow the team to produce better results than using those same people in a hierarchical structure. The big assumption is that the people in a team will actually work as a team to get the benefits of a parallel arrangement of functional experts. It means all members and managers are willing to proactively help each other in a spirit of friendship, trust, respect, learning and support for the mutual benefit of all.

Organisations with hierarchical structures seem to have the potential to deliver reliable outcomes, but in reality most perform poorly. Too many times in a hierarchical business the outcomes are wrong. What happens in such organisations to ruin their performance? One possibility is that these companies employ people who are your average guy and girl. These employees simply do their jobs as best they can. Not all of them are experts in what they do and so it is likely that occasional errors are produced from variable quality work. Or maybe each person does the work in their own way because there is no standard method, hence producing a wide range of outcomes, some of which are wrong.

This is another example of the ‘cross-hair game effect’ encountered in Chapter 3 – using a silo organisational structure that cannot deliver the results required, except by luck. Yet some businesses can take the same people and deliver outstanding world-class performance. Choosing the right organisational structure is an important difference. But there is another factor that is even more important than the structure. It is the performance of the organisation’s work quality assurance processes.

14. The Accuracy Controlled Enterprise

Our discussions have covered the effects of process variations and the disastrous financial cost of defects and failures. When variation and risk play together businesses tumble, production shuts-down, and people are injured. Are we doomed to play a game of chance every time we go to work? Is hope the only tool we have against variation? Is fluke how we control business process outcomes? Unfortunately, for more, rather than fewer businesses, that seems to be the case. Process confusion and uncontrolled interactions allows variation and risk to thrive inside their organisation. With more processes, and more process steps, comes more opportunity for ruin of one type or another. To combat ever-present variation and risk in business and its processes, quality management systems have developed [63]. Systems such as ISO 9000, Six Sigma and Lean [64] had to be invented to stop variation and reduce failure. In every organisation, from the shopfloor to the corporate boardroom, variation abounds, and only quality management systems can control it.

Hardly anyone 'gets' what quality is about. Of the estimated one million companies in the world with ISO 9001 certification in 2008 [65], few comments are observed in newspapers claiming its great worth to new booming business success. Quality management's panacea for product excellence is often seen by managers as a wasted effort, sucking-up resources for little business improvement. Yet companies like General Electric, Motorola and Toyota claim that at the root of their success was their quality management system. That success screams that there really 'is something' in quality management. There is power in a truly-functioning and inspiring quality management system.

Engendering quality into the use and care of plant and equipment is difficult because it needs committed leadership and much work building better processes, procedures and training systems. That requires overheads for document control, planning of production and maintenance, long-term management of resources and equipment, providing continual training and for the analysis of data to identify problems and discover how to solve them. The cost and effort blinds managers to the great worth that quality systems provide. Instead, maintainers and operators 'fly be the seat of their pants' and are expected to get the job done by any means.

The Precision Principle

Using a certified quality management system is not the only way to get quality. There is no need to have ISO quality accreditation to do an excellent job. Look carefully at how an expert, a total master of their craft, works. There is confidence and certainty in every activity they do. Each act meets specific requirements with great precision. They continually look for evidence that each action is producing the right results. A master craftsman uses accuracy to control variation to a narrow span of outcomes. By being everywhere accurate they do wonderful work. The controlled accuracy that a master craftsman applies needs to pervade a business if they want world-class quality. When the accuracy controlled methods, values and beliefs of the master craftsman is applied by an organisation, they minimise risk, control variation and slash enterprise-wide costs as failures plummet. They become an Accuracy Controlled Enterprise (ACE). The focus in an ACE is not the big-picture product-perfect view of quality. It is just about doing a job, every job, masterly. Whether on the shopfloor or in the boardroom. Every task is done accurately. It is the Carpenter's Creed used in every work process step.

---

[63] Hoyle, David, 'ISO 9000 Quality Systems Handbook', Butterworth-Heinemann, 5th Edition.

[64] Lean is a popular name for the Toyota Production System.

[65] Claimed on International Standards Organisation website, February 2009.

Control over variation and defect creation needs standards of quality to be met. Operations and businesses overcome failure and error with systems guaranteeing precision and accuracy. This is the Precision Principle – set clear and precise work quality requirements. Set standards for every step of a process and measure they are accurately met. A process continually achieving the precision requirements of every step automatically delivers its best quality and throughput. If a process step cannot reliably meet the standards, change its design until it correctly delivers the required result. Figure 14.1 shows what happens when the Precision Principle is applied – first quality standards are set and then the process is improved until the performance meets the standard. By this method the process is sure to deliver successful results.

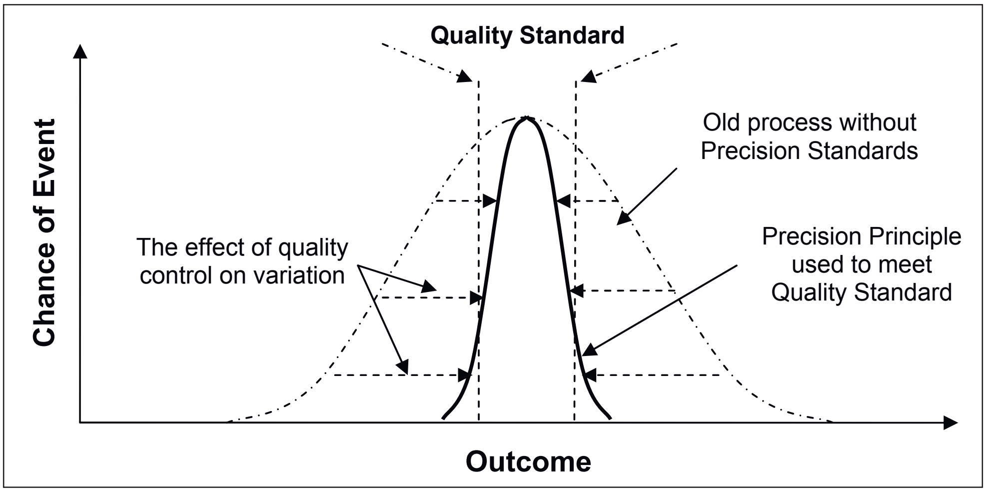


Figure 14.1 – The Effect of Controlling Process Step Quality on Variation.

We encountered a similar process improvement effect in Chapter 7 where W. Edward Deming's PDCA cycle was used to continually redesign a process until it repeatedly delivered the required quality. The Precision Principle is a tool to help you redesign your processes. Start by developing appropriate standards with specific targets, tolerances and measures. Having standards is the key – process improvement starts by setting a target. Performance and quality will follow because the process is changed until the standards are met. Once quality is continually achieved variation naturally stays within the standard because the process is designed to do that. There are far fewer problems and wastes from processes designed to ensure the presence of the skills, equipment, tools and know-how to produce high precision performance.

Plant and Equipment Defects, Failures and Errors

Highly reliable equipment is necessary to reduce production costs and maximise throughput. High equipment reliability requires quality manufacture and precision maintenance, coupled with correct operating practices, which together deliver the necessary controlled conditions that produce high reliability. You get equipment working superbly reliable when designers make the right choices, the maintenance people do their work to precision specification, and operators run equipment so that operating stresses are low. There is no downtime if the equipment design is right for the service, if its parts work in a low-stress environment, and it is operated properly. Highly reliable production is normal and natural when plant and equipment work dependably at long-term sustainable capacity.

If under operation the equipment performance is not as designed then something is amiss. Not with the equipment; the problem is in the business processes, or uncontrolled external agents are at work. Our challenge is to identify the process failures that cause defects and prevent equipment from delivering design performance. Then to act firmly to rectify the situation.

Often the fault for poor equipment reliability lies with the design itself. It can be made of the wrong material for the duty. It may not be strong enough for the stresses induced in it, or the material is incompatible with its environment and degrades. An identified design problem needs design changes to improve equipment reliability. The main reasons equipment does not meet its designed reliability is because it is installed wrongly, it is built or rebuilt poorly, or its parts are allowed to be over-stressed in operation. Usually this happens because people involved in its installation, care and running do not know the right ways.

Though operators and maintainers have training, they can never know enough to handle all situations competently (nor can anyone else know it all). In uncertain situations they use what knowledge they have to make a decision. If what they do works to fix the problem, even if it is the wrong choice, it becomes how they solve that problem again in future. Unfortunately, many decisions do not have an immediately bad effect. If there was it would be good because the person would instantly self-correct and get it right. But most errors of choice do not impact until well into the future. The chosen action has no obvious bad consequences, and since things still run fine, the operator or tradesman, and alas their supervisor, believe it is the right decision. This is how bad practices become set-in-place; through ignorance and misunderstanding.

There is nothing wrong with making a wrong decision. If corrected immediately and nothing bad happens there was no harm done. Bad things happen when wrong decisions progress through time to their natural and final sad conclusion. Regrettably, there are very few decisions that have instant replay options. If it is important in your company to have low maintenance cost and highly-reliable production equipment, then the organisation's work and business systems must support that outcome. All work done by operators, maintainers, engineers and managers needs to be right. There is great value in developing quality systems that help everyone to do their work masterly, right-first-time.

Why We Have Standard Operating Procedures

Variability in work processes leads to defects and failures. Variations in work performance arise because human skills, talents and abilities are typically normally distributed. If we gauged the abilities of a wide cross-section of humanity to do a task, we would end up with a normal distribution bell curve. Secondary and tertiary learning institutions are well aware that student performance follows a normal distribution curve. Figure 14.2 shows a normal distribution bell curve, or Gaussian curve, of a talent in a large human population.

The implication is that for most human skills and talents there are a few exceptional people, a few with astoundingly poor ability and lots in-between clustered around the middle or mean. If a workplace requires highly able people, the distribution curve of human talent warns it will be hard to get exceptional people. The talent distribution curve also explains why continual training of the workforce is so important to a company's long term success. If the available labour clusters around the mean performance level of a skill, then to get better needs additional training in the skill, along with many opportunities to use it. Training and practice has the effect of moving average performers toward the elite end of the population as shown in Figure 14.3 [66].

[66] Gladwell, Malcolm, 'Outliers – the story of success', Allan Lane (Penguin Books), 2008.

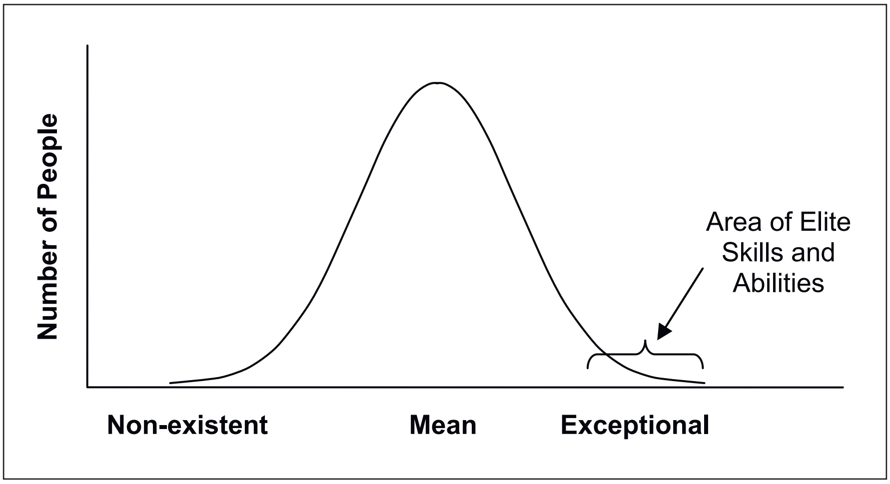


Figure 14.2 Distribution of a Talent in the Human Population.

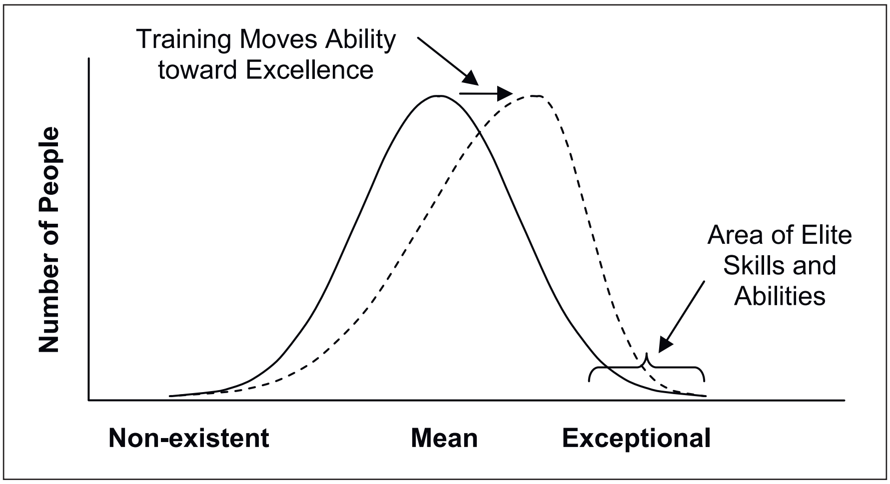


Figure 14.3 – The Effect of Training on Developing a Talent.

The Cost of Poorly Written Standard Operating Procedures

A job or operating procedure is a written systematic approach to a task that should provide clear guidance, set the required standard and stop variations in work performance. Standard operating procedures allow people from around the middle and below ability levels to do higher standard work than they naturally could do unassisted. Since standard operating procedures (SOPs) control the quality of the work performed by people not expert in a task, they are critical to the proper running of a business. Companies have long recognised that reproducible, correct results from the workforce need a proven and endorsed job procedure. It is also critically important that they are written in ways to promote maximum efficiency and make use of the least resources, while being effective at getting a task done in the fastest correct way. In the Author's workplace experience very few companies use SOPs to control production outcomes. When they are available they typically only record what to do in a task, are not self-checking and do not promote good practices. The better SOPs explain how to do the task, but most SOPs offer little practical assistance to the user in controlling product quality, or the quality of their performance in doing the task. Typically, an SOP is glanced over when operators and maintainers start a new job and then thrown to the back of the shelf.

That is a pity because they are one of the most powerful learning tools ever developed for use in the workplace.

Of the companies that have SOPs, an expert in the job most likely wrote them. They wrote the procedure already knowing all the answers. So they described tasks assuming prior knowledge. You will often see in SOPs statements such as – “Inspect lights, check switch, check fuse, and test circuit”, and “Inspect drive linkage for looseness”. Or in the case of a machine operator – “Test the vehicle and report its condition”. The problem with the use of procedures containing such descriptions is that you must first be an expert to know whether there is anything wrong with what you are looking at. Procedures without all the correct details require hiring trained and qualified people to do what may be a very simple job.

The Best SOPs Can Be Done By the Least Skilled People

Great SOPs are those that ensure workmanship quality. They contain detail and guidance, they include a target to hit, a tolerance on accuracy and regular proof-tests of compliance to guarantee job quality – they deliver masterly performance. In this way, they prevent defects from arising and so prevent future failures. With hands-on training and workplace experience even non-experts can do them well.

Standard operating procedures are quality and accuracy control devices with the power to deliver a specific level of excellence every time they are used. Few companies understand the true power of an SOP. Typically they use them because the company’s quality system demands it. People mistakenly write them as fast as they can, with the least details and content necessary to get the document approved. In reality SOPs save time, money, people and effort because they can make production outstandingly reliable by eliminating defects. They can prevent plant and equipment failures and so boost productivity.

Accuracy is the degree of conformity of a measured or calculated value to its actual or specified value. To be accurate requires a target value and a tolerance of what is acceptably close to the target. For a standard operating procedure to have powerful positive effects it needs clear and precise Targets, Tolerances and Tests – the 3Ts of masterly work – which if faithfully met will produce the required outcome.

The problem with targets is that they are not easy to hit dead-centre. If a procedural task states an exact result, then it has asked for an unrealistic outcome. A target requires a tolerance range within which a result is acceptable. There must be upper and lower limits on the required result. Even the bulls-eye in an archery target is not a dot; it is a circle with a sizable diameter. The bulls-eye in Figure 14.4 is not a pin head in size. Anywhere within the bulls-eye gets full marks. The target for each task in an accuracy-controlled procedure must have a tolerance.

Figure 14.4 – Targets & Tolerances.

Great equipment reliability and production performance naturally follows when doing work to operating procedures using the 3Ts. Figure 14.5 shows what accuracy means and how the 3Ts are used to get it. The 3Ts act to remove work variability. They create statistical process control over human activity. 3Ts put into procedures standardise performance and deliver repeatable outcomes. Instead of having a wide range of possible results the 3Ts limit the results to those you specify.

If we take the poorly specified "Inspect drive linkage for looseness" requirement from above, and apply the 'target, tolerance, test' method, a resulting description might be: "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 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 continue to list and specify any other necessary proof-tests and resulting repairs. With such detail provided it is no longer necessary to use highly qualified persons for the inspection. Anyone with mechanical aptitude can do reliable work once they are trained. Like a motor car manual for novice mechanics, top-class procedures are written with detailed descriptions and plentiful vivid images. Once novice mechanics have such manuals in-hand they can do a lot of their own maintenance with certainty of job quality. If procedures contain all the information and measures necessary to correctly rebuild equipment, or to run a piece of plant accurately, people with average skills can do the job well.

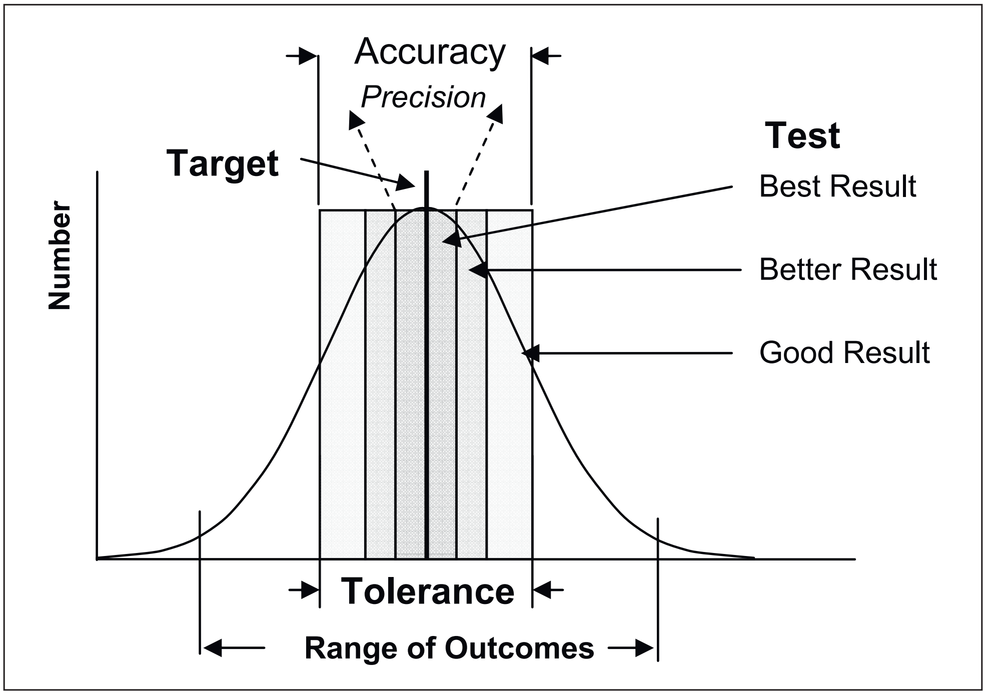


Figure 14.5 – Accuracy Control and the 3Ts – Target, Tolerance, Test.

Improving the accuracy of a task is done by using well-formulated, clearly understood standard operating procedures that contain targets to hit, tolerances for acceptable closeness and tests to prove the work is to the required accuracy. When there are high cost consequences, the first thing to do is to introduce improved SOPs to control the work variability and risk. The inclusion of 'target, tolerance, test' – the 3Ts of defect elimination – in all procedural tasks is the first rule of failure prevention. The only better solution is to error-proof so a mistake does not matter.

'Good, Better, Best' Tolerance Banding

You can drive continuous improvement in job quality by dividing the tolerance you place about a task target into 'good, better, best' tolerance bands. The bands specify levels of precision. Figure 14.6 shows tolerance banding used to challenge people to deliver high quality work.

Competent people are expected to continually achieve 'best' quality results. People developing their skills meet 'better' levels of performance. Novices are permitted to do the task to 'good' levels of accuracy. Using tolerance banding provides clear indication of what is high quality work and recognition of its achievement. Application of 'good, better, best' scales naturally challenges everyone to try and become 'the best'. It is a simple psychological tool to improve work quality.

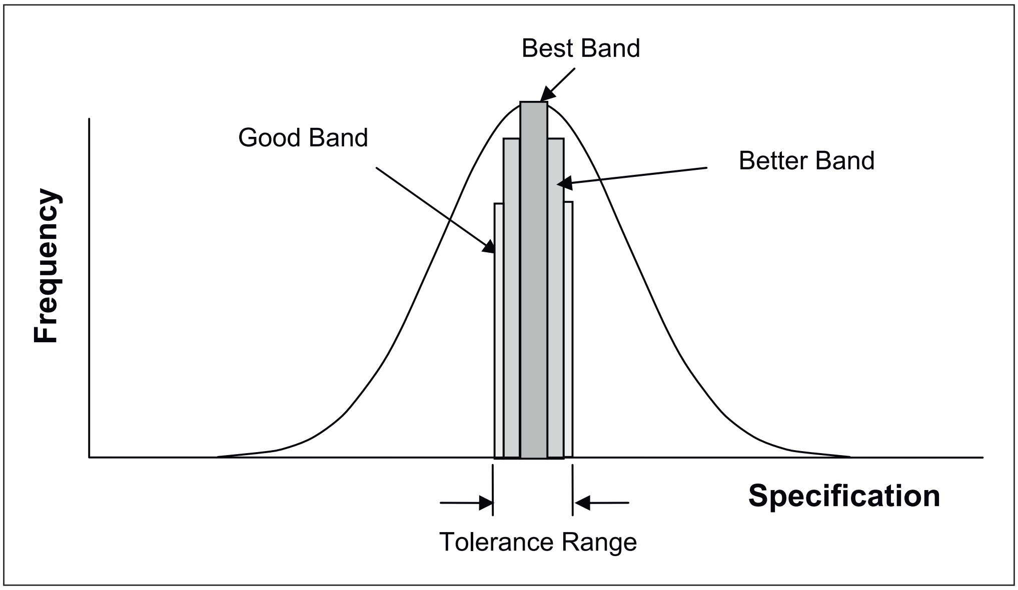


Figure 14.6 – Controlling Work Quality with 'Good, Better, Best' Tolerance Bands.

Train and Retrain Your People to Your Standard Operating Procedures

Having a procedure full of best content and excellent explanations for your workforce is not by itself enough to guarantee accuracy. How can you be sure that people comprehend what they read? Many tradesmen and plant operators are not literate, nor do they understand the true meaning of all the terms used in a procedure. To be sure your people know what to do, and can do it right, they need training and practice in the procedure. They need to know how to do the work thoroughly before they are allowed to do it unsupervised. Later they will need regular refresher and reinforcement training. The amount and extent of training varies depending on the frequency use, the skill level of the persons involved, and their past practical experience in successfully doing the work.

Procedures done annually or more often by the same people usually do not need retraining unless they are complicated, or carry great inherent risk. Because people forget, those procedures on longer cycles than annually will need refreshment training before they are next done. Training and retraining often seems such an unnecessary impost on an organisation. Managers often 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 "How many defects, errors and mistakes are you willing to pay for? What risks are you willing to carry in your operation?" If organisational risk management systems use procedures to protect the organisation from risk it is necessary to continually check and prove the protection layer is in place and operating properly. Training, retraining and auditing actual hands-on performance helps to keep that protective layer whole. Assuming that people can be 'trained once, trained for life' is a serious error of judgement. For example, if a flange leaks soon after rebuilding a piece of equipment, it is a sign that you may need to retrain your people in the correct bolting of flanges. Flanges squarely mounted, in good condition, and properly rated for the service do not leak if they are bolted-up right. When a repair re-occurs often on perfectly good equipment it is a sign that the SOP does not contain targets, tolerances and proof-tests, or the procedure is laying at the back of a shelf somewhere and people need training.

Making Your Organisation an ACE

A classic example of what great value an accuracy-focused SOP can bring is in this story of a forced draft fan bearing failure. The rear roller bearing on the fan never lasted more than about two months after a repair. The downtime was an expensive and great inconvenience. To prevent a breakdown the bearing was replaced every six weeks during a planned outage and also put on vibration analysis observation. After several replacements enough vibration data was 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 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 bolted bearing housing roundness and compare the dimensions to allowable target measurements, they would have found the oval-shaped hole at the first rebuild. There was no need for the bearing to fail after the first time. A badly written procedure had failed the organisation. Whereas an accuracy-controlled procedure with targets, tolerances and proof-tests would have found the problem on the first repair, and fixed it permanently.

Existing ISO 9000 or Six Sigma quality procedures convert to accuracy-controlled operating procedures with little development cost. The only extra requirement is that they include a target with tolerances and a proof-test in every activity to give feedback and confirmation that each task is done right as the job progresses.

A well written accuracy-controlled procedure contains clear individual tasks; each with a measurable result observable by the user and a range within which the result is accepted. With each new task only allowed to start once the previous one is within target it is possible to guarantee a top quality result. With targets in the procedure, its user is obliged to perform the work so that they are within the required tolerance. Having a target and tolerance forces the user to become significantly more accurate than without them. With all the task targets hit, the procedure is done accurately and excellent work results. The 3Ts automatically build defect elimination into a job.

Once a procedure always delivers its purpose you have developed a failure control system. No longer will unexpected events happen if work is done accurately to the requirements of the procedure. The procedure guarantees in-built accuracy that prevents failure and stops the introduction of defects.

To ensure each task is correctly completed the worker is given a measurable target and tolerance to work to. The procedure is correct when its individual tasks are all within their target limits. Using this methodology in standard operation procedures makes them quality control and training documents of outstandingly high value. Those organisations that use sound failure control and defect prevention systems based on proof-tested, accurate work, move from being a quality conscious organisation to being an accuracy-controlled enterprise; an ACE organisation. With 3T accuracy in maintenance, operation and engineering tasks, getting outstanding equipment reliability and consistently high production performance becomes normal.

The Value of Precision

The need for precision and accuracy to control variability dominate those industries that use plant and equipment. It is the most critical requirement for high reliability. Industries using machines require them to run reliably (no failures or unplanned stoppages) with high availability (ready for immediate use) and high utilisation (continuously in use) all their working life. Outstanding reliability, availability and utilisation come from being precise and accurate in equipment assembly and use. Precision and accuracy in equipment design, construction, operation and maintenance is a sure way to achieve a lifetime of high equipment performance and service with low operating costs. But it requires the patience to develop the skills and dedication to continually apply accuracy control, for its achievement. Man-made equipment and machinery only work well for a long time when they work precisely. Precision means meeting specified standards to within allowed tolerances. Precision requires that the specific standards needed for high reliability are set and continually achieved during design, manufacture, assembly, operation and maintenance. Accuracy is the lifeblood of equipment reliability. Precision results from controlling accuracy. An example of precision is the alignment between two rotating shafts shown in Figure 14.7. If two shafts are off-set to each other they run out-of-true, distorting each other and causing massive forces to be loaded onto the bearings and coupling. Eventually the bearings, coupling or shafts are destroyed because of the inaccuracy in their alignment.

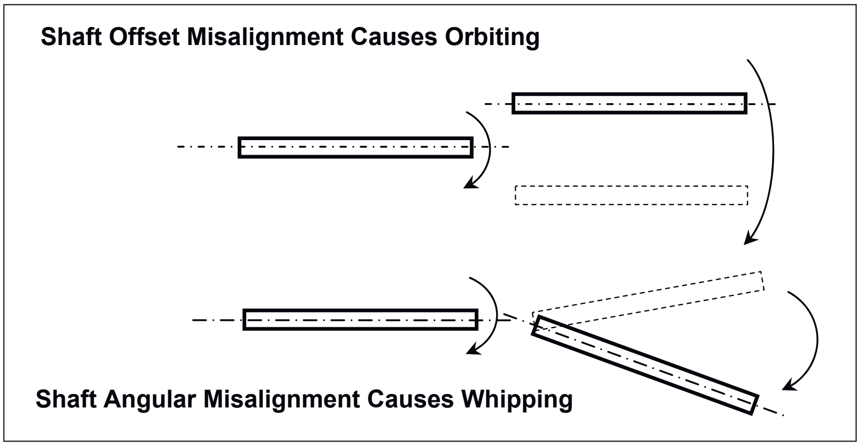


Figure 14.7 – Inaccurately Aligned Shafts Destroy Machinery.

The two shafts must align with sufficient accuracy to ensure they run without creating destructive forces. When an accuracy standard is set a requirement is established which must be confirmed by measurement. For example, an alignment standard for the two shafts in Figure 14.7 rotating at 1500 RPM is to require their axial parallel offset be aligned to better than 0.025mm (0.001”) per 100mm of coupling separation and angular alignment to be better than 0.06 degrees [67]. The standard specifies the accuracy needed to meet engineering design requirements. The positions of the shafts can now be measure and adjusted until they are precise. Introducing accuracy standards into workplace methods ensures the precision that prevents defects. This translates into highly reliable equipment with outstanding availability and reliable performance.

[67] Piotrowski, John, ‘Shaft Alignment Handbook’, CRC Press, Third Edition, 2007.

Senior Managers are the Leaders of ACE

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. ACE is subtly different because it is about instilling excellence into work; it's about helping people to be great. From the most senior person to the least, the philosophy requires that people know what an excellent outcome is in every task they do, and they strive to achieve 'good, better, best' results. An ACE has clear targets, tolerances and tests in procedures for senior management as well as for shopfloor personnel. Senior managers show leadership by placing the requirements of ACE on themselves first. They show how the 3Ts of defect elimination improve their own performance before they take ACE into the organisation. Unlike quality management systems, where senior managers place the quality demands on those below them in the organisation and monitor their performance from above, the Accuracy Controlled Enterprise focuses on individual excellence and allows managers to lead their people by example. The 'leading from the front' required for successful ACE adoption is a very powerful symbol of management commitment to improving the organisation and helping its people.

Figures 14.8 and 14.9 represent the business aims of Accuracy Controlled Enterprise work quality assurance. ACE drives quality improvement by making people responsible for the quality of their performance. It helps people to achieve precision in their workmanship by providing clear targets to meet, certainty about what is 'good enough' and a means to prove for themselves that they are doing quality work. It encourages them to improve their skills. They can even change and improve the job design and make it simpler and easier.

Examples of an Accuracy Controlled Procedure

Accuracy controlled procedures are simple for users but have demanding requirements for writers. ACE procedure writing starts with drawing a flow map of the procedural steps. The flow chart is in landscape orientation and formatted as shown in Figure 14.11 for specific reasons. The across page flow makes the process easy to visualise. Each process step box is given a brief descriptor. Reading the descriptors explains the substance of the procedure. Drop boxes below each process step box add information and explanation. The layout also makes it easy to conduct Lean Value Stream Mapping and Process Step Contribution Mapping in future.

Be clear about the importance of the procedure to the business, identify its purpose, and indicate the people affected by the work and the necessity of doing it thoroughly and correctly. This helps to establish the right mindset in the user to want to do excellent work in a timely fashion.

An accuracy controlled procedure incorporates the 3Ts of defect elimination – Target, Tolerance, and Test – in each procedural task. This provides statistical process control and allows users to identify clearly the requirements they need to meet. They check themselves that they have met each requirement before going to the next task. Explain every step in a task in simple detail using both words and images. Define and explain the information flows and the records needed. Write the SOP with the intention of using it as a record of the task and a quality control form.

An ACE 3T procedure layout is shown in Figure 14.10. The Target is shown in the 'Best' column, the Tolerance is subdivided into 'Good, Better, Best' ranges, and a Test is specified for each task. The two-sided standard of an ACE 3T procedure is far superior to a single-sided accept/reject criteria. A single-sided criteria tells you how bad you can be. But a two-sided criteria tells you how good you need to be.

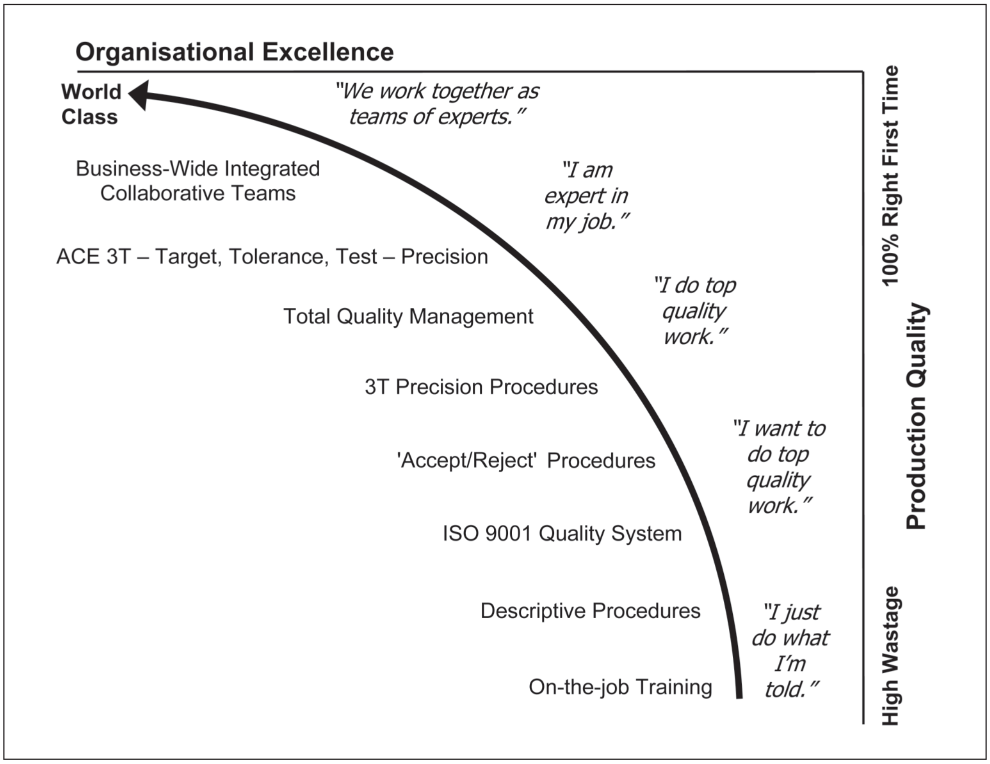


Figure 14.8 – The Quality Culture of Plant and Equipment Wellness.

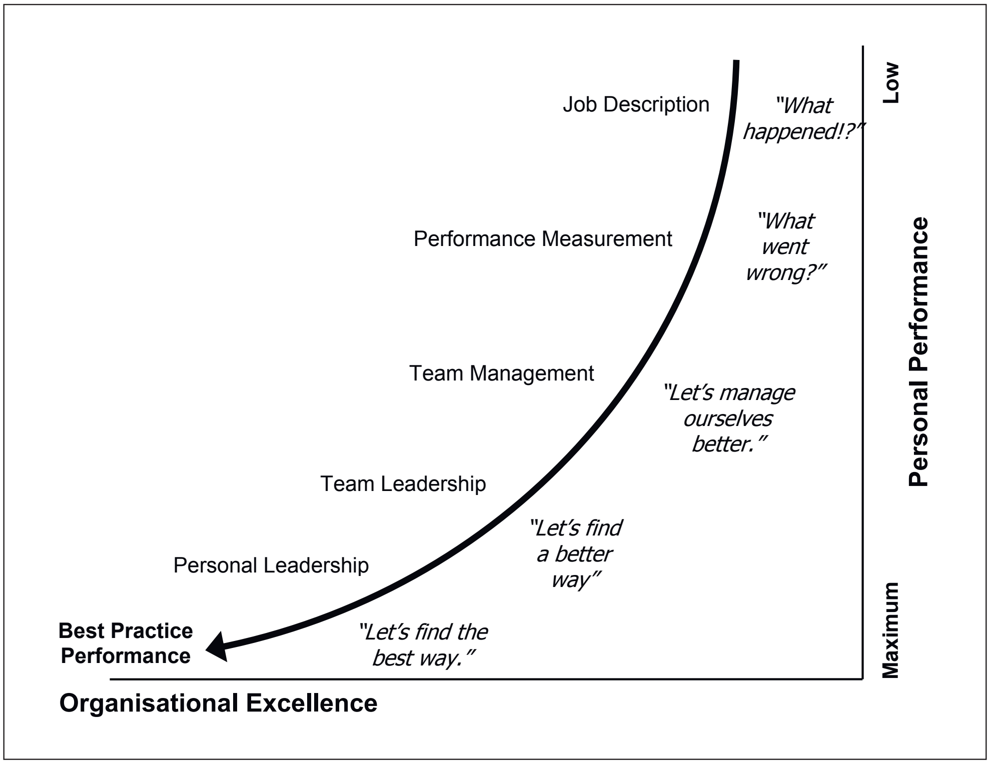


Figure 14.9 – The People of Plant and Equipment Wellness.

Task Step No	Task Step Owner	Task Step Name	Materials, Tools and Their Condition	Full Description of Task	Test for Correctness	Tolerance Range			Record Actual Result	Action if Out of Tolerance	Sign-off After Complete
		(Max 3 – 4 words)		(Include all tables, diagrams and pictures)	(Include diagrams and pictures)	Good	Better	Best			
1	2	3	4	5	6	7	8	9	10	11	12

Figure 14.10 – An ACE 3T Procedure Layout.

Two examples of an ACE procedure follow. The first is for a clerical task and sets accept/reject criteria for each activity. The second procedure, for bolting-up a pipe flange, is in the full ACE 3T format. Notice how the procedures specify the standard and quality that must be achieved on the job. The workmanship quality and standard of work is not left to the discretion of the person doing the work. As a minimum, each task step has an 'accept/not accept' standard. In the case of the ACE 3T procedure, it clearly states the minimum acceptable outcome, called 'good', and identifies the top-class performance in the 'best' column. The ACE 3T approach provides a practical and sure way to control work quality regardless of who does the job. Now everyone knows what 'good enough is' and anything less is unacceptable. Everyone also knows what top-class work is and are encouraged to strive for it.

Clerical Pass/Fail Example – Cost Report Spreadsheet Procedure

This procedure explains in detail how to create the department's monthly production costs summary spreadsheet. The department manager and the cost accountants use this spreadsheet to make their monthly business performance reports. Any errors in the spreadsheet will flow through to the monthly report presented to head office.

This procedure is our current best practice and you should follow it exactly. It is the result of many people's efforts over many years. It is the quickest, best way yet found to do the job. You are encouraged to learn the job exactly as in this document. If after you master this procedure exactly, you believe that you know of improvements, please bring them forward for discussion. You can test your ideas and compare them to the procedure. If your suggestion proves to be better, it will become the new way of doing this job.

Necessary Equipment and Tools

Computer, National Monthly Production computer file, National Monthly Production hardcopy file

Task Summary

A summary of the process for completing the spreadsheet is below. A fully detailed procedure is beneath the list. If you have a problem that you cannot solve please see your supervisor.

1. Find spreadsheet
2. Bring up spreadsheet
3. Select work sheet
4. Get hardcopy folder
5. Return with hardcopy
6. Record monthly total
7. Cross check totals
8. Totals don't agree
9. No spread-sheet error
10. Hardcopy checked
11. Update spreadsheet
12. Totals agree

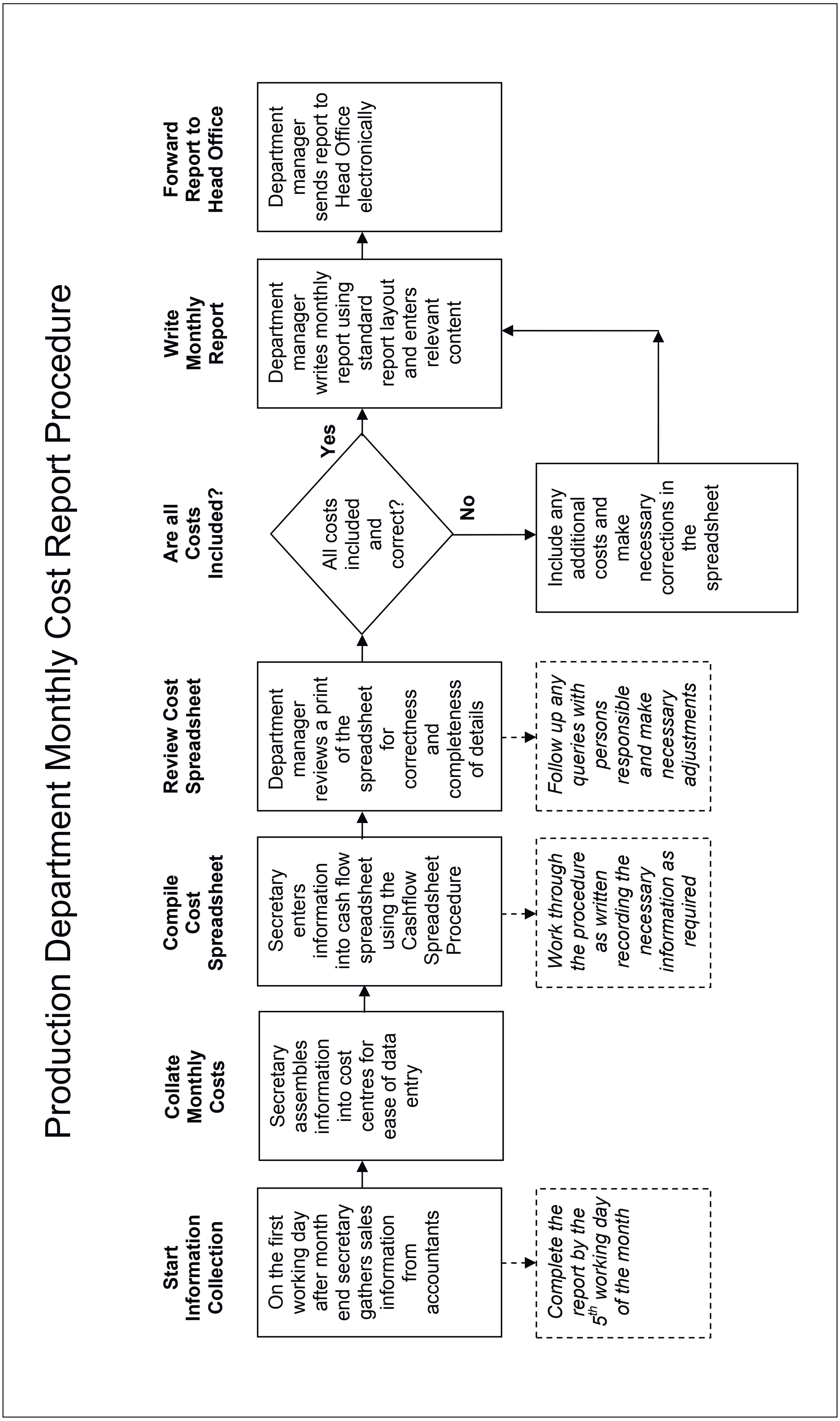
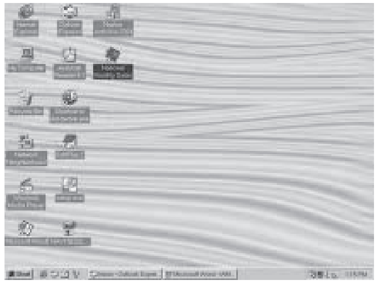
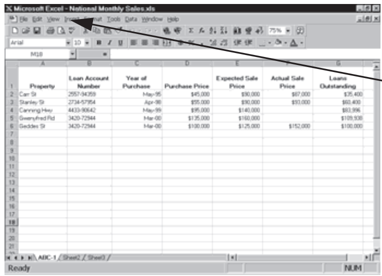
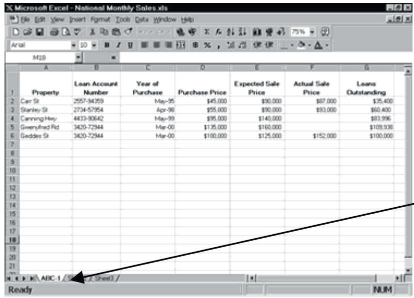
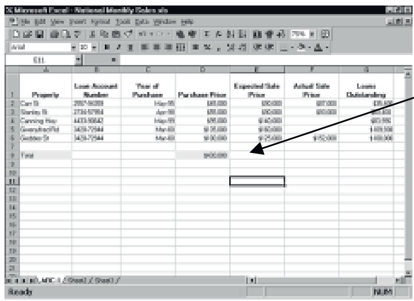
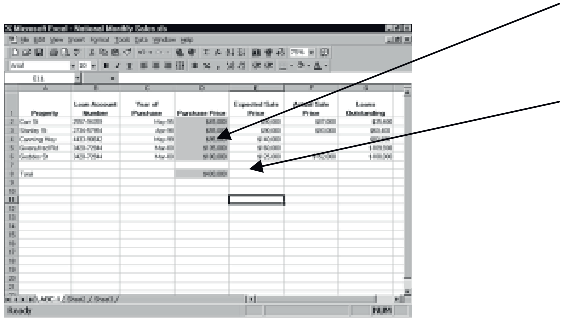


Figure 14.11 – Process Flow Map of Cost Report Procedure.

Task Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Record Actual Result	Initial After Complete
1.	Office clerk	Find spread-sheet	Find the shortcut on the screen called ‘National Monthly Production’. 	See the icon called ‘National Monthly Production’.		
2.	Office clerk	Bring up spread-sheet	Make spreadsheet ‘ABC’ active on computer by ‘double-clicking’ the icon. 	Note the name on the spreadsheet is ‘National Monthly Production’.	*(Place spreadsheet name here.)*	

Task Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Record Actual Result	Initial After Complete
3.	Office clerk	Select work-sheet	Bring up the worksheet called 'ABC-1' to use. 	See the name on the SOP and actual worksheet is 'ABC-1'.	*(Place worksheet name here.)*	
4.	Office clerk	Get hardcopy folder	Get the 'National Monthly Production' folder in the top draw of the National Sales filing cabinet in the Sales Office.	Read the file name and see it is called 'National Monthly Production'		
5.	Office clerk	Return with hardcopy	Return to your desk and open the folder to the Total National Production Report.	See that the page has the title 'Total National Production Report'.		
6.	Office clerk	Record monthly total	Total the 'Purchase Price' column for the month and put into cell 'D8'. 	Check cell 'D8' has the monthly total.	*(Could also record monthly total here.)*	
7.	Office clerk	Cross check totals	Check that the total for 'Purchase Price' in the hardcopy folder and the spreadsheet are the same.	Both totals are the same.	*(Record the total.)*	

Task Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness	Record Actual Result	Initial After Complete
8.	Office clerk	Totals don't agree	If the two numbers are not the same, check the formula in the spreadsheet matches the cells that it should. 	Check all individual cells are picked up by the formula in the Totals cell.		
9.	Office clerk	No spread-sheet error	If the spreadsheet is correct, the error lies in the hardcopy file. Report the error by telephone to the Manager National Production.	Ring the National Manager.		
10.	National Production Manager	Hardcopy checked	Confirm the totals of individual sales are recorded correctly and ring back the correct individual production figures.	National Managers advises each figure.		
11.	Office clerk	Update spreadsheet	Correct the figures in the spreadsheet with the correct values and confirm the totals are now correct.	Double check the new total against hardcopy file total.	*(Record the correct total.)*	
12.	Office clerk	Totals agree	If the totals in both documents agree, the job is complete. Save the spreadsheet, print a copy for the manager to review, close the electronic file and return the hardcopy file to the office filing cabinet.	See spreadsheet is saved and file returned.		

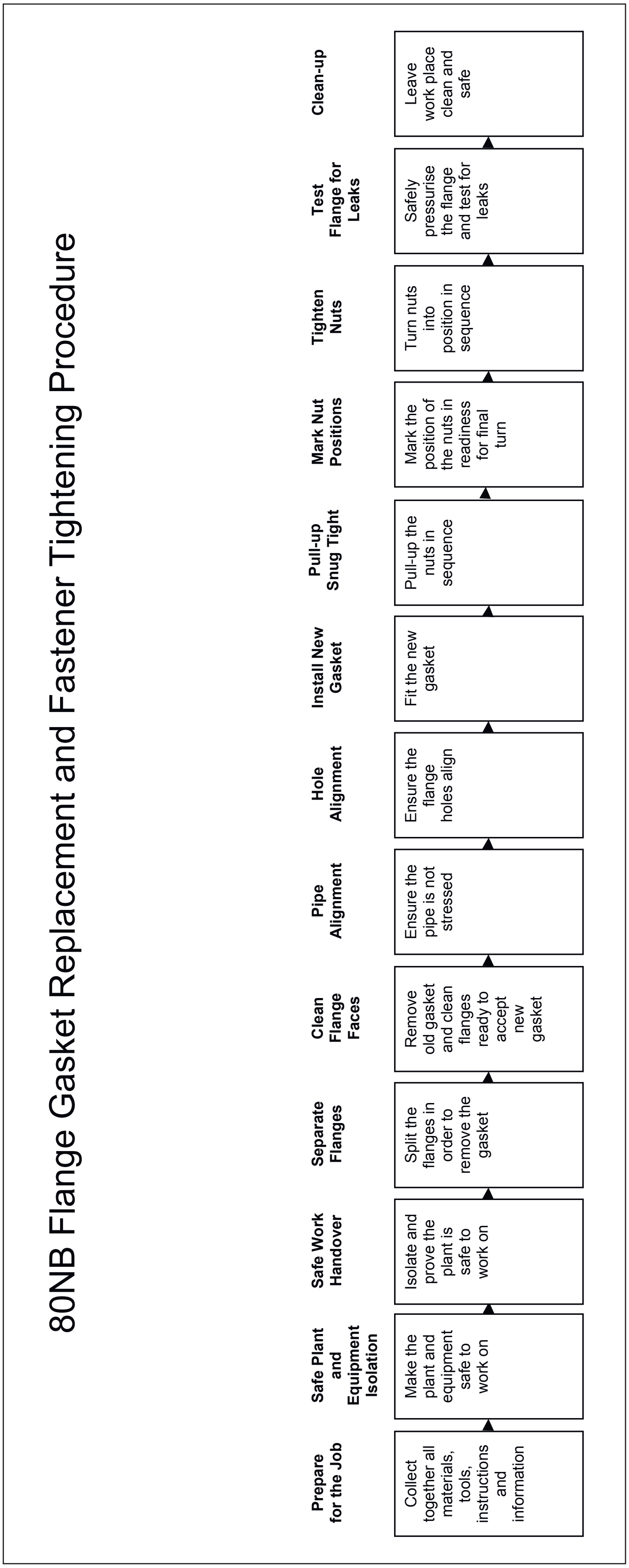


Figure 14.12 – Process Flow Map of Flange Connection Procedure.

ACE 3T Example – Flange Connection Procedure with Tolerance Banding

This is a partially complete example of an Accuracy Controlled Enterprise (ACE) 3T procedure with tolerance bands to bolt together 80 NB, ANSI B36.5, forged steel, Class 150 flanges. Each task has a target with the allowed limits banded into 'good, better, best'. Provide instruction if the tolerance is not achieved.

NOTE: The example covers the method to use to create a 3T procedure and is not the actual procedure to use when bolting-up flanges. Each organisation must research, develop and approve their safe practices and procedures for bolting flanges. The use of turn-of-nut on pressure flanges may not comply with the applicable pressure piping design codes.

Flange Connection Procedure

Importance of correctly mating flanges: This procedure explains how to bolt-up correctly a pipe flange on 80mm (3") diameter pipe. Leaks of dangerous chemicals from pipe flanges create a safety and environmental hazard that can lead to death of workmates and the destruction of production plant and equipment. Even a water leak from a flange causes slip hazards and makes an unsightly mess. Pipe flanges must be bolted-up so they never leak.

This procedure is our current best practice and you should follow it exactly. It is the result of many people's efforts over many years. It is the quickest, best way yet found to do the job. You are encouraged to learn the job exactly as in this document. If after you master this procedure exactly, you believe that you know of improvements, please bring them forward for discussion. You can test your ideas and compare them to the procedure. If your suggestion proves to be better, it will become the new way of doing this job.

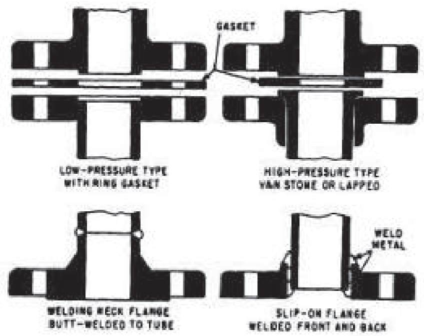
Necessary Equipment and Tools: Gasket, ring spanners (do not use adjustable shifters and pipe wrenches as they damage corners of bolt heads and nuts making their removal dangerous and unsafe), suitably load-rated studs and nuts, pencil.

Task Summary

A summary of the process of installing gaskets and making flanges is below. A fully detailed procedure is beneath the list. If you have a problem that you cannot solve please see your supervisor.

1. Get work pack, tools, NEW fasteners and NEW gasket
2. Get safe handover isolated and pipe drained
3. Place personal danger tags test if drained
4. Break and spread flange safely
5. Clean-up flange faces
6. Check and correct unrestrained pipe alignment
7. Check and correct bolt hole alignment
8. Mount gasket and insert fasteners
9. Pull-up fasteners snug tight in sequence
10. Mark nut position and turn angle past snug
11. Turn nuts to position in sequence
12. Test flange for leakage at operating pressure
13. Safely clean-up, hand-back, complete job record and sign-off Work Order

Bolt Size	Bolt Grade	Bolt Torque	Tolerance on Torque
5/8”	A193 B7 stud and nut	201 Nm (60% Yield)	+- 25% with Torque Wrench
		½ turn from snug tight	Between ½ to 5/8th turn
Gasket: Non-asbestos fibre, 1.5 mm thick, ring, grade as noted on work order			



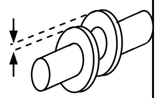
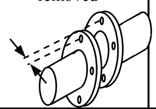
Engineering Standards

Flange Squareness:
Good: Within 1mm for every 200mm diameter
Better: Within 0.75mm for every 200mm diameter
Best: Within 0.5mm for every 200mm diameter

Stress-free Flange Bolt Hole Alignment:
Good: Centres within 2mm
Better: Centres Within 1.5mm
Best: Centres within 1mm

Bolt Lubricant: Molybdenum disulphide

Task	Task Step Owner	Task Step Name (Max 3 – 4 words)	Task Description	Mat’l – Tools and their Condition	Test for Correctness (Include diagrams and pictures)	Tolerance Bands Good	Better	Best	Reading / Result	Action if Out of Tolerance	Sign off
1	Technician	Prepare for the job	Gather together NEW studs and nuts, washers gasket, thread paste, tools, job work order, danger tags, handover permit, special instructions, PPE	5/8” ring spanner or socket, podgy spike bar, screw driver, scraper	All materials and tools are on the job before starting the job	Request and collect issued items from store	Planner arranged all items ready for issue from Store	Planner has all items at job and job is ready to do		Only start work once all requirements are gathered together	
2	Technician	Inform operator	Contact Operations personnel responsible for plant isolations and handover		Handover preparation and documents correctly done	Contact Operator when ready to start job	Operator has plant off-line awaiting work	Operator has plant isolated, tagged and drained		Job can only start when Operations safely handover plant and piping	
3	Technician and Plant Operator	Make work place safe	Place personal danger tags at isolation points and accept plant handover after proving isolations and drainage	Danger Tags	Isolation procedure is correctly done and proven safe	Operator and repair man walk circuit and identify and tag isolations and open drains	Operator has isolated plant & tagged isolations out-of-service & drained piping	Operator provides isolation point drawing and walks circuit to show previous tagged isolations and open drains		Only start work when piping is fully drained and proven to be empty and possible gas build-up vented	
4	Technician	Separate flanges	Release tension on exiting fasteners gradually in tightening sequence and then remove one fastener at a time but leaving the last fastener loosely in place if pipe springs unexpectedly, spring flanges with podgy bar	5/8” ring spanner or socket, anti-seize liquid	All fasteners removed without damage to flanges or harm to personnel or other property	Back-off all nuts half a turn in sequence and then a full turn, removing all fasteners but last one. Spring flanges with podgy	Back-off all nuts half a turn in sequence and then a full turn, catch any drops of product from flange in suitable container, remove all fasteners but last one. Spring flanges with podgy	Cover fasteners with anti-seize, back-off nuts half a turn in sequence and then a full turn, catch any drops of product from flange in suitable container, remove every second fastener and finally all fasteners but last one. Spring flanges with podgy		If flange does not spread easily review the situation and consider use of hydraulic spreader or wedges without damaging flange faces	

Task	Task Step Owner	Task Step Name (Max 3 – 4 words)	Task Description	Mat'l – Tools and their Condition	Test for Correctness (Include diagrams and pictures)	Tolerance Bands Good	Better	Best	Reading / Result	Action if Out of Tolerance	Sign off
5		Clean flange faces	Remove old gasket and clean flange faces, remove any burrs, check face is flat with straight metal ruler and 0.05mm shim in gaps, no draw marks, pits or scratches allowed across flange face	25 mm wide metal scraper, 80 grit emery cloth	Flange face are totally clean and safely usable	Loose material removed, burr-free, flat face, no draw marks or pits deeper than 0.25mm	Grooves clean, face sanded, flat face, no draw marks or pits	Bright, smooth, flat face, no groove damage or pitting, as good as new		Replace or machine flange with identical rating and grade if pits are deep, or are in close clusters, or not flat *(pictures would be necessary)*	
6		Pipe alignment	Check unrestrained pipe alignment	5/8" ring spanner x 2, or socket and ring spanner	Measure misalignment with vernier callipers on flanges with studs removed 	Flanges are unbolted and are in-line to within 2 mm	Flanges unbolted and are in-line to within 1.5 mm	Flanges unbolted and are in-line to within 1 mm		Cut pipe and remount flange to bring unrestrained flanges to within 1 mm alignment and 0.5 mm squareness to applicable procedure for the pipe material and grade	
7	Tradesman	Bolt hole alignment	5/8" ring spanner x 2	Check bolt hole alignment	Measure with vernier callipers on flanges with studs removed 	Flanges unbolted and holes in-line to within 2 mm	Flanges unbolted and holes in-line to within 1 mm	Flanges unbolted and holes in-line to within 0.5 mm		Cut pipe and realign flange to bring hole alignment of unrestrained flanges to within 0.5 mm	
8		Install new gasket and fasteners	Mount gasket and insert fasteners. Pre-cut studs to length and de-burr so that two full threads protrude out of each nut when fully tightened. Lightly lubricate the studs and the face of the nuts in contact with the flange.	Approved NEW gasket; NEW studs and nuts, bolt lubricant, podgy bar	Only new gasket and new fastener components used	Gasket slid between flanges and centred without damage and new studs/nuts fitted by hand	Gasket slid between flanges without and centred damage and studs/nuts lightly, pre-lubricated and fitted by hand within 2 minutes	Gasket slid between flanges and centred without damage and studs/nuts lightly, pre-lubricated and fitted by hand within 1 minute			
9		Bring flanges together	Pull-up fasteners snug tight in cross tightening sequence. Sung means flanges are in firm contact under about 20% of final bolt torque. It is obtained by the full effort of a well-built man pulling on a ring spanner until it can no longer be moved by hand. It can also be achieved by use of an impact wrench. When the spinning nut turns to blows, count	5/8" ring spanner or socket, feeler gauges	Flanges come together square with stress-free alignment	Wind nuts onto studs by hand so studs extend equal distance either side of flange. Tighten nuts finger tight and check that flanges are parallel to an accuracy of 0.4mm with the	Wind nuts onto studs by hand so studs extend equal distance either side of flange. Tighten nuts finger tight and check that flanges are parallel to an accuracy of 0.2mm with the	Wind nuts onto studs by hand so studs extend equal distance either side of flange. Tighten nuts finger tight and check that flanges are parallel to an accuracy of 0.1mm with the feeler gauges. Number the		If flanges are not parallel, directly 180° degrees opposite widest part of indicated gap, loosen nuts off one or more turns. Return to segment with gap and tighten until both flanges are in contact with gasket. This is necessary to prevent	

Task	Task Step Owner	Task Step Name (Max 3 – 4 words)	Task Description	Mat'l – Tools and their Condition	Test for Correctness (Include diagrams and pictures)	Tolerance Bands Good	Better	Best	Reading / Result	Action if Out of Tolerance	Sign off
			three blows, and the bolt will be snug tight[68].			feeler gauges. Pull all nuts on both flanges up sung tight in correct sequence.	feeler gauges. Pull all nuts on both flanges up sung tight in correct sequence within 5 minutes	studs in the sequence of tightening. Pull all nuts on both flanges up sung tight in correct sequence within 4 minute		flange levering over the fulcrum formed by the outer edge of the two raised faces at points in contact with gasket. The restriction will cause exceptionally high flange to gasket clamp loading at this point, with possible damage to gasket, PLUS diverting necessary clamp loading bolt torque energy to correcting alignment on the opposite segment.	
10		Match mark fasteners	Match-mark nut position **on one flange only** with a pencil when all nuts on both flanges are snug.	Pencil	Scribed marks in correct position and easily observable	Match-mark the nut and flange	Clearly match mark the nut and flange within 1 minute	Clearly match-mark the nut and flange within 45 seconds			
11		Tighten fasteners	Turn each nut **on one flange only** an extra 1/3 of a turn to final position in cross tightening sequence. Re-tension continuously until all nuts are equally tight. No rotation of stud is permitted while tightening the nut.	5/8" ring spanner or socket, Impact wrench	Fasteners correctly tensioned to required nut position in right tightening sequence	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 5 minutes.	Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence in 4 minutes.		If a stud starts to rotate as the nut is tightened it indicates that the nuts were not snug to start with. Immediately stop and undo all studs and repeat nut snug tensioning procedure	
12		Test for leaks	Test flange for leakage at operating pressure, release pressure and retighten nuts on same flange as originally tightened								
13		Clean and hand back	Safely clean-up, hand-back, complete job record and sign-off and record Work Order history								

Figure 14.12 – Process Flow Map of Flange Connection Procedure.

NOTE: The example covers the method to use to create a 3T procedure and is not the actual procedure to use when bolting-up flanges. Each organisation must research, develop and approve their safe practices and procedures for bolting flanges. The use of turn-of-nut on pressure flanges may not comply with the applicable pressure piping design codes.

[68] Sheppard, Alan T., 'High Strength Bolting', The DuRoss Group, Inc.