Maximising Maintenance Work Quality and Equipment Reliability in Shutdowns

Shutdowns and Turnarounds 2011 Conference

By

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Lifetime Reliability Solutions

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Presentation Coverage

- The connection between maintenance work quality and the time to the next breakdown,
- Using the Taguchi Loss Function to explain why work quality is important,
- Effectively specifying and measuring maintenance work quality requirements for shutdowns

Shell's Shutdown Success Indicators

- **True Shutdown Duration**

Total time taken from feed out to product back on grade

Feed out  **Product on spec**

- **Length of Interval Between Shutdowns**

Time between planned shutdowns

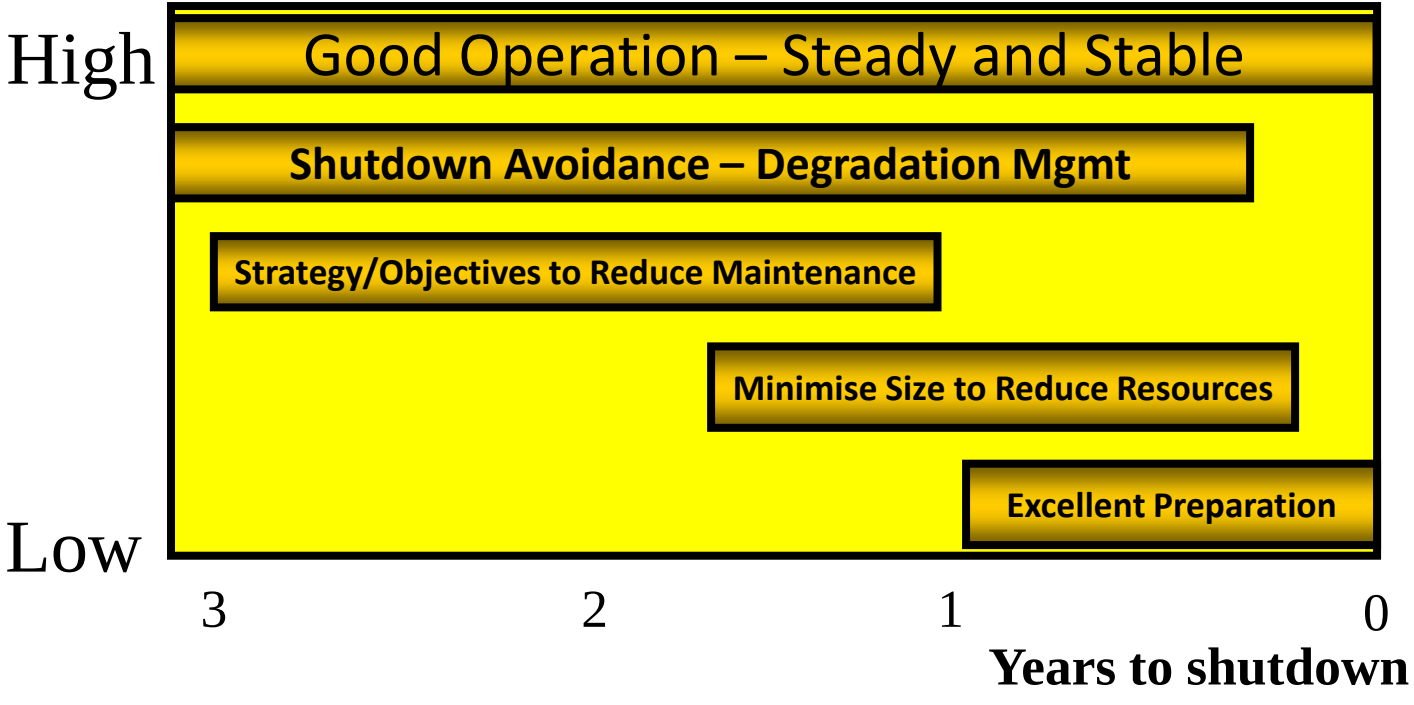
(from product on grade to feed out of two consecutive shutdowns)

Some 'best' numbers in Refining Source: Alberto Pasqualini refinery – Brazil

- Crude unit run 68 months (5-3/4 yrs)
- Crude unit "pioneer" run 90 months (7-3/4 yrs)
- Catalytic Cracker run 46 months (3-3/4 yrs)

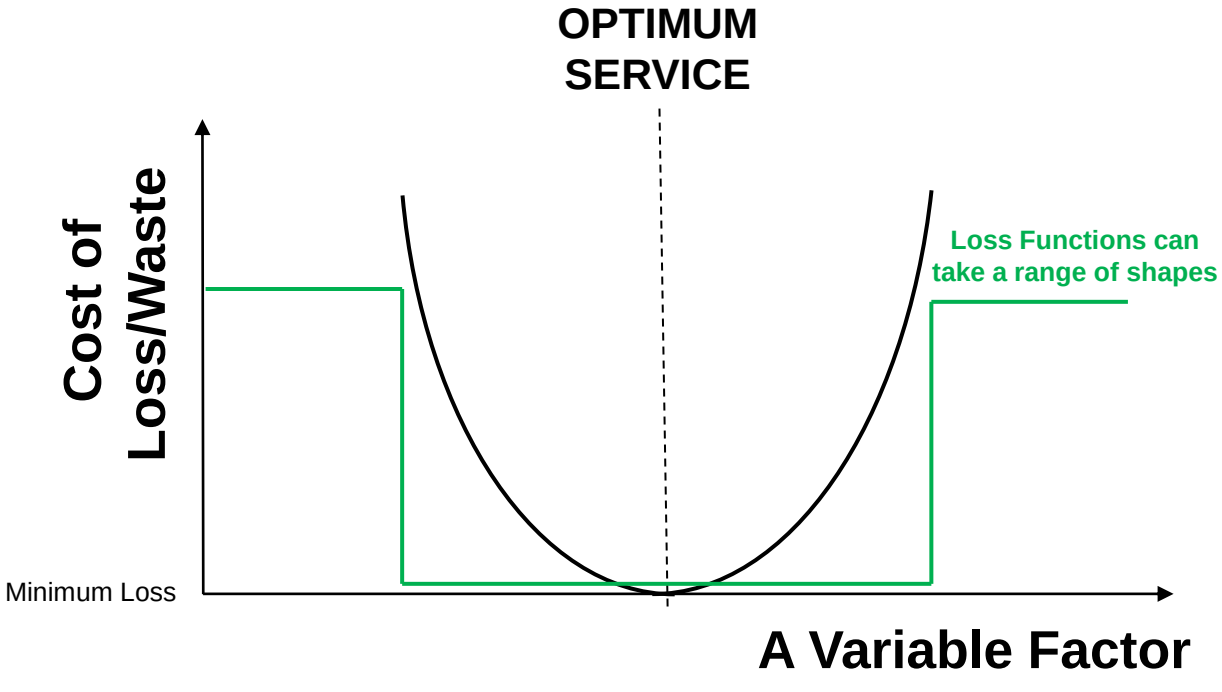
Thanks to Jim Wardhaugh, UK Consultant (30 years with Shell and Centre of Excellence Leader)

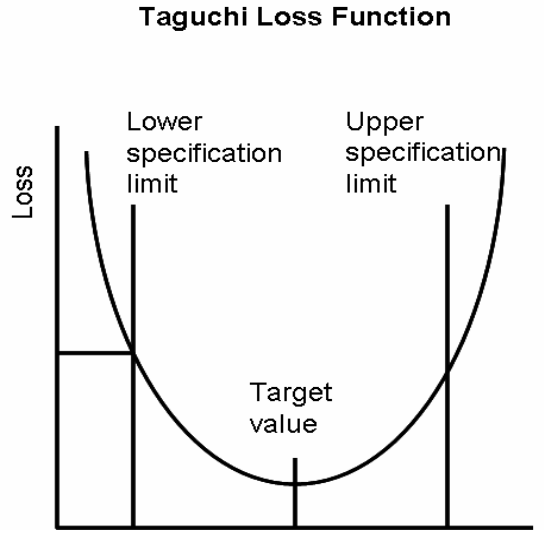
Influence on Profitability



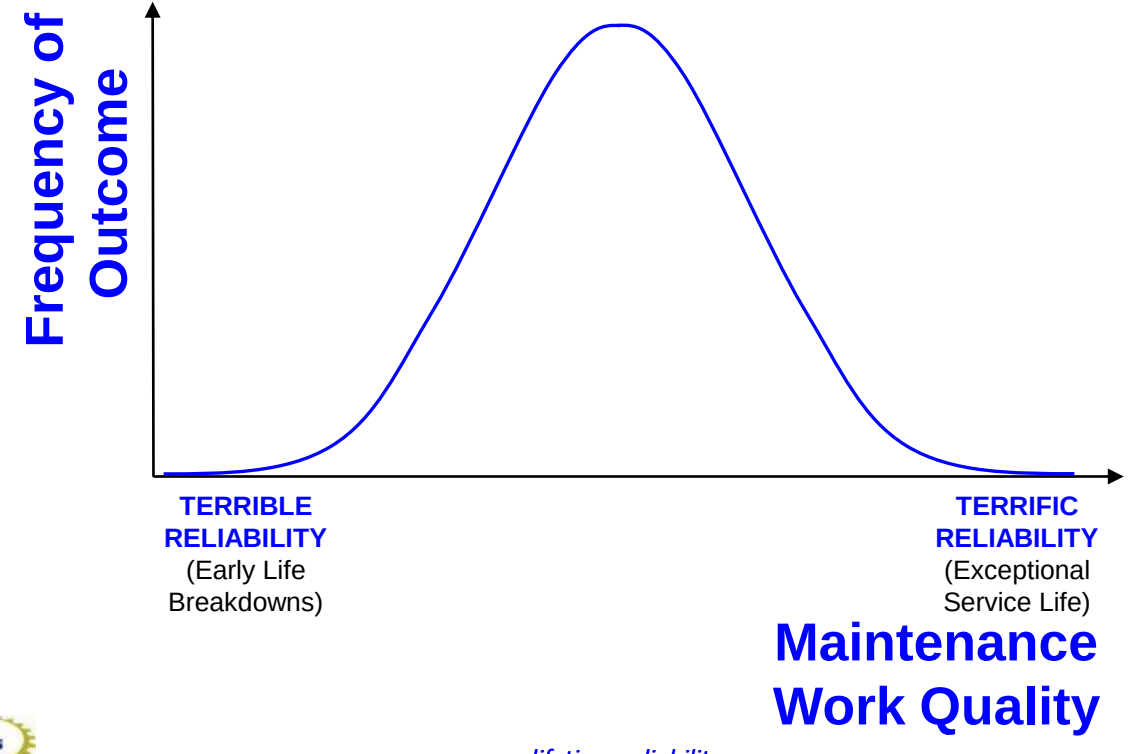
Thanks to Jim Wardhaugh, UK Consultant (30 years with Shell and Centre of Excellence Leader)

The Concept of a Quality Loss Function

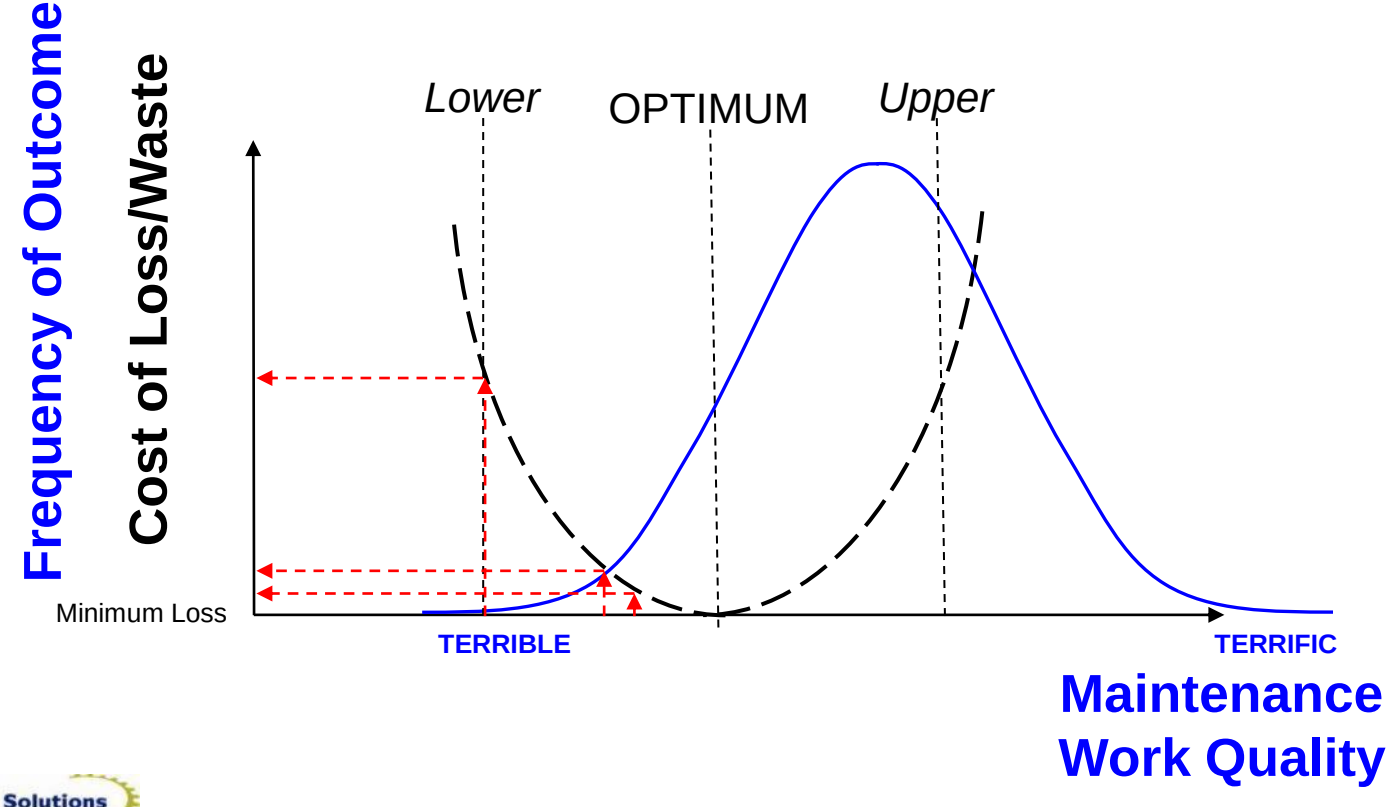




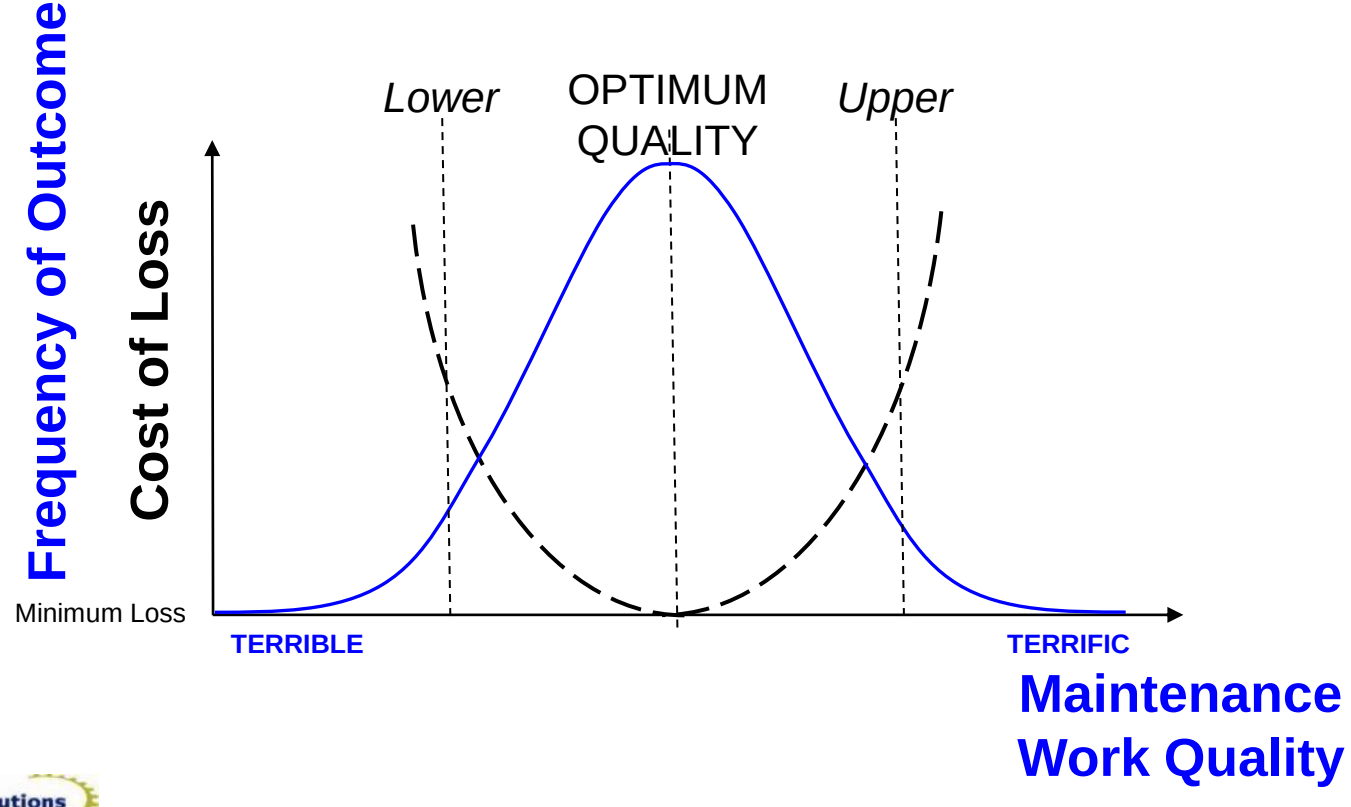
Distribution of Work Quality Performance



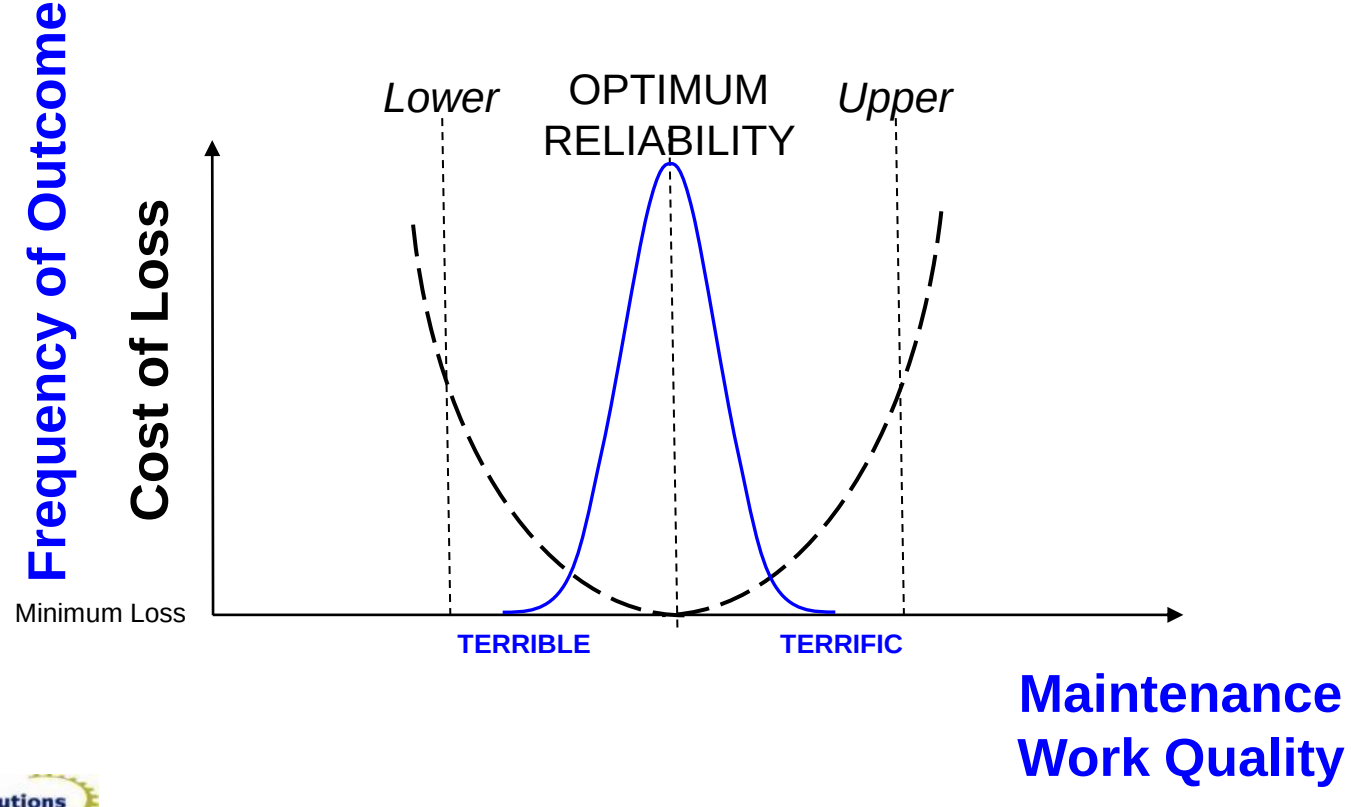
Combining Work Quality and Loss Function



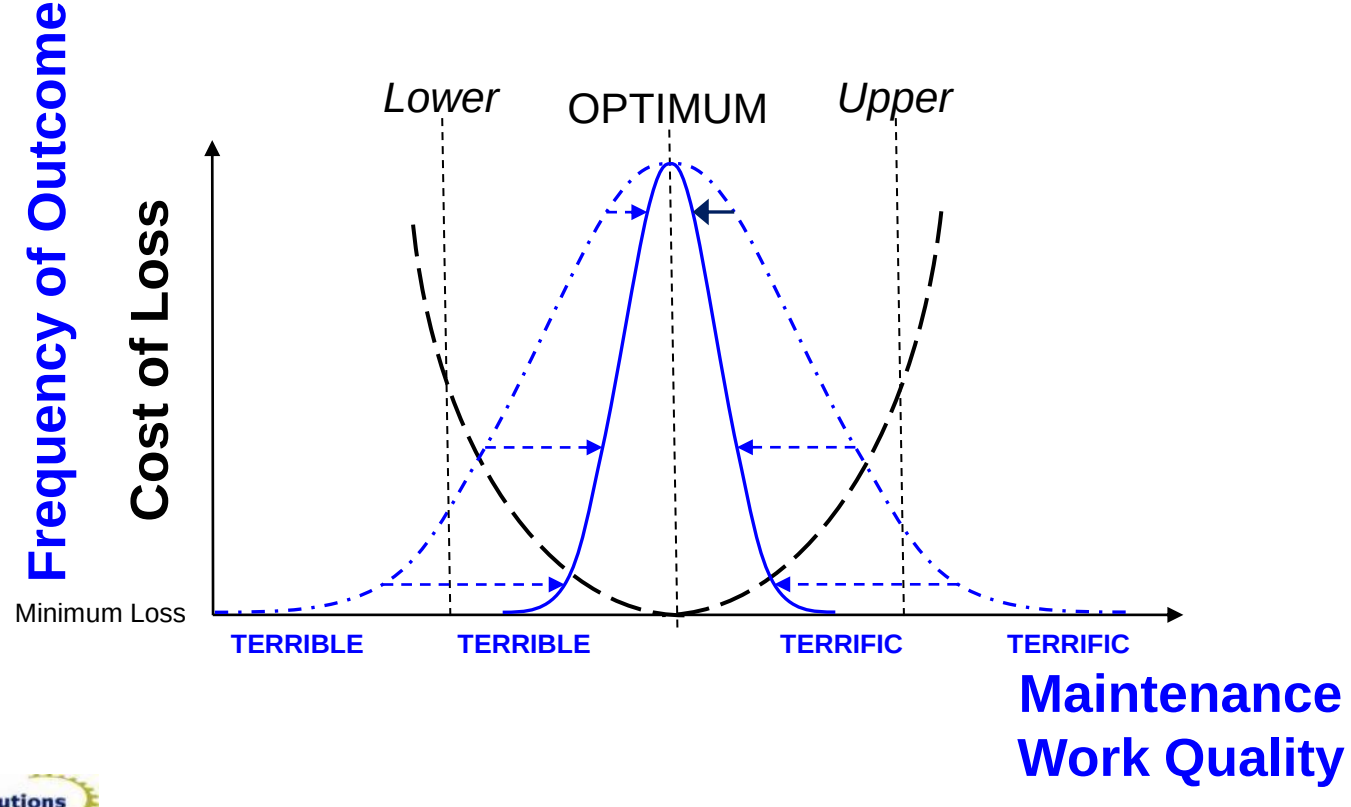
Work Quality that Minimises Loss and Waste



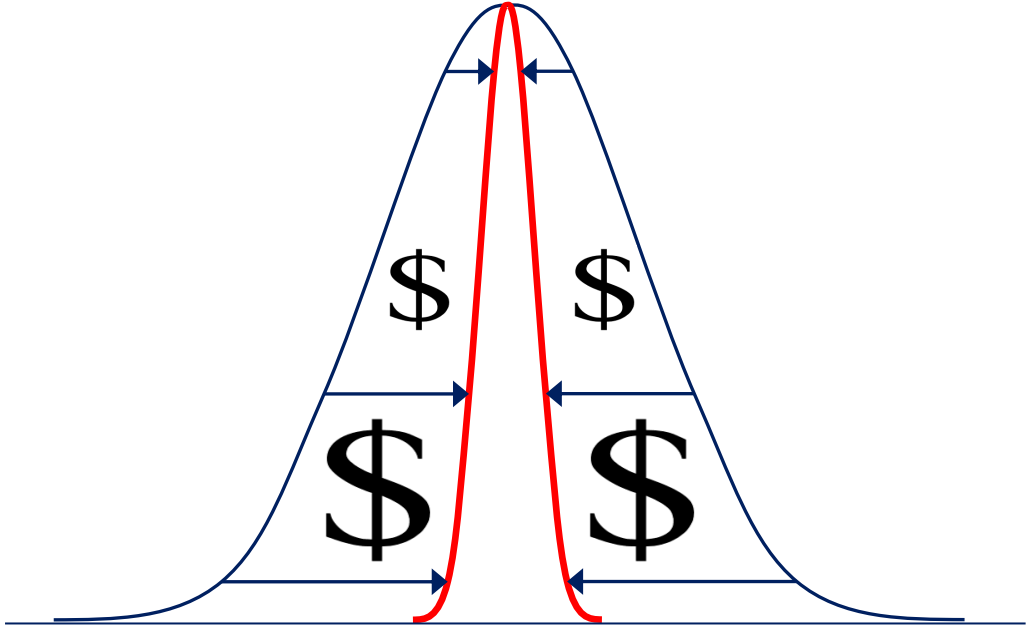
Work Quality that Optimises Reliability



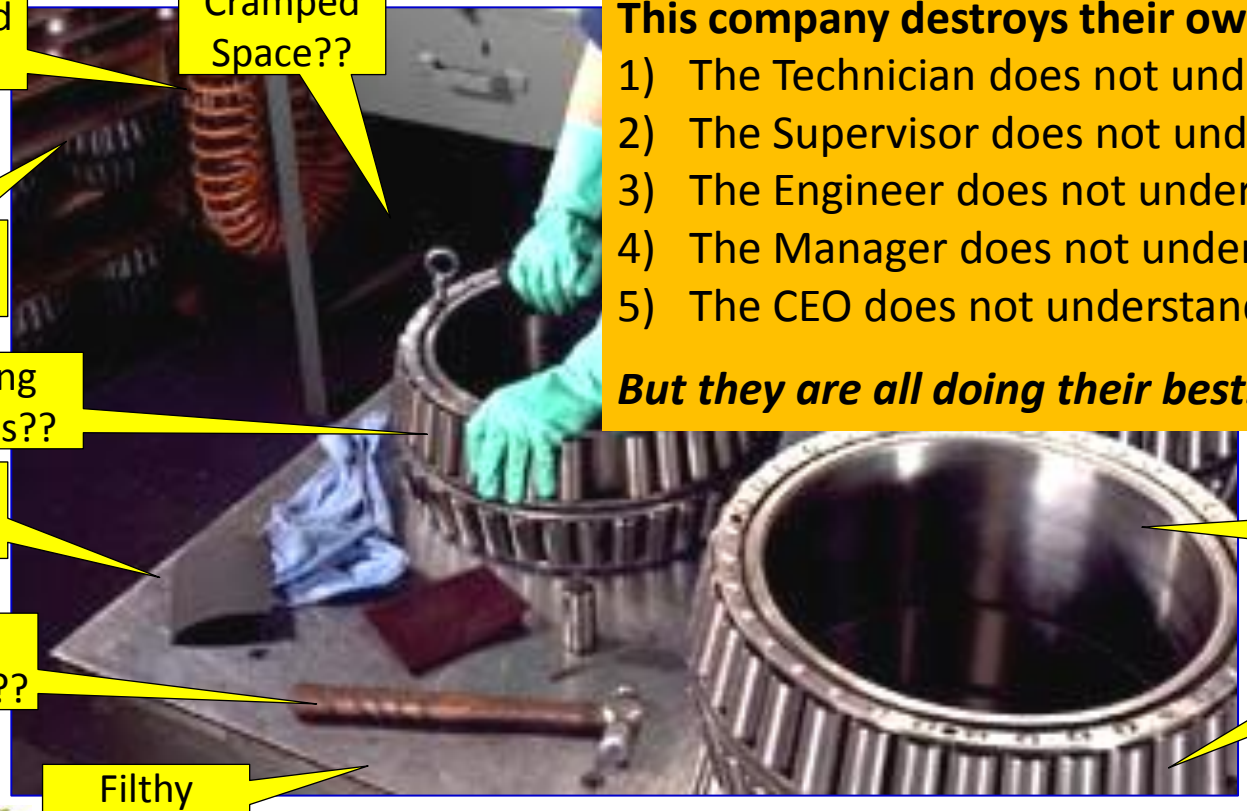
Work Quality that Makes Money



Where the Money Comes from by doing Quality Work



Where Work Quality Problems Start



This company destroys their own equipment

1) The Technician does not understand!
2) The Supervisor does not understand!
3) The Engineer does not understand!
4) The Manager does not understand!
5) The CEO does not understand!

But they are all doing their best… how sad!

Human Error Rate Table

	Error rate (per task)		
	Read/ reason	*Physical operation*	*Everyday yardstick*
Simplest possible task			
Fail to respond to annunciator	0.0001		
Overfill bath			0.00001
Fail to isolate supply (electrical work)		0.0001	
Read single alphanumeric wrongly	0.0002		
Read 5-letter word with good resolution wrongly	0.0003		
Select wrong switch (with mimic diagram)		0.0005	
Fail to notice major cross-roads			0.0005
Routine simple task			
Read a checklist or digital display wrongly	0.001		
Set switch (multiposition) wrongly		0.001	
Calibrate dial by potentiometer wrongly		0.002	
Check for wrong indicator in an array	0.003		
Wrongly carry out visual inspection for a defined criterion (e.g. leak)	0.003		
Fail to correctly replace PCB		0.004	
Select wrong switch among similar		0.005	

	Error rate (per task)		
	Read/ reason	*Physical operation*	*Everyday yardstick*
Read analogue indicator wrongly	0.005		
Read 10-digit number wrongly	0.006		
Leave light on			0.003
Routine task with care needed			
Mate a connector wrongly		0.01	
Fail to reset valve after some related task		0.01	
Record information or read graph wrongly	0.01		
Let milk boil over			0.01
Type or punch character wrongly		0.01	
Do simple arithmetic wrongly	0.01–0.03		
Wrong selection – vending machine			0.02
Wrongly replace a detailed part		0.02	
Do simple algebra wrongly	0.02		
Read 5-letter word with poor resolution wrongly	0.03		
Put 10 digits into calculator wrongly	0.05		
Dial 10 digits wrongly	0.06		
Complicated non-routine task			
Fail to notice adverse indicator when reaching for wrong switch or item	0.1		
Fail to recognize incorrect status in roving inspection	0.1		
New workshift – fail to check hardware, unless specified	0.1		
General (high stress)	0.25		
Fail to notice wrong position of valves	0.5		
Fail to act correctly after 1 min in emergency situation	0.9		

Source: Smith, David J., 'Reliability, Maintainability and Risk', Appendix 6, Seventh Edition, Elsevier – Butterworth Heinemann

The Table confirms that 'human element' error is real and <u>unavoidable</u>. We do not perform well when tasks are structured in ways that require great care and we perform especially badly under complicated, non-routine conditions. Add stress into that that mix and you get disaster.

Maintenance Error Rates

	Error rate (per task)		
	Read/ reason	*Physical operation*	*Everyday yardstick*
Routine task with care needed			
Mate a connector wrongly		0.01	
Fail to reset valve after some related task		0.01	
Record information or read graph wrongly	0.01		
Let milk boil over			0.01
Type or punch character wrongly		0.01	
Do simple arithmetic wrongly	0.01–0.03		
Wrong selection – vending machine			
Wrongly replace a detailed part		0.02	
Do simple algebra wrongly	0.02		
Read 5-letter word with poor resolution wrongly	0.03		
Put 10 digits into calculator wrongly	0.05		
Dial 10 digits wrongly	0.06		
Complicated non-routine task			
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Fail to recognize incorrect status in roving inspection	0.1		
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General (high stress)	0.25		
Fail to notice wrong position of valves	0.5		
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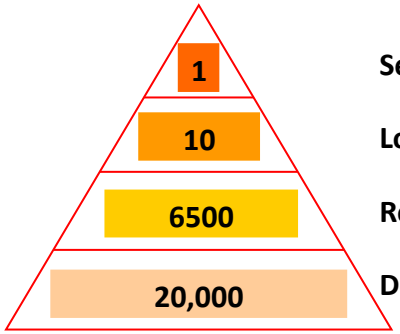


The Failure Pyramid

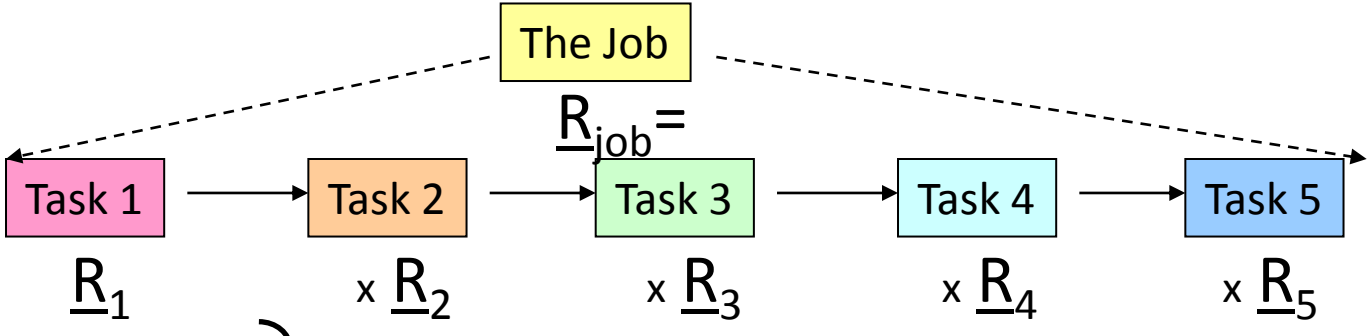
Not every error leads to failure

Source: Ledet, Winston, The Manufacturing Game

Lifetime Relia

In failure rate terms the incident rate in a plant is likely to be in the range of 20×10^{-6} per h (general human error) to 1×10^{-6} per h (safety-related incident).

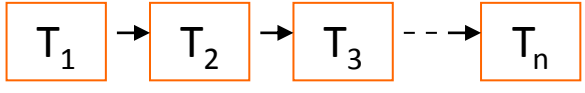
Probability of Work being Done Right



Remember this …?

We have a series process.

One fails … all fails! One poor … all poor!



$$R_{job} = R_1 \times R_2 \times \ldots R_n$$

At 10 errors/100	0.9	x 0.9	x 0.9	x 0.9	x 0.9 = **0.59**
At 1 error/100	0.99	x 0.99	x 0.99	x 0.99	x 0.99 = **0.95**

A Maintenance Job Plan

JOB PLAN TO INSTALL NEW BEARINGS IN CONVEYOR PULLEY PLUMMER BLOCKS

1. Prepare for Job in Dirt-Free Work Area
2. Safe Isolation and Handover
3. Check Parts and Materials are Correct
4. Access Plummer Blocks and Bearings
5. Check Shaft Condition and Tolerance
6. Measure Bearing Internal Clearance
7. Measure Plummer Base Plate Accuracy
8. Locate Bearings on Shaft
9. Mount Bearings on Shaft
10. Position Plummer Blocks and Place Pulley
11. Complete Plummer Block and Seals Assembly
12. Align Plummer Blocks
13. Lubricate Bearing and Seals
14. Align Plummer Blocks and Bolt Down
15. Commission and Test
16. Clean-up and Hand Back

Job Plan as a Process Flow Diagram

Prepare for Job in Dirt-Free Work Area	Safe Isolation and Handover	Check Parts and Materials	Access Plummer Blocks and Bearings	Check Shaft Condition and Tolerance	Measure Bearing Internal Clearance	Measure Plummer Base Plate Accuracy	Locate Bearings on Shaft	Mount Bearings on Shaft	Position Plummer Blocks and Place Pulley	Complete Plummer Block and Seals Assembly	Align Plummer Blocks	Lubricate Bearing and Seals	Locate Plummer Blocks and Bolt Down	Commission and Test	Clean-up and Hand Back
Collect together all materials, tools, instructions and information . Clean area of dirt and dust	Make the plant and equipment safe to work on. Isolate and prove the plant is safe to work-on	Inspect each individual item correctly matches parts list and record quantities supplied	Make the pulley safe and remove the Plummer blocks and the bearings and expose the shaft	Check shaft dimensions at adaptor sleeve locations for correct size and tolerances	Use long feeler gauges to prove roller to outer ring internal clearance meets standard	Measure housing support vertical alignment, levels and flatness meet standard	Put adaptor sleeves, bearings and rotating seal parts on shaft correctly	Drive bearing into position. Pack grease in voids of both bearings	Position Plummer Blocks loosely on mounts oriented correctly. Lower shaft assembly into place	Fit bearing cap and Taconite seals	Align shaft. Shim for vertical position. Tighten fixed bearing into place then tighten floating bearing into place	Partially fill the Plummer Block with grease and make sure grease fully fills Taconite Seals	Locate Plummer Blocks with correct pulley alignment. Use turn of nut method in cross sequence and tighten	Test the pulley operates correctly	Leave work place clean and safe

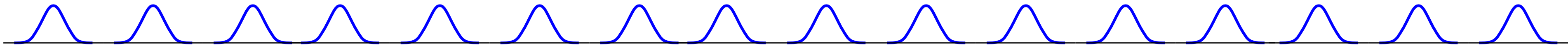
Failed Machine >>

>> Reliable Machine

"One poor; all poor."
"One wrong; all wrong."

Chance of Success in a 16 Task Job Plan

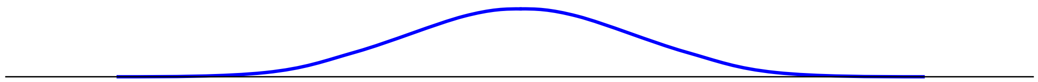
Task	Activity	Reliability
Prepare for Job in Dirt-Free Work Area	Collect together all materials, tools, instructions and information . Clean area of dirt and dust	$\underline{R}_1$
Safe Isolation and Handover	Make the plant and equipment safe to work on. Isolate and prove the plant is safe to work-on	$\underline{R}_2$
Check Parts and Materials	Inspect each individual item correctly matches parts list and record quantities supplied	$\underline{R}_3$
Access Plummer Blocks and Bearings	Make the pulley safe and remove the Plummer blocks and the bearings and expose the shaft	$\underline{R}_4$
Check Shaft Condition and Tolerance	Check shaft dimensions at adaptor sleeve locations for correct size and tolerances	$\underline{R}_5$
Measure Bearing Internal Clearance	Use long feeler gauges to prove roller to outer ring internal clearance meets standard	$\underline{R}_6$
Measure Plummer Base Plate Accuracy	Measure housing support vertical alignment, levels and flatness meet standard	$\underline{R}_7$
Locate Bearings on Shaft	Put adaptor sleeves, bearings and rotating seal parts on shaft correctly	$\underline{R}_8$
Mount Bearings on Shaft	Drive bearing into position. Pack grease in voids of both bearings	$\underline{R}_9$
Position Plummer Blocks and Place Pulley	Position Plummer Blocks loosely on mounts oriented correctly. Lower shaft assembly into place	$\underline{R}_{10}$
Complete Plummer Block and Seals Assembly	Fit bearing cap and Taconite seals	$\underline{R}_{11}$
Align Plummer Blocks	Align shaft. Shim for vertical position. Tighten fixed bearing into place then tighten floating bearing into place	$\underline{R}_{12}$
Lubricate Bearing and Seals	Partially fill the Plummer Block with grease and make sure grease fully fills Taconite Seals	$\underline{R}_{13}$
Locate Plummer Blocks and Bolt Down	Locate Plummer Blocks with correct pulley alignment. Use turn of nut method in cross sequence and tighten	$\underline{R}_{14}$
Commission and Test	Test the pulley operates correctly	$\underline{R}_{15}$
Clean-up and Hand Back	Leave work place clean and safe	$\underline{R}_{16}$



Each Activity has its own Quality Distribution

$$\rightarrow T_1 \rightarrow T_2 \rightarrow T_3 \text{ - - } \rightarrow T_n \rightarrow$$

$$\underline{R}_{job} = \underline{R}_1 \times \underline{R}_2 \times \ldots\ldots\ldots\ldots \underline{R}_{16}$$



Final Job Quality Distribution is WIDE

But this is a Job Plan, Not a Job Procedure

1. Prepare for Job in Dirt-Free Work Area
2. Safe Isolation and Handover
3. Check Parts and Materials are Correct
4. Access Plummer Block and Bearings
5. Check Shaft Condition and Tolerance
6. Measure Bearing Internal Clearance
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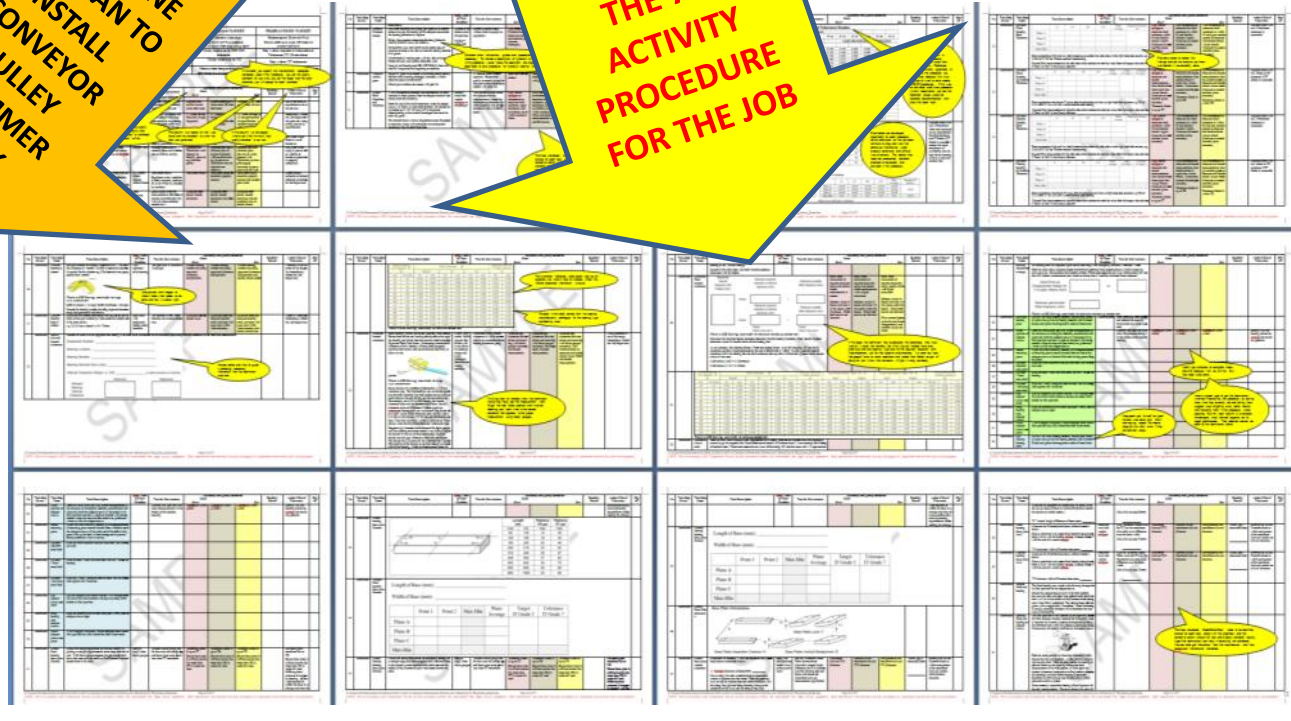
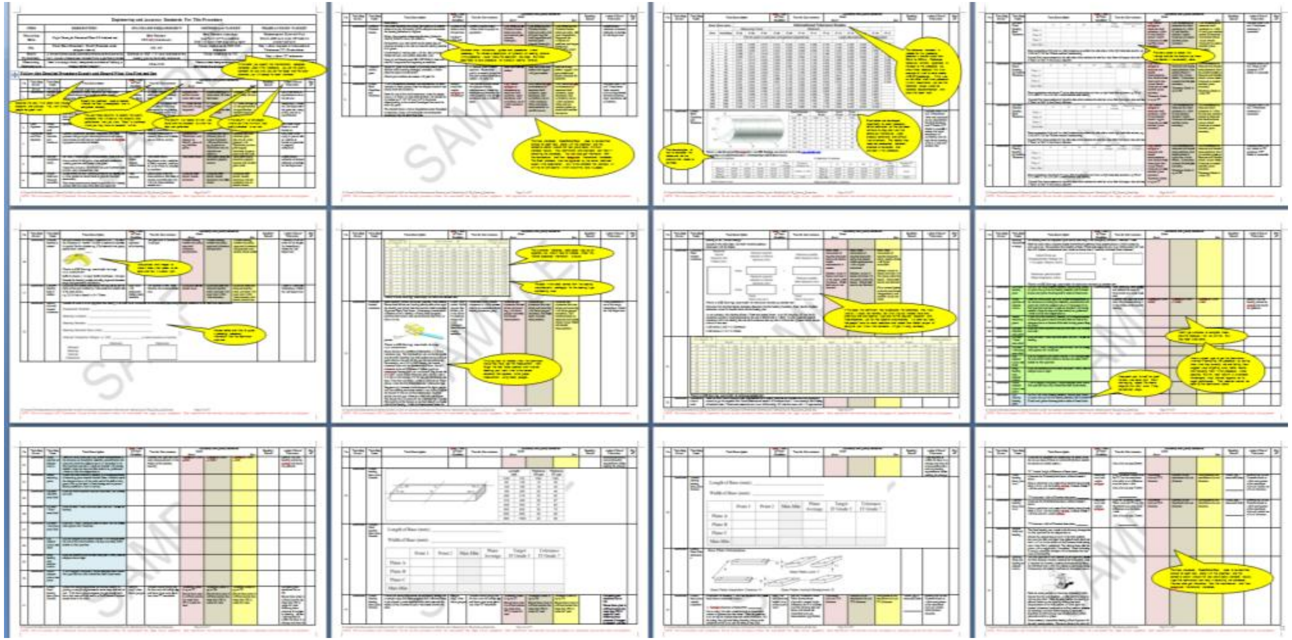
11. Complete Plummer Block and Seals Assembly
12. Align Plummer Blocks
13. Lubricate Bearing and Seals
14. Locate Plummer Blocks and Bolt Down
15. Commission and Test
16. Clean-up and Hand Back

THE 16-STEP MILESTONE JOB PLAN TO INSTALL CONVEYOR PULLEY PLUMMER BLOCK

THE 75-ACTIVITY PROCEDURE FOR THE JOB



This Job Procedure has 75 Non-Routine and Complicated Activities



$\underline{R}_{job} = \underline{R}_1 \times \underline{R}_2 \times \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \underline{R}_{75}$

No Job Procedure… Human Error Dominates

1. Prepare for Job in Dirt-Free Work Area
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3. Check Parts and Materials are Correct
4. Access Plummer Block and Bearings
5. Check Shaft Condition and Tolerance
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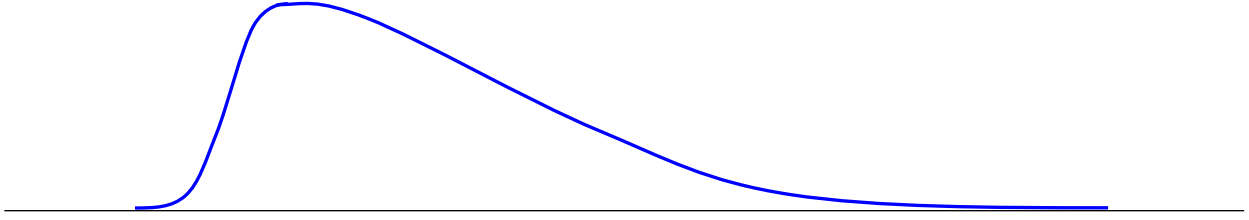


The ‘Game’ of Business

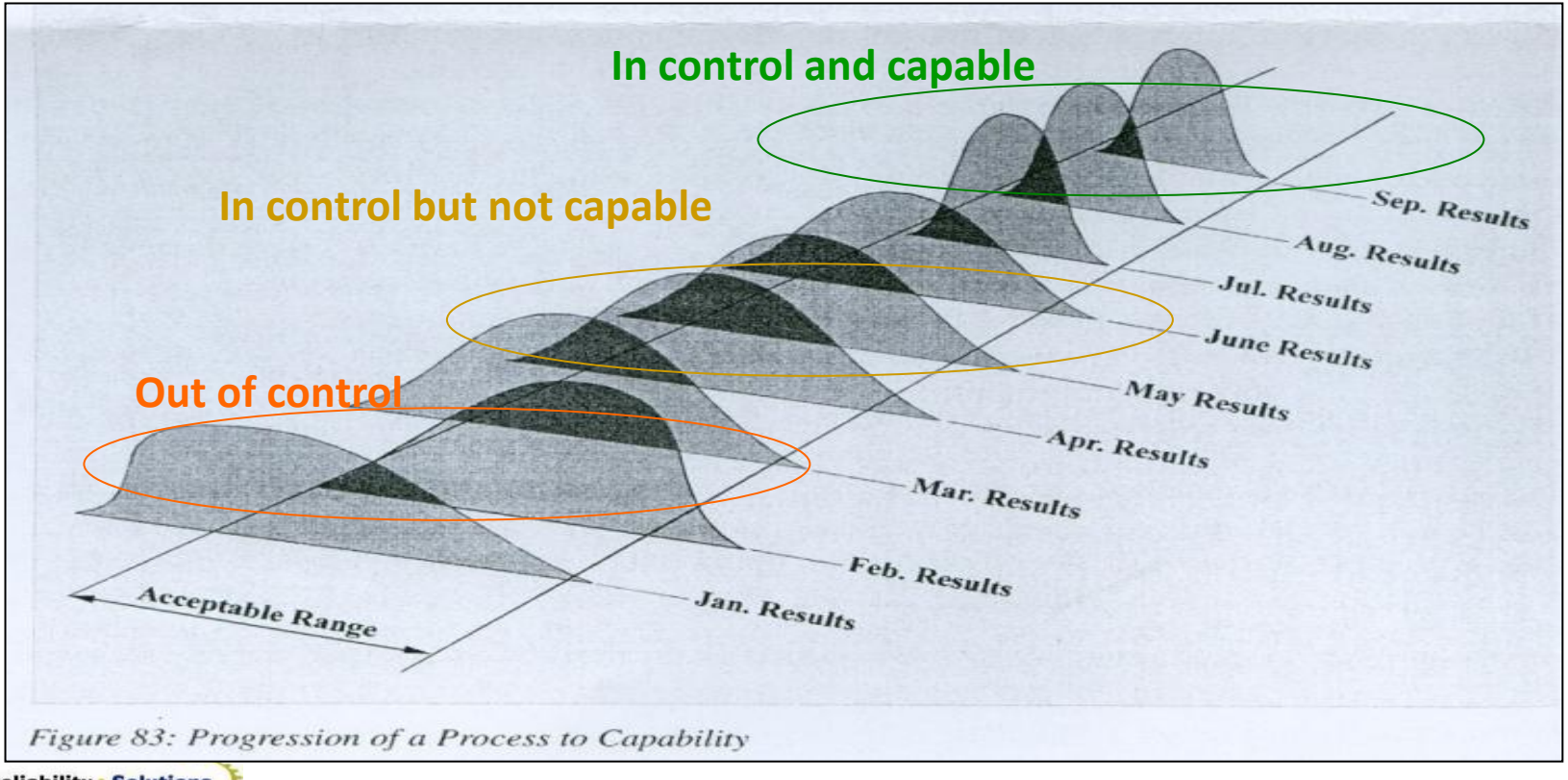
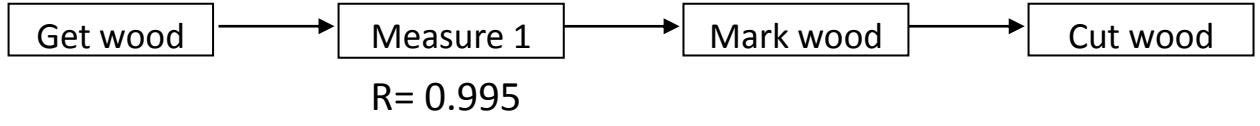
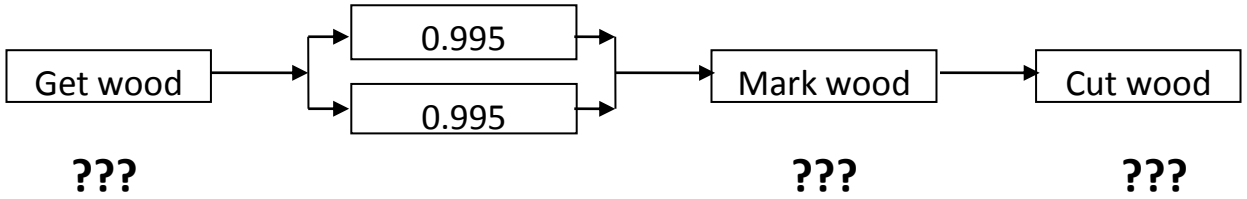


Figure 83: Progression of a Process to Capability

Carpenter's Creed: *measure twice, cut once*



1 error every 200 opportunities
~ 1 / wk



1 error every 5000 opportunities
~1 / 20 wk

This is a 'mistake proofing' method that greatly reduces the chance of an error being made and left behind in a job as a defect that will later cause failure.

Answers are in the Human Error Rate Table

	Error rate (per task)		
	Read/ reason	*Physical operation*	*Everyday yardstick*
Simplest possible task			
Fail to respond to annunciator	0.0001		
Overfill bath			0.00001
Fail to isolate supply (electrical work)		0.0001	
Read single alphanumeric wrongly	0.0002		
Read 5-letter word with good resolution wrongly	0.0003		
Select wrong switch (with mimic diagram)		0.0005	
Fail to notice major cross-roads			0.0005
Routine simple task			
Read a checklist or digital display wrongly	0.001		
Set switch (multiposition) wrongly		0.001	
Calibrate dial by potentiometer wrongly		0.002	
Check for wrong indicator in an array	0.003		
Wrongly carry out visual inspection for a defined criterion (e.g. leak)	0.003		
Fail to correctly replace PCB		0.004	
Select wrong switch among similar		0.005	

~5 sigma

~4.5 sigma

	Error rate (per task)		
	Read/ reason	*Physical operation*	*Everyday yardstick*
Read analogue indicator wrongly	0.005		
Read 10-digit number wrongly	0.006		
Leave light on			0.003
Routine task with care needed			
Mate a connector wrongly		0.01	
Fail to reset valve after some related task		0.01	
Record information or read graph wrongly	0.01		
Let milk boil over			0.01
Type or punch character wrongly		0.01	
Do simple arithmetic wrongly	0.01–0.03		
Wrong selection – vending machine			0.02
Wrongly replace a detailed part		0.02	
Do simple algebra wrongly	0.02		
Read 5-letter word with poor resolution wrongly	0.03		
Put 10 digits into calculator wrongly	0.05		
Dial 10 digits wrongly	0.06		
Complicated non-routine task			
Fail to notice adverse indicator when reaching for wrong switch or item	0.1		
Fail to recognize incorrect status in roving inspection	0.1		
New workshift – fail to check hardware, unless specified	0.1		
General (high stress)	0.25		
Fail to notice wrong position of valves	0.5		
Fail to act correctly after 1 min in emergency situation	0.9		

~4 sigma

~2 - 3 sigma

In failure rate terms the incident rate in a plant is likely to be in the range of 20×10^{-6} per h (general human error) to 1×10^{-6} per h (safety-related incident).

Source: Smith, David J., 'Reliability, Maintainability and Risk', Appendix 6, Seventh Edition, Elsevier – Butterworth Heinemann

What is Wrong with this Job Plan?

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What is Wrong with this Inspection?

Maintenance Work Instruction

Task List #	Various

Visual Inspection of Pump

Pump Inspected: _____

Visual Inspection Only

1) Check pump base - corrosion / security.
2) Check pump guards - cracked / secured / adequate.
3) Check associated pipework for support / leaks.
4) Check associated valves have handles and are in safe condition.
5) Check suction expansion joint for external wear and cracking.
6) Check condition of motor and associated cables.
7) Check condition of stop / start station.

Raise Subsequent Notification Maintenar
for any repairs required.

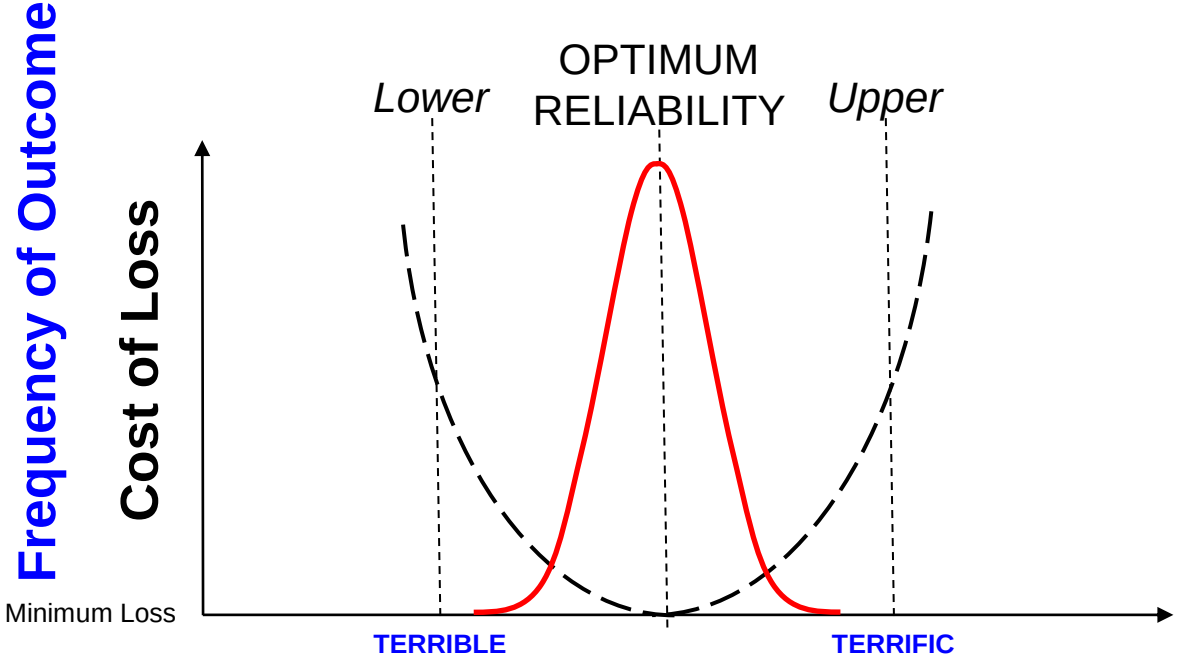
Inspected by: _____

Date: ___/___/_____

- Roving Inspection 1:10 errors
- Defined Criteria Inspection 3:1000

NOTE:
None of these task will prevent the pump and piping from failing. These tasks find failure after it has happened… and you want a healthy, reliable pump set...!??

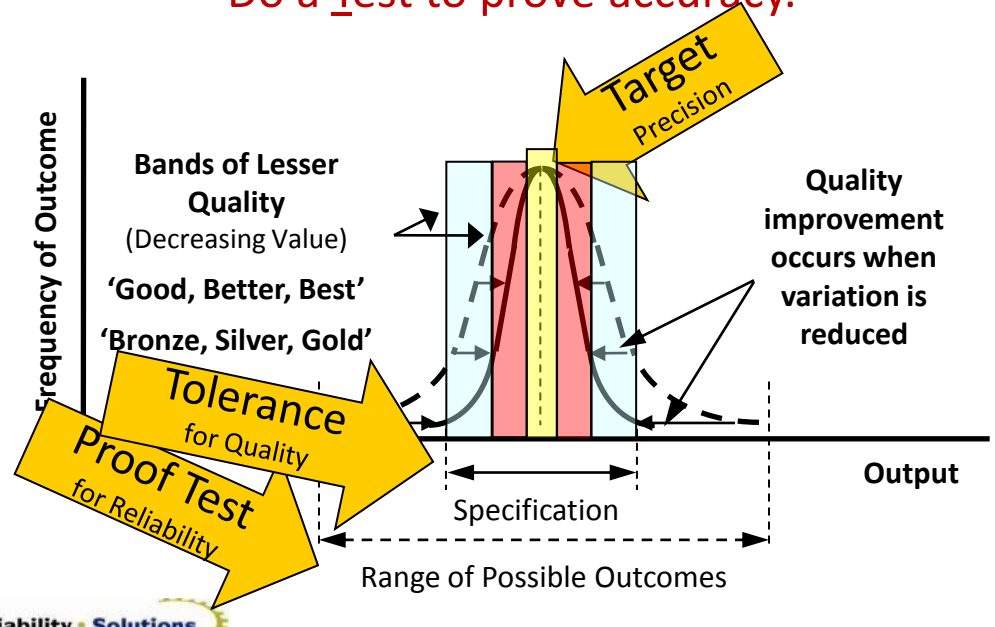
Where Shutdown Work Quality Needs to Be!



Reliability Creating 3T Error Proof Procedures

Build Mistake Proofing into your SOPs

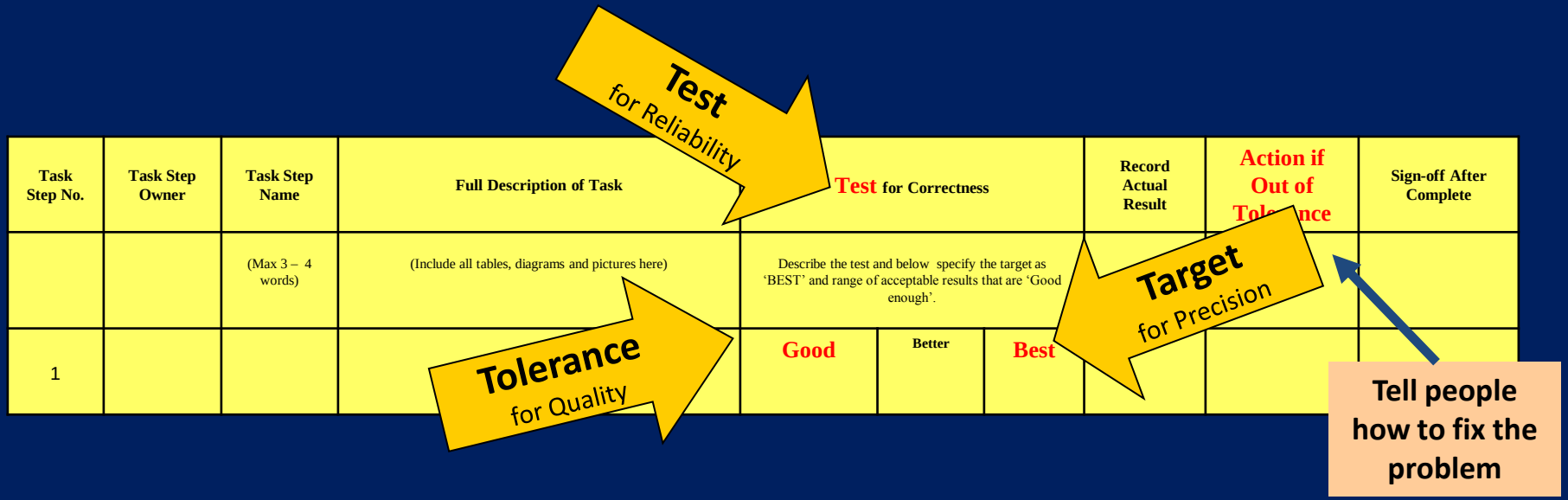
- Set a Target for each task.
- Specify the acceptable Tolerance.
- Do a Test to prove accuracy.



3Ts of Failure Prevention -
. Target
. Tolerance
. Test

Lifetime Reliability • Solutions

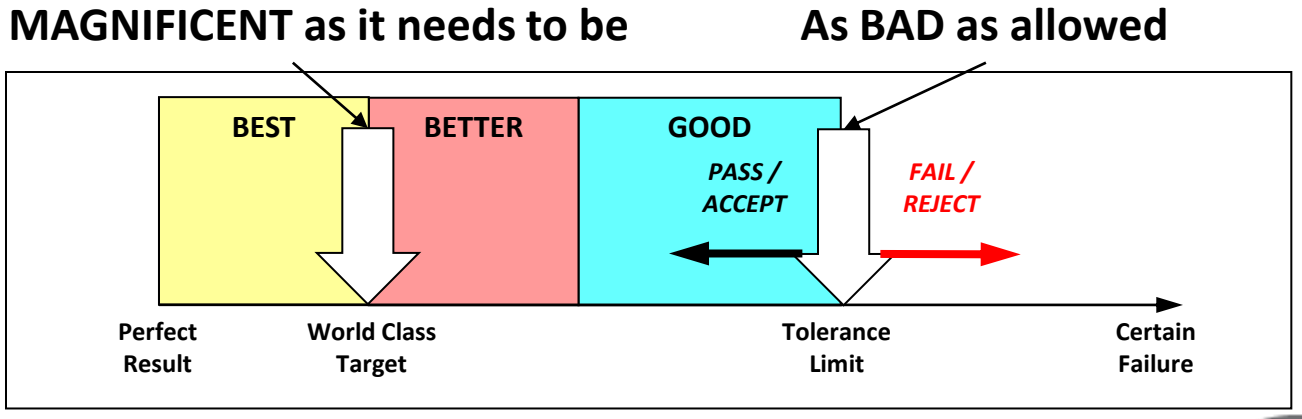
Develop & Use Accuracy Controlled Error Proof Procedures with Quality Standards to Meet



Task Step No.	Task Step Owner	Task Step Name	Full Description of Task	Test for Correctness			Record Actual Result	Action if Out of Tolerance	Sign-off After Complete
		(Max 3 – 4 words)	(Include all tables, diagrams and pictures here)	Describe the test and below specify the target as 'BEST' and range of acceptable results that are 'Good enough'.					
1				Good	Better	Best			

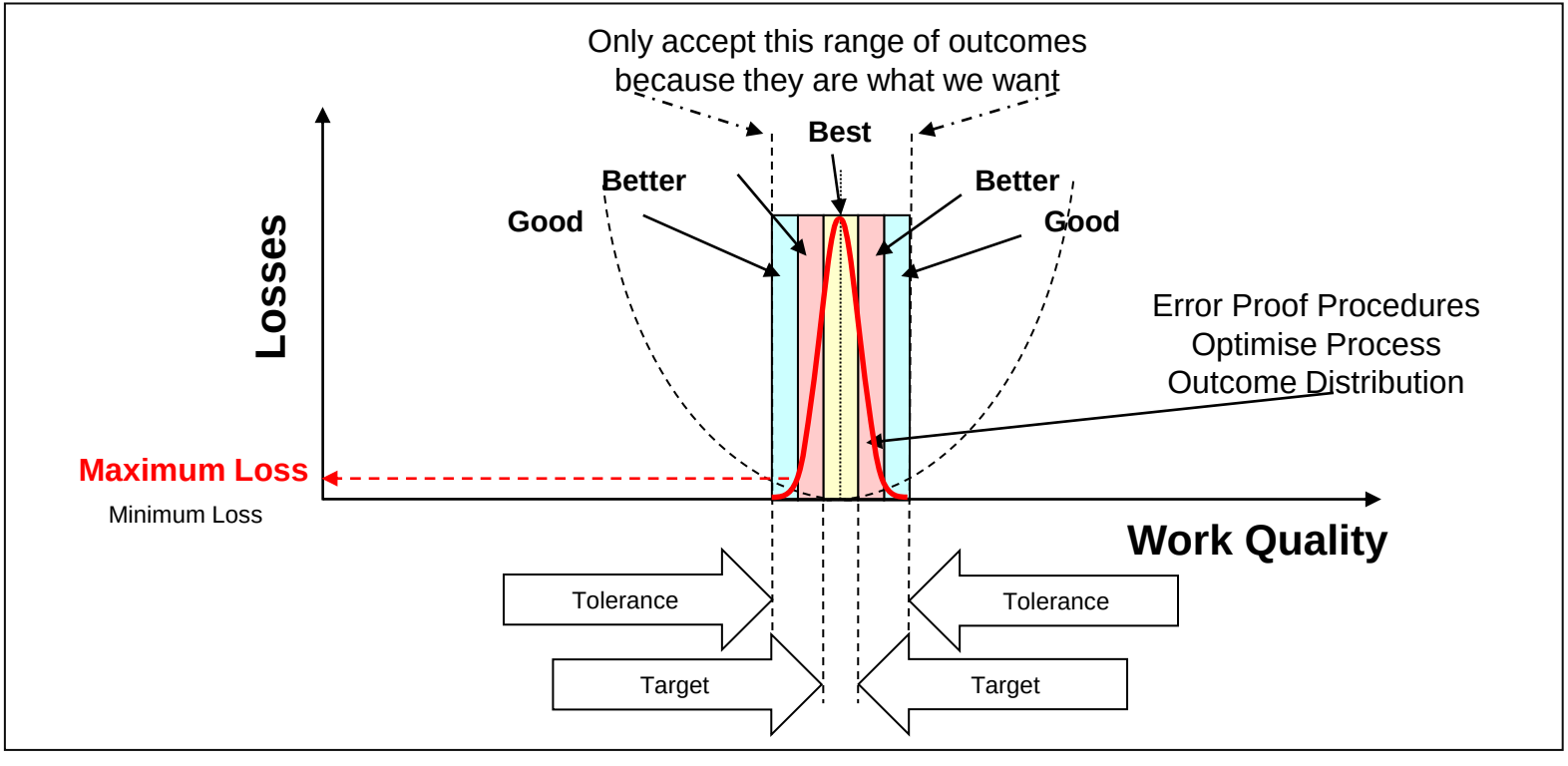
One Layout for an Accuracy Controlled 3T – Target, Tolerance, Test – Failure Prevention Procedure

How 3T's Guide Workmanship Quality

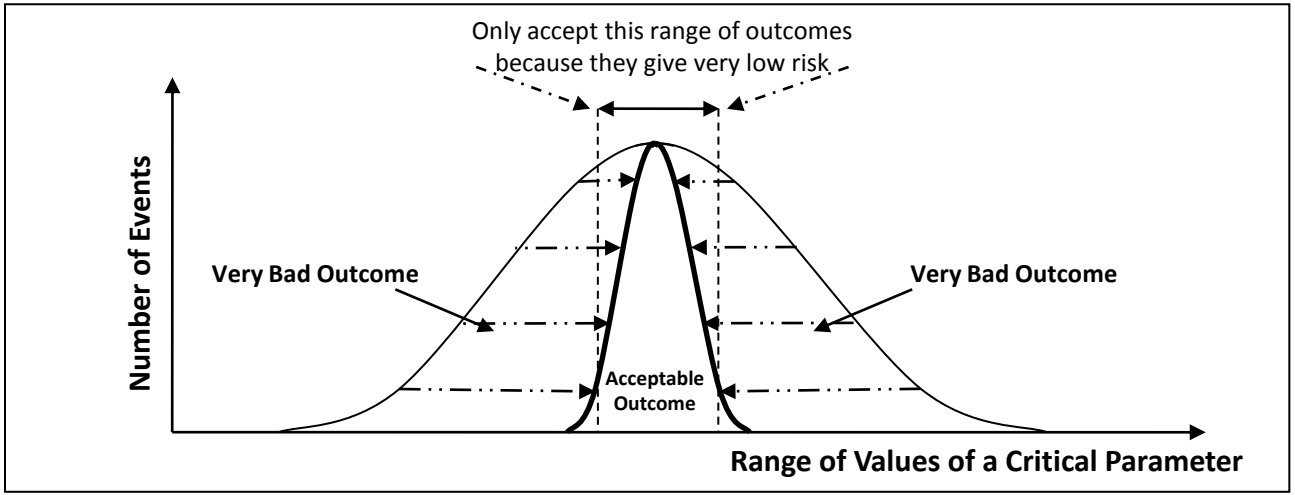


How close to Right is close enough?

3T's Centre Work Quality at the Optimum



Remove the Variability in How a Job is Done by Using Error Proof Techniques



By setting quality controls into a job you ensure the actions that create reliability are done thereby greatly reducing the chance that a mistake will be made.

In the end... reliability is a quality control issue because the standards you meet create the reliability you get

Do Quality Work and You are Always Sure to make Money