Root Cause Analysis

MÄLARDALEN UNIVERSITY SWEDEN

2016-12-09
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Approach

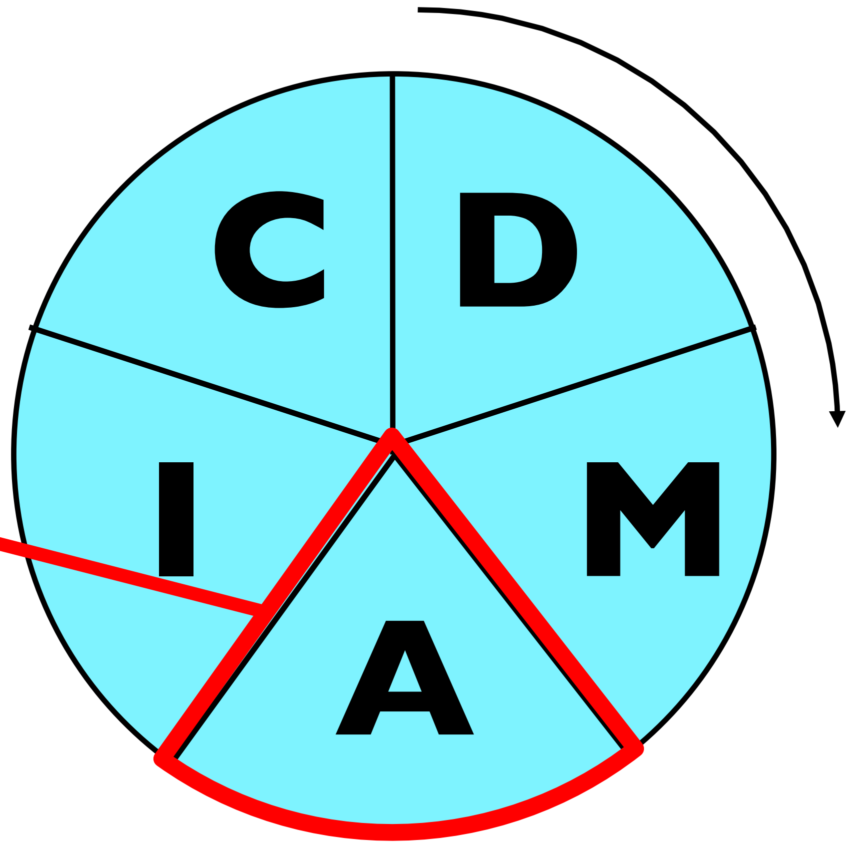
Define

Measure

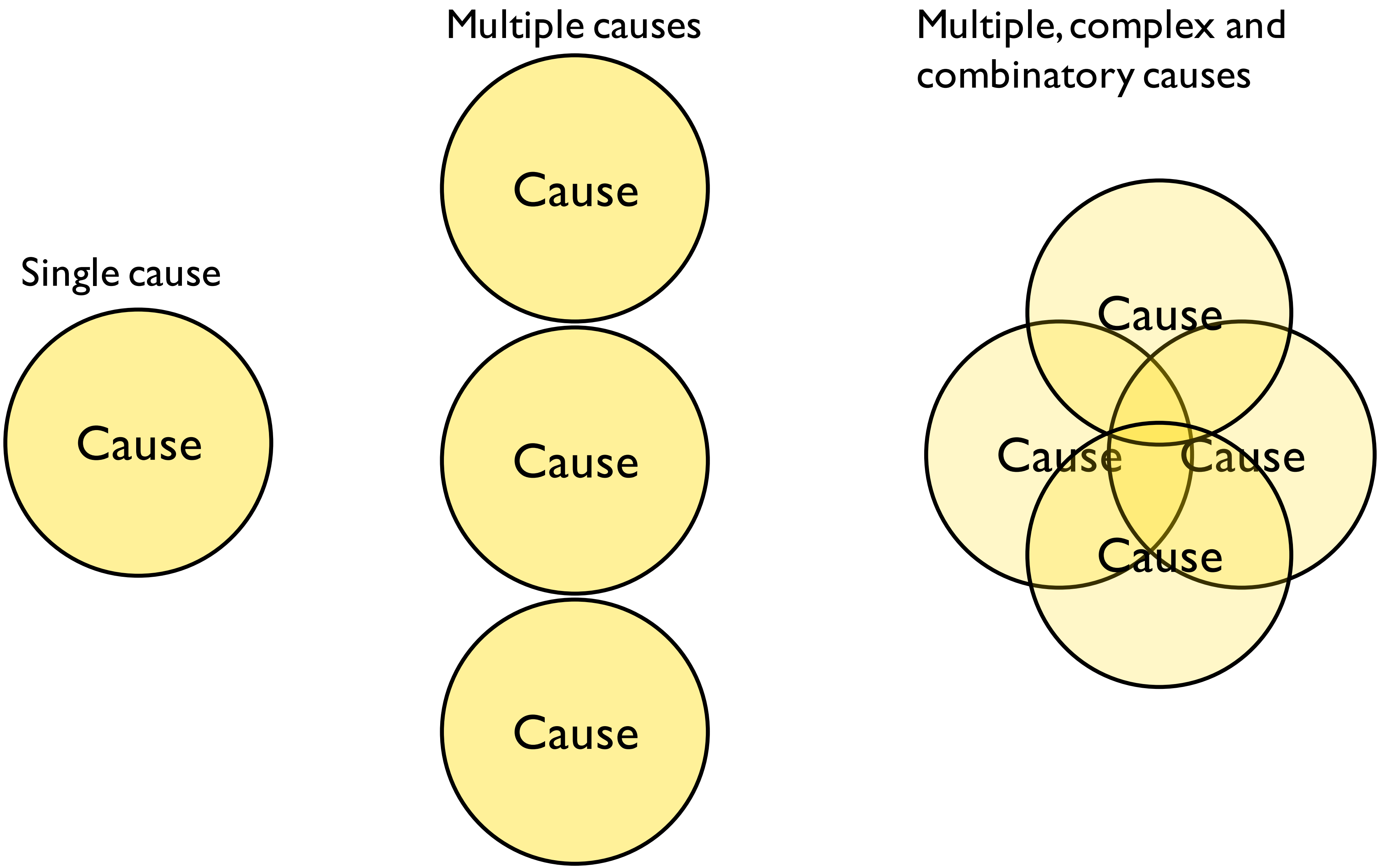
Analyze

Improve

Control



Three types of causes



7QC

The seven basic tools of quality

- The Ishikawa diagram
- The Check sheet
- The Control chart
- The Histogram
- The Pareto chart
- The Scatter diagram
- Stratification

RCA tools

Pareto chart

- Initial sorting

Five Whys

- Simple Root Cause Analysis

Ishikawa diagram

- Causality mapping

Failure Mode and Effects Analysis

- Risk estimation

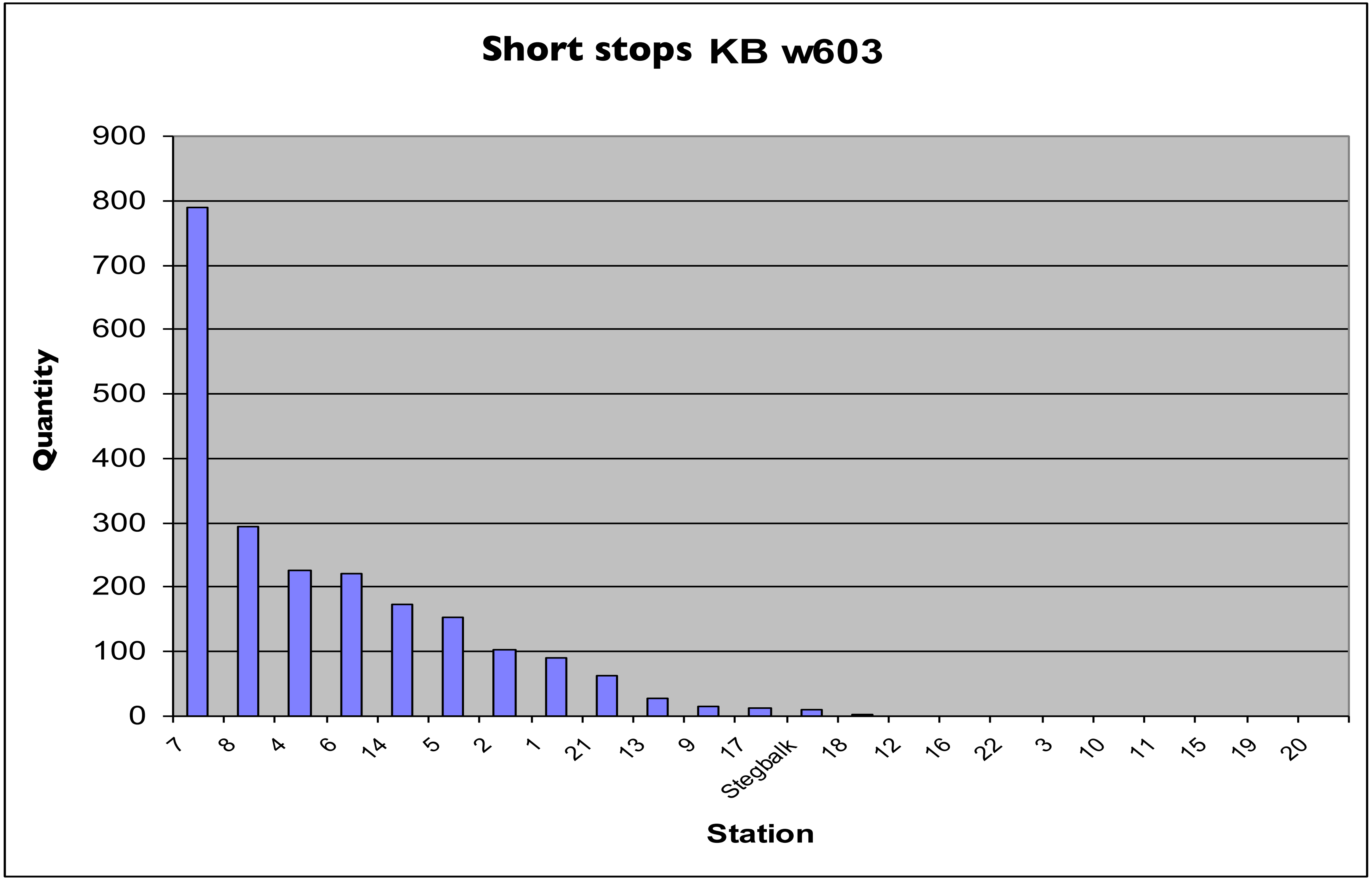
Fault Tree Analysis

- Cause and Effect Analysis

PM-analysis

- Advanced Root Cause Analysis

Pareto chart



Five Whys

Why is there a high reject rate of widgets?

- Because the plastic is stained.

Why is the plastic stained?

- Because there is excess oil in the cutting machine.

Why is there excess oil in the cutting machine?

- Because it is clogging as it is months since it was cleaned.

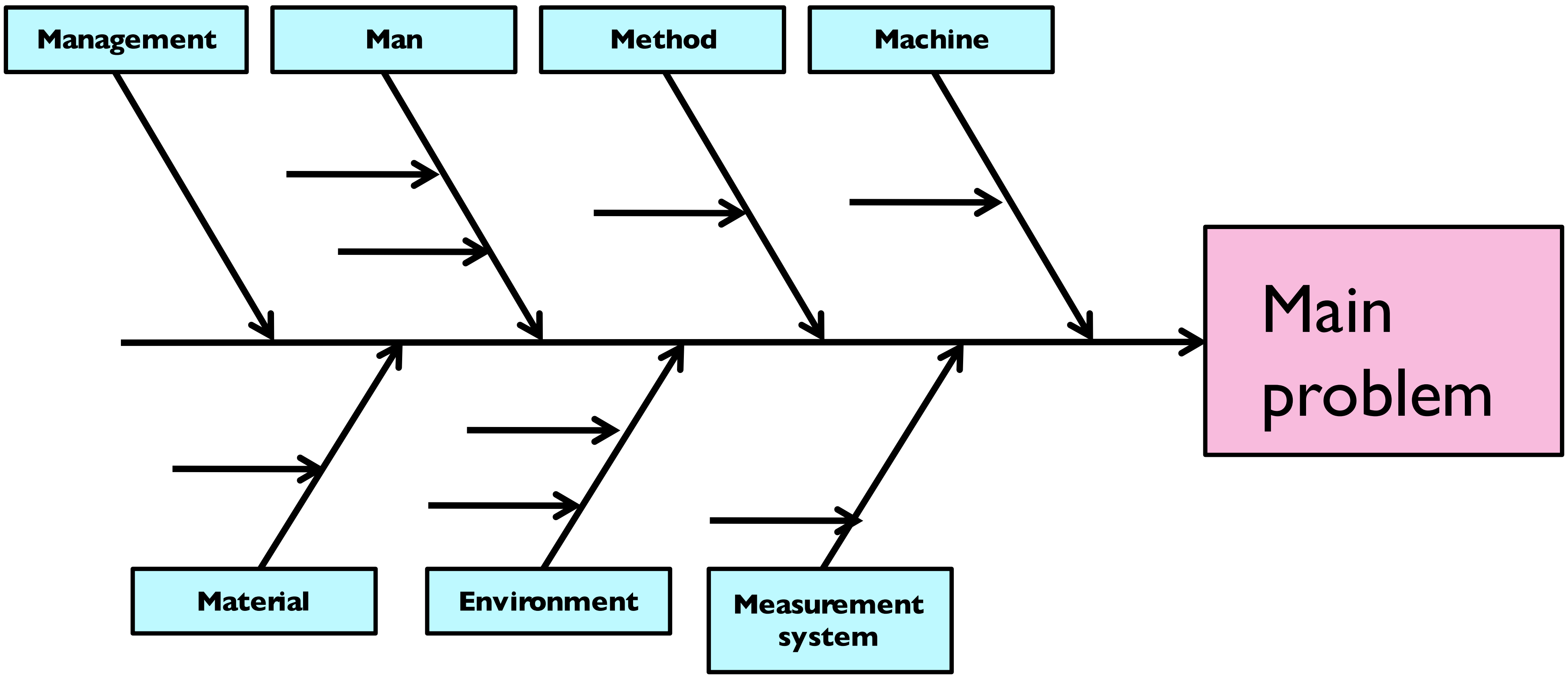
Why is it so long since it was cleaned?

- Because we only service machines when they break down, not on a preventative basis.

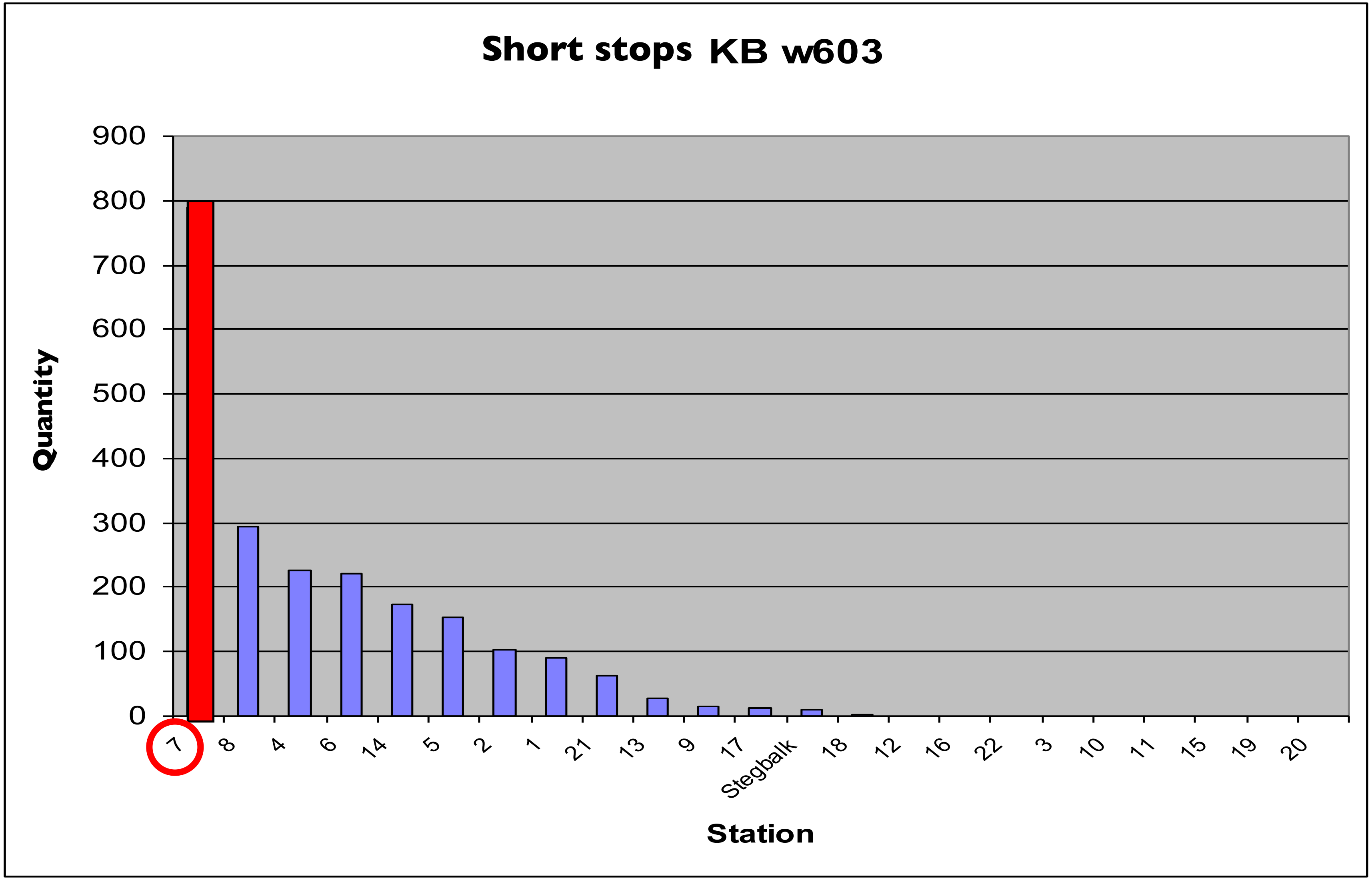
Why only service after breakdowns?

- Because maintenance says it is cheaper (but what about the cost of rejects and rework?).

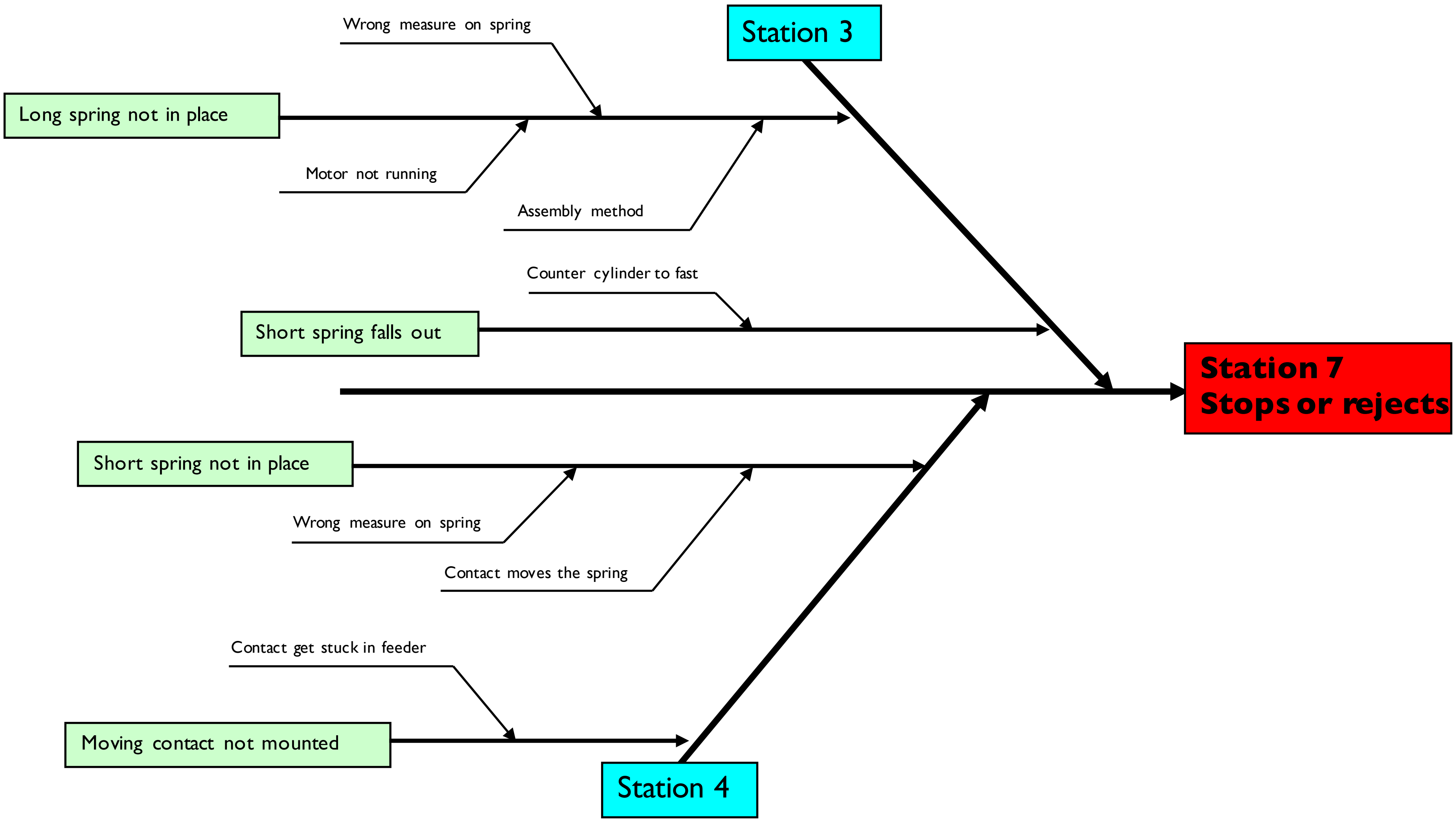
Ishikawa diagram



Example from ABB Cewe-Control



Example from ABB Cewe-Control



Failure Mode and Effect Analysis

FMEA is a systematic method for identification and analysis of a system with respect to possible failure modes, their causes and their effects, plus the consequences on the functions of the system

Failure Mode and Effect Analysis

FMEA is performed in order to…

…identify failure modes with non-wanted effects on the system’s functions

…improve the dependability and availability of a system

…identify the need for deeper diagnosis

…improvement of the maintainability of a system

Failure Mode and Effect Analysis

Webb: http://

Produced and designed: MAIL-Soft Töreboda

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S - 545 33 Töreboda
E-mail: mail-softconsulting@telia.com

Design Failure Mode and Effect Analysis V01-09

Description / Beskrivning	Part no. / Artikelnummer	Status - Hardware / Status - Hårdvara	Customer / Kund	
PCB Laila	SXK107110	Rev. A	Samhall	
Function / Funktion	Part name / Artikelbenämning	Issued by / Utfärdad av	Doc.no. / Dok.nr.	Date / Datum
Assembly	PCB	Klaus Mailer	DFMEA:99-001	990521

Operation		Characteristics of failure				Rating				Action - Status						
No.	Step	Failure mode	Causes of failure	Effects of failure on part/system	Testmethod	Po	S	Pd	RPN	Recommendations	Decisions taken	Po	S	Pd	RPN	Respons.
1	Incoming inspection	Material change not notified to Samhall	Deficient information	Goods not released, production delay	None	1	2	1	2							
2		FIFO not followed	Traceability not followed	Incurant material due to age or specification	None	2	2	1	4							
3		Interchange of PCB	Erroneous marking	Wrong PCB to production	None	6	8	10	480							
4		ESD damage to PCB	Wrong handeling	PCB will be destroyed	None	4	7	5	140							
5	Spotwelding fuse to precut Ni-strip	Mounted other way round	Lack of information	Further assembly fuse not in use	None	1	4	4	16							
6		Position natt acc to tolerances	Machinery tolerances	Fuse does not fit	None	3	4	5	60							
7	Spotwelding pos 1 to battery can on cell	Mix of tapes	Lack of information	Not as close as possible to cell	None	1	5	1	5							
8		Wrong positioning in height	Machinery tolermaces	Fues not in use (in combination with other errors above)	None	5	10	3	150							
9	Spotwelding precut Ni-strip to battery head	Fuse mounted upside down or other way around	Wrong marking	Not as close as possible to cell	None	4	4	3	48							
10		Bad welding quality	Spotwelding machine not well adjusted	Open C or bad mech strength	None	3	3	4	36							
11	Assembly tape cell lid	Bad welding quality	Spotwelding machine not well adjusted	Open C or bad mech strength	None	3	4	4	48							

Failure Mode and Effect Analysis

- FMEA should be performed in groups, preferably cross functional
- Limit the analysis to smaller systems or processes
- Use the same grading system for different FMEAs
- Include ”soft” deficiencies e.g. usability, ergonomics, etc.

Failure Mode and Effect Analysis

FMEA should not be used when:

…a system has high amount of redundancies

…a system have a high degree of common cause failures

For such systems FTA might be a better method

Fault Tree Analysis, FTA

FTA is:

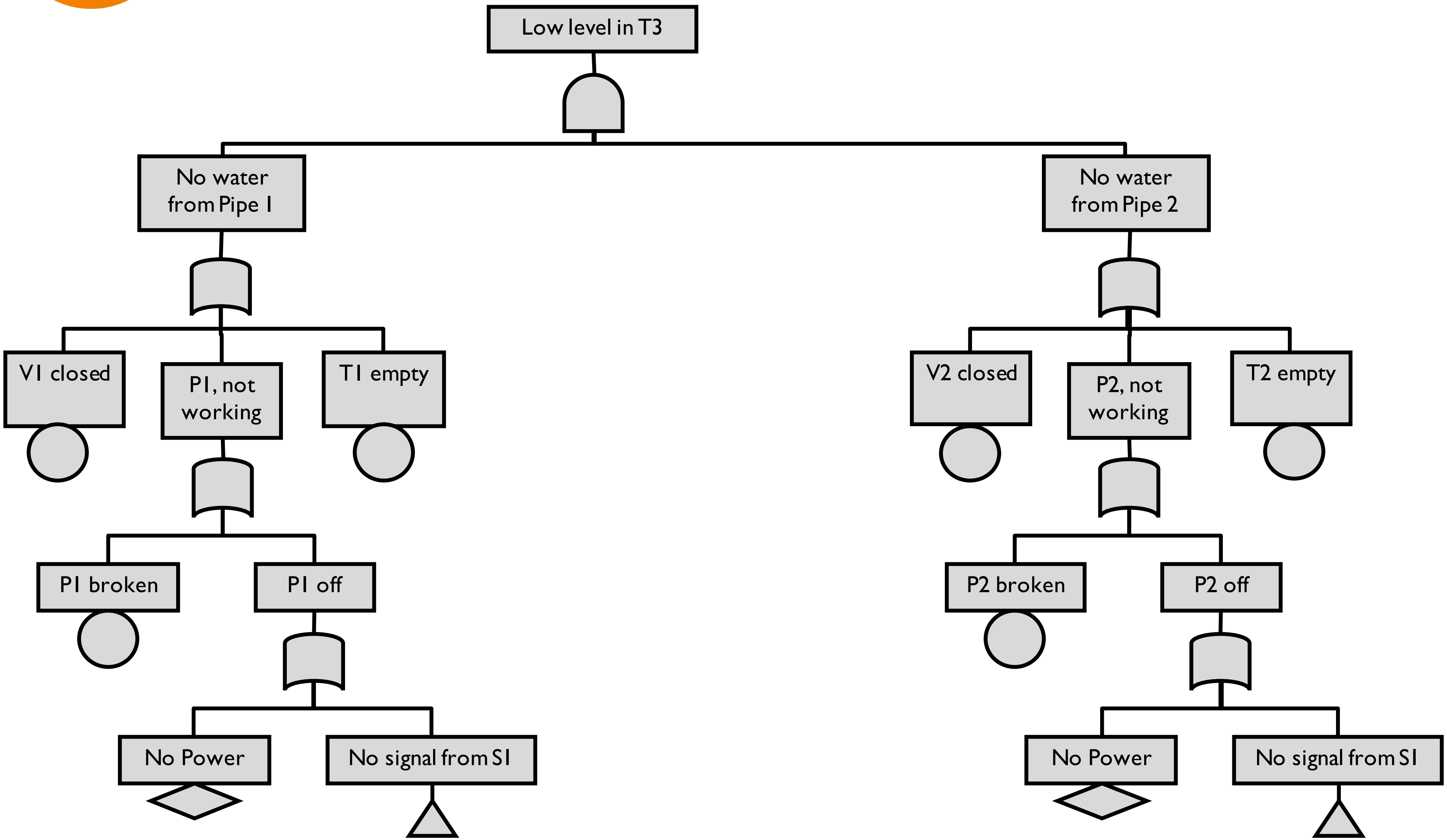
- a qualitative and quantitative method for analyzing complex systems
- a logical process that might be transferred into reliabilty block diagrams
- a top-down technique in which a possible event on system level is analyzed and broken down to component level
- developed in the aero-space industry and the nuclear power industry

Fault Tree Analysis, FTA

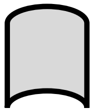
FTA is performed in order to:

- analyze and show the connection between non-wanted events in the system and the root causes to these events
- identify the events (human, environmental, technological) that might be difficult to calculate mathematically
- increase the understanding of the structures and relations in a system
- identify critical failure modes and weaknesses even in the absence of component data

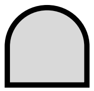
Fault Tree Analysis, FTA



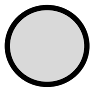
Fault Tree Analysis, FTA



The OR-gate indicates that the output event occurs if any of the input events occur

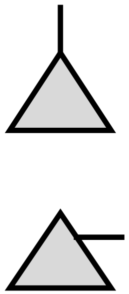


The AND-gate indicates that the output event occurs only when all the input events occur

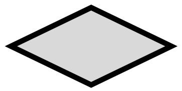


The Basic event represents a basic equipment failure that requires no further development of failure causes

The Comment rectangle is for supplementary information

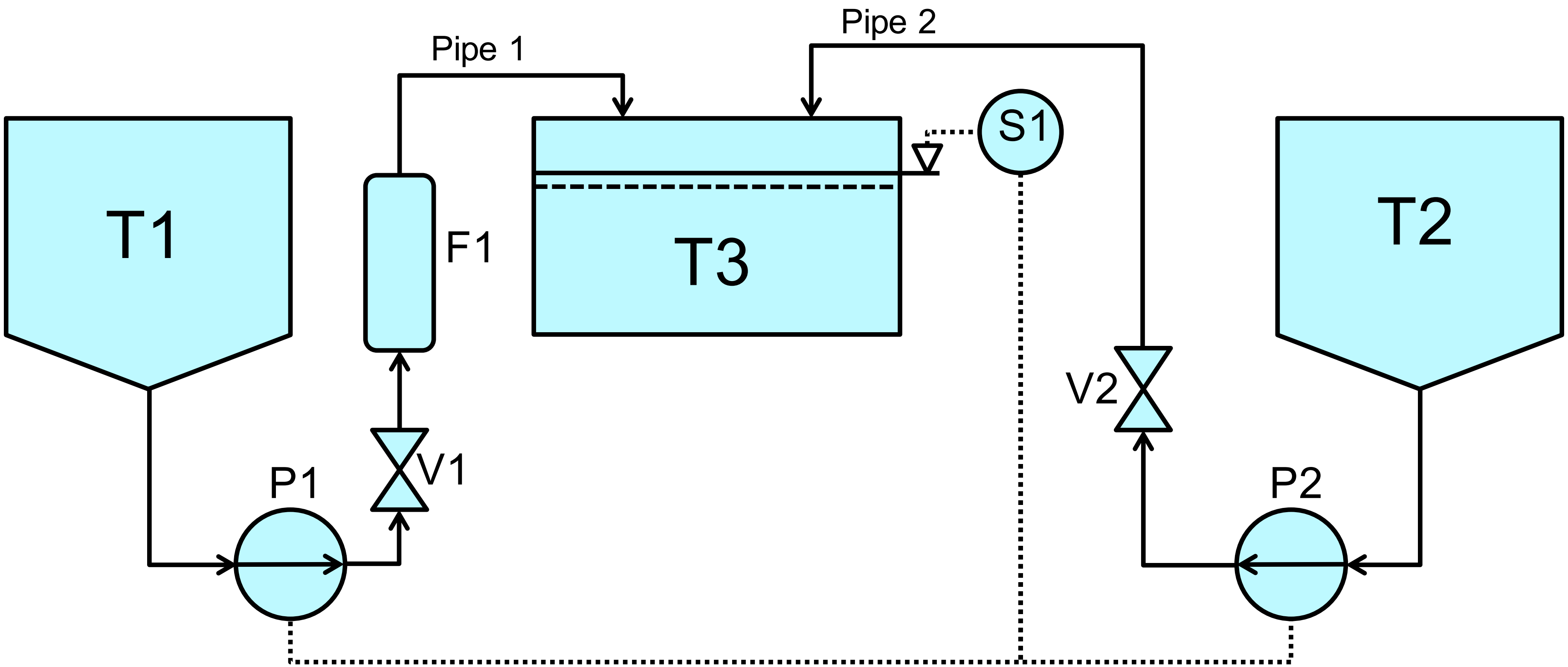


The Transfer-out symbol indicates that the fault tree is developed further at the occurrence of the corresponding Transfer-in symbol



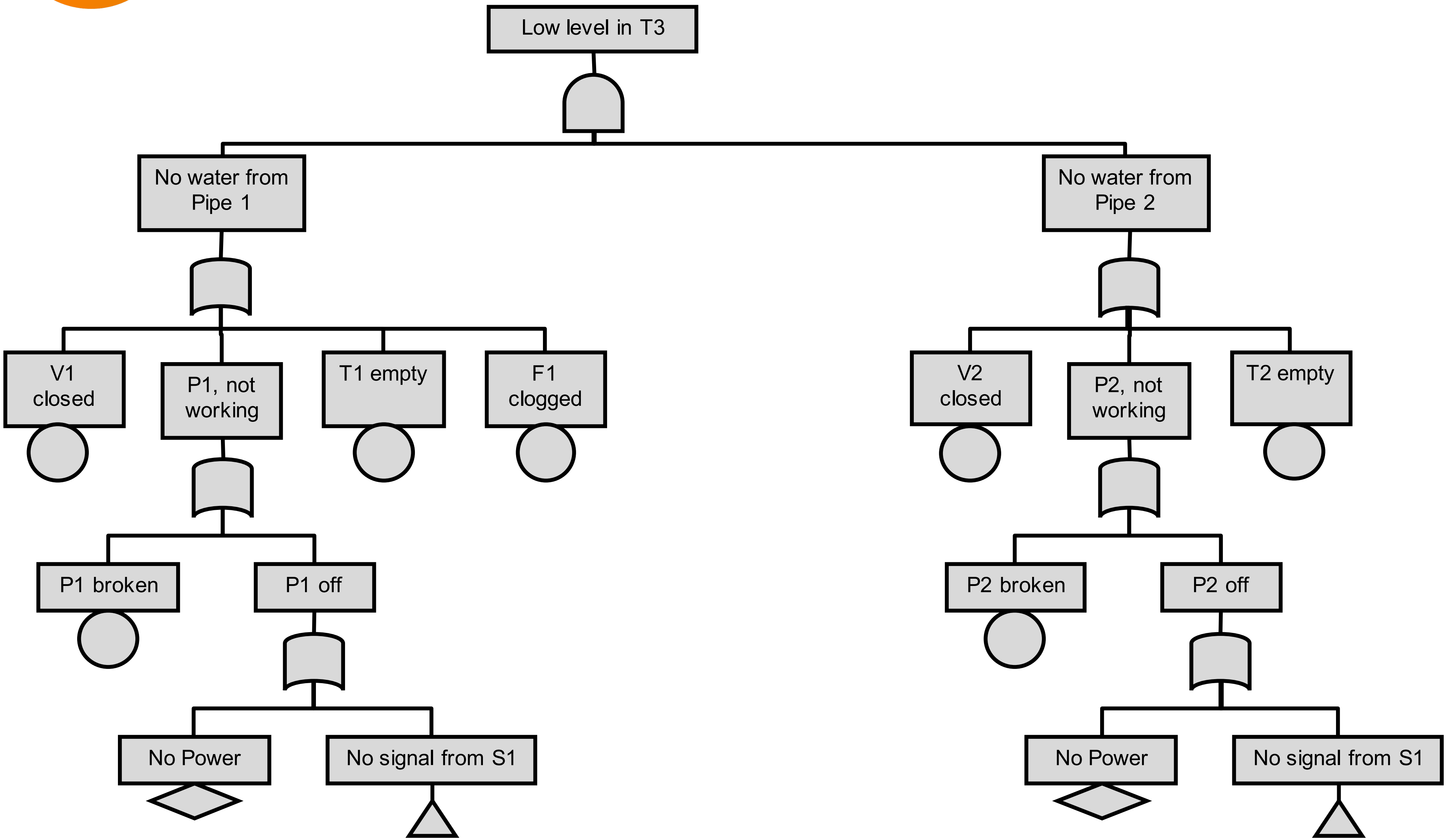
The Underdeveloped event represents an event that is not examined further because information is unavailable or because its consequence is insignificant

Fault Tree Analysis, FTA



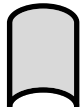
What causes are there for low level in tank T3?

Fault Tree Analysis, FTA

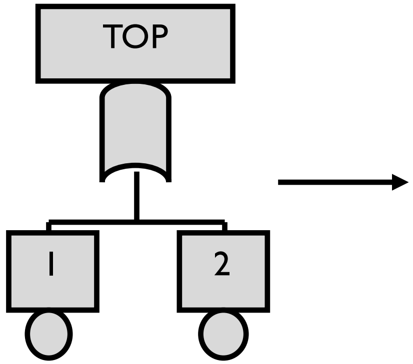


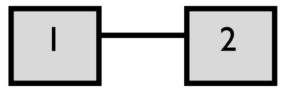
Fault Tree Analysis, FTA

How to convert FTA into reliability block diagrams:

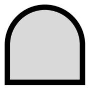


OR-gates are converted into a series structure.

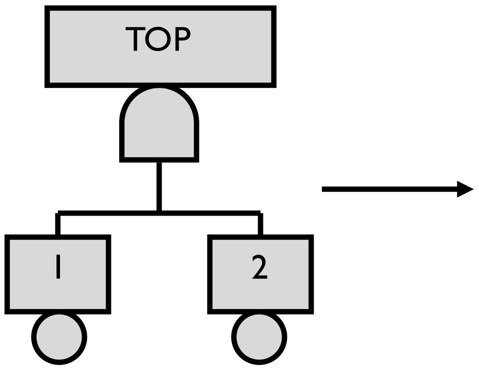


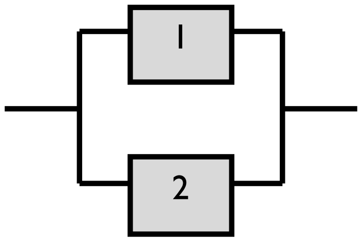


$R_s(t) = R_1(t) \times R_2(t)$



AND-gates are converted into parallel structures.

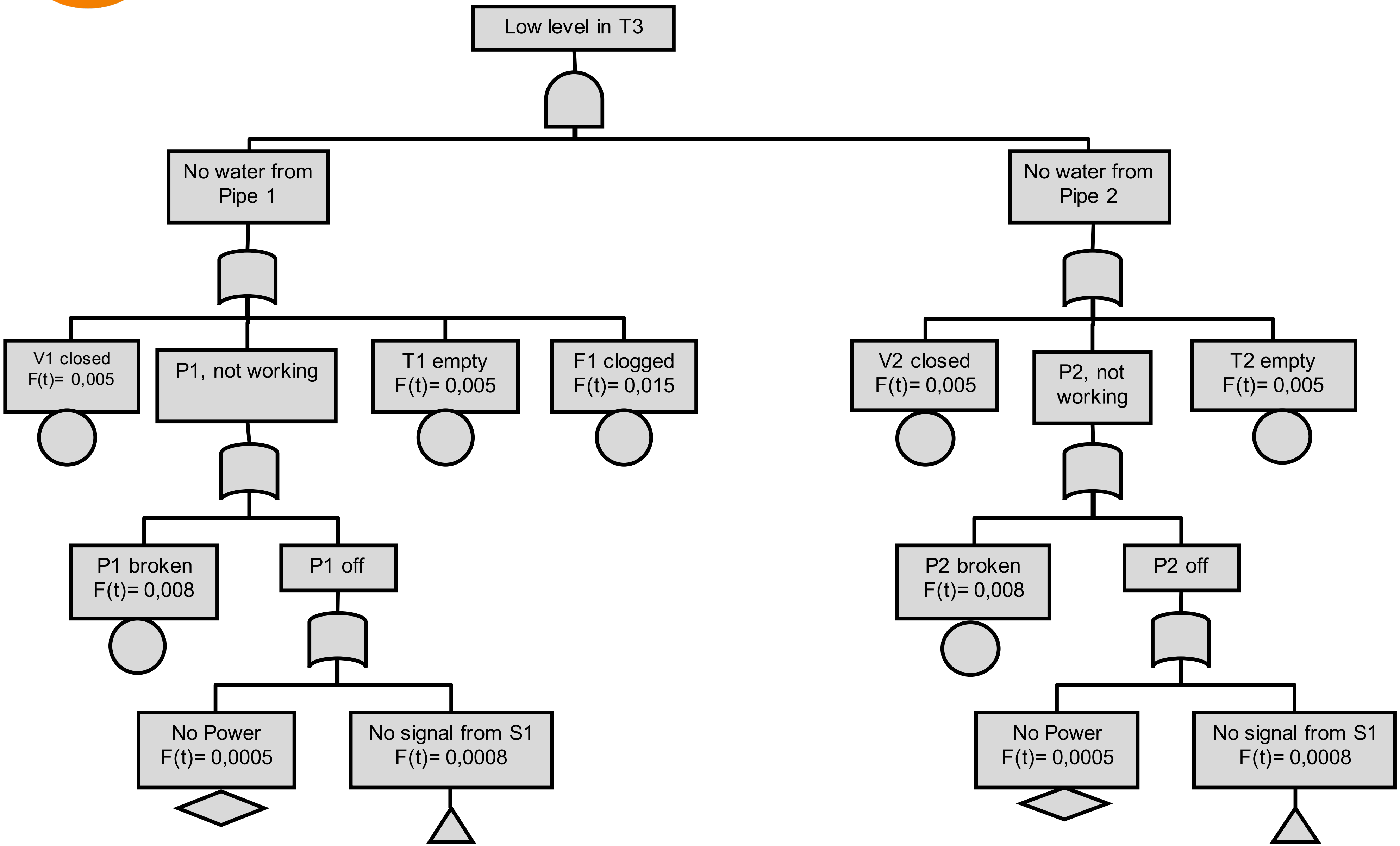




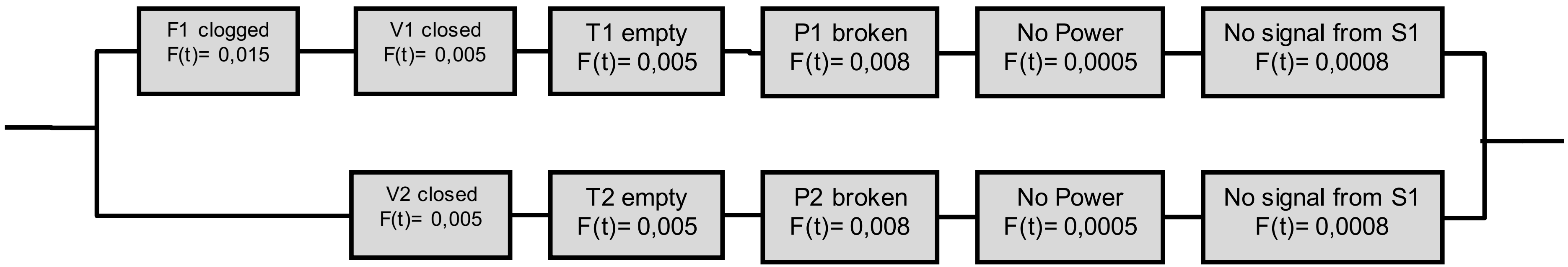
$R_p(t) = 1 - (1 - R_1(t)) \times (1 - R_2(t))$

Cont.

Fault Tree Analysis, FTA



Fault Tree Analysis, FTA



$R_{sys1\,(t)} = 0.985 \times 0.995 \times 0.995 \times 0.992 \times 0.9995 \times 0.9992 = 0.966$

$R_{sys2\,(t)} = 0.995 \times 0.995 \times 0.992 \times 0.9995 \times 0.9992 = 0.981$

$R_{sys1+2\,(t)} = 1-(1- 0.966)(1-0.981) = 0.999$

PM analysis

Aiming at reducing chronical loss to zero

Accomplished by:

- An analytical and systematic view on every phenomenon
- A study of a every thinkable factor that may cause the phenomenon
- Identification of every deviation and reduction of these to zero

PM analysis

Aiming at reducing chronical loss to zero

P: - Physical
- Phenomena

M: - Mechanism
- Machine, Man, Material, Method

PM analysis

The eight steps of PM analysis:

1. Clarify the Phenomenon
2. Conduct a physical analysis
3. Identify constituent conditions
4. Study 4M for causal factors
5. Establish optimal conditions (Standard values)
6. Survey Causal Factors for Abnormalities
7. Determine Abnormalities to Be Addressed
8. Propose and Make Improvements

PM analysis

1. Clarify the Phenomenon

The phenomenon occurs when a failure happens, and may be defined as ”the difference between a normal and an abnormal state”

A precise clarification of the phenomenon is the key to succesful problem solving

1. Eliminate preconcieved ideas
2. Study the equipment
3. Classify the phenomenon
4. Study and identify the deviations

PM analysis

PM Analysis sheet Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8

PM analysis

2. Conduct a physical analysis

Apply a physicists view on the equipment.
Define physical entities for measurement of the phenomenon

1. Identify the principles of the studied operation
2. Identify the standards of the operation
3. Identify interacting relations between equipment and products
4. Quantify physical events

PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	**Constituent conditions**	**Primary 4M**	**Secondary 4M**	**Established optimal conditions**	**Abnormalities**	**Suggested improvements**
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe						

PM analysis

3. Identify constituent conditions

Identify all fundamental causes to the problem
Find fundamental causes within all 4Ms: man, machine, method, material

PM analysis

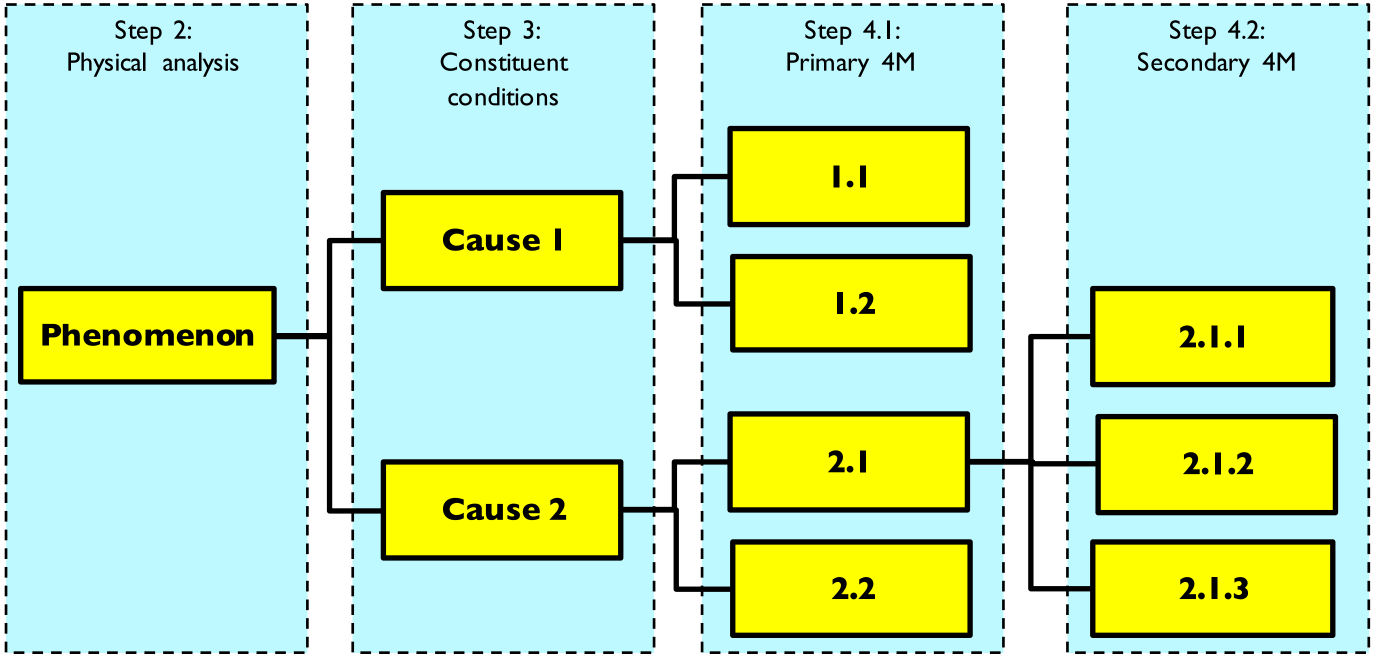
PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies					

PM analysis

4. Study 4M for causal factors

Study the relations between the fundamental causes and the 4Ms in terms of cause and effect.



PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies	3:1 The gripper don't pull the pipe to the right length				
		3:2 The gripper doesn't move the right distance				
		3:3 The position of the tube changes after the gripper has released				

PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies	3:1 The gripper don't pull the pipe to the right length	3.1.1 Locking rolls are worn 3.1.2 Too low force in the locking piston 3.1.3 Oil on the locking rolls 3.1.4 High amount of oil on the pipes 3.1.5 The pipe is misaligned in the frame 3.1.6 Debri in the steering mechanism 3.1.7 High flexibility in frame 3.1.8 Debri on the door 3.1.9 Doesn't grip because of resistance in gripper mechanism			
		3:2 The gripper doesn't move the right distance	3.2.1 Play in slewing bracket 3.2.2 Loose bracket 3.2.3 Air pressure too low			
		3:3 The position of the tube changes after the gripper has released	3.3.1 The pipe bounce on the door 3.3.2 Skew pipe is pulled up 3.3.3 Resistance in the locking mechanism makes it pull the pipe 3.3.4 Pipe bounce when the cutter positions too late 3.3.5 Wear/grades on the top of the door			

PM analysis

5. Establish optimal conditions (Standard values)

”Optimal conditions” are the conditions that are required for the equipment to function and deliver according to requirements.

PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies	3:1 The gripper don't pull the pipe to the right length	3.1.1 Locking rolls are worn	3.1.1 Max 3mm deterioration		
			3.1.2 Too low force in the locking piston	3.1.2 Minimum 80 N		
			3.1.3 Oil on the locking rolls	3.1.3 No oil		
			3.1.4 High amount of oil on the pipes	3.1.4 No oil		
			3.1.5 The pipe is misaligned in the frame	3.1.5 The pipe should run smooth		
			3.1.6 Debri in the steering mechanism	3.1.6 Absolute clean		
			3.1.7 High flexibility in frame	3.1.7 Max 30 N on inner tube		
			3.1.8 Debri on the door	3.1.8 Absolute clean		
			3.1.9 Doesn't grip because of resistance in gripper mechanism	3.1.9 No resistance		
		3:2 The gripper doesn't move the right distance	3.2.1 Play in slewing bracket	3.2.1 Max 2mm play		
			3.2.2 Loose bracket	3.2.2 Fastened		
			3.2.3 Air pressure too low	3.2.3 Pressure 5KPa		
		3:3 The position of the tube changes after the gripper has released	3.3.1 The pipe bounce on the door	3.3.1 No Bounce		
			3.3.2 Skew pipe is pulled up	3.3.2 Max skewness 0.1mm/100mm		
			3.3.3 Resistance in the locking mechanism makes it pull the pipe	3.3.3 No resistance		
			3.3.4 Pipe bounce when the cutter positions too late	3.3.4 Cutter should position when pipe is released		
			3.3.5 Wear/grades on the top of the door	3.3.5 No wear or grades		

PM analysis

6. Survey Causal Factors for Abnormalities

Measure the differences between possible root causes, according to steps 3 and 4, and the optimal conditions, defined in step 5.

PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies	3:1 The gripper don't pull the pipe to the right length	3.1.1 Locking rolls are worn	3.1.1 Max 3mm deterioration	3.1.1 OK!	
			3.1.2 Too low force in the locking piston	3.1.2 Minimum 80 N	3.1.2 Too low	
			3.1.3 Oil on the locking rolls	3.1.3 No oil	3.1.3 Oil present	
			3.1.4 High amount of oil on the pipes	3.1.4 No oil	3.1.4 Oil present	
			3.1.5 The pipe is misaligned in the frame	3.1.5 The pipe should run smooth	3.1.5 Resistance	
			3.1.6 Debri in the steering mechanism	3.1.6 Absolute clean	3.1.6 Not clean	
			3.1.7 High flexibility in frame	3.1.7 Max 30 N on inner tube	3.1.7 To high force	
			3.1.8 Debri on the door	3.1.8 Absolute clean	3.1.8 Not clean	
			3.1.9 Doesn't grip because of resistance in gripper mechanism	3.1.9 No resistance	3.1.9 Some resistance	
		3:2 The gripper doesn't move the right distance	3.2.1 Play in slewing bracket	3.2.1 Max 2mm play	3.2.1 Play exists	
			3.2.2 Loose bracket	3.2.2 Fastened	3.2.2 Loose	
			3.2.3 Air pressure too low	3.2.3 Pressure 5KPa	3.2.3 OK (if enough)	
		3:3 The position of the tube changes after the gripper has released	3.3.1 The pipe bounce on the door	3.3.1 No Bounce	3.3.1 Not evaluated!	
			3.3.2 Skew pipe is pulled up	3.3.2 Max skewness 0.1mm/100mm	3.3.2 Skewness occurs	
			3.3.3 Resistance in the locking mechanism makes it pull the pipe	3.3.3 No resistance	3.3.3 Some resistance	
			3.3.4 Pipe bounce when the cutter positions too late	3.3.4 Cutter should position when pipe is released	3.3.4 Occasionaly	
			3.3.5 Wear/grades on the top of the door	3.3.5 No wear or grades	3.3.5 Damaged!	

PM analysis

7. Determine Abnormalities to Be Addressed

Based on the survey in step 6, define which factors that truelly contribute to the problem and therefore should be dealt with.

PM analysis

8. Propose and Make Improvements

Propose improvements for correction of the identified deviations.
Prevent them from re-occurring.

PM analysis

PM Analysis sheet: Length variation in cut tubes

Physical analysis	Constituent conditions	Primary 4M	Secondary 4M	Established optimal conditions	Abnormalities	Suggested improvements
Step 2	Step 3	Step 4.1	Step 4.2	Step 5	Step 6	Steps 7 and 8
The distance (A) varies between the edge (B) of the cutting tool and the end position (C) of the pipe	3: The position of the pipe varies	3:1 The gripper don't pull the pipe to the right length	3.1.1 Locking rolls are worn	3.1.1 Max 3mm deterioration	3.1.1 OK!	Not presented
			3.1.2 Too low force in the locking piston	3.1.2 Minimum 80 N	3.1.2 Too low	
			3.1.3 Oil on the locking rolls	3.1.3 No oil	3.1.3 Oil present	
			3.1.4 High amount of oil on the pipes	3.1.4 No oil	3.1.4 Oil present	
			3.1.5 The pipe is misaligned in the frame	3.1.5 The pipe should run smooth	3.1.5 Resistance	
			3.1.6 Debri in the steering mechanism	3.1.6 Absolute clean	3.1.6 Not clean	
			3.1.7 High flexibility in frame	3.1.7 Max 30 N on inner tube	3.1.7 To high force	
			3.1.8 Debri on the door	3.1.8 Absolute clean	3.1.8 Not clean	
			3.1.9 Doesn't grip because of resistance in gripper mechanism	3.1.9 No resistance	3.1.9 Some resistance	
		3:2 The gripper doesn't move the right distance	3.2.1 Play in slewing bracket	3.2.1 Max 2mm play	3.2.1 Play exists	
			3.2.2 Loose bracket	3.2.2 Fastened	3.2.2 Loose	
			3.2.3 Air pressure too low	3.2.3 Pressure 5KPa	3.2.3 OK (if enough)	
		3:3 The position of the tube changes after the gripper has released	3.3.1 The pipe bounce on the door	3.3.1 No Bounce	3.3.1 Not evaluated!	
			3.3.2 Skew pipe is pulled up	3.3.2 Max skewness 0.1mm/100mm	3.3.2 Skewness occurs	
			3.3.3 Resistance in the locking mechanism makes it pull the pipe	3.3.3 No resistance	3.3.3 Some resistance	
			3.3.4 Pipe bounce when the cutter positions too late	3.3.4 Cutter should position when pipe is released	3.3.4 Occasionaly	
			3.3.5 Wear/grades on the top of the door	3.3.5 No wear or grades	3.3.5 Damaged!	

Time for a brake?