UNIVERSITÀ DEGLI STUDI DI TRIESTE

Prof. Ing. Raffaele Campanella

E-mail: raffaele.campanella@yahoo.it

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INDUSTRIAL PLANTS II

Chapter one ï part 5:

Lean manufacturing

OVERALL EQUIPMENT EFFECTIVENESS

SINGLE MINUTE EXCHANGE DIE

TOTAL PRODUCTIVE MAINTENANCE

FAILURE MODE EFFECTS ANALYSIS

DOUBLE DEGREE MASTER IN

ñPRODUCTION ENGINEERING AND MANAGEMENTò

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

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TOTAL PRODUCTIVE MAINTENANCE

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TPM

The machine is mine; if something happens, I feel responsible for it.
I can't blame the maintenance, it's not enough to keep it well lubricated, but I also have to keep it clean, dusting it several times a day, so that if there are any oil leaks, it doesn't all end up in a puddle, but I can notice it immediately.
I will therefore have to attend on the seals or other critical points before the machine blocks.

Harley-Davidson blue-collar

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TOTAL PRODUCTIVE MAINTENANCE

The plants and the machines must guarantee the maximum reliability of the process, to avoid the need for stocks and to have efficient material flows. To be effective, maintenance must take place continuously and promptly. The TPM responds to this purpose:

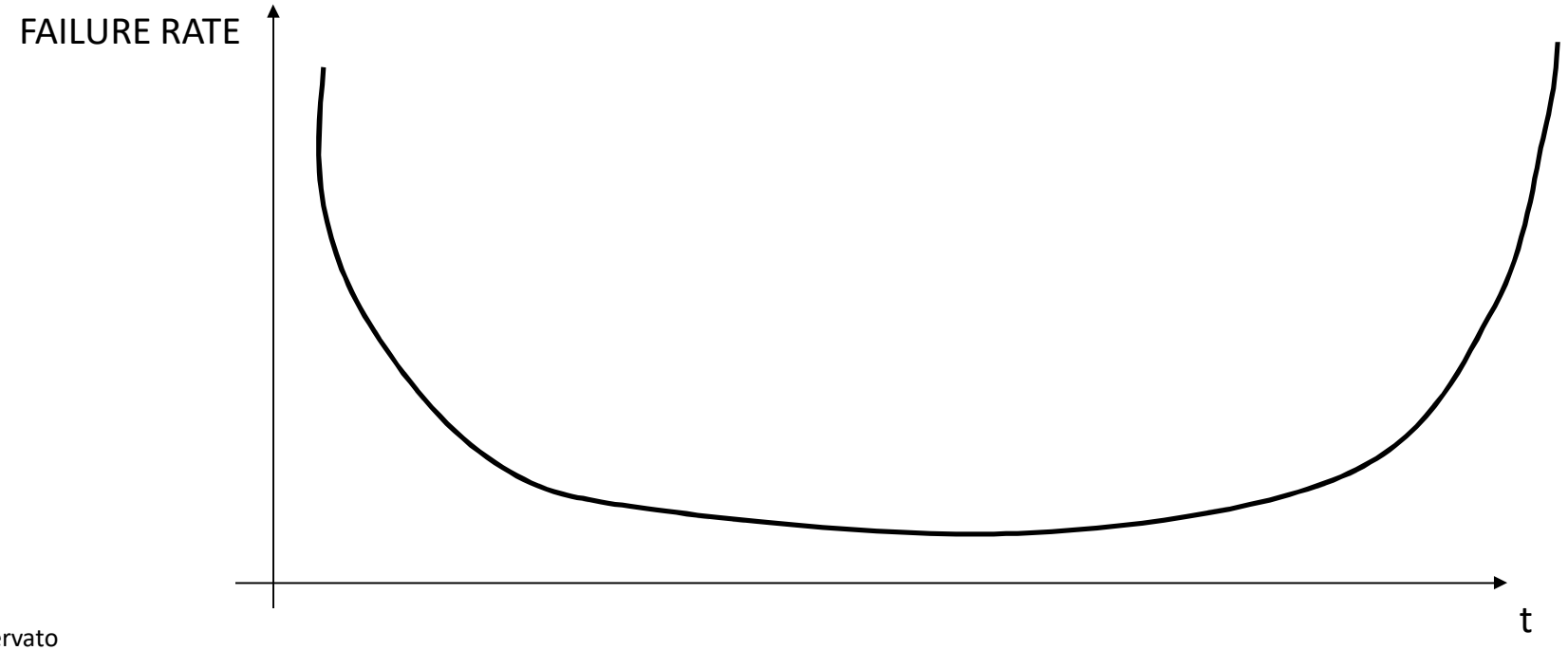
- **It pursues the achievement of the maximum possible utilization of the plants**
- **It creates a maintenance system that has as its object the life of the systems as a whole**
- **It involves all company functions in its application: from maintenance proper to technical services, to production ...**
- **It stimulate the personal participation of everyone, from the management to the front line staff**
- **It works through the action of small groups**

FAILURES

INITIAL

CASUAL

DUE TO WEAR



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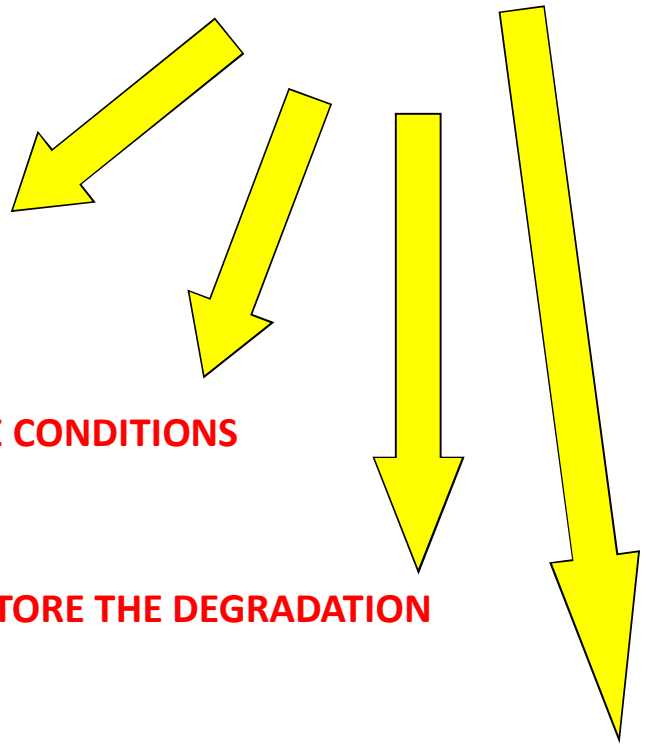
OBJECTIVES:
ZERO STOPS FOR FAILURES
ZERO STOPS FOR DEFECTS
ZERO STOPS FOR INJURIES

TPM



PREPARE THE ZERO STOPS CONDITIONS
(Cleaning, lubrication, fixing)

LOOK AT THE USE CONDITIONS

RESTORE THE DEGRADATION

INCREASE TECHNICAL KNOW-HOW FOR CONTROL, MONITORING AND MAINTENANCE

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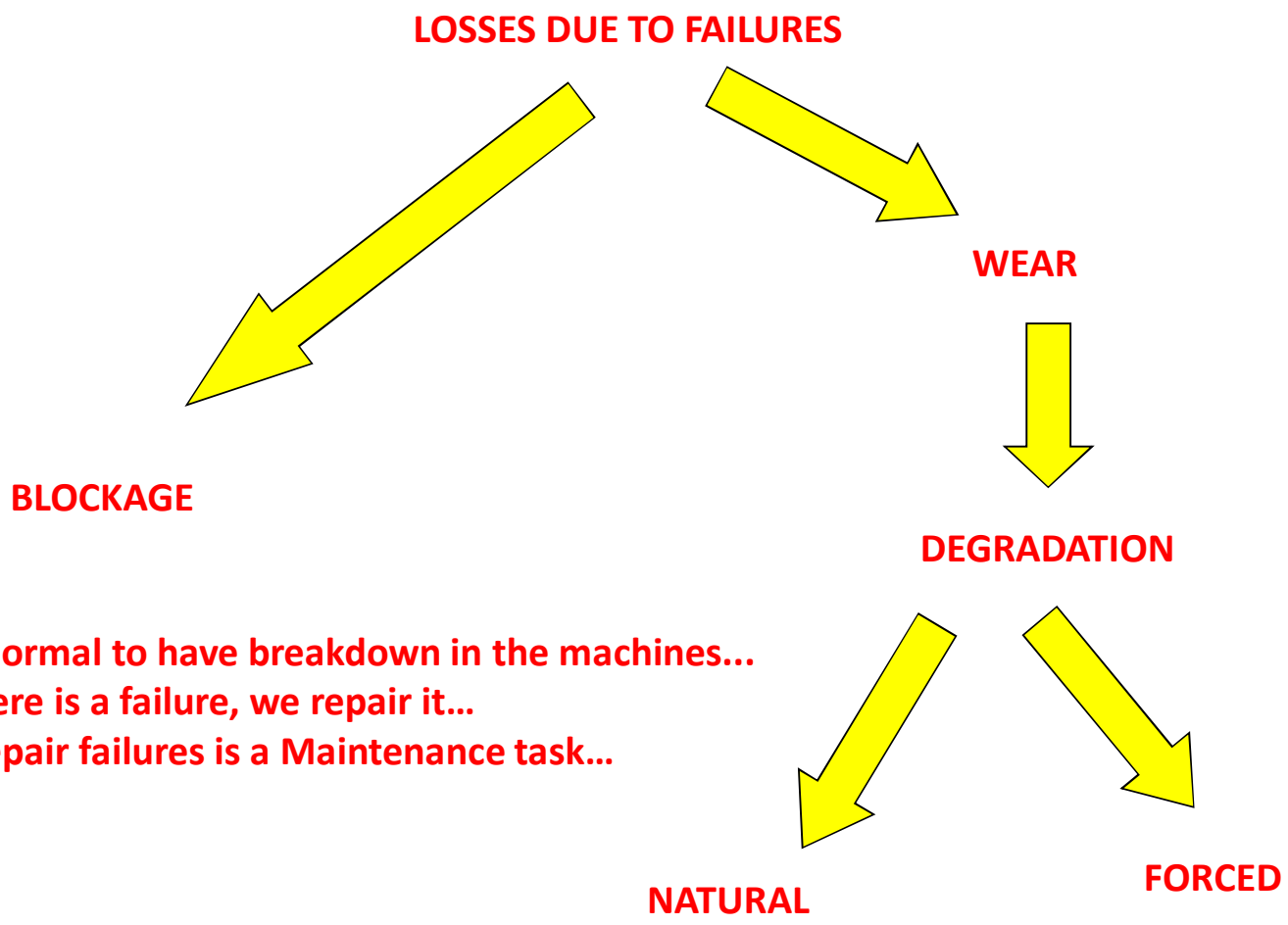
TPM



It's normal to have breakdown in the machines...
If there is a failure, we repair it…
To repair failures is a Maintenance task…

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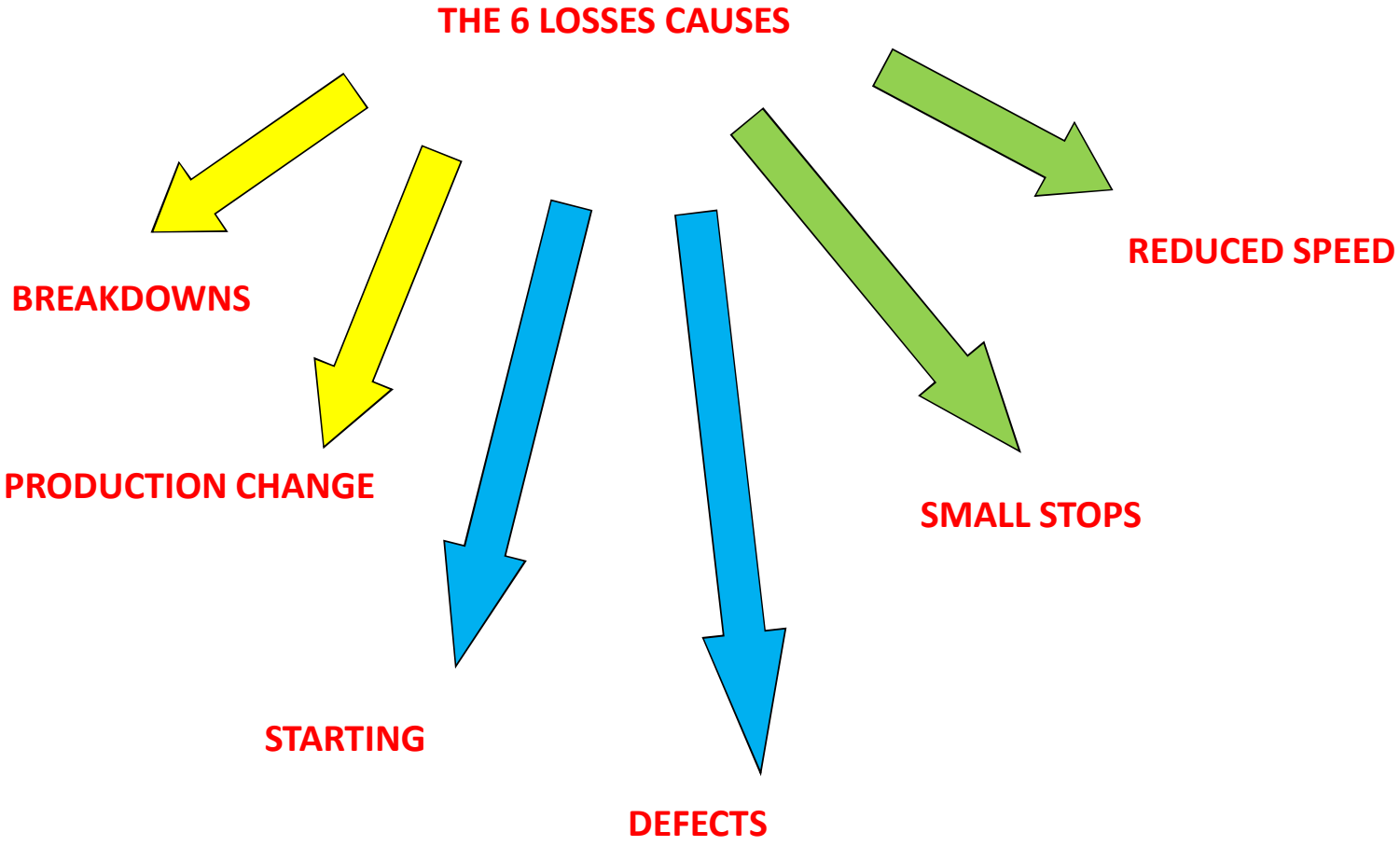
TPM



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THE 7 STEPS OF TPM

1) INSPECTION BY CLEANING:

- Complete elimination of dirt and stains, especially in the main parts of the systems.
- Lubrication and tightening.
- Discovery of the problems and their restoration, if possible. If not, red tag.

2) COUNTERMEASURES FOR THE ORIGIN OF DIRT AND POSITIONS OF DIFFICULT ACCESS:

- Dirt and stain prevention.
- Improvement of places that are difficult to access and lubricate.
- Reduction of cleaning times.

3) DEVELOPMENT OF PREVENTIVE CLEANING, TIGHTENING AND LUBRICATION STANDARDS:

- Development of standards to carry out cleaning, lubrication and tightening in a short time.

4) GENERAL INSPECTION:

- Training of technical skills for inspection, according with the manual.
- Identification of small imperfections and relative restoration.

5) AUTONOMOUS INSPECTION:

- Elaboration and application of autonomous inspection lists

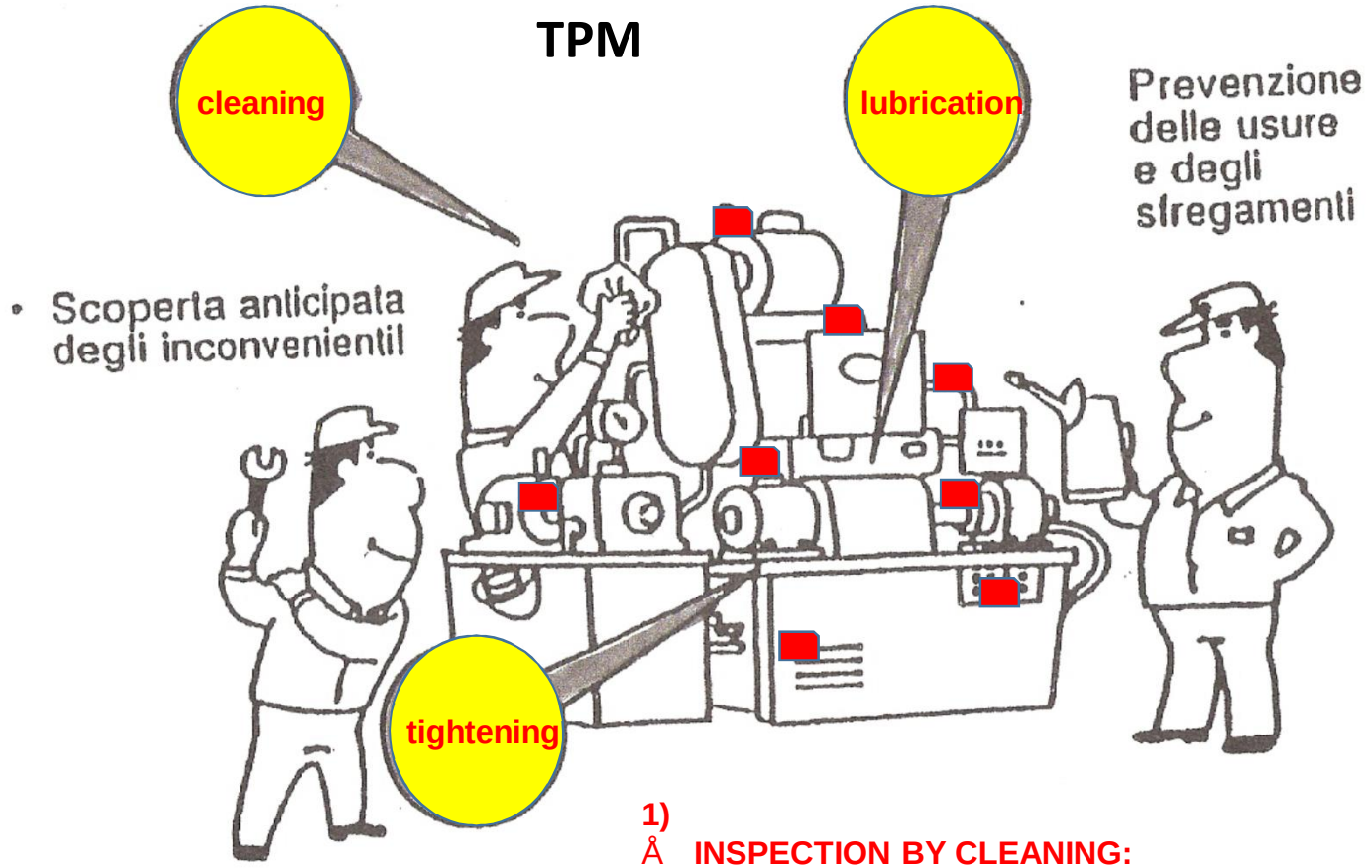
6) MAINTENANCE MANAGEMENT:

- Standardization of management topics in the various departments and creation of a complete maintenance system
- inspection standard for cleaning and lubrication
- standardization of data recording, management of molds, equipment ... ..

7) COMPLETE AUTONOMOUS MANAGEMENT:

- Regular recording of MTBF analysis, the development of objectives and improvement activities.
- Plant analysis and improvement

TPM



1)

- **INSPECTION BY CLEANING:**
  - **Complete elimination of dirt and stains, especially in the main parts of the systems.**
- **LUBRICATION AND TIGHTENING**
  - **Lubrication and tightening.**
  - **Discovery of the problems and their restoration**
  - **Red cards**

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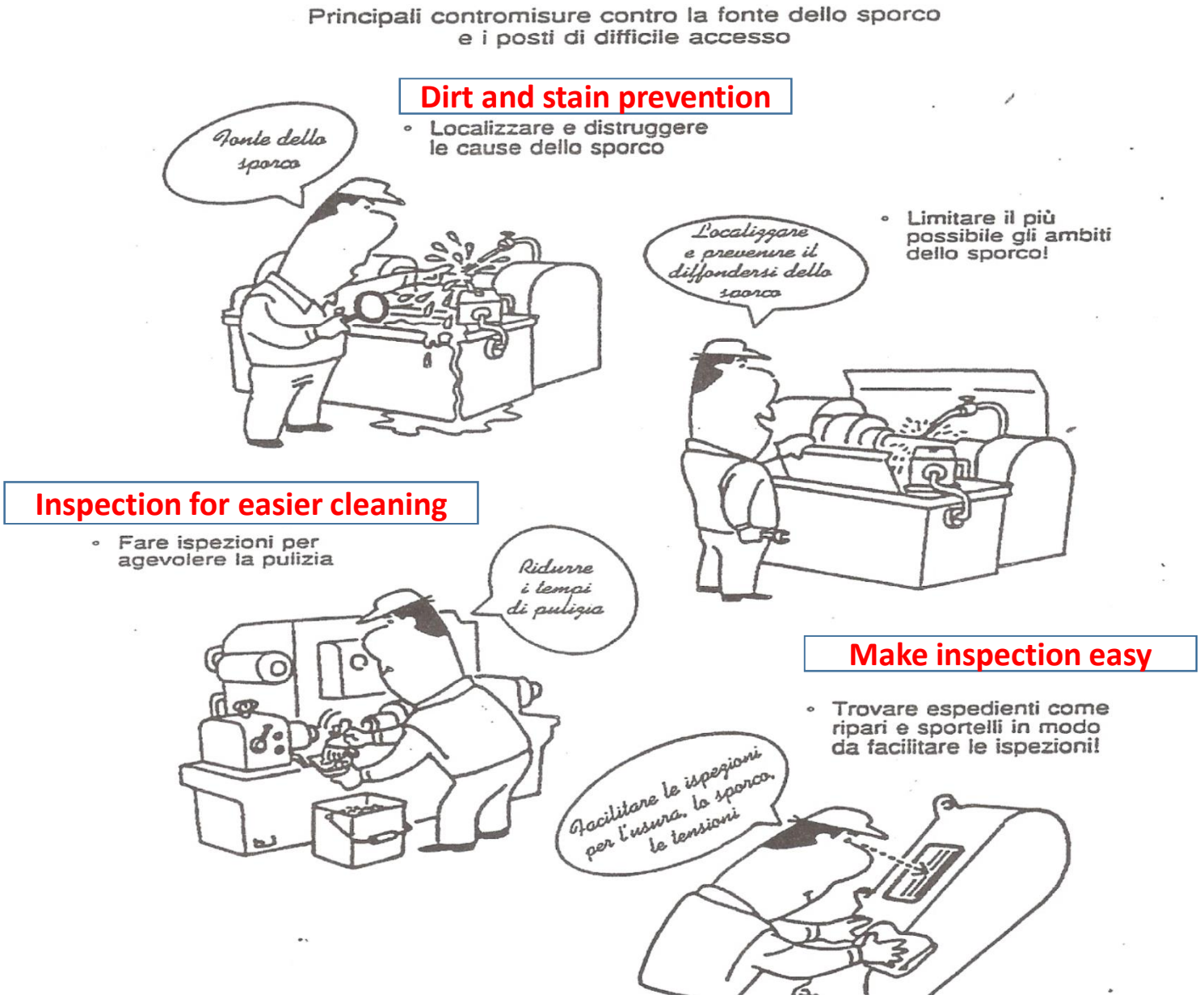
TPM

2) COUNTERMEASURES FOR THE ORIGIN OF DIRT AND POSITIONS OF DIFFICULT ACCESS:

- Dirt and stain prevention.
- Improvement of places that are difficult to access and lubricate.
- Reduction of cleaning times.



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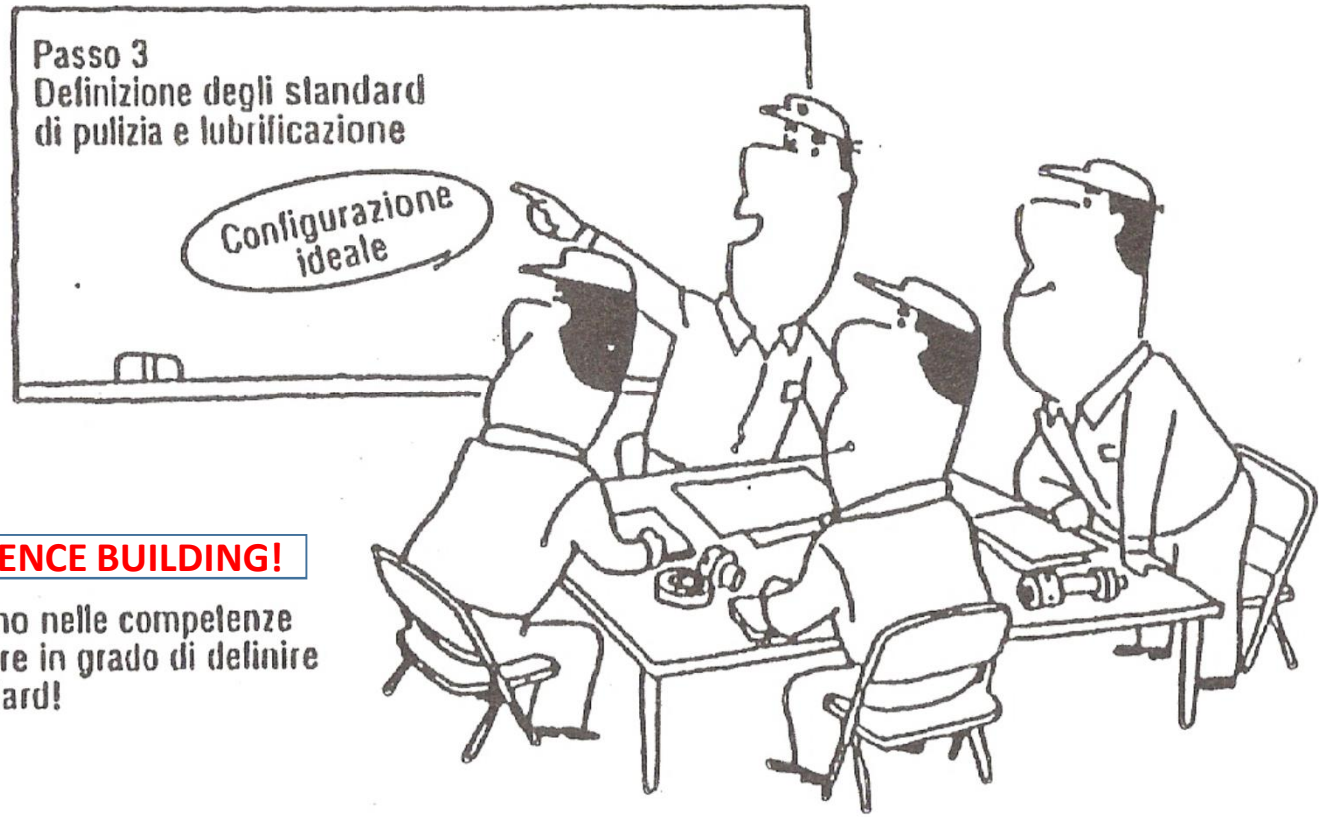
TPM

3) DEVELOPMENT OF PREVENTIVE CLEANING, TIGHTENING AND LUBRICATION STANDARDS:

- **Development of standards to carry out cleaning, lubrication and tightening in a short time.**



COMPETENCE BUILDING!

Cresciamo nelle competenze per essere in grado di definire gli standard!

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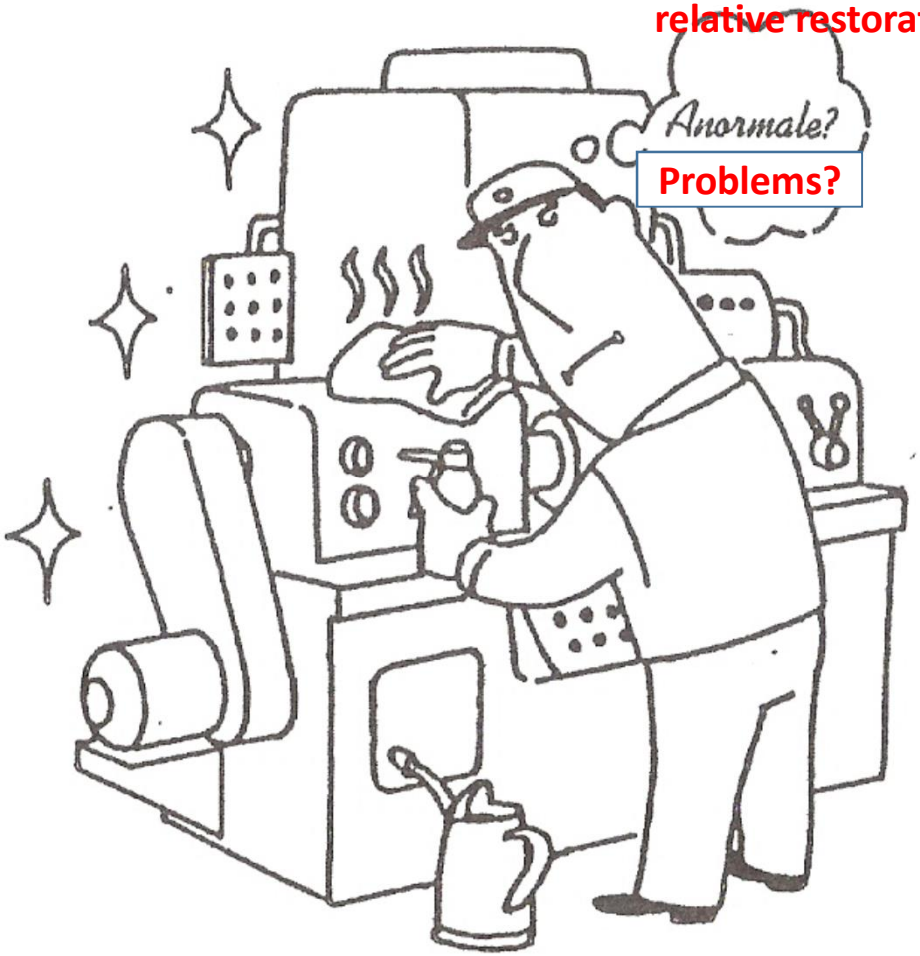
TPM

4) GENERAL INSPECTION:
Training of technical skills for inspection, according with the manual.
Identification of small imperfections and relative restoration.



Problems discovery

Problems registration

Problems solution

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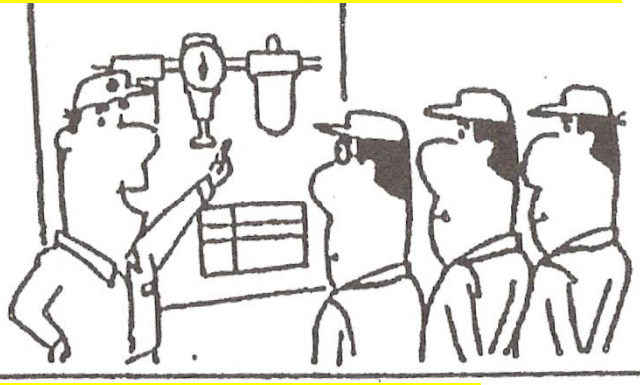
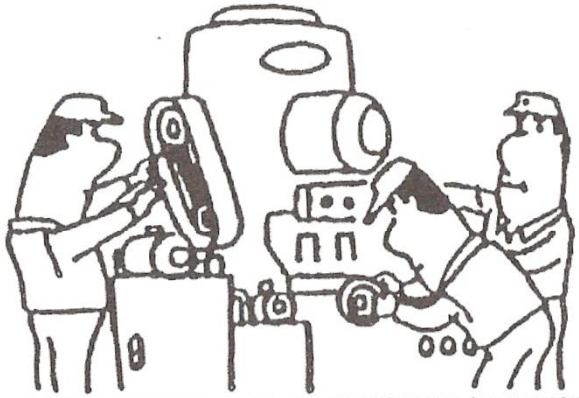
5) AUTONOMOUS INSPECTION:
Elaboration and application of autonomous inspection lists

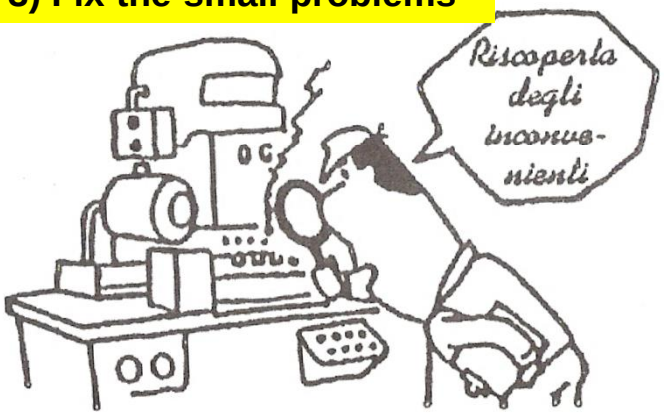
1) Learn machine structure and functions



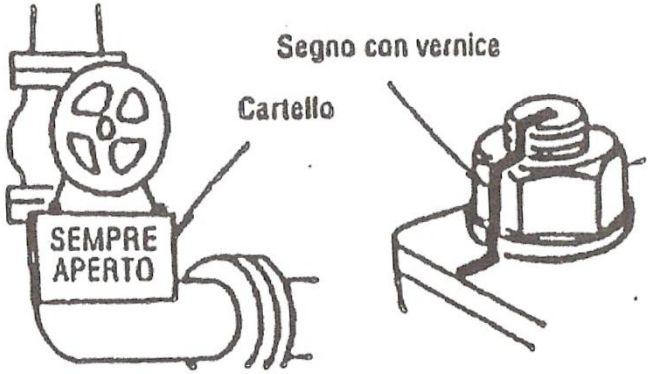
2) Try to do actual inspections



3) Fix the small problems



4) Improve visual management



Always open valve

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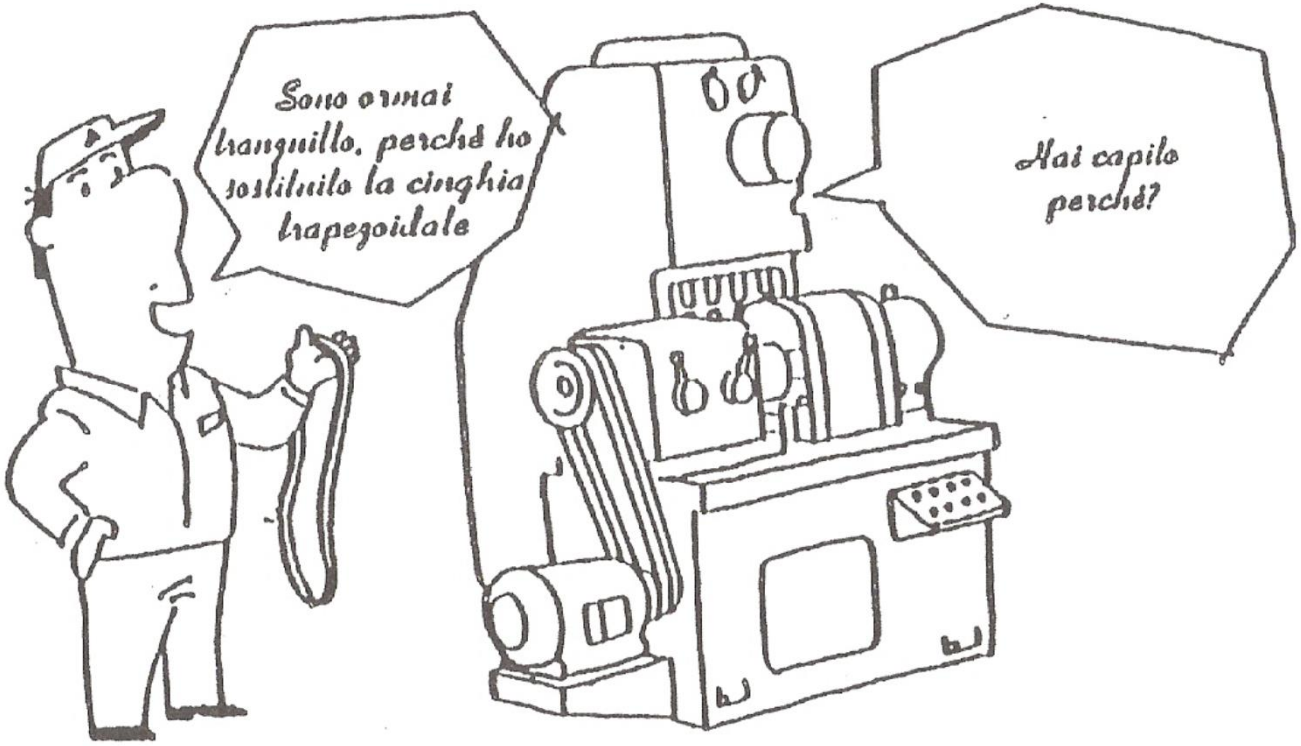
TPM

6) MAINTENANCE MANAGEMENT:

- **Standardization of management topics in the various departments and creation of a complete maintenance system:**
- **inspection standard for cleaning and lubrication**
- **standardization of data recording, management of molds, equipment ... ..**
- **Causes research**



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TPM

Take away the red card means to have fixed the problema

Let's clean even the most hidden corners

Are there strange situations?

Let's repair soon what can be repaired

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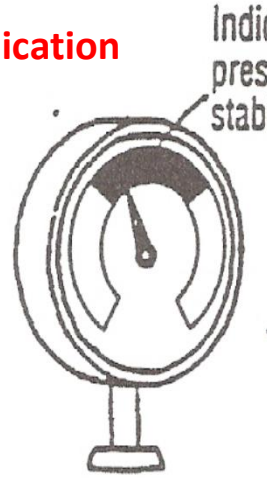
TPM
PREVENTION AND VISUAL MANAGEMENT

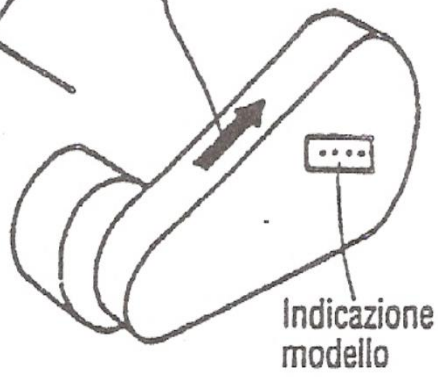
Pressure indication



Thermal label

Visual inspection

Rotation direction



Model indication

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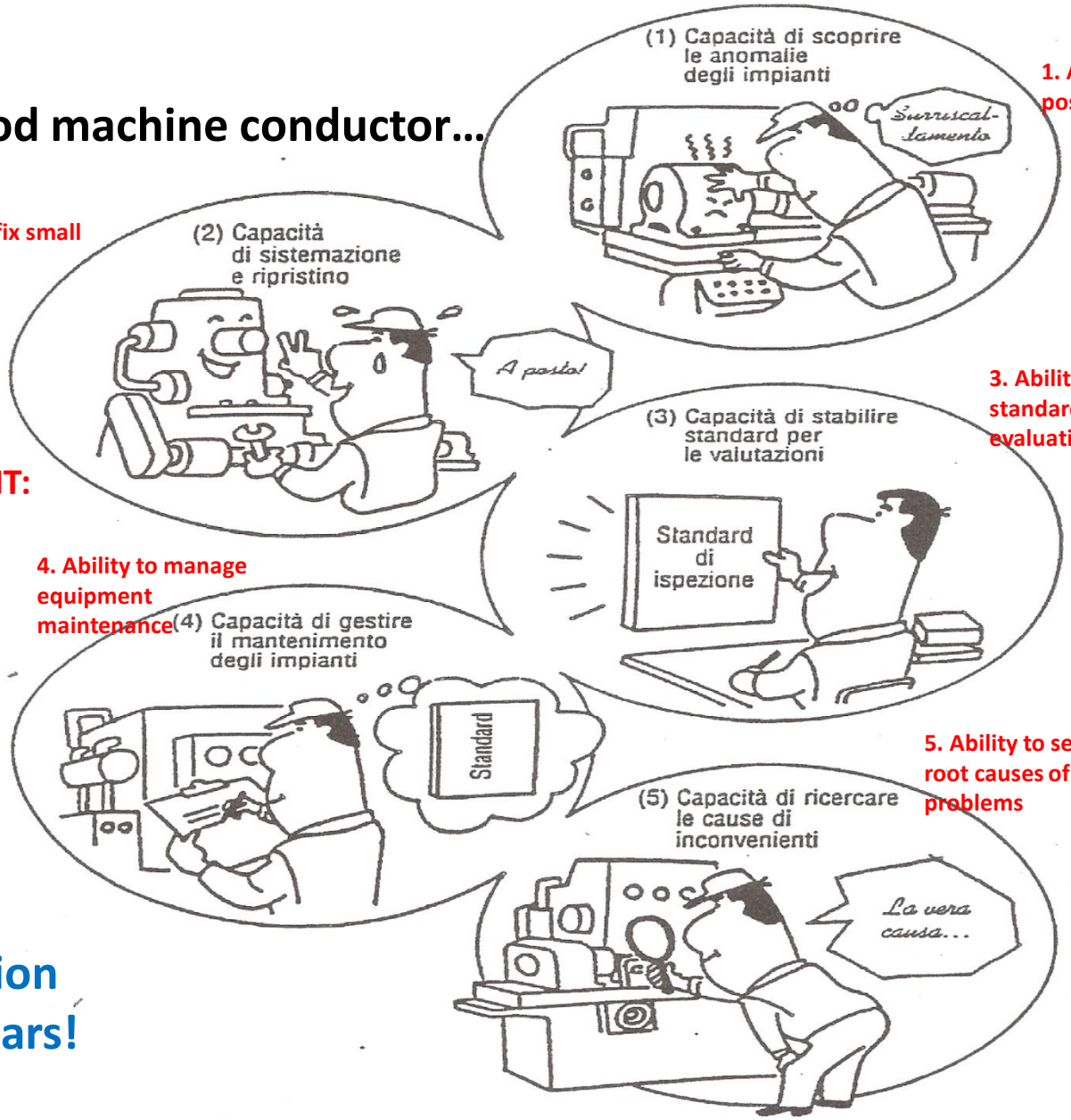
To become good machine conductor…



1. Ability to find out possible problems
2. Ability fix small problems
3. Ability to decide standard for future evaluation
4. Ability to manage equipment maintenance
5. Ability to search the root causes of the problems

7) COMPLETE AUTONOMOUS MANAGEMENT:

- Regular recording of MTBF analysis,
- the development of objectives and improvement activities
- Capacity to research roots causes
- Capacity to plant maintenance.
- Ability to decide standards
- Plant analysis and improvement

The TPM implementation can take from 3 to 5 years!

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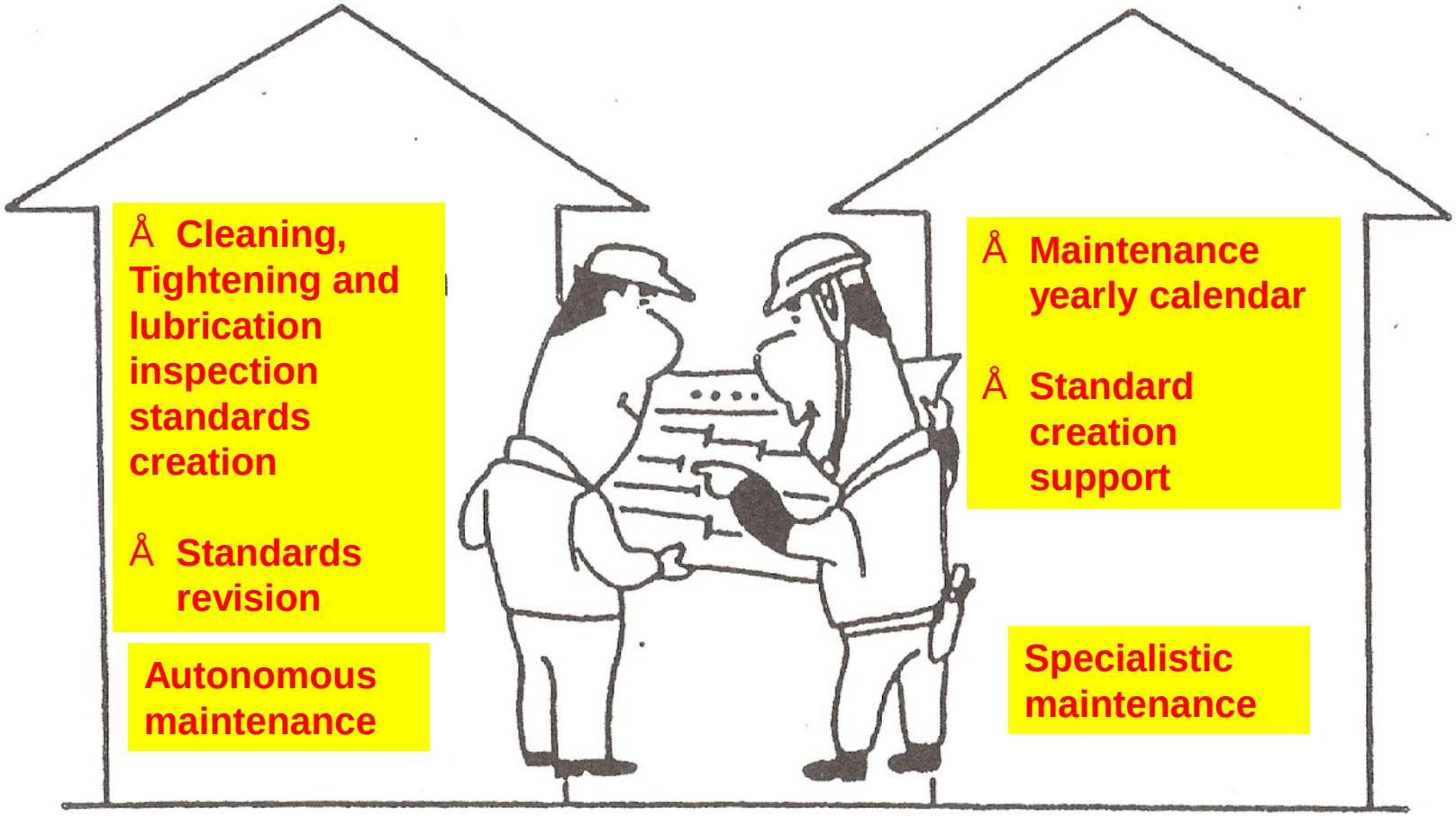
TPM



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BENEFITS OF TPM

Do the job (in small groups) for the Company and for personal satisfaction

Improvement of the Company's results

Improvement of work conditions

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TPM

LEADERSHIP IMPORTANCE

The success depends on leadership

Guide lines

Workteams activities

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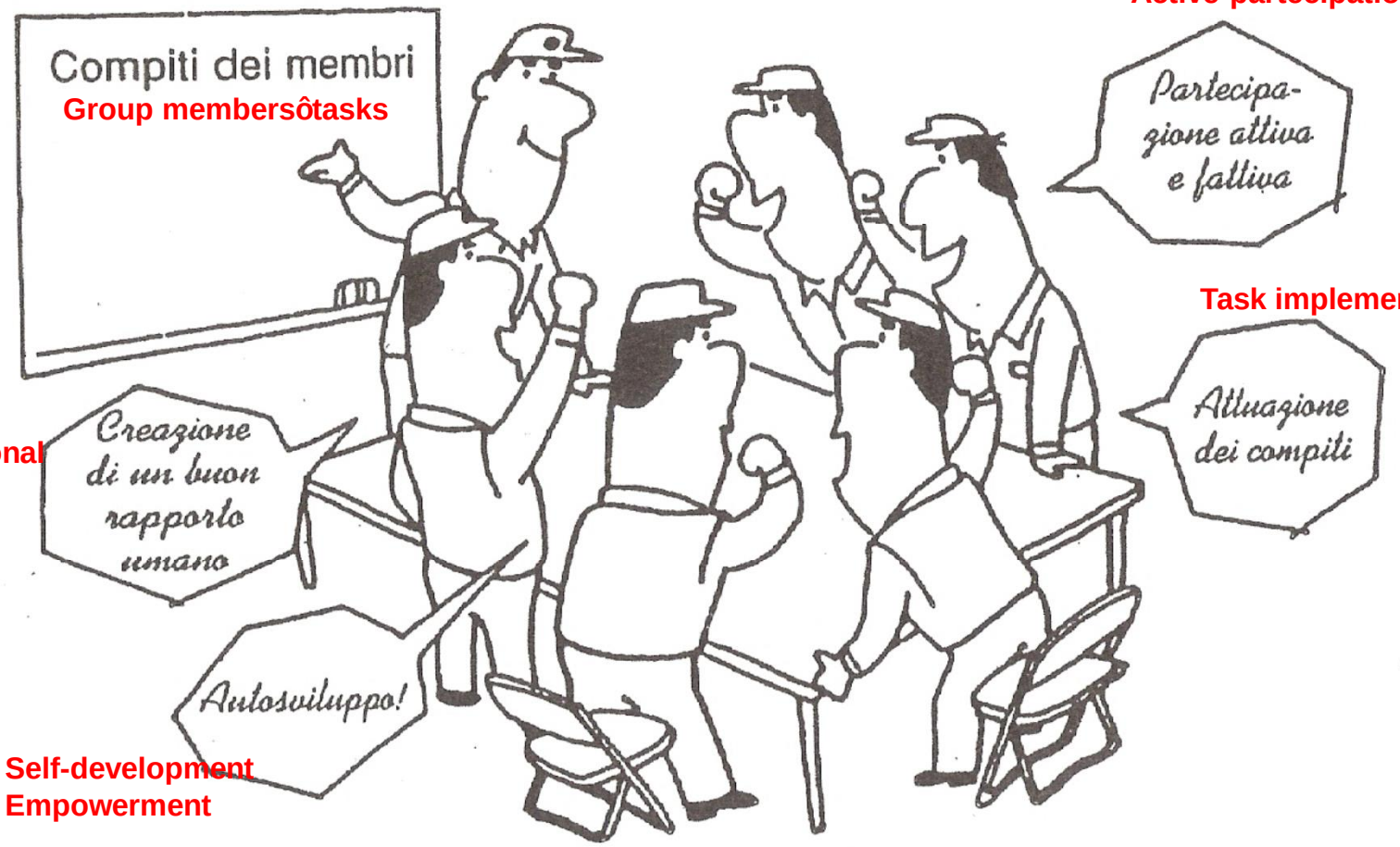
TPM

EMPLOYEES' EMPOWERMENT



Active partecipation

Task implementation

Positive personal relationships

Self-development
Empowerment

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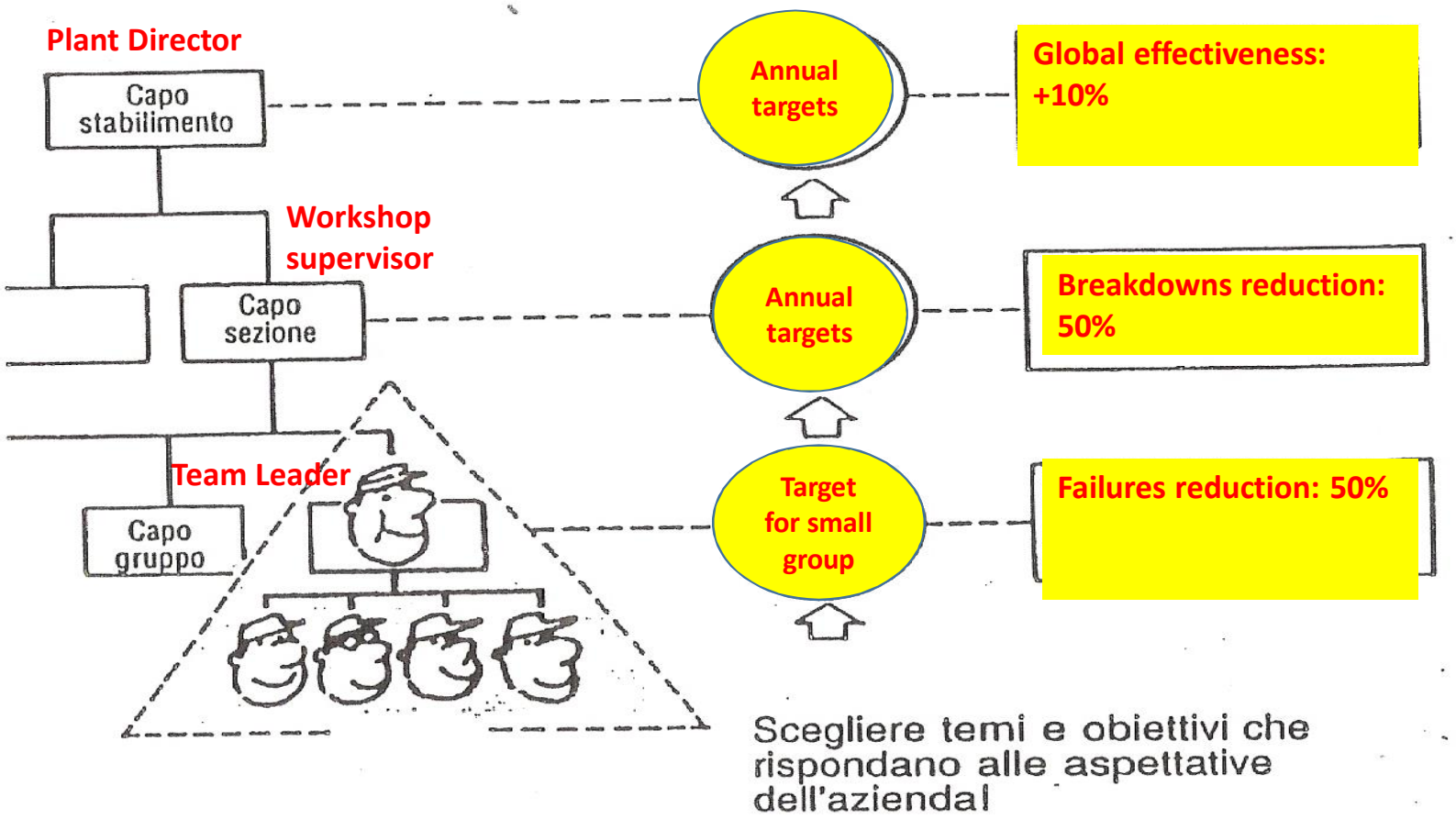
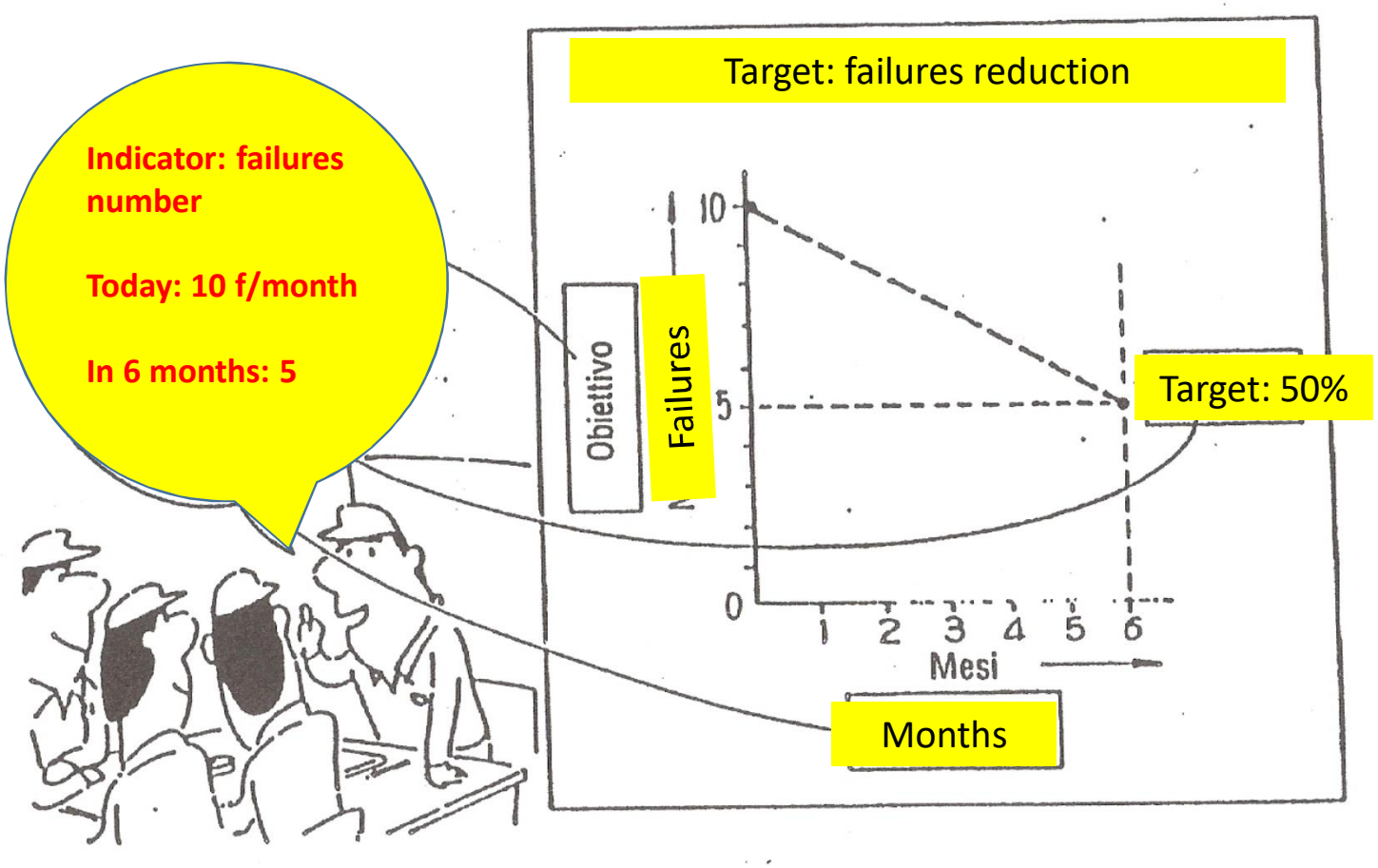
TPM INDICATORS



TPM



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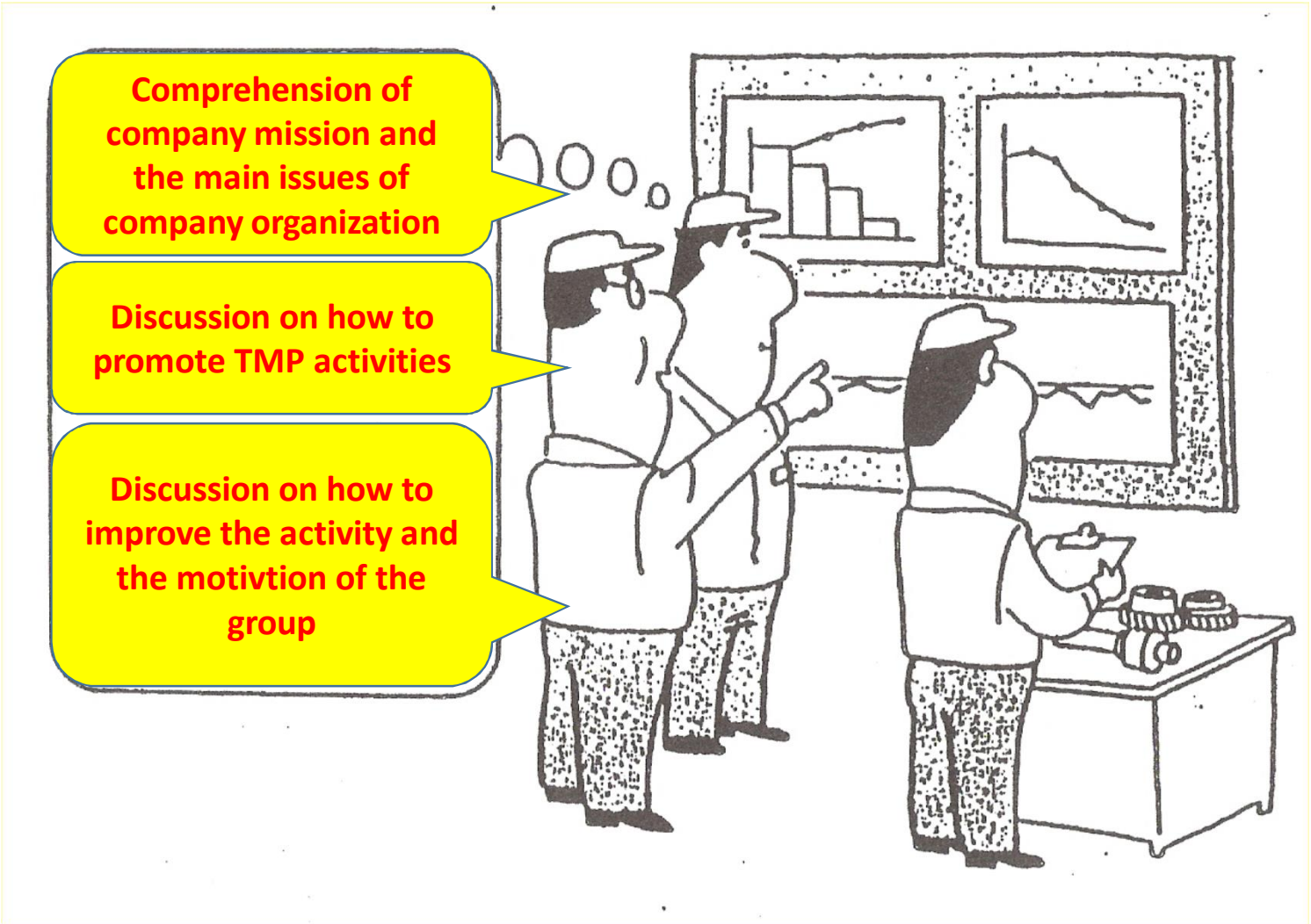
TPM

EMPLOYEES INVOLVEMENT



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FAILURE MODE EFFECT ANALYSIS

FMEA-FMECA

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FAILURE MODE EFFECT ANALYSIS

- U.S. Navy, immediately after World War II
- Weapon's systems
- issued in 1949 with MIL STD 1629 and later revised in 1980 with MIL STD 1629A.
- qualitative and quantitative analysis used to identify, analyse, solve problems, avoiding failures, before the negative events occur, both in the product design (PRODUCT FMEA), and in the production process engineering (PROCESS FMEA).

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FMEA
WHY THE MACHINE IS NOT RELIABLE ENOUGH?

MANUFACTURER

- COST WRONG TARGETS
- TOO SHORT TIME TO MARKET
- NO/BAD EVIDENCE OF DEFECTS BY THE CUSTOMERS
- DESIGN MISTAKES
- LACK OF SUITABLE TEST (MAINLY LIFE TESTS)
- NON ADEQUATE TECHNICAL KNOW-HOW
- NOT ENOUGH TRAINED WORKERS
- NOT INVOLVED SUPPLIERS
- UNCOMPLETE SPECIFICATIONS
- TOO MANY AND WRONG TRADE-OFFS
- PROBLEMS UNDER-EVALUATION
- BAD KNOWLEDGE OF COMPONENTSô SPECIFICATIONS
- BAD INSTALLATION
- BAD MAINTENANCE INFORMATION
- é é é é é .

BUYER

- PRICE WRONG TARGETS
- TOO SHORT TIME TO TRAIN WORKERS
- NO PROBLEMS REPORT
- LACK OF SUITABLE SPECIFICATION
- NON ADEQUATE TECHNICAL KNOW-HOW
- NOT ENOUGH TRAINED WORKERS
- SUPPLIER NOT INVOLVED
- NOT SUITABLE AREA
- PROBLEMS UNDER-EVALUATION
- BAD INSTALLATION
- BAD MAINTENANCE
- é é é é é .

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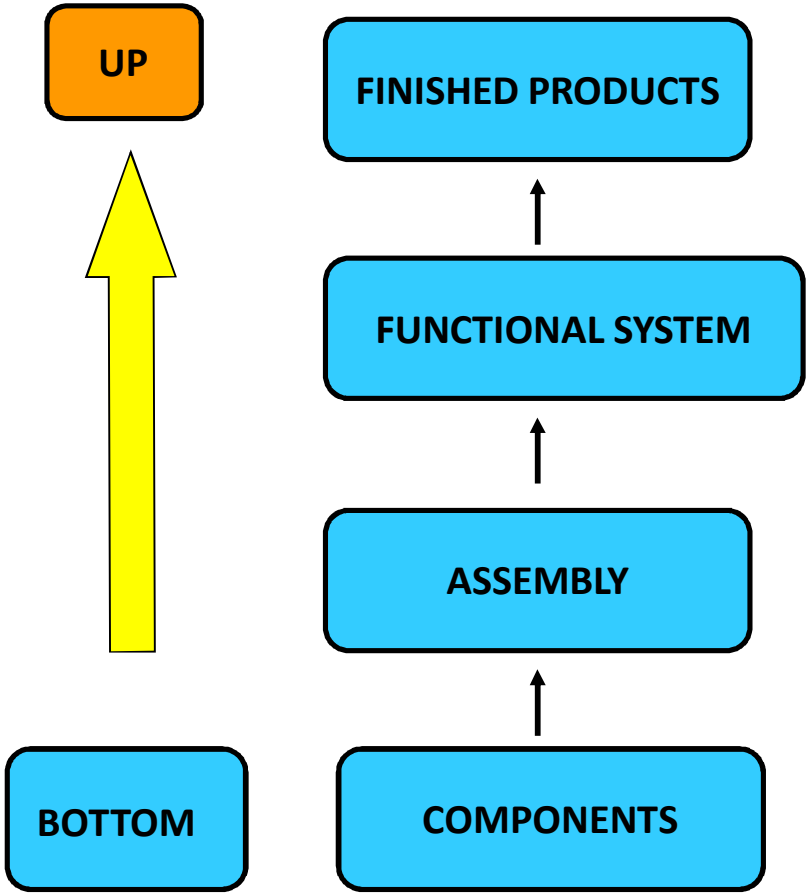
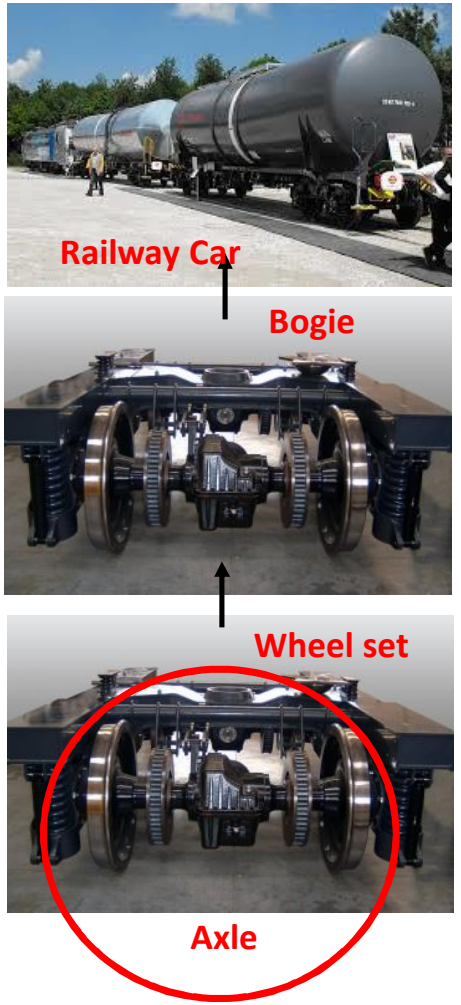
FMEA (FMECA)



The F.M.E.A. is one of the techniques used to study the reliability of a system, defined as the ability of an machine to perform a function under given conditions for a given time interval

The F.M.E.A. it is part of the inductive procedures, in which the analysis proceeds from the bottom up: the failure modes of each component are analyzed and the structure of the system is traced, evaluating the effects on the behavior of the system.



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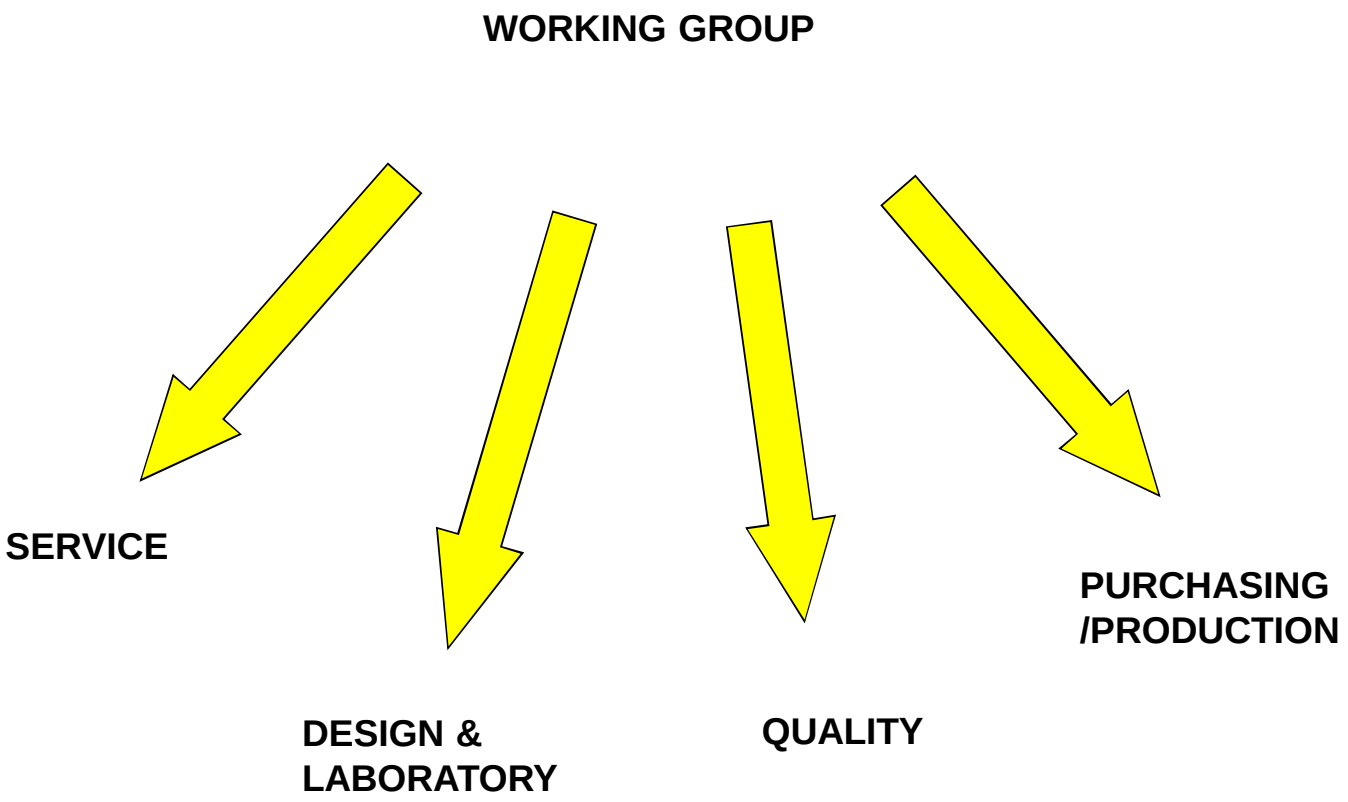
FMEA



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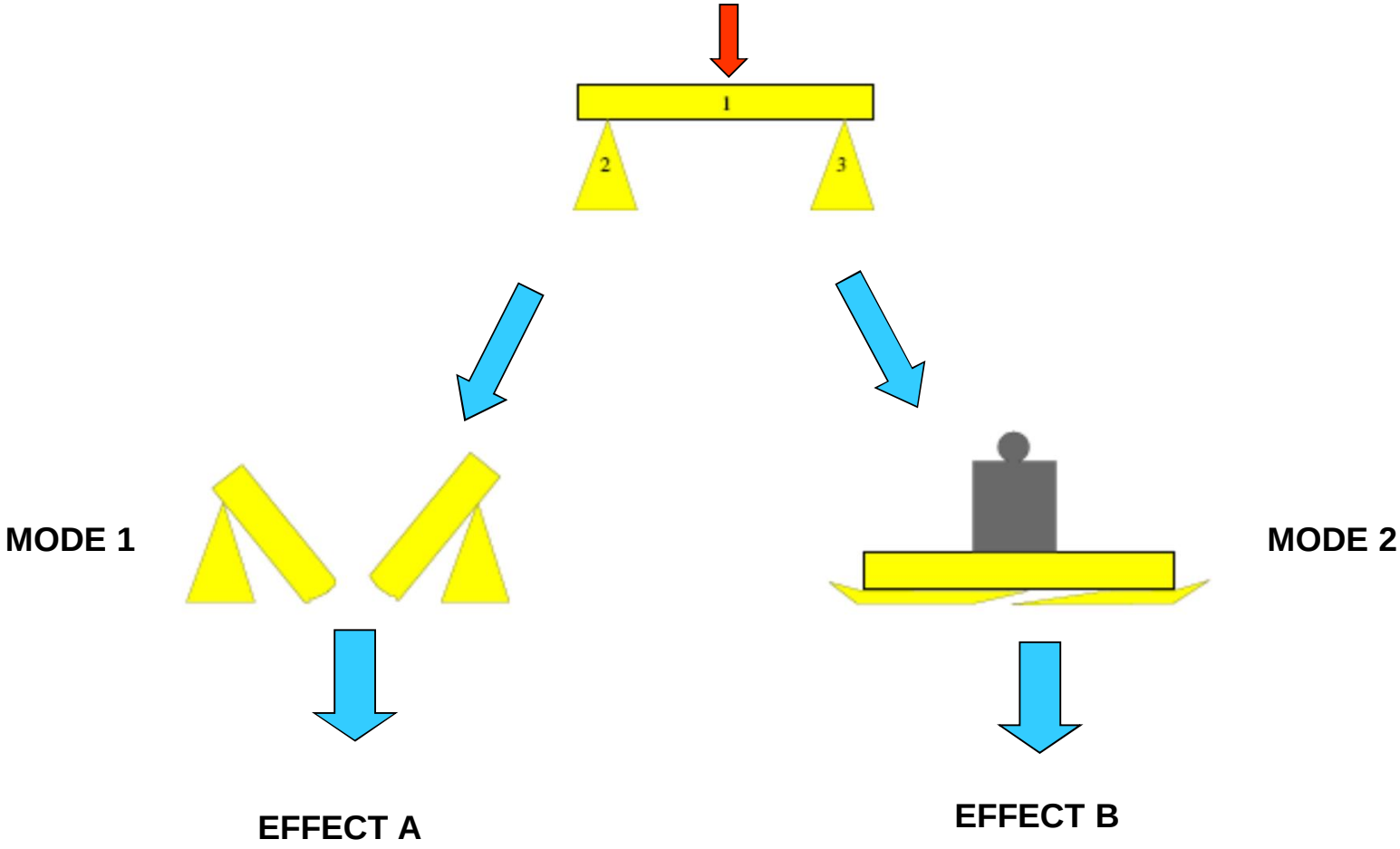
FMEA
FAILURE MODE



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FAILURE EFFECTS

In particular, it is useful to underline how:

- **The effects depend on how the structure of the system responds to the different modes (failure modes) with which a failure occurs**
- **A failure is the result of a particular condition in which a given stress causes a defect through a physical or chemical (for hardware) or logical (for software) mechanism**
- **The users of the system pay the utmost attention to the effects and not to the ways any faults may have.**
- **For a "failure" to occur, it is sufficient that a ñstress" of a mechanism exceeds the failure threshold of an element of the system.**
- **The presence of "defects" only increases the likelihood that "failures" will occur.**

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DEFECTS AND FAILURES

To carry out a F.M.E.A. we must therefore:

- **describe the system we are interested in, using a block diagram**
- **identify for each block:**
  - **the stresses and mechanisms that could lead to block failures**
  - **the defects that could occur in each block**
- **study for each block the failure modes that may have some effect on the system**
- **study which effects may occur on the system functioning as a consequence of the identified failure modes.**

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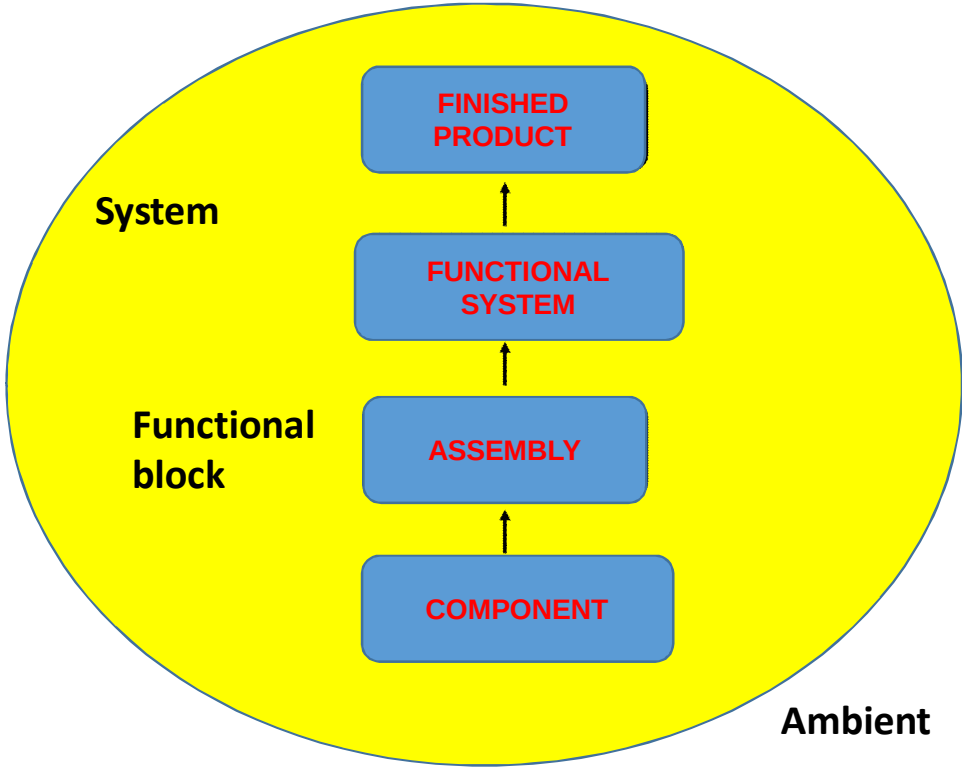
MACHINE DIVISION BY FUNCTIONAL BLOCKS

The description of the system and the level of detail to be used in the block diagram are some what arbitrary:

- **what do we consider system (the object of our study) and what ambient (the "rest of the world" that interacts with the system)?**
- **how to divide the system into functional blocks?**
- **how far to push the level of detail into further breaking down the blocks, may depend on the type of effects we are interested in**



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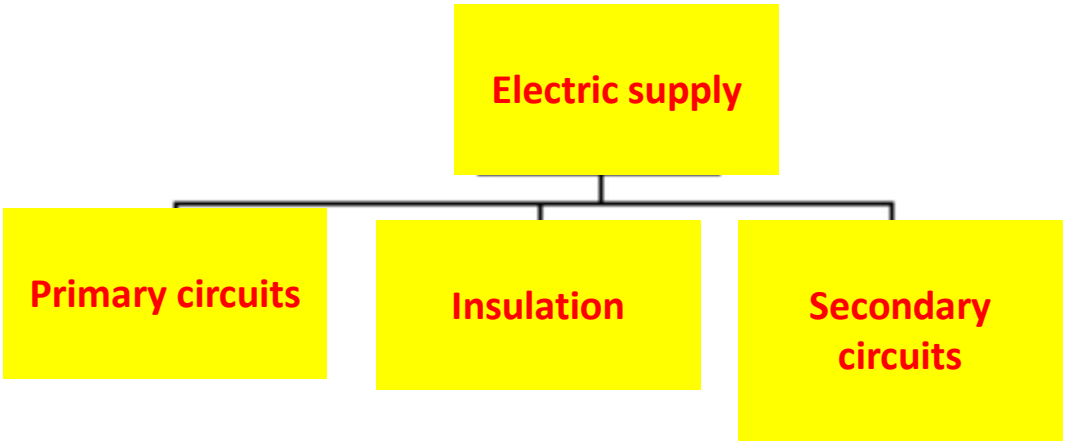
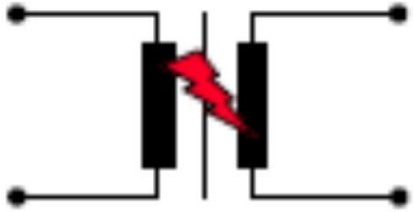
MACHINE DIVISION BY FUNCTIONAL BLOCKS



- The "insulation" block can have the "superficial spark" or ñmaterial perforation" mode.
- The effect is "live secondary circuits", temporarily or permanently



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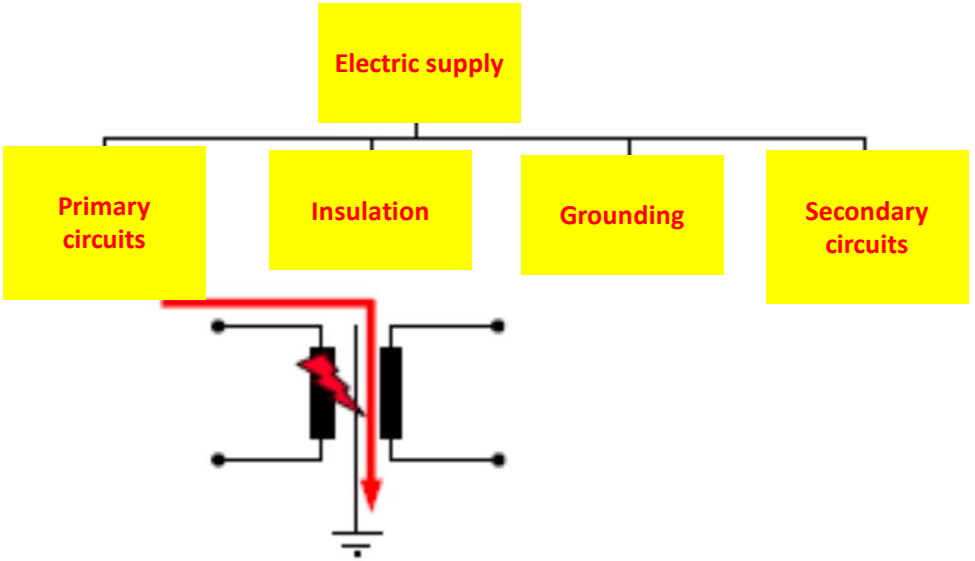
MACHINE DIVISION BY FUNCTIONAL BLOCKS



- With "grounding", insulation faults cause "overload" to the primary circuits.
- The "grounding" should also fail to have "live secondary circuits"

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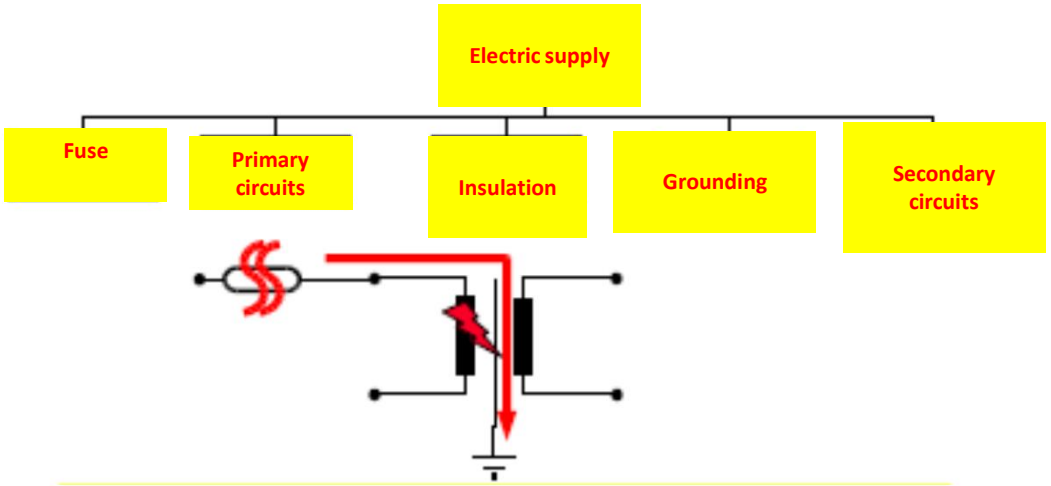
MACHINE DIVISION BY FUNCTIONAL BLOCKS

With "grounding" no single failure mode causes the dangerous "live secondary " effect.

The "overload" effect will cause the intervention of another protection, for example:

- a differential switch (part of the system, or ambient, therefore it does not affect the system)
- a fuse (part of the system, therefore to be added to the block diagram)

In the second case, the F.M.E.A. changes (the fuse can only be broken, due to its construction)



Faults in the "insulation" cause "overload" which consequentely causes the fuse to "open".

Eventually all circuits are isolated from dangerous voltages, but the power supply needs to be repaired.

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MACHINE DIVISION BY FUNCTIONAL BLOCKS

In principle, the F.M.E.A. considers failures of single blocks of the system, in the hypothesis of:

- **independence between faults in different blocks**
- **“low” probability of single failures**
- **therefore "negligible" probability of having more faults present at the same time (and precisely in an undesirable combination ...)**

But be careful! These assumptions may not be sufficient when the possible effects concern safety and are potentially serious.

The study of the system, if there are multiple faults, can be useful the Fault Tree Analysis.
For example, with fuse and grounding, to have the secondary under dangerous voltage, it should happen that in the same time:
[secondary hazardous] = [perforated insulation]
AND [fuse does not blow]
AND [broken ground]

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FAULT TRE ANALYSIS

Fault tree analysis (FTA) is a graphical tool to explore the causes of system level failures. It uses boolean logic to combine a series of lower level events and it is basically a top-down approach to identify the component level failures (basic event) that cause the system level failure (top event) to occur.

Fault tree analysis is a top down approach that was originally developed in Bell laboratories by H Waston and A Mearns for the air force in the year 1962. This concept later adopted by Boeing and today it is widely used in aerospace, automobile, chemical, nuclear and software industries especially reliability and safety related events.

Fault tree analysis can be used to perform for all types of system level risk assessment process. The purpose of FTA is to effectively identify cause(s) of system failure and mitigate the risks before it occurs. This is an invaluable tool for complex systems that visually displays the logical way of identifying the problem. Moreover system efficiency can be attained by this analysis. It can be implemented alone or complement to FMEA

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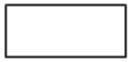
FAULT TRE ANALYSIS

S.No	Event Symbol	Description
1		Primary or basic failure event. It is a random event and sufficient data is available
2		State of system, subsystem or component event
3		Secondary failure or under developed event, can be explored further
4		Conditional event and is associated with the occurrence of some other event
5		House event representing either occurrence or non-occurrence of an event
6		Transfer in and transfer out symbols used to replicate a branch or sub-tree of the FTA

S.No	Gate Symbol	Description
1	 AND Gate	The output event occurs when all the input events occur
2	 OR Gate	The output event occurs when at least one of the input events occur
3	Priority AND Gate 	The output event occurs when all the input events occur in the order from left to right
4	 Exclusive OR gate	The output event occurs if either of the two input events occur but not both
5	 Inhibit gate	The output event occurs when the input event occurs and the attached condition is satisfied

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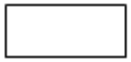
FAULT TRE ANALYSIS

S.No	Event Symbol	Description
1		Primary or basic failure event. It is a random event and sufficient data is available
2		State of system, subsystem or component event
3		Secondary failure or under developed event, can be explored further
4		Conditional event and is associated with the occurrence of some other event
5		House event representing either occurrence or non-occurrence of an event
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FAULT TRE ANALYSIS

How do you do Fault Tree Analysis:

- Define the primary failure to be analyzed in other words identify the undesirable top event
- Identify first level contributors which are just below the top level using the available technical information
- Link these contributors to top level event by using logical gates (AND, OR gates), and also see the relationship, so that it will help to identify the appropriate logical gate
- Identify the second level contributors and link to top by using logical gates.
- Identify minimal cut set
- Repeat the same steps till the basic causes
- Finally complete and evaluate the FTA
- Calculate probability of lowest level elements occurrence and also measure the probabilities from bottom up

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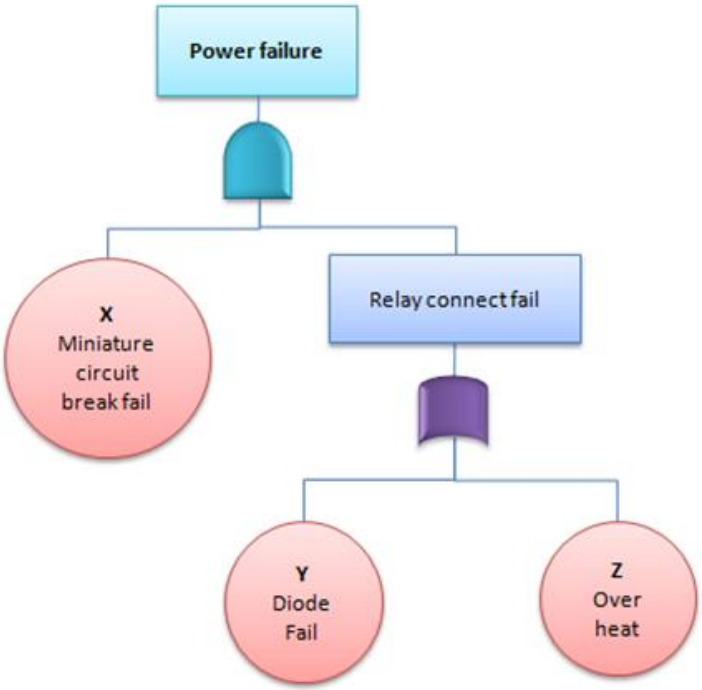
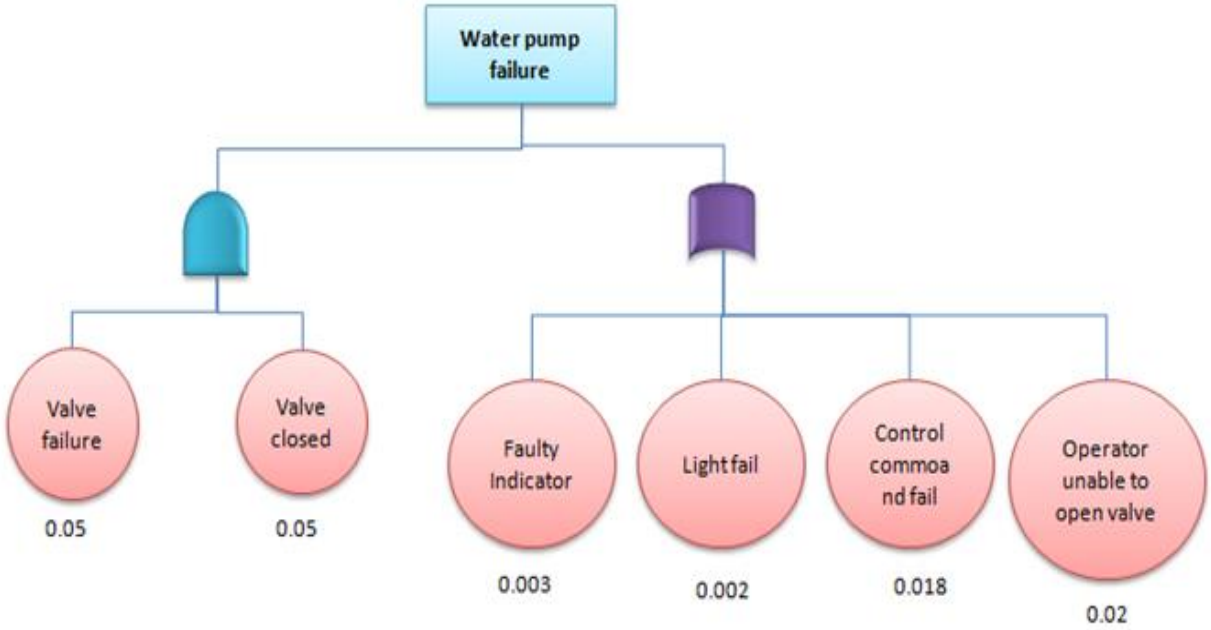
FAULT TRE ANALYSIS





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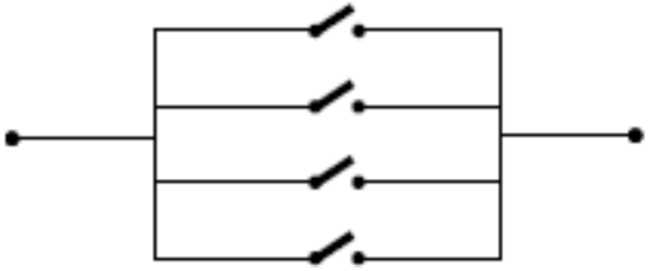
MACHINE DIVISION BY FUNCTIONAL BLOCKS

But if you are interested in the "power does not work" effect, the situation is different:
[power does not work] = [blown fuse]
OR [primary interrupted]
OR [secondary interrupted]
OR [broken connection]



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MACHINE DIVISION BY FUNCTIONAL BLOCKS

So the introduction of the fuse made:

- **less likely that the secondary circuit will become dangerous following a fault**
- **more likely that the power supply will stop working (for example because the fuse has blown ...)**

If the failures are independent, the probability of obtaining an effect is equal to:

- **P [effect] = P [fault1] x P [fault2] x P [fault3] for "series" faults in the fault tree**

- **P [effect] = P [fault1] + P [fault2] + P [fault3] for "parallel" faults in the fault tree**

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MACHINE DIVISION BY FUNCTIONAL BLOCKS

In industrial applications, the qualitative description provided by F.M.E.A. it is often not enough to guide the desired improvement actions.
In these cases, a quantitative assessment of the severity of the effects and the probability of failure modes is carried out, highlighting the most critical elements of the system in a Critical Items List (CIL);
this technique is also called:

Failure Mode Effect and Criticality Analysis (FMECA)

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FMEA QUANTITATIVE EVALUATION

The method is based on 3 parameters that define the aspects of the possible failures

1. **SEVERITY G** of the failure mode effect on the Customer

2. **PROBABILITY P** to happen of the failure mode effect causes

3. **DETECTABILITY D** that is the judgement on the controls forecasted inside the project, in order to identify the failure mode effect causes before happening.

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Effect	*SEVERITY of Effect*	*Ranking*
Hazardous without warning	*Very high severity ranking when a potential failure mode affects safe system operation without warning*	***10***
Hazardous with warning	*Very high severity ranking when a potential failure mode affects safe system operation with warning*	***9***
Very High	*System inoperable with destructive failure without compromising safety*	***8***
High	*System inoperable with equipment damage*	***7***
Moderate	*System inoperable with minor damage*	***6***
Low	*System inoperable without damage*	***5***
Very Low	*System operable with significant degradation of performance*	***4***
Minor	*System operable with some degradation of performance*	***3***
Very Minor	*System operable with minimal interference*	***2***
None	*No effect*	***1***

PROBABILITY of Failure	Failure Prob	Ranking
Very High: Failure is almost inevitable	>1 in 2	10
	1 in 3	9
High: Repeated failures	1 in 5	8
	1 in 10	7
Moderate: Occasional failures	1 in 20	6
	1 in 50	5
	1 in 100	4
Low: Relatively few failures	1 in 500	3
	1 in 1000	2
Remote: Failure is unlikely	<1 in 5000	1

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Detection	Likelihood of DETECTION by Design Control	Ranking
Absolute Uncertainty	*Design control* ***cannot*** *detect potential cause/mechanism and subsequent failure mode*	***10***
Very Remote	***Very remote*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***9***
Remote	***Remote*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***8***
Very Low	***Very low*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***7***
Low	***Low*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***6***
Moderate	***Moderate*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***5***
Moderately High	***Moderately High*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***4***
High	***High*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***3***
Very High	***Very high*** *chance the design control will detect potential cause/mechanism and subsequent failure mode*	***2***
Almost Certain	*Design control* ***will*** *detect potential cause/mechanism and subsequent failure mode*	***1***

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System	Dishwasher	Potential		Number FMEA	1
Subsystem	Dishes drying system	Failure Mode and Effects Analysis		Preparated by	xxxx
Component	---	(Design FMEA)		Date FMEA	
Project leader	xxxx	Date	yy/yy/yyyy	Revision date	
Working group				Page	1 of 1

Component	Function	Failure Mode	Failure effect	Grav.	causes of the failure mode	Prob	Control test forecasted	Detect.	RPN	Criticality	Raccomended actions	Responsibility and timing	Action Results: Action s done	new Grav.	new Prob.	new Detect.	new RPN
Drying system																	
HEATING ELEMENTS IN FORCED AIR	***THERMAL POWER GENERATION TO DISHES DRYING***	Electric dispersion	the magnet-differential circuit breaker intevenes: the dishwasher stops and does work no more	6	Rust of the external pipe done with AISI 304 of the heating elements, due to chlorids and acid rinse aid detergents	4	Life test. Ask further information to the supplier (responsible xxxx, within week 19); field test running	2	**48**	**write in the operation instructions how to install the equipment- The pipe is not incoloy 800 but in aisi 304**	Test in salty environment. Evaluate the test procedures with the supplier	R&D Laboratory from week xxxx to week yyyyy		6	4	1	24
				6	lack of Humidity barrier at the heating elements end	4	Use an epoxidic matt sealant (in the same way used in the waterproof heated elements u)	1	**24**								
				6	Quality of magnesium oxide	5	Component approval	5	**150**		Ask for certification of the magnesium oxide + write on the drawing a note (Resp. Xx ewithin week 30)			6	5	3	90
				6	Electric power density is not uniform	5	Component approval	5	**150**	**Write on the drawing a note about the pressure of oxide in corrispondence to the pipe curves**	Pressatura sulle curve mettere a disegno (Resp kk subito); verificare il processo del fornitore			6	5	2	60
		Wiring breaking	Less heat then expected	3	Electric tension peak	1	Component approval	5	**15**								
				3	Electric power density is not uniform	5	Component approval	5	**75**	**Write on the drawing a note about the pressure of oxide in corrispondence to the pipe curves**	Write on the drawing a note about the pressure of oxide in corrispondence to the pipe curves and verify supplier's process (Resp. Within week. 31)			6	5	2	60
				3	Breaking of the junction tungsten-stainless steel in cold zone	5	none	8	**120**	**To be considered in PROCESS FMEA**	Ask the supplier to provide his FMEA regarding the junction element	Resp. Yyyy within w. xx;					
				3	Exceeding the life limit of the electric wiring NB: 30000 hours of operation	4	Life test according with full customer use.	2	**24**	**What is the wiring duration in standard use conditions ?**	Ask for the wiring duration in standard conditions and wiring type. Write a note on the drawing (Resp. Yyyy within w. 20;)			3	4	1	12
		Explosion	lauch of particles of fused materila -	7	Stop of the air flow (to be studied with the fan)	10	Control of the overheating; safety thermostat with manual reset	1	**70**		apply a protection carter	Resp. zzz within w. jjj;		3	4	1	12

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System: Dishwasher

Subsystem: Washing system

Component: Water main pipe

Project leader: xxxx

Working group: xx,yy,ww,zz,aa,

(Process FMEA)
Failure Mode and Effects Analysis
AIR BLOW TECHNOLOGY

Date yy/yy/yyyy

Componnnt	Process phase	Failure Mode	Failure effect	Grav.	causes of the failure mode	Prob	Process test forecasted	Detect.	RPN	Criticality	Raccomended actions	Responsibility and timing
Washing system												
Water main pipe	***AIR BLOW TECHNOLOGY***	serious mis-omogeneity of welding	the pipe breaks along the junction line of the mold	10	dimensions of the brake for mold closing is out of control	7	Control of the pipe as indicated in the check scheme	5	**350**	**when the failure occurre the consequences for the end users are very serious (kitchen flooding)**	1. Identification of the parameters for the mold closing. 2. Internal shock test . 3. Fatigue simulation	R&D Laboratory from week xxxx to week yyyy
		Distortion of the pipe	difficult to assembly	7	Cooling time too short	2	Control pf the machine parameters	2	**28**		Review of the cooling time	production engineer within week yyyy
				7	temperature of the mold too high	2	Control pf the machine parameters	2	**28**		Review of the mold temperature	production engineer within week yyyy

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FMEA

Advantages:

- ***Identification of risks and critical areas***

- ***Significant increase the reliability of the product / process***

- **Conceptual easiness of FMEA application**

- **Possible re-use of previous FMEA on the same components**

- **It forces the workteam to analyse critically the product/process**

- **High quality cost savings in the long term**

- **Documentation of actions taken to eliminate problems**

- **Improvement of the climate and internal communications**

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FMEA - DISADVANTAGES

- **TIME EXPENDITURE**
- **COMPLEXITY**
- **TOO MANY DETAILS**
- **DEMOTIVATION**

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PRODUCT FMEA
PROBLEM: TIME EXPENDITURE

- **Method knowledge**
- **Meeting preparation:**
  1. product specification
  2. drawings and pertinent schemes
  3. functional descriptions of the component and possible functional schemes
  4. concepts statements
  5. test results
  6. physical prototypes
  7. physical components and their technical datas
  8. components samples
  9. finished product prototype

  .
- **ñrhytmò imposed by the FMEA leader**
- **Leader activity and behaviour**
- **The research of the failure mode**
- **The evaluation of design detectability**
- **The general evaluation of the score**

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SEMPLIFIED PRODUCT FMEA

SEMPLIFICATIONS:

- **FMEA extention:**
  - **Components faulty by the customers**
  - **Components faulty in production**
  - **Components faulty during laboratory tests**
  - **Components with high degree of criticality even if there are no signals on their reliability**
- **Defects and not failure modes**
- **Detectability judgement**
  - **Standardization of design activity**
  - **Manual (so-called of ñgood designò)**
- **Reduction of options numbers for gravity and probability**

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SEMPLIFIED PRODUCT FMEA

Component	Function	Fault	Gravity	Fault causes	Prob x prob	Control test forecasted	RPN	Raccomanded Actions	Responsibility and timing	new gravity	new Prob.xProb..	New RPN
Drying system												
HEATING ELEMENTS IN FORCED AIR	***THERMAL POWER GENERATION TO DISHES DRYING***	The heating element insulation is not according what required	6	Rust of the external pipe done with AISI 304 of the heating elements, due to chlorids and acid rinse aid detergents	16	Life test. Ask further information to the supplier (responsible xxxx, within week 19); field test irunning	**96**	write in the operation manual how to do correctly the installation; Imodify the material of the pipe from nAisi 304 in incoloy800	R&D and supplier from week xxxx to week yyyyy	6	4	24
			6	lack of Humidity barrier at the heating elements end	16	Use an epoxidic matt sealant (in the same way used in the waterproof heated elements u)	**96**	write in the operation manual how to do correctly the installation	Resp. Xx within week yy	6	9	54
			6	Quality of magnesium oxide	25	Component approval	**150**	Ask for certification of magnesium oxide and write on the drawing (Resp. Xx entro sett 30)	Resp. Xx within week yy	6	9	54
			6	Electric power density is not uniform	25	Component approval	**150**	Do specific test. Verify the supplier's process	Resp. Xx within week yy	6	9	54
		Wiring breaking	3	Electric tension peak	1	Component approval	**3**	none	none			3
			3	Electric power density is not uniform	25	Component approval	**75**	write soon on the drawing the new value of pression in the curve; Verify the supplier's process	Resp. Xx within week yy	3	9	27
			3	Breaking of the junction tungsten-stainless steel in cold zone	25	none	**75**	Ask the supplier an PROCESS FMEA extract regarding the joining process	Resp. Xx within week yy	3	9	27
			3	Exceeding the life limit of the electric wiring NB: 30000 hours of operation	16	Life test (Resp.xxx within week xx);	**48**	Ask for wiring duration in standard design conditions and wiring type. Write on the drawing the type of wiring	Resp. Xx within week yy	3	4	12
		Explosion	7	Stop of the air flow (to be studied with the fan)	36	Control of the overheating; safety thermostat with manual reset	**252**	apply a protection carter	Resp. Xx within week yy	3	4	12

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SEMPLIFIED PRODUCT FMEA ï STANDARDIZATION OF DESIGN ACTIVITIES

Official electric data:

- Type of insulation
- Thickness of the insulation
- Humidity percentage upper limit
- Type of welding of the terminals
- Minimum radius of curvature of the pipe
- Type of material of the pipe o Test specification by the supplier

Testing methods:

- Life tests (number of starts, overtension electric supplyé)
- Performance test in standard environment
- Corrosion test in salty environment
- Electric test at rated voltage and over voltage (+20%)
- Test of electrical rigidity (1200 V for 1 min.)
- Temperatures control

Complementary technical documents:

- Way to install the equipment to be reported in the manual

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TECHNIQUES AND TOOLS					7 TOOLS	DATA COLLECTION SHEETS	
						STRATIFICATION	
						CORRELATION	
						PARETO'S DIAGRAM	
						ISTOGRAMS	
						CONTROL CHARTS	
						ISHIKAWA DIAGRAM	
					ONE POINT LESSON		
					A3	5 WHYS	
					KEY PERFORMANCE INDICATORS		
					5 S		
				YAMAZUMI	ANDON		FLASH MEETINGS
			FMEA	TAKT TIME	VISUAL MANAGEMENT		GROUP WORK
			ERGONOMY	KANBAN	STANDARDIZATION		EMPOWERMENT
			TPM	KAIKAKU	PDCA		INVOLVEMENT
			SMED	JIT	POKAYOKE		AGREEMENT
		SPAGHETTI CHART	OEE	HEIJUNKA	KAIZEN		INFORMATION
	WASTES	STUDY	ONE PIECE FLOW	FROM PUSH TO PULL	SIX SIGMA		COMMUNICATION
	HOSHIN KANRI	CURRENT VMS	FUTURE VSM	PULL	JIDOKA		MOTIVATION RESEARCH
PRINCIPLES	DEFINE THE VALUE	IDENTIFY THE VALUE FLOW	SET UP FLOW ACTIVITIES	MANUFACTURE PULLING THE PRODUCTION	RESEARCH PERFECTION		ATTENTION TO PEOPLE
FOCUS	CUSTOMER				QUALITY		EMPLOYEES