The most significant findings on maintenance system inspections
- *deficiencies and best practices* -

capt. Iván Domján

National Directorate General for Disaster Management
Department for Hazardous Establishments

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Summary

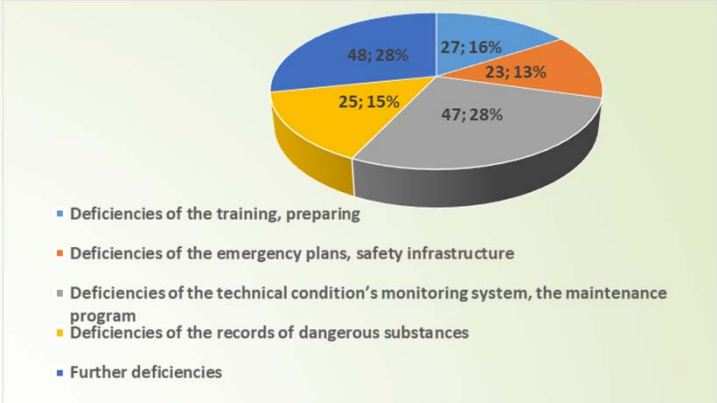
In 2018, all relevant upper-tier Seveso site has been inspected regarding their maintenance system. The presentation will go through the next information of the inspection-series:

I. History, decision making
II. The objective and the method
III. Overall picture of the results
IV. Statistic approach
V. Significantly positive aspects
VI. Significantly negative aspects (deficiencies)
VII. Good-practices related to the negative aspects
VIII. Additional good-practices
IX. The outcome of the inspection-series

History, decision making

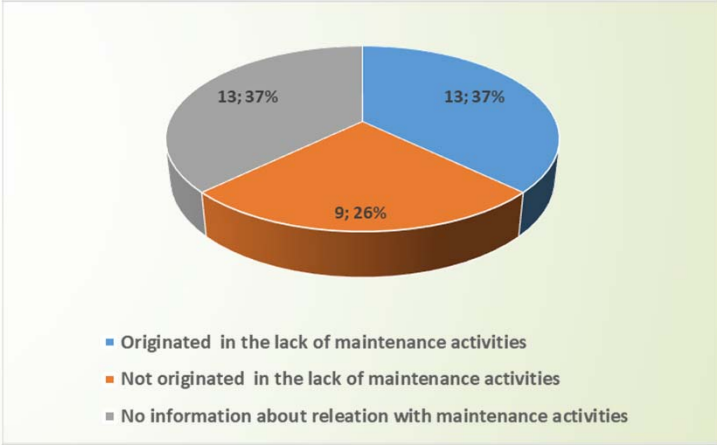
Experiences of regular inspections

During the regular inspections in 2017-18, we had registered a high number of deficiencies regarding the technical condition of Safety Critical Elements (SCEs), the technical condition's monitoring system and the maintenance program.



Lessons learnt from national industrial incidents

The experiences of the past incidents and accidents pointed out the inadequacy of some establishments' monitoring system and maintenance program. (Only less than half of the incidents were not originated somehow in the lack of maintenance activities.)



International statistics

Both the known statistics about historical accidents in the EU and the recent international accidents showed a significant correlation to the fact, that physical ageing is an up-to-date problem, therefore the maintenance programs are crucial to be in place in Seveso sites.

The objective and the method

The national inspection-series started with a pilot project. We have picked a county, called Veszprém, as the first stage. There the NDGDM (the central body of the Seveso competent authority) conducted joint inspections together with the regional colleagues. The main purpose of the joint inspections was to understand the "nature" of the widely used maintenance system better and to become able to "ask the correct questions" from the operators.

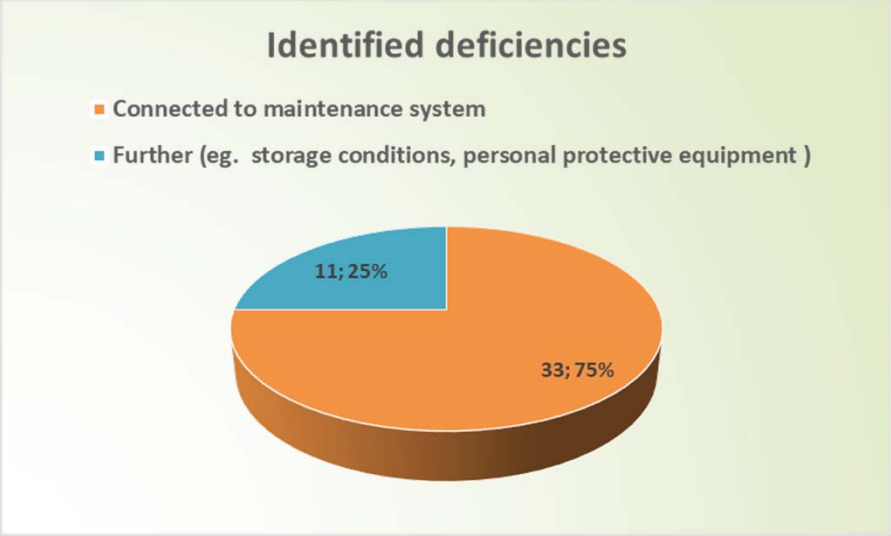
The overall goals of the exceptional, comprehensive national inspection-series were the next:

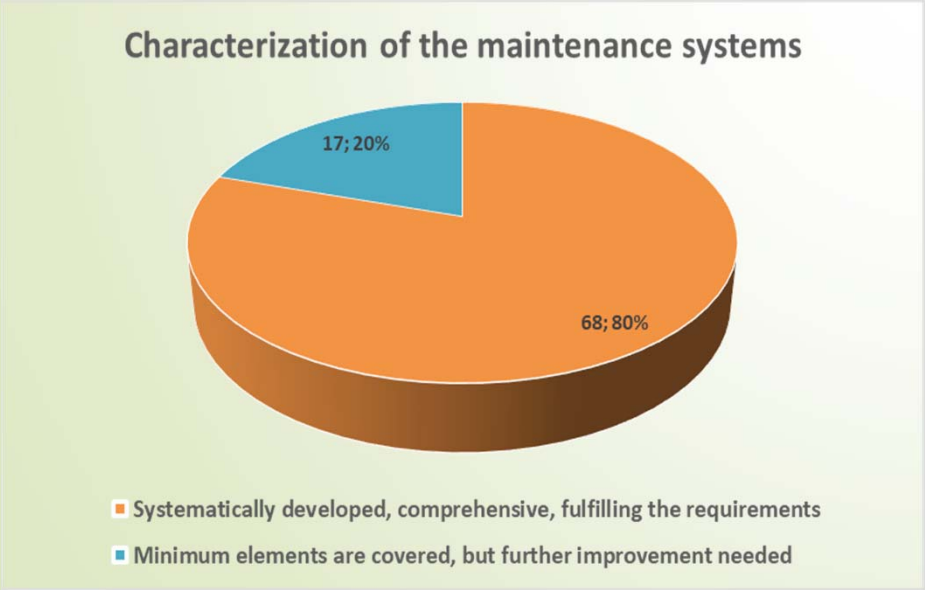
- to assess the upper-tier establsihments' maintenance strategy
- to recognize the common weaknesses of the systems
- to identify the occurrent violations (and reject them)
- to find and share good practices (especially linked to the common weaknesses)

To achieve the goal, the Department for Hazardous Establishments determined the main aspects of the inspections and created a comprehensive survey for the regional inspectors. The format of the survey was close to a "check-list" in addition that we asked for a detailed written answer for every single question and the list of the proofs, what was leading to the answer yes or no. The check-list contained 26 questions and subquestions. The survey could be an item for preparing for inspection of maintenance, as well as for summarizing the findings.

Overall picture of the results

The national inspection-series included 85 on-site inspections (1-2 day). The regional authorities found 44 serious deficiences. The majority of these deficiencies were in connection with the defect of the maintenance system. In most cases, operators understood the problem and declared that the necessary changes/improvements will be done. The authority's obligation was used just on some occasions.





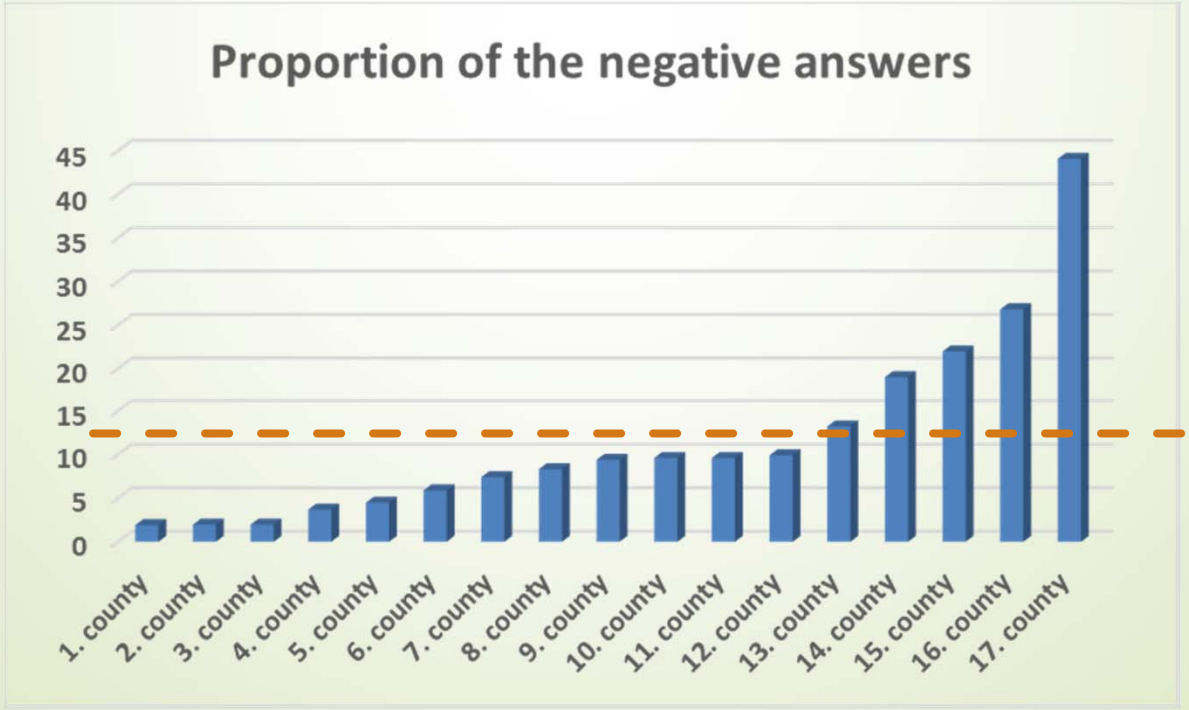
The regional inspectors had to report about their inspections to the national level. In these reports, they summarized the main findings, as well as the evaluation of the overall picture of their region. The chart shows nation-wide how many upper-tier establishments have got systematically developed, comprehensive maintenance system, which is fulfilling all of the requirements (80%). It has also to be noted that - regarding their reports - none of the upper-tier Seveso sites was identified as a dangerously defective organization, because of the series lack of awareness for physical ageing, or because of the total lack of methodical maintenance system.

Statistic approach I.

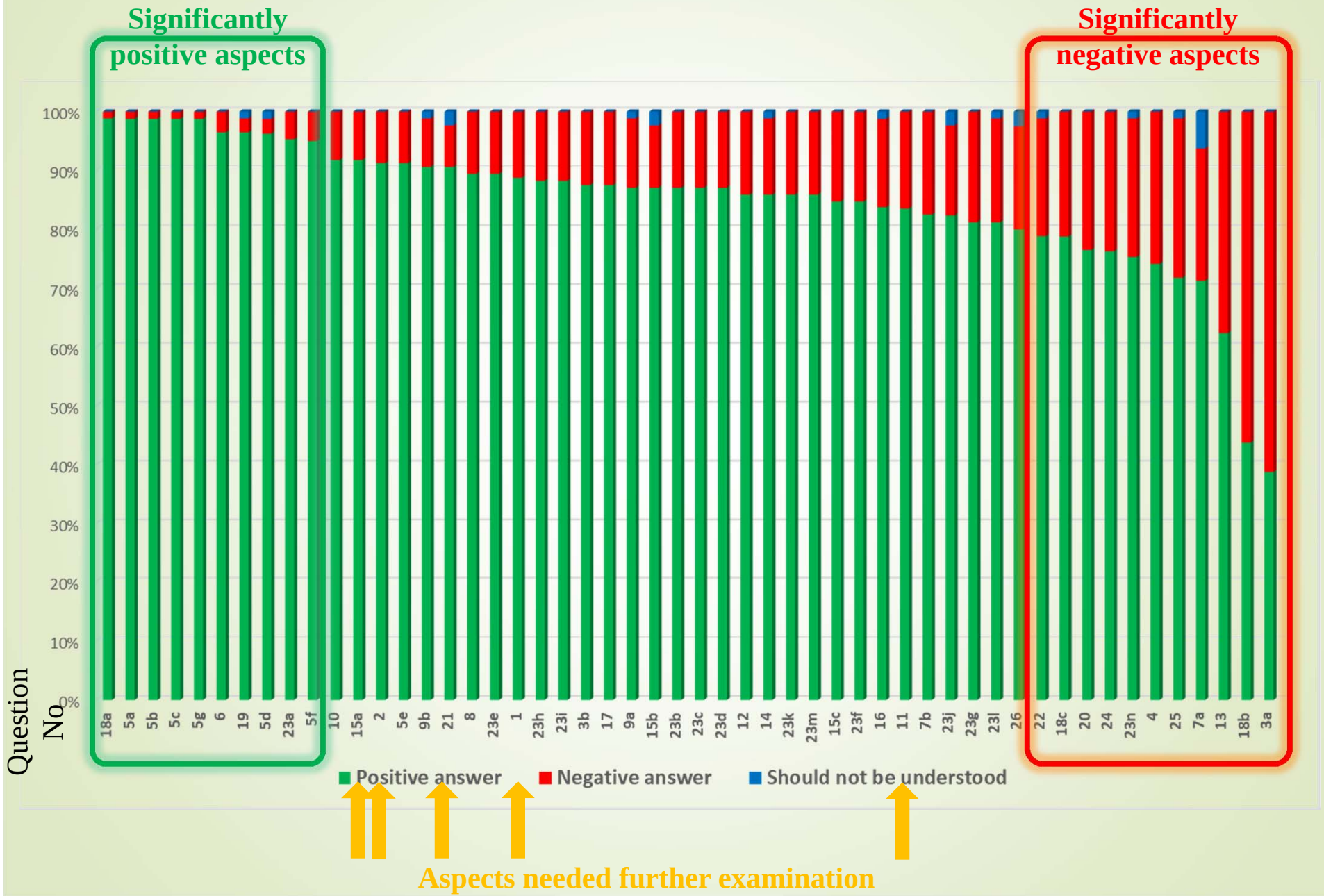
It should be taken into account that before the on-sight visits, most of the regional authorities sent out the empty check-lists to the establishments, for supporting their preparedness.

Therefore lots of the establishments made their self-evaluation with the help of the survey, which frequently showed too perfect situations.

Problem was, however, that the regional colleagues just rarely wrote over the companies' self-assessment results, so the overall statistic picture is clearly underestimating the realistic national level of the physical ageing and overestimating the level preparedness for it.



Statistic approach II.



Significantly positive aspects

a) Operators maintain preventive maintenance plans and follow up the preventive and reactive maintenance works (records) [98,82%]

b) The responsibilities are clear within the organization in accordance with the following tasks:
   - monitoring the technical condition [98,75%]
   - determining the maintenance needs and technical requirements [98,75%]
   - ordering the maintenance works (both from contractors and from employees) [98,75%]
   - quality management of the completed maintenance works [98,75%]
   - procurement of devices, machines, equipments, components [96,25%]
   - workplace hand-over [95%]

c) The records of the maintenance works contain the type of work, the date, the personnel, the result of the work, the reference to the next work/additional necessary actions. [96,47%]

d) The operators have a procedure for reporting the early signs of any malfunction. [96,47%]

e) The preventive maintenance procedures contain the accurate identification of the maintained item (by tag number) [95,29%]

Significantly negative aspects (deficiencies) I.

a) The operators do not identify the safety-critical equipments (SCEs). The preventive maintenance plans generally apply to all of the equipment, regardless of the SCE status of them (e.g. same checking period for nitrogen and propane vessels);

b) The maintenance procedures do not take into account the special operational circumstances (e.g. acidic or humid environment, extreme weather conditions);

c) The operators do not implement the maintenance plans in case of equipments which are difficult to access (e.g. had been built underground or at height, or insulated, or in tunnels under roads etc.);

d) The operators do not pay particular attention to the critical points (e.g. internal or external protective coating, welding, structural support, bottom of the tanks, depth points of pipelines etc.);

Significantly negative aspects (deficiencies) II.

e) The maintenance procedures do not take into account the results of previous consequence - and risk analyses (from safety reports);

f) The safety systems' and devices' (except the fire alarm and extinguishment system's) periodical check/test is not ensured;

g) The maintenance procedures do not contain the need for a recheck in place of hot works within a few hours;

h) The operators have not got a policy on exchanging SCEs at the end of their lifespan;

i) The operators do not review and assess the efficiency of the maintenance program during the internal audits or managerial meetings.

Good-practices related to the negative aspects I.

a) Distinguished treatment of the SCEs

The purpose of this type of distinguishment is to closely monitor the technical condition and operability of equipment potentially involved in a major accident.

- Good-practice means that there is a complete connection between the SCEs and the maintenance plan: the maintenance plan distinguishes those equipments that can be associated with major accidents. More frequented functional tests, measures, etc.
- In a plant with a high safety culture, a separate chapter of the maintenance plan exist to define the SCEs and to determine the physical-condition monitoring and maintenance systems of them. This chapter contains the list of the SCEs (eg: drain hoses, pumps, storage tanks and instrumentation, overfill protection, transfer pumps, reactors, etc.).
- An exceptional practice is to carry out a "maintenance risk analysis" of all equipment, in every third year. In doing so, the potential for failures and their impact on production taken into account. The rating of a given device (between 1 and 4) determines the level of maintenance (frequency, type). The classification is based on the possible consequences of a failure of the items (both helath&safety&productivity). The result of the classification determines the need and the way of monitoring and maintaining the given device. The classification is influenced by, among other things, the experience of recent years (eg results of technological diagnostic measurements).

Good-practices related to the negative aspects II.

b) Taking into account the special operational circumstances

It is beneficial to take into account the special conditions which could rise the ageing phenomena's speed, like aggressive materials, trapped condensate, etc. Equipment attacked by these circumstances must be controlled more frequently than others.

- Inspectors usually found that written procedures do not take this aspect into account, but in practice, the responsible person pays special attention to this. This also confirms the relevance of the question.
- It is good practice that several operators, based on their maintenance plan, check the technology unit operating in an acidic environment with increased frequency.
- The next incident has shown that even an equipment, exposed to sunlight, can be considered as such a special operational circumstance, in unfavorable conditions.
  - As a result of an investigation of pipe leakage, it was found that the wall thickness of a steel pipe started to decrease, without any external corrosion signal.

  - Based on the cut-out pattern, it was found that the loss of steel pipe wall thickness is not consistent along the circumference of the circle.
  - It is likely that there will be a greater amount of weight loss on the side of which the external heat load of the pipe is higher (sunshine, conduction containing higher temperature material).

Good-practices related to the negative aspects III.

c) Implementation of the maintenance plans in case of equipments which are difficult to access

The required control checks (measures) are usually carried out on easily-accessible parts of the SCEs. A hidden bend, an unvisible flange, etc. could be unchecked for 10-50-... years.

- The relevance of the question was prooved, as only 1 good practice was found during the 85 inspections.
- A high safety cultured plant has separate maintenance procedures for insulated pipelines and underground pipelines.
- The problem is, that we had nationwide hundreds and hundreds of installations like these:
  - underground/ground covered SCEs (vessels);
  - underground/ground covered pipelines (transporting dangerous substances);
  - overhead pipelines (transporting dangerous substances);
  - pipeline supports on pipe-bridges (critical points of corrosion);
  - constantly ice-covered parts of SCEs;
  - insulated SCEs;
  - pipes running together in a crowded place;
  - etc.

Good-practices related to the negative aspects IV.

d) Attention on the critical point of the equipment

The required control checks (measures) are usually carried out on easily-accessible parts of the SCEs. A hidden bend, an unvisible flange, etc. could be unchecked for 10-50-... years.

- It is generally true that regular non-instrumental inspections of equipments (eg daily visual inspection) do not explicitly address critical points. However, based on what operators said, critical points are included in the "normal inspection method" as well. The frequency of such inpection checks (daily, weekly) based on operational experience is sufficient to detect errors at critical points too.
- It is good practice for the operator to evaluate each piece of equipment for the degree of potential damage that is likely to occur on that piece of equipment, identifying the critical points where the degree of damage is expected to be greatest. Once identified, operator should name the measuring points for technical diagnostic checks.

Good-practices related to the negative aspects V.

- **Maintenance procedures based on the results of previous consequence - and risk analyses (from safety reports)**

The related object may be set by applying stricter requirements and shorter periods where appropriate, during operational tests, technical inspections and maintenance of the most "dangerous" equipments.

- There are operators who, in addition to defining critical equipment, perform risk assessments on the SAP system interface. The risk assessments take the possible HSE consequences into account, just like the financial, regulatory aspects, and occurrence rates. Therefore the possible equipment failure's risk determines the required review and maintenance periods.

- Elsewhere, technology hazards are analyzed using the Hazard Study method. Based on the results of the analyzes, critical equipment and devices (which are installed to prevent the occurrence of an event) are selected. Although the selection process does not take into account the scenarios of the safety report, it does, however, rank by severity.

Hazard	Causes	Init Lh...	Consequences	Init Sev	Init Risk	Risk Control Description	Cntrl Strategy	Cntrl Effectiveness	Cntrl Status	Mtgd Lh	Mtgd Sev	Mtgd Risk
Slipping and tripping hazards in work areas.	Rail sleepers and track tripping hazards	3 Possible	Trip and fall [injury]	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High	Rail Safety Worker training for all personnel	Administration	Adequate	In Service	3 Possible	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High
	Debris in work areas (inherent to rail reserve)	3 Possible	Trip and fall [injury]	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High	Daily magnetic sweeper runs	Elimination	Not Assessed	Rejected	3 Possible	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High
	Poor housekeeping with construction materials and debris	3 Possible	Trip and fall [injury]	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High	Housekeeping practices and procedures	Administration	Adequate	In Service	3 Possible	D Major injury or Occupational Illness, Permanent Partial Disability or Lost Work Case > 4 days	High
	Uneven and unsealed surfaces	4 Likely	Trip or rolled ankle	E Moderate Injury/Occupational Illness, Restricted Workday Case or Lost Work Case < 4 days or Medical Treatment Case	High	Footwear (PPE)	PPE	Strong	In Service	4 Likely	E Moderate Injury/Occupational Illness, Restricted Workday Case or Lost Work Case < 4 days or Medical Treatment Case	High
Struck by rolling stock on active lines within the work area.	Worker inattention	3 Possible	Worker struck by or crushed by moving plant [injury]	C Single fatality or Permanent Total Disability	High	Driver training programmes	Administration	Adequate	In Service	3 Possible	C Single fatality or Permanent Total Disability	High
						Procedure for eye contact before movement	Administration	Adequate	In Service			
						First aid / emergency response team on standby	Administration	Adequate	Proposed			
	Noisy work site impeding hearing	3 Possible	Worker struck by or crushed by moving plant [injury]	C Single fatality or Permanent Total Disability	High	Vehicle movement alarms for all vehicles on site	Engineering	Adequate	In Service	3 Possible	C Single fatality or Permanent Total Disability	High
	Inadequate deconfliction of movements in work areas	3 Possible	Worker struck by or crushed by moving plant [injury]	C Single fatality or Permanent Total Disability	High	Daily work safety plans to reduce conflict between work activities	Elimination	Excellent	In Service	3 Possible	C Single fatality or Permanent Total Disability	High

Good-practices related to the negative aspects VI.

f) Systematical checks/tests for safety systems

A regular operational test of the safety interlock systems would be essential.

- In many cases, emergency shut-down devices are self-testing (eg annually if they had not to be used in the last 365 day).
- We also saw a good example where the test period time was reduced (for a pressure-reducing valve) because the operator experienced low reliability during real operations.
- Testing of the fix/installed water shield systems (water curtain) is typically connected to internal emergency plan exercises, which is an acceptable good practice if the frequency of at least one year's trial is set too.

- In an upper-tier establishment, where the site has a central backup power supply (container-mounted diesel generator, with stand-by switching), the unit is classified as a safety-critical device. The operator checks and maintains the functioning of this generator with monthly start-up tests (2-3 minute test run) and annual full load test run (1-hour test run, 23 second changeover time).

Good-practices related to the negative aspects VII.

g) Follow-up on-the-spot inspection after hot works

Fire can occur when hot-spots are left without any attention to the possible damages.

It can be said that relatively few operators include the requirement for follow-up checkings in the documentation for maintenance instructions, although its relevance for the prevention of major accidents is high, based on our experience.

Good-practices related to the negative aspects VIII.

h) Policy on exchanging SCEs at the end of their lifespan

Ageing of procedures could aggravate physical ageing in a site if losing information about lifespan.

- Periodic wear and tear replacement policy were mainly found just for critical devices with short lifespans, like flexible up&unloading hoses.
- In many cases, operators inspect the condition of the hoses at every manufacturing campaign (eg 8-10 batches or monthly) and determine the need for replacement based on external signs of wear. Thus, many times when replacing, the hoses would be in good condition and fit for further use.
- We have identified designated "flange management" just in one plant. The replacement periods of the sealing were determined for the critical equipment's flanges.

Good-practices related to the negative aspects IX.

i) Reviewing and assessing the efficiency of the maintenance plan

The effectiveness of the testing/review/maintenance programs should be investigated.

- As a good-practice, we have experienced that the annual review process of the company's SMS has included an analysis of the performance and effectiveness of the inspection and maintenance programs. The annual management review included performance metrics, so the efficiency of the maintenance plan is measured by reliability and availability indicators.
- There is a multi-site domestic operator that collect maintenance-focused events (near misses, incidents, accidents) from all of its plans. The availability of the used equipments are calculated from the number of these events.

Additional good-practices

Safety of the works

- **Lock Out, Tag Out (LOTO):** is a safety procedure used in industry and research settings to ensure that dangerous machines are properly shut off and not able to be started up again prior to the completion of maintenance or repair work. It requires that hazardous energy sources be "isolated and rendered inoperative" before work is started on the equipment in question. The isolated power sources are then locked and a tag is placed on the lock identifying the worker who placed it. The worker then holds the key for the lock, ensuring that only he or she can remove the lock and start the machine. This prevents accidental startup of a machine while it is in a hazardous state or while a worker is in direct contact with it. /Wikipedia/
- During our inspections we have seen some DIY type, LOTO look like system, which were in place for the same reason, followed the same method, but not licensed/ensured by an independent company.

Additional good-practices

Asset Register

- The most wanted good-practice is when the operator registers his equipment in the SAP PM module. SAP is one of the world's leading integrated enterprise management systems, PM stands for Plant Maintenance and covers the maintenance module. It is practically a multi-level, structured technical database. In SAP PM, you can report and retrieve repair and maintenance history for a particular device by providing technical location and equipment data.
- In a plant with simple technology and a small number of equipments, the operator could record the maintenance tasks in a simple excel spreadsheet. When an equipment is added to the table, the operator should determine the classification of the device, the end of the warranty period, the review-maintenance period, etc. The table could contain color-codes for different type of tasks. For example, in a plant, green color means scheduled future maintenance activity, yellow means scheduled and due within 30 days tasks and red is for the expired tasks.
- There are some establishments, using a software, called Praevenio for asset registering. The maintenance manager prints the maintenance worksheets every week. The workers use these to carry out the maintenance works and then return the worksheets to the shift supervisor. The shift supervisor uploads the maintenance data to the Praevenio software, then the system generates the next maintenance plans.

Additional good-practices

Monitoring the technical condition

- In line with the annual downtime, the plants are also subject to an annual technical condition check. This includes at least thermal imaging, vibration diagnostics, wall thickness measuring, and crack tests, performed by the support of (sub)contractors. Based on the results of these tests, the annual maintenance plan is prepared and the expected lifespan could be refined.
- Daily and weekly diagnostic duties are performed based on pre-made checklists, which were generated to every type of equipments - depending on the priority rating (1-4). The operator can download anytime for every piece of equipment all the necessary data for the actual daily/weekly/monthly/yearly maintenance job, in a check-list form.

Additional good-practices

How to report needed maintenance work?

- In many cases, SAP PM is in use for reporting failures too (including the early warning of malfunctions). So that maintenance personnel at various locations of the plant (even at various plants, operated by the same company) can immediately see the source of the failure, the exact description of the required work and the necessary equipments/tools/materials. Confirmation of the maintenance performed is also reported through the SAP system.
- To record malfunctions, the "electronic shift handover logbooks" are sometimes containing a separate menu item, called "technology bugs".
- It is a good-practice if employees could indicate the severity category of the experienced and reported failure. There could be at least two categories (check-boxes): "near miss" and "critical", for initial prioritization.
- Well established further steps are the next:Based on the information received, the site manager generates a "failure report" in the SAP PM module, which records the detailed event conditions. The final "failure severity" is evaluated by a team, led by the Operational Maintenance Manager. The work-order is produced by this team as well.
- A multinational company uses a centralized software, called "iHistorian". Among other things, iHistorian is used for monitoring technology efficiency and carrying out maintenance and repair works.The system enables the remote display of technological parameters from 51 plants in 27 countries.With the support of this system, an international team of engineers (mechanical, electrical, analytical engineers, and SAP specialists) could assess the need for repairing the failed equipment.

Additional good-practices

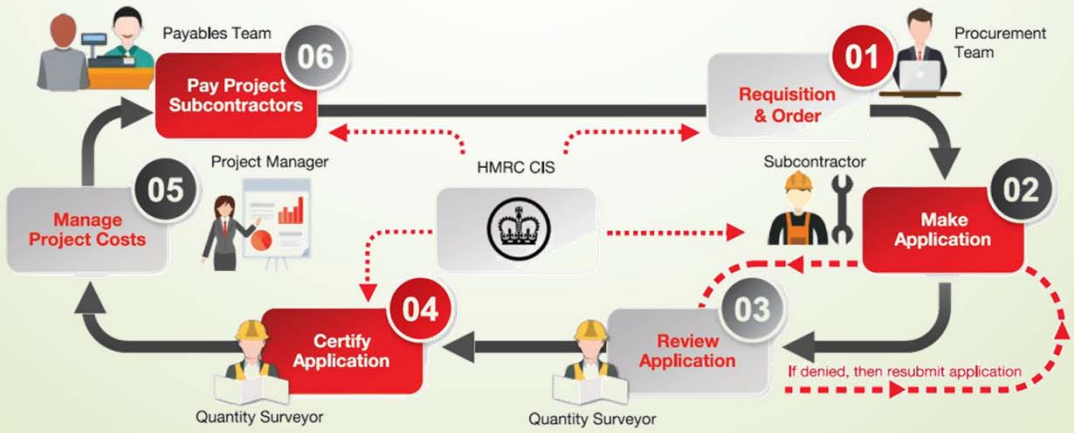
Procedures

- It is very common to prepare a worksheet for every repairing and maintenance work. Good practice means if these worksheets identify the possible dangers, the necessary precautions, and the required personal protective equipments in addition to the tasks to be performed.
- In a plant, risk assessment is performed on all equipment every 3 years. The risk assessment is taking into account the potential for failure and their consequences. The rating of a given device (between 1 and 4) determines the level of maintenance (frequency, type). The classification is based on the main aspects defined by the device type (like dangerous to life and property, technological criticality, etc.) and the sub-criteria defined according to the specific device (operating conditions, technological parameters, etc.). The result of the classification determines the need and the way of monitoring and maintaining the condition of the given device. The classification is determined, among other things, by the experience of recent years (eg. how many worksheets have been launched, results of technological diagnostic measurements, etc.). Maintenance activities are primarily determined by the diagnostic results (and not primarily by the manufacturer's recommendations).
- Good-practice is when the investigation of unexpected shutdowns/failures is conducted in every relevant case. The conscious operators are investigating these events to find the root causes, therefore they can determine relevant contra measures, tasks, deadlines and employees responsible for them.
- Following the changes in the legal background of the maintenance works is important too. In a plant, field managers (or those assigned by them) monitor weekly the recently published bulletins, regulations, and standards.

Additional good-practices

(Sub)contractors

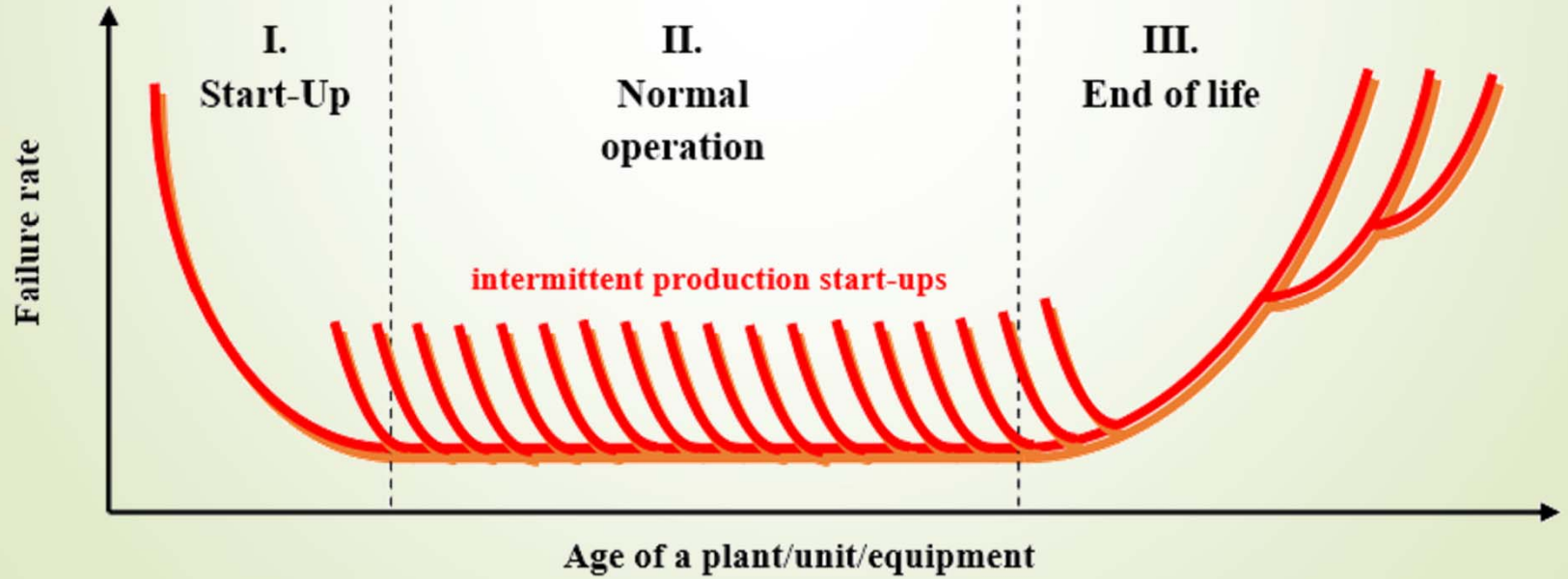
- The organizational structure set up by the operator ensures that the risk of malfunctions due to human error is reduced by using subcontractors (2nd level down) only when it is absolutely necessary. Even in these cases, their job on-site is allowed just after a very accurate pre-test and training protocol, with specialist supervision.
- It is beneficial if operators take into account the (sub)contractor's references to perform maintenance work, and not just relying on the lowest price available.
- In the case of (sub)contracting, operators should verify the presence and appropriateness of the (sub)contractors' personal and material conditions, during preliminary "audits".
- There is an example of that the issue of making work permits for (sub)contractors is subject to an examination. The person, who made the permit is responsible for supervising the work (documented in the work permit itself).
- One operator annually qualifies its partners (including the maintenance (sub)contractors), to ensure that the maintenance group has the appropriate expertise and competence.



Additional good-practices

Continues/intermittent production

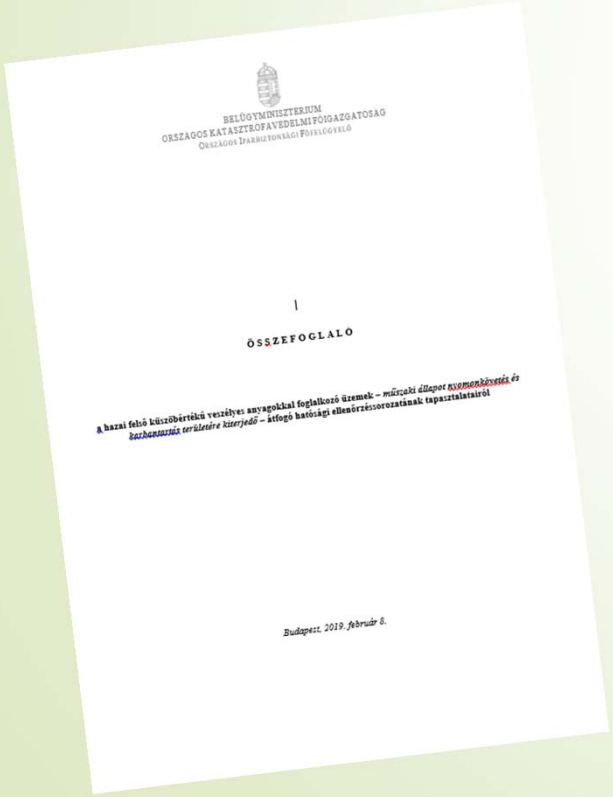
- In cyclic production mode, technological units and pipelines are pressurized by water before the start of the cycles, to eliminate leakages.
- To ensure continuous operation, some important equipments (electric motors, pumps) are duplicated (hot spares), so that even when they are taken out for maintenance, the operation of the plant can be continuous.
- It is advantageous if units that have not been in production for more than two months checked by scheduled maintenance before production begins. The operating-hours and pause-times of such equipments shall be recorded.



The outcome of the inspection-series

For further awareness-raising and a better understanding of the operators, NDGDM is going to publish a summary analysis, which is, first of all, the presentation of the national good-practices related to the most negative aspects.

We hope that sharing real, existing, first hand good-practices, delivered by real actors of the chemical and petrochemical industry community, can lead to an increase in the safety culture nationwide.



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ORSZÁGOS KATASZTRÓFAVÉDELMI FŐIGAZGATÓSÁG
Országos Iparbiztonsági Főfelügyelő

ÖSSZEFOGLALÓ

a hazai felső küszöbértékű veszélyes anyagokkal foglalkozó üzemek – *műszaki állapot nyomonkövetés és karbantartás* területére kiterjedő – átfogó hatósági ellenőrzéssorozatának tapasztalatairól

Budapest, 2019. február 8.

Thank you for your attendance!