Design of casks: Incorporating Operational Feedback from Maintenance

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Abstract
Casks are designed to conform to regulations and to client specifications. Essential areas such as easy operation, low costs of maintenance, low operation and maintenance doses, limited waste, are not explicitly covered. Notwithstanding, COGEMA LOGISTICS uses all feedback available, so that casks are designed to be easy, safe and economical to operate and maintain.
Maintenance is an activity where you do spot items that old-time designers could have made better, and things that users should not have done. Thanks to quality assurance, there are a number of data available, waiting to be collected and exploited; they have to be identified, located, retrieved, and analysed. Using information such as wear, damage, use of spare parts, access problems... helps to make casks ever better. It leads to more efficient concepts, and to upgrades on existing designs; it also allows to integrate environmental considerations, inter alia in the choice of materials and in maintenance methods.
It is necessary for the designer to interact with the users, the cask owners, the maintenance providers, in order to gather all relevant information and events. This is made easier when all these actors are "under one roof", or have very close ties.
This paper presents COGEMA LOGISTICS methods for collecting and analysing all these experiences waiting to be used. It explains our process for analysing data, preparing yearly reports that are made available to our designers. It describes how each new design is subject to a maintainability study, using this feedback, so that the cask safety is always assured, that radiological doses are kept to a minimum, and that operating and maintenance costs will remain as low as possible.

1. THE DESIGN PROCESS

For over 40 years COGEMA LOGISTICS has designed and supplied over 10 000 casks and associated equipment.
Designing a cask is a proven process well known and applied within the company. For each new design study, a Project Manager is appointed and is in charge of the overall project that starts at the delivery of the technical specifications from the client and ends with the manufacturing of the cask.
The design process consists mainly of phases like building the preliminary design, performing the shape calculations, defining the materials choices and the technical options and verifying the preliminary design. All these steps before validation of the concept are optimized with incorporating operational feedback from maintenance.

2. MAINTENANCE TYPES

Preventive Maintenance (in compliance with licensing)

Like a car, a cask is submitted to periodical maintenance operations.
The Project Manager, in his design study, has to create a concept that is the most easily maintainable. The associated maintenance program is described in the Safety Analysis Report and validated by the regulatory authorities.
Depending on the transported radioactive materials and the complexity of the packaging, the preventive maintenance operations will be more or less demanding i.e. the frequency, the duration, the complexity of the maintenance, the safety of the operators, the overall cost…

Corrective maintenance (incidents)

During normal operational conditions, cask can undergo incidents such as mechanical incident. Anticipating these incidents is part of the risk evaluation and is aimed to help the designer to improve the concept thus reducing corrective maintenance operations. The risk analysis is performed using a matrix analysis. The risks are quantified by evaluating their occurrence versus the seriousness.

3. WHAT IS MAINTAINABILITY?

Maintainability is the part of design that consists basically in investigating at an early stage how the cask will be maintained once manufactured and uses on an industrial scale. Maintainability of a concept is a major subject with high impact on operation cost, therefore it has to be specified early in the project by customers specifications.
The maintainability means: how easily will the components of the cask be to assemble/disassemble during preventive and corrective maintenance operations? How easily will the inspection be performed? How easily will the parts be replaced? How easily will the cask be decontaminated? How many waste will it produce?
All these questions should be discussed and the investigations performed with the other members of the project team in order to reach the perfect balance between effectiveness and efficiency.

Assembly / disassembly of components

- The disassembly of each part of the cask where a damage or wear is expected i.e. screws, trunnion, gasket, shock absorbing covers…
- The attachment points should be positioned and the lifting cranes and beams should be adequate,
- The tightening force of screws should be adequate to materials and component function,
- The accessibility of disassembled components should be verified,
- The friction areas (e.g. stainless steel on stainless steel) should be avoided and authorized lubricant used,
- The maintenance tools should be standard otherwise its manufacturing should be planned.

Inspection of components

- The inspection of each part of the cask where a damage or wear is expected,
- The process inspection (i.e. avoid inaccessible inspection, avoid non-interpretable inspection, avoid systematic laboratory inspection and always define acceptability criteria).

Replacement of components

A cask is made of a body and its equipment. A spare part is a part of a cask that is replaceable when worn or damaged. Therefore, the Project Manager has to create a concept that needs few spare parts and these should be easily interchangeable. However, any region of the cask where damage can reasonably be expected should be replaceable. In our case, interchangeability implies that:

- Manufacturing non-conformity must be forbidden,
- Off the shelf, standard parts are preferably used,
- Third party patented parts are avoided.

Decontamination of cask

- Avoid contamination traps (corners, insufficient gap between parts…),
- Provide decontaminable external surfaces.

Environmental considerations

As well as complying with the Safety Analysis Report, the environmental considerations have to be taken into account. Indeed, creating a new concept implies that it is an equipment that will be used and thus this will generate waste when maintained or repaired. Along with the technical, the economical, the financial and the market analysis, an environmental analysis must be performed and the impacts measured.

The environmental analysis should deal with:

- The chosen materials (i.e. the availability, the recycling-ability of each component…),
- The manufacturing processes,
- The decontamination processes (i.e. contamination trap, decontaminable surfaces…)
- The waste generation,
- The recycling processes.

4. BUILDING THE MAINTENANCE FEEDBACK

As described in the previous chapter, maintainability is a requisite in designing new concept. In order to improve the designer effectiveness, a methodology based on a process approach has been developed within COGEMA LOGISTICS. The general aim is to design an operational tool that the designer can rely on in his day-to-day work. This dedicated tool is a knowledge database build upon past maintenance experiences in order to improve maintainability of future concepts.

4.1. Data collecting process

Approximately 700 COGEMA LOGISTICS casks are being transported off-site and over 600 Maintenance operations are undertaken every year. During these maintenance operations, a number of spare parts are being used depending on the wear indicators or the damage observed on the cask. First of all, the data collecting process consists of identifying all sources of information that can be of use to build the maintenance feedback. The Maintenance Engineer is in charge of these investigations and targets the area to cover. The information sources are the Operational Non-Conformity Registration Database and the Annual Spare Parts Consumption Report. The detection of operational non-conformity and its analysis follows a Quality Assurance process. According to the type of non-conformity, the Quality Assurance Engineer decides the course of actions to be taken in order to solve the problems.

4.2. Process analysis

The process analysis is a step by step approach performed every year by the Maintenance Engineer.

Phase 1: Compilation of data

The Maintenance Engineer collects data from each maintenance facility and from the replacement parts warehouse. He compiles all the data and proceeds to a first general analysis.

Phase 2: Characterization of the research area

The topic of interests is normally related to the nature of the product line but as a general approach, investigations are focused on a clear specification of the research area.

The Maintenance Engineer characterizes and defines:

- The basic functionality i.e. shielding, confinement, criticality, handling, thermal protection, mechanical resistance, use…
- The type of non-conformity i.e. visual aspect, inspection, calibration, surface, dimensional defect, operation…

- The nature of non-conformity i.e. deformation, dimensional, geometric, regulatory plate, scanning, screw, threading, corrosion, contamination…
- The cask parts i.e. lid, shock absorber, orifice plate, pin, gasket, trunnion, basket, spacer …

Phase 3: Analysis techniques

Maintenance feedback

The Maintenance Engineer characterizes the impacts by crossing the non-conformity nature versus the cask types and set up a synthesis matrix. The frequency indicator is calculated in order to estimate and quantify the degree of dysfunction that will target the improvement actions.
The synthesis matrix is as follows:

AMEC 1

	TN 13/1	TN81	TN 17/2	TN/13/2	TN 12/2	TN28VT	DV75	TN 12/1	NTL 10	TOTAL
Number of maintained casks										
Number of NC										
Frequency indicator										

Screw / threading										
Silicone unsticking										
Stripes / shocks										
Dimension										
Geometry										
Paint										
Deformation										
…										
…										

The frequency indicator formula is:

$$Frequency indicator = \frac{\frac{d_i}{\sum d_i}}{\frac{n_i}{\sum n_i}} = \frac{\frac{d_i}{n_i}}{\frac{\sum d_i}{\sum n_i}}$$

with

$d_i = number of\ NC\ per\ cask\ type$

$\sum d_i = total\ number of\ treated\ NC\ for\ all\ cask\ types$

$n_i = number of\ casks\ per\ cask\ type$

$\sum n_i = total\ number of\ maintained\ casks$

If the frequency indicator is >100%, the frequency non-conformity is above the average.

If the frequency indicator is <100%, the frequency non-conformity is below the average

Spare parts feedback

The cask spare parts feedback is based upon quantitative statistical techniques used to determine:

- The total number of spare parts used per maintenance operation,
- The number of spare parts used per cask type and per maintenance type,
- The cost of spare parts per cask type and per maintenance type.

Phase 4: Proceeding to the analysis

Maintenance feedback

The matrix approach leads to 2 types of synthesis. The first one is a synthesis per cask type and the second one is a synthesis per non-conformity (NC).

Synthesis per cask types

On one hand, the synthesis per cask is performed in order to stress the link between the functionality, the NC type, the NC nature and the cask parts. It is aimed to give a synthetic view and help the Maintenance Engineer to retrace the path of non-conformity. The main objectives are to find as soon as possible a cure to the problem and hence sort out a corrective and if required a preventive action in order to prevent the appearance of this non-conformity type.

The following table is given as an example of current investigations:

Cask	Functionality	NC family	NC origin	Cask parts
XXX	*-Maintenance - Handling*	*-3D defect*	*-Welding*	*-Shock Absorber*
	-Use	*-2D defect* *-Corrosion*	*-Scratches or impacts* *-Corrosion*	*-Trunnion*
		-3D defect	*- Scratches or impacts* *-Detachment*	*-Basket* *-Silicone layer*
		-Operation	*-Unfitting spare parts*	*-Orifice plate*
YYY	*-Use*	*-3D defect*	*-impacts*	*-Shock Absorber*
		-Inspection	*-Deformation*	*-Basket*
		-3D defect	*-Deformation*	*-Orifice plate screws*
		-Inspection *-Contamination*	*-Leaktightness* *-Contamination*	*-Lid*
…	…	…	…	…
…	…	…	…	…

Synthesis per non-conformity

On the second hand, for each cask type a detailed analysis of the non-conformity is performed and is synthesized as follows:

Cask number / NC number/ Frequency	Indicator	COMMENTS
XXX	***2/11/248%***	*The non-conformities observed are as follows:* - *NC on the silicon gasket* - *dimensional NC due to new type of trunnion (KTA regulations)*
YYY	***2/8/180%***	*The non-conformities observed are as follows:* - *screws NC on M54 threading and M20 screw taping (test points)* - *scratch NC on tap and orifice plate* - *deformation NC on the cask and shock absorber*
…	…	…

This analysis is primordial because it gives the frequency of non-conformities with the characterization of the type of non-conformities. It is aimed to determine the weakness points of a cask and hence give the routes to follow in order to improve future concepts.

Spare parts feedback

The spare parts feedback is aimed to determine the consumption rate and its associated costs. The Maintenance Engineer has to rely on dedicated consumption indicators in order to help him to improve his knowledge about cask characteristics. Indeed, very complex concepts will undoubtedly lead to massive spare parts consumption and thus the overall maintenance costs will inflate. The goal is to keep both at a minimum value.

4.3. The report

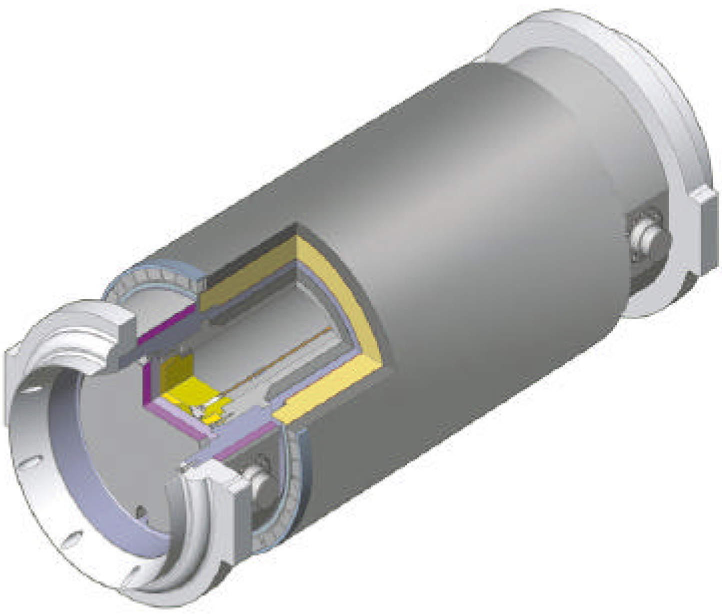
Each maintenance facility is specialized in the maintenance of specific cask types; therefore the analysis and thus the conclusion are focused on the maintenance facility and the spare parts warehouse. Four reports are yearly published for the maintenance facility and one for the spare parts warehouse. These reports represent the maintenance feedback and are available to each Project Manager when starting a new design study.

5. MAINTAINABILITY AND MAINTENANCE FEEDBACK THROUGHOUT THE DESIGN PROCESS OF THE TN™112 CASK (CASE STUDY)

5.1. Concept presentation

TN™112 is a new cask dedicated to the transport of EDF MOX spent fuel. The TN™112 design is a 112 tons packaging with an outer diameter of 2.6 meters and a length of 6.6 meters. Its total heat load is more that 45 kW and it can be loaded with 12 assemblies, either MOX or UOX. It is basically a cylindrical body equipped with fins, two lids and two shock absorbers.

Fig.1 – TNä **112**



5.2. How maintenance feedback experiences are being used?

The initial phase of preliminary design is an important step because it is at this early stage that the primary choices are made for the concept. Indeed, it is a brainstorming stage where basic experiences of maintenance feedback are being considered. Experiences from spent fuel packages have put into light difficulties during maintenance operations concerning external fins and shock absorbers.

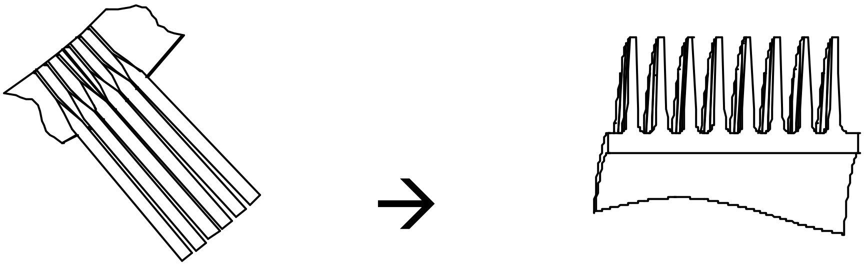
<u>External fins:</u>

Maintenance feedback:

The function of external fins is heat dissipation; these copper fins are directly welded on the body of the cask. The number, the geometry and the layout of these fins involve potential risk of shock during operation.

TN™112 concept:

The external fins are shorter, built in aluminum and positioned continuously. Thus due to its geometry, external fins will be less likely exposed to accidental shock. In case of accidental shock, the deformation will be minor regarding its size and the fins easier to repair.



Resin:
Maintenance feedback:
A silicon layer is poured to assure the waterproofness. This layer is often damaged and has to be regularly changed during maintenance operations.

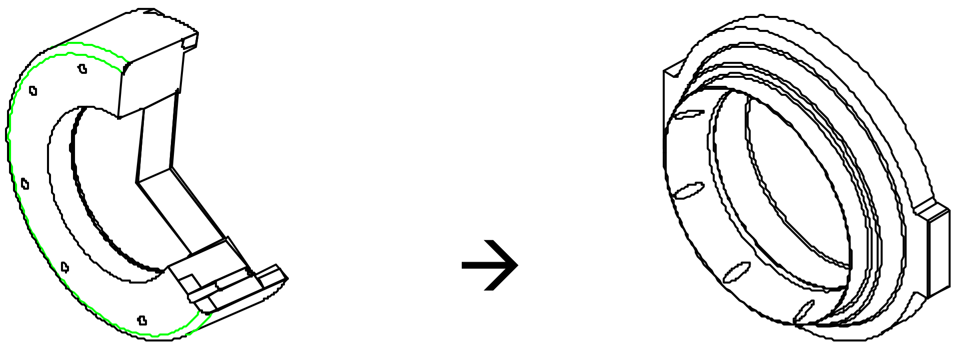
TN™112 concept:
The resin is confined in a closed section and the silicon layer is no longer required in this concept.

Trunnion protective plate:
Maintenance feedback:
A silicon layer is poured around the trunnion and the screws to ensure the waterproofness. This layer has to be regularly changed during maintenance operations.

TN™112 concept:
A protective plate confines the trunnion fixation system and the silicon layer is no longer required in this concept.

Shock absorbers:
Maintenance feedback:
Present shock absorbers include wooden blocks that are confined between steel plates. Therefore a waterproof test is required and a moisture test is performed in order to ensure the absorbing capability of the shock absorber is maintained. In addition, safety plugs useful in case of accidental events have to be frequently changed to ensure their leaktightness.

TN™112 concept:
The TN™112 is fitted with aluminum shock absorbers, which do not require those tests.



5.3. How the maintenance program is defined?
The Design Engineer in association with the Manufacturing Engineer selects the materials criteria and investigates all the technical options. In this second phase, the Design Office performs the detailed concept drawings with the assistance of the Maintenance Engineer. The spare parts are standardized using a specific homemade catalog.
During the design review, the Design and Maintenance Engineers inventory the overall components. They determine the safety functions, the operation and aging risks. In addition, the Maintenance Engineer ensures that maintenance operations permit the integrity inspection of each component. In case of dysfunction, he determines the corrective actions and evaluates its difficulty level.

TN^{TM}112 Matrix analysis

Component	**Safety function**	**Operation risks**	**Aging**	**Maintenance**
…	…	…	…	…

6. CONCLUSION

Incorporating operational feedback from maintenance in the design of casks with a systematic maintainability study is the methodology applied at COGEMA LOGISTICS. Consulting today's maintenance experts has become a pre-requisite in the design of tomorrow's casks.
The mission of the Maintenance Engineer is now extended at the very beginning of the concept study and not only restricted in maintenance operations or when dysfunction occurs.
The association of different expertise has produced a new ambitious TN^{TM}112 concept that is mainly characterized by 4 themes: safe, operational, environmental and economical.
The "maintenance analysis method" can be considered as a part of continuous improvement and could be extended to other domains such as operation.