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Testing of Engineering Projects / Plants following Construction

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Contents

1. Introduction ................................................................................................................... 3

2. Risk Assessment ........................................................................................................... 3
   2.1. Management, operator experience, contractor / subcontractor ......................... 3
       2.1.1. Complex facility construction projects ......................................................... 3
       2.1.2. Testing and commissioning, design errors ...................................................... 4
       2.1.3. Experience of Commissioning Engineers ....................................................... 4
       2.1.4. Tight project time schedule ........................................................................... 5
   2.2. Risk sharing, handover and insurance requirements in construction contracts .... 5
   2.3. Specific Perils and Vulnerabilities of Project Components .................................... 8
       2.3.1. Process industries / Oil, Petrochemical & Gas ............................................... 8
       2.3.2. Process area and non-process areas ............................................................... 8
       2.3.3. Cold testing ..................................................................................................... 9
       2.3.4. Hot testing and Commissioning ..................................................................... 9
           2.3.4.1. FLExA ...................................................................................................... 10
           2.3.4.2. NATCAT, Machinery Breakdown and DSU ........................................... 12
       2.3.5. Special scenarios: .......................................................................................... 16
           2.3.5.1. Designers risk ......................................................................................... 16
           2.3.5.2. Prototypical equipment ............................................................................ 16
       2.3.6. Training .......................................................................................................... 17
   2.4. The soft factor Issue: human errors .................................................................... 17
       2.4.1. Motivation ...................................................................................................... 17
       2.4.2. Looking around: are we the only ones having this problem? ....................... 17
       2.4.3. The difference between the airline industry and testing of engineering projects .. 18
       2.4.4. Looking behind the “curtain of human error” ................................................. 19
       2.4.5. Closing the gap: how to transfer industrial best practice to your insureds, to
           your clients ........................................................................................................... 21
           2.4.5.1. Inform and educate .................................................................................. 21
           2.4.5.2. Build up awareness ................................................................................ 22
           2.4.5.3. Analyze progress .................................................................................... 22
           2.4.5.4. Incentivize/penalize ................................................................................. 23
   3. Policy Cover .............................................................................................................. 24
   4. Conclusion ................................................................................................................... 25
   5. Abbreviations ............................................................................................................ 26
1. Introduction

According to many sources, the period for testing and commissioning is defined as the last stage before any equipment, system or project is released and certified for operational purposes.

Such tests are manifold and often very specific for the individual industries however, disregarding the potential complexity of a system or the magnitude of a project, they all have one thing in common – if at any stage of the process the impact due to an incident could be crucial, it is during testing and commissioning.

In order to illustrate the weight and importance of testing and commissioning with regard to our insurance industry, the goal of this paper is to outline various aspects of this special period and present a wide spread of influential factors which aim to prevent or mitigate incidents.

Based on this, the paper seeks to provide the reader with a better understanding and a broader view in order to give supporting background for professional assessments and risk analysis on such exposures.

2. Risk Assessment

2.1. Management, operator experience, contractor / subcontractor

2.1.1. Complex facility construction projects

Each project is characterized through a unique constellation of boundary conditions which determine processes required for the successful completion of the project. The most important boundary conditions are the project set up, financial and personnel framework and the project goal.

Undoubtedly these boundary conditions determine that most risks related to the completion of the project stem from the involvement of many project parties, tight time schedules, complicated technologies, contractual conditions and obligatory construction regulations.

From start to finish, projects are loaded with risks. During the project completion process the risks change. In the bidding phase, contract negotiation and contract signing, most of the project risks are determined. In the project execution phase the risks occurring have to be recognized in time and managed efficiently.

During the execution of a highly complex project one significant source of risk is the high number of communication/co-ordination interfaces between project parties (investor, EPC contractor, suppliers and sub-suppliers). In general there is no alternative to collaboration in the execution of complex projects. The project parties aiming for completion of the project have to coordinate their activities and the final success of the project is highly dependent on the quality of co-operation/co-ordination.

The equipment and the services included in the supplier’s scope of supply are contractually defined and normally vary widely from project to project. The delivery of equipment and services is partially, or in extreme cases, fully taken over by sub-contractors.

The quality assurance of individual systems and by that of the entire facilities being
constructed is complicated by the variation in the work division between one project and another among the different suppliers.

The contractually specified interfaces between suppliers are the result of the project manager’s concept and experience and do not necessarily correspond with experience of suppliers and their understanding of responsibilities, even if they are considered to be clearly specified.

Particularly complicated and risky are upgrade projects where existing facilities are modernized and equipped with new technology. The complete understanding of the existing facility and design of old/new interfaces are the preconditions for successful completion of such projects.

2.1.2. Testing and commissioning, design errors

The testing and commissioning phase is not only the last moment where omissions in coordination and integration of different systems in a unique facility have to be corrected, but also the period in the project execution process where non-recognition of such omissions could result in huge material losses and in extreme cases loss of life.

It is of utmost importance that the commissioning team with their experience and project wide overview takes the role of reviewer of the facility design, sees any omissions and eliminates possible safety hazards.

Further sources for errors could be in cases where the main equipment and systems have been supplied by various vendors with corresponding instructions to the responsible contractors. This increases the difficulties to fully study and analyze the necessary background required for a full and adequate testing procedure.

If, in addition, the project set up is so complex that the commissioning is contracted to a service provider who did not participate in the facility design, any possibility of recognizing major errors in the programming of the facility control and safety system is going to be impossible. Consequently huge material loss together with a delay in project completion can occur.

2.1.3. Experience of Commissioning Engineers

Members of the commissioning team have to be highly skilled in the operation of facilities and in addition specifically trained for the task of commissioning of the facility under construction. The combination of general experience and familiarity with the project and its systems plus the operational philosophy, including safety systems, guarantees sufficient risk mitigation and the final success of the project.

The standards and design rules cannot cover every possible design and engineering solution and are often influenced by the engineering traditions of the country and not related to global trends in machinery, systems and facility design.

For example, utility boilers in the USA have traditionally been designed as natural circulation boilers with a steam drum. The steam drum enables a very simple system to control the level of the drum water and consequently sufficient feed water inflow into the boiler. However the European “once through” utility boiler design does not include a steam drum and the control of the feed water flow cannot use the drum water level as a controlled parameter. Thus other parameters such as evaporator outlet temperature and/or feed water flow in relation to boiler load (firing rate) has to be used. The applicable US design standards do not provide a detailed concept for once through utility boilers and the correct design solution including such details is the responsibility of the boiler designer. He should provide the conceptual solution and the contractor is then responsible for the design of the
control system. However, the commissioning engineer must also be familiar with the control/protection system and be able to recognize possible errors.

2.1.4. Tight project time schedule

Project execution time schedules are always tight and it is not unusual for the allotted testing and commissioning schedule to be shortened due to delays in the project construction. Nevertheless, the commissioning team is forced by the project management to observe the contractual completion date. Such pressurized situations increase the risk of non-detection of design and/or installation errors occurring in earlier project phases.

It is in certain cases practice among commissioning engineers to disregard alarms in the early phase of hot commissioning. Such action is necessary in this phase since all instruments and alarm loops have not been fully checked and in order not to prolong the completion of commissioning through unnecessary stops and restarts of the facility.

Since the purpose of the alarms which are not related to automatic facility protection, i.e. which do not result with operation trip, is to provide the operator with an instrument to prevent loss of operation and support protection systems, not primarily a provision for the protection of the equipment, it is often considered acceptable to ignore these alarms, but only if all protection systems at the facility are checked before the start of hot commissioning and operational.

Unfortunately there have been situations where the commissioning engineer ignored numerous alarms although they did not completely understand the facility control system and equipment protection system. Consequently design errors were not recognized and the facility was operated in a “blind flight” mode, which resulted in a major loss.

2.2. Risk sharing, handover and insurance requirements in construction contracts

Different contractual structures for the involvement of other parties on project performance are possible. In most cases the owner does not complete the project with his own personal resources. Therefore the involvement of contractors is necessary. The contractor himself can also sub-contract part of the work. The basis for that cooperation is an engineering contract which regulates the rights and duties of the contractual parties. The engineering contract further defines which contractual party is carrying the risk for the work during a specific project period. The risk distribution is one basis for the existence of an insurable interest for all parties. Usually the contractor is responsible for the care and custody until the facility has been handed over. However, there are exceptions, for example “Force Majeure”.

In addition to the risk mitigations a risk transfer to the insurance industry takes place. The requirement for such project insurances is defined in the 'Insurance Requirements' section of the construction contract. There are different structures possible for the project insurance during a project performance. In general insurance can be bought by the contractor as well as by the owner. A limiting factor is that predominantly only the owner can insure loss of profit, because that is not an insurable interest for the contractor.

1 The World Bank - STANDARD BIDDING DOCUMENTS - Supply and Installation of Plant and Equipment: Chapter 31. Transfer of Ownership:

Notwithstanding the transfer of ownership of the Plant and Equipment, the responsibility for care and custody thereof together with the risk of loss or damage thereto shall remain with the Contractor pursuant to GCC Clause 32 (Care of Facilities) hereof until Completion of the Facilities or the part thereof in which such Plant and Equipment are incorporated.
Which party needs to buy the insurance cover is specified in the ‘Insurance Requirements’ section of the construction contract. For example, the World Bank construction contract conditions require the contractor to buy the insurance whilst the owner must be named as co-insured².

The project policy consists of cover for material damages for two different periods:
- Construction Period incl. Testing and Commissioning: all risk cover;
- Extended Maintenance Period: cover for punch list works and damages as a consequence of faulty works occurred on site and during construction;

The insurance period is also defined in the ‘Insurance’ chapter of the ‘Construction Contract’. The requirements of the FIDIC conditions are cover ‘until the date of issue of the Taking Over certificate’³.

The insurable interest of the owner and the contractor changes significantly between the two phases. With the handover of the insured plant the owner is fully responsible except for events which would be covered under the extended maintenance cover or guarantee. Therefore operational insurances are needed, such as a machinery breakdown and property cover. Such covers usually exclude the testing and commissioning and cover only risks carried by the owner. Accordingly such covers will not be effective unless the plant has been handed over to the owner after successful completion of the test run. The requirements for the successful handover are normally:
- The plant must be in accordance with the specification (mechanical completion);
- Performance tests have to be completed successfully (operational completion);

In many projects from the outset there is misunderstanding of the contractual scope. Furthermore the results of the performance guarantee test are not always easy to interpret. As a consequence the owner could decline to sign the Operational Acceptance Certificate.

Potential reasons for not achieving the contractual performance values outside of the

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² The World Bank - STANDARD BIDDING DOCUMENTS - Supply and Installation of Plant and Equipment: §34 Insurance: To the extent specified in the corresponding Appendix (Insurance Requirements) to the Contract Agreement, the Contractor shall at its expense take out and maintain in effect, or cause to be taken out and maintained in effect, during the performance of the Contract, the insurances set forth below in the sums and with the deductibles and other conditions (b) Installation All Risks Insurance

Covering physical loss or damage to the Facilities at the Site, occurring prior to Completion of the Facilities, with an extended maintenance coverage for the Contractor’s liability in respect of any loss or damage occurring during the Defect Liability Period while the Contractor is on the Site for the purpose of performing its obligations during the Defect Liability Period.

contractor’s area of influence can be:

- The specified feed is not available;
- Plant cannot operate at design capacity because there is no buffer and use for 100% of the product;
- Lack of utilities;
- Lack of raw materials;
- Open Punch Items;
- Open negotiations on change orders.

If the owner refuses to sign the Operational Acceptance Certificate\(^4\) despite the fact that the plant is already in operation, it can be unclear if a risk transfer has been achieved or not. Usually a payment is linked to that milestone.

The problem for the contractor is that as long as he has not formally handed over the plant he remains responsible and needs to prolong the insurance cover. At the same time an owner might also have difficulties to cover the plant under his industrial all risk insurance. In addition, operational covers usually have higher deductibles.

As a consequence, on projects where the Operational Acceptance Certificate has not been signed, the project policy is extended. For the EAR insurer that is problematic because during longer operating periods wear and tear already becomes an issue. Wear and tear itself might not be covered but rather the potential consequential losses. However the burden of proof is on the insurer. In many cases of functioning projects the owner has never formally taken over the plant but operates without the supervision of the contractor. The issue for the contractor is how to prove that the plant has been taken over by the owner without certification.

In some legislation the civil law regulates such cases\(^5\). The plant needs to be completed and free of substantial defects. If the contractor hands over the plant in such a condition, the owner cannot refuse the takeover. To force an owner to take over the plant would require legal action. This is a long process and not possible in all jurisdictions.

For the insurance industry there is no clear solution to the problem at the moment. It is hardly possible to refuse policy extensions and there is also a commercial aspect. As a consequence, in many cases an EAR cover is extended for years and the insurers have to deal with the consequences in the form of operational losses in combination with lower project policy deductibles. The main reasons for the risk deterioration are that an owner might treat the plant differently as long as he feels himself not fully responsible and the contractor refuses to supply spare parts and service as long as he has not received final payment.

The insurance industry should consider developing strategies in order to support contractors or manufacturers who are constructing projects abroad. Detailed knowledge regarding local civil law would be necessary.

One possible option is to insure such plants under the Munich Re CP Insurance - Endorsement 1202 (special insurance cover: property taken into use or operation). However this does not change the situation for the contractor or the insurer as long as an official handover cannot be achieved.

\(^4\) The World Bank - STANDARD BIDDING DOCUMENTS — Form of Operational Acceptance Certificate - Page 226

\(^5\) Hilgers/Buscher Der Anlagenbauvertrag - Rechtliche Grundlagen, Vertragsgestaltung und Projektdurchführung im Inlandsgeschäft; 2005 (1. Auflage) 978-3-452-25481-8
2.3. Specific Perils and Vulnerabilities of Project Components

2.3.1. Process industries / Oil, Petrochemical & Gas

Testing and commissioning of newly constructed plants is a critical but exciting milestone for each project. From an insurance standpoint it is the most exposed and critical phase in terms of the insurance contract. In many cases, the total sum insured is on-site and installed or at least in the final construction phase. If something would go wrong, the impact on the property and on the time schedule could be devastating.

For example many of the chemical, petrochemical production sites or refineries are located in developed countries and areas with a good infrastructure in place. Large new projects are however increasingly located in rural or remote areas and in emerging markets. In each case it has to be considered that in case of a loss, it can be challenging to get spare parts and skilled workforce quickly through customs and on-site.

Moreover, lead times for major equipment, general worldwide economic situation and workload at manufacturer’s workshop have to be considered.

A check of the plant's layout which gives the underwriter a general idea of the project before accepting a risk would be recommended. Areas of concern would be: location of the control room; location of the flare in relation to the general wind direction; distance between the process areas and degree of congestion in relation to the overall plant layout.

The following pages attempt to give an overview without being a complete picture of typical scenarios detailing possible errors if the right precautions and preparations are not being considered before commencing with any testing in Greenfield (new construction) as well as Brownfield projects (debottlenecking or modification projects).

2.3.2. Process area and non-process areas

In general, the insured property of a complex and integrated chemical, petrochemical site or refinery can be divided into process areas and non-process areas (utilities). A process area is the part of the site where the conversion of raw products or chemical reactions takes place. Nevertheless, large amounts of chemicals and gasses can be pumped through the non-process area or can be stored in large tank farms in these areas under high temperature or pressure, but without any chemical reaction.

We consider the process area as significantly exposed during hot testing and commissioning since chemical reactions / conversion is taking place in this area. Therefore, it is very likely that a possible devastating incident would occur in this area.

Depending on the location of the insured property, the Project Manager and the Insurer should be aware of the various NatCat exposures that could arise during the testing and commissioning (t&c) phase of the project.

In general, large operating companies and large contracting companies have well structured and defined commissioning procedures and check lists in place as well as experienced commissioning teams.

The human element should not be overlooked but can be reduced if well proven commissioning procedures are implemented and followed.

Before testing commences, safety installations e.g. safety valves, rupture disks and gas detectors must be installed. Fire fighting systems (piping completed, reservoir full, pumps running, approval from the fire marshal obtained) must be commissioned first and ready to operate before introduction of hydrocarbons can begin. Further to be ready needs to be
other utility systems (supply systems) such as electricity, compressed air or utility gases.

The commissioning team should be on-site and part of the team long before the t&c phase commences and on site in order to familiarize themselves with the location and installations.

The maintenance team should already be on board and available to the commissioning team since rotating equipment needs their first oil fills before running and require regular maintenance intervals because the whole start-up process can go on for weeks if not even for months.

2.3.3. Cold testing

Theoretically once the construction phase is finished (physical completion of the plant) the cold testing can begin. Typically, this is an overlapping process and often phased commissioning is already planned from the beginning of the project. Time delays in various sections of the construction project can add an additional uncertainty to the actual start date, duration and intensity of the cold testing.

When cold testing begins, electricity and compressed media (e.g. air, nitrogen, and steam) is available, tie-in from an outside source is established and substation/transformers have been commissioned.

In general this is a very stressful time on the project site. Many different specialists from various disciplines are on-site in order to test the correct connections between the field instruments, pumps and valves with the DCS (distributed control system) as well as turning directions of drives and correct movements of valves. Bottlenecks can occur with the responsible operators in the control room, who are in radio contact with various field engineers whilst running the various field commands and concurrently checking / correcting the documentation (P&ID, E&I control drawings, plant documentation etc.). This phase is critical, since errors can easily happen due to the high workload for the operators and engineers. A wrong field valve position (closed instead of open), or motor speed / direction of a pump can lead to significant losses during hot testing or commissioning.

It can be sometimes necessary to switch off some signals in the DCS and control room, such as level control, pressure, temperature and their alarms during the testing phase. This can be done either via software of the control panel or by hardwiring. It is essential for a safe start-up procedure that all interlocks and temporary signal amendments are removed and returned to their original position as soon as the plant is tested with process media. In order to keep track of the alarm settings, such interlocking or bridging should be tracked in a protocol and the chief commissioning manager should be informed at least in the daily morning routine.

2.3.4. Hot testing and Commissioning

Before the commission team can begin to run the individual section of a plant as a whole process, the entire plant has to be checked for blinds within the piping connection. Blinds are commonly used during the construction phase to separate various sections, to avoid uncontrolled flow or filling of vessels, pipes etc during flushing of individual sections. However, sometimes blinds are needed to separate from other units which are not ready for testing. Therefore it is recommended to have a blind register and hand marked P&ID located in the control room, where all installed blinds should be listed as well as their status.

During hot testing and commissioning, if everything is running smoothly, the plant is being ramped-up in pre-defined steps to its design limits by running at full capacity or above the design capacity for a defined timeframe; 72 hours for example. This is a critical moment for the plant, since there is rarely an exact replica plant in the world. Usually, each new plant
has “proven” technology at a larger throughput and/or larger dimensions or prototypical equipment. The commissioning team has to fully concentrate during this performance test to realize immediately if a process is going out of control and to take counter measures to avoid a major damage.

In addition, hot testing could be carried out in areas of the plant, which are still under heavy construction activity, which increases the exposure further.

Before the plant is handed over to the operations team, no major punch item which can endanger the integrity of the plant must be open on the punch list.

The following is a breakdown of a typical large petrochemical site in order to give indications of possible exposure during hot testing and commissioning for the various sections of the site. The first table focuses on FLExA as being one of the main perils applicable for all Industries.

### 2.3.4.1. FLExA

<table>
<thead>
<tr>
<th>Description of Exposure</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Control Room</strong></td>
</tr>
<tr>
<td>The location of the overpressure, blast resistant and vented control room should be somewhere on site where a potential vapour cloud and its pressure waves cannot harm the functionality of the CR in the event of an explosion. As an alternative the control room can also be placed belowground. In both cases, it must be assured, that no hydrocarbons, process media or utilities can enter the CR (e.g. via the vent system etc.) Nevertheless, in a case of total destruction of the control room, all safety relevant equipment (valves etc.) should switch to the fail-safe position (also if utilities, for example compressed air, is not available). These emergency scenarios are tested by pushing the various emergency stops during t&amp;c. In the case of a remote location of the CR without vapour cloud exposure, the fire risk is similar to that in general property buildings. However, the control room is the heart of each plant and special protection measures should always be considered to avoid larger losses due to a damaged control room. The advantage of remote locations is also that the access to the building is possible even if large sections of the plant are destroyed, and it is possible to run independent process steps while the damaged section is being repaired.</td>
</tr>
<tr>
<td><strong>2. Buildings (open structure, open air plants)</strong></td>
</tr>
<tr>
<td>Open structure buildings are usually full of pumps, compressors, vessels, reactors, columns, heat exchanger piping and fully loaded cable trays. Therefore, the potential for a vapour cloud exposure in the case of pipe, flange, vessel rupture, loose gaskets or the wrong valve position is high. A good t&amp;c procedure and skilled personnel would significantly reduce this risk.</td>
</tr>
<tr>
<td><strong>3. Buildings (closed structures)</strong></td>
</tr>
<tr>
<td>Chemical reactions taking place in closed buildings, where chemicals are pumped through pipelines, offer similar risks to open structures. Leakages of flammable media could add up and form a vapour cloud. Often, the space is rather congested. Therefore, closed buildings impose a higher explosion hazard. An internal vapour cloud should remain within the building. However, exposure from an external vapour cloud could be smaller (depending on the distance between the building and its surroundings). A good t&amp;c procedure and skilled personnel would significantly reduce this risk.</td>
</tr>
</tbody>
</table>
### 4. Columns, Process Tanks

Columns and process vessels can be constructed out of special material or have a special lining which is difficult to repair on site or has a long delivery time if damaged, since this is highly custom-made equipment. They have many flange connections for measuring equipment (temperature, pressure and level indicator) as well as in and outgoing liquids / gasses or agitator.

Vacuum breakers must be operational before closed systems like tanks are closed. Before the columns or tanks are integrated into the t&c program, the flare / waste gas incineration should be commissioned and working.

A good t&c procedure ensures that all connections are tight and that sensors work properly. The risk of emergent liquids / gasses should therefore be well controlled. However, many columns and vessels are isolated and direct leakage may not be obvious particularly if the testing period is too short. The risk of fire due to leakage is moderate but should be under control with good t&c procedures.

### 5. Piping and Pipe Racks

The overall installed length of all pipes within a plant can sum up to several kilometres. The different material, diameter pressure and temperature rating does not reduce the complexity of the overall piping system of a plant. The tightness of the flange connection has to be checked several times by visual inspection during t&c. Special attention is recommended in checking that the piping system is properly earthed (earthing strap connecting both sides at each flange connection). Incorrect earthing can lead to electric sparks, which could be the ignition source for an explosion of a vapour cloud. In addition, the plant would not be correctly protected against lightning.

Before t&c can begin, the piping systems should be cleaned / blown out during pre-commissioning with compressed air or nitrogen. Flushing with flammable gases should be avoided.

Blinds have to be removed and special start-up filters installed.

The risk of failure is low to moderate if the system gets tested and checked during cold and hot testing.

### 6. Pump Stations / Compressor Stations

Pumps / Compressors intake and outlet flange connections could be specially adjusted during the design phase to fit to the layout and piping situation at the later installed location. Often, they have long lead times. The vibration monitoring should be properly installed, tested and adjusted during pre-commissioning to avoid damage or leakages. A leaking process pump / compressor could distribute uncontrollable mounts of hydrocarbons into the plant. It would be only a question of time until these hydrocarbons would find an ignition source. This could be any electrical equipment which is not special explosion-proof rated or protected, hot surfaces of engine exhausts or heat exchangers, badly insulated steam pipes or the flare itself. This would lead to a major loss scenario in Oil, Petrochemical or Gas plants, the Vapour Cloud Explosion (VCE).

Prior to allowing process fluid to run, blinds should be removed from equipment. It is recommended to visually check whether the fluid is flowing correctly (no closed hand valve, blocked pipe, full strainer filter etc).

### 7. Metering Stations

Coarse filters should be checked and cleaned after flushing the piping system to avoid blocking a pipe.

Low to moderate risk due to lose flange connections.

### 8. Utilities/ Metering

Utilities are either provided by the process itself (e.g. steam) or provided via a pipeline from outside battery limits or neighbouring plants. Some are
Stations/Tie-in Locations

non-critical in case of leakage (water, compressed air) others (hydrogen, nitrogen, and steam) can be harmful to the plant and operators. Often the pipes are insulated. Therefore, good leakage control of flange connections and metering stations is recommended.

A good t&c procedure and skilled personnel would significantly reduce this risk.

9. Storage Tanks (large volume)

A large storage tank, once on fire, is difficult to extinguish. It would be more likely that the fire brigade would focus on securing the surroundings. The storage tank would therefore be a total loss.

To prevent damage to the tanks, the t&c team must verify that the vacuum breakers, venting is working and that the grounding is properly installed.

10. Substations/Motor Control Cabinets or Centres

Before this section is commissioned, the fire fighting systems should be up and running, emergency power should be available and the substation should be pressurized (small overpressure to its surrounding) to avoid that flammable.

In addition no significant exposure other than expected during normal operation.

However, if a loss occurs in the substation or motor control centre, the start-up cannot continue until the repair or a temporary solution is installed.

11. Cable Trays

Cable fire is possible but not considered very likely if common construction standards, specified cable size and good cable quality are used.

2.3.4.2. NATCAT, Machinery Breakdown and DSU

<table>
<thead>
<tr>
<th>1. Control Room</th>
<th>NATCAT</th>
<th>Machinery Breakdown</th>
<th>Delay in Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind: No significant exposure other than expected during normal operation. Flood: Verify its position to nearby rivers, lakes or shore lines, since chemical processes often require large amounts of cooling liquid. The elevation should be higher than the surrounding site. Earthquake: No significant exposure other than expected during normal operation.</td>
<td>Not applicable</td>
<td>A damaged or semi-damaged control room building can easily trigger a DSU claim.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Buildings (open structure, open air plants)</th>
<th>No significant exposure other than expected during normal operation.</th>
<th>There is a fair amount of rotating equipment in an open plant section. If the signal and turn direction test during cold testing was not properly done or</th>
<th>If there is a loss in this section during hot testing or commissioning, a DSU claim is very likely to occur. If key equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Buildings (closed structure)</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>Similar to open air plants. A good t&amp;c procedure and skilled personnel would significantly reduce this risk.</td>
<td>Similar to open air plants. A good t&amp;c procedure and skilled personnel would significantly reduce this risk.</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4. Columns, Process Tanks</td>
<td>If flammable liquids are temporarily vented to the atmosphere, lightning could be a hazard to be taken care of. There is no significant exposure other than above expected during normal operation.</td>
<td>Not applicable.</td>
<td>Damage to a vessel or column during hot testing could result in a long schedule delay. Considerable dismantling activities involving heavy lifting cranes on site are likely. In case of a flanged column, repair time is relatively quick. If the column needs to be reworked at the shop or a new order is required, the schedule delay is considerable.</td>
</tr>
<tr>
<td>5. Piping and Pipe Racks</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>Not applicable.</td>
<td>In some special processes, or with special material, e.g. glass fiber reinforced plastic, repair must be done by a specialist and enough spare parts should be in stock on site (e.g. pipe, elbow-, t-piece or flanges in various diameters) otherwise, lead order time must be considered. Overall, the risk is...</td>
</tr>
<tr>
<td>6. Pump Stations/Compressor Stations</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>If a pump or compressor is running without or with the wrong fluid, at the wrong speed, vibrating considerably, or has a closed valve, severe damage can easily happen. If this is not quickly rectified, a minor loss can become a total loss. A good t&amp;c procedure and skilled personnel would significantly reduce this risk.</td>
<td>Many pumps / compressors are installed in pairs or even triples. If one pump is damaged during start-up, a second pump is ready to switch on. However, for safety reasons some processes may require a fully functional second pump. The risk of a DSU claim is moderate.</td>
</tr>
<tr>
<td>7. Metering Stations</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>Not applicable.</td>
<td>No specific exposure for DSU is expected.</td>
</tr>
<tr>
<td>8. Utilities/Metering Stations/Tie-in Locations</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>Not applicable.</td>
<td>Problems stemming from the external utility provider can create a delay in the schedule, especially if there are technical problems at the metering stations. The equipment in the metering station often belongs to the external utility provider and procurement of replacement equipment, maybe their responsibility. However, the risk can be considered as low to moderate.</td>
</tr>
<tr>
<td>9. Storage Tanks</td>
<td>Wind: No significant exposure other than expected during normal operation. However, although the tank should be designed to withstand certain wind speeds even if empty, an empty tank could be considered as higher exposed than a full one. The shell of an empty tank can partially or totally collapse. The damage can vary from a minor to a</td>
<td>Not applicable.</td>
<td>Depending on how many storage tanks are required for the operation and how many are damaged, the spectrum can range from reduced operation to no operation possible. Another consideration would be, whether the site has its own jetty from which ships can be directly unloaded or loaded with only minor buffer tanks required on</td>
</tr>
</tbody>
</table>
total loss.
The often heard advice to quickly fill an empty tank with water when a storm approaches is rather of a theoretical nature. It might work for small tanks. For large tanks such as crude oil storage tanks, the pumping and piping capacity for the high flow rate is not available and not easy to acquire for a short term requirement. The risk is considered moderate to high in the case of an approaching storm.

Flood: If the tanks are empty and there is fear of flooding the potential for a loss is considered to be significant. At some flood levels around the tank, the lifting force will become greater than gravity plus the force of ground fixings of the tank. As a result, the tank will either develop leaks or float. The damage can vary from a minor to a total loss.

The often heard advice to fill an empty tank with water when a flood is expected is rather of a theoretical nature. It might work for small tanks, but for larger ones, such as crude oil storage tanks, the pumping and piping capacity for the high flow rate is not available and not easy to get for the short term requirement. The risk is considered moderate to high in case of flood.

Earthquake: The base plate of large storage tanks could be affected by an earthquake. However, this risk should not be higher than expected during normal operation. Therefore the risk is considered as low site. Alternatively, if the site is connected to the national railroad grid which would allow to continue operation of the installed facilities.
<table>
<thead>
<tr>
<th>10. Substations/ Motor Control Cabinets or Centres</th>
<th>No significant exposure other than expected during normal operation.</th>
<th>Not applicable</th>
<th>Back-up system or temporary solutions are usually available without major problems in case of an exploded or burned transformer. However, large transformers have usually a long delivery time (6 months and longer) and would possible trigger a DSU claim.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Cable Trays</td>
<td>No significant exposure other than expected during normal operation.</td>
<td>Not applicable</td>
<td>Damage to cables due to a fire during start-up can cause severe damage and consequently have an impact on the remaining schedule. Depending on the severity of damaged cables and sections, new cables have to be pulled and connected. A new signal check is required. Depending on the severity of the fire and the amount of damage this can be a time consuming effort. The risk is considered low to moderate.</td>
</tr>
</tbody>
</table>

2.3.5. Special scenarios:

2.3.5.1. Designers risk

Special attention must be given if a process owner with plants and experience in one regulated market is building a new plant in a new market with different standards (e.g. ASME vs. DIN or metric vs. Anglo-American measurements). However, since the insurance would pay only in case of a physical loss, the risk is considered to be low.

A more delicate situation can occur when materials such as special alloys or lining materials are used. During the complex pipe assembly, where many pieces are fitted on-site, the construction workers can be very creative in order to complete their job on time. There have been a few losses recently, where only 30+ years after construction the loss adjuster discovered that the wrong pipe material was used leading to unexpected corrosion and failure of the pipe, causing a severe fire and so a major damage. One wrongly installed spool piece is enough to lead to this situation.

2.3.5.2. Prototypical equipment

Prototype and scaled-up equipment needs particular attention during the whole t&c process. There is no experience with new equipment. It is therefore recommended to
exclude all losses from the insurance cover resulting from this type of equipment during t&c.

2.3.6. Training

Depending of the owner and the locality of the newly constructed plant, operators could be new to the industry and inexperienced. During the testing and commissioning phase, but also already during construction of the main equipment, is a good time and opportunity for all operators and the maintenance team to learn many things about the process and equipment and to get to know their new plant. Usually, the E&I department prepares a training environment on the DCS to allow for training of the operator on a simulated process and to prepare for “as if” scenarios.

2.4. The soft factor Issue: human errors

2.4.1. Motivation

Engineers enjoy reviewing the technical side of an engineering project. Generally there is a feeling that a good part of the underwriting and risk assessment process is spent on construction methods, soil conditions, load factors, latest designs and how proven they are etc.

But why do some projects, where all the “hard facts” boxes are checked, fail, causing heavy losses? The following section should shed some light onto the topic that can be described as “Soft Factors”.

Going through descriptions of historical losses\(^6\) we often find loss descriptions such as “human error” and “operator error” or similar. The aim is to have a look behind these descriptions and to offer some value propositions to reduce this class of loss, which will benefit the original insured. However, it has to be said that attempting to reduce human errors is not a simple exercise. Additional effort from the start is required, and the benefits remain ultimately difficult to measure.

2.4.2. Looking around: are we the only ones having this problem?

What are the particular challenges of the final phase of an engineering project?

- A high degree of proven technology involved
- Many interfaces between different (sub) systems and consequently many engineering interfaces
- Changes in delivery and erection schedules leading to changes in testing sequencing
- Several specialists involved, often from different companies. Different interests may lead to a conflict of interest when it comes to problem solving
- Time pressure leading to a high physical and psychological burden
- In international projects, language and cross cultural issues may arise
- A lot of information needs to be filtered and classified, particularly during hot testing Quick decisions need to be taken

\(^6\) http://imia.com/interesting_claims.php
• Small errors could lead to catastrophic results
• Many specialists and highly trained people with different backgrounds need to work together
• The environment, be it climatic, cultural or social, might induce additional stress for the team members

All these factors lead to an increased likelihood of errors and to increased severity if an error materializes. It would however be fatalistic to accept this class of losses as inevitable. Observation shows that other fields of human activity actually face similar challenges:

• Airline Industry
• Nuclear Power
• Healthcare, hospitals

The airline industry is probably the most obvious example for a field of activity that has evolved from pure “trial and error” in its early stages having gone through a learning curve for decades that involved design, production, operation and maintenance. This includes technical, as well as human errors, for the simple reason that it does not matter in the end if a plane crashes due to a design error or a human error during maintenance. The consequences are in both cases tragic and the social and financial costs are the same.

In the healthcare sector the US Institute of Medicine estimates each year between 44,000 and 98,000 people die as a result of medical errors 7 , a number that highlights the magnitude of the “Soft Factor” within a complex and technology-driven environment.

2.4.3. The difference between the airline industry and testing of engineering projects

The following table shows parallels and differences between the airline industry and testing of engineering projects:

<table>
<thead>
<tr>
<th>Industry:</th>
<th>Airline Industry</th>
<th>Testing of Engineering Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequences for directly involved personnel:</td>
<td>Lives are at stake</td>
<td>Usually only material damage</td>
</tr>
<tr>
<td>Financial consequences:</td>
<td>Very high cost</td>
<td>Very high cost</td>
</tr>
<tr>
<td>Impact on reputation:</td>
<td>Worldwide headlines catch attention of public, investigators and politics</td>
<td>No headlines at all as long as damage stays “within the fence”</td>
</tr>
<tr>
<td>Consequences:</td>
<td>The airline industry is in the spotlight 4 systemic approach towards minimizing adverse effects of (human) errors.8</td>
<td>As long as the damage “stays within the fence” only insurance community interested. 4 Low pressure to systematically improve.</td>
</tr>
</tbody>
</table>

Table 1: Comparing Testing of Engineering Projects with Airline Industry

7 Epidemiology of medical error - BMJ 2000; 320 doi: http://dx.doi.org/10.1136/bmj.320.7237.774 (Published 18 March 2000)
8 http://www.skybrary.aero/index.php/Main_Page
2.4.4. Looking behind the “curtain of human error”

Many traditional failure analyses try to determine if a mishap was caused by a technical issue (e.g. design, corrosion, etc.) or by human error. Failure to analyze further reveals only a part of the story. It is not often that human error can be attributed to a single case. In most cases a number of contributing factors lead to a mistake that ultimately results in the event.

In order to apply the lessons learned one needs to go beyond the human error and try to understand why this human error has occurred. An analysis tool originally developed by members of the US Department of Defense is called HFACS (Human Factors Analysis and Classification System). It is no surprise that the project was designed by the Air Force; where there was already a high awareness of safety issues from general aviation. The logic behind the HFACS is to determine active or latent failures/conditions that act as preconditions for an “Unsafe Act” that might lead to an event. The following model was setup:

![The “Swiss Cheese” Model](http://hfacs.com/)

The Active Failure causing the Unsafe Act is analyzed and moreover this model aims at discovering latent conditions contributing to this failure from:

- Preconditions for Unsafe Acts
- Unsafe Supervision
- Organizational Influences

In detail the model has several categories of contributors for each level:

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Once this analysis is done lessons learned can be applied and future unsafe acts of the same kind may be avoided.

A prominent example to show the logic behind this model is an airliner crash caused by undetected wing icing during start\(^\text{10}\). While the cause is quite clear the in-depth analysis revealed ten latent threats such as aircraft design, inadequate control by the government, management disregard for de-icing, and inadequate maintenance/training all contributed to the accident. Without a detailed post accident analysis these contributing factors remain hidden and thereby remain a threat which could potentially endanger future operations.

One of the big challenges of this approach is to get good data in order to be able to start an analytical approach. If unsafe acts are not reported even the best analytical system has no value. The error reporting tools in place in the aviation industry today are a result of many years’ persistent work involving systematic, but more importantly, cultural, change management, from an error denying culture to a culture where errors are reported and seen as a valuable lesson for improvement. It goes without saying that in the aviation industry external pressures to analyze and improve have been very high.

Learning from unsafe acts that result in damage is positive, however, it would be more beneficial if lessons were learned from unsafe acts that did not result in damage and optimal if unsafe acts from others could be used as a basis for overall improvement. For

\(^{10}\) [http://www.airlinesafety.com/editorials/CockpitCabinPsychology.htm](http://www.airlinesafety.com/editorials/CockpitCabinPsychology.htm)
example in the aviation industry a systematic error reporting system is implemented\textsuperscript{11} which helps to mitigate future incidents and is accessible to all interested users. According to the Statistical Summary of Aviation Occurrences 2010 in Canada there were 70 fatalities, 288 accidents and 815 reported incidents. With the incidents reported the knowledge database gets broader and “lessons learned” is a lot cheaper!

2.4.5. Closing the gap: how to transfer industrial best practice to your insureds, to your clients

While it is comforting that engineering insurers do not have to “reinvent the wheel” the question remains how the experience of the aviation industry might be transformed to engineering projects, where there is less standardization and more fragmentation. Of course it would be beneficial to have a fully automated tool in place, however, as mentioned earlier, even the best tool has no value if there is no or only little relevant data to fill it. Moreover, developing such a framework would be out of the scope of a Working Group Paper.

The initial focus should be on the attitude of the client towards safety. The fact that it is in the insurer's interest that losses are minimized should not distract attention from the fact that the primary beneficiary of a testing period without loss is usually the insured, as a reliable and timely performance improves their reputation amongst clients.

2.4.5.1. Inform and educate

A proposed staged process to introduce this concept to insureds could take this form: Initially, the topic of safety culture should be introduced as a concept.

\textsuperscript{11} http://www.skybrary.aero/index.php/Aviation_Safety_Statistics
• What is safety culture? What is it based on\textsuperscript{12}?

It is argued “a ‘good’ safety culture might both reflect and be promoted by at least four factors\textsuperscript{13}:

- senior management commitment to safety
- shared care and concern for hazards and a solicitude for their impacts on people
- realistic and flexible norms and rules about hazards
- continual reflection upon practice through monitoring, analysis and feedback systems (organizational learning)

- Who is involved? Everybody. Who are the drivers? From top to bottom!
- Keep in mind cultural issues. Not all cultures have the same approach towards errors and discussing them.

2.4.5.2. Build up awareness

There should be transparent information so that the safety culture has an impact on the insurer’s view of an insured but, even more importantly, how the insured is perceived by his clients. And, last but not least, there could be a positive effect on the insurance cost if loss occurrences and severities can be reduced sustainably. One of the insurance industry’s most important tools are the risk reviews which are carried out, which should focus on both the more technical aspects of information about safety culture as on the risk assessment aspect.

2.4.5.3. Analyze progress

Once the concept of safety culture is announced and introduced the progress of the insured should be analyzed.


\textsuperscript{13} Pidgeon and O’Leary 1994
Figure 6: Safety Culture Pyramid

It is important to mention that for testing of large and complex risks there are several involved parties:

- Main contractor(s)
- Sub contractors
- Owner and/or
- Owner’s engineering consultant

Each of them has his “own” safety culture. Moreover, the co-ordination between different involved parties results in an additional complexity in terms of communication:

- What are the reporting lines in a project? Who reports to whom? Are the responsibilities clearly defined? Subcontractor management.
- How do the parties communicate with each other? Language barriers? Cultural barriers?

2.4.5.4. **Incentivize/penalize**

Finally the improved safety culture should pay off twofold by:

- Safety culture sensitive insurance pricing mechanisms
- Improving the client’s reputation in the market
3. Policy Cover

The policy provides the parties with information about the period of cover as well as the anticipated duration for the testing and commissioning part.

This period should clearly be defined since different terms can apply such as deductibles, extension rates or even cover aspects such as fire fighting installations designed for the operation need to be installed and serviceable before testing starts in order to enjoy coverage.

Since there are changes in the deductible structure during testing and commissioning the description of the period is important in order to avoid misinterpretations at a later stage in case of an incident.

These definitions could be as following:

a.) Gas turbine: First firing of the gas turbine; or
b.) HRSG: the blow-out of the heat recovery steam generator; or
c.) Steam turbine: the first steam admission of steam to the turbine; or
d.) Other equipment: the energizing of the electrical system exceeding 10kV; or
e.) Oil, Chemical, Gas: Introduction of flammable media, Introduction of Catalyst
f.) Etc...

A further particularity has to be mentioned in regard of period extensions. As there are various factors that could impact the master schedule of a complex project it is clearly to distinguish between the period prior to the t&c and the actual testing phase itself. Any extension to this period has to be charged at a higher rate than pro rate since the original rate incorporates also the construction/erection period which is based on an accumulated risk profile over the period.
4. Conclusion

In summary, we can say that the testing and start-up phase together with the performance run (when the plant is brought to its design limits and beyond) is the most critical time during an erection project. It is absolutely fundamental to study the project schedule in great detail in order to assess the critical periods or to identify potential buffer zones in case of difficulties encountered during testing.

Nevertheless, it is recommended to limit the time frame during which testing and start-up is covered by the insurance. Any time longer than required to start-up a system could open opportunities for engineers and technicians to try optimizing their equipment, throughputs etc. This might cause damage that could have been avoided. Moreover, this damage might only be detected much later in the operating plant, creating in the case of a loss, new conflicts as to whether this loss is covered by the construction policy or operational policy.

Since the t&c phase is the time with the highest exposure for the insurance, and the system is no more “silently” installed but running, a higher deductible than during the construction phase is recommended. The levels depend on various factors, such as the process, involved, equipment sum insured and others.

A good contractor with well structured procedures and an experienced commission team, together with a good policy, could bring the above mentioned concerns within an acceptable level for the insurance industry.
## 5. Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFACS</td>
<td>Human factors analysis and classification system</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of defense</td>
</tr>
<tr>
<td>t&amp;c</td>
<td>Testing and commissioning</td>
</tr>
<tr>
<td>FLExA</td>
<td>Fire Lightning Explosion and Aircraft</td>
</tr>
<tr>
<td>DSU</td>
<td>Delay in Start-Up</td>
</tr>
<tr>
<td>P&amp;ID</td>
<td>Piping and Instrumentation Diagram</td>
</tr>
</tbody>
</table>