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Challenges of parallel ESS cryoplants installation and commissioning activities

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Abstract. The European Spallation Source (ESS) is a neutron-scattering facility being built with extensive international collaboration in Lund, Sweden. The world's most powerful linear proton accelerator shoots protons against a rotating tungsten target where neutrons are knocked off ("spallate") and are guided to the neutron instrument suites [1]. Three cryogenic plants and a vast cryogenic distribution system serve the cooling needs of the superconducting RF cavities in the accelerator, the cold hydrogen moderators in the target, a cryomodule test stand and the sample environments for neutron instruments. The project's demand of schedule and economic feasibility requires a high degree of parallel work for installation and commissioning of the cryogenic and auxiliary systems. The resulting challenges in aspects such as safety, interface control, utility management and planning for the phases of installation and pre-commissioning shall be discussed in this paper. The current status of the ESS cryogenic system and lessons learned are addressed as well.

1. Introduction

The cryogenic system at ESS comprises, besides the cryogenic users and a vast distribution system, three independent helium refrigeration plants: the Accelerator Cryoplant (ACCP), the Target Moderator Cryoplant (TMCP) and the Test and Instruments Cryoplant (TICP) [2]. These cryoplants vary greatly in size and number of equipment which is supplied by different companies with different delivery, installation and commissioning schedules.

Historical and architectural reasons resulted in a cryoplant equipment arrangement as illustrated in figure 1. All cryoplant compressor systems are situated in the compressor building that is connected via an underground duct to the coldbox hall containing all three coldboxes. The main work of the interconnecting piping between the buildings and along the walls fell on ESS because all piping for all cryoplants share the same space, the same support structures and often the same utility headers. For this reason, ESS developed the required technical documentation for the interconnecting piping, particularly P&IDs, interface, piping, valve and instrumentation specifications and lists. In order to facilitate pre-commissioning activities and operation a set of specific P&IDs covering the commonly used headers was also produced. The cryoplants share cooling water circuits, instrument air system, warm nitrogen supply, helium buffer lines and to a certain extend safety relief headers. Furthermore, as also described in [2], the low pressure return lines of TICP and ACCP share an interface in order to enable the TICP compressor to recover the helium from the linac in case of an unexpected power shutdown.

The piping and cabling between the single skids of one cryoplant and from the skids to the pipe ends and T-pieces on the wall is in the scope of the cryoplant suppliers. Due to the reasons given above, it soon became obvious that phases of installation, pre-commissioning and commissioning activities would overlap and different teams of people would need to work in the same time window and area. The next sections describe the related difficulties and how ESS seized the opportunity to develop and implement a digital tool aiming at coordinating multiple in-situ activities performed by contactors in a safe and efficient manner.

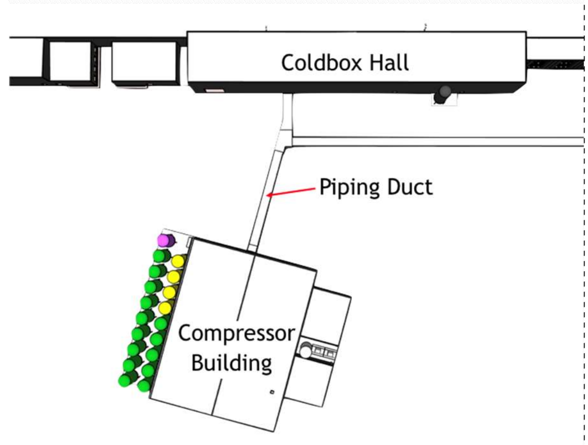

Figure 1. Sketch of the cryogenic building arrangement

Figure 2. Photo of the actual cryogenic building arrangement

2. Main challenges of parallel activities

2.1. Installation preparation

Before installation activities start, ESS requires an Installation Readiness Review (IRR) that is used to capture all relevant documentation and demonstrate that both, the partner who executes the work and the stakeholders at ESS are ready to start.

The main document that is mutually worked on in preparation of the IRR is the Work and Safety Coordination Plan (WSCP) that comprises appendices for, amongst others,

- ESS and site safety rules, site services and conditions
- Method statements and risk analyses for installation and commissioning activities
- Area Hazard Analysis (AHA)
- Equipment lists, installation schedule, transport and delivery plan
- Estimated manpower, tooling, requirements on equipment and storage
- Required safety trainings and applicability of foreign certificates in Sweden

This list is not exhaustive and the WSCP a quite comprehensive set of documents, establishing a safety framework necessary for the preparation of any activities at ESS to be conducted in a safe way.

During installation the relevant safety documentation is updated on a regular basis by the main stakeholders as the work progresses. Moreover, regular work coordination meetings take place and frequent as well as unannounced health and safety rounds are carried out.

2.2. Pre-commissioning activities and its consequences

The pre-commissioning of cryogenic plants starts with mechanical completion including pressure and leak tests and respective quality approval. It consists of a larger number of activities in mechanical, electrical, process and control disciplines. For the purpose of this paper, we concentrate on some process related activities:

- Blow down of gas lines and flushing of cooling water lines
- Evacuation, pressurization and purge cycles with clean helium
- Heating oil adsorbers, dryer beds and cold adsorbers with hot nitrogen for moisture removal

- Checking of valve functions with instrument air

It soon became clear that when pre-commissioning or even commissioning and operation phases coincide with installation phases of equipment in the same place two major risks for the workers on site arise – exposure to flowing media involving high pressure and/or high or low temperatures and oxygen deficiency hazard (ODH). To prevent the first, a *mechanical LOTO* (lock out tag out) procedure needed to be established. The next section describes the tool that was developed at ESS to accommodate mechanical LOTO on the cryogenic systems.

3. A tool for mechanical LOTO

3.1. Preparation

In a first step, the entire cryogenic system was functionally divided into smaller subsystems, e.g. the different cryoplants, the different utilities, the warm storage tanks and the different distribution systems. Each subsystem has an owner and a deputy owner in the cryogenic section.

In a second step, a permission procedure for the pressurization and – inverse – for the depressurization of a process circuit was developed [3]. In this procedure a gate keeper and its deputy have the responsibility to manage pressurization and depressurization requests in a safe manner. To pressurise a circuit, the requester needs to file a pressurisation request along with some information about reason and duration. The gatekeeper then checks with all affected subsystem owners that there is no technical showstopper (e.g. timing, conditions). Upon approval of the affected subsystem owners the gatekeeper is responsible for implementing the required safety measures on site, like marking, signposting, valve blocking, detaching instrument air, solenoids or similar as shown in figure 3 and figure 4. This even includes physical LOTO of pressure sources in many cases, He/she documents these measures and informs the initial requester once the installation has been secured. After the requesters acknowledgement the circuit is ready for pressurisation, the subsystem owners are notified and a list showing the status of each circuit is updated in a digital database.

Figure 3. Example of signposting on valves

Figure 4. Typical warning sign

3.2. Realisation

Now the before-mentioned lists were used to compile a database comprising lines, their branches, interfaces and valves. Atlassian's JIRA was used to create the database and later to realise the permission procedure. JIRA has mainly been developed to deal with bugs and issues in the software industry and is widely used in customer support routines with queues of cases. We have proven however that it can be fairly simply customized to our needs.

All related objects are connected, can be selected and, depending on access rights, manipulated. The database contains a list of the process circuits with the possible states energised, de-energised and unknown. The number of "unknowns" has to and will be minimised over time. As soon as we go into operations "energised" will be the default value.

The pressurization and depressurization requests are listed in a queue where each request represents a case with information filled by requester and gatekeeper. Notification and task acknowledgement emails are sent out automatically.

3.3. Outlook

The source files for the piping database comes from the interconnecting piping documentation that had to be produced at ESS. The limitations are the interfaces for the cryoplant vendor supplied equipment interconnections. This was useful in the early installation stages. However, the lists need to extend to full process circuits terminating at valves rather than flanges. The first task is hence to incorporate the cryoplant vendor supplied skids at least until the next process termination.

Further elements are added to the database as well – safety relief valves, pressure measurements and evacuations ports. This will support substantially capturing the details of a pressurisation / depressurisation and subsequent work orders.

Finally, this database and request tool can be used further on during operation and maintenance in combination with the planned ESS-wide EAM system that takes care of work orders, asset status etc.. Statistical tools offered by JIRA can be applied to find out about increased request frequency in a certain loop or subsystem, potentially indicating issues or process related bottlenecks.

3.4. Summary

The challenges of simultaneous installation and commissioning / operation activities have to be addressed specifically in order to ensure workers health and safety. This cannot easily be dealt with normal job hazard and area hazard analyses only. Instead a complementary look in-depth is required. At the ESS, thanks to the commitment of a cross-functional and multidisciplinary team of cryogenic, safety and IT experts, an innovative tool could be customised that supports these efforts in a systematic way.

One of the core conditions of safe operations is the discipline and commitment of every single worker involved to follow the procedures and systematically involve gatekeeper and subsystem owners during critical activities. The tool itself is rather a documentation instrument whose main purpose is to facilitate communication and enhance synergy between all stakeholders involved.

There is still more work required to make the database more useful, particularly in the operations phase. Related efforts have started and will enable the ESS to benefit from it even more in the future.

References

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