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Human-Performance Tools in Maintenance Work - A Case Study in a Nordic Nuclear Power Plant

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Abstract

The performance of maintenance in nuclear power plants is one of the cornerstones for ensuring safe and efficient operation. Maintenance work is associated with operational and occupational risks. Today, most plants use Human Performance Tools (HPTs) to contribute to reduce these risks. Despite the widespread use of HPTs, the beneficial effects remain elusive. The study was performed in a Nordic nuclear power plant. It addressed three research questions: (1) How do maintenance personnel perceive and use HPTs? (2) How may the intended use of HPTs be promoted in maintenance work? (3) How to introduce HPTs to maintenance personnel? Overall, maintenance personnel had a positive attitude to HPTs. In situations where the use of HPTs made sense to maintenance personnel, they would use HPTs as intended, i.e., attentively and resiliently, focusing on ensuring safety. In other situations, the HPTs might not be used or might be used more superficially. Introduction of HPTs should focus on practical use. The study was carried out within the framework of the Nordic Nuclear Safety Research project HUMAX.

Key words

Human Performance Tools, Maintenance Work

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Abstract

The performance of maintenance in nuclear power plants is one of the cornerstones for ensuring safe and efficient operation. Maintenance work is associated with operational and occupational risks. Today, most plants use Human Performance Tools (HPTs) to contribute to reduce these risks. Despite the widespread use of HPTs, the beneficial effects remain elusive. The study was performed in a Nordic nuclear power plant. It addressed three research questions: (1) How do maintenance personnel perceive and use HPTs? (2) How may the intended use of HPTs be promoted in maintenance work? (3) How to introduce HPTs to maintenance personnel? Overall, maintenance personnel had a positive attitude to HPTs. In situations where the use of HPTs *made sense* to maintenance personnel, they would use HPTs as intended, i.e., attentively and resiliently, focusing on ensuring safety. In other situations, the HPTs might not be used or might be used more superficially. Introduction of HPTs should focus on practical use. The study was carried out within the framework of the Nordic Nuclear Safety Research project HUMAX.

Keywords: Maintenance work, human-performance pools, nuclear power plant

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Executive Summary

The performance of maintenance on plant equipment and machines in nuclear power plants is one of the cornerstones for ensuring safe and efficient operation. Maintenance is associated with *operational* and *occupational risks*. Today, most plants use *Human Performance Tools* (HPTs) to contribute to reduce these risks. Despite the widespread use of HPTs, the beneficial effects of using HPTs remain elusive.

The study was carried out within the framework of the Nordic Nuclear Safety Research (NKS) research project HUMAX. The goal of the NKS HUMAX project is to provide knowledge of the impacts of HPTs, and how to design and effectively implement HPTs, and focus is on maintenance activities in nuclear power plants. The present study was carried out in one Nordic nuclear power plant. It addressed three research questions:

(1) How do maintenance personnel perceive and use HPTs in nuclear power plants?

(2) How may the intended use of HPTs be promoted in maintenance work, based upon insights into the factors that encourage and discourage HPT use?

(3) How to introduce HPTs to maintenance personnel to promote intended use?

Data were collected using interviews and a questionnaire survey, and all data were obtained during year 2013.

HPTs constitute a set of *discrete behaviours*, which are intended to help employees anticipate, prevent and/or catch errors, before they have negative impacts on people, plant or environment (DOE, 2009b, 1). The concept *intended use* was applied to emphasise that HTPs should be used *attentively* and *resiliently* with the aim of *fulfilling their specific functions* – overall: to promote safety, as opposed to merely using them by blindly executing the required behaviour. To achieve resilience, the person applying HPTs must have a certain level of autonomy to exercise personal judgements. In this context *intended* thus refer to the intentions which lay behind the introduction of HPTs in the plant. It was assumed that unless HPTs were used as intended, they could not be expected to contribute positively to plant safety. At the time of the study the targeted plant applied ten HPTs.

The study showed that maintenance personnel held positive views on HPTs: They found that the ten HPTs largely were useful and well-integrated into their work processes. The majority of the participants agreed or partly agreed with the statement: “Overall the use of HPTs at [the plant] contributes to promote plant safety.” Most of the maintenance personnel assessed that safety would be negatively impacted if any of the ten HPTs were no longer used at the plant. Still, the level of negative consequences was expected to differ, depending on the specific HPTs that were no longer used: The negative impacts were expected to be higher if *Pre-Job Briefing* and *Self Checking – STAR* were no longer used, than if *Post-Job Debriefing* and *Task Observation* were no longer used.

The study provided a range of suggestions as to how the *intended* use of HPTs in maintenance work could be promoted. These suggestions were decomposed across three factors: maintenance personnel's *willingness* (motivation), *ability*, and *possibility* to/for using HPTs.

- To be *willing* to use HPTs, the HPTs had to *make sense* to the maintenance personnel. This implied that the use of HPTs was seen as relevant to protect against potential risks in a particular (type of) situation – and *not* as an end in themselves (e.g. to achieve a certain target for the number of uses); that the HPTs matched the situational characteristics (e.g., that their level of performance prescription were adequate vis-à-vis the situation at hand); that they supported task performance directly; that they were as simple as possible; that they were not used routinely, if their function was to promote *special alertness regarding particular issues*, and that they were adaptable.
- To have the *abilities* required to use HPTs as intended, maintenance personnel needed to know *how* to use the HPTs in a practical setting, *when* to use the HPTs, and *why* to use the HPTs, i.e., what functions they were intended to achieve. The last requirement was seen a precondition for maintenance personnel to be able to flexibly adapt HPTs to the characteristics of the situation at hand without compromising safety, in situations where it was not possible to use HPTs as originally planned.
- In addition, maintenance personnel needed *possibilities* for using HPTs. This implied that they had available *time*, *tools* (e.g., database access to identify lessons learned), *physical space* (e.g. ability to monitor), and *required competence* (i.e. access to staff members), which allowed then to use HPTs as intended.

Finally, *Group climate* was identified as an overall factor, which impacted the use of HPTs, both with respect to the (perceived) *possibility* for using HPTs (e.g., management prioritization between effectiveness and thoroughness), and maintenance personnel's willingness to use HPTs (e.g., the (perceived) consequences of being "caught" in committing an error). Maintenance team leaders play a key role in establishing a *group climate* in which HPT use is expected and encouraged, and in which errors are seen as opportunities for improving future performances, rather than as reasons blaming.

The results suggests that maintenance personnel will use HPTs as the tools are *intended to be used* in line with the introduction of the HPTs in the plant (i.e., attentively and resiliently, focusing on ensuring safety) in situations where they assess that *using HPTs make sense*. In situations where maintenance personnel assess that the use of HPTs does *not* make sense, they may use the HPTs more superficially or not use them at all. In these cases, HPTs cannot be assumed to contribute positively to safety.

Based on the outcome of the study, it was recommended that when HPTs are introduced to experienced maintenance personnel, the introduction should focus on *practical use of the HPTs*: emphasising the overall goal of the HPTs (e.g. 3-way communication is introduced to *reduce the risk for misunderstandings*), demonstrating the benefits of using the HPTs, allowing maintenance personnel to practice use of the HPTs, and to reflect on the consequences of introducing the HPTs on their work activities.

1 Introduction

The performance of maintenance on plant equipment and machines is one of the cornerstones for ensuring safe and efficient operation of nuclear power plants (Reiman, 2011). Overall, maintenance can be said to concern: "combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" (European Standard EN 13306). Maintenance departments at nuclear power plants are responsible for regular maintenance to ensure that plant equipment and machines will not be malfunctioning, i.e., *preventive* maintenance, and for *correcting* equipment when malfunctioning has occurred, i.e. corrective maintenance.

Maintenance is an activity, which is associated with risks, both *operational* and *occupational* risks. Operational risks are risks to safety and/or efficiency of plant operation. This type of risk may occur when equipment is left in erroneous positions (e.g. opened instead of closed), when equipment has been connected in wrong ways, increasing the risk for unwanted trips, etc. Occupational risks are risks to the safety of maintenance personnel and/or other personnel on the site. They may occur due to, e.g. inadequate isolation of electrical systems or systems carrying hot steam, inadequate barriers against falling when working on high locations, inadequate barriers against radiation. Error during maintenance may in some situations have immediate impact on plant or personnel safety, or create latent conditions, which increases the risk for incidents and accidents over time.

Inadequate maintenance has been found to be one of the main contributors to unwanted events in high-risk industries (e.g., Reason, 1997, Baker, 2007). With respect to nuclear power plant operation, Gertman et al. (2002) assessed that inadequacies in maintenance (i.e. in maintenance practices and maintenance work-control errors) were present in 76% of the 48 licensee events they analysed.

Today, *Human Performance Tools* (HPTs) are used in most plants to contribute to reduce the risks, operational as well as occupational, associated with performance of the maintenance tasks. HPTs constitute a set of *discrete behaviours*, which are intended to help employees *anticipate*, *prevent* and/or *catch errors*, before they have negative impacts on people, the plant or the environment (DOE, 2009b, 1). They include practices such as, e.g., *Peer Checking* and *Independent Verification*. Usually, HPTs are introduced in a nuclear power plant as part of a *Human Performance Program*. These programs are often developed by practitioners (Oedewald, et al. 2014) and disseminated and based on insights gained from informal networks and international bodies, such as INPO (1997, 2006a) and WANO (e.g., 2002, 2006). HPTs are used by managers, supervisors, engineers and technicians, but are mostly associated with performance at the *sharp end*.

HPTs are developed based on a set of *human performance* principles concerning the observable acts of people, i.e. what they do and say, as well as the outcomes of these acts (DOE, 2009a, 1-19 – 1-20):

- People are fallible, and even the best people make mistakes.
- Error-likely situations are predictable, manageable, and preventable.
- Individual behavior is influenced by organizational processes and values.
- People achieve high levels of performance because of the encouragement and reinforcement received from leaders, peers, and subordinates.
- Events can be avoided through an understanding of the reasons mistakes occur and application of the lessons learned from past events (or errors).

HPTs are intended to contribute to promote safety. Safety can be defined as "...the system quality that is necessary and sufficient to ensure that the number of events that can be harmful to workers, the public, or the environment is acceptably low" (Hollnagel et al., 2013, 6). HPTs are typically seen as part of the barrier system in an organization (DOE, 2009a). Still, the barriers, which relay on human intervention, are not considered to be the most reliable. DOE, e.g., emphasises:

> "Controls, barriers, or safeguards tend to be more reliable when they are not dependent on people to carry out their protective functions." (ibid, 3-4.)

Modern safety research though points out that events are not necessarily predictable and thus manageable nor preventable. This is due to the complexity and tight couplings in today's safety-critical production systems (Perrow, 1984).

Despite the widespread use of HPTs, the beneficial effects of using HPTs in nuclear power plants remain elusive (Oedewald, et al., 2014). As far as we have been able to determine, no studies have been carried out to determine how much using HPTs contributes to increase the safety level in a nuclear power plant.[1] Proponents and opponent of HPTs may present a series of arguments, depending on their theoretical outlook. Put very squarely, proponents for HPTs tend to be associated with the *behavioural safety approach*, represented, e.g. in the above assumptions presented in DOE (2009a). Critiques of HPTs tend to be associated with organisational safety approach, which emphasise the impact of organisational factors on safety, rather than the impacts of individual (e.g. Anderson, 2007; Hopkins, 2006). The debates can be hard to settle, because *no commonly acceptable method exists for assessing the impact of HPTs on operational and occupational safety*. Table 1 on page 8, which is based on Oedewald et al. (2014), summarizes a subset of the potential advantages and disadvantages that are debated.

[1] We would be grateful for information about such studies: ann.britt.skjerve@hrp.no and/or christer. axelsson@vattenfall.se.

In addition, different HPTs are applied at nuclear power plants[2], and the question about the impact of HPTs on safety may also be impacted on the characteristics of the specific HPTs a plant applies.

The present study is carried out within the framework of the Nordic Nuclear Safety Research (NKS) research project HUMAX. HUMAX aims at providing knowledge of the impacts of the HPTs and how to design and effectively implement HPTs. The focus of the NKS HUMAX project is on maintenance activities.

Table 1. Potential advantages and disadvantages of HPTs.

Potential advantages of HPT	Potential Disadvantages
Instilling sound work practices that will help reduce the risk for *human errors* (DOE, 2009a).	Increase task complexity and/or the time it takes to perform a task, and thus the risk employees may take short-cuts (Hollnagel, 2009). Variability gives flexibility, and should not be entirely eliminated (Hollnagel, 2009).
It cannot be assumed that all risks in the system [plant] has been identified and dealt with and employees [maintenance personnel] have to be alert (Wachter and Yorio, 2013)	Focusing mainly on occupational safety (Anderson, 2007)
Contributing to create high level of risk awareness in the organization (DOE, 2009a).	Focusing on risks associated with performance, rather than system safety, i.e. the overall characteristics of the performance context (e.g. Hopkins, 2006)
Tools to support the performance of the operators avoid errors.	Blaming the operators for errors: Lack of thoroughness using HPTs.

The study addressed ten HPTs: *Clear Communication Techniques*, *Independent Verification*, *Peer Checking*, *Pre-Job Briefing*, *Post-Job Review*, *Procedural Use and Adherence*, *Questioning Attitude*, *Self-checking - STAR*, *Task Observation/Coaching*, and *Use of Operating Experience* (see Appendix D for a detailed description of each HPT).

[2] For an overview of HPTs see DOE (2009b).

The ten HPTs differ on several dimensions. One of these dimensions concern the level of performance prescription, addressed by Resilience Engineering (Hollnagel, 2006): The ten HPTs can be grouped into four categories, depending on their level of performance prescription (see Figure 1): The highest level of performance prescription is associated use and ***adherence to procedures*** (*Procedural Use and Adherence).* This is followed by a group of HPTs covering work practices for ***catching errors*** during or following task performance. Next is a group of HPTs, which is mainly aimed at promoting safety based on ***sharing insights and experiences to promote performance*** in various ways. Finally, the lowest level of performance prescription comprises two HPTs that simply aim at ***sensitising maintenance staff to unexpected states/events*** (*Self-checking - STAR* and *Questioning Attitude*).

Figure 1. The ten HPTs addressed in the study, structured according to their level of performance prescription.

The HPTs located in the category, ***Sensitizing to unexpected states/events***, are intended to be applied in a broad range of situations that are not fully specified in advance. They constitute what has been called *mindful safety practices* (Skjerve, 2008), i.e., discrete safety promoting work practices that may prevent the initiation of and/or interrupt unwanted but *not explicitly anticipated* types of event sequences. These HPTs may, thus, offer a *buffer functionality* to absorb excessive performance variability (cf. Hollnagel et al., 2013, 14). Seen from this perspective, this group of HPTs is aimed at ensuring that *everything goes right*, and may be associated with the safety management approaches described as *Safety-II*: "... the system's ability to succeed under varying conditions, so that the number of intended and acceptable outcomes (in other words, everyday activities) is as high as possible" (Hollnagel et al., 2013, 17). The HPT in the group *Promoting adherence to procedures/instructions*, on the other hand, rather aims at ensuring that *as few things as possible go wrong*, by prescribing how tasks should be carried out, and may thus be related to the safety management approaches described as Safety-I (Hollnagel et al., 2013).

The study was performed as part of the HUMAX project (Oedewald, et al., 2014). It addressed three research questions:

(1) How do maintenance personnel perceive and use *Human Performance Tools* (HPTs) in nuclear power plants?
(2) How may the *intended* use of HPTs be promoted in maintenance work, based upon insights into the factors that encourage and discourage HPT use?
(3) How to introduce HPTs to maintenance personnel to promote intended use?

The concept *intended use* was applied to emphasise that HTPs should be used *attentively* and *resiliently* with the aim of *fulfilling their specific functions* – overall: to promote safety, as opposed to merely using them by blindly executing the required behaviour. To achieve resilience, the person applying HPTs must have a certain level of autonomy to exercise personal judgements. For example, *Peer checking*, will only contribute to promote safety, if the *Peer checker* attentively follow the task performance of the *Peer*. If he merely watches the Peer's performance without actively monitoring for errors/unwanted events, the likelihood that Peer Checking will contribute to promote safety is limited. A similar emphasis can be found in DOE (2009b):

> "Safety is not obtained by mindlessly applying human performance tools but rather by people conscientiously applying their knowledge, skills, experience and insights, as well as the tools to accomplish their work goals" (*ibid.,* 1).

It was assumed that unless HPTs were used as intended, they could not be expected to contribute positively to plant safety.

The present study is a case study. It is based on data obtained from *one* Nordic nuclear power plant. This implies that a range of contextual factors may bias the outcome, such as work organisation, training schedule, leadership model, etc. *For readers interested in applying the insights gained in the study in relation to their home plant, it may be useful to focus at the factors identified in the report to encourage and discourage the use of HPTs to determine if these factors are present or absent in the home plant.* The report is organised as follows: Chapter 0 provides a brief introduction to the plant addressed in the study, focusing on maintenance work and the HPTs applied. Chapter 3 describes the method used to collect and analyse data. Chapter 0 presents and discusses the *global* outcome of the study: Maintenance personnel's overall perception and use of HPTs; Factors promoting intended use of HPTs in maintenance work, and lessons learned on how to introduce HPTs to maintenance personnel. Chapter 5 contains a short summary of the findings and the conclusions. **Note that an Extended Summary of the study can be found in the beginning of the report**. The Appendix contains four parts. Appendix A: Business case for the potential Return on Investment (ROI) of Human Performance at the Targeted Plant; Appendix B: Interview Guide; Appendix C: Questionnaire Survey and Appendix D documents the detailed findings in relation to each of the HPTs applied: *Clear Communication Techniques, Independent Verification, Peer Checking, Pre-Job Briefing, Post-Job Review, Procedural Use and Adherence, Questioning Attitude, Self-checking - STAR, Task Observation/Coaching,* and *Use of Operating Experience*. **For readers, which are specifically interested in the lessons learned regarding one or more of the individual HPTs, see Appendix D.**

2 The Targeted Plant

Prior to the formal introduction of HPTs at the Nordic nuclear power plant targeted in this study, a subset of the work practices that now constitute HPTs, had already been applied for several years. These were:

- STAR/Self-Checking (applied since the 1980s)[3]
- Procedure Use and Adherence (applied since the 1980s)
- Pre-Job Briefing/Post Job Debriefing (applied since the 1990s)
- Three-Way Communication - *only for control-room operators* (applied since the 1980s)

A formal Human Performance Programme with additional HPTs was introduced in 2009 to promote safety. The main reason for formalising the specific practices as HPTs[4] was that the practices, which now constitute HPTs, recurrently were found *not* to be used as intended: Important risks were not always adequately identified and addressed in Pre-Job Briefings, Three-Way Communication was not always used in situations, where managers found it was needed, etc. Moreover, the *line organization* had not been able to identify a solution to this problem. The overall purpose of formalising the existing work practices into HPTs was to help ensure that the work practices would be used as intended by plant management. The introduction of the Human Performance Program was *overall* expected *to increase safety* and *to reduce the costs due to unwanted events*. The Human Performance Program, among other things, aimed at promoting correct and systematic use of HPTs. It included a training program on how to use the HPTs. Initially, training was exclusively provided to control-room operators in their simulator training. However already one year after the Program had been implemented, the training program was expanded to also include maintaining personnel using Computer Based Training.

Axelsson (2012, 2013) has executed an elementary calculation on mean value of annual losses over a period of ten years, related to Human Performance issues (see Appendix A for details). The calculation suggests that the *annual* cost savings in reduced occupational accidents following the introduction of the Human Performance Program could be around 500.000 € (and mainly related to outage periods with 1000 staff). Concerning production losses, the *annual* cost savings were estimated to be around 3.000.000 €. The total financial investment in the Human Performance Program's roll-out and basic training during the first two years is estimated to be approximately 500.000 €. The annual cost following year is estimated to 100.000 €. Given these figures, introducing the Human Performance Program provides 35 times in return on the investment (ROI) every single year after the initial implementation phase (3.500.000 € ÷ 100.000 € = 35). Not included in this case is an actual production loss of 9 months in 2011, almost entirely related to Human Performance and at a loss of 250.000.000 €.

[3] Actually, STAR may be described as composed of the two HPTs Self-Checking and Questioning Attitude – Stop if Insure. Hence, the station concerned in this study has superimposed both these HPTs into the well-recognized STAR, as described in their guiding HPT-procedure.

[4] This description is based on what we have been able to determine based on data obtained in interviews, informal conversations and the personal experiences of the second author.

Assuming a probability for one such event per 80 reactor year in a plant comprising of four reactors, will increase the annual cost savings with another 3.000.000 €.

The ten HPTs applied at the plant (see Chapter 1) can be classified slightly different depending on whether the classification is carried out based on the categories used by INPO (2006b) or the categories used by Department of Energy (2009b) (see Table 2).

Table 2. The ten HPTs applied at the plant, as classified using the categories suggested by the Department of Energy (2009b): Individual, work-teams, and management (columns) and the categories suggested by INPO (2006b): Fundamental and Condition - and in addition INPO (2007).

Individual	**Work-teams**	**Management**
Clear Communication Techniques (***Fundamental***)	Independent Verification (***Conditional***)	Task Observation/Coaching (*) (***not classified***)
Procedural Use and Adherence (***Fundamental***)	Peer Checking (***Conditional***)	Use of Operating Experience (*) (***not classified***)
Questioning Attitude (***Fundamental***)	Pre-Job Briefing(*) (***Conditional***)	
Self-checking - STAR (***Fundamental***)	Post-Job Review(*) (***Conditional***)	

(*) = Has a separate guideline at the plant.

In this study, the concept *maintenance personnel* is used as a general reference to all personnel working in the maintenance division of the plant. Maintenance personnel can overall be decomposed into three groups, depending on the *type of maintenance* they perform:

- Instrumentation: Test and service on Instrumentation & Control systems.
- Electrical: Test and service on Electrical power systems and motors.
- Mechanics: Test and service on Mechanical equipment, engines, valves and pumps.

The ultimate safety goal for maintenance work is to protect society from radioactive exposure related to the production of energy. This is done by testing and maintaining the plant and its physical barriers, and to uphold the plant's defence-in-depth (IAEA, 1996).

Each of the above categories of maintenance types and personnel can be further decomposed into staff categories: Technicians, Engineers and Leaders.

- *Technicians* typically work in the plant with hands-on testing, calibration and service of plant equipment and machines.
- *Engineers* typically provide engineering expertise, and develop maintenance programs, plans and procedures.
- *Leaders* manage personnel, execute work planning and support coordination with other sections.

3 Method

The study was based on data collection in one Nordic nuclear power plant during year 2013. This chapter describes the method used to collect and analysed data. Figure 2 provides an overview of this process.

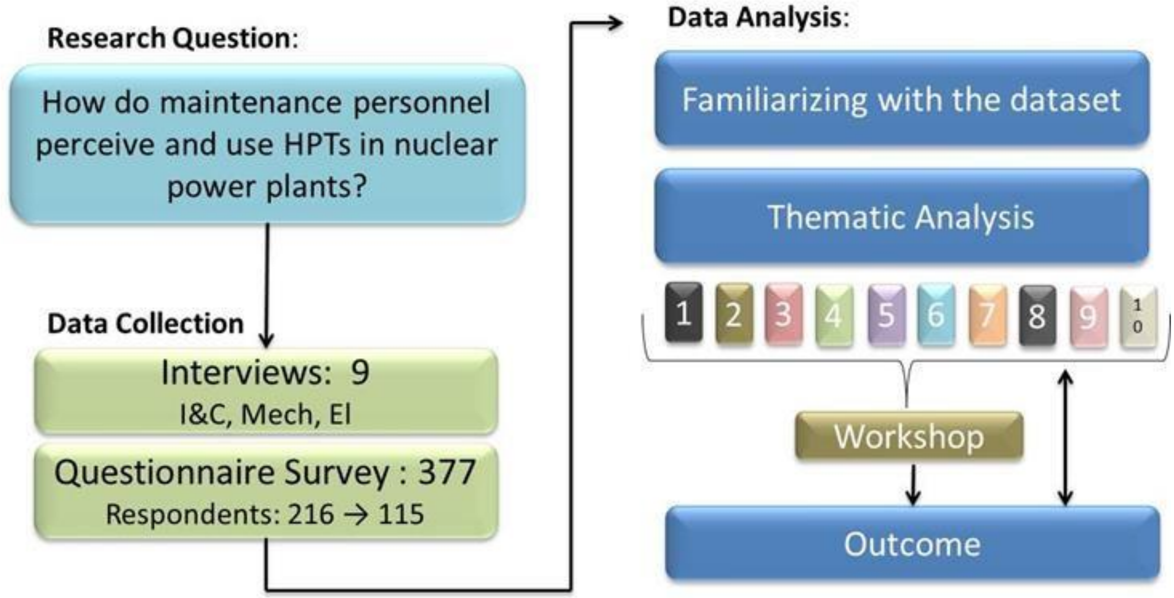


Figure 2. Overview of the data collection and analysis process.

3.1 Data Collection

Data were collected using interviews, a questionnaire survey, and a workshop with maintenance personnel.

3.1.1 Interviews

Nine people from the maintenance department were interviewed to obtain detailed insights into how maintenance personnel perceived and used the ten HPTs, which were a part of the official Human Performance Program at the targeted plant. The interviewees came from three types of maintenance groups: Instrumentation, Mechanics and Electrical. From each group, two Technicians/Engineers and one Leader were interviewed.[5]

The interviews were semi-structured, carried out based on an Interview Guide (see Appendix B). Each interview was adapted to the experience and concerns of the particular interviewees: Some interviewees had particular experiences from using some HPTs, but only limited experiences with others, etc. Six of the interviews were performed prior to the design of the questionnaire survey (see below). The data obtained

[5] For details about the different staff categories, see Chapter 2.

from these interviews contributed to the basis for developing the content of the questionnaire survey.

Three interviews were performed after the questionnaire survey had been completed. These followed overall, the same Interview Guide as the first six interviews, but had added questions based on the answers provided in the survey.

3.1.2 Questionnaire Survey

A web-based questionnaire survey was performed using LimeSurvey(R). The questionnaire survey was distributed to all maintenance personnel at the plant, based on the recordings in the plant internal phonebook (n=337). The identities of the respondents (and non-respondents) were anonymised.

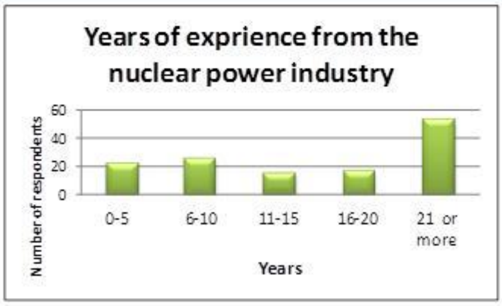
The questionnaire survey contained 73 questions (see Appendix C), including background questions and questions aimed specifically at the respondents perception of the ten HPTs comprised by the *Human Performance Program* at the plant. It was carried out over a period of four weeks in the fall of 2013, with and additional week open for responding a month later to increase the response rate.

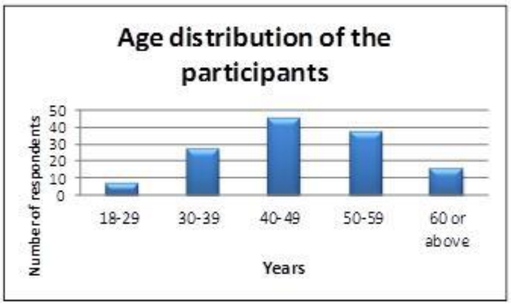
In all, 216 participants responded to the questionnaire (64%), of these, 81 participants responded to *all* of the mandatory questions in the questionnaire (24%). In practice around 115 respondents answered most or all of the questions (34%). This response rate falls within the scope of what is usually expected for web-based questionnaire surveys, i.e., 30-40% (Survey Guide, 2010).

The characteristics of the participants are summarized in Table 3 on page 15: All categories of staff in the maintenance departments participated in the study: Leaders, Engineers and Technicians from the three maintenance disciplines: Instrumentation, Mechanics, and Electrical. The number of participants, who had worked in the nuclear power plant industry for 10 years or less (48 persons) and 21 year or more (53 persons) were quite similar with a group of in-betweens on (23) persons. In all, 60% of the respondents belonged to the age group 40-59, and the respondents were distributed across all the disciplines comprised by the maintenance departments.

Table 3. Characteristics of the participants in the questionnaire survey (n = 136; and 3 = "no answer").

Position	Number of respondents
Manager	20
Supervisor	7
Planning & Coordination	7
Electrical Engineer	13
I&C Engineer	16
Mechanical Engineer	16
Quality and Analysing Engineer	10
Electrical Technician	9
I&C Technician	8
Mechanical Technician	16
Other	11
No answer	3
Total	**136**





3.1.3 Workshop

The outcome of the first (preliminary) part of the data analysis was presented at a 2-hour workshop organised at the plant. In all, 38 people, mainly from the maintenance department, participated in the workshop. The discussions at the workshop, as well as the insights provided by individual participants, were used to support interpretation of the data obtained. In particular, it contributed to the description of issues of concern (positive or negative) with respect to the individual HPTs.

3.2 Data Analysis

Data were analysed using a *thematic analysis approach* (Braun & Clarke 2006). A thematic analysis approach is a qualitative research method that makes use of labelling and iterative restructuring of data segments, to identify patterns (themes). The following procedure was applied to analyse the dataset:

Phase 1:

Familiarizing implied listening through the tape recordings and reviewing notes from the interviews, browsing through the descriptive statistics generated by LimeSurvey® and reading through the answers provided in free-text response format to the survey.

Phase 2:

Data were structured using the ten HPTs as overall grouping variables. Within and across these grouping variables themes were established based on topics that emerged during the analysis process. In addition to this, a special grouping variable was established called “*Introduction and training of HPTs*” based on the third research question (see Chapter 6).

Phase 3:

The *detailed* analysis of data implied that separated analyses where carried out for each of the ten HPTs, using all data, which had previously been associated with this HPT. The detailed analysis focused on three issues: use and perceived usefulness, factors promoting use, and factors working against use of the HPT. In addition, we extracted lessons learned on how to introduce HPT’s to maintenance personnel.

Phase 4:

The *global* analysis implied that the factors identified in relation to the individual HPTs were jointly analysed to understand how the different themes (e.g. leadership, trust, time pressure) might impact the use of HPTs. To understand how the *intended* use of HPTs can be promoted (or hindered) in maintenance work, factors identified to encourage and discourage use of the individual HPTs were re-analysed from a global perspective: They were re-structured into three categories: willingness, ability, and possibility to obtain insight into how to promote the intended use of HPT.[6] Then, data on ‘introduction and training of HPTs’ were structured to be readily related to processes for design programs aimed at introducing maintenance personnel to HPTs.

[6] This distinction had earlier been found to be useful for studying mindful safety practices (Skjerve, 2008).

4 Results and Discussion

This chapter presents the outcome of the *global* analysis of the data obtained in the study. The *detailed* findings for the ten individual HPTs are reported in Appendix D.

4.1 Maintenance personnel's Overall Perception and Use of HPTs

Overall, maintenance personnel at the targeted plant were positive to HPTs: 88% of the respondents found that HPTs were generally useful and well-integrated into their work practices, whereas only 5% considered HPTs as superfluous "add-ons" to their work practices. Of the 7%, who selected the response alternative ”Other", about half held negative and half positive views on HPTs (see Figure 3).

More than 74% of the maintenance personnel, who participated in the questionnaire survey, fully or partly, agreed that the use of HPTs contributed to promote plant safety (see Table 4 on page 18).

For each of the ten HPTs, maintenance personnel were asked to assess what they expected the safety impacts would be if the particular HPT was no longer applied at the plant. They were asked to assess the impact on operational (plant) safety and occupational (personnel) safety separately. When answering, they could select *one* of three response options: the safety level would increase, remain the same, or decrease.

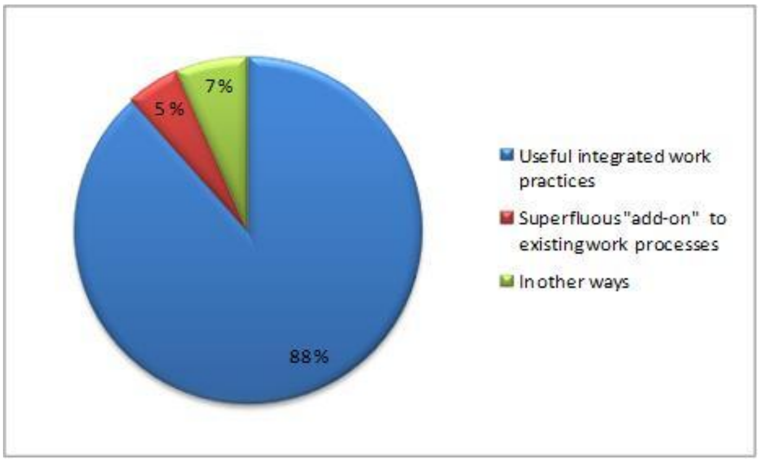
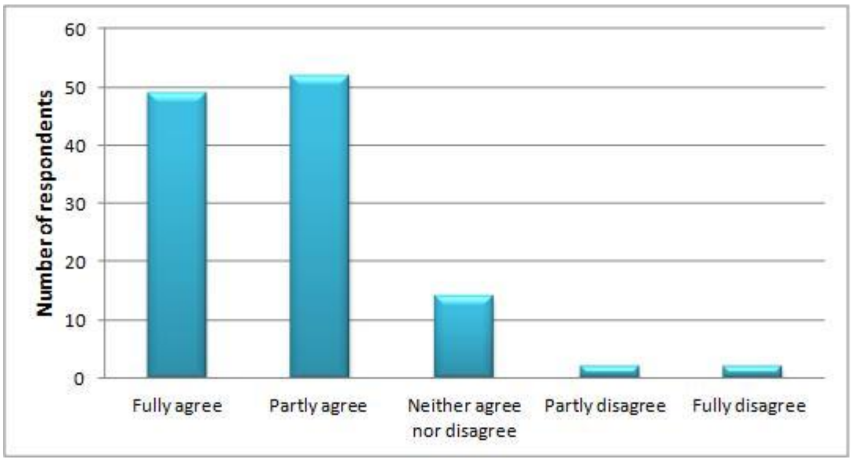


Figure 3. Maintenance personnel's relative use of HPTs, while performing routine and non-routine tasks.

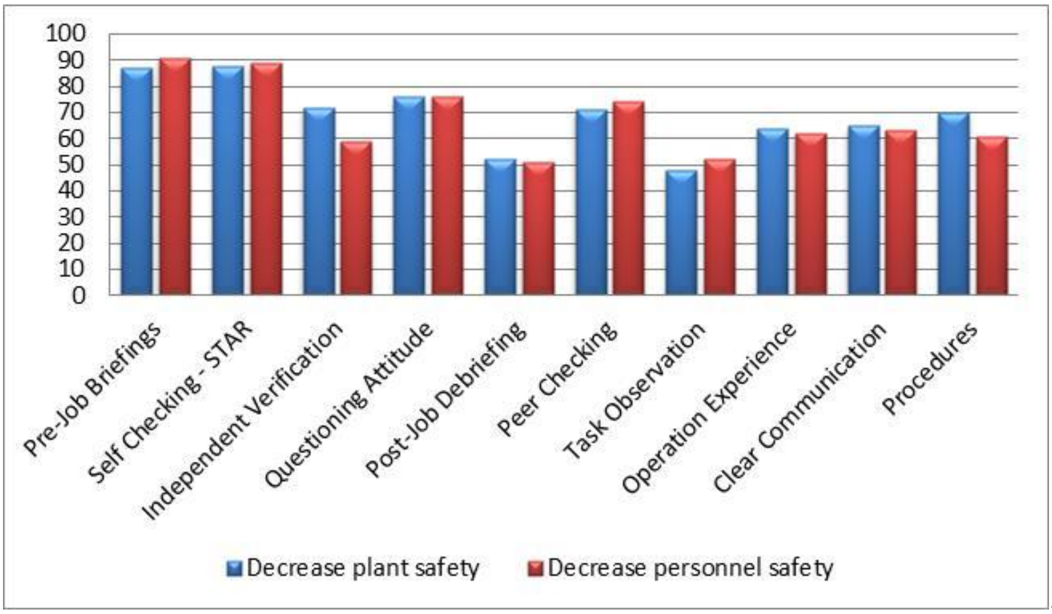
In all, 844 responses were provided, including both plant and personnel safety. Focusing on the impact on the safety level of the plant, 2% of the responses suggested that the safety level would increase, 16% suggested that it would remain the same, and 82% suggested that it would decrease. The corresponding results for the safety impact on personnel safety were: 2%, 18% and 80%.

Table 4. Maintenance personnel's level of agreement in the statement: "Overall, the use of HPTs at [the plant] contributes to promote plant safety"



In, the assessments of *negative impacts on safety* are decomposed across the ten HPTs. It can be seen that the negative impacts on safety are expected to be relatively higher if *Pre-Job Briefing* and *Self Checking – STAR* are no longer used, than if *Post-Job Debriefing* and *Task Observation* are no longer used (see Table 5 on page 18)

Table 5. The number of maintenance personnel (scale to the left), who assessed the negative impact on plant and personnel safety if the various HPTs were no longer used at the targeted plant.



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The interviews suggested that this assessment is most likely impacted by the frequency with which the individual HPTs are used today: that the negative impacts of no longer using HPTs, which are rarely used today, will be less, than the negative impacts of no longer using HPTs, which are used extensively today.

Based on this consideration, the survey also asked the respondents to report how frequently they used the individual HPTs (see Table 6 on page 19). The results showed that Post-Job Debriefing and Task Observation were the two least used HPTs, when aggregating responses indicating daily and weekly use. Those were also the HPTs that were expected to impact safety (relatively) least if no longer used. Still, when considered overall use across a year, both Clear Communication Techniques and Independent Verification were reported to be used less often than Post-Job Debriefing and Task Observation. The results further showed that Self Checking – STAR was the HPT, which maintenance personnel used most frequently, across all intervals: daily, weekly, every month, every third month, every half year, and yearly. This HPT was also among the two judged to impact safety most negatively, if they were no longer used

Still, with respect to the other HPT, which it was expected would have the most negative impact, if no longer used, *Pre-Job Briefing,* the results were not as clear. Pre-Job Briefings are among the HPTs, which are used the least on a *daily* and *weekly* basis (see 6). Still, when accumulating on *every third month*, *every half year*, and *yearly*, it is among the 2-3 most frequently used HPTs. Thus, there seems to be a relationship between the frequency with which the HPTs are used and the assessed negative impact on safety of no longer using them, but frequency alone does not seem to provide a whole answer for the assessments.

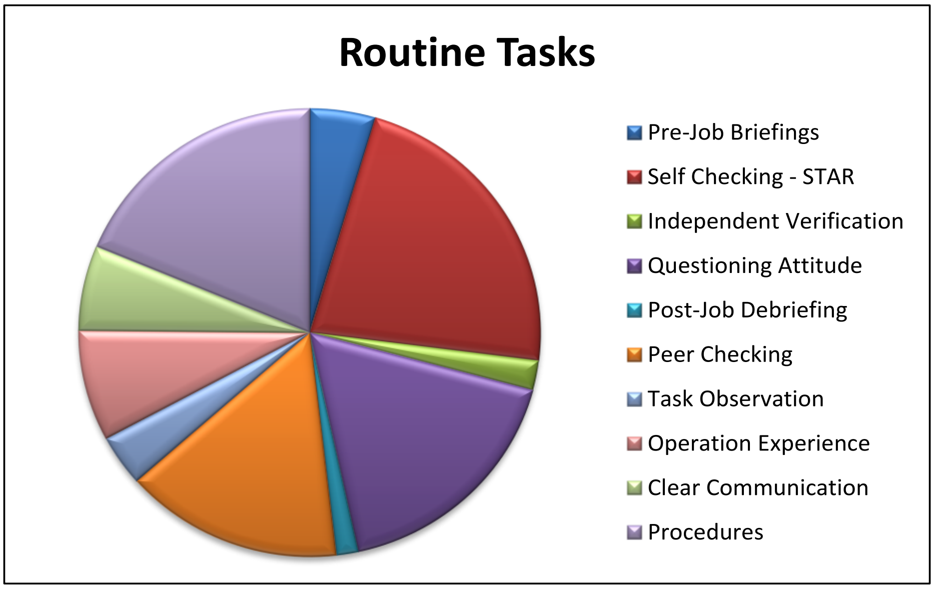
Table 6. Accumulated frequencies of use, decomposed across the ten HPTs applied at the targeted plant.

HPTs	Daily	Weekly	Every month	Every third month	Every half year	Yearly	Less than once a year
Pre-Job Briefing	3	8	38	64	71	89	103
Self Checking – STAR	44	70	83	88	88	94	95
Independent Verification	3	8	17	22	25	44	92
Questioning Attitude	29	47	61	69	70	80	86
Post-Job Debriefing	0	1	6	20	32	54	84
Peer Checking	31	44	54	63	64	69	81
Task Observation	0	1	16	22	29	50	79
Operation Experience	5	18	35	43	51	62	77
Clear Communication	8	19	29	33	38	42	76
Procedures	34	56	64	66	69	73	76

The results presented in Table 6 showed that maintenance personnel at the targeted planed used all of the ten HPTs, but with different intervals. To obtain more insights with respect to how maintenance personnel used HPTs, the questionnaire respondents were asked to mark which of the HPTs they used when performing *routine tasks* and which they used when performing *non-routine* tasks. It should be noted that it was possible to select the same HPT in both conditions.

The results (see Figure 4) showed that *Self Checking – STAR, Questioning attitude, Peer Checking* and *Procedures* were the HPTs most frequently used in relation to performance of routine tasks. This corresponded to the sets of HPTs that had the highest reported *daily* frequency of use in Table 6.

Overall, the outcomes of overall findings in the study suggest that maintenance personnel use the HPTs, which they find contributes most to promote safety – and vice versa, depending on the situation at hand.



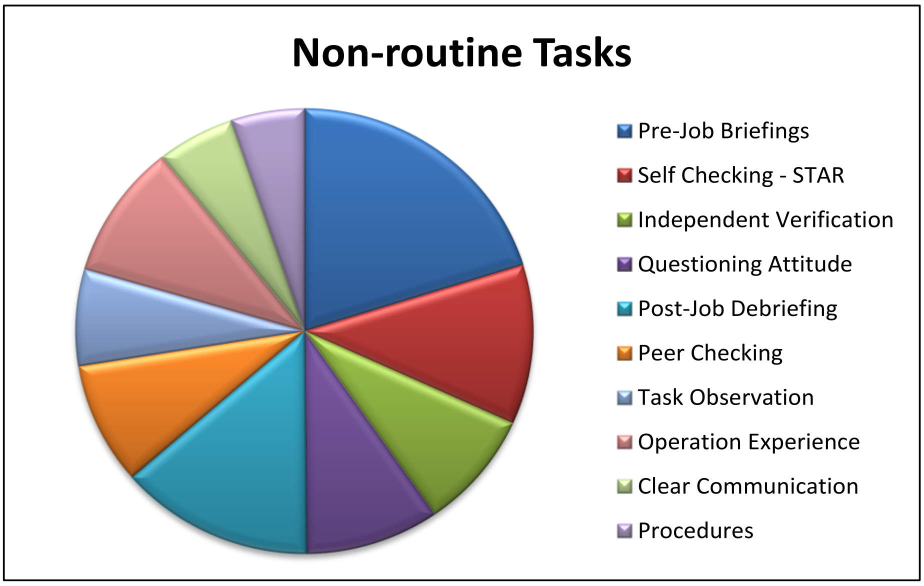


Figure 4. Maintenance personnel's relative use of HPTs, while performing routine and non-routine tasks.

4.2 Factors Promoting Intended Use of HPTs in Maintenance Work

Both the interviewees and the questionnaire respondents were asked about what factors that might *encourage or discourage* them from using each of the ten HPTs. These questions were included to obtain insights into how an organisation might promote the use of HPTs. In the analyses, distinctions were made between factors, which promoted *intended* use (see Figure 5 on page 22), and factors, which promoted use in other ways.

An analysis was carried out to determine what factors *maintenance personnel* found promoted or worked against intended use of HPTs. Data obtained from the interviews and the questionnaire survey was structured in two broad categories, and the issues mentioned most frequently were identified and documented. The factors, which maintenance personnel most often mentioned promoted intended use of HPTs, included: Situations in which safety is perceived to be *at risk*, i.e., typically when complex, non-routine tasks are to be performed; When the use of HPTs does not take more time than necessary (i.e. when the HPT is well-adapted to the situation at hand, when they are scalable); When colleagues expect HPTs will be used and/or when it feels natural to use HPTs; When the resources needed to use HPT are readily available (e.g. tools and people with the needed technical competence); When colleagues have sound interpersonal skills and are able to provide feedback in a constructive and respectful way; And, when the culture in the group/plant is learning – rather than blaming - oriented. Factors working against the use of HPTs imply the opposite of the above. Figure 5 summarizes the outcome of this part of the analysis.

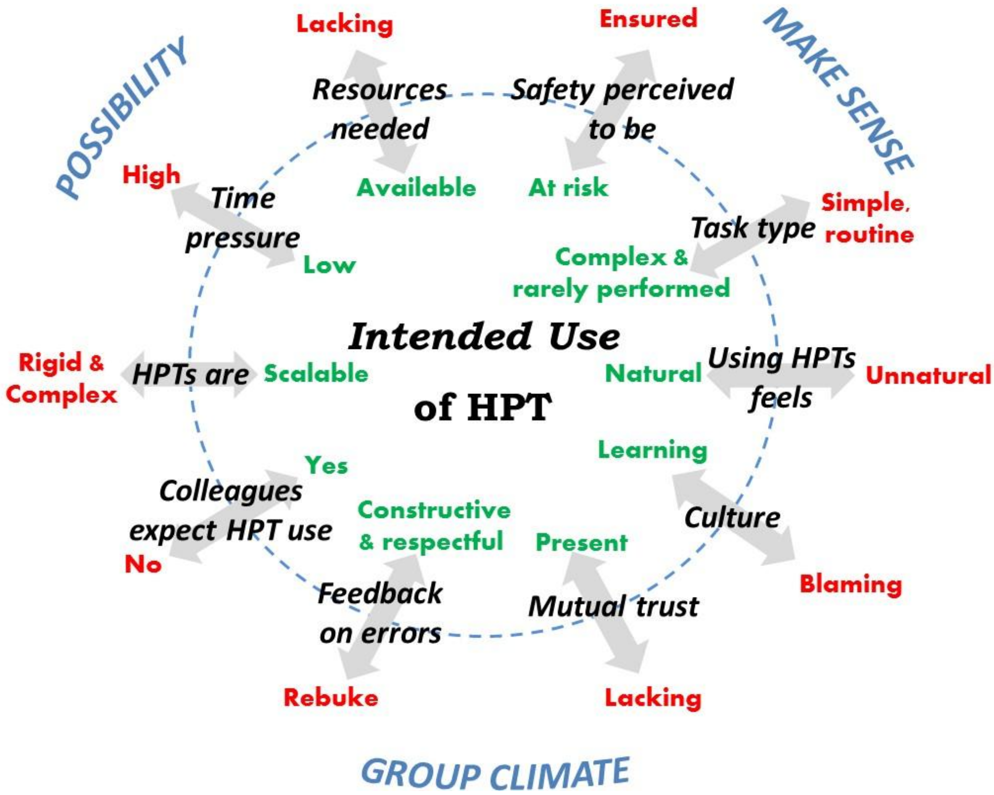


Figure 5. Factors affecting the likelihood that HPTs will be used as intended based on an analysis of the most typical responses provided by maintenance personnel.

Overall, the analysis showed that multiple factors may positively or negatively impact the extent to which HPTs will be used as intended. These findings may contribute to account for drifts in safety practices, as described by Rasmussen (1997).

Following this, a detailed analysis was performed to obtain a better understanding of the factors that impact the extent to which HPTs will be used as intended. The data obtained in relation to the ten individual HPTs (see Appendix D) were re-classified, structured using three basic categories assumed to be required to succeed with mindful safety practices: willingness, ability, and possibilities (Skjerve, 2008). It was thus assumed that these three overall conditions had to be in place to promote *intended* use: maintenance personnel should be *willing or motivated* to use the HPTs, have the *abilities* to use the HPTs, and have *possibilities* using the HPTs. It should be noted that these categories are not mutually exclusive. A key reason for this is that *possibility* for using HPTs to some extent is based on an individual's perception of the constraints in the environment, and part of these perceptions might also be interpreted from the perspective of *willingness.*

The overall outcome of the analysis is summarised in Table 7.

Table 7. Factors contributing to promote intended use of HPTs in maintenance work.

Willingness: *Make sense*	Ability	Possibility
Promote safety - not means in themselves	Understand how & have the ability to use HPTs.	Time available
Match situational requirements	Understand when to use HPTs.	Tools available
Directly support task performance	Understand why using HPTs & be able to *adapt* to requirements in the situation.	Space available (location)
As simple as possible		Competence available
Special attention (conditional)		
Adaptable		

The three following sections will account for and discuss these results.

4.2.1 Willingness to use: Making Sense

From one perspective, HPTs can be perceived as "add-ons" to the work practices required in maintenance operation: It is perfectly possible to perform the technical task without using HPTs and thus, require maintenance personnel *to do something extra* in addition to solving the technical aspects of a task. Maintenance personnel may *use* HPTs simply because they are required by the management, and in this case *willingness to use HPTs* is not a topic of concern. Still, we argue that for HPTs to be used successfully to promote safety (i.e. *as intended*), *willingness* is a key issue: To have the intended safety promoting impact, maintenance personnel needs to apply HPTs *attentively* and *resiliently*, making sound adaptions to the characteristics of the situation at hand (see Chapter 1).

From another perspective, HPTs can be perceived as necessary and integrated elements in the task performance processes of maintenance operations, as they serve as barriers towards unwanted events: In many situations, it will not have immediate negative impact on safety, if HPTs are left out of a task performance process, since errors usually do not occur, but in some situations, they may play a key role in *preventing* unwanted events.

The outcome of the present study suggested that to be used successfully, HPTs must *make sense to* the maintenance personnel, and to *make sense* the use of HPTs must be perceived as a means to *promote safety* –operational and/or occupational safety. This implies that personnel must perceive HPTs, from the latter of the two above factors.

From an overall perspective, it would seem that HPTs are perceived as making more sense if they match the characteristics of the type of situation at hand. *Procedure Use and Adherence* may be perceived as a very useful tool in situations, which can be prescribed in details, whereas *Questioning Attitude* may be more useful when new situations arise. Both during the interviews and in the questionnaire survey, maintenance personnel *objected to* the use of HPTs in situations where HPTs were perceived to be used *as an end in themselves* such as in situations where they were - perceived to be - used mainly to fulfil a *quota* of some kind. *Pre-Job Briefings* or *Task Observations* were examples on HPTs, which sometimes were perceived to be used mainly to fulfil the target sat by plant management on HPT use.

In general, maintenance personnel stressed that the most useful HPTs – and, thus, the HPTs it made most sense to use – were the ones aimed directly at supporting their task performance process. This included, e.g., *Pre-Job Briefing* and *Peer-Cheeking. Task Observation*, on the other hand, was judged by maintenance staff members – but not their leaders – to be among the least important HPTs in this respect.

To promote the use of HPTs in maintenance operation, it was seen as important that the HPTs were *as simple as possible*: If maintenance personnel (perceived) HPTs to be "*unnecessarily complex"* there was a risk that the HPTs would be applied less vigilantly than intended. For example: the procedure for *Pre-Job Briefing* was generally judged to be well-suited to prepare *infrequent* and *complex tasks*, which would involve *staff from different groups/departments*. However, if *Pre-Job Briefing* were carried out in situations, where the tasks to be performed did not hold the above characteristics, the procedure might be perceived as "*unnecessarily complex"*. This could imply, e.g. that a questions contained in a *Pre-Job Briefing* were simply "ticked off" without further ado, because they a priori were decided to be irrelevant in the present situation (e.g. that there would be no risk for radiation during task performance given the location in which tasks should be carried out, etc.). [7]

Maintenance personnel also found that HPTs, which were developed to instil *special alertness regarding particular issues* - i.e. what INPO classify as conditional HPTs (see Table 2 on page 8) - should not be used *routinely*: If this type of HPTs were used, they would come to constitute a part of the daily work practices, and they would help the maintenance personnel to be *generally* alert to safety issues, but not to be *specifically* alert to predefined issues (e.g. critical steps). For the same reason, HPTs such as *Peer Checking* should be used on *critical steps*[8] of the task performance process (as it is intended at the targeted plant), rather than across all steps.

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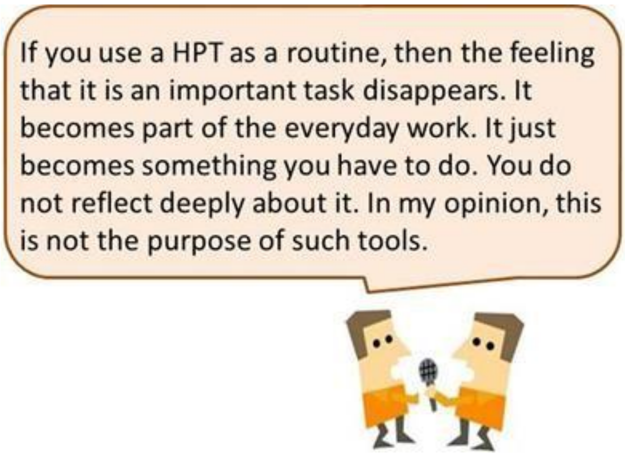
[7] It should be noted that this is a situation, which is well-known, and that the plant has later introduced a Pre-Job Briefing "Light" which is adapted to less complex and comprehensive tasks. The response from outage personnel was positive: the PJB-format made sense to them.

[8] Critical steps are *actions*, which lead to *immediate unwanted events* (plant transients, initiating events, personnel injuries, dangers etc.) if performed inadequately.

Finally, it was found that to make sense to maintenance personnel HPTs must be suitably adaptable. If the rules for when or how to use HPTs were overly detailed and inflexible, it was seen as harder to maintenance personnel to make sense of the HPTs: For example, *Peer Checking* requires one colleague to monitor the task performance of another colleague in real time. Still, in some situations, the physical location in which a job is performed is too small to allow for two persons to be present simultaneously, which exclude the use of *Peer Checking* in a strict sense. Still, if maintenance personnel is allowed to adapt *Peer Checking* to the characteristics of the situation at hand – to best fulfil the *intention* of this HPT – the two participants may work out a way to adapted *Peer Checking* to the situational characteristics and make sure that potential safety issues were adequately handled during task performance.



Participant statement (extract).

4.2.2 Ability to use: How, When and Why

For HPTs to be used successfully, maintenance personnel must *be able to* use the HPTs, and they must know *when* and *why* to use them.[9]

How to use

Maintenance personnel must know how to use HPTs. They must be familiar with the basic practices associated with using the HPTs, and have the ability to adequately apply the HPTs in a practical setting.

The interviews revealed a fair level of uncertainty about how to use some of the HPTs. *Peer Checking* was, e.g., found to mean somewhat different things to different people. One maintenance staff member perceived *Peer Checking* as largely as corresponding to "*Reader Do'er*" (i.e., one colleague reads the instruction, while the other person performs the actions): If the reader focuses on the instructions only, rather than check the activity of the task performer, none of these approaches will help prevent active errors (e.g. to inform the task performer if he works on a wrong valve). Another maintenance staff member explained that when he and his colleague could work on several tasks in parallel, *Peer Checking* was largely seen as a kind of *Independent Verification*: the two colleagues would share and individually perform their tasks and the check on the outcome of each other's tasks performance after task completion: In this situation there would be no Peer Check prior to the implementation of critical steps.

[9] In the following discussion, it will be assumed that the maintenance personnel possess relevant technical competence.

Similarly, *Procedure Use and Adherence* are encouraged by plant management. Still, if maintenance staff adheres to procedures 'blindly', they do not use this HPT as *intended*: Maintenance personnel are expected to always consider, whether the steps prescribed by the procedures are adequate in the particular situation.

A further concern with respect to use of HPTs was related to the HPT *Questioning Attitude*. Several maintenance staff members emphasised that some colleagues confused having a *Questioning Attitude* with simply asking a lot of questions. They reported that some colleagues asked questions, which seemed to serve *other purposes* than contributing to increase safety. In some situations, such series of (perceived irrelevant) questions might even come to contribute to decrease safety, as they distracted the (to be) task performer and/or made it difficult for him/her to uphold a clear focus on the safety issues associated with the job at hand.

Participant statement (extract).

When to use

Maintenance personnel also need to understand *when* to use HPTs. The interviews revealed uncertainly with respect to, e.g., when to use *Clear Communication Techniques* (three-way-communication and using phonetic alphabet). Some staff members tended to find that *Clear Communication Techniques* in principle should be used all the time. Partly due to this (erroneous) assumption, they had developed a somewhat negative attitude to this HPT: If they used *Clear Communication Techniques* the tasks would take significantly longer time, because all steps of the task performance process would have to be repeated and confirmed. When one of the authors explained that *Clear Communication Techniques* usually were intended to be used only in critical steps where misunderstandings might negatively impact safety, the response was: "OK, this makes sense."

Why to use

Maintenance personnel need to know *why* the HPTs are used, i.e. what function they are intended to achieve. This is necessary to establish preconditions, which support maintenance personnel's ability to flexibly adapt their use of the HPTs in situations, where the tools cannot be applied as originally intended, in ways where safety is not compromised.

If e.g., a maintenance staff member knows that *Clear Communication Techniques* are used to avoid misunderstandings *and* he is going to engage in communication with a non-native speaker (in this case of a Nordic language), he might – rather than using the Phonetic alphabet of his own language – use the English Phonetic Alphabet to reduce the likelihood for misunderstandings.

4.2.3 Possibility to use: Access and Resources

The study revealed a set of factors that might impact maintenance personnel's *possibility* – or in some cases their perceived possibility – for using HPTs as intended. Three factors will be addressed here: *Tools* supporting HPT use, *location, time pressure*, and *technical competence*. In addition, a set of factors, which may be associated with *group climate,* will finally be addressed.

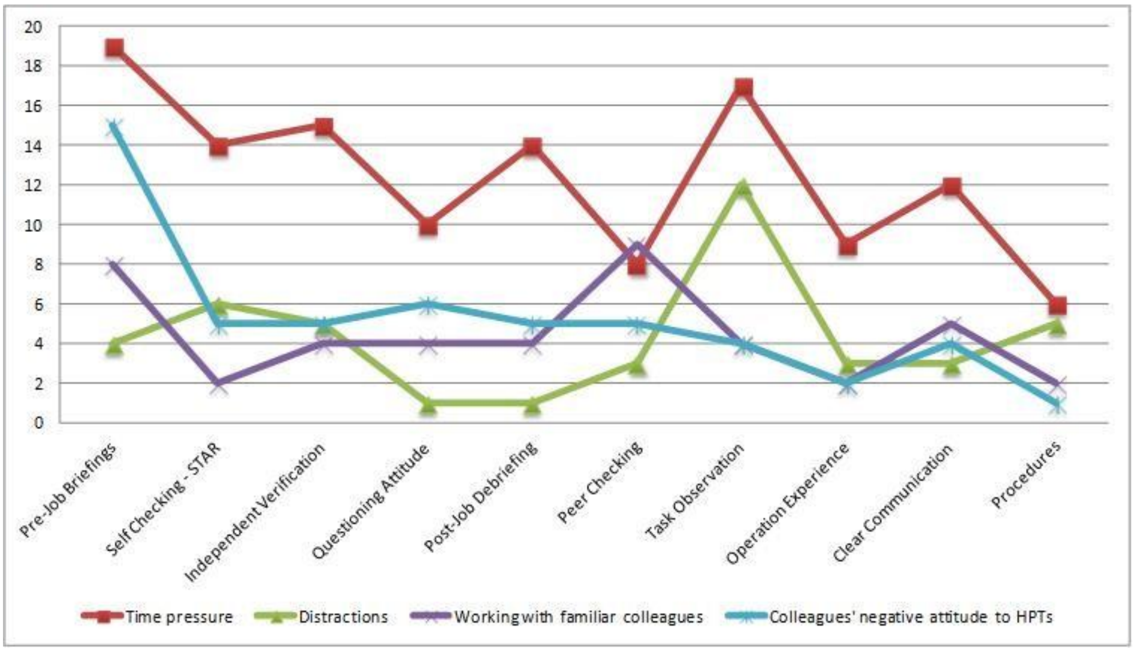
Lack of adequate tools was seen as a key reason why the HPT *Operational Experience* was used with less success than possible: Maintenance personnel reported that they *lacked good tools* for searching through the data based containing *lessons learned*. The implication was that documented lessons learned of relevance for current tasks were not always identified and used.

At the plant, the operational experience is collected in lessons learned (Just-In-Time briefs, JIT) and published on the station intranet. Also, the line organization is supported by special part-time Operating Experience Engineers. However, based on the interviews and questionnaire, it appears that operating experience is a candidate for improvements.

Participant statement (extract).

Time pressure was also a factor that to some extent impacted maintenance personnel's (perceived) possibility for using HPTs. In the questionnaire survey, the respondents were asked to assess the extent to which, time pressure, distractions, working with familiar colleagues, and colleague's holding negative attitude to HPTs, might discourage them from using the ten HPTs. Overall, the effect of these factors would seem to be limited. The most noticeable finding was that time pressure was found to be the factor, which overall had the most pronounced negative impact on the use of HPTs (see Table 8).

Table 8. The extent to which the factors: time pressure, distractions, working with familiar colleagues, and colleague's holding negative attitude to HPTs, might discourage them from using the ten HPTs. The scale to the left represents the number of respondents for each HPT and factor.



Most examples on situations in which *time pressure* was perceived to discourage the use of HPTs were related to *Outages.* During outages, maintenance personnel could sometime feel that the main focus of their leader was *to keep the time schedule.* Perceived time pressure of this type might raise the threshold for using HPTs – and/or for using them with adequate vigilance. Particularly it was mentioned that it might raise the threshold for using *Questioning Attitude* and for taking initiative to call for a *Pre-Job Briefing.*

The *location*, where a task was performed, could sometimes impede that a HPT was used exactly as prescribed: It would, e.g., not always be possible to apply *Peer Checking* because jobs sometimes was performed at locations, which did not accommodate two persons simultaneously. In such situations it would be necessary that the staff members involve would decide in advance how to best ensure safety.

In some situations, *limited availability to staff with needed competence* might discourage the use of HPTs. It might, e.g., be difficult to get hold of a person qualified to carry out an *Independent Verification*, and for this reason the used of unplanned *Independent Verification* might be discouraged.

Group climate was a factor that was generally reported to impact the use of HPTs. It was sometimes described as a factor, which impacted the (perceived) *possibility* for using HPTs, and at other times as a factor, which impacted staff member's *willingness* or *motivation* to use HPTs.

Group climate would seem to most markedly impact the use of HPTs, which implies that a maintenance staff member will seek to *identify errors in a colleague's activity*. This include, e.g., *Peer Checking* and *Questioning Attitude.*

Maintenance personnel reported that pointing out errors in a colleague's work (when having the role as *checker*) could be challenging. A questionnaire respondent e.g. wrote: "*Peer Cheeking* is difficult if a colleague takes it in the wrong way." Taking it in the wrong way might, e.g., imply that the task performer responded with anger or by being embarrassed, and/or interpreted the feedback as a general lack *of trust in his/her* professional skills.

Participant statement (extract).

Several maintenance personnel also pointed out that some colleagues were *poor at providing feedback to others*. This might imply that their feedback was easily perceived as rebuke.

A questionnaire respondent described that he felt *very uncomfortable* in situations, where an error, he had committed, was discussed by colleagues and leaders in plenum, even though he knew the aim of the discussion was that everybody should learn from what had happened. He felt embarrassed. This type of response might contribute to reduce the possibility for addressing and learning from mistakes.

In addition, the expectations of co-workers was found to impact the use of HPTs. Control-room operators at the targeted plant *expected* that maintenance personnel would use *Clear Communication Techniques,* e.g., when reporting long tag numbers to avoid misunderstandings. Maintenance personnel were aware of this expectation, and (for this reason?) used *Clear Communication Techniques* in this type of exchanges. However, when maintenance personnel communicated the exact same information to contractors, who *did not expect* them to use *Clear Communication Techniques*, several staff members reported that it felt '*unnatural'* to use *Clear Communication Techniques*. Instead, they would make sure that the tag number was accurately understood by the contractors using other means.

Establishing of a *Group Climate* in which maintenance personnel are *expected* and *encouraged* to use HPTs is thus of key importance for promoting the use of HPTs among maintenance personnel. It is important to ensure that errors are seen as opportunities for improving future performances, and not as a reason to *blame* staff members. Maintenance group leaders (and their leaders) play a key role in establishing and upholding this type of *group climate*, by formulating expectations, providing coaching, recording/storing lessons learned, and making sure that the lessons learned are actively used to improving future performance.

4.3 Lessons Learned on Introduction of HPTs to Maintenance Personnel

The questionnaire survey revealed that the majority of the maintenance personnel at the plant had been introduced to the HPTs via courses and other types of internal education (see Table 9).

Table 9. How the survey respondents were introduced to HPTs (n=80) - free text response format.

Courses / Internal Education	Division Meetings / Group Leader	Lanyard cards / Brochures	Daily practice / General communication	Other
44	13	11	16	11

During the interviews, the interviewees were asked to give advice on how HPTs should be introduced to maintenance personnel in plants, which had not used HPT before. The key advice was that the introduction allowed maintenance personnel to *see the practical use of the HPTs, as early as possible in the introductory process.*

Participant statement (extract).

Overall, both the data obtained in the interview sessions and from the questionnaire survey, showed that the question of *how to introduce HPTs* was answered differently, depending on whether the introduction was aimed at *experienced maintenance personnel* or *newcomers.*

Participant statement (extract).

At least a sub-set of the practice that are introduced as HPTs in a plant, will (most likely) have served as common work practices prior to their introduction as HPTs.[10] When *experienced maintenance personnel* are introduced to these practices as HPT, they may tend to perceive the introductory process as a *strengthening* and/or a *formalization* of existing requirements.

[10] At the targeted plant, e.g. a substantial part of the ten HPTs applied existed as required work practices before they were jointly introduced as HPTs (see Chapter 2).

Still, even though the work practices introduced as HPTs might have been used at the plant or in particular departments of the plant before, the introduction may still imply changes, i.e., changes in *how* they are used and/or changes in *when* they are used. Prior to the introduction of *Peer Checking as a HPT*, peer checking might have referred to a practice where a person checked the outcome of his colleagues work. Following the introduction as a HPT, it may imply that person should continuously check the critical steps during task performance. Similarly, *Pre-Job Briefings* may earlier have referred to the practice that maintenance personnel talked together informally on a one-to-one basis about how a job should be performed. Following, the introduction of *Pre-Job Briefing* as a HTP, it may imply that a joint meeting is organised between all the participants to discuss how a task should be performed in a safe way.

Participant statement (extract).

The introduction may also imply that existing work practices should be used in a broader range of situation, following their introduction as HPTs. It may, e.g., be required that *Three-Way Communication* is used in more situations than before.

Overall, the introduction of HPTs will often for *experienced maintenance personnel* imply *changes to current work practices.* If work practices, which maintenance personnel perceive function well, suddenly have to be changed to practices, which are perceived to be unnecessarily cumbersome, this may - as formulated by one interviewee - “kill motivation.” It is important to consider this when introducing HPTs, and to motivate personnel to engage in the required change process as a part of the introductory program.

For newcomers at the plant, the situation is different. They will typically be introduced to HPTs as a part of the introductory program to the plant, and they seem to tend to perceive HPTs and the way these are used simply as *the way we work at the plant.*

Several interviewees both experienced and less experienced maintenance personnel emphasised the importance of ensuring that new maintenance personnel were introduced to HPTs as early as possible in their career at the plant. They stressed that this promoted the likelihood that the HPT would be used *as intended*. Several interviewees emphasised that the HPTs can also be seen as a mean for transferring knowledge about how to perform maintenance work safely from experienced personnel to newcomers. Moreover, it was seen as important that experienced personnel served as *role models* with respect to the use of HPTs: Newcomers, which had been introduced to HPTs, would expect that the experienced personnel used HPTs. If the newcomers experienced that the experienced personnel did not use the HPTs, the likelihood that the HPTs would be used as intended, would markedly decrease. Overall, the use of HPTs was perceived to help promote establishment of sound safety-promoting work practices in a maintenance group/department.

Overall, the data further suggests the maintenance personnel – including the leaders - after the introduction should understand *what purpose each HPTs is intended to fulfil*. This will allow them to adapt HPTs to the characteristics of the situation, when needed. In this process, it is if *key importance* that management agrees and clarify to the maintenance personnel, when the HPT should be used *as specified* and when it is OK to achieve the purpose of the HPT using other means. For example: When should *Three-Way Communication* be used as specified, and when it is OK to transfer information to another person using other means to prevent misunderstandings?

Below is some *suggestions* raised to the specific content of introductory programs, based on the insights gained from the study:

- *Introduce the HPTs and motivate* maintenance personnel for using these:
    - Make the *purpose* of the HPTs, i.e. the *functions* they intend to fulfil, clear to the maintenance personnel as early as possible in the introductory program and demonstrate the benefits of the HPTs.
    - A good approach might be to initially show a video accounting for how the use of the HPTs has contributed to prevent unwanted situations in practice. If possible, the video should include interviews with maintenance personnel that have used the HPTs for a long time, about the advantages of using the HPTs.
    - The instructors should clarify in what situations the HPTs should be applied at the targeted plant, and account for the relationship between the HPTs and other work practices at the plant.
    - If the HPTs resembles, but are not identical to, work practices, which has been applied in the plant earlier and/or if they are now expected to be applied in a way, which differs from how they were applied earlier, this should be clarified and motivated.
- Allowing maintenance personnel to *practice* use of the HPT:
    - First, instructors should demonstrate how the HPTs should be used (role play) in a classroom setting and at the same time clarify any issues of concern to the maintenance personnel with respect to this.
    - Second, instructors may show a video demonstrating the use of HPTs, which has been recorded in the targeted plant. The video should be as realistic as possible.
    - Third, the participants should be allowed to practice using the HPTs, e.g. by Human Performance lab’s11 or the like.

[11] This is a lab to promote occupational safety and the use of HPT’s. It comprises practical training stations and informative displays to facilitate reflective dialogues on safety practices, its means and attitudes.

    - If any special competencies are required to use the HPTs as intended, such as e.g. pedagogical competencies for *Task Observation* and *Peer Checking*, this should also be addressed.

- Encouraging maintenance personnel to *reflect* about the impact of using HPTs on their task performance processes:

    - During the introductory session, the maintenance personnel should be provided with an opportunity for reflecting on how the HPTs may contribute to increase safety – how they may come to *make sense* (see section 4.2) in the context of their everyday work. This should include reflections concerning in which situations it would be useful to apply the HPTs, i.e., in which situations the *function*, which the HPTs are designed to fulfil, will be useful.

    - When experienced maintenance personnel are introduced to the HPTs, it is important that they are aware of the positive impacts on safety that follow from adapting and formalizing former practices into HPTs. The instructors should help make this clear to the maintenance personnel.

When HPTs are introduced to newcomers, it might be effective to ensure that the use of HPTs to the extent possible is trained as an integrated part of the technical task training, e.g. training Peer Checking in parallel with a colleague repairing a specific type of valve in a training session. This should promote that HPTs will not be perceived as ‘add-ons’, i.e. as something that may be opted out, but rather as a one of the practices that need to be carried out when the particular type of task is performed.

HPTs are often printed on lanyard cards, which a person may carry with him/her during task execution. However, although the information is perceived relevant by maintenance personnel these are often seen as artefacts without inherent value. Rather, maintenance personnel may be trained sufficiently and continuously to know the HPTs by heart.

5 Summary and Conclusion

The study addressed three research questions:

(1) How do maintenance personnel perceive and use Human Performance Tools (HPTs) in nuclear power plants?
(2) How may the *intended* use of HPTs be promoted in maintenance work, as determined based on insights into the factors that encourage and discourage HPT use?
(3) How to introduce HPTs to maintenance personnel to promote intended use?

The concept *intended use* was applied to emphasise that HTPs should be used *attentively* and *resiliently* with the aim of *fulfilling the function of the specific HPTs*, and overall to promote safety – as opposed to blindly following behavioural performance requirements associated with the HPTs.

The study was based on data obtained from maintenance personnel at one Nordic nuclear power plant, using interviews and a questionnaire survey. All data were obtained during year 2013. The targeted plant applied the following ten HPTs: *Clear Communication Techniques*, *Independent Verification*, *Peer Checking*, *Pre-Job Briefing*, *Post-Job Review*, *Procedural Use and Adherence*, *Questioning Attitude*, *Self-checking - STAR*, *Task Observation/Coaching*, and *Use of Operating Experience.*

Ad 1) Overall, the study showed that maintenance personnel held positive views on HPTs: They found that the ten HPTs largely were well-integrated into their work processes. The majority of the participants, thus, agreed or partly agreed with the statement: “Overall the use of HPTs at [the plant] contributes to promote plant safety.” The majority of the maintenance personnel assessed that safety would be negatively impacted if the ten HPTs were no longer used at the plant. The level of the negative impacts was expected to differ, depending on the specific HPTs that were no longer used: The negative impacts were expected to be higher if Pre-Job Briefing and *Self Checking – STAR* were no longer used, than if *Post-Job Debriefing* and *Task Observation* were no longer used.

Ad 2) The study provided a range of suggestions to how the intended use of HPTs in maintenance work could be promoted. The suggestions were decomposed across three factors: maintenance personnel’s *willingness* or motivation, *ability*, and *possibility* to/for using HPTs:

- To be *willing* to use HPTs, the HPTs had to *make sense* to the maintenance personnel. This implied that the HPTs were used to promote safety, and not as an end in themselves (e.g. to achieve a certain target for the number of uses); that the HPTs matched the situational characteristics (e.g., that their level of performance prescription were adequate vis-à-vis the situation at hand); that they *supported task performance directly*; that they were *as simple as possible*; that they were not used routinely, if their function was to promote *special alertness* regarding particular issues, and that they were *adaptable*.

- To have the *abilities* required to use HPTs as intended, maintenance personnel needed to know how to use the HPTs in a practical setting, *when* to use the HPTs, and *why* to use the HPTs, i.e., what functions they were intended to achieve. The last requirement was seen a precondition for maintenance personnel to be able to flexibly adapt HPTs to the characteristics of the situation at hand without compromising safety, in situations where it was not possible to use HPTs as originally planned.

- In addition, maintenance personnel needed *possibilities* for using HPTs. This implied that they had available *time*, *tools* (e.g., database access to identify lessons learned), *physical space* (e.g. ability to monitor), and required *competence* (i.e. access to staff members), which allowed then to use UPTs as intended.

Finally, *Group climate* was identified as an overall factor. Group climate impacts the use of HPT's in both positive and negative directions: the (perceived) *possibility* for using HPTs (e.g., management prioritization between effectiveness and thoroughness), and the maintenance personnel's *willingness* to use HPTs (e.g., the (perceived) negative consequences of being "caught" in committing an error). Maintenance group leaders play a key role in establishing a *group climate* in which HPT use is expected and encouraged, and in which errors are seen as opportunities for improving future performances, rather than as reasons for blaming.

Ad 3) Based on the outcome of the study, it was recommended that when HPTs are introduced to experienced maintenance personnel, the introduction should focus on *practical use of the HPTs*: emphasising the overall goal of the HPTs (e.g. 3-way communication is introduced *to reduce the risk for misunderstandings*), demonstrating the benefits of using the HPTs, allowing maintenance personnel to practice use of the HPTs, and to reflect on the consequences of introducing the HPTs on their work activities.

Still, the outcome of the study should be considered with some care: Only a subset of the maintenance personnel at the targeted plant participated in the study, more precisely 34% (i.e. 115 people). For this reason, the staff members, who did not take part in the study, may have viewpoints, which have not been covered – or have not been adequately covered. However, there was a high level of correspondence between the results obtained from the interviews, the results obtained from the questionnaire survey, and the feedback provided by participants in the workshop. This adds to the validity of the results.

Based on the outcomes of the study, we conclude that maintenance personnel will use HPTs as the tools are *intended to be used* in line with the introduction of the HPTs in the plant (i.e., attentively and resiliently, focusing on ensuring safety) in situations where they assess that *using HPTs make sense*. In situations where maintenance personnel assess that the use of HPTs does *not* make sense, they may use the HPTs more superficially or not use them at all. In these cases, HPTs cannot be assumed to contribute positively to safety. For example: *Three-way Communication* is usually a good tool for preventing misunderstandings in communication. However, even if the receiver of a message repeats it correctly back to the sender, it is not certain that the receiver actually has understood the message (e.g. a newcomer to the plant may be able to repeat back messages without understanding the implications). For this reason, it is important that Three-Way Communication is used jointly with *sound judgement*: From a safety perspective, the most important thing is to ensure that the receiver of a message understands its content, not that communication follows the format implied by Three-Way Communication *as such*. HPT should not "… be used as a cook book", as one participant stated: Using HPTs *as intended* implies understanding what the HPTs are intended to achieve and to the extent possible also verifying that they actually achieve their intended goal.

The extent to which HPTs are used as intended by maintenance personnel will also be is also influenced by organisational factors such as the time pressure under which work is carried out, manager's attitude to HPT use, and co-workers expectations regarding HPT use.

Another aspect that will affect whether HPT is used *as intended* is maintenance personnel's *ability* to use the HPT. When maintenance personnel is asked directly about what factors that promote and/or work against use of HPS in maintenance work, they rarely mention their own ability to use HPTs: They assume that they have the *insights and competencies* needed to use the HPTs as intended. Still, during the interviews, uncertainties and different beliefs regarding how (and when) to use HPTs surfaced several times, e.g., in relation to *Peer Checking* and *Independent Verification*. This indicates that unless maintenance personnel get feedback on how they use HPTs, uncertainty may arise, e.g. because local ways of using HPT start to emerge in various groups/department. This issue should be attended to ensure that common practices exist (if the company requires this) or ensure that the 'new' ways of using the HPTs still ensure that they achieve their intended purpose.

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Disclaimer

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Appendix

The report contains four appendixes:

Appendix A: Business case for the potential Return on Investment (ROI) of Human Performance at the Targeted Plant.

Appendix B: Interview Guide.

Appendix C: Questionnaire.

Appendix D: Detailed Findings for the Ten HPTs.

Appendix A: Business case for the potential Return on Investment (ROI) of Human Performance at the Targeted Plant

The calculation was done using expert judgement on the MTO/ITO factors concerned with actual production losses and a quantitative approach on lost time occupational health events. The losses and events have thus not been analysed one-by-one in the context of making a business case for MTO/ITO. For the production losses over 1997-2007, 63 % were assessed as MTO/ITO related. Then, in turn a fifth of those were assumed as potentially successfully addressed by HuP (e.g. that 12.5 % of total production losses have a potential to be addressed by HuP and CAP). For the occupational accidents the calculation generously and simplified assumed they could be addressed, given a *fully* working HuP and CAP System.

For production losses, the reference is a calculated mean value cost for electric energy over a period of ten years (1997-2007) at the Nordic energy market Nord Pool Spot (Svensk Energi, 2012). As a normative cost for occupational losses in the business case, calculations on the *value of a statistical life – VSL* including non-fatal accidents (Swedish Transport Administration, 2010, 2012) were used. The VSL is a calculated societal cost, whereas the targeted plant does not bear all those associated costs, any improvement in accident rate were though considered a positive outcome in a societal perspective.

<u>Occupational Health</u>

The targeted plant is staffed by 1500 staff and 1500 contractors. Based upon actual accident reports in the period 2009-2013 (Olsson, 2009-2013), average annual accident rate for *'moderate injury'* (full recovery) is calculated to 20, while *'severe injury'* (graded disability) is calculated to 0.5. The average loss of time is 15 days. There is one fatal accident in 40 years of operation.

As an economic reference the *value of a statistical life* (VSL) from the Swedish Transport Administration (STA) is normative. The VSL covers a range of injuries up to fatality. The VSL is derived from studies and research and gives a societal cost, and it is regularly updated by STA. VSL is used as a support for cost-benefit analysis on safety improvements in the transportation sector, where prioritization of investments in safety is a necessity.

Table 10. Economic impact of poor safety.

	Moderate injury	Severe injury	Fatal accident
Average per year	20	0,5	0,025
VSL (€)	13.300	300.000	2.000.000
∑ (€)	266.000	150.000	50.000

This tabulation results in 466.000 € in annual financial loss at the targeted plant due to lost time occupational accidents, and a significant amount of human trauma involved.

Occupational Health loss: Average of 466.000 € per year (≈ 500.000 €).

Safety and Trust

Due to issues related to Safety Culture and Human Performance, the targeted plant was under special surveillance for more than 40 months from the regulator by an injunction (2009-2013). As a result, the power upgrade at one reactor was put on standby with resulting financial loss. Also the public trust was affected. Although the financial loss, and the impact of loss in trust, can be calculated, it was not included in this business case.

Safety and Trust: Not calculated.

Production

The analysis was done by HuP and MTO/ITO expert judgement on the technical analysis of actual production losses. Out of the production losses (Unplanned Capability Loss Factor, UCLF) over a period of ten years (1997-2007) at Plant "A", 63 % were found to be related to HuP and MTO/ITO. Given the Nordic mean value price over ten years (1997-2007) at 33 € / MWh, the resulting loss due to HuP and MTO/ITO issues came at a total of 150.000.000 €. Then *assuming* that a fully working HuP and CAP System addresses a fifth of those (20 % of 63 %) gives the equation 0,2 x 150.000.000 € = 30.000.000 € worth of HuP related losses over ten years. Average per year is thus 3.000.000 €.

Production loss: Average of 3.000.000 € per year.

Return On Investment (ROI) at the targeted plant

Average total loss related to HuP for an average year is thus estimated to:

Occupational Health: 500.000 €

Safety and Trust: Not calculated

Production: 3.000.000 €

Sum: 3.500.000 € per year (Y3 and onwards)

Investments: 500.000 € (Y1 and Y2)

Investments includes the total cost of HuP System development and all staff HuP training man-hours spent.

Table 11 Return on investments in safety.

	Y1	Y2	Y3	Y4	Y5
Investment	250.000	250.000	100.000	100.000	100.000
Savings	0	0	3.500.000	3.500.000	3.500.000
Net ∑ (€)	-250.000	-250.000	3.400.000	3.400.000	3.400.000

Return On Investment (ROI): 3.500.000 ÷ 100.000 = 35 times (Y3 and onwards).

Appendix B: Interview Guide

Interviews were performed with maintenance team leaders and maintenance staff members. The interviews were semi-structured and carried out with reference to the below interview guide:

Table 12 Guide for semi-structured interview.

Background for inclusion /Associated Research questions	**Issues – Questions – Comments**
Calibration – interviewee and HPTs applied	Show the list of HPTs used at the targeted plant (i.e., the 10 tools): Does the interview agree that these are the HPTs applied - and adjust if necessary. Do you use HPTs, which are not among the 10 mentioned here? Do you use all 10 [/what was mentioned] HPTs?
The interviewees *global* view on HPTs	Why do you use HPTs? In general, how do you perceive the application and effects of HPTs? Can you give examples of situations where you have been able to *avoid* dangerous situations due to using HPTs? Can you give examples of situations where using HPTs has *contributed to* generate hazardous situations?
Main part of the interview	
How do maintenance personnel perceive and use Human Performance Tools (HPTs) in nuclear power plants?	Of these ten HPTs (show list), which do you use most often? [*Interviewer: Distinguish between the individual HPTs and the various aspects of the issues below, dependent on what the interviewee's focus turns out to be*] In what situations do you use these HPTs? In a particular operational state only? [e.g. during outages] Do you use the HPT when collaborating with other maintenance personnel and/or when collaborating with people from different departments and/or contractors? Is there a shared understanding in your group on how and when to use (and not to use) HPTs? Do managers/colleagues follow-up on your use of HPTs? Regarding the HPTs you never or rarely use: What is the reason for this? In addition to HPTs, what other techniques/tools/practices do you use for preventing dangerous situations?
How may the intended use of HPTs be promoted in maintenance work?	How do you identify the critical steps in relation to which it is important to use HPTs? Are there any preconditions that need to be in place for the HPTs to be effective ["intended"] (e.g., tools, information access, competence)? What are the positive impacts of using the HPTs? Depending on the individual HPTs, which is addressed: What factors encourage use of [specific HPT]? What factors discourage use of [specific HPT]?
How to introduce HPTs to maintenance personnel to promote intended use?	How were you introduced to the HPTs? What type of HPT training have *you* received? - Advantages and disadvantages If you should advice other plants, which had never used formal HPT before, on how to introduce HPTs to maintenance personnel, what would your advice be?

Appendix C: Questionnaire Survey

Human Performance Tools in Maintenance Work

The purpose of the present study is to obtain a better understanding of how Human Performance Tools (HPTs) are applied in maintenance at Ringhals. What are the lessons learned? What advantages and potential disadvantages exist and what are the possibilities for further improvements?

The main focus of the survey is the 10 Human-Performance Tools (HPTs) that are formally applied at Ringhals. These are all listed in the HuP-brochure and on the HuP lanyard card '10 tools'. Please consult these if in doubt over any of the HPT's.

To achieve the purpose of the survey, we depend on you to share your experiences and assessments of HPTs in maintenance work. The information obtained in the study will be treated confidentially, and findings from the study will be reported without reference to individuals.

We encourage you to use this survey as a mean to reflect about the factors that help you and your colleagues in working safely.

When all data has been collected, you will receive a short report that summaries the main findings in the survey. This give you an opportunity for matching you own responses with the responses of the joint maintenance staff.

Welcome!

Thank you for taking the time to participate in this questionnaire!

If you have any questions in relation to the content of the survey Please contact Christer Axelsson, Vattenfall (christer.axelsson@vattenfall.com) or Ann Britt Skjerve, Institute for Energy Technology, Halden, Norway (ann.britt.skjerve@hrp.no).

If you have any questions in relation to running the questionnaire on your PC, please contact Per-Arne Jørgensen, Institute for Energy Technology, Halden, Norway (Per.Arne.Jorgensen@hrp.no).

There are 73 questions in this survey

Consent

Prior to initiating the survey, please consider the following consent form: All information obtained about me during the study will be treated confidentially and stored securely. You have the right to examine your own data. You can do this by printing out the survey with your responses, following completion. Findings from the study will be reported in internal and international research publications. No references will be made to individuals or companies. The data may be used for research purposes within the HUMAX project and within the OECD Halden Reactor Project.

Please verify the following: I volunteer to participate in the survey. I am free not to perform or complete the survey and to refuse to sign this consent form without giving any reason whatsoever.

Response format: Yes (= proceed) or No (Leave the questionnaire).

Background

What is your job position? [Response: Free text]

How many years have you worked in the nuclear power industry? [Response, select a category: 0-5 years; 6-10 years; 11-15 years; 16-20 years; 21 years or more]

How old are you? [Response, select a category: 18-29 years; 30-39 years; 40-49 years; 50-59 years; 60 or above]

What kinds of risks are associated with your job? [Response: Free text]

How do you overall conceive HPTs? [Response: Please choose only one of the following:

- As integrated work practices which in general are useful in everyday work;
- As in principle superfluous "add-on" techniques to existing work processes;
- Other: Please explain - and a field for commenting].

How did you get familiar with the HPTs that are used at [the plant]? [Response: Free text]

Overall the use of HPTs at [the plant] contributes to promote plant safety [Response, choose only one of the following: Fully agree; Partly agree; Neither agree or disagree; Partly disagree; Fully disagree – and a field for commenting]

Application of Human Performance Tools

Please mark which HPTs you routinely use during every day work. Please choose all that apply [Pre-Job Briefing; Pre-Job Briefing; Use of Operating Experience; Procedural Use and Adherence; Self checking – STAR; Questioning Attitude - Stop when unsure; Peer Checking; Independent Verification; Clear Communication Techniques; Task Observation/Coaching]

In addition to the 10 HPTs, are there other dedicated practices you/your colleagues use to reduce the risk for errors in specific situations? [Response: Free text]

Which HPTs would you typically use when faced with non-routine situations with potential safety impact? Please choose all that apply: [Pre-Job Briefing; Pre-Job Briefing; Use of Operating Experience; Procedural Use and Adherence; Self checking – STAR; Questioning Attitude - Stop when unsure; Peer Checking; Independent Verification; Clear Communication Techniques; Task Observation/Coaching]

The ten sections followed. Each section addressed one of the ten Human Performance Tools. The same structure and questions were applied in all ten sections:

> How often do you carry out or take part in [specific HPT]? [Response, choose only one of the following: Less than once a year Less than once a year; Yearly; Every half year; Every third month; Every month; Every second week; Weekly; Daily]
>
> In what situations do you carry out or take part in [specific HPT]? [Response all options that apply and provide a comment: During outages; When a task is complex; When a task is infrequently preformed; When a task comprises especially critical steps (irreversible actions with safety consequences); Routinely – an every-day work practice; When a task involves people from several groups; Troubleshooting; Other].
>
> What do you see as the major advantages of using [specific HPT]? [Response: Free text]
>
> What do you see as the major disadvantages of using [specific HPT]? [Response: Free text]
>
> What factors may discourage you from using [specific HPT]? [Response all options that apply and provide a comment: Routine tasks; Time pressure; Working with highly familiar colleagues; Working with colleagues that have a negative attitude to use of HPTs; Distractions; None; Other?]
>
> In your opinion, what would be the effect if [specific HPT] was no longer used at [the plant]? [Response: For each of the issues: Plant safety, personnel safety, productivity, and collaboration quality, the respondent should select one of the following options: Increase, Same or Decrease.]

Concluding

Do you have any views on HPTs that you think need a particular attention in this study that has not already been covered by this survey? [Response: Free text]

Appendix D: Detailed Findings for the Ten HPTs

In the following, the quotes are adjusted based on the following principles:

- All references to specific people and specific situations, which may make people or situations recognizable to colleagues/others, have been removed. If necessary, to illustrate a particular issue, it has been substituted with similar, but not identical details.
- All pausing sounds, like ”hm…”, etc. have been removed, as well as repetitions, where the interviewee after a pause repeats him or herself. This was done to make the quotes easier to read.
- Insertions using ”[]” represents text added by the authors to help the reader understand the context in which the statement is provided.

The findings associated with each of the ten HPTs are structured using 5 headings: A Brief overview of [the specific HPT]; Usefulness of [the specific HPT]; Factors Promoting the Use of [the specific HPT]; Factors Working against the Use of [the specific HPT] and Potential Issues for Consideration.

Appendix D1: Clear Communication Techniques

A Brief overview of the Clear Communication Techniques

A brief overview of the HPT *Clear Communication Techniques* can be found in Table 13.

Table 13. A generic description of the HPT Clear Communication Techniques: Main source: Department of Energy (2009b, 26-28).[12]

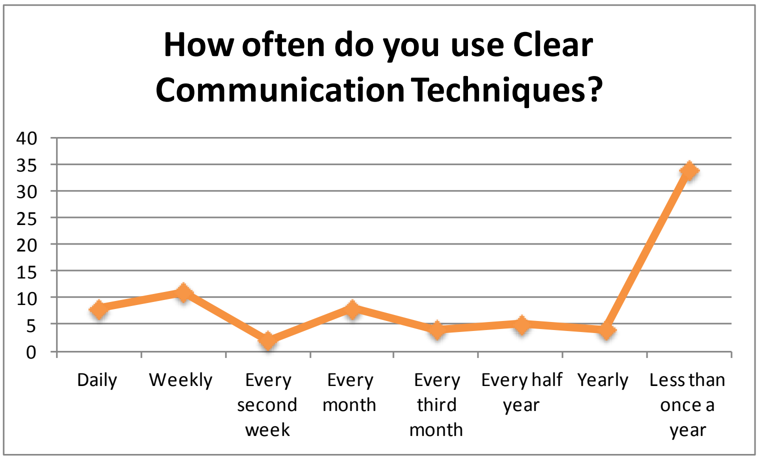
Classification	Individual HPT (Department of Energy, 2009b) Fundamental HPT (INPO, 2006b)
Main purpose	Avoid misunderstandings in communicative exchanges.
User(s)	Two persons – people involved in the act of communicating.
Time	Simultaneously.
Recommended practices when using this tool:	1. The sender gets the attention of the receiver and clearly states the message. 2. Receiver acknowledges the sender. The receiver paraphrases back the message in his or her own words. 3. Third, the sender informs the receiver whether the message is properly understood, or corrects the receiver and restates the message. The phonetic alphabet should be used when communicating alphanumeric information related to facility equipment noun names and when the risk for misunderstandings is increased, due to noise, etc.
Some threats (DOE, 2009b)	*Sender* attempting to communicate with someone already engaged in another conversation and/or the message is unclear, not adequately articulated or not stated loudly enough. *Receiver* fails to ask for clarification (if required) or start to perform the action before the communication is complete.

Usefulness of Clear Communication Techniques

The interviews and the questionnaire survey both showed that maintenance personnel perceived *Clear Communication Techniques* as highly useful HPT. They reported that *Clear Communication Techniques* reduced the risk for *misunderstandings* and thus the risk for *errors*. Some emphasised that because *Clear Communication Techniques* reduced the risk for misunderstandings, they also contributed to establish a climate of *trust* between colleagues, reducing the likelihood that conflicts would arise based on misunderstandings.

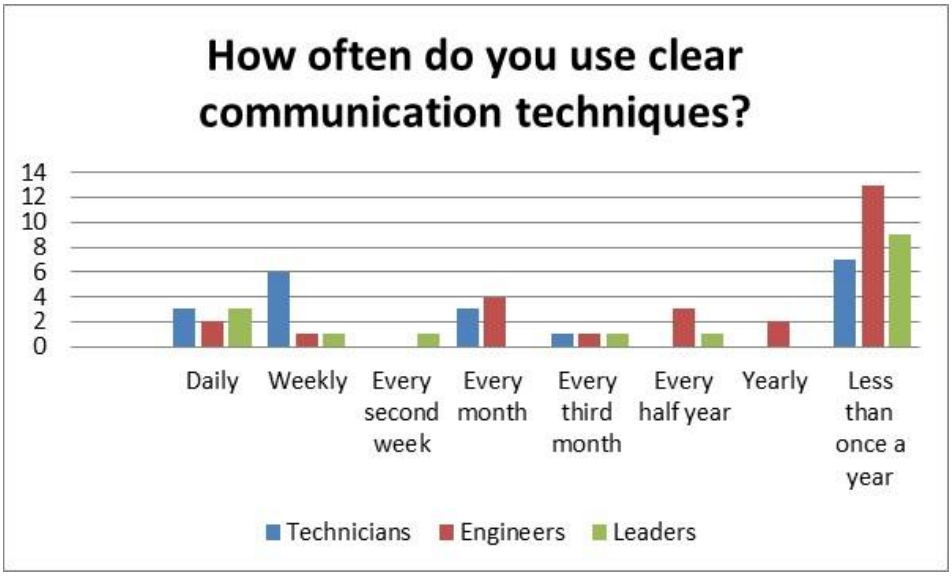
[12] The text in the table is based on extracts from the description of «Effective Communication », which largely corresponds to the HPT called "Clear Communication Technique" at the targeted plant.

Table 14. Frequency – Clear Communication Techniques (n = 76).



Giving maintenance personnel's positive views on *Clear Communication Techniques* it was surprising that that they overall reported a rather infrequent use of this HPT (see Table 14): Only 19 of the 76 maintenance personnel, who responded to this question, reported that they used *Clear Communication Techniques* on a daily or weekly basis. When decomposing the responses based on roles (technicians, engineers, and leaders), the same general pattern of results was found (see Table 15).

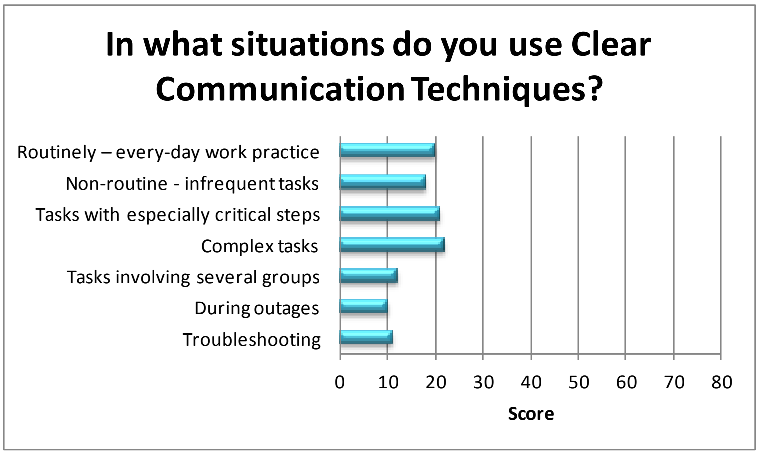
Table 15. How often do you use clear communication techniques (n=62). Technicians (n=20), Engineers (n=26) and Leaders (n=16).



Factors Promoting the Use of Clear Communication Techniques

The questionnaire survey showed that when *Clear Communication Techniques* were used, they were applied in relation to all types of operational tasks (see Table 16). The interviews revealed that maintenance personnel used *Clear Communication Techniques* in situations where **they judged that there was an *increased risk for misunderstandings*** and/or where they judged that misunderstandings might have severe consequences. Moreover, maintenance personnel used *Clear Communication Techniques* in situations where they collaborated with parties, who *expected* that they used *Clear Communication Techniques*, such as when they collaborated with the control-room operators.

Table 16 When do maintenance personnel use Clear Communication Techniques (multiple response options)?



In general, the following factors were identified to promote the use of *Clear Communication Techniques*:

- When the environment is noisy.
- When safety critical information is communicated via a telephone.
- When tag numbers are very long.
- When working with personnel, who expect maintenance personnel to use *Clear Communication Techniques.*

Factors Working against the Use of Clear Communication Techniques

Maintenance personnel at the targeted plant typically worked in pairs (see Chapter 2). This implied that they usually would stay in physical proximity during task performance. Both the interviews and the questionnaire survey showed that a large subset of maintenance personnel felt that it was *unnatural* to use *Clear Communication Techniques* in this setting. They reported that since one of them typically would check the task performance of the other (i.e., *Peer Checking,* see Appendix D3: Peer Checking), *normal communication* would generally be sufficient for ensuring safety. When critical steps were performed, the maintenance personnel engaged in *two-way communication* (i.e., one participant makes a statement and the other repeats back), rather than three-way communication, in combination with *Peer Checking.*

Some interviewees expressed uncertainty with respect to *when* they were expected to use *Clear Communication Techniques*: Some seemed to believe that they were expected to use *Clear Communication Techniques* in all exchanges during task performance (rather than only in critical steps).

Time pressure was also reported to be a factor that could discourage use of *Clear Communication Techniques.* The main reason maintenance personnel provided for this was that performing a tasks would *take longer time,* if three-way communication was used as compared to when it was omitted.

It was also found that *Clear Communication Techniques* might be used less than expected during outages because contractors sometimes lacked insights into how and/or when these techniques should be used. Thus, maintenance personnel would *sometimes* refrain from using *Clear Communication Techniques* with contractors because it felt unnatural, as the contractors would not be used to work in this way. Instead maintenance personnel would verify with the contractors using daily language that tasks had been understood/performed, etc. and thus ensure that safety was uphold.

It should be noted that none of the threats contained in Table 13, were mentioned by maintenance personnel in the present study.

Potential Issues for Consideration

- Consider if *two-way communication (*in conjunction *with peer-checking)* should have a role in HPTs.
- Clarify to maintenance personnel when *Clear Communication Techniques* are intended to be used.
- Train contractors in why, how and when they should use *Clear Communication Techniques.*

Appendix D2: Independent Verification

A Brief Overview of Independent Verification

A brief overview of the HPT *Independent verification* can be found in Table 17.

Table 17. A generic description of the HPT Independent Verification, Main source: Department of Energy (2009b, 46-48).

Classification	HPT for work teams (Department of Energy, 2009b) Conditional HPT (INPO, 2006b)
Main purpose	To catch errors of a performer.
User(s)	Two persons.
Time	The *performer* and the *verifier* are separated by time and distance.
Recommended practices when using this tool:	The *verifier*: 1. Verify that the specific element you intend to address (e.g. component) is the correct one to be verified by checking the document guiding the verification process. 2. Compare the as-found condition with the requirements. 3. If deviations are found, notify the supervisor. 4. If no deviations are found, sign/initial the guiding document. 5. Upon completion of the verification, notify relevant parties.
Some threats (DOE, 2009b)	• If the task performer and person, who carry out the verification, are co-workers and/or working together on the same job, they may be "blind" to the same errors. • The performer might be less attentive to the task, as he assumes the verifier will always catch any problems. • The verifier may be reluctant to question the outcome of a task performance process, if he/she is junior to the performer.

Usefulness of Independent Verification

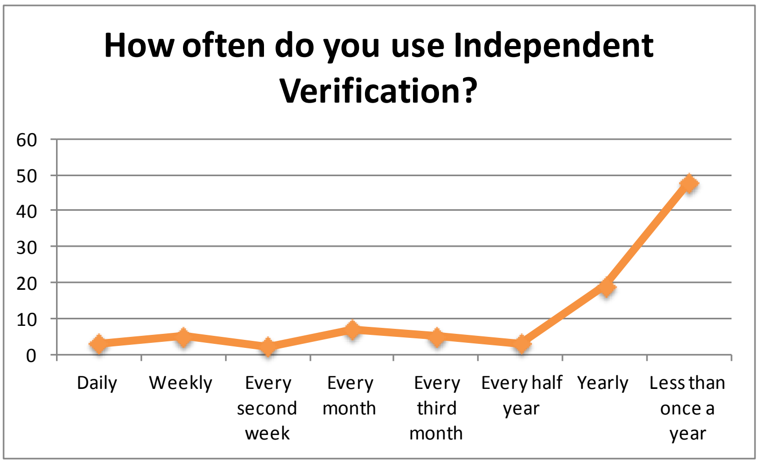
Maintenance personnel expressed favourable opinions about *Independent Verification* in both the interviews and the questionnaire survey. They found that *Independent Verification* was a good approach to help ensure that errors were spotted before they had negative consequences on plant and personnel safety. *Independent Verification* was frequently described as an 'added extra mean' for increasing safety, implying that a 'new pair of eyes' would verify the outcome of a task performance processes.

A few respondents pointed out that *Independent Verification* was necessary to prevent errors for various reasons: A questionnaire respondent, e.g., stated:

> "... many are blind to their own jobs or just do not care to take responsibility for what they do. Then you need someone to point errors out to them."

Some questionnaire respondents stressed that knowing *Independent Verification* would be carried out following task performance, would make task performers even more careful than usual, because they would not want the Verifier to discover an error.

Table 18. Frequency – Independent Verification (n = 92).



However, one respondent emphasised the second threat reported in Table 17: The respondent found that if task performers knew a Verifier would control the outcome of their task performance process, they would carry out the task in a sloppier manner.

Still, despite the positive assessment of the usefulness of *Independent Verification*, the questionnaire survey showed that *Independent Verification* was rarely used: the majority the respondents reported that they used/were exposed to *Independent Verification* only once a year or less (see Table 18). However, the data obtained from the interviews suggested that the questions-based data on the use of *Independent Verification* might be biased. There were two reasons for this: First, maintenance personnel had different understandings of what constituted *Independent Verification*. Several of the maintenance personnel found it difficult to *distinguish* between *Independent Verification* and *Peer Checking* (see Appendix D3: Peer Checking). Many times, maintenance personnel stated that *Independent Verification* implied that the outcome of a completed task was verified *by members of other groups*. If members of their own group carried out the verification, they rather conceptualized the activity as *Peer Checking*. This is reflected, e.g., the following statement made during the interviews:

> "In a way, Independent Verification is stronger than Peer Checking, because people in other groups are more *independent* than when a co-worker checks on you: the co-worker will be more prone to overlook the same issues at the colleague, who has performed the task."

Independent Verification may also be used by groups. During outages, one group of people (e.g. permanent employees) may collectively verify the activities of another group of people (e.g. contractors). An interviewee stated:

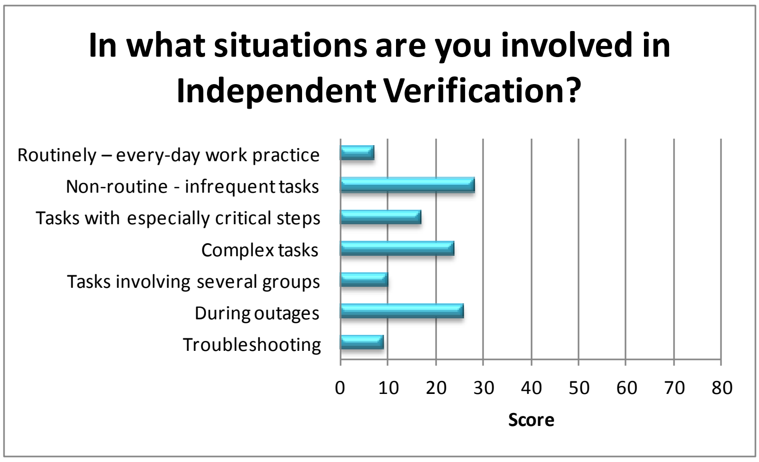
> "One group of people, the contractors, run the transmitters. Another group of people, station personnel, who work independently from the first group, controls that the valves are in the right positions."

This type of verification was also found to be very useful.

Factors Promoting the Use of Independent Verification

The questionnaire survey showed that *Independent Verification* in particularly was used in association with non-routine tasks and/or complex tasks, and during outages (see Table 19).

Table 19. When are Independent Verification used (multiple response options)?



The following factors were identified to promote the use of *Independent Verification*:

- When the location in which a task is carried out does not allow for the performance of a verifying test (e.g., because location is inaccessible).
- When non-routine and/or complex tasks are performed –because the task performer will generally be less familiar with the task performance process and/or because of the potential negative safety consequences.
- Pre start-up tests and checks following outages – where *Independent Verification* is also often a *required* activity per the plant alignment procedures.
- A person may also ask someone else to verify the outcome of a task performance process, if he or she in uncertain, as to whether the task has been executed correctly.

Factors Working against the Use of Independent Verification

Based on data obtained from the questionnaire survey, two factors that might work against the use of *Independent Verification* were identified*:*

- Overall, the use *Independent Verification* implies that extra time will be needed to complete a task, as the particular task will only be considered to be complete, when the *Verifier* has confirmed that the outcome is correct. It *may sometimes be challenging to find a person with the needed qualifications to carry out a verification and time available when the task is completed*. In a situation where many ongoing and planned activities need to be coordinated, "delays" in the completion of one task may imply that the completion of another may also be delayed etc.

- *Independent Verification* also implies that task performance will require *extra resources*, i.e. a person to perform the verification, which can make the planning process more cumbersome.

A few questionnaire respondents mentioned another factor that could work against the use of *Independent Verification.* They emphasised that it could be an unpleasant experience for the task performer to receive feedback from the *Independent Verifier*, who reviewed the outcome of his or her task performance process. A respondent wrote:

> "If the person performing the *Independent Verification* identifies problems, you feel questioned, and you do not get time, support and resources to fix the error [yourself, and another person has to correct it]."

Another respondent emphasised the importance of promoting that the person, who carry out the *Independent Verification,* do not uphold an attitude like: "The more issues I uncover, the better I am."

Thus, the group climate within an organisation may be an important issue for how *Independent Verification* will impact an organisation. If the consequence of Independent Verification is that individual maintenance personnel is *blamed* if errors are found, it may be difficult for the plant to learn from errors, e.g., understanding how the organisational context may contribute to increase/reduce the risk for errors. It may also imply that maintenance personnel will focus extra on the tasks, which they know will be exposed to *Independent Verification* – and thus somewhat lesser on other tasks.

Potential Issues Consideration

- Ensure that the difference between *Independent Verification* and *Peer Checking* is understood. This may contribute to increase the use of *Independent Verification* in practice.
- Ensure that sufficient time and resources are allocated for *Independent Verifications.*
- Ensure that maintenance personnel consider in which situations *Independent Verifications* may be useful. Several interviewees stated that even though *Independent Verification* is typically used in relation to *non-routine tasks*, it may sometimes be useful to also carry out *Independent Verification* in relation to *routine tasks, which can negatively impact the safety level in the plant*. The reason is that when a person has performed a task for a while, he or she may run the risk of getting "blind" to the associated risks.

Appendix D3: Peer Checking

A Brief Overview of Peer Checking

A brief overview of the HPT *Peer Checking* can be found in Table 20.

Table 20. A generic description of the HPT Peer Checking. Main source: Department of Energy (2009b, 42-43).

Classification	HPT for work-teams (Department of Energy, 2009b) Conditional HPT (INPO, 2006b)
Main purpose	To *prevent* a performer from making an error.
User(s)	Two persons.
Time	Simultaneously.
Recommended practices when using this tool:	1. Two people agree that a particular action should be performed on a particular component. 2. The performer takes the agreed-upon correct action. 3. The peer confirms that the action taken was correct. This process continues until the task performance process, which should be Peer Checked, is completed.
Some threats (DOE, 2009b)	*Peer* • is inexperienced with the task • is not paying close attention to the performer • is reluctant to correct a more senior performer • assumes the performer will not make a mistake. *Performer* • acts before the peer is ready to perform the peer-check • does not self-check rigorously • assumes the peer will catch any problems. *General:* If Peer Check is over-used, it will eventually lead to complacency by both parties.

Usefulness of Peer Checking

The interviews and the questionnaire survey both showed that *Peer Checking* was perceived as a ***genuinely useful* HPT**. Maintenance personnel reported that they used *Peer Checking* as a part of their daily work practices. Of the 66 maintenance personnel belonging to the categories Technicians, Engineers or Leaders, who responded to the question of how frequently *Peer Checking*, 33 reported that they used this HPT daily or weekly (see Table 21).

Table 21. How often are you take part in Peer Checking (n = 66): Technicians (n=20), Engineers (n=29) and Leaders (n=17). The scale at the left hand-side represents the number of time the responses were selected. Each respondent could only select one response.

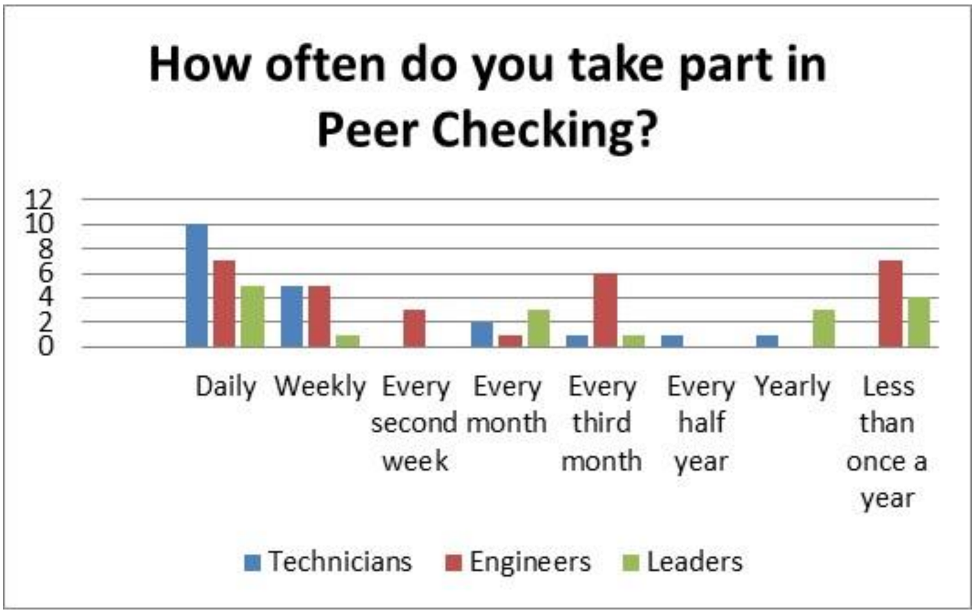
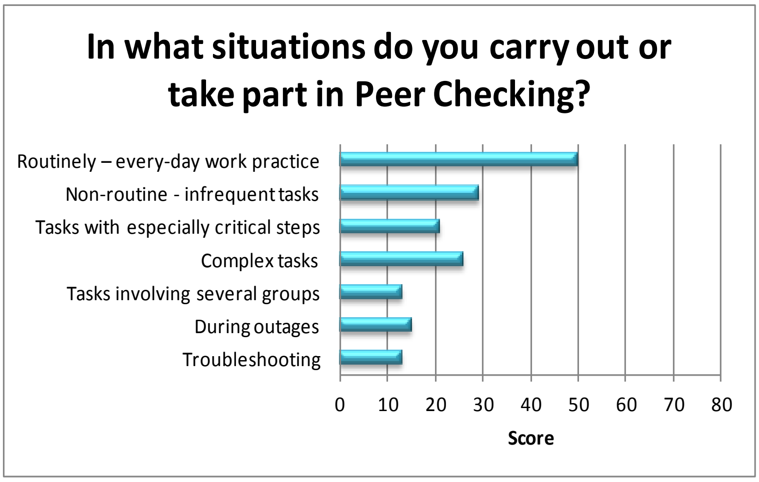


Table 22. When are Peer Checking used? (multiple response options)



Moreover, it was found that *Peer Checking* was applied both in relation to routine tasks and non-routine tasks (see Table 22). This result can be expected also to reflect the fact that the targeted plant requires maintenance personnel to generally use *Peer Checking*, when performing tasks on operational equipment in the plant.

During the interviews, maintenance personnel provided a range of examples on how *Peer Checking* had helped to prevent unwanted incidents. A person, e.g., stated:

> "Not long ago, a colleague was about to connect to a wrong location in a cabinet. Depending on what channel, he had connected to, this might have resulted in a station scram (reactor shut-down)."

Another person stated:

> ”A colleague had opened a terminal block [disconnected a circuit] to allow for measurements and had closed it again. All had been signed for. Still, during the *Peer Checking* it was discovered that one had not been closed....”

The latter example is though executed as an *Independent Verification*, and demonstrates a commonly observed misconception of the characteristics in the HPT *Peer Checking*.

Most of the maintenance personnel reported that they perceived *Peer Checking* as a *natural* way of working: They usually work in pairs. Often it will be possible for one person only to physically carry out the activity required to solve the task at the time, whereby the other is naturally in a role, where he can observe and check the task performer’s activity.

Still, as was the case with *Independent Verification*, maintenance does not always have the same conceptualization of what *Peer Checking* implies. For example, during the interviews, one person accounted for *Peer Checking* a follows:

> “One person reads out loud and the other performs the task. The person, who reads, always checks that the colleague, who performs the tasks, acts correctly. If the task performer for example is on his way to start working on a wrong component, the observer/reader will stop him.”

This concept is also known as “*Reader-Doer”*, which implies a two-way communication. Used whenever working in pairs, it inherently promotes effectiveness since it may speed up the execution of a task. Thus the check-part of the technique is at risk of lesser attention.

Another person explained that *Peer Checking* may be carried out differently depending on the situation: When it is possible for both maintenance personnel in a pair to carry out work simultaneously (e.g., because their work involves several accessible components in the same location), both will typically carry out a subset of the task on an individual basis. Following completion, they will check the outcome of the colleague’s task performance. Note that his is a practice, which traditionally would be perceived as *Independent Verification*, rather than as *Peer Checking*.

This shows that even though maintenance personnel agrees that *Peer Checking* is useful, they may not necessary have the same practice in mind when they assess its usefulness.

Factors Promoting the Use of Peer Checking

The data holds little information on how to *promote* the use of *Peer Checking*, since *Peer Checking* is used frequently at the targeted plant. Still, it shows a set of advantages associated with using *Peer Checking*, which may help explain its popularity among maintenance personnel at the plant.

Using *Peer Checking*:

- Increases plant and personnel safety: Peer Checking increases the likelihood that errors will be identified and corrected, and thus contributes to the risk for unwanted events.
- Reduces the latent errors: It helps to identify errors that otherwise would have remained unnoticed – for a while.
- Increases the likelihood that the task will be performed in the best possible way: The peer is a colleague with whom the task performer can have a dialogue about how the task should be performed. It promotes experience transfer.
- Provides the task performer with a feeling of security that more people have checked that the task has been correctly performed.
- It can feel OK to have feedback from a colleague. An interviewee stated: “It feels OK to be stopped by someone I know has a good knowledge of the area.”

Factors Working against the Use of Peer Checking

Still, a set of factors, which may work against the use of *Peer Checking*, was also identified:

- Lack of mutual respect/trust between the Peer and the Performer. This was generally seen as *the factor* that challenged the use of *Peer Checking* most markedly. It was expressed in different ways such as:

  “Peer Checking is difficult if the colleague [doing the Peer checking] does it in the wrong way.”

  An interviewee provided the following example of what would constitute wrong way:

  “If the Peer Checker stops the colleague in the middle of his/her task performance process and asks: “What did you do now?” [due to lack of task expertise]

  Others stated:

  “Peer Checking can be perceived [by the Performer being exposed to checking] as mistrust in his/her competence.”

  “Feedback following Peer Checking can be perceived as rebuke and supervision, if done in the wrong way.”

- Differences in age and/or level of experience: For younger/less experienced maintenance personnel, it can be difficult to challenge older/highly experienced colleagues’ way of working.
- Lack of time, e.g. as when both colleagues in a pair (feel that they) have to work simultaneously to complete a task ‘in time’.

- Lack of competence: The person doing the Peer Checking does not have sufficient competence to check the performance of the colleague.
- In situations where it is *perceived as unnecessary* to carry out *Peer Checking*, e.g., when the task is simple.

Potential Issues for Consideration

Two interviewees suggested that the procedure for *Peer Checking* should be reversed, i.e., that the task performer should invite his/her colleague to do a Peer Check when he/she believed a Peer Check would be useful. The purpose of this suggestion was to prevent that a given colleague would be allowed to criticise one’s own task performance without accept. The idea could be viewed as a way to increase one’s personal ability to receive feedback on one’s own task performance.

Appendix D4: Pre-Job Briefing

A Brief Overview of Pre-Job Briefing

A brief overview of the HPT *Pre-Job Briefing* (*PJB*) can be found in Table 23.

Table 23. A generic description of the HPT Pre-Job Briefing (PJB). Main source: Department of Energy (2009b, 34-41).[13]

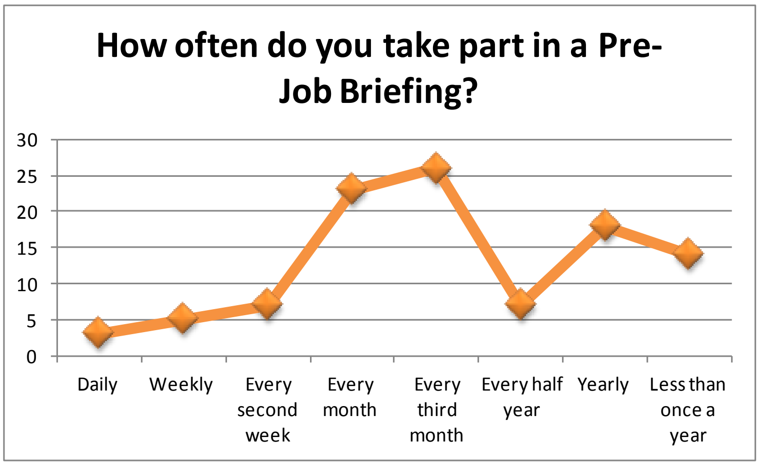
Classification	HPT for work-teams (Department of Energy, 2009b) Conditional HPT (INPO, 2006b)
Main purpose	"A pre-job briefing is a meeting of individual performers and supervisors conducted before performing a job to discuss the tasks, critical steps, hazards, and related safety precautions. This meeting helps individuals to better understand the task(s) to be accomplished and the associated hazards" (Department of Energy, 2009b, 34).
User(s)	Individual(s) involved in task performance and their supervisor(s).
Time	Prior to a work activity. Separate preparations, joint meeting.
Recommended practices when using this tool:	Prior to the PJB session, all persons involved should have prepared for their individual jobs. 1. Clarify the purpose of the task, scope, and nature of work. 2. Review procedures and all documents needed to complete the task. 3. Assign tasks, and clarify roles, and associated responsibilities and make sure the necessary preconditions for task performance is/will be established. 4. Address the HPTs needed for each critical step. 5. Specify how to avoid errors/events, which have happened in relation to performance of the task in the past (Operating Experience). 6. Define Stop-work or Pause Work criteria. 7. Define involvement of management and supervisors (oversight). 8. Address questions and concerns of the individual performers.
Some threats (DOE, 2009b)	• Discussing generalities rather than specifics • Conducting the meeting as a monologue • Individuals failing to express their concerns or ask questions • Using a "cookbook" approach to the briefing • Being insensitive to how mind-sets or expectations may disguise problems and warning signals • Conducting the meeting in a noisy or distracting environment

[13] The text in the table is based on extracts from the descriptions of «Pre-Job Briefing» and «Technical Task Pre-Job Briefing». These descriptions largely cover the key issues associated with the HPT called "Pre-Job Briefing" at the targeted plant.

Usefulness of Pre-Job Briefing

Maintenance personnel found that Pre-Job Briefing (PJB) was one of HPTs, which contributed most to promote of safety (see Table 5 on page 18). This was emphasised both during the interviews and in the questionnaire survey. The questionnaire survey showed that PJBs were not used on a daily basis. Most respondents reported that they generally took part in a formal PJB every month or every third month (see Table 24).

Table 24. Frequency - Pre-Job Briefing (n = 103).



A PJB was seen as a means to ensure that the activities required to solve a task, would be correct. It would help to ensure that all *safety issues had been identified and adequately addressed*, and that the task performance process would be well *coordinated.*

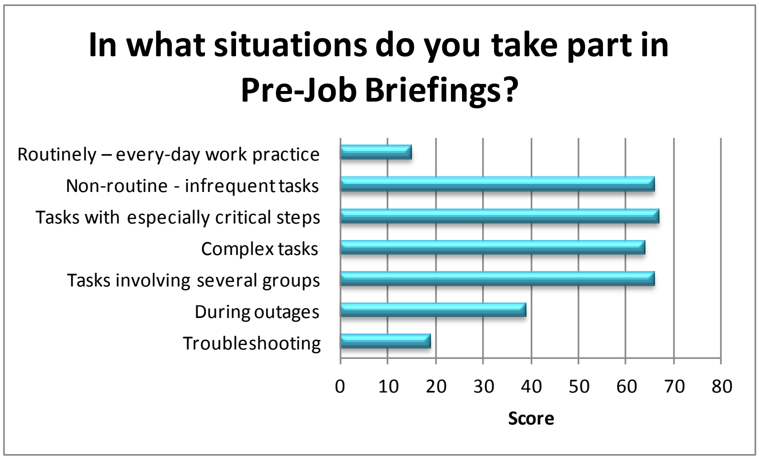
During the interviews, maintenance personnel provided several examples on situations in which a PJB had contributed to prevent an unwanted event in the plant. One interviewee described a situation, where a transmitter was about to be exchanged in the containment building: During the PJB, each participant stated what activities he/she was going to perform. When one of the participants had finished his statement, another participant suddenly added almost as a personal reflection: "Yes…... but if you do this, then wouldn't it also imply that...?" In the instant he said this, the other participants realized that he was right, and the plan for task performance was markedly adjusted. If this negative impact had not been foreseen during the PJB, the task execution would have resulted in an emergency shut-down of the reactor.

Formal PJBs, i.e., PJBs guided by instructions and documented, were introduced in the plant around four years before the present study. Before formal PJBs were introduced, maintenance personnel informally discussed how to perform a task before starting the actual work (note that this partly resembles the HPT *Task Preview* (INPO, 2006b; DOE, 2009b)). The discussions were typically constituted of a series of person-to-person conversations (rather than a joint meeting), and not all people involved in the task performance process, would have talked to each other. When asked whether PJB was a useful tool, the answer was unison "yes" from all maintenance personnel interviewed followed by the condition: If PJBs are *only* used when necessary.

Factors Promoting the Use of Pre-Job Briefing

Both the interviews and the questionnaire survey (see Table 25) showed that PJBs in general were seen as useful in situations where the task to be performed had one or more of the following characteristics:

Table 25. When are PJBs used (multiple response options)?



- a non-routine task
- requires people from different departments/professional groups to work together and/or to carry out individual but interdependent tasks
- involves one or more components of critical importance for plant operation
- is complex
- is new to some of the participants

Factors promoting the use of PJBs were identified by analysing the advantages maintenance personnel associated with using PJBs. These advantages were decomposed into three categories. The statements associated with each category heading illustrate the issues raised by maintenance personnel:

- PJBs help to ensure that safety issues (operational and occupational) are identified and optimally addressed prior to a task performance process:
    - People with different perspectives and competences participate in PJBs, which increases the likelihood that critical risks will be identified and adequately addressed.
    - All participants have mentally walked-through the task(s) they are going to carry out in details, before the work is initiated and thus have a better understanding of the global task.
    - All peopled involved understand the importance of the task.
    - A plan for what to do in case task performance does not proceed as planned will be developed.
    - The risk that anyone will take shortcuts is reduced: "After a PJB you are much less tempted to take short cuts. You have gained insights into the risks associated with performance of the task for both personnel and plant safety".
    - Promotes personnel safety: "It is good to know that the control room [operators] are aware where we [maintenance personnel] are doing tests – in case task performance does not proceed exactly according to plan".

- PJBs improve the quality of collaboration and coordination during task performance:
  - People know what they are going to do and what everyone else is going to do. This improves the ability of the people involved to adapt their activities vis-à-vis each other's activities. It promotes sound coordination of activities during task performance.
  - People get the same information at the same time. Thus, if issues need to be clarified, it can be done while all parties involved are present. This reduces the risk for misunderstandings, for making erroneous/inadequate decisions, and for forgetting to communicate a decision to all relevant parties.
  - Access to competence: "You can ask questions to the person, who knows the topic best."
  - During task performance, waiting time will be reduced and the necessary tools will be available upon need, etc.
  - Shared goal: "All participants in a task performance process have the same overall goal". This reduces the risk for inadequate prioritization between tasks, during the task performance process, should re-prioritization be needed.
  - Makes it easier to contact other parties involved during the task performance process: "You meet the other people involved in the performance of the task, and you know who to contact from the different groups if needed during task performance".
- In the longer-term perspective, PJBs promote the competence development of maintenance personnel and increase the familiarity between staff members across group boundaries:
  - When task performance involves people from other groups/departments, maintenance personnel obtains improved global insights into the task performed and insights into the jobs and work processes of people working in other groups/departments/organisations.
  - Increased competence, due to experience transfer between all participants in a PJB.
  - Helps the individual participants build a network of useful contacts to colleagues in other groups/departments.
  - Collaboration between the groups and departments are improved. One participant stated: "We use each other to get it right".

Factors Working against the Use of Pre-Job Briefing

A set of factors working against the use of PJBs were also identified. These largely included the threats listed in Table 23. The factors identified may be grouped under **7** partly overlapping headings:

1. Using PJBs as a routine may reduce the quality of PJBs: In general, the interviewees warned that if formal PJBs were required to be used *routinely,* i.e., each time a 'job' was to be performed, the value of PJBs might markedly diminish: It would increase the risk that personnel would lose the 'extra safety focus' implied by a PJB,

implying that they should be *especially* alert to safety issues during every *present* task. One interviewee stated:

> "If you carry out HPTs as a routine, then the feeling that it is an important task disappears. It becomes part of the everyday work. It just becomes something you have to do, you do not reflect deeply about it. In my opinion this is not the purpose of such a tool."

A questionnaire respondent wrote:

> "If a PJB is used too often there is a risk that quality may suffer as people may be more negligent, e.g., when PJBs are used for routine jobs. An additional risk is that people will be less alert, when an important PJB is performed."

2. When PJBs are required by management/rules in situations where they are not needed: When PJBs are required for simple routine jobs, it can create a sense of frustration for maintenance personnel. One maintenance personnel stated:

> "A PJB requires a lot of resources: People with particular competences are required to take part, even when a routine task is addressed. This may create frustration in the organization."

When maintenance staff members find that a PJB is merely required to ensure that the unit will meet a given target number of PJBs performed (e.g. because number of PJBs is used as part of the basis for calculating bonuses), rather than for safety reasons. In the questionnaire survey a participant described this type of situation as follows:

> "... [Then] PJBs become something you have to suffer through to be able to do your job."

3. When the documentation becomes too time consuming and/or the destination of the documentation is unknown: When the form participants need to fill in during a PJB requires people to consider too many issues, which are (perceived as completely) irrelevant in the particular situation. One participant e.g. stated:

> "If we should just close, replace or test something, it feels pointless to go through radiation protection, chemistry, etc. It just amounts to checking off on the form… You should not have to spend time on this, when it is not relevant for the job you are going to perform."

Other factors that may work against the use of PJBs (as intended) is when the *form used during PJBs is often changed,* and the participants need to spend time on familiarizing themselves with a new form during PJBs, and when the form is too general, implying that maintenance personnel does not feel certain that they have adequately filled in the form. Another factor mentioned to work against the use of PJB is when maintenance personnel have no idea about where the form eventually will end up – how/if the lessons learned will be used in future settings.

4. When PJBs tend to be performed in a non-optimal manner. This may include situations where PBJs are (often) lead in inadequate ways implying, e.g.:
   - a PJB is performed with a mistaken focus, it is a waste of time. For example: If the main focus of the PJB is (perceived to be) filling in the PJB form, rather than the tasks to be performed.
   - a PJB is not taken seriously by the participants, especially by the person leading the PJB, and/or if it is carried out mechanically in a closed way.
   - a PJB is too long: It can become challenging for participants to stay alert, and thus they may miss important information.

5. Waiting time may create frustration and stress. PJBs can be delayed because people, who need to take part in a PJB are away in meetings, occupied by hand-over, etc. An interviewee stated:

> "You can spend quite some time waiting for all participants to be ready for the PJB. This negatively impacts the effectiveness of work in your own group. Some mornings, we have to wait for two hours before the control room [operators] are ready to take part in a PJB."

Another interviewee stated:

> "A PJB can be delayed because the other PJB-participants need to wait, e.g. if the representative for operations is at a meeting. This can lead to irritation, because the other PJB-participants have to wait and maybe have to work overtime due to the delay. This may also imply that the PJBs are not carried out in a good way, because people are or get stressed."

6. When not all the participants, who are going to perform the task, takes part in the PJB: In some cases, it is difficult for all people who are going to be involved in a tasks performance process, to find time to meet *right before* the job is going to be performed as is intended when PJBs are carried out. In these situations, the PJB may be organized, e.g., the day before the job is to be carried out. The implication may be that the people, who participate in the PBJ, are not the ones who will actually be doing the job. This increases the risk that coordination issues may arise during task performance process, even though a PJB has been performed. An interviewee explained:

> "In these situations, the control-room crew involved in the PJB may not be at work on the following day, and coordination issues may then arise anyway."

In some cases, the personnel who are going to execute the task do not have time to participate in the PJB and hence their supervisors participate in their place. This type of practices also increases the likelihood that coordination problems will arise during the task performance process.

Further, in some situations, not all relevant parties will be invited to take part in the PJB. For instance, consultants might not be available for a PJB (e.g. because they are not at the unit the day the task is subject for a PJB, but will be present only on the day (days) during which the task is to be carried out).

7. When the variation in competence level between PJB participants is too extensive. Staff taking part in a PJB may have very varying level of competence. For this reason, knowledge sharing is an important part of a PJB. Still sometimes consultants may lack the competence needed to be able to understand the overall work processes. An interviewee stated:

> ”Not all consultants are able to grasp the global picture in line with the other participants.“

For this reason, the PJB may not always end up with a situation where all participants have an adequate and shared understanding of the upcoming task performance process.

Potential Issues Consideration

Consider the impact of the *location* in which PJBs are performed: An interviewee pointed out that the *location* in which PJBs take place might impact its outcome. He emphasised that PJBs often are performed in meeting areas, where people can sit and talk in a quiet environment, and pointed out that this had some advantages (e.g., people could readily hear what each other were saying). Still, he pointed out that it might be easier to identify all potential safety and/or coordination issues associated with the upcoming task, if PJBs were carried out at the site where the (main part of the) task, was going to be performed.

Consider whether the PJB procedure should be adapted and/or scalable in some way, depending on the task to be carried out: At the targeted plant, the PJB has later been supplemented by an additional PJB form with a shorter checklist, a *Task Preview* (INPO, 2006b), intended for less complex tasks. The interviewees were very satisfied with this solution. Several interviewees expressed that their feedback on the use of PJB had been addressed in a good way by the management of the plant.

Consider how to organise PJBs to reduce the waiting time. May the control-room operators, e.g., strive to establish a fixed period for doing PJBs during the morning shift?

Appendix D5: Post-Job Debriefing

A Brief Overview of Post-Job Debriefing

A brief overview of the HPT *Post-Job Debriefing* (*PJD*) can be found in Table 26.

Table 26. A generic description of the HPT Post-Job Debriefing (PJD). Main source: Department of Energy (2009b, 54-58).[14]

Classification	HPT for work-teams (Department of Energy, 2009b) Conditional HPT (INPO, 2006b)
Main purpose	A post-job debriefing is a method for eliciting and sharing feedback among participants, who have been involved in a task performance process, to identify lessons learned – including issues for improvement.
User(s)	The performer(s) and the supervisor(s) usually in a meeting.
Time	After a work activity.
Recommended practices when using this tool:	1. Call for a meeting. 2. Ensure that there is sufficient time for participants to share and document their observations and reflections. 3. Identify what worked well and opportunities for improvement (remember to consider all critical steps). 3. Record the lessons learned on the proper form(s), and submit to the appropriate department(s)/person(s). 4. Provide feedback to the participants on the resolution of issues identified.
Some threats (DOE, 2009b)	• Not performing a post-job debriefing or documenting feedback after having worked on risk important facility equipment. • Principal participants not involved in the post-job debriefing. • No time allotted for the post-job debriefing or done in a hurry. • Post-job debriefing or follow-up not done face to face. • Important issues not documented for reference for future Pre-Job Briefings.

Usefulness of Post-Job Debriefing

Formal Post-Job Debriefings (PJDs) are less commonly performed than formal Pre-Job Briefing (PJBs), even though a PJD in principle should be carried out in all situations where a PJB has been performed (see Table 27).

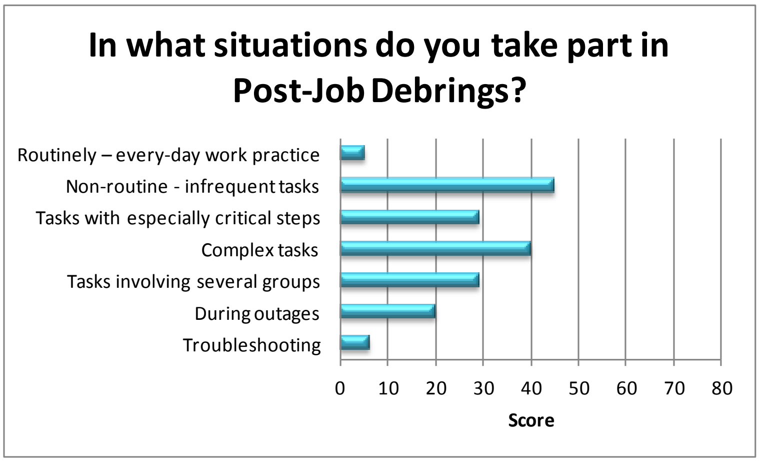
[14] The text in the table is based on extracts from the descriptions of «Post-Job Review – in the Field» and «Technical Task Post-Job Review». These descriptions largely cover the key issues associated with the HPT called "Post-Job Debriefing" at the targeted plant.

Table 27 Relationship between formal PJBs and formal PJDs.

How often do you take part in PJBs/PJDs?	PJB	*PJB (accumulated)*	PJD	*PJD (accumulated)*
Daily	5	*5*	0	*0*
Weekly	5	*10*	1	*1*
Every second week	17	*27*	1	*2*
Every month	25	*52*	0	*2*
Every third month	6	*58*	10	*12*
Every half year	15	*73*	9	*21*
Yearly	11	*84*	19	*40*

PJDs are more frequently applied following non-routine tasks, complex tasks, and tasks, which involve people from several groups, than following routine tasks (see Table 28).

Table 28. Frequency - Post-Job Debriefing (n = 84).



Most maintenance personnel, Technicians and Engineers, reported that PJDs are only useful in situations where the performance of a task did not proceed according to plan. As one participant stated:

"If a task is solved as planned, there really isn't much to talk about."

In some cases, rather than a PJD, the participants had a *brief talk* about the task performance process, without following the PJD procedure and without documenting the outcome.

Maintenance Leaders, however, argued that the number of PJDs should be increased. They emphasised that PJDs were *very useful* as a means for collecting lessons learned from task performance processes – positive as well as negative – to promote future performance.

During the interviews, both Technicians and Engineers explained that they sometimes learn much from taking part in a PJD. This could, e.g., be the case in situations where they listened to the lessons learned by members from other groups/departments, which they often collaborate with, such as the control-room operators. An interviewee stated:

“For me, it may give a great deal to hear what has happened in the control room [to understand what the operators experienced], because next time I shall do the same job, I can tell them what indicators they can expect to see on their control panel.”

Still, when listening to lessons learned from members of groups/departments with which they rarely collaborate, maintenance personnel (Engineers and Technicians) did not necessarily feel that the insights gained would improve their future performance.

Factors Promoting the Use of Post-Job Debriefing

Factors found to promote the use of PJDs included:

- The key factor promoting the use of PJDs was situations in which a task was not performed according to plan. Maintenance personnel emphasised that it in such situations was important to clarify what had happened and to come up with suggestions for how to handle similar tasks in the future.
- When maintenance personnel experience that the lessons learned during PJD are forwarded and applied in practical work.
- When maintenance personnel experience that the people involved in a task performance process may have different understandings of whether a task has been performed ‘according to plan’. It may only be possible to establish this if people involved in the task process jointly walk-through the occurrences during task execution to establish what happened, when and why.

Factors Working against the Use of Post-Job Debriefing

A set of factors was found to work against the use of PJDs:

- The *key factor* working against the use of PJDs was: When a task was (perceived to be) performed according to plan, especially if it is a routine task.
- Challenges associated with *allocating* a *time*, where all relevant people can meet and carry out a PJD:
    - A participant stated: “It can sometimes be difficult to gather people following the completion of a job. Some people have left the plant after the job has been performed. This is especially the case for contract workers. Some need to rest/sleep. If the PJD is not carried out closely following task completion, it tends not to be done at all.”
    - Another interviewee emphasised that it can be challenging to prioritize participating in a PJD, when other tasks are scheduled to be performed: “The job is done and you want to move forward to the next job.”
- PJDs are sometimes perceived to *take longer time than necessary*.

It should be noted that some maintenance personnel find that a PJD can be useful even if the people involved in tasks performance cannot participate, if others – e.g. their supervisors – take part and are able to explain what happened. Some others do not seem to share this view.

Potential Issues for Consideration

- Reviewing the procedure for PJDs, and possibly introduce a brief task review (a PJD light).
- Ensure that the lessons learned are used and/or that the participants receive feedback on why they are not used.
- Provide guidelines on how to prioritise PJD vis-á-vis other types of tasks and/activities.

Appendix D6: Procedural Use and Adherence

A Brief Overview of Procedural Use and Adherence

A brief overview of the HPT *Procedural Use and Adherence* can be found in Table 29.

Table 29. A generic description of the HPT Procedural Use and Adherence: Main source: Department of Energy (2009b, 20-21).

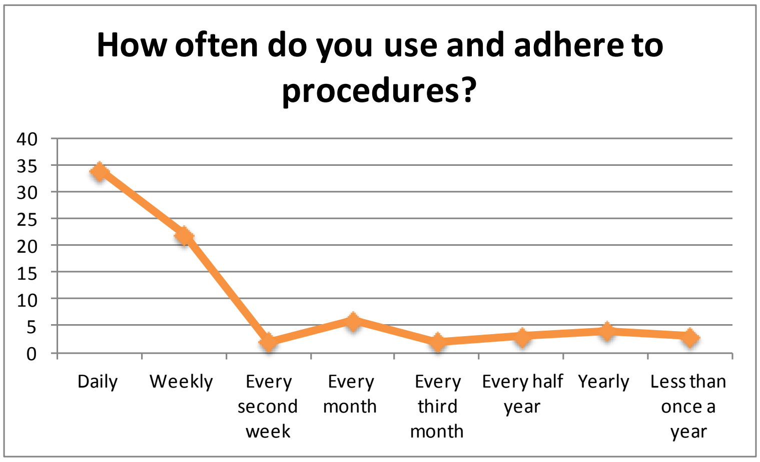
Classification	Individual HPT (Department of Energy, 2009b) Fundamental HPT (INPO, 2006b)
Main purpose	Use of and adherence to procedures will reduce the number of unwanted events.
User(s)	The task performer.
Time	Real-time.
Recommended practices when using this tool:	1. Ensure the procedure is the most recent and controlled version. 2. Review the prerequisites for the work, prior to initiating task performance. 3. Adhere to the procedure continuously, and be aware of potential impacts – positive and well as negative. 4. If people, materiel or the environment have been or may be injured/damaged, if the procedures is technically incorrect or in conflict with other procedures, if unexpected outcomes occurs, etc., then stop task performance, place the equipment/ system in a safe state, and contact a supervisor. 5. Report procedure problems and ensure they are corrected before the procedure is used again.
Some threats (DOE, 2009b)	• Not ensuring that all pages are included in the procedure, prior to use. • Commencing a procedure without establishing initial conditions. • Performing a procedure without knowing the critical steps. • Skipping steps or segments of a “routine” procedure. • Not submitting feedback on technical accuracy and usability.

Usefulness of Procedural Use and Adherence

During the interviews, maintenance personnel unanimously stated that when carrying out maintenance work in the plant, they always referred to written procedures. This is also reflected in the questionnaire survey, where almost all respondents reported that they used procedures on a daily or weekly basis (see Table 30 on page 72). They likewise responded that they utilised procedures most frequently in relation to routine tasks (see Table 31 on page 72). In the interviews maintenance personnel emphasised that use of procedures was a requirement from the authorities.

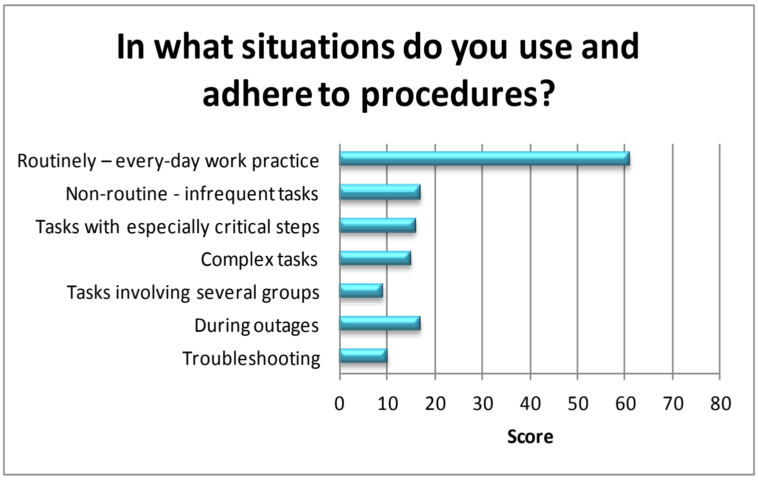
Overall, working with reference to the procedures was seen as essential and necessary: *Procedures were perceived to efficiently promote high-quality in task performance and to reduce the risk for errors.* Maintenance personnel stressed that procedures contributed to ensure that the correct activities were executed, in the right sequence. A questionnaire respondent stated that the performance of tasks based on procedures implied that the "...task is performed under a well thought out approach, which in turn reduces the risk that something unexpected will occur."

Table 30. Frequency – Procedural Use and Adherence (n = 76).



Even though procedures were seen as necessary, maintenance personnel emphasised that procedure should not be adhered to blindly: the task performer should continuously uphold a *Questioning Attitude* (Appendix D7: Questioning Attitude – Stop if Unsure): "One should not forget to think oneself", as one interviewee emphasised. If maintenance personnel followed the procedure blindly, without considering whether the steps were meaningful and/or whether the impacts of the various steps on the process system were as expected, he or she would not be able to make the (potentially) necessary adaptations to the characteristics of the situation at hand.

Table 31. In what situations do you use procedures? (multiple response options)



Blindly following procedures was also associated with a situation in which the task performer would fail in global overview of the situation, and only focus on one specific step at the time, which again made it more challenging the proactively adapt to the characteristics of the situation at hand.

Finally, blindly adhering to procedures was sometimes seen as a behaviour, which in the long run would reduce the competence level of the maintenance workers, in the sense that they not engage in reflections concerning why they carry out specific steps in the specific sequence.

It was also stressed that not all tasks can be fully covered by procedures, in particular not tasks related to troubleshooting.

Factors Promoting the Use of Procedural Use and Adherence

During the interviews, the maintenance personnel had very little to say about *Procedural Use and Adherence.* The use of procedures is a completely integrated part of their everyday work processes, and they seemed not to consider it as a HPT.

Overall, the following factors were identified to promote *Procedural Use and Adherence:*

- Ensuring procedures are always up-to-date.
- Understanding that *Procedure Use and Adherence* promotes the possibility for assisting colleagues: If all maintenance personnel perform tasks in a similar way, i.e. following the procedure, it is easier to assist each other.
- Provide training in how to use procedures, as well as the reason why the procedures have their specific content and structure.
- Insights into the negative safety impacts that may follow, if error occurs during the task execution process.
- Management emphasis on the need to adhere to the procedures.

Factors Working against the Use of Procedural Use and Adherence

Since the use of procedure is basically a requirement, the factors outlined below refer to issues that may work against that procedures are used *as intended*, rather than issues that work against the use of procedures as such:

- Overemphasis of the need to adhere to procedure, e.g. by blaming personnel, who deviated the procedures. This may lead to a situation, where procedures are adhered to blindly, to prevent being blamed. One participant stated it like this: “Using procedures implies that I have my back covered.”
- Out-dated procedures.
- When procedures are too complex, personnel may be confused and lose track of the global pictures. An interviewee stated:

> “I would like procedures to be less detailed. When they are too elaborate there is a chance you will forget to think for yourself, meretriciously adhere to the procedures, and forget about the big picture.”

Potential Issues for Consideration

Make procedures as simple and robust as possible, and ensure that maintenance personnel understand what the procedures aims at achieving, how and why.

Management should carefully consider how to respond to maintenance personnel, in situations where procedures are not adhered to. It is necessary also to understand how contextual factors impacted the occurrence.

Appendix D7: Questioning Attitude – Stop if Unsure

A Brief Overview of Questioning Attitude – Stop if Unsure

A brief overview of the HPT *Questioning Attitude – Stop if Unsure* can be found in Table 32.

Table 32. A generic description of the HPT Questioning Attitude – Stop if Unsure. Main source: Department of Energy (2009b, 10-18). [15]

Classification	Individual HPT (Department of Energy, 2009b) Fundamental HPT (INPO 06-002, 2006)
Main purpose	Alerting people to hazards in the work environment, the way in which they plan to carry out work, etc.
User(s)	One person. Often sharing/exploring/fixing/reporting of items uncovered involves other persons too.
Time	Continuously.
Recommended practices when using this tool:	1. Uphold a proactive attitude: Search for aspects in the work that flag uncertainty. Periodically, take time-outs to review the situation. 2. Ask questions and gather information to assess the issue addressed. 3. Task performer should only proceed if sure. 4. Task performance should stop if unsure, place equipment and the job site in a safe condition, and notify a supervisor.
Some threats (DOE, 2009b)	• Not stopping when uncertainties have been identified (e.g. but rather explain the issue away). • Believing nothing can go wrong. • Believing that routine tasks hold no risk.

Usefulness of Questioning Attitude – Stop if Unsure

Both the interviews and the questionnaire survey revealed that maintenance personnel found that a *Questioning Attitude* contributed to promote plant and personnel safety. A typical remark in the questionnaire survey would be that a *Questioning Attitude* "… increases the likelihood that the work will be done right from the start and that any deficiencies will be discovered."

All interviewees reported that they applied a *Questioning Attitude* on a daily basis. The survey also suggested that maintenance personnel apply a *Questioning Attitude* on a daily or weekly basis (see Table 34). The HPT was both used when carrying out routine and non-routine tasks (see Table 33).

[15] The text in the table is based on extracts from the descriptions of «Questioning Attitude – at the Activity Level", "Questioning Attitude – Work Planning and Preparation" and "Pause when unsure".

The interviews suggested that maintenance personnel overall perceived the HPT *Questioning Attitude* as a *social* or *collective* HPT, rather than as an individual HPT, as is the case in the classification system of the Department of Energy (2009b): Maintenance personnel generally talk about a *Questioning Attitude* with reference to situations, where *questions are raised in public settings, i.e., in meetings*.

When they talk about 'questioning' their own activity, they rather conceived this as *Self-Checking – STAR* (see Appendix D8: Self-Checking – STAR). This way of conceptualizing "questioning" might be the reason why not an even larger proportion of the questionnaire respondents stated that they used *Questioning Attitude* every day.

Table 34. Frequency – Questioning Attitude – Stop if Unsure (n = 82).

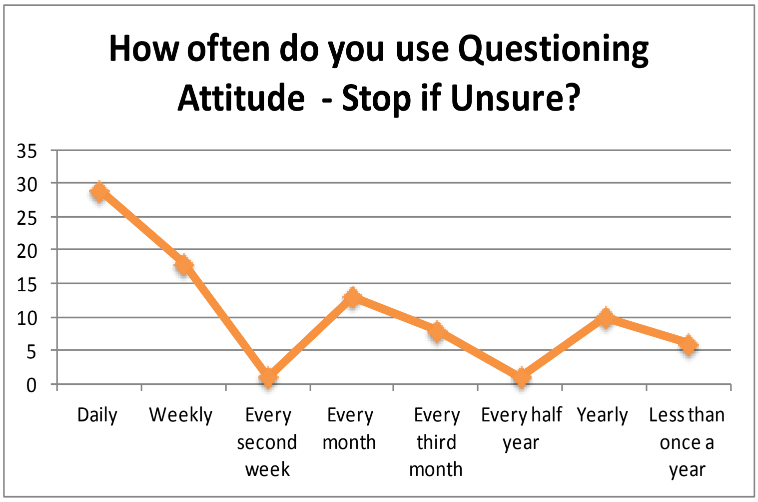
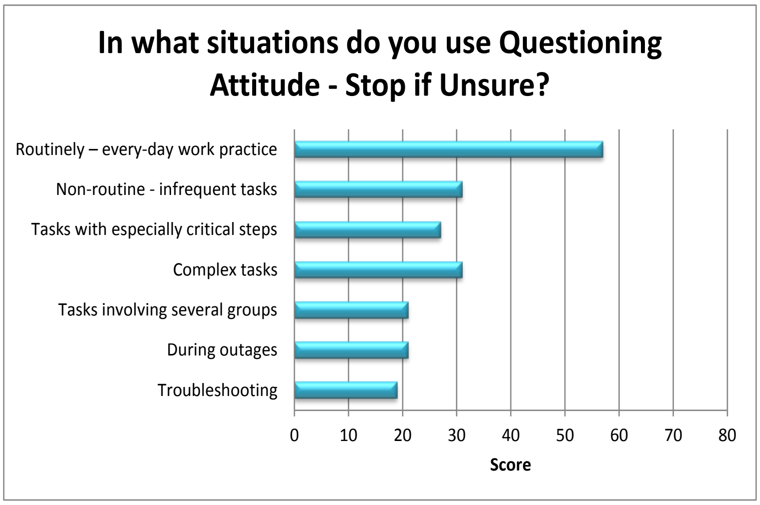


Table 33. When is Questioning Attitude used? (multiple response options)



The importance of upholding a *Questioning Attitude* was instilled in the maintenance personnel, when they started working at the targeted plant. An interviewee explained:

> "When you start working here [at the plant], you are encouraged to ask questions – both to colleagues and to the operators in the control-room. It is also well accepted that you, even as a new person, come up with suggestions. You are taught that there are no stupid questions."

The interviewees provided several examples on how employees with a questioning attitude had helped address important safety-related issues. This included questions raised by a newcomers. Valuable input had been raised by newcomers, who considered long-established work practises and routines from new perspectives.

Factors Promoting the Use of Questioning Attitude – Stop if Unsure

The following factors were identified to promote the use of *Questioning Attitude – Stop if Unsure*.

- Awareness that deviations from what is planned/expected/assumed will occur from time to time combined with a strong sense of responsibility for upholding safety.
- Earlier experiences, which had made it obvious to maintenance personnel, that conclusions reached by themselves and/or others are not necessarily correct (e.g. the conclusion was based on an erroneous or incomplete basis).
- Practices, which help maintenance to uphold a clear focus on safety. The interviewees described on such practice, which they found helped promote awareness of the need for upholding a questioning attitude:

  In their morning meetings, maintenance personnel jointly review reports on plant malfunctions. These reports may be written by people from various groups/departments, e.g. control-room operators or field operators. Maintenance personnel discuss the possible reasons for the reported malfunctions, and these discussions allow them to share their own perspectives on the error reported, and to listen to the perspective of their colleagues. From time to time, the morning meeting may even conclude that a reported malfunction actually is not a malfunction at all: the process system works according to plan, but that the person, who reported the malfunction, lacks sufficient technical competence to understand this. Through these discussions, maintenance personnel have learnt the value of examining (reported) problems with a Questioning Attitude.

- Maintenance leaders must continuously encourage maintenance personnel to *stop working*, if they feel unsure, and they must ensure that *stopping* will not have any negative implications for maintenance personnel.
- A group climate in which safety has *first* priority.
- Situations in which colleagues are appreciated for raising issues that might potentially have (had) negative safety implications: the responsibility for upholding safety should be seen as a *joint responsibility* of maintenance personnel, and issues associated with *individual prestige* related to *changing plans for how jobs should be performed* for safety reasons, should preferably be non-existent.

Factors Working against the Use of Questioning Attitude – Stop if Unsure

The factors reported to work against the use *Questioning Attitude* include:

- When questions are raised, which are camouflaged as safety concerns, but which are (perceived to be) posted for *other than safety reasons.* Interviewees, e.g. stated:

  Interviewee 1: “It can be too much if a person raises questions just to raise questions.”

Interviewee 2: “Sometimes questions are raised *ad absurdum*, everything is questioned.”

Interviewee 3: “... sometimes you get the impressions that questions are asked to delay tasks.”

- Answering questions can be *time consuming* and in some situations, it may lead to *unnecessary delays.* Maintenance personnel reported that if questions are raised *too often* it can be tedious, and it can result in delays in the task performance processes. They emphasised that there *has to be* room for questions, but also that *asking (all sorts of) questions* was not the same as using the HPT *Questioning Attitude*. In situations were “too many” questions were asked, maintenance personnel (Technicians and Engineers) perceived it to be a *leadership responsibility* to intervene. An interviewee and a questionnaire respondent stated, respectively:

  “It is good to question tasks with reference to safety. Still, sometimes we must make a decision, so that we can move forward with the task.”

  “ ... a *Questioning Attitude* should not be used as an alternative to a Pre-Job Briefing.”

- Sensitive colleagues: several maintenance personnel reported that some of their colleagues could interpret questions *in the wrong way*. These colleagues could feel that questions raised reflected questioning their professional competence. A respondent wrote that if you ask *too many* questions: “… you will get the reputation among your colleagues that you do not trust their professional judgement.”

Potential Issues for Consideration

Work to achieve an open group climate, where safety is a joint responsibility of maintenance personnel and where errors are perceived as learning opportunities. It is important to promote *mutual trust* among maintenance personnel for the HPT *Questioning Attitude – Stop if Unsure* to be used as intended. Maintenance leaders must follow-up on the use of this HPT to ensure that it is not used to fulfil other than safety purposes.

Appendix D8: Self-Checking – STAR

A Brief Overview of Self-Checking – STAR

A brief overview of the HPT *Self-Checking – STAR* can be found in Table 35.

Table 35. A generic description of the HPT Self-Checking - STAR. *Main source: Department of Energy (2009b, 18-19).*

Classification	Individual HPT (Department of Energy, 2009b) Fundamental HPT (INPO 06-002, 2006)
Main purpose	To prevent own mistakes and to quickly address own mistakes (if any).
User(s)	One person – the task performer.
Time	Before engaging in task performance – in association with pauses, before continuing.
Recommended practices when using this tool:	1. *Stop* working, focus on the task. 2. *Think* about what you should do – consider to relevant instructions - and what the expected outcomes should be before performing the task, and consider contingencies. 3. *Act*, i.e. perform the task. 4. *Review* the outcomes. If needed contingencies. If needed, notify supervisor.
Some threats (DOE, 2009b)	Not following all steps in the self-checking approach. Lack understanding of the intent of one or more procedure steps implied by the HPTs. Performing several manual actions in rapid succession. Not self-checking again after losing visual or physical contact.

Usefulness of Self-Checking – STAR

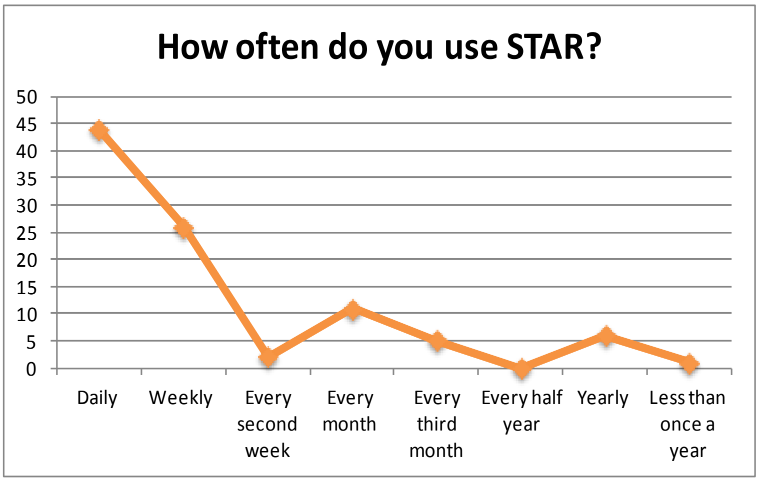
Self-Checking – STAR is a work practice that has been applied at the targeted plant for a many years – also "...before it was called something" as a questionnaire respondent stated. Maintenance personnel consider it to be among the most useful of the HPT to uphold safety (see Table 5 on page 18). They often describe the usefulness of *Self-Checking – STAR* as in the following extracts from the questionnaire survey:

> "STAR defines a basic way of working, which contributes to good personnel and plant safety".
>
> And: "[Self-checking] … is a good way to protect yourself and colleagues from accidents."

During the interviews, maintenance personnel reported that they used *Self-Checking – STAR* routinely, as a naturally integrated part of their everyday work practices.

The results obtained from the questionnaire survey supported this: almost all respondents reported that they used *Self-Checking – STAR* on a daily or weekly basis (see Table 36) and in both routine and non-routine situations (see Table 37).

Table 36. Frequency – Self-Checking - STAR (n=96).



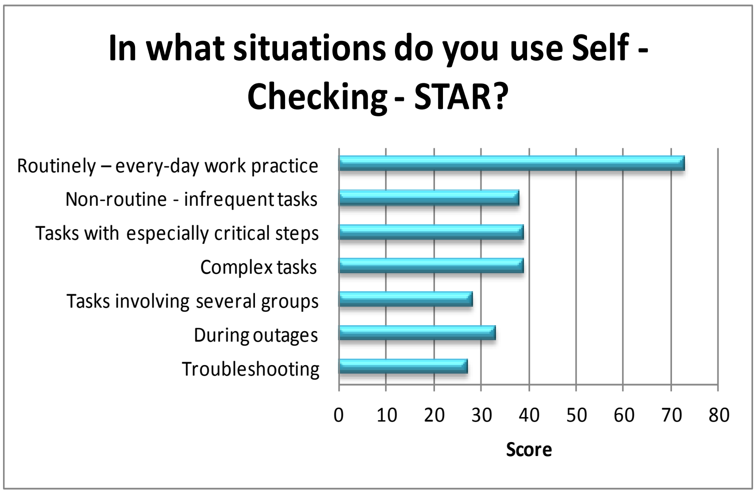
An interviewee described how he used *Self-Checking – STAR* in practice. He said:

"… all the time, "I prepare for the job: I think through what I am going to do and then do it. If I'm uncertain, I stop. It is a fully integrated part of the work process. I use it all the time. It is a part of being professional."

Self-Checking – STAR constitutes a generic way of working, which can be applied in relation to all activities in a maintenance department, i.e. not only in relation to the operational activities. A questionnaire respondent stated:

"STAR can be applied to any type of job. I work among other things with planning, and before I make major adjustments to a plan, I stop, reflect, and act accordingly. I evaluate my own work."

Table 37. When are Self-Checking - STAR used (multiple response options)?



Maintenance personnel provided several examples on how *Self-Checking – STAR* had helped to prevent unwanted events. An interviewee explained how he once had to work on a terminal block. He expected that it would be brand new; as a maintenance engineer had stressed that he was going to work on a *new* terminal block. However, when he later identified the item he should work on, he found that it was *old*. He became concerned and stopped working and started to investigate the reason for this discrepancy.

Another interviewee provided an example on a way of working which he conceived illustrated *Self-Checking – STAR*:

> "When I receive a report on a plant system malfunction, I read through the report to form my own mental picture of the situation. Then I start to search for the malfunction to correct it. After having searched for a while I re-read the report, and with my new insights about the state in the plant, in some cases I understand it in a new perspective and then I change my approach."

The above example illustrated that what was formally perceived as implied by *Self-Checking – STAR* (see Table 35), not necessarily corresponded to what a HPT was perceived to imply by employees. The above example would generally seem to work better as an illustration of the HPT *Questioning Attitude*. Still, at the plant it would seem that the HPT *Questioning Attitude* was mainly associated with situations where a person raised questions in public, whereas *Self-Checking – STAR* was reserved for reflections made by critical reflections made by the individual him or herself during task performance. Actually, STAR may be described as composed of the two HPTs *Self-Checking* and *Questioning Attitude – Stop if Insure.* Hence, the station concerned in this study has superimposed both these HPTs into the well-recognized STAR, as described in their guiding HPT-procedure.

Factors Promoting the Use of Self-Checking – STAR

The factors identified to promote the use of *Self-Checking – STAR* included:

- Early training should ensure that *Self-Checking – STAR* constitutes a common work practice among not just maintenance personnel but all employees in a plant. Maintenance leaders must continuously encourage personnel to use this HPT. On participant reported: encouraging a colleague to do *Self-Checking – STAR* "… is a good mean of putting on pressure when someone thinks it's ok with shortcuts."
- Maintenance personnel should be aware that deviations from the planned/expected/assumed may always occur, and this should motivate them to engage in the extra checks, implied when using *Self-Checking – STAR*. *Self-Checking – STAR* can be conceived as "added redundancy" as "… the extra phone call that may prevent an unwanted event", as stated by one of the interviewees.
- It is also important that maintenance personnel recognize their own fallibility. An interviewee stated: "You can make errors, and because you work in a safety-critical environment, it is important to establish sound work practices, which help to prevent and catch errors, so that they will not have negative impacts on plant safety."

Factors Working against the Use of Self-Checking – STAR

None of the interviewees suggested any factors that could work against the use of *Self-Checking – STAR*. Of the 51 participants, who responded to the non-mandatory question with a free text response format about the disadvantages of *Self-Checking – STAR*, only five suggested some potential disadvantages:

- Two respondents pointed out that with *Self-Checking – STAR*, task performance would require more time than without.
- Two respondents found that *Self-Checking – STAR* sometimes was applied to “trivial tasks,” where it actually was not needed. One of these respondents further stated: “It can be too much thinking and too little action sometimes, when priority is missing.”
- One respondent found that when applying *Self-Checking – STAR*, one did not always attend to previous experiences gained in similar situations by colleagues.

Potential Issues for Consideration

The study identified no specific suggestions for improvement in related to *Self-Checking – STAR*. This HPT is since long embedded in the industry, and integrated in everyday work practises. It constitutes a so called *mindful safety practice* (Skjerve, 2008). To ensure that *Self-Checking – STAR* will be used with good results also in the future it is important to continuously nurture, train and develop the skills of maintenance personnel on this fundamental barrier.

Appendix D9: Task Observation

A Brief Overview of Task Observation

A brief overview of the HPT *Task Observation* can be found in Table 38.

Table 38. A generic description of the HPT Task Observation. *Main source: Department of Energy (2009b, 73-74).*

Classification	HPT for Management (Department of Energy, 2009b) (INPO 2007)
Main purpose	Management reviews the quality and effectiveness of task performance (the whole job, and not just the behaviour of the person performing the task) to identify opportunities for improvements.
User(s)	Leader(s) observing how a job is carried out - and the task performer(s) being observed.
Time	Simultaneously.
Recommended practices when using this tool:	1. Plan the observation – be aware of the critical steps. 2. Check if obstacles to performance are present (availability of tools, task performer's skills and understanding of the task, etc.). 3. Verify availability of appropriate tools and spare parts. 4. Reinforce and coach performers on observed behaviours. 5. Correct people on the spot if needed (at-risk and unsafe practices). 6. Ask questions. 7. Record the findings. 8. Follow up on unresolved problems.
Some threats (DOE, 2009b)	Failure to plan for the observation. Focusing only on the task performer(s) behaviours - ignoring job-site conditions, and organizational processes and values. Unwilling to be critical and intrusive during the observation. Not correcting poor practices or stopping at-risk behaviours. Failure to record findings or to use those findings to trend performance over time, not following through.

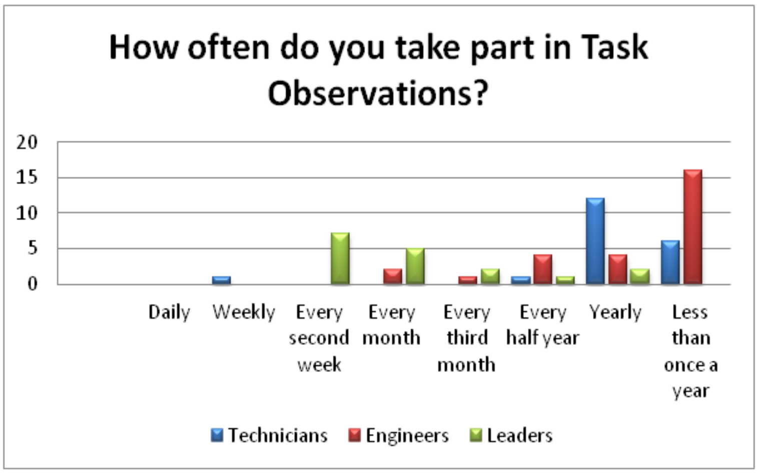
Usefulness of Task Observation

Task Observation is a HPT for managers. At the targeted plant, maintenance leaders are requested to carry out 20 *Task Observations* per year. For maintenance, Technicians and Engineers taking part in a *Task Observation* is thus a rare event. Table 39 shows that the majority of maintenance engineers are exposed to *Task Observation* once a year, and that the majority of the Technicians are exposed to *Task Observation* less than once a year. The majority of maintenance leaders, on the other hand, take part in *Task Observation* every second week or every month. The questionnaire survey indicated that

Task Observations are more frequently carried out during outages than during every-day work (see Table 40).

Overall, *Task Observation* was seen as the *least important* of the ten HPTs applied in the targeted plant, when considered from the perspective of promoting safety (see Table 5 on page 18). The result might however, as discussed in the main part of the report be the result of confounding. It might be that because Task *Observation* is rarely used, it is seen as having limited impact if it is not used at all.

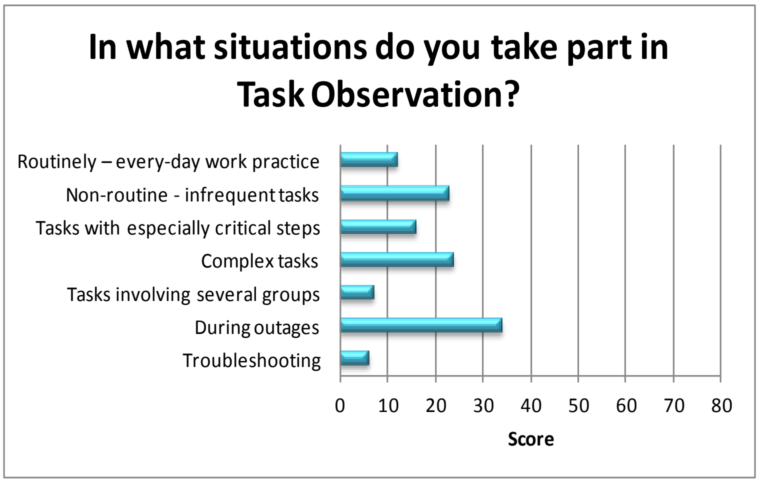
Table 39. Frequency - Task Observation (n = 64).



The interviews, however, suggested that *Task Observation* was viewed differently by maintenance leaders respectively maintenance technicians and engineers. This finding was further explored, based on the data obtained from the questionnaire survey.

It was found (see Figure 6) that when considering *plant safety:* one *manager* (or supervisor) assessed it would have no impact on the safety level in the plant (option "Same"), if *Task Observation* was no longer used, whereas 24 assessed that it would decrease plant safety. 16 *technicians* assessed it would have no impact on the safety level in the plant, if *Task Observation* was no longer used, whereas only 9 *technicians* assessed that it would decrease plant safety. The responses of the *Engineers* spread more equally across the two options: 10 assessed that it would have no impact on the safety if *Task Observation* was no longer used, and 14 that it would decrease plant safety. The same result patterns were found with respect to *personnel safety*. With respect to *productivity* and *collaboration quality*, the scores of the *technicians* and *engineers* have the

Table 40. When is Task Observation used? (multiple response options)



same direction: More responded that it would have no impact on safety, if *Task Observation* were no longer used. The result patters was opposite for the *managers*.

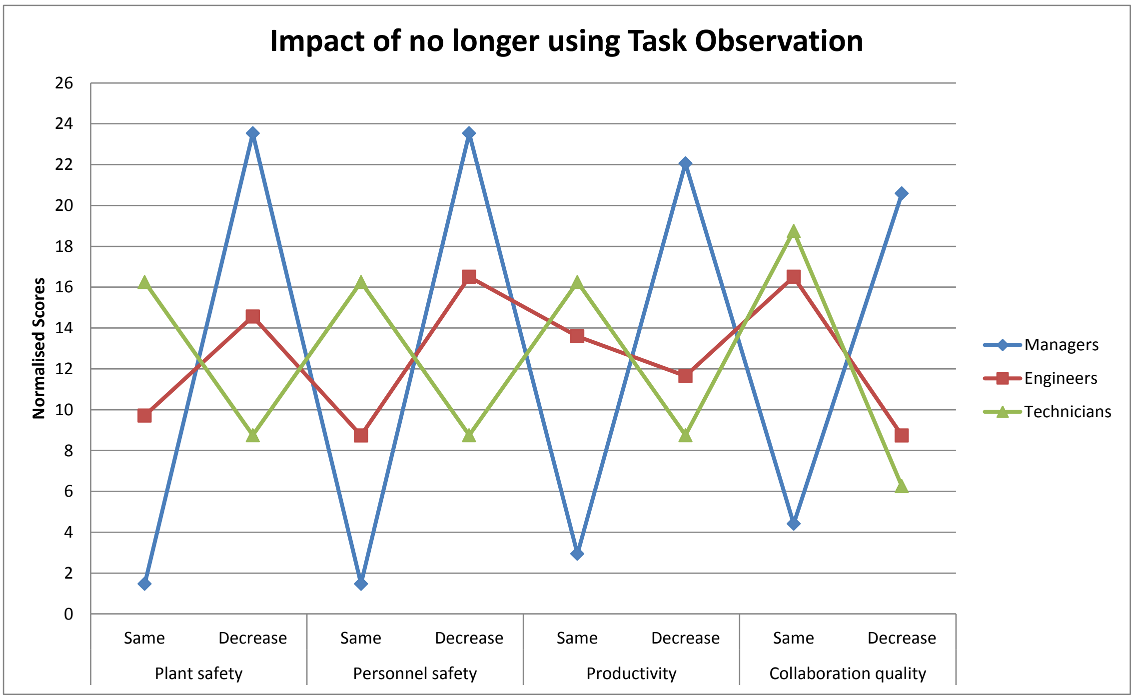


Figure 6 The impact on safety of no longer using Task Observation: none (same) or decrease safety, across three roles (Managers, Engineers, Technicians).

Maintenance managers (leaders) generally hold a positive view on *Task Observation*. They decide for themselves what tasks they will observe and when the observations will be done. Managers see *Task Observation* as a good opportunity for keeping up with practical work in the plant and for coaching maintenance Engineers and Technicians, as well as for showing interest in their work. A manager stated:

> "Task Observation is absolutely a great tool. I can also find many ways in which task performance can be improved."

Most of the maintenance staff (Technicians and Engineers) interviewed stressed that *Task Observation* was a useful and appreciated tool, when the observation was carried out by the immediate leader, i.e. the *team leader*. The reason for this was that the team leader understood the work: she/he understood what they were doing and what they wanted to achieve. For this reason, the team leader was also able to *reckon good performance* and to point of out *aspects of the task performance process that could be improved*. The maintenance staff members also saw *Task Observation* as useful, because it ensured that the team leader continuously would uphold insights into how maintenance work was carried out in practice, i.e., being updated on the impact of modifications in plant equipment, tools and work processes.

The majority of the staff reported that when *Task Observation* was performed by *other leaders* than the team leader, it might sometimes result in identification of ways in which the task performance process could be improved to better promote safety. However, in most cases they assessed that when *Task Observation* was carried out by this type of observers, it did add little to safety. Examples on this were advices from observers, who were unfamiliar with their task, and, e.g., suggestions that additional HPTs should be used during parts of the task performance process where this (from the perspective of the task performers) was clearly not needed. Examples on situations where *Task Observation* by other than their own team leader could lead to a reduction in the safety level were also presented. A key reason for this was these observers would sometimes *disturb* task performance processes by posing questions to the task performer *during task performance*. These questions typically aimed at helping the observers to understand the content of the tasks – which they according to the *Task Observation* guideline should know in advance – and/or to interrupt the task performance processes with other questions. An interviewee stated:

> "Our tasks are often complex and you would like to focus on your job and not explain to others what you are doing. Often it is not so much the way we work, which the Observer is questioning. It is more that he or she does not know what we are doing, and then asks about this. In many cases we are following procedures, and the Observer ought to read those, rather than asking so many questions."

Another interviewee stated:

> "When our leader is doing the observation, he does not have many questions [during the task performance process]. He focuses on whether we have the right procedures, work effectively, issues related to personnel safety, etc."

Both maintenance managers (leaders) and staff reported that *Task Observations* were best when carried out in a way that *promoted a dialogue between the Observers and the task performers* rather than as a *quality check.* An interviewee e.g. stated: "To be observed during work by a 'controller' is distracting and counterproductive." The maintenance staff members also underlined that the dialogue should be performed before and after the task execution process - *not during the task execution process*. Several interviewees and questionnaire respondents emphasised the importance of ensuring that the observer had an adequate level of pedagogical competence. Feedback should be provided as *coaching*, reinforcing good behaviours and typically raising questions about potential needs for changes, rather than simply by pointing out errors/mistakes/inadequacies. Task performance takes place in a context, and contextual factors should also be considered. An interviewee stated:

> "It is not meaningful if an Observer only looks for shortcomings and fails to discuss the work conditions."

Another interviewee stated:

> "It is easy to feel the feedback from an Observer as negative criticism and as an expression of his ignorance, when the wrong people carry out the Task Observation."

The perceived usefulness of *Task Observation* to some extent seems to be associated with the frequency with which the individual staff member is being observed. Since the maintenance managers (leaders) determine what tasks they will observe, a staff member, who are exposed to "many" observations may perceive it as stressful. This can be illustrated with the following three stamens:

> "If you are observed [*Task Observation*] too often, it can be disruptive and it can be perceived as a lack of confidence."

> "It may feel as if he/she [the manger/leader] wants to see what I can".

> "You can get the feeling that you are being controlled."

Some maintenance staff members found that simply *being observed*, while carrying out their task, made them feel uneasy. One interviewee described it in the following way:

> "… [*Task Observation*] stresses the task performers, because they will strive to make their way of working perfect for the Observers. You become criticized, if you do not perform exactly as specified in the instruction. If you have forgotten an important tool, you will get a bad mark and a "red light" in the Task Observation form. I find it unpleasant and stressful to have someone staring me over the shoulder all the time judging my work."

Factors Promoting the Use of Task Observation

This section outlines the lessons learned on factors that will increase the likelihood that *Task Observation* - in general - will contribute to achieve its goal of promoting safety.

- To promote learning among the task performers, *Task Observation* should most frequently be carried out by the team leader of the maintenance personnel being observed, as the team leader can provide highly qualified feedback. From *time to time,* leaders from other groups/departments should also carry out *Task Observation,* because they may provide a "fresh pair of eyes" on the task performance process and maybe spot areas for improvement, which escaped people working within the particular group.
- Task observers should not provide feedback or ask questions during the task execution process, unless immediate safety concerns arise.
- The leaders performing a *Task Observation* should have adequate pedagogical competence. It seems as if it is generally best it feedback is given in the spirit of coaching: In most situations, feedback should consist mainly of asking questions, allowing the task performers to reflect on their own task performance process and arrive at conclusions about how task performance can be improved.
- *Task Observation* is a learning opportunity for the leaders making the observation and an opportunity to showing interest in the work carried out by staff in their group. When leaders observe the task performance in their own and in others group, they increase their insights into the work processes and the production systems applied at the plant. This may be a factor motivating use of *Task Observation.*

- Some maintenance staff members emphasised that it was positive and motivating that leaders in general every now and then *controlled the quality* of task performance in the plant.

Factors Working against the Use of Task Observation

Factors working against that *Task Observation* is used as intended include:

- In situations where the workload level of managers is high, it seems that *Task Observation* often is not prioritised.
- When task performers perceive that the main purpose of the *Task Observation* is to ensure that the managers fulfil their required number of *Task Observations* (i.e. 20) per year.
- When task performers feel that they are being disturbed during the task performance process, e.g. because they feel they need to work differently than they usually do, because they feel uneasy about being observed, etc.
- When the task performers perceive that the observers are only looking for errors in the task performance process.
- When the task performers feel that the main purpose of the *Task Observation* is to educate the observer(s) - rather than to observe the task performance process to verify/improve safety.
- When the observers leave without providing any feedback to the task performers (e.g., while making notes in their observations in the Task Observation form).
- If coaching is provided in a way that interfered negatively with the task performers' ability to solve their task, e.g., the observers ask questions, which make it hard for the task performers to focus on the task.

Potential Issues for Consideration

During the interviews and in the questionnaire survey, several suggestions were provided by the participants on how *Task Observation* might be improved.

- Consider whether the responsibility for deciding what tasks processes to observe should be allocated to the task performers, rather than to the leaders. The task performers could then invite leaders to observe tasks they wanted to have reviewed, e.g. to understand if/how they could work in a safer way. In this case, many of the potential negative impacts of *Task Observation* (task observers feeling of being controlled, etc.) could be avoided.
- A participant suggested that *Task Observation* would be more useful, if the observers provided some "added value" to the task performers. Added value might, e.g., include that the observers informed about events or near misses that had occurred in association with the performance of the task at hand – at the present or at other plants.
- Consider if *Task Observation* could also be carried out by people, who are not leaders: Maintenance personnel from different units might observe and provided feedback to each other, and thus contribute to promote safety by strengthening experience transfer. At the targeted plant, maintenance leaders are encouraged to conduct *Task Observations* together in pairs with employees.

Appendix D10: Use of Operating Experience

A Brief Overview of Use of Operating Experience
A brief overview of the HPT *Use of Operating Experience* can be found in Table 41.

Table 41. A generic description of the HPT Use of Operating Experience. *Main source: Department of Energy (2009b, 90-92).*

Classification	HPT for Management (Department of Energy, 2009b). Not included in INPO (06-002, 2006).
Main purpose	Improve how work is conducted. This HTP refers to *operating experience* (OE) *programs*. OE refers to "... all events, conditions, observations, and new information that could affect how work is conducted" (*ibid*., 90).
User(s)	Management.
Time	Continuously.
Recommended practices when using this tool:	1. Collect all relevant OE information. 2. Distribute applicable OE documents (including documents from other departments and external sites) to relevant people for screening and analysis. 3. Analyse the OE information for safety significance. 4. Develop lessons learned – recommended corrective actions and successes. 5. Follow-up to ensure the required actions is completed. 6. Establish metrics to measure program performance and evaluate the effectiveness of the implemented actions.
Some threats (DOE, 2009b)	Forgetting the OE lessons learned. Doing nothing in response to the OE lessons learned. Disregarding OE lessons learned from external sources. Failure to establish performance indicators and track trends on the effectiveness of the corrective actions taken, based on the lessons learned.

At the targeted plant, the HPTs "Use of Operating Experience" is perceived to include making use of both individual experiences, experiences from the targeted plant and/or other from other plants, and experiences and/or insights distributed via international organizations, such as WANO.

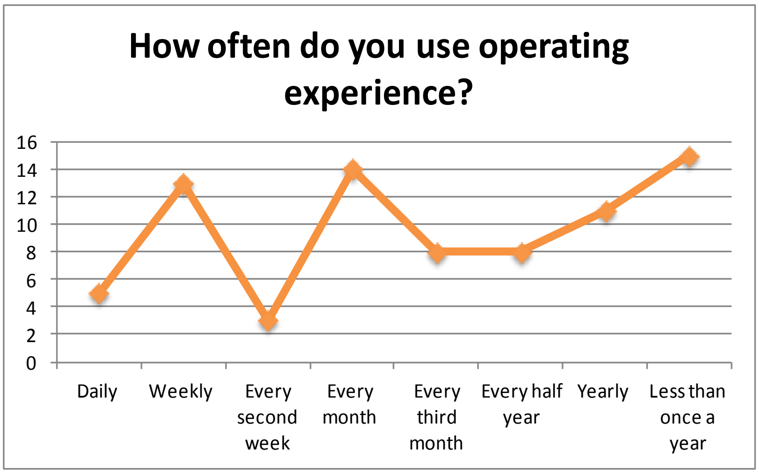
Usefulness of Use of Operating Experience

Both the interviews and the questionnaire survey suggested that maintenance personnel regard sharing and using *Operating Experience* as a useful way to approach for improving safety.

The usefulness of *Operating Experience* is most frequently mentioned in association with the performance of *Pre-Job Briefings*, where they help ensure that all risks are identified and addressed prior to initiation of the task. A questionnaire respondent stated:

"The experiences obtained by one person or in on situation, can be used by several people."

Table 42. Frequency – Use of Operating Experience (n = 103).



Maintenance personnel also emphasised that *Operating Experience* may be a means to reduce task performance time, especially when it comes to trouble-shooting tasks.

Still, the questionnaire survey indicated that *Operational Experience* is used less than might be expected based on the maintenance personnel's positive evaluation of this HPT: Only eighteen respondents indicated that they used *Operating Experience* daily or weekly (see Table 42). The questionnaire survey, however, also showed that when *Operating Experience* is used, it is used both in relation to routine and non-routine tasks (see Table 43).

Even though maintenance personnel perceive *Operational Experience* as a useful HPT, they also identify some risks in relation to use of this *Operational Experience*. Lessons learned from operational experiences may give a bias to look at the task performance process from only that angle. It would imply that certain aspects may be discarded, and perceived to

Table 43. In what situations are Operational Experiences used?

be unimportant in the present situation. Another risk is that the personnel misinterpret the lessons learned (e.g. because it is not very well-written). Use of *Operating Experience* was to some extent also seen as a barrier for innovation, as it was perceived to promote adherence to long-established routines.

Factors Promoting the Use of Operating Experience

Based on the data obtained in the questionnaire survey, as set of factors is suggested to contribute to promote the use of *Operating Experience*:

- When maintenance personnel experience that they may increase the robustness of the task performance process (avoid known errors) and raise risk awareness by using operating experiences.
- When maintenance personnel experience that they may reduce the time spent on a problem by consulting ‘operating experiences.’ This is in particular the case for troubleshooting tasks.
- Establishing a culture in which experiences are appreciated: the individual maintenance staff member must be encouraged to learn from own and others experiences to improve safety.

Factors Working against the Use of Use of Operating Experience

Some factors were found to work against the use of *Operational Experience* as intended:

- *Operating Experience* lessons learned are not *formulated in a way maintenance personnel understand*. This may lead to misunderstandings or imply that they are ignored.
- *Operating Experiences* are *difficult to retrieve:* For example, experiences may not be stored in one place: A questionnaire respondent stated: “There are many places to search for experiences. It is very difficult to know how to find the relevant experiences. It takes a lot of time to search for these.” Another questionnaire respondent stated: “It is difficult to find the right *lessons learned*, e.g., for a PJB, there is no search function, no database, no one collection of *lessons learned*.” Still another stated: “There is no simple link in our system that makes it easy to retrieve *lessons learned,* which are of relevance for a particular job.”

Potential Issues for Consideration

It is suggested that operating experiences are documented systematically and in a language maintenance personnel understands, that they are stored in one database, and that they are associated readily retrievable, i.e. associated with useful search words. In addition, maintenance personnel should have easy access to the database containing lessons learned, and training in how to identify relevant lessons learned: at the targeted plant, the lessons learned are documented in Just-In-Time briefs, JIT, and made available on the intranet. In addition to supporting structures for operating experience and lessons learned, the organisation need to encourage the personnel’s motivation to make readily use if it.

Title	Human-Performance Tools in Maintenance Work - A Case Study in a Nordic Nuclear Power Plant
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Abstract max. 2000 characters	The performance of maintenance in nuclear power plants is one of the cornerstones for ensuring safe and efficient operation. Maintenance work is associated with operational and occupational risks. Today, most plants use Human Performance Tools (HPTs) to contribute to reduce these risks. Despite the widespread use of HPTs, the beneficial effects remain elusive. The study was performed in a Nordic nuclear power plant. It addressed three research questions: (1) How do maintenance personnel perceive and use HPTs? (2) How may the intended use of HPTs be promoted in maintenance work? (3) How to introduce HPTs to maintenance personnel? Overall, maintenance personnel had a positive attitude to HPTs. In situations where the use of HPTs made sense to maintenance personnel, they would use HPTs as intended, i.e., attentively and resiliently, focusing on ensuring safety. In other situations, the HPTs might not be used or might be used more superficially. Introduction of HPTs should focus on practical use. The study was carried out within the framework of the Nordic Nuclear Safety Research project HUMAX.
Key words	Human Performance Tools, Maintenance Work

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