
Assessing Nuclear Safety from a “Human and Organizational Factors” perspective: Lessons learned from an International Benchmarking

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Abstract:

This communication presents the results of an international benchmarking focused on how Human and Organizational Factors (HOF) are assessed in the context of regulatory activities from the nuclear industry. The benchmarking was carried out between 2009 and 2011 by IRSN. Data have been collected from the Regulatory Authorities and TSOs of seven countries (Brazil, Canada, Finland, France, Spain, Sweden, US), mainly by means of interviews with HOF specialists, inspectors, managers, researchers, representatives of TSOs and licensees. The communication shows that a match exists among the material we have collected; we can talk about assessing nuclear safety from a HOF perspective as a profession needing the same specific skills and tools wherever this activity is done. Besides this match, two main approaches for assessing HOF topics – inspection and investigation – are identified. Selecting one against the other depends both on institutional parameters and on the conception of HOF adopted. Performing such assessments is complex: indeed specialists need not only have a strong background in HOF, they also need to possess a great understanding of the industrial processes, as well as a great understanding of the regulatory context in which they evolve. Therefore, managing HOF specialists towards the improvement of these skills is of first importance.

1 INTRODUCTION

Assessing nuclear and radiological risks from a Human and Organizational Factors (HOF) perspective is the focus of this communication. This relies on an international study carried out by the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), the French Technical Safety Organization (TSO) that provides support to the French regulatory authority (ASN). Data have been collected from the American, Brazilian, Canadian, Finnish, Spanish and Swedish regulatory authorities, interviews have been conducted with more than seventy HOF specialists, managers, inspectors, researchers including representatives of TSOs and licensees.

The central issue of this communication deals with whether or not a match exists among the material collected, i.e. whether or not we can talk about assessing nuclear safety from a HOF perspective as a profession needing the same specific skills and tools wherever this activity is done.

Section 2, provides the methodological aspects. Section 3 introduces the different cases and details organizational structures, resources and HOF specialists' profiles, enabling to identify first similarities regarding the organization of the HOF specialty. Similarities are again emphasized in Section 4, when we present a set of topics approached by specialists worldwide. Then, in Section 5, two approaches utilized for assessing HOF topics are identified; the choice of one specific approach is influenced by institutional parameters and may also reveal differences on the conception of assessing HOF. As these approaches reveal that assessing HOF is a complex activity that requires special skills, Section 6 presents good practices, identified during the benchmarking, with regards to the organization

of the HOF specialists and the management of their skills. Last, we recapitulate the “contingency variables” we have been able to identify through our study, which may have an impact on assessing nuclear safety from a HOF perspective. We also mention some limits and possible extensions of the current work.

2 BACKGROUND AND METHODS

A research on the HOF assessment activity in France was carried out between 2004 and 2008 [1]. Based upon thorough fieldwork¹, it enabled the detailed reconstruction of three cases assessed by the IRSN HOF Group. In France, licensees define specific safety frameworks for each facility that is periodically and deeply assessed by IRSN. Research reveals that with regards to HOF, assessment frameworks used by IRSN are not very detailed as the common principles are on a high-level basis. Actually, for each facility, a specific HOF assessment framework needs to be developed in order to tackle actual facility’s issues.

Research also shows that HOF assessments not only address implementation of rules and management tools, but also aim at evaluating the effects of these formal artifacts on operators’ activity in real work situation. For this, IRSN HOF specialists perform technical discussions with the licensees, and also complete “field studies” including interviews with workers and observations of operators’ activity. This enables HOF specialists taking into account actual facility’s issues.

This research, focused on the French situation, raised the following questions: Are the development of specific HOF assessment frameworks and the performance of “field studies” specific to France? How do other countries assess nuclear safety from an HOF perspective compared to France?

To tackle these issues, IRSN decided to carry out an international benchmarking of this activity. One criterion was, to draw up a topographical plan illustrating countries in which the regulatory authorities decided to include HOF specialists. Six countries were selected: Brazil, Canada, Finland, Spain, Sweden and the USA. The study developed in two stages. First, we visited Canada (May), Sweden (June), Spain (July) and Brazil (August) from May to August 2009. During, a second phase, which took place in 2010, we visited the USA (June) and Finland (August).

Three to five days spent in each country was estimated as essential for performing interviews with HOF specialists, managers, researchers, inspectors and possibly some representatives of TSO and licensees. The interviews topics were the following:

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| <ul style="list-style-type: none"> i) Elements of HOF assessments’ institutional history; ii) Topics and facilities assessed by HOF specialists; iii) Organizational patterns of HOF assessments within the institutional model; iv) Reference frames, investigation methods, databases used for HOF assessments; v) Analysis, monitoring and capitalization of the HOF assessments’ results; vi) Organization and management of the HOF specialists’ team. |
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Table 1: Topics to be approached

We detail below the numbers of interviews we have conducted (see Table 2).

¹About fifty meetings attended, about one hundred interviews performed, during a two year and a half-period.

	Canada	Sweden	Spain	Brazil	USA	Finland
HOF specialists	6	6	3	2	9	5
Other specialists	2	2	2	1	1	2
Heads of division and Directors	2	3	1	1	3	3
Resident and Site inspectors	1	1	2	1	0	0
Representatives of licensees	3	0	2	2	8 ²	0

Table 2: Number of interviews performed

3 THE DEVELOPMENT OF HOF GROUP WITHIN REGULATORY BODIES

3.1 Where are the HOF Specialists?

As a preliminary remark, a macro-level distinction must be done as two nuclear safety “institutional models” exist in the world: In certain countries (e.g. Finland, France, Japan), two organizations are in charge of assessing nuclear safety: a national Regulatory Authority and a Technical Safety Organization³ (TSO). In others, the technical support is performed within the regulatory authority. It is worth noticing this distinction, not only for identifying the structures where HOF specialists evolve, but also for trying to understand their behaviour and logic, by mentioning organization’s goals and missions that will potentially impact their activities. If a TSO is also a research organization, consequently the employees will be motivated by academic work. This work is not necessarily in line with a regulatory purpose. We will revert to this point later in Section 5.

Out of the seven countries selected only two countries, have a TSO i.e. France and Finland. In France, there is a public institute named Institut de Radioprotection et de Sûreté Nucléaire, IRSN. Most of the French HOF specialists belong to IRSN. In Finland, the VTT Research Centre of Finland provides the regulatory authority with scientific support. While IRSN and VTT are both called TSO, we must mention an important distinction between the two organizations: where IRSN specialists focus almost exclusively on the nuclear industry and are very much involved in the development of regulatory decisions, HOF specialists from VTT do not only focus on the nuclear area and their technical support mainly consists in carrying out applied research in other industrial areas⁴.

We can find a team of HOF specialists in all the studied countries, entirely dedicated to the HOF topics, of which origin is generally assumed as a consequence of the TMI accident. HOF divisions’ names deserve some comments, with a little historical perspective:

In Spain, HOF specialists work in the “Área de Análisis probabilistas de seguridad⁵ y Factores humanos” (APFU). Actually PSA and HF have a common history, with the development of a topic named “human reliability”, which was one of the first to be developed in almost all of the countries. Today, two groups of specialists are distinguished within this area; HOF specialists are not that much involved in PSA.

² These eight persons were not representative of licensees, but of INPO (Institute of Nuclear Power Operations).

³ In some countries, the TSO also provides licensees with its expertise (e.g. VTT in Finland).

⁴ However, VTT can also support STUK in performing inspections and investigations.

⁵ PSA stands for Probabilistic Safety Assessment.

In Sweden, HOF specialists work in the “Section Man, Technology, Organization” (MTO), a concept introduced in the 1990s (even if some HOF pioneers arrived in the 1980s). In our interviewees’ opinion, it illustrates the belief that “man, technology and organization must be assessed as a whole”⁶.

In Canada, HOF specialists work in the “Human and Organizational Performance Division” (HOPD). As we will see, human (and organizational) performance is one of the important topics currently assessed by HOF specialists (not only in Canada). It is important to mention that, inside the Technical support branch, HOPD belongs to the Directorate of Safety Management, together with three other divisions: Management Systems Division, Personal Certification Division and Training Program Evaluation Division. These three divisions assess topics that are sometimes considered as HOF ones⁷ in other countries.

In Brazil, HOF specialists work in the “Grupo de Engenharia de Fatores Humanos” (GEFH) part of the “Coordenação Geral de Reatores Nucleares” section, called “Análise de Segurança”. Topics related to organizational factors are not yet considered as a specific area.

In Finland (STUK), HOF specialists work in the Organisations and Operation section. In this section, they work together with resident inspectors, site inspectors⁸, Operating Experience Feedback specialists. HOF specialists also collaborate with technical inspectors to deal with quality and safety management issues.

In France (IRSN), HOF specialists work in the “Bureau Facteurs Organisationnels et Humains” and in the “Laboratoire Sciences Humaines et Sociales”. In ASN, one person is responsible for HOF inside the Nuclear Safety Reactors Division.

3.2 How Many HOF Specialists?

The importance of the HOF topics, is evaluated by the number of specialists in each country (see Table 3).

For the following reasons these figures must be interpreted with care:

- Number of employees: figures include all the employees of the institutions. Not all of them are dedicated to safety assessments, except in Brazil.
- Number of facilities: only nuclear facilities have been considered, hospitals are excluded.
- Number of specialists: sometimes, when considered as almost permanent from the interviewees (France, Spain), contractors have been taking into account. In Canada, the number of specialists working in the Directorate of safety management has been indicated.

These figures are difficult to compare; they show that the existence and the size of a HOF division is not easily linked with the number of nuclear facilities, even if the existence of a threshold may be assumed (e.g. in some Eastern Europe countries owning only one nuclear power site, the HOF matters are not explicitly assessed by specialists). We also would like to mention that we were told, in almost all the countries we went⁹, that the position of HOF is currently much better than it used to be during the 80s and the 90s: “in the 1990s, we used only 3 HOF specialists” (Canada); “HOF needed to be built both in [the regulatory authority] and in the licensees” (Sweden); “In the past, HOF was an expertise not so developed in our organization” (Finland).

⁶ Another explanation may be that the translation of “human factors” and “organizational factors” sounds a little weird in Swedish.

⁷ Therefore, it must be taken into account when we compare the resources allocated to each HOF team (cf. Table 3).

⁸ Where resident inspectors are based at the facility, site inspectors are based at STUK Headquarters.

⁹ The US case constitutes an exception, as after the TMI accident, a very high number of HOF specialists were hired.

	FRANCE	CANADA	SWEDEN	FINLAND	USA	SPAIN	BRAZIL
	ASN + IRSN	CSNC	SSM	STUK	USNRC	CSN	DRS (in CNEN)
Number of employees	440 + 1600	800	240	370	3800	450	150
Number of nuclear facilities (civil)	146 (inc. 58 power reactors in op.)	34 (inc. 18 power reactors in op.)	12 (inc. 10 power reactors in op.)	6 (inc. 4 power reactors in op.)	161 (inc. 104 power reactors in op.)	12 (inc. 8 power reactors in op.)	9 (inc. 2 power reactors in op.)
Division	Bureau FOH and Laboratoire SHS (IRSN)	Human and Organisation Performance Division	Man Technology Organisation section	Organisation and operation section	Several divisions ¹⁰	Área de APS ¹¹ Factores humanos	Coordenação y o Geral de Reatores Nucleares
Number of HOF specialists	1+16	15 (55) ¹²	9	4	25,5	5	2,5
Rate HOF specialists / employees	0,8%	1,9% (6,9%)	3,8%	1,1%	0,6%	1,1%	1,7%
Rate HOF specialists / nuclear facilities	0,11	0,44 (1,62)	0,75	0,67	0,16	0,42	0,27

Table 3: Some indicators regarding HOF specialists (2010)

3.3 Who are the HOF Specialists?

Obviously, all the specialists have a strong background in HOF. Two rather different profiles, in terms of education, have been met: 1) Specialists who have graduated in engineering and then have trained in HOF or in certain areas related to HOF (Psychology, Ergonomics, Sociology, Management); 2) Specialists who have graduated in areas as mentioned above and closely related to HOF. Among the factors that justify the predominance of one profile, we like to highlight that in Spain and Brazil, employees must pass exams in engineering, so that the first profile is much more present. In the other countries¹³, the second profile is predominant.

It should be specified, that there is a wide heterogeneity of backgrounds, which might have an impact on HOF specialists' practices. For instance, it can be illustrated with the existence of a distinction made in the academic world of ergonomics, between two epistemic traditions:

¹⁰ HOF specialists are present in the following divisions: Office of Nuclear Reactor Regulation, Office of New Reactors, Office of Nuclear Regulatory Research, Office of Enforcement.

¹¹ The section gathers specialists in Probabilistic Safety Analysis (APS in Spanish) and HOF. Only HOF specialists have been taking into account.

¹² These figures are those of the Directorate of Safety Management.

¹³ One French peculiarity can be notified: there, a senior, who used to be supervisor in a nuclear plant's control room, is hired for supporting the HOF specialists' team.

the rather Anglo-Saxon ergonomics approach and the rather French speaking-approach. The choice of one against the other may have a non-negligible impact on the HOF specialists' activity. The French ergonomics approach is more focused on the analysis of activity in a real context, requiring fieldwork, where Anglo-Saxon ergonomics approach is supposed to be more experimental and normative (e.g. see [2]). We will revert to this point later, in Section 5. Regarding the grade of studies, a PhD is generally welcome: "specially with the topics related to Design" (Canada); "PhD studies provide a strong theoretical background, a set of suitable methods and tools to assess and analyse licensees' performance, and abilities to critically assess and develop regulatory approaches" (Finland). However, the regulatory activity can be quite far from academic tasks: "a HOF specialist should not be too academic" (Sweden).

3.4 Conclusion: an Established and Broad Domain

HOF is a domain which in the past had some difficulties to be acknowledged as indispensable and consequently to establish itself, in the so technical world of nuclear safety. However, the legitimacy of HOF within the nuclear industry has improved; indeed, in the seven countries we studied, one team (at least) of HOF specialists is clearly identified, and as we have been told, its workforce is far bigger than it was twenty years ago¹⁴.

The names of the HOF teams reveal the historical relationship between HOF and PSA, though the link seems less and less strong. In addition, while organizational aspects are more and more mentioned, the differences between HOF and Management Systems may need further clarifications. This is detailed in section 4.2.

4 A RATHER SHARED SET OF HOF TOPICS

4.1 The Common Set of HOF Topics

Three topics, concerning nuclear facilities¹⁵, are actually shared by the seven countries studied. For most of them, international guidelines are available. For instance, many interlocutors mentioned the USNRC document, NUREG-0711 [3].

We use a Canadian presentation to comment it:

Human Factors in Design: It mainly consists of "verifying that licensees have a systematic process for effectively incorporating human factors considerations into system requirements, definition, analysis, design, verification and validation activities";

Procedures: It mainly consists of "verifying that the process for the development, validation, implementation and use of procedures takes into account human performance considerations";

Operating Experience: It mainly consists of "ensuring that there is a systematic, objective and comprehensive process for monitoring and improving safety". Assessing operating experience can cover several actions, quite different, from doing trends and statistics on a database to analyzing an event in details, or even doing a periodic assessment.

Other HOF Topics Approached in Several Countries

Other topics, which are not assessed by all of our sample's countries, must be cited here and need to be commented:

¹⁴ Except in the American case.

¹⁵ We must mention here that radiological therapy is an area, which is more and more in the HOF specialists' scope, especially in France, in Sweden and in the USA.

Human Reliability Analysis: Even if it was one of the first topics in relation with human factors dealing with nuclear safety, one can notice that a kind of split occurred, between quantitative approaches and qualitative ones. The HOF teams we have studied are generally more into qualitative approaches and, in some countries, they do not deal anymore with HRA;

Competences and Training Program Evaluation: Of course, it is a topic that is assessed in all the countries we have studied. But, only three countries (Finland, France, Sweden) consider this topic as an HOF one, assessed by HOF specialists. It is also interesting to add that there are two different practices regarding the certification of the control room's operators: the certification can be issued by the regulatory authority like in Spain and Brazil, or by the licensee, like in Canada, Finland and France. Dealing with these aspects, all of our interlocutors commented that licensees implement an approach which distinguishes the different steps of managing skills, from identifying needs to evaluating skills – this approach is known as SAT (Systematic approach to training);

Organizational Factors and Management: Except in Brazil, organizational factors are explicitly considered by all of the HOF specialists. However, their definition does not seem very consensual yet. In several countries, quality and safety management systems and audits are assessed. It can be done by HOF specialists (Finland, Sweden, and France) or others (Canada). Finland extensively uses IAEA Safety standards (Safety Requirements No. GS-R-3) [4] for defining and implementing her approach regarding this topic. In the USA, until the Davis Besse incident in 2002, this topic was more tackled by INPO. This major incident led to a change: organizational factors and management are now much better considered inside the USNRC, in particular through the activities related to the safety culture concept (see below). European countries have been worried about the consequences of the opening of the electricity markets and, especially in Spain about the impacts of licensees' mergers on safety. Organization of maintenance activities is a topic assessed in France and Sweden. Contractors management is assessed in Finland, France, Sweden and Canada. It is worth saying that for assessing organizational factors, French specialists distinguished a "macroscopic" approach (general organizational arrangements dealing with information flow, delegation of authority, coordination between teams, for example) and a "microscopic" one (organizational and human arrangements for the safety of specific at risk activities);

Working Conditions: It is a topic not explicitly considered in all the countries we have studied. In Canada, "hours of work" and "minimum shift compliment" ("minimum staff and qualifications required to successfully bring the plant to a safe state during any event") are current and actual topics; in Sweden, one specialist takes care of assessing working conditions, considering in particular the phenomenon of stress. In France, "workload" is a challenging topic that specialists try to assess. In the USA, "fatigue management" and "fitness for duty" are important HOF topics, for which regulatory standards have been developed;

Human Performance Program: it mainly consists of "verifying that programs are comprehensive, include strategies, policies, processes and practices that support excellence in human performance, have defenses that prevent and mitigate the consequences of human error". To our surprise, we discovered a very similar human performance program in all the nuclear power plants we have visited. Human performance programs are not directly evaluated by the IRSN HOF specialists, even if they deal with certain aspects through the evaluation of safety management.

Safety Culture: It is a topic present in the seven countries we visited, even if it is not directly evaluated by the Brazilian and the French specialists. Indeed there is a consensus saying that safety culture is a broad concept, very difficult to assess. It is worth mentioning that

Spain has developed a systematic tool called SISC16, imported from the American ROP (“reactor oversight process”) that soon should take safety culture into account. Finnish inspectors have integrated safety culture in their construction inspection programs at Olkiluoto 3 and formulated recommendations both to the licensee, the vendor, and even to their own organization. As well as being mindful of the safety culture of those entities they regulate, the USNRC is also trying to continuously improve the safety culture within its own organization. Regarding “external” safety culture, the USNRC has recently developed and issued a safety culture policy statement providing expectation for all entities they regulate.

4.2 Conclusion: a Rather Shared Conception of HOF

Therefore, HOF specialists seem to share a rather common interest for the topics mentioned above. Through our interviews and referring to commented documents, we also have had the feeling that HOF specialists share a same conception of HOF for safety, a conception we suggest to qualify as technologist. This means organization is perceived as a set of processes (e.g. for design, for operating experience), rules, artifacts and management tools (e.g. for managing competences) which support and influence operators’ activities. In a sense this illustrates how “Organizational Failures” [5; 6] has become a more relevant paradigm than “Human Error”, according to HOF specialists. Nevertheless, literature on safety culture has shown that “espoused values” and “basic assumptions” [7; 8] are fundamental aspects that should be addressed, in addition to this technologist conception.

5 HOW HOF TOPICS ARE ASSESSED

Dealing with approaches, we try to detail the HOF specialists’ practices, as far as our material can tell, for identifying main issues of the process of assessing HOF. Here again, we have met similarities; in fact, in all the countries, HOF specialists assess nuclear safety with inspections, a term which seems to cover rather similar practices. However, in France, for both historical and institutional reasons, HOF specialists from IRSN mostly assess nuclear safety with investigations based on field studies, of which sense will be detailed later.

5.1 First Approach: Inspection

Inspection is the most frequent methodology used by HOF specialists around the world. Basically, it consists of collecting data in the nuclear facility for assessing HOF topics under a compliance objective, mainly with interviews and documents analysis. Inspections are organized for a legal event (e.g. a renewal licensee process that must be decided by the regulatory authority), but not only for that. We have noticed that Canada and Sweden were focusing on processes that are detailed in their regulation code to carry out their inspections. For example, Canadian specialists were satisfied by the fact that “minimum shift compliment” became a topic mentioned in their national regulation code. The duration of an inspection varies (from one day to a few weeks). In Canada, two types of inspections are carried out: “type 1” inspections that are thorough and detailed with an in-depth analysis of the process; “type 2” inspections that are quick and focus mainly on the outputs of the process.

The following specificities of this methodology should be emphasized:

A collective assessment. In the seven different countries we studied, we perceived that an inspection was always a collective assessment. Indeed, as it is specific to a nuclear facility,

¹⁶ “Sistema integrado de supervisión de centrales nucleares”.

an expert from the regulatory authority, in charge of the facility's follow-up¹⁷, is obviously involved in this process. In Canada and Spain, this expert is frequently the inspection leader; a good relation between HOF specialists and regulators in charge of nuclear facilities is important for being involved in assessments, and therefore adding the HOF perspective to technical matters. In Sweden, the HOF team is so legitimate in the regulatory authority that HOF specialists are frequently team leaders. Of course, there is an expert in the Swedish authority directly concerned by the nuclear facility's follow-up, involved in the inspection process. This expert is called a site inspector. Like in France, we do not find in Sweden resident inspectors. In Brazil, Canada and Spain, resident inspectors are involved in the inspection process. All our interlocutors at the authorities stressed the importance of a good relationship between the resident inspectors on site and the HOF specialists. HOF specialists need to understand routines, informal relations and daily operation of the facility, the kind of knowledge resident inspectors have. A concrete example was given by a Canadian resident inspector dealing with "Minimum shift compliment": he identified a problem with the software that is used for checking the number of operators in the plant, and he could warn regulators and HOF specialists. In Spain, resident inspectors are also involved in the SISC process that will soon take into account HOF. For that, they will have to understand HOF and to collaborate well with HOF specialists.

A contradictory process. In the different countries we have studied, our interlocutors made us aware that inspections were a contradictory process. For instance, there are daily meetings, where the facts and main elements collected during the day are presented to the licensee, who can react. How to take into account the licensees' views is treated differently in each country (e.g. in Sweden, licensees have a few days to mention whether they understand or not the decision letter; compared to Spain, where the licensees' comments are written in a final version).

5.2 Second Approach: Investigation

Even if they are also collective assessments and contradictory processes, "investigations" done by the French HOF specialists are quite different from the inspections. The main differences we see are that 1) investigations are not founded on a detailed regulation code; indeed topics and criteria have to be defined during a framing phase in order to get an assessment framework adapted to the specificities of the facility and its context; 2) investigations generally include a rather deep field study phase with work observations and workers' interviews. This aims at understanding actors' behaviors and logics in order to challenge processes with practices and finally to evaluate the impact of organizational choices on safety.

It is important to mention two main types of investigations done by the French HOF specialists: 1) the cross-cutting assessment of a HOF topic that concerns a set of nuclear facilities operated by a same licensee; 2) the HOF contribution to the safety review of a nuclear facility.

For the first one, the framing is an important step, because the central issue of the assessment can be quite general (e.g. skills management; subcontractors' management). For detailing the assessment framework, specialists consult literature, experts in charge of the facility who know the main risks, the past events, the modifications done and the social context. Then, both the questions and the methodologies which have been defined during this step have to be discussed with the regulator and the licensee at national level. After field studies, a report is drafted, which is submitted to a long internal review process and discussed with the licensee. After various debates, decisions are finally taken by the French authority ASN.

For the second type of assessment, as already mentioned, HOF specialists use a "macroscopic" approach (general organizational arrangements) and a "microscopic" one

¹⁷ We will call them "regulators in charge of nuclear installations".

(organizational and human arrangements for the safety of specific risky activities). For this approach, risky activities are identified through collaborations with specialists in technical areas. Once again, HOF specialists observe to be able to assess how organizational and human arrangements are adapted for the safety of these activities. For the accuracy of this assessment the HOF specialists have to turn to technical nuclear specialists. On this type of assessment, horizontal integration is quite important and difficult, as specialists of different areas are involved (radiological protection, containment, criticality, fire, etc.). Here again, debates with licensees are organized and at the end, decisions are made by ASN. Therefore, in France, regarding the contradictory arrangements, the licensee has the opportunity to give regularly his points of view during investigations; the decisions made by the regulation authority are quite often the result of a long discussion.

5.3 Conclusion: two Approaches for Assessing HOF?

We have identified two approaches used by the specialists to assess HOF topics: inspection and investigation. The choice of an approach against the other may depend on institutional parameters like the use of a detailed and legal framework with regards to HOF and the possible existence of a TSO where logic of research may prevail more than logic of regulation. This choice may also depend on the structure of the country's nuclear fleet. Actually, costly HOF investigations may be more justifiable when their results address a large number of facilities, like in France with EDF.

Besides, the choice may also refer to a conception of HOF assessment which integrates or not an evaluation of the impacts of the rules, management's tools and other organizational arrangements on workers' activities: while investigations would take into account such evaluation by means of deep field studies, inspections would mostly consist of checking the actual implementation of these arrangements. We believe that this distinction between investigation and inspection is crucial to understand HOF assessments. However it would deserve a better characterization, and for that, more data than those we have collected through this benchmarking are needed.

6 KNOWLEDGE MANAGEMENT: A KEY ISSUE FOR HOF ASSESSMENT ACTIVITY

HOF assessments require a great understanding of HOF techniques (in psychology, ergonomics, social sciences...); a great understanding of the technical risks and the industrial processes, in particular in order to identify the more relevant HOF inside the facility; and a great understanding of the regulatory context in which they work. Organizing the HOF team in order to improve the skills of the specialists is therefore of first importance.

6.1 Organizing the HOF Division for Sharing Knowledge

Classical organizations of experts are viewed in literature as "partnerships" [9]: a collection of individuals, independent, autonomous and already skilled. This study reveals how inappropriate this organizational model is to describe HOF divisions; how different from partnerships these are. We have noted that HOF specialist teams are well organized to exchange information and to share knowledge.

Several "good practices" that have been observed:

Tutoring inside the HOF Division. In Canada, each new member is tutored by a well-experienced staff member, whose support is particularly valuable during the first contacts with the licensees' representatives. The well-experienced specialist shows every detail and

introduces the newcomer to every expert who might be of help. Tutoring can be time consuming as said by a Canadian manager: “we were told to employ young people. This is no doubt a good idea. However for the bachelors, 5 to 7 years are required before becoming an expert. In addition the tutorial training consumes well-experimented specialists’ time. That might be a problem.”

Doing root-cause analysis of incidents. Finnish and French HOF specialists are the only ones who carry out root-cause analyses. For new members, it is a really good exercise to learn the technical complexity, as they need to detail the micro events and HOF that have led to the incident.

Training programs. The various training programs (conferences, courses, research projects) HOF specialists organize (for example in Spain) have a great and positive impact on their knowledge of literature on ergonomics, organization and management.

Visiting programs. In some countries, internships in a foreign HOF division are not rare. One Spanish specialist has visited USNRC for a few months in 2009, and a major part of the team has visited the Swedish SSM for a week. In 2008, they received a technical visit from a Canadian specialist.

Organization of expertise and research activities. The Swedish model for organizing expertise and research activities is interesting: one well experimented specialist is responsible for the management research activities, and each HOF specialist is responsible for the development of knowledge in one HOF area¹⁸. This organization might be adapted for acquiring and sharing expertise. In Finland, as the VTT specialists do not only carry out research in the nuclear area, they learn from different industries and by means of comparison they are able to identify good practices.

Organization of expertise and assessment activities. In all the countries we visited, and particularly in France and Canada, where there are various kinds of facilities which are assessed from a HOF perspective, specialists monitor one or several nuclear facilities. This allows acquiring an extensive knowledge of the facilities.

Founding and monitoring PhD theses. In France, for a few years now, the HOF division has welcomed some PhD students; 4 PhD theses written in collaboration with Universities have been defended. It fosters exchanges with the academic world. Brazilian and Swedish specialists also have this kind of connections.

6.2 Organizing Collaborations within the Regulatory Institutions

Collaborations with other specialists inside the regulatory institutions are also crucial for the development of HOF specialists’ knowledge.

Collaboration with staff responsible for the monitoring of nuclear facilities: As they are responsible for the safety assessments of nuclear facilities, they possess knowledge related to the facility, which is important for HOF specialists.

Collaboration with specialists in other areas: Technical specialists help HOF specialists to understand the technical process and their risks. As a good practice, we can mention the French “microscopic” approach for the assessment of specific risky situations, for which both HOF and technical specialists collaborate. In Sweden, we were told that “collaborations were going well between HOF specialists and technical specialists because HOF specialists make the effort to understand well the technical process.” In Finland, STUK HOF specialists and OPEX specialists work in the same division, in order to facilitate a close collaboration.

Collaborating with site inspectors. Dealing with HOF, we already emphasized how important it was to establish a good working relationship with site inspectors, because they are the

¹⁸ These HOF areas are: Quality/safety managements systems and audits; management of organizational change, safety and economy, maintenance; safety culture and management for safety; competence, fitness for duty, suitability and staffing; working conditions; incident analysis from MTO-perspective; Design adapted to human conditions/Control room from a MTO-perspective; Coordination of regulatory activities on safety culture of the Department of Nuclear Power Plant Safety.

ones who know routines and daily operations in the facility, the most risky activities, the key persons in the plant to deal with, all the small problems, the atmosphere... This extensive knowledge is particularly well mastered by the resident inspectors, as we have been able to see in Brazil and Canada.

6.3 Managing Relationships with Licensees

Both for collecting data, as well as for establishing reference frameworks, HOF specialists must adjust their relationships with licensees. A distinction frequently used by theorists is soft regulation (compliance) versus hard regulation (deterrence) [10;11]. However, this distinction is often criticized, both in a normative way (what is the better regulation form to implement?) and in a descriptive way (it is sometimes difficult to distinguish the two forms). Moreover, the efficiency of the regulation form adopted may depend on the topic which is assessed; for example, a soft approach may not be adapted to a topic like “minimum shift compliment”. Still, this distinction can be used to admit that a wide range of relationship (from very soft to very hard) exists.

In a more descriptive approach, we would like to suggest some parameters that might influence the choice, the possibility for the HOF specialists to adopt a rather soft or firm position.

The potential power owned by HOF specialists: It seems that we must distinguish HOF specialists who work in regulatory authorities and those who work in a TSO. In fact, we could have perceived that the regulatory authorities we have studied possessed potential large power on the licensees; we were told that information was easy to get. On the other hand, we have seen that French specialists had sometimes to negotiate a lot to get access to information. It can perhaps be justified by the type of data (investigation in real work situations) they want to collect. However, their relative lack of authority can make their work more difficult.

Methodological posture of HOF specialists: Here is the counterpart of the last argument: Dealing with methods in academic disciplines related to HOF, the relation between assessors and assessed is important. For observations, French HOF specialists usually adopt a quite “naturalistic” methodological posture; a regulatory relation too strict between HOF specialists and licensees may jeopardize this approach.

Licensee’s expertise in HOF area: We already mentioned above that the regulation form has to be adapted in function of the HOF topic. The attitude of the assessor also depends on the expertise possessed by the licensees in the HOF domain. In front of a poor expertise, we have often seen HOF specialists with a pedagogic attitude. A more “regulatory attitude” can be adopted in front of a more qualified licensee.

A relation more collaborative is sometimes built up beside the assessment processes. We have seen in Brazil, Finland, Spain and Sweden that collaborative research has been carried out. It is worth mentioning this collaborative research, as research is a tool to improve knowledge both for regulators and licensees.

6.4 Conclusion: Organizing for Improving Knowledge and Effectiveness

To conclude this section, we would like to emphasize a point, for which we have been told that improvements were possible; it deals with the follow-up of the HOF specialists’ recommendations and legal decisions. If it is obvious that a better follow-up goes with a better operative effectiveness, we believe it also enables HOF specialists to improve their knowledge. In fact, this conclusion is in compliance with one of the basic principles in ergonomics and management research: “we only understand well what we can transform”. By studying what a recommendation becomes inside a facility, we believe that a HOF specialist can improve the assessment by reviewing the initial assumptions. Verbatim such

as “the follow-up depends on the good will of each specialist”; “follow-up is not centrally organized; we know we can do better” shows that follow-up can be more organized and better done with HOF specialists; as they have the liberty to define their activity, they should take advantage of it by favoring follow-up reviews.

7 CONCLUSION

This study enables us to reveal the “contingency variables” that have an impact on assessing nuclear safety from a HOF perspective; the determinants of this activity: HOF topics (HF, OF and safety culture) and approaches (inspection vs investigation); variety of technology and facilities (standardized technology, small or big licensee); influence of legal framework (regulatory tradition or not); existence of a TSO (possibly with research objectives and researchers profiles); existence of resident inspectors (special access to information); unique team of HOF specialists or not; investigations beside or along with the regulatory assessments. These contingency variables may influence both the activity of HOF specialists and the definition of a strategy adopted by HOF specialists.

Despite these contingencies, we have shown a unity, mentioning the existence of a job, which we have qualified as a complex one. Indeed the objectives and issues we have revealed are not easy to challenge: being legitimate inside the regulatory institutions for existing, facing epistemic limits for judging, managing a special relationship with licensees for generating effects.

Finally, we would like to mention one limit of this work. In this study, we have not developed too much about communicating with the civil society. Indeed, it is generally recognized as one important mission of the regulatory agencies, which can generate conflicts with the other tasks [12]. Through our comparative study, we had the feeling that the way this mission impacts the HOF specialists’ activities seems to depend in an extensive manner on the country. As an example, this impact seems very important in the US, especially through the recent example of the issue of a safety culture policy statement. As we believe this interface with the civil society will be more and more important in the future, carrying out a comparative analysis on this specific topic might be of first importance for the nuclear community. Therefore, this should be seen as a possible extension of this research. Other limits of this work comprised of the small number of the countries selected, the little time spent in each country and the small quantity of data collected. Such limits can also be seen as potential extensions of this work. Still, HOF and safety culture related topics are challenging ones, for which international cooperation is paramount to enable cross learning and continuous improvement. We hope that this communication will contribute to progress in such an ambitious and crucial aim.

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