Knowledge management approaches and tools in the Nuclear Energy Industry: Evidences and Implications from Italian Ansaldo Nucleare Spa

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Companies operating in the nuclear energy sector are recently facing many challenges. Great attention is emerging about the phase of decommissioning nuclear facilities. It depends more and more upon how effectively and efficiently their knowledge management approaches, processes and tools are applied to codify, protect and use knowledge to guarantee security and enhance process performance. Among them, particular relevance is assuming the Integrated Decommissioning Management Tools (IDMT). The aim of this paper is to present the experience – in terms of evidences and managerial implications – of the adoption of IDMT for decommissioning nuclear facilities by the Italian Ansaldo Nucleare SpA.

INTRODUCTION

Energy sector currently faces great changes. These are mainly related to the increasing world population, demands for higher standard of living, a need for less pollution, and a possible end of fossil fuels. Without energy, the world's entire industrialized infrastructure would collapse: agriculture, transportation, waste collection, information technology, communications and much of the prerequisites that developed nations take for granted. A shortage of the energy needed to sustain these infrastructures could lead to a world catastrophe. This translates into developing energy technologies that are cost-efficient, have practical applications, provide greater safety and are environmentally sustainable.

Accordingly, companies operating in the *nuclear energy sector* are facing many challenges related to the regulatory requirements as well as to technological and managerial issues. In particular, recently great attention is emerging about the phase of decommissioning nuclear facilities (Chou and Fan, 2006; Iversen, 2001; Lund, 2006; Nayliss and Langley, 2003).

The effective and no-risk management of this specific phase and the related operational mechanisms depend more and more upon the way companies manage their know-how and how effectively and efficiently their knowledge management (KM) approaches, processes and tools are applied to accumulate, articulate, codify, protect and use knowledge to guarantee security and enhance process performance (Edwards, 2007; Marr and Schiuma, 2001).

Among the KM approaches and tools developed in the nuclear energy sector, in the last years, great relevance is assuming the development and the implementation of *Integrated Decommissioning Management Tools* (IDMT)

The aim of this paper is to present the experience – in terms of evidences and managerial implications – of the adoption of IDMT for decommissioning nuclear facilities by the Italian Ansaldo Nuclear Division (Ansaldo Nucleare SpA). It is part of the Ansaldo Group, one of the most important conglomerates operating in the energy sector.

The paper is organized in the following parts. After a brief overview of the challenges in nuclear energy industry and the best practices of KM traced in energy industry, the experiences of KM developed by Ansaldo Nuclear Division (Ansaldo Nucleare SpA) is presented. In particular, functions, operations, characteristics and applications of the specific IDMT are described and discussed according to a managerial perspective.

A BRIEF OVERVIEW OF THE CHALLENGES IN NUCLEAR ENERGY INDUSTRY

The energy industry comprises all companies historically operating in oil refining, oil and gas exploration and development, power generation, power transmission, nuclear materials plus companies involved in the emerging alternative and renewable energy sector. In the last five years, the industry has enjoyed high levels of growth, due to structural and contingent factors. Traditionally, this industry is capital-intensive, and characterized the presence of few relevant global players.

The energy industry is closely tied, historically, to politics since the days of the industrial revolution. Although there has been recent liberalization in the energy market, most companies continue to have strong ties with government. The International Energy Agency stated that energy use *"is on an unprecedented increase, with most coming from developing countries, led by China and India (….) and this makes a significant contribution to meeting future road-transport energy needs, helping to promote energy diversification and reducing emissions".*

At the same time, there is an increasing debate about how to better exploit new energy sources, as well as how to avoid the starting or the reinforcement of *nuclear-based* national energy production programmes. Accordingly, different countries are developing actions to decommission nuclear facilities located in their territories.

Decommissioning is the final phase in the lifecycle of nuclear facilities. Nuclear power plant decommissioning requires a number of dismantling activities related to civil works and nuclear island systems as well as the construction of temporary facilities used for treatment and conditioning of the dismantled parts. Dismantling activities must be designed, planned and analyzed in detail during an evaluation phase, taking into account different scenarios generated by possible dismantling sequences and specific waste treatments to be implemented. The process of optimizing the activities becomes very challenging when taking into account the requirement of minimizing the radiological impact on exposed workers and people during normal and accident conditions (Chou and Fan, 2006; Iversen, 2001; Lund, 2006; Nayliss and Langley, 2003).

More specifically, information is needed within all the phases of the decommissioning project, in order to ensure technical quality and safety during decommissioning project, provide detailed dismantling process records useful for project quality assurance and radioactive waste tracing inspection, provide a distributed information database, actual cases and documents for various dismantling process, to extract information from the procedure, manage explicit knowledge and make it accessible for decision making, provide a friendly user interface to disseminate tacit knowledge, and even knowledge discovery. As far as general information on decommissioning nuclear facilities is concerned, it can be obtained from a plenty of sources. The main one should be considered the IAEA library which provides a big variety of freely available publications ranging from booklets to specialized technical reports. One of these clearly asserts that *"It is agreed that planning for decommissioning begins during the design of the facility and continues during its construction and throughout its operational life (...) Along with other objectives, this earlier planning would provide a sound basis for decommissioning cost estimation and funding provisions"* (IAEA, 2000).

Nonetheless, for nuclear facilities built at the early stage of the nuclear era, this criterion can be satisfied only at a limited extent. This is the reason why one challenging task for today decommissioning professionals is to reconstruct the plant design package in terms of modern design technologies.

According to the great attention about the phase of decommissioning nuclear facilities (Chou and Fan, 2006; Iversen, 2001; Lund, 2006; Nayliss and Langley, 2003), nuclear energy industry companies are increasingly seeking to effectively manage this kind of processes. In the light of this attention, academic and technical literature argue more and more about the role and the relevance of effectively manage tacit and explicit knowledge background to respect regulatory requirements and to enhance processes performance over time (Edwards, 2007). Specifically, they sustain that the effective and no-risk management of this specific phase and the related operational mechanisms depend more and more upon the way companies manage their know-how and how effectively and efficiently their knowledge management (KM) approaches, processes and tools are applied to accumulate, articulate, codify, protect and use knowledge to guarantee security and deliver processes.

Knowledge Management (KM), then, is recognized, as above outlined, one of the challenges facing nuclear energy industry. In the following sections we present some *basics* of a literature review focused on the investigation of the position of KM practices in the energy industries in order to better frame the development and the application of a specific KM tool by the Italian Ansaldo Nuclear Division (Ansaldo Nucleare SpA) for decommissioning some of its nuclear facilities.

BASICS OF KNOWLEDGE MANAGEMENT AND BEST PRACTICES IN ENERGY INDUSTRY

The management of knowledge and intellectual assets has, in the last two decades, been the object of research of the *Knowledge Management* (KM) field. Over the years, this research stream has evolved, including many different research topics and areas ranging from organizational to technological issues. However, fundamentally, the attention of KM is focused on the processes of employing, deploying, developing and handling knowledge and intellectual assets with the aim to solve business problems and support organizational business performance improvement.

The KM field was originally founded the work of Polanyi (1966) and his fundamental distinction between tacit and explicit knowledge. David Teece (2000) defines knowledge management as "the panoply of procedures and techniques used to get the most from a firm's knowledge assets". According to Wiig (1997), knowledge management has two main objectives: (i) to make the organization act as intelligently as possible in order to secure its viability and overall success, and (ii) to otherwise realize the best value of its knowledge assets. Three major schools of thought on knowledge management can be identified (Bollinger and Smith, 2001): the first school suggests that knowledge management is primarily an information technology issue; the second school suggests that knowledge management is more of a human resource issue; and the third school promotes the development of processes to measure and capture an organization's know-how.

To date, a major focus of scholars has been on the process aspect of knowledge management. In fact, knowledge management has been widely considered as consisting of processes that facilitate the application and development of a firm's knowledge assets. One of the most recognized and comprehensive frameworks of knowledge asset management was developed by Nonaka (1994) and then refined by Nonaka et al. (2000). They state that knowledge management includes three primary activities: knowledge generation, which describes the way employees improvise and organizations innovate; knowledge integration, which describes how employees transform their tacit knowledge into explicit knowledge by codifying their ideas into the systems of the organization; and, knowledge sharing, which describes the socialization process through which employees share knowledge with one another. More broadly, Marr and Schiuma (2001) identify seven processes to manage knowledge assets: (1) knowledge generation, (2) knowledge codification, (3) knowledge application, (4) knowledge storing, (5) knowledge mapping, (6) knowledge sharing, and (7) knowledge transfer. These processes are based on an understanding that knowledge is dynamic in nature, and on this basis they provide guidelines of how to use, transfer, share, develop, and renovate the knowledge assets of an organization. Knowledge assets are dynamic in nature, interact and depend on each other to create value (Barney, 19911; Roos and Roos, 1997). This interconnectivity is enabled by learning mechanisms and knowledge management processes (Carlucci et al., 2004; Marr and Schiuma, 2001; McGaughey, 2002).

According to this frame, it is possible to state that the energy industry is characterized by a technology-based approach to the knowledge management initiatives, enriched by a growing attention towards complementary dimensions focused on sharing best practices and routines (Edwards, 2007). This is due to the issue that, in the last decade, the energy industry has experienced rapid changes, many mergers and acquisition processes, advancement on technology, an extension of offshore drilling, the growing reliance on foreign oil sources and a focus on environmental issues and for these reasons KM initiatives have played a relevant part in making operations more effective and efficient.

Companies like Chevron, Texaco, Schlumberger and ExxonMobil represent good examples of energy industry organizations that have improved their efficiency by institutionalizing technology dimensions with a knowledge-sharing culture. When oil and gas companies have been faced with new technology, outsourcing, new partnerships, and government regulation, their KM teams have provided significant support through *technology and knowledge transfer* practices.

Moreover, many companies have been fine-tuning their best practices transfer process using *content management systems* to further minimize downtime at field sites across the globe. Since energy organizations collect large amounts of data, content accessibility and organization become pressing issues. Content management systems of people, processes and technology provide meaningful and timely information to end users by creating processes that identify, collect, categorize and refresh content using a common taxonomy across the organization. Users can access internal and external content from the same system and with the same queries. The adoption of content management systems reflects the growing strategic importance given to online services and delivery systems within the energy industry, and in particular within oil and gas and nuclear companies.

A very specific area of application for technology-based KM initiatives is in managing radioactive nuclear materials. Stoneham (2002) analyses the importance of computer modeling, pointing out that the nuclear industry and the computer industry have grown up together, and mentioning particularly the importance of modeling the lifecycle of nuclear fuel, and its implication for nuclear plant life management. Seddon (2001) looks at KM in the long-term storage of nuclear materials, where knowledge needs to be retained far beyond the lifespan of a single human being.

A further area of interest about KM in energy sector regards *Decision Support Systems* (DSSs) and several papers mention DSS for the strategic and operations management in the energy sector (Corben et al., 1999; Hesthammer and Fossen, 2000; Landryova and Irgens, 2006; Menal et al., 2000; Porcheron and Ricard, 1999; Prassl et al., 2005)

Davenport et al. (1998) and Barrow (2001) present successful KM projects in British Petroleum (BP), highlighting its “virtual teamwork” approach to *corporate culture* and *knowledge sharing* which enabled global expertise to be brought to bear on local problems, such as trouble-shooting equipment failures and explaining how the principles that had already been established at BP were used when some merger operations took place.

Another relevant issue emerging from the literature review concerning KM in energy industry is the importance of communities of practice. Energy industry companies consider *communities of practice* as the emergent step in the evolution of the modern, knowledge-based organization (Amin et al., 2001; Ash, 2005; Behounek and Martinez, 2002).

Finally, Carroll et al. (2002) examine organizational learning in high-hazard environments, of which nuclear plants are a good example. They found that teams do not have the responsibility to implement change, and as a result the managers and team members disagree. Moreover, they underline that in nuclear plants, top management have concentrated mainly on the technical aspects of the plant, but neglect people factors. Also Strater et al. (2004) focus on KM and human reliability assessment. Their paper is based on the argument that existing human reliability assessment methods do not tackle error of commission. Especially, important for KM is the authors' observation that the errors of commission are generally not errors as such, but based on an incomplete or wrong understanding of the situation, or even result from employees having been trained to do the wrong thing. There is a tension between the well-defined world of the plant itself and the human world of the operators.

The development and the implementation of integrated knowledge management tools may be considered one of the main and recent applications to improve relationships among technical aspects and people factors. In the following, the specific case of the development and the use of Integrated Decommissioning Management Tools (IDMT) for decommissioning nuclear facilities by Ansaldo Nucleare Spa is presented and analysed.

INTEGRATED DECOMMISSIONING MANAGEMENT TOOLS (IMDT) FOR DECOMMISSIONING NUCLEAR FACILITIES: THE CASE OF ANSALDO NUCLEARE SPA

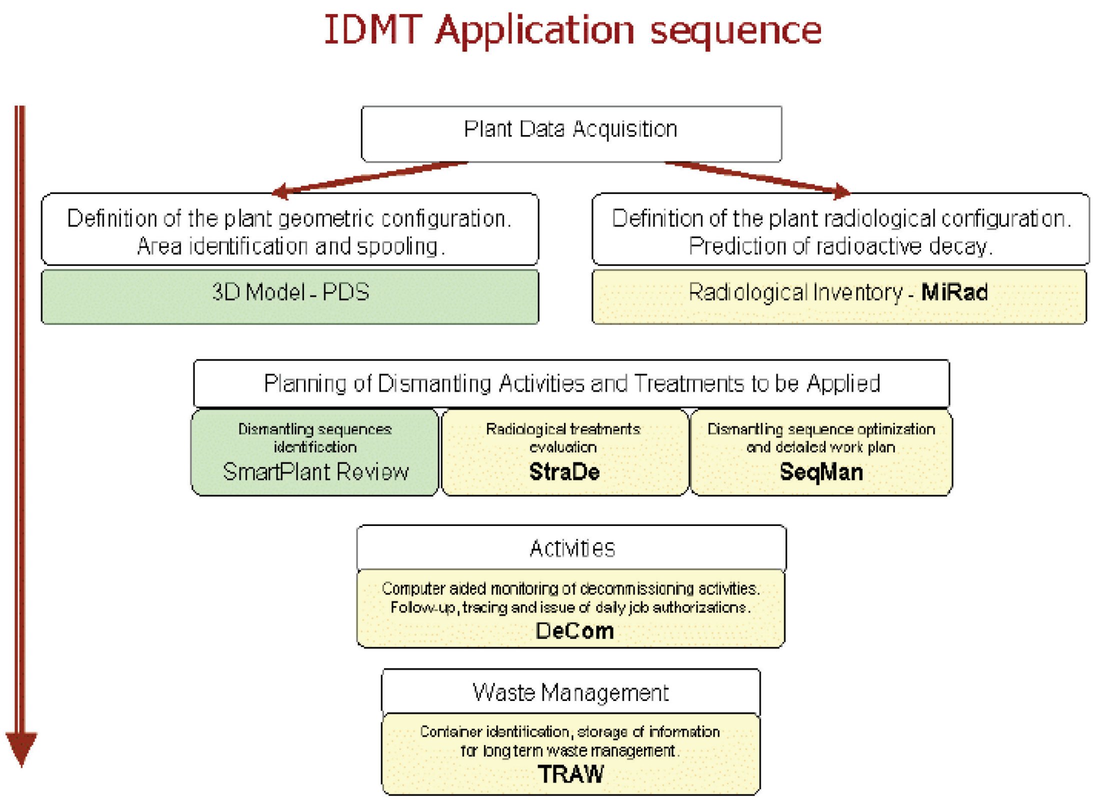
Main Functions of the IDMT Implemented in Ansaldo Nucleare Spa

Ansaldo Nucleare Spa has been strongly involved in development of a qualified and certified software environment to managing the most critical activities of a decommissioning project. The system, called "IDMT" system (Integrated Decommissioning Management Tools), is a set of software modules associated with a package of engineering activities. The software modules, each of them dedicated to a specific decommissioning phase, are designed according to OLE architecture. IDMT supports the choice and implementation of strategies inside the decommissioning project (Alemberti et al., 2005).

The basic concept of IDMT is setting up a CAD 3D Plant Model, and using it as a central repository for gathering almost all required information, based upon the "as built" configuration of plant systems and equipments, the history of modifications and accident events, and the accumulation of radioactive nuclides across the facility. After that or concurrently, validation of the information contained in the Model must be carried out. Additional database tools and appropriate user interfaces integrate with the Model to provide information management functions not available within the CAD system itself. This practice can be considered a good response to the criterion set forth by reference (Alemberti et al., 2005), since its goal is to restore all required information and put it in a form adequate to "state of the art" technologies.

The logical flow of operations and the usage of IDMT in a generic decommissioning project are represented in Figure 1. In the figure, the upper part of each rectangle represents the single decommission activity, while the lower part shows the IDTM software module that supports that activity. As shown in the figure, the IDMT system is a set of integrated tools, based on Intergraph and Microsoft technologies, designed to manage a large amount of data in a safe and centralized way. Each module is provided with a functional and user friendly interface.

FIGURE 1
IDMT MAIN FUNCTIONS



In particular, the models have the following functions:

- *3D Model* of the plant, based on PDS technology (Plant Design System by Intergraph). All plant components and systems are modelled: civil structures, pipes, metal constructions, electric and ventilation systems;
- *MiRad*, developed for the management of the radiological inventory of the plant. It stores the radiological measurements and predicts the radiological inventory at specified dates. The main purpose of MiRad is to give a realistic estimate, area by area, of the level of radiological contamination and/or activation, referred to a specific system or component before dismantling;
- *StraDe*, devoted to the study of the possible decommissioning strategies that includes a database for the storage of engineering and radiological data related to the materials of the site and for the definition of applicable treatments;
- *SeqMan,* supporting the analysis of the dismantling sequences, taking into account the radiological impact on exposed workers;
- *SmartPlant Review* strictly associated with PDS and provides a graphical presentation of the plant model. It allows the simulation of cutting and displacement of the spools, i.e. of the dismantling sequences;
- *DeCom,* the IDMT module responsible for the central management of the decommissioning activities. DeCom imports the spool data from the 3D model and stores all the documentation related to the dismantling operations, i.e. isometric view (when referred to "piping"), global drawing (when referred to "equipment"), dismantling report with details about cutting

technologies and work location, operational procedure, the document accompanying the spool during all the decommissioning phases reporting the operations;

- *TRAW,* allowing the tracking of the construction, storage, organization of conditioned containers of radioactive waste. A database provides the identification and traceability of all information related to each container to be stored at the final repository site.

In terms of characteristics, the IDMT saves in electronic format different types of data (photos, videos, measured data, procedures, as well as physical, chemical and radiological data); it allows an easy recovery of stored data and a simple selection by setting specific access keys;- it permits a simulation of the real operating conditions in order to support the study of plant procedures and identify problems related to work optimization; it simplifies the process analysis through the organization of data in tables, reports and cards; it provides all needed documentation for waste, as required by national regulation; it allows simultaneous work and multiple access to the database, depending on the complexity of the activities, on the project features and on the user profile; it allows a simple customization depending on the specific need of customer and project.

Moreover, IDMT allows the daily monitoring of the decommissioning activities and the continuous traceability of the data: the safety of database information is assured by a controlled accessibility, with different responsibility levels assigned to specific users. IDTM works in an integrated configuration to guarantee waste identification, traceability during treatment and conditioning process as well as location and identification at the final repository site. Additionally, the system can be used to identify, analyze and compare different specific operating scenarios to be optimized in terms of both economical and radiological considerations.

A limited survey of similar documented products suggests that each software project arises from a decommissioning project or from a decommissioning agency/company: for example CORA-CALCOM by Nukem, DECOMIT by UKAEA, or VNIIAES developing a custom support system for Russian NPP decommissioning. This is the case also for IDMT. Perhaps there is a strong requirement that these tools reflect the underlying vision of the decommissioning, usually strictly linked to country-specific regulations and standards or to company-specific procedures and practices. Moreover, a software toolset should be considered as a part of a global solution rather than a *stand alone* product.

IDMT Applications

Table 1 reports how IDMT modules have been supplied to different Italian nuclear facilities. Actual usage depends on actual progress of decommissioning at each site.

TABLE 1
DISTRIBUTION OF IMDT MODULES ACROSS ITALIAN NUCLEAR FACILITIES

Facility/Module	3D-Model	Mirad	Strade	Decom	Seqman	Traw
Caorso	X	X		X		
Trino	X			X		
Latina				X		
Garigliano	X			X		
Cisam	X	X	X	X	X	X

For Caorso NPP, 3-D model of Turbine Building has been constructed and has been used to derive important information for populating the various database sections. The module MiRad population was completed by December 2003 and includes 8362 assemblies. The module DeCom is currently used at

Caorso NPP to support decommissioning of turbine building: up to now the relevant database section has been populated with about 5000 spools: all of them have been removed from the plant.

For Garigliano NPP, only a specialized version of DeCom is used to manage the “work permits” documentation.

For Trino NPP, module DeCom has been adopted and it is going to be used mainly for removal of activated/contaminated item.

For the Galileo Galilei RTS1 experimental facility of CISAM (Pisa - Italy), an IDMT application with empty database has been supplied in 2004. As per Table 1, all the elements of the software package have been supplied to the Site. During the year 2006, the phase of an overall preliminary study was completed: the result was the population of the database and the preliminary design of decommissioning approach: cutting technology, plant layout re-arrangement for decommissioning, waste treatment strategies, selection of a reference dismantling sequence based upon doses evaluation. The system supplied to the site includes a Server computer equipped with operating system Microsoft Windows XP, Microsoft SQL Server (Desktop Engine version) including the IDMT database objects. The IDMT software is installed on the client computers that connect to the server over a local network. During the year 2008, the secondary system and the decationization system have been dismantled, as a first application to test and to setup the overall approach, in view of the ongoing full plant dismantling.

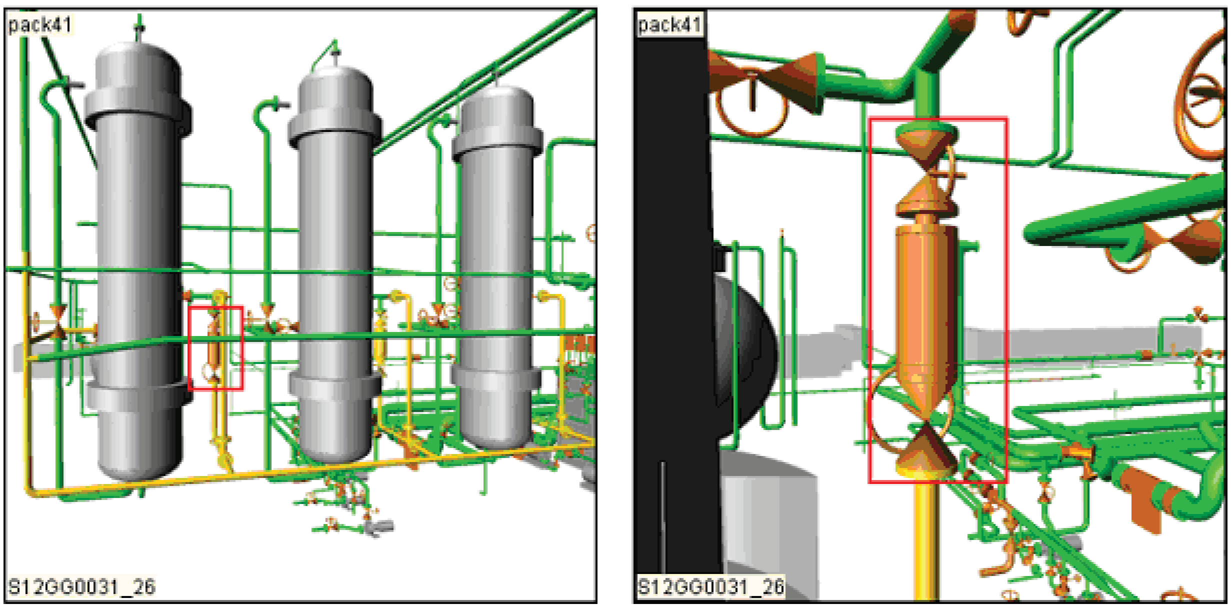
The integrated work of 3D Model with the rest of the IDMT toolset impacts in many aspects of the project. For example, Figure 2 depicts a sample of operational documentation produced for CISAM dismantling project as a support for unambiguous identification of the spool to be dismantled in terms of both visual information and part list. Everything is stored in the database and can be retrieved with simple queries: from a query a document can be generated automatically.

FIGURE 2
SAMPLE FROM OPERATIONAL DOCUMENTATION OF CISAM PROJECT

Identification of Spool: S12GG0031_26 (Area: APOS - 9 item)

Item ID	Description	L (m)
21	Piping 2"	0,020
92	Piping 2"	0,050
1014	flange	0,005
1015	flange	0,005
1016	flange	0,005
1017	flange	0,005

Item ID	Description	L (m)
1537	valve (2-way) VA0102	0,080
1576	valve (2-way) VA0106	0,100
1606	Component generic VA0032	0,150



View n. 762 View n. 763

FINAL REMARKS

Concluding, we believe that the notions and the practical insights discussed in this paper may represent a good research contribution for enriching the conceptual and empirical frameworks on how an effective knowledge management may affects processes and overall business performance within energy industry.

Accordingly, it has been underlined how successful decommissioning in nuclear energy industry depends on careful and organized planning, consistent with regulatory requirements and how decommissioning planning should ideally be fed continuously with information starting already at the first stage of facility design since it may be seen an 'evolutionary process' peculiar and specific for each facility.

It has been presented the IDMT system, developed by Ansaldo Nucleare SpA as a toolset of integrated software modules addressed to govern the dismantling operations in nuclear power plants as well as to manage operational and post-dismantling wastes in treatment facilities. The basic concept of

IDMT is setting up a CAD 3D Plant Model, and using it as a central repository for gathering almost all required information. The software modules, each of them dedicated to a specific decommissioning phase, are designed in order to guarantee high flexibility, high updatability, and high interoperable architecture by the use of a set of integrated tools, based on Intergraph and Microsoft technologies, aimed to manage a large amount of data in a safe and centralized way. Moreover, the paper has highlighted the advantages of using a structured approach to follow the waste from its early phase of dismantling until its final storage into specific containers throughout all its phases of characterization, treatment and conditioning.

Future directions for the research of KM in the nuclear energy industry can be addressed. The first one is the need for holistic, systemic and integrated approaches to deal with the ever-increasing complexity and differentiation of nuclear energy industry companies. Another challenge for researchers and practitioners is to work to unify the still-divergent theoretical base of KM in the energy industry. In particular, more and more energy companies will require different approaches to KM, in terms of the growth of awareness of the importance of KM initiatives, of the importance of codifying knowledge related to new processes and technologies, and the new role of human resources often differently trained and educated to work with experienced staff. For this purpose, we encourage further research to disentangle the complexities in the relationship between knowledge management and business performance.

More empirical inquiry and in-depth case studies are needed to define the modalities and procedures that help companies to identify their knowledge background and implement appropriate knowledge management practices ensuring the effectiveness of their business processes and in turn the value of their products and services. Finally, there is much to be gained from looking at what has been tried in other industries, in the particular the evidence-base with respect to KM initiatives and organizational learning.

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