Improvements Realized on the NiThrow™ Solution – 13075

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ABSTRACT

Two years ago we presented the first results obtained with the highly pressurized liquid nitrogen technology (HPLN) in case of cutting, surface decontamination and concrete scabbling applications. These results, carried out in non active conditions, were really promising in term of efficiency and productivity and highlighted how this technology was interesting for D&D business (e.g. cut of depth up to 30 mm for concrete scabbling application; productivity of 4 $cm.min^{-1}$ in case of the cut of a 50 mm thick stainless steel ingot …). We also found some real issues which were not compatible with its use in a radioactive environment. Indeed, the reliability of some parts of the system was not efficient enough (e.g. lancing tool, intensifiers…) to run the HPLN technology in good conditions. More than two years, after a complete study of the whole system, and after the compilation of all the required troubleshooting, AREVA with its partner Air Liquide, decided to start a complete R&D work in order to improve this cryogenic technology. Our engineers started with the lancing tool and designed a new one lighter and more reliable than the original one. After that, they improved the reliability of the pressurization unit (skid) by changing seals and other parts. As mentioned above, the goal of this work was to implement this technology in a nuclear environment the best way. We also focused our efforts on the insulation of the high pressure hoses (with a maximal distance, between the "skid - Heat exchanger" module and the lancing tool, of about 110 meters), and on the development of a quite efficient vacuum system comprising dust collection units (we can guarantee an efficiency of our system higher than 95%). Finally, the last step of our development was devoted to the design and the manufacturing of a dedicated carrier enabling the technology to move in all directions (X,Y and Z) and to reach all the positions (wall, ground, ceiling and for sure all the singularities such as corners…).

In this paper, the "step by step" strategy to achieve those ambitious developments will be presented with a special attention to the NiThrow™ carrier development.

INTRODUCTION

The NiThrow™ solution is based on the Nitrojet® concept developed by Nitrocision® LLC which consists on the spraying of liquid nitrogen at a pressure of about 3 500 bar (50,763 psi) and a temperature of -140°C (-220°F). This concept can be used to achieve the three main dismantling activities which are the cutting, the surface decontamination and the concrete scabbling. The main benefit in using liquid nitrogen instead of water (e.g Ultra-High Pressure blasting) is due to its rapid conversion into gas that eliminates any secondary waste (especially liquid effluents).

The history started in 2005 when AREVA became aware of this promising technology by doing an intensive technology forecasting on the new developments in the dismantling and decommissioning (D&D) field. Two years later, AREVA in partnership with Air Liquide, made the first trials in France (at St Ouen L'Aumône close to Paris) first, on concrete removing and secondly on surface decontamination. The first results have proven to be really interesting and led AREVA to start an industrial scale trial in order to check the HPLN comportment in this kind of environment and to learn more on how to deploy it in a close future in a nuclear environment. In 2009, this industrial scale trial session (in non active conditions) took place in one of the AREVA facility called SICN (located in Veurey close to Grenoble in the French Alps). For history, this facility was in charge of the manufacturing of nuclear fuel between 1957 and 2000. The dismantling operations started in 2006, shortly after the publication of the D&D authorizations. During three months, our engineers and workers have been able to test several parameters like the time required to mobilize and demobilize such technology, but also the endurance of the machine in case of daily start and stop phases and a few other aspects relative to the adaptation of the HPLN for the nuclear industry. Along these three months, even if the technology confirmed its interest for AREVA, it also showed some limitations which could be a handicap. Indeed, we determined that the lancing tool could be damaged after only a few hours of use (e.g rotating seal); no efficient end effectors were designed for this technology (i.e. Dissemination of the contamination); the distance was too short between the pressurization unit and the lancing tool (e.g. a few tens of meter which is not compatible with a nuclear environment for which, most of the massive and expensive equipments have to be located outside the contaminated area which is sometime 100 meters far from the working area). So, these three months were very instructive for AREVA and led our research and development department to launch an ambitious program in order to fix all of these issues.

OVERVIEW OF THE NiThrow™ DEVELOPMENTS

As mentioned above, the history around the Nitocision® LLC technology started in 2007. The chart below presents the different steps that AREVA carried out in order to be able to use this cryogenic technology in a nuclear environment.

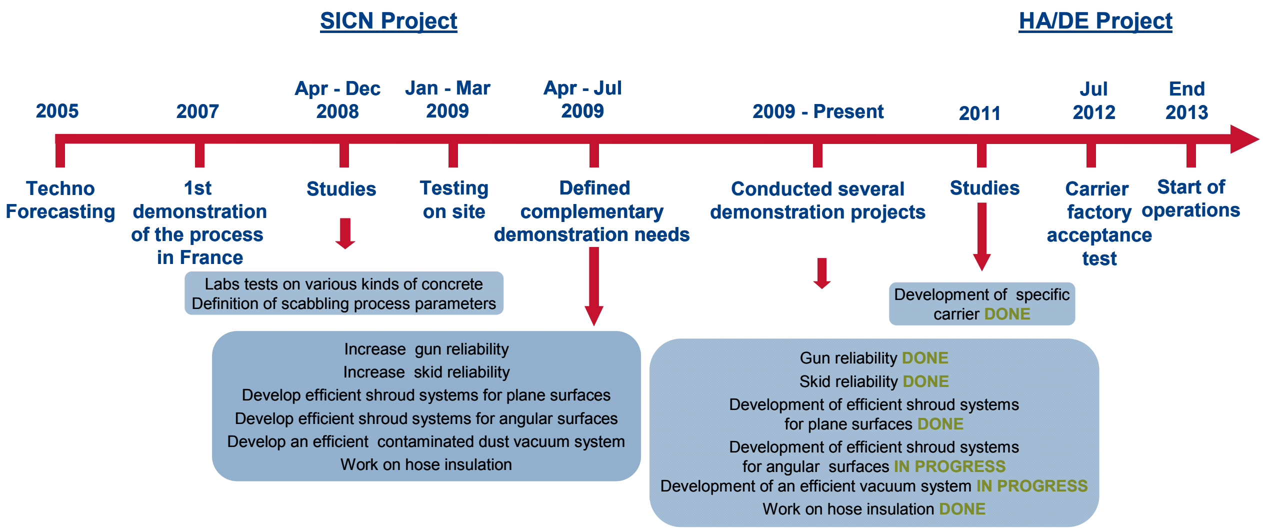

Chart. 1: History of the NiThrow™ solution

"STEP BY STEP" STRATEGY IMPLEMENTED

As mentioned previously, even if this HPLN technology appeared to be interesting and promising, several issues had to be fixed before its implementation on an active work site. To be sure to solve all of them we implemented a step by step strategy starting with the development of a new and more reliable lancing tool and finishing with the manufacture of a dedicated carrier able to carry this lancing tool in more than 9 out of 10 cases.

The table hereafter gives a brief overview of the encountered issues with the original Nitrocision® system used during the SICN project.

Table 1:

	Nature of the problem	Source of the problem	Causes of the problem	Risk(s) for nuclear application	AREVA's solutions
Lancing tool	Breaks / Ruptures	Rotating seal	The low temperature and the high pressure caused failures after a few hours of use	Difficulty to have to maintain or replace the tool every hours	Design of a new tool without rotating seal
Pressurization unit	Reliability	Software programming	Inadequacy between the pressure and the factory settings	Stop of the machine	Update of the software
	Leaks	Intensifiers' seals	The nature of the material	Stop of the machine	Replacement of the original material by a new one more reliable
Insulation of high pressure network	Effectiveness	Insulators	Nature of the insulation material	Localization of the main equipments inside the contaminated area	Calculations and research of a new material
End effectors	No system on the original configuration			Dissemination of the contamination in the cell to be treated	Calculations and designs of different systems for flat and angular surfaces
Vacuum system				Dissemination of the contamination into the cell to be treated	Calculations in order to determine the required flow rate
Carrier				Human risk No possibility to use in High Activity environment No cutting application (if uses of abrasive)	Calculations and designs of a dedicated carrier

Design of a new lancing tool

The initial Nitrocision® system has been mainly developed on the basis of the UHP water process. However, the use of liquid nitrogen instead of water induces some new constraints. Even if the pressure range is quite the same, the very low temperature (-130°C / -202 °F) may cause the weakening of the tool which was confirmed during the trial period at AREVA-SICN facility. Indeed, just after a few hours of use, one part of the tool (i.e. the rotating seal) was damaged because of the rapid decrease of the temperature. In order to avoid this type of repetitive failures, Air Liquid made some research to find some solutions and decided to develop a new free rotating seal. To reach this goal, their research was based on the capacity of the ¼" high pressure pipes (HP) to be subjected to the elastic deformations. After the realization of the first prototype (cf. Figure 1), AREVA with Air Liquid realized numerous series of tests first to check the reliability of this new tool and secondly, to compare the efficiency with the initial gun. About the first point, it is to underline that this new prototype reached the no maintenance state that is quite comfortable in a nuclear environment. Regarding the second point, no difference in the efficiency (i.e depth of cut, pass width…) has been observed. Finally, the conception took into account the weight of the tool in order to allow an easier use in manual way. Thus we were able to divide this parameter by a factor 2 (i.e. 3.5 kg instead of 7.5 kg).

Figure 1 : Prototype of the new lancing tool

Figure 2 : CAD picture of the new lancing tool

Figure 3 : New lancing tool

Work on insulation material

The temperature of the liquid nitrogen is one of the most important parameter to be controlled in order to properly operate the NiThrow™ solution, especially over a long distance (i.e. roughly 100 meters, between the heat exchanger and the lancing tool, which is quite common in nuclear environment. The goal is to store all the most expensive equipment in a non-contaminated area). In order to achieve this task, our engineers began to do calculations that helped them to define the main characteristics of the needed insulation. They took into account several parameters such as the type of HP hoses (different diameters: 9/16''or **14.29 mm**, 3/8'' or **9.52 mm** and 1/4'' or **6.35 mm**), but also the length of HP network, the temperature at the heat exchanger exit and finally, the temperature at the gun. Thanks to this work, we were able to find out the best thermal conductivity coefficient and from this point we checked the literature in order to find the most appropriate material. Three different type of material have been tested and two of them have shown some quite interesting results. Starting with those two materials, we also checked if both were compatible with the French waste laws regulation. It appears that only the type 1 will be recommended for a nuclear application according the ANDRA specifications.


Figure 4 : Insulation material Type 1


Figure 5 : Insulation material type 2

Design of a waste collection system

As mentioned in introduction, the NiThrow™ solution is mainly dedicated to be used in a nuclear environment. So, the collection of all the contaminated particles, removed from the surfaces during the operation, is a key point in order to avoid any dispersion or dissemination of the contamination into the tent and/ or the cell. Special attention has been observed for this part during the development of the cryogenic solution. Thus, a complete study has been performed to define the systems and subsystems required to achieve this filtration operation. The first important parameter we worked on was the airtightness of the whole system. So, we decided to add, onto our new lancing tool, some efficient end effectors. Calculations and design phases have been done and different types of systems have been manufactured (e.g. for flat surfaces, for angular surfaces) and tested. The main part of debris, dusts and also gaseous nitrogen are now collected and vacuumed off by those systems.


Figure 6 : Shroud system for flat surface


Figure 7 : Shroud system for external angular surface


Figure 8 : Shroud system for internal angular surface

The second important parameter to deal with was the vacuum system itself. As we did previously with the end effectors, the same way was followed by doing calculations and tests to ensure we determined the best requested flow rate. The goal was to collect all the contaminated particles over a distance of about 50 meters (not only in horizontal but also in vertical) with a minimum of dropping pressure generated by the subsystems (i.e. HEPA filters, the cyclone and the hoses). Thanks to this R&D work, we are now able to collect more than 95% of the ejected particles over the requested 50 meters (between the lancing tool and the cyclone).

Design and development of an automatic carrier

Since the beginning of the NiThrow™ solution development, our first target was to automate this process. Indeed, by driving the HPLN technology in a total automatic mode, the advantages are numerous. First of all, by using a remote system, the intervention time in a cell is reduced, inducing a decrease of the worker's dosimetry. The second one is to ease the D&D operations. At this point, it is important to underline that the strategy described hereafter has been done in order to match with the HADE project requirements but, it would be transposable to any other projects. This project is a concrete scabbling project that should take place, in 2013, on the La Hague nuclear site. The goal of this project will be to scabble all the concrete surfaces (ceiling, walls and ground) of one the facility cell called 911B. This cell is quite atypical due to its tower shape (dimensions) and the numerous singularities. The brand new carrier should be able to deal with surfaces of 4 meters high, in a cramped environment and with a limited ground load (600 $kg.m^{-2}$). Our estimations are that about 95% of the surfaces will be treated by using the automatic carrier and for the 5% remaining, an operator will be in charge to achieve the work by using the manual lancing tool. Starting from a single tool (the lancing tool), we fully designed an architecture around it in order to reach our goals. We first started with an intensive technology forecasting in order to determine the pros and cons of different systems. This task has been based on numerous criteria such as the type of surface to be treated, the stability of the system and so on. Once the best concept has been found (initially, seven different concepts have been benchmarked), a preconceptual phase allowed us to determine a first design for our automatic carrier. At the end of this phase, the conception phase started and has been built around different studies. The first target was the ultra-high pressure network. Indeed, the pipes used to transport liquid nitrogen from the heat exchanger to the lancing tool are made of stainless steel. This material is not known to have a good flexibility which does not facilitate the moves of the UHP pipes. In order to integrate those pipes, directly onto the carrier, a flexibility study (taking into account the steel grades) has been realized in order to determine the main key-figures (e.g yield strength) of the pipe network that will guarantee first, the best resistance to the cryogenic and high pressure constraints and secondly, the ease to bend it. To do this interesting task, some calculations based on an AREVA software have been done to determine the best parameters that will match with the HADE configuration. The results have shown that using a kind of "pig tail" shape for our HP network was certainly the best option we had. Indeed, using this special configuration gives some flexibility to the system.

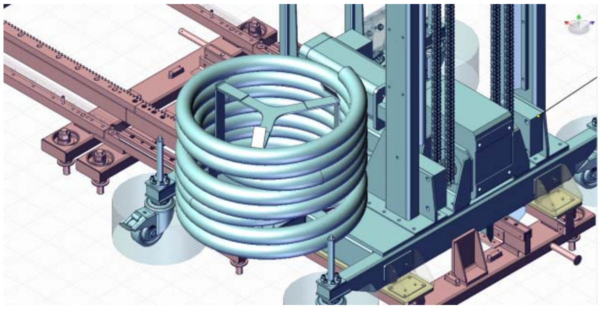

Figure 9 : "Pig tail" type design of HP hoses

Figure 10 : Installation of HP hoses on the carrier

The second target we had to deal with was the resistance and the stability of our carrier. As explained previously, the first use for scabbling application will be the La Hague project and the decontamination of a cramped cell. In this context we focused our developments on small parts which are not in line with the resistance and stability notions. Our idea has been to split the carrier in two independent moieties: the rails and the frame. The first part should be in charge of the stability of the carrier (other options such as, wheels or tracks have been canceled due to the required wheelbase) and the second one of the motion of the tool onto the surface to be treated. From this, numerous calculations have been done by our mechanical engineers in order to finely dimension the mechanical parts (e.g. engine, carrier itself…) but also to check the resistance and the rigidity (that a key point if we want to ensure a good accuracy of the lancing tool) of the whole system.

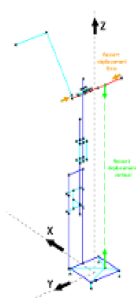

Figure 11 : Mesh of the carrier

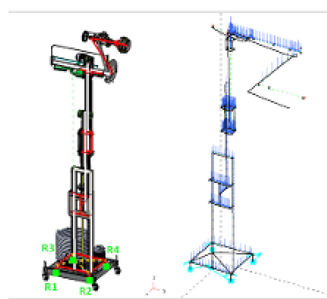

Figure 12 : CAD calculation

Once the manufactured phase was completed, the first tests in non-active conditions took place. The aim was to test the whole functions before its use on a work site. For the first time, a test factory acceptance has been done in order to check if the technical specifications were respected. After that, some new tests took place at the CTAS-Air Liquide with the connections of all equipment (e.g. the lancing tool, the UHP network…) to simulate a scabbling phase. Both phases have been successful.

Figure 13 : General view of the carrier (1)

Figure 14 : Test factory acceptance

Figure 15 : Test at CTAS-Air Liquide

Figure 16 : General view of the carrier (2)

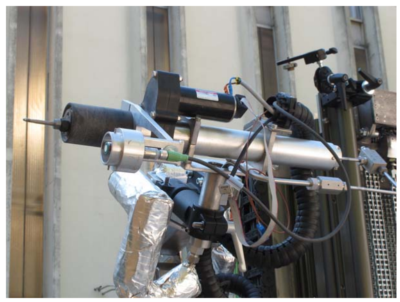

Figure 17 : The new lancing onto the automatic carrier

Figure 18 : The NiThrow™ solution (carrier; skid, vacuum system, tank)

CONCLUSION

Currently, the NiThrow™ solution appears to be one of the best ones in order to accomplish the three mains D&D operations (cutting, surface decontamination and concrete scabbling). This solution, based on the use of an inert gas (i.e. Liquid nitrogen) is environmentally friendly, non inflammable and because of its rapid conversion in gas, do not generate any liquid waste. As mentioned in this paper, even if the process was not initially designed for the nuclear industry, thanks to all the tests made by AREVA and Air Liquide since 2008 and all the improvements realized, this technology can be now effective and competitive. In case of concrete scabbling application, the obtained results are really interesting (depth of cut up to 30 mm in one pass) with no dissemination of the contaminated particle due to the add of effective end effectors linked to a dedicated vacuum system.

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