Precautions arising from the experimental campaign on contaminated metal components parameters for safely nuclear power plant components dismantling

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ABSTRACT

Caorso's Nuclear Power Plant (Boiling Water Reactor, 870 MWe), built in the 70s and fully operating in the period 1981-1986, was shut down on 1987, due to Italy's poll that abrogated nuclear power based on U235 fission. The preliminary dismantling activities have involved an experimental campaign adopting plasma and oxyacetylene metal cutting processes and concerning no activated materials (plates and tubes exposed to the coolant steam of the reactor). Analyses have been carried out of by use contaminated components below the free release level ($1 \cdot 10^4$ Bq/m^2), not yet considering radioactivity, allowing a correct evaluation of the physical and chemical characteristics of the produced aerosol, finding the possible chances related to the associated filtration systems, and, in general, important precautions for a safely NPP components disassembling.

INTRODUCTION

The most important Italian nuclear facility has been represented by Caorso Nuclear Power Plant (NPP), equipped by an 870 MWe Boling Water Reactor (BWR) with 33% efficiency. It operated correctly for nearly seven years till its maintenance stop in 1986, then, following the Italian exit by nuclear power, its dismantling activities started in 1999. Such procedures involve very difficult cutting operations, due to an underestimate of this NPP structure dismantlement: the plant, in fact, was not considered, planned and built assuming its final disassembling process. As a consequence of the incidence of contaminated materials, the reduced manoeuvrability and the constricted and insufficiently lighted places and air circulation, the "green field" conditions for the site are forecasted to be reached only in 2017.

A testing campaign to analyze gaseous emissions and, mainly, micronic dusts throughout the cutting processes has been firstly developed, the experimental conditions corresponding to the NPP working parameters [1-7]. Carbon steel with different surface treatments is the constitutive structural material of piping and servicing – in particular, the main steam line or secondary cooling system or vacuum condenser servicing, all displaced in the Turbine Building. The complete series of "simulacres" - designation for metallic pieces from Caorso NPP adopted in the same campaign -, cutting procedures and tested samples are listed in Table 1.

Table 1. Simulacre description, cutting procedures and specimens

	Simulacre	*Cutting procedures and specimens*
A	Piping spools, 4", Schedule 40S, thickness 7 mm, external diameter 115 mm, placed in horizontal axis position	a) A1 oxyacetylene cutting (3 specimens)
B	Piping spools, 10", Schedule 60, thickness 12 mm, external diameter 270 mm, placed in horizontal axis position	a) B1 oxyacetylene cutting (3 specimens) b) B2 plasma cutting (3 specimens)
C	Piping spools, 6", Schedule 60, thickness 7 mm, external diameter 168 mm, placed in vertical axis position	a) C1 plasma cutting (3 specimens)
D	Piping spools, 24"/30", Schedule 40XS/30, thicknesses 20/18 mm, external diameters 610/775 mm, placed in horizontal axis position	a) D1 two spools, oxyacetylene cutting (2 specimens for 30" and 1 specimen for 24") b) D2 two spools, plasma cutting (1 specimen for 30" spool and 2 specimens for 24" spool)
E	One thin steel plate, thickness 20 mm, one thick steel plate, thickness 40 mm, and two flanges, thickness 22 mm, diameter 626 mm	a) E1 plates, oxyacetylene cutting (2 specimens for thin plate, 1 specimen for thick plate) b) E2 flanges, plasma cutting (3 specimens)

The hot cutting processes description, the operation sequences, the results of the analyses of the contaminants (dust, Mn, Ni, Cr, Zn, Pb, nitrogen oxides and volatile organic substances) and of the environment (Hall), and those of the SEM investigations performed on the Teflon filtering supports are reported in ref. [4]. The chemical composition average data of the sampling, the dusts produced in the various cutting processes, the parameters related to the production of inhalable aerosol and their variability reference intervals, those related to the solid and volatile residues production, the numerical values of the production speeds of the inhalable dusts, and the dust concentrations during the different sessions are reported in refs. [5] and [6].

Better performances have been obtained, in general, with the oxyacetylene device than with the plasma torch, as shown, e.g., in Figs. 1-3, which are referred to a sampling time of 30 minutes.

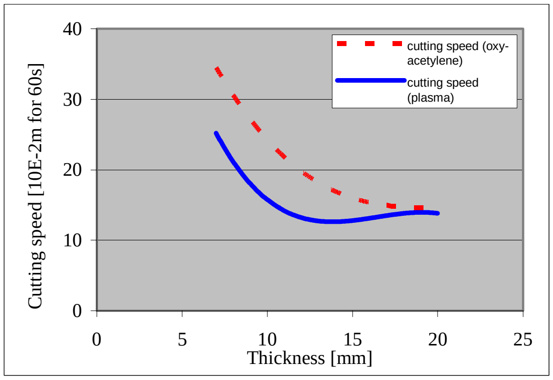

Fig. 1 Cutting rate vs. pipes simulacres thickness. Tests on 30" and 24" simulacres

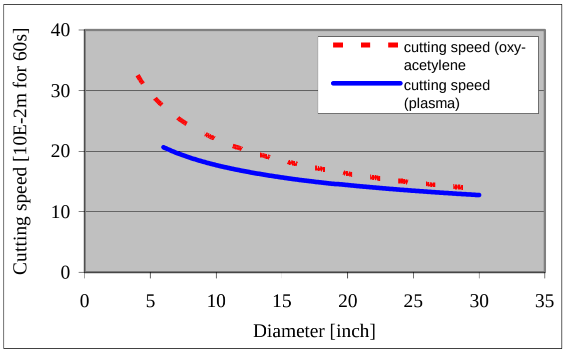

Fig. 2 Cutting rate vs. pipes diameter. Tests on 30" and 24" simulacres

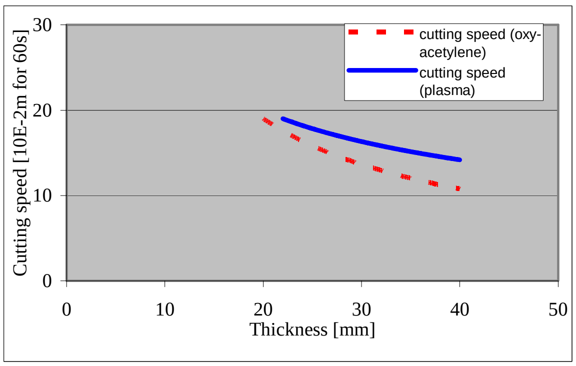

Fig. 3 Cutting rate vs. flat plate's simulacres thickness

The capture of the gaseous mixture has been applied through only one point, and it appears insufficient during the cutting procedure of pipes in horizontal position, being especially efficient if applied to the upper end of a tube in vertical position.

The operative solutions adopted in the cutting procedures, the parameters related to the production of solid and volatile residues for cut and their variability reference intervals are reported in ref. [7]. Fig. 4 shows the cutting workshop with the measurement chimney, the probe for the feeding of the filters and various instrumentation.

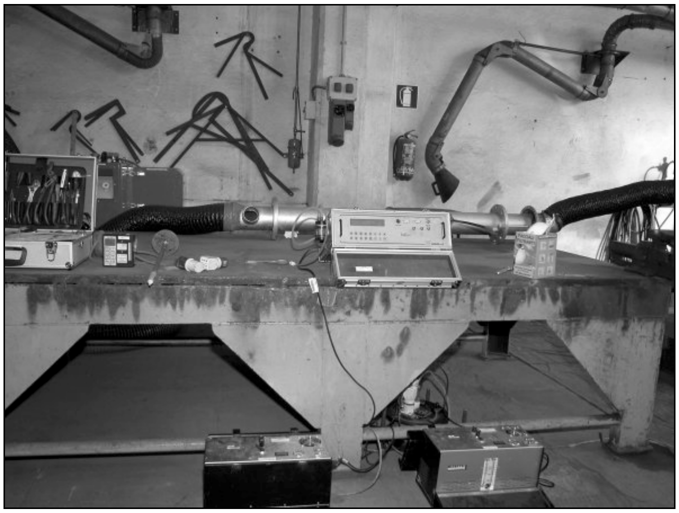

Fig. 4 The cutting workshop: close up with the measurement chimney, the probe for the feeding of the filters and various instrumentation.

CONSIDERATIONS AND SUGGESTED PRECAUTIONS FOR THE HOT CUTTING TECHNOLOGY

With reference on the solutions adopted in the hot cutting procedures [5-7] and on the data listed in Tab.1, some considerations and precautions arise, connected with the obtained environmental and technical results. The main aim of these suggestions is to give back the dismantling of contaminated components:

- secure for the operating personnel and for the material involved;
- precise, in the sense of leading with certainty the activities in the more appropriate approach without the necessity of expecting further completion;
- economically balanced, to produce residuals to dispose of in the possible minor quantity;
- rapid, to reach the purpose in suitably limited times.

It is timely to proceed following two directions, i.e. examining respectively the activities to be considered during the cut, and above all, the measures, that could be appraised with the perspective of an enhancement or a planning of the same operations, in conformity with the emphasized indications.

Precautions on the cut processes

The considerations regarding the experimental campaign involving hot cutting processes are the following:

- the effect of the ventilation in the cutting room -considering one air exchange per hour- is minimal, especially when the cut proceeds on very oxidized and/or painted pieces;
- the behaviour of the micronic dusts should be examined, in function of their proportion and their concentration, with a specific study on the aerosol;
- the suction action, performed by a unique mouth, is partial, but it is better when the suction is applied to an extremity of a pipe in vertical position, while it is low with a horizontal pipe of reduced diameter (acceptable with small diameter, 4”; scarce with greater diameter, 10” and beyond, or with a smooth surface), inadequate with short spool of large diameter (24” and 30”);
- the shape and the dimensions of the aspiration devices seem to have to be optimized in view of increasing the emission captures;
- the elimination of the dusts suspension by the absolute filter is good (the filtration of micronic particles is, however, effective, regarding either the smokes, or the air-smoke mixture present in the room);
- the dust quantity absorbed for inhalation by the operator is significant and depends from the cutting work duration, the material, the piece shape/thickness, the surface conditions, the cutting methodology, the distance between the worked piece and the worker face, etc.;
- the smokes production is larger with the plasma torch cutting process, because of the higher temperatures reached in the process;
- the cut temperature - and, in certain conditions (i.e., sectioning of plate pieces), also the cutting speed - can be higher by adopting the plasma torch;
- the enrichment in gaseous emissions of a closed environment increases with the cut duration (mainly because the absolute filter stops only the dusts);

- the dust concentrations survey should be studied to arrange the less emissive cut procedure and the instrumentation to be locally employed in order to supply information on the ventilation of the cutting room, on the continuity of the dismantling, etc.

A short consideration still can be expressed, concerning the dusts quantity inhaled by the operator. The same dusts are significant and they depend from the cut work duration, the material, the surface conditions, the possible treatments with paints or pigments, the cut type, etc. Preventions - also minimal - should be taken into account, but they could be unsatisfactory, as we established during some tests of the experimental campaign included in the research.

The emissions - dust gaseous suspension in aeriform - are very elevated by adopting plasma torch. It should be noted that, confirming previous observations, during the plasma cut tests it was necessary to open the large main entrance of the working hall. It was practically impossible to impose to the personnel, employed to the varied duties of the research and present in the environment, to work having the simple support of the environmental ventilation.

Fig. 5 is referred to the plasma torch cut of a 30" piping spool, while Fig. 6 shows the measurement chimney with the derivation for the filtering device and the apparatus for the suction of smokes and for the absolute filter.

Fig. 5 Plasma torch cut of a 30" piping spool

Fig. 6 Measurement chimney, with the derivation for the filtering device and the apparatus for the suction of smokes and for the absolute filter.

Improvement features

The measures to be adopted during the hot cutting processes of pipes and tanks in closed environment can be connected with the following types:

a) to activate the air circulation, increasing the number of air-changes per hour, introducing fresh air under pressure and eliminating fumes with monitored procedures in order to maintain cleaned, breathable and clear the room atmosphere and to allow the manual cut;

b) in presence of a reduced number of air-changes/hour, to operate by automatic remote or manual cut with a shielding at the worker inhalation, by means of very efficient protection methods such as letting in of clean air directly towards the same worker; drastic reduction of the cut times in order to limit the emissions; significant increase of the suction capacity, in order to eliminate the dust by filtration, also without reducing in any case the emissions quantity in the room;

c) to separate the room in various compartments, in which the conditions described in a) should be obtained during the cut processes, independently from the room ventilation;

d) to isolate and transfer, if it is possible, the large dimensions components to other zone (or to a specific station) of the plant where the cutting procedures could be better and securely performed;

e) to prefer, where possible, sectioning methods of the pieces -such as the mechanical cut-, which generate lower cut temperatures and thin dusts in smaller quantity.

The suggestions described in a) link to the common procedures for the sectioning in limited volume environments. The classic procedure for these events is based substantially on the activation of a forced air circulation, achieving in such a way the necessary dilution of the emissions to maintain the pollution level (environmental and/or at personnel breathing) within the advised values. The solution could not be applied for environments having a reduced ventilation capacity (e.g., one air-change per hour), that cannot be modified and adequately transformed, either because of structural problems, or due to functional and safety bonds with the outside.

The subjects in connection with the hypothesis described in b) are more complex. Firstly, even if we plan a manual dismantling, a partial automatic remote cut could be required. It is the case of big components and tanks that - because of dimensions, wall thickness, arrangement of the individual cuts to carry out, and limitation of the available spaces or of the complexity of the internals - seem correct to presume devices for the walls sectioning with the eventual assistance of the personnel, but without the direct contribution of operators. It should be selected the automatic device moved by pneumatic (or mechanic, magnetic, electric, etc.) actuator in order to optimise the execution times of the cut operations, the easiness of the arrangement in situ and, above all, the suction of the emissions to send to the filtering system (by absolute filter). Moreover, also a manual cut with a shielding at the worker inhalation, by means of very efficient protection methods (complete overalls), and a clean air flow directly towards the same worker, should be considered. This is not an agile, cheap and simple procedure, and not even easy to carry out and to maintain during the operation in situ, which obviously has characteristics of a large variability and depend strictly by the considerable complexity of layout, and a space arrangement with very discontinuous lines.

Adequate cut times planning, to limit the emissions, can represent a suggestion and an intervention that influence more the cutting feasibility than the installations or the technologies. It concerns naturally the operations management to graduate its duration, succession and pieces to be submitted to the cut operation, taking into account the attainable pollution amount as a variable. It is not a solution to discredit and modify, after having improved cut procedures, methodologies and technologies; to plan the segmentations sequence, leaving to be driven from the local instrumentation, which measures and interprets the safety conditions for the operator, can represent a last card to play.

The last alternative described in b) appears more problematic. A considerable increase of the suction capacity could be advised, to eliminate the dusts by filtration, also without reducing in any case the emissions quantity in the room. The hypothesis of an increase of the suction capacity is imposed only in the perspective of an available pump of greater capacity. It is difficult, also in this situation, to reduce the emissions quantity which can be removed with respect to that produced in the cut. It is not widely possible, in fact, to hinder the shedding of the aerosols, which are usually directed from the spread.

A possible solution concerning point c) could advise the adoption of a “calm” room. If the separation in various dismantlement compartments is possible, the ventilation of the so obtained room could be activated to the utmost, sending off the air discharge in an appropriate volume. This is preceded from a cyclone gas washer. The air deprived of large part of the dust and, if necessary, treated to subtract the eventual dangerous parts and the micronic dust through the absolute filter, is sent again into the original environment. A minor discharge of gaseous substances towards the outside results, in such way, because the air circulation is strictly maintained within the boundaries of the main environment, in which the ventilation is active.

A mix of interventions is hypothesized in e), which is not only based on the hot cutting. The mechanical cut produces richer emissions in coarse dust or, analogously, emissions with less quantity of thin and ultra-thin dusts that, once inhaled, influence negatively the human respiratory apparatus. The choice of the mechanical procedure, after being been appropriately qualified and quite characterized above all for the effects of the created aerosols, should be oriented. It should be reconsidered, beyond that to limit the previous phenomena due to the gaseous suspensions, also in connection to specific activation and intervention conditions (e.g., under-water cut). The prevention of the radioactive particles dispersion, in the case of contamination and/or activation (in worse manner if elevated) of the material to be cut, imposes still greater precautions with respect to those ordinary.

One should pay attention also to the many parameters which influence the operation (speed/cutting times, easiness of using the cut devices, requirement to increase the cut instrument pressure on the piece, wall thickness, material type, etc.). Tools provided with diamond edge disks, even if they mainly produce coarse dusts, seem to adapt better than other mechanical sectioning instruments, like hack saws, band saws, etc., in the case that mechanical sectioning is requested.
A suggestion that apparently seems antithetical with respect to the dismantling politics till now followed, could consist in transferring the large dimensions whole components in suitable cut stations, after separating the nozzles to the entrance/exit lines and, if necessary, with the support systems. The dismemberment operations can be planned and perfected in safety, following and applying one or also more than one of the above discussed measures. The dismantling cell can be made with metallic plate airtight walls (or in wood covered with plastic laminates, or in plastic fibre) to consent the necessary air-changes to avoid high levels of pollution.

Always concerning the measures to optimize the pollution levels, it could be underlined also that the two mentioned hot cutting methods are not perfectly and entirely super-imposable and mutually replaceable, not only in consideration of the environmental amounts of produced dusts, but also of that of the execution swiftness. We noticed that, in the cut of flat pieces, the plasma torch appears faster, while the oxyacetylene device reveals completely its prerogatives operating on the pipelines. Besides, the weight of the cutting tool seems to advise against the adoption of plasma torch in the cut of big thickness walls, in order not to overtire the operator, which then would prolong the intervention times.

FURTHER DISCUSSIONS

Additional consideration should be dedicated:
- to the interventions that seem timely and proper to make the dismantling operation efficient and less polluting;
- to the measures to introduce in the adjustment of the cutting room;
- to the predisposition for a ventilation enhancement, above all with the aim to adopt all those measures that reach positive results on the operators and on the other involved personnel.

Different proposals of more general nature should be presented, with the perspective of positive effects on the dismantling of metallic parts/pieces of the installation. Always in the perspective of organizing diversified interventions - also antithetical to both previous areas, i.e. the cut procedures and the most appropriate displacement of the rooms and of the pieces- it can be useful to ponder on some proposable actions feasible in the short period. The following points should be considered:
- qualification of some mechanical cut procedures, to employ on the components typologies, already used in the previous hot cutting campaign and to use selectively in the installation and in support to the hot cutting;
- qualification of the aerosol produced from thin and ultra-thin particles, above all with the purpose of stating and describing their distributive spectre (and, if necessary, some main effects);
- examination of automatic cutting processes to apply to components that, due to the specific features (thickness, forms, arrangement, dimensions, surface contamination, etc.) dissuade the adoption of manual operations;
- application of procedures of air-circulation activation, also associating secondary air flows treatment technologies ("calm", humidification and sputtering room, to intervene on the condensation of thin aerosols, absolute or mixed double filtration with the recourse to cyclone gas washers or other devices, etc.);
- market inquiries and technical checks in the field of the environmental instrumentation for the survey of the dust dragged from the cut emissions.

These aspects and others too, to which in the previous paragraphs some reference have been dedicated, are here reported with the purpose to underline the opportunity of carrying out interventions also of small extent, that can influence directly and immediately the cutting processes. Such interventions should be characterized by the achievement through the adoption of resources (human, financial, technological, etc.) limited in the time and of enough immediate application.

Finally, the specificity of the above reported proposals weights also on the work organisation procedures. Such proposals considered singularly or in association between them, can persuade to a more systematic elaboration of the interventions to put in action. This is the case of feasibility studies, which can be developed perfectly on such themes and are naturally adaptable also to arrange schemes with a gradual approach, having available fair lapses of time.

CONCLUSIONS

A safely NPP components dismantling should presuppose important precautions, which have been explained in this work and have arisen from the experimental campaign carried out on contaminated metal components parameters. As conclusive remarks, the optimization of form, position and size of the capturing devices could enhance at the maximum the elimination of the worst pollution component such as the micronic dust. An absolute filter of the gaseous mixture released during the cutting process could have a good action on dust elimination yet for the small particles, clearly on the flow crossing the filter, but it is not sufficient to check their intensity in the workshop atmosphere. The pollutant inhalation is significant also if dependent by cut time, nature of alloy, wall size/thickness, surface treatment by means of Pb products, hot cutting type and distance of the worker face from piece under sectioning. The plasma torch involves larger pollutant production and higher cutting temperatures, while the oxyacetylene device allows faster rate in cutting tube of modest size/schedule, and consequently the plasma torch for plates. The pollutants dissemination outside the cut area, in which the gaseous capture is concentrated, and the gaseous emissions and dusts concentrations evaluation and calculation should be deeply examined in order to assess the operative safeguards to defend personnel and create right procedures during dismantling processes.

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