CARBOWASTE

Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste

Grant Agreement Number: FP7-211333

Deliverable (T-2.2.3)

- Mechanical Technologies of Graphite Extraction -

Author(s): **H. Katsavos**

Reporting period: 03/2012– 02/2013

Date of issue of this report : 08/03/2013

Start date of project : **01/04/2008** Duration : **48 Months**

Project co-funded by the European Commission under the Seventh Framework Programme (2007 to 2011) of the European Atomic Energy Community (EURATOM) for nuclear research and training activities		
Dissemination Level		
PU	Public	
RE	Restricted to the partners of the CARBOWASTE project	
CO	Confidential, only for specific distribution list defined on this document	**X**

Distribution list

Person and organisation name and/or group	Comments
Carbowaste All	

CARBOWASTE		
Work package: 2 **Task: :** 2.2	**CARBOWASTE document no:** CARBOWASTE-1303-T-2.2.3 (e.g. May 2008 as date of issue: 0805)	**Document type:** Technical Report
Issued by: H. Katsavos (SOGIN, Italy) **Internal no.:** CW-2-2-3-T-c-SOGIN-D		**Document status:** Final

Document title

Mechanical Technologies of Graphite Extraction

Executive summary

The results of SOGIN work focused on the development and testing of specialist tooling for removal and handling of graphite bricks stored within Latina reactor core, are reported

Revisions

Rev.	Date	Short description	Author	Internal Review	Task Leader	WP Leader
01	08/03/2013	First issue draft	H. Katsavos (SOGIN, Italy)		Name, Organisation *Signature*	Name, Organisation *Signature*

Table of Content

1 Latina NPP Background

Latina nuclear power plant is situated at Foce Verde, near Latina, 700 m from the seashore. The power plant is based around one natural uranium, graphite moderated, carbon dioxide cooled Magnox reactor, which had a thermal output of 705 MW, giving a net electrical output of 200 MWe.

The plant operated from 1963 to 1986, and was taken out of service following a government decision in 1987.

The reactor is housed in a reinforced concrete structure, which also acts as a biological shield and forms the main part of a building 89 m x 48 m x 48 m. 12 m of the structure is constructed underground, with the boilers protruding into the open air. When it was in service, the steam generated from the six boilers was collected and fed the three main 70 MW turbine-generators and two 12 MW variable frequency turbine-generators, which supplied the gas circulators.

The reactor building is connected to the spent fuel pond, the effluent treatment plants and the waste storage facility on its south side.

The reactor design for Latina is similar to that for BNFL‘s Magnox Station at Bradwell. They are of similar dimensions, with similar ratings and constructed from similar materials at about the same time by the same company.

In the early 1990’s, the reactor was being prepared for Safestore as part of the adopted strategy for the four off SOGIN nuclear sites. This strategy was then changed to one of early dismantling.

To facilitate this, it is planned to build an Italian Radioactive Waste Repository with a proposed availability date circa 2025.

2 Reactor Decommissioning Process Overview

Concerning the dismantling of the reactor, SOGIN has developed specific studies, by taking advantage of the support of BNFL and its experiences from several decommissioning projects in the UK including work at the Magnox Decommissioning Sites, the Windscale Advanced Gas Cooled Reactor (WAGR) and the Waste Retrieval and Decommissioning projects underway at Sellafield.

According to present strategy, the reactor is to be decommissioned in a top down approach utilising Remotely Operated Vehicles (ROV), a typical example of which would be a Brokk, as the primary tool deployment mechanism.

A four metre square penetration will be made in the pile cap to allow access by the ROV into the reactor compartment. All the reactor metallic components will be released using purpose designed tooling incorporating hot and cold cutting techniques. The graphite waste will be removed using mechanical handling tools. The majority of these waste removal techniques have been based on experience from ongoing or completed decommissioning projects, applied to the specific requirements of Latina.

The waste will then be transferred into waste basket located in the reactor compartment. The capacity of this basket will be nominally 3m x 2m x 1.5m, with a capacity of 10 ton. This basket will then be raised from the reactor compartment by the Transfer Cell crane, for despatch through the Transfer Cell and Waste Route into the Waste Management Facility.

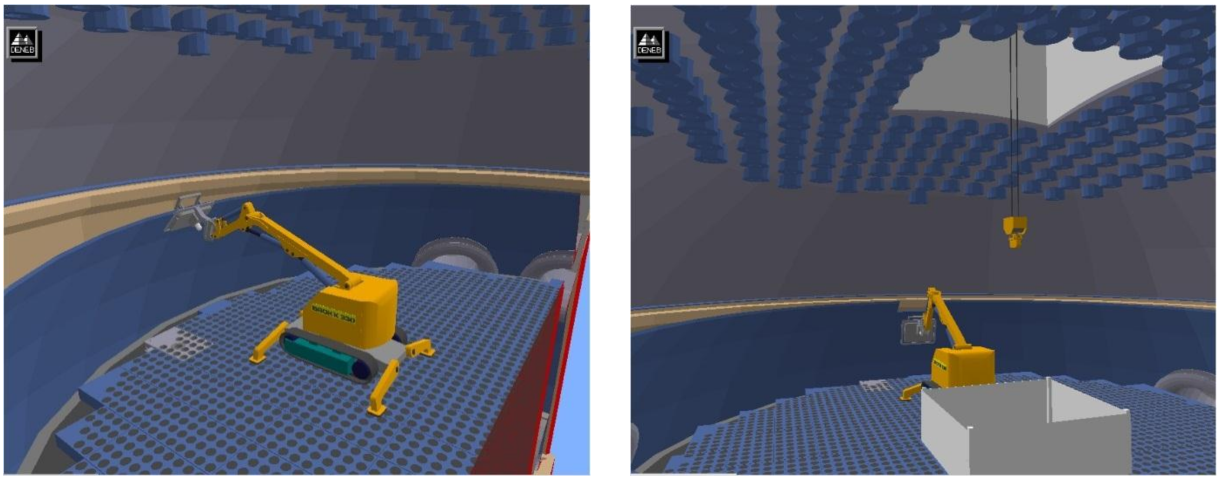

Figure 1: Conceptual model for Latina reactor dismantling. View of ROV cutting a section from the pressure vessel wall (left). Transfer cell crane hook lowered to waste basket (right)

3 Structure of Graphite Moderator and Reflector

The reactor core is built up from graphite bricks to form a 24 sided prism. The active moderator, made of high purity Grade A graphite, lies within a reflector skin of slightly less pure Grade B graphite 2 ft l0½ in. thick at the top, 2 ft 5½ in. thick radially. The bottom reflector of Grade A material is 2 ft 2 in. thick.

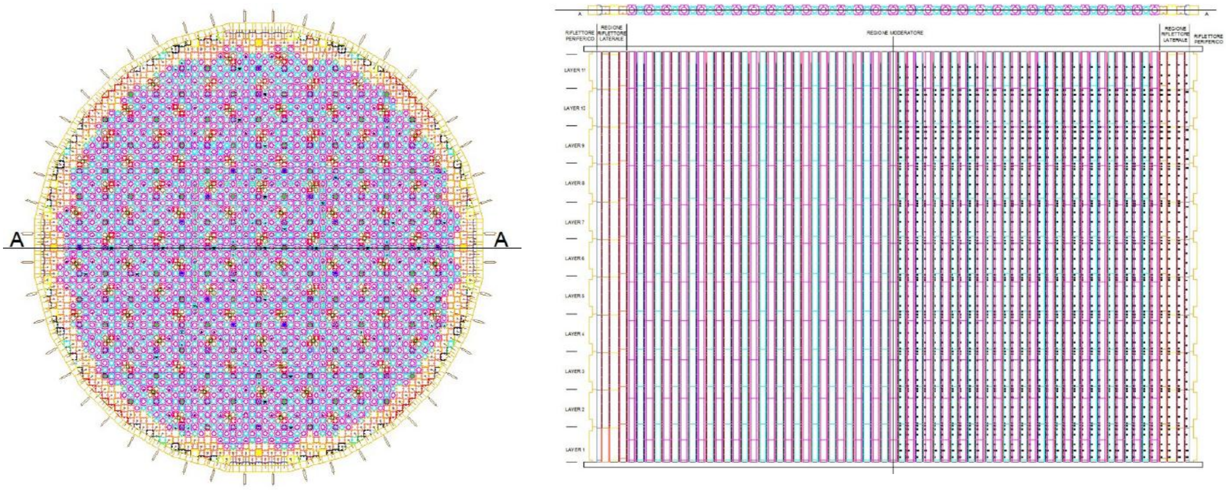

Figure 2: Sections of Latina graphite stack

A total of 3069 channels are formed by boring each brick. The bricks are laid in 11 layers so that each channel passes vertically through the active core and the upper and lower reflector layers. The columns of graphite are located at their lower ends by spigotting into the lantern which is, in turn, spigotted into the support plates.

There are two sizes of graphite bricks, a plain 7 in. x 7 in. square section and a 9 in. x 9 in. section having corner chamfers. The larger is, therefore, eight sided. The two sizes of bricks fit together to give a square lattice pitch of 8 in. channel to channel. Sufficient gap is left between columns of bricks to permit the pre-setting of the core and to allow for any Wigner growth which may occur.

The graphite columns are connected by graphite keys running axially from top to bottom of the core. The keys locate in keyways cut radially in the outside of each brick, 4 keyways being cut in the square 7 in. brick and 8 in the octagonal 9 in. brick. There are thus four axes of keying ensuring stability of the graphite structure although permitting any graphite column to expand or contract about its own centre without interfering with adjacent columns. Removal of a number of the diagonal keys evenly distributed over the core does not affect the stability of the structure.

Therefore, in addition to the 3069 channels down the centre of brick columns, 95 interstitial channels are formed, by omitting a diagonal key and cutting out the inner corners of a square of four adjacent columns. These channels are open to the Wigner gaps and their diameter is liable to small changes but they provide adequate accommodation for the absorber rods and neutron sources without reducing the number of channels available for fuel, control etc.

The horizontal joint between the graphite layers is broken by having the two sizes of brick finishing at different levels. The purpose of this overlapping effect is to give each succeeding graphite layer additional stability to resist horizontal earthquake forces.

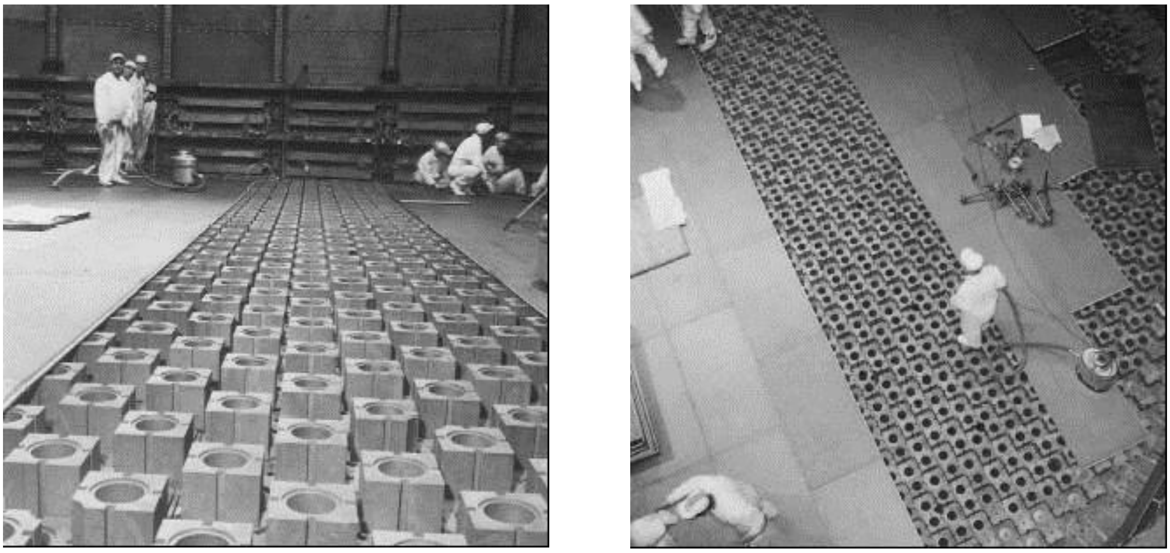

Figure 3: The Latina Reactor Core under construction

Reflector blocks are irregular in section and approximately 900mm long (maximum mass 90kg) some containing severed tie rods.

The central moderator blocks are more regular in shape comprising of bricks 178 mm square (7 in. square, 35 kg) and 229 mm square (9 in. square, 55 kg) with a 25mm chamfer to each corner all being approx. 900mm long and also having a bore through the centre.

The entire core is made up of 11 tiers, each consisting of moderator and reflector bricks. The estimated mass of the graphite core is 2100 tonnes.

4 Graphite Moderator and Reflector Removal

Various options for disposing of the Latina reactor have been considered by SOGIN and its predecessors in the past.

At present, the reference conceptual design for dismantling the reactor vessel is the result of a study developed by BNFL in 2000. According to the results of this study, the use of Remote Vehicles introduced into the reactor through an open hole in the pilecap is considered the best option for dismantling the reactor at Latina.

In order to allow this process to commence, major new facilities will be required, including:

- The construction of a shielded Waste Transfer Cell located on the Pile Cap
- The installation of Waste Route in the existing Number Six Duct Flume
- The construction of a Waste Management Facility within the confines of the East Circulator Hall

For the operations associated with removal of the graphite moderator and reflector, a combination of standard Brokk tools along with purpose designed tooling for moderator and reflector brick removal will facilitate the rapid and safe transfer of the graphite bricks to the Waste Management Facility.

In order to retrieve and handle the graphite material during dismantling operations, several types of tools will likely be deployed by the Brokk decommissioning machine.

The moderator bricks (and some of the reflector bricks) have central bores – which prove useful lifting features. The majority of the reflector bricks have no such available lifting features – so alternative removal methods need to be developed.

5 Investigations on tooling for graphite retrieval and handling

Between 2005 and 2007 SOGIN-Latina NPP performed an extensive work focused on the development and testing of special tooling for removal and handling of graphite bricks stored within the reactor core.

The purposes of the work were:

- Developing suitable equipments and tools for removing/handling the graphite bricks and other graphite core materials;

- Testing the prototype equipments in order to define their functional limits, operational ranges and possible further improvements.

6 Prototype tool for bored bricks

A prototype tool for the extraction of graphite bored bricks (reactor moderator bricks) was designed and realized having as requirements to obtain a reliable small sized, lifting device, suitable to be deployed by a remotely operated vehicle.

The tool was designed to lift a graphite brick by acting a sufficient holding pressure on the internal walls of the bore (see Figure 4).

The tool is operated by a pneumatic cylinder (piston) acting on a pantograph-like structure. Two semicircular "shells" are connected to the pantograph mechanism, so that, under the action of the piston, they can expand laterally and grasp the brick.

The surfaces of the "shells" are threaded so to improve holding performance. A picture and a scheme of the tool are shown in Figure 4 (see also Ref. 1).

The operation ranges of the piston are the following:

- Operating pressure: 0 - 10 bar
- Piston stroke : 25 mm

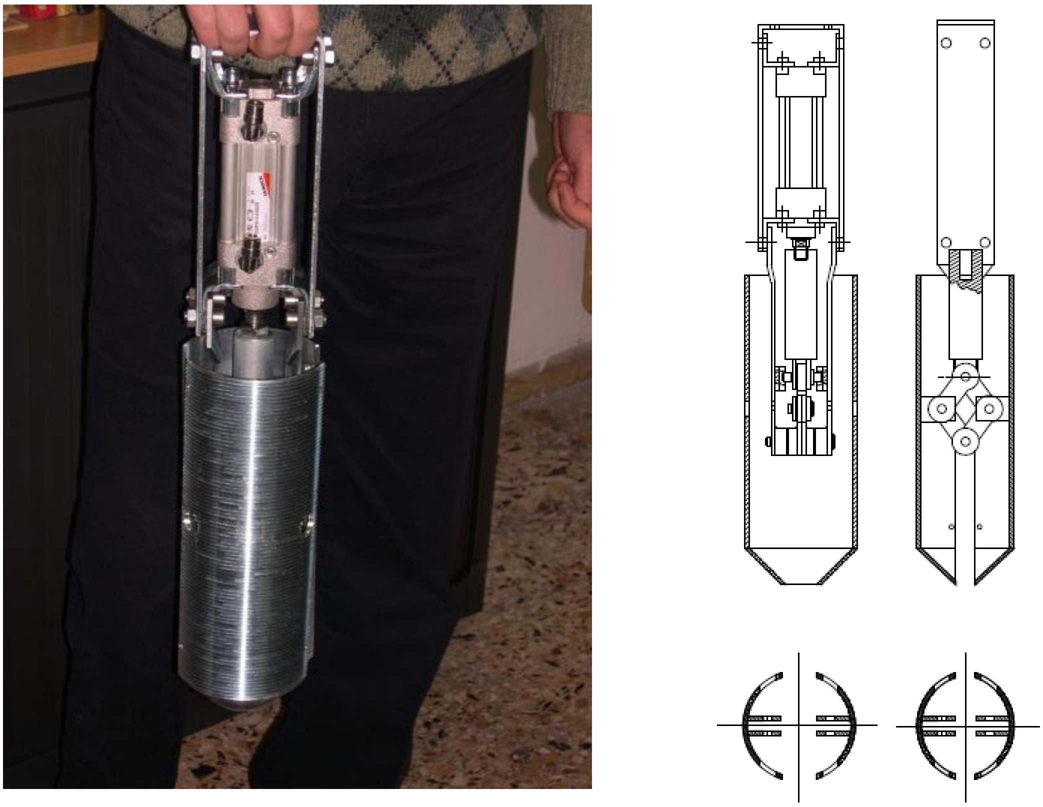

Figure 4: Lifting tool for bored graphite bricks. Picture of the prototype (left) and design cross sections (right)

6.1 Tests and results

A number of trials was performed in order to investigate the lifting performance of the tool. In particular, the tool was tested with the following purposes:

A. to check whether the operation of the tool at the maximum air pressure (10 bar) may cause a brick damage;
B. to assess the minimum pressure required to hold the graphite brick on;
C. to check whether the tool was able to lift a load corresponding to three times the maximum brick weight (about 174 kg);

Tests were carried on using three 229 mm square virgin graphite bricks (54, 55 and 57 kg respectively) and three 178 mm virgin graphite bricks (32 kg each).

Test A was carried out on 178mm square bricks, by placing the tool inside the bore of the bricks and actuating the piston at 5, 6, 7, 8, 9 and 10 bar. After each trial, integrity of the brick was examined by visual inspections. No cracks were observed after each test.

Test B was carried out on three 229mm square bricks (54, 55 and 57 kg respectively), using a crane to lift the graphite bricks. Starting by lifting each brick by the tool, the operation pressure was decreased from 5 bar (by 1bar steps), until release was obtained. The observed critical pressure was 1,0 ÷ 1,1 bar.

In Test C, a load applied to a 178mm brick, lifted on by the tool at maximum pressure (10 bar), was gradually increased until release. At 10 bar, the release was observed at 157 ÷ 160 kg. As a result, the tool did not shown an adequate lifting capacity, as required according to safety considerations.

Further details and information about the results of the test can be found in Ref.1.

On the whole, tests' results have proved the effectiveness of the general design of the tool but provided clear indications of the necessity to improve its lifting capacity.

Taking into account the results of the first tests, an upgraded version of the tool was then developed in order to improve lifting capacity and reliability (Ref. 2).

In particular, the second version device was equipped with (see Figure 5):

- a new piston with 50 mm diameter and 25 mm stroke;
- an electronic valve intended to detect pressure losses in the piston and prevent the its depressurization in case of air supply failures;
- a small air storage tank installed to balance possible air leakages;

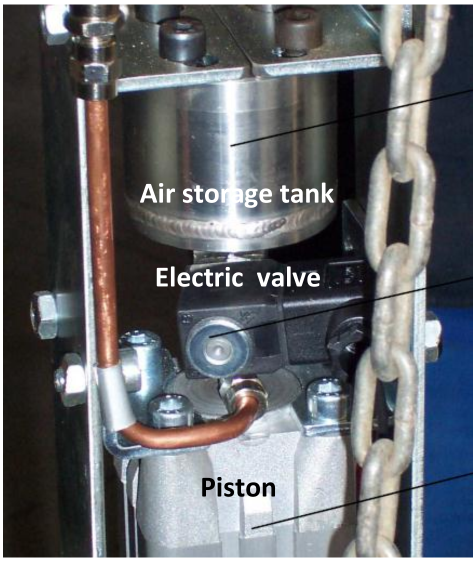

Figure 5: Detail of the arrangement of the upgraded version of the lifting tool for bored graphite bricks

6.2 Final tests and remarks

A new series of tests was carried out, according to the same criteria considered for the original version of the tool (see above), with the aim to check the validity of the developed improvements.

In particular, the tool was tested with the following purposes:

A. to check whether the operation of the tool at the maximum air pressure (10 bar) may cause a brick damage;
B. to assess the minimum pressure required to hold the graphite brick on;
C. to check whether the tool was able to lift a load corresponding to three times the maximum brick weight (about 174 kg);
D. to assess the load retention time in case of air supply failure.

Concerning the results of the test:

During Test A, no damage was observed after each investigation at different pressure values (5, 6, 7, 8, 9 and 10 bar);

Test B was repeated on two 229mm bricks (57 kg each). Starting from 5 bar, pressure was decreased by 1 bar steps until the release of the brick. In both cases values of 1,2 ÷ 1,4 were assessed.

In Test C, once selected the maximum pressure value (10 bar), the load acting on the tool was increased until the slipping down of the brick. In this case, the maximum load observed was 220 kg.

In Test D, a 229mm brick (57 kg) was lifted up using 10 bar for operating pressure; then, air supply was interrupted. After 20 minutes, since the brick was still kept on, the test was interrupted.

Tests proved successfully the effectiveness of the upgraded tool.

7 Prototype tool for unbored bricks

Concerning reflector bricks retrieval (bricks without bore through the centre) a prototype device was developed based on a “drill and tap” working configuration.

The prototype device was realized by Sogin in collaboration with an external supplier.

The design requirements were:

- to be able to lift graphite bricks using two automatic drilling and tapping tools;
- to lift up to 3 times the weight of a 229mm graphite brick (about 210 kg);
- to ensure very low production of graphite dust.

Figure 6: Lifting device developed for “unbored” graphite bricks (left). Detail of one of the two drilling and tapping tools (right). The drilling (lower) and the tapping (upper) portions of the tool are visible.

The prototype device is composed of an operating “head” equipped with two tools, each designed to drill and tap graphite (see Figure 6). Each tool measures 150 mm and presents a part for drilling (∅13mm) and a part for tapping (∅16mm).

Tools are operated by two electrical engines including a rotation speed control device (rotation speed range: 0 – 300 rpm).

7.1 Tests and results

To check the reliability of the device, a series of tests was carried out with the following purposes:

A. To investigate whether drilling and tapping can be performed successfully by the system on both graphite brick types (178mm and 229mm square);
B. To find whether the system is suitable to lift up and release graphite bricks;
C. To measure the maximum load that can be lifted by the system, and to verify if it is able to lift three times the maximum brick weight (about 210 kg);

Investigations were performed using virgin graphite bricks and an experimental station equipped with a support for the device and an automatic controlling unit (see Figure 7).

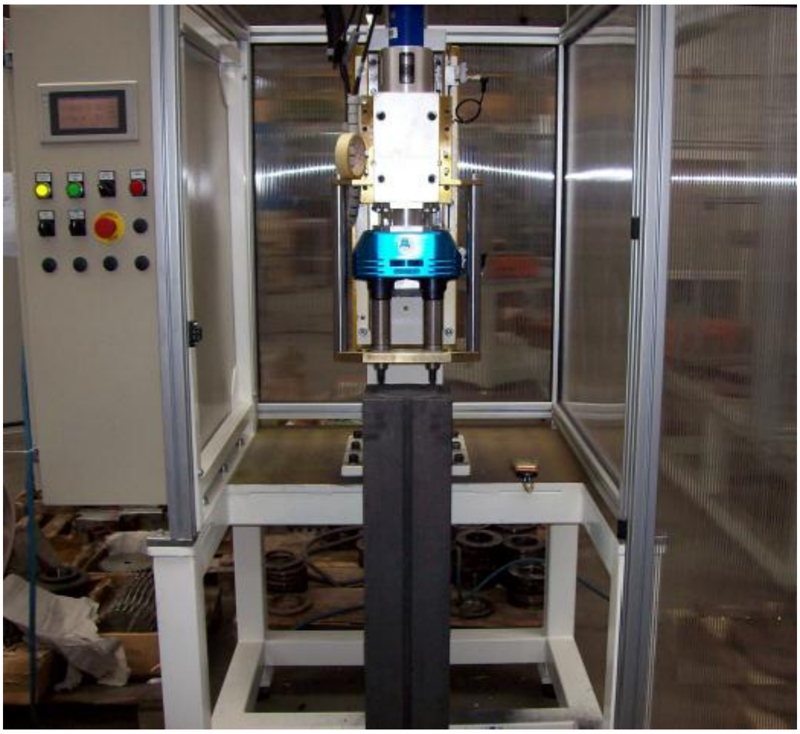

Figure 7: Arrangement of the experimental station used to test the drilling and tapping device

Test A and B were carried out on 229mm square brick (about 70 kg), selecting a rotation speed of 200 rpm and a feed rate of 5mm/rotation. After having completed drilling and tapping, the brick was lifted and kept in position for 10 minutes: no anomaly occurrence was observed. Finally, the release of the brick was correctly performed.

The same operations were repeated on a 178mm brick.

In Test C, after having ballasted a 229mm brick with additional 140 kg, the drilling and tapping procedure was performed according to the afore mentioned criteria. The ballasted brick was then successfully lifted up.

During drilling and tapping operations, aliquots of graphite dusts were sampled for grain size determination.

Analyses results pointed out that, as the rotation speed of the "drilling and tapping" tools increases, the grain size of graphite dust decreases, the overall quantity remaining unchanged.

Detailed information can be found in Ref.5.

On the whole, the device proved to successfully meet the technical specifications requirements and to be reliable.

7.2 Vacuum handling device

A prototype tool for handling graphite bricks, based on a vacuum grabbing system, was developed and tested.

Figure 8: Vacuum system for graphite bricks handling device

The objects of the tests were:

A. To check whether the system can lift and hold successfully both solid graphite brick types (unbored 178mm and 229mm); the test was repeated by adding graphite dust on the brick surface;
B. To measure the maximum load that can be lifted by the system;

C. To measure the load retention time in case of air supply failure

Regarding the Test A, it was performed on two 178mm bricks (weight: 34 and 40 kg), on two 229mm bricks (weight: 58 kg) and on a non-standard smooth graphite brick (weight: 89 kg) by using normal operating vacuum pressure (52 cm Hg vacuum). The tool was positioned manually on the bricks; the test on the 178mm brick (40 kg) was repeated after having added graphite dust on the surface of the brick (10 gr);

Test B was performed on a 229mm brick (58 kg) by increasing the load through ballasts until release;

Test C was performed on 178mm (40 kg), 229mm (58 kg) and on the non-standard graphite brick (89 kg) by stopping air supply to the system.

Results can be summarized as follows:

Good holding conditions also when graphite dust is present (a slight decrease in the vacuum pressure was observed);

Maximum load that can be lifted by the tool: 145 kg;

Retention time: 10 sec for 229mm graphite brick, 20 sec for 178mm graphite brick, 24 sec for 89 kg smooth graphite brick.

8 Conclusions and remarks

In general, Sogin programme for the development of tools suitable to be deployed in the framework of the future dismantling activities of Latina reactor, has provided a valuable experimental basis and operative suggestions.

Different types of tools have been realized and tested in order to investigate reliability, functional ranges, operational limits and possible directions for further optimization.

Obviously, limitations on the validity of the results due to the use of single virgin graphite bricks must be necessarily taken into account.

9 References

1. SOGIN, “Progetto grafite. Prova dell’attrezzatura prototipo per l’estrazione dei mattoni forati”, Rapporto di prova, LT GR 0044 Rev.00, 2005;
2. SOGIN, “Progetto grafite. Prova aggiuntiva dell’attrezzatura prototipo per l’estrazione dei mattoni forati”, Rapporto di prova, LT GR 0048 Rev.00, 2005;
3. SOGIN, “Progetto grafite. Prova dell’attrezzatura prototipo per l’estrazione dei mattoni pieni con sistema a ventosa”, Rapporto di prova, LT GR 0046 Rev.00, 2005;
4. SOGIN, “Progetto grafite. Studio per la realizzazione dell’attrezzatura prototipo per l’estrazione dei mattoni di grafite pieni”, Specifica Tecnica, LT GR 0049 Rev.00, 2005;
5. SOGIN, “Prove sull’attrezzo prototipo per l’estrazione dei mattoni di grafite pieni con il sistema di foratura e maschiatura”, Rapporto, LT GR 0068 Rev.00, 2007;