

INNOVATIVE UNDERWATER CUTTING PROCEDURES FOR THE DISMANTLING OF TWO GERMAN NUCLEAR POWER PLANTS

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ABSTRACT

The two power stations, KRB A and VAK, represent the first generation of Boiling Water Reactors in Germany. VAK (Versuchsatomkraftwerk Kahl), located in Kahl, near Frankfurt, was Germany's very first nuclear power plant and served mainly scientific purposes, while KRB A (Kernkraftwerk RWE-Bayernwerk, Block A), located in Gundremmingen, near Munich, was Germany's first commercial reactor.

Both plants are shut down and decommissioning is under way. Up to now more than 70 % of the systems have already been dismantled and decontaminated. In KRB A for instance about 6,500 tons of contaminated material has been treated, allowing to recycle 93 % and leaving only 7 % of radioactive waste for final storage.

The actual work in both projects is focused on dismantling the reactor pressure vessels and its internal components. Besides extensive experiences in both plants with mechanical tools, like sawing, shearing and grinding, two innovative cutting procedures are applied for this purpose, i.e. plasma arc cutting and abrasive water suspension jet (AWSJ). The application of plasma cutting in KRB A and AWSJ-technique in VAK has qualified these procedures as state-of-the-art in the nuclear field.

INTRODUCTION

The 250 MWe KRB A was in operation from 1966 to 1977 and the 16 MWe VAK's operational life ended in 1985 after 25 years. The decision to decommission KRB A was made in 1980 and work started in 1983. The dismantling of VAK began in 1988. The decommissioning objectives of the two units are quite different. Since KRB A shares its site with two 1344 MWe operating units, the buildings of KRB A will be kept as hot workshops. This contrasts with goal for VAK which is to directly proceed to a "green field" condition.

The decommissioning work on these two plants entails the disassembling of highly contaminated components inside the reactor buildings and the underwater cutting of the activated internals of the reactor pressure vessels. The experience gained from both projects is not limited to dismantling work alone, but also includes know-how on effective decontamination and scrap recycling procedures /1/.

While both VAK and KRB A are early boiling water reactor designs, there are differences in size and construction. A General Electric design, KRB A had three secondary circuits with recirculation pumps and steam generators to feed the turbine with supplemental steam. In the case of VAK, an AEG design, the steam generator separated the secondary circuits, so that the turbine hall was not part of the controlled area.

The dismantling experience gained at KRB and VAK can be applied to the decommissioning of both boiling water and pressurized water reactors /2,3/. A variety of tools were developed, tested, and utilized on the projects. The differences in plant design and resulting tooling requirements provides significant decommissioning experience allowing a comparison of the results from both projects.

THE DISMANTLING OF HIGHLY ACTIVATED REACTOR COMPONENTS IN VAK

Both projects are in a final stage of dismantling in the meantime. Looking back on several years of experience it always made sense to carry out these two projects in close co-operation. As an example, VAK's turbine hall is used to test and qualify the tools for dismantling work at both VAK and KRB A. For this purpose a common test basin was built in which procedures and equipment are tested and demonstrated on a full scale mock up.

The RPV in VAK has a diameter of only 2.4 m and a total height of 8.2 m. As a special feature the fuel element pool is not connected to RPV, so that all the dismantling work on the internal components had to be done within the small RPV itself. For this purpose mainly mechanical cutting techniques were used in special applications. At first the sprinkler ring was cut with a hack saw, which required about 100 man hours. The main advantages of the hack saw are the high flexibility, the tool stiffness and the generation of large swarf particles, which causes no problems in observation under water.

The dismantling of the chimney above the core was performed by a nibbler. This tool had to be modified with respect to the under water handling and the shape of the chimney, but it turned out as a reliable tool with a high cutting speed.

The upper grid plate was cut by means of a grinder. This tool was guided by a special device, which had the shape of a fuel element channel. Every position of a fuel element could therefore be used as a cutting position, which made the handling very easy. The diameter of the grinder disc allowed to perform two cuts at the same time.

A more difficult cutting task was the dismantling of the condensate sparger ring. Referring to its size and its position very near to the RPV-wall, conventional cutting tools could not be used. Different cutting techniques were tested in cold tests and finally the EDM (Electro Discharge Machining) was chosen to cut the ring into several sections.

The last remaining internal components were the lower core shroud (about 1 m in height with a thickness of 50 - 150 mm) and the thermal shield, being about 2 m high and 30 mm thick. For this purpose an innovative cutting procedure was used: A high pressure water jet technique. The so called abrasive water suspension jet (AWSJ) is a very effective technology to cut underwater activated components during decommissioning. The first application of this AWSJ-tool in the nuclear field at all took place at VAK in early 1998.

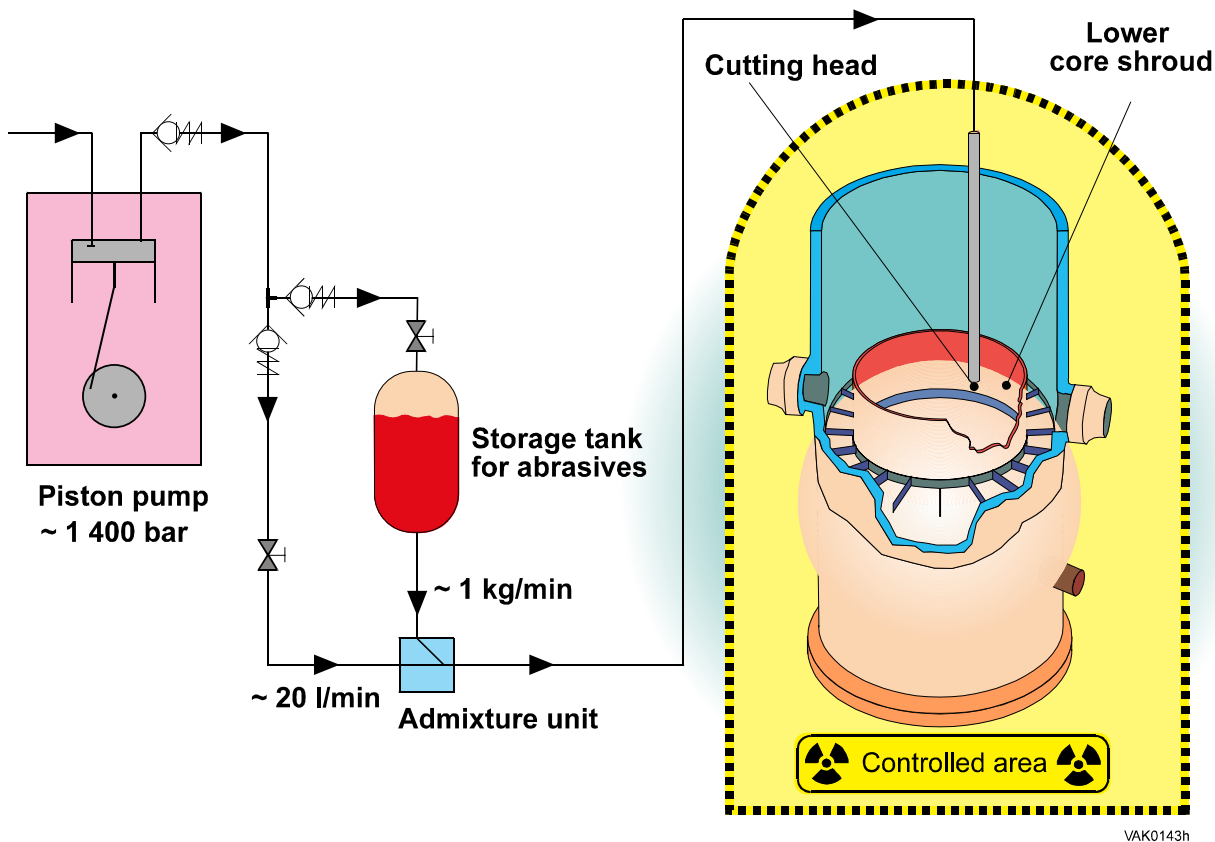


Fig. 1: High pressure water jet cutting with suspended abrasives

The AWSJ-technology differs essentially from the better known abrasive water injection jet (AWIJ), which is state of the art in different industrial applications, such as industrial manufacturing and cleaning. The feature of the AWIJ-technology is a three-phase jet (water, abrasives and air), that leaves the mixing tube. The application in the nuclear field was limited by the high portion of air in the cutting jet, that would cause the spreading of radioactive aerosols. The innovation of the AWSJ-technology is a premixed suspension of water and abrasive, that eliminates the air in the jet completely. The suspension is pressed with 1400 bars through a nozzle of 0,5 mm in diameter. Also the flow rate of water and abrasives could be reduced drastically in this 2-phase procedure. Compared to an AWIJ-jet of the same hydraulic power with an identical abrasive mass flow rate, the suspension jet is able to cut twice as deep or two times faster.

A main advantage is that the complete cutting device is located outside the controlled area. Only the nozzle and the hose pipe are used as cutting tools (Fig. 1). Hose pipe lengths of even several hundred metres are possible, which makes the tools very flexible. There is no generation of aerosols and due to the small width of the produced kerf the amount of radioactive secondary waste is nearly negligible. However the amount of abrasives has to be considered as additional secondary waste and at the same time it may affect the visibility in the water. In VAK a special filtering device was developed, which allows to keep a sufficient water quality over the whole cutting process. The dismantling of the core shroud - ready for packaging - ended up in only two drums (200 litre) of abrasive material as additional secondary waste. Figure 2 shows the nozzle and the guiding device at a mock-up of the lower core shroud. Thicknesses of more 130 mm could be cut with this technique.

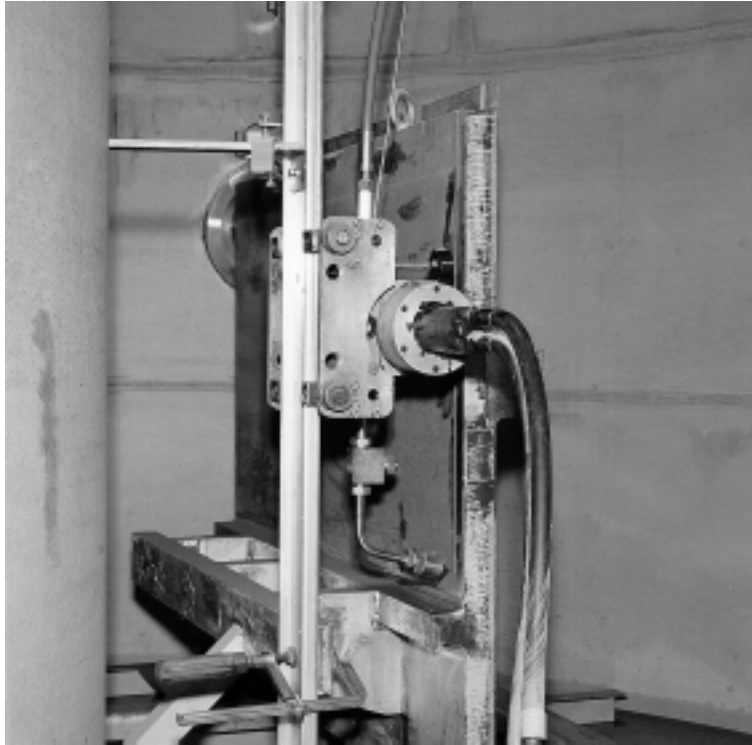


Fig. 2: Mock-up for the AWIJ cutting technology

The AWSJ-cutting procedure was found to be a flexible and reliable tool for cutting activated components even under water. After the core shroud has been cut successfully with this technology, the complete system was improved. In the meantime the pressure was raised to 2000 bar for cutting the thermal shield. The actual planning includes the use of the AWSJ-cutting even for the dismantling of the pressure vessel itself in 1999.

THE KRB A PROJECT

In KRB A three main working areas can be used for the remote controlled dismantling of the activated components under water: As a first possibility the big fuel storage pool is mainly used for storing transfer containers with dismantled material. But also the control rod blades and the guiding tubes were cut in this pool with a special under water shear compactor. In this case the compactor itself, but also the transfer containers for packaging required sufficient room for working and storing. The second pool is the reactor well and the pressure vessel itself, which must be used for segmenting components like the core shroud, that cannot be removed completely. At the same time the third and main dismantling area - the equipment storage pool for steam separator unit during refuelling - is used for all removable components and for post dismantling. All pools are connected to each other, so that the transport of highly activated components can be done under water.

The dismantling of reactor internals under water can be executed with mechanical or thermal cutting procedures /4,5/. Every tool is characterised by various features, e.g. tool size and weight, reaction forces, application flexibility, aerosol generation and secondary waste. But for tool selection also subsidiary and set-up times must be taken into account.

The experience especially in using mechanical cutting tools like sawing, shearing and grinding for the dismantling of highly contaminated and activated components is very extensive in the

meantime, so that the expenditure for future applications and for further components may be well estimated.

The plasma arc technique is the method-of-choice for underwater cutting in KRB A. It is used for cutting components of the reactor in a water depth down to 15 m. A plasma torch with 100 kW output power is installed in a special tool carrier which is mounted on a turntable in the steam dryer pool. The plasma torch can cut material up to 100 mm thick. It is backed up by a mechanical hacksaw which is used for thin walled pipes and a hydraulic shear. The Contact Arc Metal Cutting (CAMC) technique is used to cut off small parts or material that could disturb the linear movement of a standard tool.

Compared to mechanical techniques, thermal cutting tools, like plasma arc cutting, are hardly used in the field of decommissioning today. Nevertheless its obviously an advantage to have a very powerful cutting tool, which at the same time is small and flexible. Furthermore, no restoring forces have to be taken into account for construction layout of handling tools. But granulate, hydrosols and aerosols have to be considered as secondary waste and also for radiation protection purposes /6/. The arc of the plasma procedure generates high temperatures, which melt and partly evaporate the metal. The plasma gas blows the molten material out of the gap. Small particles in the water may for example contaminate handling tools and radioactive aerosols rise into the atmosphere.

The principle features of plasma arc cutting always seemed a likely assumption, that visibility is poor after a short time of cutting because of fine particles in the water. Another question is the spreading of activity by aerosols, especially when cutting highly contaminated and activated components.

Prior to the first use of plasma arc cutting under water in KRB A the amount of expected aerosols were evaluated in inactive tests. First positive results were gained shortly afterwards from real application during cutting the shell of the water steam dryer in 1991. The steam dryer had a mass of 7 tons and was low activated. The diameter of the component was 3.4 m, the height nearly 4 m. The outer shell had a contamination of about 6 000 Bq/cm². About 60 vertical standpipes were welded orbital to the support rings. The dryer bundles were arranged in two rings in the upper centre part. The given layout of the steam dryer necessitated the establishment of a dismantling concept based on segmenting from the outside to the inside and from the upper part to the lower part.

All the work was done under water. Before cutting, adherent contamination on the component was cleaned by high pressure water jet, in order to avoid aerosol generation. During dismantling the complete component with mainly plasma arc cutting, at no time the process was interrupted by cloudy water.

The aerosols arising from the thermal cutting tools were captured and filtered at the water surface by a special suction device. Measurements of the aerosols showed that the concentration in the exhaust duct of the local suction device was 18 Bq ⁶⁰Co/m³ at the maximum. Also no increase of the specific activity in the water could be found. Suspended particles in the water from the cutting process were filtered by the existing filter system of the storage pool and by a back washing filter, which was additionally installed at reactor pressure vessel. Most of the swarf and debris dropped into the collecting baskets at the ground.

Also the dismantling of the water separator was performed by combining the use of thermal and mechanical cutting tools. The water separator was located on top of the core shroud during operation and therefore the bottom part was already activated noticeably. A small increase of activation in the exhaust duct of the suction device could be measured, but no other protection measures for the operational staff was necessary.

Especially when cutting such complex structures it always turned out to use the different tools in combination is the best strategy. During cutting the standpipes of the water separator, it could be proofed, that with an identical set-up time plasma cutting is about 100 times faster than the mechanical hack saw. However, special cutting tasks require special cutting tools, so that the quickest tool is not the best choice in all cases.

Moreover it was desirable to possess another simple dismantling technique to back up the standard tools in unusual situations, such as cutting small parts, which might disturb the chosen cutting path. For this purpose the contact arc metal cutting (CAMC) has been qualified for the use in KRB A. This is a powerful electric cutting technique, which uses a graphite electrode, that is connected in short circuit with the workpiece with low voltage and high amperage. During contact the electrode ignites an arc, that melts the steel but not the graphite (Figure 3). This very simple process combines the features of the saw and the plasma torch. It allows to cut smaller parts with a minimum of set-up time, works without restoring force, but may only be used for a linear movement.

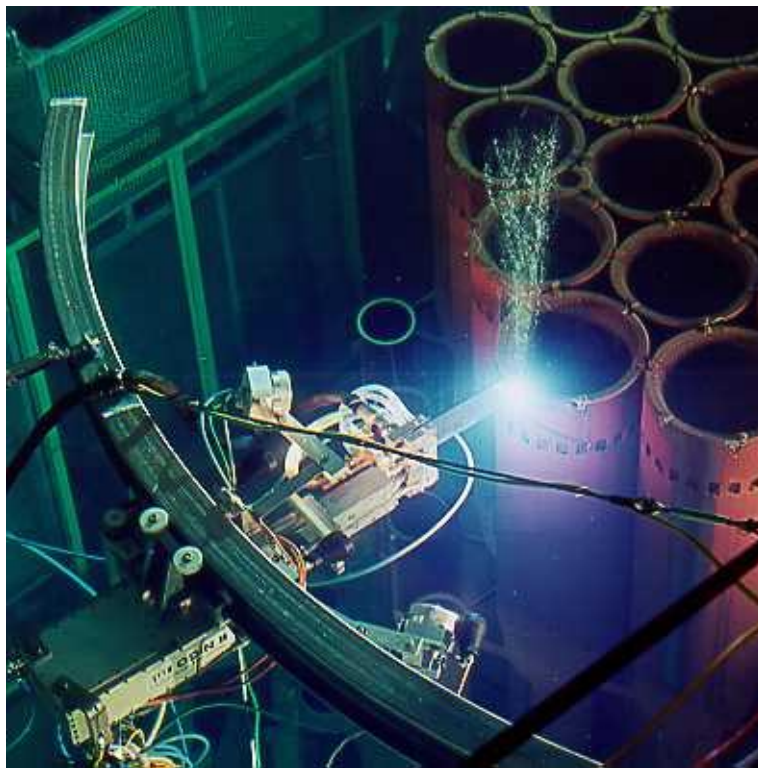


Figure 3: The guiding machine working with a CAMC-cutting tool at the water separator.

Recently the most activated component of the reactor, the upper grid plate, has been dismantled by sawing and plasma cutting. Although the grid plate had a dose rate of up to 50 Sv/h, it could be cut as usual. Compared to components that were cut so far, the activation in the exhaust duct was distinctively higher, but again nearly no activity could be measured in

the working area of the staff. The suction device over the water surface proved again to work sufficiently.

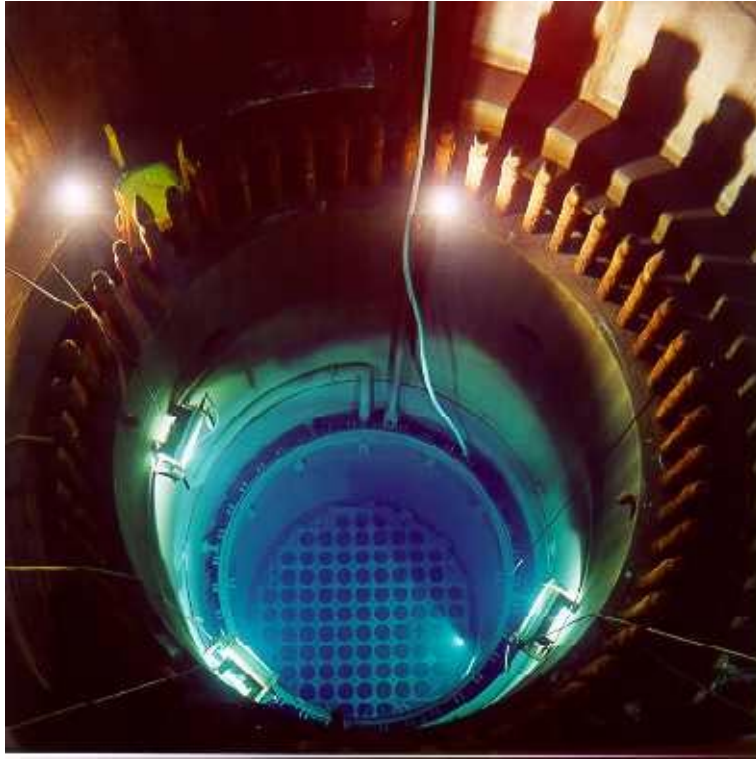


Fig. 4: View into the RPV in KRB A. Except the core support and core shroud, all other components have already been dismantled under water with thermal and mechanical cutting techniques.

The present situation (end of 1998) is shown in figure 4. The remaining components within the RPV are the core support and the core shroud. Where as the core support can be removed and dismantled as usual, the core shroud is fixed in the RPV and must be dismantled in situ.

For this purpose a special manipulator has been designed and constructed. The manipulator is foreseen to position and fix itself within the cylindrical core shroud. It can guide and rotate a plasma torch by 360° and subsequently cut and transport ring segments from the core shroud to the post dismantling area.

CONCLUSIONS

The first generation of nuclear power plants in Germany, KRB A in Gundremmingen und VAK in Kahl, were shut down and are under dismantling. Most of the material is already segmented, decontaminated and recycled. Only a low amount of material will remain as nuclear waste. Presently the work is concentrated on the dismantling of the reactor pressure vessels and the internals.

The experience gained in both projects demonstrate, that the dismantling of nuclear power plants is possible with reasonable costs and with no impact on the staff or the environment. For this a detailed planning of dismantling work, sensible radiation protection measures and appropriate techniques are necessary and available.

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