Servicing and repair of key equipment when suppliers disappear or stop offering support

JEAN-MICHEL WAGNER AUTHOR, HUBERT HAFEN AUTHOR
Wälischmiller Engineering GmbH
Schießstattweg 16, 88677 Markdorf, Germany

ABSTRACT

Since the beginning of the industrial civil use of hot cells, remote handling is key equipment. For safety reasons, hazardous materials have to be moved or manipulated by telemanipulators. Therefore operating companies emphasise the operativeness of manipulators and are demanding customers in regard to service and maintenance.

The nuclear industry started its expansion in the 1950s and experienced a massive growth in the period between the 1960s and the 1970s. The development of remote handling technology was associated with this expansion. The first master-slave manipulator that Wälischmiller delivered was for the Research Center in Karlsruhe in 1963. Since then, the company is constantly developing new manipulators and expanding its portfolio. The ageing manipulators and their regular wear force companies to renew their equipment to maintain the output capacity that is lost through deterioration. But what is happening when a manufacturer is not available anymore on the market?

In the last decades, many manufacturers of remote handling equipment disappeared or ceased to support the nuclear market. This situation is a real challenge for operating companies. They have to find new suppliers, able to offer servicing or even replace the manipulators. Stricter regulations, new materials and remote installation in highly contaminated cells are examples of difficulties that encounter remote handling manufacturers. Adaptation efforts with affordable solutions are usual issues that have to be solved. In addition remote handling technology has improved in the last decades. Mechanical design improvements, complex robotic functions and force feedback are examples of progress in that sector and allow modernisation investments. They enable higher productivity and process improvements. The success of replacement projects can only be reached by close contact and regular discussions between contractor and customer.

This continuous evolution in the nuclear industry raised key questions: How can hot cells be used on a long-term basis when equipment is ageing? When is replacement valuable? What are the challenges? What are the solutions offered today on the market?

As manufacturer with a long-time experience, Wälischmiller Engineering is regularly involved in replacement projects. This paper will concentrate on four case studies of projects we realised, to answer these questions. It will be divided as following:

1. Short presentation of Wälischmiller as full range supplier of remote handling solutions and reliable partner.
2. Replacement of a “remote controlled power manipulator” on a telescopic mast in a hot cell of the Belgian Nuclear Research Centre SCK•CEN.
3. Additional power manipulator as spare manipulator for the next decommissioning and disposal campaigns. To guarantee a continuous operation during the processing, the spare manipulator has to be available at the beginning of the disposal campaigns to enable a quick installation if needed.

4. Electrical manipulator A4000 with robotic function: replacement of a standard master slave manipulator to improve the accessibility of the working area. Additionally the equipment must have enhanced dextrous movements to operate within the confines of nuclear cell work areas.
5. Replacement of a floor manipulator through a power manipulator A1000 driving on floor rails and equipped with a parallelogram. In addition a second A1000 was delivered for in-cell support. This manipulator is driving on the same bridge as the in-cell crane. The hot cell is dedicated to the dismantling of a research reactor. The particularity of this project was the complete remote handling commissioning.

About Wälischmiller: Wälischmiller Engineering has been providing safe, smart and cost-effective remote handling solutions with the famed German quality and reliability for 70 years worldwide. Our handling systems offer various mechanical telemanipulators for a wide range of applications. Our models A100 and A200 series were successfully employed in Sellafield, Cadarache and Chernobyl. Other products include remote controlled power manipulators from the A1000 series for handling heavy loads; intervention systems with servo-manipulators for repair and maintenance tasks in hazardous and inaccessible zones as well as remote-controlled and automatic equipment for positioning, transport and sampling tasks.

1. Introduction

1.1. What does Wälischmiller do?

Wälischmiller Engineering is a German company which has been providing safe, smart and cost-effective remote handling solutions with the famed German quality and reliability for over 60 years worldwide.

Wälischmiller Engineering specializes in manufacturing remote-handling systems, radiation protection equipment and robotics for hazardous environments for application in nuclear and chemical industries. Our work includes projects in the most difficult nuclear environments including, Sellafield, Rokkasho and Chernobyl.

Wälischmiller has a hard earned international reputation for performance, excellence in engineering and exceptional robotic hardware. In the most difficult and challenging nuclear environments, Wälischmiller has demonstrated the ability to bring solutions and success to many of the most difficult high-radiation remediation challenges.

Our handling systems offer various mechanical telemanipulators for a wide range of applications, our models A100 and A200 series were successfully employed in Sellafield, Cadarache and Chernobyl. Other products include remote-controlled power manipulators from the A1000 series for handling heavy loads; intervention systems with servo-manipulators for repair and maintenance tasks in hazardous and inaccessible zones as well as remote-controlled and automatic equipment for positioning, transport and sampling tasks.

Our special TELBOT® robot is a multi-functional, modular and automatic system with unique capabilities which includes unlimited rotation in all axes, no wiring inside or outside the Telbot arm, and unlimited fast and precise movement which made TELBOT® the star of clean-up operations. TELBOT® systems have been successfully employed in Rokkasho vitrification plants and for decommissioning power plants in Rheinsberg and Greifswald.

At Wälischmiller Engineering we take pride in offering turnkey solutions. We provide a fully integrated service that extends from planning and product development all the way to manufacturing, installation and service.

By working closely with our specialist engineers and project managers, you can be confident of receiving not just an off-the shelf product, but a custom-tailored solution to your remote handling challenges; that offers the highest quality and guarantee of long-term operational safety to even the most-demanding customers.

Our quality management system has been certified to DIN EN ISO 9001:2008 and the KTA 1401 safety standard of the Nuclear Safety Standards Commission.

2. Replacement of a “remote controlled power manipulator”

2.1. Requirements to the new equipment

In 2015 Wälischmiller Engineering was approached by the Belgian Nuclear Research Centre SCK•CEN to replace a “remote controlled power manipulator on a telescoping mast” to ensure a continuous production. The manipulator has to be installed in one of the hot cells of the Belgian Research Reactor N° 2 (BR2) in Mol.

SCK•CEN is amongst others strongly involved in conducting gamma and neutron radiation treatments for commercial purposes (production of radioisotopes). The customers can be found in the electronics and medical industry and hospitals (X-ray equipment and derivatives).

The replacement consists of the installation of a new power manipulator arm, a new telescoping mast and a new carriage. The ensemble has to be installed directly on the existing boom swing arm. The boom swing arm requires also new AC motors for its movements, in order to sustain the working time. The motors have to be controlled via the power manipulator control console. Preferably the weight of the combination carriage, telescope mast and manipulator should not exceed 600 kg. Hence traverse, boom hoist and boom swing arm mechanically remain as they are.

The swing arm allows making a circular movement in a horizontal plane. The boom swing arm is fitted to a boom hoist. This boom hoist allows a vertical movement of 6 000 mm. The boom hoist is fitted near a hot cell wall on a traverse. This traverse allows a horizontal movement of 2 286 mm (see figure 1 for an overview).

Fig. 2: Picture of the previous manipulator taken from bottom directed to top of the hot cell

The scope of delivery includes:

- pre-acceptance of the power manipulator at factory
- delivery of the equipment
- installation and commissioning. The installation includes the integration of traverse, boom hoist and boom swing motions.
- acceptance tests
- handover of the installed equipment
- documentation
- training of the SCK•CEN operators

The figure 2 shows the layout requirements of the manipulator arm and consists of an interface assembly towards the telescoping mast, a shoulder pivot joint, a shoulder hook, an upper arm, an elbow pivot joint, a forearm, a wrist pivot joint, a rotating wrist assembly and a jaw hand. The manipulator should also be able to rotate around its shoulder.

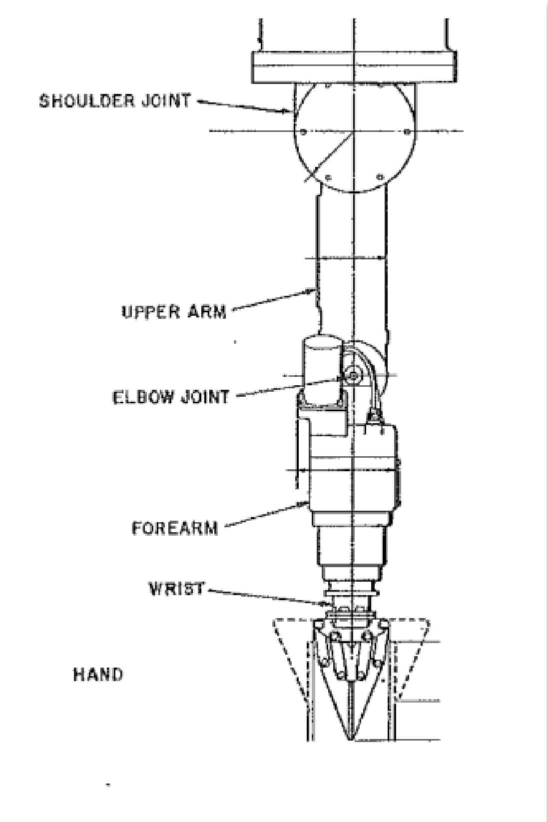

Fig. 3: Drawing of the current manipulator without wrist pivot joint

The shoulder hook is necessary to lift loads up to approximately 500 kg. The manipulator wrist, the forearm and upper arm should be constructed in such a way that easy inspection and maintenance is possible of the components fitted in the wrist, forearm and upper arm structures, e.g. via access plates. The complete wash-down of the manipulator requires a design to comply with IP66.

2.2. The power manipulator A1000 as response to the requirements

To replace the previous power manipulator, Wälischmiller Engineering delivered a power manipulator type A1000 with an integrated carriage/ telescope and a short arm of 1058 mm, including an additional 70 mm hand extension and a gripper opening of 150 mm (see figure 4)

All suitable parts (some telescopic tubes, telescopic plate, arm bodies, etc.) were manufactured out of high-strength aluminium instead of carbon steel to save weight and reached approx. 565 kg. The design principle of the A1000 in variable subassemblies made possible to reach the requirements.

On the telescope hook loads until 500 kg can be lifted and the manipulator arm can handle loads until 75 kg in all positions and full extension. The telescope travel is 2300 mm. The radiation resistance is 1 MGy.

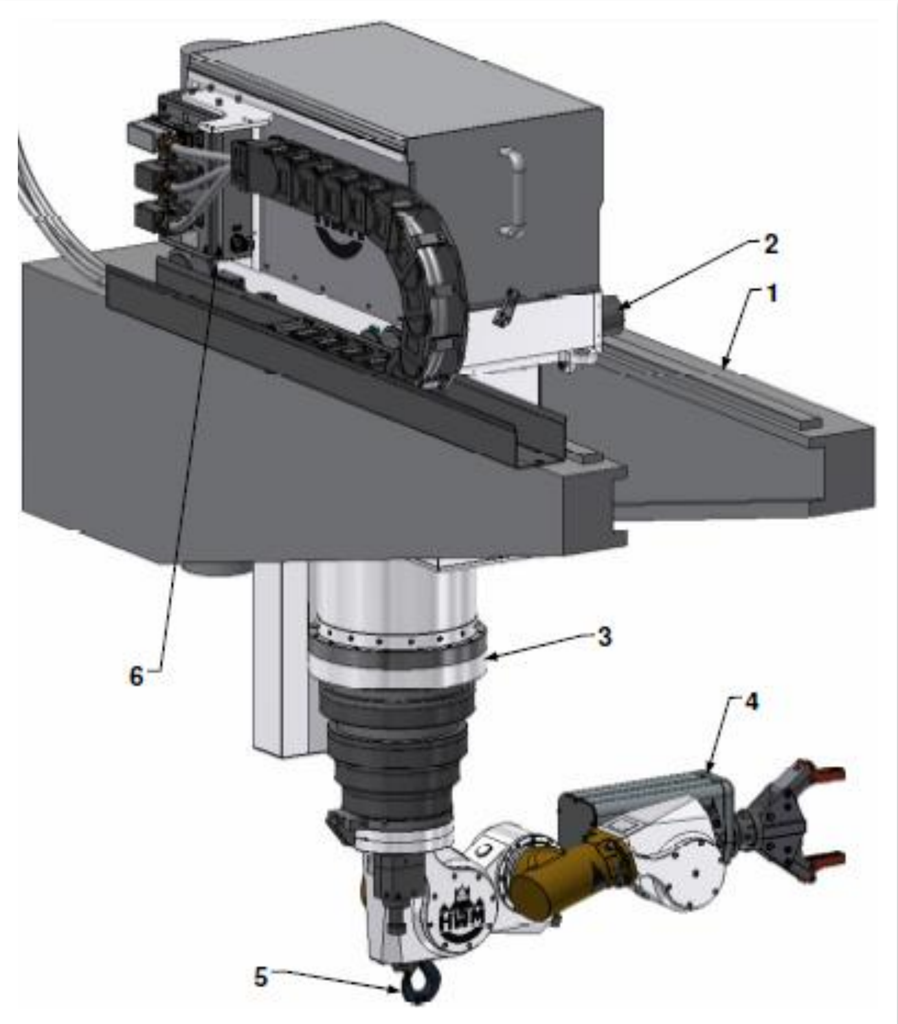

Fig. 4: Power manipulator

1. Boom swing arm (from the operator)
2. Carriage
3. Telescope
4. Manipulator arm
5. Load hook
6. Electrical equipment

The manipulator is controlled by a Simatic S7-300 U PLC controller. The individual components of the manipulator as well as the customer boom swing arm are operated with control panels. Forces applied and speed of the individual axis can be continuously regulated to ensure save and precise motion of the system.

The scope of supply included a standard hardwired control panel (figure 5) and a wireless control panel (figure 6).

Fig. 6: Standard hardwired control panel

Fig. 7: Wireless control panel

2.3. Challenges

Due to the short time frame of the refurbishment procedure at BR2, the whole project from start to finish (completed SAT) needed to be completed in nine months which is shorter than usual standard power manipulator projects including on-site assembly.

Another challenge remained for the on-site assembly team on how to lay the cables in the cell and how & where to connect the holding brackets for the cable chains. Those challenges were overcome by a continuous, solution oriented and trust based cooperation between the responsible persons at SCK•CEN and Wälischmiller Engineering that facilitated steady progress in this project environment.

Further challenges were imposed by the non-standard nature of the required power manipulator, being considerably lighter and having smaller arm component sizes than usually supplied, while at the same time staying commercially competitive with the high-strength aluminum solutions applied.

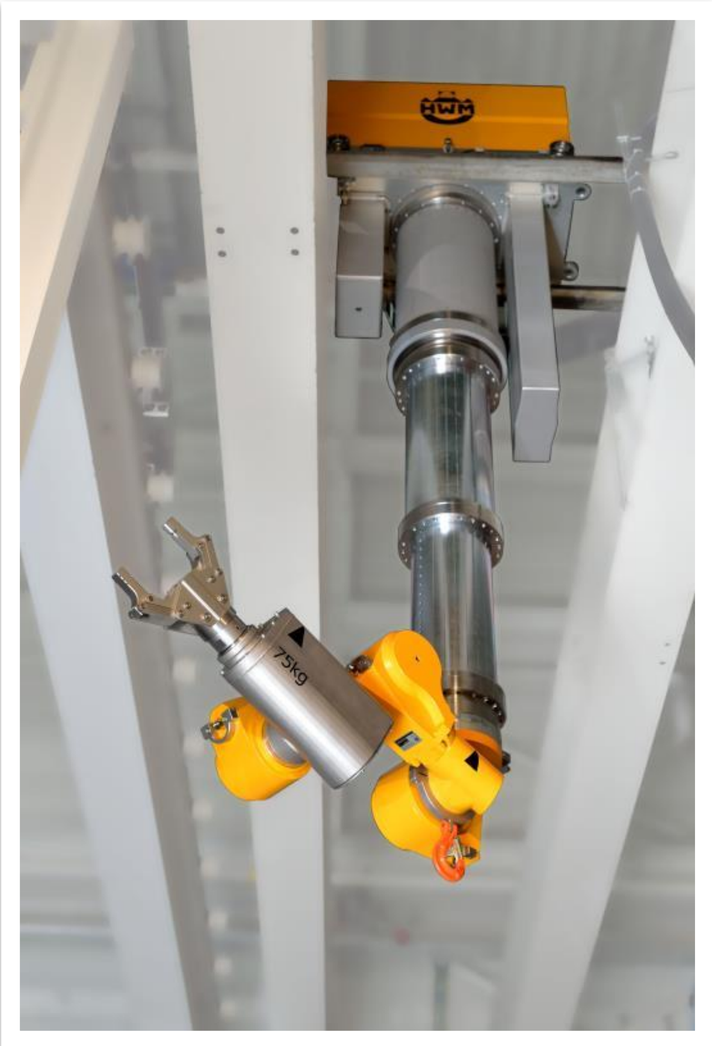

Fig. 8: Power manipulator A1000

3. Additional power manipulator as spare manipulator

3.1. Generality

The WAK Rückbau- und Entsorgungs- GmbH (Decommissioning and Waste Management Company) pools all activities relating to the decommissioning of nuclear facilities and waste management at the premises of the former Research Centre Karlsruhe, today´s KIT. Partner of WAK is the Federation-owned Energiewerke Nord GmbH (EWN). The company is financed by the Federal Ministry of Education and Research and the Baden-Württemberg State Ministry of Finance and Economics.

In the HDB-MAW facility, the power manipulator H32 is used since 2001 mainly for the handling of radioactive materials with high dose rate. The extreme field of application requires reliability and a maintenance- and repair-friendly design. The power manipulator H32 is based on a power manipulator of the company Wälischmiller and has proven one's worth.
In the next years, radioactive residual products in MAW quality will increasingly be delivered in the MAW facility due to the decommissioning projects at place. To guarantee a continuous operation during the processing, a spare manipulator has to be available at the beginning of the disposal campaigns to enable a quick installation if needed. Within the refurbishment of the MAW facility, an identically constructed power manipulator has to be delivered. The identical construction ensures a flexible reaction in case of failure. The whole manipulator, as well as single functions, such as bridge, telescope or arm parts can be replaced.

Fig. 9: Power manipulator arm

3.2. Power Manipulator A1000 “Henry”

The power manipulator system A1242 for the MAW facility is based on the A1000 system. It consists of:

- rail mounted, mobile bridge
- carriage, which drives on the bridge
- telescope with a load hook
- power manipulator arm with 3 joints

The A1242 is also equipped with:

- 10.5 to auxiliary hoist on additional and parallel carriage
- emergency drives for bridge and carriage
- emergency drive for telescope turn movement
- emergency lifting unit for telescope
- cameras on the wrist
- a tilt and pan holder for camera on the telescope

Fig. 10: Power manipulator A1242 for MAW-scrapping

The power manipulator arm has 6 movements, bridge, carriage and telescope together 4. All movements are driven electrically and via a PLC-control. The switches, controllers and displays required for the operations are displayed on a control panel with screen (figure 11) and on a wireless control panel (figure 7). Speeds and forces are continuously adjustable. Excluded is the telescope. The travel of the telescope is carried out in two speeds.

The bridge has a span of 7480 mm and the carriage a drive of 5500 mm. With the telescope hook loads up to 500 kg can be lifted and the manipulator arm can handle loads up to 200 kg in all positions and full extension. The telescope travel is 3000 mm. The radiation resistance is 1 MGy.

Fig. 11: Control console with screen

3.3. Challenges

The project has been successfully achieved in spring 2016. It was the first time that Wälischmiller Engineering had to deliver an auxiliary hoist with a capacity of 10.5 to. The bridge had to be designed accordingly. A good cooperation with the customer made the success of the project possible.

Fig. 12: Loading test with 2 to

4. Electrical manipulator A4000 with robotic function

4.1. Project overview

Dounreay Site Restoration Limited DSRL is presently contracted to decommission the Dounreay Nuclear Site. As part of this decommissioning process the nuclear facilities are being safely disassembled. Much of the hazardous decommissioning will be carried out using remote handling equipment.
DSRL has a requirement for remote handling equipment that is capable of working at a greater reach than presently achievable with a standard Master Slave Manipulator (MSM). Additionally it must have improved dextrous movements to operate within the confines of nuclear cell work areas.
Initially the remote handling equipment is required for one facility, the Dounreay Fast Reactor Fuel Reprocessing Plant. This facility has a number of former process cells that were previously used for nuclear fuel reprocessing.
The remote handling equipment technology is expected to be utilised on similar decommissioning projects elsewhere on the Dounreay Site.
The Reprocessing Plant cells were constructed in 1957 and are heavily contaminated with various radioactive nuclides. The majority of the cells have high internal radiation levels with the highest levels in cells reaching several Sv/hr. The cells are constructed from concrete with steel linings which were built to safely handle nuclear fuels in liquid form.

4.2. Requirements

The remote handling equipment is for the completion of the following activities:

- Design of the remote handling equipment and tooling;
- Manufacture and assembly of the remote handling equipment and tooling;
- Factory Acceptance Testing;
- Training of the purchaser’s operation staff
- Production of contract close out documentation
- Delivery of the remote handling equipment and tooling to the Dounreay Site

The equipment shall be readily configured to operate in the layout and environment within the nuclear hot cells. The equipment’s control system and supply carriages should, where possible, be located external to the cells to simplify maintenance and operation. Hydraulically operated systems are not favoured due to criticality control issues and reliability concerns.

The purpose of the remote equipment will be to reduce size and remove contaminated equipment consisting of pipework and vessels and place it in the waste containers being utilised to decommission the Dounreay site.

Adaptable modular technology will reduce future engineering and regulatory costs, enabling rapid deployment to accommodate the evolving needs of the Dounreay site.

The cell configurations will require the deployment of the equipment both vertically and horizontally. There are limited existing penetrations available for use so appropriate penetrations for deployment will have to be formed. The larger these penetrations are, the more they will compromise operator shielding and ventilation control and this will be factored into the chosen design.

4.3. Electrical manipulator A4000 with robotic function for installation in a shielding wall

4.3.1. Technical Data

The electrical manipulator A4000 is a manipulator for the remote handling of components and for handling of tools for working on components, as well as for dismantling, maintenance and repair tasks and for the transport of loads within confined and inaccessible spaces. As the designated use includes works on radioactive components, all parts of the manipulator are resistant to radiation.

The manipulator suits to a horizontal installation in a shielding wall in a 300 mm through-wall liner. The manipulator is also suitable for a vertical installation trough a ceiling orifice.

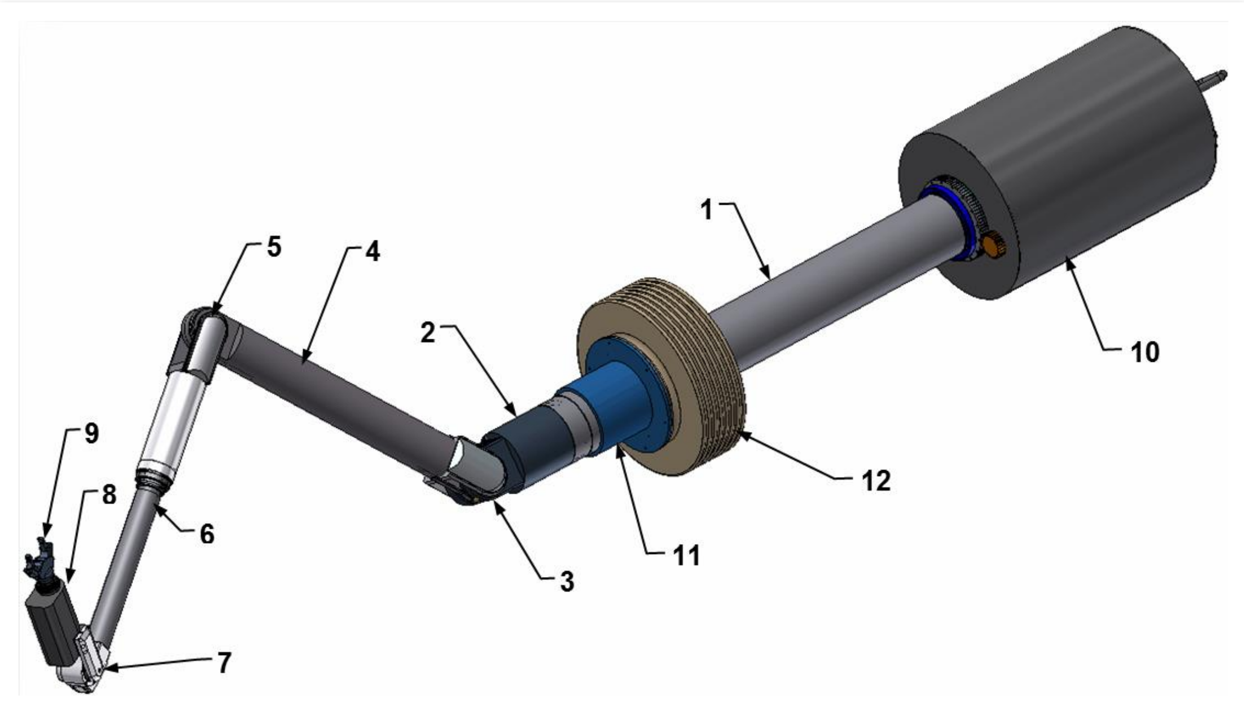

Fig. 13: 3-D Model of the electrical manipulator A4000

1	External (fixed) tube of arm segment 1	7	Wrist joint (axis 5)
2	Internal (rotating) tube of axis 1	8	Arm segment 4 (wrist)
3	Shoulder joint (axis 2)	9	Gripper (axis 6 / axis 7)
4	Arm segment 2 (upper arm)	10	External drive unit assembly (axes 1 – 3)
5	Elbow joint (axis 3)	11	Wall tube (BFE)
6	Arm segment 3 (lower arm rotation / axis 4)	12	Evacuation sleeve (protective sleeve system)

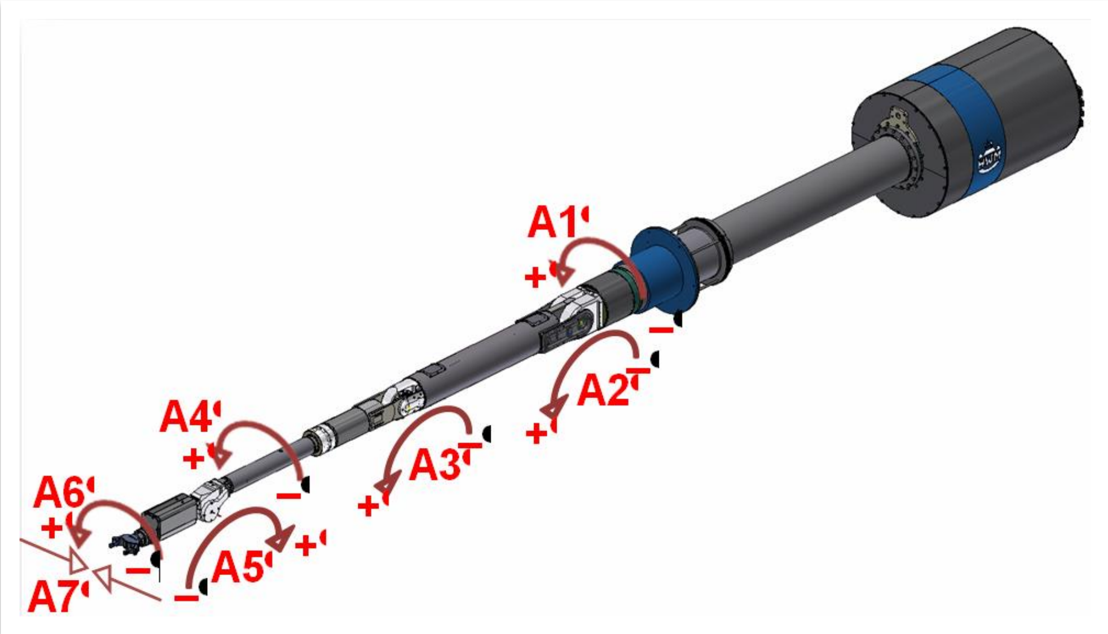

Fig. 14: Axes and rotation directions of the manipulator

• Max. load capacity	30 kg
• Length of arm	3500 mm
• Rotation axis 1	± 190°
• Rotation shoulder joint (axis 2)/ Upper arm pivot	± 110°
• Rotation elbow joint (axis 3)/ Lower arm pivot	± 120°
• Rotation lower arm (axis 4)	unlimited
• Rotation wrist joint (axis 5)	+ 90° / - 155°
• Rotation gripper (axis 6)	unlimited
• Gripper opening width	100 mm

Fig. 15: Electrical manipulator A4000

4.3.2. Control System

The Power Manipulator Arm is controlled by a programmable control system. The control programs are stored on two computer modules:

- One industrial PC in the electrical cabinet
- One computer in the casing of the screen

The computer modules are linked by an Ethernet network. Indication and selection of various operating modes of the control system are carried out via a graphic user interface (GUI) on the touch panel screen. The movements of the manipulator are driven by position-controlled three-phase motors with rotation angle measurement by absolute value encoders.

Fig. 16: programmable control system

4.4. Challenges

The biggest challenge was to introduce the manipulator to an existing through-wall liner with a diameter of 300 mm. The hot cell is highly contaminated; therefore it was not possible to increase the diameter of the opening. The consequence for the manipulator design was that all components such as gears and chain wheels had to be able to be reduced maximally and simultaneously be able to reach a handling capacity of 30 kg in each position with an arm length of 3.5 m. Consequently the high torques and size reductions needed a very compact and well-thought-out design. The assembly of the subassemblies in the narrow spaces was also a challenge itself.

5. Replacement of a floor manipulator

5.1. Background for the replacement and requirements to the equipment

The Phénix power station was a prototype fast breeder reactor, located at the Marcoule nuclear site, France. It was a pool-type liquid-metal fast breeder reactor cooled with liquid sodium. After its final shutdown, the preparatory operations to the final closure were started. They consist mainly to evacuate the nuclear materials of the installation. This phase was used to prepare the treatment of core objects and treatment of sodium and sodium-bearing objects.

Phénix decided to replace the overhead lifting unit and to use the opportunity to also replace the functions of the previous power manipulator installed on the floor. The new equipment called “floor manipulator” consists of a carrier driving on the rail of the existing power manipulator and of a manipulator arm. The arm enables the access to the equipment place in the lower area of the cell. The existing power manipulator will not be removed immediately from the cell. For that reason the floor manipulator will be moved with the lifting unit in order to circumvent the existing power manipulator.

Additionally to the floor manipulator, Phénix decided to install a power manipulator driving on the same bridge as the overall crane. The combination of an upper power manipulator and a floor manipulator allows covering the whole cell which is 18 896 mm long, 6 500 mm wide and 10.7 m high at the highest area. One of the two grippers should access any point in the cell. An overlapping area (min. 500 mm) to transfer equipment between the manipulators is required.

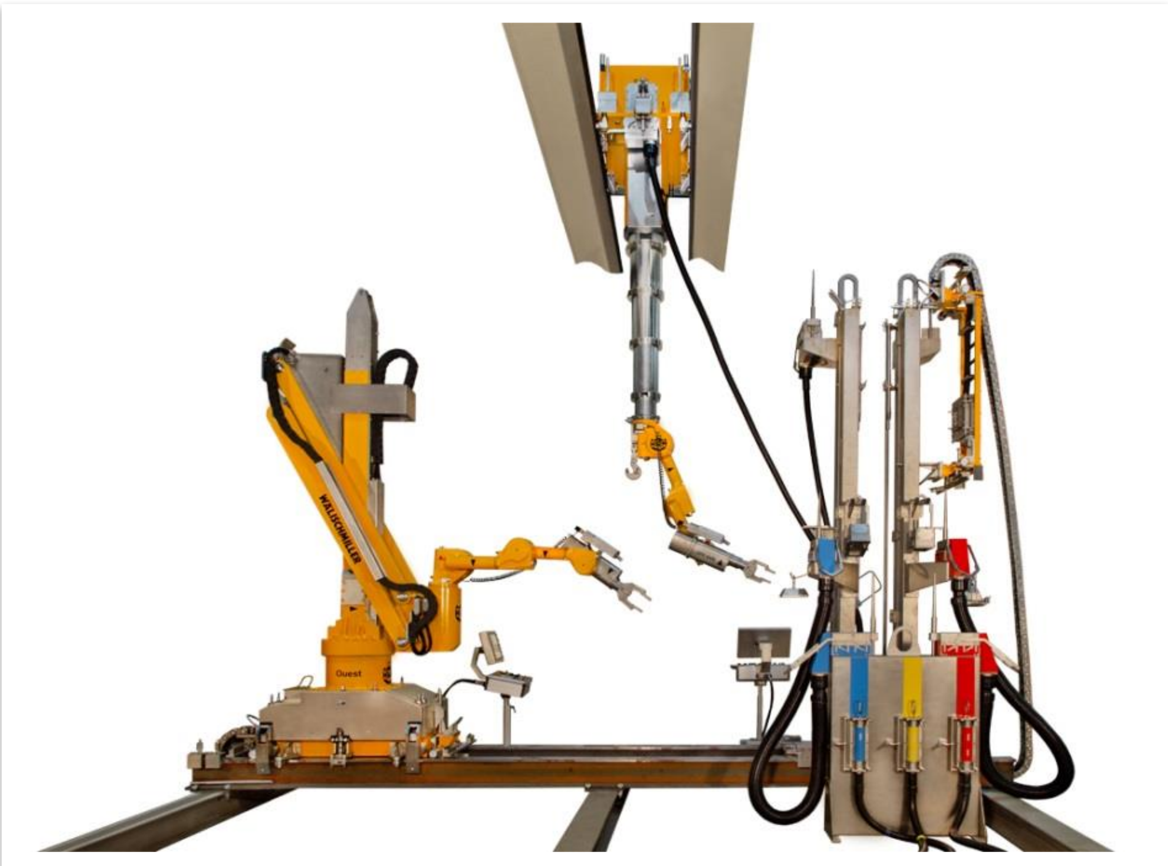

Fig. 17: On the left is the floor manipulator, in the middle is the upper power manipulator and on the right is the in-cell electrical equipment with remote handle compact connectors.

5.2. Characteristics of the floor manipulator

The manipulator is divided as follows:

- rolling carrier for the movement of the manipulator on the rails on the floor of the cell
- mast for the rotation of the vertical unit and the manipulator arm
- vertical unit for the lifting and for the rotation of the manipulator arm
- manipulator arm for the handling and the transport of loads
- electrical installation for the power supply for the whole installation
- control command for the command of the movements and the monitoring

The manipulator can be introduced and removed via remote handling. It can be transferred in and out of the cell without dismantling in subassemblies.

1. carrier
2. mast
3. vertical unit
4. manipulator arm
5. camera

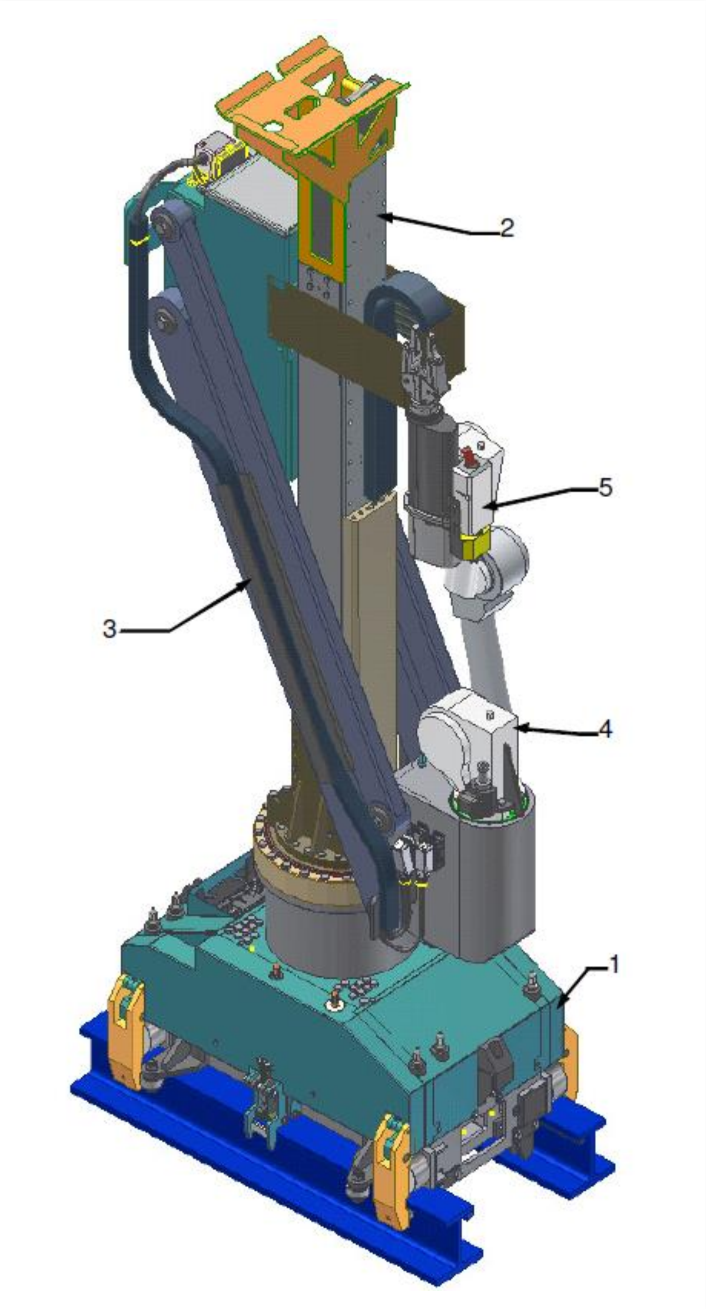

Fig. 18: 3-D model of the floor manipulator

- Max. load capacity — 200 kg
- Length of arm — 1650 + 120 mm
- Drive of the carrier — 2 960 mm
- Rotation of the mast — maxi. min-1 0.8
- Vertical unit, pivoting of parallelogram — -64° / +35° (from the horizontal)
- Shoulder base, pivoting or arm — -180° / +120°
- Shoulder, pivoting of upper arm — 270°
- Upper arm, pivoting of forearm — 270°
- Forearm, pivoting of wrist — unlimited
- Pivoting gripper — unlimited
- Arm extension — 120 mm
- Gripper opening — 200 mm

A control console is available for the control of the system. Each movements can be run separately. Forces applied and speed of the individual axis can be continuously regulated to ensure save and precise motion of the system.

Fig. 19: control console

5.3. Challenges

A challenge was imposed by the non-standard nature of the required power manipulator and the customised design of the carrier, mast and vertical unit (parallelogram). Those challenges were overcome by a continuous, solution oriented and trust based cooperation between the responsible persons at Phénix and Wälischmiller Engineering that facilitated steady progress.

Another challenge was the remote installation of the manipulator and the cables without human access. A complex procedure step by step had to be created to introduce the manipulator in the cell. A failure by the installation would have as consequence that the manipulator would have to be rescued with difficulties. The installation was successful and without any incident.

As the floor manipulator will be moved with the lifting unit in order to circumvent the existing power manipulator, special compact remote handled connectors were developed. It allowed a quick and easy connection/ disconnection of the cables in the cell (figure 21). The lever is operated with the overhead lifting unit.

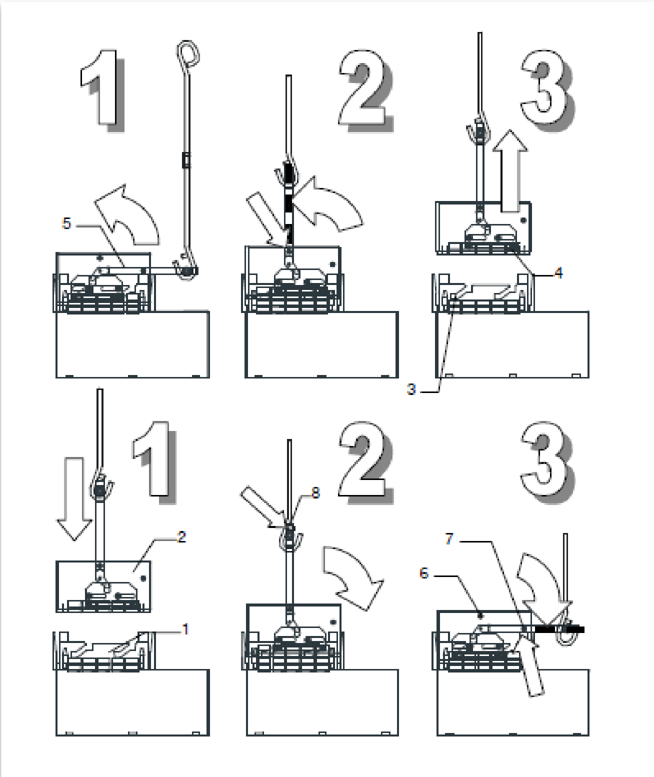

Fig. 20: compact connectors

6. Management key suppliers Wälischmiller

The use of manipulators depends on the delivery of spare parts. Even though our production is optimally designed for the complexity and breadth of our products, we rely on key suppliers. Should one supplier fail or a product no longer be available, we have to find an alternative. From one part to the other the interfaces might be different. Already by the design of the manipulators we have to consider the exchangeability of components. Motors for our power manipulators are for example after many years no longer available on the market and we have to find alternatives. To solve the issue with the interfaces, we use a flange between motor and our drive unit. Should the interface be different from one motor to the other, we have only to adapt the flange. The advantage is that we do not depend on a certain supplier and are more flexible. Consequently we are able to deliver spare part kits as long as the manipulator is working. We deliver spare parts for equipment which is in use since 30 years and is still working.

7. Conclusion

As shown by this paper, the replacement of equipment is possible with a design principle in variable subassemblies like the power manipulator system A1000. Since decades we strive to develop customisable solutions to our customers and their different needs. No project is like the other, because each facility is different. Trust and solution oriented relationship is in our opinion the key of the success of refurbishment of manipulators. For that reason, we develop our products by keeping in mind the needs of our customers and see it with their eyes.

In the future, we know that many very difficult remediation challenges will require new remote handling equipment and replacement of previous manipulators to achieve success.

The retrieval, transport, reprocessing and ultimate disposal of radioactive material, from the most difficult locations is the hard part and must employ remote solutions to protect the work force and the environment. The solutions to these programs must me rugged, reliable, and nimble and be a “work horse” over a long remediation schedule.

Products continue to improve to meet customers’ needs and will continue to look for “creative destruction”. As we enter the next stages of decommissioning in both the commercial and government arenas; we must look for long-life solutions and equipment that meet the precise need of the situation and protect the workers and the environment in new and effective ways. Wälischmiller has always been at the forefront of remote handling and robotic innovation and we plan to stay there. Thank You!!