

**PLASMARC<sup>®</sup> – VITRIFICATION OF RADIOACTIVE WASTE**

Holger Weigel and Karl Heinz Roeder  
TECHNIP GERMANY GmbH;

Dr. Wolfgang Hoffelner  
MGC Plasma AG

**INTRODUCTION**

The traditional management of low level nuclear waste (LLW) is a combination of different steps in collection, separation, pre-treatment, treatment and final demobilisation before intermediate or final disposal.

All this steps need own equipment, administration and organisation. Personnel can be exposed to radiation risk in many ways.

Even if this way of treatment of LLW is considered as safe and proven since many years efforts to develop new approaches are made in the previous years.

PLASMARC<sup>®1</sup> is a one-step-process which summarises a ten year development to a proven and safe technology for the treatment of low level mixed waste.

PLASMARC<sup>®</sup> is a process from feeding of LLW to final product.

The main advantages can be described as follows:

- the complete range of LLW, including combustible waste, non combustible waste but also ion exchange resins can be processed;
- as an end-product for final storage an inert and non leachable slag with no need for further stabilisation remains; and
- the process leads to the highest volume reduction.

All this advantages can be offered to the market at the same or even lower costs than traditional processes request.

**DEVELOPMENT**

The development of the process started in 1990 with a first large scale plasma plant. This plant was established for research and integration of new technologies. From the beginning we focused our activities on the following aspects:

- as less as possible contact between personnel and waste;
- best property for final products; and
- wide flexibility for input material.

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Such demanding requirements are state-of-the art mainly in the fields of nuclear waste treatment and treatment of highly toxic material, such as chemical warfare agents.

In 1991/1995 we received an order for the engineering and approval procedures for two large plants in Germany and Switzerland – one for the treatment of chemical warfare agents and one for the treatment of nuclear waste at the Swiss Zwiilag. For both plants we received the EPC contract by 1994/1996 after successful passed erection approval.

Also in 1991 we set up an own research and integration facility, at Muttenz, Switzerland, in a one to one:1 scale. This plant is in operation now for more than 8 years. In 1995 we decided to add a second research facility – a mobile unit with a throughput of 40 – 80 kg waste per hour – for demonstrations and small campaigns on-site.

With both research plants we have processed many different wastes – in our workshop at Muttenz simulates and onsite real toxic and radioactive materials. The range of treated material various from filter dust containing dioxins, asbestos, from combustible and non combustible waste to complete drums with bitumized ion exchange resins, and Hg contaminated waste material from natural gas production (on-site campaign in 1997) and chemical warfare agents (destruction campaign for the Swiss army in 1998).

In 1995 we have started developing our own plasma torches. The systems have been optimised regarding working in different atmospheres always focused upon customers benefit.

More than ten years of experience with own plants and extensive experience in EPC contracting as a main business is enabling us to provide always a complete and tailor made system for the treatment of low level nuclear waste, specified to the customers wishes.

In 1998 we have created a strategic alliance with the company Siemens AG, Germany, to enhance and complete our detailed nuclear know-how and to open and go for new opportunities and challenges in new and different markets.

We continue all our efforts to achieve a status where we are able to stay in the front line of technology providers. our development day by day to stay in the first line of technology.

## **TECHNOLOGY**

### **Transferred Plasma for nuclear waste**

The main purpose of an incineration is to bring the thermal energy into the material which has to be processed. The better heat transfer into the material the better the result of the incineration.

From all incineration normally processes residues remain. These residues can be either not complete incineration ash or inert dust which both have to be processed through a secondary treatment or a stabilisation stage like cementation. In addition, secondary wastes such as filter candles, zeolites, ion exchange resins occur which also have to be disposed off.

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All follow-up or secondary treatments as compaction or cementation have the disadvantage of additional equipment, additional operation-costs, additional safety risks and additional personnel exposure.

An optimal process requests not only a safe thermal treatment of a large range of feeding material but also a good conditioning of the so-called fly ash in addition to the possibility to feed the resulting internal secondary wastes back to the system.

Furthermore the system should be a closed box with a large flexibility in feeding and one well defined end product.

In general there are different possibilities to bring heat into a system:

	<b>Fossil Burning</b>	<b>Pyrolysis</b>	<b>Electric Arc furnace/ Non transferred Plasma</b>	<b>Induction Furnace</b>	<b>Transferred Plasma</b>
<b>Temperature</b>	800 - 1200°C	550 - 700°C	> 1200°C	>1200°C	1200 – 1600°C
<b>Size of Feeding material</b>	Should be limited, longer treatment	Should be limited, incomplete pyrolysis	Not so important	Not limited for metals	Limited only by feeding device
<b>Combustible waste</b>	Yes	Yes	Yes	No	Yes
<b>Non combustible waste</b>	No	No	Yes	No	Yes
<b>Metals</b>	No	No	Yes	Yes	Yes
<b>Secondary wastes</b>	No	No	No	No	Yes
<b>Fly ashes / slag conditioning</b>	Occur, secondary treatment like cementation	Occur, secondary treatment like cementation, in addition pyro-cook, has to be incinerated	Slag, bad conditioning of the slag, not defined end product	Slag, good conditioning of the slag	Glass/slag, perfect conditioning
<b>Best to treat</b>	Combustible	Combustible with high energy content	Metals	Metals	Combustibles, non-combustibles, metals
<b>Volume reduction</b>	Good	Medium	Good	Good	Good
<b>Including secondary treatment</b>	Bad	Bad	Good	Good	Excellent
<b>Energy consumption</b>	Medium	Low	High	High	Medium/high

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A transferred plasma – as our nuclear application of the Plasma technology, the PLASMARC<sup>®</sup> system - is a system where the electrode is used as a cathode and the melt as an anode. That means that beneath the electric arc, which heats up the system via radiation and convection, the melt will be heated via Joule Energy itself. Therefore this system can perform combustion, melting of non-combustibles and metals and conditioning of slag in one process step. Here the advantages of conventional incineration, electric arc furnaces and induction furnaces are combined.

The PLASMARC<sup>®</sup> plant is a closed reactor vessel equipped with a powerful transferred plasma torch and an oxygen-fuel lance.

Electrical energy for the plasma torch is an expensive way to keep an system simply on temperature. Therefore we add the oxygen-fuel lance to:

- heat up the system; and
- to keep the reactor on required temperature during treatment of low caloric material.

Electrical energy is used exactly where it makes sense to have the high energy densities – to melt the non-combustibles and metals and to condition the slag:

### **TYPES OF WASTE**

The PLASMARC<sup>®</sup> reactor is constructed to treat:

- Combustible waste: PE, PVC, wood, paper, protection clothes, activated carbon etc.;
- Ion exchange resins: N and S containing, wet and dry, conditioned and non conditioned;
- Non-Combustible waste: Cement, asbestos, filter, sludge, decontamination liquids etc.; and
- Conditioned waste: bitumized and cemented leaking drums for direct processing.

The limitation of the plant is only given by:

- Maximum grain size agreed with the customer. (Proven feeding systems up to complete 220 litre drums are available.)
- Maximum layout of the off-gas treatment concerning chlorine and sulphur.
- Maximum layout of the secondary combustion.

In our own research facilities we have proven the treatment of all different types of waste up to a one to one scale for more than 8 years. These demonstrations have been made for own process optimisation but also for customers and authorities to grant public approvals for the plants already under construction.

Among others, reports and studies for all different types of existing nuclear wastes are available. Complete mass balances and nuclide distributions are the base of our experience.

## **QUALITY OF END-PRODUCTS**

Flexibility in input material in combination with an well defined end-product is the main philosophy during engineering and design.

Within a Plasma reactor the amount of dust in the off-gas is normally low. Therefore the resulting fly ashes will be accumulated at a rate of nearly 100% in the slag. Depending on the feeding material and the distribution of already existing glass formers like  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{CO}_3$  etc. in the fly ash we add cheap and easy available and easy to handle inert materials like used glass, calciumcarbonate, dolomite. With this additional glass formers – normally not more than 20 % of the total amount of fly ash – we correct the multiphase slag. The goal is to reach a zone in the phase diagram  $\text{SiO}_2/\text{CaO}/\text{Na}_2\text{CO}_3$  where a good quality of glass can be established.

Depending on the needs of the customer we can produce a slag or glass which fulfils all demands in relation to required mechanical, physical and chemical as well as to leaching properties.

The slag can be poured either into drums for final disposal or in molds defined by the customer.

In all cases we are able to reach the highest possible volume reduction with the best end-product for final disposal. Also metals can be molten easily, reaching the highest volume reduction.

## **PLASMARC<sup>®</sup> SYSTEM - TYPES OF PLANTS**

To enable a less expensive and flexible solution for the customers benefit, we developed a modular system which consists of:

### **Feeding devices**

composed of:

- liquid feeding lances;
- screw feeder;
- drum feeder;
- bulk feeder.

All feeding devices are proved in our own research facilities or already in use with customers.

### **Reactor**

Depending on the feeding system, the capacity and the maximum grain size, we are able to offer different reactor types. The overall design, including slag removal is similar but the inner diameter is different.

### **Plasma Torch**

We can offer three different types of transferred plasma torches from 150 kW to 1.200 kW.

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This types are in use in our own facilities for quite some years now and have been proved under quite a large number of different conditions. The torches and the complete power supply is designed and fabricated in our workshop.

For the design of the plasma torch we do apply the following preconditions:

- the costs for consumables have to be as low as possible
- the torch has to withstand all different atmospheres
- the lifetime of the torch has to be sufficient enough
- the change of the electrode should be as easy as possible

The lifetime of the electrode could be extended up to more than 300 h continuous operation by maximum feeding rate for the reactor. The continuous improvement of our plasma torches is related to our long term experience and various practical application under different projects.

### **Slag removal**

Depending on the customers need we are able to offer different slag and metal removal systems. All systems are proven and based upon a safe design.

### **General**

Through different improvements in design and construction we are in a situation to offer PLASMARC<sup>®</sup> plants at the same investment level as conventional incinerators.

All parts of the system already went through different approval procedures with detailed safety analysis and environmental impact studies. We received operation licenses not only for nuclear application but also for the treatment of explosives and chemical warfare agents.

### **OFF-GAS TREATMENT**

Besides the plasma reactor the off-gas system is the main equipment to ensure a safe and secure operation.

The off-gas treatment is optimised for the waste material which has to be processed. The off-gas treatment consists of the following main units:

- Secondary Combustion
- Quench
- Scrubber (basic, acid)
- HEPA filter
- Fan
- DeNO<sub>x</sub> (if required)

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Volatility of waste material at high temperature has been investigated with special research programs. Nearly all nuclides remain inside the slag or melt during the first thermal step. Also Cs will remain in the slag in a high amount. The volatile part will be washed out in a wet cleaning phase as part of the well experienced off-gas treatment process. The gaseous release meets finally the relevant regulations.

This technology can be considered as a state-of-the-art system, already proven in several thermal treatment plants for nuclear wastes around the world.

If requested also dry or hybrid systems are available for the off-gas treatment system.

## **MAINTENANCE**

### **General**

One of the main aspects during design of the PLASMARC<sup>®</sup> process is to provide a system which reduces the need for maintenance as much as possible. In addition, the maintenance activities in hot areas should be as easy and fast as possible, without major risks for personnel.

### **Feeding**

The design of the feeding system is made in such a way that blocking and mechanical disturbance within the feeder even with difficult feeding material can be prevented. All parts which have to be maintained do have a good access from outside. For repair the complete feeding system can be removed and decontaminated.

### **Plasma Reactor**

We do have a large experience in design and construction of refractory walls for different uses in the plasma reactor. The refractory in the lower chamber is covered with a glass layer. This glass layer has a function as an additional protection against corrosion. Most of the nuclides are accumulated in this layer. Before changing the refractory after a certain amount of time we use the plasma torch to melt a part of the refractory. Therewith we can remove the highest contaminated part of the reactor.

The refractory itself can be vitrified in the same way as concrete or other inert material. The plasma torch has enough power to melt even this material.

### **Plasma Torch**

The plasma torch is designed in such a way that only the wear parts of the electrode have to be changed after a certain time of operation. All our plasma torches are own developments - in operation in our own plants for quite some years now.

Typical changing times for electrodes depend on the size of the torch:

1200 kW Torch: 300 h lifetime; changing time 5 minutes

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200 kW Torch: 50 h lifetime; changing time 3 minutes

We provide additional torch heads to enable quick change without interruption of the process. The change can be done during pouring so there is no time loss in processing.

The electrodes as wear parts will be delivered by ourselves.

### **Off-gas system**

Here we have standard components for replacement.

## **SAFETY ASPECTS**

### **PLASMARC<sup>®</sup> System**

We do have semiautomatic and automatic systems which have been in operation in our own plants for several years. The opening process is optimised in that way that fast burning or deflagration of energetic material is prevented. Several test demonstrated the reaction kinetics for example after opening of complete drums with bitumized ion exchange resins.

In a facility for the German Army (plant for the destruction of chemical warfare agents) we have been granted approval for feeding up to 25 kg pure explosives per hour.

We do have solutions for:

- liquid feeding, including energetic liquids;  
(example: decontamination fluids from detoxification of chemical warfare agents);
- drum feeders up to 220 litre drums even with energetic materials  
(example: low level radioactive waste);
- feeders including pre-treatment for old chemical munitions  
(example: detonation chambers with direct connection to the plasma furnace);
- sludge feeding  
(example: chemical warfare agents; residues from remediation of arsenic contaminated soil);
- bulk feeders  
(examples: radioactive contaminated scrap, pipes; bottles with different chemical warfare agents);
- solid waste feeders  
(examples: low level radioactive waste; chemical warfare agents; dunnage material).

The shielding and exposure concept for personnel is well proven and licensed.

### **Personnel protection**

Exposure to radioactivity is minimised through:

- no separation of feeding material;



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- automatic or semiautomatic process;
- well calculated shielding concept;
- maintenance friendly design;
- minimisation of maintenance in hot areas.

The change of the electrodes will be done in a closed system. The used electrodes can be treated in the PLASMARC<sup>®</sup> furnace, too.

### **COMMERCIAL ASPECTS**

A PLASMARC<sup>®</sup> 150, with a throughput of 150 kg combustible or inert material has an invest volume including off-gas treatment and bulk feeder which is in the same region as a conventional incineration.

Taking into account, that a customer saves the investment and operational costs for intensive collection and pre-separation, pre-treatment and demobilisation the specific costs per kg nuclear-waste will be less than the conventional solutions.

Our product is ready for final disposal. No further treatment or demobilisation is necessary.

### **CONCLUSION**

For decades there was no significant improvement in the treatment of LLW/MLW.

With the PLASMARC<sup>®</sup> technology we are able to offer a new way in nuclear waste disposal by providing new perspectives.

Simultaneous reduction of costs with improvement of the end-product is a major achievement. We are quite confidence that the new end-product has such a quality that it will have an major impact on the overall discussion on final disposal sites.

For the reason that the product meets the highest possible standards the requirements for the final disposal site can be reduced. A positive impact on approval procedures required can be expected and discussions with environmental groups might lead to new stand-points.

We are more than confident that PLASMARC<sup>®</sup> will provide a new thinking and possible new trust in the disposal of nuclear wastes.

### **FOOTNOTES**

<sup>1</sup> MGC and TECHNIP GERMANY are offering different applications of the PLASMA-technology: PLASMOX for treatment of toxic wastes; PLASMARC for the treatment of radioactive wastes and PLASMAREC for the recycling of valuable metals. For more information please contact Mr. Holger Weigel, TECHNIP GERMANY GmbH, 40472 Düsseldorf, Germany, Theodorstrasse 90, Phone: +49 (0) 211 659 24 93, Fax: +49 (0) 211 659 21 51, email: hweigel@technip.de.