Industrial Treatment of Radioactive Waste by Plasma Technology.

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ABSTRACT

Large amounts of historical and actual low-level radioactive waste, with varying characteristics, are stored and continue to be generated from the operation and maintenance of nuclear power plants, the nuclear fuel cycle, research laboratories, pharmaceutical and medical facilities. Virtually all of these waste streams can be treated by plasma technology, resulting in a final product with a high volume reduction factor (VRF) that is free from organics, liquids and moisture and undoubtedly meets the acceptance criteria for safe storage and disposal.

Plasma is a highly desirable heat source. Its high temperature of up to 10.000 °C can treat the radioactive waste as is. The inorganic materials are melted into a glassy slag, containing most of the radioactive isotopes, while the organic material is vaporized into a syngas, subsequently oxidized in an afterburner and finally purified in an off-gas cleaning system. This technology is very suitable for historical waste containing mixtures of inorganic and organic waste, liquids, sludge, etc. as almost no preparation of the waste is required and therefore, with minimum risks for radioactive contamination and exposure. Plasma technology can therefore also be used to recondition previously conditioned waste packages that don’t meet the present acceptance criteria for final disposal.

This paper explains the principles of plasma, feeding systems and off-gas treatment, and describes in more detail the industrial plasma plant for low-level radioactive waste at Kozloduy NPP in Bulgaria. In addition, the paper presents the results of full-scope tests with simulated bitumen and concrete waste drums in a plasma test facility.

1. PLASMA PRINCIPLES

1.1 INTRODUCTION

Plasma is considered by many to be the fourth state of matter, following the more familiar states of solid, liquid and gas. Plasma consists of a collection of free moving electrons and ions and energy is needed to strip electrons from atoms to make plasma. With insufficient sustaining power, plasma recombines into neutral gas. Heat energy, where added to liquid, converts the liquid into gas. The addition of heat energy to a gas converts the gas into plasma. Lightning is an example of the plasma state of matter. Lightning is not a flame, but rather a very high temperature beam of energy.

It wasn't until NASA's space program during the sixties that considerable development in plasma technology was achieved in an effort to produce an intense heat source for carrying out reliability tests on re-entry heat shields of space crafts and missiles.

After more than four decades, plasma technology is used worldwide in many industrial processes, e.g. metal cutting, metallurgical application, vitrification of fly ash from municipal incinerators, treatment of problematic chemical wastes. Thousands of hours of successful testing on surrogate radioactive waste on different plasma systems have been carried out. Also a full-scale industrial plant for treatment of low-level radioactive waste started up in the beginning of 2004 in Switzerland and in 2018 another plasma facility was taken into nuclear operation in Bulgaria.

This unique fourth state of matter, plasma is a highly desirable heat source for treatment of radioactive waste. Its high temperature of up to 10.000 °C can treat the radioactive waste as is. The inorganic materials are melted into a glassy slag, containing most of the radioactive isotopes, while the organic material is vaporised into a syngas and subsequently oxidised in an afterburner.

1.2 PLASMA TORCHES

The plasma torch is a design comprising several concentrically-arranged tubes that are water cooled. The outermost tube can be cladded with refractory material to enable the burner to withstand the high temperatures within the processing chamber.

Plasma torches contain the following main components:

- torch with the electrodes;
- power supply unit;
- control and instrumentation system;
- cooling water circuits;
- process gas supply (e.g. N_2, air or O_2).

Two main torch types can be distinguished: the transferred torches or non-transferred torches. For the transferred ones, the plasma torch transfers electrical energy from the anode to the molten slag which serves as the cathode. By this principle the energy is transferred directly to the waste material. Most common are the non-transferred torches containing two metallic tubular electrodes (upstream and downstream with respect to the plasma flow direction), separated by a gas injection chamber. An electrical arc flows between the negative and positive electrodes and therefore the gas flow injected into the chamber is ionized. The result is a high temperature gas flow coming from the downstream electrode in a plasma jet.

Power ratings typically range from 100 kW to several MW. Process conditions can vary from inert (e.g. Ar or N_2) to oxidizing status (e.g. air or pure O_2) through the selection of the plasma gas.

Sensitive components of plasma torches are the electrodes. The first electrodes had lifetimes of only several hours. Nowadays, electrodes lifetimes, depending on the power, vary from hundreds to several thousands of hours.

1.3 FEED SYSTEMS

The choice of feed systems has a direct effect on processing parameters. One distinguishes two main feed systems:

- batch feed system;
- continuous feed system.

In a batch feed system, the whole 200 l-drum containing the radioactive waste such as the metals, concrete debris and organic material is fed into the primary chamber via a drum feeder. In case the waste contains a lot of organic material the off-gas system should be sized for the large instantaneous flue gas flow caused by the vaporisation of the organic material. Metering with a shredder gives a more continuous feed and smooths and reduces peak off-gas flow rates.

Shredders allow e.g. a 200 l drum to be fed into a primary chamber that is otherwise too small to accept a whole drum.

1.4 SLAG PRODUCTION

The waste containing e.g. metals, concrete debris, different types of inorganic granulates and organic materials is fed to the primary chamber containing the plasma torch. Due to the intense heat of the “plasma flame”, the metals are melted and partially or fully oxidized. Concrete debris, sand, inorganic granulates, insulation material such as mineral rock wool and even asbestos are melted. Their crystalline structure is destroyed and transformed into a chemical inert and amorphous glassy slag. The liquids and organic materials in the waste are vaporized resulting in a residue free of organics.

Similar to conventional radioactive waste incinerators, the non-volatile isotopes such as Co, U, Pu stay in the slag residues while a part of the typical semi-volatile isotope Cs-137 transfers to the off-gas system. Based on experimental measurements of plasma test facilities the non-volatile isotopes such as Co-60 are trapped for about 90% or more in the slag, while semi-volatile isotopes such as Cs-137 are trapped for about 50%. The rest of these isotopes are carried over to the off-gas system and will be found in the collected fly ash. At the end of the cycle, the collected fly ash can be sent back to the plasma furnace or the drum containing the collected fly ash can be supercompacted and embedded in grout.

1.5 THERMAL OXIDATION AND OFF GAS TREATMENT

Similar to what happens in conventional radioactive waste incinerators, the flue gasses, leaving the primary treatment chamber, are passed through a secondary (thermal oxidiser) chamber followed by an appropriate off-gas treatment. In the secondary chamber the syngas containing hydrocarbons, whether or not linked with sulfur or halogens, CO, H_2 is oxidised to primary components such as CO_2, H_2O, HCl and SO_2.

Off-gas treatment systems for radwaste have proven their high cleaning performance, safety and reliability, as well as low production of secondary waste.

The off-gas cleaning is a multi-step procedure to eliminate chemical compounds such as fly ash, HCl, SO2, and radioactivity. The released off-gas reaches levels which safely comply with both applicable conventional and radiological regulations. Due to the high temperature of the plasma torch more NOx is produced, which also has to be eliminated by DENOX systems depending on the release criteria. The entire system is kept under pressure by redundant extraction fans.

1.6 END WASTE FORM AND QUALITY CONTROL

With thermal treatment processes a high VRF is obtained. But the higher VRF in comparison with non-thermal waste treatment processes such as sorting out, supercompaction, drying and immobilisation with grout, is not the only driving force. Due to the increasingly higher requirements for acceptance criteria for final disposal of radioactive waste, these technologies are often not sufficient. Even conditioned drums (e.g. cemented) don't comply with current acceptance criteria. For example, the final waste packages cannot contain any or only few amounts of organic solid residues, and no sludge or moisture. Plasma technology can treat these complex and problematic waste mixtures in one single process with a high VRF, free from organics, liquids and moisture, and meeting the acceptance criteria for long-term storage or final disposal. Indeed, by means of a plasma beam of approximately 5000°C, the inorganic materials such as concrete debris, sand, inorganic granulates, insulation material and even asbestos are melted into an amorphous glassy slag, containing the concentrated radioactive isotopes. Finally the end package free from external radioactive contamination can be stored safely and isolated from the environment in dedicated storage facilities for conditioned waste.

Due to the high volume reduction factor, which can be between 6 and 80, the slag contains the concentrated radioactivity. One should make sure that the slag stays in the category of low-level waste. Therefore, operational limits regarding radioactivity content for the incoming waste should be set up. Higher radioactivity content could lead to medium-level waste, which would require additional precautions and would lead to more expensive storage costs.

Homogeneous slag

A homogeneous durable glassy slag similar to that of vitrification can be obtained, without the need for an additional conditioning step. Using plasma torches equipped with oxygen or more simply compressed air, the metals such as Fe in the slag are oxidized to magnetite (Fe_2O_3). The hot plasma plume melts, oxidizes and brings movements and turbulence in the melted bath, obtaining a homogeneous like slag. Waste types containing slag forming granulates such as concrete, mineral insulation, etc. give a better guarantee for obtaining a homogeneous slag. If not, slag forming additives such as glass can be added in order to obtain a less viscous liquid bath and a better homogeneous slag.

1.7 ADVANTAGES

Plasma treatment of radioactive waste provides the following advantages:

- One single process can treat the waste as is. There is no need for costly sorting infrastructure and other treatment facilities for non-burnable waste.
- The process undoubtedly meets ALARA principles. There is no need for pre-treatment of the waste and entire waste drums are fed unopened, virtually eliminating the amount of direct radiation exposure and contamination risks to personnel.
- A robust waste form, similar to that of the vitrification process, is obtained, free from any organic and liquid material and suitable for long-term storage and disposal.

- Important VRF. Volume reductions including the waste containers can range from 6 for drums containing mostly metals to more than 80 for primarily organic waste.
- The plasma furnace can be equipped with proven off-gas systems similar to those used for conventional radwaste incinerators.
- Environmentally friendly process and much better accepted by the public. The heat source is a plasma instead of fuel or gas, thus there is less production of flue gasses and greenhouse gas CO2.

1.8 SELECTION OF THERMAL TREATMENT TECHNOLOGY

Table 1 shows a summary of the applicability of different thermal technologies currently used for various types of radioactive waste both solid and liquid. Depending on the technology, the waste has to be sorted out in organic and inorganic material. It is clear that plasma technology can treat virtually all radioactive waste types. In particular, plasma technology is suitable for historical waste, which is present in a lot of nuclear facilities all over the world. These historical waste types can contain mixtures of inorganic and organic waste, liquids, sludge, etc., and can be treated with a high VRF and with limited preparation and minimum risks for radioactive contamination.

Technology	**Waste type**						
	Organic liquids	Inorganic liquids	Organic solids	Inorganic solids	Mixed organic-inorganic solids	Mixed organic-inorganic liquids	Spent resins
Incineration	A	A	A	NA*	NA*	A	A
Melting	NA	NA	NA	A	NA	NA	NA
Plasma	A	A	A	A	A	A	A
Pyrolysis	A	NA	A**	A**	A**	A	A
Vitrification	NA	A	A**	A**	A**	NA	A

Table 1. Thermal technologies to common waste types Source: IAEA TecDoc 1527

Legend:
A Technology is applicable to this waste type
NA Technology is not applicable to this waste type
* Small inorganic pieces are acceptable without causing damage or plugging of the system
** Applicable only for granular or powder form of this waste type

2. INDUSTRIAL PLASMA FACILITY FOR RADIOACTIVE WASTE IN BULGARIA

2.1 FUNCTIONAL DESCRIPTION

A new full-scale plasma facility was ordered for the Kozloduy Nuclear Power Plant site from the Joint Venture Iberdrola Ingeniería y Construcción - Belgoprocess (JV) as an engineering, procurement and construction (EPC) contract. The Project was co-financed through a grant by Kozloduy International Decommissioning fund (KIDSF) administered by the EBRD and through Bulgarian national funding. The KIDSF is funded by the European Union as well as by the contributors to the KIDSF – Austria, Belgium, France, Grece, Ireland, The Netherlands, Spain, United Kingdom and Switserland. The facility is operated by the State Enterprise of Radioactive Waste in Bulgaria (SERAW).

The facility consists of a tilting plasma furnace equipped with a non-transferable torch of 500 kW as heat source and can treat 250 tons per year, spread over 40 operational weeks.

The tilting furnace developed by the JV has been designed to pour the slag in a controlled way into a slag mould. This concept of the furnace with the fixed waste feeder, the off-gas equipment and the closed confinements around the slag pouring, prevents the release of radioactive or hazardous gasses and particles into the work area and into the atmosphere, thereby improving the safety features of the plasma facility.

Solid waste to be processed will be delivered in:

- bags containing mainly organic waste;
- metallic 200 l drums containing pre-compacted organic waste and metal particles;
- pucks with heights up to 40 cm resulting from the super compaction of metallic 200 l drums containing mixtures of concrete, wood and other organic material.

Typical specific radioactivity of the waste is about 5E5 Bq/kg and contact dose rate is lower than 2mSv/h. It can also treat liquids and drummed spent ion exchange resins.

The incoming waste is transferred to a shredder and from there to the feeder tube. Close to the furnace, the feeder tube has a rotating connection so that the feeder tube of the shredder is fixed-mounted in relation to the tilting furnace. On the opposite side of the furnace, the contaminated hot gasses with a temperature of 1300°C are diverted to the afterburner chamber.

The system processes mixtures of organic waste such as plastic and celluloses, with inorganic waste such as concrete, mineral insulation, glass and metals. Depending on the incoming waste composition, a glassy-like slag or a metal-like slag is obtained. When about 200 litres of slag are produced, the slag is poured into the slag mould. After pouring, about 50 litres of slag remain in the furnace and that is used as a thermal flywheel for the next waste batch. The remaining slag also forms a protection for the refractory against the high temperature of the plasma flame.

The tapping of slag into the slag mould is carried out in a confinement in order to prevent spreading of contamination in the normal work area and the environment.

The tilting furnace offers a number of innovative features for treating radioactive or hazardous waste that eliminate the drawbacks of existing systems:

- completely closed system so there is no escape of radioactive or hazardous substances;
- good control of the pouring cycle, which can be stopped at any time;
- easy accessibility of the tapping hole;
- a minimum of moving parts of the plasma furnace that become contaminated and need maintenance and a lot of precautions in order to protect maintenance personnel;
- flexible treatment of glassy-like or metal-like slag.

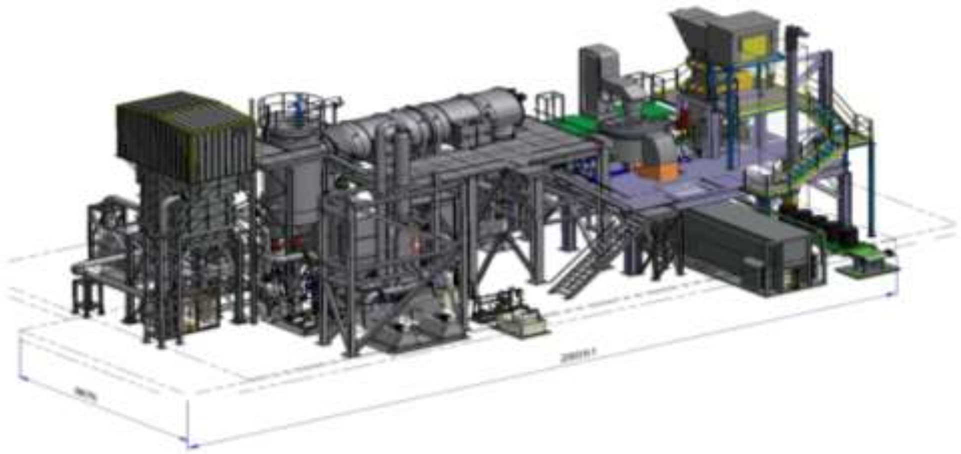

Figure 1. Overview plasma facility

The plasma facility consists of the following main components as shown in Figure 1:

- a robust dual shredder with extruder feeder with a nitrogen blanketing system;
- a primary treatment chamber equipped with a non-transferable torch and a sealed slag collection chamber;
- a secondary combustion chamber in which the syngas is mixed with excess air to complete oxidation of primary combustion components;
- a boiler to cool the off-gasses;
- off-gas filtration and radiological purification, consisting of a bag-house with bag filters and high efficiency particulate air (HEPA) redundant filters;
- a wet off-gas scrubbing system, consisting of a quench tower and a counter current scrubbing tower to remove HCl and SO2;
- redundant flue gas extraction fans for keeping continuous negative pressure in the entire system and evacuating the flue gasses;
- a DENOX system provided with a catalyst in order to reduce the NOx;
- at A continuous emission monitoring (CEM) and radiomonitoring system.

2.2 TESTING STAGES

In 2017, a site acceptance test (SAT) was conducted starting with input/output verification of the different PLC systems and finalisation with the integration test of all the systems starting with the heating up and feeding of the waste. In this stage the whole plasma facility was tested in hot conditions under normal and abnormal situations such as level 1 alarms, loss of normal power and starting of emergency power by the diesel generator. During this stage different simulated waste batches of metal drums containing organic and metal debris, bags with organic waste such as plastics and celluloses, spent resins, drums containing concrete, glass, brick work and other types of inorganic granulates, supercompacted drums containing concrete and wood were treated in the shredding system and afterwards fed to the plasma furnace where the waste was gasified and melted in order to produce a glassy-like slag.

Finally, there was the official 72 hours SAT test, which was the last step before going over to nuclear operation. During this test, capacity, VRF, safe functioning of the facility in normal and abnormal conditions and different operational modes and emissions were verified. Afterwards, SAT test final documentation and application for nuclear operation was prepared.

Nuclear operation

The 120h test with real radioactive waste was organised in May 2018. After heating up the system to operation temperature, the 120h started. During this period, different types of low-level radioactive waste had to be treated and some downtime was planned for doing emergency tests. The treated waste consisted of:

- concrete, building debris in 200l steel drums;
- mixtures of organic waste and inorganic waste in 200l steel drums;
- drums with organic waste (wood, plastics, textiles, PVC, etc).

In total 57 pieces of 200l drums or 6,4 tons were treated and melted resulting in the pouring of 7 slag molds of 170l with the resulting hot slag. The typical pouring temperature was 1400°C. After about 24h, the resulting slag had cooled down to about 55°C. At the end capacity fulfilled with the required value as well the VRF. The required VRF towards the final volume of slag for this waste batch was a VRF of 5,7 while the real VRF was 9,6.

Also the releases (chemical and radiological) in chimney and waste water were well within operational limits.

Up to the end of 2020, the operator SERAW has treated approximately 330 tons or about 1700m³ of radioactive waste mostly packed in 200l drums. The final VRF was about 26 which illustrates the good performance of the facility.

3. TEST WITH CONDITIONED WASTE TYPES SUCH AS BITUMEN AND CONCRETE AS CONDITIONNING MATRIX.

3.1 INTRODUCTION

There is a growing interest for plasma technology. Common technologies to treat different waste types are sorting, supercompaction, drying and immobilisation grouting. But due to the increasingly higher requirements for acceptance criteria for final disposal of radioactive waste these technologies are often not sufficient. Even conditioned drums with e.g. bitumen matrix don't seem to comply with current acceptance criteria. The innovative plasma technology can treat these complex and problematic waste mixtures in one single process with a high VRF, free from organics, liquids and moisture, and meeting the acceptance criteria for safe storage and disposal. Potential users of the plasma technology want to do tests on simulated conditioned waste which has to be reconditioned. One can do tests on a laboratory scale on smaller samples and torch capacities of e.g. 50kW but Belgoprocess wanted to do more realistic and reliable tests. Therefore, Belgoprocess contracted with Phoenix Solutions Co (PSC) who has a full-scope test facility equipped with a 1200kW plasma torch for treatment of simulated conditioned waste. By means of the full-scope plasma tests the beneficiary can observe that plasma treatment of these waste types is realistic, evaluate the obtained VRF and check the quality of the resulting glassy slag. If needed, the beneficiary can organise additional composition analyses, leachabilty and other tests on the obtained slag.

For a first contract, simulated homogeneous 200l (55 gallon) concrete drums with on the one hand concentrates and on the other hand spent resins were selected. A total of 6 concrete drums as conditioning matrix with concentrates and spent resins were treated and melted in the plasma testing facility.

For a second confidential contract simulated 200l (55 gallon) bitumen drums were treated. The drums contained different pucks of compacted waste such as rags, used filters, granulates, etc. The pucks were stacked in the 200l drums and subsequently embedded with bitumen. A total of 6 drums were treated in the plasma facility.

3.2 DESCRIPTION OF THE PLAMSA TEST FACILITY

The different systems that constitute the arc plasma melting/gasification facility used for the test are the following:

- drum feeder;
- plasma chamber;
- off-gas system;
- slag collection system.

Through the feeding system, whole single 200l drums can be fed directly into the plasma treatment chamber (see figure 2 below). The drum feeder is separated by a sealed thermally-protected slide gate. The plasma chamber is a high temperature (refractory-lined with 1500ºC max temperature) furnace. The fully articulating plasma torch of up to 1200 kW is a non-transferred arc plasma torch.

After plasma treatment, the flue gases entered into the off-gas system to remove the chemical species to an acceptable level in the process obtaining flue gases practically dust free. The hot slag is poured into a containment vessel that allowed the cooling to form an inert glassy slag of minimum volume. After the cooling process, the slag is transferred to different 200l drums by keeping traceability of the original test drum. At the end, all the collected slag was available for the beneficiary.

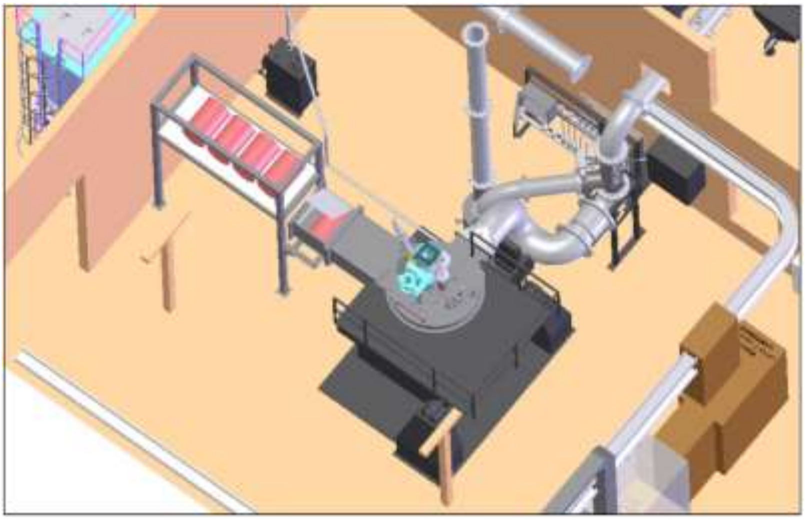

Figure 2. Feeding system for plasma processor at PSC's Hutchinson Test Facility

3.3 TEST WITH CONCRETE WASTE TYPES

First a general control of the test facility was carried out for controlling proper functioning of all the equipment. After heating up, 6 drums were processed during a 3-working-days test period. The first 4 drums (simuli 1-4) contained the homogeneous conditioned concentrates in a concrete matrix. The filled 200l drums typically weighed 420kg and contained 68l of concentrate solution with a density of 1,35kg/l. The concentrates were mainly composed of different types of sodium salts (borates, sulphates, chlorides, nitrates). Drum identification simuli 2 was only filled for half of the volume so the weight is only 180kg. The last 2 drums (R1-R2) contained the homogeneous conditioned cationic and anionic resin in a concrete matrix. They weighed almost 400kg per 200l drum and contained 68l of resins. Figures 3 to 6 illustrate the different stages of treatment of a drum with concentrates.

Figure 3. Concentrates in concrete

Figure 4. Pouring of hot slag

Figure 5. Collected slag just after pouring

Figure 6. Representative sample of slag

Figure 3 illustrates the drum with removed lid with the homogeneous conditioned concentrates in a concrete matrix. For the plasma melting the whole drum inclusive lid and bolts for closure are fed to the furnace. Figure 4 shows the pouring of the hot slag at around 1450°C at the end of the melting process. Figure 5 illustrates the amount of collected slag of 1 drum. After cooling down, the volume of the slag was determined in the calibrated receptacle and subsequently the VRF can be calculated. The volume is less than the original drums as the bounded water with cement is evaporated. At the end a more dense slag of around 3kg/l is obtained in comparison with the original density of about 2.2kg/l. Figure 6 gives a representative picture of the obtained slag, illustrating that the final product is similar to that of a vitrification process.

Leaching tests were already carried out on the plasma samples in KOH solution at pH 13,5 and illustrate results similar to those of inactive reference nuclear glass from a vitrification process. Next steps to confirm the chemical durability are more long-term experiments.

Table 2 gives an overview of the concrete drums with original weights, applied power and VRF.

Drum identification	Drum weight, kg	Torch power, kW	VRF
Simuli 1	445	1200	1.3
Simuli 2	180	1200	1.3
Simuli 3	414	1200	1.4
Simuli 4	437	1200	1.3
R1 IRN 77	392	1200	1.6
R2 IRN 78	368	1200	2.0

Table 2. Results with VRF

3.4 TEST WITH BITUMEN WASTE TYPE

For a second contract, simulated 200l (55 gallon) bitumen drums were treated. The drums (see figure 7) contained different pucks of compacted waste such as rags, used filters, granulates, etc. The pucks were stacked in the 200l drums and subsequently embedded with bitumen. A total of 6 drums were treated in the plasma facility.

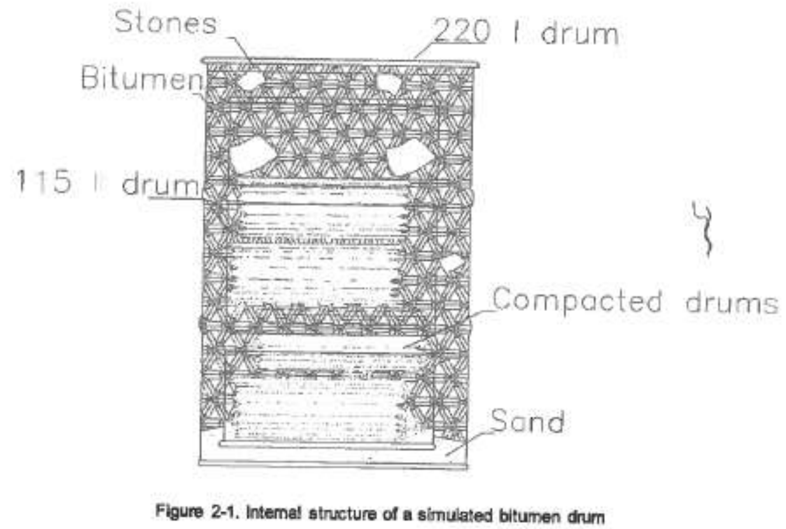

Figure 7. Simulated 200l bitumen drum (SBD) with compacted 115l drums

Each drum contained 140kg of bitumen which corresponds with a power production of 1600kW. When these drum are loaded into the hot furnace as is, a high instantaneous gas production will be developed and subsequently the oxidiser and off gas cannot keep up in order to complete oxidation of the flue gasses to primary products such as CO_2, H_2O, HCl and SO_2.

Therefore, the drums were fragmented one by one in another facility. The fragmented material was subsequently collected in different drums taking into account the full traceability. The simulated bitumen drums each weighed approximately 250kg and contained 140kg bitumen as conditioned matrix. Six of these drums were shredded or fragmented and collected in 30- or 55-gallon steel drums. After shredding, each original SBD resulted in 4 drums. These 24 drums were then packed and transported to the Hutchinson Test Facility.

During a 3-day test period, all 24 drums resulting from 6 original drums were treated in the plasma test facility during day time. The drums were loaded in the hot furnace one by one with the torch off. During about 30 minutes the drums containing the high amounts of bitumen were gasified. The unburned gasses and soot were then sent to the oxidizer with addition of a maximum amount of air in order to obtain complete combustion and low CO content of the flue gasses (less than 50mg/Nm³). After that, the plasma torch was operated at a power of a 700kW for about 20 to 30 minutes in order to melt the inorganic materials such as granulates and steel.

At the end, all the slag was collected in one receptacle (see figure 8) in 2 pours at temperatures of about 1400°C resulting in 235l slag. One could observe that the slag contained a lot of Fe_2O_3 (magnetite) coming mainly from melting and oxidizing the different steel drums containing the fragmented bitumen. The slag was free of any organic material.

Figure 8. Collected total amount 235l slag in a 272l receptacle

During fragmentation the material was repacked in 24 additional steel drums. The empty 24 steel drums had a total weight of 316kg which resulted in 436kg Fe_2O_3. Taking into account the density of 5.18kg/l for magnetite, an additional 84l were added to the slag.

At the end the conservative and realistic VRF can be calculated. The conservative VRF can be defined as the ratio between the six incoming drums (6*217l) and the total volume of the receptacle (272l) which gives a VRF of 4,8. Taking into account the volume of the 24 steel drums, the real VRF is 8,6 as in reality, shredded drums will be sent directly to the plasma furnace without repacking.

4. CONCLUSIONS

- Plasma is a proven technology which can treat problematic radioactive waste types on an industrial scale, resulting in a slag free of organics and similar to the product of vitrification.

- Plasma technology can treat the waste “as is” with limited preparation efforts, so it meets the requirements of the ALARA principle and the acceptance criteria for conditioned waste, free from organics and liquids, resulting in a final product with a high VRF.

- Off-gas systems for treating the radioactive contaminated flue gasses can be taken over from the conventional radwaste incinerators, which have proven their high reliability and safety standard.

- Particular test cases on reconditioning simulated conditioned waste with bitumen matrix and concrete matrix containing concentrates and resins were successfully carried out.

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