플라즈마 및 전기유도가열을 이용한 중·저준위 방사물 처리기술 개발

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A Development of Technology for Low- and Intermediate-Level Radioactive Waste Treatment utilizing Inducton heater and Plasma torch

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Abstract

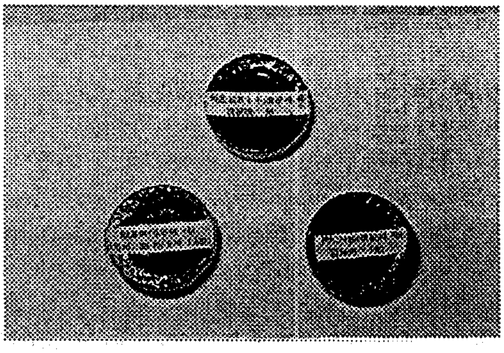
Currently, there is a need for the development of an advanced new technology for Low-and Intermediate-Level Radioactive Waste (LILW) treatment from nuclear power plants. The vitrificaton and melting technology by the use of the electrical equipments such as induction heater and plasma torch based furnace, along with off-gas treatment are considered as the most promising one of the LILW treatment technology since they can produce a very stable waste forms as well as considerably large volume reduction, which is a world-wide trend to apply fo radioactive waste treatment. Korea Electric Power Research Institue(KEPRI) has already completed a feasibility study on LILW treatment and conceptual system design of a demostration plant to be constructed. For this research, KEPRI selected a cold crucible melter(CCM) for the vitrification of combustible waste, and plasma torch based furnace(PT) for the melting of noncombustible waste, along with off-gas treatment for the volatile radioisotopes such as cesium.

1. Introduction

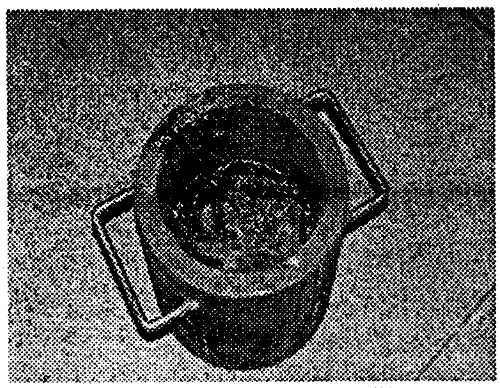
Korea has sixteen nuclear power plants; twelve under commercial operation and four under construction, with a result that the amount of the radioactive waste has been increasing from year to year. Along with safety of nuclear power plants, a safe and effective treatment of radioactive waste generated from domestic nuclear power plants is regarded as an important factor for nuclear policy. Thus, the development of an advanced volume reduction technology for LILW has become necessary due to high concern for the environment preservation, high cost disposal and difficulty in selecting disposal site by NIMBY syndrome over the country. KEPRI has regarded that the application of vitrification technology utilizing a CCM for the volume reduction and stabilization of combustible LILW such as protective clothings, wood, paper, vinyl sheets spent resin etc., would be advantageous and that the application of melting technology utilizing a plasma torch based furnace to the stabilization of noncombustible waste such as metal scrap, concrete, sand, spent filter, glass etc., would be appropriate. This program is being conducted in four phase in order to develop and to optimize overall process for industrial appilcation.

2. Orientation tests

Generally, LILW generated at the domestic nuclear power plants can be catagorized as combustible and noncombustible radioactive wastes, spent resin, spent filter etc. In order to obtain fundamental information for the design of the pilot-scale vitrification plant to be constructed in Korea and to verify the feasibility of direct vitrification with pyrolysis of the combustible radioactive wastes such as paper, vinyl, protective clothes, plastics etc. a cold crucible melter(French induction heating system) with its sub-systems was selected for uilizing to vitrification of combustible waste. For treating certain categories of the LILW such as meltal scraps, concrete, spent filter, sand etc.,which is not suitable for handling by CCM, a plasma torch based furnace was employed. A Plasma torch provides very high temperatures to melt noncombustible waste as well as combustible waste and converts to stable waste form. Utilizing electrical equpments such as plasma torch based furnace and cold crucible melter, the orientation test as first phase research is being carried out on a small scale pilot plant. Figure 1 is a photograph of vitrified waste



(a)



(b)

Fig. 1 Vitrified waste
(a) Vitrified waste by CCM
(b) Vitrified waste by PT

3. Elecrical facilities

3.1 Cold crucible melter

The principle of the cold crucible is based on self-heating of the material in the bulk by using the Joule effect from currents induced by powerful external high frequency inductors. It is possible to cool the walls by circulating water, since the heat is not transmitted by conduction from the walls. A thin layer of solidified material then coats these walls and protects them from the melted bath. Heating of the material in the bulk is accomplished by means of an electromagnetic field produced by an external coil. The frequency of the electromagnetic wave must be adapted to the material to be heated for an efficient energy coupling. The frequency should be quite low from 1 to 10 kHz when metals are concerned, and much higher 100 to 500kHz in the case of glass or dielectric materials. During operation, the choice of the frequency of the electromagnetic wave is very important as it determins directly the power efficiency of the process. The depth of penetration of the induced current depends on the resistivity of the material and on the frequency of the current in the inductor. The CCM has been applied to combustible LILW vitrification. Figure 2 is a photograph of CCM

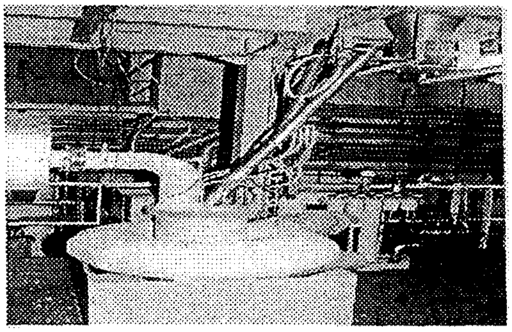


Fig. 2 Cold crucible melter

3.2. Plasma torch based furnace

Plasma is any ordinary gas that has been conditioned to respond to electric fields and magnetic fields. The plasma torch(PT) is a devece that generates and maintains a gaseous electrical conducting element(plasma), and that uses the resistance of the plasma to convert electricity into heat energy. A plasma torch may be characterized by its operating parameters such as operating power, operating mode, operating gas, operating electrode and method of startin etc. There are three basic types of plasma torch by a counter-electrode, namely the transferred, non-transferred and convertable method. Recently, Plasma melting technology has been considered for treating noncombustible LILW in an environmentally safe and cost effective manner. The rationale for using plasma torch is its ability to destroy orgaic and biological components, to produce a non-leachable, glass-like slag suitable for landfill and to provide better control of processing and more efficient use of energy. The plasma technology may far surpass conventional methods. Figure 3 is a photograph of PT.

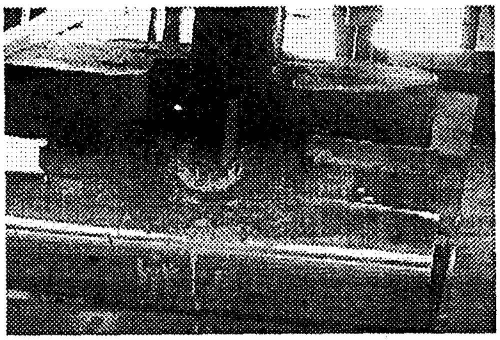


Fig. 3 Plasma torch based furnace

4. Construction of vitrification process

The technical asscessment resulted in that along with off-gas treatment system, the CCM was the most promising equipment for combustible waste, and the PT for noncombustible waste. Thus, KEPRI has completed the conceptual design of pilot plant. Both the CCM and the PT are employed to LILW treatment on the ground of the following; (1)The molten glass of CCM has good retaining capability for nuclides and toxic materials of which boiling point is low, and the spent scrubbing solution can be recycled to the CCM. (2)The PT can treat all kinds of waste without pre-treatment, especially, noncombustible wastes such as metal scraps and spent filter etc. By the use of plasma torch based furnace , KEPRI's current study is focusd on finding an optimum composition ratio of various noncombustible waste for easy melting, investigating pysical properties of molten slag, and obtaining operating parameters for continuous operation, also, by the use of the cold crucible melter, an factor for direct vitrification of combustible waste, investigating pysical prorerties of molen glass, and obtaining operating parameters for continuous operation.

5. Conclusion

It is belived that the plasma melting technology is suitable for treating noncombustible radioactive waste, and the cold crucible melter for combustible radioactive waste. The plasma flame transforms noncombustible waste into a vitrified mass of rock-like material. Also, the cold crucible melter converts combustible waste inte glass or glass-like substances. The final product is expected have very high resistance to leaching and durability charateristics for minimizing of any contaminant release and safe disposal to the environment. In addition, KEPRI believe that the combined vitrification technology with CCM and PT offers great potential to achieve volume reduction and stabilization of LILW generated from the domestic nuclear power plants.

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