Development of Plasma Torch Melter for Treatment of Noncombustible Radwaste

S.J. Maeng, Y. P. Moon, T. W. Hwang

Korea Hydro and Nuclear Power Co,. Ltd(KHNP), 150 Dukjin-dong, Yusung-gu, Daejon Korea

sjmaeng@khnp.co.kr

Plasma technology was first developed in the 19th century and has been extensively applied to various fields of industry such as metallurgy and chemical industry. In 1980s increase in environmental concerns and disposal cost took an important role in applying the plasma torch to treatment of hazardous waste. At the end of 1990, KHNP launched a vitrification research program for treatment of low-level radioactive waste with a view to reduction of waste volume and enhancement of its disposal integrity. A first phase of the research led to the conclusion that "combined process" which is to treat combustibles with cold crucible melter(CCM) and noncombustibles with plasma melter would be appropriate in economic and technological point of view. Thereafter, CCM technology was successfully developed and the first CCM is under construction in Ulchin Nuclear power site and expected to operate in 2008. As for development of noncombustible radioactive waste treatment, a 200kW plasma torch melter was built at KHNP and series of pilot tests have been performed. Based on the pilot tests, a commercial-scale 500kW plasma torch has been decided to be installed in order to enhance reliability of design data, and help licensing. This paper describes major findings of the KHNP's pilot tests, recent status of plasma melting technology development and core technologies for its commercial application. An appropriate type of the commercial-scale plasma torch melter is also suggested.

◦ Pilot tests using a 200kW plasma torch melter

Based on a small-scale melting tests, a 200kW plasma melting system comprising a convertible plasma torch(500V/400A) and a refractory melter(30ϕ×40cm) was constructed at KHNP in 1999. Pilot tests was conducted for various type of simulated wastes often found in nuclear power plants. Concretes were observed to be fully melted after 20 minutes of torch operation at power level of 150kW but its viscosity was found to be somewhat high. Internal temperature of the melter was measured to be in the range of 1,500 ~ 1,600℃. Volume reduction ratio of cements, soil and the filter casing was evaluated to be 1.74, 1.19 and 26.9 respectively and dependent on their shape and bulk density. Associated leaching tests showed that slag was in compliance with TCLP limits. Retention ratio of Co was analyzed to be 76.4% after 30 minutes of melting whereas retention of Cs in slag was quite low.

To evaluate effective thermal energy used for melting wastes, a thermal energy transfer model was set up and a melting test showed that 11% of the total energy applied to the torch was utilized for heating waste. In one hand, the tilting method was identified to be ineffective in pouring slag because the torch could not be operated and thus, its viscosity increased during the pouring period because the pouring port was shared by the offgas exit.

In consideration of the pilot test results, a water cooling melter(59ϕ×68cm), a 3 D torch movement system, and a water-cooled pouring port were added to the existing system in order to enhance pouring capability, evaluate the concept of disposal melter and increase thermal efficiency and nuclide retention in slag. Pilot tests showed that continuous feeding was more effective in melting and dust generation than batch type feeding. Melting characteristics were, as expected, dependent on the size of waste with good performance for 1cm or less. Heating efficiency was also measured to be around 9.5% which is a little lower than that of refractory melter and the melting around the cooled wall was required to be improved. Initiation of pouring by oxygen torch was inappropriate for future commercial application because of dispersion of contaminated slag. Cs retention in slag was found to decrease with time due to the dust carryover to the offgas and comprehensive evaluation of the nuclide attached on dust and the facility needs to be performed for quantitative analysis in the future.

◦ Status of the plasma torch melting system for treatment of radioactive wastes

The plasma torch melting system is composed of the torch and melter. There are 3 types of torch such as transferred, non-transferred and dual mode whereas 2 types of melter, fixed and rotational melters. Non-transferred torch operates stably regardless of waste characteristics with lower heating efficiency. On the other hand, transferred torch capable of utilizing Joule heat of waste itself transfers more energy to the waste than non-transferred one and its electrode lasts longer. However, its dependency of arc stability on the electric resistivity of the melt is main disadvantage. Recently, Retech and MSE have developed several dual type torches generating transferred arc which is covered by non-transferred arc to enhance stability of transferred arc and those torches are being used at Tsuruga nuclear power plant and Zwilag melting facility for treatment of low-level radioactive wastes.[1]

Although erosion problem of refractory for fixed melters was raised in the past, refractory life has been extended to 3000h or longer in case of Radon's and Retech's melters. Since they have no moving parts in the melter, the maintenance could be easily facilitated. The centrifugal melter used at Tsuruga power plants is reported to have less refractory problem and enhance throughput by increasing contact area and reaction time of arc flame with waste. It was also investigated that various pouring devices are available such as the cooling plug, centrifugal force, inductors, and disposal melters eliminating pouring process. Optimum device could be selected for waste characteristics, and specific purposes.

Reduction of volatility of nuclides present in waste is one of the core technologies. Retention of Co, an activated corrosion product, is reported to be relatively high regardless of wastes whereas Cs retention especially for metal is very low due to its high vapor pressure and less chemical affinity to iron(table 1). It was investigated that Cs retention could be enhanced by melting metal with inorganic waste or by recondensing volatized Cs at the sacrifice of heating efficiency. It could be captured in the offgas treatment filters and then recycled to the melter or melted with low-melting temperature glass.

Table 1. Nuclide Retention

Facility		Zwilag [2]	Pluton [3]	Infanite[4]
Wastes		Metal+Organic+Inorganic		Metal
Nuclides	Cs	86.7%	88%	4%(slag)
	Co	89.8%	97.5%	90%

◦ Conclusion and future work

Based on the analysis of KHNP's pilot tests and recent status of plasma application, core technologies for commercialization were defined to be heating efficiency, minimum maintenance, component durability and maximum nuclide retention. In conclusion, a commercial-scale 500kW plasma melting system of dual mode torch with fixed refractory melter was suggested. In the future, series of pilot tests with the plasma melter to be newly installed at NETEC are required to be conducted for process optimization for Cs retention, evaluation of life time for major components and production of reliable design data development of commercial plasma torch melter.

References

1. M.W. Shuey, P.P. Ottmer,"Operational Experience using a Plasma ARC Centrifugal Treatment," Proceedings of WM '06, Tucson, Arizona, 2006.

2. W. Heeper, "Zwilag Incinerator and Melting Furnace," Proceeding of Global 2005, Tsukuba, Japan, 2005

3. S.A. Dmitriev, "Development of Plasma Technology of Mixed Radioactive Waste Treatment,"Proceedings of ISRSM, Nov. 2-4, 2005, Daejon, Korea.

4. G. Imbard, "Melting of Cs contaminated Ferritic from G2/G3 Reactors," Seminar on Melting and Recycling of Metallic Waste Materials from Decommissioning, " Krefeld, Germany, October 27-29, 1993.