MOLTEN SALT TREATMENT TO MINIMIZE AND OPTIMIZE WASTE

Uri Gat and S. M. Crosley
Oak Ridge National Laboratory*

R. L. Gay
Rockwell International Corp.

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Uri Gat and S. M. Crosley
Oak Ridge National Laboratory
P. O. Box 2009, Building 9108
Oak Ridge, Tennessee 37831-8088
(615) 574-0560

R. L. Gay
Rockwell International Corp.
6633 Canoga Park Avenue
Canoga Park, California 91303
(818) 586-6110

ABSTRACT

A combination molten salt oxidizer (MSO) and molten salt reactor (MSR) is described for treatment of waste. The MSO is proposed for contained oxidization of organic hazardous waste, for reduction of mass and volume of dilute waste by evaporation of the water. The MSO residue is to be treated to optimize the waste in terms of its composition, chemical form, mixture, concentration, encapsulation, shape, size, and configuration. Accumulations and storage are minimized, shipments are sized for low risk. Actinides, fissile material, and long-lived isotopes are separated and completely burned or transmuted in an MSR. The MSR requires no fuel element fabrication, accepts the materials as salts in arbitrarily small quantities enhancing safety, security, and overall acceptability.

INTRODUCTION

This paper describes a proposed comprehensive option to treat radioactive and hazardous waste. Particular emphasis is put on the treatment of mixed waste (i.e., hazardous and radioactive waste), and on dilute waste. The molten salt oxidizer (MSO) waste treatment is combined with a molten salt reactor (MSR) to treat wastes that contain fissile materials, long-lived radioactive isotopes, and/or hazardous wastes. At the present time, these wastes can be handled only with extreme difficulty, and in many cases there is no acceptable disposal solution. The major issue with these wastes is their persistence in the environment. Their containment for long periods of time, often measured in millennia, with no possibility of leaching or otherwise dispersing out of their confined space is all but impossible.

Hazardous waste can often be destroyed by incineration. However, their complete destruction, to satisfy the current laws and regulations, requires extraordinary precautions which are very costly and often not very reliable. Failures are expensive in recovery cost and penalties. When the hazardous materials contain elements that are hazardous per se or contain radioisotopes, incineration no longer is a viable option for the treatment, because the complete containment of all materials at all times is exuberantly expensive. When the waste is very dilute, the off-gas treatment system must accommodate large volumes that make the required containment and cleanliness a difficult task.

MOLTEN SALT OXIDIZER

The molten salt oxidizer (MSO) process for treatment of hazardous waste has been known and discussed for a long time.[1] The principle of the MSO is simple; into a hot bath of molten salt, the organic and/or dilute waste is introduced and air is also sparged in at the same time. The molten salt bath is generally maintained between 600 and 1100°C. A salt commonly used is sodium carbonate (see Fig. 1). The bath may consist of either one or two stages. A two-stage unit may be maintained as a slightly reducing bath in the first stage to enhance retention of metals, and as an oxidizing bath in the second stage to assure complete oxidation of the acid gases. A second stage may also function as a gas scrubber.

Organic waste is introduced into the MSO and oxidized. Molecular carbon and hydrogen exit as carbon dioxide and water vapor. Also, any water is evaporated. Most metals are retained in the molten salt. Any halogens that are present are retained as a halogen salt releasing carbon dioxide from the carbonate salt. Retention rates are considered very good.[2] Nevertheless, a filter is provided on the off-gas to prevent escape of entrained materials.

The molten salt's prime function as distinguished from an incinerator is to retain and contain the waste, the nonbenign products, and the residue particularly the metals. The molten salt also acts as a solvent for the reactants, the waste, and the oxygen in the air; it thus greatly reduces the reactor volume. The salt acts as a heat transfer medium and a conductor, in some cases it provides catalatic enhancement of the reaction. This makes the reaction volume more uniform, better controlled, and avoids hot spots or reaction bursts. The salt also chemically binds the halogens. The salt acts as a scrubber for particulates. MSO treatment of explosives has been proposed and successfully tested.[3]

MIXED WASTE

Mixed waste, that is waste that contains hazardous waste and radionuclides, can also be treated in an MSO. The organic component of the hazardous waste will be oxidized in the MSO and the radionuclides will be retained in the salt. This will convert mixed waste into radioactive waste. This treatment is limited to those radioactive elements that are retained in the salt. As a rule, this includes the metals but does not include such non-metals as carbon (fourteen).

The residue embedded in the salt can be disposed of as waste. However, the residue can also be further processed to recover the salt and reduce radioactive waste volume or mass, as will be discussed later.

DILUTE WASTE

Dilute waste, including mixed waste, can be treated in MSO. The diluent, presumably water, will be evaporated and removed with the off-gas as part of the vapor in the exhaust gas. Under optimal conditions, the exothermic energy content of the waste oxidation is sufficient to sustain continuous operation with no need for external energy supplement, other than for the initial start-up. Temperature control can be maintained by changes of the energy losses through the insulation, or by slight augmentation of the energy with an external energy source.

For those cases in which the energy content of the waste is not sufficient to evaporate the water, a possibility is to mix two waste streams, the one with deficient energy and one with excess energy, so that together they meet the desired optimum to sustain the oxidation temperature while evaporating the water. When such a mixing is either not possible or not desirable, the energy can be supplemented by adding fuel to the waste for that purpose. Another possibility is to use a furnace and supply external heat.

An important group of radioactive or mixed dilute waste that may be suitable for the MSO treatment is some of the defense waste that has accumulated over the years. Portions of that waste contain a variety of elements and materials, including special nuclear materials, mixed with and dissolved in large volumes of water.

TREATMENT OF WASTE RESIDUE

The waste residue, that is the retained metals in the salt, can be disposed of as is. Depending to some extent on the combination of the metals in the mix, stabilization and encapsulation may be required.

The more desirable alternative to disposal, and in some cases a necessary one, is to treat the residue. The residue is already contained in a molten salt, and as such is amenable to chemical processing. The processing can occur immediately at the MSO. Several goals for the processing are possible. A basic goal for the processing can be the restoration and separation of the salt, usually to the carbonate and recycling of the salt for repeated use in the MSO. The motivation for this action is primarily economic and there is need to compare the (total) cost of recycling of the salt with disposal and replacement of the salt.

Another goal can be the recovery of economically valuable elements from the mixture for recycle. This would be applicable to precious materials for which it would be economical to do the separation. Another reason for removing some elements from the waste is to lower the disposal cost of the waste and in some instances it may be necessary to permit the disposal of the waste. Some combination of materials are prohibitively expensive to dispose of. This is true for long-lived radioactive isotopes and some special nuclear materials where long time safe storage is needed. The separated materials can be brought into a form, shape, and containment which will make their disposal acceptable, for example by reducing their volume and stabilizing them in a nonleachable matrix and encapsulating them.

Processing the waste for disposal makes it possible to bring the waste to an optimum for the disposal. This optimum regards the final chemical composition to which the waste is taken. The concentration of the waste can be in any added material mixture that is desired. The mixture with which it is combined can be one that fixes it, such as glass, ceramic, concrete, or the like. The waste can be encapsulated to protect it from leaching or diffusing into the environment. Since the waste is encountered in a liquid form, it can, in most cases, be poured into its final container, which in turn can take on any size or shape. The waste can also be transported to the disposal sites in any desired quantity per shipment so that any risk can be minimized. Special consideration is due for radioactive waste. This waste must be specifically protected due to the emanating radiation and due to its internal energy release. To protect the waste from reaching excessive temperatures and to shield its radiation, long, narrow rods are one of the possible useful shapes. The temperature rise to the center of the rod can be easily kept within a desired limit and the shielding necessary, per unit of length, can be kept within low limits. Further, such rods can be readily remotely handled and stored. The ability to have small sizes is important when fissile materials are involved and criticality and safeguarding are important issues.

ACTINIDES, FISSILE MATERIAL, AND LONG-LIVED ISOTOPES

Wastes containing actinides, fissile materials, and/or long-lived isotopes require special attention. Fissile materials must be configured to prevent criticality under any circumstances. Fissile materials must also be safeguarded such that neither diversion nor proliferation is possible. Actinides, fissile materials, and long-lived isotopes require very long-term safe disposal sites for disposal. Disposal of these materials is expensive and at the present time is an unresolved issue. The selective separation of these materials from the waste in the spent salt processing of an MSO facility will alleviate the rest of the waste from these expensive special concerns.

The actinides, fissile materials, and long-lived isotopes (actually the elements of which these isotopes are part) once they have been reduced to a minimum mass can be introduced into a nuclear reactor or any transmuting device, such as the Accelerator Transmuter Waste (ATW) with the fuel. The fissile materials will become part of the fissile fuel, will fission, and contribute their share to the energy generation. This will convert them from a problematic waste to a beneficial energy source. The actinides and the long-lived isotopes will be transmuted in the reactor.

A particularly suitable reactor for the utilization of fissile material and the transmutation of the actinides and long-lived isotopes is the molten salt reactor. Materials emerging from a molten salt waste treatment process can readily be converted to the salt that can be directly fed into the molten salt reactor.

MOLTEN SALT REACTORS

Molten salt reactors (MSRs) are fluid fuel reactors with partial, or complete on-line processing of the reactor fuel.[4-6] MSRs are particularly suitable to accept the actinides, fissile materials, and long-lived isotopes from molten salt oxidizer. The MSO can provide the materials as a salt and the MSRs accept the salts. There is no fuel fabrication for MSRs and the feed from the MSO to the MSR can be direct. This also means that there is no need for storage or accumulation of these materials at any time or location due to the logistics of the reactor.

The MSR can accept the materials in arbitrarily small quantities and at irregular intervals. Hence shipments of materials can be limited to small quantities at a time so that no accumulation or storage is needed and the risk associated with each shipment can be low. Also when fissile materials are involved, the safeguards and security needed are limited and the concern for criticality accidents is all but eliminated.

The MSR can be operated in a way that will completely transmute the actinides and completely consume the plutonium. This is done for the MSR with limited processing by leaving the materials in the reactor or for the MSR with full processing by returning these materials to the core. At the end of life, the reactor is fed only fissionable uranium either from an external source (another MSR) and/or from converted thorium in the reactor itself. No new actinides are produced and those in the core are, including plutonium, transmuted and consumed. The uranium in the salt is quantitatively removed with the efficient uranium volatility process. The remaining salt contains the waste and can be disposed of. In some cases, further treatment will be required.

SUMMARY AND CONCLUSIONS

A methodology is proposed for treating waste that combines a molten salt oxidizer and a molten salt reactor that can treat waste that is otherwise very difficult to treat. The methodology can simplify the treatment of mixed wastes and dilute mixed or radioactive waste and is very suitable for wastes containing actinides, fissile material, and long-lived isotopes.

Mixed and dilute waste are first treated in a MSO to oxidize the hazardous waste leaving only the metals in the mixture. Dilute wastes are treated to evaporate the water. When the waste energy content is insufficient to evaporate the water, it is matched with a waste that has excess energy or some fuel or external heating is supplied. This action removes the organic hazardous materials and in many cases changes a mixed waste to a radioactive waste. The waste is now concentrated in the salt mixture.

The waste mixture in the salt can be processed to optimize it for disposal. Optimization can include:

- the separation of elements for reuse,
- the stabilization of the waste in a desired chemical form,
- the concentration, or dilution, with other materials for better handling,
- the fixing in a matrix such as glass, ceramic, or concrete,
- the encapsulation in a protective canister, and
- the forming into size, shape, and configuration that is best for the disposal.

For highly radioactive waste, configuration into long, narrow rods is a possibility. The rods are an effective heat-transfer configuration that will avoid melting or evaporation, and can be readily shielded. Rods are also convenient for remote handling and disposal.

Shipments are made in arbitrarily small quantities so that the risk is minimized.

When actinides, fissile material, or long-lived isotopes are present they can be separated and fed into a molten salt reactor for complete burning or transmutation. The MSR can accept small quantities on an irregular schedule in the form of a salt. No fabrication or other special preparation steps are required. Accumulation, storage, safeguards, criticality safety, and security can be minimized. In its final operation, the reactor can be operated such that the final waste will contain no fissile material, nor actinides, and few long-lived isotopes.

The combination of MSO and MSR treatment can relieve many of the more serious concerns and difficulties of waste disposal. It can avoid mixed wastes, reduce the volume and mass of materials to be disposed. It can bring the waste into an optimal shape, concentration, and configuration. It can reduce the risk of transportation and storage and reduce handling. For radioactive waste, it can remove fissile materials alleviating criticality safety, safeguards, security, and the very long-range assurance issues. The long-range assurance is also eased by removing actinides and long-lived isotopes from the waste. All of this results in better economics and more acceptable waste treatment.

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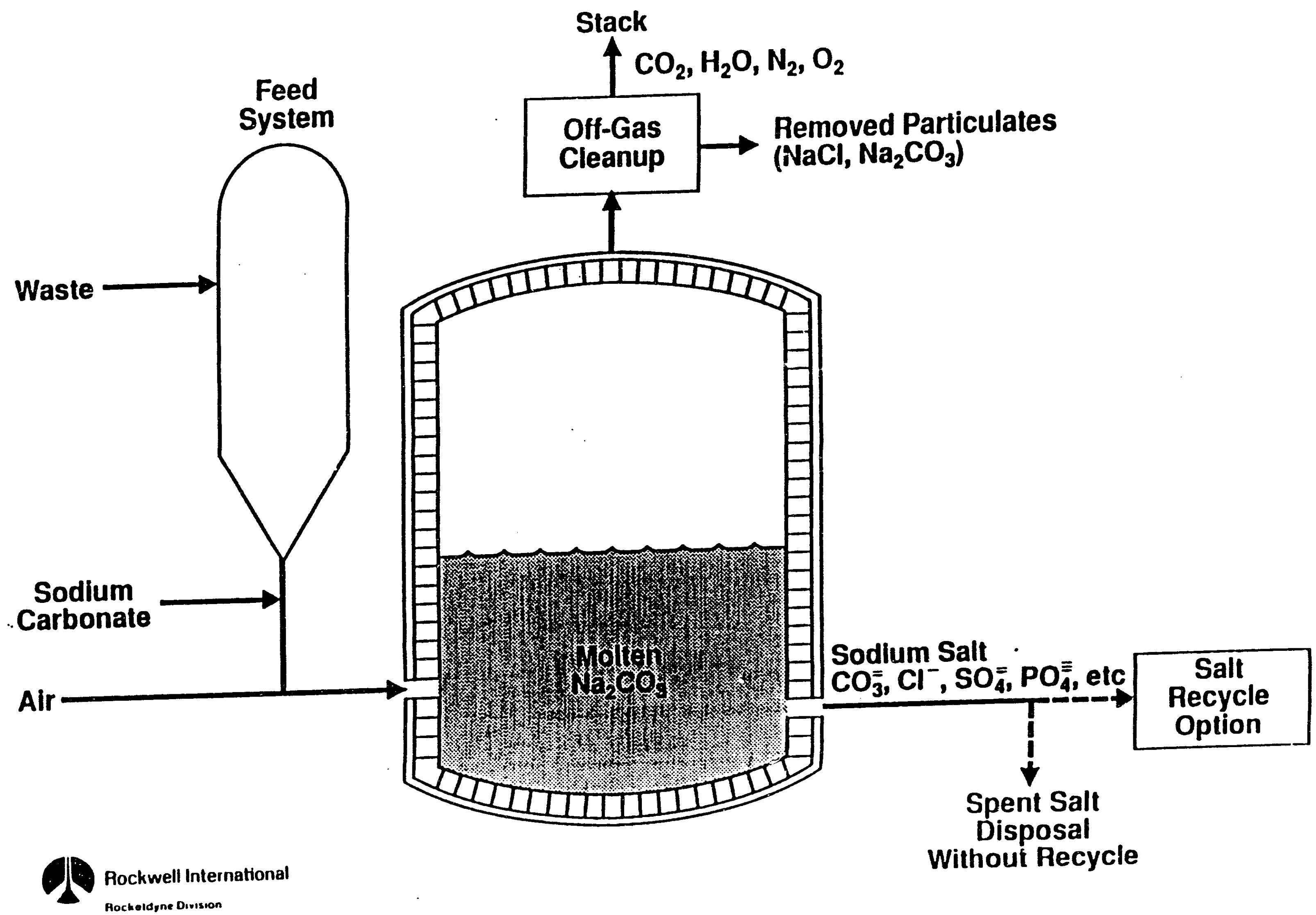

Figure 1. Molten Salt Oxidation System Concept

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