RECOMMENDATIONS TO THE DEPARTMENT OF ENERGY FROM THE PANEL ON EMERGING TECHNOLOGICAL ALTERNATIVES TO INCINERATION

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ABSTRACT

This paper provides information derived largely from the report of the Blue Ribbon Panel on Technological Alternatives to incineration, a task force of the Secretary of Energy Advisory Board. The report was published December 15, and can be seen on web site: http://www.hr.doe.gov/SEAB.

The paper includes a description of the Panel charter, procedures, and a history of the Panels activities. A description of the wastes considered by the panel was provided, including Transuranic and mixed wastes at the INEEL as well as other mixed wastes in the DOE complex. The basis for treating these mixed waste was provided, including treatment for organic destruction under the Resource Conservation and Recovery Act, as well as for Transuranic waste transportation. A description of the treatment alternatives considered by the Panel was provided, including 1) Thermal treatment without incineration, 2) Aqueous based chemical oxidation, 3) Dehalogenation, 4) Separation, and 5) Biological treatment. Criteria used by the Panel in evaluating the alternatives were provided. The Panel's conclusions were summarized, which resulted in the grouping of the alternatives considered into three categories, 1) Most Promising, 2) Potentially Promising Technologies with Unresolved Issues, 3) Lowest Priority Technologies.

The paper summarized the conclusions and recommendations of the Panel regarding the alternative technologies that should be considered for development and demonstration, as well as a number of specific recommendations on how DOE should proceed in the developing, testing, and funding of alternatives treatment technologies to incineration. Also included was a summary of the Panel's evaluation of the DOE plan for research, development, demonstration, and deployment of alternatives to incineration.

STATUS

This paper provides information derived from the report of the Panel published December 15, 2000 and provides much of the information in the report for the benefit of the WM01 meeting. The report is quoted extensively in this paper. The full report can be seen on web site: http://www.hr.doe.gov/SEAB. As announced by Secretary Richardson on January 8, 2001, the Department accepts the recommendations of the Panel which provides a workable solution to the problem of treating mixed waste at the INEEL without incineration, while still allowing the DOE to meet its commitments to the state of Idaho to remove and dispose of this waste. The recommendations also chart a course for innovative waste treatment at Energy Department sites across the country.

The DOE is presently preparing an action plan in response to the report. The presentation of the Panel findings in this paper does not necessarily mean full endorsement of all of the recommendations by DOE. The Department believes the Panel has made a significant contribution to providing DOE with recommendations that will allow us to engage in a planning process that is responsive to the issues and concerns raised by the Panel and will result in the selection, testing, implementation, and deployment of a technology or technologies that will get the job done and demonstrate good faith to all parties that have an interest in seeing the job is well done.

WHAT THE PANEL WAS ASKED TO DO

The Panel's Charge

The Blue Ribbon Panel of Emerging Technological Alternatives to Incineration was a task force of the Secretary of Energy Advisory Board (SEAB). The Panel was created following a dispute over the proposed construction of an incinerator for treatment of hazardous waste at the Idaho National Engineering and Environmental Laboratory (INEEL), which resulted in the Department of Energy's April 2000 commitment to appoint a "blue ribbon" panel of independent scientific experts to explore technological alternatives to incineration that may become available for use at DOE facilities nationwide.[1]

Secretary of Energy Advisory Board Terms of Reference

More details on the Panel's mission appear in the Terms of Reference subsequently established by the SEAB, based on the Settlement Agreement:

> "The SEAB Panel...will evaluate and recommend emerging nonincineration technologies for treatment and disposal of mixed waste on which the Assistant Secretary of Environmental Management's Office of Science and Technology should focus efforts for development, testing, permitting and deployment. The Panel will evaluate technologies to treat low-level, alpha low-level and transuranic wastes containing polychlorinated biphenyls (PCBs) and hazardous constituents, including the up to 14,000 cubic meters of such wastes that the DOE had planned to incinerate in the Advanced Mixed Waste Treatment Facility (AMWTF) at INEEL. The Panel will also evaluate whether these technologies could be implemented in a way that would allow the department to comply with all the legal requirements, including those contained in the Settlement Agreement and Consent Order signed by the State of Idaho, DOE and the Navy in October 1995. That agreement requires the Department to remove 65,000 cubic meters of waste at the INEEL from Idaho by the end of 2018."

The Panel's History and Procedures

The Panel consisted of nine members, appointed by the Secretary of Energy (five members), the Governors of Idaho and Wyoming (one member each), and public interest groups (two members).

The Panel held five formal meetings, and as required by the Federal Advisory Committee Act (FACA), all meetings were open to the public. The Panel sought public comments at each meeting. Briefings to the Panel at these meetings covered applicable regulations, inventory and characteristics of the waste, technology state-of-the-art and DOE plans for research and development on alternatives to incineration. In addition, the Panel issued a Request for Information (RFI) through the Commerce Business Daily (CBD) on August 25, 2000, to solicit industry and academic views on mixed waste treatment options. A sub-Panel, consisting of five Panel members, initially reviewed the responses to the RFI and reported their findings to the full Panel. The sub-Panel received technical assistance from three independent reviewers and a DOE review team.

In addition to the Panel meetings, five full-Panel conference calls and four sub-Panel conference calls were held to prepare, discuss and organize materials for the formal meetings.

WASTES CONSIDERED BY THE PANEL

For purposes of the Panels deliberations, "mixed waste" was considered to be waste that contains both hazardous waste and radioactive material that is subject to the requirements of the Resource Conservation and Recovery Act (RCRA) and the Atomic Energy Act (AEA), which apply to generation of waste and to wastes already stored. In some cases, this waste is also contaminated with Polychlorinated Biphenyls (PCBs), which are regulated by the EPA under the Toxic Substances Control Act (TSCA). EPA and the States enforce the requirements imposed by RCRA. DOE sites that store, treat, or dispose of mixed waste are regulated under both RCRA and the AEA. In addition, mixed waste buried in the ground at DOE facilities is subject to section 120(a)(2) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended.

Origin, Forms and Status of the Stored Mixed Wastes at INEEL

DOE currently stores approximately 65,000 cubic meters of radioactive waste at the Transuranic Storage Area (TSA) at the Radioactive Waste Management Complex (RWMC) at the INEEL. This waste is managed as transuranic waste, although not all of this waste meets the current definition of such waste. Approximately 95 percent of this waste is classified as "mixed waste." Some contains polychlorinated biphenyls (PCBs), which are regulated under the Toxic Substances Control Act (TSCA). Most of this 65,000 cubic meters of waste resulted from nuclear weapons production operations at the Rocky Flats Plant in Colorado and was transported to the INEEL before the current definition of TRU waste was established (prior to 1982).

Of the 65,000 cubic meters, approximately 52,000 cubic meters (80 percent) is in wooden boxes and metal drums that were stacked on an asphalt pad and covered with tarps, plywood, and then soil to form an earthen-covered berm. The earthen-covered berm is enclosed within a metal building called the Transuranic Storage Area Retrieval Enclosure (TSA-RE), a RCRA interim status facility. Approximately 13,000 cubic meters of the waste (the remaining 20 percent) is stored in adjacent RCRA-permitted facilities at the RWMC. These 65,000 cubic meters of waste represent the INEEL waste that could be treated by alternatives to incineration.

Without treatment, a portion of this waste does not currently meet requirements for shipping and disposal at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico or other regulatory requirements for waste disposal and transportation, which are reviewed in subsection C below. Initial planning for the AMWTP incorporated the assumption that approximately 78% of the waste would require incineration in order to meet these requirements. This included all non-debris and combustible debris (typically paper, rags, plastic and rubber). Changes in the planning assumptions have resulted in successively lower estimates, and by early 1997 the AMWTP contractor had determined that only non-debris waste should be incinerated. As a result, the amount to be treated was reduced to approximately 22% of the total.

In 1996, waste designated for disposal at WIPP was exempted from the RCRA Land Disposal Restrictions (LDR), further reducing the quantity of waste to be treated. Only a fraction of many of the waste streams will require treatment. The current estimate is approximately 1,500 cubic meters, based on review of the envelope of waste comprising the full 65,000 cubic meters, published information about the waste, anecdotal evidence, and subsequent analysis or examination of the wastes. The actual volume requiring treatment will be determined only after individualized analysis of each drum, which must be completed before any waste is shipped Physical and chemical characteristics of the wastes are described below in Table III.

Table III: Description of Major Waste Types

Major Waste Types	Waste Type	Description
Solidified aqueous sludge	Inorganic Homogeneous Sludge	Generated by liquid waste treatment operations. The liquids were treated with base (sodium hydroxide) to precipitate the radioactive and chemical contaminants (e,g. iron, magnesium, plutonium and americium). The resultant precipitate was filtered and solidified by adding Portland Cement or diatomite. *NB*. Sometimes other items (e.g. gloves) were also added.
Solidified organic sludge	Organic Homogeneous Sludge	Oil and chlorinated solvents generated from the machining and degreasing of plutonium metal. These organic liquid wastes were mixed with a synthetic calcium silicate to form a grease or paste like material. An absorbent (e.g. Oil Dri) may have been added to remove any free liquid.
Solidified aqueous waste	Inorganic Homogeneous Sludge	Generated by liquid treatment operations. Aqueous wastes were received from numerous sources and the radioactive and chemical contaminants removed by a variety of methods (e.g. precipitation, flocculation and evaporation). The resulting slurry was then filtered to leave a moist sludge that was dried, and a sorbent or cement added.
Solidified Inorganic Sludge	Inorganic Homogeneous Sludge	Sludge generated from the waste treatment of, for example, shower water, acid and base. Portland cement was added to solidify the aqueous waste.
Cemented sludge	Organic Homogeneous Sludge	Organic sludge generated, for example, from a plutonium recovery incinerator. It may consist of fly ash with a damp, paste like consistency. Portland cement may have been added to remove liquids.
Light metal	Metal Debris	Various light metal items that were routinely used during plutonium operations (e.g. iron, copper, brass, aluminum, stainless steel, wire, cable and tools) that have been contaminated with acids, bases and flammable solvents.
Filters	Inorganic Debris or Heterogeneous Debris	Various filters used in plutonium operations (e.g. HEPA, Ful-Flo) and contaminated with particulates, acids, bases and solvents.
Evaporator salts	Inorganic Homogeneous Sludge	Consists of a salt residue generated from the concentration and drying of liquid waste from aqueous waste treatment operations in solar evaporation ponds.
Glass	Inorganic Homogeneous Sludge	Various glass items (e.g. bottles, vials) used during routine plutonium operations. Also whole or ground up raschig rings.

These wastes will be received for inspection, characterization and then shipment or processing in 55-gallon drums (which are generally lined with a high density polyethylene liner), wooden boxes, or bins. Sometimes the waste is contained in a plastic bag alone or in a smaller container (such as a one gallon polyethylene container) that has been placed in a 55-gallon drum.

Where the condition of the 55-gallon drum is suspect, it will be placed in an 83-gallon overpack drum to prevent the spread of contamination.

WHY DO MIXED WASTES REQUIRE TREATMENT?

Wastes must be treated for two principal reasons: (1) to meet transportation requirements and (2) to meet Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC). Elements of these two overlapping sets of requirements are specified by regulations or set by permits. Transportation requirements restrict the shipment of materials that would create a hazard during transit. The WIPP WAC restrict the amount and nature of waste components that can be disposed of. Three INEEL waste components can trigger a need for treatment: potential hydrogen generators, volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs).

Hydrogen generation rates are limited by WIPP WAC and by TRUPACT II (shipping container) specifications. Hydrogen can be produced by the action of alpha particles on water or organic materials and the restriction calls for evaluation of steady-state hydrogen release rates for every container.

VOCs are limited both by transportation requirements, which are aimed to avoid fire hazards during shipping, and by WIPP WAC, which restrict the loading of VOCs into disposal vaults. VOCs must be measured in the headspace of every container.

PCBs are restricted by WIPP WAC to concentrations below 50 parts-per-million. The PCB concentration must be verified by acceptable knowledge or by records of sampling and analysis.

At INEEL, the Advanced Mixed Waste Treatment Plant will process previously stored mixed transuranic waste and mixed low-level waste in preparation for disposal at WIPP or another appropriate facility. The process will include waste retrieval, characterization, sorting, size reduction, repackaging, sorption, supercompaction, certification, and loading of the waste for shipment. Waste that does not meet the applicable disposal requirements will remain in storage at INEEL until appropriate processing is available.

One recurring issue for the Panel was the option of transporting the INEEL mixed wastes without further treatment, either to WIPP or a commercial disposal site. As indicated earlier, this is not possible under today's regulations; for example, WIPP cannot accept wastes with PCB concentrations of 50 ppm or greater. Those regulations could change over the period of the DOE/Idaho agreement; indeed, applications now pending before the EPA and the State of New Mexico seek amendments to WIPP's Waste Acceptance Criteria that would affect the treatment required in order to ship INEEL mixed wastes to WIPP. But any such regulatory changes would require extensive consultations with interested parties and states, and no amendments in the WIPP Criteria are possible without the consent of the State of New Mexico. Accordingly, while the Panel recognized that waste disposal regulations can evolve and will influence any long-term RDD&D strategy, the Panel's recommendations did not assume amendments to the current regime.

ALTERNATIVES CONSIDERED BY THE PANEL

A host of parties provided to the Panel a broad array of technological alternatives to incineration. A large number of options at very different stages of development were considered by the Panel. From the perspective of research, development, demonstration and deployment (RDD&D), the challenge is to apply inevitably constrained resources productively without prematurely narrowing the field of potential winners. The Panel's aim was to help DOE assemble an RDD&D technology portfolio that is diverse in both technology characteristics and vintages; to that end, they identified the most promising of the relatively mature and the still emerging options. The Panel also attempted to narrow the field in a productive way. Some elements of the portfolio should be ready for comparison testing on an aggressive schedule over the next several years, while others will need substantially more time (while still being potentially available in time to meet DOE's commitments to the State of Idaho).

Thermal Treatment without Incineration

Thermal treatment of hazardous waste involves use of high temperature as the primary means to change the chemical, physical, or biological character and/or composition of the waste in the absence of air or oxygen and without a flame. High temperatures volatize and decompose organic compounds and break their chemical bonds to form organic fragments that may require subsequent oxidization or reduction.

Thermal treatment processes not involving incineration include plasma arc melters, DC-arc melters, metal melters, steam reformers, molten salt oxidation, and supercritical water oxidation, each of which operates under different thermal and environmental conditions.

- Plasma or DC-arc melters may be operated in at least three modes: an oxidation mode in which sufficient oxygen is supplied to oxidize the organic material; a pyrolysis mode (e.g., an oxygen deficient atmosphere); or a steam reforming mode. In the steam-reforming mode, steam provides both hydrogen and oxygen to react with the high temperature decomposition products.

- Metal melters operate in a reducing mode in which the molten metal (such as iron or aluminum) has a high affinity for oxygen.

- Steam reformers operate in the absence of free oxygen; steam provides a source of both hydrogen and oxygen to produce a combustible gas mixture of CO, H_2, CO_2, H_2O, CH_4, HCl and low molecular weight hydrocarbons.

- In molten salt systems, organic waste and oxygen are injected into a hot molten salt bath that provides the thermal energy to break the chemical bonds of the organic material, and a medium that enables intimate contact between the oxygen and the organic fragments.

- Supercritical water oxidation is a thermal process in which high temperature and high pressure are used to generate a supercritical state of water. Supercritical water readily dissolves organic material and stimulates rapid reaction between the organic material and the oxygen to produce CO_2 and H_2O. This reaction is similar to, but much more rapid, than the non-critical chemical processes described next.

Chemical Oxidation (Aqueous Based)

Chemical oxidation uses chemical, or electrochemical oxidants other than oxygen or air as the primary means to destroy or detoxify hazardous materials. Moderate increases in temperature can be used to accelerate the rates of the organic destruction reactions, but the temperature alone is not sufficient to break the chemical bonds. Chemical oxidation processes use strong oxidants in an aqueous, acidic solution. Examples of strong inorganic oxidants are nitric acid, Ag^{2+}, Ce^{4+}, Fe^{3+}, and ammonium peroxydisulfate [$(NH_4)_2S_2O_8$]. The organics are typically converted to H_2O, CO_2, HCl, and mineral salts. Because the reactions are strongly surface area dependent, solids and some liquids require significant size reduction and/or mixing for adequate oxidation to occur, whereas soluble organics are more easily oxidized. Because the reactions take place at low temperature and in a liquid state, the times required for the reactions are much longer than for thermal systems, and there is typically more secondary waste generated by the oxidizing agents.

Dehalogenation

Dehalogenation refers to chemical reactions in which halogens (chlorine, bromine, iodine) are removed from the molecular structure of organic compounds and replaced by other molecules to form non-hazardous or less hazardous products. For example, the solvated electron process is used to replace chlorine in PCBs with hydrogen. Byproducts from treating PCBs include petroleum hydrocarbons, sodium chloride, and sodium amide.

Separation

Three types of separation processes are used for removal of organic material from a waste matrix: soil washing, solvent extraction and thermal desorption.

- Soil washing uses an aqueous solution and detergent to remove organic material from the surface of soil particles and to separate fine particulates (which contain most of the organic contaminants in the porous fines) from the coarse soil. Soil washing does not destroy the organic material but produces three products: a wastewater stream, a sludge of contaminated fine particulates, and soil that may contain regulated levels of heavy metals and radionuclides.

- Solvent extraction uses a solvent to remove soluble contaminants from the waste (not unlike dry cleaning). A subsequent step removes the contaminants from the solvent, which can be re-used, leaving the liquid organic contaminant to be treated by other means.

- Thermal desorption uses heat, and sometimes a vacuum, to volatilize organic contaminants from a solid waste. Volatile and semi-volatile organic contaminants are condensed and collected in an offgas system for subsequent treatment by other means. In some cases, heat and vacuum can pyrolyze non-volatile organic material (plastics, wood, PVC, etc.) to produce volatilized organics and an ash that remains in the desorber.

Biological Treatment

Biological treatment (or biodegradation) refers to the processing of organic waste material using microorganisms such as bacteria and fungi. Aerobic degradation is performed by microorganisms that require oxygen for growth. Aerobic process residues are usually CO_2, H_2O, salts and biomass sludge (dead cell material). Anaerobic degradation is carried out in the absence of oxygen and yields CH_4, CO_2, and biomass. Since the contaminants must be available to the microorganisms, contaminants that are not water-soluble (e.g., solids and immiscible organics) are more difficult to treat. Chlorinated organics are difficult to treat because their degradation does not benefit the bacteria. Nonetheless, some bacteria do degrade chlorinated organics in the course of metabolizing other, more easily degraded compounds.

CRITERIA FOR EVALUATING TECHNOLOGICAL ALTERNATIVES TO INCINERATION

The Panel adopted seven criteria for evaluating alternatives to incineration, and included them in the August 2000 Commerce Business Daily Request for Information:

1. Environmental, Safety and Health (ES&H) Risk Considerations. The safety of the system, potential ES&H risks and the difficulty in designing and constructing a system to meet the safety and environmental health requirements in radioactive service with special emphasis on upset conditions.

2. Stakeholder and Regulatory Interests. The degree to which there may be resistance or delays in implementing the technology or system due to either public concerns or regulatory requirements.

3. Functional and Technical Performance. The technical performance of the treatment process to include destruction efficiency, volume reduction capability, secondary waste generation, robustness and flexibility of the system, final waste form performance and capability to be shipped.

4. Operational Reliability. The reliability and availability of the treatment process, its complexity, and the potential exposure to maintenance workers.

5. Pre- and Post-Treatment Requirements. The pre-treatment and post-treatment requirements of the waste, and the requirements for treating the effluents from the process.

6. Economic Viability. The total life cycle cost of the system, the cost per unit volume of waste treated, the market for the technology, and the potential that the technology will be commercially available to treat the waste.

7. Maturity. The level of development of the technology, field experience with the technology in radioactive service, and whether the technology will be available in the time frame required.

In its application of the criteria, particularly those bearing on health and safety, the Panel placed special emphasis on performance under potential "upset conditions." Additionally, the Panel considered worker safety as an important part of its ES&H criterion.

Although meeting all applicable environmental, safety, and health regulations is an essential criterion for any technology, the Panel believed that this is not an adequate criterion. Specifically, the Panel recommended that a technology be highly favored if it can demonstrably meet such regulations by very large margins, thereby affording much higher degrees of protection, and much higher confidence in that protection.

PANEL'S EVALUATION OF ALTERNATIVES CONSIDERED

In aid of its evaluation, the Panel formed a Technical Sub-Panel and engaged other independent technical experts to review responses to a Congressional Business Daily request for information, and to provide objection evaluations or those responses.

The choice of technologies depends on the purpose of the treatment. As indicated earlier, this purpose consists of removal from the waste stream of potential hydrogen generators, VOCs, PCBs and possibly the ignitable and corrosive streams that carry the D001 and D002 EPA hazardous waste codes.

The Panel evaluated the technological alternatives described above using the published criteria. Most, but not all, technologies were brought to the Panel in response to the RFI described previously. The Panel's intent was not to endorse or reject specific commercial applications, but rather to focus on categories of technologies, identifying those that appear most promising for near-term application and for longer-term developmental funding. The technological alternatives were grouped in three categories for discussion: (1) those that clearly appear promising and should have highest priority for funding; (2) potentially promising technologies for which important unresolved issues remain; and (3) technologies to which the Panel accords lowest priority. The Panel concluded that even the most promising alternatives are not yet fully demonstrated, in particular with mixed waste. Also, none of the alternatives are ready for immediate implementation, and require development and testing prior to implementation. The following sections summarize the Panel findings on the reviewed technologies.

Most Promising Technologies

The most promising technologies are relatively mature, so that (a) there are fewer issues regarding their capabilities to treat the DOE waste in question; (b) they generally are robust (e.g., they can treat a variety of waste types with a minimal pre-treatment); (c) they have minimal secondary wastes, which can be successfully treated; and (d) they appear to pose less risk to workers, the public and the environment. The first category of technologies includes Steam Reforming, Thermal/Vacuum Desorption, DC-Arc Melting, and Plasma Torch.

For each of these most promising alternatives, the Panel's views are summarized below.

a. Steam Reforming

Steam reforming coupled with volatilization directly from waste drums is a very promising technology to remove and destroy organic components in the waste stream. It is a robust, mature technology, applicable to a wide variety of waste streams and requiring little or no pretreatment. It operates in a reducing environment (i.e., in the absence of oxygen), producing an off-gas stream consisting of organic effluents (syngas), carbon dioxide and water vapor. This gaseous stream requires treatment to decompose the organic effluents (e.g., oxidation by a high-temperature ceramic catalyst), but the emissions to the environment can be measured and controlled and are likely to be minor. The relatively low temperature should allow the plutonium and most other radionuclides and heavy metals to be retained in the residue, which can be sent to a disposal site. However, some radionuclides and metals may be volatilized and must be captured by off-gas systems.[2]

b. Thermal/Vacuum Desorption

This separation process removes volatile and semi-volatile organics from the inorganic portion of the waste stream and pyrolyzes non-volatile organics in an oxygen-starved atmosphere to produce organic vapors and a solid residue. The volatilized organics may be treated by some other means: oxidized in a high-temperature ceramic catalyst or absorbed onto a carbon bed or condensed back to a liquid for subsequent destruction, or possibly treatment at an existing commercial facility. The low gas flow and low temperature minimizes particulate carryover into the off-gas system and should allow the plutonium and most other radionuclides and heavy metals to be retained in the residual solids. Thus, the emissions to the environment can be controlled and are likely to be minor. Little or no pretreatment is required for a wide variety of wastes.

c. DC-Arc Melter

This is a process with very high destruction efficiency. It is very robust, can treat any waste or medium with minimal or no pretreatment, and produces a stable waste form. The DC-arc melter uses carbon electrodes to strike an arc in a bath of molten slag. Use of consumable carbon electrodes that are continuously inserted into the reaction chamber eliminates the need to shut down for electrode replacement or maintenance and the need for a torch gas. The high temperatures produced by the arc convert the organic waste into light organics and primary elements in a steam-reforming or reducing atmosphere. The combustible syngas is cleaned in the off-gas system and oxidized to CO_2 and H_2O in ceramic bed oxidizers. The potential for air pollution is low due to the use of electrical heating in the absence of free oxygen and the low amount of off-gas. The inorganic portion of the waste is retained in a stable, leach-resistant slag, which may be necessary for a mixed non-TRU waste that will be disposed of in a RCRA-regulated landfill.

d. Plasma Torch

Plasma torch systems are similar to DC-arc systems in that an arc is struck between a copper electrode and either a bath of molten slag or another electrode of opposite polarity.[3] As with DC-arc systems, the plasma torch system has very high destruction efficiency, is very robust, and can treat any waste or medium with minimal or no pre-treatment. The inorganic portion of the waste is retained in a stable, leach-resistant slag, which may be necessary for mixed non-TRU waste that will be disposed of in a RCRA-regulated landfill. However, the water-cooled copper torch must be replaced periodically to prevent burn-through at the attachment point of the arc and a subsequent steam explosion due to rapid heating of the released cooling water. The air pollution control system is somewhat larger than for the DC-arc due to the need for an arc-stabilizing torch gas. Concerns have been raised regarding the reliability of this technology.

2. Potentially Promising Technologies with Unresolved Issues

From the RFI and other sources, the Panel identified a number of technologies that may contribute to solving the INEEL waste treatment problem. However, potentially significant issues need to be addressed before final decisions are made about integrating these technologies into DOE's RDD&D program. These technologies are generally less mature than those in the first category, are less robust, or have questionable ability to safely treat DOE waste. These technologies include mediated electrochemical oxidation, microwave decomposition, supercritical water oxidation, and solvated electron dehalogenation.

For each of these potentially viable alternatives, the Panel's views are summarized below.

a. Mediated Electrochemical Oxidation

Mediated electrochemical oxidation relies on an oxidizing element (e.g., silver or cerium) to destroy organic compounds. Metals, including plutonium and americium, may be dissolved in the anolyte solution. Recovery of the oxidizing element from the anolyte and reuse back in the process is critical for economic operation. It is not clear if recovery/reuse is possible or economically viable in the presence of radionuclides. Also, to reduce process retention times and increase solubility of organic constituents, waste streams are fed to the system as liquids or slurry. This may require significant waste pre-treatment. Other issues include the capability to treat PCBs adequately, and the highly corrosive nature of the process and related safety concerns.

Positive characteristics include low temperature, low off-gas, and an apparent ability to treat diverse waste streams. The Panel's concerns centered on 1) recovery/reuse of the anolyte solution; 2) amount of pre-treatment; and 3) corrosion and erosion of the system components.

b. Microwave Decomposition

This technology involves a specific type of chemical decomposition, and may have promise for the treatment of INEEL wastes, but it has been applied only to limited waste streams (medical waste and tires). Research and development is needed to determine its efficacy for treating radioactive and TRU wastes. Other potential unknowns and concerns include this technology's ability to treat PCBs, amount of pre-treatment, nature of the effluents, including the level of off-gas treatment required, and radionuclide accumulation in carbon precipitated on the walls of the treatment chamber (this char could present significant decontamination and worker safety issues).

Positive attributes include low off-gas and low system operating temperature and pressure.

c. Supercritical Water Oxidation

At supercritical pressure and temperature conditions, water can dissolve organic constituents. This is a relatively mature technology with a long history of development for specific applications. Positive attributes of the supercritical water oxidation system include very low off-gas, high destruction efficiencies for organics, and effluents that are relatively easy to manage, including brine, filtered solids and salts.

On the other hand, the high pressure (and the difficulty in injecting particulate-laden erosive slurries into the process) and corrosiveness of the system present significant safety concerns. Moreover, the waste stream feed must be in a liquid or slurry form, which requires substantial pre-treatment of wastes. Proponents anticipate using a bulk feed system, but key details are lacking on its design and development.

d. Solvated Electron Dehalogenation

In this technology, solvated electrons, created in a mixture of anhydrous ammonia, sodium metal, and waste, remove halogens (primarily chlorine) from organic molecules. This is a relatively mature and simple technology that operates at low temperature with low off-gas and good destruction efficiencies for chlorinated compounds.

Potential concerns with the solvated electron technology include: 1) the management of treatment residues, including further treatment of non-chlorinated organics to meet WIPP WAC; 2) the amount of pre-treatment needed to maximize exposure of the chlorinated compounds to the electron solution; 3) the process's ability to treat the diversity of INEEL wastes (waste pH and moisture content appear to be important); and, 4) safety associated with handling sodium and anhydrous ammonia and high system pressure (200 psi) in a radioactive environment.

3. Lowest Priority Technologies

In its review, the Panel was impressed by the number and variety of treatment processes submitted for consideration in response to the RFI. Given constrained R&D resources, the Panel felt compelled to adopt a winnowing process to yield a manageable number of candidates for further testing and development. Most of the treatment options submitted to the Panel clearly have promise for some forms of waste, but the Panel's charge compeled a focus on very specific wastes.

The Panel concluded that technologies not recommended in their report for further development and testing were qualitatively less promising, across the full range of characteristics necessary to deal with the INEEL wastes. Several of these technologies were not applicable to the DOE wastes in question, others had serious safety issues, and others were so immature or had so little information available that an informed evaluation was impossible. In reviewing candidates for near-term testing, the Panel sought convincing evidence of technological maturity; where the issue was eligibility for further development; with the focus being the promise of superiority in simplicity, efficiency and economics.

The technologies examined by the Panel and placed in this third category include iron chloride catalyzed oxidation, molten aluminum, solvent extraction, high temperature hyperbaric chamber, silent discharge plasma, soil washing with a chelating agent, treatment with sodium in mineral oil followed by chemical oxidation with peroxydisulfate, and biological treatment.

PANELS CONCLUSIONS AND RECOMMENDATIONS

The Panel found that there are promising technological alternatives to incineration. However, at present, they did not believe such technologies have not been fully demonstrated and need to be further developed, adapted and tested with actual mixed waste streams.

In the Panel's judgment, a varied set of technologies deserve a place in DOE's RDD&D program. The Panel's recommendations also included basic scientific work that should broaden the base of technologies further.

The Panel recommended that DOE seriously consider technologies identified in the most promising category as alternatives for an incinerator at the AMWTP. They emphasized that tests of these should be conducted on both surrogates and actual wastes to demonstrate their applicability. The Panel concluded that these tests should be completed within 3 to 5 years, and should include total system evaluations including pre- and post-treatment requirements and should seek to identify performance under potential upset conditions.

The Panel also noted that no single technology may by itself be adequate to meet the desired ES&H standards and achieve the desired destruction of hazardous and PCB waste. They acknowledged that robust solutions are likely to require combinations of several technologies, considering some of the most promising technologies yield secondary wastes that require further treatment and/or stabilization prior to disposal.

The Panel also recommended that DOE consider less mature technologies for further development and testing, with the aim of either advancing them to readiness for deployment or eliminating them from further consideration.

The Panel also emphasized that a program of basic and applied research should be pursued to identify and nurture the next generation of technologies. They noted that it is important and appropriate for DOE to address the completion of relatively near term waste management actions such as meeting the agreement schedule for removal of stored mixed TRU and low-level waste from Idaho. However, they acknowledged that other wastes will need to be treated, and the total problem will not be quickly solved.

DOE'S EVOLVING PLAN FOR DEVELOPING ALTERNATIVES TO INCINERATION

In mid-2000 DOE began preparing an RDD&D plan for developing and deploying safe, cost-effective and timely technological alternatives to incineration. The preliminary DOE plan includes the stages of development from basic science research through full-scale integrated demonstrations and ultimate deployments. The RDD&D plan will be initiated in FY 2001 by DOE's Transuranic and Mixed Waste Focus Area (TMFA) and it includes provision for regulatory and public involvement. Regulatory issues will be addressed by working directly with the various State and Federal agencies (e.g., the Environmental Protection Agency/EPA and State permit writers) throughout the alternatives development process. A DOE-EPA Memorandum of Understanding is already in place for this purpose. Developers would be informed of the data needed for permitting purposes, and would be notified of pending regulatory changes that may effect the future applicability of their alternative technology.

Technical issues would be addressed through an effort involving testing and demonstration of emerging alternative technologies. Ideally, comparative demonstrations at a single location, performed by third party technicians would be conducted to provide objective data for technology assessment. However, current conditions dictate that testing and demonstration opportunities be exploited wherever possible, including DOE sites, non-DOE sites, and vendor facilities. Technologies selected for comparative study would initially be relatively mature. The comparative study would collect the necessary performance, design, scale-up, and permitting data for each selected technology. Testing with prescribed waste surrogates and/or actual wastes would ensure that each alternative technology demonstration generates comparable data. In addition, the next generation of alternatives to incineration would be pursued through research in the basic sciences and through applied research solicitations. The

RDD&D Plan would develop a balanced portfolio of technology investment from basic research to deployment of available, fully demonstrated technologies.

The Panel's Conclusions and Recommendations Regarding the DOE RDD&D Plan

The Panel appreciated and generally supported DOE's substantial ongoing efforts to devise a strategy for developing technological alternatives to incineration. This section presents the Panel's recommendations for designing and executing that strategy. If these recommendations are followed, the Panel believed that DOE should be able to achieve results consistent with the deadline of the Idaho Settlement Agreement, other regulatory requirements, and broader public interest considerations applicable to mixed waste throughout the nation.

The Panel endorsed the scope of work proposed by the DOE and made recommendations for additional funding. The Panel also believed that more basic work on processes will identify much-improved alternatives that could pay off handsomely down the road. The Panel also recommended real waste testing as a required step in ensuring technology acceptance and successful deployment. The Panel recommended that DOE first categorize in detail the wastes that need to be treated, then, link the actual wastes to processes in proposed work scopes. To simplify for emphasis: DOE must identify which processes are to treat what wastes.

In evaluating the most promising alternatives to incineration, the Panel urged the DOE to take a systems approach, and to consider the alternative technologies (especially the air effluent containment technologies) as a system under both normal and upset conditions. In particular, the Panel urged rigorous evaluation of whether the reliability and efficacy of the various effluent control systems would be sufficient to protect workers, the public, and the environment. The Panel also urged DOE and other federal agencies independently to evaluate the air effluent containment systems with surrogate and alpha-emitting waste, to determine the appropriate decontamination factors.

The Panel recommended that DOE use the seven criteria listed earlier in evaluating alternative technologies in the comparative and integration phases of the RDD&D. The primary emphasis should be on the alternative's protection of the environment, safety, and health. DOE's initial selections of alternative technologies should be made on the basis of the Panel recommendations.

The Panel believed that citizen stakeholder involvement at all stages of the process is essential for successful deployment of waste treatment technologies. Citizen stakeholders should include people of various expertise from around the country and region. The Panel endorsed development of a 2001 national conference on alternative technologies to incineration. Conference objectives should include public education, and discussion of an ongoing role for stakeholder groups in the RDD&D process. A third party facilitator and participation by interested companies and agencies were also recommended.

Given the likelihood that the DOE plan itself will change in light of this report, the Panel asked the full SEAB to review progress and continue to advise the Secretary on these matters after the Department has had the opportunity to recast its initial proposal to reflect the Panel's findings and recommendations.

DOE Plans Resulting from the BRP Recommendations

DOE is preparing and Action Plan that will define more specifically the activities, performers, schedules and milestones that will embody the DOE response to the Panel recommendations, and will lay the groundwork for the next revision of the DOE RDD&D Plan. The Action Plan should be complete by the end of March 2001.

The DOE accepted the Panel's recommendation for more funding and plans to pursue it. The Environmental Management program will confirm the specific amount of appropriate funding through a thorough technical review, and is prepared to add fund this fiscal year based on the results of the technical review. The Department plans to apply the same process for determining the right amount of funding in fiscal year 2002.

A meeting with regulators from the US EPA, many of the states, technology vendors, DOE staff, DOD and other interested parties is being planned for April in Salt Lake City, UT. Any interested citizens can attend and with the DOE develop a greater appreciation for the array of technologies available, and their capabilities and limitations. Additional information will be available shortly through the Weapons Complex Monitor and on the Exchange Monitor Publications web site (http://www.exchangemonitor.com).

At this time stakeholder involvement plans are evolving within the DOE. Specific actions, schedules and plans will be included in the DOE Action Plan that is forthcoming.

FOOTNOTES

1. Settlement Agreement: Keep Yellowstone Nuclear Free v. Richardson, et al.; No 99 CV 1042J (D. Wyo.).
2. To the extent that some steam reforming technology variants require fluidization of a heterogeneous mixture, significant technical issues remain for resolution.
3. The plasma torch technologies evaluated by the Panel should be distinguished from 'plasma arc incinerators,' as defined by EPA in 40 CFR section 260.10.