Chapter 3
Current Technology and Alternatives

CURRENT TECHNOLOGY

The Army's CW Disassembly and Incineration Technology

The Army's current chemical weapons (CW) disposal program involves robotic, machine disassembly of the chemical weapon as appropriate for each specific munition. The various waste materials from disassembly are incinerated separately. These include the chemical agent, explosives and propellants, empty munitions and nonexplosive (storage) containers, and shipping and packing materials (dunnage). Preliminary separation produces individual waste streams that are relatively homogeneous, which makes it feasible to optimize conditions for the incineration of each.

To handle the various waste streams produced by disassembly, four different furnace systems are required:

- Incinerator for the liquid chemical agent and process liquid waste;
- Rotary kiln furnace for the destruction of explosives and propellants, with an accompanying heated discharge conveyer to remove leftover materials;
- Metal parts furnace to decontaminate by incineration the empty bulk containers, shells, and bombs; and
- Dunnage incinerator for the combustion of waste packaging.

The resulting gases and other products of incineration are treated with a variety of modern pollution abatement equipment, including a quench tower, venturi scrubber, scrubber tower, demister, and for the dunnage furnace, a baghouse for removal of particulate. Brine produced by the scrubbers is evaporated, and the resulting salts are packed in drums for eventual landfill. The final products that will require disposal such as landfill are scrap metal, drums of salt, and ash (l).

The time required to dispose of the stockpiles at the eight continental U.S. sites after the incinerators begin to work was estimated in the 1988 Programmatic Environmental Impact Statement (PEIS) to be from 11 months (at Lexington-Blue Grass Army Depot, Kentucky) to 41 months (at Tooele, Utah). This was recently revised in the Army's March 1991 Program Implementation Schedule (Rev. 3) to 11 months (at Newport, Indiana) and 63 months (at Tooele) (see table 2-3).

EXAMPLES OF ALTERNATIVE TECHNIQUES

A number of techniques have been suggested for disposal of chemical weapons. To be applicable to the current CW stockpile, a technology must be able to effectively destroy or decontaminate the chemical agents, the drained and empty munitions and containers, the associated explosives and propellants, and the munition packaging material (dunnage). The dunnage is largely conventional packing material such as wooden pallets and crates. However, the possibility that the dunnage may be contaminated with CW agents requires that it be treated as if it were contaminated.

In 1991 the international environmental organization Greenpeace published a review of nonincineration alternatives for CW destruction, "Alternative Technologies for the Detoxification of Chemical Weapons: An Information Document" (5). This review was very broad in scope and included many reports of the destruction of a CW agent or related compounds. Virtually none of these alternative techniques with the exception of chemical neutralization has been demonstrated for use with actual CW agents on the scale required for the current disposal program. The Greenpeace review avoids specifically endorsing any single technique and concentrates on those methods that would be most applicable to the destruction of liquid CW agents. Many of the technologies proposed would handle only the chemical agent and the other waste materials would need some other treatment or disposal method.

Many of the CW destruction alternative techniques or technologies discussed in the Greenpeace report or proposed by others are not new and were proposed for CW destruction in the early 1980 or before. In response to a 1982 request to industry for proposals on techniques for CW destruction, the Army received suggestions for agent destruction from eight private companies. These included:

conversion to nontoxic useful chemical products; chemical destruction (neutralization); molten metal, plasmas, pyrolysis; molten salt incineration; acid roasting; cement kiln; large kiln; use of a rotary hearth furnace; supercritical fluid (oxidation); and thermal tower destruction (2). Although these and other techniques might be developed into technologies appropriate for CW destruction, none appears at present to be in a position to serve as an immediate alternative to incineration. Moreover, in the absence of more specific information about alternative technologies for CW disposal, it is impossible to predict which technique could be developed into an acceptable CW disposal technology. The Army rejected these alternatives primarily because it believed they would require much more time to develop or prove capable.

The following is a brief review of four techniques selected only because they have been specifically suggested by various interested groups or technology developers as appropriate for CW destruction: chemical neutralization, supercritical water oxidation, steam gasification, and plasma arc pyrolysis. Many other techniques have been suggested that are not reviewed here. There is no technical basis upon which to select (or reject) these or any other specific technology. Application of the last three techniques to dioxin-contaminated soil has recently been reviewed (3). It is quite possible that if a successful alternative technology is developed for CW destruction, it will be none of these. The proponents of these alternatives believe that they offer advantages because air emissions may be more readily controlled and minimized and because of possible improved safety during on-site handling and transportation. More details of these techniques are provided in appendix A.

Chemical Neutralization

The alternative technology for CW destruction having the greatest amount of available information is chemical neutralization. The U.S. Army had extensive experience with this process for the destruction of CW agents. Chemical neutralization via alkaline hydrolysis was successfully used to destroy a substantial proportion of at least some classes of CW agents in the current stockpile. Hydrolysis is the reaction of water with a chemical, such as the CW agent, using an acid or base catalyst, to produce compounds of greatly reduced toxicity. In principle, alkaline hydrolysis could be a means to chemica.lly neutralize the agents GB, VX, and mustards. Problems encountered by the Army with alkaline hydrolysis of all types of CW agents may be surmountable today in view of new techniques (see appendix A) that were not considered at the time of the Army's research in this area and of the increased pressure to exploit existing nonincineration techniques in CW destruction. Neutralization technology was, however, rejected by the Army as unsuitable for the current CW destruction program. (Appendix A gives a further description of the Army's work with and decision to abandon neutralization.)

Most experience with large-scale chemical neutralization of chemical weapons has been with the agent GB. This agent was successfully neutralized on a large scale by the use of aqueous sodium hydroxide. Approximately 8.4 million pounds of GB (17 percent of the total weight of all agents to be destroyed in the current program), taken from various munitions and storage tanks, were neutralized at Rocky Mountain Arsenal and Tooele, Utah, between 1974 and 1982. From 1979 to 1981, 13,951 M55 rockets containing GB (approximately 3 percent of today's stockpile and 20 percent of the M55 rocket stockpile at the Lexington-Blue Grass Army Depot) were destroyed by this combined chemical neutralization/incineration process (4).

The drained empty munition and ton (bulk storage) containers left over from this process were treated in a furnace where the explosives were incinerated and the metal parts thermally decontaminated. In general, chemical neutralization applied only to the drained chemical agent itself, and disposal of the remaining waste relied on incineration. Another variation in some of the work performed involved decontamination of drained cluster bomblets and ton containers with a caustic wash to neutralize any residual agent. However, the caustic wash treatment was also followed by incineration.

Although the agent VX, which is structurally similar to GB, can also be chemically neutralized, by hydrolysis with aqueous sodium hydroxide, the Army only demonstrated this on a small scale. Mustard agent has also been shown by the Army to be hydrolyzed under alkaline conditions on a small scale, although only very slowly at ambient temperature. The effectiveness of alkaline hydrolysis of mustards at elevated temperature was not reported (4).

Supercritical Water Oxidation

Supercritical water oxidation (SCWO) has been suggested as a plausible alternative for destruction of the agents contained in chemical weapons (2, 5). Supercritical water refers to water that has been heated and pressurized to a transition point between gas and liquid phases, and thus has some of the properties of both. Organic materials in solution with supercritical water can be oxidized by oxygen introduced from air. This technology is currently under development by U.S. companies (General Atomics, Modell Corp., and Modar) and by at least three major universities, for the destruction of a variety of hazardous wastes including dioxin-contaminated soil (3, 6, 7). Although these companies have prototype devices, none has demonstrated its use with an actual CW agent. Current prototypes would be most appropriate for the destruction of only the liquid chemical agent. However, many nontrivial technical details remain to be worked out before SCWO will be suitable for use even with CW agents alone; no actual CW agents have even been tested with SCWO destruction technology (6) (see appendix A for more details). Their design would not be suitable for decontamination of drained munitions and containers, or for destruction of the explosives and propellants loaded into burster tubes, etc., associated with CW munitions. SCWO is being developed commercially as a general technology for the destruction of many different organic hazardous materials, and the destruction of CW agents is conceived by its developers as, at most, a minor application of its use.

SCWO in principle may have certain advantages over incineration for the oxidation of organic waste. It is similar to incineration in that it involves oxidation of organic compounds to carbon dioxide and inorganic acids or salts. However, SCWO operates at much lower temperatures than incineration. Further, it does not require a large airflow. SCWO carries out oxidation at lower temperature, and the reaction medium (water) can be contained until tested to be safe. Potential products of incomplete combustion (PICs) are entrained in solution rather than emitted in stack gases. The apparently superior control of emissions is an attractive feature of SCWO technology. The effluents from SCWO, in contrast to the exhaust stack gases from incineration, may be collected, analyzed, and even recycled to achieve more complete destruction.

Steam Gasification

Steam gasification (or reformation) has been proposed for the destruction of chemical weapons by Greenpeace and by Kentucky citizen groups. Steam gasification would treat organic materials such as chemical agents (as well as propellants and explosives) with high temperature steam to produce simple organic molecules. One vendor is developing and marketing a portable device using high-temperature steam gasification for the destruction of gaseous, liquid, and solid organic-containing wastes (8). The machine is designed to handle bulk objects such as 55-gallon drums fried with waste, and therefore may be suitable for handling certain munitions and bulk CW containers. However, the device has not been tested with actual CW agents or actual CW munitions.

In contrast to conventional incineration, steam gasification does not use an airflow, so the gas produced by the process is minimized. The same vendor is currently working on CW disposal problems for the DOE, such as solvent contaminated soil, that do not involve chemical weapons. It proposes the use of one or more of its mobile devices operating directly in or next to a CW storage igloo. With proper modification, the igloo might serve as a secondary confinement container. The vendor claims that this system could avoid the risks associated with transporting chemical weapons out of the igloo, a major concern to some citizen groups that live around such facilities.

Plasma Arc Pyrolysis

Plasma arc pyrolysis, currently in the development stage, has also been proposed for destruction of chemical weapons by Kentucky citizen groups. In this process, chemical substances are dissociated into their atomic elements in a thermal plasma field created by passing an electric current through a low-pressure airstream. The entire system is transportable on a tractor-trailer bed. The most significant limitation of plasma arc pyrolysis treatment is that only liquids can be treated. Contaminated soil and viscous materials cannot be processed by the system (3). Therefore, plasma arc pyrolysis technology in its current form would not be suitable for the treatment of contaminated, drained munitions or of the containers, explosives, propellants, and dunnage associated with chemical weapons.

Improved Interim Continued Storage—The CW Demilitarization Alternative

In view of the current uncertainty about when any technology will be available for destruction of the CW stockpile, an interim alternative that would involve the transfer of chemical agents from munitions to superior-quality, long-term storage tanks has been proposed (9, 10). It is not clear if the approach of interim storage would conflict with either bilateral or multilateral treaties on CW disposal. The advantage of interim storage would be to secure the CW agents in the existing stockpile, particularly those in the M55 rockets, while developing some alternative destruction technology. Although not analyzed in this report, in principle the separation of chemical agents from explosives and propellants could enhance the safety of storage. This would still require a mechanical weapons disassembly process for removal of the chemical agents, as well as subsequent decontamination and disposal of the drained munitions and corresponding explosives and propellants.

Although it is likely that solving these problems may be no less difficult than disposal of the CW agent itself, an analysis of separating the chemical agents from the M55 rockets has been carried out for the Army (11). That study presented a conceptual engineering design, cost estimate, and risk assessment for draining and storing in bulk containers the chemical agents from the explosive and propellant portions of the M55 rockets. The remaining rocket components were to be chemically decontaminated and stored for latter disposal. The report did not address the issues of the storage and ultimate destruction of the separated rocket components, the chemical decontamination solutions or the CW agents. Moreover, the report indicated that the rocket separation concept was in an extremely early stage of development and should be viewed as preliminary in nature. As with any new unproven technology that might be applicable to CW destruction, pilot-plant testing and verification of the process would be required before it could be implemented (11). A possible interim solution for the leaking M55 rockets would be to place all of the rockets now in storage into the protective steel "overpack" containers that the Army already uses only for leaking rockets (see box l-C).

Alternatives Involving Transportation and Relocation of the CW Stockpile

In the 1988 PEIS, the Army considered and rejected the alternative of partial or complete relocation of the U.S. CW stockpile to either regional or national sites for disassembly and incineration because the overall risk was calculated to be higher. However, CW relocation may in principle be considered with whatever destruction technology is selected. In 1987 the Mitre Corp. prepared a risk assessment for the Army that compared various transportation alternatives (12). Further details of this report are given in Appendix B.

Since the condition of the U.S. CW stockpile has not received rigorous analysis, many conclusions about the relative safety of various transportation options will remain questionable regardless of the specific destruction technology used. The only options considered in the Mitre report were continued storage (the "no-action" alternative) versus on-site destruction, and partial or complete relocation, for destruction via disassembly-incineration. The Mitre risk comparisons considered only relative risks to the general population and excluded risks to workers at the CW destruction facilities.

The risks associated with different options will be borne by different populations. Thus, the risk of continued storage will be borne mostly by the population surrounding the storage site, whereas the risks associated with transport will be borne largely by populations along the transportation corridor and at the final destination (12). The fact that the risks for various alternatives might generate controversy among the different populations involved was not considered in the Mitre risk assessment.

According to the Mitre report, the continued storage option had significantly greater expected fatalities than all other alternatives when considering the combined risks at all eight U.S. sites. Using appropriate safety procedures, on-site incineration was estimated to be significantly less risky than any other alternative considered. Combining the total risk at all eight U.S. sites, the continued storage alternative-even with appropriate safety procedures-had the greatest expected fatalities associated with it, whereas on-site destruction involves the least risk. Regional, national, or partial relocation and disposal alternatives, respectively, have increasingly greater expected fatalities than on-site destruction (12). The

on-site disposal alternative also had the lowest probability of causing one or more fatalities, and partial relocation the highest. For the on-site disposal alternative, transportation activities accounted for 44 percent of the expected fatalities and plant operations for 48 percent. In this situation, the M55 rockets in the CW stockpile accounted for 50 percent and bulk containers 42 percent of the expected fatalities.

The general conclusions reached about the relative risks of transportation alternatives for the combined eight sites often differed significantly from the conclusions reached by site-specific analyses. For example, the risk from continued storage with appropriate safety procedures was much lower at the Lexington-Blue Grass Army Depot than at the seven other U.S. sites. Although the risk of continued storage was clearly greater than that of on-site disposal at the Aberdeen (Maryland), Newport (Indiana), Pueblo (Colorado), Tooele (Utah), and Umatilla (Oregon) sites, this was not the case with Lexington-Blue Grass Army Depot (Kentucky) and Pine Bluff (Arkansas) facilities.

Transportation of chemical weapons from their current sites to regional or national locations for destruction may be challenged by the States through which they would have to be moved. The Army 1988 PEIS stated that rail is the preferred mode for the transportation alternative (13). It described a regional relocation plan using rail shipment to relocate all continental U.S. chemical weapons to the Tooele (Utah) and Anniston (Alabama) sites. This plan requires CW transport from 730 to 1,800 miles, through 5 to 11 States. A national relocation plan described by the Army in its 1988 PEIS calls for rail shipment of all chemical weapons within the continental United States to the Tooele site. This plan requires CW transport from 730 to 2,670 miles, through as many as 20 States. A partial relocation plan was also considered that calls for moving the chemical stockpiles from the Lexington-Blue Grass Army Depot and Aberdeen sites to Tooele for destruction. This plan specified approximately 2,100 to 2,700 air flights over 1,500 to 2,060 miles.

CHAPTER 3 REFERENCES

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