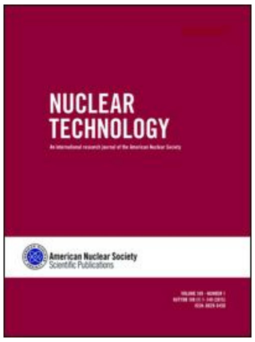

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UNITED STATES ATOMIC ENERGY WASTE MANAGEMENT PROGRAMS AND OBJECTIVES

KEYNOTE PAPER
WASTE MANAGEMENT
SYMPOSIUM

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KEYWORDS: *USAEC, radioactive waste management, environment, safety, nuclear power plants, planning, containers, radioactive waste storage*

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The responsibilities of the Director of the U.S. Atomic Energy Commission's (USAEC) Division of Waste Management and Transportation include the development, construction, and operational programs for (a) the long-term storage and disposal of all radioactive waste which has been, and continues to be, generated by the USAEC's activities, and (b) the management of any commercially generated radioactive waste which is delivered to the USAEC for storage and disposal.

The paper, however, will be confined to the phase of my responsibility which deals with the receipt and subsequent safe management of the commercially generated radioactive wastes. This is for two reasons. First, reasonable considerations of space will not allow adequate coverage of our programs in both areas, and second, I feel that the greatest public interest centers in the problems, real and assumed, of assuring that the radioactive waste to be generated by commercial nuclear power activities does not impose unacceptable risks to the health and safety of the public or unacceptable impacts on the environment.

Before I move into a brief discussion of our technical plans and programs for the safe management of the commercial radioactive waste, I would like to spend a few moments discussing some of the nontechnical aspects of the problem which are, if anything, more difficult and more challenging than the relatively straightforward technical problems of positively containing the radioactive materials, and the radiations they emit. I am, of course, referring to the basic problem of convincing the public, and those who are most influential in molding public opinion, that the real and potential hazards to public health and the environment are recognized by the USAEC and can be more than adequately countered for the near-term—decades to centuries—by careful application of completely demonstrated, currently available, scientific and engineering technology, and for the long-term—tens to hundreds of thousands of years—by application of scientific and engineering technology which has been developed through laboratory and field experimentation to the point where all that remains to be done is actual demonstration by operation of pilot plant facilities.

I realize that the problem of convincing the public in this regard is not easy. I recognize the atmosphere of public fear and emotion which is understandably generated by the thought of widespread use of an energy source which was introduced to the world by the awesome mushroom cloud of Hiroshima and Nagasaki. I thoroughly understand the legitimate public concern regarding the sociological, as well as technical implications of generating a waste material which must be isolated from man's biological environment for periods of time which are measured in hundreds of thousands of years. And I in no way underestimate the magnitude and scope of the effort which will be required to counteract these fears, concerns, and emotional feelings.

I believe, however, that this can and will be done by

1. An expanded effort on the part of the USAEC, by means of a programmatic environmental impact statement, to appraise the public of the magnitude and scope of the problem, of the potential impact of the management of radioactive waste on man and his environment, and of the various approaches which can be used to meet the management demands.

2. An honest effort on the part of the public and the media to review and understand the report of the USAEC and to present rational

technical comments based on such review and understanding.

It is only by such a mutual approach that the current atmosphere of misunderstanding, misconception and, in many cases, mistrust can be dispelled and the real problems openly discussed and resolved.

In keeping with this objective, the Commission announced on Apr. 16, 1974, that it will make *no* decisions on management of commercial high-level radioactive waste until it has received written comments on a draft environmental impact statement, issued in September 1974, and has held a public hearing on the matter.

While it was not included in the Apr. 16, 1974, announcement, the Commission has also decided, partially because of comments it has received from the public, to expand the scope of the programmatic environmental impact statement to include, in addition to high-level radioactive waste, discussion of all commercially generated waste containing, or contaminated with, transuranium nuclides. A notice of this expansion of the scope of the statement was published in the Federal Register.[1]

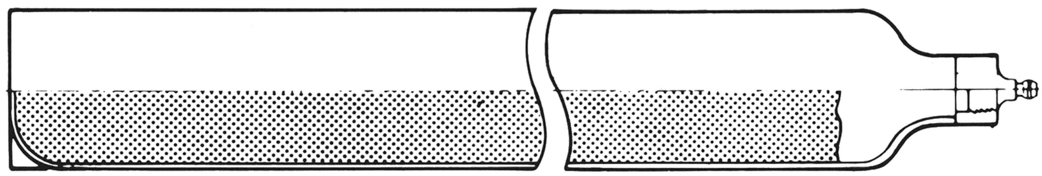
The use of the programmatic environmental impact statement and public hearing as a means of presenting information to the public for analysis and comment prior to the time the Commission makes its decision is in conformity with the requirements of the National Environmental Protection Act, and it certainly offers an ideal vehicle for the public to make its questions and comments known. However, as I indicated earlier, for the system to work properly, it is essential that the public carefully review and study the statement and base its comments and questions on the knowledge it gains by such review. I have noted that very often members of the public, and especially the media, have not accepted the responsibility to study what is available and have made their comments, statements, and innuendoes based on ignorance and assumptions rather than on fact. Unless both parties make a sincere effort to meet their responsibilities—the Commission to assure that all facts are presented, and the public to assure that it has considered and understands the facts—the gap of misunderstanding and misconception can never be bridged, and a true public analysis of the relationship of public benefit to public risk in the use of nuclear fission to help meet our serious energy problems is not possible. As an example, may I cite the oft repeated idea, put forward by those who have generally not bothered to analyze all the known facts, that until we have completely developed, proven, and placed in operation the methods for the ultimate disposal—as opposed to retrievable storage—of radioactive waste, we should halt all actions which generate such waste.

The facts are than the only requirement for safe waste management is to assure that the waste is isolated from man's biological environment for as long as its radioactivity is at a level where it could harm man or the environment. Such isolation can be accomplished, theoretically, in any one of three ways. It can be placed in man-made multiple barrier containment which can be continuously monitored and reparied to ensure against escape. It can be placed in geologic formations, which are outside of man's biological environment, in a way which will ensure that it cannot migrate into that environment before it has radioactively decayed to innocuous levels. Or it can be removed from the total earth environment by transportation to outer space. We have made studies and evaluations of all three approaches and have analyzed the current state of technology for each.

This analysis shows that we do not today have all the technology needed to ensure that the extraterrestrial approach can be used safely and economically. The development of the basic space technology which would allow us to consider this approach would encompass a very extensive and expensive effort which cannot be justified for the sole purpose of radioactive disposal and which must be based on other national objectives. In this regard, we look upon the potential for extraterrestrial disposal of radioactive waste as being completely dependent on the development efforts which, if they are carried out, will be for purposes other than waste management. If such programs are pursued, and a space technology is developed with adequate safety and reliability to economically dispose of radioactive waste in outer space, consideration of the relative advantages of this approach can be made.

On the other end of the scale, our analysis has shown that we do have available *today* all the technology necessary to package radioactive waste in multiple barrier man-made containment and to store this packaged waste on the surface of the earth in a manner which will afford the surveillance and maintenance required to assure that the contained waste does not escape to the biological environment.

Between these extremes lies the approach of placing the waste in geologic formations, which will ensure that the waste material will not migrate to the biosphere. Here, an extensive laboratory and field experimental program has shown that at least one formation, deep-lying bedded salt, has the properties and characteristics needed to ensure isolation from the biosphere for periods well in excess of those needed for decay of even



	DIAMETER	LENGTH
RANGE	6 TO 24 in.	2 TO 10 ft.
TYPICAL	12 in.	10 ft.

Fig. 1. "Typical" canister.

the very long-lived radionuclides. There does remain, however, need for a final "demonstration," under actual operating conditions, of an integrated system to receive, emplace, and store the waste. Such final "demonstration" would require a design, construction, and operating period covering several decades.

Thus, today the technology for retrievable surface storage is at a point where we can safely use this approach for the radioactive waste initially produced by the nuclear power industry, and we can continue to use it safely for such periods of time as we are willing to supply the manpower and money needed for continuous monitoring and necessary repair of the multiple containment upon which isolation depends.

Further, technical feasibility of geologic disposal has been shown, but there is still need for certain integrated *in situ* operations with full-level radioactive waste to demonstrate all aspects of such disposal. This demonstration can be accomplished in a few decades at most, but not in time to use this disposal approach for initial management of the waste.

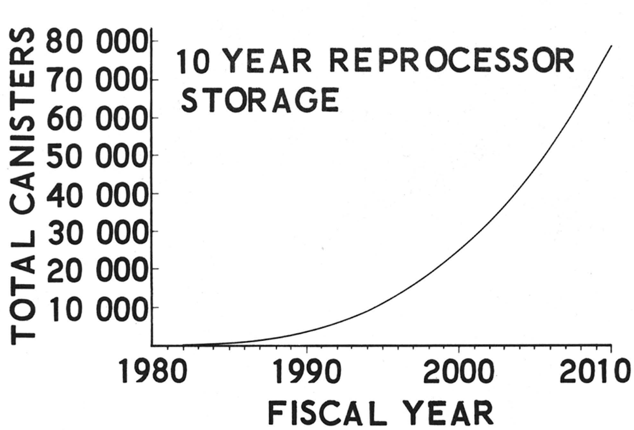


Fig. 2. Retrievable surface storage facility cumulative canisters.

In the final analysis, the only basic difference between monitored and maintained surface *storage* and geological *disposal* is that the former places reliance on continued positive action by man, while the latter relies on geologic stability for periods of time that are long when measured on human time scale, but short when measured on geologic time scales.

While I agree with those that suggest that we should not expect the human race to shoulder a burden of surveillance and maintenance for hundreds of thousands of years, I see no problem with assuming that such a burden can safely be borne by man for a few decades while the almost completely proven technology of deep geologic disposal is thoroughly demonstrated, or, for that matter, for even longer periods until some of the less well-developed technologies have advanced to the point where they can be considered.

The point I want to make is that there is no technical reason why man cannot manage waste by storage on the surface in a completely retrievable system, whose integrity can be maintained by standard proven methods for the short periods of time he needs to carry out programs to demonstrate procedures for ultimate disposal of that waste.

I will now turn to the more technical aspects of the development work we are now doing to furnish information on which the Commission can make its decisions on the program it will follow to ensure that the radioactive waste from the commercial power effort is managed safely.

First let us look at the so-called "high-level" radioactive waste that is generated from the first cycle of the spent fuel processing operation. This waste is generated as a nitric acid solution containing essentially all of the fission products and transuranics (other than plutonium) produced by exposure of the fuel in the reactor. In addition, it contains small, but significant, quantities of plutonium which do not follow the main plutonium stream because of less than perfect efficiency of the solvent extraction process.

Under Commission regulations, this acid solution must be converted to a stable solid within five years of its generation; the solid must be sealed in manageably sized stainless-steel canisters which must be delivered to the USAEC for subsequent management within ten years of the time of initial generation of the aqueous acidic waste stream. The size of the canisters will vary somewhat but will generally be in the range of 1 ft in diameter by 10 ft in length.

Figure 1 shows a schematic drawing of a canister. The 1-ft-o.d. × 10-ft-long "reference" canister will hold ~6.25 ft^3 of waste solidified by the fluid bed calcine technique. The waste in one "reference" canister would be that generated from the processing of ~3 tons of spent fuel. Thus, a 1000 MW(e) reactor would generate approximately ten "reference" canisters of waste per year under equilibrium operations. The radioactive decay of the fission products releases heat. The amount of heat in each canister will vary with exposure level of the fuel and time since its removal from the reactor. On the average, each canister will generate ~3 kW of heat ten years after it is filled. For design purposes, we have assumed 5 kW per canister.

Based on the projected growth of nuclear power, we estimate that between now and the end of the century, some 75 000 "reference" canisters will be produced. Figure 2 shows the expected delivery of waste canisters to the USAEC assuming the processor retains his waste on site for the full ten years allowed under USAEC regulations.

The total volume of waste in these canisters is <500 000 ft^3—an amount which would occupy a one-story building 200 ft on a side.

Actual storage will require between 100 and 1500 acres, depending on the storage concept selected.

For the past two years, we have been evaluating the various engineering techniques that can be used to store the solidified radioactive waste in surface facilities for extended periods of time. I will briefly review the status of this evaluation, but I must first emphasize that extended surface storage of radioactive waste material introduces

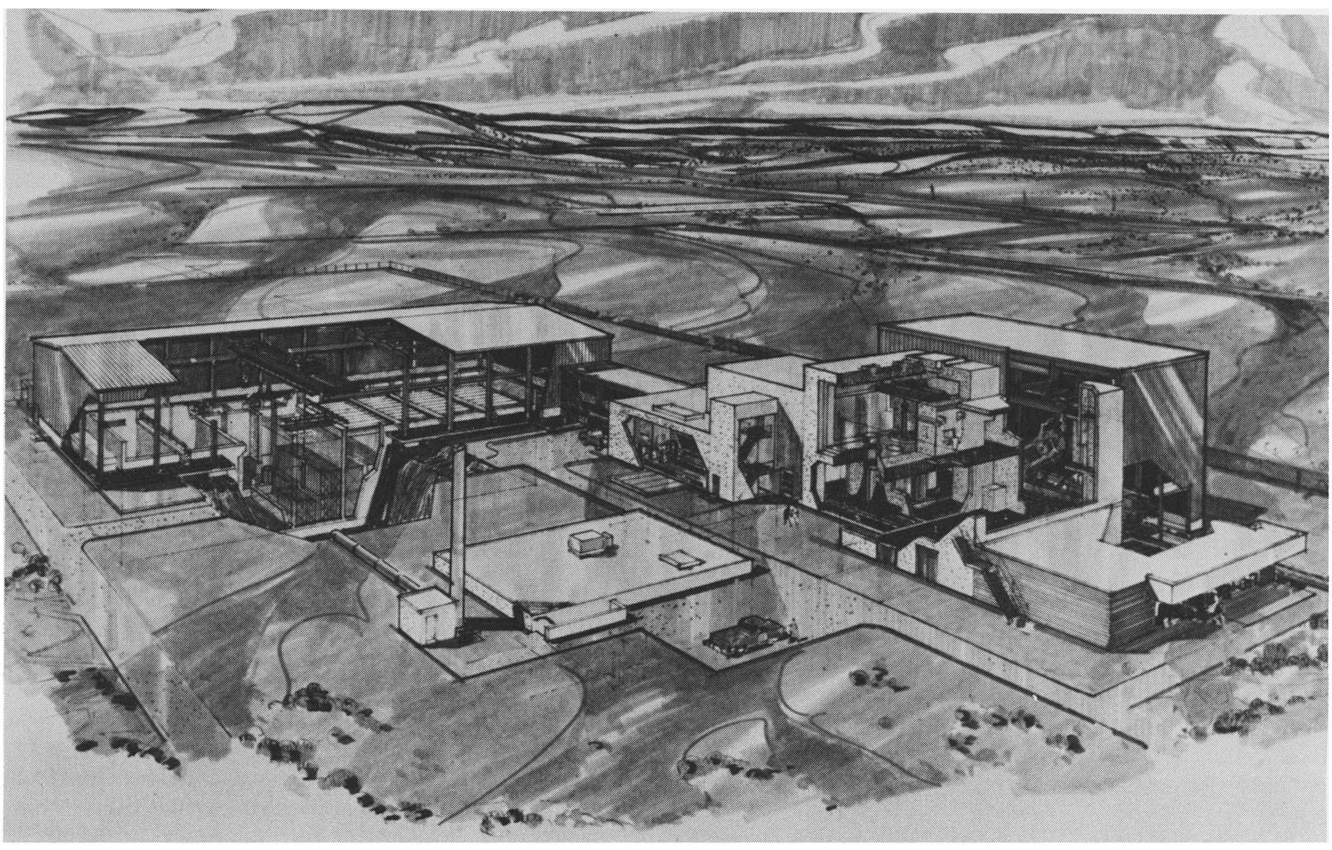


Fig. 3. Retrievable surface storage facility. Water basin concept. Cutaway view.

some problems that do not exist for short-term storage required for spent fuel awaiting processing, or even solidified waste in storage at the spent fuel processors' sites for up to ten years awaiting transfer to the USAEC. Techniques which might be perfectly acceptable for such interim storage might not be optimum or even acceptable for extended storage.

What then is required for safe extended storage of high-level radioactive waste, and how do the various concepts we have considered meet these requirements?

Simply stated, the only things we must accomplish in storage are: to prevent the radioactive waste from escaping to the environment; and to protect the operating personnel and the public from penetrating radiation during the time the radioactive material is being stored. Here, I would like to remind you that storage is passive, not an active operation.

Protection against penetrating radiation, regardless of the storage concept or its location, is accomplished by isolation, by shielding, or by a combination of the two. Standard shielding materials—concrete, steel, water, earth, uranium, lead, etc.—can be used and the choice is more or less one of economics.

The techniques for preventing the waste from escaping to the environment are also quite basic. Specifically, we must anticipate such things as (a) internal pressure buildup in the container; (b) various chemical, grain boundary, stress, galvanic, and other forms of corrosion, both internal and external; (c) weld failure; (d) excessive heat; (e) radiation damage; and (f) physical forces. The only requirement of safe surface storage is that

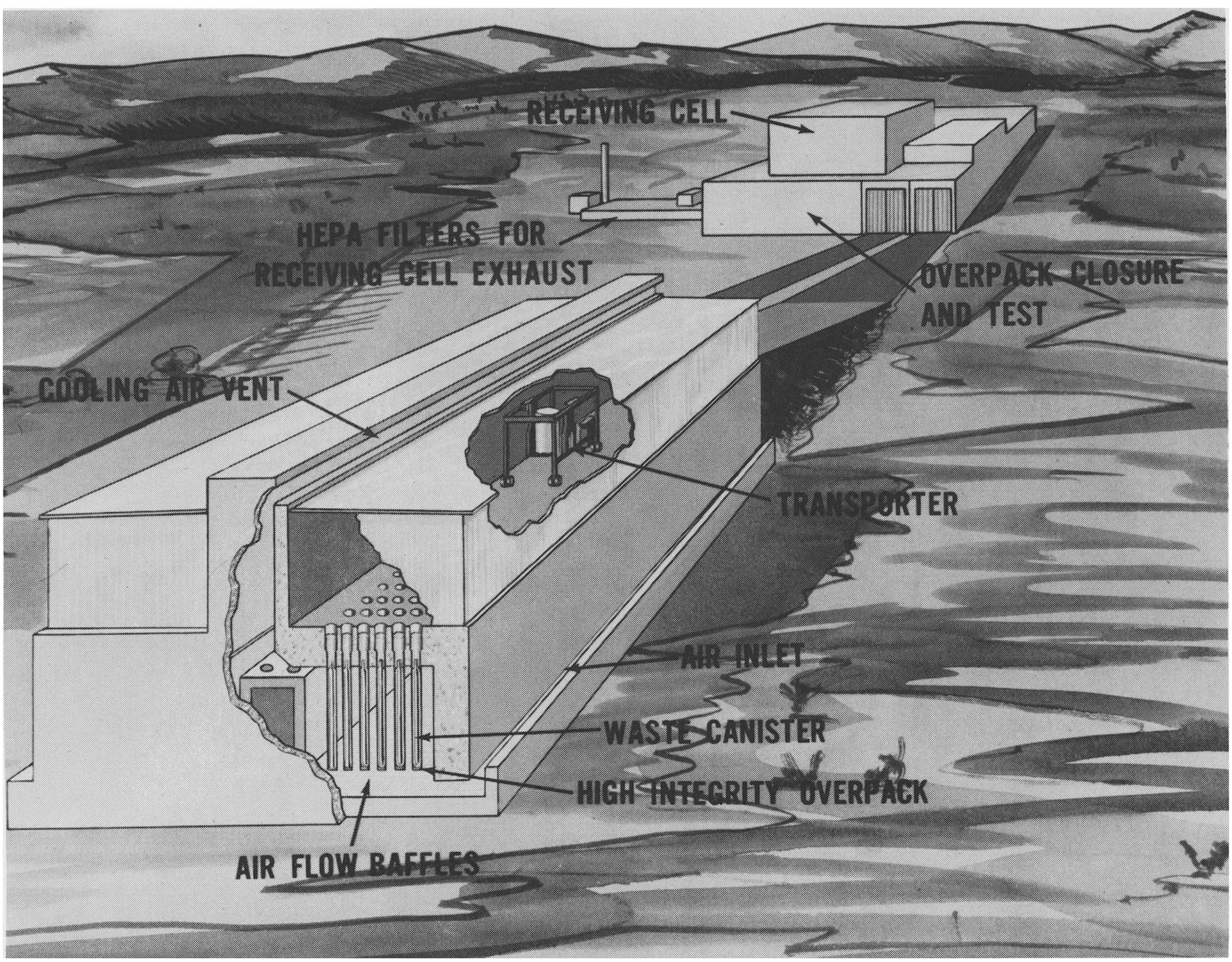


Fig. 4. Retrievable surface storage facility. Air-cooled vault concept.

escape to the environment is prevented by multiple barriers. The engineering design challenge is to ensure that when a containment barrier is breached, the system of surveillance will detect the failure in time to allow the system of maintenance to repair the breach before radioactive material has escaped to the biosphere.

When we examine the various forces which can be instrumental in barrier breach, we find that some of them result from the form of the contained waste, others from the geometry, materials of construction, quality of fabrication, and welding of the barriers themselves, others from the methods of heat removal, and still others from the characteristics of the storage site.

When we initiated our program for evaluating the various engineering options for extended surface storage, it soon became evident that there were several factors which had to be considered, each of which could have an important bearing on the safety, efficiency, and acceptability of a storage concept. In general, these are as follows:

1. method of heat removal
2. method of shielding
3. interaction of coolant and waste containers
4. reliability of mechanical equipment
5. method(s) of surveillance of waste containers
6. methods of removal of waste containers
7. methods of maintenance of waste containers and structures
8. construction and operating costs
9. vulnerability to natural or man-made catastrophic events.

A major factor is the coolant to be used to remove the heat generated by the radioactive decay of the waste. As I mentioned earlier, each canister of waste will generate in the range of 2 to 5 kW of heat when it is delivered for storage. This heat will, of course, decrease with time, essentially on a half-life of 30 years since the principal heat generators are ^{90}Sr and ^{137}Cs with half-lives in that range. For the purposes of design, planning, and evaluation, we have assumed, as I pointed out before, that the initial heat load of

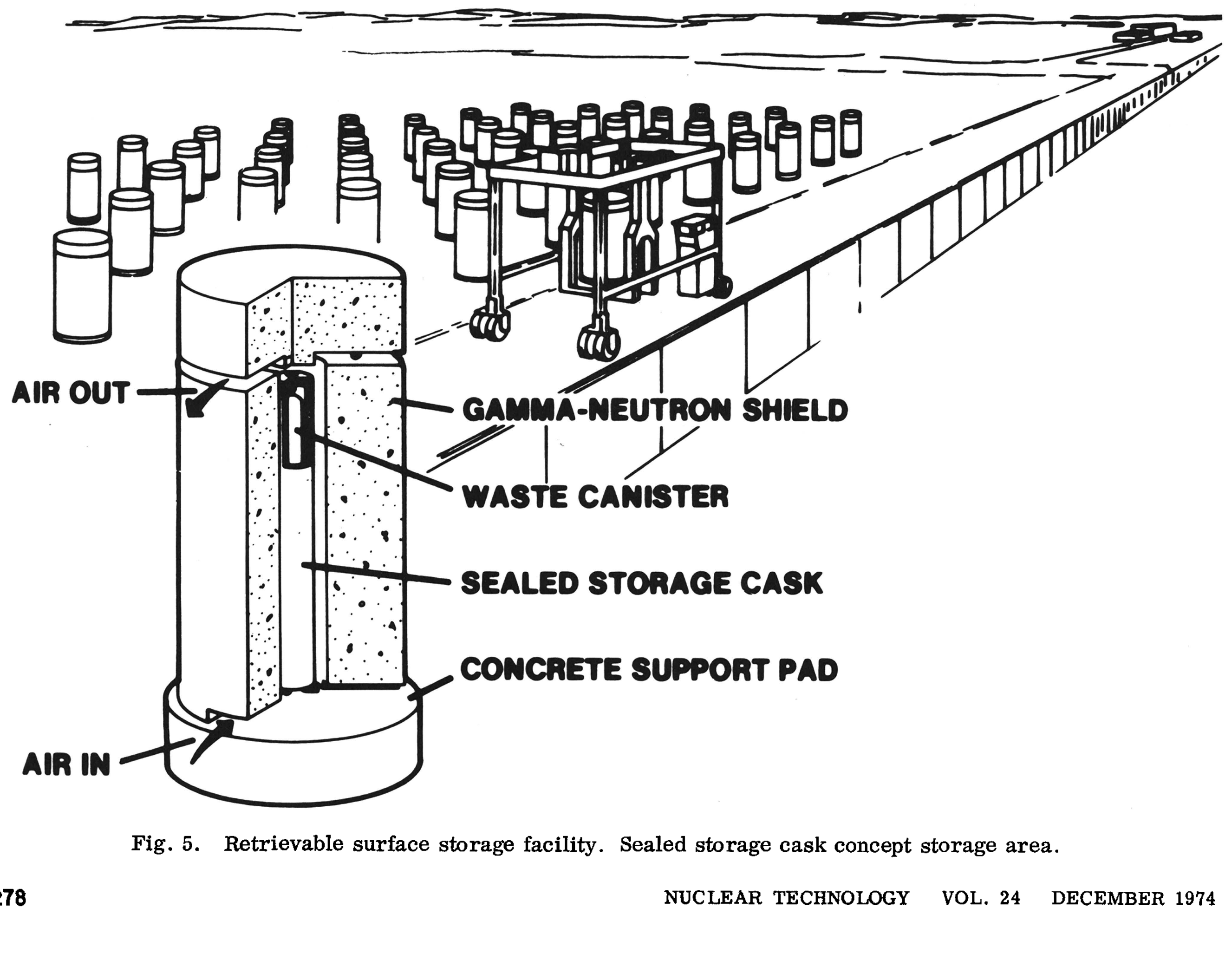


Fig. 5. Retrievable surface storage facility. Sealed storage cask concept storage area.

each reference canister (1 ft o.d. × 10 ft. long) will be 5 kW.

We evaluated both water and air coolants, and studied both mechanical and convective circulation. We examined storage of multiple canisters in modular cells or basins versus isolated storage of single canisters, and we evaluated storage of the waste in the "as-received" packages, as well as in recanned or overpacked storage containers. After preliminary evaluation of many combinations of the variables, we decided that we would make a conceptual design study of a forced circulation, water-cooled system in which 500 canisters—either "as-received" or overpacked—would be stored in steel-lined water-filled concrete modules. Each module would have its own pump, heat exchanger, and cooling tower. This concept, shown in Fig. 3, was established as the "reference design" against which other concepts could be evaluated.

We also developed a conceptual design for a modular natural-circulation air-cooled vault concept in which overpacked canisters would be stored in steel-lined concrete vaults through which air would be convectively circulated. Figure 4 shows a schematic drawing of this approach.

And, finally, we developed conceptual designs for several variations of an approach in which one to three "as-received" canisters are sealed in mild steel casks with wall thickness ranging be-

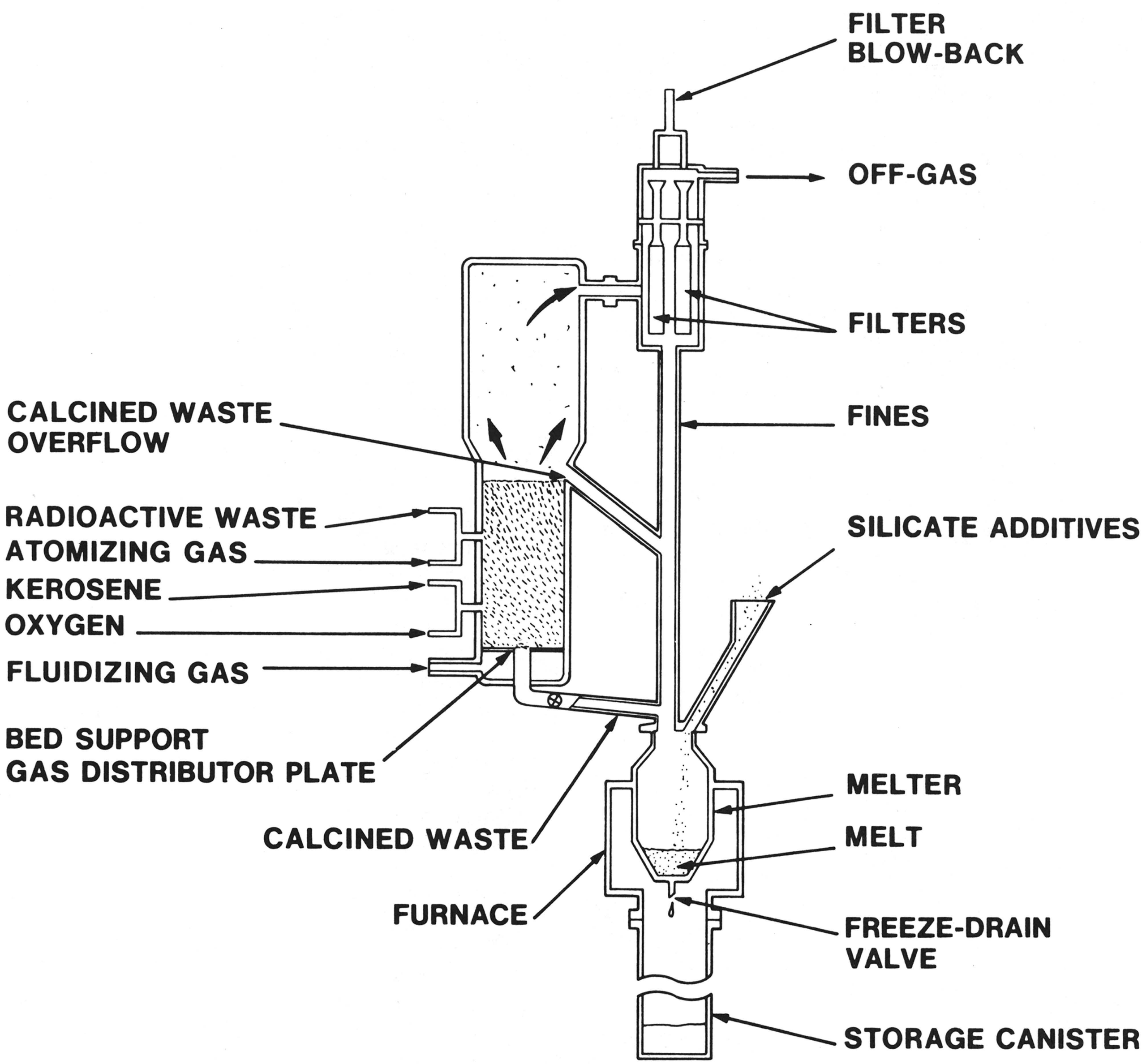


Fig. 6. Fluidized bed calciner and continuous silicate glass melter.

tween 2 and 16 in. and surrounded by concrete sleeves of a thickness to afford necessary shielding against gamma and neutron radiation. The shielded sealed casks would be individually placed on pads on the surface of the ground, and cooling would be accomplished by convective circulation of air between the concrete sleeve and the sealed steel cask. Figure 5 shows a schematic drawing of this concept, using a cask wall thickness of ~2 in. and ~3 ft of concrete shielding. Each of these concepts can ensure that waste does not escape to the biosphere.

I would like now to discuss briefly the criteria important in evaluating sites which could be considered as potentially acceptable for surface storage of high-level radioactive waste. I will not list all of the selection criteria, but I will mention the most important.

Obviously, such factors as (a) relative construction and operating cost, (b) USAEC or other government ownership, (c) distance from present and expected future locations of spent fuel processing plants, (d) geology, hydrology, seismology, climatology, and soil characteristics, (e) availability of multiple modes of transport, (f) isolation, (g) available acreage, (h) availability of power and water, and (i) availability of an adequate manpower force are all important. In addition, a factor of great importance in the final choice is the availability of facilities in which developmental, troubleshooting, and process and equipment improvement activities could be carried out, and of the scientific, engineering, and technician

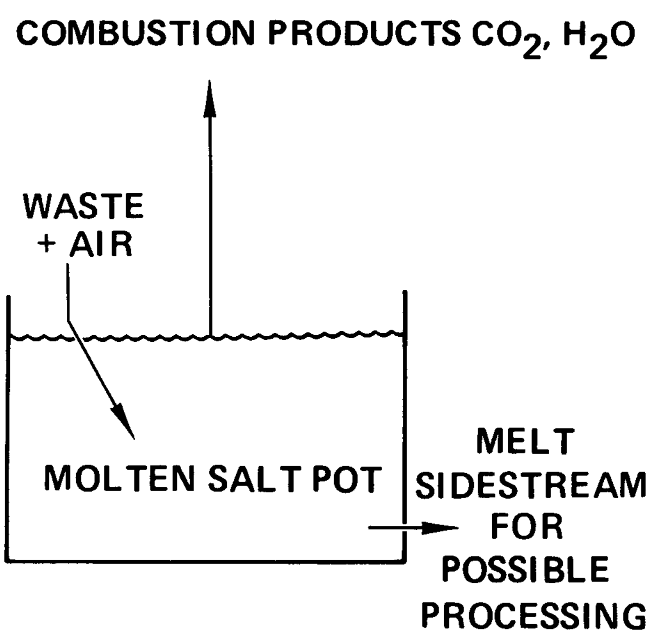


Fig. 7. Molten salt combustion disposal concept.

talents to man these facilities in programs to support the waste management activities. Another very important factor is the likelihood that other interesting and challenging nuclear activities would continue at the location to ensure long-term availability of technical and engineering support for the storage activity which in itself might not attract the high caliber of scientific and engineering talent needed to ensure continued improvement of storage techniques. And, of course, a most important factor in final choice is acceptance by the local populace and their local and regional political leaders.

I indicated earlier some of the forces which could influence the potential for breach of containment barrier. I also emphasized that extended surface storage might call for different approaches than those that could logically be used for short-term storage.

We are now carrying out experimental programs and evaluations on the extent to which the form of the solid waste which is stored retrievably on the surface for extended periods is important either because of its influence on barrier breach or because of the consequences should there be an accidental release of the waste from its containment.

Factors which are being considered are (a) the possibility of pressure buildup with time due to presence of small amounts of such things as nitrate and water in the solid waste, and (b) the probability of transport to man in the event of release due to dispersibility and leachability of the solid.

While our studies are not yet complete, we are gathering data which indicate that while the solid produced by a relatively low temperature fluid bed calcination technique is completely acceptable for short-term storage and transport, it may not be optimum for extended surface storage.

We are therefore developing technology which would allow the high-level radioactive waste to be incorporated in a glass, or other massive low leachable form, which is produced at temperatures high enough to remove all traces of nitrate, water, etc. And we are holding discussions with various segments of the industry to determine the best way to get the waste into such a form—if our work shows it is necessary—at the earliest possible time.

Figure 6 shows one method which we have used in a pilot plant operation to produce glass with up to 25% waste incorporated in the structure.

I would now like to say a few words about our recently reoriented and expanded program to develop acceptable techniques for permanent disposal, as opposed to extended surface storage, of the commercial high-level radioactive waste. As

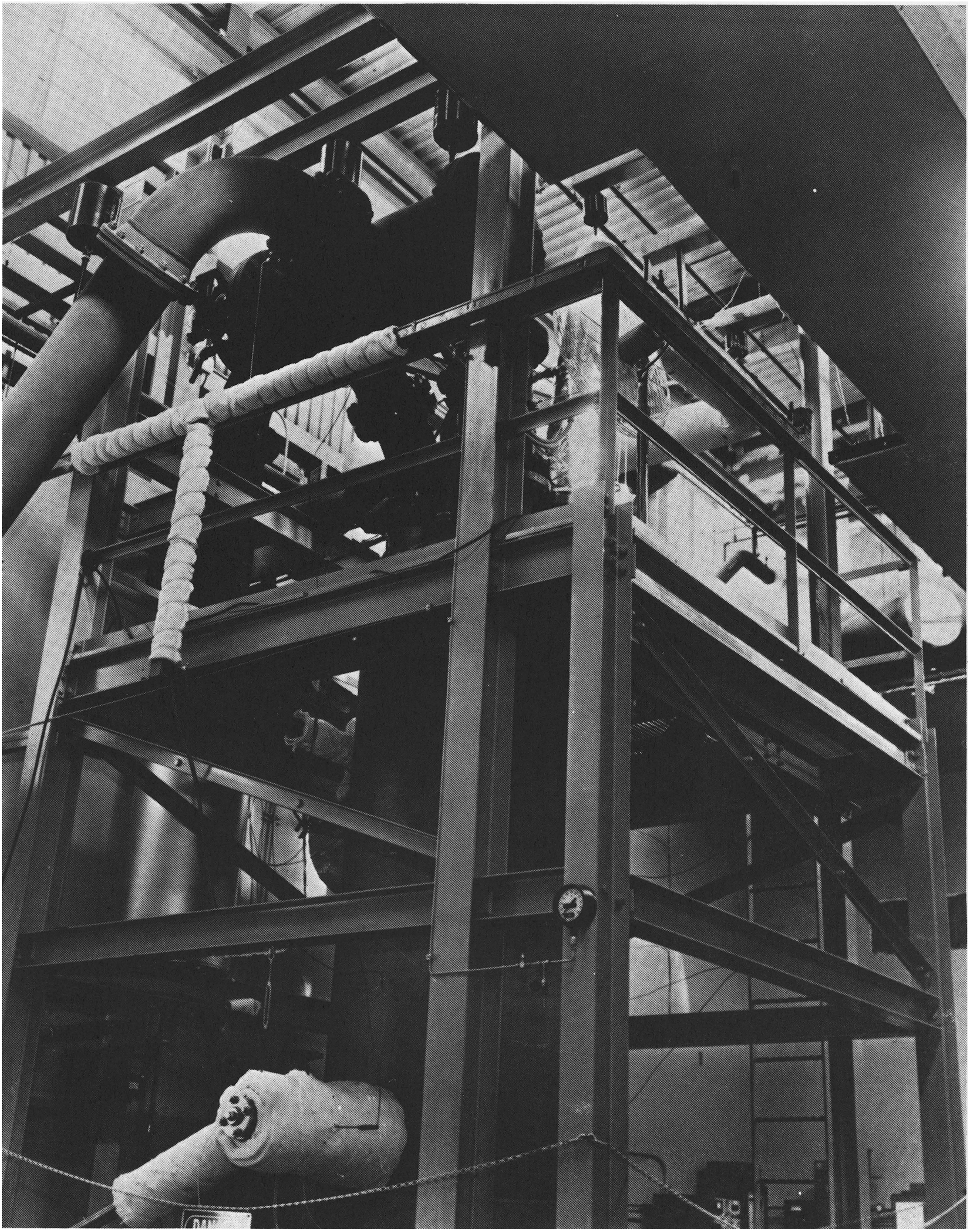


Fig. 8. Battelle waste pyrolysis burner.

we have progressed on our program for surface storage, we have become completely convinced that this approach can be used for extended periods of time to safely manage the waste, and that our R&D program on disposal in geologic formations should be expanded to include formations other than bedded salt on which all of our past effort has been expended.

As I stressed earlier, there seems to be no real urgency to develop a permanent disposal system now. We feel that we should expand our study, evaluation, and experimental effort to include other geologic formations which have characteristics that make them potentially as good as, or possibly even better than, bedded salt for this purpose. We are now analyzing such formations as granites, limestones, dolomites, shales, gneiss, schist, and mudstones, as well as domed salt and salt anticlines, to establish a more extensive program of investigation. Using the techniques which we developed in connection with our bedded salt work, we would bring our knowledge on one or more of these formations to the same point as that on bedded salt. This would allow us in a few years, to select a program for the *in situ* pilot emplacement of waste in a formation which has

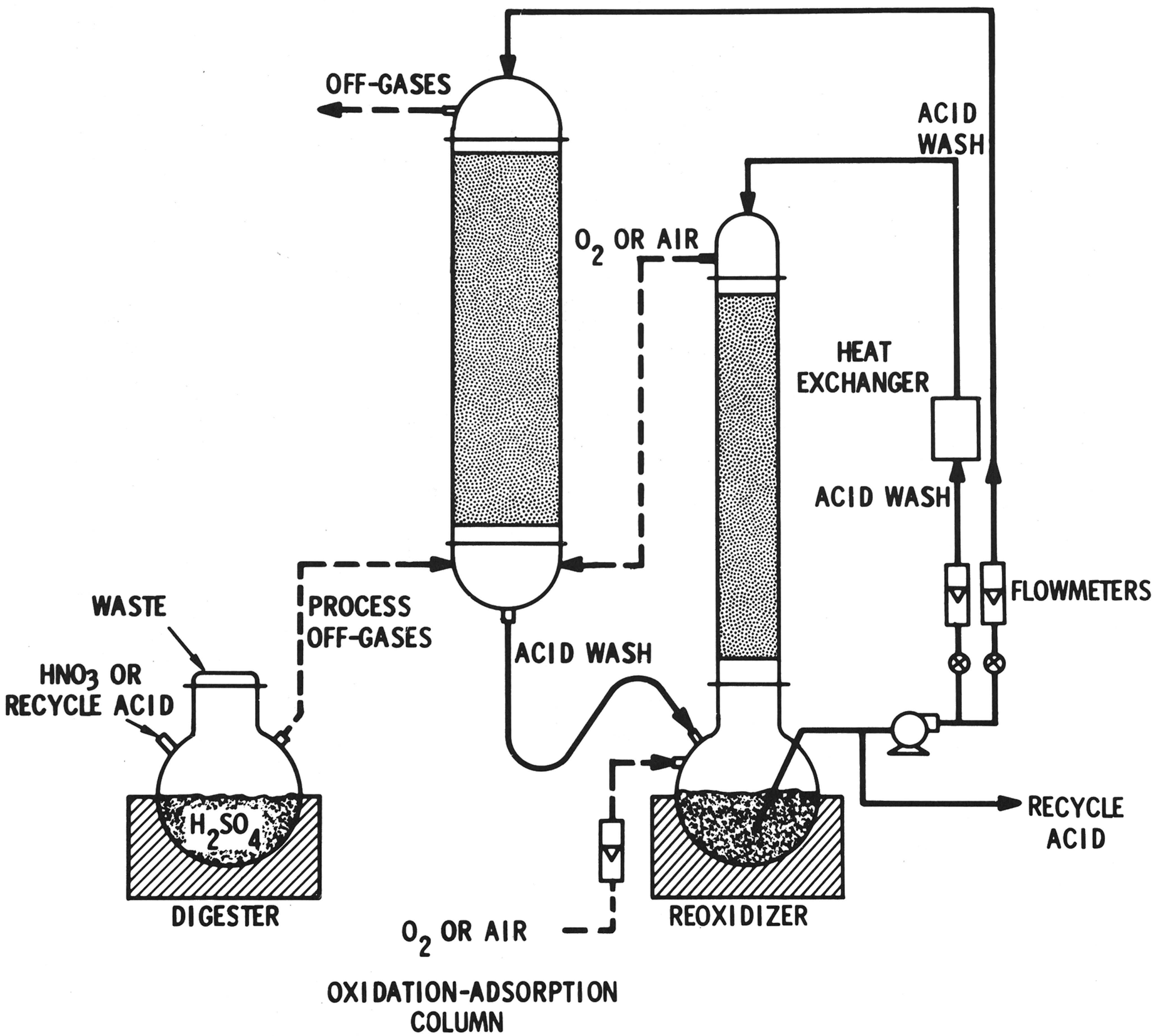


Fig. 9. Acid digestion pilot plant.

been shown, by a comparative analysis of experimental data rather than by well-founded, but subjective, judgment, to be the best for disposal of radioactive waste.

Another point of interest is that, in addition to our efforts to develop surface storage and evaluate geologic formations for permanent disposal, we are also studying advanced disposal concepts. A comprehensive study of a host of alternative long-range methods for managing high-level waste has been completed for the Commission by Battelle Northwest Laboratory. The study discusses three basic types of management: disposal in the earth, extraterrestrial disposal, and transmutation. A four-volume report of the study has received wide public distribution.[2] A synopsis of this study, written for broad public understanding, has also been issued. In this continuing program, we plan to (a) determine whether we should initiate specific developmental projects related to one or more of the promising long-range disposal concepts to further evaluate their feasibility and economic practicality for application, (b) investigate systems for long-term management of other radioactive waste materials, and (c) initiate studies to identify and plan for the management of waste from new power producing reactor systems, including the HTGRs and LMFBRs and the controlled fusion systems.

To this point in my discussion, I have limited my remarks to commercial high-level waste. I would now like to say a few words about those other radioactive wastes which will be generated by the nuclear industry and which will either contain or be contaminated with significant quantities of transuranium nuclides such as plutonium.

As I mentioned at the beginning of this paper, this category of radioactive waste will be covered

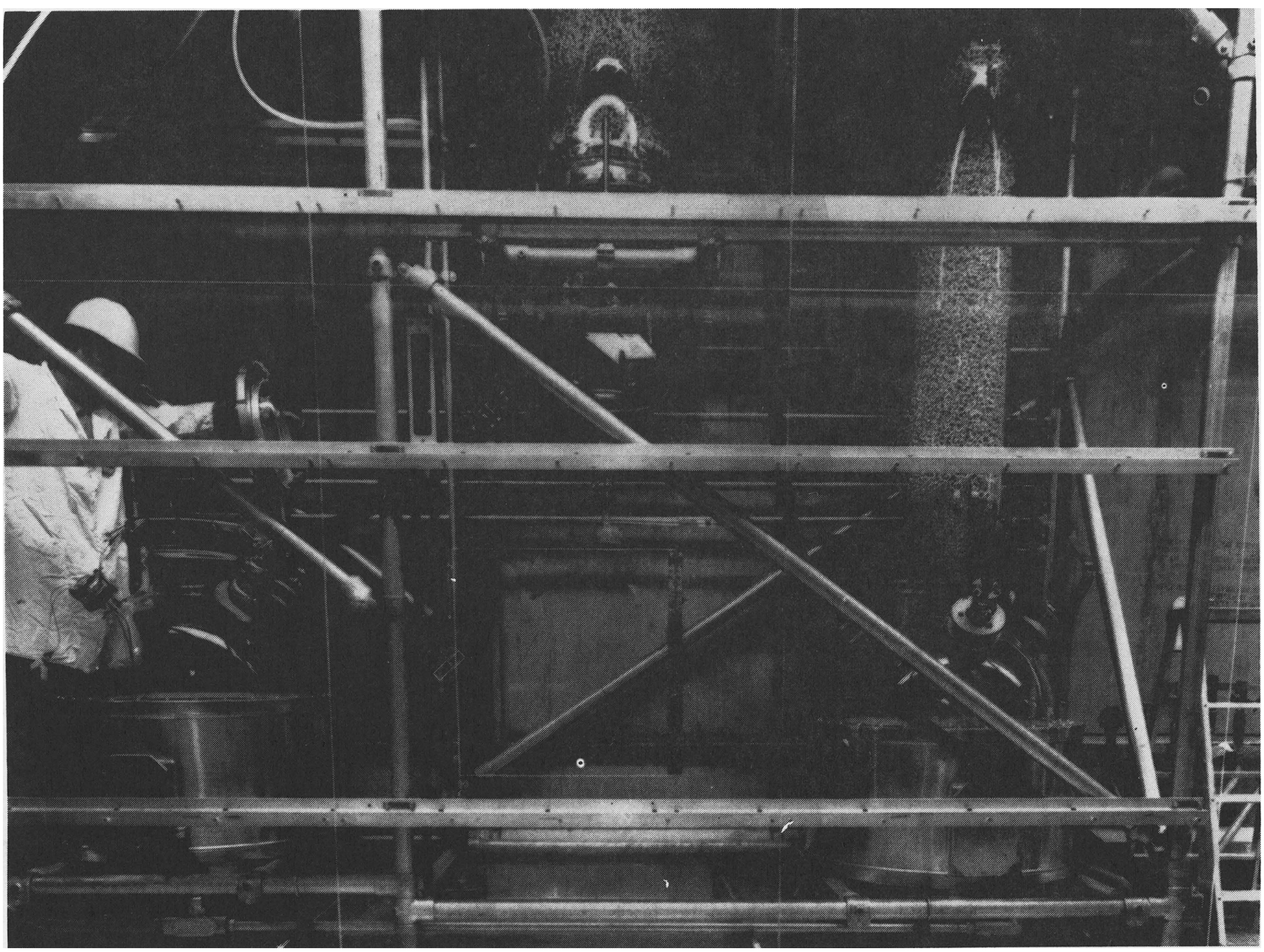


Fig. 10. Acid digestion pilot plant during assembly.

in detail in the environmental impact statement, and I will only mention here a few important factors which must be considered in developing the management techniques to be applied to such waste.

First, transuranic waste arises from several operations in the nuclear fuel cycle. The hulls and cladding material produced by the "chop-leach" technique used in the processing of spent reactor fuel fall in this category, as do most of the other waste streams generated by the spent fuel processing operation. In addition, the fabrication operations used in the preparation of plutonium bearing fuels for recycle in water reactors or fast breeders generate various waste products which are contaminated with small but significant quantities of plutonium.

Second, the major activity of the transuranium wastes is long-lived alpha, but some waste streams in this category also have small amounts of fission products and, in some cases, induced radioactivity.

Third, the volume of the transuranic waste will be much larger than that of the solidified high-level waste, and its composition and form as produced will be highly variable. Some will be mixed with rags, paper, plastics, protective clothing, and other combustibles. Some will be in the form of small and large tools and contaminated equipment. Some will be in the form of solids produced by evaporation and calcining.

Further, the penetrating radiation and heat levels of this category of waste will be very low compared to those of the high-level waste, but will in some cases be high enough to require special handling in storage or disposal.

And finally, in the long-term, the management problems for this category of waste are the same as for the high-level waste since after a few hundred years the radionuclides of the high-level

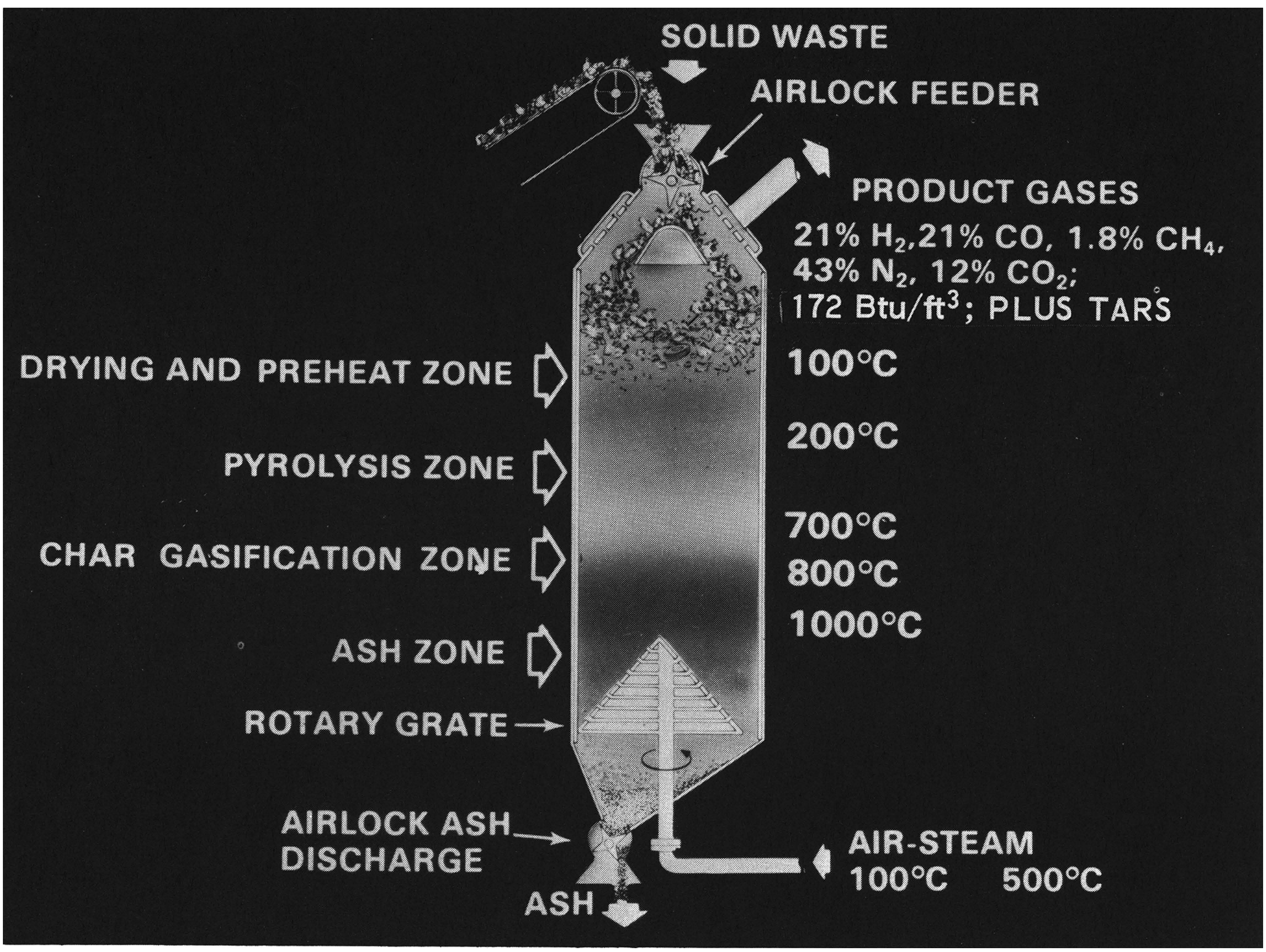


Fig. 11. Schematic drawing of Battelle gasification process.

waste, other than the transuranics, have decayed to the point where further control is no longer necessary and the continued long-term problem of the two is the same.

One of the major technical problems in the management of transuranic waste is reduction of the volume in which it is contained to a level which makes its management somewhat simpler. This is not to say that the volume is so large as to be a "land-use problem," but only that it is not technically logical to manage large volumes if they can be reduced.

One of the instances where volume reduction can have a real impact is the waste which has resulted from slight contamination of large amounts of combustible material. Here we expect to be able to reduce the volume by a factor of 100 or more. We have a program of developing the safest and most efficient methods for "incinerating" such waste. Figures 7 through 11 show the basis of each method and the current status of our program to demonstrate the method.

Volume reduction of contaminated tools, equipment, hulls, and other solid material can probably not be as drastic as for the combustibles, but we are working on methods for removal of contamination to the point where storage or disposal of the equipment is not necessary, and we are looking at the feasibility of physical compaction to reduce volume.

The management of transuranic waste will probably involve three phases: (a) interim storage, (b) treatment, repackaging, and extended storage, and (c) ultimate disposal by the same techniques that will be used for the high-level radioactive wastes. As I mentioned before, the problems of heat and radiation during in-term extended storage are such that techniques for such storage can be used which are different from those used for high-level waste.

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