EG&G Idaho, Inc.

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# INTERNAL TECHNICAL REPORT

Title: Final Report: Task Force Evaluation of TRU Waste Retrieval Methods

Organization: Waste Management Program

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NOTICE





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# FINAL REPORT:

# TASK FORCE EVALUATION OF TRU WASTE RETRIEVAL METHODS

EG&G Idaho, Inc.

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Prepared for:

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DEPARTMENT OF ENERGY
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## SUMMARY

A task force review of the concepts for removal of buried TRU waste at INEL was performed at the request of the DOE. This task force, composed of members from outside the EG&G Waste Management Division, was selected for their particular expertise applicable to retrieval of buried TRU waste.

The application of a figure-of-merit procedure to provide an orderly evaluation was selected. The conclusion of the task force was that the design concept submitted by FMC corporation for a mechanized retrieval system has the highest potential of satisfying the requirements for safe removal of the 2.5 million $ft^3$ of buried waste before the year 2000 at a reasonable cost. Recommendations for further design improvements, investigative work, and studies are provided.

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TASK FORCE ON TRU WASTE RETRIEVAL

# 1.0 INTRODUCTION

## 1.1 PURPOSE

The retrieval task force was formed at the request of the manager, Waste Management Division, to provide an independent evaluation of conceptual designs of systems to retrieve the buried transuranic (TRU) wastes at the Radioactive Waste Management Complex (RWMC) located on the Idaho National Engineering Laboratory (INEL) site. This evaluation was to identify the conceptual design that should be pursued as well as any problem areas needing resolution before entering into any design phase.

## 1.2 TASK FORCE MEMBERS

A task force consisting of personnel not directly associated with the waste management activities was convened. The membership of the task force consisted of the following:

H. M. Burton, Chairman, EG&G Project Management Division
C. W. Bills, EG&G, Management Staff
J. R. Fielding, EG&G, Safety Division
J. S. Schofield, Allied Chemical Corporation
J. Warren, Los Alamos Scientific Laboratory
C. Wickland, Rockwell - Rocky Flats
*W. J. Whitty, Los Alamos Scientific Laboratory

The members of the task force have over 50 years of experience directly related to the task of TRU waste retrieval and were specifically selected because of this experience. Brief resumes of task force members are provided in the Appendix.

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*Consultant on evaluation methods.

## 1.3 TASK FORCE ACTIONS

The task force held three meetings to fulfill the subtask assignments outlined in Reference 1. The first meeting initiated task force action with a review of materials and establishment of assignments. A figure-of-merit (FOM) procedure was selected for use by the task force in evaluating concept designs. Evaluation criteria were selected and are presented in Section 3.0.

The second meeting was held in San Jose, California, to acquaint the members with the FMC and Kaiser Engineers (KE) conceptual designs and to allow first-hand questioning of those who did the design work. Ranking and weighting of the evaluation criteria presented in Section 3.0 were completed. This ranking and weighting are presented in Section 4.0.

The final meeting of the task force was held to allow each individual to present the results of his evaluations of the candidate process designs for a given evaluation criteria. These evaluations are presented in Section 5.2. Following the formal meetings, each task force member reviewed the results, presented comments, and identified specific items of concern for further consideration by the Waste Management Division.

## 1.4 OBJECTIVE OF RETRIEVAL OPERATION

The objective of the retrieval operation, to which the task force efforts were addressed, was to retrieve and package for onsite processing, 70 800 $m^3$ (2,500,000 $ft^3$) of buried TRU and intermixed beta-gamma waste and associated contaminated soil at RWMC before the year 2000 safely and at reasonable cost.

## 1.5 SUMMARY OF FINDINGS

Based on the methods employed by the task force, the design concept submitted by FMC Corporation for a mechanized retrieval system has the highest potential for satisfying the retrieval objectives (see 1.4). Table 1 shows the total FOM rankings for the design concepts studied. Detailed FOMs for each of the main evaluation criteria considered are given in Table 24 (Section 6.0).

TABLE 1

| System | Corporation | Total FOM |
|---|---|---|
| FMC Mechanized | FMC Corporation | 0.71 |
| KE Remote | Kaiser Engineers | 0.59 |
| FMC Remote | FMC Corporation | 0.58 |
| Retriever 1 | -- | 0.55 |
| ACC Manual | Allied Chemical Corporation | 0.53 |
| KE Manual | Kaiser Engineers | 0.49 |

## 2.0 TECHNIQUE OF CONCEPT EVALUATION

Every evaluation method needs one or more criteria by which characteristics of potential alternatives can be compared. In a formal evaluation, criteria that represent the major areas of importance or concern need to be well defined. The next step is to link the properties or characteristics of alternatives with the evaluation criteria. This is done by selecting performance measures which, for any particular alternative, will be expressed as numbers, called levels of performance.

An example will clarify these concepts. If the objective is to reduce the volume of waste being processed, then a criterion would be the effectiveness of the process in reducing the volume of waste. The performance measure selected could be the volume reduction factor, which is the ratio of the original waste volume to the final volume. A particular process under evaluation might have a volume reduction factor of 25 to 1, which is the level of performance.

For multiple criteria decision problems, the performance measures usually have dissimilar units. For example, another performance measure could be the percent downtime. A method must be selected for relating the different units of the performance measures to a common unit of measure. In many cases, the actual worth of a particular level of performance is not the number itself, but a subjective value judgment made by the evaluator. Thus, for different people, the perceived value, called worth, may be different. The relationships between levels of performance and performance worth are usually called value functions in decision problems where uncertainty is not taken into account. (They are called utility functions in decision problems under uncertainty.) The transformation of the performance measures to performance worth by the value functions places all performance measures on a common unit of measure. The worth of different levels of performance can be combined to produce a single scalar of overall system worth.

In this project, the worth of a system is called the figure-of-merit (FOM) of the system. It is assumed to be a function of the performance measures and is represented by

$$FOM = U(X_J \mid j = 1, \ldots, m) \tag{1}$$

where U is a function of the m performance measures, $X_j$. The numerical values of the performance measures, the levels of performance, can be displayed in vector form

$$x = (x_1, x_2, \ldots x_m. \tag{2}$$

It is assumed that, for all practical purposes, the set of performance measures adequately satisfies the set of criteria, and the vector X can be specified.

The procedure used to compute the FOM is to partition the component problem into m one-component problems, with each being easier to solve than the original, and then to combine the m solutions. The foundation of the procedure is a linear additive model of the form

$$FOM = \sum_{j=1}^{m} w_j \, u_j(x_j) \tag{3}$$

where $u_j(x_j)$ is the one-dimensional worth of a particular level of performance; $x_j$ and $w_j$ is a positive scaling constant. The $w_j$'s, called weights, express the relative importance of the criteria to the overall FOM. The $x_j$'s, $u_j(x_j)$'s, and $w_j$'s are numbers. The choice of the range of the $w_j$'s and $u_j(x_j)$'s is arbitrary, but it is convenient for them to be

$$0 \leq U_j \, (x_j) \leq 1, \tag{4}$$

$$0 < w_j < 1 \quad \text{for} \quad j = 1, \, .., m \tag{5}$$

and

$$\sum_{j=1}^{m} w_j = 1 \text{ (Whitty, 1978).} \tag{6}$$

The constant-sum method (Torgerson, 1958)[2] was selected for calculating criteria weights. In this method, one hundred points are distributed between every pair of criteria and a set of weights is produced by appropriate arithmetic operations. The constant sum method uses m(m-1/2) evaluations whereas only m-1 are needed to construct the weights. However, all estimates are used to check for inconsistencies and to calculate composite scale values. The scale values are given by

$$s_j = \text{antilog}\left(\frac{1}{m}\sum_{\substack{k=1 \\ k \neq j}}^{m} \log[(P_{jk} /(100 - P_{jk})]\right) \qquad (7)$$

where $P_{jk}$ is the number of points assigned to criterion j when compared to criterion k. The scale values are normalized to produce the weights by

$$s_j = \frac{s_j}{\sum s_k}, \; j, \; k = 1, \ldots, m \qquad (8)$$

With the weights established, the evaluation scheme can be completed by constructing value functions relating levels of performance to worth of performance. To construct a value function, an evaluator uses a sheet of graph paper to sketch a curve that represents his judgments about the worth of performance for various levels of performance. Equation (4) is interpreted as meaning that the least preferred or worst level of a performance measure is equal to zero and the best level is set to one. With the end points or range of a performance measure established, the evaluator must estimate enough coordinates so that a graph can be constructed. (For more detail, see references 1, 3, 4, and 5.)

When an evaluator is completing a graph, it is important that he consider only the performance measure at hand. If two or more performance measures are varied at the same time, the independence of the value functions will be suspect. If the value functions are not independent, then the additive formula (Eq. (3)) is not valid.[6], [7] Value independence means that an evaluator's preferences for a specific level of one performance measure do not influence his preferences for levels of any other measure. (Keeney[8] calls this preferential independence.) Yntema and Torgerson[9] found that dependencies may not significantly affect the ordering of alternatives but may distort their overall worths (FOM's). Miller[5] and Gustafson, et al,[7] advocate eliminating performance measures only where substantial interactions occur. Careful attention given when the criteria and performance measures are defined can eliminate many problems. Further precaution when the value functions are being drawn can minimize the effects of interactions. This project had no major dependencies but several minor ones were indicated by the individuals when they were preparing the value functions.

## 3.0 EVALUATION CRITERIA

The evaluation criteria and their definitions are provided below:

(1) Effectiveness is a measure of the system's ability to provide the waste in a suitable temporary container for disposal or processing while minimizing the volume to be processed and maximizing the production rate.

(2) Operability is the level of operational complexity in terms of visability, mobility, dust and contamination control, facility movement, and human factors.

(3) Health and Safety is a measure of the degree of protection to the operating personnel from radiation, contamination, and physical and chemical hazards in accordance with codes, standards and regulations, and "as low as practicable" guidelines. The ability to prevent or mitigate the consequences of unusual occurrences is a consideration.

(4) Availability is the fraction of time the system is capable of performing its intended function. This includes consideration of system maintainability, reliability, and ease of decontamination.

(5) Flexibility is the ability to retrieve and package variable waste forms to ensure contamination and exposure control while maintaining an acceptable production rate.

(6) Project Risk is a measure of the ease to technically meet the requirements of the system, including development, design, manufacturing, and testing.

(7) Resource Use is a measure of the capability to optimize consumption of significant regional energy and nonrenewable materials and to restrict use of excessive skilled manpower requirements.

It is important to note that the definitions are strictly applied in this study to prevent evaluation of different concepts to variable criteria which may have served as the basis of design.

## 4.0 RANKING AND WEIGHTING CRITERIA

After the main criteria and performance measures were defined, each task force member ranked the criteria. The Kendall Coefficient of concordance,[10] a standard statistical measure of the overall agreement among members in ranking items, was used to determine if a group consensus existed. A significant value for the coefficient suggests that there is reason to believe that there is agreement among the members. If there is agreement, then the best estimate of the correct group ranking is given by the order of the sums of the rank.[10], [11] The coefficient was significantly different from chance at higher than the 0.01 level. (See Kendall,[10] or any statistics book for an explanation of significance levels.) Since there was group agreement, the constant-sum method was used by each task force member to determine weights for the seven main criteria. It should be mentioned that individual rankings of the main criteria changed slightly as the project progessed. However, in each case there was group agreement beyond the 0.01 level. The final ranking produced, by far, the highest degree of agreement.

In addition to group agreement, it was necessary to check for transitivity of individual and group rankings. Transitivity means, basically, that the ranking is valid because if criterion A is more important than criterion B and if B is more important than C, then criterion A is more important than criterion C. For a discussion on transitivity, see Fishburn.[12] The paired comparisons produced by the constant-sum method used to verify that each evaluator was behaving transitively. Paired comparisons, using all individual ranks and majority rule, showed that the group ranking was also transitive. Because there was group consensus and the rankings were transitive, the main criteria weights were averaged to produce a set of weights for the group. The final set of group weights for the main criteria is presented in Table 2.

TABLE 2

MAIN CRITERIA WEIGHTS

| Criteria | Weights |
|---|---|
| Effectiveness | 0.21 |
| Operability | 0.19 |
| Health and Safety | 0.17 |
| Availability | 0.14 |
| Flexibility | 0.13 |
| Project Risk | 0.09 |
| Resource Use | 0.07 |
| TOTAL | 1.00 |

It was elected to assign specific individuals the task of determining certain subcriteria weights and value functions. The individuals assigned these tasks presented a written description of their reasoning to all task force members. These descriptions were discussed in detail and the weights and value functions were modified where appropriate. The group participation had a direct influence on the final subcriteria weights and value functions. Subcriteria weights are given in Tables 3 through 9, and the value functions are provided in Section 5.2.

TABLE 3

SUBCRITERIA FOR EFFECTIVENESS

| Criteria | Weights |
|---|---|
| Rate | 0.60 |
| Volume | 0.40 |
| TOTAL | 1.00 |

TABLE 4

SUBCRITERIA FOR OPERABILITY

| Criteria | Weights |
|---|---|
| Mobility | 0.22 |
| Visibility | 0.18 |
| Human factors | 0.18 |
| Facility movement | 0.18 |
| Contamination control | 0.18 |
| Dust Control | 0.06 |
| TOTAL | 1.00 |

TABLE 5

SUBCRITERIA FOR HEALTH AND SAFETY

| Criteria | | Weights |
|---|---|---|
| Protection during routine operations | | 0.80 |
| Contamination control | 0.60 | |
| Physical hazards | 0.20 | |
| Radiation protection | 0.10 | |
| Chemical hazards | 0.10 | |
| TOTAL | 1.00 | |
| Unusual occurrence | | 0.20 |
| Prevention of unusual occurances | 0.90 | |
| Mitigate the consequences | 0.10 | |
| TOTAL | 1.00 | |
| TOTAL | | 1.00 |

TABLE 6

SUBCRITERIA FOR AVAILABILITY

| Criteria | | Weights |
|---|---|---|
| Equipment | | 0.50 |
| Maintainability | 0.33 | |
| Reliability | 0.33 | |
| Ease of decontamination | 0.34 | |
| TOTAL | 1.00 | |
| Facility | | 0.50 |
| Maintainability | 0.33 | |
| Reliability | 0.33 | |
| Ease of decontamination | 0.34 | |
| TOTAL | 1.00 | |
| TOTAL | | 1.00 |

TABLE 7

SUBCRITERIA FOR FLEXIBILITY

| Criteria | | Weights |
|---|---|---|
| Variable waste forms | | 0.40 |
| Size | 0.34 | |
| Shape | 0.33 | |
| Weight | 0.33 | |
| TOTAL | 1.00 | |
| Retrieve and package | | 0.35 |
| Discriminate | | 0.15 |
| Depth | | 0.10 |
| TOTAL | | 1.00 |

TABLE 8

SUBCRITERIA FOR PROJECT RISK

| Criteria | Weights |
|---|---|
| Degree of complexity | 0.50 |
| Degree of modification | 0.50 |
| TOTAL | 1.00 |

TABLE 9

SUBCRITERIA FOR RESOURCE USE

| Criteria | Weights |
|---|---|
| Skilled manpower | 0.34 |
| Nonrenewable resources | 0.33 |
| Regional energy use | 0.33 |
| TOTAL | 1.00 |

# 5.0 PROCESS DESIGN EVALUATION

This section describes the process concepts evaluated by the task force and presents the results of these evaluations.

## 5.1 CANDIDATE PROCESS CONCEPT EVALUATIONS

Brief descriptions of the process concepts considered by the task force are provided in this subsection. The order presented is in increasing mechanization or automation. Only concepts for which at least conceptual design was completed, or could be extrapolated, were considered, since the task force had insufficient time to develop new concepts or combinations of existing concepts.

### 5.1.1 Allied Chemical Corporation (ACC) Manual Retrieval System

A number of "manual" retrieval options are described by R. A. Brown, 1975[13] which center around the same basic type of waste retrieval operation--a combination of unskilled labor plus one or more backhoe units--but vary as to building design. The concept discussed below as the "manual process for retrieving buried waste at the RWMC" is basically an expansion of the Early Waste Retrieval (EWR) process, but upgraded where necessary to allow feasible operation on a production basis.

#### 5.1.1.1 Building Design

The basic criterion for building design is to provide a double containment system for the retrieval process. To meet this requirement, the options listed in reference[13] include both buildings inside of other buildings and double wall facilities.

In the former category the options considered are: (a) an air support building surrounding a metal siding type retrieval building (similar to the EWR concept), (b) a quonset hut on rails surrounding a smaller enclosed space, or (c) a large metal siding building surrounding a smaller but similar building. In the double wall facility category there are both large and small double wall metal siding buildings.

The building design selected for task force evaluation of a "manual" retrieval process is a double wall unit similar in size (150 x 250 ft) to the FMC retrieval building. Hanging inner partitions are used to localize contamination spread to the immediate working area as much as possible. This is a modification of one of the options described in reference[13] and was selected to allow comparison of a "manual" retrieval mode with the remote FMC approach, without building factors influencing the comparison process.

The building will be maintained on rails spanning an entire waste pit or series of trenches and moved using several tractors. Movement will be required once or twice a year. The building skirt is sealed to the rail except when the building is being moved, to prevent potential contamination escape to the atmosphere.

#### 5.1.1.2 Waste Retrieval Method

An excavation will be made part or all the way across the building width. Each side of the working face will be isolated from the building environment by a flexible hanging curtain. The curtain in front of the work face will have partitions to allow passage of men and equipment, while the curtain to the rear of the work face will be solid. Waste is retrieved by three or four backhoes located between the working face and the flexible curtain working down from above. Work is done in conjunction with three or four bubble-suited unskilled laborers per backhoe. The laborers aid in the retrieval process by excavating around buried waste containers or aiding the retrieval process as necessary to minimize contamination releases and removal of noncontaminated soil.

Removed waste and soil is placed in recyclable containers or consumable cardboard boxes. Containers are passed through the partition by monorail to a pass-through at the far end of the building. There the containers are loaded onto a truck for transport to a waste treatment facility.

Backfilling the excavated hole is accomplished by placing fill material in back of the solid curtain as the working face is advanced down the length of the building. Fill material is brought into the building by dumping through a hopper or entering the end of the building to the rear of the working face. A bulldozer within the building is used to perform the actual backfill operation.

Building ventilation is provided by blowers drawing air through several parallel banks of roughing and HEPA filters. It is assumed that the filter inlet(s) will be located adjacent to the working face so that all air flow will be into the area bounded by the two curtains. Recirculating electrostatic precipitators can be used to aid in reducing airborne contamination and dust levels. Water sprays or addition of an organic binder to the soil and/or waste surface will further reduce dusting and contamination problems.

### 5.1.2 Kaiser Engineers (KE) Manual Retrieval Process

This process, described in detail in a report,[14] is a slight increase in mechanization over the ACC manual retrieval system.

#### 5.1.2.1 Manual Retrieval Enclosure

The KE manual retrieval enclosure consists of a mobile, double-walled aluminum, dome-roof structure, approximately 150 ft diameter and 120 ft high, using successively reduced pressures for air in-leakage to prevent the escape of contaminants to the environment.

Two double-walled production airlocks, a vehicle airlock, one personnel airlock, and an emergency exit will be provided through the enclosure walls. The production airlocks will be fitted with machinery to automatically move waste transfer containers into and out of the enclosure. The vehicle airlock will be removable from the enclosure and used only to move the retrieval equipment into and out of the enclosure for maintenance purposes. The personnel airlock will be fitted out as a ready room and will provide space for backup personnel.

Support auxiliaries such as power, compressed air, instrumentation, etc., are supplied from trailers and are connected to the enclosure through one central connecting panel.

5.1.2.2 Equipment

Portable, custom-designed equipment and instruments, as described in the following paragraphs, will be used for excavation and waste retrieval, sorting and testing of soil according to contamination levels, loading soil and waste into special waste containers, and moving containers through the production airlocks into the transport vehicle.

Personnel working within the retrieval facility will wear specially designed "bubble-suits". An hydraulically operated, self-propelled, telescoping boom crane will be provided. The end of the boom will be equipped with an adaptor which can accept either clamshell buckets or grapples. The grapples will be used for handling drums and boxes of waste, and the clamshell bucket will be used for excavating and handling soil and loose waste.

A rough terrain, battery-powered forklift will be provided to transfer boxes of waste from the excavation to the production airlocks.

A vehicle turntable equipped with portable ramps will be located immediately inside the vehicle airlock and will facilitate the removal and reentry of the excavating equipment for maintenance purposes.

Waste containers utilized in the retrieval facility will be recyclable metal boxes to hold soil, loose waste, and damaged drums;

pallets to hold sound drums; and transfer containers to hold both pallets and tote boxes for transport to the treatment facility.

### 5.1.2.3 Retrieval Operations

At the beginning of the retrieval operations, one corner of a pit or group of trenches will be selected for commencement of the retrieval. The surface of the ground adjacent to this area will be graded smooth and level and will then be stabilized by spraying it with a coating such as asphaltic cement.

After the retrieval enclosure has been moved to its first retrieval position, the vehicle turntable and ramps will be set up within the enclosure, and the crane, forklift, and large waste processing equipment will be brought into the enclosure through the vehicle airlock.

For retrieval from pits, the crane, starting at ground level, commences excavation of a circular hole into the waste pit. As the hole becomes deeper, a ramp is constructed to enable the forklift to move waste on pallets and in tote boxes out of the excavation to the production airlocks.

For retrieval from trenches, the excavation of the circular hole will not be performed; instead,the waste and soil will be removed from within the confines of the trenches. The soil between the trenches will be left undisturbed insofar as is possible.

### 5.1.3 Retriever 1

Retriever 1 is a concept that was developed in the early 1970's to retrieve the buried TRU waste at the RWMC. Limited documentation on this concept exists.

The Retriever 1 consists of a mobile, self-contained facility which can move over a buried waste area. It has a manually controlled retrieval system and was designed around many commercially available components. The unit consists of two areas, a facilities support area and an operations area. The operational area is fitted with a lowered skirt that provides a seal with the ground. The room directly above the working zone is about 70 ft in diameter and 50 ft high. The operating deck is around the walls and a circular, rail-mounted excavator traverses the hole and digs up the waste. The excavation area is maintained under a negative pressure.

The waste is initially sorted to separate gross dirt from the identifiable waste. The waste may be packaged in standard containers and sent to the storage area or processing facility.

The entire Retrieval 1 unit is self-contained and has its own power source to move from one location to another and to support mechanical operations and other needs when in a production mode. It is believed that two such units could dig and package 300,000 $ft^3$/yr in a production operation, thus satisfying design requirements.

The track is sized to move over buried waste with a ground loading that would not crush the buried waste. Various attachments were proposed for the working boom, and the boom has rotational and lifting access to the waste down to about 20 ft into the circular hole.

The main excavator operator would work in a shielded air controlled cab. Other personnel would work in bubble suits on the main deck and, on occasion, go into the pit to maintain transportation carriers if necessary. Fire protection systems are included.

The waste would be removed from the facility through an airlock and into a trailer truck for transport. The overall size of the unit is 75 x 140 ft.

### 5.1.4 <u>FMC Mechanized Retrieval System</u>

The FMC Mechanized Retrieval System Conceptual Design is documented in reference (15).

The basic components of the FMC System, as presently visualized, include the following:

(1) Retrieval building

(2) Airlock attachment building(s)

(3) Decontamination/size reduction facility

(4) Mobile waste retrievers (2) (MWR's)

(5) Special equipment for removal of large, bulky, or special wastes

(6) Support equipment including tub hauler and possibly some form of personnel/emergency vehicle

Power for all operations is electrical.

### 5.1.4.1 Building Design

This is a 150 x 300 x 40-ft-high, double wall metal building. The system is moved by means of hydraulic jacks to raise the building. It has wheels for support, a steel U-channel track for the wheels, and a system for regulation of the lifting force along the walls. Flexible joints at regular intervals (20 or 50 ft) could facilitate movement. An overhead services rail, spanning the 150 ft width and movable over most of the length of the building, is used to distribute power and carry the communications cables used by internal equipment pieces. The overhead rail is designed for easy decontamination. Building ventilation provides for a negative internal pressure and HEPA filtered exhaust. Attached to the retrieval building is a separate movable airlock/decontamination building used for access to and exit from the facility. A separate airlock facility is provided to allow removal of filled waste containers and return of emptied containers. A third airlock attachment could be used as one means of bringing in clean backfill dirt.

5.1.4.2 Waste Retrieval Process

Waste (and soil) is removed from along the working face of a pit or trench by two Mobile Waste Retrievers (MWR's). Each MWR is operated by personnel in a controlled environmental cab. Curtains are used around the MWR to contain contamination, with the inner working area having separate ventilation for dust and contamination control. Waste removed by the MWR is placed into containers for removal from the retrieval facility. The working face of a pit or trench that is not within the confines of the MWR curtain is "fixed" to prevent contamination spread. Soil fixation and the use of fogs or mists within the working area (inside curtained area) are applied to control contamination and dust.

Primary support equipment includes "tub" haulers, special equipment for "special" waste, and personnel support/emergency equipment. Equipment working in front of the working face rides on a thin layer of asphalt or other material to prevent dust.

Support facilities include an attachable control facility, personnel facilities, air filtration, and standby electric generator facilities.

5.1.5 Kaiser Remote Retrieval System

The Kaiser Remote Retrieval System consists of a polar crane suspended from the ceiling of a mobile, dome roof structure. The structure is a double walled, rigid building approximately 75 ft in diameter and 35 ft high. It will be of aluminum construction. Negative air pressure will be maintained in the space between the outer and inner walls. A further negative pressure will be maintained within the building. Rubber seal skirts around the perimeter of the building will provide a seal with the ground.

An environmentally protected control room will be suspended from the top of the building. The control room will be equipped with windows to permit direct viewing of all operations. Egress of personnel to and from the control room is by stairs on the outside of the building and through an airlock into the control room.

Extending below the control room is a polar crane consisting of four arms. The four arms are individually operated. These arms telescope and have full $360^{0}$ wrist action. The telescoping booms can be equipped with a clamshell, backhoe, grapple, or other attachments, dictated by the size and shape of the waste to be retrieved.

Under normal operating conditions, personnel will not be required to be within the retrieval enclosure. The building will be positioned over a pit or trench. Retrieval will begin by digging a circular hole progressively into the waste pit. The waste and associated soil (noncontaminated and contaminated) will be placed into a hopper of a conveyor system. The conveyor will transport the waste to another location in the building for automatic packaging in tote boxes. The tote boxes will then be packaged in metal transfer containers. The containers will be transferred out of the containment building through an airlock for transport to a processing facility. No details have been provided on the automatic loading of the containers or how they will be transported from the containment building to a processing facility.

The retrieval operations will continue until the working range of the fixed polar cranes has been reached. The building will then be decontaminated and the excavated area backfilled with noncontaminated soil. The building will then be prepared for movement to another location. Air bearings will be used to move the building. A steel plate track will be positioned, extending beyond the walls to the new building location. The seal skirts will be raised, the air bearings activated, and a caterpillar tread tractor(s) will pull the building to the new location.

The above operation will be repeated until all waste is retrieved.

### 5.1.6 FMC Remote Retrieval System

The basic difference between the FMC Mechanized concept and the FMC Remote concept is the latter version would employ a portable remote control center similar to the supervisor's control center of the FMC Mechanized Retrieval System. The remote control center would move along the side of the retrieval building and have sensors and controllers that would plug in below the side windows. The major piece of equipment would be the MWR. Since no conceptual design has been completed on this concept, further description would be conjecture. Evaluation is on the basis of remote control of a system similar to the FMC Mechanized Retrieval System.

## 5.2 CRITERIA EVALUATION

An indepth discussion of the criteria identified and defined in Section 3.0 are presented in this subsection. Format for this discussion follows the outline shown below for each criterion:

Subcriteria definitions
Value functions
Weighting of subcriteria
Evaluation of designs

### 5.2.1 Effectiveness

Effectiveness of a buried waste retrieval system was selected as first in importance as a selection criteria with an overall weight of 0.21. It was defined by the task group as:

> "A measure of the system's ability to provide the waste in a suitable container for disposal or processing while minimizing the volume to be processed and maximizing the production rate."

#### 5.2.1.1 Subcriteria Definitions

The subcriteria definitions are as follows:

Rate is a direct measure of the volume of contaminated waste material exhumed per year and placed in temporary containers for processing or disposal. The ease of a system design to meet or exceed the minimum requirements is a consideration.

Volume ratio is the ratio of the volume of contaminated waste to the total waste handled and, as such, is a direct measure of the ability to retrieve waste packages while minimizing the handling and recovery of noncontaminated soil. The expected norm for volume ratio used as a design basis is equal parts of uncontaminated soil and waste (i.e., waste volume ratio of 1/2).

#### 5.2.1.2 Value Functions

The value functions developed for evaluation by the two subcriteria are presented in Figures 1 and 2.

The assignment of worth for retrieval rate is such that if a particular design would be difficult to develop in order to meet the minimum requirement of 250,000 $ft^3/yr$ of the contaminated waste, its overall worth would be low. Worth or capability to exceed design requirements is linear as related to operating costs.

The value function for volume ratio was developed as a basic linear function, in that handling, processing, and storage costs would be approximately linear with volume.

#### 5.2.1.3 Weighting of Subcriteria

Subcriteria weights are shown in the following tabulation:

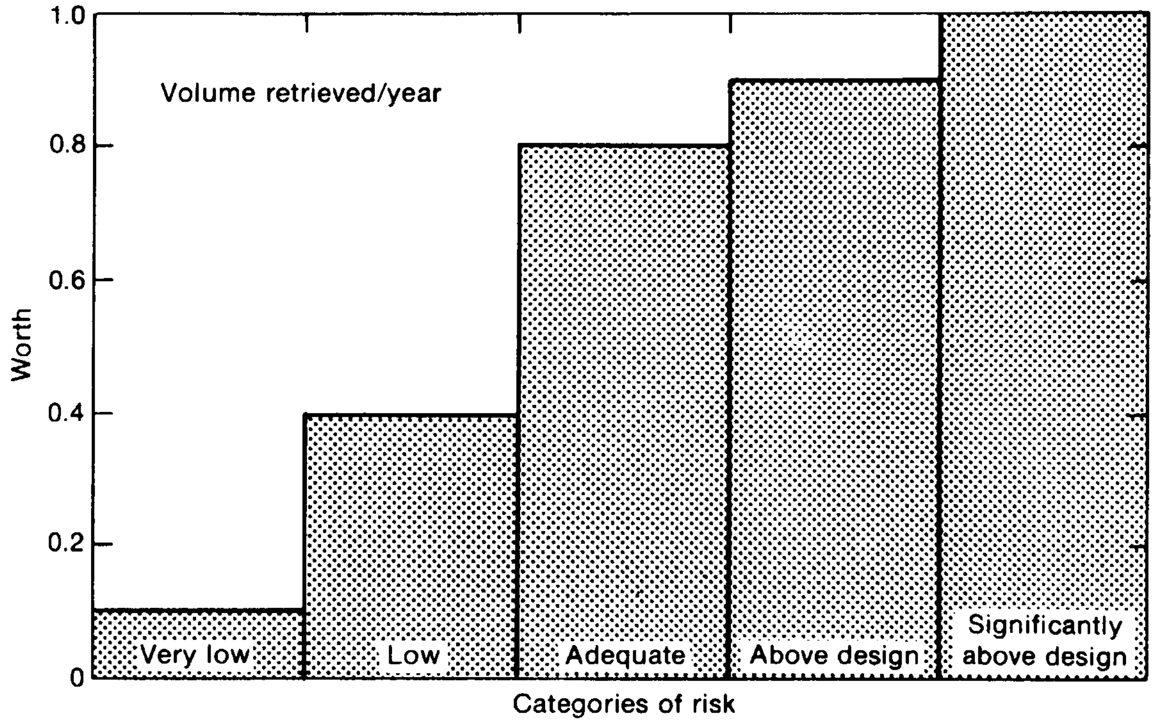


Fig. 1 Value function for rate volume retrieved per year.

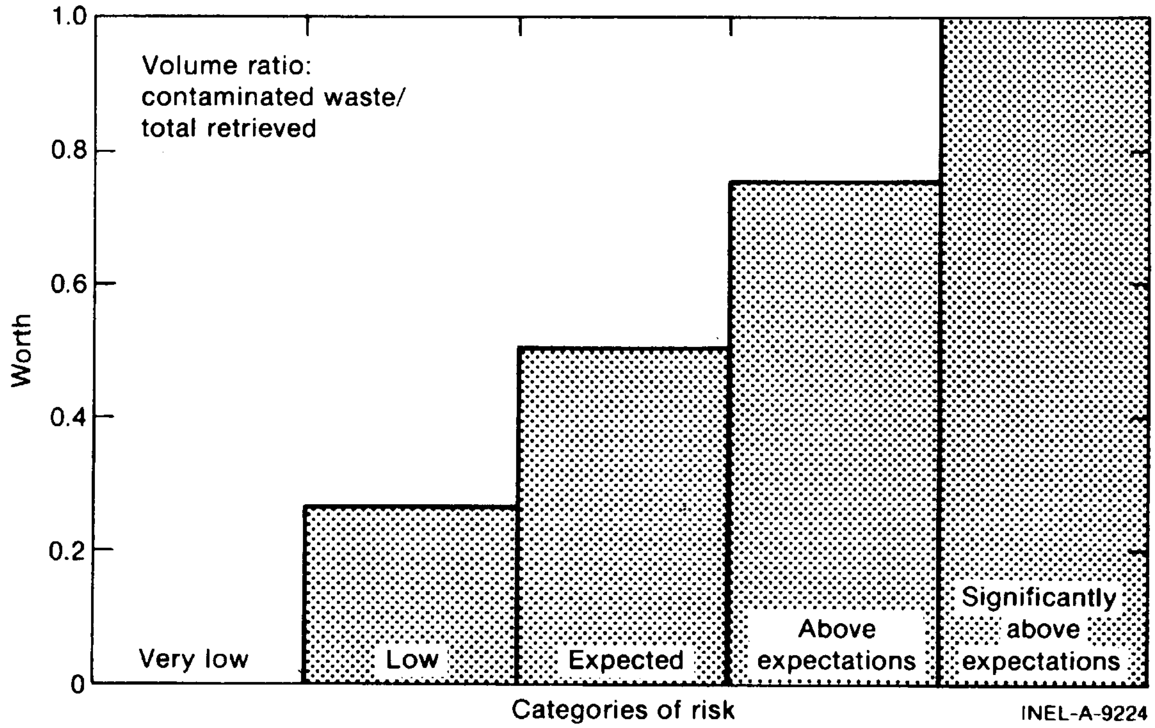


Fig. 2 Value function for volume ratio

EFFECTIVENESS SUBCRITERIA RANKING AND WEIGHTING

| Subcriteria | Weight |
|---|---|
| 1. Rate | 0.60 |
| 2. Volume ratio | 0.40 |

Weighting was determined by engineering judgement.

### 5.2.1.4 Evaluation of Designs

A summary of the effectiveness evaluation for each of the six candidates retrieval processes are presented in Table 10.

In addition, a performance summary of the worth (Figures 1 and 2) times the weight (see 5.2.1.3) of each subcriteria is presented in Table 11.

Further discussion of the reasons behind the effectiveness criterion evaluations follows. The discussion is presented in order of the evaluations from lowest to highest levels of automation.

ACC Manual

This process rated lowest of the six processes. Extrapolating from EWR experience of approximately 15,000 $ft^3$/yr of total waste removed and a ratio of less than one part of soil to one part of waste, a crew and equipment size approximately 40 times as large would be required. By depending on such a large labor force (in excess of 150), production rates would be extremely vulnerable to work stoppages, threats of hazards, etc. The high rating for volume ratio, being an effective discriminatory method, is insufficient for raising performance up to the levels of other systems.

TABLE 10

EVALUATION SUMMARY - EFFECTIVENESS JOB CRITERIA

| System | Rate | | Volume Ratio | |
|---|---|---|---|---|
| | Worth | Reason for Judgement | Worth | Reason for Judgement |
| ACC Manual | Very low | Ability to meet minimum rate in doubt with manual methods. Time personnel can spend in bubble suits very limited and productivity is low. Multiple facilities required | Above expectations | Largely manual operation allows high degree of discrimination of contaminated waste from uncontaminated |
| KE Manual | Low | Same as ACC Manual except more sophisticated retrieval equipment | Expected | Use of more sophisticated & larger machinery decreases volume ratio. Requires backfill & re-retrieval movement. With facility handling of clean soil, potential for contamination exists |
| Retriever I | Low | Same as KE Manual | Expected | Same as KE Manual |
| FMC Mechanized | Above design | Design can meet and likely exceed requirements. Building movement would be key factor in being able to exceed requirements. Single facility with capacity for multiple retrieval units | Above expectations | Use of working face & high visibility allows good discrimination. Large facility minimizes re-handling of significant backfill |
| KE Remote | Adequate | Design can likely meet requirements with two facilities and four retrieval units in each | Low | Low visibility from remote locations and small facility increases handling of clean soil above that of KE Manual facility |
| FMC Remote | Adequate | Although equipment is basically the same, the added complexity of remote control lessens the potential for exceeding design requirements due to added down times while process analysis of trouble items occurs | Expected | Decreased visibility from that of FMC without remote control, but same facility allows meeting expectations |

## TABLE 11

PERFORMANCE SUMMARY - EFFECTIVENESS SUBCRITERIA

| System | Rate (Worth X Weight) | + | Volume Ratio (Worth X Weight) | = | Total |
|---|---|---|---|---|---|
| ACC Manual | 0.1 X 0.6 | | 0.75 X 0.4 | = | 0.36 |
| KE Manual | 0.4 X 0.6 | | 0.5 X 0.4 | = | 0.44 |
| Retriever 1 | 0.4 X 0.6 | | 0.5 X 0.4 | = | 0.44 |
| FMC Mechanized | 0.9 X 0.6 | | 0.75 X 0.4 | = | 0.84 |
| KE Remote | 0.8 X 0.6 | | 0.25 X 0.4 | = | 0.58 |
| FMC Remote | 0.8 X 0.6 | | 0.5 X 0.4 | = | 0.68 |

### KE Manual

This concept tied for second lowest of the six processes. The use of conventional equipment supported by personnel in "bubble suits" again requires a large labor force and the efficiency is very low. The volume ratio worth was as "expected" since this is basically an EDR process with slightly more flexible equipment in a much improved facility (in size). A higher rating for volume ratio cannot be given for circular excavation areas due to the re-handling of backfill after facility movement.

### Retriever 1

This concept tied with the KE manual process since the effectiveness of the two would be very similar. The larger KE facility and the more mobile Retriever facility tend to balance in worth.

### FMC Mechanized

The FMC mechanized concept clearly rated highest in effectiveness. The use of a working face, variety of equipment, and large size of the facility ensure high waste removal rates while still maintaining a volume ratio in excess of that possible with the more conventional retrievers found in the KE Manual or Retriever 1 designs.

KE Remote

The KE remote concept ranked in the middle of the concepts. The basically integral facility and retrievers could restrict the effectiveness of the operation in event of contamination releases, fires, etc., basically stopping all operation. The small facility size was a detriment to worth on a volume ratio basis since so much rehandling would be required over the pits of backfill as dictated by the required angle of repose. The use of conveyer systems may also affect overall retrieval rates. Poor visibility was also a key factor penalizing this system for volume ratio since it allows for little discrimination.

FMC Remote

Although no conceptual design has been completed, the FMC Remote concept is rated slightly below the FMC Mechanized concept in effectiveness. Experience with hot cells and other remote operations indicate a slow and tedious pace is the rule rather than the exception. Added complexity, increased risk of downtime, and the accident (problems) potential will impact production rate. Remote operations definitely will decrease the ability to minimize handling of noncontaminated waste materials. Because indentification and segregation of noncon- taminated soil and materials would be time consuming, overall produc- tion rates would be reduced.

5.2.2 Operability

Operability of a buried waste retrieval system was selected as second in importance as a rating criteria with an overall weight of 0.19. The original definition of operability, as defined by the Task Force was:

"Operability is the level of operational complexity in terms of visibility, mobility, dust and contamination control, monitoring, and human factors."

Subsequent to deriving this definition, monitoring was deleted and facility movement added as subcriteria.

5.2.2.1 Subcriteria Definitions

Operability subcriteria are defined below:

Mobility is defined as the capability of the equipment to reach and operate effectively in all areas of the retrieval process easily and with a minimum of delay.

Visibility is the capability to observe all waste retrieval and handling operations in sufficient clarity to enable personnel to perform operations safely and effectively. It is highly desirable, although not mandatory, that personnel be capable of reading labels or markers on the sides of the buried waste containers.

Human Factors are such subjective items as human physical capabilities or limitations, personnel comfort, morale, job desirability, and all other items that affect job performance.

Facility Movement is a measure of the factors affecting facility movement including initial ground surface preparation requirements, degree of difficulty in moving, retrieval process downtime, and problems with moving the facility in other than a straight line.

Contamination Control is a measure of the capability of a process to minimize contamination releases to the building environment and to control the spread of contamination during or following such occurrence.

Dust Control is a measure of the capability of a process to minimize the formation of dust particles within the retrieval building so that vision is not impaired, filtration systems are not excessively plugged, and damage to electronic equipment is negligible.

5.2.2.2 Value Functions

Subjective value functions were formulated for each of the subcriteria. Figures 3 through 8 present the graphs used for value function ratings. Each value function was formulated based on a subjective assessment of the subcriteria. Due to a lack of detailed information on the designs being evaluated, all value functions are based on subjective performance levels, such as high, average, low, etc., rather than objective parameter values. Half of the subcriteria were assumed to have linear functions and the others were considered to be best represented by approximate S-type curves. The mobility value function was assumed to be nonlinear with a marked decrease below an average rating. Any form of significant mobility impairment was considered in the evaluation.

The visibility value function was assumed to be best represented by an S-type curve, as any rating less than good would mean some form of visual impairment resulting in delayed retrieval operations.

The assessment of human factors is entirely subjective. The value function was assumed to be linear over its range.

Facility movement was assumed to be represented by a linear value function as it was assumed that a change in the difficulty of moving the facility would create a proportional impact on downtime for the retrieval process.

Contamination control was assumed to be represented by a modified S-curve. Contamination problems will occur regardless of the retrieval process, but a proportional increase in contamination problems would eventually lead to a far greater impact on personnel exposure and retrieval operations.

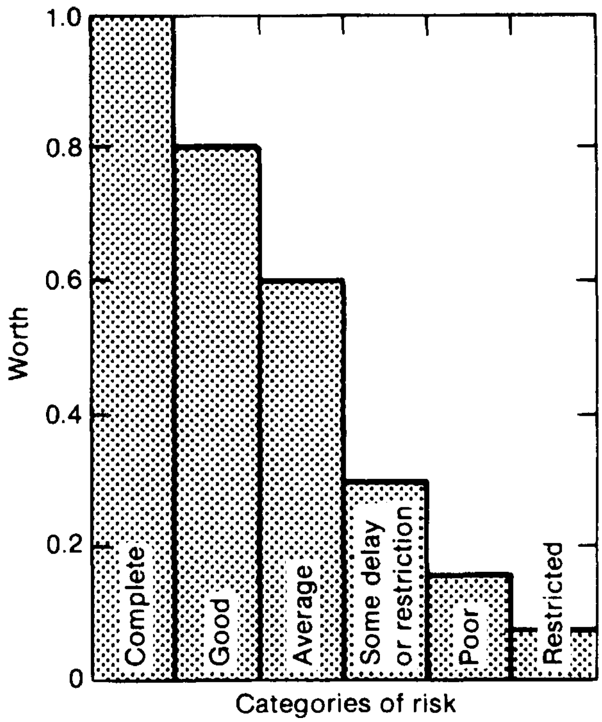


Fig. 3 Mobility value function.

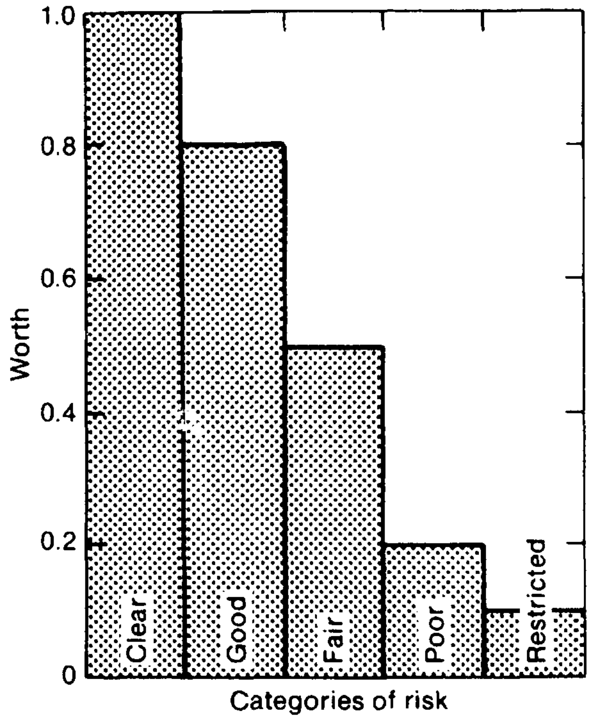


Fig. 4 Visibility value function.

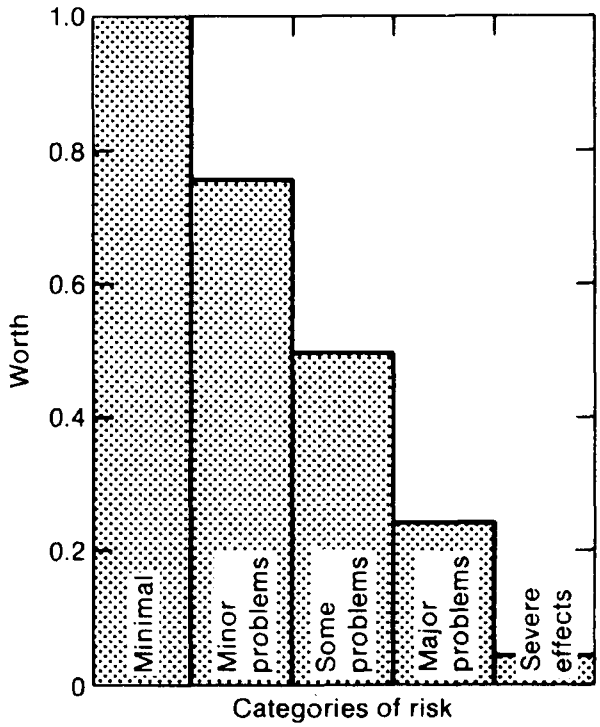


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Fig. 5 Human factors value function.

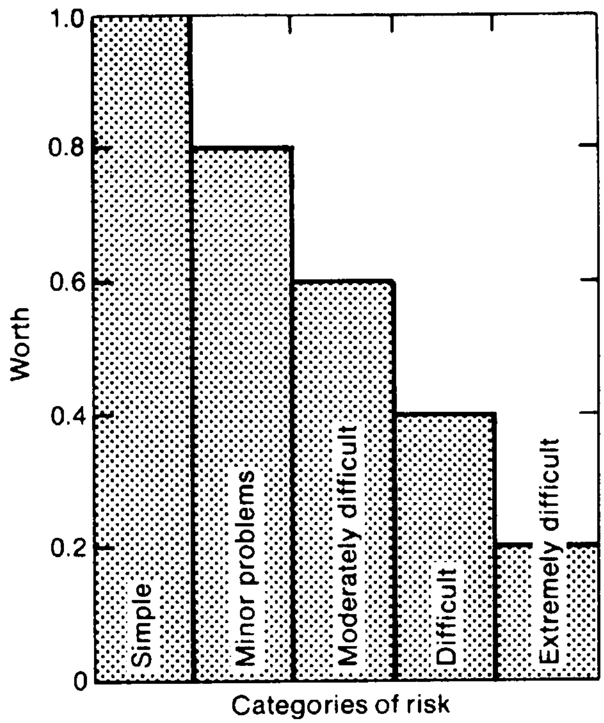


Fig. 6 Facility movement value function.

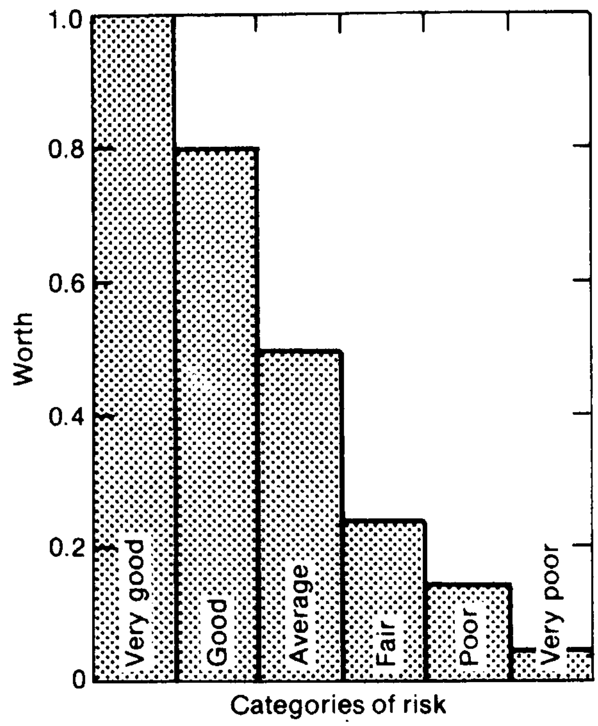


Fig. 7 Contamination control value function.

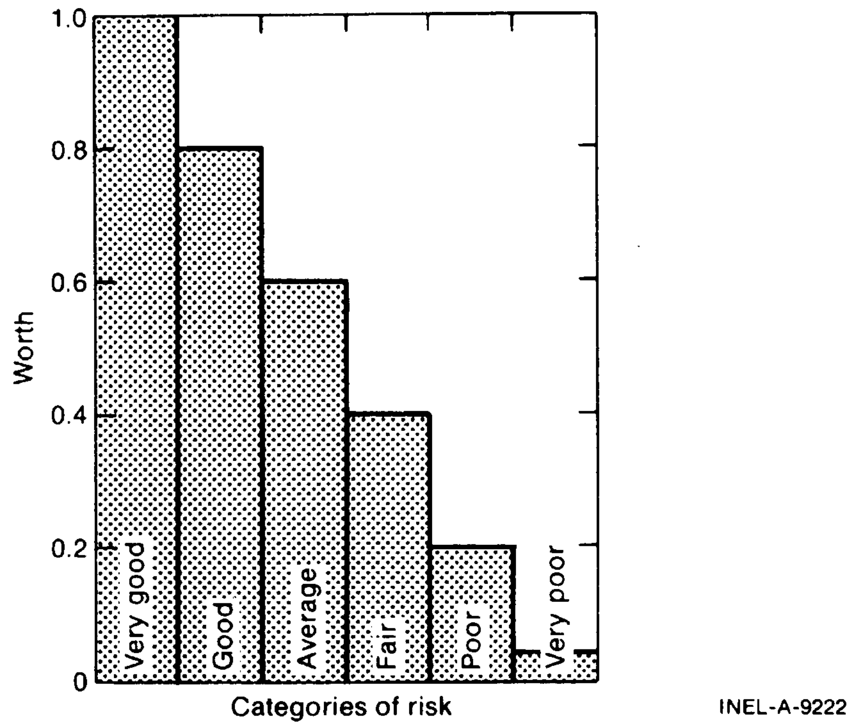


Fig. 8 Dust control value function.

Dust control was arbitrarily assumed to be represented by a linear value function.

### 5.2.2.3 Weighting of Subcriteria

All of the subcriteria were assumed to be of approximately equal importance, with the exception of dust control and mobility. Dust control was deemed to be of rather minor significance providing adequate methods are included in the process design phase for dealing with dusting problems. Equipment mobility was ranked slightly above the other subcriteria as it was felt it could be the limiting factor with retrieval capability. A summary of the subcriteria rank and weights is presented in the following tabulation:

OPERABILITY SUBCRITERIA WEIGHTING

| Subcriteria | Weight |
|---|---|
| Mobility | 0.22 |
| Visibility | 0.18 |
| Human Factors | 0.18 |
| Facility Movement | 0.18 |
| Contamination Control | 0.18 |
| Dust Control | 0.06 |

### 5.2.2.4 Evaluation of Designs

Table 12 is a summary of the evaluation of the six retrieval processes in the six subcriteria categories. Each process was given an overall category rating based on a subjective judgement (e.g., high, low, etc.) for each subcriteria. The numerical value function was then assigned based on the graphs presented in Figures 3 through 8, and an estimate of where the process should lie within the rating span is indicated in those graphs.

Table 13 summarizes the performance ratings and briefly explains the reasons for the ratings. Further elaboration of the reasons for the various ratings is given below.

TABLE 12

EVALUATION SUMMARY - OPERABILITY SUBCRITERIA

| System | Mobility | Visibility | Human Factors | Facility Movement | Contamination Control | Dust Control |
|---|---|---|---|---|---|---|
| ACC Manual | Good<br>Mobility for the system is good except for the delay involved during some operations due to the slower manual operations | Good<br>Visibility is clear in all directions for the manual operators, but is restricted for the backhoe operator working down over the edge | Severe Effect<br>Working in a bubble suit for years on a job will result in both severe morale problems and inefficiency. | Difficult<br>Building is immense and may have flexing problems during movement. May need considerable soil grading prior to building placement. Seal method not fully evaluated. Turning building at end of movement in one direction every few years will be extremely difficult and hasn't been fully evaluated as yet | Average<br>Greater care in retrieval than for most other processes is possible due to care by operators. There will still be considerable contamination problems if the system is to operate on a production basis, however. | Good<br>Overall rating is good but will have a few minor problems with backhoe operations and equipment exhaust leakage. Can minimize much of dusting by sprays or binders |
| KE Manual | Average<br>Location of the crane at the bottom of the pit places it within reach of essentially the entire waste area. Movement of equipment into and within the building is somewhat restricted, and the method for the crane "eating" its way down to the bottom of the pit is inefficient | Good<br>Visibility of the waste retrieval operation is excellent for the crane operator, but his view of operations above the working face is somewhat limited | Major Problem<br>Inefficiency of system and the operation in bubble suits will result in similar problems as in the ACC Manual approach, but probably not as severe | Difficult<br>Building size may make it easier to move than the one above, but this is felt to be more than offset by the surface preparation requirements. Moving building in more than one direction is much simpler than building above | Poor<br>Lack of any method for taking a lot of care with system plus no ready method of localizing contamination by hanging curtains or providing air sweep into certain area | Average<br>Similar to ACC Manual approach. Less care in excavation may produce more dust, but this dust generation may not be greater than for the ACC System |

TABLE 12 (Cont)

EVALUATION SUMMARY - OPERABILITY SUBCRITERIA

| System | Mobility | Visibility | Human Factors | Facility Movement | Contamination Control | Dust Control |
|---|---|---|---|---|---|---|
| Retriever 1 | Good<br>Essentially all the excavation is accomplished by one or more backhoe/grappler units capable of reaching all areas of the process. The limited size of the opening may make it difficult to retrieve large items adjacent to walls of the pit | Good<br>Visibility is good in all directions for the crane operator with the exception of straight down | Some Problems<br>Problems will be similar to those above, but not as severe. Crane operator may not have to use a bubble suit, and auxiliary manpower may not always be necessary | Minor Problems<br>One of the major advantages of the unit is the relative lack of necessary surface preparation and its ability to go in any direction, although with a large turning radius. May be some problems with sealing opening underneath | Average<br>System has relatively small area in which contamination can be confined. Also is capable of being modified to draw an air sweep into opening in floor to further control activity | Very Good<br>No equipment is moved across a dirt surface & the system lends itself to pulling an air sweep into the floor opening to further reduce dust problems |
| FMC Mechanized | Good<br>Mobility for this system was rated good due to the design of the mobile waste retriever and associated equipment. Few problems should be encountered in reaching & operating in all areas of the facility, but bulky equipment may be rather slow | Clear<br>Visibility is good in all directions for the retrieval process. Auxiliary operations may be somewhat restricted on work directly underneath, depending on M.W.R. cab design | Minor Problems<br>Morale and efficiency should be fairly good. May be a few problems due to isolated location of workers inside building | Difficult<br>Same as ACC Manual | Average<br>With use of curtains and sprays, should be able to control activity to a certain extent but not as well as the ACC Manual system due to less care in excavation | Average<br>Similar to ACC Manual but not as good due to more equipment moving across the dirt surface |

TABLE 12 (Cont)

EVALUATION SUMMARY - OPERABILITY SUBCRITERIA

| System | Mobility | Visibility | Human Factors | Facility Movement | Contamination Control | Dust Control |
|---|---|---|---|---|---|---|
| KE Remote | Good | Good | Minor Problems | Difficult | Fair | Average |
| | Ability to reach all areas of the process is good. Distance between the waste and the operator may cause some problems. The rigid design of the system caused it to be rated slightly lower than the FMC Mechanized | Use of TV cameras severely limits depth perception and field of view. Depending on design, control booth could be located to minimize these problems but distance to waste would still be extreme | Few problems foreseen unless frequent building entry required. May be some efficiency problems due to distance from waste | Same as KE Manual | System does not lend itself readily to methods of contamination control except fixation of surface with water or a binder. Building is smaller than the the KE Manual facility and will require less personnel access so it is rated slightly better than the KE Manual | Similar to KE Manual. Location of control room above instead of below working surface will cause dust to have an effect on operations, but moving conveyer belt could cause greater dusting than equipment travel |
| FMC Remote | Good | Fair | Minor Problems | Difficult | Average | Average |
| | Mobility is essentially the same as for the FMC Mechanized but is rated slightly lower due to the slower operations which would result from use of remote control | Use of TV cameras severely limits depth perception and field of view. Depending on design, control booth could be located to minimize these problems, but distance to waste would still be extreme | Same as KE Remote | Same as ACC Manual | Same as FMC Manual except the remote operation of equipment will allow less care in retrieval operations with a corresponding decrease in contamination control capability | Similar to FMC Mechanized |

TABLE 13

PERFORMANCE SUMMARY - OPERABILITY SUBCRITERIA

| System | Mobility | Visibility | Human Factors | Facility Movement | Contamination Control | Dust Control | Total |
|---|---|---|---|---|---|---|---|
| ACC Manual | 0.65 | 0.65 | 0.05 | 0.30 | 0.40 | 0.65 | 0.43 |
| KE Manual | 0.40 | 0.80 | 0.20 | 0.25 | 0.15 | 0.60 | 0.38 |
| Retriever 1 | 0.70 | 0.75 | 0.45 | 0.65 | 0.50 | 0.85 | 0.63 |
| FMC Mechanized | 0.80 | 0.90 | 0.70 | 0.30 | 0.35 | 0.60 | 0.62 |
| KE Remote | 0.75 | 0.80 | 0.75 | 0.25 | 0.20 | 0.60 | 0.56 |
| FMC Remote | 0.75 | 0.30 | 0.75 | 0.30 | 0.30 | 0.60 | 0.50 |

Mobility - All processes were rated in the "good" category with the exception of the KE Manual which was rated "average." The latter rating was given because of the fixed location of the central crane and the relative difficulty in working its way downward. The value function range among the remaining processes was narrow, but the FMC Mechanized approach was rated best overall due to the variety of equipment and its capabilities. The ACC Manual was rated the lowest among the "good" ratings, because of the slower performance rate expected.

Visibility - All processes were rated "good" with the exception of the FMC Mechanized and FMC Remote systems which were rated "clear" and "fair," respectively. The FMC Mechanized was rated the best because of the combined view of both the waste retrieval and auxiliary operations. The FMC Remote system would require TV cameras that would have limited depth perception and viewing area; this resulted in a low rating for this system. The remaining systems were approximately similar in rating although the ACC Manual approach had to be downgraded somewhat due to the limited view available to the backhoe operator.

Human Factors - The effect of human factors was essentially proportional to the degree of remoteness involved. The ACC Manual system was given a "severe effect" rating because a large number of personnel would have to perform the retrieval operations in bubble suits. The KE Manual system would have similar problems but to a lesser degree. Retriever 1 would also have similar problems but to a lesser degree since the crane operator would not have to wear a bubble suit, and support by personnel in bubble suits may not be required at all times. The remaining systems were rated "minor problems" only because of the separation between personnel and the waste. The Mechanized FMC method was rated slightly lower because of the greater number of personnel involved.

Facility Movement - Only the Retriever 1 process was judged to have solved the facility handling problem sufficiently. The ACC Manual and the two FMC processes would have huge buildings which could require significant reinforcement prior to movement, would be difficult to seal adequately, and would be extremely difficult to move laterally once movement along the pit or trench centerline has been completed. The Kaiser systems would be easier to move laterally and should be structurally stronger for movement, but the soil surface preparation for the air pad transport were judged to be extremely restrictive to ensure an adequate move. For this reason, the Kaiser Systems were rated the lowest of all the processes for facility movement.

Contamination Control - System ratings for contamination control ranged from "poor" to "average." The KE Manual system was rated the lowest because of the lack of care inherent in the retrieval process and the lack of any means to readily localize contamination by hanging curtains or air sweeps. Retriever 1 was rated best because of the relatively small size of its retrieval room area and its ability to reduce contamination problems by means of an air sweep into the retrieval opening. The remaining processes were rated based on the amount of care that could be exercised in the retrieval operations, the size of area which could be contaminated, and the available means of minimizing contamination hazards.

Dust Control - Overall system ratings for dust control were from "average" to "very good." Retriever 1 was rated best due to the air sweep possible into the retrieval opening, and the lack of any equipment or personnel moving directly across a soil or waste surface. All other processes were rated equal, except the ACC Manual, which was rated slightly higher due to the greater handling care available with that system.

### 5.2.3 Health and Safety

Health and Safety of a buried waste retrieval system ranked third in importance as a rating criteria with an overall weight of 0.17. Health and Safety was defined as follows by the task group:

"Health and Safety is a measure of the degree of protection to the operating personnel from radiation, contamination, and physical and chemical hazards in accordance with codes, standards, regulations, and 'as low as practicable' guidelines. The ability to prevent or mitigate the consequences of unusual occurrences is a consideration."

5.2.3.1 Subcriteria Definitions

Health and Safety subcriteria are defined below:

Routine Operations: Protection of operating personnel during routine operations is a measure of the engineered features of the facility and equipment to prevent personnel injury or property damage for anticipated events over the life cycle of the facility.

Contamination Control: Contamination control is a measure of the effectiveness of engineered features to localize radioactive contamination at the working face of the TRU recovery area and prevent this contamination from spreading to operating personnel, ancillary equipment, the confinement building, and the outside environment.

Physical Hazard: Physical hazard control is a measure of the number and kind of controls needed to reduce to acceptable levels the possibility or probability that a specific material or device will cause a threat to personnel or system components. The complexity of equipment, number of personnel exposed, and the degree of protection from falls, flying or falling objects, moving and rotating equipment, electrical hazards, explosions, etc., are all considerations.

Radiation Protection: Radiation protection is a measure of the controls, i.e., shielding and/or distance, that are engineered into the facility to minimize the exposure of operating personnel to direct radiation.

Chemical Hazard: Chemical hazard control is a measure of engineered protective devices or administrative procedures to protect against toxic, pathogenic, carcinogenic, pyrophoric, teratogenic, or asphyxiant agents that may be encountered in the TRU exhumation process.

Unusual Occurrence: Unusual occurrence is a measure of the controls to withstand, prevent, or mitigate unplanned events that sometimes (but not necessarily) are injurious or damaging, and that interrupt the completion of an activity and are invariably preceded by an unsafe act and/or unsafe condition.

Prevention of Unusual Occurrences: Prevention of unusual occurrences is a measure of the design, location, and arrangement of facilities and equipment needed to preclude equipment damage or personnel injury from natural and man-made events. Fire, explosion, floods, earthquakes, work accidents, weather extremes, etc., are all considerations.

Mitigation of Consequences: Mitigation of the consequences of incidents and accidents is a measure of the number and complexity of engineered facility and equipment protective devices as well as the administrative measures to control and/or moderate the effects of accident situations.

### 5.2.3.2 Value Functions

The six proposed designs for exhumation of TRU were reviewed using the Health and Safety subcriteria defined above. A risk-value function, Figure 9, was used in this evaluation. A risk value form "none" to an "extensive" risk was assigned to each proposed design for each of the evaluation criteria identified in 5.2.3.1.

### 5.2.3.3 Weighting of Subcriteria

Subcriteria were assigned a weighting (worth) value based on individual experience and engineering judgement. The following tabulation lists each health and safety evaluation subcriteria and associated weights.

WEIGHTING OF HEALTH AND SAFETY SUBCRITERIA

| Subcriteria | Weight | |
|---|---|---|
| Routine Operation | | 0.80 |
| Contamination Control | 0.60 | |
| Physical Hazards | 0.20 | |
| Radiation Protection | 0.10 | |
| Chemical Hazard | 0.10 | |
| Unusual Occurrences | | 0.20 |
| Capability to withstand or prevent unusual occurrences | 0.90 | |
| Mitigation of Consequences | 0.10 | |
| TOTAL | | 1.00 |

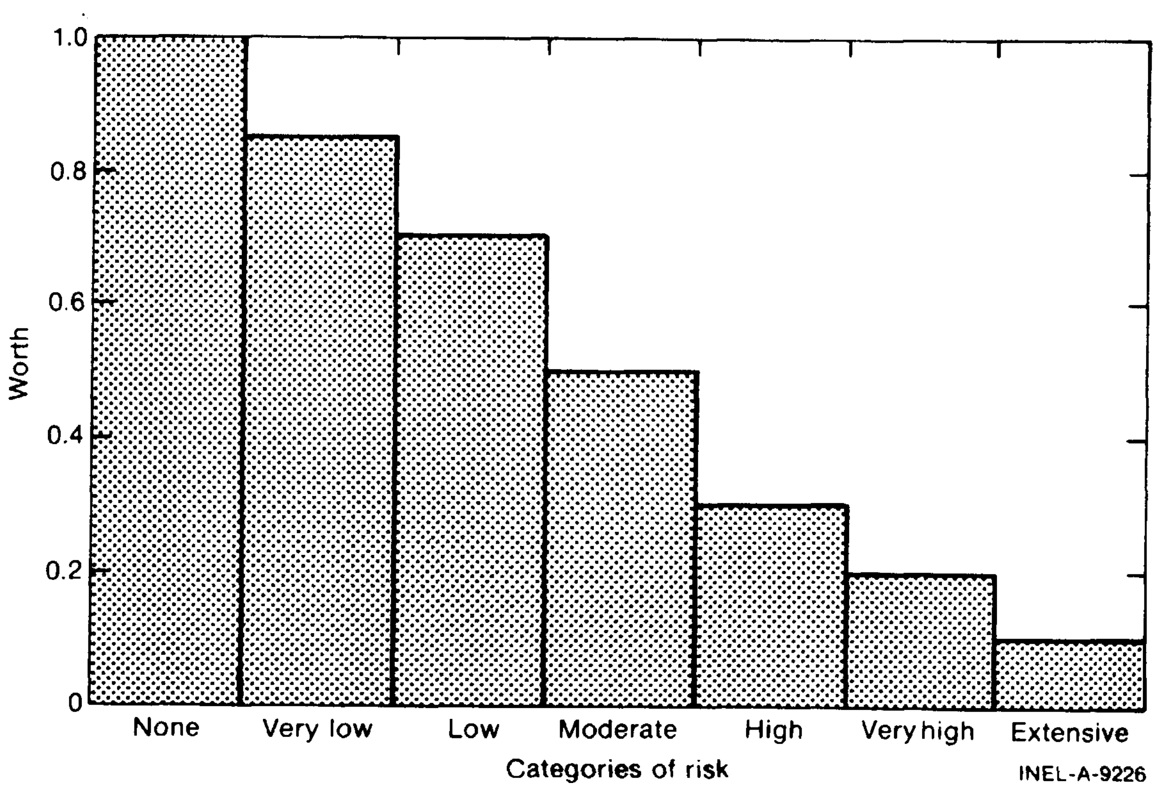


Fig. 9 **Health and safety risk value functions.**

#### 5.2.3.4 Evaluation of Designs

Table 14 is a summary of the design evaluation of each of the six exhumation design concepts. The worth is identified qualitatively for each concept. Brief remarks supporting the qualitative judgments are also provided in the reason columns of Table 14. Discussion of evaluation considerations is presented in the following paragraphs. Table 15 presents, for each concept, the worth, the weighted values (worth x weight) and the overall weighted rankings (addition of weighted values for each subcriteria).

Radioactive contamination control is considered to be the most significant element of health and safety criteria. Other health and safety aspects are more amenable to standard safety design or administrative procedures. By employing standard commercial safety standards to the design of equipment and facilities in conjunction with administrative procedures, reasonable protection is provided against industrial hazards, chemical and toxic agents, and direct radiation hazards. Therefore, TRU contamination control is considered most important.

TRU contamination control has been considered in each of the exhumation design concepts, and most designs consider double containment enclosures. The enclosure in these design concepts is generally a double-walled building. The building varies in size depending upon the concept. Some of the buildings are relatively large allowing for operation of portable and fixed equipment within the structure. Although this design allows for flexibility of movement of equipment within the building, the interior of the building and equipment are susceptible to contamination. Since the building seal has to be broken when the building is moved from one location to another, there is a risk of contaminating the outside environment if the building interior and components are not decontaminated prior to movement. This appears to be a major problem both in cost and potential personnel exposure during decontamination.

Table 14

EVALUATION SUMMARY - HEALTH AND SAFETY SUBCRITERIA

| System | Contamination Control | Physical Hazards | Radiation Protection | Chemical Hazard | Capability to Withstand or Prevent Unusual Occurrences | Mitigation of Consequences |
|---|---|---|---|---|---|---|
| ACC Manual | Low | Moderate | High | Low | Moderate | Moderate |
| | Confinement area small, can control contamination at the source; past experience available; deliberate and slow pace can avoid problems | Men and Equipment working together in small area; bubble suits and air hoses - tears, leaks, air interruption, etc. | Contact work. No distance or shielding provided | Bubble suits and air lines susceptible to damage concurrent with energy release (explosion) and dispersal of toxic agents. Close proximity to working face of pit | No engineered safeguards, only administrative control; workers vulnerable to explosion and direct radiation | No automatic fire-fighting equipment; bubble suits provide only limited mobility during emergencies; contamination spread possible to outside environment |
| KE Manual | High | Moderate | High | Low | Moderate | Low |
| | No contamination control at working face; moving equipment, conveyors, etc., are source of contamination spread; all workers wear bubble suits, failure of which could cause personnel exposure; continued egress of personnel through air locks is possible source of contamination spread | Personnel operating equipment will have restricted movement and vision with bubble suits; equipment and personnel in close proximity; moving equipment and rotating belts and conveyors added risks | No shielding designed into system; personnel operating equipment in close contact with waste equipment limited to cope with waste in high direct radiation fields. | Same as ACC Manual | Building and equipment susceptible to contamination spread; workers vulnerable to explosion and direct radiation; bubble suits and air supply vulnerable to failure | Boom mounted $CO_2$ system for fire protection; bubble suits limit mobility during emergencies; no provisions for rescue of workers |

TABLE 14 (Cont)

| System | Contamination Control | Physical Hazards | Radiation Protection | Chemical Hazard | Capability to Withstand or Prevent Unusual Occurrences | Mitigation of Consequences |
|---|---|---|---|---|---|---|
| Retriever 1 | Low | Low | High | Low | Very Low | Very Low |
| | Contamination controlled. All workers wear bubble suits except crane operator. Crane cab environmentally protected. Small volume provides better contamination control | Equipment incorporated into one unit; personnel working in close proximity to equipment. Restricted working area | No radiation shields provided; mobile and can be moved from source. However, close proximity of personnel to retrieved waste may result in prohibitive shielding requirements or radiation exposures | Personnel protected in environmental cabs, or bubble suits. Small area exposed to toxic airborne contaminants; air filtration provided | Contamination confined; minimum equipment requirements; very mobile. Not susceptible to earthquakes, severe weather, or floods | For any accident the area affected would be small. Fire protection available. Not susceptible to earthquakes, severe weather, or floods |
| FMC Mechanized | Moderate | Low | Low | Very Low | Low | Very Low |
| | No contamination control at pit working face; workers protected by environmental cabs; equipment susceptible to contamination spread | Equipment designed to commercial safety standards; however, total number of operating, moving equipment adds to the risk | Radiation shields provided for operators; escape routes provided; equipment available to retrieve or cover multisized radioactive objects | Workers protected in environmental cabs; ability to exhume individual package with minimum damage to package | Building and equipment susceptible to contamination spread. Design problems with large building and stresses thereon during its movement. Open at working face, susceptible to flooding | Firefighting equipment, emergency exits, dust control, rescue vehicles, and equipment shielding are all provided |

TABLE 14 (Cont)

| System | Contamination Control | Physical Hazards | Radiation Protection | Chemical Hazard | Capability to Withstand or Prevent Unusual Occurrences | Mitigation of Consequences |
|---|---|---|---|---|---|---|
| KE Remote | Moderate<br><br>No contamination control at pit working face; although the building is smaller and there are fewer pieces of mobile equipment they are still susceptible to contamination; Entrance for maintenance, etc., requires bubble suits; control room environmentally controlled; moving belts and conveyors | Low<br><br>Manpower and equipment requirements are low and reduce risk. Equipment designed to commercial safety standards; moving belts and conveyors added risk | Moderate<br><br>No shielding in control room. Only one escape route; operators in center of building over exhumation area where direct radiation would be highest | Very Low<br><br>Multiple equipment attachments for digging will minimize damage to packages; workers protected in environmental control room or bubble suits | Very Low<br><br>Digging area small, good flood protection; smaller building design results in sturdiness and less risk of accident during movement. Mobile equipment limited reduces risk of incidents; building and equipment, although smaller, is susceptible to contamination spread | Low<br><br>Boom mounted $CO_2$ system for fire protection; auxiliary equipment limited for handling emergencies; control room somewhat remote and one escape route adds to the risk |
| FMC Remote[a] | Low<br><br>No contamination control at pit working face; building and equipment susceptible to contamination spread. Good personnel protection | Very Low<br><br>Personnel protection excellent; however, remote visibility problems (TV, etc.) will add risk of damage to facility and equipment | Very Low<br><br>Remote operation will provide distance and shielding. Design will provide necessary personnel protection | None<br><br>Remote operation and separate air supply should preclude personnel exposure to toxic chemicals | Low<br><br>Building and equipment susceptible to contamination spread causing concerns for building movement; good personnel protection provided | Low<br><br>Reduced flexibility of remote operations may hinder actions to mitigate emergencies |

[a]No detailed design provided; assume remote operation outside FMC building.

Table 15

PERFORMANCE SUMMARY - HEALTH AND SAFETY SUBCRITERIA

| System | Contamination Control | Physical Hazard | Radiation Protection | Chemical Hazard | Capability to withstand Occurrence | Mitigation of Consequences |
|---|---|---|---|---|---|---|
| ACC Manual | 0.7 | 0.5 | 0.3 | 0.07 | 0.05 | 0.05 |
| KE Manual | 0.3 | 0.5 | 0.3 | 0.07 | 0.05 | 0.07 |
| Retriever 1 | 0.7 | 0.7 | 0.3 | 0.07 | 0.85 | 0.85 |
| FMC Mechanized | 0.5 | 0.7 | 0.7 | 0.85 | 0.07 | 0.85 |
| KE Remote | 0.5 | 0.7 | 0.5 | 0.85 | 0.85 | 0.07 |
| FMC Remote | 0.7 | 0.95 | 0.85 | 1.0 | 0.07 | 0.07 |
| | Weighted Values for each System | | | (Worth x Weight) | | |
| ACC Manual | 0.34 | 0.08 | 0.02 | 0.06 | 0.09 | 0.01 |
| KE Manual | 0.14 | 0.08 | 0.02 | 0.06 | 0.09 | 0.04 |
| Retriever 1 | 0.34 | 0.11 | 0.02 | 0.06 | 0.15 | 0.02 |
| FMC Mechanized | 0.24 | 0.11 | 0.06 | 0.07 | 0.13 | 0.02 |
| KE Remote | 0.24 | 0.11 | 0.04 | 0.07 | 0.15 | 0.01 |
| FMC Remote | 0.34 | 0.14 | 0.07 | 0.08 | 0.13 | 0.01 |
| | Weighted Ranking (addition of weighted values) | | | | | |
| FMC Remote | 0.77 | | | | | |
| Retriever 1 | 0.70 | | | | | |
| FMC Mechanized | 0.63 | | | | | |
| KE Remote | 0.62 | | | | | |
| ACC Manual | 0.60 | | | | | |
| KE Manual | 0.40 | | | | | |

Serious consideration should be given to controlling and confining the contamination in a small area near the working face of the exhumation process. Several design concepts such as plastic curtains, hard-walled buildings, shielded enclosures, etc., should be investigated. These concepts should include a separate heating and ventilating system for differential pressure control with respect to the secondary containment building. A transparent enclosure that provides light and enhances vision appears to be the most feasible and practical.

The exhumation and other equipment that comes in contact with contamination should be designed for ease of decontamination. Some of the equipment observed or described for the program is very complex; decontamination of this equipment would be most difficult.

In summary, the health and safety aspects of the various proposed designs, in general, have been designed into each concept. However, better control of the contamination would be realized if the contamination was confined to a small area near the working face of the exhumation process. This would reduce the risk of personnel exposure and environmental contamination. Overall decontamination costs would be expected to be lowered significantly.

### 5.2.4 Availability

Availability of a buried waste retrieval system was selected as fourth in importance as a rating criteria with an overall weight of 0.14. The task force definition of availability was:

> "Availability is the fraction of time the system is capable of performing its intended function. This consideration includes system maintainability, reliability, and ease of decontamination."

#### 5.2.4.1 Subcriteria Definitions

The three availability subcriteria are defined below:

Maintainability

Equipment: The ease with which the equipment can be repaired, either while contaminated in the facility or decontaminated and removed from the facility. The simplicity of having multiple units is also a consideration.

Facility: The ease with which the facility can be maintained contamination free or easily decontaminated to facilitate equipment maintainance and moving to new locations.

Reliability

Equipment: The degree that complexity of equipment design, or usage records, provide assurance of being available for use.

Facility: The degree that the facility lends itself to repair, movement, penetration control, and pressure testing to ensure a high use factor.

Ease of Decontamination

Equipment: An estimate of the time and exposure required to prepare the equipment for maintenance, major repair, and relocation.

Facility: Same as above for equipment.

#### 5.2.4.2 Value Functions

Availability value functions are depicted in Figures 10 through 12. The reasons for the value functions, as shown on these figures are discussed below.

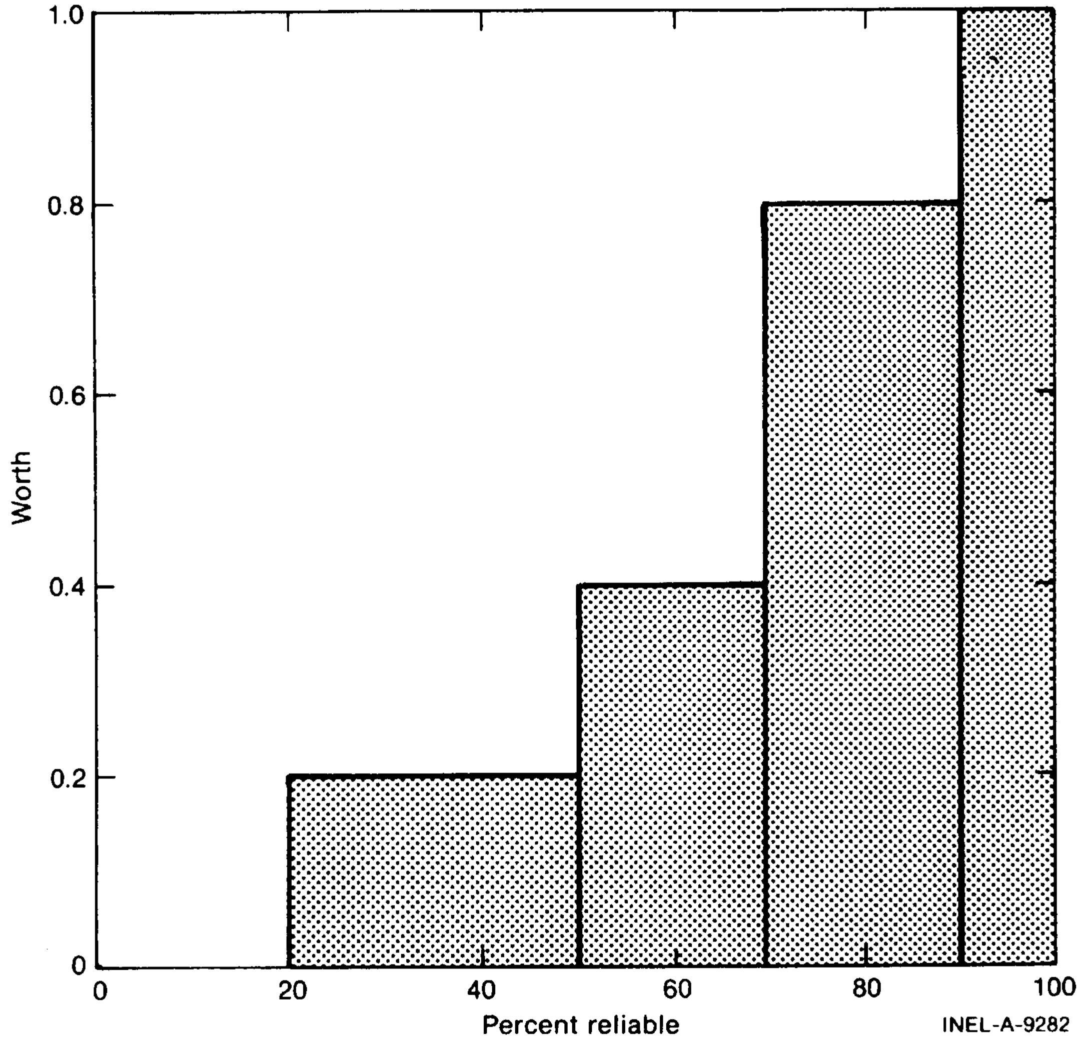


Fig. 10 Reliability value function.

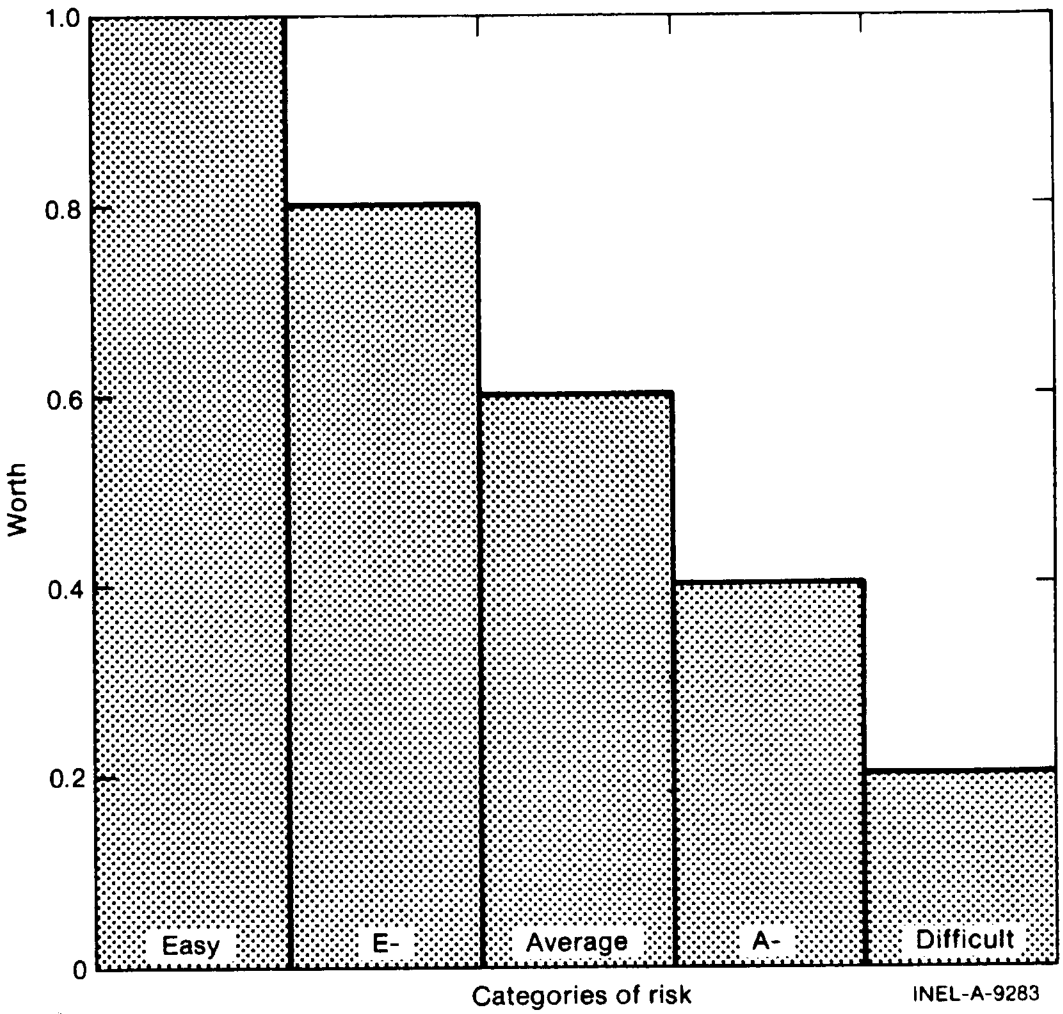


Fig. 11 Ease of decontamination value function.

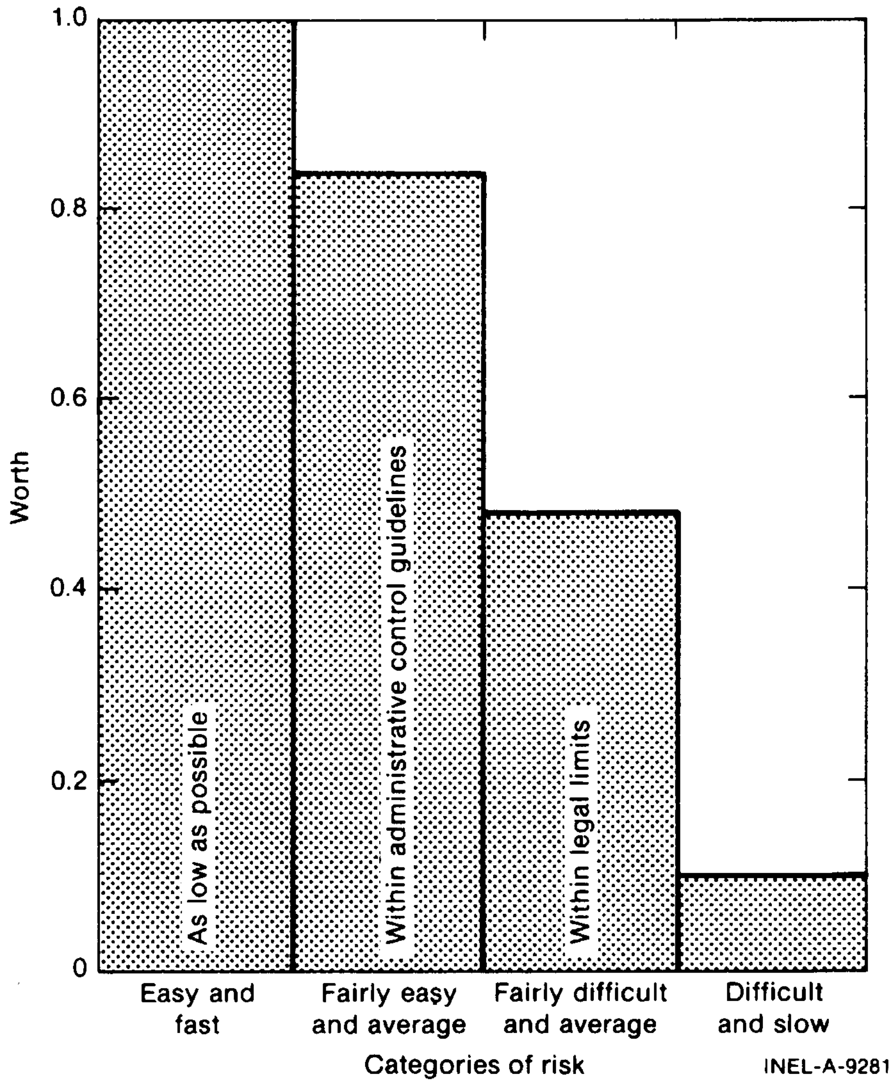


Fig. 12 Maintainability value function.

Any equipment or facility that has a good possibility of 90% availability, or better, would be given full value for reliability. Any equipment or facility that has less than 50% availability (necessitating one backup spare or equivalent maintainance) would tend to be in the marginal range with regard to reliability.

The highest value is given when the equipment and facility lend themselves to decontamination in compliance with the "as low as possible" exposure philosophy and in a timely manner. Little penalty would be assessed if administrative exposure limits and time appear reasonable. To the extent that manual contact requires extending normal administration limits to legal limits, the value decreases rapidly; also, long time factors decrease value rating.

The maintainability is considered to be "easy" if the equipment or facility is simple, incorporates state-of-the-art design, has quick-replacement capability, and has reasonable cost and available spare units for major maintenance. Maintainability is considered to be difficult if equipment or facility is highly specialized, if development is complex, or if either the equipment or facility is large and vulnerable.

5.2.4.3 Weighting of Subcriteria

The subcriteria used in evaluating the availability of the various design concepts were considered to be of approximately equal weight both for equipment and the facility as shown in Table 6.

5.2.4.4 Evaluation of Designs

Table 16 summarizes the design evaluation for each of the six retrieval concepts. The worth (weight) is identified qualitatively for each concept. Brief remarks supporting the qualitative judgements for each subcriteria are also provided in the appropriate columns for equipment and facility. Table 17 summarizes the availability criteria performance for each system.

TABLE 16

EVALUATION SUMMARY - AVAILABILITY SUBCRITERIA

| System | Maintainability | | Reliability | | Ease of Decontamination | |
|---|---|---|---|---|---|---|
| | Equipment | Facility | Equipment | Facility | Equipment | Facility |
| ACC Manual | Equipment is fairly simple and state of the art with good maintenance records, medium sized excavator. Quality air supply needed | Facility is off-the-Shelf, replaceable, expandable and relatively low cost to repair and maintain | Equipment is simple with good reliability experience. Unit cost makes backup and spares available | Has good service record, but is slow to move | Equipment is relatively easy to decon and to move out if necessary | Surface smooth, but may be harder to decon than metal surfaces |
| KE Manual | Equipment is similar to above, but excavator is more specialized. Quality air supply needed | Specialized double wall metal building will be harder to repair | Should be comparable to above with slightly higher costs due to some special units | Specialized building may have some environmental control problems and takes special care to move, but being rigid it should be movable in a few days | Equipment fairly easy to decon or can be moved out for decon | Fairly smooth metal interior, but since air lift is used to move, a low decon level needed to move |
| Retriever 1 | General state-of-art equipment with good maintenance history. Most can be removed for maintenance. Needs a quality of air supply | May be vulnerable since it is an integral unit and power is critical | Integral unit dependent upon facility services. Cab is specialized. Other equipment should be reliable | May be hard to maintain; high availability because of being an integral unit | Generally good decon features but excavator harder to remove than for KE Manual | Fairly smooth metal surfaces but working deck provides added surface and complication around walls |

TABLE 16 (Cont)

| System | Maintainability | | Reliability | | Ease of Decontamination | |
|---|---|---|---|---|---|---|
| | Equipment | Facility | Equipment | Facility | Equipment | Facility |
| FMC Mechanized | State-of-the-art equipment very rugged with good maintenance history in dust environment. Lots of units can be moved out for maintenance | Big, fairly complicated double walled-lots of penetrations and may be hard to keep right atmosphere and/or to repair after moves | Has two excavators and spares are available. Units are complicated and costly to provide backup units. Good records in rough service | Could have pressure and sealing problems and may take a long time to move. Restricted in movement sideways and if contaminated is hard to decon | Hard to decon and lots of motors, hoses, cables, etc. Covering may cause heating problems. Lots of hard-to-get at surfaces | Generally smooth surface but lots of it |
| KE Remote | More specialized added remote equipment to maintain and monitor. Slower maintenance but no air supply to worry about | Same as KE Manual with added complications of inflexibility of remote cleaning and repair | Less reliable than KE Manual because of remote features and longer time and higher cost of units to keep full backup and spare supply | Less reliable since the remote features require more time for hookup and checkout on moves and more penetrations and dead areas to maintain | Fairly confined to excavator arm and transport system; not easily removed for decon; slower | Same as KE Manual but slower and restricted by remote features and methods |
| FMC Remote | Most equipment could be taken out but would have to be decontaminated or changed with remote changes and equipment. Not built for remote maintenance | Same as FMC Mech; much slower with limitations of fixed visibility and access to big building | Would be available less than FMC Mechanized due to slow maintenance and decon | Would be available less than FMC Mechanized due to slow maintenance and decon | Harder to do remote decon; thus slower and harder than FMC Mechanized | Harder to do remote decon, thus slower and harder than FMC Mechanized |

TABLE 17

PERFORMANCE SUMMARY - AVAILABILITY SUBCRITERIA

| System | Weighted Composite Worth |
|---|---|
| ACC Manual | 0.93 |
| KE Manual | 0.80 |
| Retriever 1 | 0.60 |
| FMC Mechanized | 0.62 |
| KE Remote | 0.50 |
| FMC Remote | 0.46 |

### 5.2.5 Flexibility

Flexibility of a buried waste retrieval system was selected as fifth in importance as a rating criteria with an overall weight of 0.13. The task force definition was:

> "Flexibility is the ability to retrieve and package variable waste forms assuring contamination and exposure control while maintaining an acceptable production rate."

#### 5.2.5.1 Subcriteria Definitions

The four flexibility subcriteria are defined below:

Retrieval and Packaging is the ability of the retrieval system to excavate waste from its buried location and convert it into a waste package.

Variable Waste Forms is the ease that the system can accommodate or handle all buried waste forms. Consideration is given to size, shape, and weight. Size is the ability to handle a large variety of sizes. Shape is the ability to handle all shapes of waste. Weight is the ability to handle varying weights of waste.

Discrimination is the ability to select and maintain segregation of waste and soil into retrievable > 10 nCi/g categories.

Depth is the ability of the system to exhume waste at any reasonable depth.

### 5.2.5.2 Value Functions

A value function (Figure 13) was assigned to each proposed system according to its ability to meet the flexibility subcriteria.

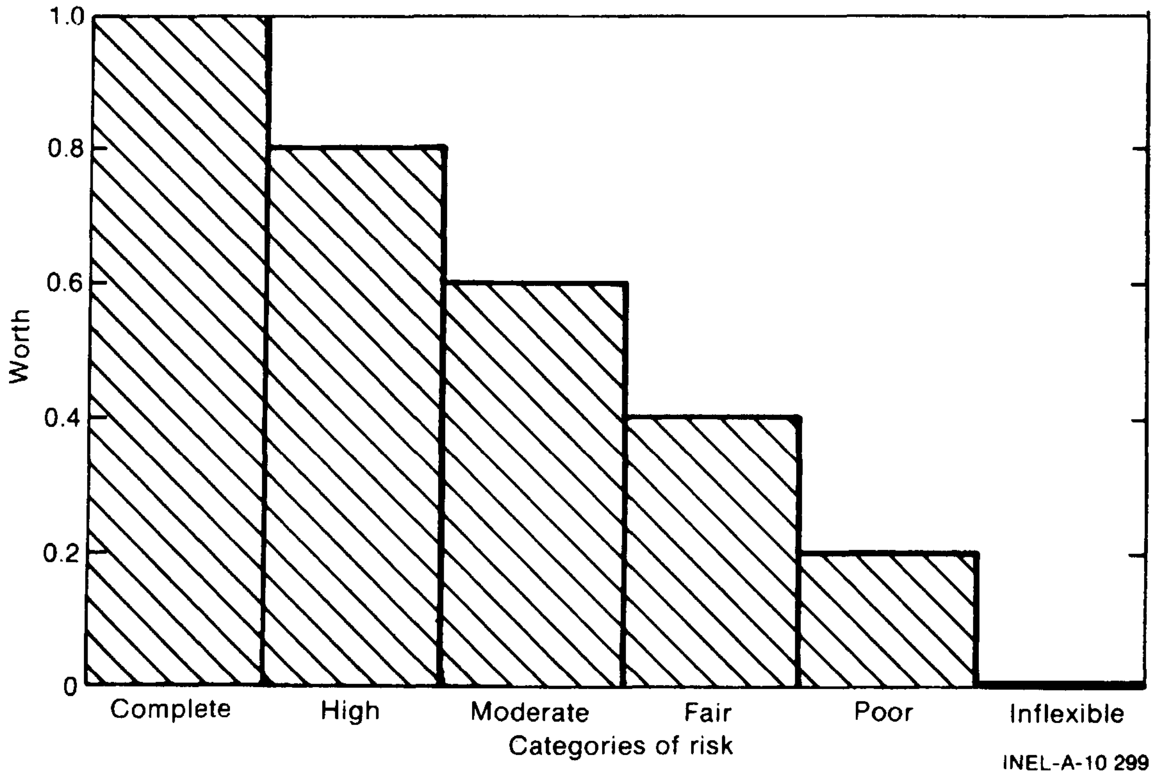


Fig. 13 Flexibility risk value functions.

5.2.5.3 Weighting of Subcriteria

Each subcriterion was weighted as to its relative importance to each other. Similarly the three categories of waste forms were ranked in order of importance and weighted as to their relative importance as shown in the following tabulation:

| Subcriteria | | Weight |
|---|---|---|
| Variable Waste Forms | | 0.40 |
| Size | 0.34 | |
| Shape | 0.33 | |
| Weight | 0.33 | |
| Retrieve and Package | | 0.35 |
| Discriminate | | 0.15 |
| Depth | | 0.10 |
| TOTAL | | 1.00 |

5.2.5.4 Evaluation of Design

Table 18 summarizes the design evaluation for each of the six candidate retrieval concepts. The worth of each concept is identified qualitatively in the rating column. Brief remarks supporting the qualitative judgements for each subcriteria also are provided in the appropriate columns of the table.

Table 19 presents the performance summary for the flexibility subcriteria.

5.2.6 Project Risk

Project risk of a buried waste retrieval system was selected as sixth in importance as a rating criteria with an overall weight or 0.09. The task force definition of project risk was:

TABLE 18

EVALUATION SUMMARY - FLEXIBILITY SUBCRITERIA

| System | Retrieval and Packaging | Variable Waste Forms | Discrimination | Depth |
|---|---|---|---|---|
| ACC Manual | Moderate | High | Complete | Moderate |
| | Personnel and equipment can readily move about in the inner building. Packaging is accomplished by merely dumping the bucketful of waste into the package w/o regard to contamination. Contamination is spread w/i the inner building. Dumps waste instead of placing it into package | If the backhoe is large enough, it can handle maximum size, shape, and weight. With presence of personnel, small items can easily be accomplished | Personnel aiding in excavation can monitor the waste and sort closely, thus providing the best and most timely separation into retrieve and nonretrieve catagories. Readily accommodates any shape of pit, X-Y mode | If the backhoe has long enough boom it can accommodate maximum depths. Smaller backhoes with Sherta booms can handle shallow wastes. Must reach from surface to pit bottom |
| KE Manual | Fair | Moderate | Fair | Complete |
| | Bucket or grapples are filled and dumped into package; must be sized for maximum form, thus may have difficulty with transferring into a package. Dumps waste rather than placing it into package | If the crane and bucket are large enough, it can handle all sizes, shapes, and weights. Flexibility limited by single sized bucket | Limited to radius of crane boom. Discrimation is limited to grapple or bucket load. In order to meet maximum forms, it is poor at discrimination. Operation radial mode | Telescoping boom can adapt to varying depths can operate from bottom of pit |
| Retriever 1 | Moderate | Moderate | Moderate | Fair |
| | Single unit with 3 attachments. Some attachments can place waste onto conveyor. Requires separate packaging after sorting. Downgrade flexibility by one position due to requirement of additional equipment | Three attachments designed to handle maximum forms. Additional attachment could aid in handling smaller forms. Requires changing attachments | Segregation of waste waste is accomplished by monitoring and sorting. Good discrimination, but added complexity radial mode downgrades by one position | Maximum Depth 20 ft |

TABLE 18 (Cont)

| System | Retrieval and Packaging | Variable Waste Forms | Discrimination | Depth |
| --- | --- | --- | --- | --- |
| FMC Mechanized | High | High | High | Complete |
| | MWR with multiple heads retrieve typical or standard wastes. Additional large equipment. Some of waste is dumped, some is placed into packages | MWR with multiple heads retrieve typical or standard wastes. Special large equipment handles maximum forms. Flexibility increased by multiple equipment | Operates in X-Y mode. Use of various equipment provides segregation waste | Operates from base of pit across face of the stack |
| KE Remote | Moderate | High | Moderate | High |
| | Four booms with assorted attachments. Dumps waste onto conveyor to be sorted ed and packaged. Downgrade by one position due to requirement of additional equipment | Multiple attachments allow variability to handle various waste forms well | Discrimination with conveyor and sorting system is good; however, due to radial mode and complexity of conveyor and sorting equipment downgrade by one position | Presumably can reach bottom of pit |
| FMC Remote | Moderate | Moderate | Moderate | High |
| | Similarity to FMC (Manual) system but, because remote controlling is more difficult to accomplish, lower values of flexibility were assigned. Reduce all FMC Manual risk categories by one position. | | | |

TABLE 19

PERFORMANCE SUMMARY - FLEXIBILITY SUBCRITERIA

| | Risk Categories | | | | Weight X Value | | | | |
|---|---|---|---|---|---|---|---|---|---|
| System | Retrieval and Packaging | Variable Waste Forms | Discrimination | Depth | R&P | VWF | Discrimination | Depth | Total |
| ACC Manual | 0.6 | 0.8 | 1.0 | 0.6 | 0.24 | 0.28 | 0.15 | 0.06 | 0.73 |
| KE Manual | 0.4 | 0.4 | 0.4 | 1.0 | 0.16 | 0.21 | 0.09 | 0.10 | 0.56 |
| Retriever 1 | 0.6 | 0.6 | 0.6 | 0.4 | 0.24 | 0.21 | 0.09 | 0.04 | 0.58 |
| FMC Mechanized | 0.8 | 0.8 | 0.8 | 1.0 | 0.32 | 0.18 | 0.11 | 0.10 | 0.82 |
| KE Remote | 0.6 | 0.8 | 0.6 | 0.8 | 0.24 | 0.28 | 0.12 | 0.08 | 0.72 |
| FMC Remote | 0.6 | 0.6 | 0.6 | 0.8 | 0.24 | 0.21 | 0.09 | 0.08 | 0.62 |

"Project risk is a measure of the ease to technically meet the requirements of the system including development, design, manufacturing, and testing."

The "requirements of the system" are defined in 1.4 as the removal of $2.5 \times 10^6$ $ft^3$ of TRU waste and soil, by the year 2000, safely and at reasonable cost.

### 5.2.6.1 Subcriteria Definitions

To evaluate project risk for the six alternative concepts, two subcriteria of equal weights are identified: (a) degree of complexity required of the system to meet design goals and (b) degree of modification of existing equipment or system required to meet design goals.

Detailed definitions for these subcriteria are provided below:

Degree of Complexity of System includes consideration of machinery required, manpower required, and dependence on complex manpower/machinery interaction. The more complex a system in any or all of these areas, the greater is its assumed potential for failure (greater project risk). Complexity in a mechanical system is measured largely according to the types of machinery and machinery interactions required. Thus, a highly integrated system in which retrieval equipment, enclosure, and supporting systems are all highly interactive would have a higher project risk than a system subdivided into several independently operated subsystems. The overriding assumption here is that development/design/testing problems should be more easily solved with modification of one or more independent components than modification of the entire system.

Degree of Modification of a system is a measure of the extent to which a proven or working system, including equipment, has to be modified to meet retrieval system requirements; i.e., retrieval rate, contamination control, health and safety to operators, etc. Here a black box that can do everything but which has never been used or tested will have a much higher project risk than a system using known or tested components. Similarily, a system with only bench scale experimentation is assumed to have higher project risk than a proven system.

### 5.2.6.2 Value Functions

The value functions used for both subcriteria is assumed to be the same (Figure 14.) A judgement function was used to assign values to the project risk subcriteria. This function was selected because it tends to give a higher worth to a process having greater probable success. Similarily, a process assigned a high project risk was assigned low worth.

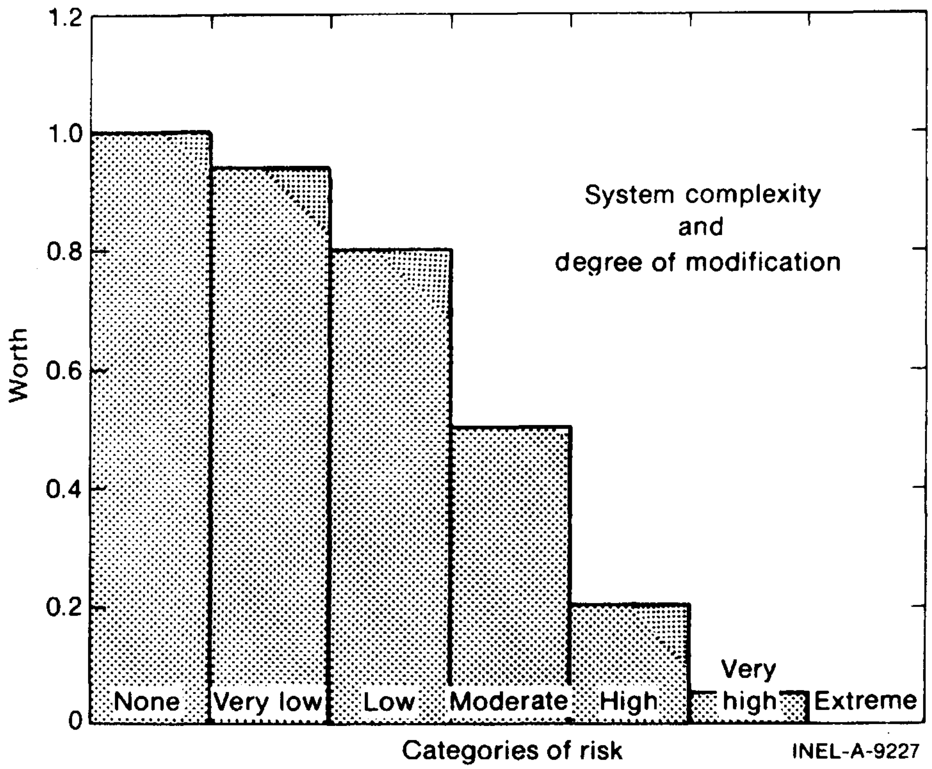


Fig. 14 Project risk value function.

5.2.6.3 Weighting of Subcriteria

Both subcriteria were assumed to be equal.

5.2.6.4 Evaluation of Designs

Table 20 summarizes the design evaluation for each of the six candidate retrieval concepts. The worth (weight) of each concept is identified qualitatively in the rating columns of the table.

Values for project risk, as determined by evaluation of the exhumation systems against the two subcriteria are provided in Table 21.

For an interpretation of these values, on the scale 0 to 1.0, a project risk of zero for a system would indicate that the system was incapable of meeting the design objective; a value of 1.0 would indicate an absolute assurance of success.

5.2.7 Resource Use

Resource use of a buried waste retrieval system was selected as last in importance as a rating criteria with an overall weight of 0.07. The task force definition of resource use was:

> "Resource use is a measure of the capability to optimize consumption of significant regional energy and nonrenewable materials and to avoid the excessive use of skilled manpower."

5.2.7.1 Subcriteria Definitions

Subcriteria definitions are provided below:

Nonrenewable Resources are those nonrenewable resources used directly by the retrieval process in significant quantities on a nonrecyclable basis.

# TABLE 20

## EVALUATION SUMMARY - PROJECT RISK

| System | System Complexity | Degree of Modification |
|---|---|---|
| ACC Manual | Very High<br><br>Large number personnel; requires complex system plus interaction for personnel support, waste handling and removal, and contamination control | High<br><br>Experience on small scale units. Requires major modification expansion of system to meet output requirements while maintaining acceptable levels of Health and Safety contamination control, etc. |
| KE Manual | Moderately High<br><br>Complex personnel/equipment interaction in removal area. Building move is a complex operation | Moderately High<br><br>Considerable design and testing required to demonstrate safety and contamination control. Slight modification required to existing earthmoving equipment |
| Retriever 1 | Very High<br><br>Highly complex, interactive unit with all components interdependent. Also requires complex personnel/equipment interaction | High<br><br>A first-of-a-kind unit incorporating some proven technologies in excavation technique and facility movement |

TABLE 20 (Cont)

| System | System Complexity | Degree of Modification |
|---|---|---|
| FMC Mechanized | Moderate | Moderate |
| | Generally independent components; complex equipment pieces with proven reliability. Building move would be difficult due to large size | Modification of existing, proven equipment primarily for operator health and safety and decontamination; proven success in moving large volumes of materials. Building concept less proven and will require development work |
| KE Remote | Moderately High | Moderately High |
| | Facility move very complex as with KE Manual. Dependent on single item of equipment having high degree of complexity | Considerable modification of existing and proven components |
| FMC Remote | High | High |
| | Same as FMC Manual with additional modification for remote operation; highly complex | Additional to FMC manual for remote operation. Requirements for TV cameras, better lighting, etc. |

TABLE 21

PERFORMANCE SUMMARY - PROJECT RISK

| System | Rating |
|---|---|
| ACC Manual | 0.125 |
| KE Manual | 0.350 |
| Retriever 1 | 0.125 |
| FMC Mechanized | 0.50 |
| KE Remote | 0.35 |
| FMC Remote | 0.20 |

Skilled Manpower Usage refers to those personnel whose job would require special schooling or experience.

Regional Energy Use refers to the energy used in the retrieval process, whether electrical or otherwise, supplied from sources within the Northwest or Intermountain Region.

### 5.2.7.2 Value Functions

Figures 15 through 17 show the value function ratings for each risk category and each of the subcriteria.

Each value function was formulated based on a subjective assessment of the subcriteria. Due to a lack of detailed information on the designs being evaluated, all value functions were based on subjective criteria such as high, average, low, etc., rather than objective judgements.

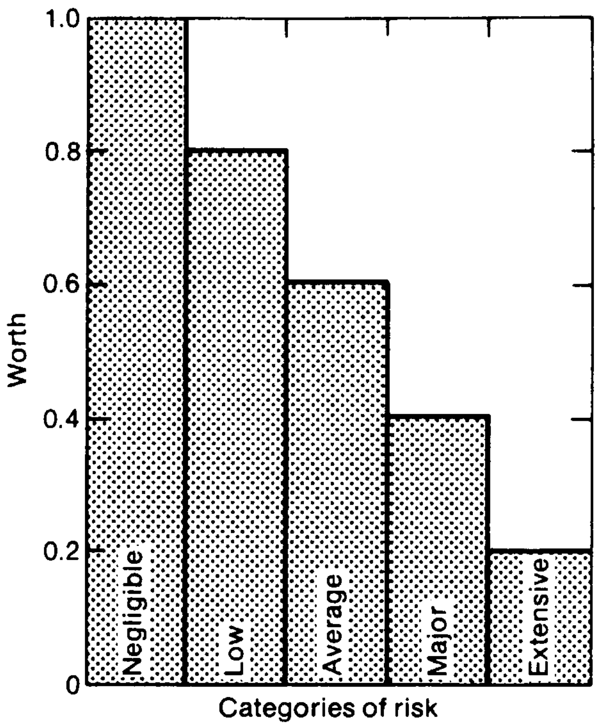


Fig. 15 Nonrenewable use value function.

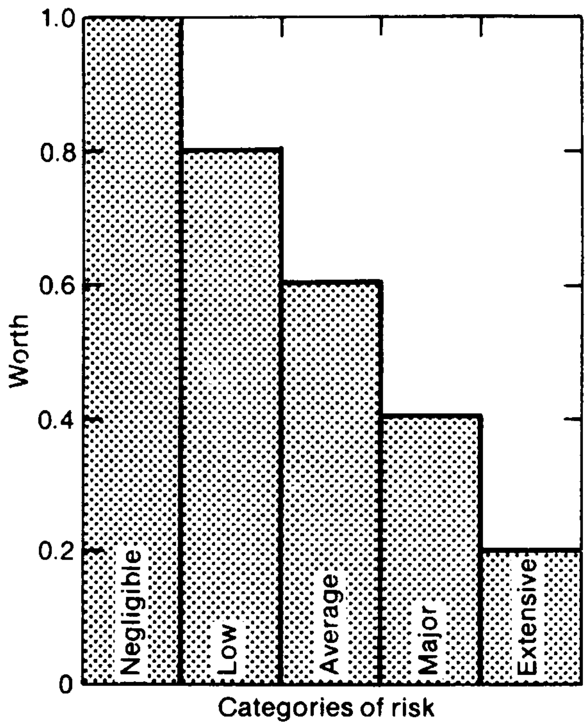


Fig. 16 Regional energy use value function.

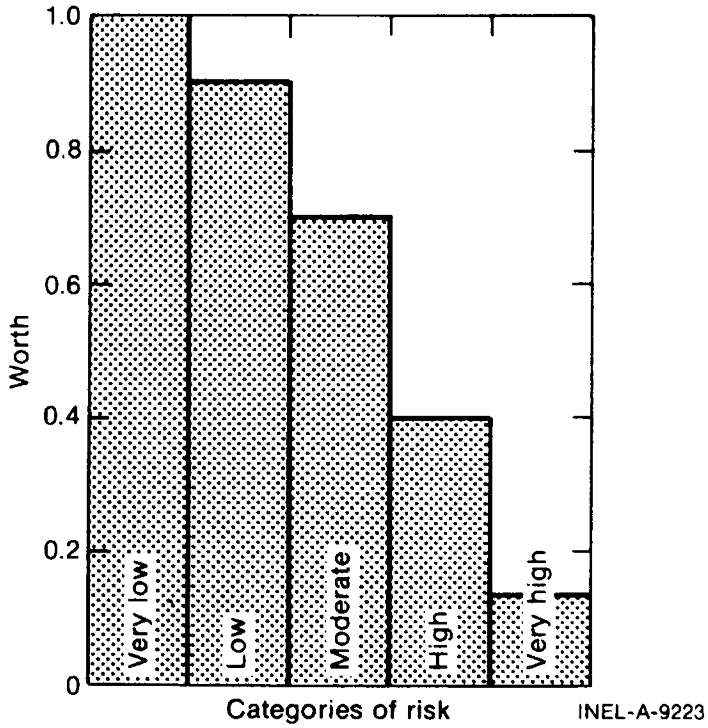


Fig. 17 Skilled manpower use value function.

5.2.7.3 Weighting of Subcriteria

All subcriteria were assumed to be of equal rank, although skilled manpower was felt by some to be slightly more important. Weighting is summarized in the following tabulation.

RESOURCE USE SUBCRITERIA WEIGHTS

| Subcriteria | Weight |
|---|---|
| Skilled manpower | 0.34 |
| Nonrenewable resources | 0.33 |
| Regional energy use | 0.33 |

5.2.7.4 Evaulation of Designs

Table 22 presents an evaluation summary for resource use and provides a brief rationale for that rating. The reasoning for the various ratings are further elaborated below.

Skilled Manpower Usage - All systems were given a "low" rating as there will be few skilled manpower needs with any retrieval process. The FMC and ACC manual approaches were rated slightly lower within the category due to the slightly higher number of heavy equipment items in each which would require skilled manpower to operate. All other systems were judged to require approximately equal skilled manpower forces.

Nonrenewable Resources - All systems were rated from "low" to "average". The manual systems were rated the lowest due to their greater use of clothing, shoe covers, etc. Waste containerization was not considered for any system as it was assumed containers would be the same for all. Building decontamination wastes also were not considered.

TABLE 22

EVALUATION SUMMARY - RESOURCE USE

| System | Nonrenewable Resources | Regional Energy Use | Skilled Manpower Reqd |
|---|---|---|---|
| ACC Manual | Average | Average | Low |
| | Manual process will require a much larger quantity of consumables such as shop covers, coveralls, etc. | All systems about the same, but manual will require considerable building heat during winter and cooling in summer | Few skilled workers required except backhoe operators |
| KE Manual | Average | Average | Low |
| | Similar to ACC Manual, but less usage of consumables | Similar to ACC Manual | Essentially same as ACC Manual, but less skilled workers required |
| Retriever 1 | Low | Average | Low |
| | Similar to above, but slightly less consumables usage | Lower energy usage due to smaller size and slightly less equipment being used | Similar to above |
| FMC Mechanized | Low | Average | Low |
| | Low consumables usage as personnel are transported around inside sealed bus | Similar to ACC Manual, but more electrical equipment usage. Uncertain whether building cooling or heating required, but assumed not | Similar to above but a few more equipment operators required |
| KE Remote | Low | Low | Low |
| | Little consumables needed except during decon | No facility heating or cooling required except for control room | Similar to Retriever 1 |
| FMC Remote | Low | Average | Low |
| | Similar to KE Remote | Similar to FMC Mechanized | Similar to above |

Note: All systems considered are assumed to use the same type of waste containerization technique, so waste containers were not considered under nonrenewable resources usage. Building decon needs will vary with size of building and necessity of decon.

Regional Energy Usage - All systems were rated from "low" to "average". Equipment electrical power and fuel usage were considered, but major impact could be heating/cooling requirements depending on personnel requirements. For these reasons primarily, the two manual systems were rated the lowest and the KE remote process the highest.

Table 23 is a performance summary of the six retrieval systems in the three subcriteria categories. Each system was given an overall category rating based on subjective judgement (i.e., high, low, etc.) for each subcriteria. The numerical value function was then assigned based on the information presented in Figures 15 through 17 and an estimate of where the process should lie within the rating span indicated on these graphs. A composite rating is also shown for quick comparison.

TABLE 23

PERFORMANCE SUMMARY - RESOURCE USE SUBCRITERIA

| Subcriteria Process | Skilled Manpower Usage | Nonrenewable Resources | Regional Energy Usage | Composite Rating |
|---|---|---|---|---|
| ACC Manual | 0.50 | 0.55 | 0.85 | 0.63 |
| KE Manual | 0.60 | 0.55 | 0.90 | 0.68 |
| Retriever 1 | 0.65 | 0.65 | 0.90 | 0.73 |
| FMC Mechanized | 0.75 | 0.60 | 0.85 | 0.73 |
| KE Remote | 0.80 | 0.75 | 0.90 | 0.81 |
| FMC Remote | 0.80 | 0.60 | 0.90 | 0.77 |

# 6.0 EVALUATION SUMMARY

The task force members responsible for subcriteria weights and associated value functions were assigned the responsibility of evaluating all six alternatives against those value functions. Table 24 shows the contributions of the various criteria to the FOM and the FOM for each alternative. According to the method employed here to evaluate each retrieval system, the FMC Mechanized approach stands out as the best alternative. It is possible that the two remote systems are equal and that Retriever 1, the ACC Manual method, and the KE Manual method are equal. The spread of FOM's for the two remote systems, Retriever 1 and the ACC Manual System (0.53-0.59) is so small that it is difficult to say that they are not equal. When numbers are close, such as the two remote systems, it is necessary to pay careful attention to sensitivity analysis before picking a final system.

Each of the leading systems should be evaluated against total cost and a complete sensitivity analysis conducted before making a decision.

TABLE 24

FINAL EVALUATIONS AGAINST MAIN CRITERIA

| System | Effectiveness | Operability | Health & Safety | Availability | Flexibility | Project Risk | Resource Use | Total (FOM) |
|---|---|---|---|---|---|---|---|---|
| FMC Mechanized | 0.18 | 0.12 | 0.11 | 0.09 | 0.11 | 0.05 | 0.05 | 0.71 |
| KE Remote | 0.12 | 0.11 | 0.11 | 0.07 | 0.09 | 0.03 | 0.06 | 0.59 |
| FMC Remote | 0.14 | 0.10 | 0.13 | 0.06 | 0.08 | 0.02 | 0.05 | 0.58 |
| Retriever 1 | 0.09 | 0.12 | 0.12 | 0.08 | 0.08 | 0.01 | 0.05 | 0.55 |
| ACC Manual | 0.08 | 0.08 | 0.10 | 0.13 | 0.09 | 0.01 | 0.04 | 0.53 |
| KE Manual | 0.09 | 0.07 | 0.07 | 0.11 | 0.07 | 0.03 | 0.05 | 0.49 |

## 7.0 ADDITIONAL TASKS FOR FINAL PROCESS SELECTION

The following items are suggested for further study:

(1) Plans for Equipment Development - As yet, plans to do preliminary equipment development work have not been made. It is recommended that considerable time and money be allotted in future budgets for development of key pieces of equipment once a retrieval method has been tentatively selected. This should be done prior to detailed design of a retrieval process. A detailed engineering study and design of at least the leading two alternative systems should be continued with the goal of better defining equipment, facilities, and operating techniques.

(2) Contamination Spread - It has to be realized and accepted that the interior of any retrieval structure will become contaminated. It is highly desirable to investigate means of minimizing the spread of radioactivity by enclosing the actual retrieval location and/or spraying of waste with a fixing agent. The methods of sizing large pieces of equipment presently scoped in the FMC process will result in large scale contamination releases within the building. The need for sizing wastes should be reevaluated so that operations are kept to a minimum. All waste sizing activities should be done in an enclosed area either within the retrieval building or the adjacent processing facility. Alternative methods of sizing, such as compaction in a filtered enclosure or cutting with a plasma torch, should be investigated. A definitive study should be made to optimize contamination control methods. This will probably impact the system selected, and will certainly impact the operational procedure. Movable curtains to localize small work areas should be considered. The designs with working faces could be improved by concentrating contamination control nearer the working face. This could allow many

pieces of equipment to have emergency air provisions rather than controlled environmental cabs. It is also possible that several equipment pieces could be combined, including the personnel emergency repair and firefighting units.

(3) Retrieval Building - While it has been realized that building design and movement will be a major facet of the retrieval project, more work needs to be done to bring the conceptual building designs up to the level of design for other equipment. Specifically, this should include the following:

(a) The topography of the RWMC should be studied to determine the quantity of soil needed for leveling the area. This could affect the total quantity of soil to be subsequently processed and/or influence retrieval equipment size.

(b) A more definitive evaluation should be made of the method for backfilling the areas from which waste has been retrieved. At present, a backfilling method has not been seriously considered for any of the concepts.

(c) Stresses which could be induced during building movement should be evaluated in sufficient depth to give an understanding of all the problems involved, and the reinforcing necessary to ensure building integrity.

(d) Building movement methods need to be looked at further. Kaiser has done a more complete job than FMC in this respect, but neither has fully addressed methods for moving the building sideways. Ground clearances and building flexing (see c above) should be investigated.

(4) More Definitive Criteria Needed - A number of items should be clarified before further design effort continues. Specifically, this should include the following:

   (a) Delineation of the volumes of soil and waste to be retrieved, their locations, and any specific problems.

   (b) Better delineation of sizes and radiation levels. A 20-ton 6,000 R/h source has been mentioned several times. Design personnel need at least a rough estimate of the quantity of high radiation level or large volume pieces.

   (c) Provision of guidelines as to exactly what items are to be retrieved and what are to be left in place.

   (d) Provision of decontamination guidelines. The necessity to decon the building interior, vehicles, or other equipment should be studied further.

   (e) Provision of maximum permissible waste dimensions in order to determine waste sizing requirements.

(5) Sensitivity Analysis - A sensitivity analysis of all leading alternative systems should be performed.

(6) Figures of Merit (FOMs) - The FOMs should be recomputed at a future time when more data will be available. If the FOMs for the leading alternative systems are redone, it may be useful to consider different criteria; also better costs will be available.

(7) Error Estimates - The error estimates of the leading alternative systems should be computed if the FOMs are recomputed and if the evaluators take part in the entire evaluation. Error estimates are available now only on the main criteria weights.

(8) Waste Removal vs Continued Burial - Specific decisions need to be made regarding problem wastes and a determination of which wastes must be removed and which may remain buried. Reference here is to very large items such as concrete blocks and very highly contaminated beta-gamma active waste items. Such decisions should be made as soon as possible as they significantly impact the required capabilities of the exhumation system.

(9) Waste Assay - Assay of exhumed waste is a highly significant factor of the entire exhumation process and, possibly, can be paramount in reducing the volume of waste requiring treatment and eventual repository disposal. The design and development of assay systems for exhumed waste should receive more emphasis so that overall program planning can be more useful.

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APPENDIX

TASK FORCE RESUMES

Resumes of the task force members are provided below and on the following pages.

HAROLD M. BURTON

Mr. Burton has been employed for the last 2 years as Assistant Division Manager of Project Engineering at EG&G Idaho, Inc., where he directed senior project engineering personnel in projects ranging from 50 thousand to 40 million dollars for EG&G programs at the Idaho National Engineering Laboratory.

During the previous 7 years, for EG&G and Aerojet Nuclear Company, he worked first as an engineer performing special technical assignments on the Loss of Fluid Test (LOFT) Project; later, as supervisor of the LOFT Mobile Test Assembly (MTA) Systems Section, and finally, as manager of the Experimental Systems Branch of the LOFT Technical Support Branch.

Earlier he was engaged in reactor work as a licensing engineer and a fluid systems engineer for Babcock and Wilcox, at their Power Generation Division in Lynchburg, Virginia. His early career in nuclear science included responsible engineering positions with Douglas United Nuclear and with the General Electric Company at its Hanford Atomic Products Operation at Richland, Washington.

Mr. Burton has a B.S. in chemical engineering from the University of Texas and an M.E. in nuclear engineering from the University of Virginia.

C.W. BILLS

Dr. Bills currently is Assistant to the General Manager at EG&G Idaho, Inc. For the 8 years previous to joining EG&G he was Assistant Manager of Production and Technical Support for the Idaho Operations of the Energy Research and Development Administration (now Department of Energy). During the preceding 3 years at ERDA, Idaho Falls, he was deputy director of the Health and Safety Division. Earlier for the Atomic Energy Commission, he worked successively as branch chief for the Geochemical and Geophysics R&D Branch in Denver, Colorado, and as a nuclear chemist for the Chemical Separations Branch at the Hanford Operations Office in Richland, Washington. During his early career he worked as a research chemist and as a corrosion chemist for the Los Alamos Scientific Laboratory, Standard Oil and Gas Company, and Mallinckrodt Chemical Works.

His specific experience includes waste management chemical processing, nuclear technology, materials management, test reactor operations, water reactor safety, geothermal technology, engineering and construction, low head hydro power, contract management, and others.

Dr. Bills obtained his B.S. in chemistry from Colorado State University in 1947, his M.S. in organic and radiochemistry from the University of California in 1952, and his Ph.D. from the University of California in 1954.

## J. R. FIELDING

Mr. Fielding has 16 years of varied experience with the operating contractors at the Idaho National Engineering Lasboratory (INEL). His work experience includes writing environmental statements, safety analysis reports, hazard evaluations, and safety assessments. Currently, he is manager of the EG&G Idaho Safety Division.

Specific representative work includes environmental monitoring, data evaluation, and reporting of radiological results of the SNAPTRAN Program (an airborne nuclear power supply) at the INEL during the 1960s. Later he coordinated the writing of an environmental statement for the waste management operations. He also provided the initial draft of a safety review document for the Radioactive Waste Management Complex (RWMC). He has been intimately familiar with the RWMC operating practices for the past 16 years, and has a working knowledge of internal and external radiological dose calculations including the various models for transfer of radionuclides through environmental pathways to man.

Mr. Fielding received a B.S. in math and physics from Brigham Young University in 1970.

J. S. SCHOFIELD

Mr. Schofield recently joined the New England Nuclear Corporation as a senior staff scientist in their Nuclides and Sources Division. Before this assignment, he served for 2 years with Allied Chemical Corporation as Group Leader responsible for development of processes to retrieve all stored, high level calcined waste at the Idaho Chemical Processing Plant (ICPP) at the Idaho National Engineering Laboratory. He also set up the high temperature gas-cooled reactor (HTGR) at the ICPP and was responsible for fuel storage basin cleanup operations. Earlier, for Allied General Nuclear Services (AGNS), he served as technical liaison between AGNS and Bechtel Corporation on design of liquid and solid waste treatment facilities. He also provided design criteria and performed safety reviews of solid transuranic and nontransuranic waste storage and handling areas.

His career began with the Atlantic Richfield Hanford Company where he served for 4 years as a shift engineer at their purex plant and later as a process startup engineer at their $^{137}Cs$ and $^{90}Sr$ encapsulation plant.

Mr. Schofield recieved a B.S. in chemical engineering from Kansas State University in 1970.

JOHN L. WARREN

Mr. Warren has been employed for the last 6 years by the Waste Management Group at the Los Alamos Scientific Laboratory (LASL) in New Mexico.

For the past 3 years, as section leader of Solid Waste Disposal Operations he has been responsible for handling, treatment, disposal, and storage of radioactive solid and hazardous chemical wastes. For 2 years previous to this assignment he was a project leader in the same organization. His earlier work at LASL included studies to characterize defense transuranic waste and the development of criteria for interim storage of transuranic waste.

Before joining LASL, he was engaged for 2 years in postdoctoral research in radiochemistry at Ames Laboratory, Iowa State University.

Mr. Warren received a B.S. in chemistry in 1966 and a Ph.D. in radiochemistry in 1970.

## C. E. WICKLAND

Mr. Wickland has been employed for 21 years at the Rocky Flats Plant in Colorado. For the last 3 years, he has been in Waste Management and currently is manager of Waste Technology and Planning. The previous 10 years were spent in manufacturing, specifically uranium and plutonium metallurgical operations. Earlier he spent 8 years in R & D, specifically plutonium metallurgy.

Mr. Wickland obtained a B.S. in metallurgical engineering from the University of Michigan in 1952.

WILLIAM J. WHITTY

Mr. Whitty has been employed for the last 4 years by the Waste Management Group at the Los Alamos Scientific Laboratory where he has been involved in different studies using decision analysis and statistics. Before joining LASL he was responsible for mathematics, statistics, and computer applications related to pollution analyses with the Phelps Dodge Corporation in Tucson, Arizona. Other prior experience includes systems analyses activities with the Dikewood Corporation in Albuquerque, New Mexico, and with the Center for Computer Sciences and Technology, National Bureau of Standards, Garthersburg, Michigan.

Mr. Whitty has a B.S. in biological sciences with a minor in engineering from Drexel University and an M.S. in systems engineering from the University of Arizona. He is a member of the Operations Research Society of America and the Institute of Management Sciences.