TECHNICAL CONCEPT FOR A GREATER CONFINEMENT DISPOSAL TEST FACILITY

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For the past two years, Ford, Bacon & Davis has been performing technical services for the Department of Energy at the Nevada Test Site in specific development of defense low-level waste management concepts for greater confinement disposal concept with particular application to arid sites.

The investigations have included the development of Criteria for Greater Confinement Disposal, NVO-234,(1) which was published in May of 1981 and the draft of the technical concept for Greater Confinement Disposal,(2) with the latest draft published in November 1981. The final draft of the technical concept and design specifications are expected to be published imminently. The document is prerequisite to the actual construction and implementation of the demonstration facility this fiscal year. The GCD Criteria Document, NVO-234 is considered to contain information complimentary and compatible with that being developed for the reserved section 10 CFR 61.51b of the NRCs proposed licensing rule for low level waste disposal facilities.(3)

BACKGROUND

The first question to be answered is "Why greater confinement disposal?"

As a result of past Federal government operations, nearly 70 million cubic feet of low-level radioactive waste have been accumulated at burial and storage facilities around the country.(4) By the turn of the century, this accumulated volume is expected to exceed over 113 million cubic feet of government-generated waste.(5) At the same time, the generation of low-level waste by commercial sources (fuel cycle, institutional and industrial waste) is increasing at a rate which exceeds the rate of low-level waste generated by the Federal government. The Oak Ridge National Laboratory has estimated that, by the year 2000, the accumulated low-level waste volume from all sources will exceed over 283 million cubic feet.(5) This volume does not include the high-level, transuranic, or the remedial action radioactive wastes which have been and will continue to be generated during the same period.

The radioactivity associated with much of this waste, particularly defense type low-level waste, is made up of mixed fission products, activation products, tritium, and traces of some longer lived transuranic elements. In the past, this waste has been normally stored or disposed of using the shallow land burial concept. However, high-specific-activity wastes and long-lived low-level waste are not suitable for shallow land burial as a result of their high radioactivity and persistence respectively and because of their potential hazard to man at shallow depths. Costly disposal in deep geologic repositories, in the past, has been viewed as the most attractive disposal method for high specific activity and long-lived waste types. However, in the light of the large volume of high-specific-activity low-level waste being generated in the near future, a safe alternative to shallow land burial and an economic alternative to deep geologic disposal is clearly needed. The concept of greater confinement disposal (or GCD) is proposed as such an alternative.

DEFINITION OF GREATER CONFINEMENT DISPOSAL

Greater confinement disposal has been defined by the National Low-Level Waste Program as the "disposal of low-level waste in such a manner as to provide greater containment of radiation, reduce potential for migration or dispersion or radionuclides, and provide greater protection from inadvertent human and biological intrusions in order to protect the public health and safety."

Several waste disposal methods fall within this definition for application in humid and arid locations and are listed below in Table I.

TABLE I

GCD LAND DISPOSAL ALTERNATIVES

Disposal Concept	Site Condition	
	Arid	Humid
Improved shallow land burial (thicker cover, engineered barriers)	-	X
Intermediate depth burial pit (much thicker cover, arid site disposal)	X	-
GCD borehole	X	-
Mine cavity (adit)	X	X
Deep well injection (beneath aquifer)	X	X
Disposal in hydrofractured strata	X	X

Two concepts for greater confinement disposal investigated for implementation at the Nevada Test Site are shown in Fig. 1. They include the intermediate depth pit or trench concept for disposal of large volumes of low specific activity wastes, and the GCD borehole concept for disposal of high specific activity wastes.

ADVANTAGES AND DISADVANTAGES OF GCD

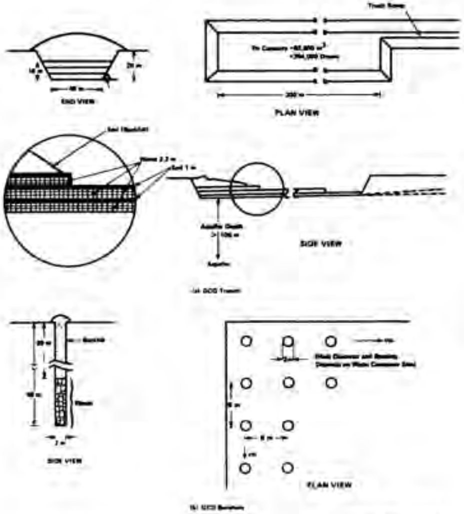
GCD has several technical advantages, primarily related to the reduction of exposure pathways, e.g., surface phenomena effects, such as erosion, or subsidence which reduce the material cover over the waste burial location. These effects and other pathways of exposure reduced by GCD include those due to nuclide migration, dispersion, vapor transport to the surface and the effect of plant root penetration and animal burrowing into the waste.

Greater burial depth provided by GCD may also allow for earlier release of disposal sites to public use than what is currently anticipated for shallow land burial.

One of the chief advantages of locating a greater confinement disposal facility at an arid site, such as the Nevada Test Site, is the fact that the area is characterized by low precipitation, high evapotranspiration and the presence of caliche or hardpan just below the surface which serves as an aquitard. Such characteristics combine to limit the infiltration of moisture into the unsaturated zone to a depth of but a few meters. As a result, the migration of contaminants out of the site by moisture movement is expected to be negligible.

Perhaps one of the most important pathways which affects shallow land burial is that of human intrusion. Intrusion into a waste site by a human being can take the form of constructing a home on the site, tilling or farming the area, drilling a well through the site or looking for artifacts of value. Greater confinement disposal does not assume to eliminate the human intrusion scenario, but by providing for disposal of waste at greater depths (for example in the range of 10 to 50 meters below the surface, i.e., 150 feet down, the probability of such intrusion is minimized as much as practicable.

The two major disadvantages of GCD, when compared to shallow land burial, are the potentially higher cost and the fact that the waste is located closer to a water table. Recent studies by Ford, Bacon & Davis indicate that the cost difference can be rather minor ranging from a cost equivalent to that of shallow land burial facilities to several times higher, dependent upon geology and volumes of waste disposed. Because of the water table consideration it was necessary as part of the development of criteria for GCD to develop the concept of optimal burial depth (compared in Figure 2 for arid and humid sites). (At the Nevada Test Site, where the aquifer is over 200 meters below the surface, the



SOURCE: REFERENCE 1.3

FIG. 1. GREATER CONFINEMENT DISPOSAL WITH POSSIBLE DIMENSIONS

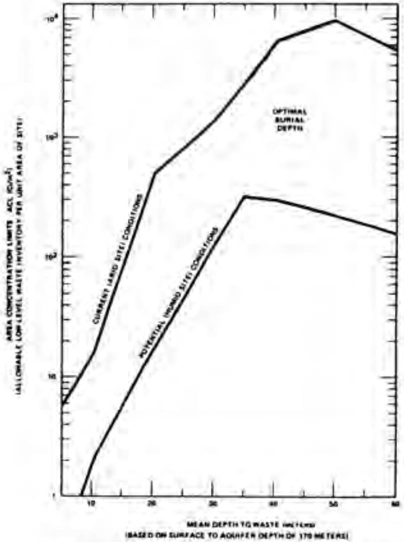


FIG. 2. ALLOWABLE AREA CONCENTRATION LIMITS FOR DISPOSED LOW-LEVEL WASTE AS FUNCTION OF BURIAL DEPTH

difference in the effect of migration from a GCD facility to the aquifer versus the same effect from a SLB facility would hardly be noticeable.

This consideration may, however, be important for humid sites or at other sites where a more permeable geology exists in the form of lava tubes, fracture zones, etc.

RELATIVE DOSE IMPACTS OF GCD VERSUS SLB

A calculation of maximum individual dose factors in units of rem per curies per square meter of disposal area, demonstrates that the concept of GCD (for burial of waste at 35 meter depth) results in a signficant reduction in the radiological dose impact for an equivalent source (in curies) of waste disposed in a typical 2 meter deep shallow land burial facility. See Fig. 3 for a comparison of SLB and GCD for non-transuranic wastes and Fig. 4 for a comparison of SLB and GCD for transuranic waste disposal. As seen from the figure, burial of waste by GCD results in a significant reduction (i.e. by two or more orders of magnitude) in the dose impact of such problem isotopes as C-14, Ra-226, Ni-59, Cs-135, and practically all transuranic isotopes including Np-237.

TYPES OF WASTE COMPATIBLE WITH GCD

Under the current NRC requirements, proposed by the draft rule 10 CFR 61, for land disposal of low level waste in near-surface burial facilities, low-level wastes may be classified Class A, B, or C. Class B waste will likely require processing to increase the stability of the waste form prior to disposal. Similarly Class C "intruder waste" will not only required an improved waste form to minimize leaching, but will also require the development of a high integrity waste disposal canister, which some advocate will last 300 years. The period of 300 years represents the time required for certain high specific activity low-level waste types, e.g., Sr-90 or Cs-137, to decay to 0.1% of their original source strength, thus reducing substantially the health hazard to the public.

In Table II, the area disposal concentration limits for humid and arid greater confinement disposal sites can be compared to the disposal limits for Class A near surface burial waste as defined by 10 CFR 61.

Greater confinement disposal (i.e. at greater depths of about 30-35 meters), and particularly disposal of wastes in an arid climate, may offer a cost effective alternative to both the processing and high integrity container requirements of Class B and C wastes, by permitting such wastes to be buried deeper with minimum 100 year integrity packaging. Elimination of the processing and special packaging requirement (10 CFR 61) for certain types of problem wastes should not only reduce the waste handling requirements but ultimately the occupational dose for the entire waste disposal process.

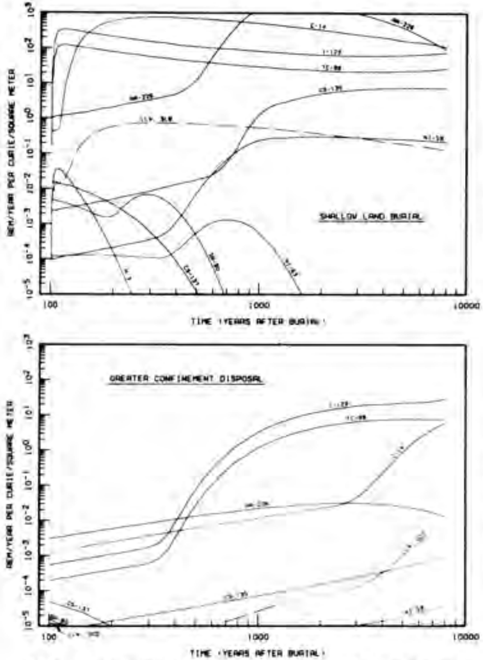


FIG. 3. LONG-TERM DOSE/CURIE PER SQUARE METER FOR NON-TRU LOW-LEVEL WASTE

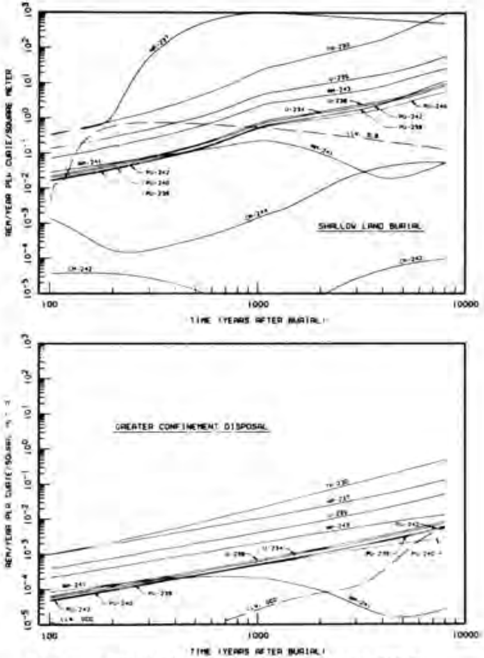


FIG. 4. LONG-TERM DOSE/CURIE PER SQUARE METER FOR TRU LOW-LEVEL WASTE

TABLE II

AREA CONCENTRATION DISPOSAL LIMITS, ACLs (Ci/m^2) FOR
NON-NEAR SURFACE OR GREATER CONFINEMENT DISPOSAL FACILITIES[a,b]
(Reference 1)

	Humid Site[c] Greater Confinement (Limiting Case)	Arid Site[d] Greater Confinement (Expected Case)	Comparison Shallow Land Burial[e]
H-3	940	6,500,000	40
C-14	2.3	3.8	.8
Ni-59	3.7	240	2.2
Ni-63	220	24,000	3.5
Co-60	(f)	(f)	700
Sr-90	36	5100	.04
Tc-99	1.1	1.1	.3
I-129	0.0011	0.05	.008(g)
Cs-135	16	690	84
Cs-137	12,000	13,000	1.0
Ra-226	0.011	6.3	(h)
Th-230	0.0099	0.38	(h)
U-234	14	310	(h)
U-235	0.4	9.3	0.04
U-238	(f)	(f)	0.05
Np-237	0.13	19	(i)
Pu-238	23,000	54,000	(i)
Pu-239	5.5	210	(i)
Pu-240	11	420	(i)
Pu-241	68,000	2,100,000	(i)
Pu-242	4.5	170	(i)
Am-241	2400	7,600	(i)
Am-243	1.4	51	(i)
Cm-242	2,100,000	(f)	(i)
Cm-244	2400	150,000	(i)
Unidentified LLW	330	2,900	—

(a)Minimum Area Disposal Concentration Limits for non-near surface disposal represent the inventory of nuclides in waste (in curies) which can be safely disposed per unit area (in square meters) rather than per unit volume of dedicated site at a mean depth of 35 meters. The limits assume 100 yr container integrity, and are based on Pathway Analysis developed in Appendix A of Reference 1.

(b)Application of ACLs for specific waste forms, is discussed in Appendix M of this document.

(c)Assumes a vertical groundwater velocity of 5m/yr and dispersion of 100 m^2/yr.

(d)Assumes a zero vertical groundwater velocity and dispersion of 0.1 m^2/yr.

(e)Minimum near-surface disposal concentration limits per unit site area are from Reference 3 (column 1), assuming a 1 m waste thickness.

(f)The calculated allowable area concentration limit, ACL, exceeds the specific radioactivity of the nuclide.

(g)Near-surface isotopes concentration limits exceed or may be incompatible with those calculated for greater confinement disposal.

(h)Isotope concentration limit is not listed in Reference 3.

(i)Isotope concentrations are limited to 10 nanocuries/gram under current guidelines (i.e. <0.02 Ci/m^2).

As such GCD represents a potentially viable option for a broader grouping of waste types, including transuranics, than as presently indicated by the small quantity of low-level wastes in the categories between Class C intruder waste and high-level waste.

OBJECTIVE OF GCD BOREHOLE DEMONSTRATION TEST

The objectives of the GCD facility demonstration test are to:

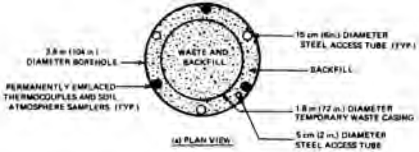
- Define equipment and procedures required for GCD facility operations
- Establish the cost of constructing and operating a GCD facility
- Determine the impact of waste emplacement on the hydrogeologic characteristics of the perturbed soil media as an indicator of the potential effect on nuclide migration.

To accomplish the last objective, three principal experiments have been defined:

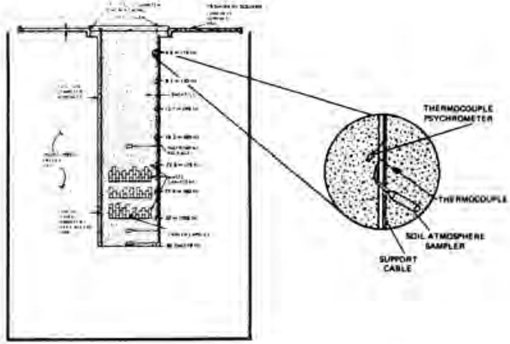
- To perform a hydrogeological characterization of the perturbed system surrounding the borehole, and measure moisture movement. This data will be used to evaluate and verify parameters used in models for development of the GCD disposal concentration limits.
- To quantify the thermal response of the geologic medium to the buried heat-generating waste (probably strontium-90 and cesium-137).
- To identify and quantify if possible nuclide migration, most particulary tritium.

It should be noted that the waste to be buried in the GCD facility will be encapsulated in relatively high integrity containers with expected lifetimes well beyond the five-year duration of the monitoring efforts for the demonstration test. As a result, radionuclide migration from the facility from the actual waste canisters, is expected to be insignificant. Monitoring efforts will thus be concentrated on obtaining moisture movement and temperature response data, and to some degree, radionuclide migration data from tracers. The data will be used as input to appropriate models to predict long-term performance.

Fig. 5 shows the relative cross sectional vertical location of the selected instruments and Fig. 6 the plan view orientation of the permenently emplaced instrument strings and open cased holes for gamma and neutron logging.



(a) PLAN VIEW



(b) SIDE VIEW

FIG. 5. ARRANGEMENT OF INSTRUMENTATION IN WASTE BOREHOLE

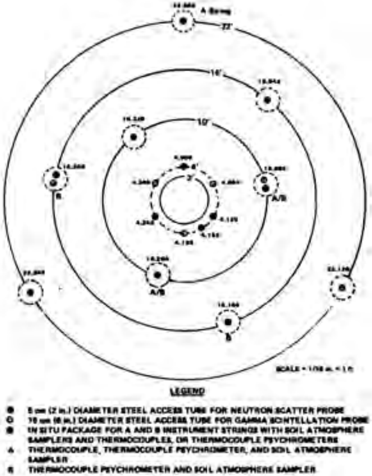


FIG. 6. PLAN VIEW GCDF BOREHOLE AND INSTRUMENTATION MONITORING SYSTEM

Soil atmosphere samplers (Fig. 7) will be used to collect the sample and determine the rate of moisture movement by measuring the ratio of the deuterium tracer, triggered after the waste is emplaced, to the normal water vapor in the sample. Other moisture data will be obtained using thermocouple psychrometers to measure moisture potential, and the portable neutron scatter logging probe, to measure moisture content. The thermal response of the soil media will be measured using thermocouples and/or the thermocouple psychrometers that are permanently emplaced around the borehole.

The occurrence of nuclide migration will also be monitored although not much is expected during the 5 year period of the test. A germanium diode crystal, which again is a portable device, can be lowered down the open casing on an infrequent basis, to take gamma logs which may help identify the existence of possible radionuclde migration. The shielding characteristics of the soil should reduce the level of background gamma radiation from the waste source sufficiently to observe the activity of migrating radionuclides in the vicinity of the probe.

ENGINEERING AND TECHNICAL ISSUES

One of the engineering difficulties with instrumenting the borehole is the fact that it is very difficult to drill a small diameter hole through the alluvium without encountering boulders which may deflect the drill shaft, thus causing nonvertical alignment to the borehole.

To determine where the instruments would be located, it was necessary to determine the temperature distribution (Fig. 8) around the borehole to determine what locations would provide the best data and also assure the environmental conditions for instrument operations are properly specified. To emplace the instruments, it is currently proposed to tie the instrument packages to a nylon or steel cable. These instrument "strings" would be connected to an anchor "wheel" which would be lowered along the inside of the borehole. The borehole would then be backfilled leaving the instruments in direct contact with the backfilled material. It is expected that the backfilled material will be designed and its density controlled in such a way as to simulate as nearly as possible the natural soil media.

In addition to the instrumentation system surrounding the borehole, a number of laboratory support experiments are also recommended(2) to provide additional support and interpretation of the field data, as well as provide information that can be useful, along with field data, in verifing the performance of the predictive models.

FIGURES OF MERIT TO GAUGE GCDF PERFORMANCE

There are many factors (Table III) that, in some way or another, are being investigated as part of the demonstration test.

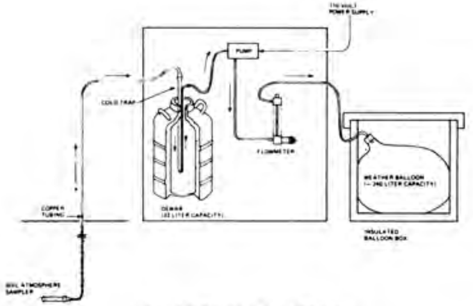


FIG. 7. SOIL ATMOSPHERE SAMPLING SYSTEM

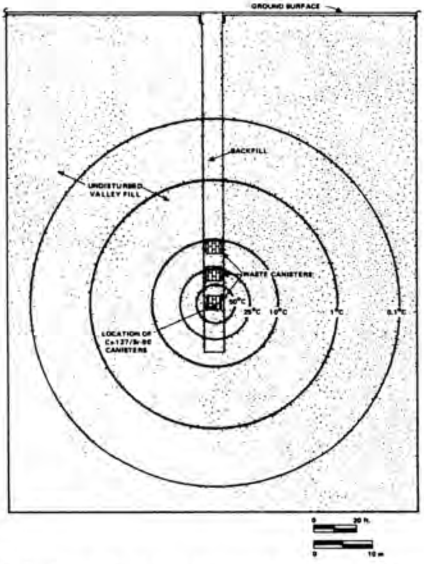


FIG. 8. GCDF SECTION SHOWING PREDICTED INCREASED TEMPERATURE ABOVE AMBIENT CONDITIONS DUE TO Cs-137 AND Sr-90 DISPOSAL

TABLE III

FACTORS AFFECTING GCDF PERFORMANCE

Geologic Medium

Thermal
Mechanical
Hydrologic
Contaminant Transport
Structural
Homogeneity

Facility Design

Emplacement Depth
Waste Volume
Dedicated Land Surface
Backfill Materials/Operation
Waste Canister
Monitoring System

Facility Operation

Operations Sequence
Waste Emplacement Method
Waste Handling/Transfer Method
Site Maintenance
Decommissioning

Waste Factors

Leachability
Radionuclide Mobility
Radioactivity Inventory
Thermal Characteristics
Packaging
Handling

There are two principal factors, however, that stand out in terms of providing figures of merit for evaluation of facility performance. These are the thermal response of the facility, and the rate of moisture movement through the soil media. The two parameters are assumed to be coupled. At this time, a final judgment has not been made as to what the actual figure of merit parameters or values will be. Some concepts to determine the figures of merit are being investigated. For the thermal response, an analysis has been performed to provide an expected temperature configuration around the waste cell, as shown in Fig. 8. The monitoring experiment, of course, will make measurements to refine and verify the theoretical calculations.

A possible figure of merit may be that of determining what temperature variance above ambient is acceptable so as not to produce a major effect in the rate of nuclide migration, or in reality for this experiment, the tracer. The figure of merit may be as little as one degree temperature variance or greater; this has to be determined experimentally.

With respect to the hydrological figure of merit, most of the data obtained by this experiment will be in the form of moisture data which, through the application of Darcey's law, Eq. (1), can be used to obtain moisture velocity or solute velocity through the soil.

$$V_x = \frac{-Kx(\Theta)}{\Theta}\frac{dh}{dx} = \frac{-K(\Psi)}{\Theta}\frac{dh}{dx} \qquad (1)$$

where:

V_x = The soil-water Darcy moisture velocity (L/T)

K_x = Hydraulic conductivity (L/T)

Θ = Volumetric moisture content (L^3/L^3)

Ψ = Matric potential (F/L^2 or L)

$\frac{dh}{dx}$ = Energy gradient as F (depth, Ψ, temperature)

The moisture velocity would be measured directly by the deuterium experiment with the soil atmosphere samplers. Moisture velocity can also be calculated using data provided by the thermocouple psychrometers and the neutron moisture probe. A possible figure of merit for satisfactory performance of the facility may be to demonstrate that the measured velocity (in meters per year) is much less than what might be defined as the limiting carrier velocity, Eq. (2).

$$V_x \leq V_c \qquad (2)$$

where

$$V_c = \frac{D}{10\,(T_{1/2})}$$

and

V_c = Limiting nuclide carrier (moisture) velocity

D = Pathway distance (depth) of waste to biosphere

$T_{1/2}$ = Half-life of dominant nuclide

The carrier velocity is that velocity which is equal to the depth of the facility divided by the number of years equivalent to ten half lives of the nuclide in question such as tritium. The number of half lives represents the amount of time necessary to reduce the initial inventory by a factor of a thousand. This number, of course, is arbitrary. The value sufficient to verify the performance of the site will be developed by analysis as the monitoring data is obtained. This example, in any case, shows the value of the GCD demonstration test and experiment in providing data feedback in the process of developing, for example, the area disposal concentration limits, defined in the GCDF Criteria Document. As the demonstration project proceeds, this data can be refined and the viability of GCD as a disposal concept can be verified.

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