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DESIGN STUDY (II) ON GEOLOGICAL ISOLATION
SYSTEM FOR HIGH LEVEL RADIOACTIVE WASTES

(1981)

Summary

February, 1982

Shimizu Construction Co., Ltd.

C O N T E N T S

DESIGN STUDY (II) ON GEOLOGICAL ISOLATION SYSTEM FOR HIGH LEVEL RADIOACTIVE WASTES

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1. Introduction

Among various methods for disposal of high level radioactive wastes, geological isolation is considered the most promising, and developments are under way in various countries. On the basis of the results obtained in the "Research on the Geological Isolation System for the Disposal of High Level Radioactive Wastes" conducted the previous year, the present study aims at elucidating the concept of a system which is the most suitable for this country.

Fig. 1 is the flow chart of the study on the design of geological isolation system for high level radioactive wastes.

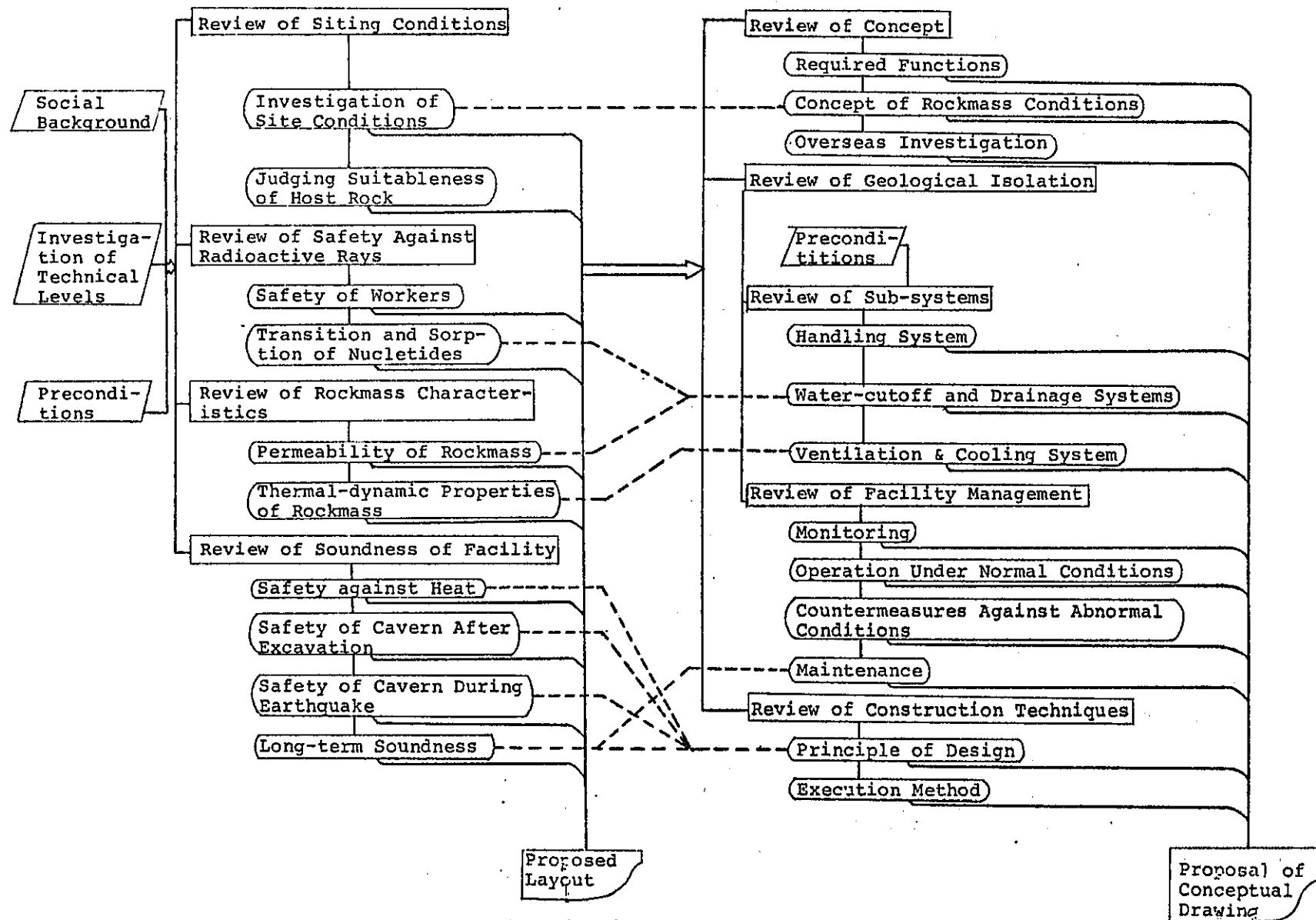


Fig. 1: Flow of Design Study on Geological Isolation
System for High Level Radioactive Wastes

2. Concept of Geological Isolation System

2.1 Functions Required for Geological Isolation

The geological isolation system can be defined as an integral system which includes a layout for effectively utilizing the natural and the artificial barriers, procedures for enabling secure and safe burial of high level radioactive wastes and the management of the system. Various functions required of the system are divided into those before and after the burial (state when all the facilities have been removed and back-filled), and listed in Table 1.

Table 1: Functions of Geological Isolation System

Domain to be provided with functions	<ul style="list-style-type: none"> • Artificial barrier (Geological isolation facilities which include surface facilities) 	<ul style="list-style-type: none"> • Artificial barrier (Geological isolation facilities) • Natural barrier (hostrock)
Major functions	<ul style="list-style-type: none"> • Functions required for operation of facilities. • Functions after burial should not be impaired. 	<ul style="list-style-type: none"> • Isolation functions for harmful nuclides
Detailed functions	<ul style="list-style-type: none"> *That canisters may be handled securely and safely. *That monitoring may be conducted safely. *That countermeasures against abnormalities may be taken. *That workers may be sufficiently protected from radioactive exposure. *That sound environmental conditions for workers, facilities and wastes may be secured. *That the underground structures are sound against rock pressure, earthquakes, and heat. *That the facilities are safe against natural disasters. 	<ul style="list-style-type: none"> *That nuclide concentration refluxing in biosphere is below the permissible level. *That the facilities are sufficiently safe against natural phenomena such as active faults, volcanoes, and erosions. *That the facilities are sufficiently sound against human intrusion such as excavation and boring.

2.2 Estimated Amount of Waste Form

Numerical estimation at the beginning of disposal of the waste was conducted in order to study the required capacity of the repository and the schedule for construction and operation.

Estimated amount of nuclear power generation will form the basis for generation of the waste. As there are many variable factors such as prospect in energy supply and demand, diversified types of reactors, etc., the waste generation was estimated based on the plan for reprocessing and solidifying plants as the guideline for forecasting the next half century.

If the plant capacity is estimated to be at about 10,000 canisters and the annual operation days 220 days, the construction sequence will be as follows.

Table 2: Construction Sequence for repository

Disposal Plant	Start-Finish of Operation (Operated years)	Number of Canisters	Frequency of Receiving Canisters			
			Per Year		Per Day	
			Min.	Max.	Min.	Max.
1st Plant	2010-2024 (15)	9,390	210	1570	0.95	7.14
2nd Plant	2025-2028 (4)	9,040	1760	2560	8	11.6
3rd Plant	2029-2032 (4)	10,240	2560		11.6	

2.3 Rockmass Conditions for Siting

2.3.1 Preferred Conditions in Design

Our report on Results for 1980 discussed siting conditions for the geological isolation facilities. In this section, we shall discuss the natural environmental aspects of the siting conditions from the standpoint of designing, and show the results in Table 3.

2.3.2 Conditions for Granitic Bedrocks

- (1) Prevailing Conditions of Granitic Bedrocks in Japan
Prevailing conditions of granitic bedrocks are listed in Table 4.

- (2) Concept of a Repository Assumed from Bedrock Conditions

1. Structure and Configuration of Tunnels

The tunnels in the granitic bedrocks are strong enough without support at 1,000 m below the surface if the tunnel cross section is approximated to a circle.

2. Layout of Tunnels

When there exist several medium-scale fractured zones per every 1,000 m, it is not possible to lay out the disposal tunnels regularly. The layout becomes irregular as the fractured zones must be avoided.

Table 3: Preferred Natural Conditions for Siting Geological Isolation

Items		Conditions Required for Siting	Conditions Preferred for Siting	Remarks
Soundness of host rock	Strength of host rock	Uniaxial compressive strength of host rock: 600 kg/cm ² or more. Rockmass of Class C _H or more. (After Kikuchi et al.)	The higher rock strength (1000 - 1500 kg/cm ² or more), and the lesser ruptures and joints are preferred.	
	Soundness of host rock against heat		Soundness against thermal stress is preferred. That host rock is unlikely to undergo thermal changes.	Soundness may be secured by lowering the heat generation of canisters.
Capacity to restrain nuclide migration	Width of host rock	No large scale fractures nearby. Rockmass of Class C _H or more extends for 1000 m.	Extension of more than 1 km ² is preferred. No medium scale fractured zone inside the site is preferred.	Disposal tunnels may be laid out by avoiding several medium scale fractured zones. Fractures in the main tunnel may be processed by grouting, etc.
	Thickness & depth of host rock	Rockmass of Class C _H or above should exist in thickness of (500 - 1000 m) and at depth of (500 - 1000 m).	The thicker, the more preferable	
	Macro scale ground water flow	Hydraulic gradient which causes groundwater flow should be small. Permeability coefficient K < 10 ⁻⁵ cm/sec is set as a provisional standard.	Hydraulic gradient is preferred to be as close as 0. K < 10 ⁻⁶ to 10 ⁻⁷ cm/sec is preferred.	Canisters may be isolated from the seepage water until completion of burial. Improvement to K = 1 x 10 ⁻⁵ cm/sec is necessary by grouting.
	Nuclide sorption capacity of host rock		Higher capacity for sorption of nuclides is preferred.	Clay minerals are advantageous.
Matters concerning environment inside the facilities	Bedrock temperature	100°C or less is set as provisional standard.	30 - 40°C or less is preferred.	60°C or less is passable.
	Average ambient temperature		20°C or less is preferred.	Even if it is higher, air conditioning solves problems.
Matters concerning earth science	Earthquakes	No active faults are in the vicinity.	Area with frequent earthquakes is not preferred.	Underground structures are stable against earthquakes.
	Volcanic activities	That the site is not within the volcanic belt.		
Matters concerning ground surface	High tide caused by typhoons	That the site is not in the area susceptible to high tide.	Altitude of 20 m or more above ground is preferred for the shaft mouth.	
	Land slides, floods, etc.	That the site is not in the area susceptible to land slides, floods, etc.		
	Tsunami waves	That the site is not in the area susceptible to Tsunami waves.	Altitude of 20 m or more above ground is preferred for the shaft mouth.	

Table 4: Actual Bedrock Conditions of Granite in Japan

Conditions Required		Actual Conditions of Bedrock in Japan (Estimated)
Soundness of bedrock	That it is hard and sturdy.	Bedrocks of which uniaxial compressive strength exceeds 1000 - 2000 kg/cm ² are widely distributed. (No-support type is possible if the tunnel configuration is selected.)
	That it is high temperature resistant.	*Granite undergoes transition at 573°C, and andesite at 200 - 300°C. Design temperature should be controlled to be lower than these.
Capacity to restrain nuclide migration	That bedrock is expansive.	*As granite is distributed in masses, and takes up 13% of the land, it is considered possible to select a site by avoiding large scale fractured zone. *Even at a considerable depth, 2 to 3 medium scale fractured zones per 1000 m are expected to be present.
	That bedrock has the thickness and the depth.	*Rockmass of 500 - 1000 m both in depth and thickness is present. *Granite is assumed to be extending to the depth of about several km. Volcanic rocks such as andesite are distributed in layers or in veins, and therefore they are inferior to granite.
	That there are less macro scale groundwater flows.	Since granite has less possibilities of containing mineral resources, the groundwater flow is less likely to be disturbed.
	That they have the smaller permeability.	Granites with $K = 10^{-6}$ to 10^{-8} cm/sec exist in bedrock.
	That they have the bigger capacity of sorption of nuclides.	No information available.

2.3.3 Conditions for Sedimentary Rocks

(1) Distribution of Sedimentary Rocks in Japan

The sedimentary rocks take up about 60% in the total exposed rocks in Japan, which can be classified into the Paleozoic layer (12%), Mesozoic layer (9%) and Tertiary layer (19%) as the prospective sedimentary rocks for siting a repository.

(2) Dynamic and Thermal Properties of Sedimentary Rocks

a. Dynamic Properties of Sedimentary Rocks

Dynamic properties of sedimentary rocks vary greatly depending on the deposited geologic times and the stratigraphic depths (the maximum thickness of the stratum which is assumed to have extended above the layer). Fig. 2 shows the relation of uniaxial compressive strength (q_u) with the void ratio (e) of sedimentary rocks (sediments) of the Quaternary to the Paleogene. The uniaxial compressive strength increases in proportion to the decrease in the void ratio: However, the older the geologic time, the uniaxial compressive strength would become greater when the void ratio is of a similar degree. Since the uniaxial compressive strength must at least be greater than 600 kg/cm^2 , the sedimentary rocks which can be excavated for geological

disposal plants are limited substantially to the regions indicated as (3) in Fig. 2.

The strength of bedrock in case of hard rocks depends on the rupture distribution rather than the strength of the rocks itself. Therefore, there are not many sedimentary bedrocks of the older geologic time that are ranked as Class C_H or higher.

The general temperature dependency of the strength of sedimentary rocks is not yet fully known as there have been a few measurements taken. Fig. 3 shows changes in the uniaxial compressive strength and tensile strength of sandy tuff caused by the temperature. Compared to granite, the strength hardly changes by the temperature. Whether such a tendency is also observed in sedimentary rocks is not known.

Measurements on the temperature dependency of the deformation characteristics of sedimentary rocks is also scarce. The static elasticity modulus does not depend so much on the temperature. Like other rocks, the ductility of sandstones increases as the temperature rises.

Table 5: Area of Rocks Exposed to Surface in Japan

(A.Miyashiro , 1965)

Rocks	Area (km ²)	Area (%)
Regional metamorphic rocks	13,300	3.6
Granite	49,300	13.3
Basic & ultra basic intrusive rocks	5,800	1.6
Tertiary & Quaternary volcanic rocks	75,400	20.4
Plaeozoic sedimentary rocks	45,200	12.2
Mesozoic sedimentary rocks	34,400	9.3
Tertiary sedimentary rocks	69,900	18.9
Quaternary sedimentary rocks	76,500	20.7
Total	369,800	100.0

b. Thermal Properties of Sedimentary Rocks

Thermal characteristics of sandstones prior to the Paleogene are listed below.

- (a) The thermal conductivity at normal temperatures is in the range of $(4 - 9) \times 10^{-3}$ cal/cm·sec.°C (1.44×3.24 kcal/m·hr.°C); this is identical or somewhat smaller than that of granite. The thermal conductivity decreases with the rise in temperature.

(b) The linear expansion coefficient at normal temperatures is in the range of $(5 - 10) \times 10^{-6}/^{\circ}\text{C}$, which is substantially the same with that of granite.

(3) Hydrological Properties of Sedimentary Rocks

Substantial portions of sedimentary rocks in Japan have been subjected to alteration due to active diastrophism during the Tertiary and Quaternary times, and unlike the American or European continents, there are probably fewer chances of locating bedrocks that are homogeneous and impermeable.

(4) Concept of the Repository Assumed from the Bedrock Conditions

The foregoing description on the bedrock conditions of sedimentary rocks in Japan can be summarized as follows.

- (1) The strength of sedimentary rocks prior to the Paleogene is rigid, but there are not many bedrocks of Class C_H or higher which satisfy the required strength as the host rock for the repository.
- (2) Hydrological features of sedimentary rocks are not remarkably different as compared to granites. The concept in designing a geological isolation system in sedimentary rocks will not be different from that of granitic rocks.

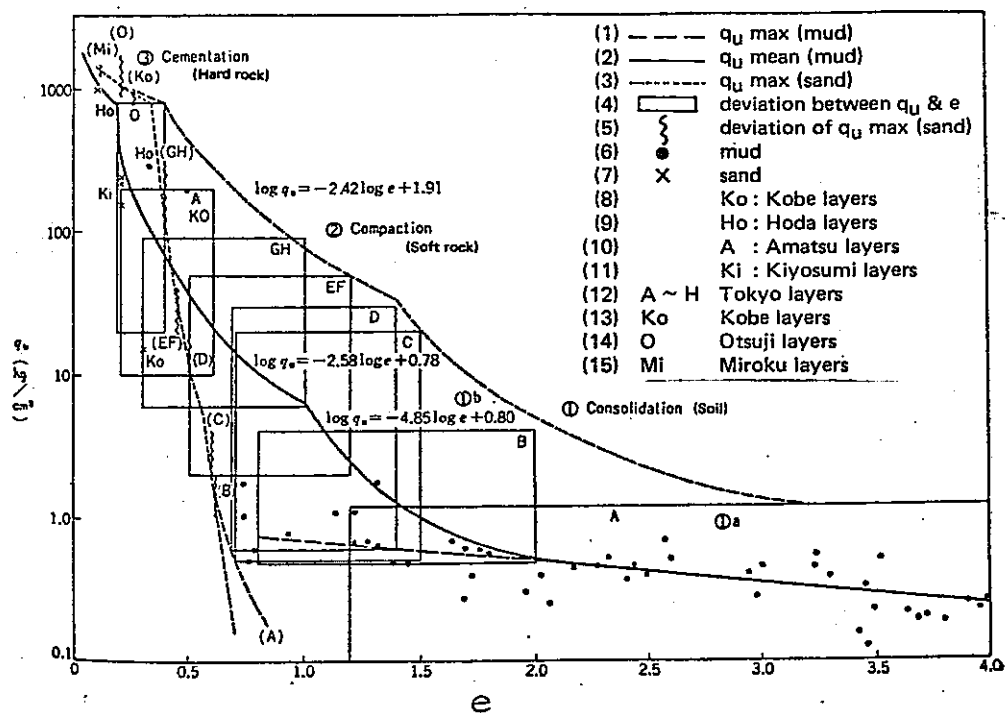
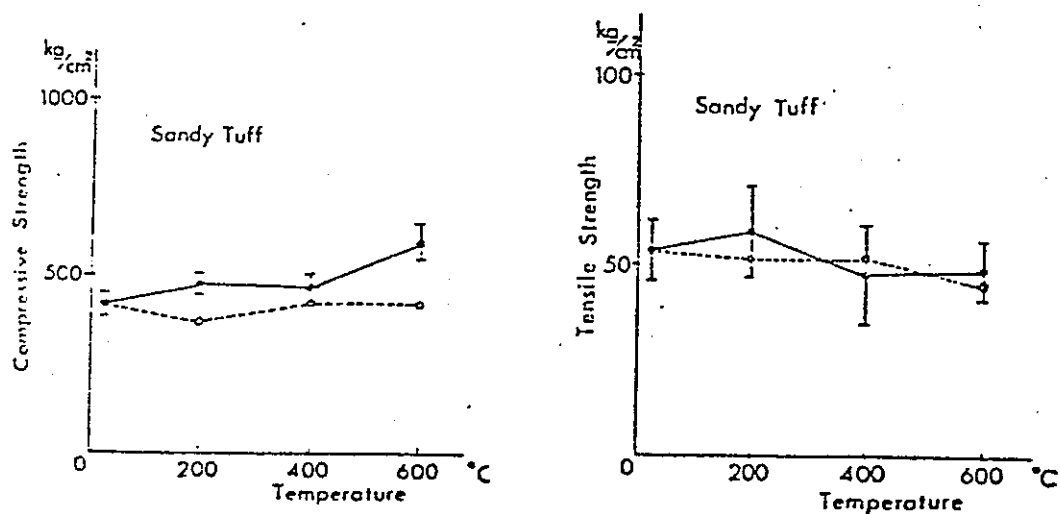


Fig. 2: Relation between Uniaxial Compressive Strength q_u and void ratio e (Kojima), 1972



a) Uniaxial Compressive Strength b) Tensile Strength

Fig. 3: Temperature-related changes in strength of sandy tuff (Izu-Aoishi Rock)
Solid lines indicate that at high temperature, dotted lines that when cooled to normal temperature (Kuriyakawa), 1978)

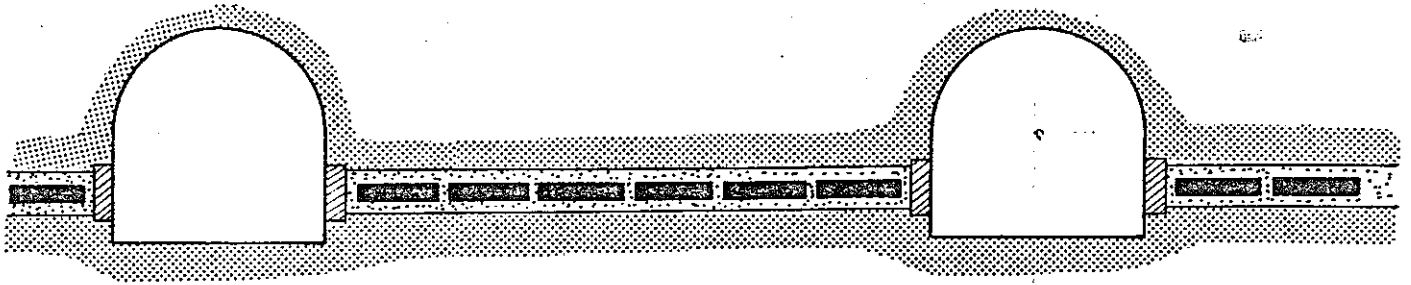


Fig. 4: Layout for Disposal Tunnel and Pit (Option A)

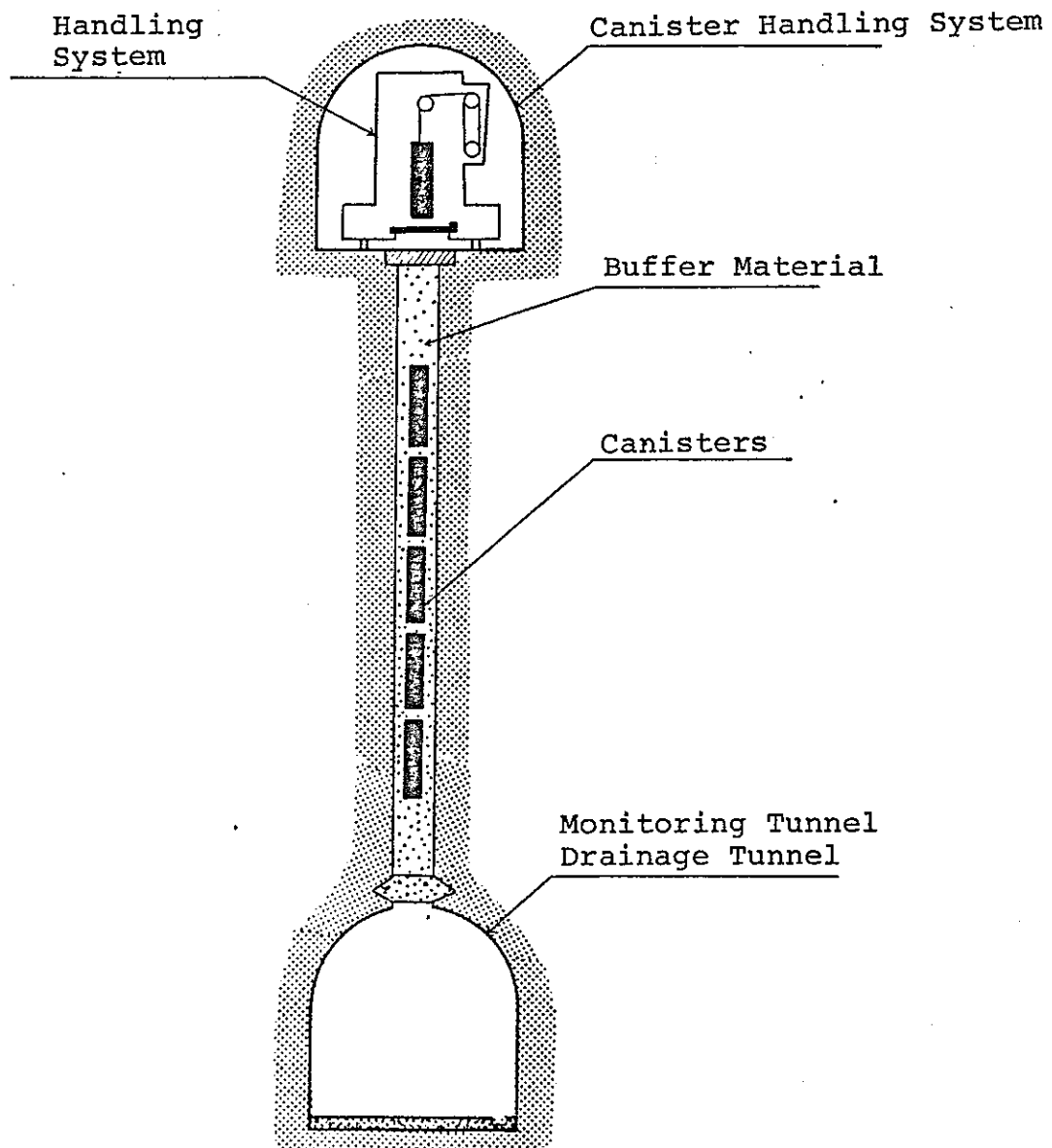


Fig. 5: Layout for Disposal Tunnel & Pit (Option B)

Perspective View

Plan View

Canister Delivery Shaft

Medium-scale
Fractured
Zone

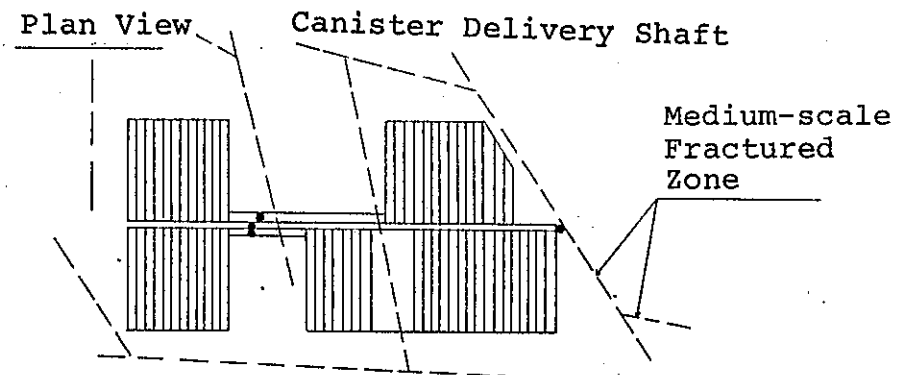
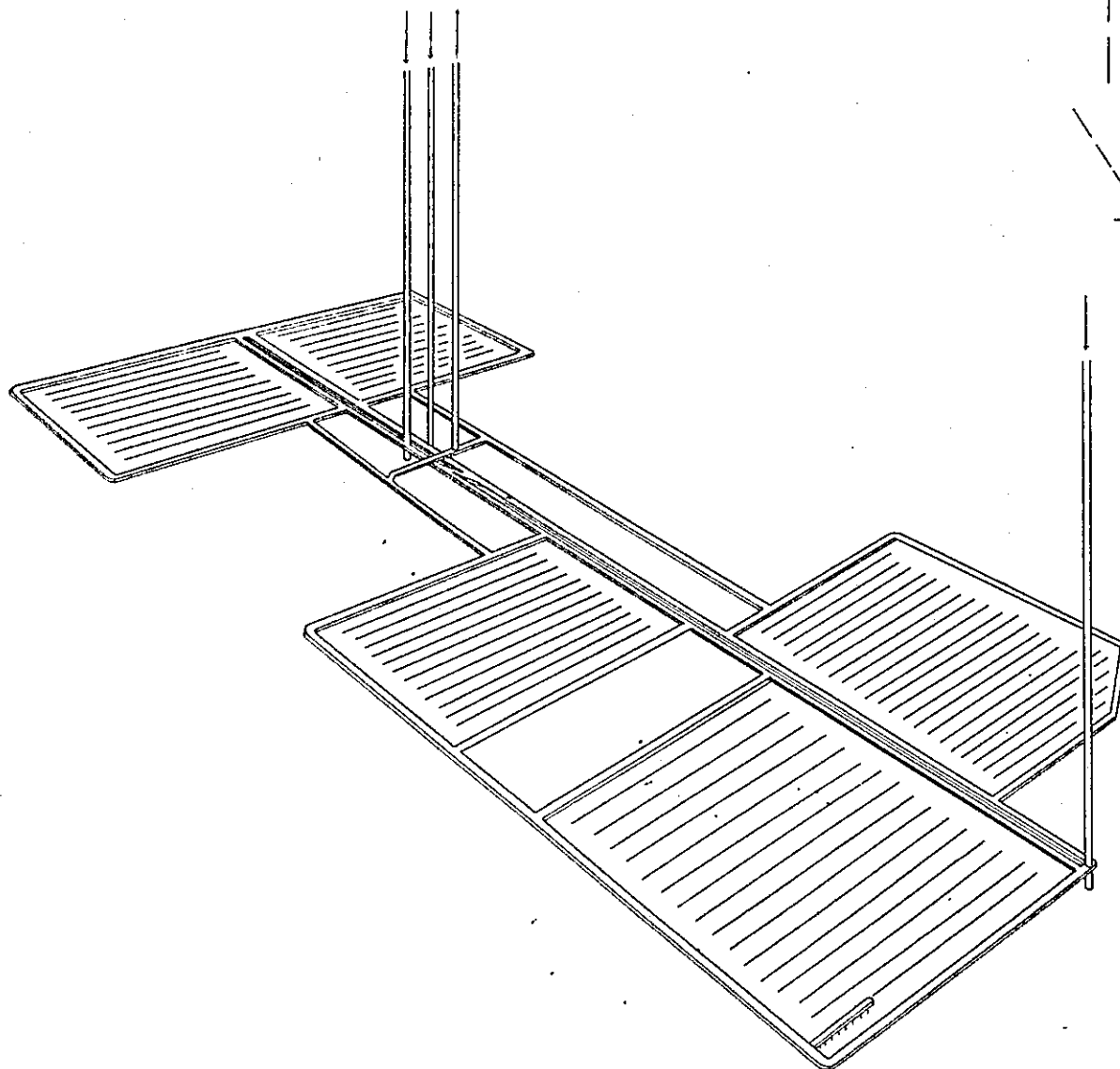


Fig. 6: Perspective View to Show the Whole Geological Isolation System
(Layout to avoid Medium-scale Fractured Zones)

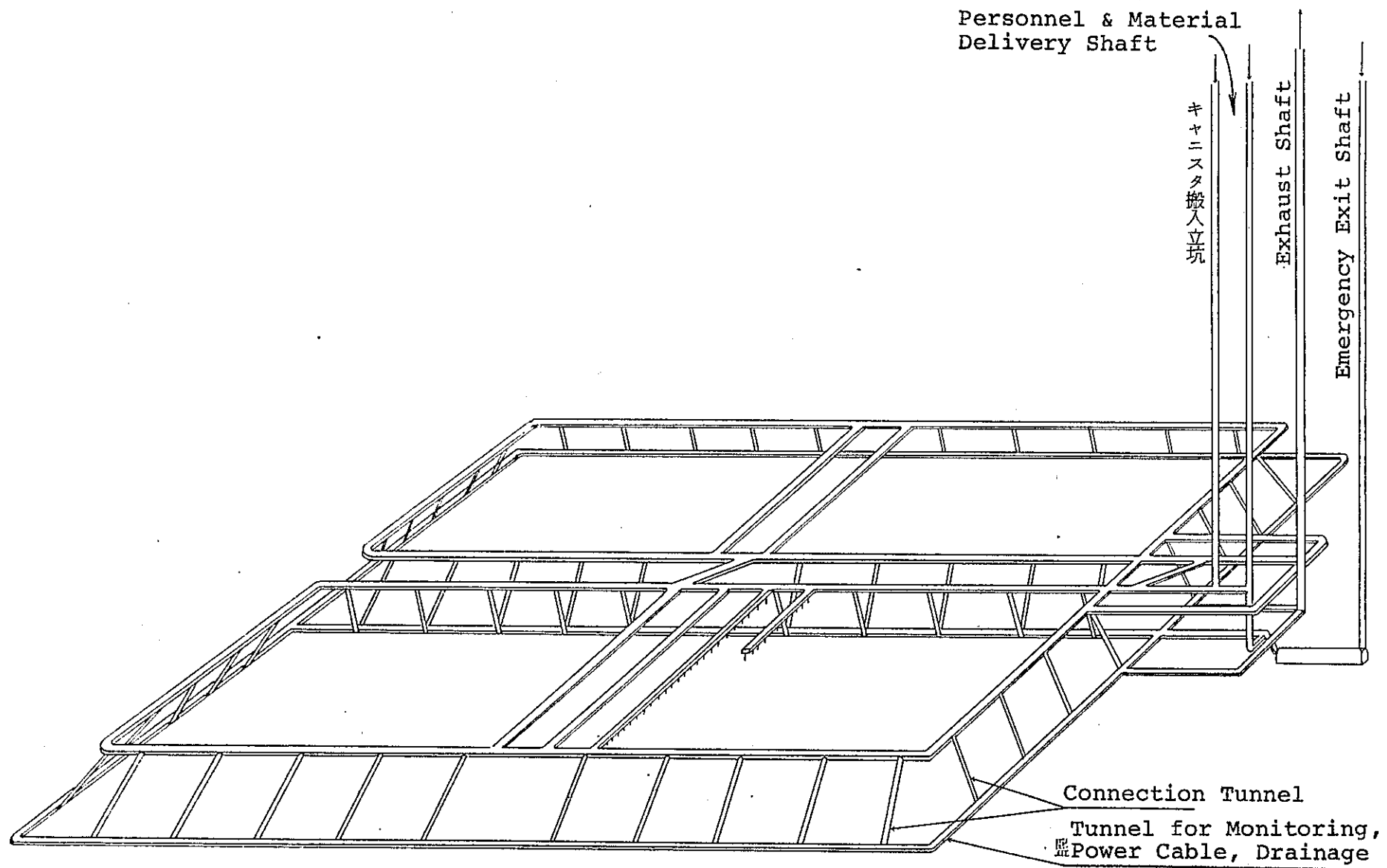


Fig. 7: Perspective View for Geological Isolation System
(with Options C, D and E)

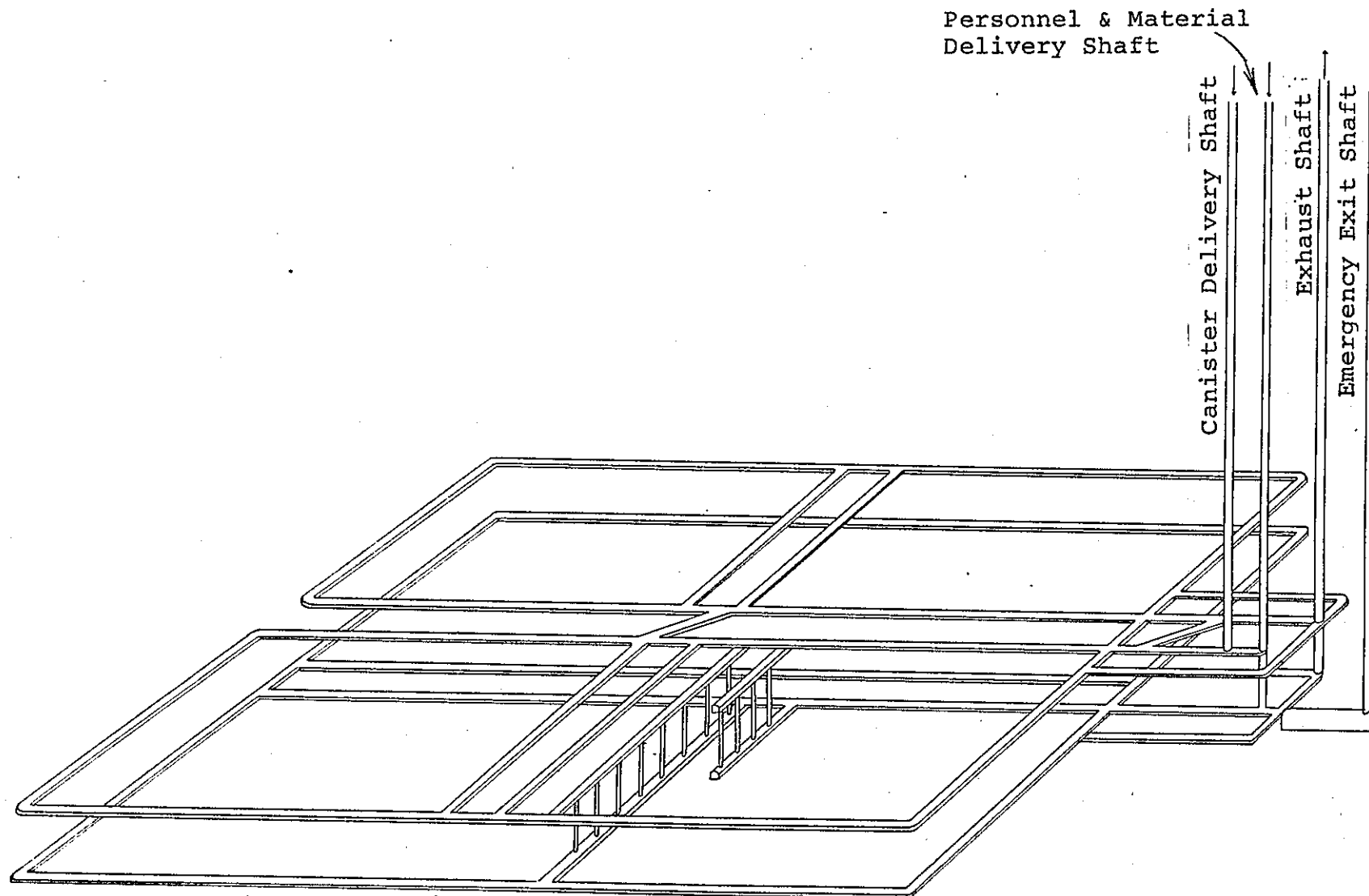


Fig. 8: Perspective View for Geological Isolation System
(with Options B, C and E)

2.4 Conceptual Drawing of Geological Disposal Plant

2.4.1 Conceptual Drawing of Geological Disposal Plant

The 1980 Report employed the conceptual drawing of KBS project in Sweden as a reference. This year, we propose a layout for geological disposal plant emphasizing the following points.

- (1) When a number of canisters is placed in disposal pit.
- (2) When drainage, water drain shaft, emergency water pool tunnel are installed in disposal plant (area).
- (3) When an emergency exit shaft is installed.
- (4) When handling system is made easy to retrieve.
- (5) When there is a need to locate disposal tunnels to avoid medium ruptures.
- (6) When a combination of various options listed above are employed.

2.4.2 Concepts for Geological Isolation System in Various Countries

Studies on geological isolation systems are being conducted in various countries and their results with proposed layouts are published.

3. Management of Facilities

A disposal plant essentially requires the isolation of the wastes alone. Thus, there will be no such activities as retrieval (recovery), monitoring or restoration of the wastes after completing burial. Since the wastes are temporarily stored from the time of handling until completion of burial, management of the disposal facilities will be necessary.

Items related to the facility management before burial were classified and summarized in Table 6.

Table 6: List of Items Related to Management of Geological Disposal Plant Before Burial

o: Items related to design of overall system

◎: Items studied in the present report

			Objects of Management (*1)					
			Handling System	Ventilation & Cooling System	Water Cutoff & Drainage System	Power Station	Structures (including buffer)	Personnel (mainly workers)
Design of Various Elements			◎	◎	◎	o	o	o
Operations	Monitoring	Facilities, Radioactivity	◎	◎	◎	o	o	o
	Counter-measures during Normal Operation	Running Facilities	◎	o	o	o	o	o
	Counter-measures during Abnormal Operation	Disasters by Radioaction Leakage	◎	o	o	o	-	o
		Disasters by Other Causes	o	◎	◎	o	o	◎
		Invasion Into Facilities	-	-	-	-	o	o
	Maintenance	Facilities	◎	o	◎	o	◎	-

Note: 1) Includes various control data such as identity & location of wastes, measurement data, etc.
2) Partially studied in the Report for 1980.
3) This Report deals with shafts and underground facilities.

3.1 Monitoring

3.1.1 Monitoring Behavior of Radioactive Wastes

Objectives of monitoring during normal operations are listed below.

- i) Confirm that the air dose and the concentration of airborne radioactive substances in the environment above the ground are sufficiently lower than the permissible level.
- ii) Confirm that the air dose and the concentration of airborne radioactive substances are sufficiently lower than the permissible level when workers enter the disposal facilities (both underground and above the ground).
- iii) Confirm that there is no leakage of wastes from canisters during handling and back-filling operations.

If any abnormalities are detected in the above conditions through measurements or by any other means, objectives of monitoring will then become the following:

- i)' Learn the air dose and the concentration of airborne radioactive substances in the environment above the ground.
- ii)' Learn the air dose and the concentration of airborne radioactive substances in the facilities for workers entering there during abnormal

situations.

iii)' Learn the emission of radioactive substances in the environment.

3.1.2 Monitoring the Ventilation and Cooling System

Items to be monitored are listed below.

- (1) Concentration of radioactive substances in the air ventilated in and out of the disposal plant.
- (2) Temperature, humidity and wind velocity in the areas where workers enter.
- (3) CO and O₂ gas concentrations in the air ventilated in and out of the disposal plant.
- (4) Operating conditions of the central parts (main fan, cooling unit) of the ventilation/cooling system, and degree of opening of the regulator.

3.1.3 Monitoring the Drainage System

It will be sufficient if the abnormalities in the drainage system can be monitored in addition to the measurement of radioactive concentrations in the waste water.

Detection of the water level in the underground water pool will discover failures in the switching control of drainage pumps and facility. Piping system may be monitored by daily maintenance and inspection.

3.2 Operation During Normal Conditions

Operation and management of the disposal system during normal conditions consist mainly of handling the waste forms

by means of the system shown in Table 7. The objectives, items and methods of management are listed below.

3.3 Countermeasures Against Abnormal Conditions

3.3.1 Measures To Be Taken During Abnormal Behavior of Radioactive Substances

If any abnormal values are detected by the radiation monitoring system as discussed in Section 3.1, the frequency of monitoring should be increased first. Measurements in each monitoring units are used in assuming causes for the abnormal values.

When the cause for the abnormal conditions is uncovered, countermeasures against extraordinary exposure of workers are taken for eliminating causes.

3.3.2 Measures During Abnormal Conditions of Ventilation

When ventilation conditions in the disposal plant exceed the environmental requirements, these can be restored by adjusting the wind-air distribution, the in-coming air temperature, etc. while checking the main fan and the degree of opening of the regulator. Since abnormal values in CO and O₂ gas concentrations may lead to fires, etc., it is necessary to monitor by a TV camera to learn the trouble points and to isolate them by closing the regulator. In the worst case, workers may be ordered to evacuate.

Table 7: Control of Handling Operation for Waste Forms

Object of Control	Items Controlled	Method of Control
(1) To receive waste forms within the capacity of repository	Quantity and schedule for waste forms received	*Formulate proper receiving plans within the disposal repository capacity by coordination with the generating side, and control receiving
(2) Receive sound waste forms	Soundness of waste forms	*Perform necessary physical examinations at the time of delivery
(3) Receive and handle waste forms as planned	(i) ID number of waste forms	(i) Confirm ID number of waste forms upon delivery, and record in the registry
	(ii) Work hours, Number of canisters handled, Start up and operation of mechanical systems	(ii) Confirm that the operation is proceeding as planned by checking the items controlled
	(iii) ID number of disposal pits	(iii) Confirm and record ID number of disposal pits in which waste forms have been placed
(4) Maintain soundness of the handling system	Start up and operation of mechanical systems Abnormality detection system Items for periodical checks Periodical repairs & replacements	*Monitor normal operation, detect abnormalities immediately, and take countermeasures *Secure reliability by periodical checks, replacements and repairs *Have repair system ready
(5) Secure soundness of disposal pits	State of disposal pits	*Check and confirm if disposal pits are suitable by observation and measurements *Confirm by TV monitor if waste forms are correctly placed

3.3.3. Measures Against Abnormal State in the Handling System

One shaft is not sufficient to cope with the failures or accidents of the handling system. By providing a canister and delivery shaft and auxiliary shafts for access by workers and emergency materials, it will be easier to deal with abnormal situations.

3.3.4. Emergency Exit

An emergency exit is provided so that workers in the disposal plant can come out to the surface by themselves. Spiral staircase or ladder step will be provided in the emergency shaft. If it is desirable to avoid using the exhaust shaft as an emergency exit at the time of fire, etc., an additional shaft may be provided.

3.4. Maintenance - Maintenance of Shafts -

Manuals for technical supervisors in charge of the maintenance, the standards for technical inspection and servicing, and the method of recording will be prepared based on the related laws and regulations.

(1) Shaft Structure

Construction of a shaft with a longer life and without seepage is possible with the conventional technology. The maintenance will therefore include the following items in order to check cracks, percolations, or seepage.

- * Periodical (e.g. biannual): naked eye investigation, knocking by hammer, and photographic survey

- * After the earthquake (e.g. magnitude 4 or greater):
naked eye investigation, knocking by hammer
- * Study on effects of water freezing (e.g. icicles) in
cold climates

Appropriate measures should be taken, if necessary,
to keep the records of these activities.

(2) Hoist, Tower

- * Main parts of the hoist and tower will stand the
use of more than 100 years as the thickness and
types of materials can be suitably selected at the
time of designing so as to assure safety of the
facilities.
- * The main motor and other electrical parts are
periodically replaced within the life of insulating
materials of about 50 years.
- * The main rope is used for 10 years at the longest,
and Standards for its inspection and replacement are
governed by the related laws and regulations.
Generally, the detailed inspection is conducted twice
a year and the performance test once a year.

(3) Facilities for the Shaft Mouth and Bottom

- * These are managed under the standards meeting the
criteria of radiation protection depending on the
mode of handling the wastes at the shaft mouth and
bottom.

(4) Equipment in the Shaft

*Buntons: They will stand the use of more than 200 years if designed, manufactured and installed suitably in respect of the types and thickness of materials and the shaft wall fixing.

Inspection of the buntons will be performed at the same time as the shaft structure.

*Power Cable: durability of 50 years or longer is assured by the special design. Generally, detailed inspection is conducted at the same time as the annual inspection of the electrical equipments.

*Drainage Piping, etc:

Detailed inspection to check corrosion on the inner and outer surfaces, safety of support and fixing means for the piping, etc. will be conducted once a year by means of knocking and thickness meter.

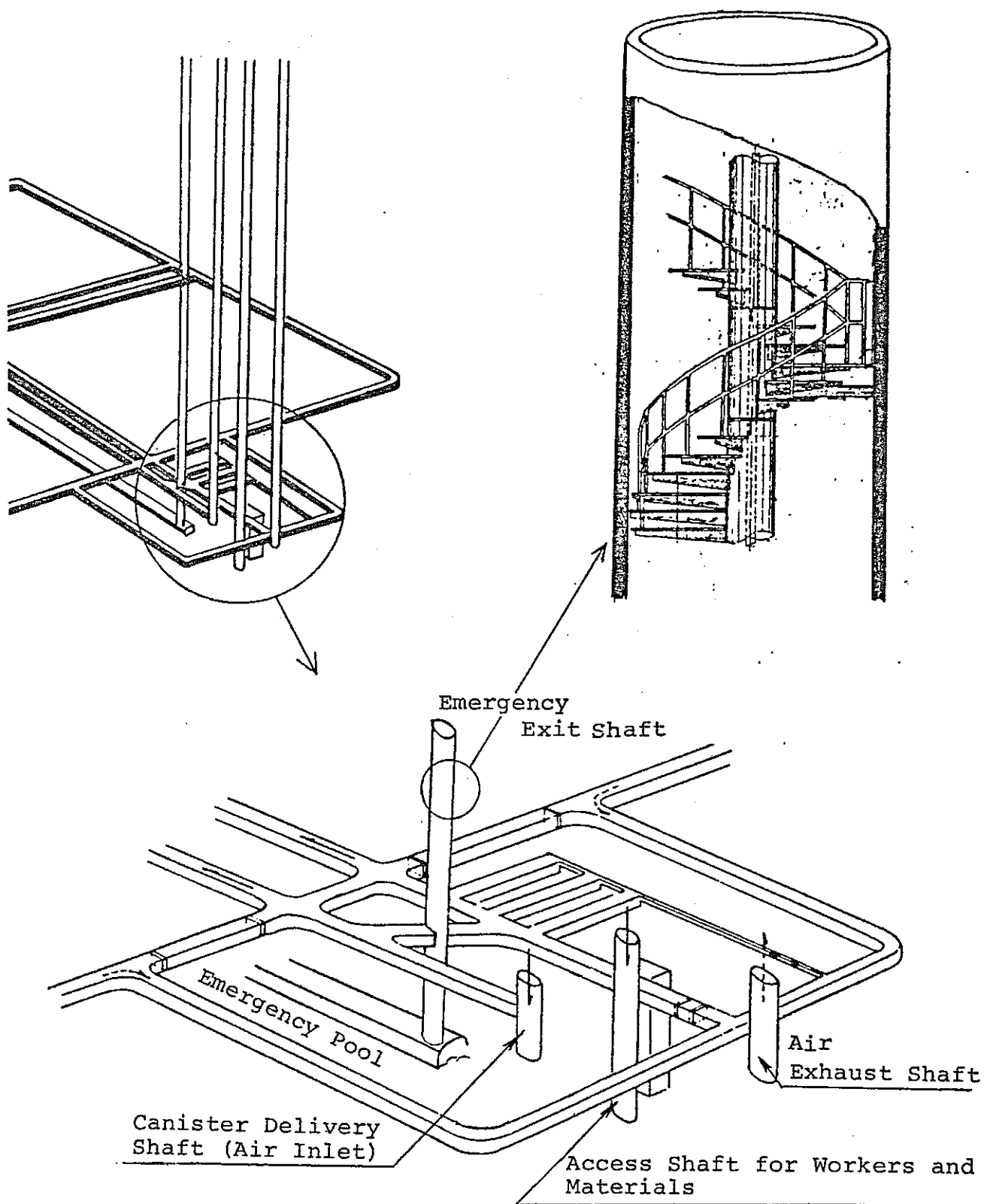


Fig. 9: Emergency Exit Option - 1

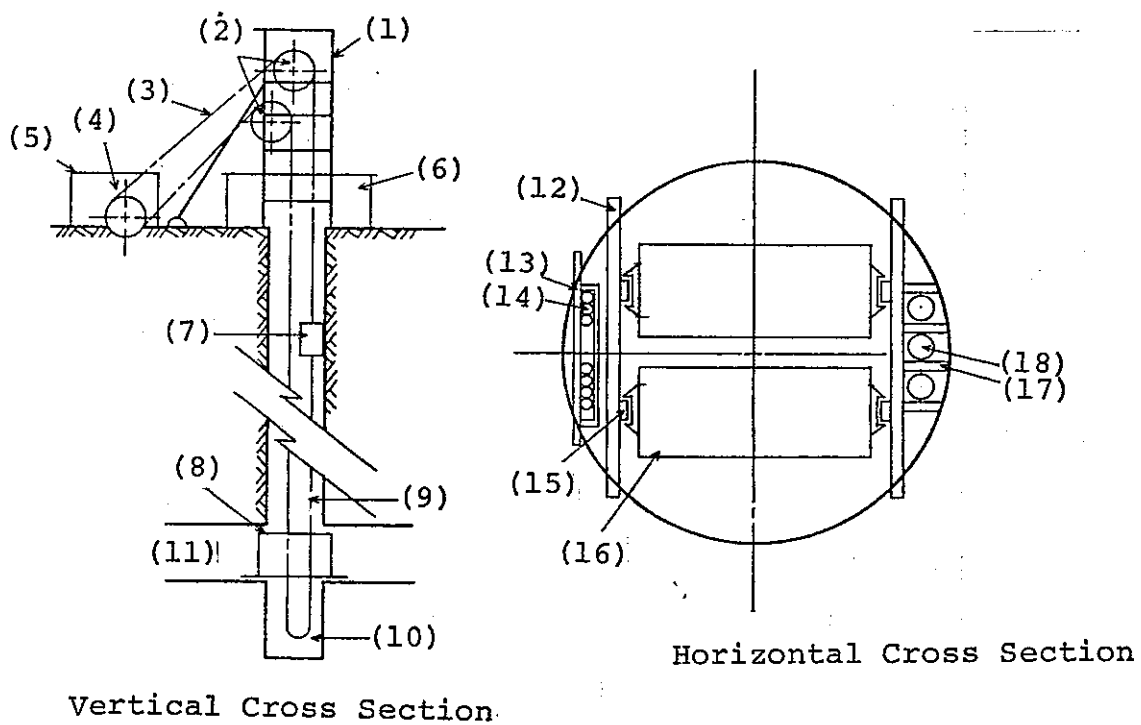


Fig. 10: Schematic View of Shaft

- | | |
|----------------------------|----------------------------|
| (1) Tower | (10) Shaft Bottom |
| (2) Head Sheave | (11) Main Tunnel |
| (3) Rope | (12) Bunton for Cage Guide |
| (4) Hoist | (13) Bunton for Cable |
| (5) Hoist Head | (14) Cables |
| (6) Shaft Mouth | (15) Guiderail |
| (7) Cage | (16) Cage |
| (8) Underground Facilities | (17) Pipe Bunton |
| (9) Tail Rope | (18) Pipes |

4. Review of Individual Systems

4.1 Review Conditions

4.1.1 Concept

- (1) The geologic disposal system aims at isolating the high level radioactive wastes from the biosphere by effectively utilizing the natural and artificial barriers. It is a comprehensive system for the procedural management of secure and safe burial of high level radioactive wastes.
- (2) These are the final disposal system consisting of shaft connecting the disposal tunnels excavated at 1,000 m below the ground and surface equipments to receive the canisters.
- (3) The disposal plant can place 10,000 canisters.

4.1.2 Layout of a Disposal System

- (1) Depth of the disposal tunnel: 1,000 m below the
ground
Location of surface equipment: flat area
Depth of the shaft: 1,000 m
- (2) The layout diagram is the same as given in the Report for 1980 (center to center distance of tunnels is 15.5 m).
- (3) The cross section of the shaft is a circle of 6 - 8 m in diameter.
- (4) The size and shape of the receiving facilities at the

shaft bottom may be selected arbitrarily.

(The cavern is preferred to be less than 15x15x15.)

- (5) The ventilation plan is also identical to that of the Report 1980.
- (6) Review of the handling system and the ventilation/cooling system is not necessarily limited by the tunnel cross section proposed in the Report 1980.

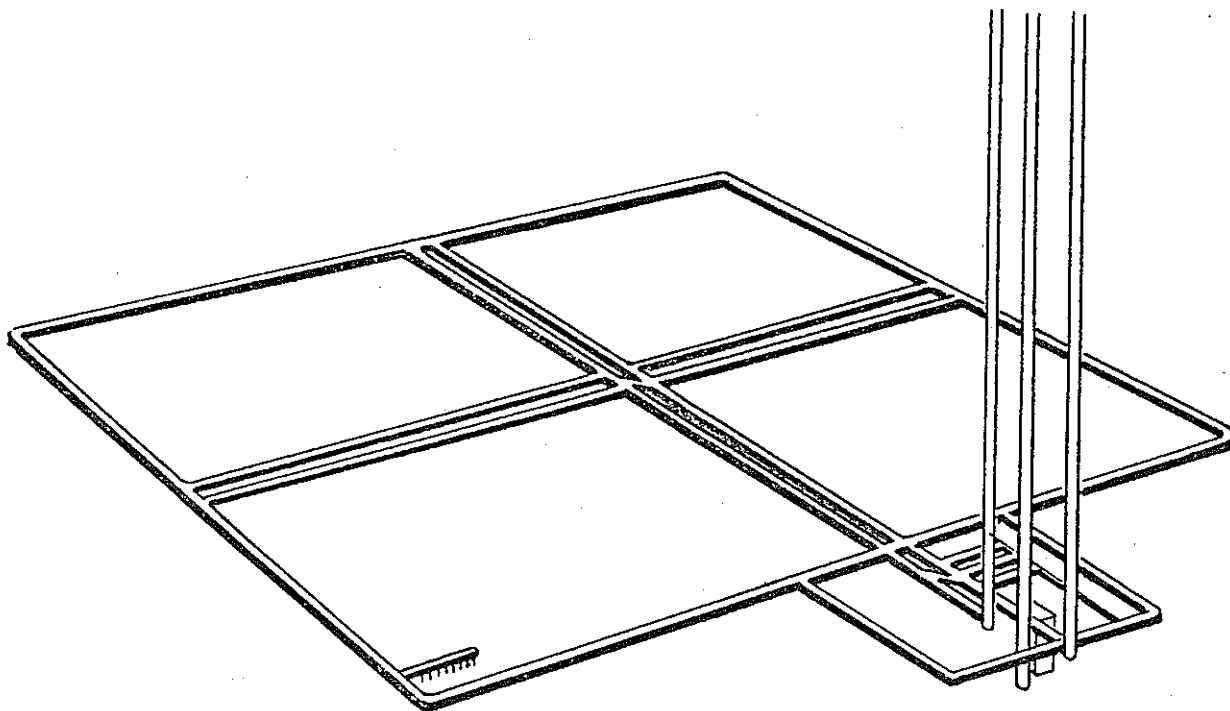
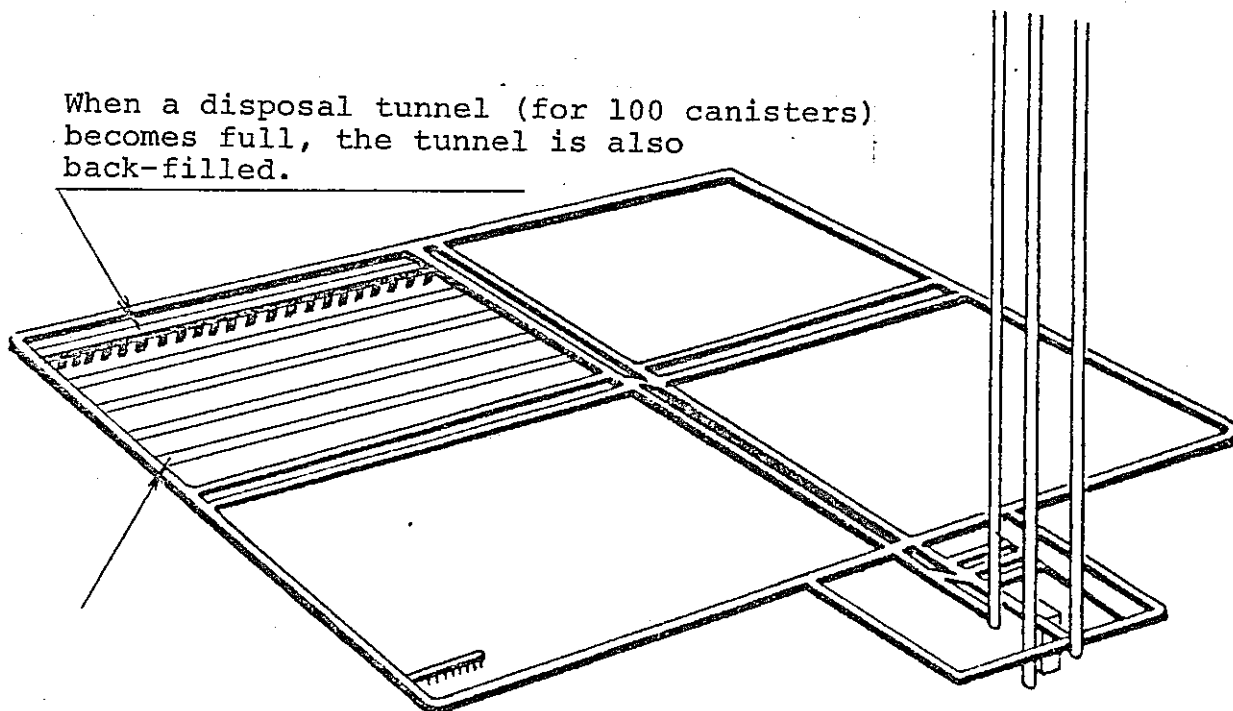


Fig. 11: Perspective View for Geological Disposal Plant

When a disposal tunnel (for 100 canisters) becomes full, the tunnel is also back-filled.



Tunnels should be ventilated & cooled in advance successively.

Fig. 12: Conceptual Drawing of Operational Schedule for Geological Disposal Plant

4.1.3 Operational Schedule for the Disposal Plant

- (1) Immediately after canisters are placed in the disposal pits, the pits should be back-filled. Buffer of 100% bentonite is used for back-filling.
- (2) Canisters are buried successively from the inner-most end of the disposal tunnel (at the exhaust air side), and the tunnel is back-filled immediately after the tunnel is fully filled with canisters.
- (3) Ventilation - cooling for disposal tunnels must be started one year before the handling operation starts. (Fig. 12)
- (4) The number of canisters to be handled in one day is 12.
- (5) Operation and construction work must be carried out in separate sections and should not affect each other.

4.2 Handling System

4.2.1 Functions of the Handling System

One of the functions of the present disposal system is "safe and secure handling of canisters", which also forms the objective of the handling system.

This system is defined to cover the functions of "from receiving the wastes transported into the surface facilities to placing them into the disposal pits".

In order for the system to achieve its objective, "safe and secure handling", the following functions should

be met:

- * that canisters are placed in the disposal pit in a sound condition,
- * that safe operation is secured,
- * that the predetermined receiving and storage capacities at the disposal plant are kept.

(1) In order to secure the soundness of canisters, it is essential,

- * that canisters have sufficient durability,
- * that the "force" which the handling system imposes on canisters is minimized.

(2) In order to prevent workers from radiation exposure and to assure safe operation, it is essential to shield the radiation source as well as to keep a sufficient distance between workers and the radiation source. The remote control operation is a requisite for these purposes.

The system should, therefore, be designed taking into consideration the following:

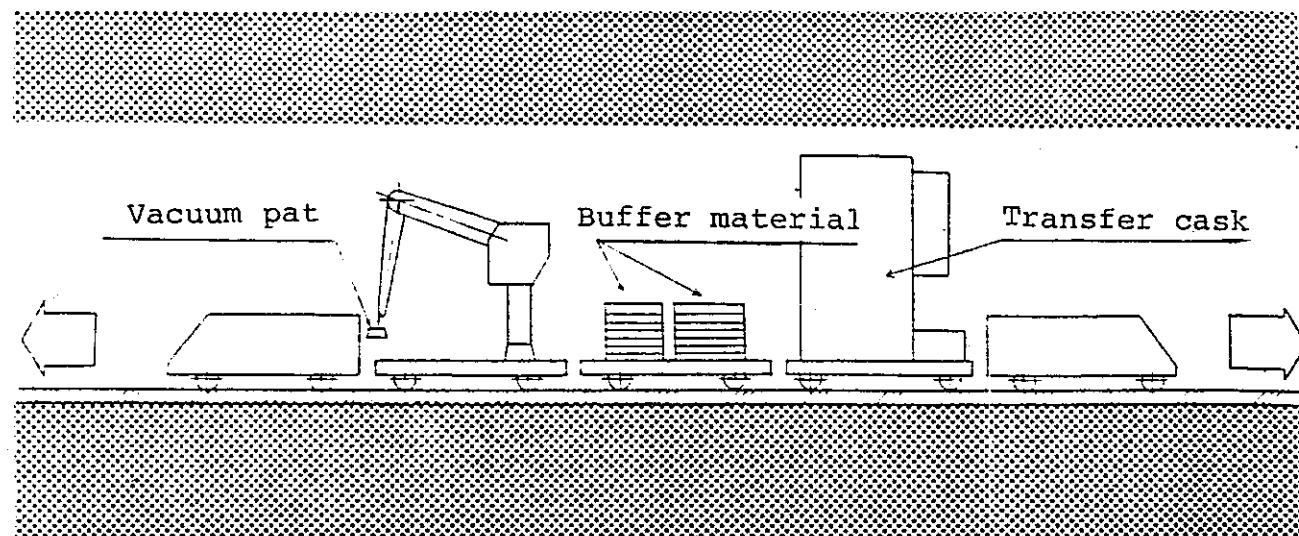
- * abnormalities of a sub-system should not affect the remote control operation,
- * abnormalities of a sub-system can be restored by the remote control operation.

(3) In order for the system to maintain its predetermined capacity as a disposal plant, its receiving function

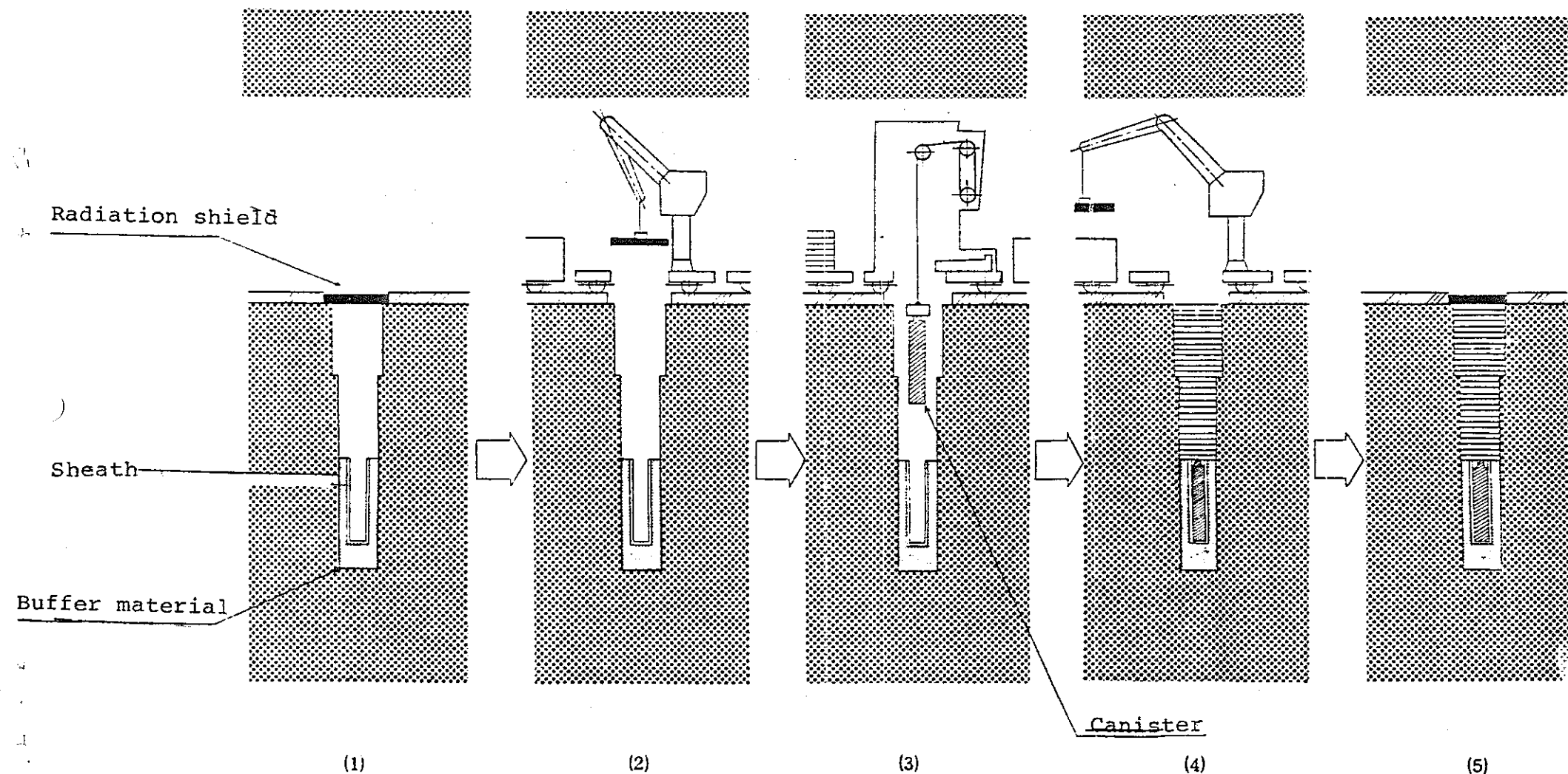
must be constantly maintained and that an area for temporarily storing the received casks must be secured.

The system is required to have a high reliability and safety for handling high level radioactive wastes. The important points are:

- * that probability of accidents is minimized,
- * that damage caused by accidents is minimized.



① ② ③ ④ ①



<Composition of Horizontal Handling System>

- (1) Battery car
- (2) Truck for back-filling machine
- (3) Truck for buffer materials
- (4) Truck for transfer cask

<Canister Transfer Steps in Disposal Tunnel>

- (a) Canisters and buffer materials for back-filling are conveyed on their trucks by elevator to the shaft bottom.
- (b) Trucks are pulled out from the elevator by the battery car arranged as shown in the figure.
- (c) The trucks thus arranged are run to the disposal pit and canisters are placed therein.
- (d) After burial, the trucks return to the bottom of shaft, placed on the elevator to return to the surface.

<Canister Placing Steps in Disposal Pit>

- (1) Prior to canister delivery, fill the buffer material up to the crown of sheath pipe (iron) in the disposal pit. There is no possibility for radiation exposure.
- (2) The horizontal handling system approaches, and the radiation shield is removed.
- (3) Canisters are inserted into the sheath.
- (4) Solidified buffer disks are suspended down. (It is also possible to compact the powdered buffer material.)
- (5) Cover the pit with radiation shield.

Note: When it is necessary to retrieve the canisters, remove the buffer with machine to the crown of the sheath. Since there is a clearance between a canister and the sheath, suspension is quite easy. When the retrieval function is to be added as an option, the top cover should be added to the sheath.

Fig.14: Schematic Diagram of Handling System

4.2.2 Concept of Sub-system

(1) System Structure

Features of the system may greatly depend on the structure. Fig. 13 shows the basic structure. The feature of the present system is that the functions of horizontal transport and handling are satisfied by one sub-system, and that the monitoring system for the transport is made an independent system. The vertical transport system (elevator) does not have the receive/release function, where the horizontal handling system itself can get on and off the elevator. This is expected to considerably reduce malfunctions caused by abnormalities of a sub-system.

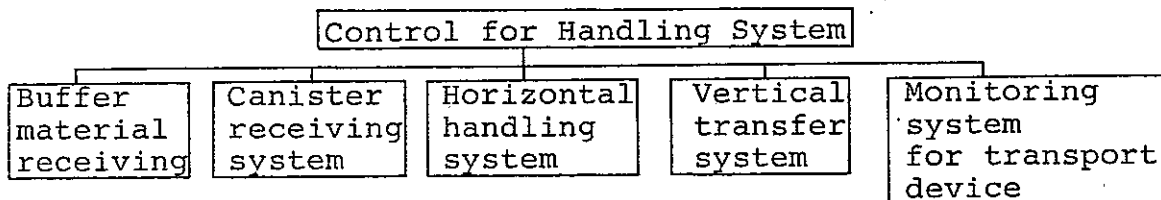


Fig. 13: System Composition

(2) Basic Functions of Sub-system

① Control System for the Handling System

The overall control of the handling system is its essential function. The system is computerized, and is a part of the integral control

system for the disposal plant.

② Concept of the Horizontal Handling System

Functions of this system are:

- * to transport canisters on the surface and in the disposal tunnels respectively,
- * to transport buffer materials on the surface and in the disposal tunnels respectively,
- * to place canisters in the disposal pits,
- * to back-fill the buffer after placement,
- * to monitor radiation by means of a monitoring instrument installed in the system,
- * to retrieve before disposal (option).

Fig. 14 shows a conceptual drawing.

③ Other Sub-systems

Their functions are:

- * Canister receiving/releasing system: to unload canisters without removing the casks. The handling can be relatively easy if the heavy casks are made a truck type.
- * System to receive the back-filling material: to receive buffers for back-filling. The structure is simple, but care should be taken not to damage the buffer disks.
- * System for vertical transport: an elevator would be most suitable. Safety can be ensured

by providing devices at multiple levels to prevent falls such as those used commonly in buildings.

* Monitor for the transport system: Although each sub-system has a self-checking function, a separate monitoring function is also provided to achieve a still higher reliability.

(3) Mode of Operation

The mode of operation is classified as follows at the different levels.

① Fully automatic operation

Normally, the operation is fully automatic and computer-controlled. Data related to handling are stored in the computer, which transmits instructions to each system according to the procedure and decision logics previously set.

② Manual remote operation

Used in case of break-down in the computer system, and test operations.

③ Manual manned operation

Used in case the operation modes ① and ② break down, or for test operations.

④ Maintenance operation

Used only when functions are checked for the maintenance of the system. This cannot be used

for actual operation and is different from the mode (3) in that the interlock for preventing operational errors is released.

4.3 Ventilation and Cooling System

4.3.1 Requirements for Ventilation and Cooling System

The ventilation and cooling system primarily functions to provide sufficient oxygen for workers in the underground disposal facilities and to dilute or exhaust toxic gas generated or formed in the tunnels. Secondly, it supplies sufficient fresh air into the cavern in order to improve the climate in the tunnels (temperature, humidity, wind velocity, etc.) even if the rock temperature is high.

The system is therefore required to function in the following manner:

- (i) Ventilate the required and sufficient amount of the air.
- (ii) Ventilate the air necessary for improving the air conditions in the tunnels as required.
- (iii) Monitor the contamination degree in the tunnels and limit the routes for the contaminated air.

4.3.2 Concept of the Ventilation and Cooling System

(1) Principal items reviewed

Following is conceivable in respect of the radiation contamination of the air current in the tunnels.

- (1) Since canisters are solid, there are no positive

contamination.

- ② Since the system is of a forced exhaust type, the air pressure over the entire underground facilities (intake shaft -- main tunnels -- burial tunnels -- main exhaust tunnel -- exhaust shaft) is smaller than atmospheric pressure, and the nearer a tunnel is to the exhaust shaft, the greater the degree of negative pressure. Thus, even if contaminated, the air does not mix with the intake air (the upwind current), thereby rendering the control and countermeasures simple and easy. It is also possible to provide suitable devices to keep the concentration of the radioactive material below the permissible levels in underground facilities, the exhaust shaft mouth, or the fan room. Monitoring of and countermeasures against the radiation contamination can be very well managed by other systems, and therefore the main items to be reviewed for the ventilation and cooling system will be the climate in the tunnels.

(2) Study of the Tunnel Climate

The atmospheric temperature and humidity, the amount of wind, the rockmass temperature, the wet ratio of

the rockmass surface, thermal properties of the rockmass, dimensions of the tunnels, etc. are the factors affecting the climate in the tunnels. We estimated the temperature and humidity distribution of the central ventilation system of a forced exhaust type proposed by our report for 1980.

Fig. 15 shows the dry- and wet- bulb temperature distribution and the temperature fluctuations in the shafts, the main tunnels and the disposal tunnels.

(3) Proposed Conceptual Drawing

① Objective of the system

The objectives of the ventilation and cooling system are the stable and sufficient supply of the fresh air, appropriate maintenance and control of the climate in the tunnels.

② Fundamental structure of the system

- 1) Review of the layout proposed in the Report for 1980 will be continued.
- 2) Improvement and maintenance of the climatic environment are essentially achieved by sufficient ventilation. Sufficient ventilation such as shown in Fig. 15 should give Wet Kata index of ca. 20.
- 3) The ventilation shall be a central (or contra-positional) system of a forced exhaust type.

As the air pressure over the entire ventilation area is negative and the main fan can be installed above the ground, the required air supply and the ventilation control are easily and stably secured.

- 4) Ventilation and cooling for each disposal tunnel with a sufficient amount of the air should be started one year before the actual burial of canisters.
Sufficient preliminary ventilation for more than one year should adjust the climatic environment to an acceptable state despite the high rock temperature as shown in Fig. 15.
- 5) Radiation contamination in the disposal area will be observed by monitoring, etc.
- 6) The rock temperature of the site at the time of construction is very high (ca. 50°C) and therefore the working places should be air conditioned using suitable mechanical cooling devices, although the air conditions in the tunnels leading to the operation base can be improved by sufficient ventilation alone.

③ Conceptual Drawing

Fig. 16 shows a conceptual drawing of the ventilation and cooling system.

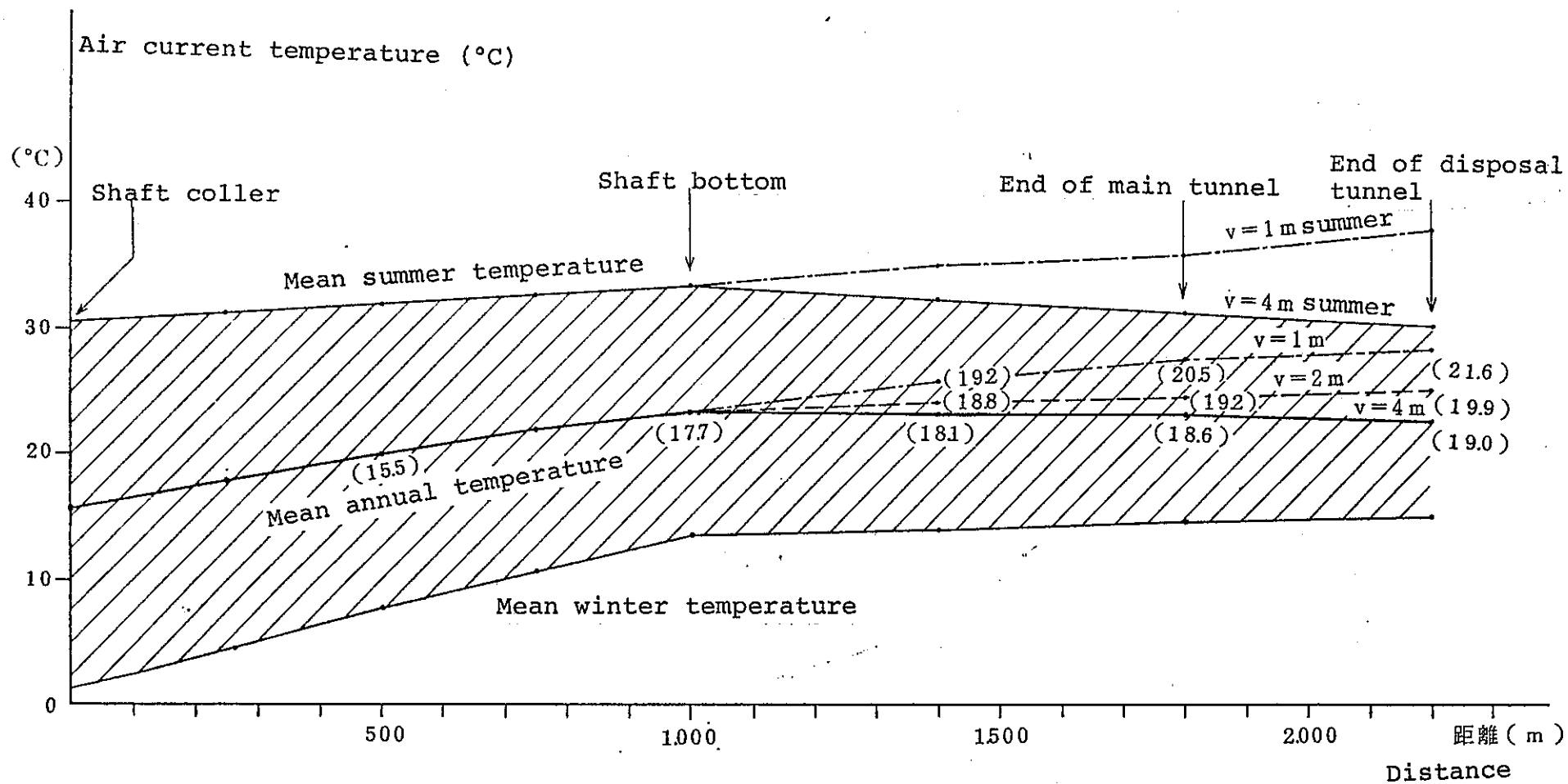


Fig. 15: Dry & wet-bulb temperature distribution
 Figures in parenthesis are wet-bulb temperatures (°C)

Place canisters from
the innermost portion
When 100 canisters
(for 1 tunnel) are
filled, back-fill the
tunnel

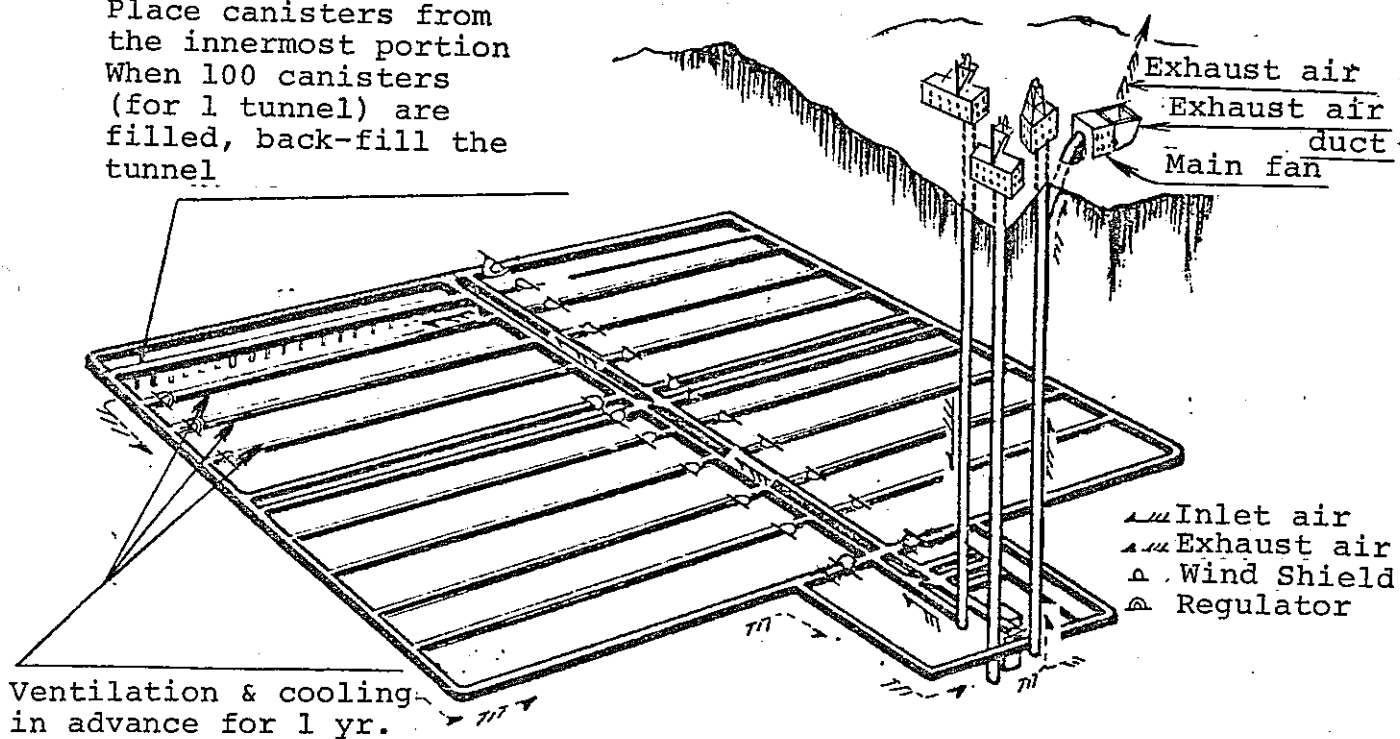


Fig. 16: Conceptual Drawing of Ventilation & Cooling System

4.3.3 Thermal Analysis after Back-Filling

(1) Conditions for Determining Canister Installation

Pitches

① Upper Limit of the Canister Temperature

Inside temperature : 450°C

Surface temperature : 350°C

② Upper Limit of the Buffer Temperature Depending On the Material

In case the water cutoff performance of buffers should decrease due to the temperature rise and fail to satisfy the required functions, the buffer temperature should be limited.

③ When the rockmass of the disposal area consists of rocks such as granite which contains quartz, the crystalline structure of the quartz changes at 573°C.

④ The Rockmass Stability Against the Thermal stress in the Near Field Including the Disposal pits and Tunnels

Decrepitation was observed in the rockmass around the pits at 300°C in the heating test at Stripa. It is difficult at this stage to determine what is the critical temperature in terms of stability, but we estimate that the upper limit of the rock-mass temperature would be 300°C.

- ⑤ Groundwater Flow in the Bedrock.. under High Temperatures
Viscosity, potential, etc. of the water change as the bedrock temperature rises.

Of the conditions mentioned above, there still remain a number of problems for items ② and ⑤, and therefore we shall not discuss them in this Section. The item ④ is severer than the item ③, and the item ① or ④ remains as the condition to be met. For the time being, the canister surface temperature is limited up to 300°C as a condition which satisfies both ① and ④.

(2) Overseas Studies on Thermal Analyses

Since the number of references reviewed is limited, it seems still untimely to discuss whether methods and results of these studies are suitable. We therefore introduce here only the analytical methods employed in these references.

INFCE classifies regions around canisters into the following:

- ① very-near-field: the waste canisters and the host formation within a few meters of the canister.
- ② near-field : the repository itself - the rooms, pillar and corridors.

- ③ far-field : the host formation and the
surrounding strata away from
the repository

In the thermal analysis, different methods are employed for different regions. Figures 17 to 21 illustrate analytical models.

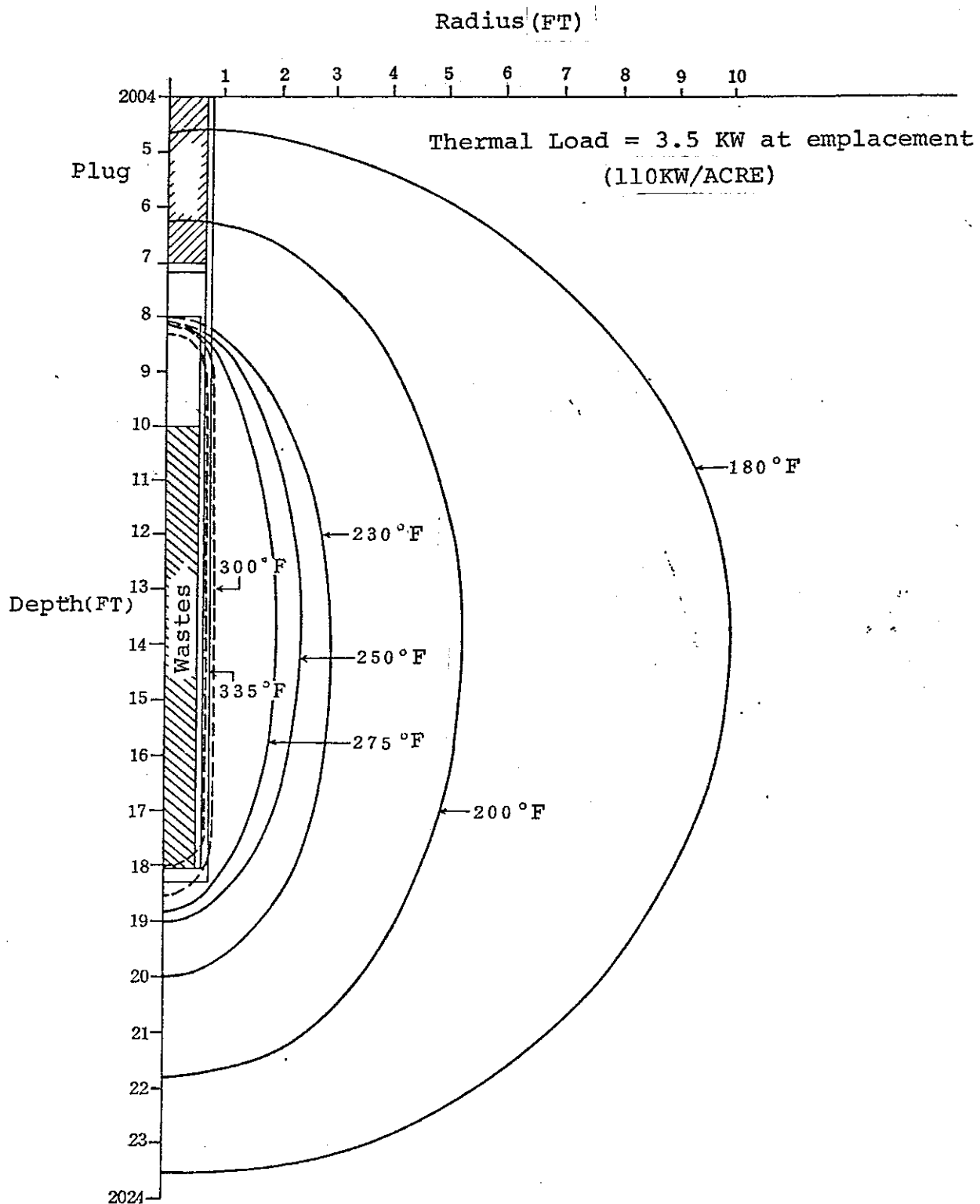


Fig. 17: Isotherms in Immediate Vicinity of Canister,
Time = 5 years

(Assuming that canisters are uniformly arranged in infinite lines, cylindrical unit cell is used as a model. OWI)

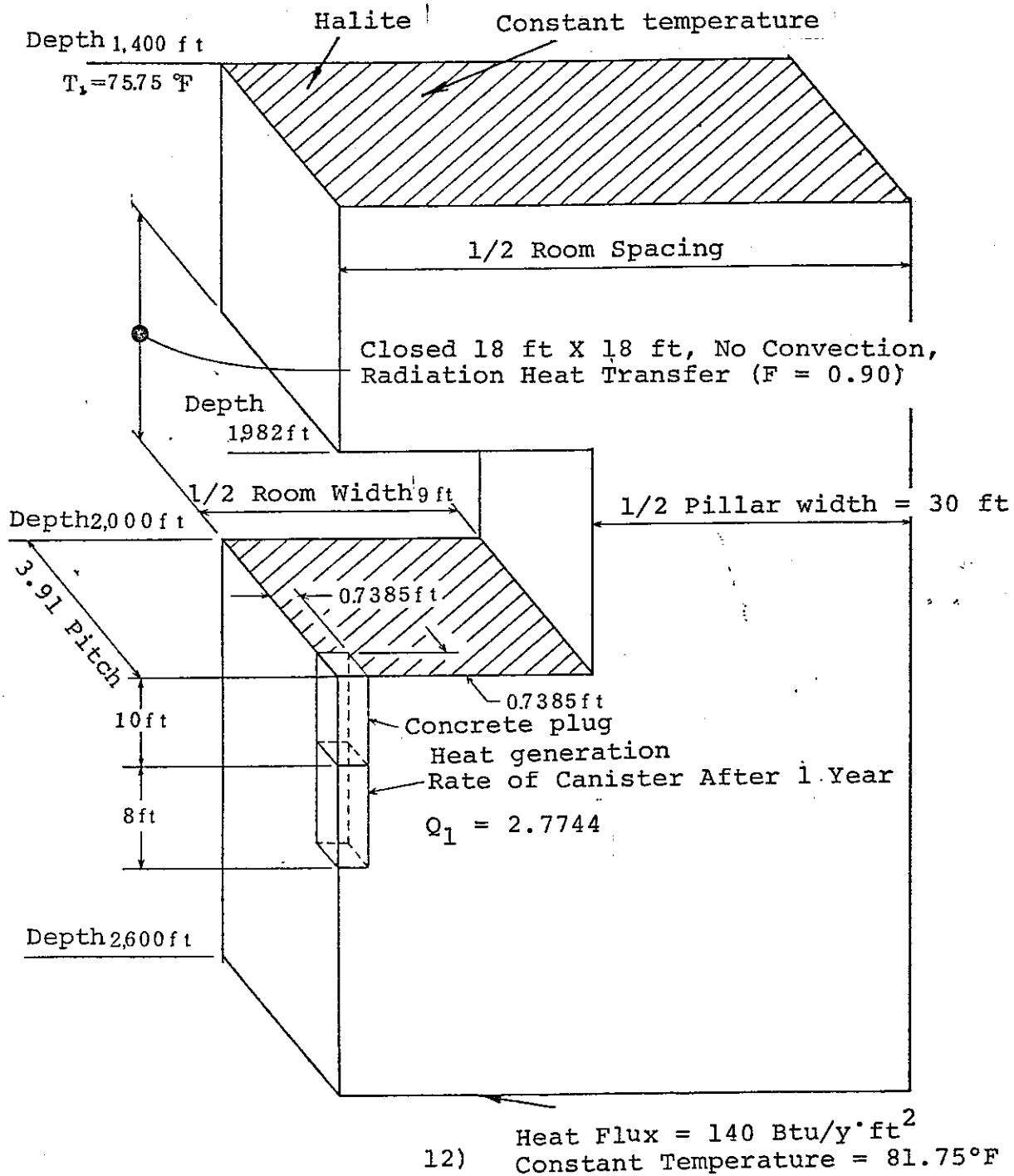


Fig. 18: Three-dimensional Unit-cell Model
 (Unit cell model where canisters are proximated to quadrangle pillar was used to calculate the maximum temperature rise of the Halite by the three-dimensional finite element method)

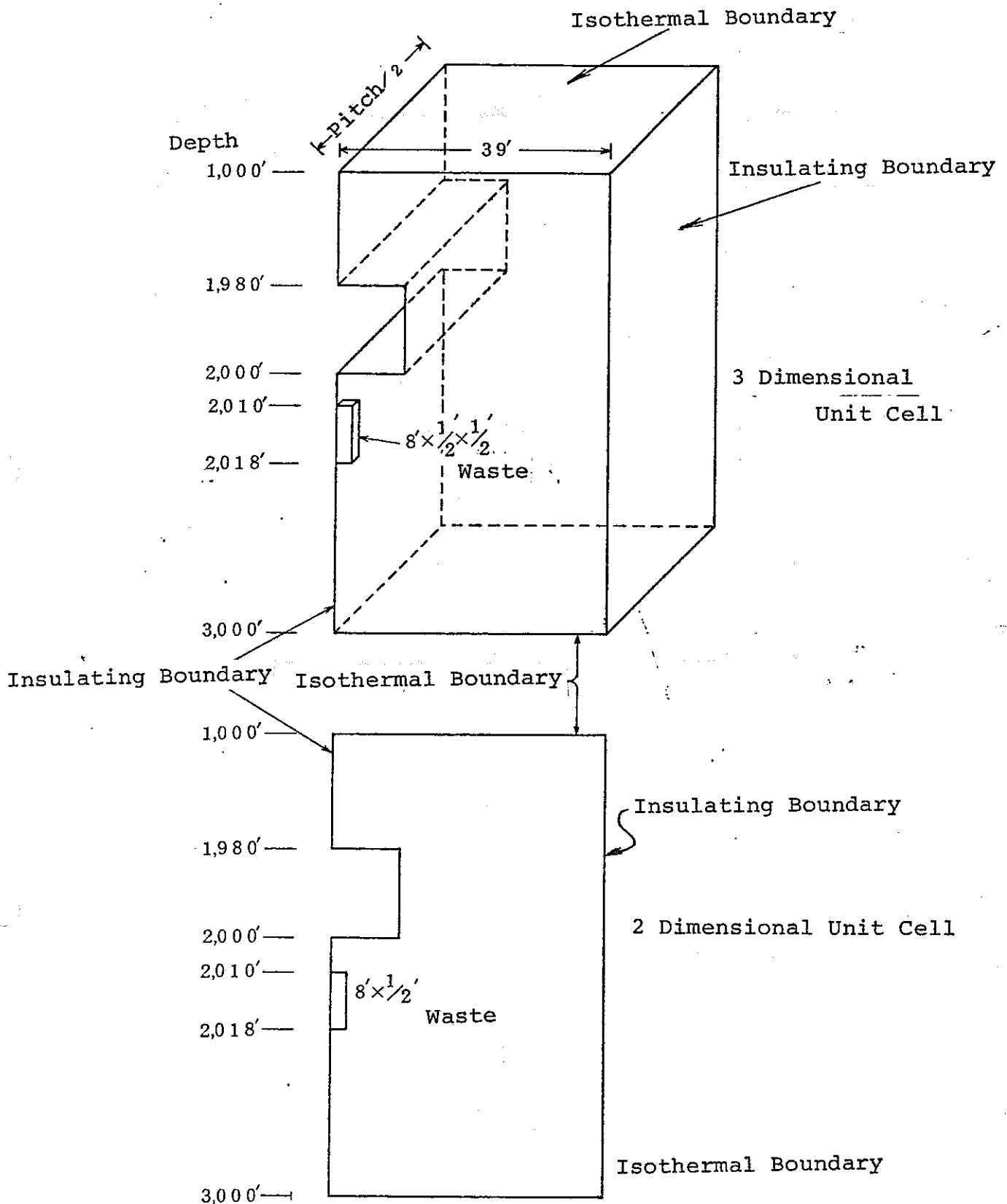
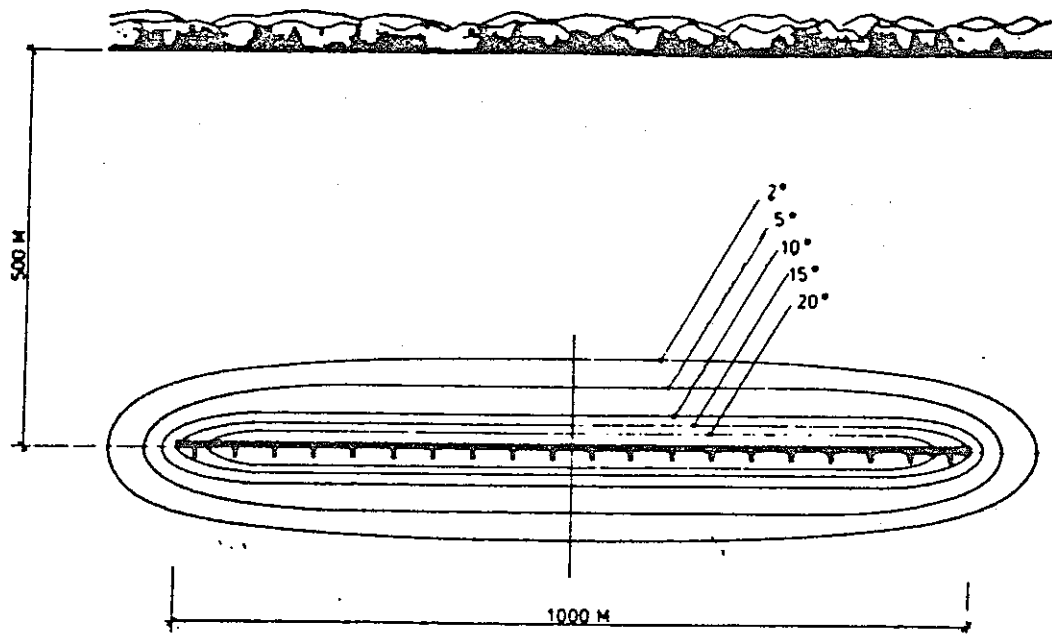
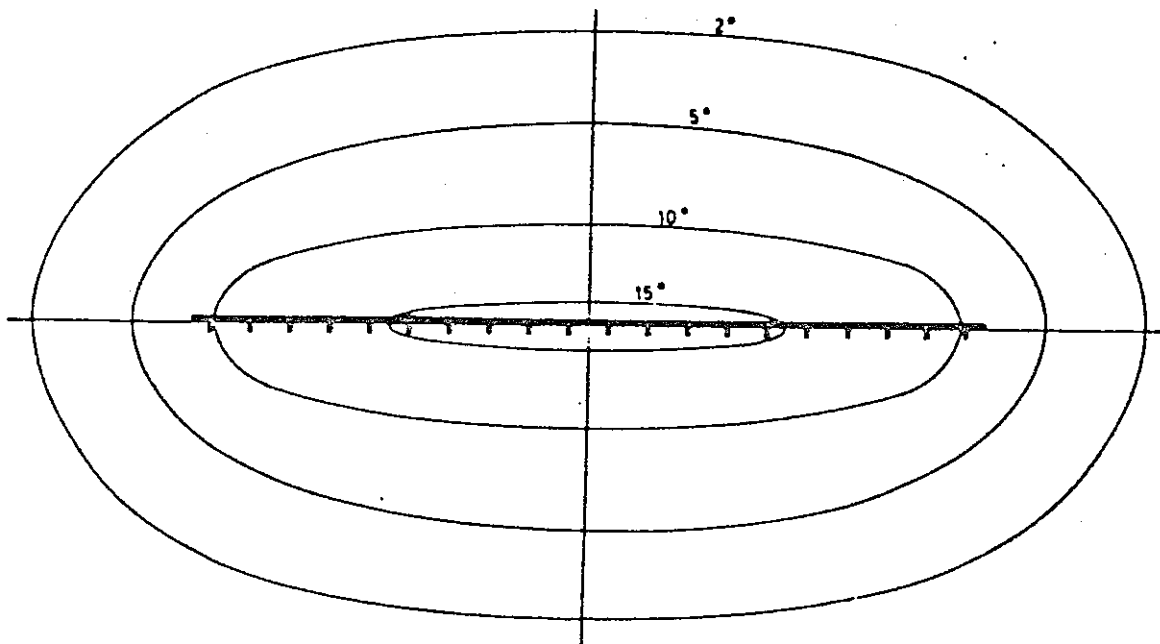


Fig. 19: 2 Dimensional and 3 Dimensional Unit Cells for HLW (Analysis by two- and three-dimensional unit cell models. Ventilation and convection in disposal tunnel are disregarded, but radiation is considered. Result of two-dimensional unit cell model analysis coincides very well with that of three-dimensional unit cell model. (OWI))



50 years after deposition



600 years after deposition

Fig. 20: Temperature Increase in the Rock Formation around the Final Repository

(The final repository is assumed as a plane thermal source in two-dimensional analysis.)

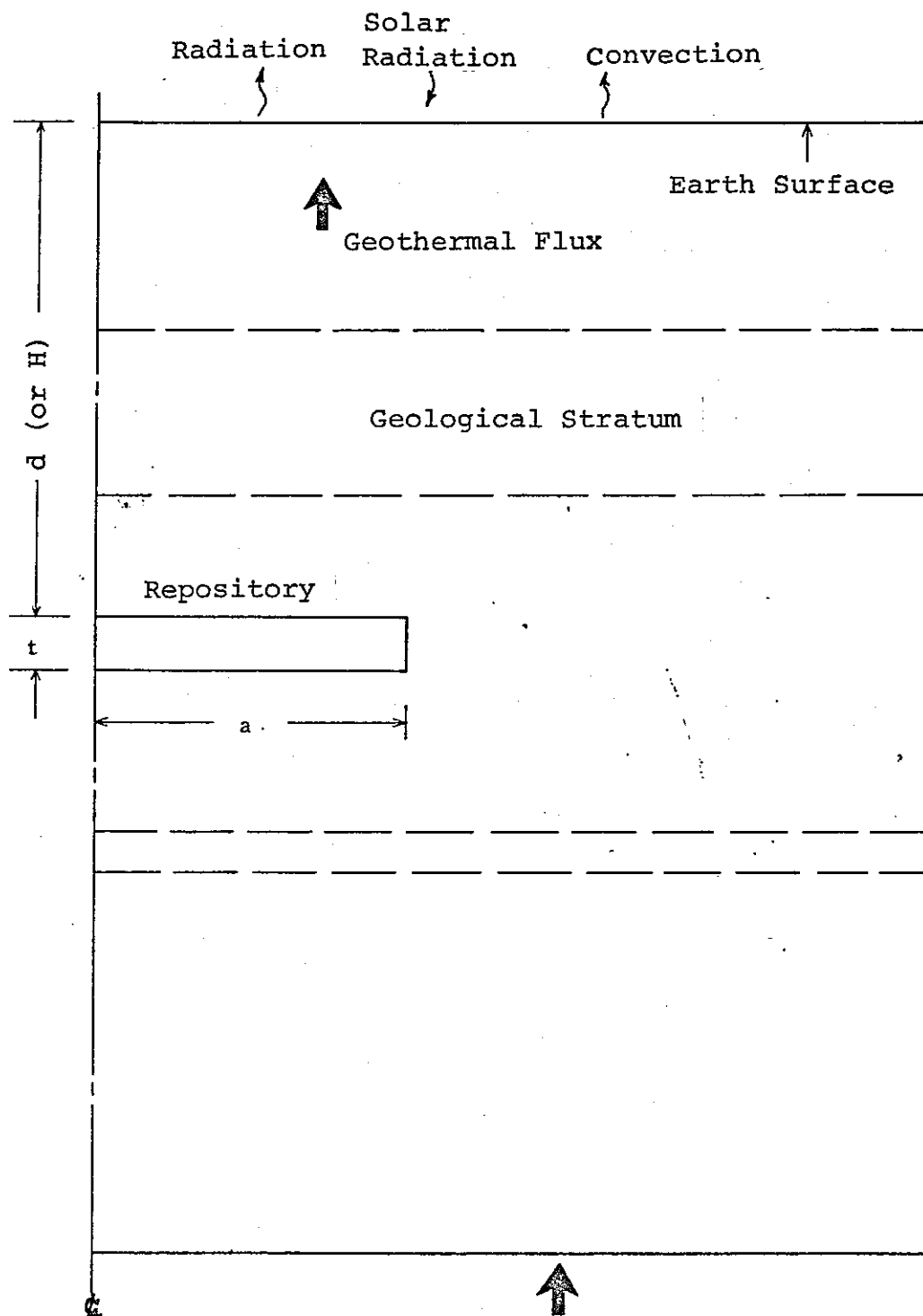


Fig. 21: R-Z Unit Cell Model for the Far-field Calculations (Repository is modelled as a circular disk, and temperature distribution is calculated by axial symmetrical analysis. Heat balance at the earth surface is reviewed. (OWI))

(3) Proposal for A New Analytical Method

As discussed before, the upper limit of canister temperature plays a decisive role in determining pitches for disposal pits. We, therefore, propose a theoretical solution for obtaining the canister surface temperature. The theoretical solution is based on the assumption that a canister is a cylindrical space in an infinite solid and provides a thermal flux which decreases in the order of exponential function at the surface of the cylindrical space by consideration of heat generating characteristics of canister. At the present stage, the solution is obtained in respect of one canister only.

- ① The approximate equation for heat generation per one canister is given as:

$$Q(t) = 0.49e^{-0.0225 \cdot t_{KW}}$$

- ② Thermal characteristics of the host rock

The thermal characteristics of the host rock are the same as those employed in the previous study.

thermal conductivity $k = 2.5 \text{ Kcal/m} \cdot \text{hr} \cdot ^\circ\text{C}$

specific heat $C = 0.22 \text{ Kcal/kg} \cdot ^\circ\text{C}$

density $p = 2.65 \text{ t/m}^3$

initial temperature $\theta = 50^\circ\text{C}$

The thermal characteristics of the buffer material are assumed to be the same as those of

the host rock.

③ Canister surface temperature

Chronological changes in the canister surface temperature are shown in Figs. 22 and 23. In case there is one canister, its surface temperature reaches the maximum (114.5°C) after about 5 years. This value sufficiently satisfies the temperature limit (surface temperature 300°C) given in the foregoing.

④ Effects on adjacent disposal tunnels

Figs. 24 and 25 show the temperature distribution in the host rock around canisters. Since the center to center distance of disposal tunnels is 15.5 m, the host rock temperature in the adjacent tunnels will rise by about 10°C (after 50 years) and the effect will be negligible.

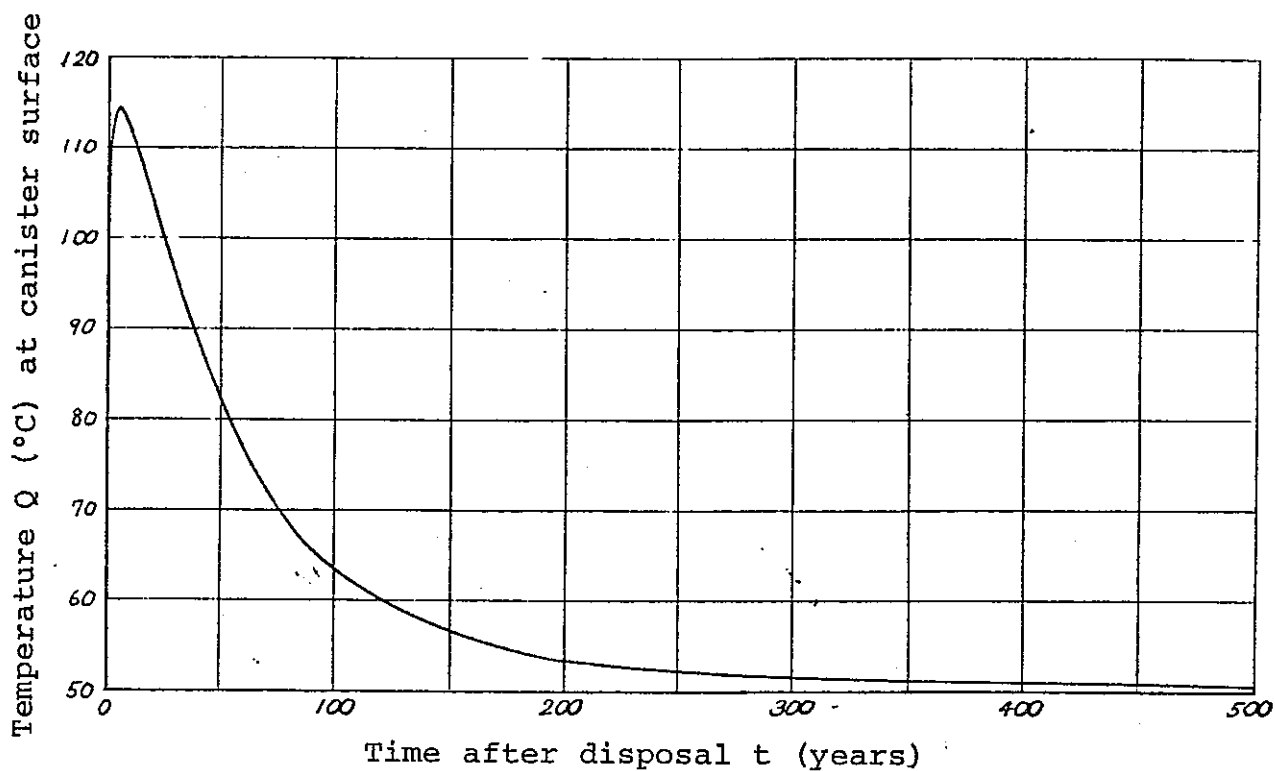


Fig. 22: Temperature at Canister Surface

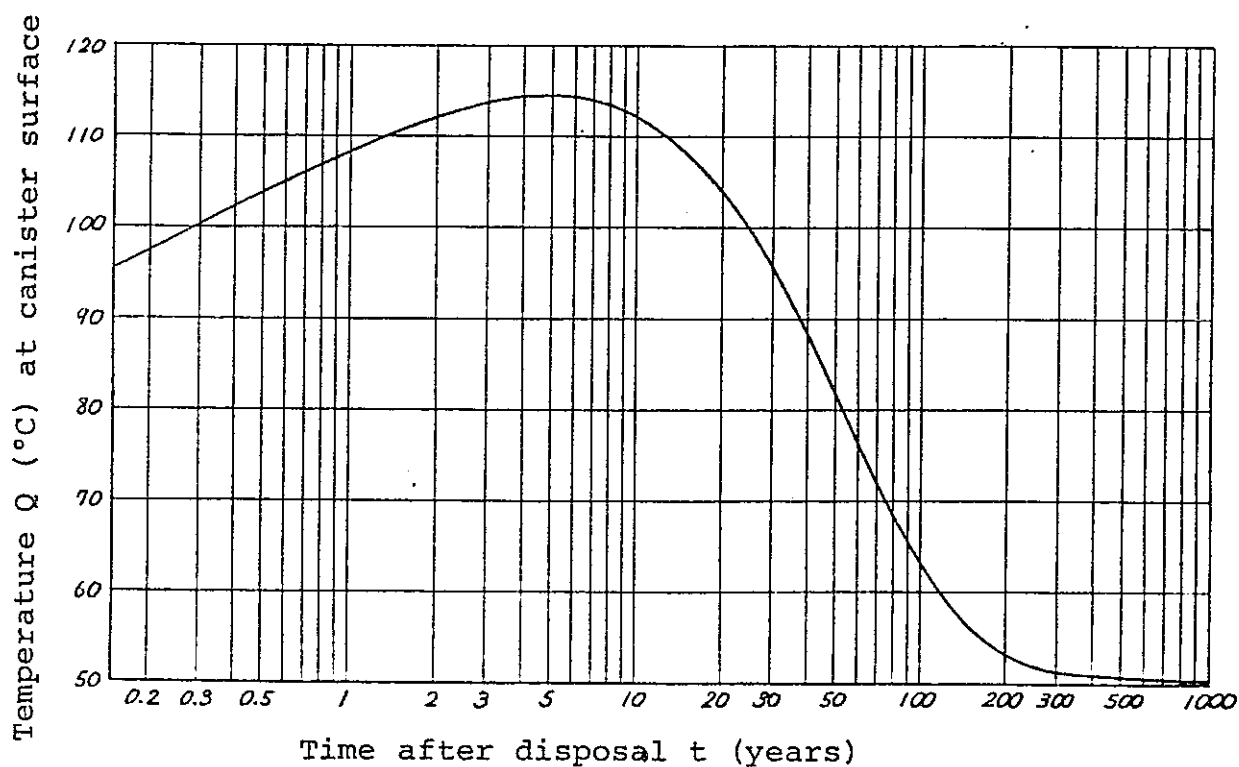


Fig. 23: Temperature at Canister Surface

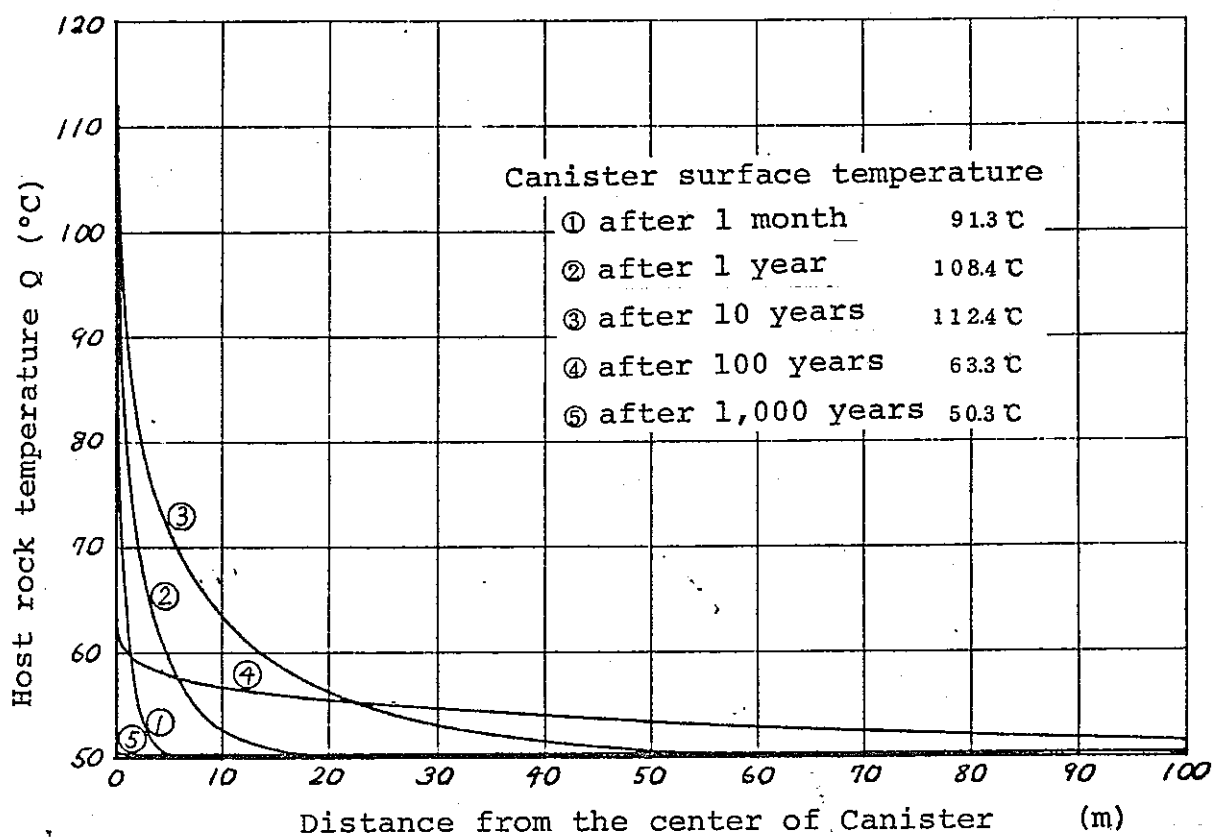


Fig. 24: Temperature distribution of host rock

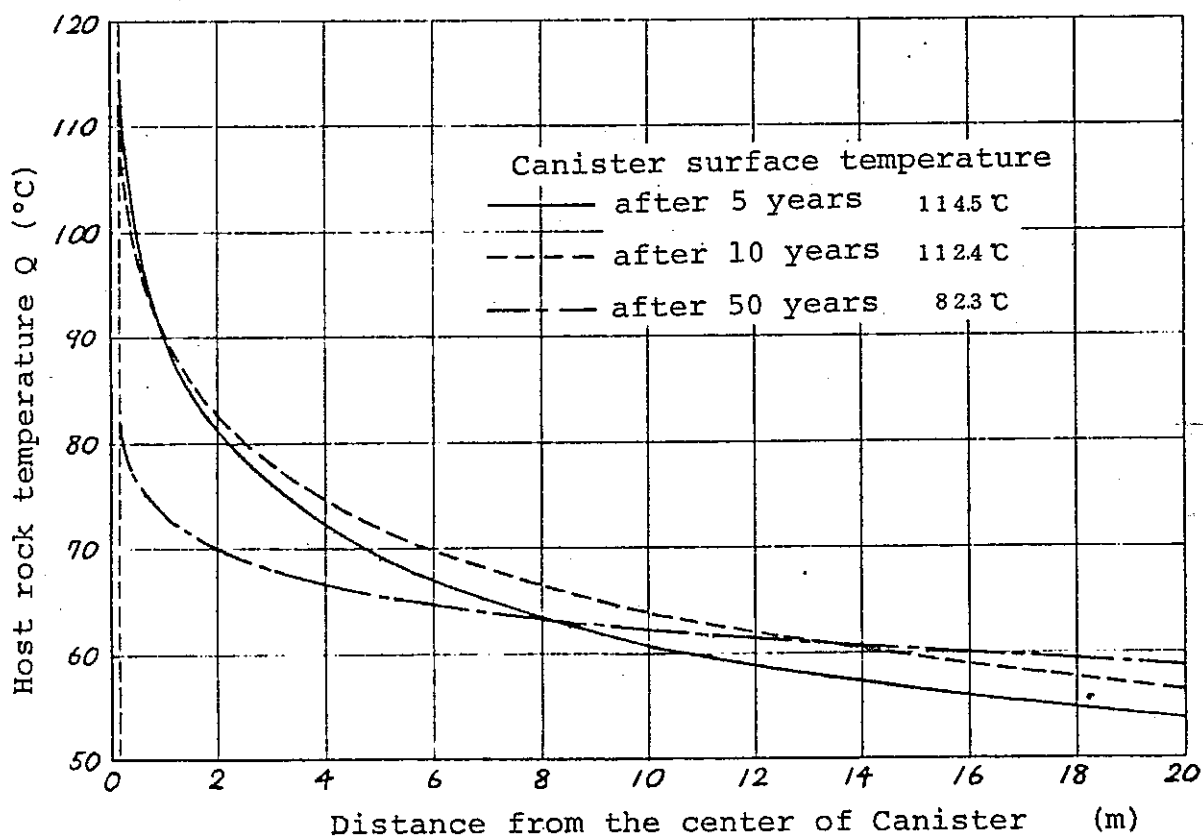


Fig. 25: Temperature distribution of host rock

4.4 Water Cutoff and Drainage System

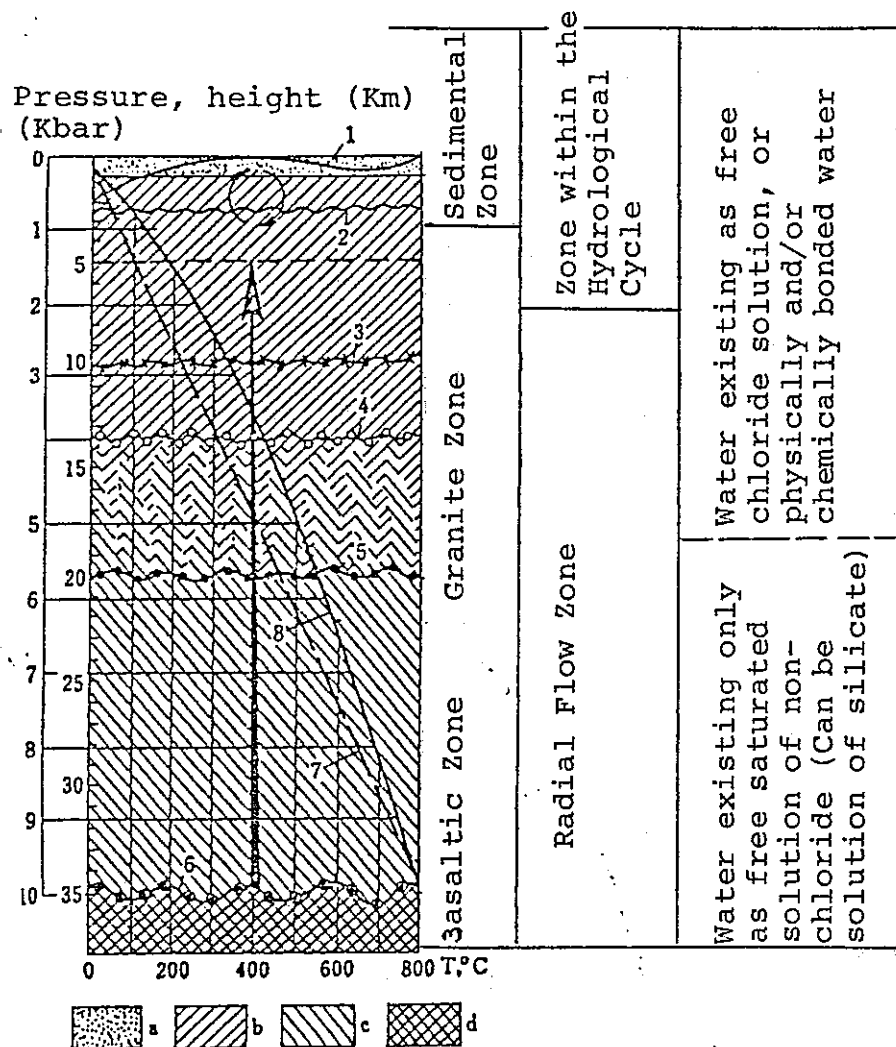
4.4.1 Groundwater Regime in Deep Geological Formation

The groundwater in the deep geological formation of up to about 1,000 m is considered to be circulating and connected with the surface water.

This is based on the fact that the boundary between the crystalline water and the gravitational water exists at about 2,500 m depth and that there always exists about 1 to 4% of effective porosity to the depth of about 1,000 m. The heat balance theory related to geothermal areas also assumes that the water is very likely to circulate at the depth of about 1,000 m. (Fig. 26)

Although seepage in sedimentary rocks is usually less than in granitic rocks, the sedimentary rocks in Japan are less extensive compared to other countries and are substantially metamorphized in many areas. Their homogeneity is considered inferior to that of granitic rocks.

As for permeability of sedimentary rocks, there are measurements of seepages at coal mines and the permeability coefficient assumed from the seepage amount transition is given as $1.1 \times 10^{-5} - 9.0 \times 10^{-7}$ cm/sec.



a. Sediment Zone. b. Free Chloride Solution(Upper Area - Sodium Chloride Solution, Toward Deeper Depth - Solution of Calcium Chloride and Solution of Magnesium Chloride); and physically and/or chemically bonded water. c. Free Saturated Non-chloride Water, probably Silicate Solution. d. Upper Mantle.

1. Upper limit of underground hydrochloride zone.
2. Upper limit of crystalline H_2O formation.
3. Upper limit of H_2O , OH^- , H_3O^+ , H^+ formation.
4. Upper limit of rock metamorphism
6. Conrad discontinuity surface.
7. Mohorovici's discontinuity surface.
8. Rock temperature curves ($^{\circ}C$)
9. Lithostatic pressure Line (Kb)

Fig. 26: Estimated Model for Continental Type Groundwater
(By Delvgoritz)

TABLE 8: Rock classification (UNESCO; 1972)

Rock types	Porosity		Permeability range (cm/sec)						Well yields			Type of water-bearing unit	
	Primary (grain)	Secondary (fracture) ¹	10 ⁸	10 ⁶	10 ⁻⁴	10 ⁻⁶	10 ⁻⁸	High	Medium	Low			
Sediments, unconsolidated													
	%												
Gravel	30-40		_____					_____				Aquifer	
Coarse sand	30-40			_____				_____				Aquifer	
Medium to fine sand	30-35				_____			_____				Aquifer	
Silt	40-50	Occasional				_____						Aquiclude	
Clay, till	45-55	Rare (mud cracks)					_____				_____	Aquiclude	
Sediments, consolidated													
Limestone, dolomite	1-50	Solution joints, planes	_____					_____				Aquifer or aquifuge	
Coarse, medium sandstone	< 20	Joints and fractures		_____				_____				Aquifer or aquiclude	
Fine sandstone, argillite	< 10	Joints and fractures			_____							Aquifer or aquifuge	
Shale, siltstone	—	Joints and fractures				_____					_____	Aquifuge or aquifer	
Volcanic rocks													
Basalt	—	Joints, fractures	_____					_____				Aquifer or aquifuge	
Acid volcanic rocks	—				_____						_____	Aquifuge or aquifer	
Crystalline rocks													
Plutonic and metamorphic		Weathering and fractures decreasing as depth increases			_____						_____	Aquifuge or aquifer	

¹. Rarely exceeds 10 per cent.

1. Rarely exceeds 10 per cent.

4.4.2 Present State of Water Cutoff Technology Using Injection Method

There is a report that the use of water glass type injection material with a longer hardening time can achieve the water cutoff of about $1 \times 10^{-6} - 10^{-7}$ cm/sec for a bedrock of about 1×10^{-5} for which grouting has so far been impossible by cement type injection material. However, cement grouting seems more suitable when considering durability, etc. In this case, the improvement achieved will be 1.0×10^{-5} cm/sec at best, because of the permeability limit imposed by the cement particle size.

4.4.3 Concept of the Cutoff System

(1) Before Burial

- ① Grouting to reduce seepage into the disposal tunnels, pilot boring and pre-grouting are essential. These should reduce the overall host rock permeability in the range of about 1.0×10^{-7} to 1.0×10^{-5} cm/sec and the mean value of about 1.0×10^{-6} cm/sec.
- ② Grouting to prevent seepage in the delivery shaft from flowing to the disposal tunnels. As the shaft is constructed to penetrate from the surface through the aquifer, a substantial seepage is expected. This should be prevented by the cutoff technique such as grouting.

③ Buffer material for back-filling the canister placement pit

Canisters may be protected from the groundwater by filling the pit with bentonite powder, etc. which cuts off the water by its swelling action. However, even the permeability of bentonite is not zero and therefore if the pressurized water is percolating, it will certainly penetrate the buffer even when the cutoff effect is maintained for a considerable period of time. The buffer should therefore be considered a temporary cutoff before the water pressure becomes high.

(2) After Burial

The grout system after burial should be viewed from the entire flow of the geological disposal. The grout system shown in Fig. 27 forms the outermost of the artificial barrier.

After burial, the groundwater seeps into the disposal tunnel from the surrounding bedrock, and the grout system functions to restrict the seepage amount. The object of the system is to reduce the seepage and to delay the time when the water around canisters is completely saturated and the canisters are directly imposed the groundwater pressure of the host rock. The seepage will eventually corrode canisters and

become medium for nuclide transfer from the waste form. The system is also required to restrain the groundwater flow at this time from the disposal tunnel into the surrounding bedrock.

The critical factor in the grout system is its durability. The longer is the durability, the better is it for restricting the seepage before burial and for shielding the groundwater after burial. According to the existing technology, use of a cement type injection material should obtain the durability similar to that obtained by concrete. The exact figures for its durability are unknown.

In this study we reviewed the system within the scope of existing technology, and hope that a grouting material with less permeability, higher durability and using no water would be developed.

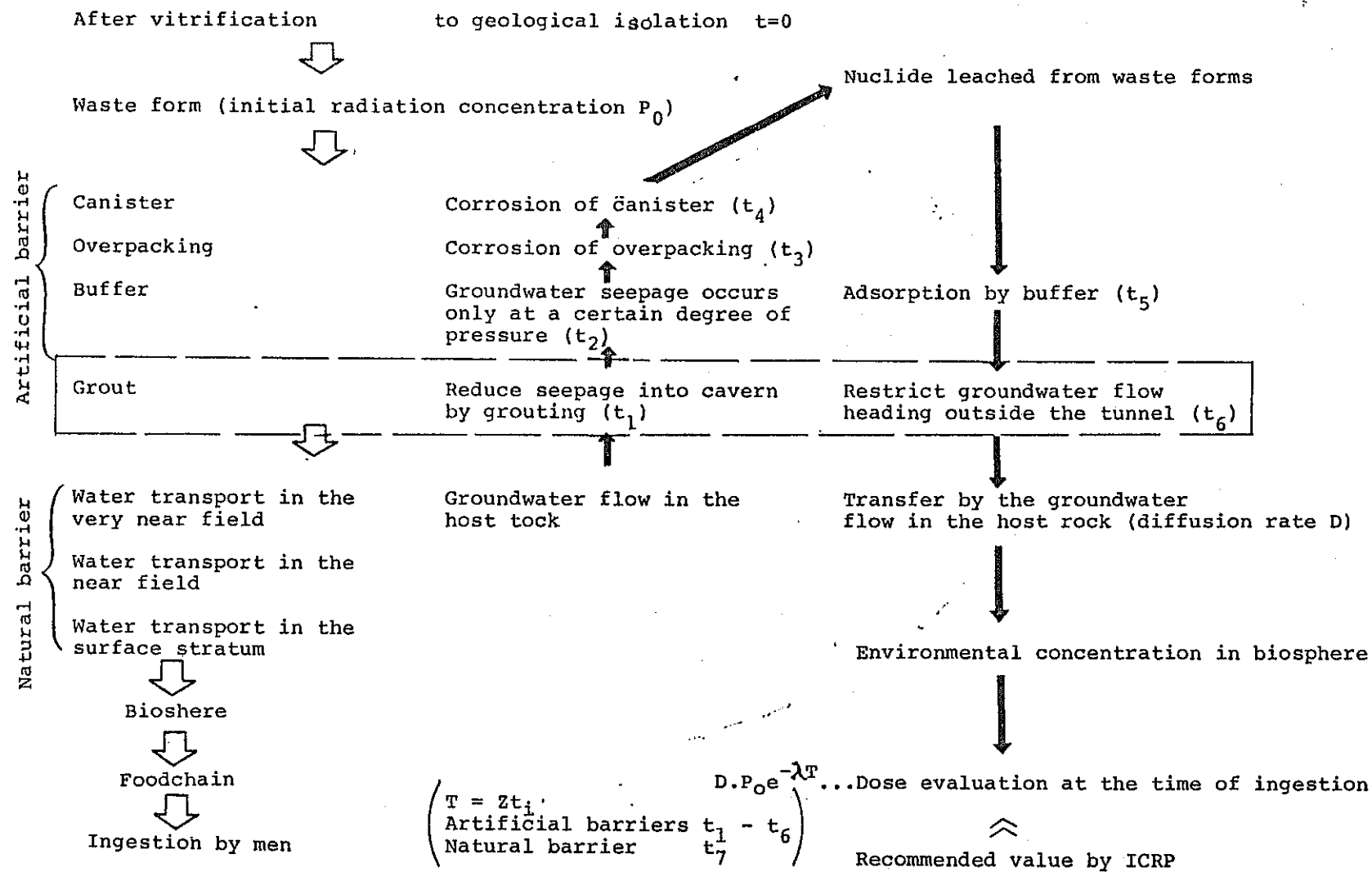


Fig. 27: Nuclide transfer in geological isolation

4.4.4 Concept of Drainage System

(1) Drainage in the Tunnels

The seepage in the disposal tunnels is drained by the gravity through side drains and collected in the underground water pool. This is the most reasonable method and is free of pumping troubles, etc.

Fig. 28 shows the flow chart and the conceptual drawing for drainage.

(2) Central Pumping Facility at the Underground Facilities

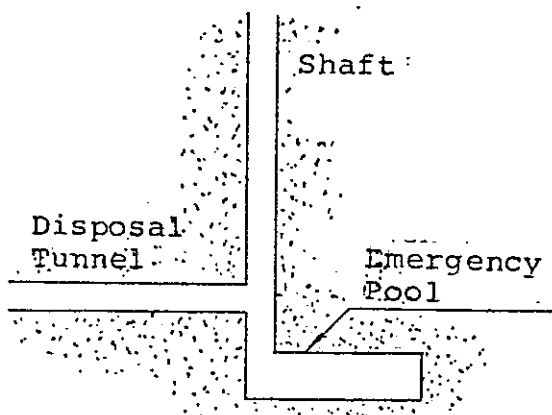
As the shaft penetrates the aquifer near the surface having a higher permeability, it should be grouted to cutoff the water. There is no need for special drainage.

Fig. 28 shows the concept of the central pumping facility in the underground facilities schematically.

(3) Countermeasures against Abnormal Conditions

The underground drainage can be maintained by constantly operating the pump. It will be safe, however, to provide an emergency power plant against accidents such as the power failure.

(1) Option 1: Cavern for Emergency Water Pool



By providing a cavern for pooling water during emergencies (shown in the figure), seepage may be collected.

- ② Option 2: Emergency pool which also acts as a drainage tunnel

The cavern for emergency pool is also used as a drainage tunnel. By extending the drain boreholes from the water collecting tunnel, seepage into the pit before burial can be prevented.

(Fig. 30)

- ③ Option 3: Auxiliary tunnels are used as drainage, power cable path, emergency pool, and drain tunnel. (Fig. 31)

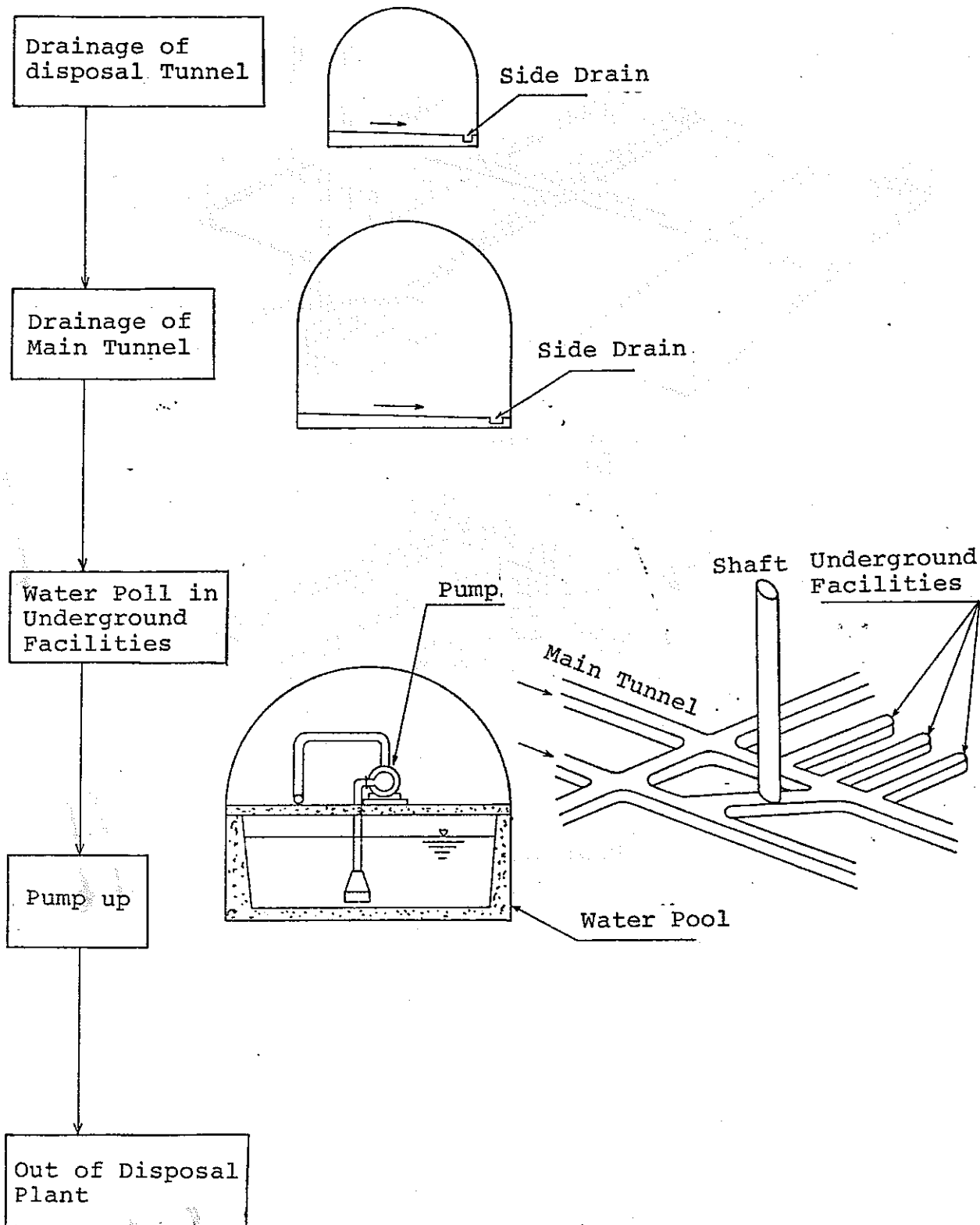


Fig. 28: Flow Diagram for Drainage From Tunnels

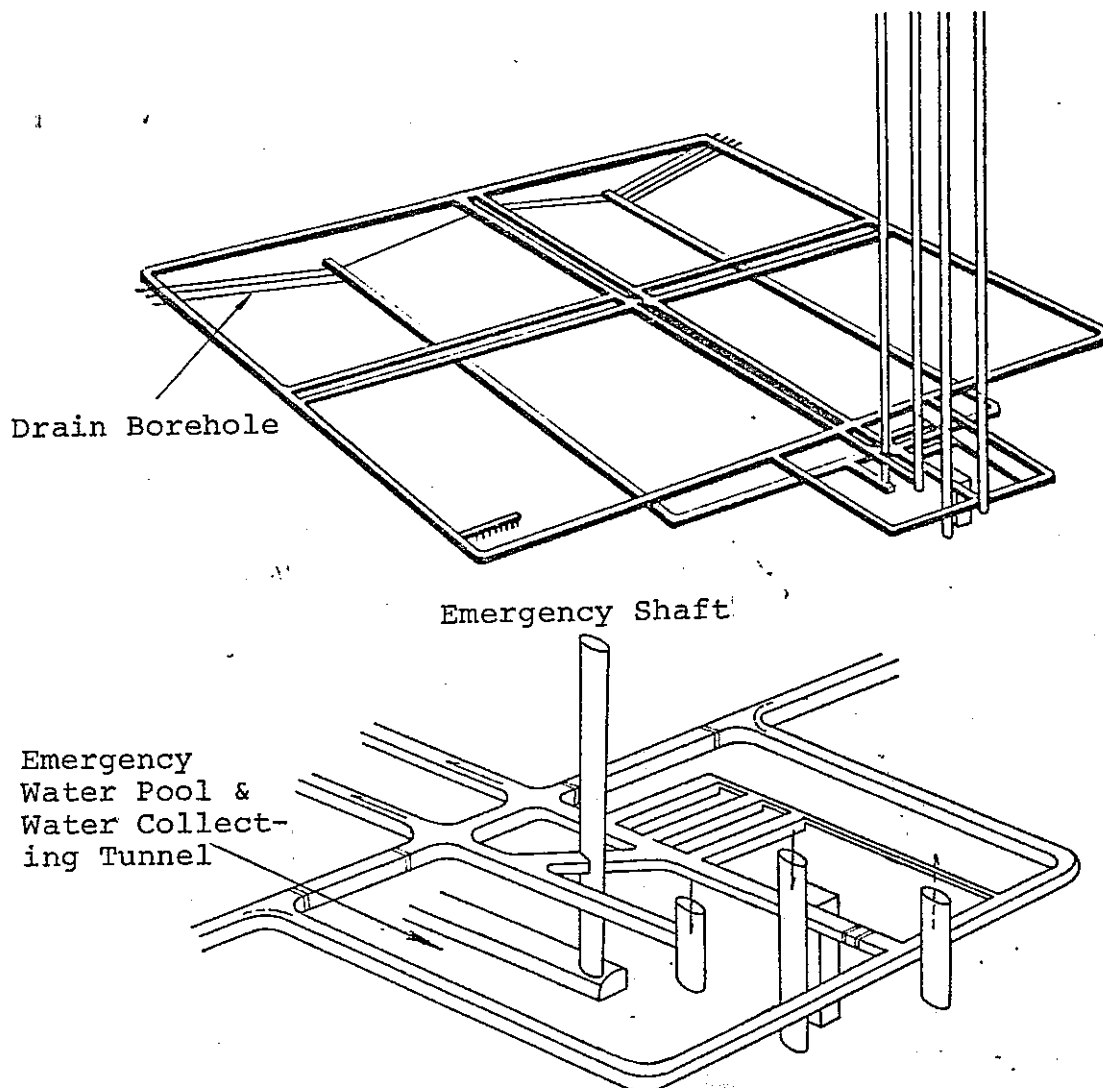


Fig. 30: Perspective View of Emergency Water Pool acting also as Drain

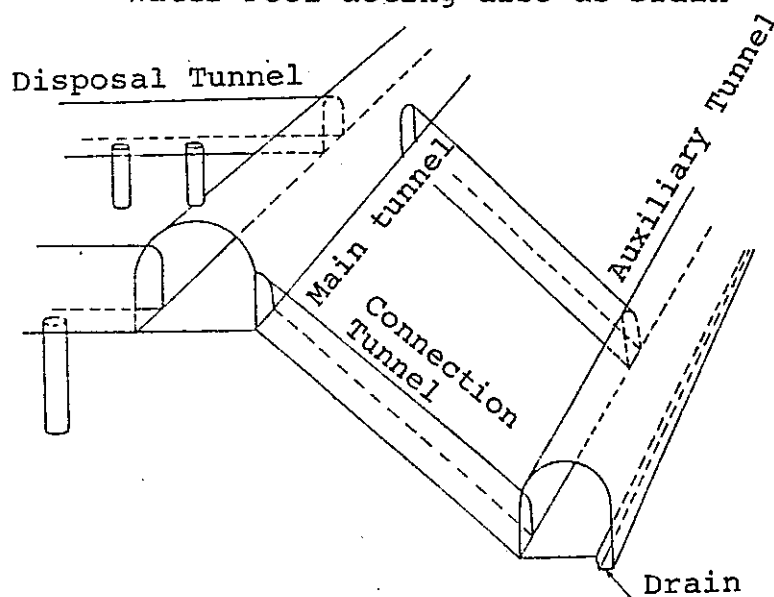


fig. 31: Schematic View of Auxiliary Tunnel for Drainage

5. Review of Construction Techniques

5.1 Design Principle for Underground Structures

The geological isolation system requires a structural design in addition to the system design.

5.1.1 Design Principles as a Step of Achieving Geological Isolation

In constructing and operating a geological disposal plant, and disposing wastes by burial, there are involved many steps such as investigation, designing, measurement, etc., as shown in Fig. 32. The principal item in the structural design in the course of design → approval → execution is probably the stability of the cavern.

5.1.2 Approaches to the Structural Design for Underground Structures

In the tunnel engineering, number of researchers have conducted studies on various mechanical phenomena, rock pressures, etc. However, since objects and phenomena of studies are complex and diversified, results can not readily be reflected upon the design and execution. That is why the tunnel engineering is still considered as an academic field involving empirical factors. However, the yearly progress in rock mechanics and its analytical methods using computer is rapid in recent years. The measurement data have been accumulated in the meantime, and the reliability of these analytical methods is steadily improving.

The design methods for underground caverns and structures are expected to be further improved in the near future.

(1) Design Principles for Tunnel Structures

The conventional underground structures in the bedrock are represented by tunnels. Tunnels (rock tunnel) are generally designed according to the standard design without evaluation by mechanical analyses.

(2) Principles for Stability of Caverns after Excavation

A large cavern (width 15 - 30 m, height 20 - 50 m) is excavated in the bedrock and engineered to stabilize it for use as an underground structure such as the underground power plant, and the underground fuel storage facility. Design of these structures can not be dealt with methods based on the earth pressure theory. Theories of elasticity, plasticity and viscosity are incorporated in analyzing geological stability of the host rock.

Recently, numerical analyses of the stress state around caverns are carried out to assume the scale of released areas, and results are reflected in the reinforcement design. In this case, the behaviors of caverns in the host rock are measured to carry out works suitable for the actual site conditions. Thus, incompleteness of the numerical analyses is supplemented.

《Design·Construction》

《Investigation·Test》

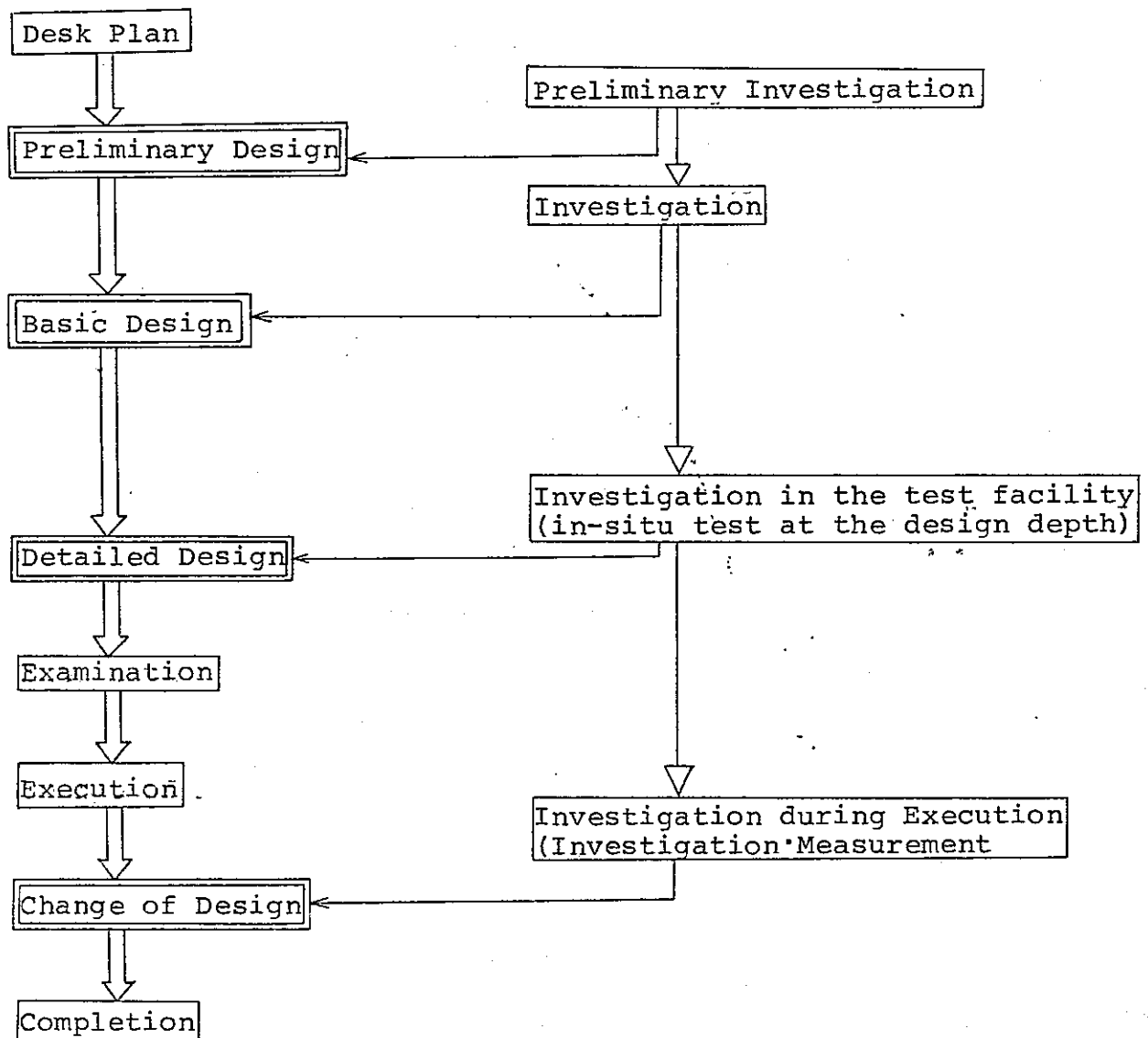


Fig. 32: Flow Chart for Design, Investigation, and Execution for Geological Disposal Plant

(3) Principles of Aseismatic Design of the Cavern

① Earthquake Resistance of the Cavern

Large scale natural caverns are found all over the world and have been preserved for several thousands of years. Limestone caverns in various parts of Japan have survived great earthquakes. At present, there are 175 underground hydro-electric power plants in the world, 31 of which are in Japan. These plants do not need any provisions against earthquakes as in the above cases. For example, Miboro Power Plant (Kita Mino Earthquake, $M = 7.0$, 1961), Okutadami Power Plant (Niigata Earthquake, $M = 7.5$, 1964) and, Kurobe No. 4 Power Plant have experienced earthquakes. These underground caverns suffered no damages and it is reported that they did not even realize there was an earthquake.

② Principles of Aseismatic Design of the Cavern

Stability of caverns at the time of earthquake has to be discussed based on the assumed earthquake conditions, and practical approaches are also essential in analyses and evaluation.

"Technology Guideline for Underground Oil Storage Facilities (Proposed)", (May, 1980) published by Japanese Society of Civil Engineering states

that "when constructing a cavern in a stable bedrock, there is no need for aseismatic design computations".

③ Principles for Earthquake Resistance of Geological Disposal Plant

Earthquake resistance of a structure is one element of the anti-disaster plan, and the required standard differs depending on the importance and the use of the subject structure. It also varies in time because of the changes in social consciousness, degree of development and technological progress. In the case of nuclear facilities, the guidelines for siting and aseismatic design require far more strict conditions than the general structures because of the great latent risk involved. Geological disposal plant requires such a consideration against earthquakes only for the time before burial. Geological disposal before burial mainly involves handling and storage of canisters with a good sealing property, and is considered to have less social impact as compared with nuclear power plants. However, since it handles radioactive substances, we must be able to explain the stability against earthquakes quantitatively.

5.2 Review of Execution Methods

In this section, various items are reviewed for constructing a geological disposal plant which satisfies the requirements of a geological isolation system.

5.2.1 Methods for Constructing Shafts

The present construction technology can sufficiently cope with constructing a shaft having the depth of 1,000 m. There have been examples of shafts of 1,000 m class in Japan. Major problems in engineering are seepage and soft layers. Even a small amount of seepage causes grave difficulties in shaft construction, and infiltration of the groundwater into the disposal plant should also be avoided. These should be dealt with water cutoff of pre-grouting method. Since excellent host rock is selected as a site for geological disposal plant, problems of seepage and soft layers are probably local and limited to the areas near the surface.

Fig. 33 shows a conceptual drawing of a general shaft construction method.

3rd Platform

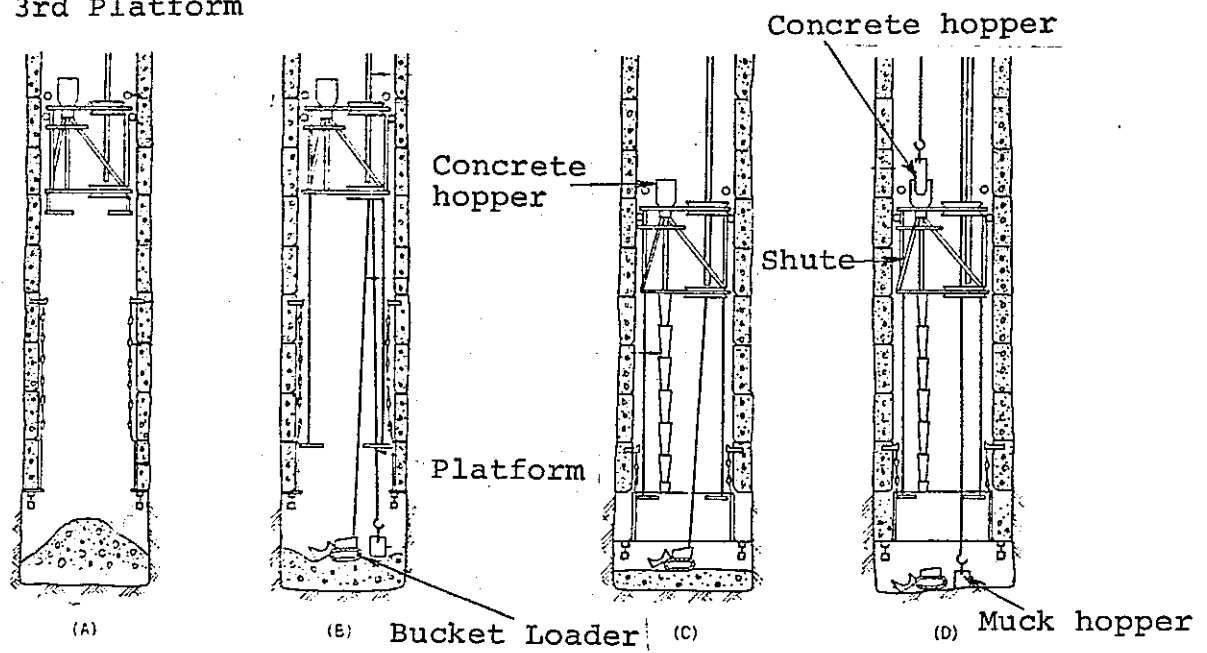


Fig. 33: Conceptual Drawing for Shaft Construction
by Short step Method (Inage & Ito, 1980)

5.2.2 Construction of Main Tunnels and Disposal Tunnels

Besides tunnel boring machine and blasting, such rock excavation methods as water jetting (hydraulic excavation), jet-flame drilling, use of laser, etc. have been studied. None of these latter methods is yet practical.

The most popular excavation method at present is blasting, which is superior to the tunnel boring machine in terms of economy. A tunnel boring machine will achieve a cavern of a better quality. Each has merits and demerits, and it is necessary to study respective methods and improve demerits.

5.2.3 Operation Schedule for Disposal Plant and Flow Chart of Construction Works

(1) Expansion Works of Disposal Plant

After the disposal schedule is established, it is necessary to store about 2,500 canisters each year. In other words, a disposal plant having a capacity of 10,000 canisters is to be constructed every four years.

Since disposal sites cannot always be secured on schedule, there may arise a need to expand the existing disposal plant. This is economically advantageous since the existing shafts can be used. As the expansion works must be unavoidably conducted while the disposal plant is being operated, exclusive

shafts for construction (for taking out muck : 1, for conveying workers, materials and machines : 1) must be provided as a separate transportation channel in order to separate the disposal plant operation from the construction works. Construction of additional shafts can be accelerated by effectively utilizing the mucking capacity of existing shafts.

(2) Construction Schedule for the Disposal Plant

It takes about 15 years to fill the first disposal plant. After the disposal schedule becomes smoothly operative, it is necessary to add or expand a plant every four years. As the first plant requires the operation as a pilot plant, its construction will probably proceed as shown in Fig. 34.

Fig. 34 shows the flow chart for constructing an underground test facility → pilot plant → first plant → expansion (second disposal plant) and so on. In order to materialize the test disposal in the year 2015, it is not too late to start constructing the underground test facility in or about 1985.

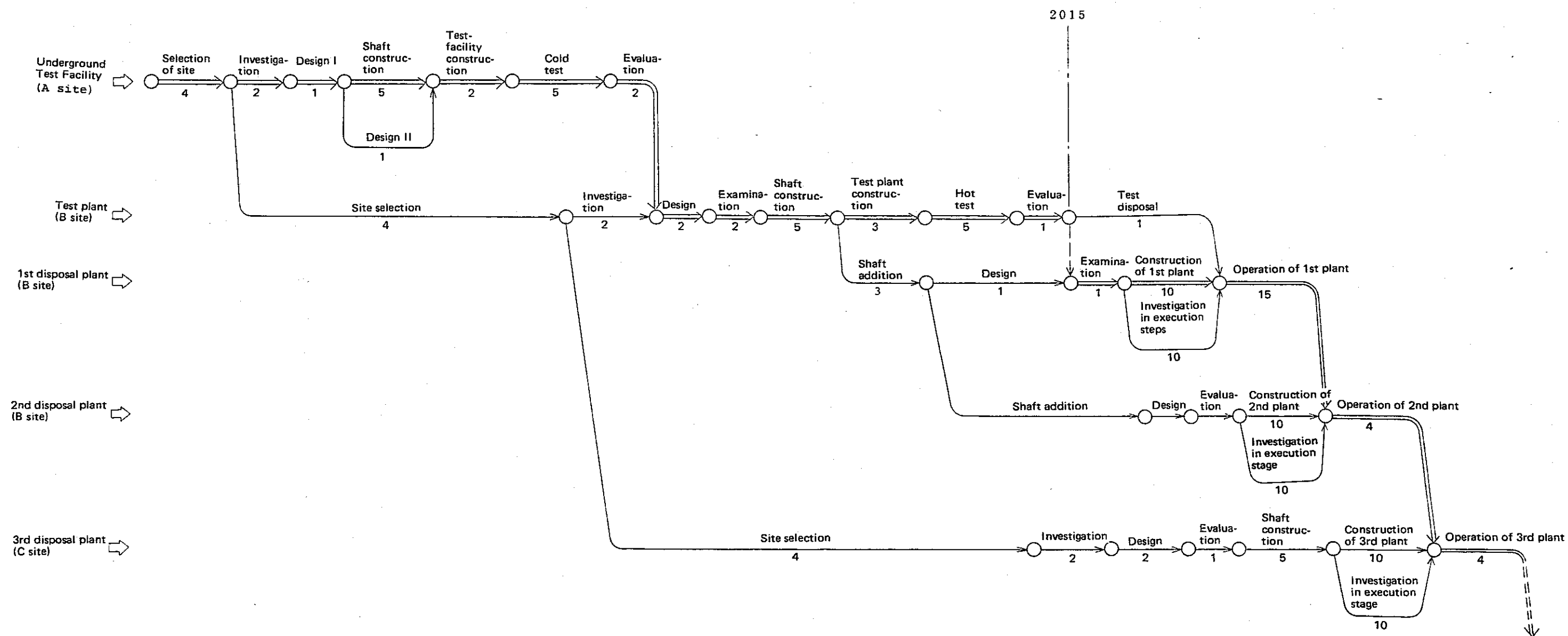


Fig. 34: Example of schedule for disposal plant construction (figures indicate estimated years required)

6. Overseas Investigation

The investigation was carried out according to the proposal for 1981 study.

The investigation is outlined below:

1. OECD/NEA : Workshop of waste management engineers
Workshop from OECD member countries was held
(U.S.A.) and our representatives participated.
Approaches to the disposal technology differ from country to country. Move for international cooperation is gathering momentum. These countries are still in the research stage.
2. NSTF : A test site on a rocky desert in the
(U.S.A.) great basin, Washington State. Tests are now being conducted in tunnels near the surface with an aim to site a geological disposal plant in basalt.
3. Stripa • A test site in granite for the inter-
(Sweden) national joint project participated by 6 countries including Japan. The test is most advanced.
4. SKBF : Public Corporation for Nuclear Fuel
(Sweden) Supply, Sweden. It is responsible for various researches such as nuclear fuel cycle at KBS, CLAB, etc. as well

as Stripa Project. This time, we met only with people in charge of Stripa Project.

5. CLAB : Central storage facilities for spent
(Sweden) nuclear fuel; it is stored in a pool in the cavern. Nuclear fuel cycle is in steady progress.
6. ASSE : Low and medium level wastes are
(West Germany) tentatively disposed in caverns in the salt dome. Handling is very simple.
7. Gelsenkirchen : We visited the coal mine in Ruhr as an
(West Germany) example of underground facility at -1,200 m.

7. Conclusion

Following the research of the previous year, we furthered the review of required functions in order to elucidate the concept of a geological isolation system suitable for Japan. Various sub-systems and siting conditions in Japan were further studied based on the review, and a few conceptual drawings of a geological disposal plant are proposed. Basic design and construction of systems can be sufficiently dealt with by the present technology, but it is necessary to review the following items in order to elaborate the concept.

- i) Review of optimal shape and size in vertical cross section which satisfy various requirements as a main tunnel and a disposal tunnel and are mechanically stable.
- ii) Review of thermal problems after burial of the geological disposal plant.
- iii) Further review of the handling system for each step.
- iv) Accumulation of references and review of analytical methods to clarify the earthquake resistance of a disposal plant.
- v) Review of concept for each scene for executing construction and operation of a disposal plant according to the disposal scenario of high level radioactive wastes.

On the other hand, it goes without saying that an

underground test facility is required to confirm the data concerning deeper geological formation in Japan, since the construction requires detailed design of a disposal plant. When considering the schedule for construction and operation of a disposal plant, it is necessary to delineate types of investigation, items, method and procedure of the test to accelerate construction of an underground test facility.

Finally, we would like to acknowledge the guidance and support for the present design study rendered by Power Reactor & Nuclear Fuel Development Corporation.