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G. R. Silvan

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STRUCTURAL EVALUATION
OF THE
PUREX NO. 1 BURIAL TUNNEL

by

G. R. Silvan

September 1980

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

SUMMARY

The physical integrity of the Purex number one burial tunnel has been a concern since 1971. Several surveys were performed on the tunnel but none of these surveys dealt with the actual strength of the wood by direct testing. In May, 1980, three four-inch diameter cores were cut from the roof of the tunnel and tested for strength using a static bend test. The results of these tests showed that the wood beams in the burial tunnel are within standards for present day new wood and design calculations performed on the tunnel have shown it to be within safe limits. Collapse of the tunnel is not expected at this time, but a prediction of actual tunnel life is not possible due to the many unpredictable factors affecting wood strength. Since eventual tunnel failure is certain, the manner and time of tunnel deactivation must be determined. If the tunnel contents must be removed and stored elsewhere, or buried, the tunnel should be deactivated as soon as is practical, but if the tunnel contents can be buried in place, deactivation can be deferred to a later date. It is recommended that a study on the options for deactivation be completed within two years.

DESCRIPTION

The Purex No. 1 Burial Tunnel is located at the southwest end of the Purex building and is an extension of the railroad tunnel. The burial tunnel consists of three areas: the water filled door, the storage area and the vent shaft (see figure 1).

The water filled door is at the north end of the burial tunnel and connects the burial tunnel with the railroad tunnel. The door is constructed of one-half inch steel plate and is hollow so that it can be filled with water to act as a radiation shield when it is in the down (closed) position. When in the up position, the door is surrounded by a three foot thick cement enclosure. The basic dimensions of the door are 24½ by 21½ by 7 feet. The electric hoists for raising and lowering the door are located on top of the cement enclosure, and the pumps and valves for filling and draining the door are located in a room just northwest of the enclosure. Controls for the operation of the water filled door are located on the north wall at the east end of the Pipe and Operating Gallery (P & O) in the Purex building.

The storage area is the main section of the burial tunnel. It is 358 feet long, 22 feet high and 19 feet wide. The ceiling and walls are composed of 12 by 14 inch creosote treated douglas fir timbers arranged side by side with the exception of the first one-hundred feet of the east wall which is three foot thick reinforced concrete. Ninety pound roofing material and tar were laid over the timbers and the entire structure was covered with eight foot of dirt fill. The floor consists of a railroad track laid on a gravel bed. The tracks are on a one percent downward slope to the south to prevent railroad cars from accidentally rolling out of the tunnel, and a railroad car bumper is located at the south end of the tracks to act as a stop. The capacity of the storage area is eight modified (shortened to 40 - 42 feet) railroad cars.

The vent shaft is located at the south end of the tunnel and provides a means by which a filter and fan can be connected to the storage area. The shaft is approximately three feet square and composed of reinforced concrete.

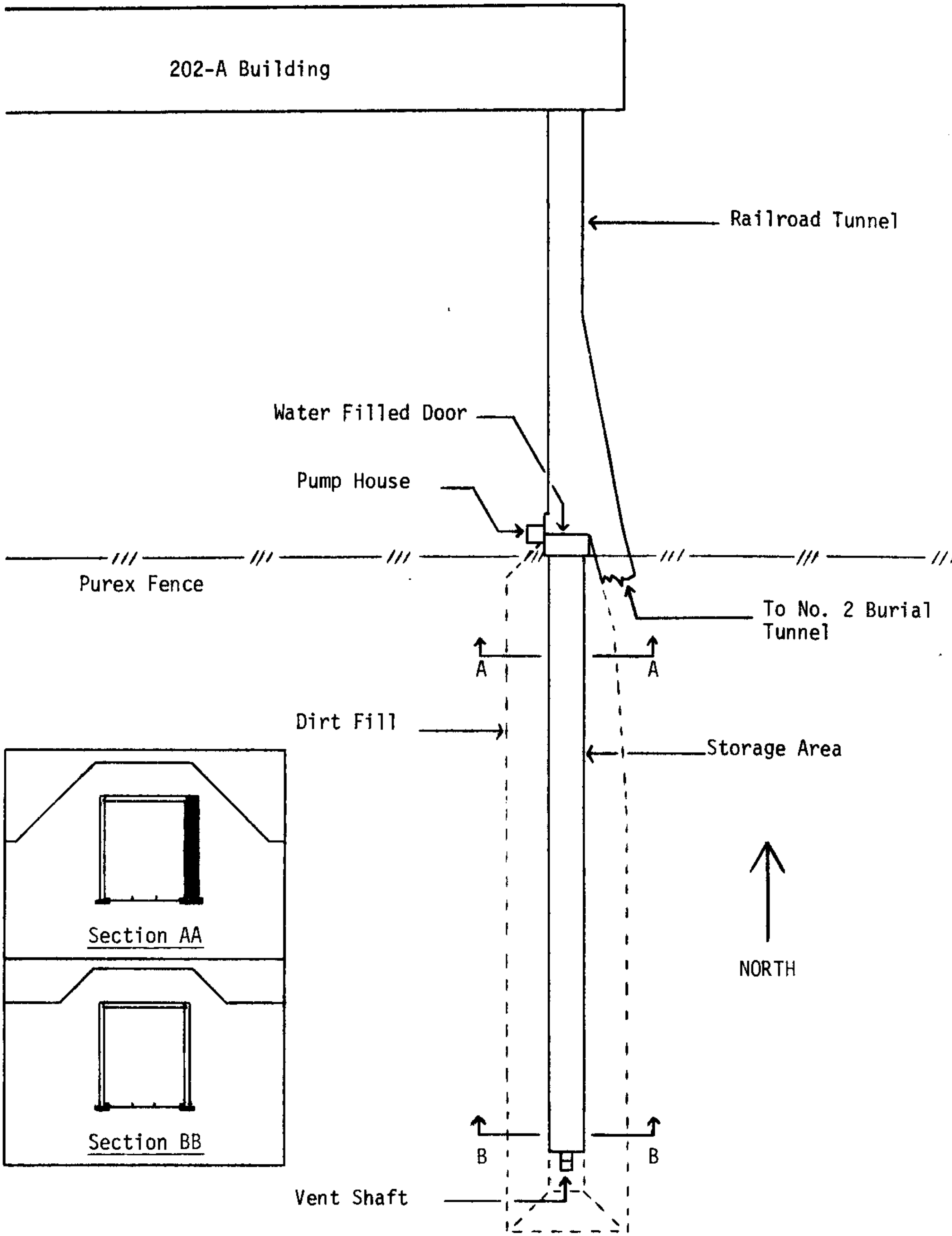


FIGURE 1: PUREX NO. 1 BURIAL TUNNEL - PLOT PLAN

HISTORY

Construction and Burials

Construction of the burial tunnel was completed in 1956 and the first two burial cars were loaded into it in June, 1960. Between this date and January, 1965, six more cars were loaded into the tunnel. Table 1 contains a list of the burial cars and their contents. During the loading of the number seven car, the burial tunnel was pressurized due to the heat given off by the contents of the car. To alleviate this problem, a blower fan and filter were connected to the vent shaft. Also, two air sample and temperature probe risers were mounted in the roof of the tunnel to allow occasional monitoring of the tunnel environment. These risers were placed at locations 60 and 240 feet south of the water filled door enclosure (see figure 2). After the last car was loaded in 1965, the water filled door was deactivated.

TABLE 1: PUREX NO. 1 BURIAL TUNNEL INVENTORY

Burial Car No.	Burial Date	Contents	Initial Dose Rate
1 & 2	6-60	HA Separations Column Box of Misc. Jumpers	5 r/hr @ 60'
3	7-24-60	E-F11, 1WW Waste Concentrator	12.5 r/hr @ 100'
4	12-24-60	G-E4 Centrifuge Two Concentrator Tube Bundles Box of Misc. Jumpers	1.5 r/hr @ 150'
5	1-4-61	E-H4, 3WB Concentrator	150 mr/hr @ 50'
6	4-21-61	E-F6, 2WW Waste Concentrator	5 r/hr @ 20'
7	2-8-61	E-F11, 1WW Waste Concentrator	25 r/h @ 150'
8	1-22-65	E-F6, 1WW Waste Concentrator	Unrecorded

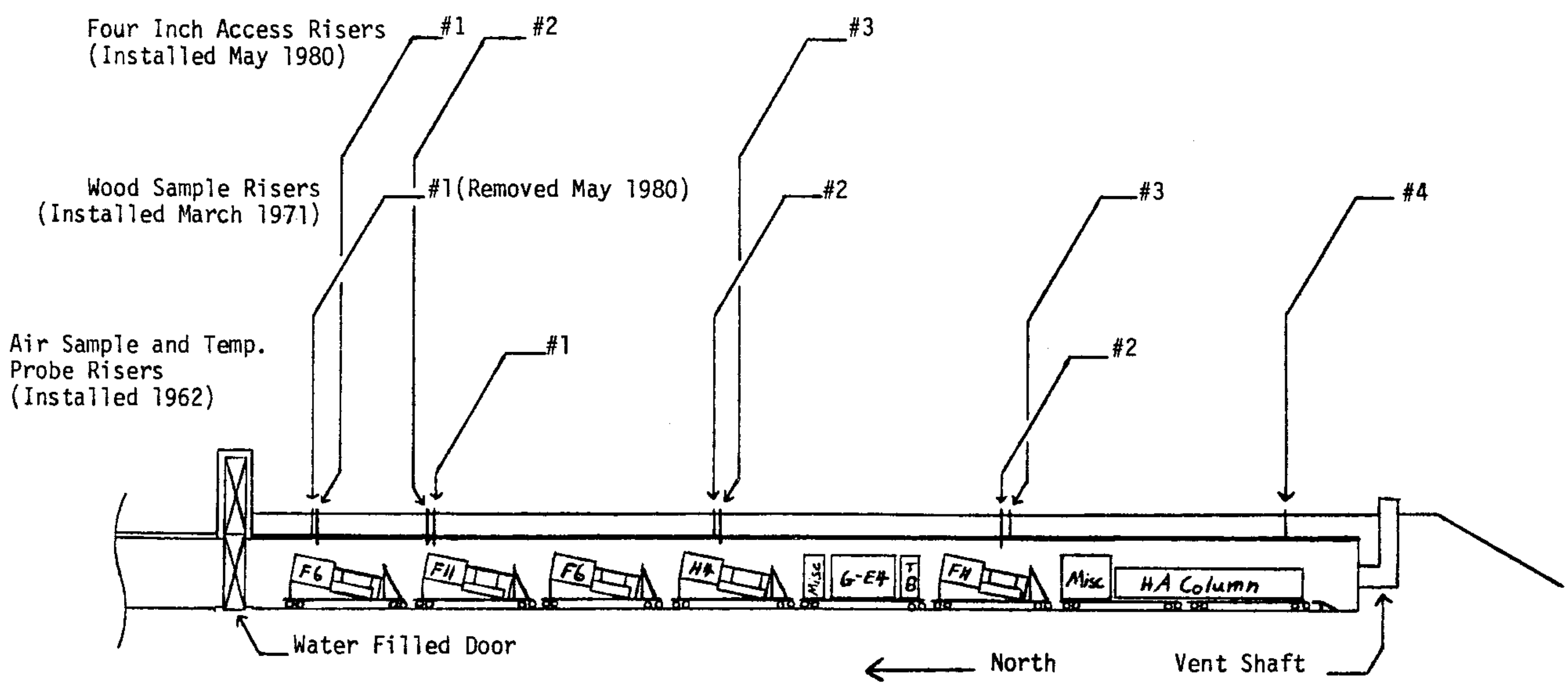


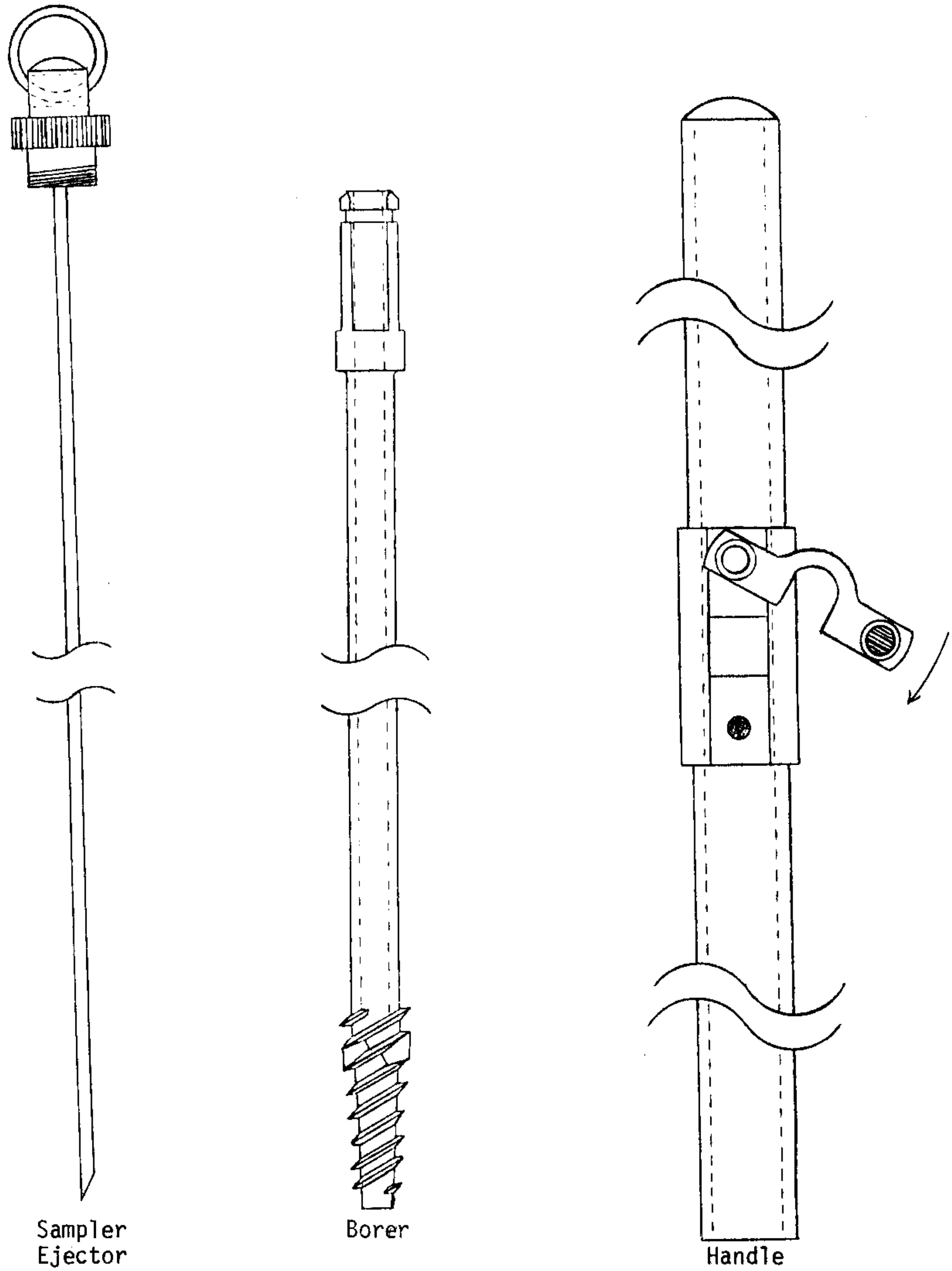
FIGURE 2: PUREX NO. 1 BURIAL TUNNEL

1971 Wood Sampling

Concern about the structural integrity of the tunnel was first raised in December, 1970. Since the wood timbers had been in place for almost fifteen years, doubts had been raised as to the condition of the wood. To determine the integrity of the wood, four 1½ inch steel pipes were sunk through the dirt fill down to the roof of the burial tunnel. These risers were located approximately 20, 149, 245 and 336 feet south of the water filled door enclosure (see figure 2). Using a Swedish, Increment Borer (see figure 3) four 3/16 inch diameter samples were obtained. The samples were examined visually and determined to be sound. This effort was completed in March 1971.

1973 Fire Hazards Study

The possibility of a fire starting in the burial tunnel by spontaneous combustion was questioned next, and in July, 1973, a fire and explosion hazard evaluation was completed by the Health and Safety Administration of the United States Department of the Interior. The report concluded that the danger of an explosion in the tunnel was non-existant, and the possibility of fire was extremely remote. However, a recommendation was made that the tunnel atmosphere be monitored for hydrocarbon content and that a sprinkler system which would be activated by a carbon monoxide monitor be installed. To date, such a system has not been installed, but an effort was made to flood the tunnel with carbon dioxide. The water filled door was caulked with a plastic sealant and the vent shaft was disconnected from the blower fan and sealed off. Six tons of carbon dioxide were then pumped into the tunnel through one of the air sample and temperature probe risers. The carbon dioxide quickly diffused through the gravel floor of the tunnel, and the attempt to create a non-combustible environment in the tunnel failed.



FIRGURE 3: SWEDISH INCREMENT BORER

1978 Evaluation of the Tunnel Environment

In July, 1978, an evaluation of the burial tunnel environment was performed. A one-half inch tygon tube was lowered into each of the air sample and temperature probe risers (for location, see figure 2), and several air samples were withdrawn from the tunnel using a vaccuum pump. These samples were tested for airborne radioactivity, gaseous chemical composition and relative himidity. In addition, temperature and radiation exposure were determined by lowering iron constantan thermocouples and thermoluminescent dosimeter chips into the tunnel. Results of these tests are shown in table 2. No conclusions were made from these results, but it was recommended that the tunnels' wood timbers be sampled and tested to verify their structural integrity.

1979 Wood Sampling

The wood timbers of the burial tunnel were once again sampled in June 1979 by lowering a Swedish Increment Borer (see figure 3) down the existing wood sample risers (for location see figure 2). The samples obtained, however, were of such poor quality that a visual examination could yield no usable information. A chemical analysis by Pacific Northwest Laboratories (PNL) to determine the amount of degraded cellulose in the wood also proved unsuccessful. The study concluded that the existing wood sample risers were no longer useful in obtaining samples from the tunnel and an alternate method would have to be developed.

TABLE 2: RESULTS OF THE JULY 1978 EVALUATION OF THE No. 1 BURIAL TUNNEL ENVIRONMENT

Sample Location		No. 1 Air Sample and Temperature Riser						No. 2 Air Sample and Temperature Riser					
Distance Below Tunnel Ceiling at Which Sample Was Taken (ft)		-1.5	0	1.5	2	4.5	5	0	2	3	5	6	9
Tests Performed													
Airborne Radioactivity $\times 10^{-10}$ µCi/ml	Radon		770				770	770			770		
	Long-Lived Isotopes		5.5				0.022	5.5			0.022		
Air Composition[1]	wt.% CO_2[2]		0.20				0.12	0.20			0.12		
Relative Humidity	% / ppm H_2O		7 / 900				4 / 750	7 / 900			4 / 750		
Temperature[3] ± 1°F			64		64		64	64	64		64		
Dose Rates[4] R/hr		0.166		121		153				17.7		30.2	37

[1] Gases other than CO_2 were at normal concentration for dry air

[2] Normal concentration of CO_2 in dry air is 0.04% wt%

[3] Temperatures were determined by lowering an iron constantan thermocouple into the tunnel

[4] Dose rates were determined by lowering thermoluminescent dosimeter chips into the tunnel

CORE SAMPLING OPERATION

Purpose and Site Locations

Three core samples were taken from the roof of the burial tunnel to be used for static bending tests to determine the structural strength of the tunnels support timbers. The cores measured 4 1/8 inch in diameter and 13 1/2 to 14 inches long. This size was selected because the cores would be large enough to be cut into samples for static bending tests yet small enough to prevent the timbers from which they were removed from being severely weakened. A structural study made by G. R. Wagenblast of Rockwell's Engineering Mechanics unit showed that as long as the cores were taken three to six feet from the tunnel centerline, the tunnel roof would not be adversely affected.[6]

The core sample locations are as follows (see fig. 2):

Location Number 1: Approximately 18 feet south of the water filled door and 4 feet east of the tunnel centerline.

Location Number 2: Approximately 54 feet south of the water filled door and 4 feet west of the centerline.

Location Number 3: Approximately 154 feet south of the door and 4 feet east of the centerline.

Locations one and two were selected because they were the areas that appeared to have received the largest amount of radiation exposure, and location number three was selected as a reference.

Method

In preparation for the core sampling, six feet of the eight foot dirt fill over each sample location was removed using a crane with a clam-shell attachment. An area sufficiently large enough for four people was dug out and the sides of the excavation were sloped at a forty five degree angle to eliminate the need for shoring. Next, a two foot square hole was dug down to the timbers using the crane, and a plywood shoring box was placed in the hole to prevent the dirt from caving in over the work area. Any remaining dirt was swept from off the timbers using a broom and a dust pan equipped with an extension handle. Following this, the tar and roofing material on top of the timbers were chipped off using long handled wood chisels. A one foot diameter, 2½ foot long fiberglass pipe was then placed over the sample site and filled in around with dirt. Figure 4 shows a typical prepared sample site. The two inch thick lead donut shown in the figure was lowered down into the fiberglass pipe to provide additional radiation shielding.

After all three sample sites had been prepared, the cores were drilled using a specially designed hole saw. The lead donut was moved from site to site as it was needed. As each core was removed, a steel riser was placed in the newly created hole in the timber and liquid neoprene was poured around the riser to caulk it. When all three sites had been core drilled, the excavations were backfilled to their original grade. No effort was made to recover the plywood shoring boxes or the fiberglass pipes.

Equipment

Hole Saw. Since no commercially available device existed for obtaining large wood samples, a hole saw capable of obtaining a 4 1/8 inch diameter and 14 inch long core was designed and built on-site. The entire device consisted of the hole saw and four accessories: the drill cap, the starter drill, the core holder and the core holder chamber (see figure 5).

The hole saw was made from a 15 inch long piece of 4 inch stainless steel pipe into which twenty four saw teeth had been cut. The number of teeth was later reduced to twelve with carbide tips attached to each tooth. A 1/4 inch thick back plate was welded on the other end of the pipe. The back plate contained a one inch diameter hole in the center and four 1/2 inch diameter holes located equidistant from each other, and 1 5/8 inches from the center. A 4 foot long 3/4 inch steel pipe was inserted into the one inch hole and welded in place to act as a shaft. The other end of the pipe shaft was threaded with standard NPT pipe threads. Four support bars were welded to the shaft and the back plate at a forty five degree angle. The hole saw could cut

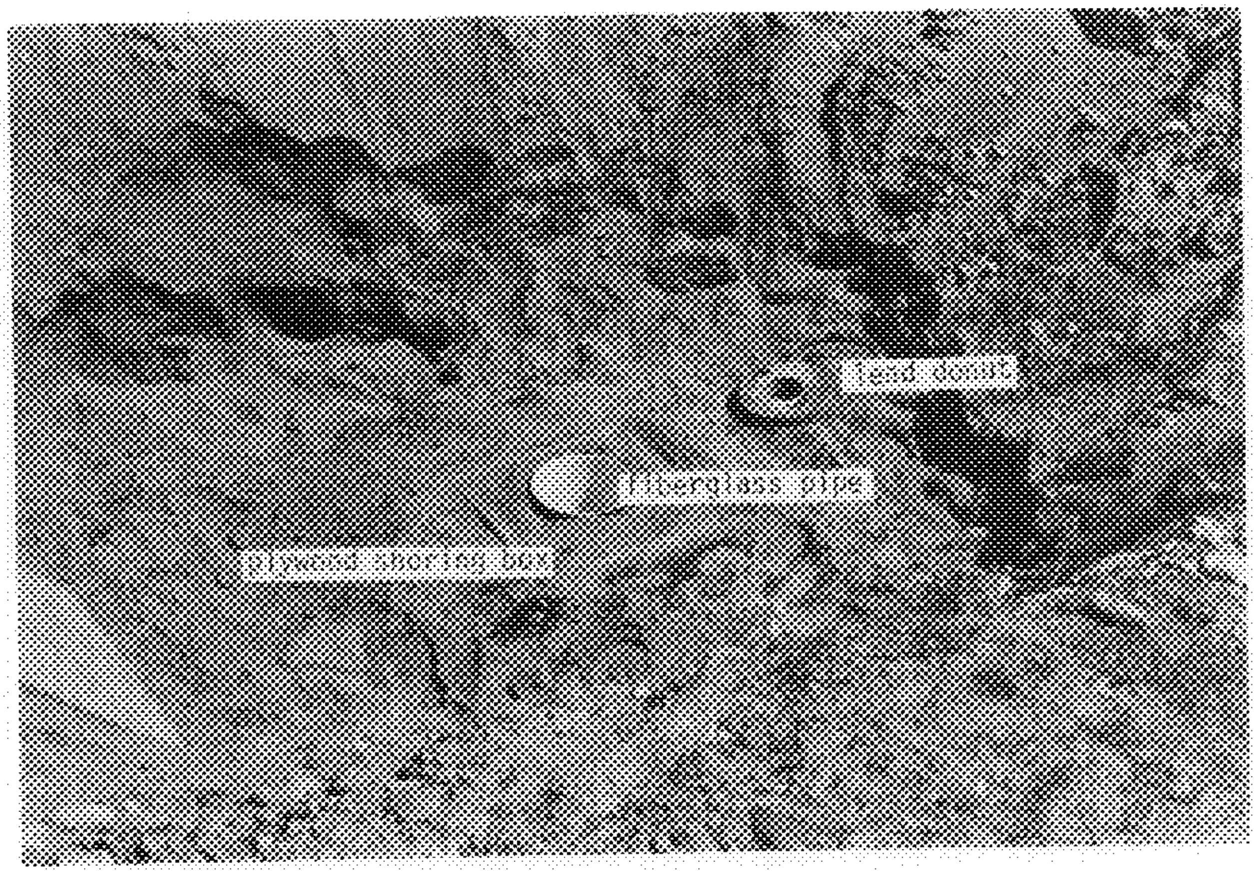


Figure 4: Typical Sample Site

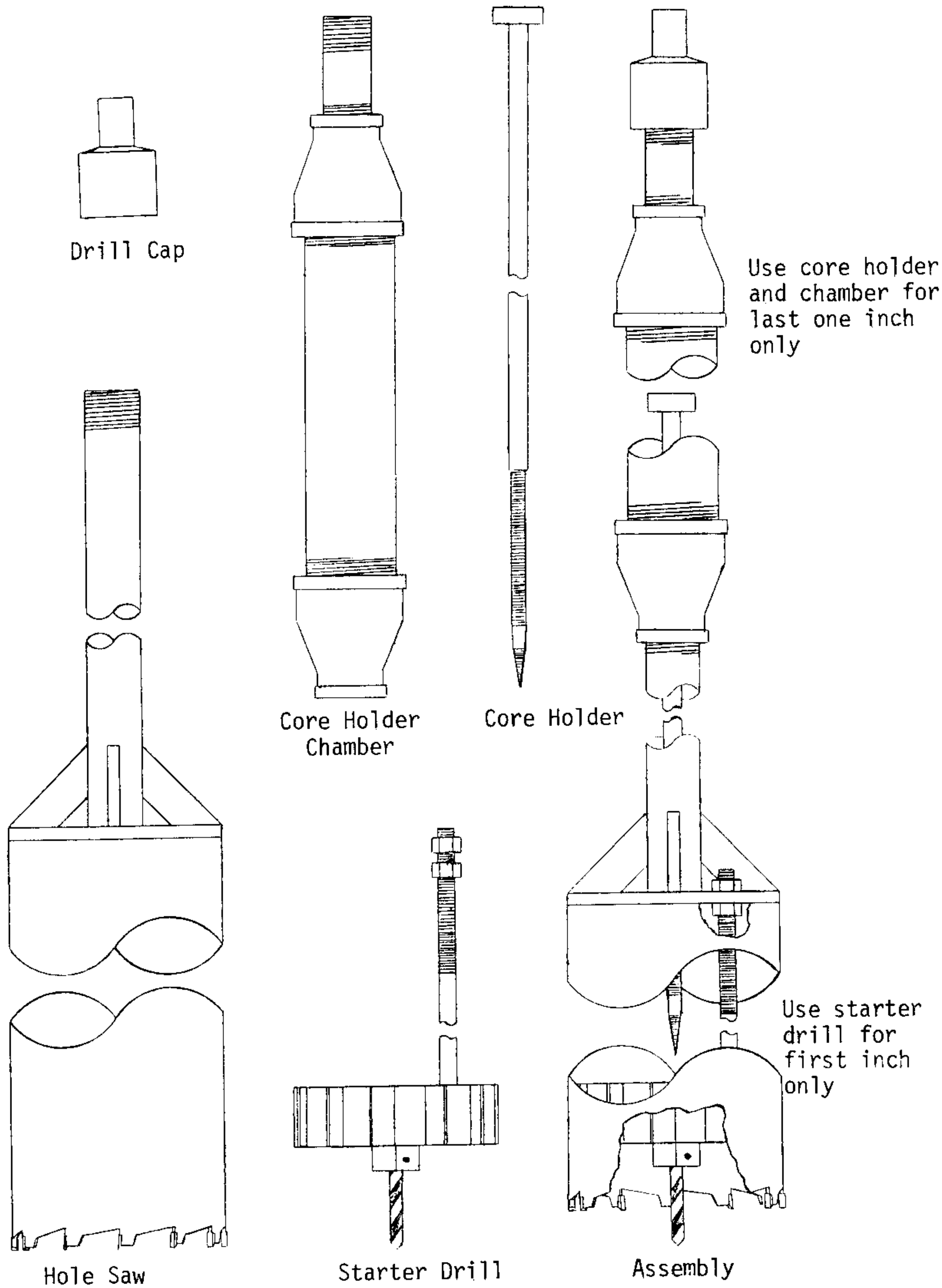


FIGURE 5: HOLE SAW - PUREX NO. 1 BURIAL TUNNEL CORE SAMPLING

a core about 4 1/8 inches in diameter and leave a 4 1/2 inch diameter hole.

The drill cap was designed to screw on top of the hole saw's shaft and fit into a three-quarter inch drill chuck. The cap was machined from a solid piece of stainless steel with one end fashioned like a pipe cap and the other like a three-quarter inch bit.

To prevent the hole saw from moving out of position when it was first cutting into a timber a starter drill was designed to be inserted into the hole saw to act as a guide. The starter drill consisted of a 3/16 inch twist drill mounted in a 1 1/4 inch thick aluminum plug. The plug was grooved on the edges to allow it to slide past the saw teeth when inserted into the hole saw. A 3/8 inch diameter threaded steel rod was attached to the other side of the aluminum plug so that when the starter drill was inserted into the hole saw, the steel rod would fit through one of the 1/2 inch holes in the hole saw's back plate. The starter drill was held in place by two hex nuts and was used only during the first inch of cutting. After that, the hole saw could guide itself.

The core holder and core holder chamber were used during the last inch of cutting to prevent the core from falling out of the hole saw and into the tunnel when the hole saw penetrated a timber. The core holder was a 5 foot long 3/8 inch steel rod with wood screw threads on one end and a one inch "T" handle on the other. The core holder chamber consisted of two 1 1/2 to 3/4 inch bell reducers, a nine inch long piece of 1 1/2 inch pipe, and a three inch long 3/4 inch pipe nipple. To attach the device, one of the bell reducers was screwed onto the hole saw shaft and the core holder was inserted into the shaft and screwed into the wood core. After that, the 1 1/2 inch pipe, the other bell reducer and the pipe nipple were screwed on in that order. The drill cap was then screwed on top of the assembly and the cutting continued until the hole saw penetrated the timber.

Drill Motor. A modified three-quarter inch portable drill was used to turn the hole saw. To allow for greater control of the hole saw and to prevent the operators from standing directly over the sample site, two extension handles were attached to the drill motor. The switch in the motor's handle was taped in the closed position and the drill was controlled by using a foot pedal switch. Figure 6 shows the drill motor in operation.

Sawdust Clearing Apparatus. Since the hole saw was not self-clearing, a method of cleaning the sawdust from the cut became necessary. This was accomplished by using an air blow. After cutting one to two inches into a timber, the hole saw was removed and the sawdust was blown from the cut with compressed air. The cutting then resumed for another one to two inches. The air blow device consisted of a ball valve connected to a four foot long 1/2 inch pipe which had been nippled down to a one inch long 1/8 inch diameter pipe on the other end. Compressed air at 90 psi was supplied to the device by a portable air compressor.

To prevent the possibly contaminated sawdust from escaping into the atmosphere, a mini hood was created using a piece of clear vinyl sheeting and a vacuum hose. Figure 7 shows the air blow device and the mini hood in use. Vacuum for the hood was supplied by a Sears sixteen gallon shop vac. which had been equipped with a 1000 CFM HEPA filter on the exhaust end (see figure 8).

Risers. In order to plug the holes created by the core drilling, three 4 inch risers were fabricated. The risers were made from four inch schedule forty steel pipe and measured ten feet three inches. Slip on flanges were welded onto the pipes fifteen inches up from the bottom to prevent the risers from slipping into the tunnel, and the areas below flanges were trimmed slightly to allow the risers to fit easily into the holes in the timbers. Standard four inch pipe caps were screwed onto the tops of the risers. Two of the three risers are shown in figure 9. After the risers were positioned and the dirt filled in around them, the tops of the risers were one foot above ground level.

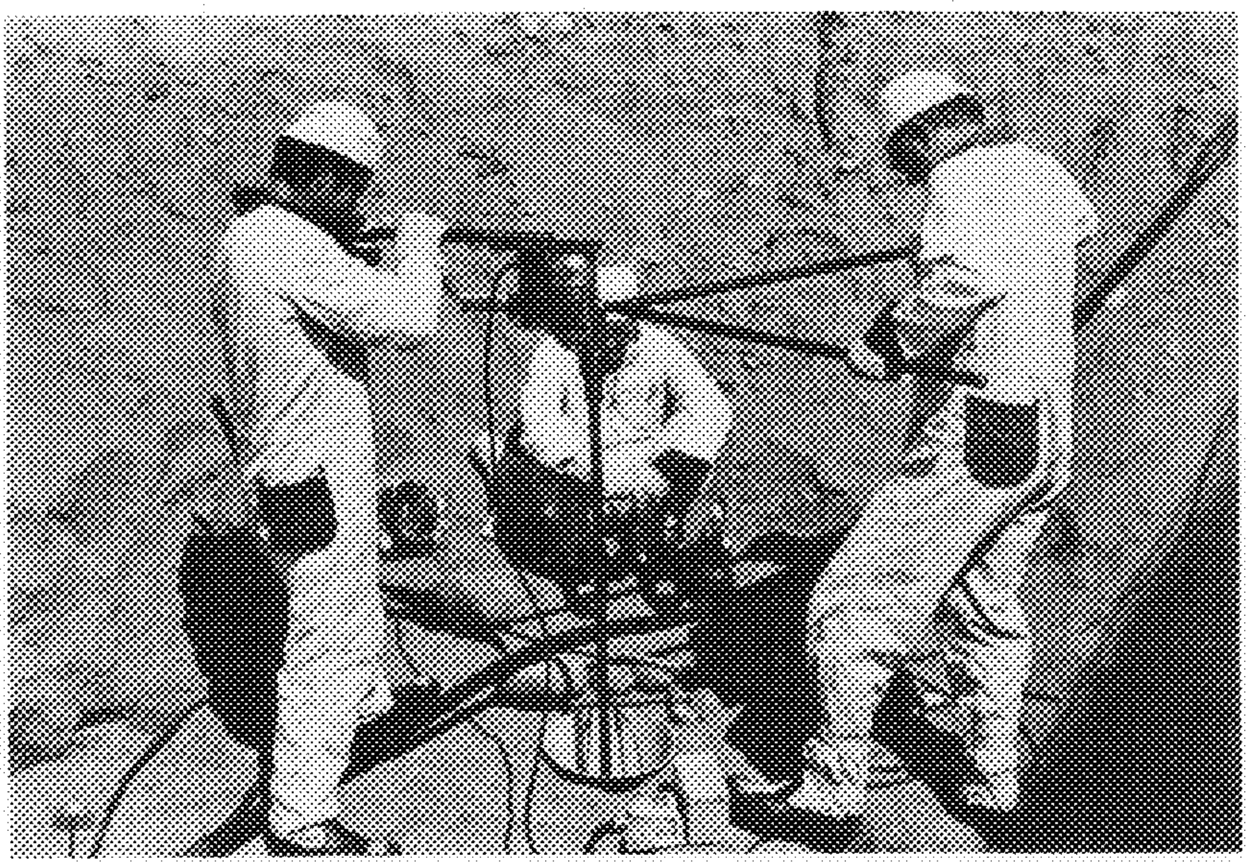


Figure 6: Drill Motor in Use

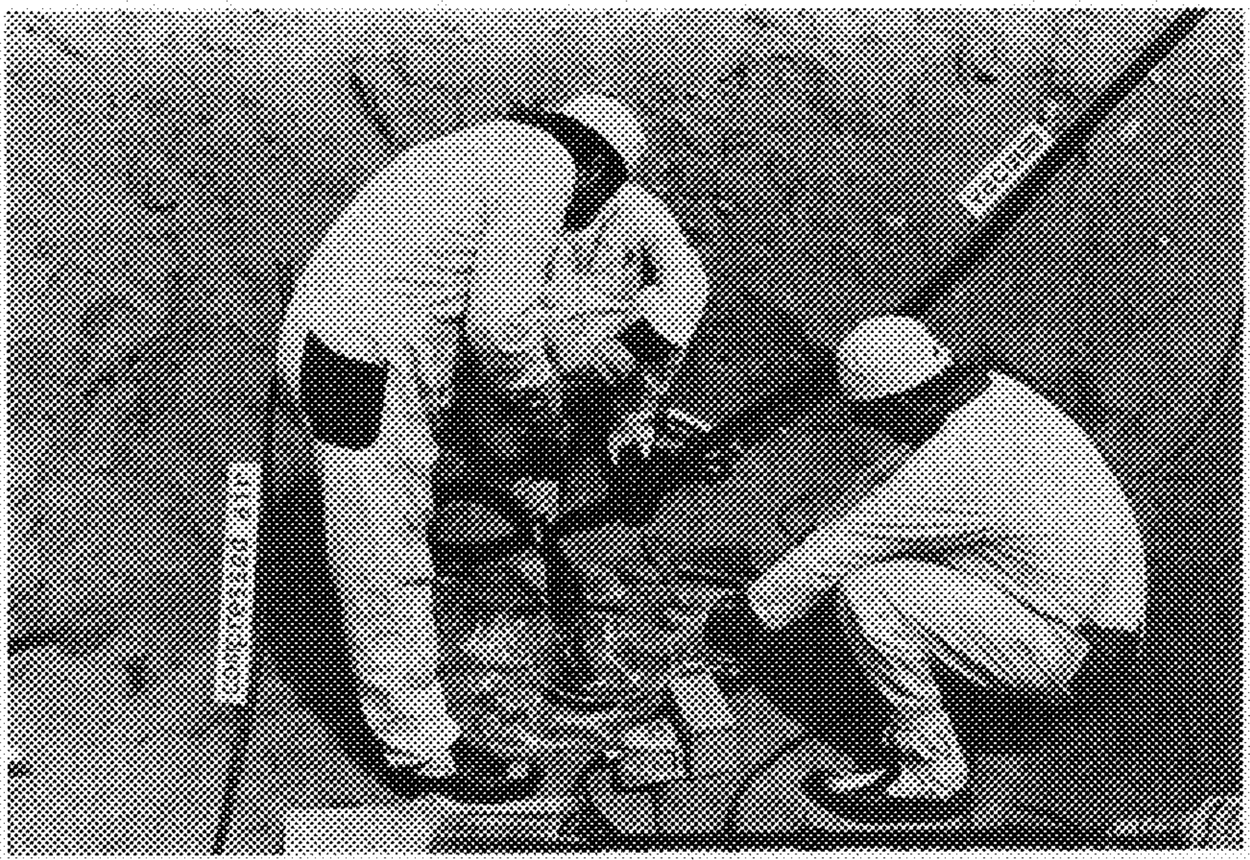


Figure 7: Sawdust Clearing Apparatus in Use

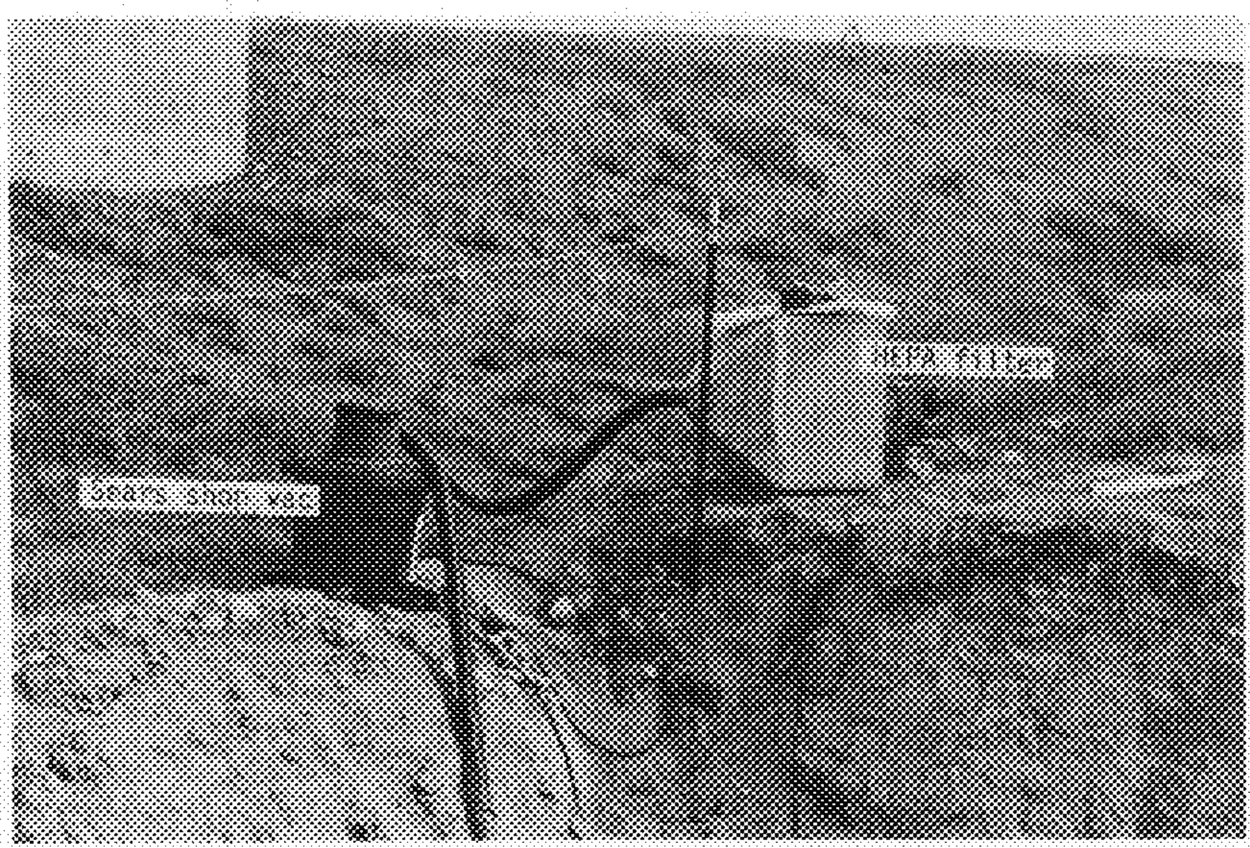


Figure 8: Vacuum Supply for the Sawdust Clearing Apparatus

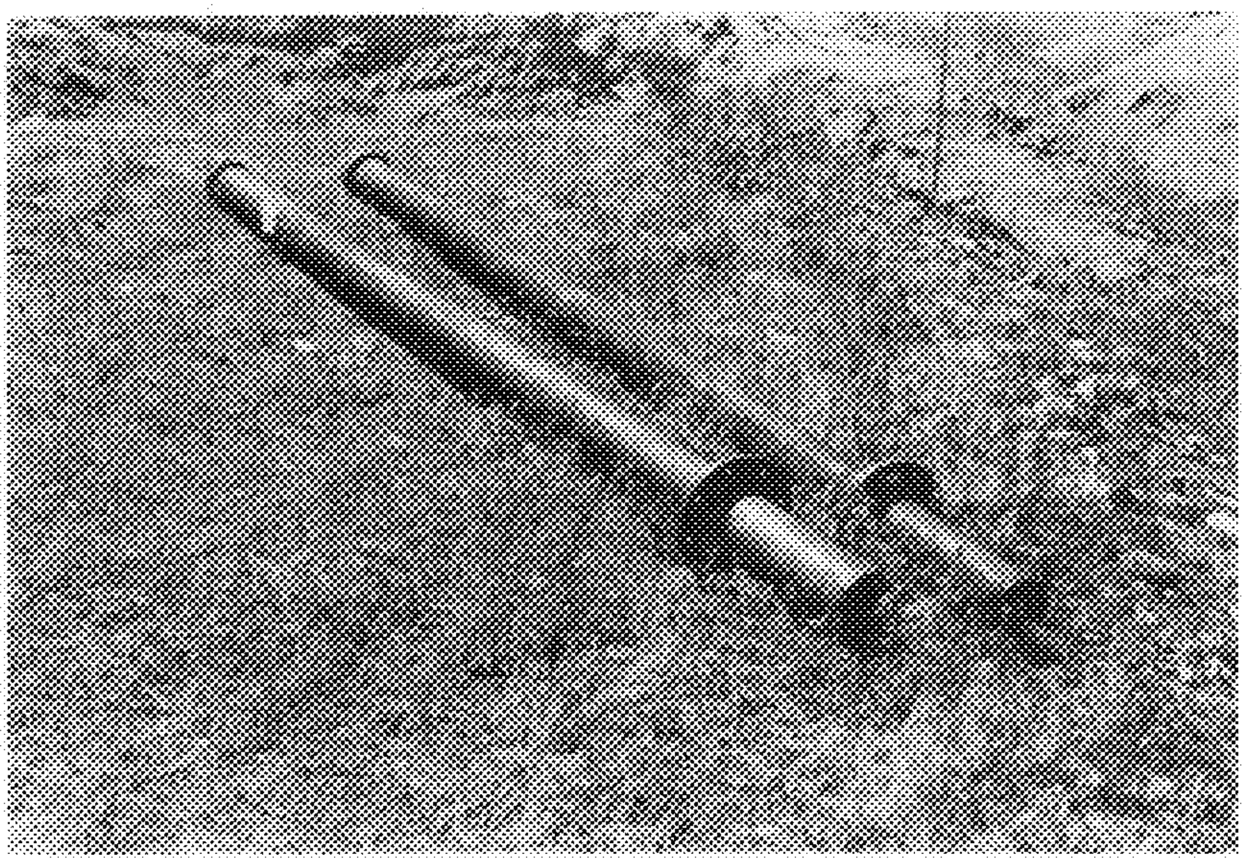


Figure 9: Burial Tunnel Risers

Observations

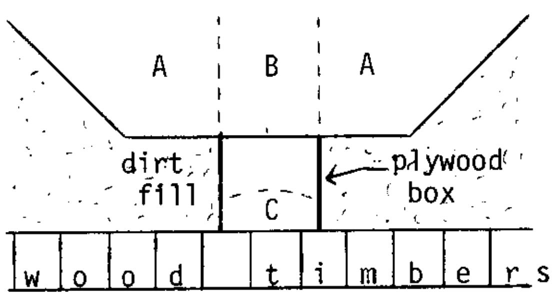
Site Preparation. Excavation of the sample sites began on Monday, May 5, 1980 and was completed with the plywood shoring boxes in place two days later. During the digging of the number one site, the number one wood sample riser (see figure 2) was struck by the clamshell and had to be removed. Exposure rates at the number one and number two locations presented a problem for the workers while they were removing the last bit of dirt and scraping the tar from off the timbers (see table 3). However, by using extension handles and by rotating personnel, radiation exposure was kept well below allowable limits. Once the fiberglass pipe was in place, the amount of exposure to personnel was cut considerably. Also, insertion of the lead donut into the fiberglass pipe just prior to core drilling further reduced the amount of exposure to well below acceptable limits. The largest dose received by any one man during the entire operation was one hundred miliroentgen. Preparation of all three sample sites was completed on Friday, May 9.

Core Drilling. Because of low radiation exposure, location number three was chosen to be sampled first and core drilling began on Tuesday, May 13. High winds and problems with the stainless steel saw teeth getting dull too fast forced the operation to be suspended for the day, and the core drilling was completed the next morning. To eliminate the need for constant sharpening, the number of saw teeth on the hole saw was cut in half, and carbide tips were attached to the reamining teeth. After the hole saw was modified, core samples from locations one and two were obtained without difficulty. All core sampling was completed on Friday, May 16. The wood cores are shown in figures 10 through 12. The cores appear blackened on the ends because the timbers had been creosote treated before use.

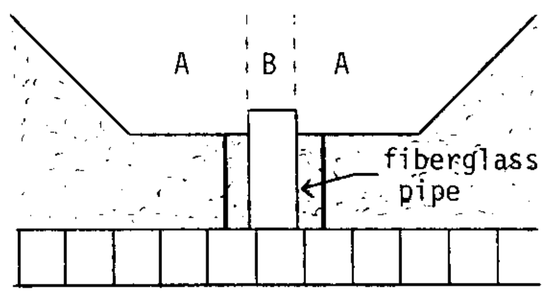
Although a release of radioactive contamination from the burial tunnel during the core drilling operation was expected, air samples taken at the time showed no sign of any contamination release. In addition, surveys of all the equipment used during the core drilling and of the work areas didn't reveal any detectable contamination. A small amount of contamination (less than one hundred fifty counts per minute) was

TABLE 3: EXPOSURE DURING CORE DRILLING OPERATION (mR/hr)

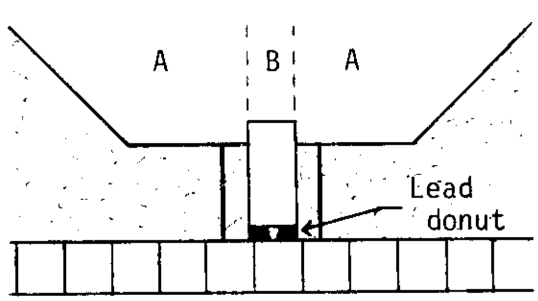
Sample Location No.	First Stage			Second Stage		Third Stage	
	Area A	Area B	Area C	Area A	Area B	Area A	Area B
1	150-200	700	2,000	20	250	8	8
2	300-500	2,000	8,000	50	450	10-15	10-15
3	0	0	15	0	0	0	0



First Stage: Plywood shoring box in place



Second Stage: Fiberglass pipe in place



Third Stage: Lead donut in place

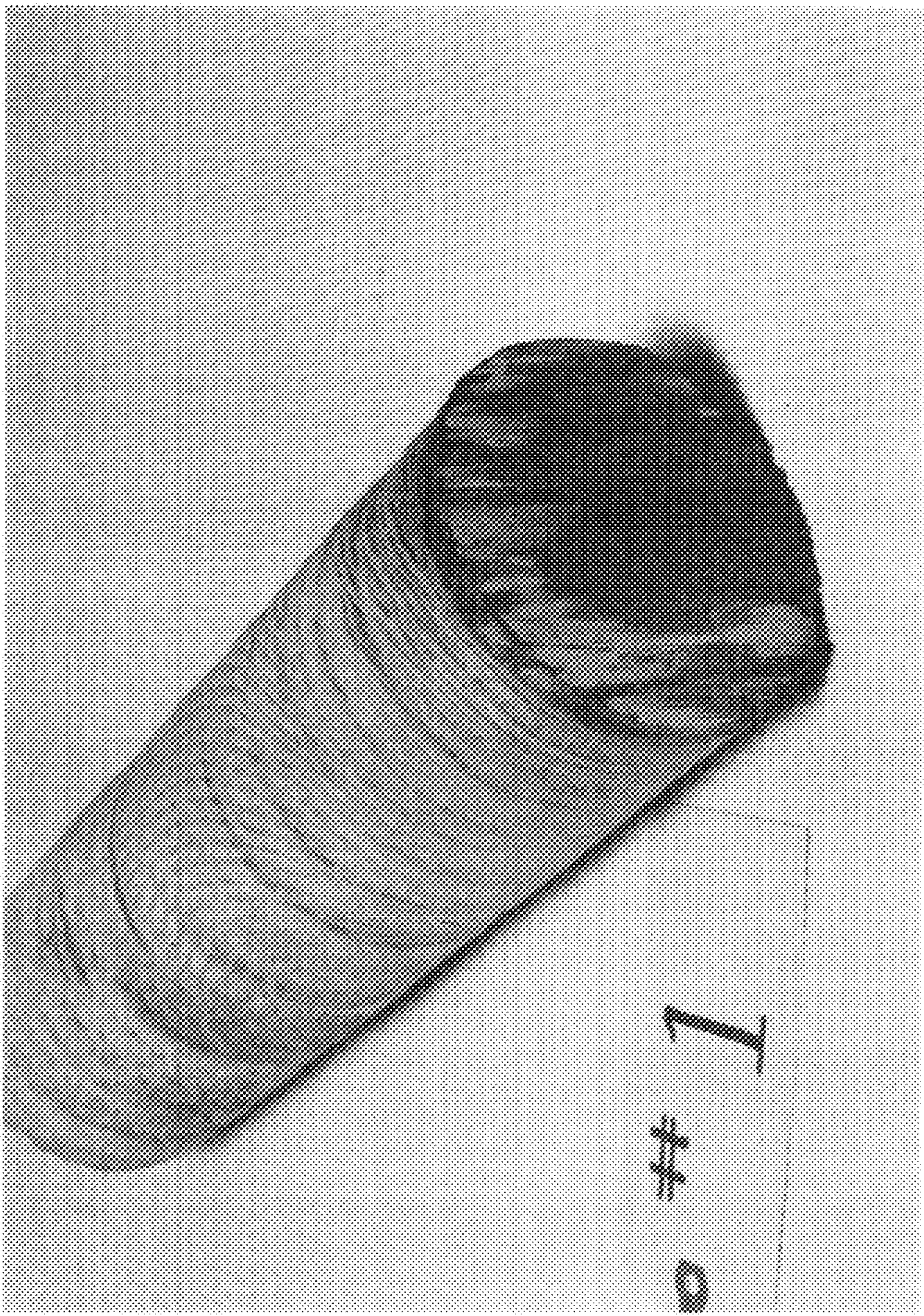


Figure 10: Core Sample, Location No. 1

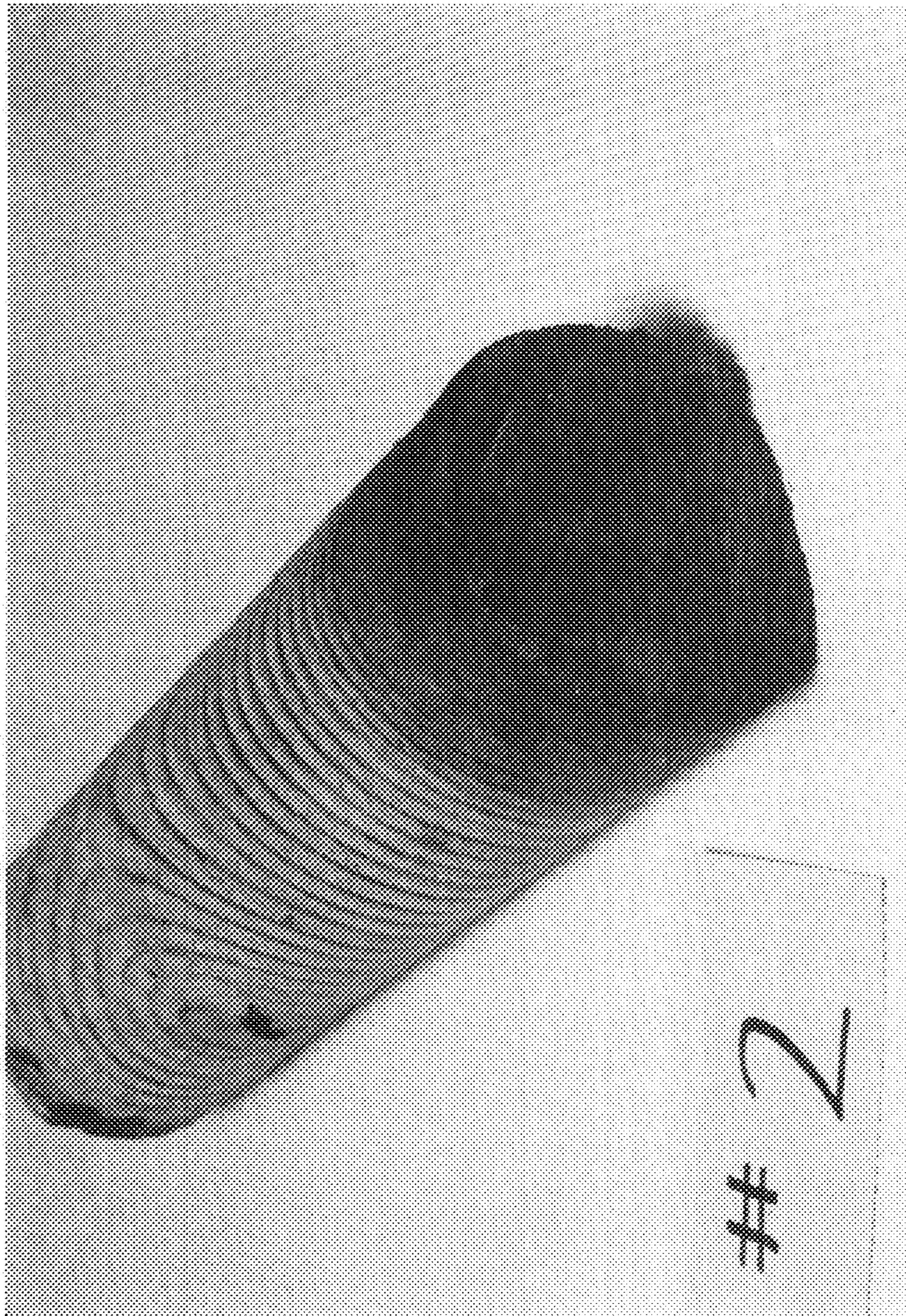


Figure 11: Core Sample, Location No. 2

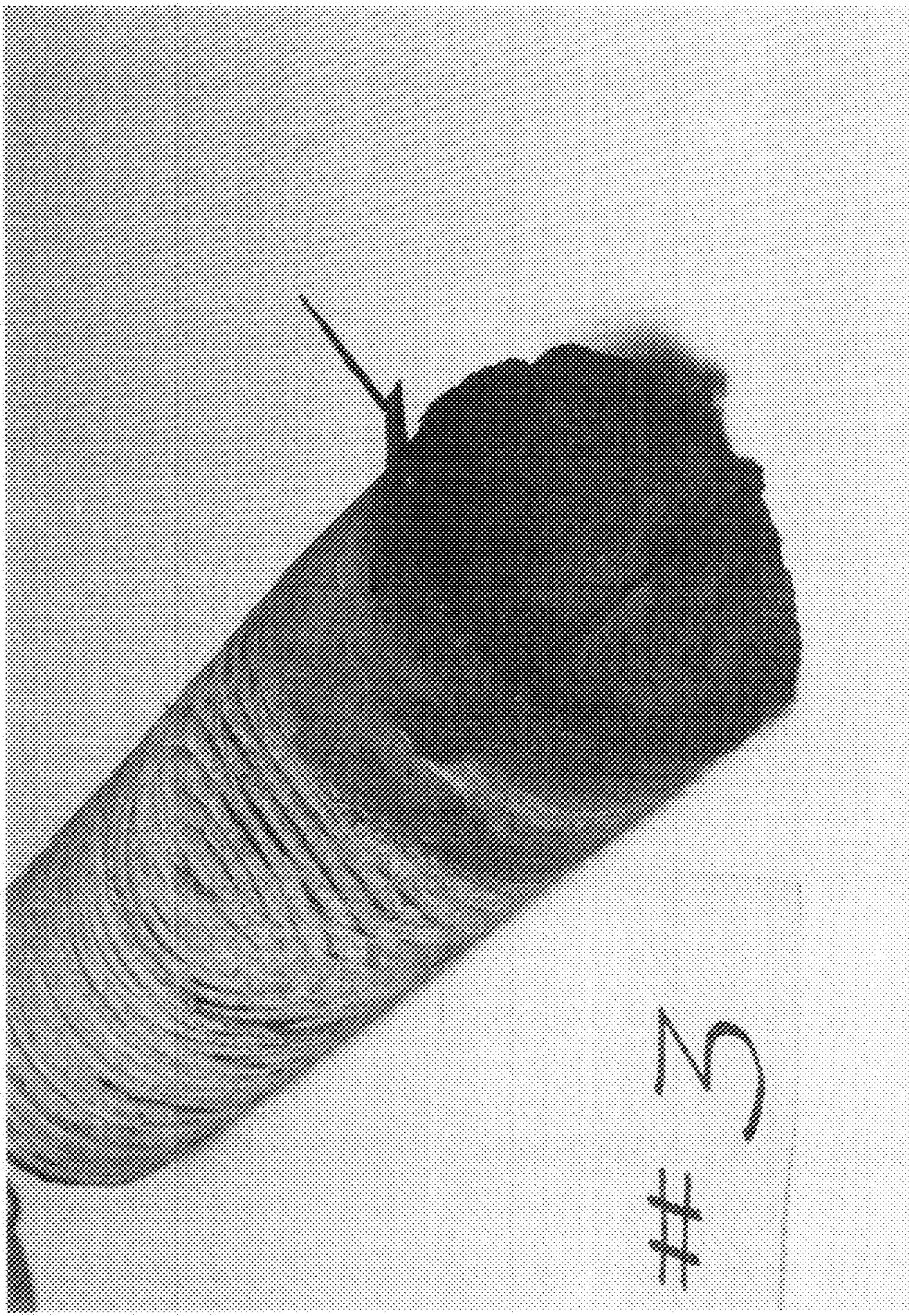


Figure 12: Core Sample, Location No. 3

found on the bottom ends of the three core samples, but this was removed by cutting the bottom one-quarter inch off of each of the cores.

Site Refilling. Refilling of the sample site was scheduled for May 19 but was delayed due to the ash fallout from the May 18 eruption of Mount Saint Helens, which necessitated cleaning and testing the crane. Filling of the sites began the following monday and was completed on Friday, May 30.

SAMPLE TESTING

Method

Two types of static bend tests were performed on the core samples. The first type was a modified version of ASTM standard number D-143. The second was according to ASTM-D-805.

In the first test, four 3/4 inch square by 3 1/2 inch long samples were cut from each of the three cores. These samples were then subjected to a center load static bend test. The results were compared with those of new wood of the same moisture content, ring count and density. The new wood was next tested using the standard three-quarter inch square and fourteen inch long sample called for in ASTM-D-143. The results of this test were used to scale up the results of the tests on the smaller samples.

The second test used samples that measured 0.2 by 2 by 3 1/2 inches. These samples were subjected to a centerload static bend across the width as specified in ASTM-D-805. This standard was meant for testing veneer but can also be used for bend tests on very short specimens.

Results

The results of the two tests are shown in Table 4:

TABLE 4: RESULTS OF STATIC BEND TESTS - PUREX NO. 1
BURIAL TUNNEL CORE SAMPLES

	MODULUS OF RUPTURE (psi)				
Location Number	Modified ASTM-D-143	ASTM-D-805	Average	Moisture Content	Specific Gravity
1	12,226	12,679	12,453	12%	0.6
2	11,325	11,312	11,319	12%	0.6
3	16,834	16,814	16,824	12%	0.6
Control (New Wood)		17,313	17,313	12%	0.58
Industry Average			12,000	12%	0.48

All three samples have a specific gravity higher than the industrial, and since modulus of rupture is roughly proportional to specific gravity(12), they should all have a higher than average modulus of rupture. This is true with sample number three and the control sample but not true with samples number one and two, and would suggest that these timbers may have been weakened by an environmental influence. The probable cause of this loss of strength will be discussed later in greater detail. In any case, all of the samples fall within the acceptable range for modulus of rupture and the wood in the burial tunnel can be assumed to be compatible with present day douglas fir (see letter in appendix).

DISCUSSION

The Committee on Timber Structures of the American Society of Chemical Engineers Structural Division has determined that if old timbers are in good condition, they can be assigned the same working stresses as new lumber of the same grade and species.[10] The test results on the three core samples have shown that the wood in the burial tunnel is still within specie requirements, and so the present day design values can be used for evaluating the integrity of the tunnel. The grade and species of wood used in the tunnel is number one post and timber douglas fir.[15]

For the purpose of simplicity, only bending stresses will be considered in this section since the preliminary structural evaluation by G. R. Wagenblast had shown that timber failure would be by bending stresses. [6] The design value of extreme fiber in bending (F_b) for number one post and timber grade douglas fir is 1,200 psi.[9] This number is lower than the lab test value of 12,000 psi because a number of reduction factors must be applied to obtain a practical design value.

Reduction Factors

Moisture and Seasoning Effects. Green wood has a moisture content of 30%. This large amount of moisture will reduce the bending strength of the wood to a factor 1.62 [12] below the lab value for dry wood (12% moisture content). Even though this strength is gained back when the wood is dried and seasoned in the case of large timbers, it is offset by defects in the timber which form as a result of the drying and seasoning process.[7] The bending strength adjusted for moisture becomes 12,000 ÷ 1.62 = 7,410 psi.

Variability. Design strengths are based upon the average strength of a species and so most of the timbers will either be stronger or weaker than the average. To account for the weaker timbers the strength value is reduced by 25%. The bending strength adjusted for variability becomes 7,410 x 0.75 = 5,560 psi.

Duration of Load. The ability of wood to withstand a given stress decreases logarithmically with time for continuously applied loads.(12) For example, a normal bending strength test lasts about two to three minutes, and a stress of 12,000 psi is required to break the sample. However, a 8,040 psi stress applied continuously for one year will break the same sample. Similarly, a ten year 7,500 psi stress or a fifty year 7,200 psi stress will break the sample. Normal duration of load is considered to be ten years, and the bending strength is reduced by 3/8 to accommodate the loss of stress resistance during this period.(8) The corrected bending strength now is 5,560 x 5/8 = 3,475.

Natural Defects. Defects such as knots, cracks and splits in the grain will reduce the strength of a timber according to the size and type of defect. Each grade of wood is assigned a maximum reduction in strength resulting from defects. Lumber is assigned to the various grades according to number and size of defects.(13) In the case of number one grade douglas fir, the maximum loss of strength due to defects is 43%. Adjusting the bending strength for defects yields 3,475 x 0.57 = 1,980 psi.

Safety Factor. Even after applying the above reduction factors the bending strength is still a factor of 1.65 greater than the design value of 1,200 psi. This number is called the near minimum factor of safety (8) and allows for such things as accidental overloading, and public and worker safety. This factor, however, does not take into account severe overloading stresses such as those in an earthquake. It should be noted that each reduction factor contains a certain margin of safety, and when all these factors are combined the actual safety factor is usually between 2.0 and 2.5.(8)

Factors Not Included in the Design Strength

The reduction factors explained above have been determined on the basis of normal loading, construction and maintenance. When conditions go beyond these assumptions the design strength must be reduced accordingly.

Duration of Load Beyond Ten Years. As stated earlier, the normal duration of load is assumed to be ten years. If the timbers are to be loaded for longer periods of time, as in the case of the burial tunnel, the design strength must be reduced by another 10%. This will compensate for any further loss of strength due to duration of load for the entire life of the tunnel. The design strength adjusted for long term loading is 1,200 x 0.90 - 1,080 psi.

Size Factors. The design strength is only applicable for timbers up to twelve inches in depth. For larger timbers the strength must be reduced by the following equation:

$$C_F = \left(\frac{12}{d}\right)^{1/9}$$

where d is the depth of timber and C_F is the size factor. The timbers in the burial tunnel are fourteen inches deep and the design strength is reduced to 1,080 x 0.983 = 1,060 psi.

Decay and Insect Attack. The effects of decay and insect attack are so varied and hard to predict that no adjustment to the design strength is made, but the possibility of loss of timber integrity by these causes must always be kept in mind. Generally, as long as the timbers are kept dry, decay or insect attack is not likely since both need moist wood to get started.(7) In the case of the burial tunnel, the timbers were creosote treated and are kept in a very dry atmosphere (7% relative humidity - see table 2). Decay or insect attack is not considered to be a current problem. However, the possibility of decay or insect attack occurring can never be totally eliminated.

Radiation. Several locations in the tunnel have been exposed to large amounts of gamma radiation due to the presence of the failed process equipment in the tunnel. Studies have shown that large amounts of gamma radiation can lower the strength of wood.(1) The results of the core sample tests bear this out. Samples number one and two which have received large dose of radiation are noticeably weaker than sample number three even though they are similar quality wood. Fortunately, even though the wood has been weakened, it is still within allowable strength limits. A worse case radiation profile has been prepared (see appendix) and is shown in figure 13. The most severe effects

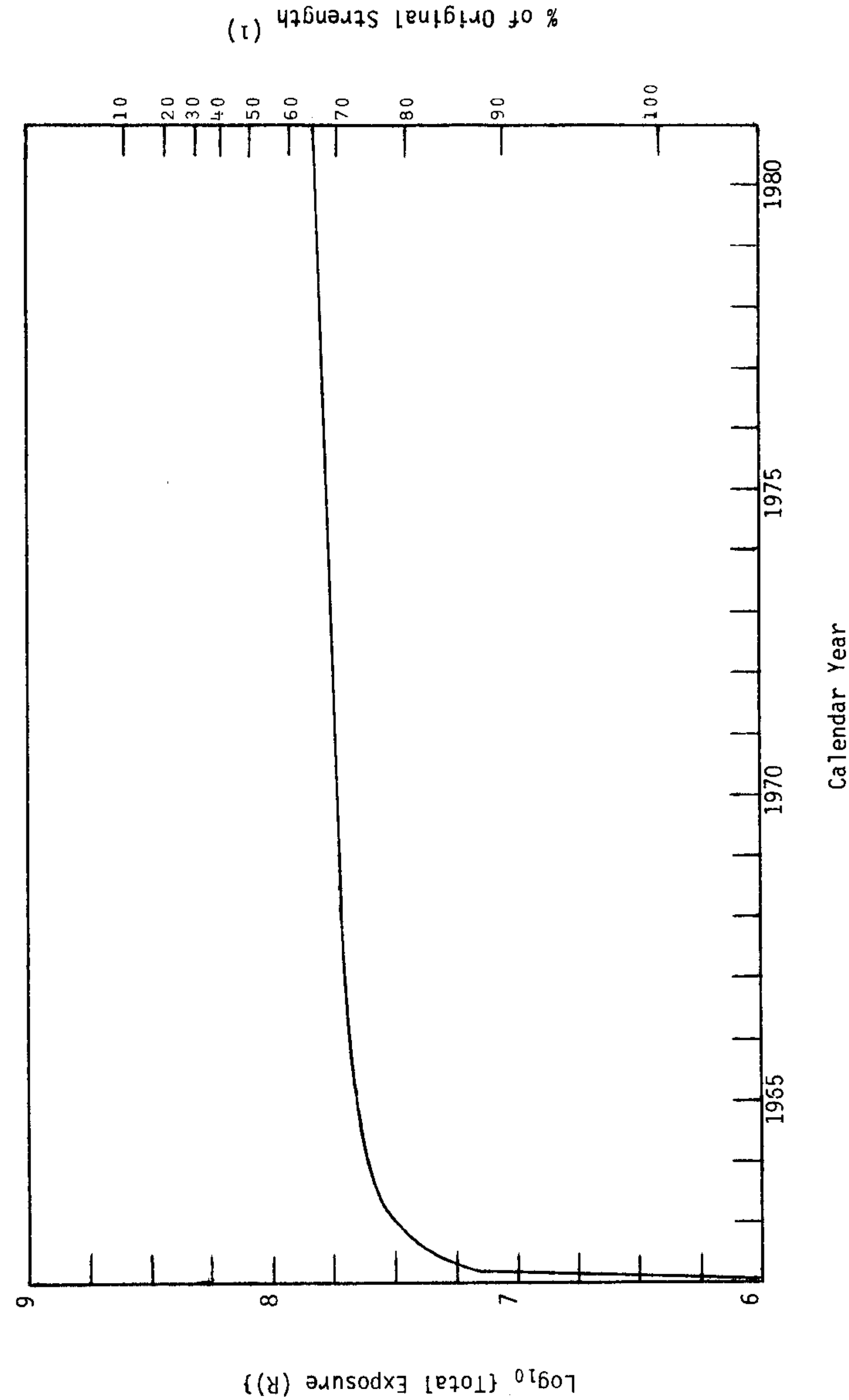


FIGURE 13: WORSE CASE EXPOSURE PROFILE

of the gamma radiation occur in the first three years and the effects gradually tapered off thereafter. Radiation is not expected to be a major factor in any future weakening of the tunnel.

Calculation of Present Tunnel Integrity

The weight a wood beam is designed to hold if loaded uniformly is given by the following equation.(7)

$$Wd = \frac{8F_b \; w \; d^2}{6 \; L}$$

Where:

W_d = Design weight

F_b = Design bending stress = 1060 lb_f/in^3

w = Timber width = 12 in.

d = Timber depth = 14 in.

L = Timber length = 19 ft. = 228 in.

Substituting in the above values:

$$W = \frac{8 \; (1,060) \; 12 \; (14)^2}{6 \; (228)} = 14,600 \; lb_f$$

The weight actually held by the beam is given as follows:

$$Wa = (\rho e \; HewL + \rho w \; dwL) \; \frac{g}{gc}$$

Where:

Wa = actual weight in lb_f

ρe = density of the earth fill = 110 $\frac{lbm}{ft^3}$

H_e = height of the earth fill = 8 ft.

ρw = density of the wood beam = 37.4 $\frac{lbm}{ft^3}$

g = acceleration of gravity = 32.2 $\frac{ft.}{sec^2}$

gc = force constant = 32.2 $\frac{lbm \; ft.}{lb_f \; sec^2}$

Therefore:

$$Wa = \{(110) \; (8) \; (\tfrac{12}{12})(19) + (37.4) \; (\tfrac{14}{12}) \; (\tfrac{12}{12}) \; (19)\} \; \frac{32.2}{32.2}$$

$$Wa = 17,500 \; lb_f$$

As can be seen, the actual weight on the tunnel exceeds the design weight by 20%. Since the near minimum safety factor is 1.65, however, the tunnel can safely handle loads up to 65% in excess of design value. Therefore, even though the tunnel will not meet current design criteria, it is structurally sound and is not in danger of failure at this time, but a prediction of how long the tunnel will last is not possible due to unpredictable factors that could affect timber integrity.

Consequences of Tunnel Failure

The immediate radiological consequences of the tunnel failure are relatively minor since the contamination in the tunnel is generally well fixed and airborn activity is relatively low. Also since personnel are not normally on the tunnel, personnel safety risks are low. Public relations consequences, however, could be large due to the present attitudes regarding nuclear waste handling.

Eventually tunnel failure will occur as a few side-by-side timbers fail. The timbers will break and fall into the tunnel along with the soil that is on top of them. This will either cause a depression in the fill on top of the tunnel or open a hole to the tunnel interior. Total tunnel collapse is not expected except in a major seismic event. Should the tunnel fail, two courses of action exist: 1) bury the tunnel contents in place or 2) remove the equipment for burial or relocation. Removing the equipment after a tunnel failure could require removing the soil and timbers which had fallen into the tunnel to allow the equipment to be removed. This would be costly and could result in personnel danger and radiation exposure, depending on the degree to which the work can be accomplished remotely. Therefore, if the equipment is to be removed, it should be done while the tunnel is still structurally sound.

CONCLUSIONS

The Purex Number One Burial Tunnel is considered to be structurally sound for the present time assuming the present loading conditions remain unchanged. An accurate prediction of future tunnel life is not possible due to unpredictable factors that can affect timber integrity such as wood decay or insect attack.

Since the tunnel will eventually fail, the question is not "whether" it should be deactivated but "when" and "how" it should be deactivated. If the contents of the tunnel must be removed, it should be deactivated as soon as is practical to ensure the tunnel is still structurally sound during the removal operation. If the equipment is to be buried in place, tunnel deactivation can be deferred to a later date depending upon the burial method selected.

A deactivation study should be initiated to recommend whether the tunnel contents must be removed or whether they can be buried in place. This study should be completed within two years.

APPENDIX

CALCULATION OF
A
WORSE CASE RADIATION EXPOSURE PROFILE

<u>Calculate percent of original integrity</u>

$$\frac{\text{MOR of No. 2 Sample}}{\text{MOR of New Wood}} \times 100 = \frac{11,319}{17,313} \times 100 = 65.4\%$$

From Figure A-1, Total Exposure = $10^{7.81} = 6.46 \times 10^7$ Rads.

As derived from information in HW-75978 [6], the basic relationship for exposure from mixed gamma emitting fission products (K reactor type fuel) follows the equation:

$$E = a + bt^{-2.5} \qquad \text{(Eq.1)}$$

Where:

E = Exposure in R/yr

a & b are constants

t = time in years ($0<t\leq 20$)

The integrated form is:

$$TE = a\ (t - 1) + \frac{b}{1.5}\ (1 - t^{-1.5}) \qquad \text{(Eq.2)}$$

Where:

TE = Total Exposure (R)

The No. 7 car was placed in the tunnel in 1962 assuming one year aging of the fission products before burial:

$$t = Y - 1961 \qquad \text{(Eq.3)}$$

Where:

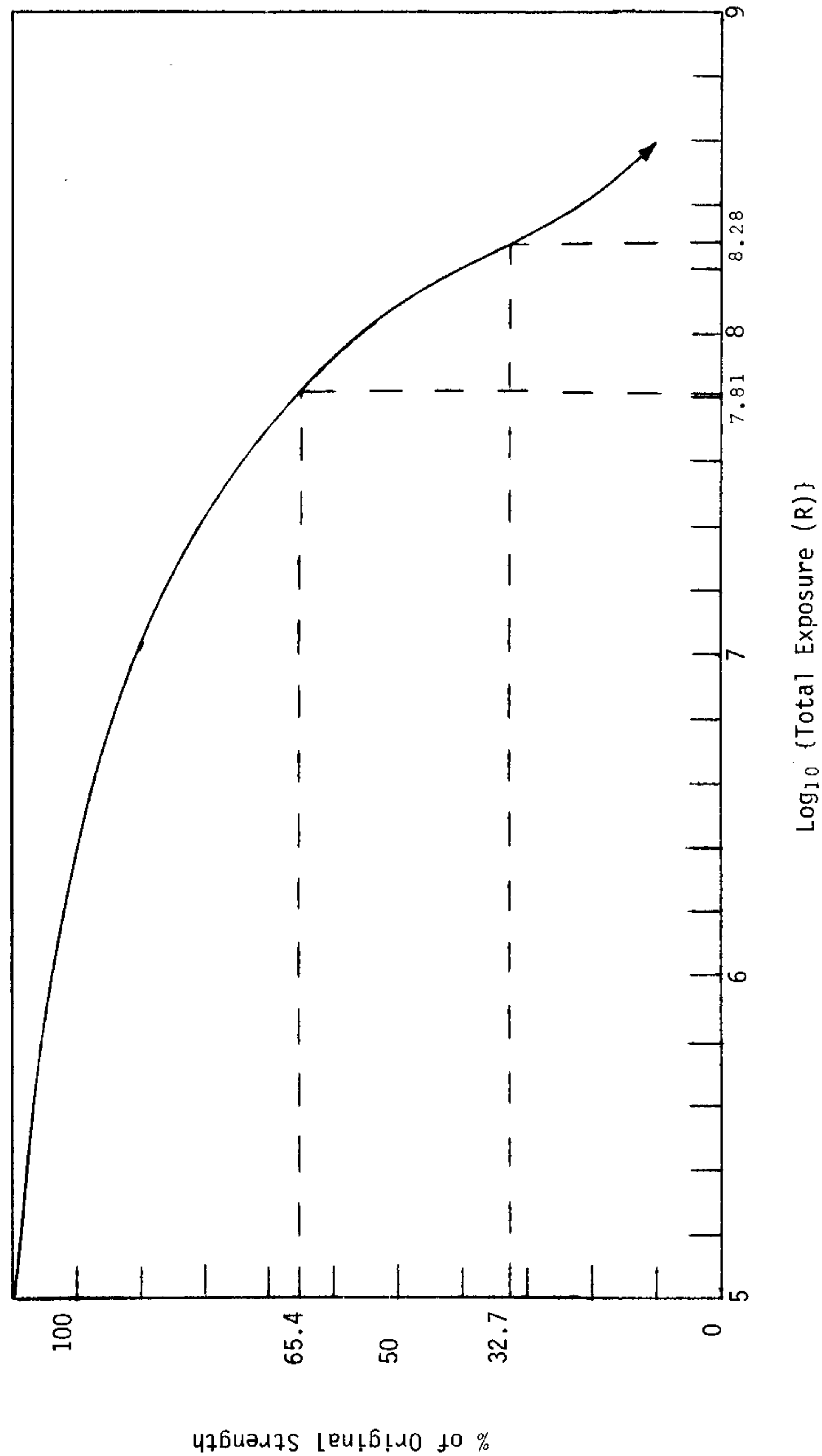
Y = Calendar Year

Two points exist:

In 1978 (t = 17) $\quad E = 121\ ^{R}/_{hr} = 1.06 \times 10^6\ ^{R}/_{yr}$

In 1980 (t = 19) $\quad TE = 6.46 \times 10^7$

FIGURE A-1: EFFECT OF GAMMA RADIATION ON WOOD BENDING STRENGTH[1]



Substituting into Equation 1 and 2

$$1.06 \times 10^6 = a + b\,(17)^{-2.5} = a + 8.39 \times 10^{-4}b$$

$$6.46 \times 10^7 = a\,(19-1) + \frac{b}{1.5}\,(1-19^{-1.5}) = 18a + 0.659b$$

Solving simultaneously

$a = 1 \times 10^6$ $\qquad$ $b = 7.07 \times 10^7$

Substituting into Equation 2

$$TE = 1 \times 10^6\,(t-1) + 4.71 \times 10^7\,(1-t^{-1.5})$$

TIMBER
PRODUCTS
INSPECTION

August 21, 1980

Rockwell Hanford Operations
Energy Systems Group
P.O. Box 800
Richland, Washington 99352

Attention: Mr. Greg Silvan

RE: 80-432 Rockwell International

Sample - 3 - Douglas Fir Wood cores, 4 in. diameter, marked #"1", #"2" and #"3".

To compare static bend tests and compare with specie averages.

SCOPE & PROCEDURES

The grain direction is across the 4 inch diameter of the sample. To determine the bending strength of the lumber it was tested in two ways.

A static bend, center load, was run on roughly 3/4 inch square specimens, 3½ inch span, four from each piece. These were compared with similar control specimens from sawn lumber of similar density, ring count, and moisture content. Static bends using official procedure for ASTM D-143, 3/4" x 3/4" - 14" span was then run on specimens from the sawn lumber. A factor between the MOR from the D-143 sample and the 3½ inch span sample was developed from the sawn lumber control and applied to the three samples from the core samples submitted by Rockwell.

Specimens were then cut from the cores in accordance with ASTM-D-805. This procedure is for testing veneer, but provides an official bend test for very short specimens.

Results of the two tests follow:

Control - 5 Rings/inch - ASTM-D-143-Static Board-Average MOR-13,886 PSI
30% Summer wood - 12% M.C.

Control - 3/4 inch square specimens, 3½ inch span - Static Board-Average
MORE-7,005 PSI-.48 sp growth

RATIO - 13,886/7005=1.982

P.O. Box 919 • Conyers, GA 30207 • (404) 922-8000
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ROCKWELL SAMPLES	STATIC BEND	SAME SPECIMENS	STATIC BEND-Per ASTM-D-805		
Ring Count % Summer Wood	3/4" Sq. Specimen 3½" Span	Times 1.982 Calculate	.2 x 2 in. x 3.5 3½" Span		
	MOR	MOR	MOR	MC	DENSITY
#1-5 Ring/In.-30%	6167 PSI	12,226 PSI	12,679 PSI	12%	.6 Spg
#2-3 Ring/In.-20-25%	5713 PSI	11,325 PSI	11,312 PSI	12%	.6 Spg
#3-5 Ring/In.-20-25%	8492 PSI	16,834 PSI	16,814 PSI	12%	.6 Spg
Control 5 Rings/In. 30%	7005 PSI		17,313 PSI	12%	.58 Spg

AVERAGE - published MOR for Douglas Fir @ 12% M.C.
.48 aver Spg - 12,000 PSI

DISCUSSION

The average clear wood value for Douglas Fir as a specie includes wood more and less dense than these samples and control. The control, and sample #1 and #3 were above average Douglas Fir density. The values for #1 and #3 and the control are above the specie average strength values, which is to be expected of clear wood above average density. Sample 2 has lower ring count and lower percentage summer wood (the brown dense layer) than the other two samples, and therefore may be expected to have lower strength than the other two samples and the control. Sample #1 and #3 appear to be very similar wood. While so small a sampling leaves some questions, there is an indication that there may have been an environmental influence on sample #1 and #2. Regardless, all three samples test within strength range for specie requirements.

The two procedures used to determine the bending strength provide substantial agreement.

Submitted - August 21, 1980
TIMBER PRODUCTS INSPECTION, INC.

Gifford L. Martin-Sr.

Gifford L. Martin-Sr. - P.E.
Technical Director

Encl.

GLM/ss

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