Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

1221503

91-EAB-218

SEP 6 1991

Mr. Paul T. Day
Hanford Project Manager
U.S. Environmental Protection Agency
712 Swift Blvd. Suite 5, MSIN: B5-01
Richland, Washington 99352

Mr. Timothy L. Nord
Hanford Project Manager
State of Washington
Department of Ecology
Mail Stop PV-11
Olympia, Washington 98504-8711

Dear Messrs. Day and Nord:

AN EVALUATION OF THE STRUCTURAL INTEGRITY OF PUREX STORAGE TUNNEL #1 (S-2-1)

In reference to letter received from the State of Washington Department of Ecology (Ecology) to S. H. Wisness, DOE Field Office, Richland (RL), "Notice of Deficiency (NOD) for the PUREX Storage Tunnels Dangerous Waste Permit Application," dated February 5, 1991, enclosed is one copy of the Los Alamos Technical Associates (LATA) Report, "An Evaluation of the Structural Integrity of PUREX Storage Tunnel #1." This report was prepared in response to concerns identified by Ecology regarding the structural integrity of Tunnel #1 (Reference, comments no. 22 and 37). This report addresses questions raised by Ecology regarding the structural integrity of the tunnel.

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If you have any questions regarding the report, please contact Mr. C. E. Clark, RL on (509) 376-9333.

Sincerely,

E. A. Bracken, Director
Environmental Restoration Division
DOE Field Office, Richland

ERD:CEC

R. E. Lerch, Manager
Environmental Division
Westinghouse Hanford Company

Enclosure:
Report - An Evaluation of the Structural Integrity of PUREX Storage Tunnel #1

OPD comments and ERD comments on this transmittal letter have all been incorporated or otherwise dealt with as appropriate. The letter is ready for signature
C E Clark 9/6/91

cc w/encl:
D. L. Duncan, EPA
R. E. Lerch, WHC w/o encl.
M. E. Lerchen, Ecology

bcc w/o encl:

ERD Off File	C. E. Clark, ERD w/encl.& bkgrnd
ERD Rdg File	R. M. Carosino, OCC
EAB Rdg File	L. G. Musen, TSD
AME Rdg File	S. S. Clark, OPD w/encl. File: PUREXTUN.EL1
CCC Rdg File	File Code: 40.7.15

Record Note: This letter is transmitting a copy of the LATA report, "An Evaluation of the Structural Intregrity of PUREX Storage Tunnel #1. This report was prepared in response to NOD comments received from Washington Department of Ecology on the PUREX Tunnels Part B permit application. It is due ~~to Ecology as~~ soon as possible and should be transmitted no later than COB on August 9, 1991. This completes action #7609, letter #I91-EAB-470.

The desire to submit this by 8/9/91 was discussed with Ecology in Unit Managers meetings. Ecology was also informed that it would be sent later after it was clear that it would not get out by that date. Since this was not a firm date mandated & it has not been a major issue of disagreement or regulatory requirement, we will do that as soon as possible. Ecology has requested that we get it to them as soon as possible.

RECEIVED SEP 0 6 1991 RL/CCC

OFFICE >	ERD	OPD	OPD	OPD	OCC	ERD
SURNAME>	CLARK/HOLT	HUFFMAN	CLARK	MECCA	CAROSINO	BRACKEN
DATE >	8/07/91	------previously concurred------				

(Please Return To

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An Evaluation of the Structural Integrity of PUREX Storage Tunnel # 1

May 17, 1991

by

F. R. Hand and V. J. Stephens

Los Alamos Technical Associates, Inc.

Contents

Executive Summary

Westinghouse Hanford Company requested Los Alamos Technical Associates, Inc. (LATA) to make an independent evaluation of the structural integrity of PUREX Storage Tunnel #1 in response to questions by the State of Washington Department of Ecology as to the advisability of continuing to store dangerous waste in Tunnel #1. LATA finds that there is very low probability of any degradation of the timbers in the tunnel due to decay or insect attack. The only structural degradation that is occurring is due to the continued exposure of the timbers to the high gamma radiation field in the tunnel, and this effect is minor. In the Silvan evaluation of the tunnel (Silvan 1980), the strength of the timbers at that time was determined to be 65.4% of the original strength. Based on the same methods of calculating radiation damage effects as used in the Silvan report, it is conservatively estimated that the strength of the timbers will be 60% of original strength in the year 2001. At that time it is recommended that the structural integrity of the tunnel be reevaluated in light of tests being conducted by the United States Forest Product Laboratory and others on the resistance of treated wood to damage by decay or insect attack.

An Evaluation of the
Structural Integrity of PUREX Storage Tunnel # 1

1.0 Introduction

In September, 1990, a dangerous waste permit application for the PUREX Storage Tunnels (DOE, 1990) was submitted to the Washington State Department of Ecology by the United States Department of Energy - Richland Operations Office. The PUREX Storage Tunnels are a storage unit located on the Hanford Site in the 200-East area. The unit consists of two earth-covered railroad tunnels that are used for storage of process equipment (some containing dangerous waste) removed from the PUREX Plant. The radioactively contaminated equipment is loaded on railroad cars and remotely transferred into the tunnels for long-term storage. Storage of the mixed (dangerous and radioactive) waste associated with the equipment is regulated under the *Resource Conservation and Recovery Act (RCRA) of 1976* and under the Washington Administrative Code, WAC Chapter 173-303, *Dangerous Waste Regulations* (WAC, 1989).

On February 5, 1991, the State of Washington, Department of Ecology, issued a Notice of Deficiency (NOD) for the PUREX Storage Tunnels Dangerous Waste Permit Application (Nord, 1991). In the NOD, the Department of Ecology questioned the advisability of leaving dangerous waste stored in Tunnel #1 in light of statements made by Silvan (1980) about the structural integrity of Tunnel #1 (see the Appendix for a copy of the statements in the NOD). Westinghouse Hanford Company (WHC), the operating contractor responsible for the PUREX Storage Tunnels, requested Los Alamos Technical Associates, Inc. (LATA) to make an independent evaluation of the structural integrity of PUREX Storage Tunnel #1.

2.0 Background Information

PUREX Storage Tunnel #1 is located in the southeast quadrant of the PUREX plant site (see Figure 1). The north end of the storage tunnel is near the southeast end of Building 202-A, the main process building at the PUREX site. The storage tunnel is a straight-line continuation of the north-south railroad tunnel that enters Building 202-A at the northeast corner. The storage tunnel consists of three areas: a water fillable door housed in a reinforced concrete structure that separates the storage tunnel from the PUREX railroad tunnel; the storage area proper that is 358 feet long and is constructed from wood timbers covered with earth; and a reinforced concrete vent shaft at the extreme southern end of the storage area. The area of concern is the storage area proper.

There are only two reasonable alternatives to leaving the dangerous waste in Tunnel #1, these alternatives are:

- make permanent disposition of the material; or
- move the material to another storage location.

Ultimately, permanent disposition of all of the material in both storage tunnels will have to be made; therefore, the ideal solution to the problem is to make permanent disposal of the dangerous waste in Tunnel #1 immediately. Disposal options have been evaluated by Henckel (1990). Options studied included:

- backfilling the tunnels with gravel;
- injecting the tunnels with grout;
- a combination of grout injection and backfilling;
- retrieving the equipment and disposing of it in the PUREX Plant;
- retrieving the equipment, performing size reduction procedures in the PUREX Plant, and disposing of the resulting material;
- retrieving the equipment and transporting it to the Waste Receiving and Processing (WRAP) facility (Module 2);

- retrieving the equipment and transporting it off the Hanford Site for treatment and disposal; and
- constructing a new facility for retrieving, processing, and treatment of equipment for disposal.

Based on the evaluation criteria used, three of the alternatives were closely ranked. In order of ranking, highest to lowest, the three were: retrieval and disposal in PUREX; in situ grouting; and retrieval and size reduction in PUREX. Even though it was the lowest ranking of the three, the alternative of retrieval and size reduction in PUREX was the alternative recommended because this alternative would be in compliance with RCRA regulations and is technically feasible.

Because of the interaction and dependency on other disposal actions taking place throughout the Hanford Site, none of the options studied can be accomplished in the near term. Therefore, the alternative of permanent disposal is not a viable option for the resolution of the NOD. This leaves moving to another storage location as the only reasonable alternative.

The only other storage location available for storing the dangerous waste now stored in Tunnel #1 is PUREX Storage Tunnel #2. Assuming that in-situ disposal will not be the final disposal option selected, moving the dangerous waste from Tunnel #1 to Tunnel #2 would violate the as low as reasonably achievable (ALARA) principal because operating personnel would be exposed to as much, or more, penetrating radiation during the move as during final disposition. In order to achieve exposure ALARA, it is highly desirable to leave the dangerous waste in Tunnel #1 if the structural integrity of the tunnel is acceptable. Leaving the material in Tunnel #1 has the added advantage of making more space in Tunnel #2 available for failed equipment storage during any future PUREX process operations.

3.0 Construction Features of Tunnel #1 Storage Area

Construction of Tunnel #1 was completed in 1956 as part of the PUREX Plant construction. The tunnel was designed by General Electric. Sketches of Tunnel #1 are provided in Figures 2 and 3. Copies of selected plans and sections from the original design drawings are shown in Figures 4 through 7. The original drawings for the tunnel are H-2-55586 to H-2-55595.

The tunnel is divided into three main parts - the water fillable door at the north end, the 358-foot long tunnel proper, and the reinforced concrete vent structure at the south end. Only the timber portion will be described in detail since the condition of the timbers is the essence of the NOD.

The timber portion of the tunnel is 358 feet long and is composed of two typical sections. The inside dimensions of the tunnel are 22 feet in height and 19 feet wide and are same for both typical sections. The first 103-foot length of the tunnel closest to PUREX Plant (northern part of tunnel) is composed of a 3-foot thick reinforced concrete wall on the east side and timber west wall and roof. The reinforced concrete wall section would allow for later construction of Tunnel #2 without disturbing the existing and buried Tunnel #1. The remaining 255-foot length of tunnel (south portion) is composed of two timber walls and timber roof. The same type of timbers are used in both sections.

The entire timber area of the tunnel is composed of 12-inch by 14-inch creosoted timbers arranged side by side with the 12-inch face exposed. Vertical side wall timbers were placed on a reinforced concrete footing 3-feet wide and 1-foot thick. A 9-inch high curb on the interior face of the footing restrains the timbers and resists forces imposed by the earth backfill. Continuous creosoted wood rail ties between the east and west footings carry the steel rails and permit soil loads to be transferred from one footing to the other. All timbers and rail ties are No. 1 Douglas fir.

All exterior surfaces of the timber structure were covered with mineral surfaced, 90-lb roofing. All joints in the roofing were cemented, lapped, and nailed on 3-inch centers. Cracks between timbers wider than three-quarters of an inch were covered with 26 gage galvanized steel nailed in place before the roofing was placed. The entire structure was then covered with earth fill to provide a minimum cover of 8 feet.

The materials used in and the construction of the tunnel were controlled by the original drawings and specifications (GE, 1855). These are used to expand the material descriptions given above.

Timbers - The timbers are Douglas fir No. 1 Posts and Timbers as produced and graded under the Standard Grading and Dressing Rules of the West Coast Lumberman's Association. The timbers are rough sawn to 12"x14".

The timbers are pressure treated with creosote in conformance with American Wood Preservers' Association (AWPA) Standard C2-54 for the Preservation Treatment of Lumber, Timber, Bridge Ties and Mine Ties by Pressure Process. The minimum retention is 8.0 pounds of creosote per cubic foot of wood.

All cutting, framing and drilling of holes was performed prior to pressure treating.

Roofing - Mineral surfaced roofing is asphalt saturated felt, surfaced with mineral granules and weighing at least 83 pounds per square (referred to as "90 pound roofing"). Material conforms to the requirements of ASTM Designation: D 249-50T, Specifications for Asphalt Roofing Surfaced with Mineral Granules.

Plastic roofing cement was Koppers "Flashing Cement", or approved equal.

Backfill - Heavy construction equipment was not operated over the tunnel structure at any time. A light weight farm type tractor was permitted for finish grading over top of tunnel.

Material for non-load bearing backfill was placed in layers not to exceed 24 inches loose measurement.

Care was exercised during backfilling to prevent excessive loads on walls and to insure balanced loading on opposite walls.

Six inches of clean sand free from stones over 1 inch in diameter were placed over tunnel roofing material prior to placing embankment material.

4.0 Previous Studies and Their Evaluation

4.1 1971 Wood Sampling

The integrity of the wood in the tunnel was evaluated. Four 1½ inch steel pipes were sunk through the dirt fill down to the roof of the burial tunnel. Using a Swedish, Increment Borer 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.

This 1971 study did not yield numerical test results but does indicate that the timbers are in satisfactory condition after 15 years in service.

4.2 1978 Evaluation of the Tunnel Environment

In July 1978, an evaluation of the storage tunnel environment was performed. A one-half inch tygon tube was lowered into each of the air sample and temperature probe risers and several air samples were withdrawn from the tunnel using a vacuum pump. These samples were tested for airborne radioactivity, gaseous chemical composition and relative humidity. Temperature and radiation exposure were determined by lowering iron constantan thermocouples and thermoluminescent dosimeter chips into the tunnel. Result of these tests are shown in Table 1. No conclusions were made from these tests at that time, but it was recommended that the tunnels' wood timbers be sampled and tested to verify their structural integrity.

This 1978 study gives environmental data but no structural data. The environment data represents conditions after 22 years of service. The tunnel was sealed following placement of the last rail car in 1965. There is little reason to expect the temperature and relative humidity values to have changed between 1965 and 1978 or from 1978 to the present (1991). The temperature is a relatively cool 64 degrees and should experience little seasonal fluctuation. The relative humidity is a very dry 7-percent. This should shift slightly with changes in temperature but no major variations are expected. The Hanford climate is relatively dry and no major seasonal changes in relative humidity are expected in the tunnel due to the depth of burial.

4.3 1980 Core Sampling

Three core samples were taken from the roof of the storage tunnel to be used for static bending tests to determine the structural strength of the tunnel support timbers. The cores measured 4-1/8 inches in diameter and 13½ 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. The core samples were tested by Timber Products Inspection, Inc. Two types of static tests were performed. The first test was a modified version of ASTM-D-143 using a 3/4" square specimen and a 3½" span rather than the standard 14" span. The second test was according to ASTM-D-805 using a 0.2 x 2 x 3.5 inch specimen. The test results are given in Table 2.

This 1980 study yields numerical test results and represents the condition of the timbers after 24 years in service. The test results show that the Douglas fir as tested is equal to or better than the species average for new wood even after 24 years of service. The 12 percent moisture content of the wood is in agreement with the low relative humidity value from the 1978 environmental study.

5.0 Findings

The structural integrity of the tunnel, the possibility of decay of or insect attack on the timbers, and the effect of gamma radiation on wood strength are addressed.

5.1 Structural Evaluation

A previous structural evaluation of the PUREX Storage Tunnel #1 has been made by Silvan (1980) in which it was found that the timber structure was structurally sound at the time of the study assuming the present loading conditions remain unchanged. LATA has reviewed the report, confirmed the reasonableness of the values used, and agrees with the findings regarding the structural integrity of the timber structure. No new structural calculations were performed nor are any needed. However, it was stated in the report that; "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." Discussions with experts on the subject of wood decay and insect attack and review of literature on the subjects reveals that it is possible to evaluate the ability of the structure to resist such attack and to make a reasonable prediction of the minimum expected time before decay or insect attack would be expected to affect the structural integrity of the creosoted timbers in the tunnel.

5.2 Wood Decay and Insect Attack

The specification for the timbers used in the tunnel (GE, 1955) required that the timbers be pressure treated with creosote solution in accordance with American Wood Preservers' Association (AWPA) Standard C2-54 for the Preservative Treatment of Lumber, Timbers, Bridge Ties and Mine Ties by Pressure Process. Experts consulted on the subject of wood decay, insect attack, and wood preservation included the staff of the AWPA, Union Pacific Railroad, and United States National Forest Products Laboratory. The AWPA staff member expressed the opinion that timbers treated per AWPA-C2-54 should last much longer in the environment of Tunnel #1 than the 35 years normally expected from timbers so treated.

In discussions with the engineering staff of Union Pacific Railroad in Omaha, Nebraska, it was stated that they experience a 50-year life for their creosote treated timber bridges. They also have a 65 to 80 year life expectancy for timber tunnel liners. They have struts in tunnels built 60 to 70 years ago and they are still in service. Specific examples are a 255 foot tunnel built in 1917 in Plaza, Idaho; a 129 foot tunnel built in 1911 in northern Idaho; a 2000 foot tunnel built in 1912 in eastern Oregon; and a tunnel built in 1909 in Barnheart, Oregon. All are still in service with original timbers. Union Pacific tunnel liners, based on experience in their 22 state service area, suffer distress due to water saturation and fault zones. The bottom end of the strut will suffer distress if it is allowed to stand in water. None of these adverse conditions are present in the PUREX storage tunnel

Staff of the United States Forest Products Laboratory (FPL) were also consulted on the subject of wood decay, insect attack, and wood preservation. They expressed the opinion that the treated Douglas fir timbers would last long beyond the typical 35-40 year life because of the dry climate at Hanford, the very dry atmosphere in the tunnel, the presence of the 90-lb roofing, the AWPA-C-2 treatment, and the low hazard area (for termite attack).

The FPL has an ongoing program of comparing wood preservatives in wood stake tests. A progress report (Forest Products Laboratory, 1989) is available that gives results of decay and termite attack on wood stakes treated with creosote and other preservatives. The report states that 2-by 4-by 18-inch pine sapwood stakes furnish an effective means for testing the protection provided against decay and termite attack by various wood preservatives. Stake tests were initiated in 1938 at Saucier, Mississippi; Madison, Wisconsin; Bogalusa, Louisiana; Jacksonville, Florida; and the Canal Zone, Panama. Wisconsin is at the same latitude as Hanford although it has a much wetter climate. Per discussion with FPL staff the Hanford site (Eastern Washington) is a low hazard area and is less prone to decay and insect attack than Madison, and that Madison is less prone to decay and insect attack than Saucier. It was judged that of all of the sites at which tests were made or are in progress, the results of tests conducted in Madison, Wisconsin would be the most nearly representative of results to be expected at the Hanford Site.

Tests with southern pine stakes (2 x 4 in. nominal x 18 in.) treated with coal-tar creosote were started at Madison Wisconsin in September 1940. Condition of the stakes in December 1985 (45+ years of service) as contained in Table 4 of the Forest Products Laboratory were as follows:

- all 10 stakes with an average retention of 0.71 pounds of creosote per cubic foot of wood (brush treatment, 2 coats) had been destroyed by decay fungi at an average life of 8.4 years;
- all 10 stakes with an average retention of 1.8 pounds of creosote per cubic foot of wood (15-minute dip at room temperature) had been destroyed by decay fungi at an average life of 12.4 years;
- all 10 stakes with an average retention of 4.3 pounds of creosote per cubic foot of wood had been destroyed by decay fungi at an average life of 37.9 years;
- 1 out 9 stakes with an average retention of 8.0 pounds of creosote per cubic foot of wood had been destroyed by decay fungi and 9 stakes were still serviceable but

showing some decay;

- all 9 stakes with an average retention of 11.8 pounds of creosote per cubic foot of wood were still serviceable with 4 in good condition and 5 showing some decay;
- all 10 stakes with an average retention of 16.4 pounds of creosote per cubic foot of wood were still serviceable with 5 in good condition and 5 showing some decay; and
- none of the creosote treated stakes showed any evidence of termite attack.

A copy of Table 4 from the report, as well as a copy of Table 6, is included in the Appendix.

The data in Table 4 and elsewhere in the FPL report indicate a ratio of average life of 1, 1½, and 3 for the Canal Zone, Saucier, and Madison sites, respectively. Applying these ratios to the Table 4 data for 4 and 8 pcf retentions, we can project a 2x4 stake average life of approximately 57 years at Madison. This is reasonable since only one of nine stakes has failed in 45+ years at Madison. Recognizing that Madison is more susceptible that Hanford, we would project an average life in excess of 60+ years for the 8 pcf creosote treated timbers.

Table 6 summarizes the results from tests with stakes of different sizes and demonstrates that for the same preservative retention, large stakes have a longer expected life than small stakes. As shown in Table 6, with average retentions of 8 pcf, the average life increases from 17.1, 23.6, to 26.6 years for ½, 1, and 1½ inch square specimens, respectively, and is not yet determined after 44½ years of service for 2x4 specimens. This would indicate that the timbers in the tunnel would be expected to last longer than the stakes.

Handbooks reviewed on the subject of decay, insect attack, and wood preservation included *Timber Construction Manual* (AITC, 1974); *Wood Handbook: Wood as an Engineering Material* (Forest Products Laboratory,1974); and *Wood Technology in the Design of Structures* (Hoyle, 1973).

The *Timber Construction Manual* has a part on design specifications which includes "Treating Standard for Structural Timber Framing," AITC 109-69, that states in part:

"**2.1 Decay.** Decay of wood is caused by low forms of plant life (fungi) that develop and grow from spores just as higher forms of plants do from seed. These microscopic pores are likely to be present wherever wood is used. The plant-like growth breaks down the wood substance, converting it into food required by the fungus for development. However, like all forms of plant life, these wood destroying fungi must have air, suitable moisture, and favorable temperatures, as well as the food if they are to develop and grow. If deprived of any of these four essentials, the spores cannot develop and the wood remains permanently sound, retaining its full strength. Wood permanently and totally submerged in water cannot decay because the necessary air is excluded. Wood will not decay when its moisture content is continuously less that 20%. Temperatures above 100°F and below 40°F will essentially stop the growth of the decay fungi. Growth will begin again each time favorable climatic conditions exist. Since rainfall and temperature conditions principally influence the rate of decay , a Southern coastal region presents a greater decay hazard that a Northern inland region.

"**2.2.1** Examples of installations where properly designed and constructed wood structural members are permanent without treatment include:

"**2.1.1.1** Enclosed buildings for which good roof coverage, proper roof maintenance, good joint details, adequate flashings to direct rain water, ventilation, and a well drained building site assure continuous moisture content of wood below 20%.

"**2.1.1.2** Arid or semi-arid regions where climatic conditions are such that the equilibrium moisture content seldom exceeds 20% and then only for short periods."

The conditions described in **2.1.1.1** existed at the time of completion of construction of the tunnel and would continue to exist as long as the mineral surfaced roofing system installed on the roof and side walls of the tunnel was intact. *Plant Engineering Handbook* (Staniar, 1959) states that the major cause of failure of felt roofs is sunlight (Staniar, 1959). The material on the tunnel is well protected from sunlight by the 8-feet of earth cover. It is stated in the same reference that surety-bond guaranties on materials, which binds the manufacturer of the materials, are generally furnished for periods of 10, 15, and 20 years. Because of the protection provided by the earth cover, the roofing material will provide protection to the timber for much longer than 10, 15, and 20 year periods discussed above.

The conditions outlined in **2.1.1.2** are also judged to be applicable to the tunnel structure. Average annual precipitation at the Hanford Site is 6.3 inches and the average annual estimated evaporation rate is 53 inches, which essentially eliminates deep infiltration in the soil (DOE, 1982). The water table, representing the upper limit of the unconfined aquifer, ranges from 150 to 328 feet beneath the ground surface at the PUREX facilities and slopes toward the Columbia River (DOE, 1982). The temperature of the tunnel when measured in 1980 was 64° F and the relative humidity was 7% at the ceiling and 4% 5-feet below the ceiling. Under these conditions, the equilibrium moisture content of the timbers would not be expected to ever exceed 20%. This assumption is substantiated by the fact that the moisture content of the wood in 1980 was 12% (Silvan, 1980).

5.3 Gamma Radiation

Silvan (1980) stated that radiation is not expected to be a major factor in any future weakening of the tunnel timbers. This is a true statement if the assumption is made, as Silvan did, that final disposition would have been made circa 1982. However, if final disposition is delayed until the year 2001, for example (ten years from today), and the material is left in the tunnel, some further degradation of the timber can be expected.

The percent of original integrity at any year can be estimated based on the same assumptions as made by Silvan (1980) in the Appendix of his report. By the year 2001, the percent of original integrity is estimated to be 60%. The calculations that are the basis for the estimate are as follows:

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

where: TE = total exposure (R)

When t = 2001 - 1961 = 40

$$TE = 1 \times 10^6 (40-1) + 4.71 \times 10^7 (1-40^{1.5}) = 8.59 \times 10^7$$

$$\text{Log}_{10}(8.59 \times 10^7) = 7.93$$

Percent of Original Strength = 60% (from Figure A-1 of Silvan [1980], see the appendix for a copy of Figure A-1 with the new data superimposed).

The result of this additional loss of strength would be minimal.

The amount of gamma radiation induced strength loss required to reduce the safety factor of the tunnel to zero maybe determined. This load state would correspond to the degraded tunnel just reaching its ultimate load capacity and being in a state of incipient collapse. Using the numbers and procedures in Silvan, this critical state will be reached when the standard factor of safety (which is 1.65 per Silvan) is reduced to zero. The corresponding gamma radiation degraded stress value is 0.727 of the 1980 value. Silvan calculated the degraded stress at 65.4 percent of original value. An additional reduction of 0.727 of this value, or 47.5 percent of original value, is required for the safety factor to equal zero.

6.0 Conclusions and Recommendations

Based on the results of the wood stake tests (Forest Products Laboratory, 1989) as outlined in Section 5.0, there is no evidence of termite damage to timbers treated with creosote at latitudes similar to Hanford Site, but with much greater rainfall. The tests also show no significant damage by decay fungi after 45 years of testing on wood treated with creosote at a retention of 8.0 pounds per cubic foot, the average retention of the timbers in Tunnel #1. Further, wood in the environment that exists in the tunnel, is considered permanent except for the effects of gamma radiation. The rate of loss of strength due to gamma radiation is diminishing with time so that even by the year 2001, the timber will still have 60% of its original strength.

Therefore, it is recommended that the dangerous waste in the tunnel remain as is and that if a decision for final disposition is not made by the year 2001, that the structural integrity again be evaluated in light of any then available information including any further tests on wood preservation that may have been completed at that time. Further tests of the timbers in the tunnel, either destructive or non-destructive, are not indicated at this time.

7.0 Options for Further Study

At the option of Westinghouse Hanford Company, experts in the field of wood preservation can be retained to further validate, or invalidate, the conclusions reached by LATA which were based on a reasonable search of readily available literature.

8.0 References

American Institute of Timber Construction (AITC), "Timber Construction Manual," Second Edition, John Wiley and Sons, Inc., 1974.

Forest Products Laboratory, "Wood Handbook: Wood as an Engineering Material," Agriculture Handbook No. 72, Forest Service, U.S. Department of Agriculture, revised August 1974.

Forest Products Laboratory, "Comparison of Wood Preservatives in Stake Tests, 1987 Progress Report," Research Note FPL-RN-02, Forest Service, U.S. Department of Agriculture, revised May 1989.

General Electric Company (GE), "Specifications for Disposal Facility for Failed Equipment," HWS-5638, Project CA-513-A, Hanford Atomic Products Division, April 25, 1955.

Henckel, G. C. III, "The PUREX Storage Tunnels Engineering Study," WHC-SD-EN-ES-003, Rev. 0, Westinghouse Hanford Company, September 27, 1990. Also included in DOE/RL-90-24 (DOE, 1990) as Appendix 11A.

Hoyle, R. J., "Wood Technology in the Design of Structures," Third Edition, Second Printing, Mountain Press Publishing Company, Missoula, Montana, October 1973.

Nord, T. L. to S. H. Wisness, "Notice of Deficiency (NOD) for the PUREX Storage Tunnels," State of Washington, Department of Ecology, 9100743, February 5, 1991.

Silvan, G. R., "Structural Evaluation of the PUREX No. 1 Burial Tunnel," RHO-CD-1076, Rockwell Hanford Operations, Richland WA, September 1980.

Staniar, W., Editor-in-Chief, "Plant Engineering Handbook," McGraw-Hill Book Company, 1959.

United States Department of Energy (DOE), "Draft Environmental Impact Statement: Operation of PUREX and Uranium Oxide Plant Facilities," DOE/EIS-0089D, Hanford Site, Richland Office, May 1982.

United States Department of Energy (DOE), "PUREX Storage Tunnels Dangerous Waste Permit Application," DOE/RL-90-24, September 1990.

Washington Administrative Code (WAC), "Dangerous Waste Regulations," Chapter 173-303 WAC, Washington State Department of Ecology, amended January 1989.

TABLE 1 RESULTS OF THE JULY 1978 EVALUATION OF THE No. 1 STORAGE 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 x 10^{-10} $\mu Ci/ml$	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

TABLE 2 RESULTS OF STATIC BEND TESTS - PUREX NO. 1 STORAGE TUNNEL CORE SAMPLES

Location Number	Modified ASTM-D-143	ASTM-D-805	Average	Moisture Content	Specific Gravity
	MODULUS OF RUPTURE (psi)				
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

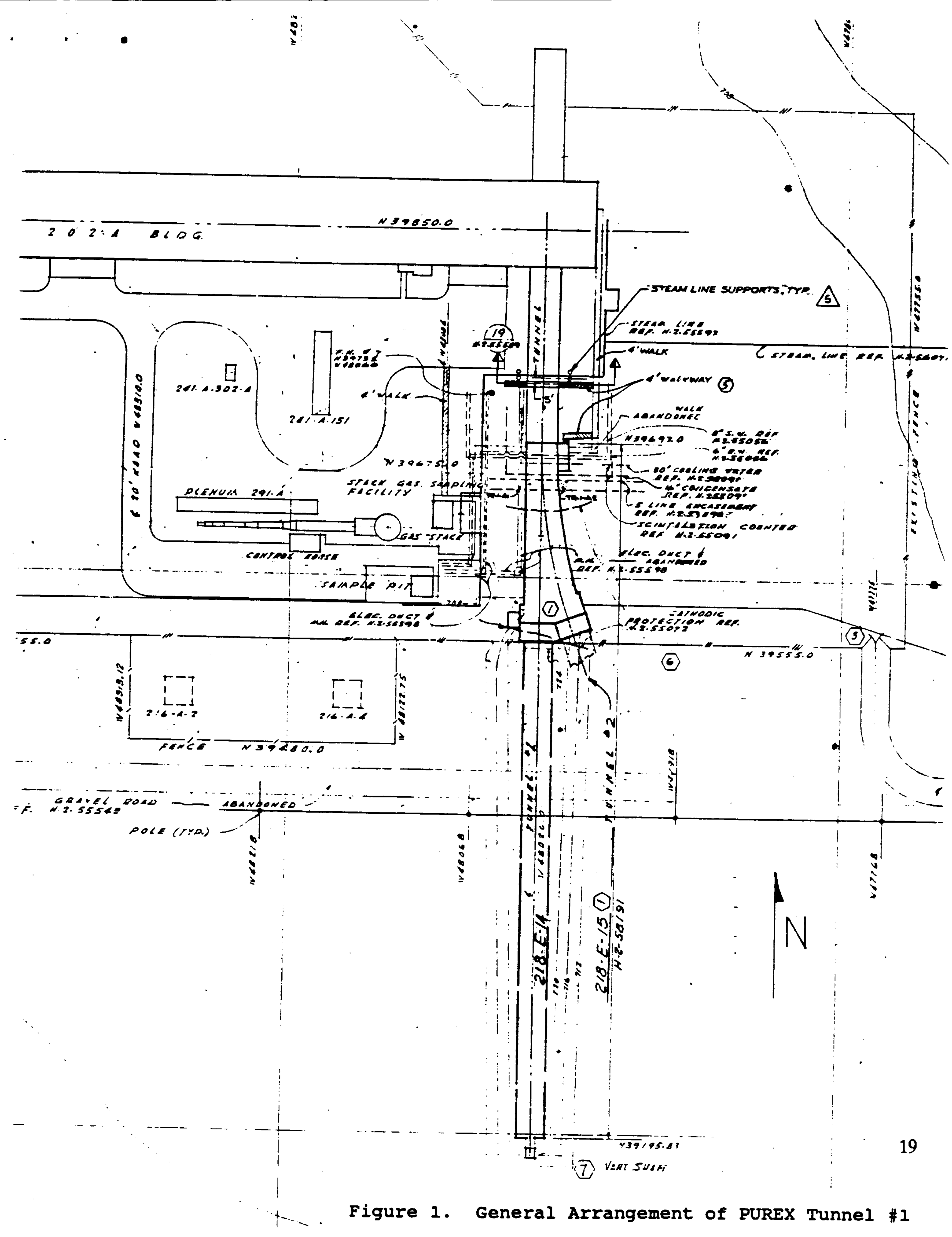

Figure 1. General Arrangement of PUREX Tunnel #1

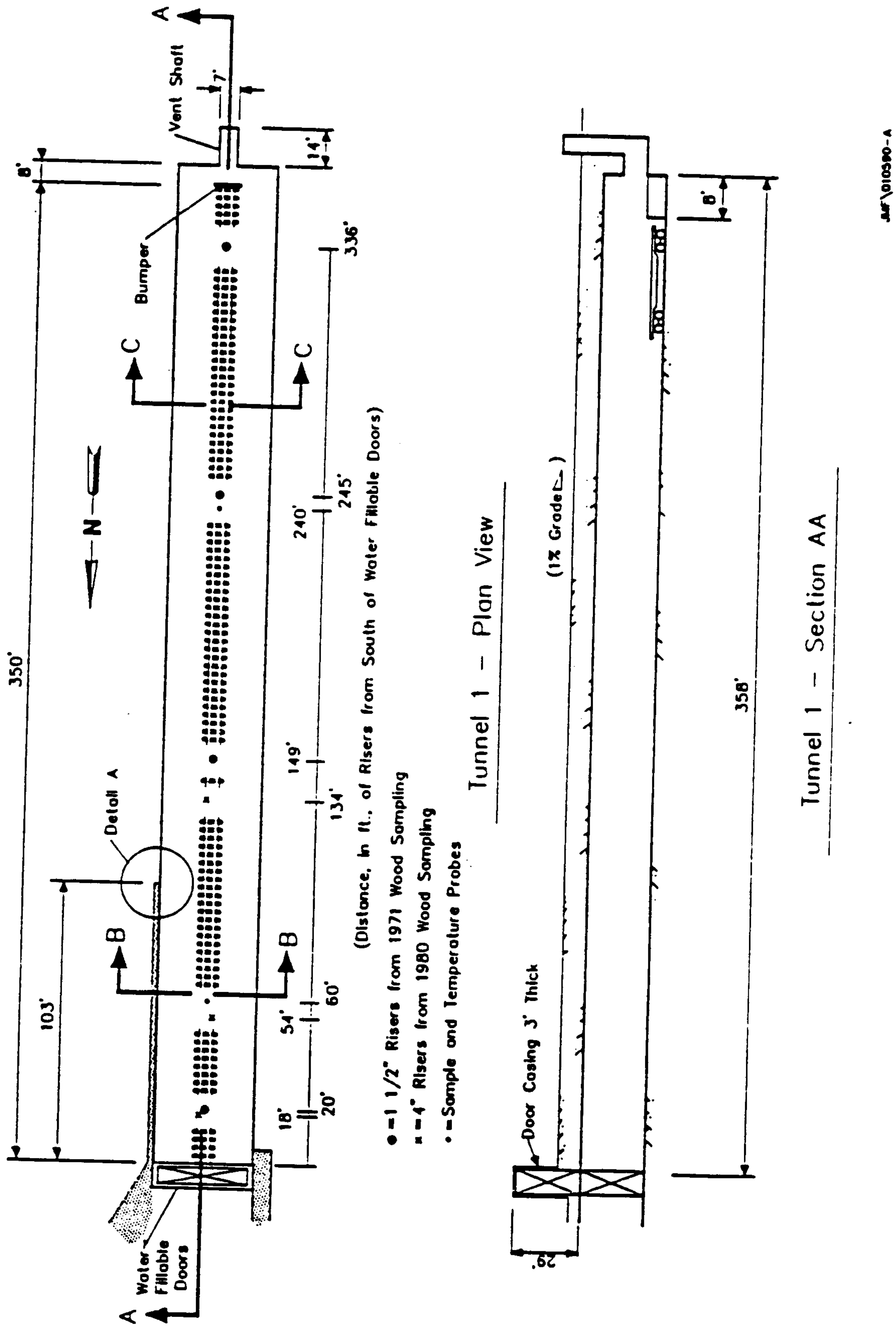

Figure 2. Sketch of PUREX Storage Tunnel 1 (218-E-14).

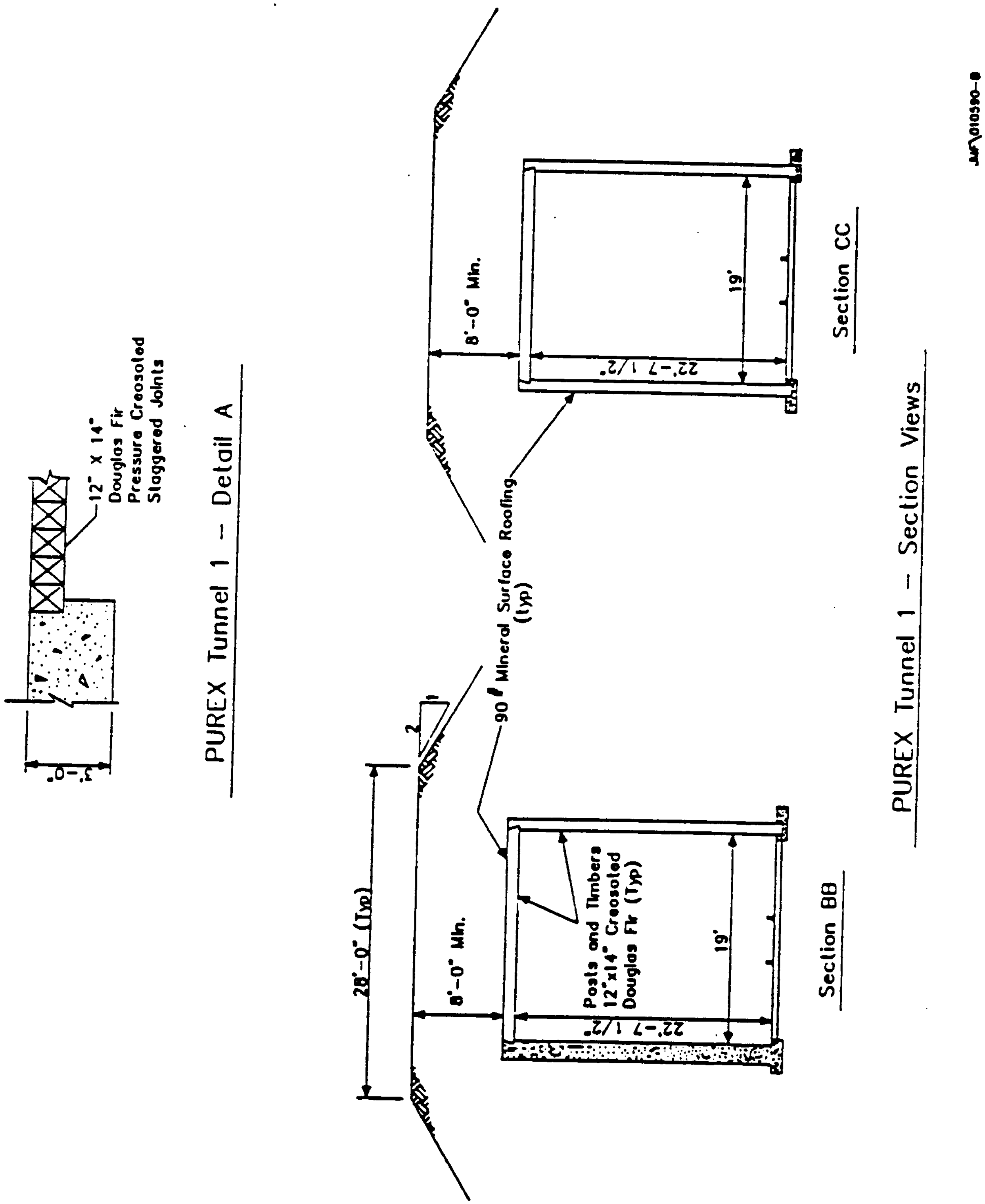

Figure 3. PUREX Storage Tunnel 1 Section Views.

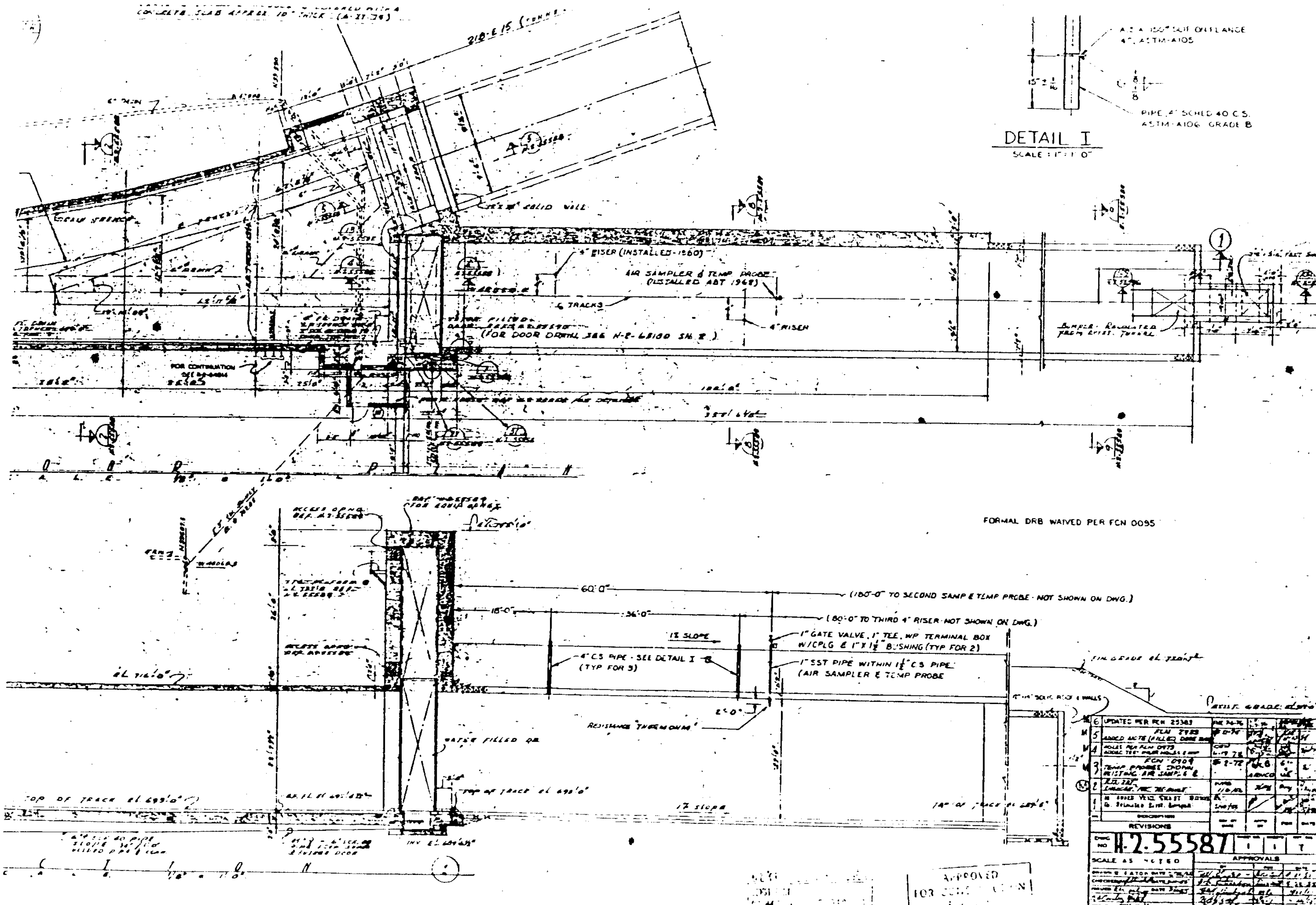

Figure 4. Tunnel Floor Plan and Longitudinal Section

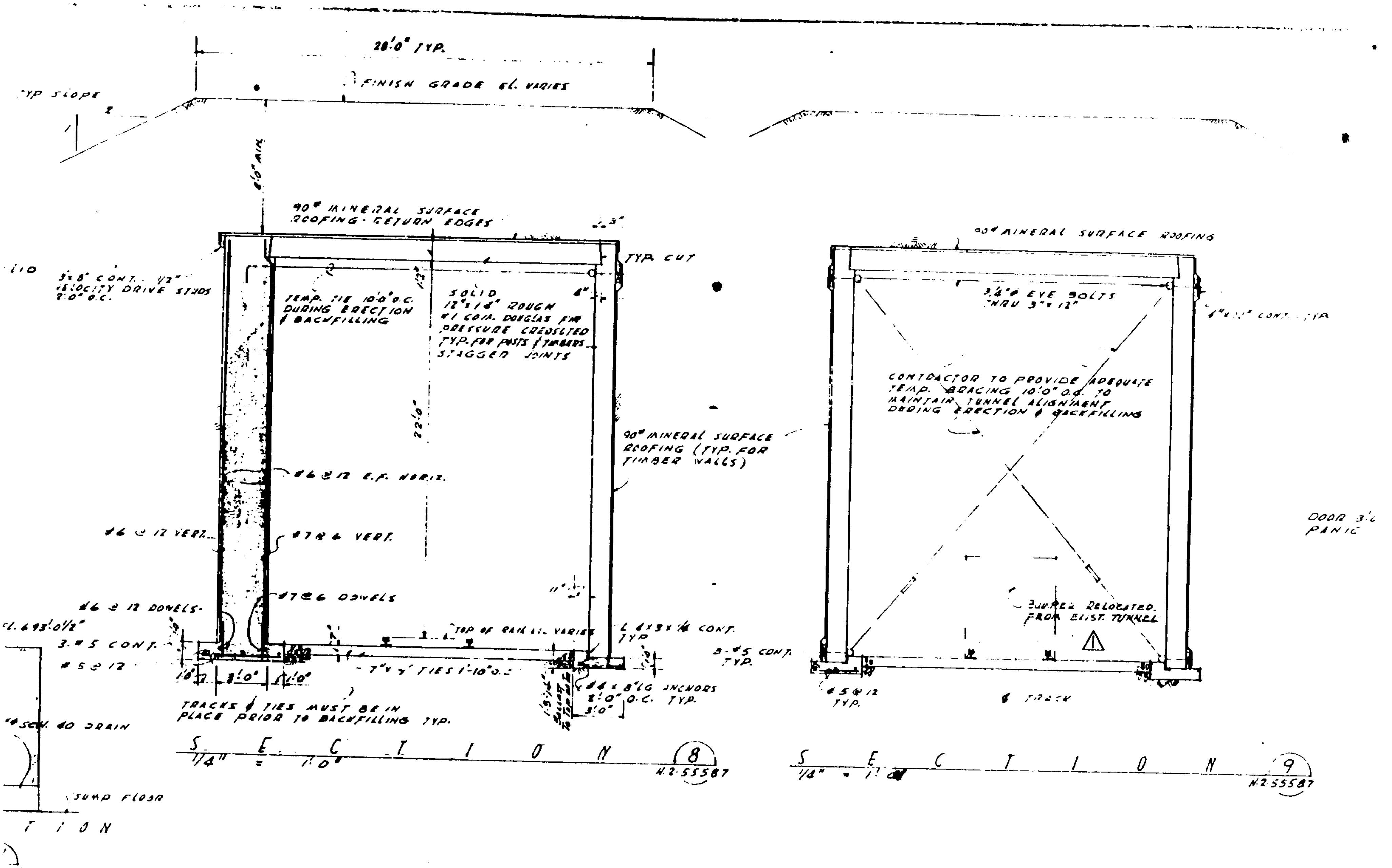

Figure 5. Tunnel Transverse Sections 8 and 9

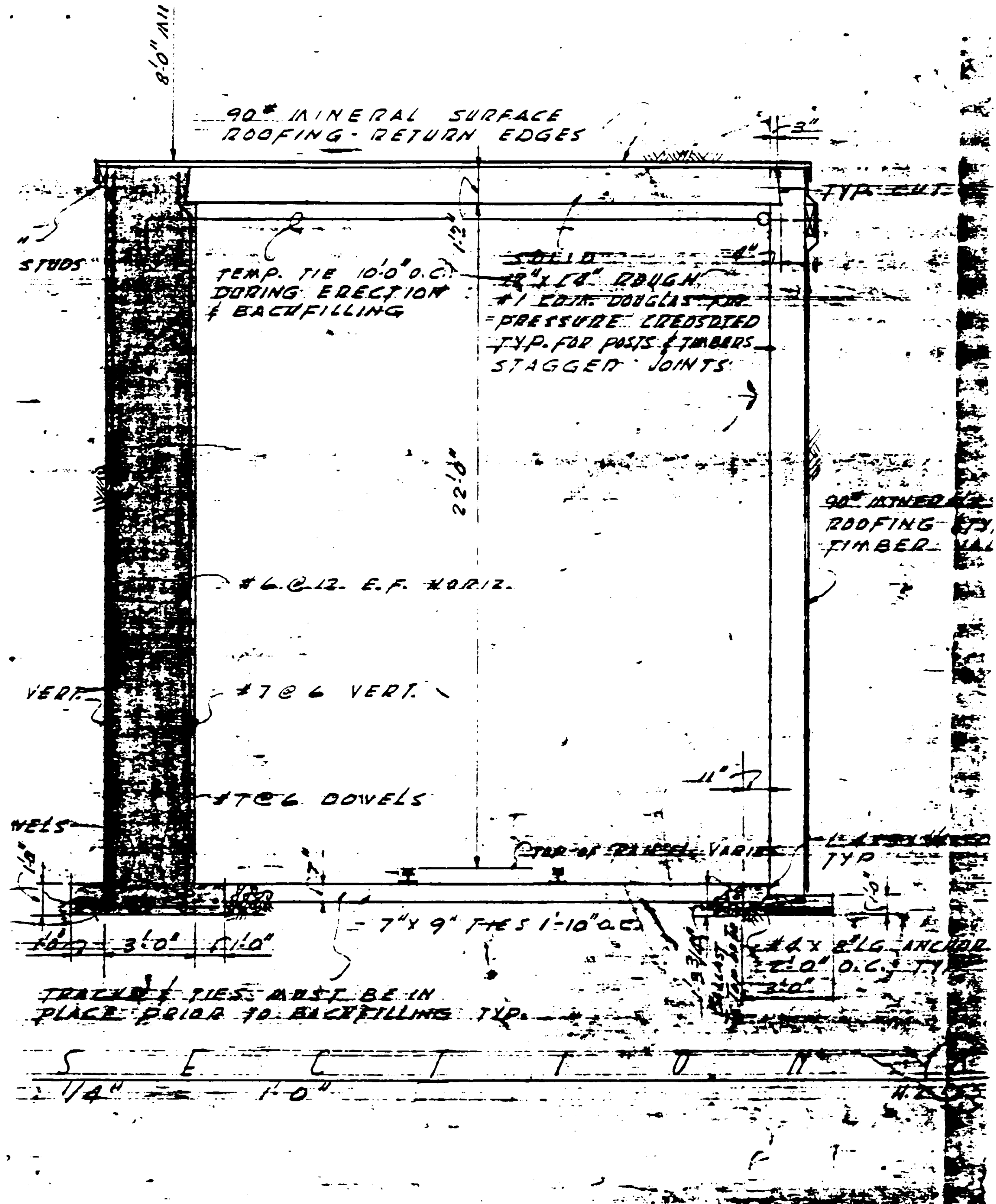

Figure 6. Tunnel Section 8 - Copy from Full Size Blue Print

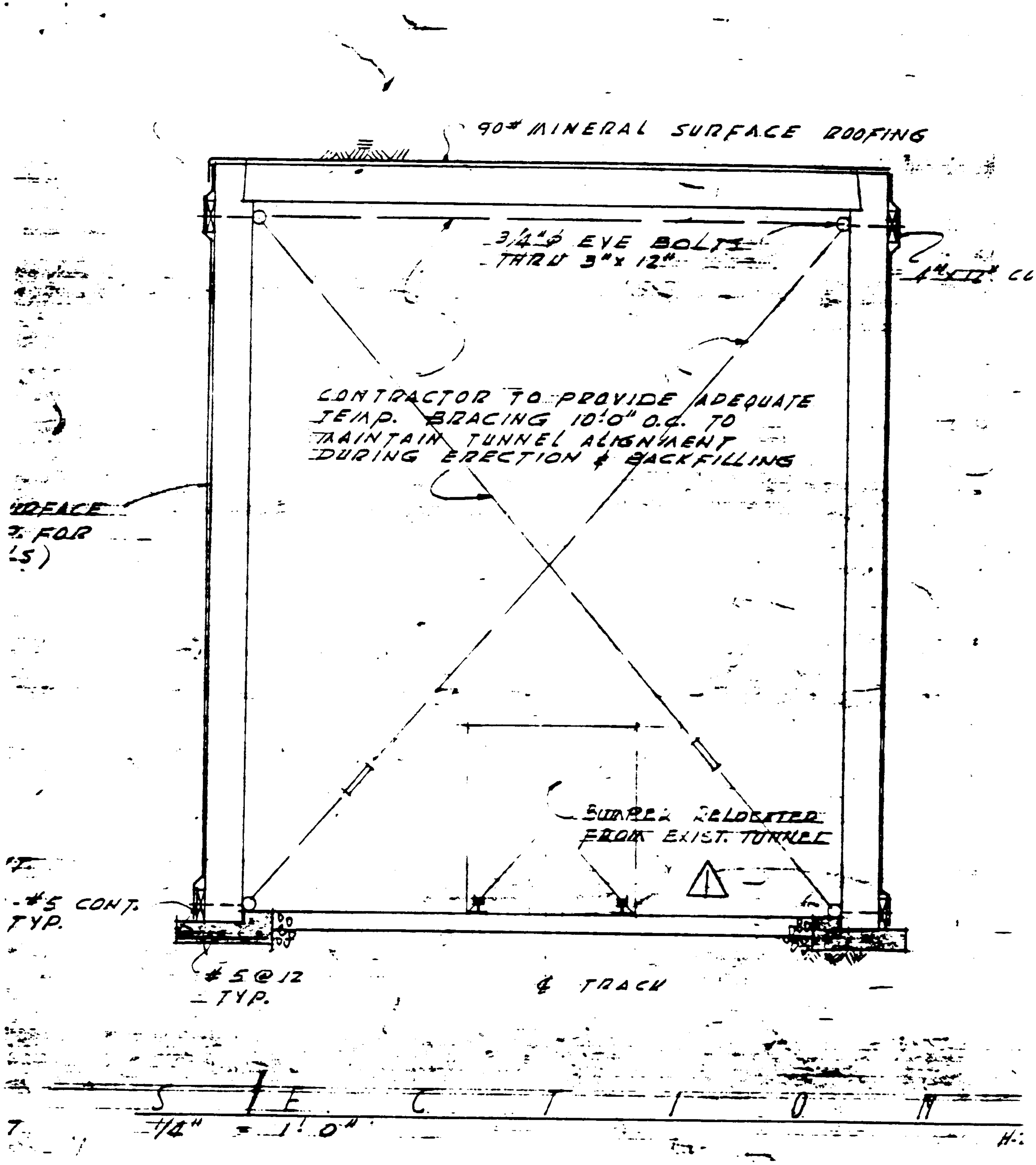

Figure 7. Tunnel Section 9 - Copy from Full Size Blue Print

APPENDIX

The two comments in the Notice of Deficiency (Nord 1991) that relate to the structural integrity of PUREX Storage Tunnel #1 are reproduced below. The original was not suitable for copying.

22. 11-4/7 Comment: The plan states, "No partial closure is anticipated for the PUREX Storage Tunnels."

Requirement: Discuss this statement with regard to the conclusion of RHO-CD-1076 (September 1980, G. R. Silvan), which states on page 33, "If the contents of the tunnel must be removed, it should be deactivated as soon as possible to ensure the tunnel is still structurally sound during the removal operation."

37. 11A-11 - Comment: It is assumed that the closure activities for the PUREX Tunnels will occur in conjunction with the closure activities for the PUREX Plant. This may be appropriate for Tunnel 2, but Tunnel 1 was found to be of adequate but questionable integrity in 1980.

Requirement: Evaluate the assumption that both tunnels will be closed in conjunction with the PUREX Plant. Demonstrate that postponing closure of Tunnel 1 will not result in a more difficult closure due to failure of the timbers. Refer to the second paragraph of page 11A-16.

Table 4.--Condition of southern pine stakes (2 x 4 in. nominal x 18 in.) treated with chromated zinc arsenate (Boliden salts), zinc chloride, and coal-tar creosote after 15 to 45-1/2 years of service. Stakes placed in test at Madison, Wis., September 1940; Harrison Experimental Forest, Saucier, Miss., June 1940; and Barro Colorado Island, Canal Zone, September 1940 (Plot 4)

Preservative	Location	Average retention: Oil	Average retention: Dry salt[b]	Number in test	Condition of stakes December 1985[a]: Good	Serviceable but showing some--: Decay	Serviceable but showing some--: Termite attack	Serviceable but showing some--: Decay and termite attack	Destroyed by--: Decay fungi	Destroyed by--: Termite attack	Destroyed by--: Decay fungi and termite attack	Total removed		Average life
		---- Pcf ----			------------- Pct -------------							Number	Pct	Yr
Zinc chloride	Wis.	--	0.50 (.30)	10	--	--	--	--	100	--	--	10	100	14.8
	Miss.	--	.50 (.30)	10	--	--	--	--	60	--	40	10	100	14.2
	Canal	--	.49 (.29)	10	--	--	--	--	--	--	100	10	100	3.0
	Wis.	--	1.03 (.61)	10	--	--	--	--	100	--	--	10	100	19.8
	Miss.	--	1.02 (.61)	10	--	--	--	--	60	10	30	10	100	14.4
	Canal	--	1.01 (.60)	10	--	--	--	--	--	--	100	10	100	3.6
	Wis.	--	1.51 (.90)	10	--	--	--	--	100	--	--	10	100	22.3
	Miss.	--	1.51 (.90)	10	--	--	--	--	60	--	40	10	100	18.1
	Canal	--	1.49 (.89)	10	--	--	--	--	--	--	100	10	100	4.5
Chromated zinc arsenate (Boliden salts)[c]	Wis.	--	.33 (.22)	10	--	--	--	--	100	--	--	10	100	19.6
	Miss.	--	.33 (.22)	10	--	--	--	--	30	--	70	10	100	33.0
	Canal	--	.33 (.22)	10	--	--	--	--	--	--	100	10	100	9.2
	Wis.	--	.44 (.29)	10	--	--	--	--	100	--	--	10	100	26.1
	Miss.	--	.44 (.29)	9	--	--	--	11	11	--	78	8	89	--
	Canal	--	.44 (.29)	10	--	--	--	--	30	10	60	10	100	11.6
	Wis.	--	.60 (.40)	9	--	--	--	--	100	--	--	9	100	24.9
	Miss.	--	.58 (.38)	10	--	--	--	70	10	--	20	3	30	--
	Canal	--	.58 (.38)	10	--	--	--	--	60	40	--	10	100	14.6
	Wis.	--	.78 (.52)	10	--	--	--	--	100	--	--	10	100	34.6
	Miss.	--	.78 (.52)	10	--	--	--	100	--	--	--	--	--	--
	Canal	--	.78 (.52)	10	--	--	--	--	100	--	--	10	100	15.1
	Wis.	--	1.06 (.70)	9	--	11	--	--	89	--	--	8	89	--
	Miss.	--	1.06 (.70)	10	--	--	--	100	--	--	--	--	--	--
	Canal	--	1.05 (.69)	10	--	--	--	--	100	--	--	10	100	15.3
Coal-tar creosote	Wis.	4.3	--	10	--	--	--	--	100	--	--	10	100	37.9
	Miss.	4.2	--	10	--	--	--	--	60	--	40	10	100	17.8
	Canal	4.3	--	10	--	--	--	--	40	--	60	10	100	13.4
	Wis.	8.0	--	9	--	89	--	--	11	--	--	1	11	--
	Miss.	8.0	--	10	--	--	--	30	30	--	40	7	70	--
	Canal	8.0	--	10	--	60	--	10	30	--	--	3	30	19[d]
	Wis.	11.8	--	9	44	56	--	--	--	--	--	--	--	--
	Miss.	11.8	--	10	--	--	--	80	10	--	10	2	20	--
	Canal	11.8	--	10	--	60	--	--	40	--	--	4	40	18[d]
	Wis.	16.4	--	10	50	50	--	--	--	--	--	--	--	--
	Miss.	16.5	--	10	40	--	10	50	--	--	--	--	--	--
	Canal	16.5	--	10	--	90	--	10	--	--	--	--	--	--
	Wis.	1.8[e]	--	10	--	--	--	--	100	--	--	10	100	12.4
	Miss.	1.8[e]	--	10	--	--	--	--	10	30	60	10	100	7.7
	Canal	1.8[e]	--	10	--	--	--	--	--	80	20	10	100	4.8
	Wis.	.71[f]	--	10	--	--	--	--	100	--	--	10	100	8.4
	Miss.	.76[f]	--	10	--	--	--	--	--	50	50	10	100	4.2
	Canal	.76[f]	--	10	--	--	--	--	--	90	10	10	100	2.5
Untreated controls	Wis.	--	--	10	--	--	--	--	100	--	--	10	100	6.2
	Miss.	--	--	10	--	--	--	--	--	50	50	10	100	2.2
	Canal	--	--	10	--	--	--	--	--	90	10	10	100	1.1

[a] Final inspection at Canal Zone, January 1956.

[b] Retention values in parentheses are based on preservative oxides.

[c] Retention based upon total anhydrous salts: $ZnSO_4 + H_3AsO_4 + Na_2HAsO_4 + Na_2Cr_2O_7$.

[d] Estimate based upon percentage of stakes remaining after final inspection.

[e] 15-min dip at room temperature.

[f] Brush treatment, 2 coats.

This study was initiated by R. M. Wirka.

Table 6.--Condition of southern pine stakes of different sizes, treated with coal-tar creosote, toluene, and creosote-toluene mixtures, after 44-1/2 years of service. Stakes placed in test on the Harrison Experimental Forest Saucier, Miss., May 1941 (Plot 6)

Preservative	Size of stakes	Average retention	Number in test	Condition of stakes December 1985: Good	Serviceable but showing some--: Decay	Serviceable but showing some--: Termite attack	Serviceable but showing some--: Decay and termite attack	Destroyed by--: Decay fungi	Destroyed by--: Termite attack	Destroyed by--: Decay fungi and termite attack	Total removed: Number	Total removed: Pct	Average life
	In.	Pcf		Pct	Pct	Pct	Pct	Pct	Pct	Pct	Number	Pct	Yr
Coal-tar creosote	1/2 by 1/2 by 18	7.8	8	--	--	--	--	88	--	12	8	100	17.1
	1 by 1 by 18	8.0	10	--	--	--	--	40	--	60	10	100	23.6
	1-1/2 by 1-1/2 by 18	7.9	10	--	--	--	--	50	--	50	10	100	26.6
	2 by 4 (nominal) by 18	3.3	10	--	--	--	--	10	--	90	10	100	24.9
	2 by 4 (nominal) by 18	7.8	10	--	--	--	40	20	--	40	6	60	--
	2 by 4 (nominal) by 18	13.2	10	--	--	--	80	10	--	10	2	20	--
Toluene	2 by 4 (nominal) by 18	29.5	10	--	--	--	--	--	90	10	10	100	2.2
Coal-tar creosote: 11.25 pct by weight in toluene	2 by 4 (nominal) by 18	3.4[a]	10	--	--	--	--	30	--	70	10	100	19.1
25.2 pct by weight in toluene	2 by 4 (nominal) by 18	8.1[a]	10	--	--	--	80	10	--	10	2	20	--
39.0 pct by weight in toluene	2 by 4 (nominal) by 18	12.6[a]	10	10	--	--	90	--	--	--	--	--	--

[a] Creosote only.

This study was initiated by R. M. Wirka.

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