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QUANTITATIVE ANALYSIS REPORT OF ALTERNATIVES FOR INTERIM REMEDIATION OF K-65 SILOS

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REPORT

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QUANTITATIVE ANALYSIS REPORT OF ALTERNATIVES FOR INTERIM REMEDIATION OF K-65 SILOS

JULY 1988

REVISION 0

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1.0 EXECUTIVE SUMMARY

During the early (mid-1950s) operational history of the Feed Materials Production Center (FMPC), uranium ore, particularly pitchblende, was processed for uranium content. The result was an accumulation of radium-bearing residues. These materials, along with similar sludges from earlier off-site uranium refining, have been stored in two silos, designated at "K-65" (from the code name of the original residues). At present, the radiation exposure rates on the surfaces of the two silo domes are approximately 145 and 185 mr/hour, and the radon emission levels have been found at 20 to 45 pCi/liter.

The radiation levels, and particularly the continual emission of radon, have created the need for a specific remediation program. The problem has been exacerbated by structural weakness in the center 20 feet of each of the two K-65 silos. Thus, the purpose of the studies presented herein is to respond to Item 6 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section of the Federal Facilities Compliance Agreement (FFCA) between the Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). To accomplish these goals, the study includes provisions for the interim control of radon gas and radon decay product emissions, as well as consideration of the structural integrity of the silos.

A group of 13 alternatives for radon attenuation were screened together with four silo dome support methods and combinations. From these, two classes of support systems emerged: foam-in-place expanded polymer layers and loose-fill granular materials such as sand.

No continuous polymer foam structure of these dimensions (80 feet diameter) has ever been produced to date. Uncertainties about application methods and dimensional stability led to the request by Westinghouse Materials Company of Ohio (WMCO) to make a large-scale pilot study before proceeding further with this option. A consideration of the economics of the pilot test obviated the continuance of this option.

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The remaining preferred alternatives were explored further as to methods of application, technical feasibility, structural assessment (at a later date), radiological impacts, health and safety considerations, and approximate costs. The most suitable interim remediation at this time appears to be addition of a layer of sand approximately 4 feet deep over the surface of the K-65 sludges within each silo. Structural analysis has shown (will show) that this solution will not significantly increase chances for failure of the domes. Additional details of schedules and steps to implement this procedure are given at the conclusion of this study.

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2.0 INTRODUCTION

2.1 SITE DESCRIPTION AND HISTORY

The Feed Materials Production Center (FMPC) was constructed and began operations at the Fernald site in the early 1950s. The U.S. Atomic Energy Commission, predecessor to the U.S. Department of Energy (DOE), established this integrated production complex for processing uranium and its compounds from natural uranium ore concentrates for the needs of the United States government. Initially, uranium ore concentrates, and presently, recycled materials, are converted to either uranium oxides or uranium ingots and billets. They are machined or extruded into tubular form for production reactor fuel cores and target fuel element fabrication.

From 1953 through 1955, the FMPC refinery processed pitchblende ore from the Belgian Congo. No chemical separation or purification was performed on the ore before it arrived at the FMPC. Beginning in 1956 the refinery feed consisted of uranium concentrates (yellowcake) from Canada and the United States.

No uranium ore is currently being received at the FMPC. The basic process performed now is the conversion of uranium-containing residues, uranium hexafluoride, and uranium tetrafluoride to uranium metal.

2.2 K-65 SILO HISTORY AND DESCRIPTION

The two K-65 silos, which are on the west side of the FMPC, were constructed in 1951 and 1952. The silos are used for storage of radium-bearing residues, a by-product of the uranium ore processing. The silos are structurally solid with the exception of a 20-foot diameter center section of the dome. At present, two interim stabilization projects are underway to provide radon release control and provide some structural reinforcement to the degrading condition of the dome center section. Phase I, the external foam application results, are reported in WMCO's TD: 88-056 letter. Phase II, the internal attenuation layer application, is scheduled for fall 1988.

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2.3 K-65 SILO WASTE CHARACTERISTICS

The current volume of K-65 residues contained in the silos is estimated to be 195,000 cubic feet (8700 MT). The chemical and radiological characteristics of the K-65 residues are summarized in Paragraphs 2.3.1 and 2.3.2 below. The total void volume above the stored residues is estimated to be 87,500 cubic feet (No. 1 of 38,000 cubic feet and No. 2 of 48,000 cubic feet).

2.3.1 Chemical Characteristics

Approximately 40 percent of the K-65 material is composed of silicates (SiO_2). The other constituents that make up 1 percent or more of the residue include calcium, iron, magnesium, and lead. No organic constituents are known to be present in the K-65 residues, although confirmatory data are not available.

2.3.2 Radiological Characteristics

The radiological constituents of the K-65 residue have been estimated to include 11,200 kg of uranium (0.71 percent U-235) and 3000 Ci of radium (Ra-226). The radium concentration is 311 mg Ra-226/ton residue. Radon flux measurements made in October 1984 at 24 locations on each silo ranged from 123 pCi/m^2/sec to more than 3 x 10^7 pCi/m^2/sec. The highest flux values were obtained on surfaces that contained observable cracks.

At present, the radiation exposure rates on the surfaces of the K-65 silo domes are approximately 145 and 185 mrem/hour, and the radon emission levels monitoring results are 45 pCi/liter and 20 pCi/liter, respectively.

2.4 INTERNAL ATTENUATION LAYER SELECTION

The internal attenuation layer is intended to reduce both the levels of radon gas and gamma radiation emitted from the silo residues. Initially, this layer was also intended to provide support for the weakened portion of the silo roof; however, recent inspection of the silos and other developments have resulted in decoupling the roof support from the attenuation layer so that independent systems that provide either attenuation or roof support can be evaluated separately. This report discusses the various methods and combinations of methods proposed to accomplish these tasks and the selection of the methods determined to be the most feasible.

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3.0 INITIAL SCREENING OF ALTERNATIVES

The initial development of various alternatives for the attenuation of the radon and gamma and the support of the silo roof resulted in the following list.

RADON ATTENUATION METHODS

- Venting of air space in silos
- Modification of existing radon treatment system
- Three-foot rigid foam layer on sludge surface
- Three-foot foam layer on top of sludge with elastomer seal to silo
- Permanent or reversible gels
- Organic melts
- Latex emulsion
- Bentonite
- Cementitious materials
- Activated carbon
- Magnesium sulfate, silica gel, etc.
- Transfer of Silo 3 material into Silos 1 and 2
- Other granular solids and combinations.

SILO DOME SUPPORT OR COMBINATION

- Dome cover
- Elastomeric membrane
- Loose/supporting material over radon attenuation layer
- Inflated bladder within top of silo.

These options were evaluated according to the following criteria:

- Application ease
- Exotherm
- Dimensional stability
- Technical complexity
- Impact on final remediation
- Public perception
- Environmental and safety considerations.

Reference Appendix A for the June 1988 report entitled "Qualitative Feasibility Study of Alternatives for Interim Remediation of K-65 Silos."

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3.1 DISCUSSION AND SELECTION OF ALTERNATIVES FOR FURTHER EVALUATION

The listed alternatives provide either radon and gamma attenuation, or roof support. In order to provide both roof support and radon attenuation, some combination of alternatives may be necessary. Those combinations will be addressed in later sections of this report. The alternatives in this section will only be evaluated relative to their performance for that criteria and relative to the others in the category.

Radon can be controlled by either stopping or reducing the emission from the sludge by placing a barrier over the sludge or by collecting and treating the radon as it is emitted from the silo. The first two options treat the emitted radon by controlling the release. The first option was eliminated from further consideration because it did not provide positive control of the radon and no reduction in the gamma emitted from the silo. The second option would require further testing to determine carbon capacity since radon treatment systems utilizing activated carbon are designed for intermittent use. The degree of capacity loss due to the decay products is not known. Gamma emission is not reduced.

The application of a spray foam layer to attenuate the radon by stopping its diffusion into the atmosphere was considered to be a likely candidate. A detailed study of this option was presented to WMCO in the report, "Engineering Study of the K-65 Storage Silo Radon Mitigation and Dome Reinforcement Project at the Feed Materials Production Center," August 20, 1987, by IT Corporation and Advanced Science, Inc. However, no continuous polymer foam structure of these dimensions (80-foot diameter) has ever been produced to date. Uncertainties about application methods and dimensional stability led to the request by WMCO to perform a large-scale pilot study. The draft of the "Mock-up and Demonstration Plan for Foaming of K-65 Silos" is provided for reference in Appendix B. The conceptual cost estimate for the test of approximately $300,000 eliminated this option from further investigation.

Addition of some type of organic polymeric-type materials, including gels, asphalts, and latex emulsions, had some interesting possibilities but were finally rejected because the materials had not been tried before and no real data existed for this type of application. In addition, all materials had the potential for producing a mixed waste.

Inorganic slurries and cement-type materials were also considered but finally rejected because they also required some development. Lightweight cements were finally rejected because of the potential for cracking and lack of dimensional stability.

Activated carbon, magnesium sulfate, silica gel, and similar materials were rejected because the water in the slurry would be adsorbed into the material and reduce the radon attenuation capacity. The concept of a dessicant layer between the sludge and the carbon was eliminated because there is more water in the sludge than can be adsorbed in a dessicant layer that would fit inside the silo.

The transfer of Silo 3 material into Silos 1 and 2 was considered because the material was available, already a low-level waste, and could attenuate the radon and gamma. It was finally rejected because of public and regulatory concerns for handling the material twice (i.e., transferring to the silos and in the final remediation).

The granular fill option is considered the most promising. Sand, fly ash, contaminated soil, gypsum, or lime could be used. These materials are readily available and pose no significant development or handling problems since they are all currently available in bulk. Uranium mill tailings and radium tailings are currently attenuated with a layer of soil. This option will be developed further.

Dome supports that were rejected include an inflatable bladder, a dome cover, and an elastomeric seal. The bladder was rejected because of installation and potential puncture problems. The dome cover and the elastomeric seal were rejected because of installation problems. They would also have to be combined with a radon/gamma attenuation layer, and as such do not offer any advantage over the addition of a loose fill above the attenuation layer for silo roof support.

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The preliminary evaluations have resulted in the following combinations for final screening:

- Granular fill material to provide a radon attenuation layer only
- Granular fill layer combined with loose fill to provide silo roof support
- An elastomeric membrane above the granular fill to provide an impervious seal on the attenuation layer, both with and without the loose fill.

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4.0 FINAL SCREENING OF ALTERNATIVES

As a result of the initial screening, the following granular fill/loose fill combinations will be evaluated further for the temporary remediation of the K-65 silos:

1. A loose fill of styrofoam "peanuts" only
2. A loose fill of vermiculite/perlite only
3. A 4-foot layer of sand
4. A 4-foot layer of fly ash
5. A 4-foot layer of sand/fly ash with an elastomer seal
6. A 4-foot layer of sand/fly ash with peanut fill
7. A 4-foot layer of sand/fly ash with elastomeric membrane and peanut fill.

A total of about 76,000 cubic feet is required to completely fill both silos. For the 4-foot attenuation layers alone, only 40,000 cubic feet are needed for both silos together. The evaluations are done with the same criteria as in the initial screenings except for the exotherm criteria, which is not applicable in these cases, and the addition of a cost criteria.

4.1 STYROFOAM PEANUTS

Summary

Styrofoam peanuts are extensively used for packaging and protection of all types of materials. These peanuts are lightweight and, of the materials considered here, are probably the easiest to add to the silo. The peanuts can be airveyed into the silo from the bulk carrier. The application method would also allow the silo to be completely filled, and would minimize the ALARA concerns because no one would be on top of the silo except to assemble, locate, and move the airveying system. A screen with a high-efficiency particulate air (HEPA) filter would be needed over the exhaust manhole to vent

How much radon + radon daughters will collect and accumulate on the filter? Is this a safe situation?

the air. Radon and gamma mitigation would be minimal due to the extremely low bulk density of the peanuts. Upon remediation, the peanuts could be sucked or blown out, compacted, and then buried or burned.

Evaluation Criteria

Application Ease - Because the peanuts are lightweight and can be applied with air, the installation would be relatively simple. The delivery trucks usually come equipped with a blower for the transfer of the peanuts. A transfer duct from the truck to the silo would have to be constructed and a screen with a HEPA filter placed on an exhaust manhole for the air to escape. (1)

Dimensional Stability - The peanuts, because they are loosely packed, will settle and may require an additional application to fill the voids caused by settling. (2)

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Technical Complexity - Minor, because this type of material handling is commonplace.

Impact on Final Remediation - Because the bulk density of the peanuts is about .338 pound/cubic foot and the absolute density is .665 pound/cubic foot, the (3) material can be compacted to reduce the volume. Hot melt roll compactors are available to compress and melt the peanuts. They could also be burned. (4)

Public Perception - Would probably meet with some skepticism.

Environmental and Safety Considerations - The peanuts would provide minimal mitigation of the radon and gamma radiation due to its low density and high void space. The filled silo would provide some protection against roof failure except that the peanuts may compact under the weight of any concrete that may fall and compromise the mitigating effect of the material.

(5) Cost - The cost of 76,000 cubic feet of peanuts is about $44,000 including freight. Installation costs would include construction of the portable duct work, the exhaust system, and installation technicians. About 2 hours per

truck are required for unloading. At four trucks per day and a total of 20 trucks to supply the necessary amount of peanuts, 5 days are required to install the peanuts. This assumes there are 76,000 cubic feet of peanuts stockpiled somewhere, so a long lead time may be required to accumulate that much material.

4.2 VERMICULITE/PERLITE

Although vermiculite and perlite are technically different materials and each material comes in various grades, they will be considered as one for this application because the major physical characteristics of the two materials are similar.

Summary

This material is used as poured fill insulation in concrete block walls, filter aids, additives for concrete etc. The material is an expanded form of an inorganic silicate that exhibits excellent insulating properties, moisture resistance, and nonflammability. Unfortunately, the material is only available in 4-cubic foot bags so the installation would require handling bags of material in addition to the conveying and distribution of the fill in the silo. The bags could be emptied into a hopper and airveyed into the silo; however, the vendors do not recommend this method because vermiculite tends to clog the transfer system. The normal method of adding the material is to dump from the bags directly into the silo. This would cause additional ALARA concerns because personnel would have to be on the silo during the operation. The vermiculite would provide some radon and gamma attenuation although its bulk density is relatively low. Material and installation costs are higher than the costs of styrofoam peanuts, and the ALARA concern would be greater.

Evaluation Criteria

Application Ease - The addition of the vermiculite/perlite would be more complex than the peanuts since the material comes in bags and would require more handling and exposure to the silo contaminants.

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Dimensional Stability - The material is more dense than the peanuts and exhibit less of a tendency to settle; however, some settling may still occur. Additionally, it would be difficult to fill the area under the dome and above the manholes to provide support to that portion of the dome.

Technical Complexity - The additional handling associated with the bags and the difficulty of filling under the dome makes this more difficult than peanuts alone.

Impact on Final Remediation - The material could be compressed somewhat prior to disposal, but not nearly as much as the peanuts. Removal could be done by vacuum; however, the same problems that are evident with airvey installation may occur. Because the material is a loose fill, it could be removed with the silo contents and disposed.

Public Perception - The public may not be convinced about the applicability of this attenuation method.

Environmental and Safety Considerations - The vermiculite/perlite would provide better attenuation of the radon and gamma than the peanuts; however, it may not provide positive support to the dome because it would be difficult to get the material under the dome and above the manholes.

Cost - Enough vermiculite to fill the silo would cost about $83,000, including delivery. Additional costs for installation and the ALARA concerns would make this option very expensive.

4.3 SAND

Summary

Sand is a readily available, inert material that could be used to mitigate the radon and gamma radiation and provide silo support. A 4-foot layer of soil is commonly used for radon mitigation of radium tailings, so an equivalent layer of sand should provide similar results. Sand is relatively cheap and easily handled. Air could be used to install the sand; however, its density (about

100 pound/cubic foot) would require a sizable blower and its tendency to dust would create problems with the silo exhaust air. A portable conveyor would probably be the most efficient method of installation. Sand is available in bulk. As with the vermiculite, sand would be difficult to fill in the area of the silo above the manholes and below the dome so some measure of silo support could be lost. An even layer may also be difficult to achieve, but if the minimum thickness is obtained, this should not be a problem. Sand is not compressible, so remediation would have to contend with the entire volume of sand added. ALARA concerns would be improved since the installation is done remotely (conveyor) and the sand would provide adequate attenuation of the radon and gamma.

Evaluation Criteria

Application Ease - The sand is relatively dusty so the installation procedure would require an efficient dust control system, including a HEPA filter.

Dimensional Stability - The density of the sand and its particle size would make it quite stable. Very little settling would be expected if the moisture level in the silo does not change. Based on recent video tape data obtained by WMCO, the silo contents appear to be packed and stable enough to support the sand. The sand would not be expected to dry and crack after installation since the silo is under essentially constant humidity.

Technical Complexity - Bulk transport and handling of sand is common.

Impact on Final Remediation - Removal with the contents would be the most desirable. The sand may be able to be separated into a contaminated layer and uncontaminated layer for ultimate disposal. Volume reduction is not otherwise possible.

Public Perception - Probably better than with peanuts or vermiculite.

Environmental and Safety Considerations - This probably provides the best overall safety margin for radon and gamma attenuation because soil is commonly used for radon attenuation. Even though the sand may not be able to fill the void under the dome above the manholes, the thickness of the sand at that point would provide adequate protection from roof failure because the falling concrete would probably not impact the sand deeply, and sand provides excellent support for falling material.

Cost - Sand is quoted in Cincinnati at $4.60 per ton delivered locally. Material costs for the 4-foot attenuation layer in both silos would be approximately $12,466. Bulk delivery to the portable conveyor and installation should be fairly simple.

4.4 FLY ASH

Summary

Other than a lower density (about 45 pound/cubic foot) and a different overall inorganic composition, fly ash would have similar characteristics as sand for this application. Fly ash has one major advantage over sand in that it is "free", on-site and has to be disposed of somehow anyway. Radon attenuation, silo support, and ALARA considerations should be similar to sand. Gamma attenuation will be less for the same thickness of fill. Installation procedures would be similar to sand and the same concerns for dusting would have to be addressed.

Evaluation Criteria

Application Ease - Other than having to load the material onto trucks to transport to the silos, the application should not be much different than sand.

Dimensional Stability - Similar to sand. Some settling may occur but it should be insignificant. Drying and cracking should not be a problem.

Technical Complexity - Process involves the bulk handling of a dusty material.

Impact on Final Remediation - The fly ash has to be disposed of at some point anyway, although it currently is not low-level waste. It is not "new" material to be disposed of as any of the other methods would create.

Public Perceptions - Should be fairly positive.

Environmental and Safety Considerations - The other methods introduce a new material that has to be remediated; this method does not. The fly ash would provide radon attenuation and silo support equivalent to the sand; gamma attenuation would be lower in comparison, and ALARA would be slightly higher because of the lower gamma attenuation.

Cost - Probably the lowest of all methods because the only cost will be installation. Installation cost will be slightly higher than sand because the fly ash has to be picked up and transported.

4.5 SAND OR FLY ASH WITH AN ELASTOMERIC MEMBRANE SEAL

Summary

Application of a spray coating of an elastomeric membrane on top of a layer of fly ash/sand could add additional radon attenuation; however, it would not provide any additional gamma attenuation or protection from silo roof failure. The application of the membrane would be complex because an additional step is required. This additional step is also a complex spraying application that requires uniform distribution across the surface of the fill material. ALARA concerns would be increased because additional personnel would be on top of the silo for a longer period of time; although during the membrane addition step, the fill material would be providing increased protection from the radon and gamma radiation. Failure of the silo roof would breach the membrane and the fill material would be left to provide attenuation.

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Evaluation Criteria

Application Ease - The addition of the elastomer would provide additional complexity to the installation of the materials.

Dimensional Stability - The granular fill would be quite stable. The membrane, by definition, is flexible.

Technical Complexity - The membrane addition is more complex than any of the previous options.

Impact on Final Remediation - The membrane would have to be disposed of along with the silo contents. The volume of the material would be small compared to the silo contents.

Public Perception - Politically, a "seal" on the silo contents may have positive public perception.

Environmental Safety Concerns - The membrane would provide a relatively impervious seal to radon diffusion; however, a sufficient sand/fly ash layer would also provide adequate attenuation. The membrane would not provide any protection from roof failure because it would be breached by the concrete, and attenuation would be based on the fill layer alone.

Cost - The membrane application would add significant cost to the project.

4.6 SAND OR FLY ASH WITH PEANUT FILL

Summary

This option is an extension of the sand or fly ash option with the addition of peanuts (or vermiculite) to the space under the dome where the sand or fly ash cannot be placed. This provides no additional radon or gamma attenuation, but may provide some roof support.

Evaluation Criteria

Application Ease - Somewhat more complicated because the additional step for the peanut fill has been included.

Dimensional Stability - No significant settling of the sand/fly ash fill is expected; although, the peanut fill may settle somewhat, this should not present a problem.

Technical Complexity - Obviously more complex than sand or fly ash alone, but because the volume of peanuts required will be relatively small, this should not be too much of a problem. The air transfer system may cause some dusting of the fill already in the silo.

Impact on Final Remediation - The peanuts would have to be removed, compacted, and then burned or buried. They may not be low-level waste. The other fill would be disposed of with the silo contents. Some of this fill could be segregated.

Public Perception - May perceive the roof support as positive although the peanuts may be seen with some skepticism.

Environmental and Safety Considerations - The peanuts on top of the fill material do not gain any significant technical or safety advantage over fill alone. Political impact may be positive. ALARA concerns about the additional time to add the peanuts could be offset by the attenuation provided by the fill material.

Cost - The cost for 36,000 cubic feet of peanuts will add $21,000 to the cost of the fill material used.

4.7 SAND OR FLY ASH WITH AN ELASTOMERIC MEMBRANE AND PEANUT FILL

Summary

This option includes an attenuation layer of sand or fly ash, an elastomeric membrane, and peanut overfill. The purpose of this combination would be to provide attenuation, seal the silo, and provide roof support. The peanuts would protect the membrane from damage if the roof were to fail. Installation of this combination would be the most complex of the options discussed here. This option offers little improvement in radon and gamma attenuation and provides negligible roof support. Installation of this combination would be very complex and expensive. Public perception may be positive.

Evaluation Criteria

Application Ease - The most complex of all the options. Three steps: installation of the fill, spray application of the membrane, and fill with the peanuts.

Dimensional Stability - Sand or fly ash should be stable; membrane will stretch and shrink as needed, and the peanuts may settle and compact somewhat.

Technical Complexity - Several steps of application will increase the complexity of the project. The application of the membrane over an uneven layer of sand or fly ash may be difficult.

Impact on Final Remediation - More material to remove. Styrofoam peanuts and membrane will be disposed as organics. They should not be contaminated with radioactivity. The fill will be removed with the silo contents.

Public Perception - This may be perceived as the most acceptable method for temporary silo remediation.

Environmental Safety Considerations - The membrane is impermeable to the radon; however, the sand or fly ash layer should be sufficient to attenuate the radon. Therefore, the membrane only increases the margin of safety. The membrane provides no gamma attenuation. The peanuts only provide cushion for roof failure and protection from membrane penetration by falling debris. A layer of sand or fly ash thick enough to attenuate the radon and gamma radiation will be sufficient, to provide protection should the roof fail. The additional time required to install the membrane and peanuts, in contrast to the attenuation provided by the fill material, will have to be evaluated for ALARA concerns.

Cost - Material costs of $21,000 for the peanuts, $12,466 for the sand, and the cost of installation for the membrane make this option the most expensive of all the alternatives.

4.8 DISCUSSION

The overall, unweighted evaluation of the options considered in the final screening clearly shows that the sand and fly ash attenuation layers alone are the best alternatives of those considered (see Table 4-1). These two options provide effective radon and gamma attentuation, as seen from the ALARA evaluation. The use of sand/fly ash is an extention of the Uranium Mill Tailing Remedial Action Program (UMTRA) findings. Reference "Engineering Guides For Estimating Cover Material Thickness and Volume for Uranium Mill Tailings" in Appendix C. A minimum 4-foot layer provides an effective barrier from debris should the roof fail. Radon and gamma attenuation are provided by the sand/fly ash layer, and the dome roof integrity is not critical. Recent video tape information obtained from WMCO of the inside of the silos showed no scaling of the concrete roof, which indicates the integrity is better than the earlier reports had indicated. Roof failure into the silo therefore is less likely. The addition of peanuts or vermiculite on top of the attenuation layer provides no additional support of the roof. It does, however, enhance the safety margin by acting as a plug and cushioning the attenuation layer if the roof should collapse. The addition of peanuts adds a significant difficulty in application, cost, and final remediation. The installation of a membrane over the sand or fly ash, and with or without the loose fill (peanuts or vermiculite), also adds significant cost and difficulty in application without any technical improvement in attenuation. The loose fill alone provides essentially no attenuation.

The option chosen as the preferred alternative is the 4-foot sand or fly ash attenuation layer. Both sand and fly ash will be evaluated because the similarities and advantages are comparable.

Table 4-1. Evaluation Comparison Chart

Option	Evaluation Criteria A	B	C	D	E	F	G	Overall
Peanuts	1	7	1	3	7	7	4	30
Vermiculite	4	6	4	4	5	6	5	34
Sand	2	1.5	2	2	4	4	2	17.5
Fly ash	3	1.5	3	1	3	4	1	[redacted]
S or FA + Peanuts	5	4.5	5	5	6	4	3	32.5
S or FA + Membrane	6	3	6	6	2	2	6	31
S or FA + Membrane + Peanuts	7	4.5	7	7	1	1	7	34.5

Overall ranking is the sum of the individual rankings with no weighting. Each ranking is 1 for best to 7 (there are seven options) for worst of each criteria. A 7 does not necessarily mean that the item does not meet minimum performance requirements for that criteria; it just means the other cases are better at that particular criteria.

Evaluation criteria are defined as:

A. Application ease
B. Dimensional stability
C. Technical complexity
D. Impact on final remediation
E. Public perception
F. Environmental safety considerations
G. Cost.

5.0 DEVELOPMENT OF PREFERRED ALTERNATIVES

5.1 APPLICATION

5.1.1 Method

The preferred alternatives for development are to inject a mitigation layer of sand or fly ash into the silos. The application method at the silos is identical for both alternatives. The only difference lies in transport of the material to the silos. Sand would be received in bulk trucks from off site. Fly ash is currently stockpiled on site. It would have to be loaded into a dump truck and hauled to the silos.

The current application plan is to utilize front end loaders, feed hoppers, belt conveyors, spreaders, and a dust collection system as illustrated in Figure 5-1. Two complete lines of equipment will be used to minimize fill time (to approximately 17 hours). Use of commonly available rental conveyors 68 feet in length requires that a 10 by 23 feet in length section of the embankment around each silo be excavated. This would need approval by WMCO and should be considered when performing the structural assessment.

Sand or fly ash will be hauled to the silo in 20-ton dump trucks. The material will be alternately offloaded next to the feed hopper of each system creating two stockpiles. A Bobcat® will be used to load the stockpiled material into the feed hopper. There is a slide gate valve at the hopper discharge to throttle the granular material onto the conveyor. The rubber cleated belt conveyor will carry the material up to the discharge chutes mounted on the manholes. At the two access manholes, spreaders will be installed to distribute the material evenly throughout the silo. Displaced air from the silo will be vented by a blower or fan through a dust collector and HEPA filter. The current intent is to support the spreaders and discharge chutes from the manholes, unless the structural assessment by Carmargo indicates that this is not feasible.

The radon removal system will be operated prior to removal of the manholes. It will not be operated during the filling operation due to dusting. If work

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STARTING DATE: 6-21-88	DATE LAST REV.:	INITIATOR: K. SHELL	DRAWING NO.: 303317 B M01
DRAWN BY: GUIGNARD	DRAWN BY	PROJ. ENGR: D. HARMER	PROJECT NO.: 303317

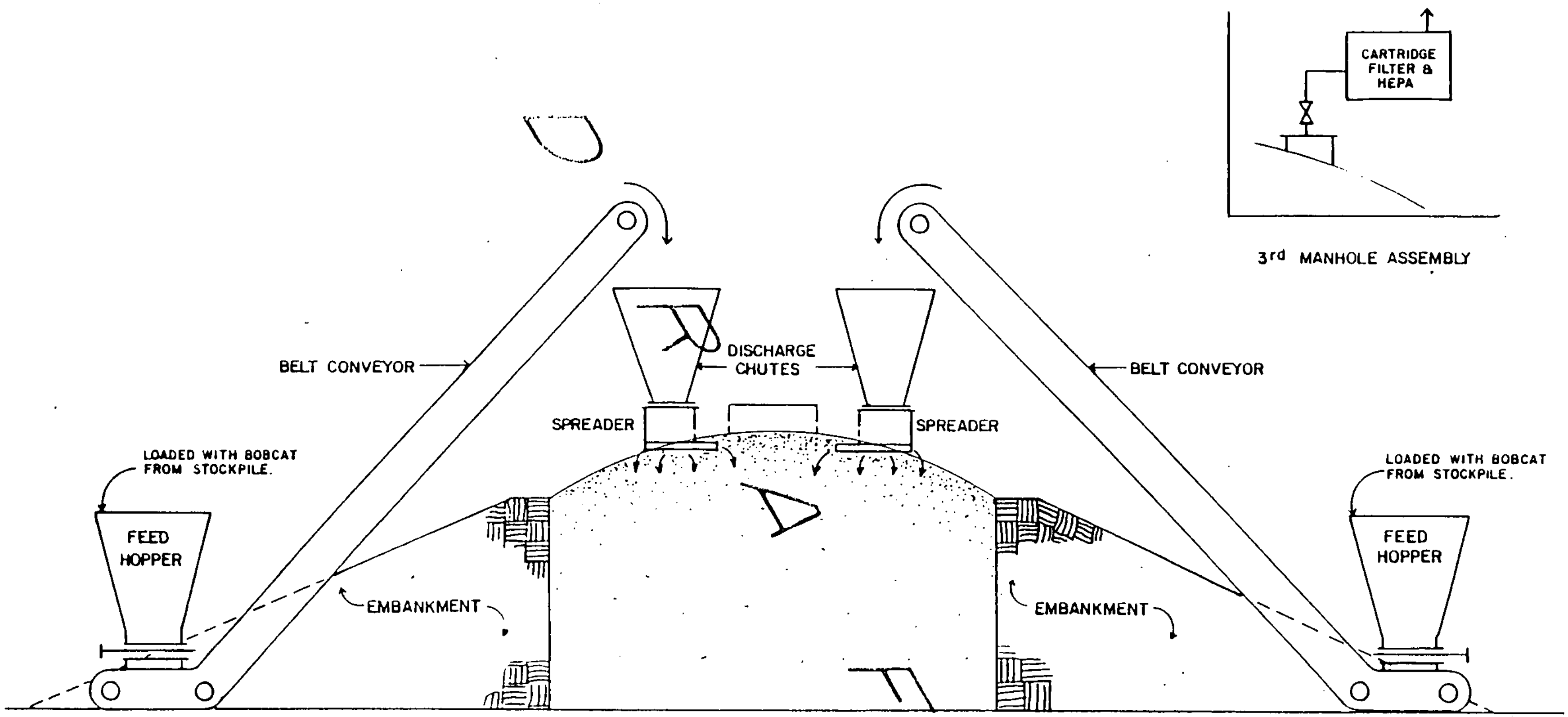

FIGURE 5-1, PROPOSED GRANULE ADDITION SYSTEM FOR K65 SILOS.

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is delayed for more than one work shift, radon monitoring equipment will be used to determine radon level in the silo head space. If radon levels exceed 3.0×10^6 pCi/l in the silos, the radon system will be reinstalled and accumulated radon removed before work is continued.

5.1.2 Equipment

The list of major equipment is provided in Table 5-1. All equipment can be rented except for the spreaders, dust collector, and HEPA filter, which must be purchased.

5.1.3 Availability

Rental equipment is available locally. Reference vendor telephone conversations documented in Appendix E. The dust collector, HEPA filter, and spreaders are stock items with 2- to 4-week delivery.

5.1.4 Schedule

The earliest start date is 4 weeks from the receipt of a signed task order dependent on equipment delivery. Site work duration is estimated at 1 week. Actual application duration is estimated at 2 days. Reference the schedule provided in Figure 5-2.

5.2 TECHNICAL FEASIBILITY

The addition of sand or fly ash to the K-65 silos is a relatively simple procedure and should effectively reduce radon emissions from these silos. The fill material will have the added benefit of reducing the gamma radiation from the silos. Although it is not expected that the addition of sand will cause structural problems with the silos, this must be confirmed by performing a detailed structural analysis (the Carmargo Report is being revised). Also, while the sand or fly ash cannot support the dome structure, they will provide radon containment even if the dome collapses. During the addition of the sand or fly ash to the silos, air emissions of radon and particulate will be controlled. Sand and fly ash are excellent fill materials because they are inert, not affected by radiation, not hazardous, not flammable, and readily available. The recent video inspection of the interior of the silos has reduced earlier concerns that the sand might displace or sink into the sludges

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Table 5-1. Major Equipment

Number Required	Item
2	Conveyors (Minimum 68 feet long)
2	Spreaders
2	Hoppers
4	Bobcats
1	Dust collector
1	HEPA filter
1	Hydraulic power unit
1, 3[a]	Front end loader
2[a]	20 ton dump truck
2	Conveyor discharge chutes

[a]For fly ash only.

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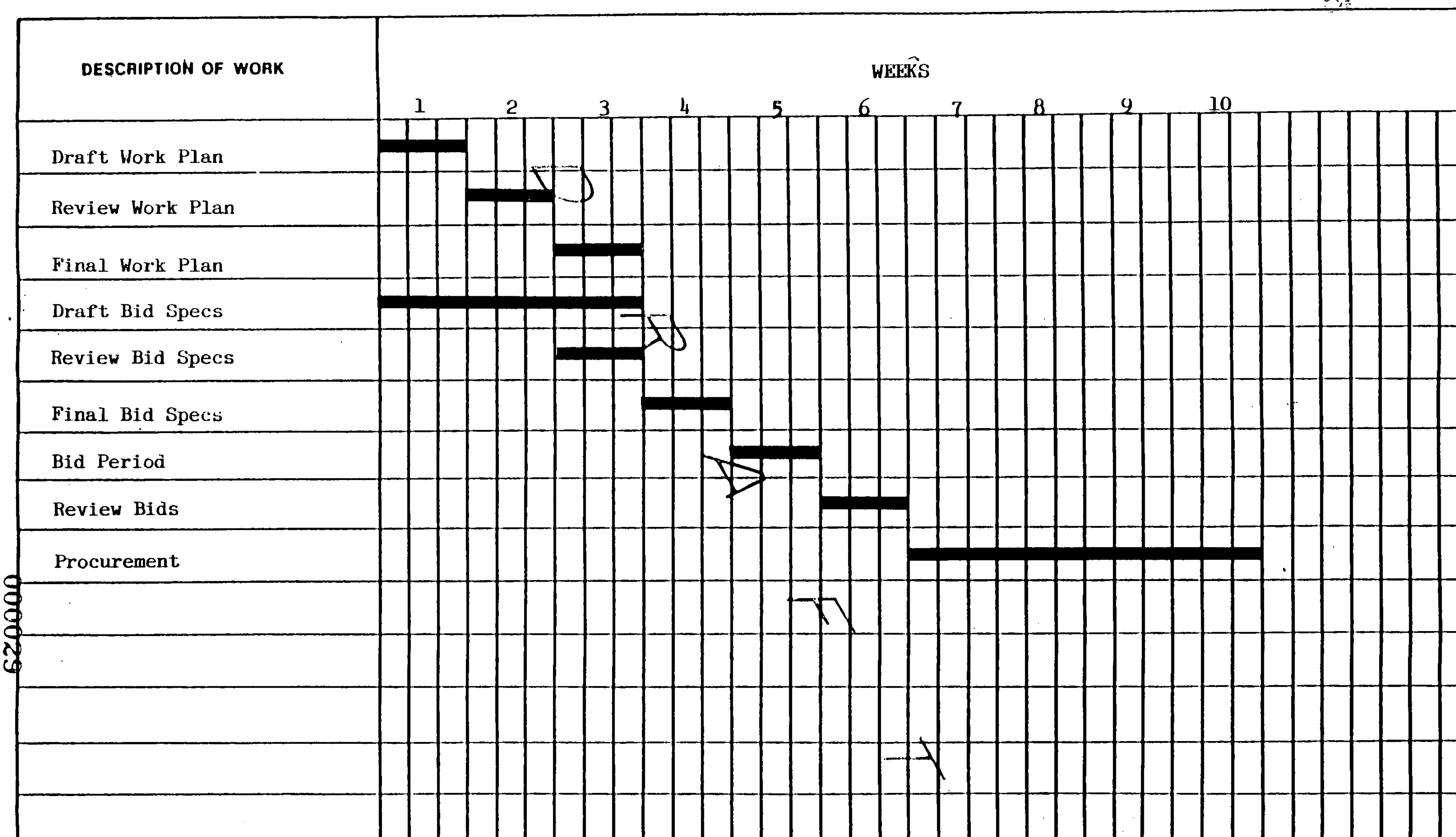


REMARKS:

MADE BY: K. Shell

DATE: 6/16/88

LAST REV. DATE:

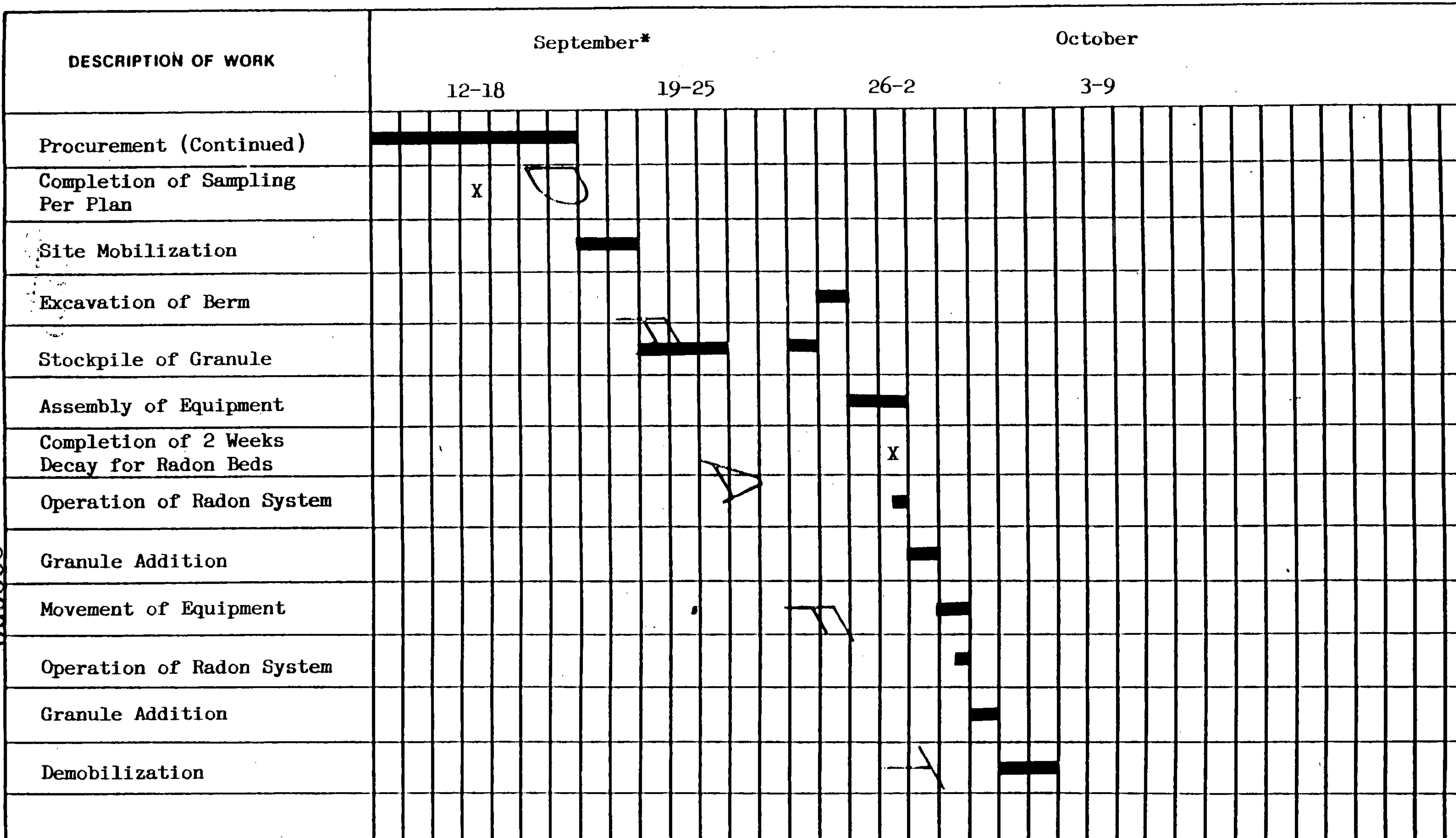
Figure 5 [illegible] Proposed
Projec[illegible]hedule

PROJECT SCHEDULE

FOR: Mitigation of K-65 Silos
Phase I

JOB NO. 303317

SHEET 1 OF 2



REMARKS:

*Assuming Week 1 of Phase I Begins July 1

MADE BY: K. Shell

DATE: 6/16/88

LAST REV. DATE:

Figure 5-2. Proposed Project Schedule

PROJECT SCHEDULE

FOR: Mitigation of K-65 Silos

Phase II

JOB NO. 303317

SHEET 2 OF 2

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in the silos. The silo wastes are now reported to be dry enough to form surface cracks and should support the sand.

5.2.1 Radon/Gamma Reduction

The effectiveness of various thicknesses and types of sand is discussed in a draft report by G. S. Mihalouich of Rogers and Associates Engineering (RAE). This report is attached in Appendix C. In this work, computer models were used to predict the diffusion of radon and shielding of gamma radiation through a bed of sand. The model predicted that, depending on the type of sand used, radon emission reduction by a 5-foot deep bed ranged from 100 to 89 percent. Gamma reduction for the same cases was 83 to 73 percent. A masonry sand provided the highest reduction of both radon and gamma radiation and would be recommended. Because particle size, density, and moisture content for the fly ash are not available, the effect on radon emissions cannot yet be modeled. This should be studied if fly ash is to be considered.

5.2.2 Structural Implications

The proposed remedial action is to provide a layer of sand approximately 4 feet in thickness on top of the existing K-65 material. Assuming the sand weighs 100 pounds per cubic foot, the increase in weight of the total contents is approximately 20 percent.

Because the weight increase is significant, the silo should be evaluated to determine what impact this increase will have. This should be a detailed structural analysis of the silo with the additional weight.

5.2.3 Structural Assessment (to be added)

5.3 ULTIMATE REMEDIATION FEASIBILITY

One of the major advantages of this option is that the sand or fly ash should not complicate the final remediation of the K-65 silos. The silo residues are similar in physical form to sand or fly ash such that they could be remediated together. This would, however, add approximately 20 percent to the amount of

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material to be remediated and ultimately disposed. This would probably result in a proportionate increase in remediation cost as a result of the increased volume.

Some remediation procedures, such as solidification and vitrification, require addition of sand and other materials to enhance the treatment process. If solidification or vitrification is chosen as the final remediation method for the silos, then the addition of the sand or fly ash becomes a benefit.

Overall, the effect of the addition of the sand or fly ash to the silos as an attenuation layer would have a minimal impact on the final remediation of the silos and their contents.

T

5.4 ENVIRONMENTAL AND SAFETY CONSIDERATIONS

F

5.4.1 ALARA

An ALARA review of the K-65 residue Silos 1 and 2 was conducted in accordance with the Statement of Work. Various granular fill materials were considered in multiple depths for radon attenuation and gamma shielding. The mode of material conveyance into the silos was determined using good engineering practices and giving considerations to efficient operations and ALARA concerns.

A R D

The fill materials reviewed were styrofoam "peanuts", vermiculite, sand, and fly ash. Given bulk densities and desired depths of materials, estimated necessary manpower, and time required for transfer, dose estimates were made (reference Table 5-2 and Appendix D). Using the time, distance, and shielding components of ALARA, the component that has the most bearing on dose reduction is time. The greatest dose for this fill project is contributed by the relatively short duration spent on the unshielded silo roof performing setup tasks. Each type of fill requires essentially the same setup time, and obviously the estimated dose for this event for various materials differed very little.

The next ALARA factor of greatest impact is the distance afforded by remote filling methods. Shielding is one of the desired results of the fill, and at least initially, little shielding is afforded.

Table 5-2. Summary of Dose Estimates

Shield Material	Rate[a] (mR/hr)
Air	71.04
Sand	
1 foot	5.31
2 foot	.46
3 foot	.04
4 foot	.005
Styrofoam peanuts (fills airspace)	66.33
Vermiculite (fills airspace)	16.72
Fly ash	
1 foot	22.32
2 foot	6.81
3 foot	2.19
4 foot	.73

[a]Dose point at 81 cm above surface of dome lid.

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The estimated radiation exposure for the K-65 Silo granular fill project ranges from 1917.5 mrem to 3250 mrem depending on the material used. Given the practical knowledge that a slippage in the schedule could adversely affect the exposure estimate, a correction factor of 2.5 was assigned to the calculated dose estimates. The correction factor, 2.5 x, is consistent with previous ASI assumptions. Density (shielding property) of the materials and the mode of conveyance affect the final dose assessment.

Material Versus Dose

- Styrofoam peanuts - Complete fill dose at silo dome reduced from 72 mR/hour to 66.3 mR/hour at the expense of 813 mrem exposure
- Vermiculite - Complete fill dose at silo dome reduced from 72 mR/hour to 16.7 mR/hour at the expense of 1300 mrem exposure
- Sand - Four feet fill dose at silo dome reduced from 72 mR/hour to 0.005 mR/hour at the expense of 767 mrem exposure
- Fly ash - Four feet fill dose at silo dome reduced from 72 mR/hour to 0.73 mR/hour at the expense of 845 mrem exposure.

In addition to determining the gamma shielding effect, radon attenuation afforded by the various fill materials is a major factor in the final selection for mitigation. Only the sand, with its limited suggested depth of 4 feet, effectively eliminates all measurable radon emissions.

5.4.2 Health and Safety

This section covers non-ALARA health and safety concerns. In general, the work under this project will follow the guidelines of the most current revision of the Fernald RI/FS Health and Safety Plan. A specific Health and Safety Plan for the project should be included in the project work plan. This plan should include an evaluation of the possible hazards that may be encountered, training requirements, protective equipment requirements, monitoring and engineering controls, and the measures to control the release of hazardous and radioactive materials to the environment. The specific non-ALARA hazards from this operation include the possibility of entraining dusts from the silo wastes into the air, radon emissions, dusts from handling the fly ash or sand, and mechanical hazards typical of solids-handling equipment. These can all be addressed by engineering controls. The dusts from the silo may contain heavy metals and silica, as well as radioactivity, and will be removed from silo ventilation air by dust collectors and HEPA filters. The dust from the sand and fly ash will be controlled to meet exposure limits to silica and any metals or alkali components of the fly ash.

5.5 COST

Cost estimates are provided for budgetary purposes only with ±30 percent accuracy. Back-up information is provided in Appendix E.

	Sand ($)	Fly Ash ($)
Equipment costs per silo	12,220	16,380
Material costs per silo	6,233	0
Labor costs per silo	68,440	71,640
- Subtotal	86,893	88,020
Total for two silos	173,786	176,040[a]

[a]Does not account for savings from using ash currently on site and incurring disposal costs one time.

APPENDIX A

DRAFT

QUALITATIVE FEASIBILITY STUDY OF
ALTERNATIVES FOR INTERIM
REMEDIATION OF K-65 SILOS

DRAFT

Prepared by: IT/ASI

June 1988

Rev. 1

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CRT1393COV
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TABLE OF CONTENTS

1.0 INTRODUCTION

SITE DESCRIPTION AND HISTORY

The Feed Materials Production Center (FMPC) was constructed and began operations at the Fernald site in the early 1950s. The U.S. Atomic Energy Commission, predecessor to the U.S. Department of Energy (DOE), established this integrated production complex for processing uranium and its compounds from natural uranium ore concentrates for the needs of the United States government. Initially, uranium ore concentrates, and presently, recycled materials, are converted to either uranium oxides or uranium ingots and billets. They are machined or extruded into tubular form for production reactor fuel cores and target fuel element fabrication.

From 1953 through 1955, the FMPC refinery processed pitchblende ore from the Belgian Congo. No chemical separation or purification was performed on the ore before it arrived at the FMPC. Beginning in 1956 the refinery feed consisted of uranium concentrates (yellowcake) from Canada and the United States.

No uranium ore is currently being received at the FMPC. The basic process performed now is the conversion of uranium-containing residues, uranium hexafluoride, and uranium tetrafluoride to uranium metal.

K-65 SILO HISTORY AND DESCRIPTION

The two K-65 silos, which are on the west side of the FMPC, were constructed in 1951 and 1952. The silos are used for storage of radium-bearing residues, a by-product of the uranium ore processing. The silos are structurally solid with the exception of a 20-foot diameter center section of the dome. At present, two interim stabilization projects are underway to provide radon release control and provide some structural reinforcement to the degrading condition of the dome center section. Phase I, the external foam application results, are reported in Westinghouse's letter TD: 88-056. Phase II, the internal attenuation layer application, is scheduled for fall 1988.

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K-65 SILO WASTE CHARACTERISTICS

The current volume of K-65 residues contained in the silos is estimated to be 195,000 cubic feet (8700 MT). The chemical and radiological characteristics of the K-65 residues are summarized in Paragraphs 2.3.1 and 2.3.2 below. The total void volume above the stored residues is estimated to be 87,500 cubic feet (No. 1 of 38,000 cubic feet and No. 2 of 48,000 cubic feet).

Chemical Characteristics

Approximately 40 percent of the K-65 material is composed of silicates (SiO_2). The other constituents that make up 1 percent or more of the residue include calcium, iron, magnesium, and lead. No organic constituents are known to be present in the K-65 residues, although confirmatory data are not available.

Radiological Characteristics

The radiological constituents of the K-65 residue have been estimated to include 11,200 kg of uranium (0.71 percent U-235) and 3000 Ci of radium (Ra-226). The radium concentration is 311 mg Ra-226/ton residue. Radon flux measurements made in October 1984 at 24 locations on each silo ranged from 123 $pCi/m^2/sec$ to more than 3×10^7 $pCi/m^2/sec$. The highest flux values were obtained on surfaces that contained observable cracks.

At present, the radiation exposure rates on the surfaces of the K-65 silo domes are approximately 145 and 185 mrem/hour, and the radon emission levels monitoring results are 45 pCi/liter and 20 pCi/liter, respectively.

INTERNAL ATTENUATION LAYER SELECTION

The internal attenuation layer is intended to reduce the levels of radon gas emitted from the silo residues along with a subsequent reduction in the gamma radiation levels. In addition, this layer was to provide support for the weakened portion of the silo roof; however, roof support can be decoupled from the attenuation layer and independent systems can be evaluated that provide only attenuation or roof support. This report discusses the various methods and combinations of methods proposed to accomplish these tasks.

2.0 RADON ATTENUATION METHODS

VENTING OF AIR SPACE IN SILOS

Summary

Currently, barometric pressure changes result in some release of radon gases from the silo air space. A vent would be installed to control the barometric "pumping" action. The vent would be connected to a closed system or a treatment system to prevent release of radon.

Evaluation Criteria

Application Ease - Installation of a vent system and connection to a separate radon control mechanism could make use of the existing piping and site connections. Structural support of the dome would probably be required in addition to this alternative.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The technical complexity would be relatively low for the vent system.

One possibility is venting to a sealed pillow tank. The tank would contain the radon gases while controlling the pumping action due to barometric changes. This system would require means to isolate the pillow tank periodically and verify its integrity.

Alternatively, the vent system could vent through a gas dryer and carbon adsorption filter much like the current radon system.

Impact on Final Remediation - The vent system would not significantly impact the final remediation activities.

Public Perception - The vent system alternative should be acceptable from the public perception standpoint. However, "vent" incorrectly implies a release of material. A better name might be "pressure control system".

Environmental and Safety Considerations - A passive vent system would not lower the radon concentration in the silo's air space. Also, internal pressure would be slightly greater than ambient pressure. Releases of radon would be decreased due to control of "puffing". In conjunction with one of the dome-sealing alternatives, the vent system may provide acceptable results.

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MODIFICATION OF EXISTING RADON TREATMENT SYSTEM

Summary

The existing radon collection and treatment system would be modified for extended runs, either continuous at lower flow or on an intermittent schedule as required, to prevent radon release from the silos.

Evaluation Criteria

Application Ease - The existing system worked very well for lowering the level of radon gases in the silos, and thus reducing the risk of exposure to workers.

Modifications to the system would be designed to optimize long-term performance with minimal operating and maintenance attention.

Most modifications would be made in the portable building that houses the equipment.

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Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The existing radon removal system has been proven in service. Modifications would involve changing capacities of equipment and improving the control system.

Impact on Final Remediation - Modification of the radon removal system would not adversely impact future remedial activities.

Public Perception - Public perception of the radon removal system would probably be acceptable. However, this alternative does not provide any structural support of the dome. Public perception may compel steps to prevent dome failure, or to contain any release due to dome failure.

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Environmental Safety Considerations - The primary safety considerations with respect to the radon removal system would be monitoring and control of the discharge air.

Another alternative would be required to address the possibility of a dome failure and/or a release.

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THREE-FOOT RIGID FOAM LAYER ON SLUDGE SURFACE

Summary

Installation of a three-foot layer of foam to attenuate the radon instead of filling the entire silo simplifies the installation. Drawbacks include shrinkage, difficulty in achieving even application, and upon final remediation, disposal of the low-level radioactive waste that the foam becomes. Sampling would have to be done through a stovepipe or similar device. This method would be much simpler than foaming the entire silo.

Evaluation Criteria

Application Ease - Simpler than full foam.

Exotherms - System is adiabatic; maximum temperature is independent of amount added; will be below degradation temperature.

Dimensional Stability - Some shrinkage will occur.

Technical Complexity - Foam application is common; however, this application will require innovation.

Impact on Final Remediation - Foam will have to be cut out and treated as a low-level radioactive waste. Additional waste volume is created.

Public Perception - The public would probably be receptive of this idea because it resembles the foaming option previously publicized. Their concern of no internal dome support would have to be dealt with.

Environmental Safety Consideration - This method will reduce radon, but not eliminate it.

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THREE-FOOT FOAM LAYER ON TOP OF SLUDGE WITH ELASTOMER SEAL TO SILO

Summary

This method would be essentially the same as the three-foot foam layer, except the elastomer would seal the gap formed by shrinkage. Less radon would be released. The application of the elastomer would be more difficult than foam alone.

Evaluation Criteria

Application Ease - More difficult than foam alone.

Exotherms - Same as foam; elastomer should not be significant.

T

Dimensional Stability - Elastomer seals gap produced by shrinkage.

F

Technical Complexity - More difficult application.

A

Impact on Final Remediation - Same as foam; may be more difficult to remove with elastomer seal in place.

R

Public Perception - The public would probably be receptive of this idea because it resembles the foaming option previously publicized. Their concern of no internal dome support would have to be dealt with.

D

Environmental Safety Considerations - Would reduce more radon release than foam alone.

PERMANENT OR REVERSIBLE GELS

Summary

Gels are usually installed in a liquid form which become gel-like with time. The use of a pumpable gel would allow the installer to pump a liquid into the silo. The liquid would form a more consistent thickness over the silo before gelling. A reversible gel uses chemical additions either to liquify or gel depending upon the need. The gel would have to be remediated as a radioactive waste or a mixed waste. Additional waste volume is created. These gels may be more expensive than other methods.

Evaluation Criteria

Application Ease - Pumping a liquid into the silo would be relatively simple.

Exotherms - Gels release very little heat; the reaction is relatively slow.

Dimensional Stability - The gel would be flexible enough to adsorb movements of the silo and contents.

Technical Complexity - Choosing the right gel formula may be time-consuming.

Impact on Final Remediation - Permanent gels would be treated similar to foams. The reversible gels would be changed to liquid and pumped out. Both gel types would be treated as radioactive waste.

Public Perceptions - The public may not perceive this option as a "solid" solution. They may still envision walls cracking and gel running out with the sludge.

Environmental Safety Considerations - The gels should provide good attenuation of the radon due to the nature of the gel. Expansion and contraction effects would be minimal. The gel would be a radioactive waste.

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ORGANIC MELTS

Summary

Molten organic materials, such as asphalt, petroleum based waxes, and carbowax (PEG), could be used to seal the top of the sludge. The materials would be pumped in as hot liquids and would solidify as they cooled. Some of these compounds have low densities and would float on water, which might be desirable if the sludges are liquid and have low capacity for supporting other materials. Flashing of water may be a problem as the sludges contact the hot melts.

Evaluation Criteria

Application Ease - These materials can be poured but melting and pumping will require heated equipment and traced lines.

Exotherms - Not a problem.

Dimensional Stability - Expansion of silo may open cracks that will result in minor increases in radon leakage.

Technical Complexity - Low.

Impact on Final Remediation - Some organic materials will not be as easily disposed of as mineral-based caps. They might be mixed waste or require incineration.

Public Perception - The public may become concerned over adding hot material and flashing wastewater into the environment.

Environmental and Safety Considerations - These materials will probably provide uniform seal, but may be damaged by debris from dome. Flammability may be a concern.

LATEX EMULSION

Summary

A latex emulsion, similar to latex paint, could be used to attenuate the diffusion of radon from the sludges. This emulsion would contain bentonite or similar clays to provide a thixotropic character. The emulsion would be pumped in and partially cured by lowering the humidity in the silo so that a latex film is formed. Multiple layers of film and emulsion could be built up. This system should be "self-repairing" if damaged by debris from the dome. Acrylic as well as other elastomeric emulsions could be considered.

Evaluation Criteria

Application Ease - This would be one of the easier systems to install. The most difficult aspect would be dehumidifying the silo to cure the film.

Exotherms - Not a problem.

Dimensional Stability - Self-adjusting to expansion cycles and settling.

Technical Complexity - Low.

Impact on Final Remediation - Emulsion may require solidification. May be more difficult to remove than some methods, although not as difficult as foam.

Public Perception - The public may perceive this method to be too simple.

Environmental Safety Considerations - Should effectively seal sludge and tolerate debris from dome and installation uncertainties.

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BENTONITE

Summary

Bentonite is effective in attenuating radon because it can retain significant amounts of moisture for extended periods of time.

Application Ease

Bentonite slurry is routinely used in various construction processes, and its handling characteristics are known. Bentonite could be slurried into the silos.

Exotherms - There is no exotherm associated with bentonite.

Dimensional Stability - Volume change of bentonite is dependent on moisture content. Because the environment inside the silo is relatively moist, the bentonite slurry would retain its moisture and therefore would not significantly change in volume.

Technical Complexity - The radon attenuation characteristics of bentonite and other clay materials are well documented. Applications of this type have been previously studied.

Impact on Final Remediation - The bentonite would add volume to the existing waste material in the silos and would require disposal as a low-level radioactive waste.

Public Perception - Public perception should be no different from that of using foam. However, this alternative does not provide support for the weakened section of the dome.

Environmental Safety Considerations - Bentonite is not a hazardous material and would pose no environmental concerns during installation. The effect of dome collapse on the bentonite would require study to ensure that this event would not alter the performance of this material as a radon barrier. If the bentonite were placed so that it was plastic, the material would be "self-healing" in the event of a dome collapse.

CEMENTITIOUS MATERIALS

Summary

Cementitious products, such as concretes, grouts, gunnites, and sodium silicates, could be used to form a cap on top of the sludges to provide an effective radon seal. Multilayer combinations of these materials could be used to form a more effective seal. For example, a thin layer of fast-setting sodium silicate could be used to improve the strength of the sludge surface. A layer of lightweight concrete could serve as the primary radon barrier. This layer might then be coated with gunnite for strength and protection from debris from the dome.

Evaluation Criteria

Application Ease - These materials can be poured or applied by gunning. Poured mixes can be formulated for good flowability so that complete coverage of the sludge surface is assured.

Exotherms - Not a problem.

Dimensional Stability - Expansion of material will have to be considered. Settling and cracking could be a problem.

Technical Complexity - Low for concrete or gunning mixes. Sodium silicate formulations may be more difficult to control.

Impact on Final Remediation - Easier to remove than foam; more difficult than loose, granular material.

Public Perception - The public may become concerned about cracks similiar to those found in driveways.

Environmental and Safety Considerations - Radon attenuation will depend on thickness and integrity of cap. Settling cracks could increase radon leakage.

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ACTIVATED CARBON

Summary

Activated carbon is used in the radon removal system to trap the radon until it can decay. Pouring a layer of activated carbon on the top of the sludge could trap the radon. However, in the presence of moisture, radon removal on carbon approaches zero. The silo humidity is saturated and the carbon would not absorb the radon, therefore this technique will not be evaluated further.

MAGNESIUM SULFATE, SILICA GEL, ETC.

Summary

Magnesium sulfate and similar materials act as drying agents and could be applied in a layer between the sludge and the carbon. Theoretically, this method would work. However, too much water exists in the sludge, making this impractical. Therefore, this technique will not be used.

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OTHER GRANULAR SOLIDS AND COMBINATIONS

Summary

Many different combinations of granular solids exist that could be used for the radon attenuation. Some of these include sand, gypsum, or flyash. Also, these solids could be layered with each other or with an elastomer to provide an additional seal. The more complicated the system, the more difficult it will be to install. The solids will be difficult to place in a consistent thickness. Gypsum may react with the water to form a plaster-of-paris type skin that may help seal the radon. The addition of an elastomer to improve diffusion resistance would make application and remediation more difficult.

Evaluation Criteria

Application Ease - Solids could be air-conveyed in; maintaining a constant thickness would be difficult. Addition of an elastomer would be much more difficult.

Exotherms - None with solids; elastomer would not add significant heat.

Dimensional Stability - As material absorbs moisture, it may clump and cake, forming cracks. Elastomer may seal these.

Technical Complexity - For solids alone, application in constant layers would be difficult; elastomer application increases complexity.

Impact on Final Remediation - These materials would be easier to remove than the foam but would be radioactive waste. If flyash, gypsum, or lime is used, they could become part of the remediation by assisting in solidification. Elastomer, if installed, would have to be removed separately.

Public Perception - The public may perceive that this material could "sink" into the sludge waste.

[illegible] Environmental and Safety Considerations - Radon attenuation will depend on thickness. Roof failure into solid bed should not impact radon release if bed is thick enough.

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TRANSFER OF SILO 3 MATERIAL INTO SILOS 1 AND 2

Summary

Silo 3 material is a dry metal-oxide, low-level radioactive waste material. This material generates very little radon. It is not much different from the other solids mentioned before, e.g., sand, gypsum, etc., except it is already a radioactive waste material. It could attenuate the radon as well as the other solids. Enough material is present in Silo 3 to fill both silos, providing some roof support. Silo 3 may be emptied. No additional waste is generated. The environmental impact of the transfer would have to be evaluated.

Evaluation Criteria

Application Ease - Similar to other solids, except removal from Silo 3 will have to be evaluated.

Exotherms - None.

Dimensional Stability - A loose, granular solid that should exhibit good stability.

Technical Complexity - Transfer from one silo to another will have to be evaluated.

Impact on Final Remediation - May put all waste in two silos. Does not produce additional waste. Silo 3, if emptied, could be remediated.

Public Perception - The public may have reservations on transfer of material. If Silo 3 can be emptied into other two silos, early remediation of Silo 3 may show progress and relieve some pressure.

Environmental and Safety Considerations - Transfer of waste may have some impact. Radon release would be reduced. If silo is filled, silo support is provided.

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3.0 SILO DOME SUPPORT OR COMBINATION

DOME COVER

Summary

A lightweight, self-supporting dome cover could be placed on each silo. This cover would extend over the entire silo and would minimize the environmental consequences of dome collapse.

Evaluation Criteria

Application Ease - The cover could be manufactured and shipped to the site. Final assembly would take place at the site. The dome cover could be set by a crane or assembled in place. These covers can be readily obtained and installed in a relatively short amount of time.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - Using the dome cover as a radon barrier is probably more complex than other alternatives because radon attenuation depends on (1) the material used to construct the dome, and (2) how airtight the dome could be made, particularly with respect to the dome-silo interface.

Assuming the dome cover could function as a radon barrier, the area where the existing concrete dome meets the wall would possibly allow radon to escape because the earth cover at this location is minimal.

However, the dome cover could function as a secondary containment when used in conjunction with a radon barrier placed on top of the K-65 residue. It would minimize the environmental consequences of dome collapse by maintaining the interior of the silo in its present state.

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Impact on Final Remediation - If the dome cover is used as a barrier and subsequently became contaminated, it would have to be disposed of as a radioactive waste. However, if the dome cover is used in conjunction with a radon barrier, it may not become contaminated and could be reused or disposed of as ordinary scrap.

Public Perception - Public perception would be positive because the covers would provide additional protection in the event of dome collapse. Also, the dome covers would be visible.

Environmental and Safety Considerations - A dome cover used in conjunction with a radon barrier located on top of the K-65 residue would maintain the present environment of the silo interior if the existing silo dome were to collapse.

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ELASTOMERIC MEMBRANE

Summary

An elastomeric membrane could be placed over the existing dome and along the top and sides of the berm where there is limited soil thickness.

Evaluation Criteria

Application Ease - The application is comparable to the recent operation in which a layer of rigid foam was placed on the dome. Removal of existing vegetation on the affected area of the berm would be required.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The elastomeric membrane seal was proposed to provide a seal between the rigid foam and the silo wall in the original design. Therefore, it is technologically feasible for this application.

If collapse of the center dome portion occurs, the existing temporary cover would provide support for the membrane.

Impact on Final Remediation - The membrane would have no impact on final remediation because it is located completely outside the silo.

Public Perception - Public perception should be favorable, provided the public is made aware that this is a temporary solution.

Environmental and Safety Considerations - This alternative does not provide support for the weakened section of the dome. It could be used in conjunction with other alternatives, such as venting the air space in the silo or a radon treatment system.

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LOOSE SUPPORTING MATERIAL OVER RADON ATTENUATION LAYER

Summary

Addition of a "fill" material over other radon attenuation material (such as styrofoam "peanuts", vermiculite, or perlite), could be used to fill the void space over the attenuation layer to provide some silo roof support. The fill material would not necessarily be considered a radioactive waste. The fill material could be used alone, but if so, it may not provide sufficient radon attenuation and would be considered radioactive waste.

Evaluation Criteria

Application Ease - Material is easily handled by air.

Exotherms - None.

Dimensional Stability - As a loose fill, would allow for all silo movements. Material is used as packing for shipping fragile cargos.

Technical Complexity - Simple.

Impact on Final Remediation - Fill over radon barrier could be incinerated. Fill alone would be radioactive waste.

Public Perception - Public perception should be positive if envisioned as a means of internal dome support or cushion. Perception of use of "fill" material alone would be poor considering porosity.

Environmental and Safety Considerations - Would provide some roof support. Final disposal would depend on use; some may be radioactive waste.

INFLATED BLADDER WITHIN TOP OF SILO

Summary

A bladder could be inserted into the void space above the waste material, and then inflated sufficiently to fill the space and provide some support of the dome.

Application Ease

The bladder would need to be inserted through one of the existing manholes. Cutting a larger opening would not be advisable due to existing structural problems with the dome. Therefore, the thickness of the bladder material would be a critical factor in the compactness of the bladder when uninflated.

Mechanical damage of the bladder during installation or damage from possibly exposed reinforcing steel in the dome would be difficult or impossible to repair with the bladder in place, and would destroy the effectiveness of the bladder. Therefore, this alternative will not be considered further.

APPENDIX B

MOCK-UP AND DEMONSTRATION PLAN FOR
FOAMING OF K-65 SILOS

REV. 0

Prepared by: IT/ASI
June, 1988

Job No. 303317.09.05

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CONTENTS

APPENDIX

FIGURE

MOCK-UP AND DEMONSTRATION PLAN

1.0 SCOPE

This mock-up and demonstration plan outlines the use, application, installation, and installation monitoring of foam and elastomer material proposed for use on the K-65 Silo foaming project.

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2.0 APPROACH

ASI/IT currently plans to subcontract Foam Enterprises to design, construct, and perform the mock-up and demonstration according to the following plan.

There shall be two test forms prepared for the study. The small form will be a form approximately 8 feet in dimension. The large form will be dimensionally equivalent to a quarter section of the K-65 Silo. A circumference arc of 90 degrees will be fabricated. A 20-inch ring representative of the manhole flanges will be suspended above the form.

An application technique will be defined through the use of the small form. This form is convenient and economical for multiple tests, with minimum preparation time and waste generation.

Full-scale demonstration of the application technique resulting from the series of small-scale tests will be performed using the large form. The actual application feasibility of the foam and elastomer through a 20-inch manhole suspended above the sludge will be further defined.

Layering will consist of a 3-foot layer of wet sand (approximately 40 percent moisture), a 3-foot layer of rigid foam and, optionally, a sealant layer of elastomer applied along the circumference of the foam/silo interface. Monitoring equipment will measure relative humidity, temperature in the area, temperature at the core of the rigid foam pour, surface temperature of the rigid foam pour, and volumetric expansion and contraction of the foam during cream time and cure. Cutouts of the small-scale pours will indicate layer interface properties. Adhesion of the rigid foam and elastomer to the concrete wall and to each other can be visually inspected.

3.0 MATERIAL SELECTION

3.1 WET SAND

A 3-foot layer of 40 percent moist sand will be placed in the bottom of the form to simulate the damp sludge in the silos. Time permitting, the sand will sit until it reaches ambient temperature.

3.2 RIGID FOAM

The rigid foam proposed for use on the K-65 Silo foaming project is Foam Enterprises formulation MG-2B, a polyurethane foam (reference Appendix A for vendor literature). This foam was proposed during the initial foaming plans. It was tested and confirmed at that time for as low as reasonably achievable (ALARA) radon attenuation properties.

3.3 ELASTOMER

The elastomer proposed for use on the K-65 Silo foaming project is Foam Enterprises Formulation FE7053, a polyurethane elastomer (reference Appendix A for vendor literature).

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4.0 SMALL-SCALE TESTING

4.1 FORM

The 8-foot form will be fabricated of plywood to a depth not less than 8 feet. The form will be constructed to facilitate reuse for more than one foam formulation.

4.2 MONITORING

Temperature-sensing thermocouples will be positioned at the sand/foam interface, along the foam/wall interface, in the approximate center of the foam pour, and on the foam surface after pour. The foam layer interface condition will be checked by cutting out a section after cure.

Two scaled reference poles will be positioned 6 feet apart in the foam to measure volumetric foam movement. Foam depth and pole span measurements will be recorded at 1-minute intervals for the first 5 minutes after pour, at 5-minute intervals for the first hour after pour, and every 30 minutes thereafter until equilibrium spans 1 hour. Measurements shall continue to be taken twice daily until no 24-hour change is detected.

The relative humidity of the area will be measured with a hygrometer. Ambient temperature will be measured with an outside thermometer.

4.3 TESTS

Actual tests may differ based on findings of previous runs. After successful completion, acceptance by WMCO, and duplication (if required) of any test methods, subsequent tests are not necessary. The following series of tests are preliminary recommendations:

- First test: 3-foot layer of damp sand; continuous pour of a 3-foot layer of rigid foam at maximum application rate of equipment
- Second test: 3-foot layer of damp sand, 1.5-foot layered application of the rigid foam; wait 15 minutes between applications or until failure condition of the first test is satisfied

- Third test: 3-foot layer of damp sand. 1-foot layered application of the rigid [illegible]; wait 15 minutes between applications or until failure conditior[illegible] prior test(s) is satisfied.

- Fourth [illegible] 3-foot layer of damp sand, 6-inch layered application of the [illegible] foam; wait 15 minutes between applications or until failure [illegible]ition of prior test(s) is satisfied.

4.4 ACCEPTANCE [illegible]ERIA

A rigid foam app[illegible]tion may be considered successful if the following conditions are me[illegible]

- Integrity of the foam structure is m[illegible]tained throughout.

- Temperature does not exceed the temperature of elastomer degradation at any measured point during the application or subsequent to the pour.

- Expansion does not exceed the 6 percent allowed for in the structural evaluation.

- Contractio[illegible] is kep[illegible] to a [illegible]nimum, wh[illegible] increases the feasibility of sealing wi[illegible] the e[illegible]ome[illegible]

- Layer interface is intact w[illegible] no degr[illegible]ation of the foam structure.

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5.0 LARGE-SCALE TESTING

5.1 FORM

The full-scale quadrant will be designed according to the sketch in Figure 5-1. The arc will be fabricated of plywood with optional plexiglass sections for visible inspection of the layer. A test section of concrete blocks will be designed in one of the straight sides to test adhesion of the foam and elastomer to concrete. The remaining sidewalls will be fabricated of plywood. The 20-inch diameter ring will be suspended above the foam at the approximate location of the manhole on the silo. The form shall have a minimum depth of 8 feet to contain the foam. The form will be designed to facilitate reuse.

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5.2 MONITORING

The full-scale test will be set up with monitoring equipment similar to the small-scale tests. Temperature-sensing thermocouples will be positioned at the sand/foam interface, along the foam/wall interface, in the approximate center of the foam pour, on the foam surface after pour, and in the elastomer layer after application.

F A R

Two scaled reference poles will be positioned 35 feet apart in the foam to measure volumetric movement. Foam depth and pole span measurements will be recorded at 1-minute intervals for the first 5 minutes after pour, at 5-minute intervals for the first hour after pour, and every 30 minutes thereafter until equilibrium spans 1 hour. Thereafter, measurements shall be taken twice daily until no 24-hour change is detected.

D

The relative humidity of the area will be measured with a hygrometer. Ambient temperature will be measured with an outside thermometer. A sample of the damp sand layer will be taken for moisture analysis at a laboratory.

5.3 TEST

The full-scale test will be performed to demonstrate the following:

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By ______ Date [illegible] Subject [illegible] Sheet No. ____ of ____

Chkd. By ____ Date ________ Proj. No. [illegible]

Figure 5-1 Conceptual Large Scale [illegible]

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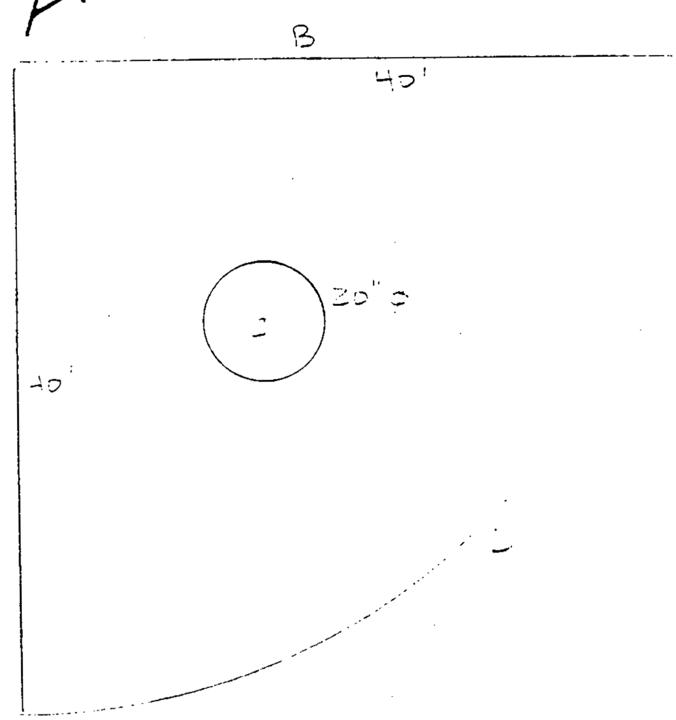

Sides A & B [illegible] of Plywood, [illegible]

Side [illegible] Fabricated of Plywood

Opening C may be a metal [illegible]

108-10-8

- Feasibility of wand application of the rigid foam through a manhole with limited visibility
- Control of foam distribution and depth under simulated conditions
- Duplication of application approach as defined during small scale testing
- Feasibility of wand application of elastomer along the outer perimeter of the silo
- Temperature build-up and dissipation in the rigid foam layer and elastomer layer
- Volumetric expansion and contraction of foam.

The full-scale test will be developed based on the results of the small-scale tests. Equipment used will be similar to that proposed for the actual silo foaming. Application rates and other pertinent data will be recorded and referenced when the procedures for actual silo foaming are developed.

5.4 ACCEPTANCE CRITERIA

The full-scale test will be performed and data will be collected. If results significantly differ from the small-scale test results, additional tests may be required whereby known variables (such as application rate or the cure time between layers) are adjusted. Additional tests may be performed at the request of or with the confirmation of WMCO.

6.0 EQUIPMENT

Foam Enterprises will use equipment similar in control, size, and capacity to that used during actual foaming of the K-65 Silos. The rigid foam will be applied with a truck-based system. The maximum application rate is 200 pounds per hour. The elastomer, if used, will be applied with a similar system at a maximum rate of 4.0 gallons per hour. Also, reference the original foam report, "Engineering Study of the K-65 Storage Silo Radon Mitigation and Dome Reinforcement Project at Feed Materials Production Center," submitted August 1987 for detailing of equipment to be used, wand cleanout, raw material requirements, utility requirements, etc.

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7.0 FINAL REPORT

The results of the mock-up and demonstration will be analyzed and presented in a Quantitative Analysis Report. Primary areas to be addressed are (1) the use of a rigid foam alone or in combination with an elastomer seal, as demonstrated and documented in the mock-up and demonstration, and (2) the conceptual use of an alternative material in place of the layer of rigid foam. Draft copies of the report will be submitted to WMCO for review and comment per the task order.

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APPENDIX

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A

FIGURE

MOCK-UP AND DEMONSTRATION PLAN

1.0 SCOPE

This mock-up and demonstration plan outlines the use, application, installation, and installation monitoring of foam and elastomer material proposed for use on the K-65 Silo foaming project.

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Two scaled reference poles will be positioned 6 feet apart in the foam to measure volumetric foam movement. Foam depth and pole span measurements will be recorded at 1-minute intervals for the first 5 minutes after pour, at 5-minute intervals for the first hour after pour, and every 30 minutes thereafter until equilibrium spans 1 hour. Measurements shall continue to be taken twice daily until no 24-hour change is detected.

The relative humidity of the area will be measured with a hygrometer. Ambient temperature will be measured with an outside thermometer.

4.3 TESTS

Actual tests may differ based on findings of previous runs. After successful completion, acceptance by WMCO, and duplication (if required) of any test methods, subsequent tests are not necessary. The following series of tests are preliminary recommendations:

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- Second test: 3-foot layer of damp sand, 1.5-foot layered application of the rigid foam; wait 15 minutes between applications or until failure condition of the first test is satisfied

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- Fourth test: 3-foot layer of damp sand, 6-inch layered application of the rigid foam; wait 15 minutes between applications or until failure condition of prior test(s) is satisfied.

4.4 ACCEPTANCE CRITERIA

A rigid foam application may be considered successful if the following conditions are met:

- Integrity of the foam structure is maintained throughout.
- Temperature does not exceed the temperature of elastomer degradation at any measured point during the application or subsequent to the pour.
- Expansion does not exceed the 6 percent allowed for in the structural evaluation.
- Contraction is kept to a minimum, which increases the feasibility of sealing with the elastomer.
- Layer interface is intact with no degradation of the foam structure.

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- Feasibility of wand application of the rigid foam through a manhole with limited visibility
- Control of foam distribution and depth under simulated conditions
- Duplication of application approach as defined during small scale testing
- Feasibility of wand application of elastomer along the outer perimeter of the silo
- Temperature build-up and dissipation in the rigid foam layer and elastomer layer
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APPENDIX A
VENDOR LITERATURE

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GENERAL INFORMATION

The recommended application and handling procedures for the specific product being used should be known and followed by the foam applicator. A small "test area" of spray foam should be applied and inspected prior to commencing the project. This simple, low-cost test area can indicate inadequate adhesion, improper surface preparation and/or primer, surface contamination, improper substrate and/or ambient temperature, equipment malfunctions, material contamination or improper application technique. A simple visual inspection of a sample cut from a test and periodic job samples can reveal potential problems that may be due to one or more of the above conditions.

CAUTION

The use of foamed plastic in interior applications on walls or ceilings may present an unreasonable fire hazard unless the foam is protected by an approved, fire-resistive thermal barrier which has a finish-rating of not less than 15 minutes.

The information herein is to assist customers in determining whether our products are suitable for their applications. Our products are intended for sale to industrial and commercial customers. We request that customers inspect and test our products before use and satisfy themselves as to contents and suitability. We warrant that our products will meet our written specifications. Nothing herein shall constitute any warranty express or implied, including any warranty of merchantability or fitness, nor is protection from any law or patent to be inferred. All patent rights are reserved. The exclusive remedy for all proven claims is replacement of our materials and in no event shall we be liable for special, incidental or consequential damages.

FOAM ENTERPRISES, I[illegible]
13630 WATERTOWER CIRC[illegible]
MINNEAPOLIS, MN 5544[illegible]
(612) 559-3266 (800) 328-3[illegible]

5978

twin city testing
and engineering laboratory, inc.

REPORT OF: TESTS OF POLYURETHANE FOAM

PROJECT: MATERIAL, EQUIPMENT AND PROCEDURE EVALUATION

DATE: June 3, 1977

REPORTED TO: Foam Enterprises, Inc.
13630 Watertower Circle
Plymouth, Minnesota 55441
Attn: Mr Dennis Holbert
President

FURNISHED BY:

COPIES TO:

LABORATORY No. 7-7280

T

INTRODUCTION:

This report presents the results of a series of tests conducted on Class I polyurethane foam, nominal density (open mold) 2.0 pounds per cubic foot The tests were performed at the request of Mr. Dennis Holbert, President, Foam Enterprises, to satisfy his contract with Marinette Marine Corp, Marinette, Wisconsin, to provide foam in place flotatio[n] per Navsea Drawing 191-5014996 (MMC Drawing 1240-001-191). This material is to meet requirements of Mil-P-21929B, Class I. Mil-P-29129B is the Military Specification, Plastic Material, Cellular Plyurethane, Foam-In-Place, Rigid, 2 and 4 Pounds Per Cubic Foot, dated 11, August, 1969.

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SUMMARY OF TEST RESULTS:

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Property	Class I Requirement	Tested Value
Density	2.0 ± 0.5 pcf	2.28 pcf
Compressive Strength (@ 10% deformation)	20 psi min.	26.2 psi
Humidity Aging		
Volume change, % of original	±10	+5.07%
Compressive Strength change, % of original, max.	20	Less than 1%
Compressive Set, % max.	3.5	2.0%
Water Absorption, lb./ft^2 of surface area, max.	0.12	0.07 lb./ft^2
[illegible] Resistance	no softening or visible change	No evidence of softening or visible degradation
Fire Resistance	non-burning and no flaming droplets	All specimens either self-extinguis[hed] or did not ignite, therefore, mater[ial] is non-burning. There [illegible]

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REPORT OF: TESTS OF POLYURETHANE FOAM

DATE: June 3, 1977

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MIXTURE AND DISPENSING OF CHEMICALS:

The chemicals used to produce the foam meet the F.E.- MG2A and MG2B specifications. F.E. -MG2A covers the isocyanate and MG2B covers the resin. During the foam production, the chemicals were used in a 1:1 ratio (by volume).

Equipment used for foaming was the F.E.- GV60 air powered pumping system, which is of Empro design and manufacture. It is equipped with two equally sized proportioning fluid pistons powered by a reciprocating air motor. At the dispensing head, the materia[illegible] manifolded into a static mixer which introduces air for dynamic mixing, and bl[illegible] [illegible]ts for the frothing and cooling of the reacting chemicals.

During the foaming of the material in the laboratory, temperature control of the MG2A and MG2B was maintained, as well as the method of introducing them into the proportioning pumps. The compressed air pressure was controlled to the pump and the mixing head. The correct amounts of blowing agents, which are necessary to quality and density, were controlled by the operator.

The basic chemicals, equipment and procedures, when applied together by foam technicians under the guidance of Dennis Holbert, resulted in the foam meeting the requirements of MIL-P-21529B for Class I material.

INTIAL TEST PREPARATION:

Two test molds were fabricated for preparation of two free-rise samples of the polyureth[illegible] foam. The molds measured 13" x 13" x 25" inside dimensions, and were fabricated from [illegible] aluminum plate, with bolted connections on all corners and edges for ease of removal of the sample block from the mold. After two unsuccessful attempts to attain the correc[illegible] density in the sample blocks, the blocks were foamed at 60°F and 80°F, which were the temperature extremes expected to be encountered on the job site.

[illegible] two aluminum molds were pre-conditioned for a minimum of 4 hours on March 7, 1[illegible] [illegible]ore the sample blocks were foamed. Then both the 60°F and the 80°F sample bloc[illegible] [illegible]er [illegible]amed and held for a minimum of 48 hours before the samples blocks were removed from the molds.

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REPORT OF: TESTS OF POLYURETHANE FOAM

DATE: June 3, 1977

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LABORATORY No. 7-7280

INITIAL TEST PREPARATION:

The post-cured densities of the two blocks were:

60°F sample - 2.65 pcf.

80°F sample - 2.28 pcf.

t this time, it was decided between Foam Enterprises & Marinette Marine Corp. to test only the 80°F block, since the 60°F sample was our of spec for density.

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TESTS:

Color and Odor -

The sample block did conform to color and odor requirements.

Density -

After removal from the mold, the 80°F sample block was trimmed of surface skin to a block size of 11.75" x 11.75" x 22.75". The weight of this block was determined to be 4.154 lb., giving a density of 2.28 pounds per cubic foot.

Homogeneity of Cured Foam -

The sample block was sliced into twelve 1" thick (nominal) layers. The remainder of the block was set aside for future use, if necessary. A visual examination of both faces of each of the twelve layers comprising the test specimen revealed that the cur foam was free of non-foamed, or soft and tacky particles. The foam was composed of sc

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REPORT OF: TEST OF POLYURETHANE F AM

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cells of approximately the same size. Blow holes were encountered during the visual examination, but none were larger than ½" and not more than one occurred in any proje area of 6" x 6". Also, no more than 3 blow holes were present in any 3 adjacent 1" t layers.

Compressive Strength -

Three 4" x 4" specimens were tested in accordance with procedure A of ASTM D-1621. T tests specimens were selected from layers 3, 9 and 12.

Specimen Numb	Area, in.^{2}	Density, pcf.	Load at 10% Deformation, lb.	Compressive Strength, psi.
3	16.32	2.24	450	27.6
9	16.36	2.37	415	25.4
12	16.44	2.19	420	25.5
			Average -	26.2 psi

Humidity Aging -

Six specimens measuring 4" x 4" were subjected to humidity aging, three of which were tested afterwards for change in compressive strength.

Volume Change

Specimen Number	Original Volume, in.^{3}	Volume Change After 1 day	Volume Change After 7 days
3-1	16.52	+4.54%	+5.57%
6-1	16.61	+4.52%	+4.52%
9-1	18.00	+2.22%	+5.11%
		Average -	+5.07%

No reversion was detected during the 7-day conditioning period at 140°F and 100% R.H.

Compressive Strength Change

Specimen Number	Area, in.^{2}	Density, pcf.	Load at 10% Deformation, lb.	Compressive Strength, psi.
3-1	16.81	2.23	455	27.1
6-1	16.81	2.21	430	25.6
9-1	17.22	2.27	435	25.3

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Compression Set -

Three specimens measuring 2.250" diameter were subjected to a static load of 5 psi at 158°F for 24 hours. After a 30 minute recovery period, the thicknesses were remeasured.

Specimen Number	Original Thickness, in.	Final Thickness, in.	Compression Set, %
1	1.250	1.230	1.6
2	1.150	1.120	2.6
3	1.150	1.130	1.7
		Average -	2.0%

Water Absorption -

Water absorption was determined in accordance with ASTM D-2127 except specimens wer immersed in distilled water at 4.35 psi for 48 hours.

Specimen Number	Cut Surface Area, ft^2	Original Weight, g.	Final Weight, g.	Water absorption lb/ft^2 of cut surface area
3	0.33	9.55	17.87	.056
6	0.34	10.60	20.82	.067
9	0.30	9.60	21.42	.076
			Average -	0.066 lb/ft^2

Oil Resistance -

Four specimens measuring 1.129" x 1" thick (nominal) were immersed for 70 hours in ASTM #2 reference oil at 70°F and 50% R.H. Four control specimens were held at 70° and 50% R.H. for comparison after the test. After 70 hours, the specimens were removed from the oil, the excess oil was blotted away, and the specimens were examine No evidence of softening or visible degradation was detected.

Fire Resistance -

Fire resistance of the foam was tested both before and after aging at 140°F and 100 R.H. for seven days. Specimen size was ½" x 2" x 6". Procedures outlined in ASTM D-1692 were followed for the test. Applied flame time for all specimens was 60 sec twin city testing and engineering laboratory, inc.

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Specimen Number	Time, sec.	Burn Length, in.	Burn Rate, in/sec.	Remarks
Before conditioning:				
1	130	4.0	.03	Self-extinguished
2	81	1.5	.02	Self-extinguished
3	60	0.5	.01	Did not ignite
4	60	0.5	.01	Did not ignite
5	60	0.5	.01	Did not ignite
After conditioning:				
1	72	1.5	.02	Self-extinguished
2	60	1.0	.02	Did not ignite
3	65	2.0	.03	Self-extinguished
4	70	2.3	.03	Self-extinguished
5	80	2.3	.03	Self-extinguished

All specimens either self-extinguished or did not ignite during the fire resistance test. Therefore, the material is non-burning. Also, we observed no evidence of flaming droplets during the test.

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REMARKS:

We hereby certify that this polyurethane foam when produced under the above conditions, meet the specified requirements of Mil-P-21929B for Class I material.

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

Ward A Blandin, M.E.

INTERNATIONAL TECHNOLOGY CORPORATION

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By J. Snow Date 6-2-88 Subject K-65 Elastomer Sheet No. 1 of 2

Chkd. By ____ Date ____ Proj. No. 330317

Polyurethane Elastomer - Foam Enteprises NO. FE 7053

Application - A 50 MIL layer to be sprayed on outer edges of rigid foam to seal the foam to the silo wall. It is anticipated that a width of approximatley 24" will be necessary.

Total volume is πd x width x height

$\pi(80) \times 24'' \times .05 = 3619$ sq in $\div 231 = 15.7$ gal

Application time - 4 gallons per hour MAX output
- 4 gallons per 1/4 segment
- 1 hr between each segment for setup
- 2 hrs for initial setup

7 hrs estimate for elastomer application

Cure time - 2-4 minutes

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FOAM ENTERPRISES, INC.

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Minneapolis, MN 55441-3785
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TECHNICAL DATA SHEET FOR FE 7053

FE 7053 is a polyurethane elastomer system formulated for spray application. FE 7053 is designed for below ground application as a secondary container barrier for fuel spills. This barrier is intended as a temporary containment after a fuel spill.

The ground area is first sprayed with the FE 502 foam system at a thickness of 1/2 to 3/4 inch. The FE 7053 is then applied over the FE 502 at a 1/8 to 3/16 inch thickness.

APPLICATION:

EQUIPMENT: Graco (Viscount II) variable ratio Hydra-Cat and Foam-Cat heater with a 35:1 Senator (954-517) resin pump and a #2 Cylinder (207-862) isocyanate pump. A Binks 43P spray gun modified with a dynamic shear mixer before the 0.029 spray tip is recommended.

Pump pressures 1700-2500 psi with a preheat and hose temperature range or 115-1[illegible] °F. are recommended. A calibrated weight ratio of 100 B component to 56 A component is required.

PHYSICAL PROPERTIES

PROPERTY	TEST	RESULTS
Density, pcf	Immersion	40 - 50
Tensile, psi	ASTM D-412	200 - 400
Elongation, %	ASTM D-412	100 - 210
Tear Strength, PLI	ASTM D-1004	65 - 85
MVT, Perm	ASTM E-398	0.75 - 0.95
Hardness	Shore A	48 - 60
Scaling Resistance, 80 Cyles	ASTM C-672-76	"O", No Scaling
Abrasion Resistance	ASTM D-4060 (1)	
Wear Index		0.20 - 0.26
Weight Loss		0.20 - 0.26
Wear Cycles/Mil (2)		135 - 145

Strips of FE 7053 were immersed in water and thirty weight oil (separately) for six months. The strips were evaluated as follows:

PROPERTY	TEST	RESULTS
Tensile, psi	ASTM D-412	200 - 400
Elongation, %	ASTM D-412	100 - 210
Weight Change, %	FETP #16	
Water		+15 to +30
Oil		+7 to +9

(1) Utilized an H-18 abrasion wheel, 100 gm. weight and 1000 rpm.

(2) Number of cycles of abrasion required to wear a film through to the substrate per mil (0.001 inches) of film thickness.

APPENDIX C

DRAFT

RAE-31-1

ENGINEERING GUIDES FOR ESTIMATING COVER MATERIAL THICKNESS AND VOLUME FOR URANIUM MILL TAILINGS

DRAFT

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ABSTRACT

Five nomographs have been prepared that facilitate the estimation of cover thickness and cover material volume for the Uranium Mill Tailing Remedial Action Program. Key parameters determined include the cover thickness with either a surface radon flux or a boundary radon air concentration criterion and the total volume of cover material required for two different treatments of the edge slopes. Also included in the engineering guide are descriptions and representative values for the radon source term, the diffusion coefficients and the key meteorological parameters.

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1. INTRODUCTION

The thickness and volume of cover material required for uranium mill tailings reclamation are often determined by a radon flux or concentration criterion which must be satisfied. The general approach used in estimating the required thickness and volume of a cover can be divided into two phases. First, the characteristic parameters of the tailings/cover system must be measured or estimated. These include the radon diffusion coefficients, porosities and moistures of the tailings and cover, and the radium content and emanating power of the tailings. Second, the thickness of cover needed to achieve a prescribed radon flux is determined by iteratively calculating radon fluxes for various cover thicknesses until the thickness giving the prescribed flux is found. Alternatively, an approximate expression can be used to calculate the cover thickness directly. With the cover thickness specified and with detailed contour maps of the site, the detailed cover configuration can be defined and the cover material volumes calculated.

Quite often, cover thickness and volume estimates are needed rapidly, and insufficient time and resources are available to collect all of the pertinent data and perform the exercise described above. In these instances, a simple, straightforward procedure is needed that requires a minimal amount of site-specific data, yet is sufficiently accurate for conceptual planning purposes. Such a procedure has been developed and is documented herein.

This guide is purposefully brief, to facilitate its use by a wide range of personnel with varying backgrounds, training and experience. The procedure is presented in nomograph form with instructions and examples accompanying each nomograph. One important advantage to the nomograph format is the ease and clarity with which the effects of variations of key parameters are shown. The key parameters needed for the nomograph are:

- Tailings pile dimensions
- Radon diffusion coefficients
- Radon flux from the bare tailings
- Required flux from the covered tailings surface
- Desired side slope ratio
- Meteorological parameters

A later section contains information for estimating the diffusion coefficients, bare tailings flux and the meteorological parameters. The mathematical basis for the nomographs is contained in the appendix.

2. PROCEDURES FOR ESTIMATING COVER MATERIAL THICKNESSES AND VOLUMES

2.1 COVER THICKNESS

The first nomograph, given in Figure 1, is used to calculate the thickness of cover material required to achieve a specified reduction in surface radon flux. Key parameters for this nomograph are the diffusion coefficient for the cover, D, and the ratios J/J_t and a_c/a_t where J is the surface radon flux, J_t is the bare tailings flux and a_c and a_t are defined as:

$$a_c = D(1 - 0.74\ m)^2\ P_c^2 \qquad (1)$$
$$a_t = D_t(1 - 0.74\ m_t)^2\ P_t^2$$

where

P_c = cover material porosity

m = fraction of moisture saturation for cover material

P_t = tailings porosity

m_t = fraction of moisture saturation for tailings

D_t = diffusion coefficient for tailings

The required cover thickness, x_c, is found by first determing the ratios J/J_t and a_c/a_t and then referring to the nomograph in Figure 1. The value of the ratio J/J_t is found on Column A and the value of a_c/a_t on Column B. These two values should be connected with a straight line, and a value read from Column C at the intersection with the line. That same value is located on the modified scale C' and a second line is drawn from that value on C' to the value of D on Column D. The intersection of the resulting line with Column E gives the cover thickness, in units of either meters or feet. As an example of the use of the nomograph, a system with the following parameters is considered:

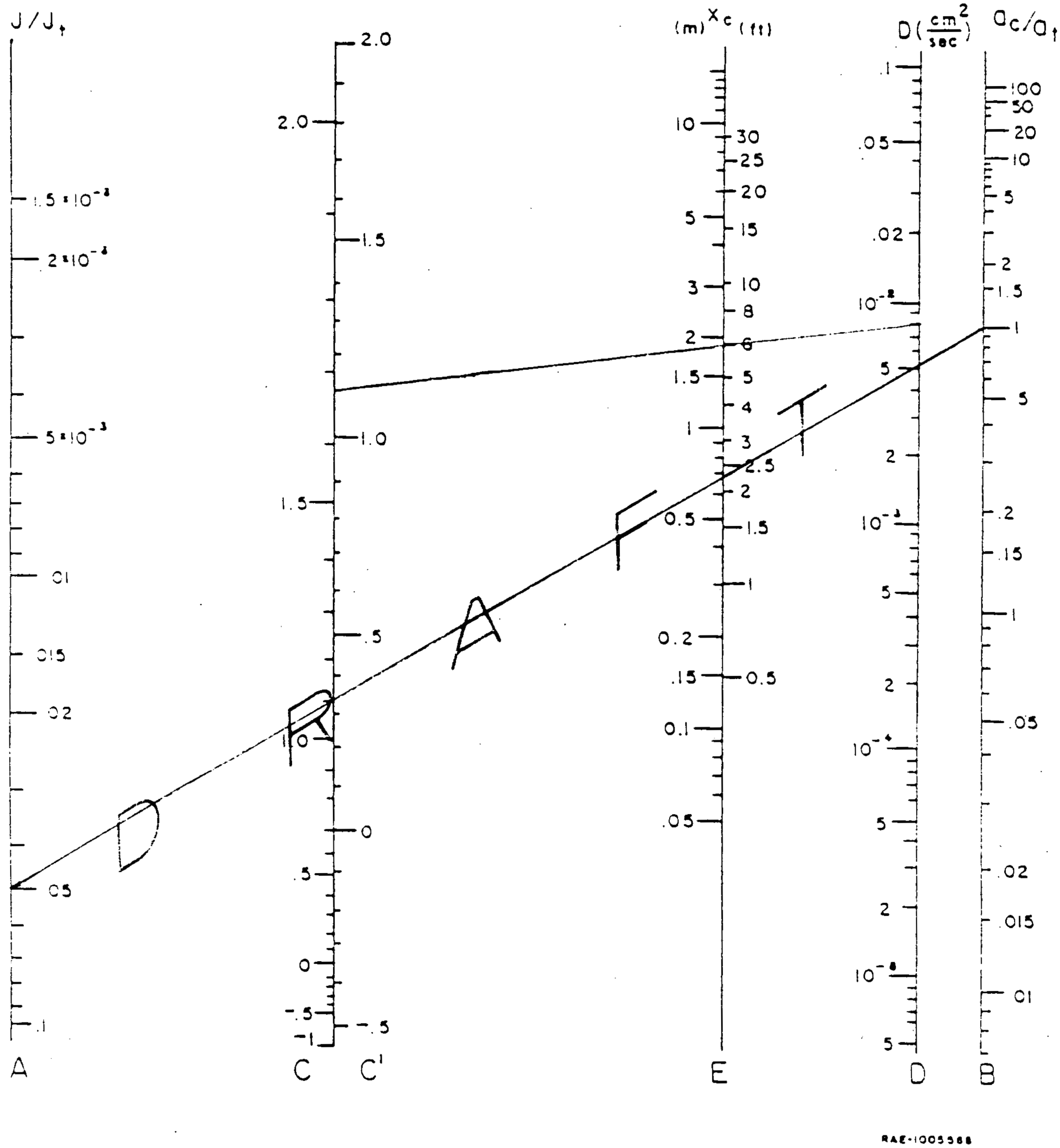

FIGURE 1. NOMOGRAPH FOR ESTIMATING NECESSARY COVER THICKNESS FOR RADON ATTENUATION.

$J_t = 400\ pCi/m^2s$

$J = 20\ pCi/m^2s$

$P_c = P_t = 0.30$

$m_c = m_t = 0.30$

$D_c = D_t = 0.008\ cm^2/s$

These values give a J/J_t of 0.05, located on Column A and a_c/c_t of 1, located on Column B. An intermediate parameter value of 1.1 is read from Column C. The same value is located on the modified scale on Column C'. This value is then used with the diffusion coefficient of the cover, located on Column D to obtain the cover thickness from Column E. For this example the cover thickness is about 1.8 m (5.9 ft).

An even simpler way to use the nomograph is to substitute the value of D_c/D_t for a_c/a_t; i.e., the quantity P (1 - 0.74 m) is assumed to be the same for the tailings and the cover. To account for the variations in the ratio of P (1 - 0.74 m) for the cover to the tailings, the rule of thumb may be used that the cover thickness decreases by 0.1 m for every 0.2 decrease in the ratio. The tailings diffusion coefficient also has only a secondary effect on x_c, so that, as an additional rule of thumb, x_c changes by 0.1 m for every factor of two change in D_t. The direction of the change is determined from the following: if D_t is increased by a factor of 2, but J_t is unaffected by the change, then x_c <u>decreases</u> by 0.1 m. On the other hand, if J_t is calculated from other parameters, one of these parameters being D_t, then J_t also varies with D, so that the resulting effect is that x_c <u>increases</u> by 0.1 m for every factor of two increase in D_t. With these rules of thumb, the cover thickness can be obtained from the nomograph using a value of unity for the ratio a_c/a_t, and then modifying x_c accordingly. For example, if D_t equals 0.002 cm^2/s instead of 0.008 as given above, and the value for J_t is a measured value that does not change, then the x_c of 1.8 m is increased by 0.2 m to a value of 2.0 m, because the D_t is reduced by a factor of four. Furthermore, if P_c were equal to 0.25 instead of 0.3, then the porosity ratio decreases by about 0.2, so that x_c is decreased from 2.0 m to 1.9 m. If in the original example J_t were based upon a calculated value instead of a measured value so that a change in D_t affects value of J_t, then a reduction in D_t by a factor of four would yield a reduction in the cover thickness of 0.2 m, from 1.8 m to 1.6 m.

2.2 COVER VOLUME

Once the required cover thickness is known, the volume of the cover material can be easily obtained. As shown in Figure 2, it is assumed that the edges of the tailings pile are contoured to conform to the slope criterion, S, where S is the horizontal distance per unit vertical rise of the sloped sides. This procedure is less costly than using only clean cover material to establish the sloped edges of the pile.

The required cover material volume presumes a relatively flat surface, is independent of the shape of the pile, and is easily determined by considering two components.

$$V_c = V_o + V_s \quad (2)$$

where

V_c = total cover volume

V_o = base cover volume

V_s = cover material needed for side slopes

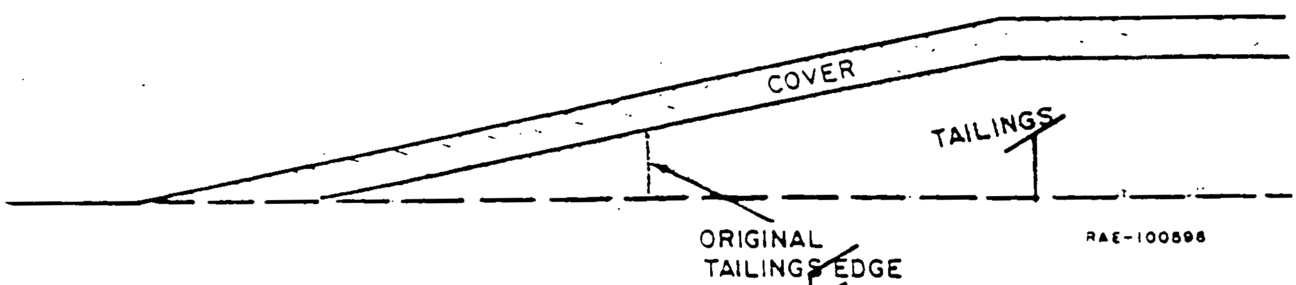

FIGURE 2. CONFIGURATION FOR THE SLOPED EDGES OF A COVERED TAILINGS PILE.

The base cover volume, the largest component, is the product of the cover thickness and the planar area of the pile, A_p.

$$V_o = A_p x_c \qquad (3)$$

This volume is easily calculated or estimated from the nomograph in Figure 3. To use the nomograph, the cover thickness obtained from nomograph 1 is located on Column A, the area of the pile is located on Column B and the base volume is read from the intersection of the line on Column C. For example, if the cover thickness is 2 m and the pile area is 2.5 x 10^5 m^2, then V_o is 5 x 10^5 m^3.

The determination of V_s requires a knowledge of the pile perimeter, P, and the slope criterion, S, in addition to the cover thickness. It is obtained using the nomograph in Figure 4. To use the nomograph, the cover thickness is located on Column A and the value of the pile perimeter is located on Column B. An intermediate value is located on Column C and is used, along with the value of S on Column D, to form a line which intersects Column E at the correct value of V_s. For example, assume x_c = 2.0 m, P equals 2000m and S equals 5. First locate x_c on Column A and P on Column B. The intersection of the line between the two points with Column C is the start of a new line drawn to the number 5 on Column D. The intersection of that line with Column E yields the value of 8 x 10^4 m^3 for V_s. For this example, V_s is about 16 percent of V_o, so that V_c is 5.8 x 10^5 m^3.

The nomograph in Figure 4 assumes that the ratio of the tailings thickness to the cover thickness is three. The V_s can be modified for other ratios of x_t/x_c using the nomograph in Figure 5. The value of V_s from Figure 4 is located on Column A, and the ratio of x_t/x_c is located on Column B. The intersection of

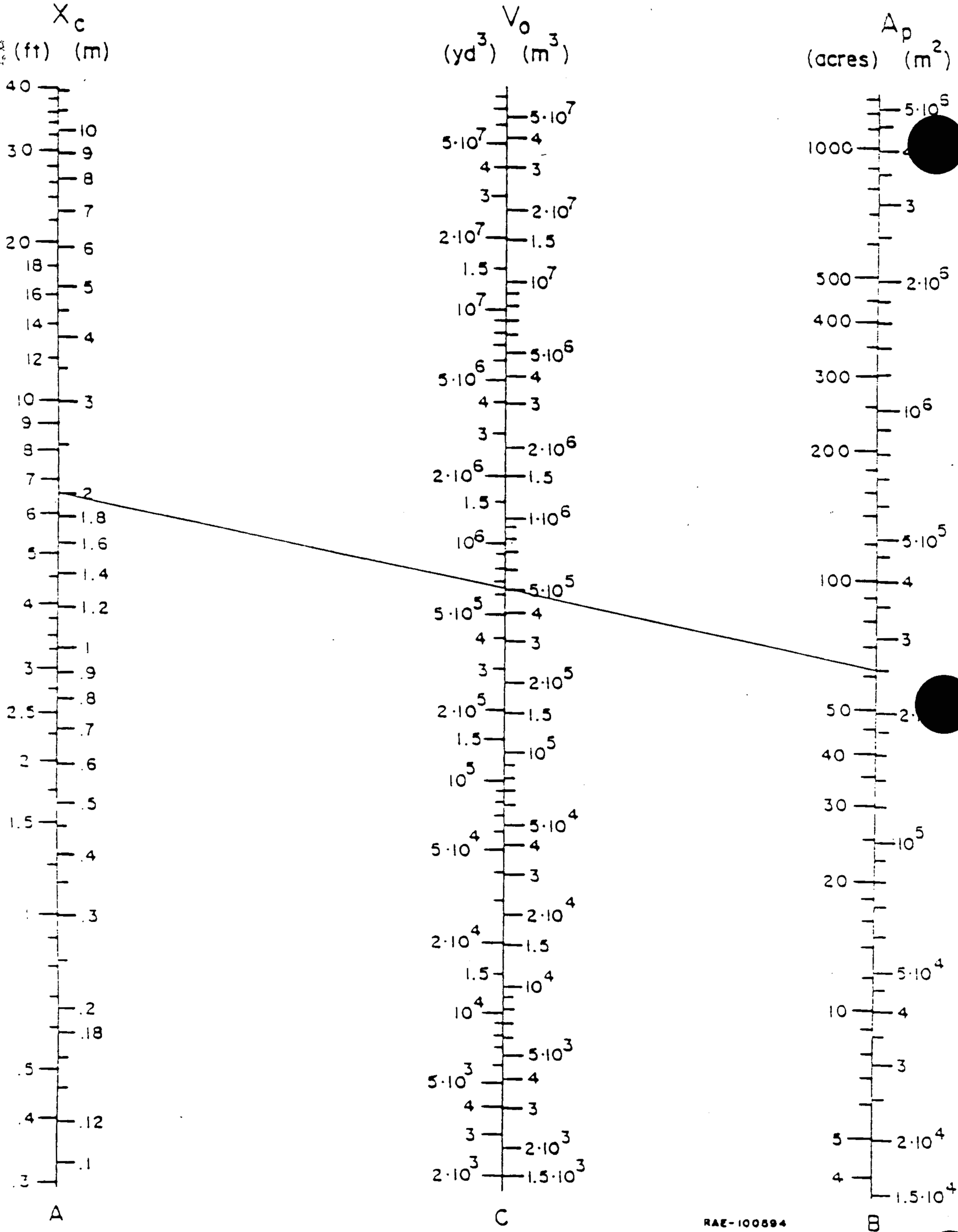

FIGURE 3. NOMOGRAPH FOR DETERMINING COVER MATERIAL VOLUMES.

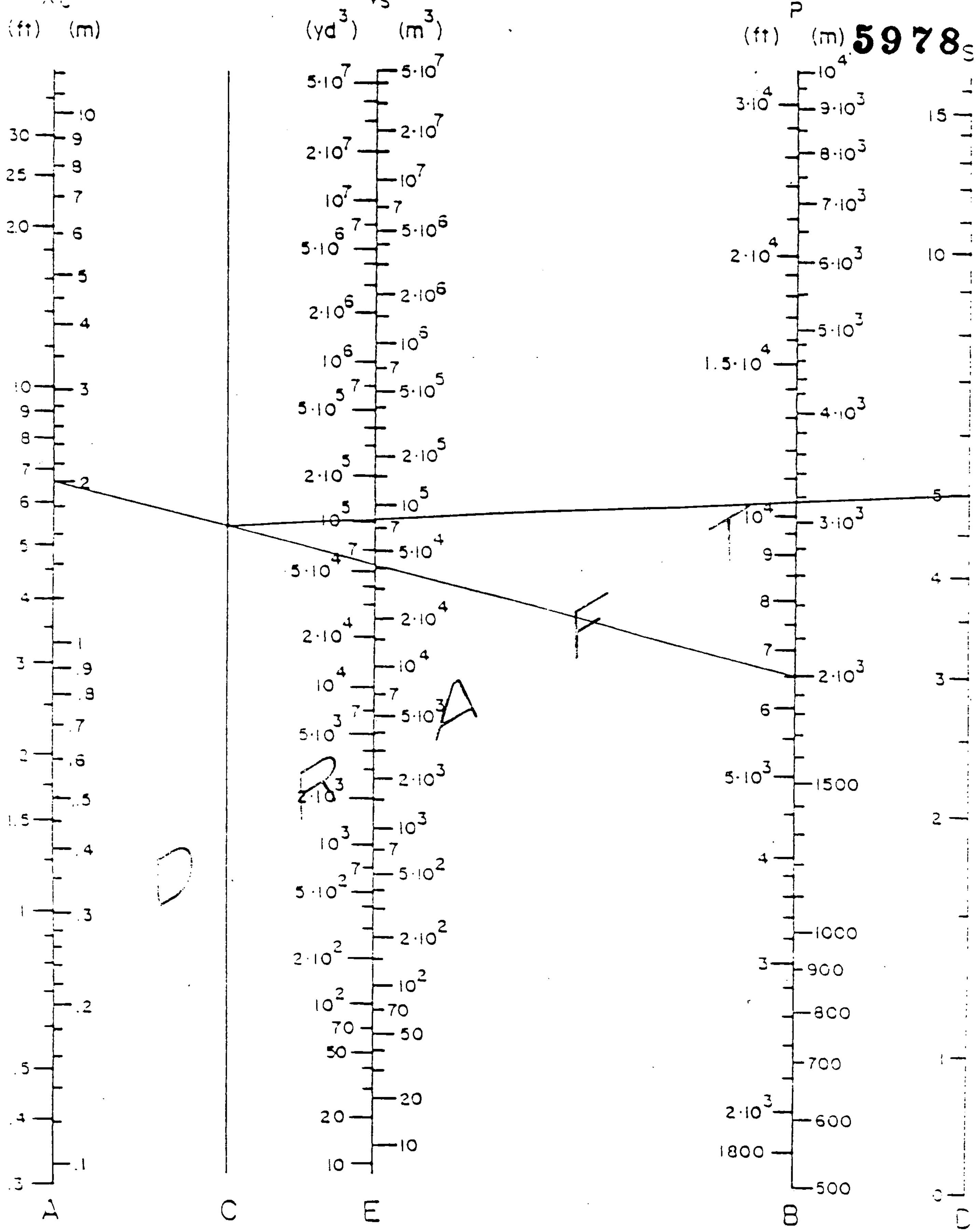

FIGURE 4. NOMOGRAPH FOR DETERMINING VOLUME OF COVER MATERIAL NEEDED FOR THE SLOPED EDGES.

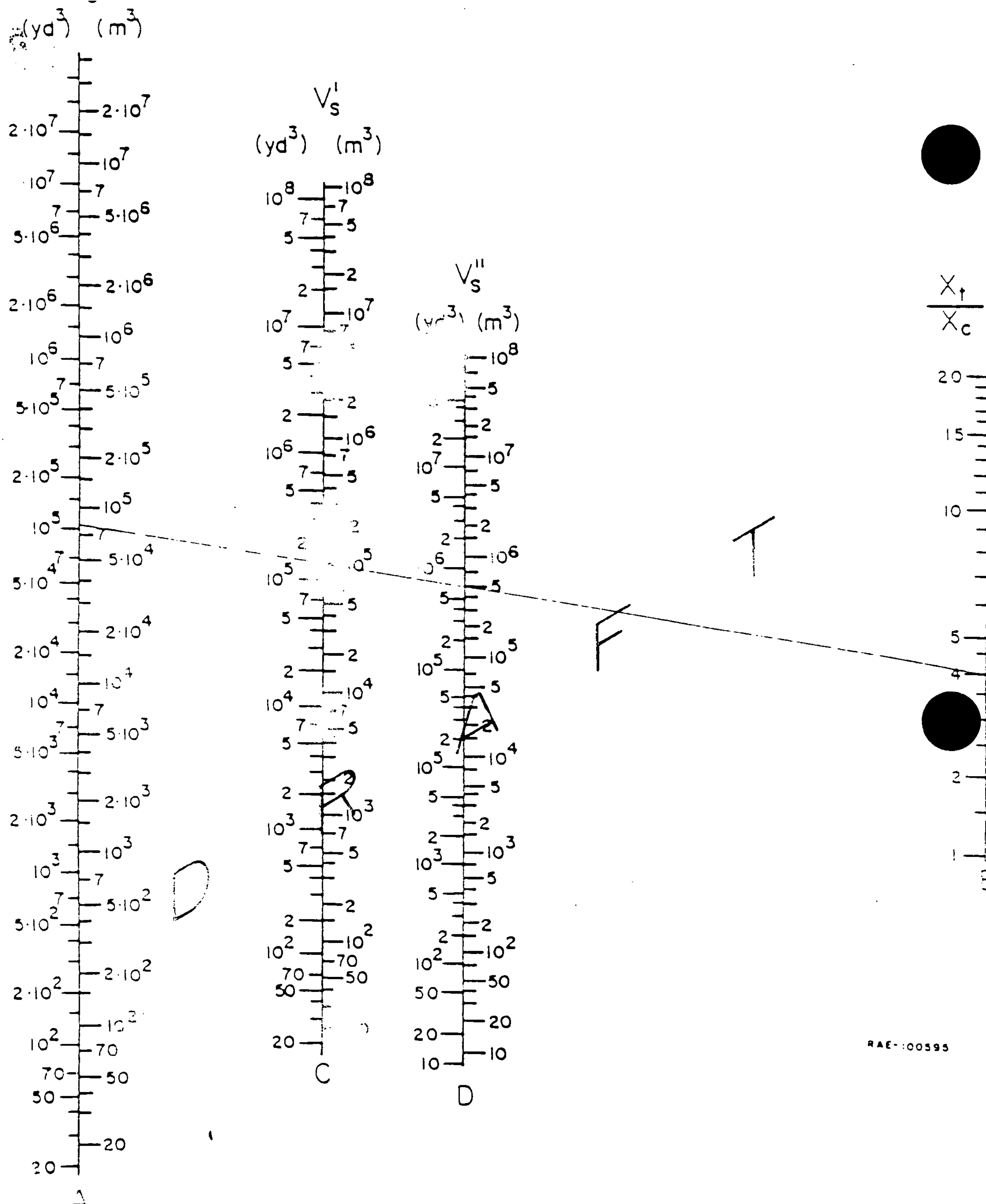

FIGURE 5. NOMOGRAPH FOR DETERMINING COVER MATERIAL VOLUMES FOR THE PILE EDGES.

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the line connecting these two points with Column C gives V_s', the corrected value of V_s. For example, if the ratio of the tailings to cover thickness were 4:1 in the previous example, then the value of 8×10^4 is located on Column A. A line connects this point and the value of 4 located on Column B. A value of 1×10^5 m^3 for the modified V_s' is found from the intersection of the line with Column C.

The nomograph in Figure 5 can also be used to obtain V_s'' for the case in which the tailings are not recontoured with a slope S, but in which only the cover material is used to form the side slopes. For this case the V_s as obtained from Figure 4 is located on Column A and the ratio x_t/x_c is again located on Column B. The intersection of the resulting line with Column D yields the appropriate value for V_s''. In the previous example a value of 8×10^4 m^3 was obtained for V_s from Figure 4. If the sloping sides are formed only with the cover material and if x_t/x_c is equal to four, then the appropriate value for V_s'' is 3×10^5 m^3, which is as large as V_o.

It should be noted that the volumes determined above are in-place volumes at the desired density. Usually, densities of earthen material as loaded on a truck are at least 25 percent less than the desired in-place density. This should be considered when estimating cover material costs and volumes.

2.3 RADON CONCENTRATION AT SITE BOUNDARIES

It is desirable for some applications to be able to estimate the radon concentration at a site boundary that would occur after the implementation of a particular remedial action. Since the value of the concentration is partially dependent upon the surface radon flux, a relationship can be derived that relates the annual average flux, J, and the annual average boundary concentration, C. Using this relationship, a surface radon flux can also be estimated from a specified boundary radon concentration, and then the previous nomographs can be used to estimate the required volumes for the cover material. However, the additional uncertainties in modeling the topography and micrometeorology at each site could add as much as an order-of-magnitude error to the estimates of the annual average radon concentration at the boundary.

The key parameters needed to relate the annual average flux to the radon concentration at the boundary are the following:

- A_p = area of the pile
- P_f = perimeter of fence boundary
- A = atmospheric stability factor
- u = mean wind velocity in the direction from the pile to the boundary location
- f = four sector (90^0) wind frequency in the direction from the pile to the boundary location

The fence-line boundary perimeter P_f is evaluated by first determining the distance x_f, between the pile edge and boundary location at which the radon concentration is desired, then calculating the perimeter length for a boundary the same shape as the pile perimeter and a distance x_f from the pile edge. For a square pile of length L, P_f is equal to $4(L + 2x_f)$. For a circular pile of radius R, it is equal to $2\pi(R + x_f)$. For most problems of interest, P_f can be set equal to the pile perimeter P with negligible loss of accuracy.

The atmospheric stability factor A is related to the vertical atmospheric dispersion parameter, σ_z, averaged over a portion of the pile length. The values of A are given in Table 1. If site specific stability data are not known, an annual average stability class of D can be assumed.

TABLE 1

VALUES OF THE ATMOSPHERIC STABILITY FACTOR

Stability Class	A(m)
A	3.85
B	2.32
C	1.58
D	1.00
E	0.60
F	0.30

The frequency f is obtained from a standard windrose. It is the maximum four-sector (90^0) sum of wind frequencies applicable to the site.

The ratio C/J is obtained using the nomograph in Figure 6. First, the meteorological parameters (Au/f) are determined. The product (Au/f) is located on Column A and a line is drawn from this point to the value of P_f located on Column B. The intersection of this line with Column C is the starting point for another line through the pile area located on Column D to Column E. The intersection of the second line with Column E gives the value of C/J. One of these parameters can then be readily obtained given a value for the other parameter. It is important to include the effects of calm weather in the windrose. This can be accomplished by dividing the frequency for calms equally among all sectors and assuming a windspeed of 0.7 m/s for it. If average velocities are given for each sector, then the average u for the correlation is obtained from

$$\frac{1}{u} = \frac{1}{f} \sum_{i=1}^{4} \frac{f_i}{u_i} \qquad (4)$$

where

u_i = velocity for sector i

f_i = wind frequency for sector i

Furthermore, if the windrose is given as a function of stability class, then the $(\frac{Au}{f})$ is obtained from

$$(\frac{f}{Au}) = \sum_{j} \sum_{i=1}^{4} \frac{f_{ij}}{A_j u_{ij}} \qquad (5)$$

where

f_{ij} = wind frequency for sector i and stability class j.

u_{ij} = wind velocity for sector i and stability class j.

A_j = stability factor for class j.

Use of the nomograph in Figure 6 is illustrated by an example calculation for the Vitro (Salt Lake City) site. The windrose data for Salt Lake City,[1] given in Table 2, yields an f value of 0.548, averaged over the ESE, SE, SSE, and S sectors, and an average velocity of 3.7 m/s (8.3 mi/hr). For lack of more detailed information, a D stability condition is assumed so that A has the value 1.00 m. The effect of including the calms was to reduce the average velocity from 4.4 m/s to 3.7 m/s. Combining these parameters yields a value of 6.8 for (Au/f). Other pertinent parameters for this site are: A_t equals 4×10^5 m^2 (100 acres) and P_f equals 2.6×10^3 m. The value 6.8 is located on Column A and a line is connected from it to the value 2.5×10^3 m on Column B. A new line is then drawn from the point of intersection with Column C through the 100 acre point on Column D to the 0.025 point on Column E. Thus C/J equals 0.025. If J is 20 pCi/m^2s, then C is 0.5 pCi/l at the maximal location on the boundary. If an isotropic windrose is assumed, then (Au/f) becomes 14.8, C/J is 0.0077 and C is 0.15 pCi/l. This value is more representative of the average boundary concentration around the pile.

The nomograph given in Figure 6 is formulated so that either C or J can be

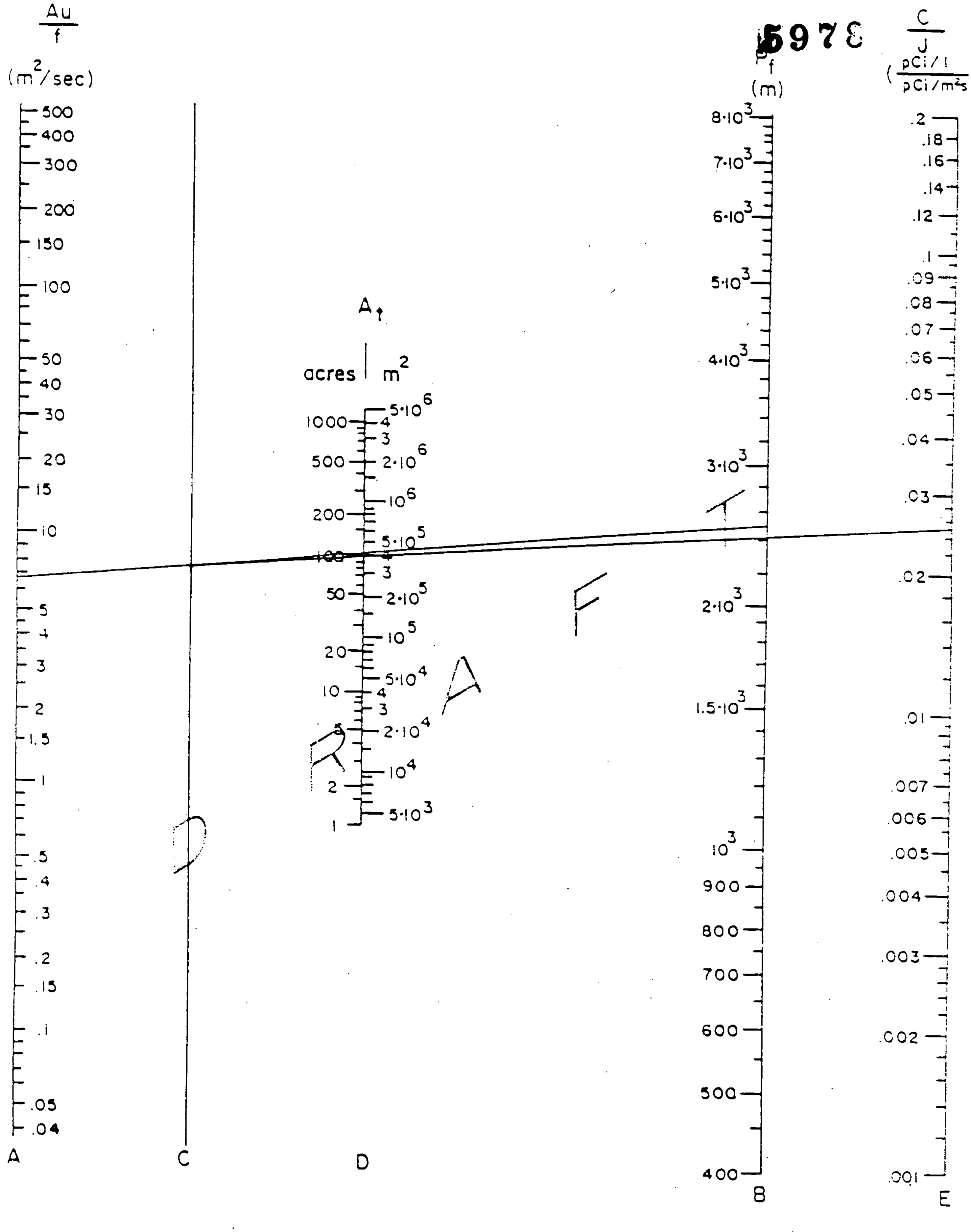

FIGURE 6. NOMOGRAPH FOR DETERMINING RADON CONCENTRATIONS AT THE BOUNDARY.

readily obtained, given the other parameter. This nomograph can also be used with the others to obtain cover material volumes. If a limiting boundary concentration is the criterion, then the necessary surface flux J can be obtained from the nomograph in Figure 6 and used in the nomograph in Figure 1 to obtain the cover thickness.

TABLE 2

WIND DATA FOR SALT LAKE CITY
(Cumulative 1951-1960)

Direction	Frequency (%)	Average Speed (mi/hr)
N	6.9	7.9
NNE	2.4	7.8
NE	2.3	6.2
ENE	0.6	5.9
E	1.5	6.7
ESE	3.6	8.2
SE	17.4	8.9
SSE	18.9	10.4
S	13.5	11.3
SSW	2.6	9.7
SW	2.5	6.9
WSW	1.2	6.9
W	3.1	7.4
WNW	3.8	8.8
NW	7.8	8.8
NNW	6.5	9.0
Calm	5.4	---
TOTAL	100.0	8.7

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3. SUPPORTING DATA FOR KEY PARAMETERS

There are three key parameters used in the nomographs that warrant further discussion, particularly with regards to methods to estimate their value for particular sites. These parameters are the diffusion coefficient, the tailings source term, represented by J_t, and the meteorological parameter (u/f). This section contains a discussion of values for these parameters.

3.1 DIFFUSION COEFFICIENT

Diffusion coefficients for radon have been measured in a wide variety of earthen materials under several research projects at Rogers and Associates over the past two years. The measurements have generally been aimed at determining the suitability of the materials as tailings covers. A data base of radon diffusion coefficients was recently assembled from the results of the various measurements and was used to evaluate the overall ranges and typical values of diffusion coefficients of earthen materials. The data base includes the dry densities and moisture contents of the soils and thus allows examination of variations with moisture and compaction.

Much of the diffusion data in the data base has been previously reported in a variety of topical and technical progress reports. One set of data on eight western U.S. soils(2) also includes sieve analyses, water drainage characteristics, and other soil parameters. Although these are not generally available for most of the other soils, several of the eight well-characterized soils are also used in later studies on the effects of moisture on diffusion coefficients(3) and in comparing time-dependent and steady-state measurement techniques.(4) Measurements under ambient field moisture and compaction conditions are also reported.(5)

The results of 103 radon diffusion coefficient measurements on the various soils are illustrated by the graph in Figure 7. The data were mostly measured by the time-dependent technique, but also included thirteen steady-state measurements. As illustrated, the diffusion coefficients are relatively constant at dryness, averaging 0.061 ± 0.006 cm^2/s for the seven dry soils tested. Increasing moisture causes lower diffusion coefficients, as has bee previously observed[6-10] and predicted from a diffusion model.[10]

Considerable scatter in the data is noted in Figure 7. This is a result of several variables, including uncertainty in the diffusion coefficient measurement, uncertainty in the degree of moisture saturation, and variation in key soil parameters such as total porosity, pore size distribution, tortuosity or grain shape factors, and homogeneity of the soil sample. It was shown by a random pore combination model for radon diffusion that the soil pore size distribution can account for very large variations in the moisture dependence of diffusion coefficients.[10] This model predicts small variations among different soils due to tortuosity differences at dryness ($m = 0$) and saturation ($m = 1$), but one to two order-of-magnitude variations at intermediate moistures.

Although the variation in diffusion coefficients at intermediate moistures can be largely attributed to varying pore size distributions, the variation at high moistures ($m = 0.9$-1.0) cannot. Instead, this variation results from the very steep variation in diffusion coefficients with moisture as m approaches unity. This causes large apparent errors in diffusion coefficients to result from relatively small errors in sample moisture content, density, or specific gravity estimates from which the saturation, m, is estimated. The diffusion model predicts an even steeper slope for this region than is shown in Figure 7, suggesting two-order-of-magnitude variations in diffusion coefficient in changing m from 0.95 to 1.0 for a relatively well-graded soil.[10] The large variation near saturation in the figure is therefore attributed to uncertainties in the degree of

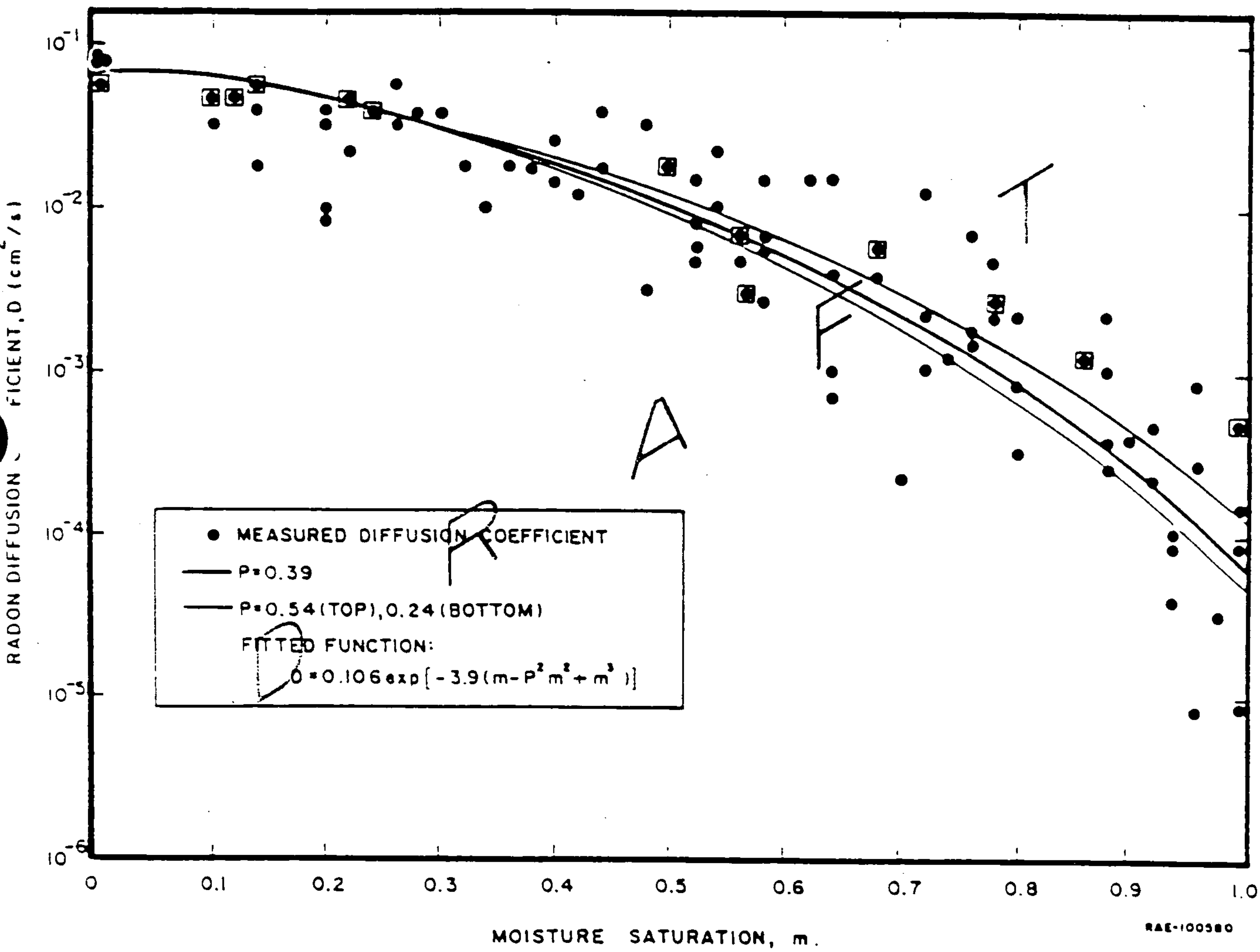

FIGURE.7. COMPARISON OF MEASURED RADON DIFFUSION COEFFICIENTS WITH A SIMPLE CORRELATION FUNCTION ASSUMING DIFFERENT POROSITIES.

moisture saturation of the soil samples.

A bias is noted in comparing the diffusion coefficients at saturation in Figure 7 with the expected value of $\sim 6 \times 10^{-6}$ cm^2/s. This is due to difficulty in completely saturating a sample, and also to truncation of the lower part of the distribution of these coefficients. The truncation occurs because diffusion coefficients of $\sim 10^{-5}$ cm^2/s require about seven days for detection of the radon gas front(4) and measurements were often terminated before this time. Although upper limits such as $<10^{-5}$ cm^2/s were estimated from the termination time, these values were not included in the data base.

A correlation of the data with moisture and porosity was performed based upon insights gained from applying the diffusion coefficient model. An analysis of the tortuosity equations(10) in the model and a reasonable correlation between porosity and widths of the pore size distributions indicated that the porosity could represent the effects of tortuosity and distribution widths. Although a good correlation was obtained between the diffusion coefficients and the saturation data, as indicated in Figure 7, the soil porosities did not correlate as well as expected. Examination of the data reveals no compelling trend of the data with porosities; that is, porosities both higher and lower than the average occur both above and below the correlation curve in Figure 7 using the average porosoty value.

It is expected that high porosities may generally correlate with higher diffusion coefficients at a given degree of moisture saturation. This is due to their generally less-tortuous diffusion pathway, and also to the higher porosities usually associated with narrow pore-size and grain-size distributions. In the present data set, many soils were analyzed at densities well below the standard Proctor density, however, and the expected relationship between porosity and distribution widths may be less pronounced.

Several trial functions were compared with the data in Figure 7, and the correlation function chosen to represent that data was

$$D = 0.106 \exp\left[-3.9(m - P^2m^2 + m^3)\right], \qquad (6)$$

where

D = radon diffusion coefficient of the soil pore space (cm^2/s)

m = fractional moisture saturation ($m>0.1$)

P = soil porosity

This function was chosen over others because it had the lowest geometric standard deviation from the data, 2.5. It was noted that several other functions with different porosity terms also had a geometric standard deviation which was nearly as low as 2.5, thus suggesting that the degree of porosity dependence of the function is not highly important. The three lines plotted in Figure 7 represent the mean porosity for the data set and its 2σ confidence interval. The remaining variation not explained by this function is attributed to soil properties such as pore distribution widths which are not as readily available from engineering parameters.

For comparison with two previous diffusion coefficient correlations,[6-9] the present data set was also analyzed with respect to the earlier equations and found to exhibit higher geometric standard deviations. New fitting parameters were estimated from the present data for the correlation[9]

$$D = a\left[P(1-m)\right]^b + 6.6 \times 10^{-6} \frac{m}{1-m}. \qquad (7)$$

For the best fit of the present data set, a changed from 0.74 to 0.359 and b changed from 1.16 to 2.32. The geometric standard deviation from the present data set using these parameters was 3.7.

Equation (6) has a similar form to the other previous correlation of diffusion coefficients with moisture, preserving an exponential decrease with moisture[10] from the maximum value for the diffusion coefficient of radon in air, 0.106 cm^2/s. Because of tortuosity in the soils, this value is not reached even at dryness, however, so the function is truncated and held constant at $D = 0.06\ cm^2/s$ for $m<0.1$. The exponential argument is a simple power series in m, where the first term defines the general downward slope. The squared term contains the porosity influence and also causes a more gradual decrease with moisture in the pore filling region. The cubic term accounts for major pore blockage near saturation and causes the more rapid decreases needed in this region. Only the constant 3.9 in equation (6) was varied in the fitting process. Because of the data limitations near saturation, equation (6) is considered valid over the range $0.1<m<0.95$, even though the fit to the data set extended over the range $0 \leq m \leq 1$.

Equation (6) can also be expressed in a form containing standard engineering parameters of the cover material, specifically, the bulk density d, the moisture content on a dry weight percent basis, M, and the specific gravity of the material, G. In these terms equation (6) becomes

$$D = 0.106 \exp\left[-3.9\left[\left(\frac{GdM}{G-d}\right)^3 - (dM)^2 + \left(\frac{GdM}{G-d}\right)\right]\right] \qquad (8)$$

For most earthen materials a value of 2.7 g/cm^3 can be used for G.

3.2 SOURCE TERM

The source term used in the evaluations is expressed as the bare tailings flux, J_t. It can be calculated from the following expression:

$$J_t = 10^{4} R d E \sqrt{\lambda D_t}\ \tanh \sqrt{\frac{\lambda}{D_t}}\ X_t\ , \qquad (9)$$

where

R = radium content of the tailings (pCi/g)

E = emanation coefficient

λ = radon decay constant (2.1×10^{-6} sec^{-1})

An alternate way to obtain an estimate of J_t is from direct measurements on the bare piles. Some of the available experimental data for J_t on representative UMTRAP sites[1] is summarized in Table 3.

TABLE 3

RADON FLUX DATA FOR REPRESENTATIVE UMTRAP SITES

Site	Average Flux (pCi/m^{2}s)
Ambrosia Lake	120
Canonsburg	70
Durango	225
Grand Junction	550
Green River	95
Gunnison	150
Maybell	125
Mexican Hat	400
Monument Valley	20
New Rifle	270
Old Rifle	700
Riverton	65
Salt Lake City	250
Shiprock	110
Tuba City	180

3.3 METEOROLOGY DATA

The meteorological information needed for the nomograph in Figure 6 consists of the wind frequency in the maximal 90^0 sector, the associated wind-speed, u and the stability class. For lack of further information an annual average stability class of D can be assumed so that the factor A becomes 1.0 m. Representative values for f and u for some of the UMTRAP sites(1) are tabulated in Table 4.

TABLE 4

METEOROLOGICAL DATA FOR SOME UMTRAP SITES

Site	f	u(m/s)	u/f
Ambrosia Lake	0.35	3.6)	10.3
Canonsburg	0.57	1.8	3.2
Durango	0.50	3.6	7.1
Grand Junction	0.46	4.8	10.4
Green River	0.29	1.9	6.6
Gunnison	0.24	3.9	16.1
Maybell	0.45	2.7	5.9
Monument Valley	0.26	1.2	4.5
Rifle	0.35	1.0	2.9
Riverton	0.48	3.1	6.5
Salt Lake City	0.55	3.7	6.7
Shiprock	0.36	2.7	7.7

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APPENDIX

MATHEMATICAL BASIS FOR NOMOGRAPHS

A.1 COVER THICKNESS

The nomograph for estimating cover thicknesses, given in Figure 1, is based upon the exact diffusion theory solution to the two-region proglem.[11,12] The surface flux is given by,

$$J(x_c) = \frac{2J_t\, e^{-b_c x_c}}{\left[1 + \sqrt{a_t/a_c}\ \tanh b_t x_t\right] + \left[1 - \sqrt{\frac{a_t}{a_c}}\ \tanh b_t x_t\right] e^{-2b_c x_c}} \qquad \text{(A-1)}$$

where

$b_i = \sqrt{\lambda/D_i}$ (i = c or t)

$a_i = P_i^2\, D_i \left[1 - (1-k)\, m_i\right]^2$

$k = 0.74$

The value of x_c for a specified flux can be obtained by rearranging this equation, assuming the tailings are more than 2m thick and approximating $\exp(-b_c x_c)$ by $(j/J_t)^2$. The result is

$$x_c = \sqrt{\frac{D_c}{\lambda}}\ \ln\left[\frac{2J_t/J}{(1 + \sqrt{a_t/a_c}) + (1 - \sqrt{a_t/a_c})(J/J_t)^2}\right] \qquad \text{(A-2)}$$

Equation (A-2) is plotted in the nomograph using standard techniques.[13]

A.2 MATERIAL VOLUMES

The nomographs for material volumes are based upon standard geometric expressions. It is assumed that the tailings pile edges are contoured before the pile is covered. This contouring is assumed to consist only of sloping the edges of the pile to conform to the slope criterion S, as shown in Figure 2. Two cases are considered: a rectangular pile and a circular pile, however, the resulting expressions are independent of pile shape.

Rectangular Tailings Pile

A rectangular pile with initial length, width, and thickness, L, W, and x_t is contoured by sloping the sides of the pile to a slope ratio, S. The cover material is then added to a vertical depth, x_c. The total volume of tailings and cover is

$$V = (L-Sx_t)(W-Sx_t)(x_t+x_c) + (L+W-2x_tS)(x_t+x_c)^2S + \frac{4}{3}(x_t+x_c)^3S^2 \qquad \text{(A-3)}$$

The volume of tailings is LWx_t so the volume of cover material is

$$V_c = V-LWx_t = \left[LW-x_tS(W+L) + x_t^2S^2\right] x_c + (L+W-2x_tS)(x_c^2 + 2x_cx_t)S +$$

$$\frac{4}{3} S^2(x_c^3+3x_c^2x_t+3x_cx_t^2) \qquad \text{(A-4)}$$

Letting $V_o = LWx_c = A_px_c$ (A-5)

and

$$V_s = S(L+W)(x_c^2+x_cx_t + S^2x_cx_t^2 + 2S^2x_c^2 x_t + \frac{4}{3} S^2x_c^3 \qquad \text{(A-6)}$$

we obtain

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$$V_c = V_o + V_s \qquad \text{(A-7)}$$

In general, the first term on the right-hand side of equation (A-6) dominates so that it may be written as

$$V_s = \frac{1}{2} SPx_c^2 (1 + x_t/x_c) \qquad \text{(A-8)}$$

If it is assumed that $x_t = 3x_c$, then equation (A-8) becomes

$$V_x = 2SPx_c^2 \qquad \text{(A-9)}$$

Equation (A-5) is the basis of the nomograph in Figure 3 and equation (A-9) is the basis of the nomograph in Figure 4.

A circular tailings pile yields the same expressions for V_o and V_s' as given in equations (A-5) and (A-8). The tailings pile of initial radius R and thickness x_t is contoured so that the sides are characterized by a slope ratio S. With a cover of thickness x_c added the total volume of tailings and cover is

$$V = \pi(x_c + x_t) \left[R^2 + RSx_c + S^2 \left(x_c^2 + \frac{x_c x_t}{2} + \frac{x_t^2}{4}\right) \right] \qquad \text{(A-10)}$$

Subtracting the tailings volume, $\pi R^2 x_t$, gives a cover volume

$$V_c = \pi R^2 x_c + \pi(x_c + x_t) \left[RSx_c + S^2\left(x_c^2 + \frac{x_c x_t}{2} + \frac{x_t^2}{4}\right) \right] \qquad \text{(A-11)}$$

Letting $V_o = \pi R^2 x_c$ and (A-12)

$$V = \pi(x_c + x_t) \left[RSx_c + S^2 \left(x_c^2 + \frac{x_c x_t}{2} + \frac{x_t^2}{4} \right) \right] \qquad \text{(A-13)}$$

we again obtain

$$V_c = V_o + V_s$$

For most applications equation (A-13) can be written as

$$V_s = \frac{1}{2} SPx_c^2 \; (1 + x_t/x_c) \;, \qquad \text{(A-14)}$$

a form identical to equation (A-8).

Equations (A-8) and (A-9) can be combined so that the more general expressi for V_s (call it V_s') can be expressed in terms of the V_s given in equation (A-

$$V_s' = V_s \; (1 + x_t/x_c)/4 \qquad \text{(A-15)}$$

This expression is the basis for the nomograph in Figure 5.

If cover material is used for the side slopes, and the tailings are not contoured at the edges, more material is needed than for the above case. The material needed for the side slopes is easily determined to be

$$V_s'' = \frac{1}{2} SPx_c^2 \; (1 + x_t/x_c)^2 \;, \qquad \text{(A-16)}$$

or, in terms of equation (A-9)

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$$V''_s = V_s\ (1 + x_t/x_c)^2/4 \qquad \text{(A-17)}$$

This equation is the basis for Column D in Figure 5.

A.3 BOUNDARY RADON CONCENTRATION

Relating the surface radon flux to a boundary concentration requires detailed quantification of the site micrometeorology, topology, tailings size, etc. Even standard Gaussian Plume techniques for area sources have shortcomings because of source configuration approximations and because the pertinent distances are less than the range of applicability of the dispersion coefficients. Furthermore, limitations of nomographic techniques impose severe restrictions on the complexity of the mechanism being represented. Therefore, a relatively simple mass balance approach was used for the nomograph in Figure 6. Comparison of the results with experiment and with calculations using RADAD-III[14] and MILDOSE[15] computer models, yields uncertainties that are comparable to the more complex calculations.

First, a maximum scenario is modeled in which the wind always blows across the length of a rectangular tailings pile and the boundary is at the edge of the pile. Equating the radon production rate with the radon loss rate past the edge of the pile yields

$$JL = C\ uH \qquad \text{(A-18)}$$

where

J = surface flux

L = length of pile

C = radon concentration at pile edge

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u = windspeed

H = effective mixing height or vertical dispersion coefficient

Rearranging equation (A-18) gives

$$C/J = \frac{L}{uH} \tag{A-19}$$

Next, an irregular shaped pile and an isotropic windrose is considered. The rate balance yields

$$C/J = \frac{A_p}{P_f uH} \tag{A-20}$$

where

A_p = area of the pile

P_f = boundary perimeter

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If a nonisotropic windrose is considered, equation (A-20) becomes

$$C/J = \frac{16\ f\ A_p}{n\ P_f\ uH}\ , \tag{A-21}$$

where

n = number of sectors contributing radon to the specific boundary point

f = wind frequency summed over n sectors

16 = total number of sectors

The appropriate value for n can be estimated by considering the maximal case for a square pile and one-directional wind. For this case, equation (A-21)

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becomes

$$C/J = \frac{16}{4n} \frac{L}{uH} \qquad \text{(A-22)}$$

Comparison of equations (A-22 and (A-19) gives a value of four for n; thus

$$C/J = \left(\frac{A_f}{P_f}\right) \frac{4f}{uH} \qquad \text{(A-23)}$$

The characteristic vertical mixing height, H is estimated from the vertical dispersion coefficient, σ_z, used in Gaussian Plume calculations.

The Briggs formulation(16) for σ_z is integrated to obtain an average of the inverse of σ_z over a distance L. This is denoted by $\bar{\sigma}_z$ and can be approximated by

$$\bar{\sigma}_z = BL^{2/3} \quad ,$$

where B is a constant that differs for each atmospheric stability class. A value of 250 m for L was selected as representative, and the corresponding value for $\bar{\sigma}_z$ was set equal to H. Thus,

$$H = 40B \quad . \qquad \text{(A-24)}$$

Equation (A-23) becomes

$$C/J = \left(\frac{A_p}{P_f}\right)\left(\frac{f}{A\ u}\right) \quad , \qquad \text{(A-25)}$$

where

$A = 10B.$

Values of A are given in Table 1.

Equation (A-25) is the basis of the nomograph in Figure 6.

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REFERENCES

1. "Engineering Assessment of Inactive Uranium Mill Tailings" USDOE reports DOE/UMT-0102 to DOE/UMT-0120 (1981).

2. K.K. Nielson, et.al., "Laboratory Measurements of Radon Diffusion Through Multilayered Cover Systems for Uranium Tailings," Department of Energy Report UMT/0206, December 1981.

3. K.K. Nielson, et.al., "Comparison of Radon Diffusion Measurement Methods for a Moist Soil," Rogers & Associates Engineering Corp. Letter Report to Pacific Northwest Laboratory RAE-9L1, May 1982.

4. K.K. Nielson, et.al., "Transient Measurements of Radon Diffusion Coefficients," Rogers & Associates Engineering Corp., Nuclear Regulatory Commission Report NUREG/CR-2875, November 1982.

5. "Composite Cover Optimization for Uranium Mill Tailings," Rogers & Associates Engineering Corp. Quarterly Progress Report to Pacific Northwest Laboratory, RAE-9Q8, June 1982.

6. V.C. Rogers, et.al., "Characterization of Uranium Tailings Cover Materials for Radon Flux Reduction," Nuclear Regulatory Commission Report NUREG/CR-1081, March 1980.

7. A.B. Tanner, "Radon Migration in the Ground: A Review," in The Natural Radiation Environment (eds. J.A.S. Adams and W.M. Lowder) Rice University, Houston, Texas, pp. 161-190 (1964).

8. A.S. Serdyukova and Y.T. Kapitanov, "Radon Isotopes and Short-Lived Products of Their Disintegration in Nature," Atomizdat, Moscow, 1969; Translated from Russian for U.S. Bureau of Mines, TT72-51014 (1978).

9. R.W. Nelson, G.W. Gee and C.A. Oster, "Radon Control by Multilayer Earth Barriers," Symposium of Uranium Mill Tailings Management-III, Ft. Collins: Colorado State University, pp. 79-88 (1980).

10. K.K. Nielson and V.C. Rogers, "A Mathematical Model for Radon Diffusion in Earthen Materials," Nuclear Regulatory Commission Report NUREG/CR-2765, October 1982.

11. V.C. Rogers and K.K. Nielson, "A Handbook for the Determination of Radon Attenuation Through Cover Materials," Nuclear Regulatory Commission Report NUREG/CR-2340, December 1981.

12. V.C. Rogers, et.al., "Measurements and Calculations of Radon Flux Attenuation by Western U.S. Soils," Symposium of Uranium Mill Tailings Management-V, Ft. Collins, Colorado State University, (1982).

13. D.S. Davis, Nomography and Empirical Equations, 2nd ed., Reinhold Publishing Corp., (1962).

14. V.C. Rogers, et.al., "Radon Releases and Potential Health Impacts from Four Inactive Uranium Mill Tailings Sites," Rogers and Associates Engineering Corp. Report to Ford, Bacon and Davis Utah/DOE, RAE-11-4 (November 198

15. D.L. Strenge and T.J. Bander, "MILDOS - A Computer Program for Calculating Environmen Radiation Doses from Uranium Recovery Operations," U.S. NRC report NUR R-2011 (April 1981).

16. "Environmenta Analysis of the Uranium Fuel Cycle, Part IV - Supplementary Analysis - 1976," U.S. Environmental Protection Agency, EPA 520/4-76-017, (July 1976)

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ANALYSIS OF THE IMPACT OF VARIOUS SANDS AND THICKNESSES ON RADON ATTENUATION AND GAMMA SHIELDING ON THE K-65 SILOS

by:

Gary S. Mihalovich

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ANALYSIS OF THE IMPACT OF VARIOUS SANDS AND THICKNESSES ON RADON ATTENUATION AND GAMMA SHIELDING ON THE K-65 SILOS

by: Gary S. Mihalovich

TASK- A task was defined to determine the effects of various sand types and thicknesses on the K-65 silo relative to radon attenuation and gamma shielding. The task was to determine using various thicknesses and types of sand the optimum cover that could be achieved.

METHOD- The method that was used involves the use of various computer codes, types and thicknesses of sands. A series of computations using the computer programs was to be completed based on input data from previous work, data obtained from sand vendors, and input generated from in-house calculations. The results of this data would then be graphically plotted to provide results of the data in a logical and visual form.

COMPUTER CODES- The computer codes that were used for calculation of the attenuation and shielding are: 1) "Radiation Attenuation Effectiveness and Cover Optimization with Moisture Effects" RAECOM. (Ref. 1); and 2) "A Combinatorial Geometry Version of QAD-P5A, A Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculation Using the GP Build-Up Factor" QAD-CGGP, (Ref. 2). The computer program that was used for determination of the statistical validity of the data was "A Proprietary Statistical and Data Base Management System, STAT-PRO, (Ref. 3). The computer programs that were used for compilation of the data and plotting of the results were "Lotus Development Company, LOTUS 123" LOTUS 123, (Ref. 4) and "Lotus Freelance Plus", FREELANCE, (Ref. 5). All codes and programs were either initially run against known inputs or outputs, or have been previously approved for use without this requirement.

INPUT DATA- The following sets of input data were used. They are provided in tabulated form for information.

INPUT DATA FOR RADON ATTENUATION CALCULATIONS (Ref. 6)

Radium Content	2×10^5 pCi/g
Density	1.6 grams/cm^3
Emanating Power	0.2
Porosity	0.3

INPUT DATA FOR GAMMA SHIELDING CALCULATIONS (Ref. 7)

Gamma Surface K-65	613 mrem/hr.
Calculated Radium	3,211 Curries/both

INPUT DATA FOR SAND MATERIALS (Ref. 8)

	Masonry Sand	Portland Cement Sand	Coarse Bituminous Sand
Moisture %	15%	12%	9%
Distribution by Sieve Size:			
# 04	99%	99%	99%
# 08	99%	99%	88%
# 16	93%	84%	66%
# 30	80%	72%	36%
# 40	76%	44%	22%
# 50	45%	22%	9%
# 70	22%	11%	5%
#100	12%	4%	2%
#200	6%	2%	1%
Porosity	38%	37%	34%

OUTPUT DATA-

Output Data for Gamma Shielding

Distance From Source (all readings in mrem/hr)

	Masonry Sand	Portland Cement Sand	Coarse Bituminous Sand
Surface	613	613	613
1 foot	425	430	430
2 feet	312	318	314
3 feet	208	243	254
4 feet	152	181	198
5 feet	106	152	168

Output Data for Radon Attenuation

Distance From Source (all readings in $pCi/m^2/sec$)

	Masonry Sand	Portland Cement Sand	Coarse Bituminous Sand
Surface	70	70	70
1 foot	62	63	65
2 feet	51	53	55
3 feet	32	37	42
4 feet	2	17	25
5 feet	0	3	8

(NOTE) The output data was inputted and run through a statistical validation program to determine if the data was representative and if any anomalies existed. The results of these calculations indicated that the data was statistically valid and that the correlations were within the 95% confidence level. The data was then plotted against a standard linear regression analysis to produce a smooth curve. This assisted in analysis of the data. (See References # 3, #4, and #5)

RESULTS-

The output data indicates that in radon attenuation and gamma shielding the use of the Masonry Sand produces the optimum results with the minimum amount of material. Four feet of Masonry Sand effectively eliminates all measurable radon emissions to the environment and produces a 75% reduction in gamma. This reduction in gamma could significantly reduce the skyshine from these two sources and result in a reduced off-site and on-site population dose.

The same amount (four feet) of Portland Cement Sand results in a 75% reduction in radon emissions and a 70% reduction in gamma. The Coarse Bituminous Sand, when filled to four feet, only produces a 62% reduction in radon emissions and a 65% reduction in gamma.

The determination of which type of sand to use would indicate that using the Masonry Sand would achieve the maximum reduction for the least amount of material. Since large quantities of sand will be required it is logical to assume that the cost differential between the various sands would not be significant. The savings in radon emissions and gamma dose to the population would appear to more than justify difference in cost.

The data is represented graphically on Attachment 1 and Attachment 2.

REFERENCES

Ref. 1 "Radon Attenuation Effectiveness and Cover Optimization with Moisture Effects" RAECOM. The Raecom Code, NUREG/CR, PNL 4878. RAE-18-5, V.C. Rogers, et.al by Rodgers and Associates Engineering Corporation.

Ref. 2 "A Combinatorial Geometry Version of QAD-P5A, A Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculation Using the GP Build-Up Factor" QAD-CGGP. The Radiation Shielding Information Center, RSIC Computer Code Collection, CCC-493.

Ref. 3 "A Proprietary Statistical and Data Base Management System" STAT-PRO. Developed by the Massachusetts Institute of Computer Technologies, September 1984. ISBN # 0-534-02831-4.

Ref. 4 "Lotus Development Company, Lotus 123" LOTUS 123. Developed by the Lotus Development Corporation, Cambridge, Massachusetts, 1985.

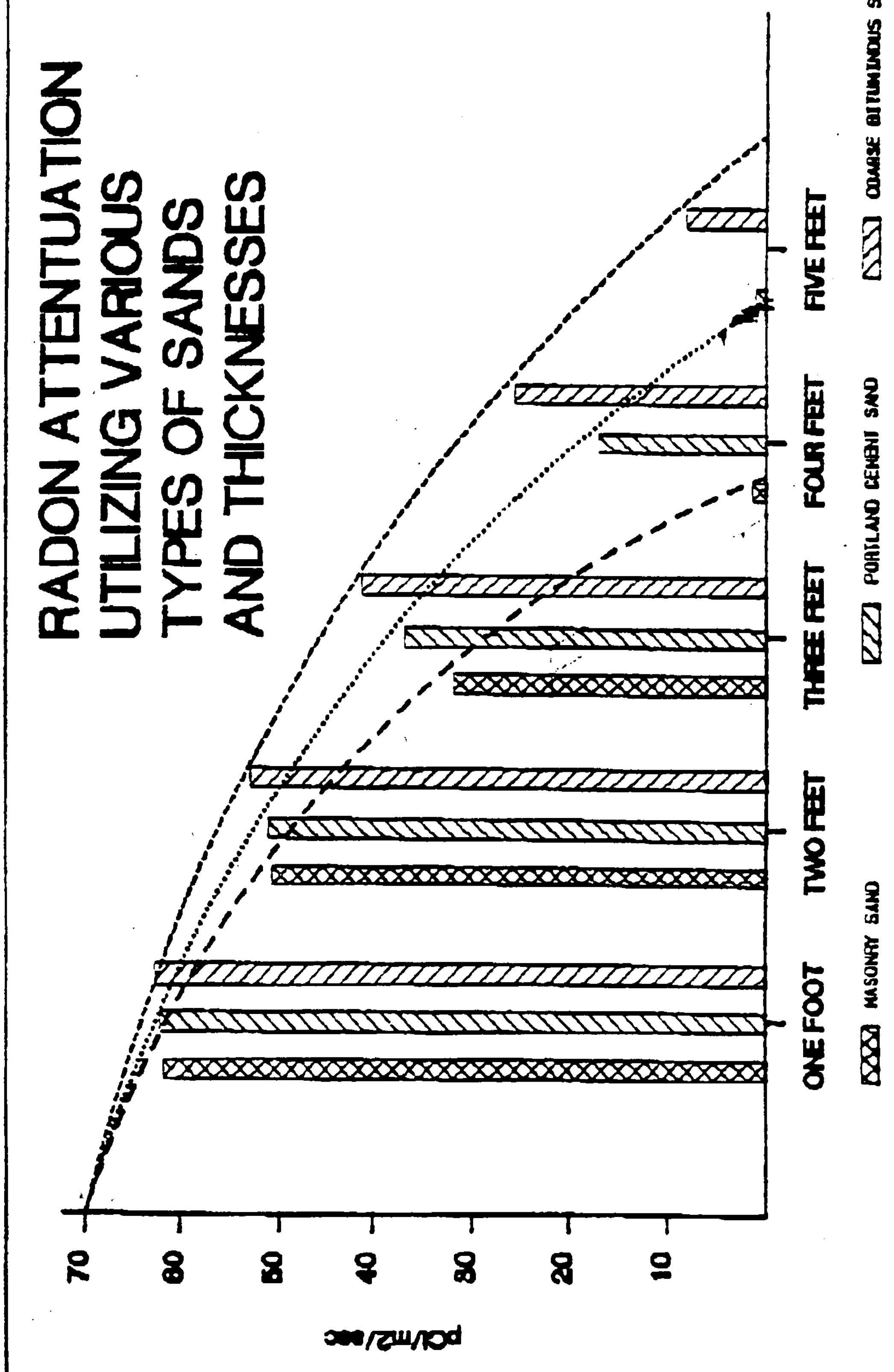
Ref. 5 "Lotus Freelance Plus" FREELANCE. Developed by the Lotus Development Corporation, Cambridge, Massachusetts, 1986.

Ref. 6 "Radon Diffusion Coefficient Measurements of Polyurethane Materials and Radon Attenuation Calculation for K-65 Silos", TIM-9700/18. K.K. Nielson and V.C. Rogers, Rodgers & Associates Engineering Corporation, October 13, 1987.

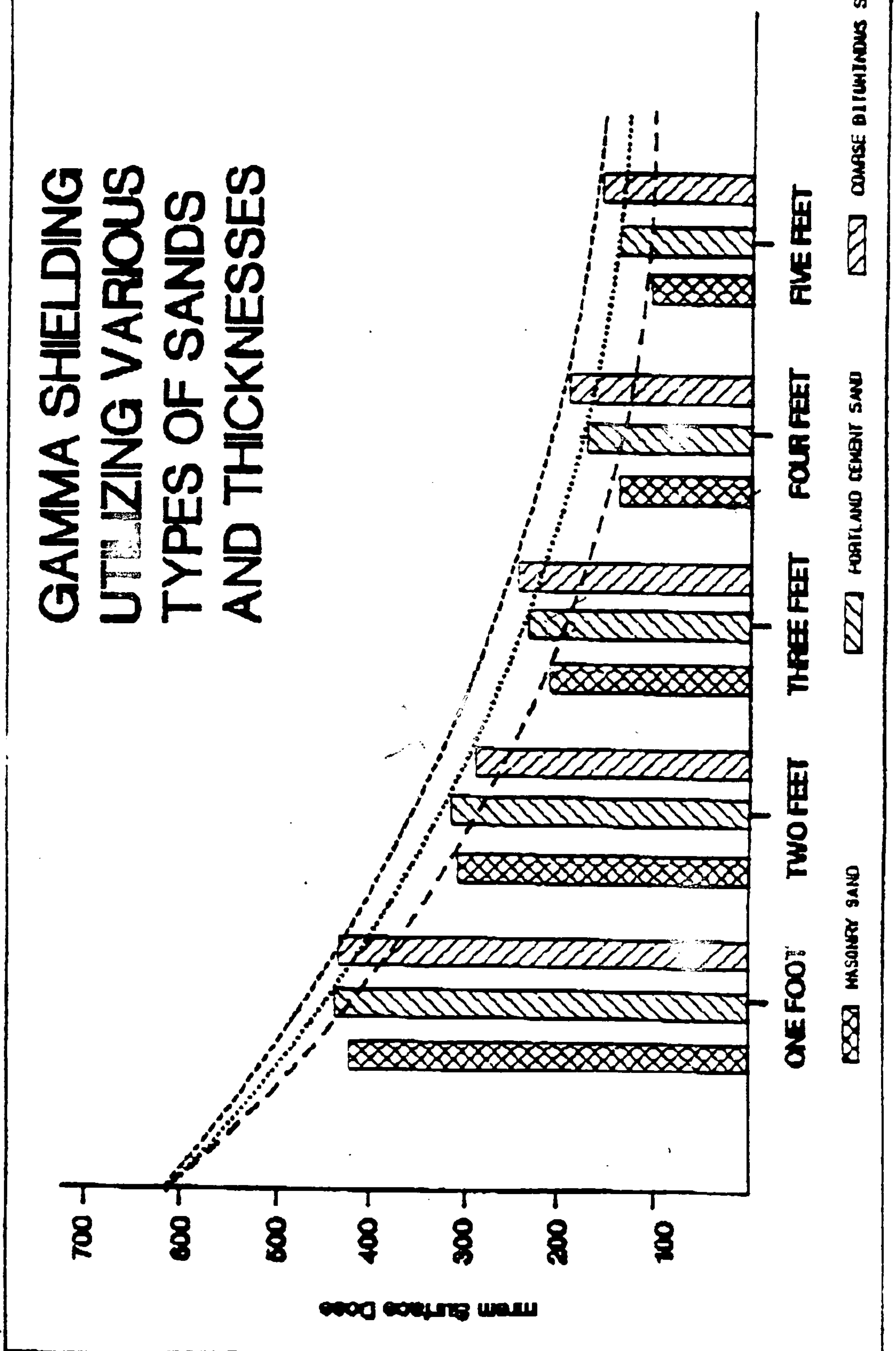
Ref. 7 "Results of Gamma Radiation Measurements Made Inside K-65 Tank (South)" FMPC Radiation Survey conducted 9/6/78.

Ref. 8 Telecon with Dravo Sand and Gravel Company, Cincinnati Ohio, 6/7/88.

ATTACHMENT 1



ATTACHMENT 2



APPENDIX D

APPENDIX D - ALARA CALCULATIONS

1.0 ASSUMPTIONS

1. Silos 1 and 2 contain:
   - 7222 cubic yards of wet residue
   - 11,200 kg uranium or 3.73 curies of U-238
   - 3593 curies of Ra-226 at 311 mg Ra-226/ton residue
   - The total curie content of both silos is distributed equally between Silos 1 and 2.

2. Thirty-seven curies of Rn-222, in equilibrium with its daughters, are evacuated from silo void via operation of the existing radon removal system. Each silo is evacuated within 10 hours before start of work, and work is finished before 50 hours have elapsed since evacuation was completed.

3. Density of Silos 1 and 2 material (119 pounds/ft^3 or 1.9 g/cc).

4. Average silo dome dose equivalent at the end of evacuation is 72 mrem/hr. This value comes from radiation survey results as documented in the "Completion Report K-65 Interim Stabilization Project Exterior Foam Application/Radon Treatment System Operation," dated December 1987.

5. Dose rate calculations were made using Microshield, "A Program for Analyzing Gamma Radiation Shielding," Version 3, Grove Engineering, Inc., Washington Grove, Maryland.

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2.0 ALARA REVIEW SUMMARY
STYROFOAM PEANUT COMPLETE FILL

1.	Valving on radon system (2 X 15 min X 72 mR/hr) =	36 mrem
2.	Removal of two manholes (2 X 30 min X 72 mR/hr) =	72 mrem
3.	Piping up Airvey line (2 X 30 min X 72 mR/hr) =	72 mrem
4.	Fill check after each load (1 X 20 min X 69.2 mR/hr) =	23.1 mrem
5.	Truck unloading (2 X 20 hrs X 0.4 mR/hr) =	16 mrem
6.	Removal of Airvey lines and replace manholes (2 X 45 min X 66.3 mR/hr) =	99.4 mrem
	Subtotal	318.5 mrem
	Support personnel (11 X 20 hrs X 0.4 mR/hr)	88 mrem
	406.5 mrem	X 2 silos
	Total 813[a] mrem	

---

[a]Estimated total exposure obtained to attentuate gamma radiation from an average 72 mR/hr down to 66.3 mR/hr with inefficient radon attenuation.

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3.0 ALARA REVIEW SUMMARY
VERMICULITE COMPLETE FILL

1.	Valving on radon system (2 X 15 min X 72 mR/hr) =	36 mrem
2.	Removal of four manholes (2 X 60 min X 72 mR/hr) =	144 mrem
3.	Conveyor/equipment setup (2 X 60 min X 72 mR/hr) =	144 mrem
4.	Fill check (1 X 20 min X 44.4 mR/hr) =	14.8 mrem
5.	Material unloading (1 X 475 hrs X 0.4 mR/hr) =	190 mrem
6.	Conveyor removal/replace manholes (2 X 60 min X 16.7 mR/hr) =	33.4 mrem
	Subtotal	562.2 mrem
	Support personnel (11 X 20 hrs X 0.4 mR/hr)	88 mrem
	650.2 mrem	
		X 2 silos
	Total 1300.4[a] mrem	

[a]Estimated total exposure obtained to attentuate gamma radiation from an average 72 mR/hr down to 16.7 mR/hr with incomplete radon attenuation.

4.0 ALARA REVIEW SUMMARY
SAND (FOUR FEET)

1.	Valving on radon system (2 X 15 min X 72 mR/hr) =	36 mrem
2.	Removal of three manholes (2 X 45 min X 72 mR/hr) =	108 mrem
3.	Conveyors/equipment setup (2 X 60 min X 72 mR/hr) =	144 mrem
4.	Fill check (1 X 20 min X 1.4 mR/hr) =	0.5 mrem
5.	Material unloading (1 X 16 hrs X 0.4 mR/hr) =	6.4 mrem
6.	Conveyor removal/replace manholes (2 X 60 min X 0.005 mR/hr) =	0.01 mrem
	Subtotal	294.91 mrem
	Support personnel (11 X 20 hrs X 0.4 mR/hr)	88 mrem
	382.9 mrem	
		X 2 silos
	Total 766.6[a] mrem	

---

[a]Estimated total exposure obtained to attentuate gamma radiation from an average 72 mR/hr down to 0.005 mR/hr with only 4 feet of material and almost completely attenuate the radon.

5.0 ALARA REVIEW SUMMARY
FLY ASH (FOUR FEET)

1.	Valving on radon system (2 X 15 min X 72 mR/hr) =	36 mrem
2.	Removal of four manholes (2 X 60 min X 72 mR/hr) =	144 mrem
3.	Conveyor/equipment setup (2 X 60 min X 72 mR/hr) =	144 mrem
4.	Fill check (1 X 20 min X 8.0 mR/hr) =	2.7 mrem
5.	Material unloading (1 X 16 hrs X 0.4 mR/hr) =	6.4 mrem
6.	Conveyor removal/replace manholes (2 X 60 min X 0.73 mR/hr) =	1.5 mrem
	Subtotal	334.6 mrem
	Support personnel (11 X 20 hrs X 0.4 mR/hr)	88 mrem
	422.6 mrem	X 2 silos
	Total 845.2[a] mrem	

[a]Estimated total exposure obtained to attentuate gamma radiation from an average 72 mR/hr down to 0.73 mR/hr, and provide some radon attenuation.

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6.0 MICROSHIELD DOSE RATE CALCULATIONS FOR SILOS 1 AND 2

Given:

Average on-contact dose rate determined from measured values for Silos 1 and 2: (radon removed from airspace)

$$\text{Average} = (68 + 76)\ \frac{\text{mr/hr}}{2} = 72\ \text{mr/hr}$$

Calculation of Adjustment Factor:

An adjustment factor is applied to each value of the microshield outputs incorporating measured dose rates into calculated dose rates. The factor is the ratio of the average measured dose rate and the calculated dose rate as determined by Microshield at 1 cm above the dome lid. This method of calibrating the Microshield outputs by means of measured dose rates on the silos corrects for unknown distribution (diffusion) of radon within the K-65 sludges.

$$\text{Factor} = \frac{72\ \text{mr/hr}}{127\ \text{mr/hr}} = .567$$

Results

The dose rates shown in Table 5-2 are listed for varying types and thicknesses of shielding. The factor .567 has already been included.

Micros [illegible]eld 3.08

(I.T. Corporation - #073)

Page : 1
File : SILOVOID.MSH
[illegible]n date: June 16, 1988
[illegible]n time: 2:01 p.m.

File Ref: ________
Date: ___/___/___
By: ________
Checked: ________

CASE: DOSE RATE AT 1 CM ABOVE SILO (VOID AIRSPACE)

GEOMETRY 10: Cylindrical source from end - slab shields

Dist[illegible]e to detector...........................	X	925.8	cm.
Sour[illegible] cylinder radius.......................	R	1220.	"
Sourc[illegible]linder length.........................	T1	640.080	"
Thickn[illegible] of second shield....................	T2	274.320	"
Thickne[illegible] third shield.......................	T3	10.2	"
Microshield inserted air gap......................	air	1.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Air gap
Air		.001220		.001220
Al[illegible]num				
Carbon				
Concrete	1.[illegible]		2.350	
Hydrogen				
[illegible]on				
[illegible]ad				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water				
[illegible]rconium				

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File: SILOVOID.MSH

CASE: DOSE RATE AT 1 CM ABOVE SILO (VOID AIRSPACE)

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BUILDUP FACTOR: based on GP method.
Using the characteristics of the materials in shield 3.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	1.538e+04	2.441e+01
2	1.6272	2.166e+13	2.873e+04	4.959e+01
3	1.1592	1.902e+13	1.346e+04	2.511e+01
4	.8263	8.251e+12	3.278e+03	6.554e+00
5	.6041	3.182e+13	7.265e+03	1.504e+01
6	.4677	1.219e+12	1.741e+02	3.554e-01
7	.3522	2.474e+13	2.060e+03	4.243e+00
8	.2755	1.831e+13	9.227e+02	1.832e+00
9	.1797	2.180e+12	4.020e+01	7.224e-02
10	.1172	3.601e+07	1.050e-05	1.658e-08
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	7.131e+04	1.272e+02

Page : 1
File : SILOVOID.MSH
n date: June 16, 1988
n time: 10:24 a.m.

File Ref: ________
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By: ________
Checked: ________

CASE: DOSE RATE AT 81 CM ABOVE SILO (VOID AIRSPACE)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	1005.8	cm.
Source cylinder radius......................	R	1220.	"
Source cylinder length......................	T1	640.080	"
Thickness of second shield..................	T2	274.320	"
Thickness of th . shield....................	T3	10.2	"
Microshield inse ted air gap................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Air gap
Air		.001220		.001220
Aluminum				
Carbon				
Concrete	1.60		2.350	
Hydrogen				
on				
ead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water				
Zirconium				

File: SILOVOID.MSH

CASE: DOSE RATE AT 81 CM ABOVE SILO (VOID AIRSPACE)

5978

BUILDUP FACTOR: based on GP method.
Using the characteristics of the materials in shield 3.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	1.509e+04	2.396e+01
2	1.6272	2.166e+13	2.827e+04	4.880e+01
3	1.1592	1.902e+13	1.328e+04	2.478e+01
4	.8263	8.251e+12	3.241e+03	6.480e+00
5	.6041	3.182e+13	7.190e+03	1.488e+01
6	.4677	1.219e+12	1.724e+02	3.519e-01
7	.3522	2.474e+13	2.040e+03	4.201e+00
8	.2755	1.831e+13	9.134e+02	1.814e+00
9	.1797	2.180e+12	3.976e+01	7.145e-02
10	.1172	3.601e+07	1.034e-05	1.632e-08
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	7.024e+04	1.253e+02

Microshield 3.08
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(I.T. Corporation - #073)

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File : SLOSND1.MSH
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By: ____________
Checked: ____________

CASE: DOSE RATE AT 81 CM ABOVE SILO (1 FT OF SAND)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	1005.8	cm.
Source cylinder radius......................	R	1220.	"
Source cylinder length......................	T1	640.080	"
Thickness of second shield..................	T2	30.480	"
Thickness of third shield...................	T3	243.840	"
Thickness of fourth shield..................	T4	10.2	"
Microshield inserted air gap................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENS TIES cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60			2.350	
Nitrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND		1.60			

CASE: DOSE RATE AT 81 CM ABOVE SILO (1 FT OF SAND)

5978

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	1.739e+03	2.760e+00
2	1.6272	2.166e+13	2.490e+03	4.299e+00
3	1.1592	1.902e+13	7.908e+02	1.476e+00
4	.8263	8.251e+12	1.342e+02	2.682e-01
5	.6041	3.182e+13	2.344e+02	4.851e-01
6	.4677	1.217e+12	3.867e+00	7.892e-03
7	.3522	2.474e+13	2.499e+01	5.146e-02
8	.2755	1.831e+13	6.655e+00	1.321e-02
9	.1797	2.180e+12	1.269e-01	2.281e-04
10	.1172	3.601e+07	2.020e-07	3.185e-10
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	5.425e+03	9.361e+00

Microshield 3.08

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Page : 1
File : SLOSND4.MSH
Run date: June 16, 1988
Run time: 11:10 a.m.

CASE: DOSE RATE AT 81 CM ABOVE SILO (4 FT OF SAND)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector..........................	X	1005.8	cm.
Source cylinder radius........................	R	1220.	"
Source cylinder length........................	T1	640.080	"
Thickness of second shield....................	T2	121.920	"
Thickness of third shield.....................	T3	152.4	"
Thickness of fourth shield....................	T4	10.2	"
Microshield inserted air gap..................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60			2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND		1.60			

File: SLOSND4.MSH

CASE: DOSE RATE AT 81 CM ABOVE SILO (4 FT OF SAND)

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	2.956e+00	4.692e-03
2	1.6272	2.166e+13	1.840e+00	3.176e-03
3	1.1592	1.902e+13	1.750e-01	3.265e-04
4	.8263	8.251e+12	9.566e-03	1.913e-05
5	.6041	3.182e+13	5.267e-03	1.090e-05
6	.4677	1.219e+12	2.698e-05	5.508e-08
7	.3522	2.474e+13	4.201e-05	8.653e-08
8	.2755	1.831e+13	3.081e-06	6.117e-09
9	.1797	2.180e+12	5.751e-09	1.033e-11
10	.1172	3.601e+07	4.410e-16	6.961e-19
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	4.986e+00	8.225e-03

Microshield 3.08
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'e : SLOSTYRO.MSH		Date:	___/___/___
date: June 16, 1988		By:	___________
n time: 11:24 a.m.		Checked:	___________

CASE: DOSE RATE AT 81 CM ABOVE SILO (STYROFOAM FILLS AIRSPACE)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector..........................	X	1005.8	cm.
Source cylinder radius........................	R	1220.	"
Source cylinder length........................	T1	640.080	"
Thickness of second shield....................	T2	274.320	"
Thickness of third shield.....................	T3	10.2	"
Microshield inserted air gap..................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Air gap
Air				.001220
Aluminum				
Carbon				
Concrete	1.60		2.350	
drogen				
on				
ead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water		.0050		
Zirconium				

 File: SLOSTYRO.MSH

CASE: DOSE RATE AT 81 CM ABOVE SILO (STYROFOAM FILLS AIRSPACE)

BUILDUP FACTOR: based on GP method.
Using the characteristics of the materials in shield 3.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	1.429e+04	2.268e+01
2	1.6272	2.166e+13	2.658e+04	4.589e+01
3	1.1592	1.902e+13	1.237e+04	2.309e+01
4	.8263	8.251e+12	2.993e+03	5.984e+00
5	.6041	3.182e+13	6.578e+03	1.361e+01
6	.4677	1.219e+12	1.564e+02	3.192e-01
7	.3522	2.474e+13	1.831e+03	3.772e+00
8	.2755	1.831e+13	8.120e+02	1.612e+00
9	.1797	2.180e+12	3.465e+01	6.227e-02
10	.1172	3.601e+07	8.412e-06	1.328e-08
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.743e+14	6.565e+04	1.170e+02

Microshield 3.08

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File : SLOVERM.MSH
Run date: June 16, 1988
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By: ______
Checked: ______

CASE: DOSE RATE AT 81 CM [illegible] SILO [illegible]

GEOMETRY [illegible] slab shield

[illegible]		1005.8	[illegible]
[illegible]	R	[illegible]	"
[illegible]		540.080	"
[illegible]	T2	274.320	"
[illegible]	T3	10.2	"
[illegible] gap	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Air gap
Air				.001220
Aluminum				
Carbon				
Concrete	1.[illegible]0		2.350	
Hydrogen				
Iron				
Lead				
Lithium				
Nickel				
Tin				
Titanium				
Tungsten				
Urania				
Uranium				
Water				
Zirconium				
SAND		.0960		

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000156

CASE: DOSE RATE AT 61 CM ABOVE SILO (VERMICULITE FILLS AIRSPACE)

BUILDUP FACTOR: based on GP method.
Using the characteristics of the materials in shield 3.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)................ 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
[illegible]-214	1.[illegible]595e+03	Ra-226	1.[illegible]765e+03	Rn-222	1.75[illegible]5e+03
[illegible]230	[illegible]00e+00	U-234	2.4300e+00		

RESULTS.

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	4.594e+03	7.292e+00
2	1.[illegible]272	2.166e+13	7.500e+03	1.295e+01
3	1.[illegible]592	1.902e+13	2.876e+03	5.367e+00
4	.8263	8.251e+12	5.775e+02	1.155e+00
5	.6041	3.182e+13	1.038e+03	2.147e+00
6	.4677	1.219e+12	2.057e+01	4.199e-02
7	.3522	2.474e+13	1.930e+02	3.975e-01
8	.2755	1.831e+13	6.899e+01	1.570e-01
9	.1797	2.180e+12	1.892e+00	3.400e-0[illegible]
10	.1172	3.601e+07	[illegible].136e-07	1.793e-10
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.[illegible]43e+14	1.687e+04	2.949e+01

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Microshield 3.08
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Date: ___/___/___
By: __________
Checked: __________

CASE: DOSE RATE AT 81 CM ABOVE SILO (1 FT OF FLY ASH)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector...........................	X	1005.8	cm.
Source cylinder radius.........................	R	1220.	"
Source cylinder length.........................	T1	640.080	"
Thickness of second shield.....................	T2	30.480	"
Thickness of third shield......................	T3	243.840	"
Thickness of fourth shield.....................	T4	10.2	"
Microshield inserted air gap...................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60	.720		2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND					

File: SLOASH1.MSH

CASE: DOSE RATE AT 81 CM ABOVE SILO (1 FT OF FLY ASH)

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 51
Number of radial segments (radius) 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+0[illegible]
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	5.855e+03	9.293e+00
2	1.6272	2.166e+13	9.759e+03	1.868e+01
3	1.1592	1.902e+13	3.853e+03	7.192e+00
4	.82[illegible]	8.251e+12	7.998e+02	1.599e+00
5	.6041	3.182e+13	1.723e+03	3.565e+00
6	.4677	1.219e+12	3.508e+01	7.1[illegible]e-02
7	.3522	2.474e+13	2.927e+02	6.029e-01
8	.2755	1.831e+13	9.764e+0[illegible]	1.939e-01
9	.1797	2.180e+12	2.[illegible]26e+00	4.899e-03
10	.1172	3.601e+07	6.424e-06	1.014e-08
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	2.242e+04	3.937e+01

Microshield 3.08

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File : SLOASH2.MSH
Run date: June 16, 1988
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By: ____________
Checked: ____________

CASE: DOSE RATE AT 81 CM ABOVE SILO (2 FT OF FLY ASH)

GEOMETRY 10: cylindrical source from end - slab shields

Distance to detector...........................	X	1005.8	cm.
Source cylinder radius...........................	R	1220.	"
Source cylinder length...........................	T1	640.080	"
Thickness of second shield......................	T2	60.960	"
Thickness of third shield.......................	T3	213.360	"
Thickness of fourth shield......................	T4	10.2	"
Microshield inserted air gap....................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60	.720		2.350	
Nitrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND					

File: SLOASH2.MSH

CASE: DOSE RATE AT 91 CM ABOVE SILO (2 FT OF FLY ASH)

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	2.153e+03	3.417e+00
2	1.6272	2.166e+13	3.171e+03	5.474e+00
3	1.1592	1.902e+13	1.046e+03	1.953e+00
4	.8263	8.251e+12	1.836e+02	3.671e-01
5	.6041	3.182e+13	3.320e+02	6.871e-01
6	.4677	1.219e+12	5.642e+00	1.152e-02
7	.3522	2.474e+13	3.755e+01	7.735e-02
8	.2755	1.831e+13	1.014e+01	2.013e-02
9	.1797	2.180e+12	1.885e-01	3.388e-04
10	.1172	3.601e+07	2.358e-07	3.721e-10
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	6.939e+03	1.201e+01

Microshield 3.08
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File	: SLOASH3.MSH	Date:	___/___/___
Run date:	June 16, 1988	By:	____________
Run time:	1:44 p.m.	Checked:	____________

CASE: DOSE RATE AT 81 CM ABOVE SILO (3 FT OF FLY ASH)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	1005.8	cm.
Source cylinder radius......................	R	1220.	"
Source cylinder length......................	T1	640.080	"
Thickness of second shield..................	T2	91.440	"
Thickness of third shield...................	T3	182.880	"
Thickness of fourth shield..................	T4	10.2	"
Microshield inserted air gap................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60	.720		2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND					

CASE: DOSE RATE AT 81 CM ABOVE SILO (3 FT OF FLY ASH)

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle seg ts (Npsi)................ 51
Number of radial se nts (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.79 5e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.43 0e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	8.059e+02	1.279e+00
2	1.6272	2.166e+13	1.049e+03	1.810e+00
3	1.1592	1.902e+13	2.889e+02	5.392e-01
4	.8263	8.251e+12	.279e+01	8.555e-02
5	.6041	3.182e+13	.482e+01	1.342e-01
6	.4677	1.219e- 2	187e-01	1.875e-03
7	.3522	2.474e+13	4.881e+00	1.005e-02
8	.2755	1.831e+13	1.067e+00	2.118e-03
9	.1797	2.180e+12	1.324e-02	2.379e-05
10	.1172	3.601e+07	8.817e-09	1.392e-11
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	2.1 e+03	3.862e+00

Microshield 3.08
=================
(I.T. Corporation - #073)

Page : 1
File : SLOASH4.MSH
n date: June 16, 1988
n time: 1:49 p.m.

File Ref: ___________
Date: ___/___/___
By: ___________
Checked: ___________

CASE: DOSE RATE AT 81 CM ABOVE SILO (4 FT OF FLY ASH)

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector........................	X	1005.8	cm.
Source cylinder radius......................	R	1220.	"
Source cylinder length......................	T1	640.080	"
Thickness of second shield..................	T2	121.920	"
Thickness of third shield...................	T3	152.4	"
Thickness of fourth shield..................	T4	10.2	"
Microshield inserted air gap................	air	81.2	"

Source Volume: 2.99298e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2	Shield 3	Shield 4	Air gap
Air			.001220		.001220
Aluminum					
Carbon					
Concrete	1.60	.720		2.350	
Hydrogen					
Iron					
Lead					
Lithium					
Nickel					
Tin					
Titanium					
Tungsten					
Urania					
Uranium					
Water					
Zirconium					
SAND					

File: SLOASH4.MSH

CASE: DOSE RATE AT 81 CM ABOVE SILO (4 FT OF FLY ASH)

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 4.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)............... 51
Number of radial segments (Nradius)........... 51

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Bi-214	1.7595e+03	Pb-210	1.7595e+03	Pb-214	1.7595e+03
Po-214	1.7595e+03	Ra-226	1.7965e+03	Rn-222	1.7595e+03
Th-230	2.4300e+00	U-234	2.4300e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	2.1424	7.112e+12	3.052e+02	4.845e-01
2	1.6272	2.166e+13	3.507e+02	6.053e-01
3	1.1592	1.902e+13	8.058e+01	1.504e-01
4	.8263	8.251e+12	1.006e+01	2.012e-02
5	.6041	3.182e+13	1.277e+01	2.643e-02
6	.4677	1.219e+12	1.510e-01	3.082e-04
7	.3522	2.474e+13	6.410e-01	1.320e-03
8	.2755	1.831e+13	1.136e-01	2.255e-04
9	.1797	2.180e+12	9.420e-04	1.693e-06
10	.1172	3.601e+07	3.355e-10	5.296e-13
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.343e+14	7.602e+02	1.289e+00

APPENDIX E

INTERNATIONAL TECHNOLOGY CORPORATION

Appendix E

By K Sheil Date 6/16/88 Subject GRANULAR COST ESTIMATE Sheet No. 1 of 8

kd. By ___ Date ___ (CONCEPTUAL ONLY) Proj. No. 3033

& REFERENCES ATTACHED.

UNIT NUMBER	REF No	ITEM	UNIT COST	DURATION	COST
2	1	CONVEYORS	\$90 + \$885/WK	1 WK/EA	[illegible]
2	2	SPREADERS	\$412	—	82[illegible]
2	1	HOPPERS	\$90/WK	1 WK	18[illegible]
4	3	BOBCATS	\$25/HR	48 HR/EA	48[illegible]
1	4	DUST COLLECTOR / HEPA FILTER	\$326	—	32[illegible]
1	3	FRONT END LOADER	\$40/HR	16 HRS	64[illegible]
1		HYDRAULIC POWER UNIT		—	30[illegible]
2		CONVEYOR DISCHARGE CHUTE		—	20[illegible]
					\$922[illegible]

ADDITIONALLY FOR FLY ASH TRANSPORT

2	3	FRONT END LOADER	\$40/HR	32 HRS/EA	2[illegible]
2	3	20 TON DUMP TRUCKS	\$25/HR	32 HRS/EA.	16[illegible]
					\$416[illegible]

SMALL EQUIPMENT

1	5	TOOLS	8[illegible]
—	6	PROTECTIVE CLOTHING (\$85/CASE CLOTHING, GLOVES \$7.95/DOZ. × 3, RESPIRATORS \$82.00/EA × 10, \$27.83/[illegible])	10[illegible]
1	6	LAYDOWN PLASTIC FOR MANHOLES	\$64[illegible]
1	7	VIDEO CAMERA	\$160[illegible]
6	8	GASKETS FOR MANHOLES (12)	\$48[illegible]
		~~POWER~~	
		~~DIESEL FUEL~~	
2	9	HYDRAULIC HOSES TO POWER SPREADER (\$3.60/FT × 20')	\$7[illegible]
1	2	SPARE SPREADER SPINNER \$148	\$14[illegible]
1	10	CANVAS SHROUD FOR ASH PILES (FLY ASH)	4[illegible]

Total Approx Est. \$3000 For Small Equip.

BACK-UP TO THOSE VALUES FOLLOW.

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108-

MATERIAL COST:

SAND: BULK TRUCKS = 20-25 TONS

TRUCKING COSTS PER REF. NO. ⑧

(2.00/TON + 2.60/TON) + 35/HR WAITING TIME.

FOR 4' BED: REQUIREMENTS

$\pi r^2 L = \pi (40')^2 (4')$

$= 20106\ FT^3$

$20106\ FT^3 \times \frac{100\ lb}{FT^3} = 2.01 \times 10^6\ lb$ (1005 TONS)

TOTAL TRUCKLOADS = (1005 T × TRUCK/22T) = 46 TRUCKS/SILO

1005 TONS × 4.60/TON + (46 × \$35) = \$6233/SILO

FLY ASH: ON-SITE - MATERIAL COST IS \$0.

TRANSPORT COST: (2) DUMP TRUCKS @ \$45/HR INCL. LABOR REF. ⑤

(2) FRONT END LOADERS @ \$70/HR INCL. LABOR REF. ⑤

FRONT END LOADER HAS 1 yd³ = 27 FT³ × 45 lb/FT³ = 1215 lb/LOAD

EACH DUMP TRUCK HANDLES 22 TON SAND @ 100 lb/FT³

$22T \times \frac{2000\ lb}{1T} \times \frac{FT^3}{100\ lb} = 440\ FT^3$

$440\ FT^3 \times \frac{45\ lb}{FT^3} = 19800\ lb$ /TRUCK LOAD

$20106\ FT^3 \times \frac{TR}{440\ FT^3} = 45.7$ TRUCKLOADS

TOTAL FLY ASH = $20106\ FT^3 \times \frac{45\ lb}{FT^3} \times \frac{1}{2000}$ = 452 TONS

INTERNATIONAL TECHNOLOGY CORPORATION

By K. Shell Date 6/16/88 Subject COST ESTIMATE Sheet No. 3 of 8

By ____ Date ____ Proj. No. 303317

ASSUME FOR 20106 FT3 x BUCKET LOAD / 27 FT3 = 745 BUCK LOADS

1 BUCKET LOAD EVERY 2 MIN

745 LOADS x 2 MIN / 1 BUCKET LOAD x 1 HR / 60 = 24.8 HRS

KEEP EQUIPMENT FOR (4) 8 HOUR SHIFTS

(2 x $45/HR x 32 HRS) + (2 x $70/HR x 32 HRS) = $7360/SILO

UNIT COST = $7360/SILO / 452 TONS = $16.28/TON

VERSUS $6.20/TON SAND

SAND IS CHEAPER ON UNIT COST, HOWEVER THE FLY ASH WOULD REQUIRE DISPOSAL ANYWAY, AND SAVINGS WOULD PROBABLY BE OFFSET.

INTERNATIONAL TECHNOLOGY CORPORATION

5978

By K Shell Date 6/17/88 Subject Cost Estimate Sheet No. 4 of 8

Chkd. By ___ Date ___ Proj. No. 303317

LABOR COST:

NO	LABOR	RATE	HRS	COST ($)
1	SITE MANAGER	$90/HR	120	10800
1	SITE ENGINEER	$70/HR	120	8400
1	HEALTH PHYSICIST	$70/HR	28	1960
2	CONVEYOR OPERATORS	$30/HR	40	1200
4	BOBCAT OPERATORS	$25/HR	80	2000
1	FRONT END LOADER OPERATOR (EXCAVATE BERM)	$30/HR	16	480
2	FRONT END LOADER OPERATORS (FLY ASH)	$30/HR	64	1920
2	DUMP TRUCK OPERATORS (FLY ASH)	$20/HR	64	1280
2	TECHNICIANS (RADON SYSTEM & EQUIP.)	$35/HR	120	4200
1	PROJ. MGR	$90/HR	80	7200
1	ENGINEER	$70/HR	460	32200
				$71,640

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INTERNATIONAL TECHNOLOGY CORPORATION

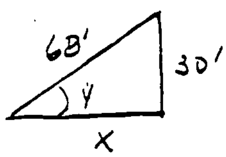
By K. Shen Date 6/17/82 Subject COST ESTIMATE Sheet No. 5 of 8

Ckd. By ____ Date ________ Proj. No. 303

OPERATION PLAN: STOCKPILE SAND/ASH, LOAD VIA A BOBCAT INTO LIVE BOTTOM HOPPER ONTO A CONVEYOR BELT WHICH WILL CARRY IT UP INTO A CHUTE ATTACHED TO THE MANHOLE. IT WILL DROP FROM THE CHUTE ONTO A SPREADER FOR EVEN DISTRIBUTION.

CONVEYOR & HOPPER: NOTE REF ①

68 FOOT CONVEYOR IS PROBABLY ONE OF LARGEST RENTALS AV



$\cos y = 30/68$

$y \cong 64°$ THIS STEEP FOR SAND HOWEVER THE CLEATED BELT SHOULD OVERCOME

$30^2 + x^2 = 68^2$

$x = 61'$

THUS APPROXIMATELY $(76' + 8' - 61' = 23')$ 23 FOOT OF BERM WILL NEED EXCAVATED FOR POSITIONING CONVEYOR & HOPPER

HOPPER AVAILABLE IS 5' TRIANGLE, 3' HEIGHT WITH 1'×1'×1' GATE

APPROXIMATE VOLUME USING A CONE IS

$$V = \frac{\pi}{3} r^2 h$$
$$= \frac{\pi}{3} (5)^2 (3)$$
$$= 78.5\ ft^3 \times 100\ lb/ft^3 = 7854\ lb\ (4\ TON)$$

CONVEYOR DRAW-OFF @ MAX PER REF 1 IS:

$$400\ \frac{ft}{min} \times \frac{18''}{12''} \times \frac{1.5''}{12''} = 75\ ft^3/min$$

Bobcat Bucket Dimensions @ 67" wide w/ 1 Ton Capacity or 10.9 Ft^3

Front End Loader Bucket is 9' wide and won't fit hopper

Spreader limits per Ref No. 2 is 10.5 Ft^3/min.

Based on limitations of Spreader, Hopper, & Bobcat to ~10 Ft^3/min, Application will be with (2) complete systems for a combined rate of 20 Ft^3/min.

$$2016 \text{ Ft}^3 \times \frac{\text{Min}}{20 \text{ Ft}^3} \times \frac{\text{Hr}}{60 \text{ min}} = 16.8 \text{ hrs} \cong \underline{\underline{17 \text{ hrs}}}$$ Fill operation per silo

Hours of Operation (Labor) Estimate:

Work Plan	Proj. Mgr	40 hr	x $90/hr	= $3600
	2 Eng.	160 hr	x $70/hr	= $11,200
Bid Specs	Proj. Mgr.	40 hr	x $90/hr	= $3600
	2 Eng.	240 hr	x $70/hr	= $16800
Procurement	1 Eng.	60 hr	x $70/hr	= $4200

Site Mobilization Site Mgr 15 days = 120 hrs
Site Eng. 15 days = 120 hrs

Excavation of Berm
Front End Ldr Op. 8 hr
Tech. 8 hr

INTERNATIONAL TECHNOLOGY CORPORATION

By K. Shell Date 6/17/88 Subject COST ESTIMATE Sheet No. 7 of 8

Ckd. By ____ Date ____ Proj. No. 303

STOCKPILE OF GRANULE

SAND WOULD BE INCLUDED IN MAT. COST.

FLY ASH - 2 FRONT END LDR OPS. 4 DAYS = 32 HRS EA
2 DUMP TK. OP. 32 HRS EA

ASSEMBLY OF EQUIPMENT

2 TECHS. 16 HRS

OPERATION OF RADON SYSTEM

1 TECH 8 HRS
1 HP 8 HRS

GRANULE ; ITION

4 BOBCAT OPS. 20 HR
2 TECHNICIANS 20 HR
1 HP 20 HR
2 CONVEY. OPS 20 HR

DEMOBILIZATION

1 FRONT END LDR. OP 8 HR
2 TECHNICIANS 16 HR

NOTE: TIME ESTIMATE AND COSTS ARE CONCEPTUAL ± 30% FOR BUDGETARY USE ONLY, GOVERNMENT RATES WERE NOT CHECKED AGAINST THESE FIGURES.

000173

INTERNATIONAL TECHNOLOGY CORPORATION

By K Shell Date 6/17/88 Subject COST ESTIMATE Sheet No. 8 of

Chkd. By ____ Date ____ Proj. No. 303317

SUMMARY:

HOURS BY LABOR TYPE ARE TOTALED AND LISTED ON PG. 4

LABOR COST ESTIMATE ± 30% IS $71,640 FOR FLY ASH /SILO
± 30% IS $68,440 FOR SAND /SILO

MATERIAL COST WAS CALC. ON PG. 2 & 3

SAND = $6233 /SILO
ASH = -0-

EQUIPMENT COSTS PER PG. 1

HOURS ESTIMATED PER SCHEDULE FIGURE 5-2 & LABOR ESTIMATES

	SAND	FLY ASH
LARGE EQUIPMENT	9220	13380
SMALL EQUIPMENT	3000	3000
	$12220	$16380

TRIP/TELEPHONE REPORT

TELEPHONE ✓ DATE: 6/15/88 X ORIGINATOR PLACED CALL

VISIT __ LOCATION: Knoxville __ ORIGINATOR RECEIVED CALL

ORIGINATOR: [illegible] PROJECT NO. ______

CONVERSATION WITH: Arnold Fox TELEPHONE NO. [illegible]

TITLE: ______ DEPT: ______

ORGANIZATION: Old Fort[illegible] Equipment

ADDRESS:

SUBJECT: Conveyor For Sand Transport

COMMENTS:

Cleat[illegible] belt conveyor w/ 115' [illegible] reach at [illegible]

longest conveyor is 63' [illegible] belt @ 45° [illegible]

Belt Speed [illegible] 18" [illegible] belt, 1½" [illegible]

[illegible] work [illegible] something like concrete chute

Could possible level [illegible] with pressurized air (D[illegible]

Rental rate $[illegible]/day $335/wk $[illegible]55/month [illegible]

Delivery $45 & $[illegible]

Ground Hopper 5' Triangular w/ Gate (Front End [illegible]) [illegible] Height

Gate is 1' Triangle

3 units 68' Hopper Costs - $30/day $[illegible]/wk $[illegible]

ACTION:

Cost on Front End loader -

[illegible] on [illegible] - (Contact [illegible]

* Time [illegible] - ½ hr. to set equip. after grading [illegible] & notice for shipping - [illegible]

_ Original: Central Files (File No. _____-A1)

QH-F21-R0

TRIP/TELEPHONE REPORT

TELEPHONE X DATE: [illegible] X ORIGINATOR PLACED CALL

VISIT ___ LOCATION: ___ ___ ORIGINATOR RECEIVED CALL

ORIGINATOR: [illegible] PROJECT NO. ___

CONVERSATION WITH: TIM SKINNER TELEPHONE NO. [illegible]

TITLE: ___ DEPT: ___

ORGANIZATION: [illegible]

ADDRESS: ___

SUBJECT: ___

COMMENTS:

18" SPINNER PLATE - SPREAD TO [illegible] .30' [illegible]

SAND IS HANDLED EFFECTIVELY

[illegible] HYDRAULIC MOTOR

SPINNER MOTOR $214.00

SPINNER PLATE $140.90

[illegible]

RECOMMEND [illegible] SPINNER PLATE TO HANDLE [illegible]

OF MATERIAL

WHAT CAPACITY CAN THE UNIT PUT OUT? ([illegible])

ACTION:

WHAT SIZE HYDRAULIC MOTOR - MODEL NO. ETC.

MANUFACTURER CHAR-LYNN Model #: 101-1001-007 [illegible]

Flow: 12 gal/MIN. : [illegible] Pressure: 2250 psi ; MOTOR SIZE: (4 [illegible] flange) Face to edge of motor 5.2" ; outside housing [illegible] per TIM SKINNER

_ Original: Central Files (File No. ______-A1)

THE GLEDHILL ROAD MACHINERY CO.

Manufacturers of Road Maintenance Machinery

AREA 419. 468-4400 GALION, OHIO 44833. P. O. BOX 567

FACSIMILE TRANSMISSION COVER LETTER

PHONE: (419) 468-4400 FAX: (419) 468-4004

TO: I T Corp 615-690-3626

ATTN: Kathy Shell

FROM: Tim Skinner

SPECIAL INSTRUCTIONS:

This transmission consists of 2 pages plus cover page. If there are any problems during transmission, or documents being received are incomplete, please call us immediately at (419) 468-4400 and ask for ______________________.

TRIP/TELEPHONE REPORT

TELEPHONE X DATE: 6/15/88 X ORIGINATOR PLACED CALL

VISIT __ LOCATION: [illegible] __ ORIGINATOR RECEIVED CALL

ORIGINATOR: K. [illegible] PROJECT NO. ______

CONVERSATION WITH: Tom TELEPHONE NO. 553-[illegible]

TITLE: ______ DEPT: ______

ORGANIZATION: Air & Hydraulic Equipment Inc [illegible]

ADDRESS: ______

SUBJECT: Hydraulic Power Unit

COMMENTS:

[illegible]

[illegible] Motor [illegible] & RPM & [illegible]

[illegible]

[illegible] actual [illegible] the [illegible] Power Unit [illegible] the smaller unit.

[illegible]

[illegible] 5327 [illegible] 2 gal [illegible] 15 hp [illegible] 5 gal [illegible]

4-way D03 valve return line filter [illegible]

[illegible] 2250 psi [illegible]

ACTION:

[illegible] 1500 psi [illegible]

[illegible] than needed - with more information could get a different unit & less cost

_ Original: Central Files (File No. ______-A1)

QH-F21-R0

TRIP/TELEPHONE REPORT

TELEPHONE ✓ DATE: ______ ✓ ORIGINATOR PLACED CALL

VISIT ___ LOCATION: [illegible] ___ ORIGINATOR RECEIVED CALL

ORIGINATOR: ______ PROJECT NO. ______

CONVERSATION WITH: [illegible] SR. TELEPHONE NO. [illegible]

TITLE: ______ DEPT: ______

ORGANIZATION: INBICOM

ADDRESS: ______

SUBJECT: EARTH MOVING EQUIPMENT - [illegible]

COMMENTS:

[illegible]

LOADER - 977 - #70/HR W/ OPERATOR [illegible]

BOBCAT - 1/5 yd - #50/HR W/OPERATOR [illegible]

[illegible]

20 TON DUMP TRUCK - $45/HR W/ OPERATOR [illegible]

[illegible] 25 EQUIP [illegible]

ACTION:

_ Original: Central Files (File No. _____-A1)

000179

QH-F21-R0

TRIP/TELEPHONE REPORT

TELEPHONE X DATE: 6/16/93 X ORIGINATOR PLACED CALL

VISIT _ LOCATION: Knoxville _ ORIGINATOR RECEIVED CALL

ORIGINATOR: K. Snell PROJECT NO. 303317

CONVERSATION WITH: Frank Russo TELEPHONE NO. [illegible]

TITLE: DEPT:

ORGANIZATION: Filtration Engineering

ADDRESS:

SUBJECT: Dust Collector & Hepa System [illegible]

COMMENTS:

Full Assembly

Hooded Air Intake 20" x 7" [illegible] -

Steel Cost - Top & Bottom Tank

Hepa [illegible] [illegible] 1/2" [illegible]

Urethane is PVC Black

2" Nozzle [illegible] to it

[illegible]

Cost [illegible] $32 Each

Replacement Pre-Filter [illegible]

Hepa Element $110 /ea

ACTION: Breathes both ways

Will Send Literature

_ Original: Central Files (File No. ______-A1)

000180

QH-F21-R0

Filtration Engineering
A DIVISION OF FILTRATION MANUFACTURING, INC.
P.O. Box 467, Hester Street
Portland, PA 18351
(717) 897-6141 FAX. (717) 897-5974

DATE: 6/16/88

CUSTOMER FAX. NUMBER: (615) 690-3626
TOTAL NUMBER OF PAGES: 2

COMPANY: INTNL TECHNOLOGY CORP.
ADDRESS:
CITY, STATE, ZIP: KNOXVILLE TN
ATTN: KATHY SHELL

MESSAGE:

ATTACHED IS A COPY OF OUR LITERATURE SHOWING A UNIT THAT IS SIMILAR TO THE HEPA GRADE UNIT WE DISCUSSED EXCEPT YOURS WOULD CONTAIN TWO ELEMENTS (ONE INSIDE THE OTHER)

YOUR 'A' DIMENSION WOULD BE 20"
'B' DIM = 9" + 'C' DIM 7½."
YOUR PRICE FOR THE COMPLETE ASSEMBLY IS $326.00 EA.

Sincere regards,

[signature]

000181

TRIP/TELEPHONE REPORT

TELEPHONE X DATE: 6/15/93 ✓ ORIGINATOR PLACED CALL

VISIT ___ LOCATION: [illegible] ___ ORIGINATOR RECEIVED CALL

ORIGINATOR: [illegible] PROJECT NO. [illegible]

CONVERSATION WITH: Ron Durbin TELEPHONE NO. [illegible]

TITLE: DEPT:

ORGANIZATION: [illegible] Sand and Gravel Co.

ADDRESS:

SUBJECT: K-65 Silo

COMMENTS:

Bulk Truck Shipment [illegible] 20-25 Ton

Trucking Cost & Material [illegible] ~200/Ton + ~[illegible]/Ton [illegible]

Inside Fernald [illegible] ADDITIONAL $[illegible]/HR [illegible]

[illegible] BELT [illegible] FOR TRANSFER

Normally [illegible]

Elevation at 3' of take-off on [illegible] DOOR

$35 [illegible]

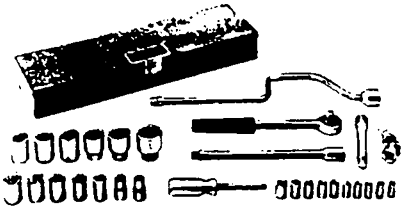
2000 TONS – [illegible] Ton/Day No Problem

ACTION:

Original: Central Files (File No. ______-A1)

QH-F21-R0

29-Pc. 1/4" and 1/2" Drive Socket Set

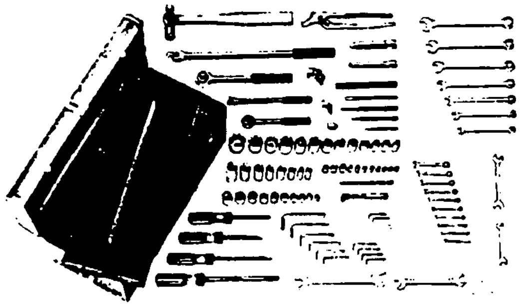


A convenient middle size set packed in a sturdy metal box. The box size is 18 1/4" long × 5 1/4" wide × 2 1/4" high.

1/4" DRIVE
6-Point Sockets 1/4", 9/32", 5/16", 11/32", 3/8", 7/16", and 1/2".
8-Point Special Sockets 1/4", 5/16", and 3/8". Will drive both square and hex nuts.
6" Spinner Handle
1/2" DRIVE
12-Point Sockets 7/16", 1/2", 9/16", 5/8", 11/16", 3/4", 13/16", 7/8", 15/16", 1", 1 1/16", 1 1/8", and 1 1/4"
Universal Joint
17 1/4" Speeder
10 1/2" Reversible Ratchet
Extension 5" and 10"

No. 5563A5 .... NET/SET $160.43

100-Pc. 1/4", 3/8" and 1/2" Drive Socket and Tool Set

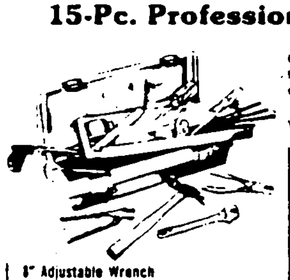


Easy-to-carry flat top metal tool box is 20" long × 8 1/2" wide × 9 1/2" high. The 8-point special sockets can be used for both square and hex fasteners.

1/4" SQUARE DRIVE
6-Point Standard Sockets 3/16", 7/32", 1/4", 9/32", 5/16", 11/32", 3/8", 7/16", 1/2"
8-Point Special Sockets 1/4", 5/16", 3/8"
5" Flex Handle
5 1/2" Bar
3/8" SQUARE DRIVE
6-Point Standard Sockets 3/8", 7/16", 1/2", 9/16"
6-Point Deep Sockets 3/8", 7/16", 1/2", 9/16", 5/8", 11/16", 3/4", 13/16"
9 3/8" Flex Handle
Universal Joint
12-Point Standard Sockets 5/8", 11/16", 3/4", 13/16", 7/8"
7 1/2" Ratchet
5" Extension
Adapter 3/8" Female × 1/4" Male
1/2" SQUARE DRIVE
12-Point Standard Sockets 7/16", 1/2", 9/16", 5/8", 11/16", 3/4", 13/16", 7/8", 15/16", 1", 1 1/16", 1 1/8", 1 1/4"
10 1/2" Ratchet
18" Flex Handle
5" Extension
Universal Joint
Combination Wrenches 3/8", 7/16", 1/2", 9/16", 5/8", 11/16", 3/4"
Open End Wrenches 3/8" × 7/16", 1/2" × 9/16", 5/8" × 11/16", 3/4" × 13/16"
Miniature Combination Wrench Set 5/32" × 3/16", 3/16" ...; 13/64" × 7/32", 7/32" ...; 15/64" × 1/4", 1/4" ...; 9/32" × 5/16", 5/16" ...; 11/32" × 3/8", 3/8" ...
Chisels (3/8", 1/2")
Center Punch (1/4")
Pin Punch (3/16")
Starter Punch (3/16")
10" Groove Joint Pliers
16-oz. Ball Peen Hammer
Round Shank Slotted Screwdrivers (4", 6", 8")
Phillips Screwdriver #2
Hex Key Set .028", .035", .050", 1/16", 5/64", 3/32", 7/64", 1/8", 9/64", 5/32", 3/16", 7/32", 1/4", 5/16", 3/8"

No. 7231A13 .... NET/SET $487.90

15-Pc. Professional Tool Set



A popular selection of 15 quality tools. Packed in a rugged, high-impact, molded plastic tool box 19" long × 6 1/2" wide × 4 1/2" high, with a removable tray.

8" Adjustable Wrench
7" Tongue-and-Groove Pliers
6" Slip Joint Pliers
Screwdrivers: 2 Slotted, 1 Phillips
Wooden Hand Awl
Hacksaw with Four Blades: Two 10", two 12"
File
6-Ft. Steel Tape Rule
10-Oz. Ripping Hammer

No. 8395A61 .... [redacted]

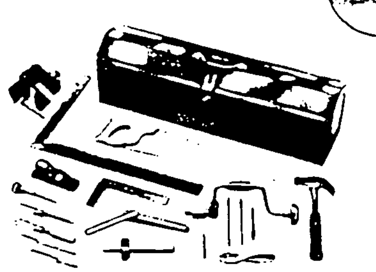
5-Pc. Maintenance Tool Set

Handy five-piece tool set will handle most basic adjustment and repair jobs. Packed in a convenient roll-up pouch.

Chrome Plated 10" Adjustable Wrench: 1 1/8" capacity. Cushion grip.
Chrome Plated 10" Groove Joint Pliers: Cushion grip handle.
10" Straight Cutting Metal Snips: With 2 1/4" long blade and cushion-grip handle.
Phillips Screwdriver: #2 × 4" round blade.
Heavy-Duty Slotted Screwdriver: 5/16" × 6" round blade.

No. 7274A11 .... [redacted]

19-Pc. Carpenters' Tool Set



High grade tools for all types of carpentry work. Packed in a black-enameled steel tool chest with machine riveted handles. Size: 32" long × 8" wide × 9" high.

16-Oz. Nail Hammer
Round Blade Slotted Screwdrivers: 5/32" × 7 1/8", 5/16" × 6 3/8"
8" Try Square
3/32" Nail Set
5/16" × 5" Screwdriver Bit
6 3/4" Block Plane
Wood Marking Gauge 5" long, graduated in 16ths".
1/4" and 3/4" Butt Chisels
Scratch Awl, 6 1/2" Long
24" × 2" Carpenters' Square Yellow; embossed graduations.
10" Bit Brace
1/4" and 3/4" Auger Bits
4 1/2" Vise
6-Ft. Folding Rule Graduated in inches, 16ths.
6" Slip Joint Pliers
20" Hand Saw

No. 6553A14 .... NET/SET $330.27

INTERNATIONAL TECHNOLOGY CORPORATION

5978

DATE 04-04-88 TIME 1045

PROJECT NO. 303317

NAME K-65 Silo

RECORD

OF TELEPHONE CALL

TELEPHONE NO. (615) 254-0841

TO Fred Nance/Brian Anderson OF Fehan

FROM Peter Keegan OF IT Corporation

Follow-up: Kathy Shell

SUBJECT DISCUSSED

ACTION TO BE TAKEN

Fehan Safety Products, Inc.
P.O. Box 101177
1100 Elm Hill Pike, Suite 145
Nashville, TN 37210

Quote: Glovebag — Approx $385/each
Two sets of gloveports
One 10" diameter sleeve ~ 40' long
Glovebag ~ 24" diameter

Icepans: 85¢/piece.

Tyvek Clothing: Gloves — $85/case (25 pair)
Suit
Head Cover — Later Gloves $7.95/doz.
Booties

Barracade Tape: $4.00/roll

Respirators: [redacted] Full Face w/ organic filter & Hepa Fil — $82.00/piece — $27.83 / [redacted] No. GMA combined [redacted]

Hard Hats: $6.00/ea

WHITE: ORIGINATOR YELLOW: FILE 19A-7-85

Gloves: Rubber/Leather → $12.50/doz

000184

TRIP/TELEPHONE REPORT

TELEPHONE X DATE: 3/31/88 X ORIGINATOR PLACED CALL

VISIT _ LOCATION: Knoxville _ ORIGINATOR RECEIVED CALL

ORIGINATOR: Porter PROJECT NO. 303317

CONVERSATION WITH: Virgil Rounds TELEPHONE NO. 584-6211

TITLE: DEPT:

ORGANIZATION: Advance Audio Visual

ADDRESS: 333 Troy Circle

Knox TN

SUBJECT: ~~Video~~ Camera Rental

COMMENTS:

Full function Video Camera, pan, focus, sound

160.00/wk or 480/mo.

Cart for camera 15.00/day or 180.00/mo.

ACTION:

_ Original: Central Files (File No. ____)

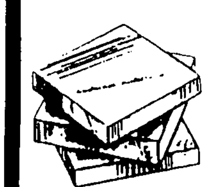
000185

QH-F21-R0

NEOPRENE SHEETING

000186

597[illegible]



Hi-Grade Neoprene Rubber Sheeting

General purpose rubber sheeting recommended for use around petroleum oil which decomposes natural rubber.

Neoprene has greater heat resistance than natural rubber. Excellent weathering and ozone resistance. Resistant to abrasion, tear, and impact damage. Good compression set characteristics. Flame resistant.

Resistant to alkalies, ketones, paint, and ink dryers. Not recommended for oxidizing acids, aromatic hydrocarbons, chlorinated hydrocarbons, and lacquer solvents. Neoprene is not recommended for electrical insulation.

Color is black. Meets ASTM-D-2000-75e, Type BC. Temperature range is −20°F to 170°F. Tensile strength is 1500 psi.

Available in standard 36" wide rolls and in precut sheets 12" × 12" and 12" × 24".

HARDNESS: SHORE A DUROMETER

Thick.	35-45A Soft No.	NET/LIN. FT.	45-55A Medium No.	NET/LIN. FT.	55-65A Firm No.	NET/LIN. FT.	65-75A Hard No.	NET/LIN. FT.
STANDARD 36" WIDE ROLLS								
1/16"	8568K11	$6.93	8568K31	$7.19	8568K19	$6.78	8568K41	$8.94
3/32"	8568K12	10.81	8568K32	11.33	8568K21	10.41	8568K42	10.40
1/8"	8568K13	11.71	8568K33	12.00	8568K22	11.83	8568K43	11.88
3/16"	8568K14	18.09	8568K34	19.01	8568K23	18.58	8568K44	17.83
1/4"	8568K15	20.52	8568K35	22.24	8568K24	21.76	8568K45	22.12
3/8"	8568K16	31.06	8568K36	34.03	8568K25	33.94	8568K46	33.16
1/2"	8568K17	42.36	8568K37	45.91	8568K26	45.00	8568K47	44.26
3/4"	8568K58	61.39	8568K68	61.39	8568K78	61.39	8568K88	61.39
1"	8568K59	80.95	8568K69	80.95	8568K79	80.95	8568K89	80.95

Thick.	35-45A Soft No.	NET EACH	45-55A Medium No.	NET EACH	55-65A Firm No.	NET EACH	65-75A Hard No.	NET EACH
12" × 12" SHEETS								
1/16"	8568K511	$2.86	8568K611	$2.96	8568K711	$2.79	8568K811	$2.88
3/32"	8568K512	4.43	8568K612	4.64	8568K712	4.29	8568K812	4.32
1/8"	8568K513	4.82	8568K613	4.93	8568K713	4.86	8568K813	4.83
3/16"	8568K514	7.43	8568K614	7.79	8568K714	7.64	8568K814	7.43
1/4"	8568K515	8.04	8568K615	8.71	8568K715	8.54	8568K815	8.07
3/8"	8568K516	12.18	8568K616	13.36	8568K716	13.32	8568K816	13.61
1/2"	8568K517	16.64	8568K617	18.04	8568K717	17.68	8568K817	18.18
3/4"	8568K518	24.36	8568K618	27.21	8568K718	26.79	8568K818	28.84
1"	8568K519	30.57	8568K619	36.25	8568K719	35.43	8568K819	36.43
12" × 24" SHEETS								
1/16"	8568K521	$5.13	8568K621	$5.32	8568K721	$5.03	8568K821	$5.23
3/32"	8568K522	8.03	8568K622	8.42	8568K722	7.74	8568K822	7.84
1/8"	8568K523	8.71	8568K623	8.90	8568K723	8.77	8568K823	8.84
3/16"	8568K524	13.42	8568K624	14.13	8568K724	13.81	8568K824	13.42
1/4"	8568K525	14.58	8568K625	15.81	8568K725	15.45	8568K825	16.42
3/8"	8568K526	22.06	8568K626	24.16	8568K726	26.68	8568K826	24.81
1/2"	8568K527	30.30	8568K627	32.61	8568K727	35.39	8568K827	32.87
3/4"	8568K528	44.10	8568K628	49.23	8568K728	48.42	8568K828	51.61
1"	8568K529	55.29	8568K629	65.61	8568K729	64.10	8568K829	66.87

Neoprene Rubber Sheets

COMMERCIAL GRADE. Withstands hot and cold oils and nonaromatic solvents. Resistant to sun and ozone checking.

Applications include flange material on pumps, tanks, and pipelines carrying mineral oils, gasoline, and greases. Conforms to irregular flange joints and will seal under minimum bolt loads.

Hardness, Shore A Durometer is 50. Tensile strength is 1000 psi. Temperature range is −20° to +220°F. Color is black.

STANDARD WIDTH IS 36"

Thick.	No.	NET/LIN. FT.
1/32"	9455K1	$3.80
1/16"	9455K2	4.68
3/32"	9455K3	7.03
1/8"	9455K4	9.37
3/16"	9455K5	13.69
1/4"	9455K6	19.10

SUPER SOFT. One of the softest rubbers available. Its outstanding softness makes it an excellent medium for preventing, damping, and absorbing vibration. Although highly resilient and as pliable as most sponge formulations, it is nonporous and uniform. Exposure to weather and severe temperatures will not affect these characteristics.

Applications include motor mounting pads, airtight sealers for vacuum testers; gaskets exposed to weather, and conveyor belts for delicate components.

Hardness, Shore A Durometer is 5-10. Temperature range is −60° to +180°F. Tensile strength is 575 psi. Color is black.

Thick.	12" × 12" No.	NET EACH	20" × 20" No.	NET EACH	23" × 43" No.	NET EACH
1/16"	8639K12	$20.84	8639K212	$30.00	8639K312	$48.00
1/8"	8639K13	25.33	8639K213	39.33	8639K313	60.66
3/16"	8639K14	30.73	8639K214	49.61	8639K314	80.00
1/4"	8639K15	35.93	8639K215	60.10	8639K315	100.61
5/16"	8639K16	40.67	8639K216	67.04	8639K316	114.04
3/8"	8639K31	46.35	8639K231	76.99	8639K331	130.66
7/16"	8639K32	52.81	8639K232	86.92	8639K332	148.04
1/2"	8639K19	58.59	8639K219	96.85	8639K319	164.72
3/4"	8639K33	68.55	8639K233	120.05	8639K333	240.04
1"	8639K22	87.72	8639K222	155.20	8639K322	296.66

NYLON INSERTED NEOPRENE DIAPHRAGM SHEETS. Diaphragm sheet packing consisting of neoprene with one ply nylon inserted for each 1/16" of thickness. Has a higher tensile strength and is more durable than cloth inserted sheets. Excellent oil, heat, and ozone resistance. Durometer Shore A is 70. Tensile strength is 1500 psi. Temperature range is −40° to 220°F. Color is black.

STANDARD WIDTH 48"

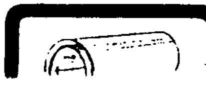
Thick.	No.	NET/LIN. FT.
1/16"	8599K11	$16.33
3/32"	8599K12	24.00
1/8"	8599K13	29.36
3/16"	8599K14	41.90
1/4"	8599K15	55.64

CLOTH INSERTED NEOPRENE SHEETS. Neoprene sheet with one ply 6.7 oz. cotton inserted per 1/16" of thickness. Fabric reinforcement provides the extra strength needed for high-stress applications.

Oil, heat, and ozone resistant. Hardness, Shore A Durometer is 60. Tensile strength is 1000 psi. Temperature range is −20° to 220°F. Color is black.

STANDARD WIDTH 36"

Thick.	No.	NET/LIN. FT.
1/16"	8698K31	$10.46
3/32"	8698K32	13.44
1/8"	8698K33	17.01
3/16"	8698K34	24.74
1/4"	8698K35	32.06



FDA Approved Neoprene Rubber Sheeting

Withstands oily, greasy, and abrasive conditions, especially in food handling, drug and cosmetic manufacturing, and wherever nontoxic, nonallergenic, and nonmarking properties are required. Smooth fin-

Thick.	No.	NET/ LIN. FT.
1/16"	8618K22	$14.00

RUB[...]

Nitrile (Buna-[...]

Blended commercial grade nitrile rubber she[...]ing is widely used for its superior resistance[...] petroleum and vegetable oils, as well as solve[...] and gasoline, under conditions which would [...] lack natural rubber.

Buna-N matches natural rubber in gene[...] chemical resistance, but has better weatheri[...] characteristics and lower tensile strength. Oth[...]

HARDNES[...]

Thick.	35-45A Soft No.	NET/ LIN. FT.	45-55A Medium No.	L[...]
1/32"	8635K19	$6.63	8635K29	
1/16"	8635K11	7.37	8635K21	
3/32"	8635K12	11.00	8635K22	
1/8"	8635K13	14.50	8635K23	
3/16"	8635K14	19.43	8635K24	
1/4"	8635K16	27.43	8635K25	
3/8"	8635K17	41.15	8635K27	
1/2"	8635K18	50.70	8635K28	
3/4"	8635K51	69.16	8635K61	
1"	8635K52	92.19	8635K62	

Nitrile ([...]

Nonhardening nitrile elastomer with 14.3-oz. co[...] Used for flat diaphragm service on reducing valv[...] handling low pressure water, gas, and air. Excellen[...]ping. Hardness, Shore A Durometer is 55-65. Tens[...] psi. Temperature range is −40°F to +275°F. Color i[...] and 1/8" sheets are 1 ply; 3/16" and 1/4" sheets are 2 [...]

Red Nitrile FDA Rubber Sheeting

Quality nitrile (Buna-N) nontoxic sheet for general gasketing in all phases of food processing and the manufacture of pharmaceuticals and cosmetics. Produced from FDA approved ingredients.

Will provide long service life. Excellent abrasion resistance. **Hardness, Shore A Durometer is 50-60.**

Tensile strength is 1200 psi. Temperature range is −25°F to 220°F. Color is red. Smooth finish.

STANDARD WIDTH IS 36"

Thick.	No.	NET/ LIN. FT.
[illegible]	8649K21	$9.18
[illegible]	8649K22	12.70
[illegible]	8649K23	15.92
[illegible]	8649K24	22.78
[illegible]	8649K25	31.12

EPDM Rubber Sheeting

Resists steam, heat, weather, and ozone. Not oil resistant. Smooth finish. Color is black. Meets ASTM D-2000-75E, Type BA. Hardness, Shore A Durometer is 60. Tensile strength is 1000 psi. Temperature range is −40° to 240°F.

STANDARD WIDTH IS 36"

Thick.	No.	NET/LIN. FT.
[illegible]	8610K22	$5.49
[illegible]	8610K11	6.52
[illegible]	8610K33	8.50
[illegible]	8610K12	11.33
[illegible]	8610K34	15.64
[illegible]	8610K35	17.86

SB[...] sign[...] air, h[...] sista[...] Hard[...]

Sta[...]

Type [...] sista[...] satur[...] −20°[...]

Sta[...]

Thick.
1/16"
3/32"
1/8"
3/16"
1/4"
3/8"
1/2"
3/4"
1"

Extru[...] Ideal fo[...] buffer s[...]

Hard[...]

Materia[...]
U-CHAN[...]
EPDM ...
ROUND[...]
EPDM ...
EPDM ...
EPDM ...
RECTAN[...]
Neopren[...]
Neopren[...]
Neopren[...]

Buty[...]

Offers good weather resistance and low permeability to air. Excellent dielectric properties. High resistance to ketones, ozone, paint, and saturated inorganic solutions. Not resistant to oil.

Meets ASTM D-2000 [illegible]

am Hos(

0001

ıt Food Suction/Transfer Hose

ıade, crystal clear, material handling uction and discharge applications. with a convoluted cover for in- lexibility and secure handling. ıre eliminates material buildup and npeded flow.
; with FDA and USDA requirements ınitary Standards.

Ideal for pneumatic conveying of powders, pellets, and granular materials. Recommended for pneumatic system dry material transfer only. Service temperature is −4°F to 150°F under static conditions and 14°F to 104°F under dynamic conditions.

Series 5179K has an embedded copper static wire for grounding where required.

Hose OD	Working Pressure @ 68°F, PSI	Vacuum @ 68°F In. Hg.	Min. Bend Radius	No.	NET/FOOT
HOUT STATIC WIRE					
1.30"	55	28	2"	5199K71	$1.14
1.60"	50	28	2"	5199K72	1.39
1.92"	50	28	3"	5199K73	1.61
2 40"	40	28	4"	5199K74	2.18
2.99"	40	28	5"	5199K75	3.39
3.64"	40	28	6"	5199K76	4.36
4.21"	35	28	8"	5199K77	7.20
4.72"	35	24	10"	5199K78	7.40
5 74"	35	24	16"	5199K79	12.42
6 81"	30	24	18"	5199K81	14.13
H STATIC WIRE					
1.83"	50	28	5"	5179K34	$3.34
2.40"	40	28	4"	5179K35	4.61
2 99"	40	28	5"	5179K36	5.57
3.64"	40	28	6"	5179K37	7.43
4.72"	35	24	9"	5179K38	11.87

ɛ Thermoplastic Food Hose

h as rubber but without the bulk and ade of a specially formulated multiıne elastomer with high-tensile steel forcement for pickup and/or dis- liquids, gases, and solids. Complies regulation 177.1680 for dry foods and ıutical materials. Can handle cereal, ȷrain, sugar, salt, flour, and other dry ɛrials. Also for vacuum and venting. ɐ of its construction, this hose can be ɓ lighter than fabric reinforced hose. k, collapse, or balloon when used at nded pressures. Excellent chemical resistance. Can be grounded.

Temperature range is −60° to +180°F. Negative pressure is 15 In. Hg. Compresses from 20-40% of extended length. Maximum continuous length is 25 feet.

Hose ID	Hose OD	Min. Bend Radius	Work. Pres. PSI	No.	NET/FOOT
2"	2.2"	1"	13	9914K52	$7.47
3"	3.2"	1½"	12	9914K53	8.48
4"	4.2"	2"	10	9914K54	9.36
5"	5.2"	2½"	7	9914K55	11.00
6"	6.24"	3"	7	9914K56	11.69
7"	7.24"	3½"	7	9914K57	14.04
8"	8.24"	4"	5	9914K58	16.86

Food Service Hose

FDA requirements for sanitary transıible fluids. Materials used in this ıect food products from any chance ɔr odor transfer.
ıghly flexible, yet strong and light- ɐ is suitable for gravity flow, presı suction service.
ı wire reinforcement allows tight bends without interfering with product flow.

The tube is white butyl rubber reinforced with a spiral wire helix between plies of polyester fabric. The gray hypalon cover with white spiral stripe is compounded to resist damage from oil, chemicals, sunlight and abrasion and is nonmarking.

Couplers are C and E quick couplers.

MAXIMUM CONTINUOUS LENGTH AVAILABLE IS 100 FT.

D	Work Pres. PSI	Min. Bend Radius	Hose No.	Hose NET/FOOT	Stainless Steel Couplers Attached No.	NET/PAIR
5/16"	150	3"	5555K16	$9.93	5555K26	$66.53
33/64"	150	4"	5555K17	10.30	5555K27	69.65
1/32"	150	5"	5555K11	11.30	5555K21	84.33
19/32"	150	8"	5555K12	13.73	5555K22	103.97
21/32"	150	12"	5555K13	19.48	5555K23	193.70

h Pressure Steam Hose

FOR SATURATED STEAM UP TO 406°F AT 250 PSI
FOR SUPER-HEATED STEAM UP TO 450°F AT 250 PSI

to handle the high pressure steam to wash vats, conveyors, piping and ıcks in the food processing, meat , and dairy industries.
le enough for easy handling. The tube is EPDM rubber reinforced with a double wire braid for high strength. Cover is made of EPDM for resistance to heat and abrasion.

Couplings: Malleable iron high pressure, male and female, interlocking clamp type.

FEET
ı feet

Couplings (Attached) No.	NET/PAIR
5301K21	$23.56
5301K22	36.76

STAN[illegible]D HIGH PRESSURE STEAM HOSE ASSEMBLIES

6[illegible] in 25-ft. and 50-ft. lengths with high pressure male and fe[illegible]ocking clamp type couplings attached.

ID	25-Ft. Lengths No.	NET EACH	50-Ft. Lengths No.	NET EACH
1/2" × [illegible]/64"	5301K31	$94.93	5301K41	$166.87
3/4" × 1 7/32"	5301K32	121.07	5301K42	206.11

Steam & hydraulic hose

Steam Hose

Available in three grades to handle a variety of open ended discharge steam applications at various working pressures.

Types 5300K52 and 5300K54 are especially suitable for use on steam cleaning equipment in maintenance departments and garages.

Tube is made of EPDM. Hose is reinforced with multiple plies of heavy insulated fabric. The cover is SBR wrap with moderate oil resistance. Maximum continuous length is 50 ft.

COUPLINGS ATTACHED

Couplings are malleable iron high pressure, male and female, interlocking clamp type.

For Hose ID	No.	NET/PAIR
1/2"	5300K71	$23.98
3/4"	5300K72	38.89
1"	5300K73	53.07
1 1/4"	5300K74	68.84
1 1/2"	5300K75	80.49
2"	5300K76	133.13

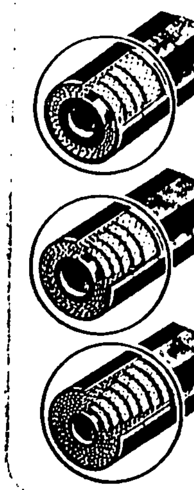
ASSEMBLIES—25 Feet, M × F High Pressure Couplings Attached.

Hose ID	No.	NET EACH
Grade 1—50 PSI Working Pressure ♦		
1/2"	5300K81	$86.44
3/4"	5300K82	128.75
1"	5300K83	162.40
Grade 2—100 PSI Working Pressure ♦		
3/4"	5300K85	135.60
1"	5300K86	179.51
Grade 3—150 PSI Working Pressure ♦		
3/4"	5300K88	147.00
1"	5300K89	190.91

HOSE
STANDARD LENGTH IS 25 FEET

Hose ID × OD	Ply	No.	NET/FOOT Cut Lgths.	NET/FOOT Std. Lgths.
Grade 1—50 PSI Working Pressure ♦				
1/2" × 1 3/16"	4	5300K12	$2.72	$2.45
3/4" × 1 7/16"	4	5300K14	3.75	3.38
1" × 1 11/16"	4	5300K16	4.49	4.06
1 1/4" × 2 1/8"	5	5300K18	6.88	6.25
1 1/2" × 2 3/8"	5	5300K21	7.92	7.20
2" × 2 15/16"	6	5300K31	10.66	9.69
Grade 2—100 PSI Working Pressure ♦				
1/2" × 1 5/16"	5	5300K32	$3.60	$3.27
3/4" × 1 1/2"	5	5300K34	4.07	3.73
1" × 1 25/32"	5	5300K36	5.27	4.80
1 1/4" × 2 3/16"	6	5300K38	7.78	7.12
1 1/2" × 2 13/32"	6	5300K41	8.55	7.76
2" × 3 1/16"	8	5300K43	12.64	11.56
Grade 3—150 PSI Working Pressure ♦				
1/2" × 1 5/16"	6	5300K52	$3.60	$3.28
3/4" × 1 9/16"	6	5300K54	4.67	4.23
1" × 1 13/16"	6	5300K56	6.25	5.69
1 1/4" × 2 1/4"	7	5300K58	8.59	7.85
1 1/2" × 2 9/16"	8	5300K61	10.45	9.52

♦ Open end discharge.



Grade 1
50 PSI

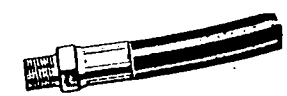
Grade 2
100 PSI

Grade 3
150 PSI

Hydraulic Hose Assemblies

Strong, flexible hose and hose assemblies are available in four constructions providing service from low pressure to extra high pressure. All hoses are designed to be used with petroleum based hydraulic fluids. Cover is made of synthetic rubber formulated for excellent resistance to weather, sunlight, abrasion, oil, grease, and gasoline.

SAE 100R3—Used in low and medium hydraulic applications. Hose has two rayon braids for reinforcement. Temperature range is −40°F to 200°F. SAE 100R1-AT—Used for medium presure hydraulic lines on mobile equipment and machine tools. Has one braid of high tensile steel wire for reinforcement. Temperature range is −40°F to 200°F. Conforms to USCG. MSHA approved cover. SAE 100R2-AT—Used for high pressure lines on off-the-road equipment, machine tools, farm machinery, and marine and railroad equipment. Has two high tensile steel braids as reinforcement. Temperature range is −40°F to 200°F. Conforms to USCG. MSHA approved cover. Extra High Pressure—Hose not sold separately due to high pressure applications. Combines very high burst strength with superior resistance to impulsing and flexing. The 3/4" and 1" sizes have four spiral wires of high tensile steel for reinforcement, and the other sizes have six spiral wires. Temperature range is −40°F to 250°F.



All assemblies are furnished with permanently attached rigid male pipe threaded couplings on both ends. Coupling size is same as base ID size. When ordering, specify number, length, and couplings if required.

Hose ID × OD	Work Pres. PSI	Min. Bend Radius	Hose No.	Hose NET/FOOT	Cplgs. Attached No.	NET/PAIR
SAE 100R3 LOW AND MEDIUM PRESSURE HYDRAULIC SERVICE						
1/4" × 9/16"	1250	3"	5279K111	$1.80	5279K511	$2.05
3/8" × 3/4"	1125	4"	5279K112	1.95	5279K512	2.64
1/2" × 15/16"	1000	5"	5279K113	2.91	5279K513	5.39
3/4" × 1 1/4"	750	6"	5279K114	3.76	5279K514	7.51
1" × 1 1/2"	565	8"	5279K115	4.77	5279K515	10.39
SAE 100R1-AT MEDIUM PRESSURE HYDRAULIC SERVICE						
1/4" × 17/32"	2750	4"	5279K211	$1.33	5279K611	$4.16
3/8" × 11/16"	2250	5"	5279K212	1.42	5279K612	4.41
1/2" × 13/16"	2000	7"	5279K213	1.67	5279K613	4.86
3/4" × 1 3/32"	1250	9 1/2"	5279K214	2.48	5279K614	8.02
1" × 1 7/16"	1000	12"	5279K215	3.42	5279K615	10.39

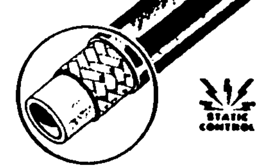
Hose ID × OD	Work Pres. PSI	Min. Bend Radius	Hose No.	Hose NET/FOOT	Cplgs. Attached No.	NET/PAIR
SAE 100R2-AT HIGH PRESSURE HYDRAULIC SERVICE						
1/4" × 19/32"	5000	4"	5279K311	$1.67	5279K711	$4.16
3/8" × 3/4"	4000	5"	5279K312	1.91	5279K712	4.41
1/2" × 7/8"	3500	7"	5279K313	2.23	5279K713	4.86
3/4" × 1 5/32"	2250	9 1/2"	5279K314	3.29	5279K714	8.02
1" × 1 1/2"	2000	12"	5279K315	4.35	5279K715	10.39
EXTRA HIGH PRESSURE HYDRAULIC SERVICE						
3/4" × 1 17/64"	5000	9 1/2"	5279K414	$13.66	5279K814	$22.28
1" × 1 33/64"	5000	12"	5279K415	26.54	5279K815	27.87
1 1/4" × 1 31/32"	5000	16 1/2"	5279K416	34.03	5279K816	43.05
1 1/2" × 2 1/4"	5000	20"	5279K417	40.29	5279K817	52.49
2" × 2 5/8"	5000	25"	5279K418	54.60	5279K818	82.03

Nonconductive Hydraulic Hoses

Conductivity is less than 50 microamps at 75,000 volts AC per 12 inches of hose. Type SAE 100R8 hose meets SAE J517 specifications. Compatible with almost all common hydraulic fluids. Good chemical resistance. Nonmetallic construction eliminates corrosion problems. Tubes are nonswelling.

Tube: Polyester. Cover: Orange polyester. Reinforcement: Kevlar. Temperature range: −40° to 200°F. Burst strength: 4 to 1.

Hose ID × OD	Work Pres. PSI	Min. Bend Radius	No.	NET/FOOT 1-49 Ft.	NET/FOOT 50 Ft. & Up	MPT Couplings Attached No.	NET/PAIR
3/16" × .42"	5000	3 1/2"	5639K12	$1.98	$1.66	5639K42	$4.00
1/4" × .51"	5000	4"	5639K13	2.22	1.85	5639K43	4.38
3/8" × .67"	4000	5"	5639K15	2.63	2.20	5639K45	6.74
1/2" × .83"	3500	7"	5639K16	3.37	2.82	5639K46	9.08
3/4" × 1.10"	2250	9 1/2"	5639K17	4.78	4.00	5639K47	18.90
1" × 1.41"	2000	[illegible]	5639K18	6.24	5.21	5639K48	42.36



STATIC CONTROL

Pipe [illegible]g Bands and Seals

All-weather aluminum bands [illegible] are ideally suited for banding and fastening pipe coverings.

Band Width	Bands (200-Ft. Roll) No.	NET/ROLL	Seals No.	NET/100

5978

TRIP/TELEPHONE REPORT

TELEPHONE ___ DATE: 6/23/88 ✓ ORIGINATOR PLACED CALL

VISIT ___ LOCATION: 312 DD ___ ORIGINATOR RECEIVED CALL

ORIGINATOR: M. Caperton PROJECT NO. 303317

CONVERSATION WITH: Harold Hipp[illegible] TELEPHONE NO. (615) [illegible]

TITLE: Sales DEPT:

ORGANIZATION: ETP of Knoxville

ADDRESS: 3300 Rhdu St.

Knoxville TN

SUBJECT: * sheeting 50' x 100' Imported Poly Tarp (Blue) [illegible]

COMMENTS:

in stock: 12'x12' mint high density resin: 1½ mil polyethylene: both sides laminated; rust resistant and welded seams; water proof; Last over 1yr. if weighted heavily price: 50'x100' - $400.00 + tax - order by quantity - price reduced: 5-$320.00 10-$296.00 ; different sizes available 25'x50', 30'x40', 40'x40'

50'x100 Vinyl coated nylon - 14 oz. - will last years - $.50/sq. ft.
25'x50' - $.44/sq. ft.

ACTION:

_ Original: Central Files (File No. 303317-A1)

QH-F21-R0

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