LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although portions of this report are not reproducible, it is being made available in microfiche to facilitate the availability of those parts of the document which are legible.

2

CONF-871045--5

LA-UR--87-2532

DE87 013168

LA-UR-87-2532

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: **FISSILE MATERIAL STORAGE VAULTS - DESIGNING TO ENHANCE SAFETY AND EFFICIENCY**

AUTHOR(S): T. P. McLaughlin, HSE-6

SUBMITTED TO: Nuclear Criticality Safety
Tokyo, Japan
October 19-23, 1987

Los Alamos — Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO. 836 R4
ST. NO. 2629 5/81

FISSILE MATERIAL STORAGE VAULTS - DESIGNING TO ENHANCE SAFETY AND EFFICIENCY

THOMAS P. MCLAUGHLIN
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545 USA
505-667-7628

ABSTRACT

There are several, sometimes conflicting, interests which must be accommodated in fissile material storage vaults. These include criticality safety, radiation safety, fire protection, accountability, and safeguards in addition to the operational requirements of efficiency and, for automated vaults, reliability. A combination of these factors coupled with increasing demands on available vault space and the desire to minimize on-site transportation of special nuclear materials has resulted in current design and construction activities for three major fissile material storage vaults and the renovation of an existing vault at the Los Alamos National Laboratory. Two of these new vaults will be provided with automated stacker-retriever systems similar to those common in large warehouse operations while the third vault, being smaller and having less potential for radiation exposures will be operated in a hands-on mode.

INTRODUCTION

The need for new and improved fissile material storage capacity at Los Alamos is largely a result of two factors:

- Overcrowding of current vaults leading to both criticality and radiation exposure concerns.

- Long range goals to locate major Special Nuclear Material (SNM) operations at the site of the current plutonium facility. This will reduce transportation requirements and improve operational efficiency as well as minimize safeguards and security costs.

These factors have led to: 1) recent completion of a new vault to consolidate SNM storage within the Chemistry Metallurgy Research (CMR) Facility; 2) design of a new vault for the plutonium facility with construction planned for 1988; 3) a new Nuclear Materials Storage Facility (NMSF) located at the site of the plutonium facility and scheduled for completion in 1988; and 4) substantial enhancements for both criticality and radiation safety with the existing vault in the plutonium facility.

The three new vaults will be capable of storing both uranium and plutonium of varying isotopics and in a wide range of physical forms such as metal, compounds, and scrap. In addition, there will be the need to store some hydrogen bearing (i.e., moderated) materials. Due to its smaller size and operational considerations such as frequency of use and diversity of stored material the newly completed CMR vault is operated in a hands-on mode. The new vault within the plutonium facility will offer entirely automated stacker-retriever storage and the existing vault will be maintained for hands-on operations. Due to its intended use as the major central storage facility for the Laboratory as well as the primary shipping/receiving and assaying focus at Los Alamos the NMSF will contain both hands-on and automated stacker-retriever storage.

The major retrofits to the existing vault are: 1) substantially enhanced computer and administrative controls on shelf selection and item identification criteria; and 2) storage drawers with boron loaded, fire retardant inserts which provide positive item spacing, neutron moderation and absorption, and significant reductions in radiation levels.

GENERAL DESIGN CONSIDERATIONS

Since both radiation safety and criticality safety were major considerations in these vault designs let us review common practices to minimize personnel exposure and maintain criticality safety for vault operations.

- Automated stacker-retriever material storage and retrieval. This method is in use at the Rocky Flats Plant and at Westinghouse Hanford operations. The extent to which radiation exposures are controlled depends heavily on the thickness, material type, and design of shielding between the SNM and operations personnel, particularly at the loading/unloading stations. Important considerations are: 1) neutron poisoning of shielding/structural materials, e.g., boron loaded concrete, and 2) whether or not shield doors are opened and closed each time a storage drawer is retrieved from the vault. Increasing the shield thickness and minimizing line of sight exposure to operations personnel at the loading station may preclude the need for shielding doors. However, doors may be considered a desirable or even essential feature by safeguards regulations.

- Using boron-loaded concrete or similar material in hands-on vaults. This is in use at the ZPPR facility at ANL-West at the Idaho National Engineering Laboratory.

While control of both radiation exposure and criticality safety are obvious requirements for fissile material storage vaults, several other concerns must be accommodated. These include: accountability, safeguards and security, fire protection, operational efficiency, and reliable access. Over-emphasizing any of these concerns will usually detrimentally effect several if not all of the others. For example:

1) Criticality and safeguards concerns are often reduced by multiple personnel being involved in and confirming the accuracy of an operation whereas a single person operation may reduce the total personnel exposure;

2) Safeguards criteria generally favor consolidation of SNM as much as possible while both criticality safety and radiation protection concerns will often be aggravated by close-packing materials;

3) Accountability usually requires frequent physical inventories which will lead to increased radiation exposures and the possibility of item misplacement causing criticality concerns.

4) Fire protection, if provided by water, may aggravate criticality concerns as well as the spread of contamination. Other methods such as Halon or administratively controlling quantities of combustibles may be considered less effective.

Controls for improving safety, safeguards, and accountability usually detract from rather than enhance efficiency and productivity. Thus, such controls, must be designed and implemented for ease of use by operations personnel to encourage compliance.

CMR Vault

This vault was completed this year and represents both increased capacity for and consolidation of the contents of several smaller vaults. Some of these were within the CMR facility while others were at neighboring sites. Control of safeguards costs through SNM inventory reductions at these nearby locations was a major consideration in the justification for this new vault. It consists of one medium size room divided by fencing into several areas individually under the control of different organizations. Due to the types, forms, and quantities of the stored material it was decided to design this vault for hands-on operation.

Relatively low neutron and gamma backgrounds are expected thus alleviating concerns for personnel radiation exposures. Analyses indicated that even under worst-case SNM loadings, borating construction concrete used in walls, ceiling and floor would only marginally (few percent) increase vault capacity and reduce radiation exposures. Also, interior walls of borated concrete were analyzed and found not cost effective considering the floor area they consumed. Thirdly, shelf liners of neutron poison material were considered but also deemed not cost-effective in view of the relatively small potential increase in vault capacity. Criticality control is provided by a combination of hardware and administrative measures:

- Individual shelves (60 x 120 cm) have limits for different material types.

- Wiremesh doors afford access to only one 120 cm wide column of shelves at a time.

- o *Shelf spacing is only adjustable at 15 cm intervals, assuring this minimum vertical separation.*

- o *Individual non-hydrogenous items are packaged such that the maximum density of fissile material, averaged over the outer container volume is at most a few kilograms per litre. For loose oxides and other compounds this is automatically adhered to; for metals this maximum density is controlled closer to 2 kg/l or less.*

This last point is a key factor in criticality control in this and, in fact, in all fissile material storage operations at Los Alamos. Thus considering the relationship between critical mass and density:

$$m \propto \rho^{-n} \quad \text{where} \quad 1 \leq n \leq 2$$

it becomes apparent that maintaining a maximum density of 5-10% of theoretical increases the critical mass by much more than a factor of ten. An extreme example of the safety built into this storage practice may be seen by considering a worst case accident scenario whereby all cans are displaced from their shelves and end up in a heap on the floor during a hypothetical earthquake. The surface density of the resulting accumulation of cans is likely to be below the critical surface density. If this is the case then double or even triple batching of cans on an individual shelf will not result in a close approach to critical.

For loose oxides and compounds, or any dispersibles, density is obviously well below theoretical. However, an additional consideration must be given to handling and storage of these materials if flooding of individual containers is deemed credible, namely, the combination of shape and volume which maintains a single unit subcritical for this accident condition.

Similarly, for hydrogenous material storage it is desirable if the combination of container shape and volume maintains the unit subcritical for optimum moderation conditions.

PLUTONIUM FACILITY AUTOMATED VAULT

The existing vault in the plutonium facility has become increasingly overcrowded during the last few years leading to accountability, criticality safety, and radiation exposure concerns. Obviously this situation impacted other operations within the facility. Thus, in addition to actions taken to alleviate these concerns within the constraints of the current vault, a year ago it was decided that additional vault capacity with improved radiation exposure control was warranted. The design of this new vault, as an integral part of the existing plutonium facility, is essentially complete and construction is planned for 1988. It is intended to supplement the existing vault and support the daily operations of the facility. Major design features include:

- o *Automated storage only, with stacker-retriever units in each of two corridors. Storage drawers range from floor to ceiling on either side of each aisleway. Figures 1, 2, and 3 give cross sections of possible layouts and illustrate these features.*

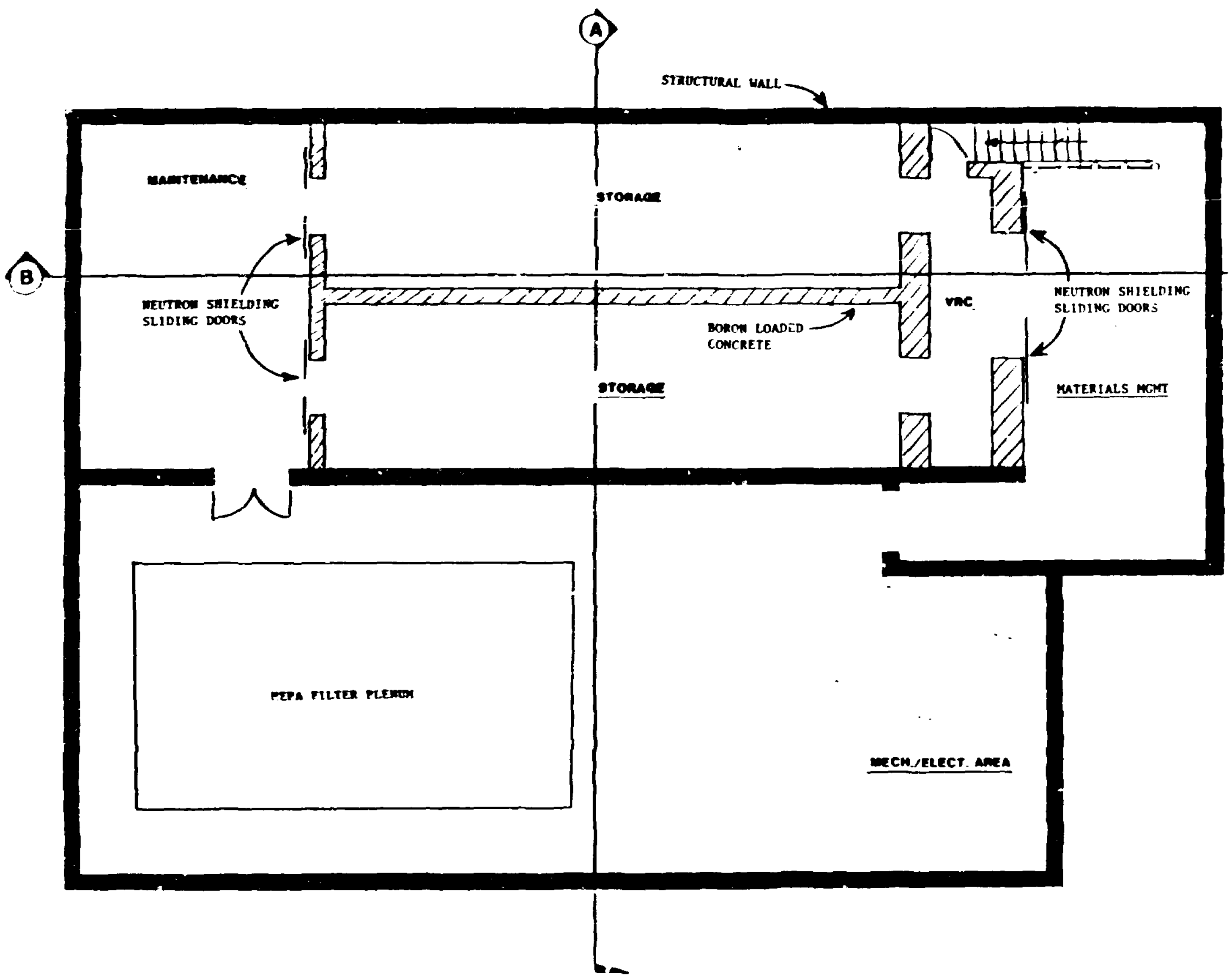
- o *Boron-loaded concrete is scheduled for both the central wall separating the two corridors and in the front walls separating personnel access areas from the fissile material storage areas.*

- o *Dry-pipe, preaction fire suppression system with sprinkler heads only over the stacker-retriever units. Design and spacing of the drawers will discourage sprinkler water entry. All stored material will be packaged in metal containers.*

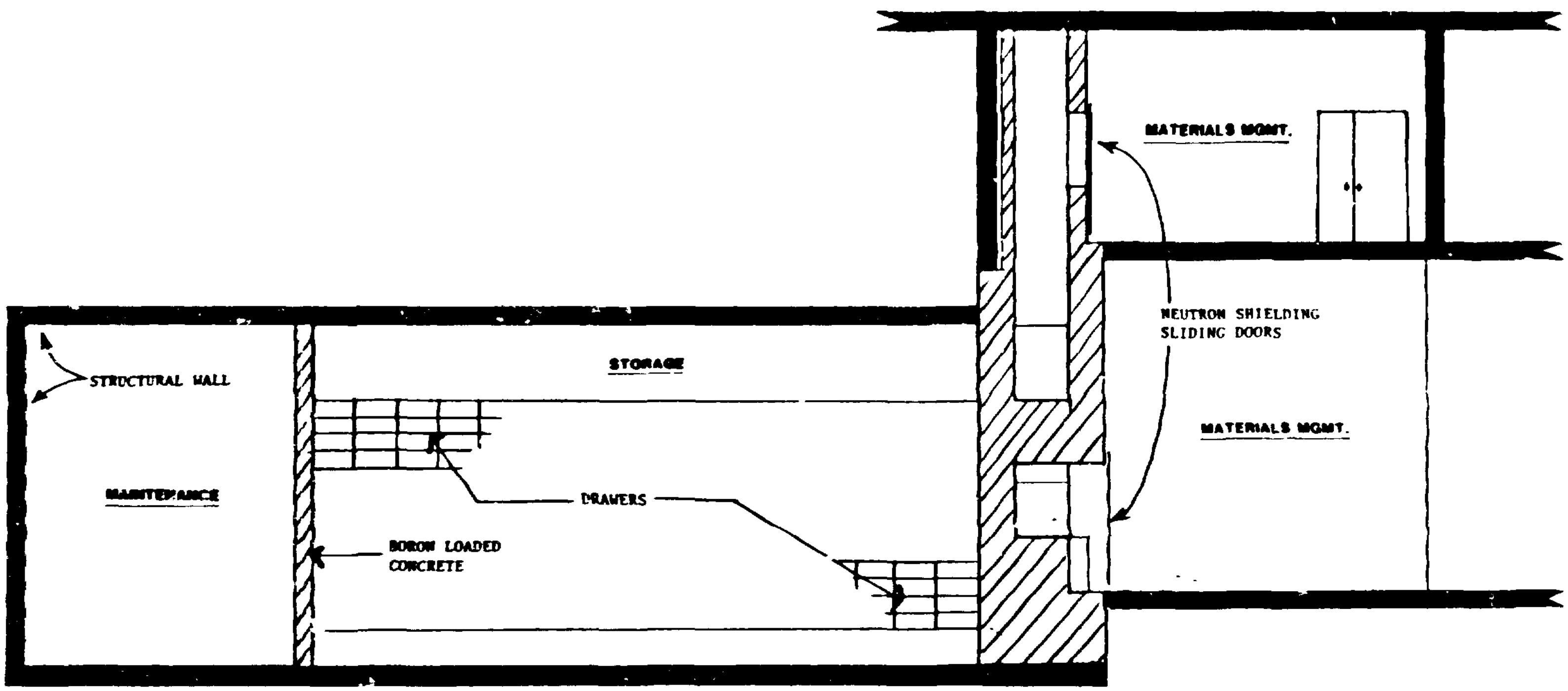
- o *The criticality alarm system for the facility will be extended into this new area, although it would be difficult to justify such a system for a stand-alone facility based solely on cost-effective risk control.*

- o *Storage drawers will have inserts to enhance positive spacing between units and outer container volumes will control average fissile material densities to a maximum of 2 kg/l for non-hydrogenous materials. Combinations of shape and volume control of cans containing dispersibles and hydrogenous materials will provide criticality controls for single unit flooding accidents.*

Design considerations not finalized include the thickness and material of neutron shielding doors separating the material storage area from the maintenance area and from the materials management area. Preliminary results indicate that 10 cm thick doors of BISCO NS-4 or equivalent will reduce radiation levels to



STRUCTURAL WALL
MAINTENANCE
STORAGE
NEUTRON SHIELDING
SLIDING DOORS
VRC
BORON LOADED
CONCRETE
NEUTRON SHIELDING
SLIDING DOORS
STORAGE
MATERIALS MGMT
HEPA FILTER PLENUM
MECH./ELECT. AREA



SECTION B

FIGURE 2. POSSIBLE CONCEPT FOR A PLUTONIUM FACILITY AUTOMATED VAULT, SECTION B

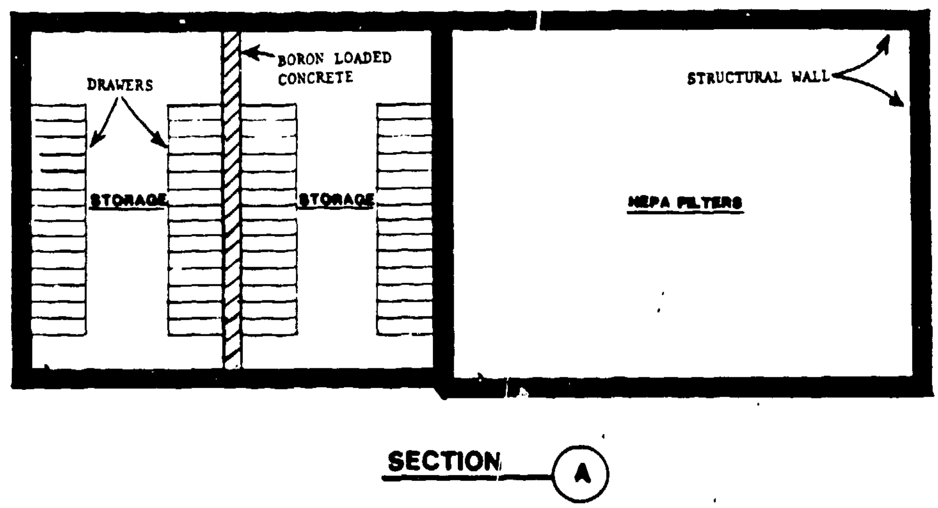


FIGURE 3. POSSIBLE CONCEPT FOR A PLUTONIUM FACILITY AUTOMATED VAULT, SECTION A

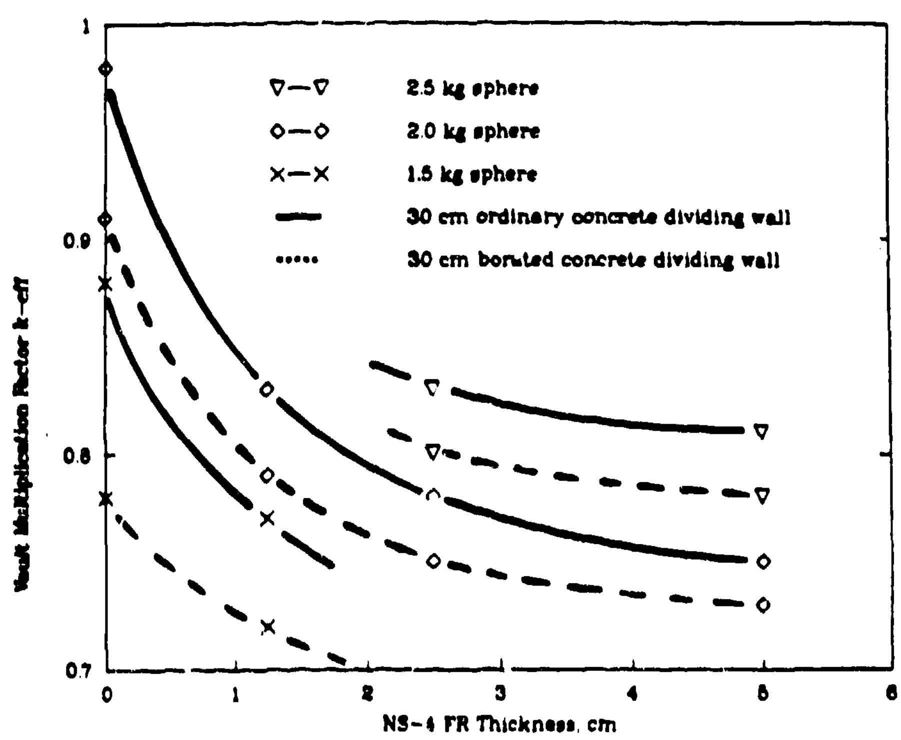


Figure 4 Multiplication factor for plutonium metal spheres equally spaced, 30 cm center to center in both horizontal directions. Drawers were 90 cm (3 spheres) deep, vertical spacing was 25 cm.

acceptable levels.[1] The Monte Carlo code MCNP has been used for shielding and dose analyses.

Examples of calculational results which led to the decision to borate the wall dividing the two corridors but not exterior walls are shown in Figure 4. A calculational model similar to the vault layout shown in Figures 1, 2, and 3 was the basis for the analysis. The KENO code with the Hansen-Roach cross sections was the computational tool. As is apparent, one can achieve additional storage capacity in a fixed volume by either poisoning the concrete or by providing drawer liners of neutron absorbing materials. The combination of both of these is of marginal additional effectiveness beyond a liner thickness of about 2.0 cm.

Our analyses of the variation of multiplication factor with boron loading in the concrete confirmed that reported by others.[2] The design value is six kilograms of natural boron per cubic meter of concrete. For this loading a 30 cm thick concrete wall provides more than 70% of the benefit of an infinitely thick wall of the same composition. This wall thickness is also consistent with common structural requirements.

Current plans call for drawers without neutron absorbing liners. The basis for the storage limits will be a maximum (calculated) multiplication factor of 0.80 assuming each drawer is loaded to its administrative limit. This value is consistent with limits in use in existing vaults at Los Alamos and provides (calculated) margins for variations in hydrogen content of the concrete, double batching individual drawers and even many drawers, but not the entire vault, and for the lack of experimental data.

Should operations in the future lead to a situation where once again additional storage capacity (mass not volume) is desired then one could retrofit shelf liners in the drawers and gain perhaps another 30% in fissile mass capacity. One would, however, have to maintain oversight for the continuing presence of the liners.

NUCLEAR MATERIALS STORAGE FACILITY (NMSF)

Consistent with Los Alamos's long range plans for collocating major fissile material operations at the site of the plutonium facility, a large, central storage facility has been in design and is now under construction. Operation is scheduled for 1988. It will also provide a Laboratory wide focus for shipping, receiving, and assaying of items packaged for transport.

In contrast to the day vault nature of the automated vault planned for the plutonium facility, this storage facility will be a staging area for incoming shipments destined for other Laboratory sites or for outgoing shipments from the Laboratory and will store material on a long term basis.

It will contain many of the features associated with the planned automated vault for the plutonium facility: it will house automated storage areas with stacker-retrievers operating in two adjacent long, tall corridors. Storage drawers will run from floor to ceiling; each drawer will be 60 cm x 120 cm with a vertical spacing of 30 cm. This is to accommodate different container sizes. Once again, this vault will also provide positive criticality control via a packaging requirement which stipulates that fissile density averaged over the outer container volume routinely be ≤ 1 kg/l. Drawers will have spacers to provide positive separation between stored items. Automated, remote accountability control via a bar code label and reader system is planned.

For operational efficiency and enhanced safeguards, below-grade tunnels connect to the existing plutonium facility and will be extended to future collocated facilities.

In addition to automated storage areas this central facility will contain space for shipping container storage and special items not physically amenable to automated storage. Since hydrogen-bearing items require very different storage limits than non-hydrogenous items and since the fraction of stored items containing hydrogenous materials is expected to be at most a few percent, it is planned to store these items outside the automated vault in available hands-on areas.

This separation of items having very different criticality limits and characteristics should assist in maintaining low operator error frequencies. Thus all metals and non-hydrogenous compounds of any species will be stored in the automated vault under uniform limits. Should radiation exposures to personnel working in hands-on areas become excessive then shielding can be added, as was done in the existing plutonium facility vault. However, in an effort to forestall a potential problem it was decided to borate the concrete in the wall separating the two stacker-retriever rooms and in the walls and ceiling separating the automated vault from personnel areas.

EXISTING PLUTONIUM FACILITY VAULT ENHANCEMENTS

About two years ago a coordinated effort was made to recommend improvements to the existing hands-on vault in the plutonium facility. This was driven by criticality safety, radiation exposure, and accountability concerns all associated with a vault severely overcrowded from the standpoint of volume but not fissile mass. A task force representing the above disciplines as well as operations supervision made the following recommendations:

- *design and build a new, automated, day vault (this is happening),*
- *Upgrade the computer software which logs material into and out of the vault. This has happened and has resulted in both a marked decrease in items being misplaced within the vault and a more efficient storage/retrieval process resulting in reduced radiation exposures. In particular, for a vault with about 2000 transactions in a typical month, operations have been going on over a year now without evidence of a mis-shelved item.*
- *Consider distinctive labeling for easily confused items, notably hydrogenous material and alpha and delta plutonium. This was implemented successfully.*
- *Outfit some of the vault rooms with shielding to house those items of particularly high specific dose and all the hydrogenous items.*

This last recommendation was made both to reduce radiation exposures and to collocate all hydrogenous material thus reducing further the likelihood of this material being mis-shelved with nonhydrogenous. To accomplish this we purchased cabinets with 60 cm x 60 cm roller drawers and then ordered neutron and gamma ray absorbing inserts for these drawers. This castable single piece insert is made with a 2.5 cm thick bottom and sides and a 7.6 cm thick front. It is fire retardant and has high hydrogen and boron contents and provides excellent attenuation for soft gamma rays such as from ^{241}Am. The insert is made from BISCO's NS-4 but similar materials are available from other suppliers.

CONCLUSIONS

There are several, often competing, concerns which must be accommodated in current fissile material vault operations. Recent years have seen the advent of significant complexities imposed by accountability and safeguards/security regulations. For the Los Alamos National Laboratory, increased operations with fissile material have meant elevated radiation exposures and concern for criticality controls. An aggressive vault construction and retrofit program Laboratorywide is beginning to come to fruition, namely,

- *Radiation exposures and criticality safety limit violations are reduced from prior years for plutonium facility vault personnel.*
- *A new, larger, central vault in the CMR facility will enhance efficiency for operations personnel, reduce crowding, and improve safeguards.*
- *A new, central shipping, receiving, staging, assaying, and storage facility (NMSF) is about to become operational. It will consolidate inventories from several smaller vaults throughout the Laboratory and improve criticality safety, radiation exposure control, accountability, and safeguards in its automated storage areas.*
- *A new working (i.e., day) vault is scheduled for construction in 1988 as an integral part of the current plutonium facility. It will provide automated storage and significantly reduce radiation exposures and overcrowding in the hands-on vault.*

For each of these projects consideration has been given to: 1) automated storage; 2) borated concrete in structural walls; 3) neutron absorbing drawer liners; and 4) neutron and gamma ray shielding drawer inserts. These features primarily impact criticality safety, radiation levels, and vault capacity and efficiency. Fissile material storage at Los Alamos will benefit from the tailoring of cost effective combinations of these features to the needs of each facility.

REFERENCES

1. *BISCO PRODUCTS, INC., (1420 Renaissance Drive, Park Ridge, IL 60068)*
2. *BORATED CONCRETE FOR ZIPPER FUEL STORAGE, J. Gasidlow (Argonne National Laboratory, Idaho), Proceedings of a Topical Meeting, Jackson, Wyoming, September 8-11, 1985., American Nuclear Society.*