MARKETS FOR LEAD IN THE NUCLEAR INDUSTRY

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by

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I was pleased when Bob Zigfield asked me to again talk to you about the nuclear market for lead, because much has happened in the nuclear industry during the past four years since I last met with the Lead Industry Association.

I. CENTRAL STATION POWER REACTORS

The most significant developments have occurred in the power reactor market which in the long term will be the most important segment of the nuclear industry. But this unfortunately has also been the biggest nuclear area of unfilled promises. In 1954 when the civilian nuclear industry was created by the passage of the Atomic Energy Act, wide scale use of nuclear power was estimated to be just around the corner. Utilities rushed to build small prototype nuclear power plants. Four experimental power reactors including the Shippingport reactor were announced in 1954, and five more including the Dresden, Yankee and Indian Point power reactors were announced in 1955. Figure 1 shows by year of announcement, the cumulative capacity of power reactors ordered to date. Almost 1,000 megawatts of nuclear power capacity were ordered in 1954 and 1955.

But in 1955-1958, the new power reactor manufacturing industry ran into many development problems. This was hardly surprising for a new technology but it resulted, as you can see from this chart, in a stretch-out in nuclear power growth.

Most utilities in the late 1950's decided they should await the completion and initial operation of plants under construction before they considered ordering nuclear plants so they could analyze construction costs, operating experience and operating costs.

The Yankee plant in Rowe, Mass. and the Dresden plant near Chicago each have now been operating for about five years. Their performance has exceeded even the most optimistic estimates and they are producing far cheaper power than was expected.

Because of this good operating experience and because the reactor manufacturers have improved their design and lowered costs, many utilities are now taking a hard look at nuclear power whenever they plan a new power plant. This type analysis is based strictly on power generating costs. In many parts of the country, nuclear power is competitive with fossil fueled plants.

As a result, two major nuclear plants were announced in 1962, three in 1963, one in 1964 and two in 1965. Several other utilities have indicated they will place orders for nuclear plants during 1965. These potential contracts are indicated in lighter grey on the top of the bar graph for 1965. Clearly 1965 should be a big year for nuclear power.

Looking ahead for the next 15 years, figure 2 is a forecast of annual additions of new steam-generating power plants by utilities (the top line). The lower shaded area shows the portion of this new capacity that will probably be nuclear. For example, the utility industry will add 13,000 megawatts of new capacity in 1968 and 11% or 1,400 megawatts of this will be nuclear. By 1970, the utilities will be adding 15,000 megawatts of new capacity and 19% of this will be nuclear.

Thus nuclear power is a growing force in a growing market area. Looking ahead to 1980, the utilities will be adding steam capacity at twice the annual rate as in 1968 and they will be adding nuclear capacity at more than five times the annual rate in 1980 as in 1968.

These are impressive statistics but what will this rapid switch to nuclear power mean for the lead industry. I shall look first at the lead requirements of the power plant and I'll then consider the shipping cask requirements.

A sobering fact for the lead industry is that most of new capacity announced during the past three years is for boiling and pressurized water reactors and these plants thus far have the least requirements for lead of all nuclear power plants.

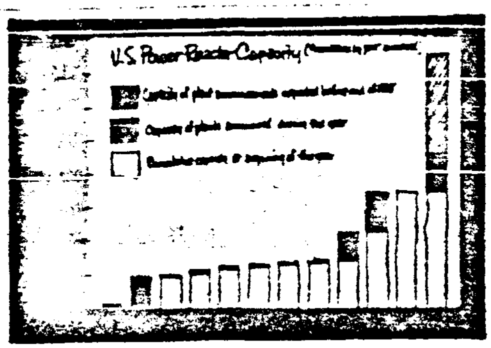

Figure 1

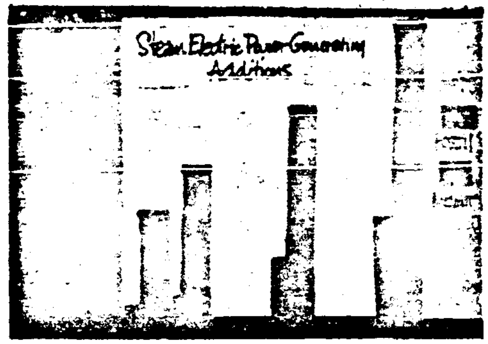

Figure 2

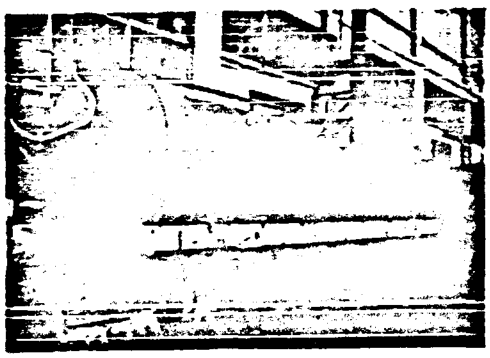

Figure 3

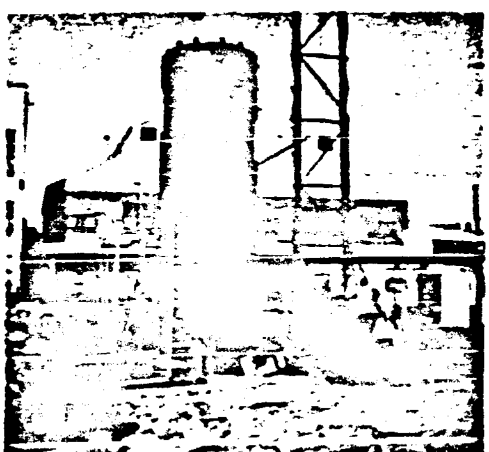

Figure 4

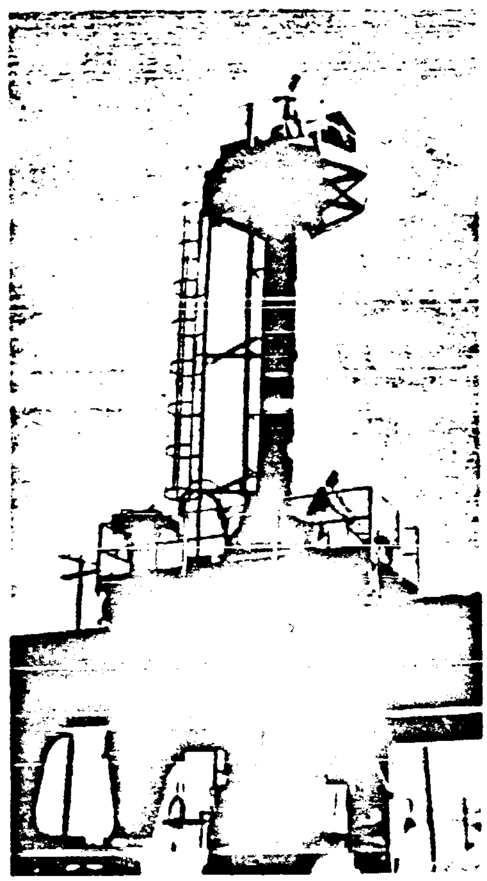

Figure 5

Most of the bulk shielding in these plants will be concrete. Penetrations through the walls are often lead lined, doorways are calked with lead and some lead plate may be used to beef up shielding around the doors. And these doors may be lead lined, steel or concrete. But designers of these plants have found ways of avoiding major applications of lead.

There also continues to be interest in this country in nuclear power plants other than water-cooled reactors. And these types of plants create a much more favorable climate for the lead producer.

Figure 3, for instance, is the fuel service machine for the Boiling Nuclear Superheat Reactor, the BONUS reactor, in Puerto Rico. National Lead built this and they also built the service machine for the Experimental Gas-Cooled Reactor (figure 4). Public Service Company of Colorado plans to build a large gas-cooled reactor. Several experimental power reactors are cooled by liquid sodium--the advantage of this coolant is its higher operating temperature and thus the reactor has greater efficiency. There is still considerable interest in this type reactor. The Hallam reactor is sodium cooled and requires a refueling machine that contains 135 tons of lead (figure 5).

II. SHIPPING CASKS

One of the largest lead requirements of the nuclear power industry is for shipping casks. The granddaddy of shipping casks is the M-130; the one shown in figure 6 was built by P. F. Avery Company. The M-130 is actually used for transporting by railroad nuclear navy fuel, but this type cask may be used for power reactor fuel.

Much spent power reactor fuel will also be trucked. A cask used by National Lead under an arrangement it has with Tri-State Trucking Company for transporting spent fuel is shown in figure 7.

Figure 8 shows one of three truck-mounted casks built for Knapp Mills for Commonwealth Edison Company. Each cask contains about 18 tons of lead.

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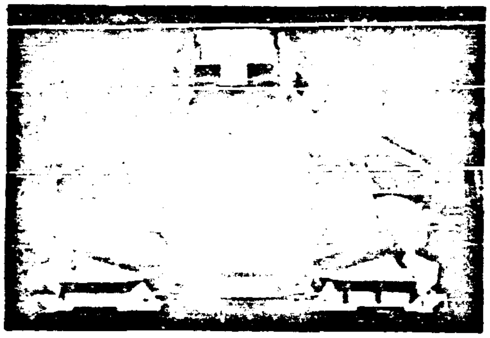

Figure 6

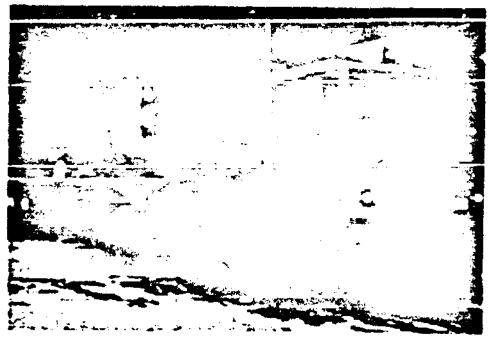

Figure 7

Figure 9

Figure 8

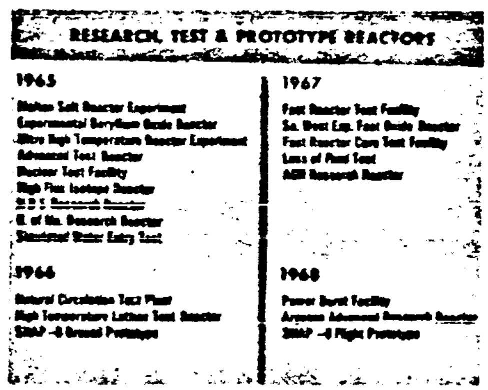

Figure 10

As shown in figure 9, the internal structure of these casks can be extremely complex. Usually each power reactor requires its own shipping casks because the fuel elements have unique shapes and dimensions. Power reactor manufacturers are trying to standardize more in their fuel element design to reduce the requirement for so many different casks.

III. NUCLEAR DESALTING PLANTS

A development related to nuclear power is nuclear desalinization for which large reactors would be used for combination power generation and water desalting. This field is moving very rapidly, partly because of its great technical and economic promise, and more importantly for the near term, because it has the support of President Johnson, who predicted a few months ago:

> "The time is coming when a single desalting plant, powered by nuclear energy, will produce hundreds of millions of gallons of fresh water and large amounts of electricity every day."

The desalting program also includes work on energy sources other than nuclear although nuclear energy seems very well suited.

IV. RESEARCH AND TEST REACTORS

I would like to now quickly review the market for research and test reactors. These smaller reactors have created excellent markets for lead--not only in the construction of some of these reactors but also in the experimental areas around the reactors.

Figure 10 lists research and test reactors now under construction by the years they'll be completed. This market continues to be quite active.

I'll quickly show some typical uses of lead by some of these facilities.

Figure 11 shows the 50 ton refueling machine built by National Lead for the Plutonium Recycle Test Reactor.

Figure 12 shows the 50 ton gamma and thermal shield for the Georgia Tech Research Reactor and figure 13 shows the thermal and gamma shield of the National Bureau of Standards Reactor. Both of these were fabricated by O. G. Kelley.

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

The research facilities accompanying research and test reactors continually are changing as various experiments are performed. These experiments involve radiation and radioactive materials and lead is a flexible, space-saving shielding material.

Figure 14 shows a general view around the Brookhaven research reactor where many uses for lead are apparent.

A lead pig used on another face of the same Brookhaven reactor is shown in figure 15. The Low Intensity Reactor at Oak Ridge has all the pigs shown in figure 16 that can be used for experiments.

Considerable shipping containers have been supplied for transporting research and test reactor fuels. This 20 ton cask, which has a self-contained cooling system to remove the heat generated by the spent fuel, was built by O. G. Kelley for a test reactor Westinghouse is operating (figure 17).

Although research reactors use smaller fuel elements, they still become quite radioactive. Knapp Mills built these casks for research reactor fuel (figure 18).

V. MARITIME REACTORS

The maritime or merchant ship market for nuclear power plants is something of an enigma. There is considerable interest in nuclear merchant ships because nuclear power is looking increasingly favorable. Also, within the past year, four companies have announced major advances in merchant ship reactors. These companies are Babcock and Wilcox, Allis-Chalmers, Combustion Engineering and United Nuclear.

The first nuclear merchant ship, the Savannah, has functioned very well technically and the economics look very good for merchant ship reactors that could be constructed today. Ship operators are interested in nuclear-powered merchant ships.

The major stumbling block is that the government, which subsidizes our

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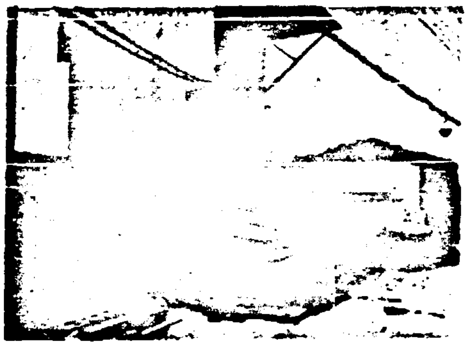

Figure 16

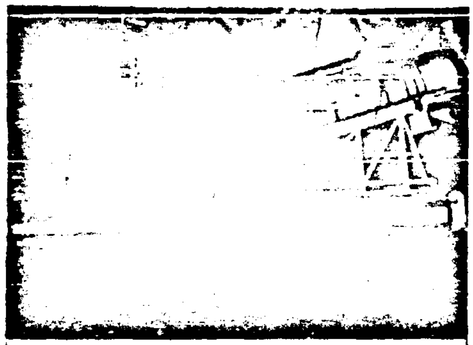

Figure 17

Figure 18

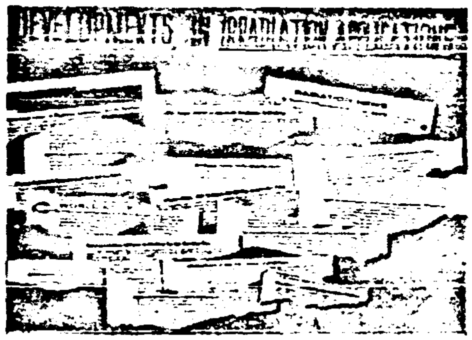

Figure 19

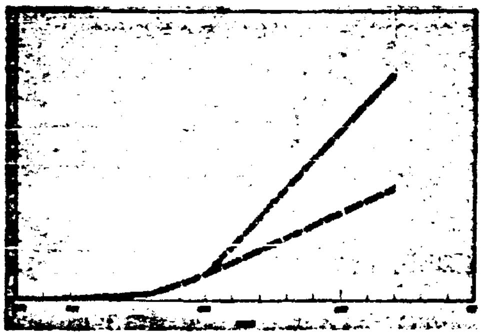

Figure 20

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merchant ship fleet, just isn't sure what direction to take and thus is doing virtually nothing. The general consensus is that the U. S. merchant fleet is in a bad way competitively with other nations and rapidly getting worse. Nuclear power could provide a real opportunity for the United States to re-establish its dominant position but Congressional support is required.

Almost inevitably, nuclear merchant ships will be ordered, and this could happen very suddenly. Several cargo ship lines are talking about multiple orders for nuclear merchant ships--one mentioned four ships.

When nuclear-powered merchant ships are built, they will have shielding requirements similar to the Savannah which required more than 500 tons of lead for bulkhead shielding. Savannah required additional tons of lead shielding for penetrations through the containment sphere and to beef-up shielding in certain areas.

I'd now like to talk just for a moment about the nuclear Navy which clearly has been the single best nuclear customer for the lead industry. The aircraft carrier Enterprise, which has eight reactors aboard, contains an incredible amount of lead shielding. Also 44 nuclear powered attack submarines, 42 nuclear powered Polaris-missile carrying submarines and 4 nuclear powered surface ships are either funded, under construction or at sea.

The nuclear Navy has been a very good customer for many of your companies and although the rate of nuclear ship construction has slackened, there is pressure on the Defense Department to begin establishing nuclear-powered task forces. There will probably be funds in the budget for fiscal year 1967 for a new nuclear-powered carrier. I also anticipate a dramatic increase in demand for other nuclear-powered surface ships within the next several years.

VI. RADIOISOTOPE APPLICATIONS

I'd now like to discuss an increasingly important nuclear market area that utilizes reactor by-products -- namely, radioisotopes.

Some people still view the whole field of gamma irradiation and isotope utilization with skepticism because, as with nuclear power, this nuclear by-product was the subject of much speculation and blue-sky thinking in the late 1950's. The irradiation field was beset by many unfulfilled hopes and promises.

Within the past year or so, however, there has been a sharp increase in research programs and actual products that require irradiation and irradiators. These headlines typify recently announced program that will utilize radio-isotopes (figure 19).

This increased demand for isotopes, and particularly for cobalt 60, really began in 1962. Figure 20 plots actual sales in North America of cobalt 60 through 1964. I have also plotted the conservative and the liberal forecasts of cobalt 60 sales through 1972. Either way, the forecast is quite intriguing if you consider that not until 1962 did the annual sales of Co 60 by North American suppliers exceed 1 million curies. Yet even when less than a million curies of Co 60 were used annually, irradiators were built and they required considerable quantities of lead.

The conservatives peg 1972 sales of Co 60 at about 20 million curies while the more optimistic expect sales in 1972 to reach an annual rate of 40 million curies. The major suppliers of Co 60 will be Atomic Energy of Canada Ltd., Oak Ridge National Laboratory, the AEC's Savannah River plant and General Electric. Power reactors may also eventually use excess neutrons to product Co 60.

Lead will be used in many different forms in these new irradiators. For batch-type research, there will be an increased demand for flexible irradiators such as one supplied by National Lead for marine products irradiation (figure 21).

Atomic Energy of Canada, Ltd. built the first truck-bed mounted irradiator (figure 22). This model has 10 tons of lead. AECL is currently using

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Figure 21

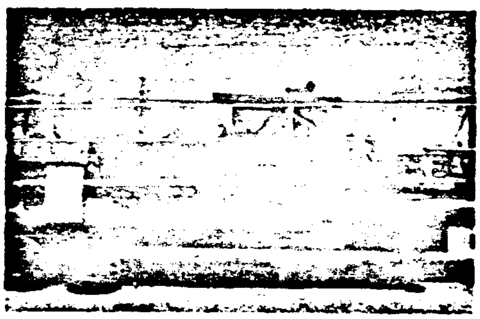

Figure 22

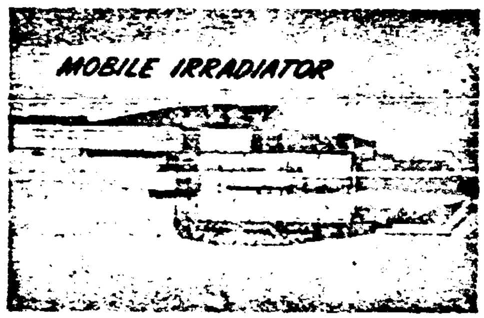

Figure 23

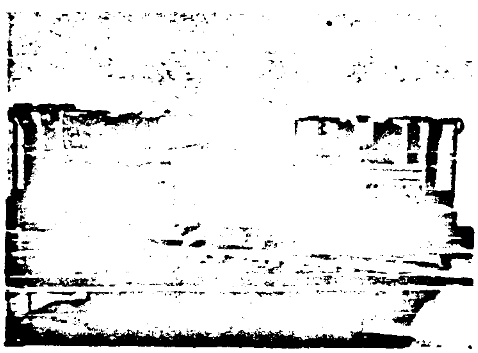

Figure 24

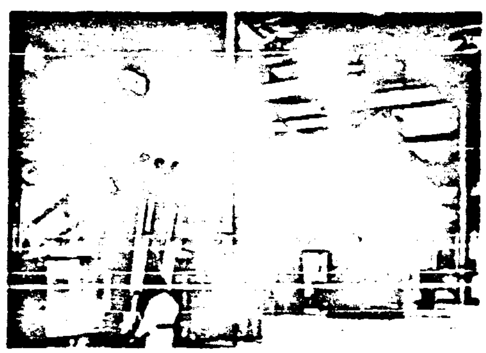

Figure 25

about 300 tons of lead per year for its commercial isotope requirements. Several mobile irradiators are currently being planned in this country. Vitro Engineering designed an irradiator for the AEC (figure 23) and I believe the construction contract will be awarded shortly. It will require about 30 tons of lead.

The biggest requirement for Co 60 will be for stationary irradiators that will use tens and even hundreds of thousands of curies of Co 60. Figure 24 shows a model of the High Intensity Radiation Development Laboratory at Brookhaven. This facility, as you see, is extremely complex. The primary shielding is concrete and many penetrations in the concrete were required. Many of these were beefed-up with lead to prevent streaming of gamma rays. The laboratory has two 24-ton lead filled doors (figure 25). The Co 60 sources are stored in the cell floors and the storage bins utilize about 10 tons of lead. Separate shipping containers are used for transporting these sources. Brookhaven will purchase about 50 tons of lead-filled casks this year.

A typical stationary irradiator will require a storage pig for the Co 60 source that will also double as the shipping cask. Irradiator access doors may be lead filled, steel or concrete. Cell walls will probably be made of concrete.

In conclusion, there are several key factors about the irradiation market:

First, it is growing -- it will require five times as much Co 60 in 1965 as in 1962 and it will use between four and eight times as much Co 60 in 1972 as in 1965.

Second, the primary irradiation source will be Co 60, a gamma source for which lead is an excellent shield.

Thirdly, the demand for lead may not grow proportionately with the demand for Co 60 because larger sources require proportionately less shielding and because lead is not the only shielding material used.

VII. HOT CELLS

Hot cells continue to be required by the nuclear industry. A hot cell may be a massive concrete cell such as this one with lead-glass windows (figure 26); it may consist of walls of lead bricks erected as a temporary barrier in a research or power reactor building (figure 27) or it may be a small, portable lead cell such as this one built by Knapp Mills (figure 28). I see no reason for the hot cell market to show substantial growth but it should continue with its modest requirement for lead.

Thus far, we have looked at the various nuclear markets for lead. In virtually every nuclear application for lead, it is used because of its high density which makes it a good shield for gamma rays. But concrete and steel and other dense materials can do the same thing, although a large volume of material is required.

Furthermore, in many nuclear shielding applications, neutrons may also be present and lead is a poor shield for neutrons--especially energetic or fast neutrons for which water, polyethylene, and densified wood are better shields. All types of reactors require gamma and neutron shielding.

In addition to being a poor neutron shield, lead has a very low melting point and poor structural stability. And it has increased considerably in price over the past several years. At this point you may wonder about the purpose of this talk. I assure you, it is not to tell you on the one hand that the nuclear field is growing and then to say "but lead really isn't a suitable nuclear material". It is obvious from the examples of applications I have gathered from members of your industry, that lead is a good and widely used shielding material.

But many types of shielding materials of varying densities are available. Most are cheaper than lead, so two important questions, therefore, are: For what purposes is lead selected as a shielding material? Why?

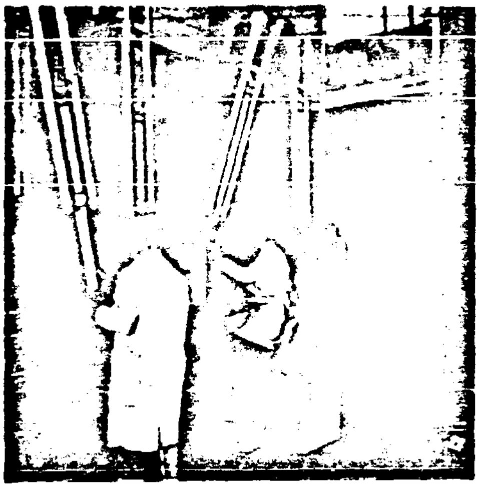

Figure 26

Figure 27

Figure 28

PROPERTY	SHIELD MATERIAL					
Comparison of Shield Characteristics	Lead	Cast Carbon Steel	Stainless Steel	Concrete	Tungsten	Depleted Uranium
Density	2.6	1.6	1.5	0.5	4.0	4.3
Corrosion Resistance	3.0	3.3	3.0	3.3	3.0	3.0
Strength (Tensile)	4.0	6.0	4.0	4.0	4.0	4.0
Thermal Conductivity	2.4	1.3	0.6	0.07	3.5	2.1
Specific Heat	1.6	2.1	2.0	3.0	1.0	2.0
Comparison of Practical Factors						
Availability	15.0	15.0	12.0	15.0	4.5	0.0
Design Versatility	15.0	10.0	5.0	1.5	1.5	3.6
Ease of Fabrication	15.0	10.0	10.0	9.0	7.5	7.5
Ease of Testing	15.0	12.5	12.5	7.5	10.0	10.0
Lowest Cost of Finished Component	25.0	7.0	4.0	6.9	0.2	0.15
Final Shield Score	90.0	70.3	42.6	[illegible]	41.0	41.2

Shield Material Evaluation for Spent Fuel Shipping Cask [illegible]

Figure 29

To answer these questions, I have established three categories of shielding related to lead which are:

1. Applications where lead is clearly the favored shielding material
2. Applications where lead faces serious competition from other materials
3. Applications where lead is virtually out of contention as a shielding material

Lead is clearly the favored shielding material firstly, where space is at a premium, such as on a ship; secondly, where mobility is important, such as shipping casks; thirdly, where weight is a significant factor and shipping casks are again a good example; and fourthly, where flexibility is required such as lead brick walls. In these cases, one or more of the attributes of lead overcome its disadvantages. Knapp Mills prepared a chart (figure 29) to help the designer of shipping casks select a shielding material and lead is the favored material within the parameters listed here.

In the second group of applications, lead is continually compared with competitive materials--sometimes it's selected and sometimes the choice is steel, dense concrete, regular concrete or possibly depleted uranium. Where several materials are being considered, a number of variables will be evaluated and weighed.

Even in selecting a straight-forward item like an irradiator door, many factors are involved including the biggest variable of all--people.

Otto Kuhl at Brookhaven designed the High Intensity Radiation Development Laboratory (figure 25) facility and he selected lead-filled doors because of space limitations and heavy concrete doors would have been 4 feet thick, steel doors would have been 30 inches but the lead doors are only 15 inches thick. Nevertheless, under similar circumstances, a second person could probably have justified concrete and a third would have gone to steel.

What is important in these cases, therefore, is to be sure that lead is given every possible consideration when it is contrasted with other shielding materials.

The third category of shielding is that where lead currently has virtually no acceptance. This includes bulk shielding for stationary power reactors, walls of large stationary cells built to contain radiation sources such as stationary irradiator walls and large hot cell walls.

In this category we are considering thousands of tons of shield material per year. I mentioned that boiling water and pressurized water power reactors are designed to use virtually no lead. They even use concrete and water to shield the refueling channels rather than lead-shielded refueling machines.

The Connecticut Yankee plant will use about 30,000 tons of concrete that will function both as primary and secondary shielding and for structural purposes.

The reason I am discussing lead and its competitive shielding materials is that I feel on the one hand, in this country because of ingenious design and sound fabricating techniques, lead has found good utilization in the nuclear field. In Europe, for instance, shipping casks are all steel or even concrete because suitable lead shielded casks that the nuclear industry could have confidence in could not be produced.

But, on the other hand, while talking with people who design and specify nuclear shielding, I found they try to avoid using lead whever possible.

I found some small evidence of research resulting in increased uses of lead in combination with other shield materials.

Chemtree Corporation is marketing a concrete and lead product that is finding some acceptance as a gamma and neutron shield. A research group is trying to develop a combination lead, polyethylene and boron shield as a gamma and neutron shield. Some companies have had considerable success in bonding lead and other shielding materials. Conceivably, the lead industry can do more to stimulate research into combination materials that will have the combined attributes of lead and other shielding materials.

I would, therefore, like to conclude with a statement and a question.

Statement: The nuclear industry is now using hundreds of thousands of tons of shielding material annually. Quite a small percentage of this material is lead. Question: Can the lead industry through research, through education, through product information dissemination or through other techniques do anything more than it is now doing to capture a larger share of the nuclear shielding market?