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May 27, 1998

Mr. Randolph A. Blough Director Division of Nuclear Materials Safety Region I Nuclear Regulatory Commission 475 Allendale Road King of Prussia, Pennsylvania 19406-1415

Re: Disposal Variance Under 10 C.F.R. § 20.2002

Dear Mr. Blough:

On behalf of The International Metals Reclamation Company Inc. ("INMETCO"), we are writing this letter to obtain Nuclear Regulatory Commission ("NRC") approval, pursuant to 10 C.F.R. § 20.2002, to dispose of, in the manner described below, approximately 220 tons of electric arc furnace ("EAF") dust that was inadvertently contaminated with small concentrations of cesium-137 ("Cs-137"). Below is a description of the material at issue, the manner in which it was contaminated, and INMETCO's proposed disposal option. INMETCO also requests an opportunity to meet with you to discuss this variance request in greater detail.

BACKGROUND

INMETCO operates a high temperature metals recovery ("HTMR") facility in Ellwood City, Pennsylvania. HTMR is a process used to recover nickel, chromium, and iron values from metalbearing waste streams. INMETCO's primary feedstocks are EAF dust, mill scale, and swarf generated by the EAF specialty steel industry. EAF steel mills manufacture steel products through the process of melting and refining scrap metal in EAFs. During the EAF melting process, impurities contained in the scrap metal are driven from the molten steel in the form of a flue dust that is captured and controlled by emission control baghouses. Because it contains cadmium, chromium, and lead, EAF dust is regulated by the U.S. Environmental Protection Agency ("EPA") as a hazardous waste (EAF dust carries the hazardous listing code "K061"). Under the Resource Conservation and Recovery Act ("RCRA") and EPA's implementing regulations, before EAF dust can be land disposed, it must first be treated to levels achievable by "best demonstrated available

Mr. Randolph A. Blough May 27, 1998 Page 2

technology" ("BDAT"). HTMR is BDAT for K061. Consequently, a large percentage of North American stainless steel producers send their EAF dust to INMETCO for processing.

At issue in this variance is a 22.7 ton shipment of dust that INMETCO received from one of its Canadian specialty steel customers (the "Canadian dust"). The dust, which was exported from Canada pursuant to the procedural requirements of the U.S. Canadian Transboundary Agreement on Hazardous Wastes ("Agreement") and in full compliance with the U.S. Department of Transportation's and Transport Canada's shipping requirements, contained Cs-137 at levels higher than "background."^{1/} Upon receipt of the dust, INMETCO initiated its metals recovery process.

The HTMR process itself generates an emission control dust. This dust is derived from and therefore regulated in the same manner as K061 and must be treated to meet applicable treatment standards before it can be disposed. Thus, INMETCO sends its emission control dust to Horsehead Resources Development Company ("HRD") for further "treatment." Following its normal business practice, INMETCO shipped the emission control dust that was generated during the processing of the Canadian dust to HRD for processing. However, HRD rejected the load because it tripped the alarm on its radiation detection device, which is set slightly above background levels. HRD returned the rejected load to INMETCO. Immediately upon learning of the rejected load, INMETCO ceased processing the Canadian dust. However, by that time, INMETCO had already processed approximately 80 percent of the Canadian dust, thereby generating an estimated 220 tons of Cs-137 contaminated emission control dust and 50 tons of filter cake.

INMETCO subsequently notified NRC and the State of Pennsylvania, contained the dust and filter cake, and decontaminated its facility. INMETCO also contacted the Canadian steel company to ascertain the origin of the Cs-137. According to the Canadian company, the EAF dust was contaminated by an inadvertent melting of a Cs-137 source that had been buried within a charge of scrap metal that was melted in an EAF. The Canadian company did not manifest the dust as a "radioactive" waste because Environment Quebec, after investigating the accidental melting, concluded that the low levels of Cs-137 did not warrant characterizing the material as "radioactive." Had the dust been manifested as a radioactive waste, INMETCO could not have accepted the dust for processing.

INMETCO has made several attempts to return the contaminated dust to Canada, its country of origin, pursuant to the U.S. Canadian Transboundary Agreement on Hazardous Wastes. Article 6 of that Agreement provides that "the country of export shall readmit any shipment of hazardous

^{1/} NRC considers any material with Cs-137 greater than two picocuries per gram ("pCi/g") to be above background.

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waste that may be returned by the country of import or transit." INMETCO worked closely with the Canadian company that generated the material, Canadian disposal facilities that were willing to dispose of the material (including the Canadian disposal facility that disposed of the contaminated EAF dust that was not exported to INMETCO), NRC, and EPA in this effort. However, Environment Quebec ultimately refused to allow the importation of the material due to its "radioactive" characterization under U.S. law. The Canadian steel facility has provided no further assistance in this matter.

All of the material is now being stored in containers within a restricted-access warehouse. Because of its "mixed-waste" status, INMETCO has not been able to identify an economical means of disposing of the material. A mixed waste is one that is regulated by EPA under RCRA as a hazardous waste and by NRC under the Atomic Energy Act as a radioactive waste. Currently, there are no cost-effective options for treating and disposing of low-level mixed wastes in the United States. Indeed, we are aware of only one facility in the United States, Envirocare of Utah, that is licensed to treat, store, and dispose of mixed wastes. In addition to being cost prohibitive,^{2/} Envirocare's reputation and license status have recently been called into question. See Attachment A.

As you probably know, the issue of inadvertent smeltings of Cs-137 sources is a major concern of the U.S. EAF steel industry, and one that the industry has been working with the NRC to resolve for several years. In an effort to provide some relief to the numerous facilities that have become victims of the illegal disposal of NRC-licensed sources, NRC, in coordination with EPA, issued a staff Technical Position (see 62 Fed. Reg. 13,176 (March 19, 1997)) that may be used, in case-by-case requests, by appropriate licensees to dispose of Cs-137 contaminated EAF dust at RCRA-permitted disposal facilities.^{3/} However, the NRC Technical Position has been of little utility because of the exorbitant cost of treating the contaminated dust to meet the applicable RCRA treatment standards as required by the Technical Position. INMETCO has received several bids from outside sources to treat and dispose of the dust pursuant to the Technical Position. The cost figures run as high as approximately \$2 million. INMETCO does not believe that the cost of treating and disposing of the material as a radioactive waste is commensurate with the risks posed by the extremely low Cs-137 concentrations found in the dust. If a cost-effective option does not become available, INMETCO may have no choice but to continue storing the material indefinitely.

^{2/} The estimated cost of disposing of the material at Envirocare is \$1.9 million.

 $[\]underline{3}$ / When it issued the Technical Position, NRC made is clear that the existence of the Technical Position would not foreclose individual facilities from obtaining other site-specific variances.

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CHARACTERISTIC OF THE CONTAMINATED DUST

An estimated 220 tons of Cs-137 contaminated dust is being stored in approximately 260 triwall cardboard boxes, one cubic yard in size, with an eight mil thick polyline (LLDPE) bag liner. Each box is on a 1m x 1m pallet, which are arranged in numerous groups to accommodate storage space within a restricted-access warehouse. Radiation survey readings of the boxes indicate that the average Cs-137 concentration of the boxed dust is between 15 to 30 pCi/g. Using a conservative concentration of 50 pCi/g, the calculated dose rate at a distance of 1 m and an area factor of 0.20 is $3.64 \ \mu \text{rem/hr}$, 500 times lower than the 2,000 $\ \mu \text{rem/hr}$ limit for unrestricted public areas set forth at 10 C.F.R. § 20.1302.

POTENTIAL DISPOSAL OPTIONS

Attached for your review is a report, "Risk Assessment of Alternatives for Disposition of Baghouse Dust Contaminated with Cesium-137," prepared by Stanley E. Logan, Ph.D., of S.E. Logan and Associates, Inc. ("Logan Report") on behalf of INMETCO (Attachment B).^{4/} The Logan Report analyzes the risks associated with four potential disposal alternatives: (1) continued storage; (2) direct processing at HRD, a HTMR recycler that typically processes the dust generated by INMETCO; (3) blending of contaminated dust with non-contaminated material at INMETCO prior to processing by HRD; and (4) shipment of treated dust to a RCRA disposal facility pursuant to the NRC Technical Position. The Logan Report concludes that the "low concentrations of Cs-137 in the contaminated EAF dust currently being stored at INMETCO does [sic] not cause any significant risk for any of the alternatives considered." Logan Report at 39. None of the disposal options would result in an exceedance of applicable dose rates.

Not discussed in detail or at all in the Logan Report, however, are the regulatory or economic barriers associated with each of the above four alternatives. With respect to the first alternative, continued storage at INMETCO only delays the inevitable. INMETCO will eventually have to find an environmentally-sound and economical disposal option. Unfortunately, this is not possible under NRC's and EPA's current regulatory system. In order to process the contaminated material at HRD, INMETCO would need to obtain not only NRC permission, but also HRD's. Thus, even if NRC were to grant a variance, which it should based on the fact that processing the dust at HRD would not pose any significant risk, there is no guarantee that HRD would subsequently agree to accept any material above two pCi/g. The third option (aggregating the dust prior to shipment to HRD, but still at a level above background) would present the same problems as the second option, plus the added

 $[\]frac{4}{}$ NRC relied on an earlier Dr. Logan report prepared for a steel company that experienced an inadvertent melting of a Cs-137 source when preparing its Technical Position.

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risk of increasing the volume of contaminated dust that must be disposed of. The alternative of disposing of the dust at a RCRA disposal facility pursuant to the NRC Technical Position is cost prohibitive.^{5/}

Consequently, INMETCO is seeking NRC approval to pursue a fifth option discussed below.

BLENDING OF CONTAMINATED DUST WITH NON-CONTAMINATED DUST TO REDUCE Cs-137 CONCENTRATIONS TO BACKGROUND LEVELS OR BELOW <u>PRIOR TO SHIPMENT TO HRD FOR PROCESSING</u>

According to a letter to William Guerry, Jr. from NRC Executive Director for Operations, James M. Taylor, dated May 25, 1993, EAF dust is considered radioactive only if Cs-137 concentrations in the dust exceed two pCi/g. This is the same level that HRD uses as a benchmark for accepting dust for processing at its HTMR facility. Consequently, if INMETCO were to reduce the Cs-137 concentration in its contaminated dust to two pCi/g or below, the material would no longer be considered a mixed waste and could be sent to HRD without limitation.

One of the disposal alternatives discussed in the Logan Report is the blending of contaminated dust with non-contaminated dust generated daily at INMETCO to reduce the overall Cs-137 concentration of the dust prior to shipment to HRD for processing. INMETCO has the ability to feed contaminated material directly into its dust handling line after the baghouse, as newly generated dust from its normal operations is being transported to its storage silo. INMETCO's normal HTMR operations generate 1,660-2,100 pounds of dust per hour. The process of feeding contaminated dust into its dust handling line would promote mixing and dilution of the overall Cs-137 concentration.

The Logan Report analyzes six blending ratios (newly generated dust to contaminated dust), ranging from 2:1 to 10:1, and calculates the estimated operating time and corresponding dose limits, both on a full time and 40-hour a week basis. According to the Logan Report, blending at ratios of 2:1 to 10:1 would not pose a risk to workers involved in the blending operations. The maximum individual dose worker exposure for a worker exposed for the full duration of the operation and for 40-hour work weeks are 1.9 mrem and 2.2 mrem, respectively. Again, these are minimal dose levels.

These blending ratios were selected based on the following two premises: (1) allowing EAF dust with Cs-137 contamination levels of 50 pCi/g to be processed at HRD would pose virtually no

^{5/} Again, the bids that INMETCO has received to date are as high as \$2 million.

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risk; and (2) nevertheless, reducing the Cs-137 concentration (preferably to 20 pCi/g) prior to sending the material to HRD would lower any potential risk even further. A blending ratio of approximately 50:1, which is an approximation of what would be required to reduce the Cs-137 concentration to two pCi/g or below, was not discussed in detail primarily because Dr. Logan assumed that the estimated operating time associated with this ratio would be unacceptable to INMETCO, not because it would pose an unacceptable risk. Indeed, individual maximum and realistic worker exposure levels would still be below applicable exposure thresholds.

As discussed above, although INMETCO would prefer a disposal option that entails sending unblended dust or dust blended to a 20 pCi/g level to HRD for HTMR recycling, it believes that too many variables (i.e., approvals by NRC, EPA, and HRD) are involved. Thus, INMETCO has decided that the "best" option, albeit a longer and more expensive one, would be slowly to blend the contaminated dust with newly generated dust to reduce Cs-137 levels to two pCi/g or below.

If a disposal variance were granted, the entire blending process, as well as the continued storage of material awaiting blending, would be managed pursuant to a radiation protection program under the supervision of a NRC-licensed contractor that would ensure that no workers or the general public were exposed to unacceptable dose levels. Newly generated dust would be pneumatically blended with the contaminated dust at a 50:1 ratio in order to reduce Cs-137 concentrations to or below background levels (<u>i.e.</u>, two pCi/g).^{6/} This equates to the blending of one-half box of contaminated dust (260 boxes in total) to each of the 600 shipping loads (<u>i.e.</u>, shipments of emission control dust to HRD) that would be required to complete the project. The blended dust would then be sent to HRD for processing to meet EPA's treatment requirements.^{1/2} Because blended dust would be below regulatory levels, no risk assessment for processing the dust at HRD would be required. Indeed, the blended dust would pose no more of a risk than any other load of EAF dust processed by HRD. The entire process is estimated to take approximately 18 months to complete.

 $[\]underline{6}$ A 50:1 blending ratio contemplates the fact that "non-contaminated" emission control dust can itself be expected to contain elemental Cs-137 at a level of about 1.5 pCi/g.

 $[\]frac{7}{1}$ Although EPA has a general "anti-dilution" policy, it would not be triggered by this option because the blending would not render the dust nonhazardous under RCRA, thereby allowing INMETCO to avoid its treatment obligations. The RCRA constituents will still be treated by HTMR.

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CONCLUSION

We recognize that this is a unique request. However, unique situations require unique and innovative solutions. INMETCO is approaching NRC as a last resort; it has exhausted its other options. INMETCO's request for one-time approval to blend contaminated EAF dust – dust that INMETCO itself did not generate, and which was generated in the first instance only as the result of an inadvertent melting of a Cs-137 source that was disposed of improperly – to below regulatory levels is an environmentally-sound, safe, and practical solution to a difficult problem. If there were another reasonable, cost-effective option, INMETCO would pursue it. Given the limited quantity of material, the extremely low Cs-137 concentrations of the material, and the exorbitant costs associated with disposing of the material at Envirocare or pursuant to the Technical Position, we believe that NRC has ample justifications to approve this request.

At your earliest convenience, we would like to meet with you to discuss this request and our proposed solution in more detail. We appreciate your assistance and look forward to hearing from you soon.

Sincerely,

John L. Wittenborn Chet M. Thompson Counsel to INMETCO

Attachments

cc: Mr. Ken Money, INCO United States Mr. John Onuska, INMETCO Monday, April 6, 1998

A Dump's Murky Deals Nuclear Waste Facility Paid Regulator

By JOBY WARRICK Washington Post Staff Writer

CLIVE, Utah—Deep in the Great Salt Lake Desert, 40 miles from the nearest town, freight cars are lined up before dawn, laden with hazardous cargo. Tractor-trailers and dump trucks arrive as the sun climbs, adding to the procession of radioactive waste haulers that snakes for a mile across the sand.

Delays can stretch for hours or even days here, for this is the home of Envirocare, the only private dump in America that handles the U.S. government's nuclear waste. Since 1993, more than 14 million cubic feet of lightly radioactive dirt and junk from the Department of Energy (DOE) has been entombed at this isolated dump—mostly because there was nowhere else for it to go.

Envirocare has won contracts worth as much as \$250 million from the DOE alone and is projected to receive another \$350 million from the department over the next five years. In exchange, the dump has given the federal government something it needs very badly: a reliable way to get rid of mountains of low-level radioactive debris without breaking budgets or triggering lawsuits from states and communities near contaminated sites around the country.

But this mutually beneficial relationship has become clouded by

See WASTE, A12, Col. 1

Nuclear Waste Dump Paid Utah Regulator

WASTE from A1

a scandal that threatens the dump's future, and with it the government's plans for cleaning up contaminated Cold War bomb factories, uranium processors and other facilities.

In a series of revelations over the past year. Envirocare founder and owner Khostow Semnani acknowledged paying \$600,000 to then-Utah Radiation Control Division Director Larry Anderson, the state regulator responsible for the dump's license and safety.

The nature of the payments remains in dispute, and there is no evidence so far of serious safety problems at the dump. But the scandal has raised questions about the validity of Envirocare's license and the adequacy of the state's response to the dump's history of safety violations—which include chunks of radioactive material literally falling from boxears and top managers scoring a perfect zero on radiation competency tests.

Perhaps more important, the controversy has focused attention on the government's near-dependency on a single private dump, and how it has responded to Envirocare's problems.

Paced with a massive backlog of waste and lew available alternatives, three federal agencies apparently chose largely to ignore the budding Envirocure scandal and keep the waste stream flowing. A fourth, the DOE, which supplies most of the waste, cut a deal with Envirocare that forced Semnani to step down temporarily as president but guaranteed that the company could continue to receive waste and bid on new contracts.

Top DOE managers strongly detend their response to the scandal. Freezing the shipments based on energe allegations, they say, would surely have exposed the government to litigation and long delays in the cleanup of scores of hazardons waste sites around the country.

"We made a hard business decision on behalf of the taxpayers," said one senior official, who insisted on anonymity because of pending lawsuits. "And we were the only ones who did squat."

But a federal judge, ruling in a related Texas case, said DOE policies that allowed Envirocare to retain its virtual monopoly suggest that "something is amiss" at the department. "It may be a case of incompetence, or it may be something far worse," said U.S. District Judge Jee Kendall.

Meanwhile, the loss of Envirocare's services—the thing government officials sought most to avoid—may already be occurring. An injunction issued by Kendall has temporarily frozen the awarding of new DOE contracts to Envirocare, stalling the cleanup of 1 million tons of contaminated waste at a federal plutonium production facility in Fernald, Ohio. An Envirocare rival subsequently asked Kendall to expand his injunction to halt all government waste shipments to the Utah dump.

A federal grand jury in Salt Lake City investigating the payments to Anderson could issue indictments within days or works, indiced offi-



A container of radioactive waste is moved from a rail car to a truck at the Envirocare dump in Clive, Utah.

Neither Semnani nor Anderson would agree to be interviewed, but their accounts of the relationship emerged from a highly unusual lawsuit filed by Anderson in late 1996. In the suit, Anderson acknowledged receiving money from Semnani but denied there was anything improper about the payments. In fact, Anderson claimed in the suit that the dump owner broke their agreement and shortchanged him by about \$5 million.

Semnani, in a response to the Anderson suit, acknowledged making the payments of \$600,000 in cash, gold coins and a condominium in Utah's Park City ski resort. But he characterized the payments as extortion, saying he feared Anderson would cause problems for his company or even shut him down. He did not report the alleged crime to authorities because he feared he would not be believed, a spokesman



Envirocare of Utah is the nation's only privately owned dump for radioactive wastes. Since 1994, it has been the exclusive commercial disposal service for nearly all the U.S. government's low-level radioactive wastes.

LOCATION

On a salty desert plain 80 miles west of Salt Lake City. Very dry and geologically stable, it is more than 40 miles from the nearest town and has naturally poor groundwater.

WASTE

Mostly contaminated soil and construction materials from Cold War-era bomb factories and uranium processing facilities as well as tailings from uranium mines. It is the only dump licensed to handle the federal government's "mixed wastes," which contain both radioactive and chemical hazards. Etwirocare also receives commercial radioactive refuse from universities and industries.



The U.S. government buries millions of tons of low-level radioactive waste at the sprawling Envirocare dump in Clive, Utah.

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SAFETY

Most of the waste is deposited in clay-lined pits and covered with several feet of clay and rock. Mixed waste receives additional treatment and is sometimes encased in plastic before burial. The pits are designed to remain stable until the radioactive elements decay--a period that can range from a century to several millennia.

for Semnani said.

Regardless of the nature of the payments, the dump flourished unler Anderson's watch from 1987 to 1993. A confidential state report from 1990 concluded that Anderson appeared to have "lost objectivity with regard to Envirocare." The division director repeatedly overruled his staff by reducing fines against Envirocare, and he once pressured workers to complete in three months a license review that would normally take 1½ years, the report said. One clearly exasperated state worker told the auditors: "He [Anderson] listens to Mr. Semnani more than he listens to his staff.

State enforcement files from the time of the payments portray a company struggling to handle its job. Especially in the early years, inspectors' reports describe sloppy management and chronic violations that drew small fines, if any penalty at all. Clouds of contaminated dust were left to blow across the dump site into the open desert. Waste was buried before it was properly analyzed and labeled. Once, in a routine test of Envirocare's ability to measure the radioactivity of incoming waste, company officials failed to correctly label any of the 10 samples they were asked to identify.

Charles Judd, a Semuani lieutenant who took over as Envirocare's president after the scandal emerged, acknowledged "rough spots" in the company's early history, but denied the dump was given special favors. "Envirocare was just starting up," he said. "You'd expect that there would be issues. But we learned, and Anderson and his people learned."

Despite DOE's increasing reliance on the dump, federal oversight was relatively limited until the scandal broke in January 1997. DOE and the Environmental Protection Agency launched extensive investigations that resulted in hundreds of thousands of dollars of fines against Envirocare, but those inquiries had barely begun when DOE decided against severing its relationship with the facility.

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The DOE entered into a "consent agreement" that forced Semnani to resign as president and withdraw from the daily optration of the company for 18 months.

But the deal, signed in May, allowed Semnani to retain his 100 percent stake in Envirocare and to install his longtime vice president as his successor. The agreement, drafted in consultation with Envirocare attorneys, also allows Envirocare to continue to bid on new government contracts. Days after it was inked, Envirocare was awarded \$7 million in new business from Kaiser-Hill Inc, a Denver-based DOE contractor that is supervising the cleanup of

See WASTE, A13, Col. 2



THE WASHINGTON POST

NATIONAL NEWS

s Monday, April 6, 1998 A13



KHOSROW SEMNANI ... opened Envirocare in 1987

U.S. Has Become Dependent on Single Private Waste Facility

WASTE_From A12

waste from DOE's Rocky Flats weapons complex.

The deal prompted Sen. Lauch Faircloth (R-N.C.) to send a letter to Energy Secretary Federico Peña questioning why the department had not sought tougher concessions. "The consent agreement makes it appear that the Department needed Mr. Semnani ... and would, therefore, agree to his terms," Faircloth wrote.

But DOE officials defend the

agreement as the only reasonable alternative, given the lack of formal charges in the Envirocare case. "We had allegations, the initiation of an investigation and not much more than that," one senior spokesman said. "A year later, there's still no indictments, much less a conviction." Energy officials say they don't like

Energy officials say they don't like their dependence on Envirocare either and are taking steps to encourage competition. But for now, at least, the DOE relies on commercial disposal for some of its waste, and Envirocare is the only company that provides it. "We can only dump in a regulated facility," the DOE spokesman noted.

The agency can, if it chooses, authorize new dumps under the powers granted to it by the Atomic Energy Act. DOE officials recently began studying that option, but they acknowledge that step would be controversial and would overturn a long-standing department policy of deferring to states.

The permit issue is at the heart of the October injunction against DOE by Judge Kendall, who temporarily halted the department from awarding new disposal contracts. Kendall ruled in favor of a Texas company, Waste Control Specialists LLC, which spent \$50 million to develop a dump site in west Texas but until now has been denied a chance to bid on contracts because it lacks a waste permit from the state.

"The DOE had all kinds of options, but they were comfortable," said Martin Malsch, a former NRC deputy general counsel who now represents WCS. "Incredibly, nobody foresaw the problems that

come from having a monopoly."

The DOE is hoping the immediate crisis will ease this week when a federal appeals court considers whether to throw out Kendall's order. But critics say the DOE will have to find new ways to encourage competition soon or it could find itself in the same predicament.

"There are other companies out there that can do the job, and some are being turned away ... for reasons that are bogus," said New Hampshire's Smith. "It doesn't pass the straight-face test for me."

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RISK ASSESSMENT OF ALTERNATIVES FOR DISPOSITION OF BAGHOUSE DUST CONTAMINATED WITH CESIUM-137

by Stanley E. Logan, Ph.D.

Prepared for

INMETCO The International Metals Reclamation Company, Inc. 245 Portersville Road Ellwood City, PA 16117

December 1997

SELA-9701

RISK ASSESSMENT OF ALTERNATIVES FOR DISPOSITION OF BAGHOUSE DUST **CONTAMINATED WITH CESIUM-137**

by Stanley E. Logan, Ph.D.

Prepared for

INMETCO The International Metals Reclamation Company, Inc. 245 Portersville Road Ellwood City, PA 16117

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December 1997

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Stanley E. Logan, Ph.D., P.E.

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ABSTRACT

INMETCO (The International Metals Reclamation Company, Inc.) received a shipment of Electric Arc Furnace (EAF) dust from a North American stainless steel producer for processing that was contaminated with radioactive cesium from inadvertent smelting of a commercial Cs-137 source. After processing at INMETCO with dilution by non-contaminated material, the radiation level was too high for acceptance at Horsehead Resource Development Co. (HRD) for further recycling processing by High Temperature Metal Recovery (HTMR). The contaminated material is currently in storage at INMETCO awaiting disposition. Review of available data indicates that the average Cs-137 concentration in the stored material does not exceed 30 pCi/g (picocuries per gram). For risk assessment purposes, 50 pCi/g is assumed. The risk assessment reported here evaluated four alternatives: 1) continued storage, 2) direct processing at HRD, 3) additional blending with non-contaminated dust at INMETCO prior to HRD processing, and 4) send to RCRA landfill. Background information about cesium, radiation dose and related regulations is presented. It was found that the low concentration of Cs-137 in the stored contaminated EAF dust does not cause any significant risk for any of the alternatives considered. To avoid potentially exceeding air emission regulations in the unlikely event of a baghouse failure at HRD, modest further blending at INMETCO with a total mixture to contaminated material blending ratio of three or four is recommended. Regulatory agencies should be requested to allow a relaxation in the acceptance criteria at HRD, preferably to as much as 20 µR/hr above background. Continued storage until relaxed conditions are obtained is recommended.

INMETCO (The International Metals Reclamation Company, Inc.) operates a hazardous/nonhazardous waste reclamation facility in Ellwood City, Pennsylvania. Feed stock includes mill scale, baghouse dust and swarf from stainless steel producers. INMETCO is also the major recycler of nickel-cadmium batteries. Processing is by a Rotary Hearth Furnace and Submerged Arc Smelting Furnace to recover nickel, chromium, and iron. A side facility recovers cadmium from nickel-cadmium batteries. Impurities in the materials are removed during melting via slag, in filter cake from the water treatment plant, and in the off-gas dust collection system. The co-product slag is sold as an aggregate. The off-gas carries dust, containing a number of metals, to the bag house where the dust is trapped and recovered. Hazardous components: lead, cadmium, and chromium, cause the dust to be designated as U.S. EPA listed hazardous waste No. K061. This dust also contains more than 20% zinc, a valuable byproduct for recovery. The Electric Arc Furnace (EAF) dust, along with Rotary Hearth Furnace filter cake, is sent to the Horsehead Resource Development Co. (HRD), for processing to recover zinc, lead, copper, and cadmium. The remaining HRD Iron Rich Material (IRM) from this recycling process is released for unrestricted use.

In October 1995, INMETCO received a 22.73 ton shipment of EAF dust from a North American stainless steel producer who had inadvertently smelted an industrial gauge radiation source, containing the radioisotope Cs-137. The source apparently was included in a load of scrap steel charged to one of the arc furnaces. This source along with its encapsulation and holder were melted and the cesium was released into the off-gas system where it was collected in the bag house dust. The radioactive content was far below the minimum level to be classified as radioactive material and transport to INMETCO was permitted. Further shipments of EAF dust from the cesium smelting incident were not accepted by INMETCO.

Approximately eighty percent of the contaminated material was processed through the INMETCO facility, blended with non-contaminated material, producing an estimated 220 tons of EAF dust and 50 tons of filter cake. The first shipment of this dust to HRD in a pneumatic tanker was not accepted because radiation readings greatly exceeded their alarm level of 2-3 μ R/hr above background. The dust is now being stored in approximately 260 cardboard boxes, one cubic yard in size, awaiting disposition.

Unfortunately, a regulatory gap exists for disposition of the slightly radioactive contaminated EAF dust. The low activity does not justify the expense of handling as low-level waste, yet it is not of zero activity. The situation is further complicated by the presence of hazardous constituents, making the radioactively contaminated hazardous waste a "mixed waste," not yet covered by regulations except on a case-by-case basis. In March 1997, the NRC issued guidance, with their position coordinated with the EPA, in the form of a technical position, that may be used in case-by-case requests to dispose of incident-related EAF dust contaminated with Cs-137 in a Subtitle C, RCRA-permitted, landfill facility. While this disposal alternative is now available, it can involve a lengthy approval process. Regulatory relief does not yet exist for recycling by a High Temperature Metal Recovery (HTMR) process such as at HRD.

The study reported here has two objectives. First, evaluate alternatives for disposition: 1) continued storage, 2) recycling HTMR processing, and 3) disposal of contaminated EAF dust

in a RCRA landfill. Second, perform a risk assessment of the significant environmental pathways as an aid in obtaining regulatory relief to permit a more cost-effective and environmentally acceptable disposition.

The format of this report first provides background information on cesium contamination, radiation dose, and related regulations, in Section 2. The four alternatives considered for disposition of the stored contaminated dust are stated in Section 3. Direct radiation exposure concepts, involved in all of the alternatives, are covered in Section 4. The risk assessment modeling and calculated results for each of four alternatives are presented in Sections 5-8. Finally, Section 9 provides a discussion of results, and Section 10 presents conclusions. Throughout the report, various numerical values are stated to two and three significant figures to more clearly trace the calculations. Because of uncertainties, it should not be construed that accuracy actually extends to three significant figures.

Acknowledgement is extended to John C. Onuska, Jr., Manager-Environmental, Health & Safety at INMETCO who served as our contact and who furnished extensive data and information about INMETCO and HRD operations.

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2. CESIUM CONTAMINATION AND REGULATIONS

2.1 Cesium

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Cesium is a volatile metal; the pure metal melts at 28.5°C and boils at 670°C. As a chloride in industrial sources, CsCl melts at 646°C and sublimes at 1,290°C. After being subjected to temperatures as high as 1,700°C in an arc furnace, the form of cesium in EAF dust is likely as one of the oxides. It is because of the volatility that the cesium in a melting incident leaves in the off-gas and ends up in the EAF dust; there is none detected in slag or in the steel product.

The radioactive isotope Cs-137, used in industrial sources, has a half-life of 30 years. This means that the level of activity decreases to one-half in 30 y, to one-fourth in 60 y, etc. After 100 y, the level is 0.1 of the initial level, after 200 y is 0.01, and after 300 y is 0.001.

The decay scheme of Cs-137 is as follows:

$$Cs^{137} \xrightarrow{30 \text{ y}} Ba^{137} + \beta^{-}$$

$$Ba^{137m} + \beta^{-}$$

$$Ba^{137m} + \beta^{-}$$

$$Ba^{137m} + \beta^{-}$$

$$Ba^{137} + (X-ray)$$

The cesium decays with a 30 y half-life by emission of a beta particle (β ⁻). An unstable "daughter", Ba-137m, an isomer of barium, is formed in 94.6% of the Cs-137 decays. The Ba-137m then decays with a half-life of only 2.6 minutes to the stable form of barium, <u>Ba-137</u>, with emission of a 0.662 Mev (Million electron volts) X-ray. It is the X-ray that is the penetrating emission from this decay process. While the emission is an X-ray, it behaves similarly to gamma radiation, and dose from exposure to this radiation is therefore loosely referred to as "gamma dose." Because of the almost immediate decay of the barium isomer, dose conversion factors combine the two decay steps into one for "Cs-137+D" (cesium plus daughter).

The specific activity of pure Cs-137 is 89.7 Ci/g (Curie per gram). One Curie represents an activity of 3.7×10^{10} disintegrations per second. The density of CsCl is 3.97 g/cm³; the volume specific activity for this form becomes 280 Ci/cm³ (Curie per cubic centimeter). The density of Cs₂O is 4.36 g/cm³; the volume specific activity for this form becomes 370 Ci/cm³. To illustrate the very small amount involved in a cesium source smelting, the volume of 100 mCi (millicurie) of either chemical form is therefore less than 0.4 cubic millimeter (a diameter as a sphere of less than one millimeter)!

2.2 Industrial Cesium Sources

An industrial gauge radiation source, such as Cs-137, is used in conjunction with an ion chamber detector to measure the presence and density of intervening material. Applications include non-contacting measurement of level and/or density of liquids, solids, or slurries. Gamma (or X-ray) energy is absorbed by the mass of any material between the source and detector; the fraction of gamma energy absorbed increases with the mass of absorber in the path of the beam. The source material is doubly encapsulated in stainless steel and located in the center of a leadfilled welded steel holder. A shutter in the holder blocks a passage in the lead shielding, but is opened to permit emission of the beam for measurement use. The geometry of the shielding produces a highly collimated narrow beam of gamma energy. A source with source holder and shutter is an integral assembly without ready access to the source material. While the presence of the shielding material surrounding the radioactive material provides protection in applications, it prevents readily detecting a source in scrap metal with radiation detectors. When inadvertently smelted in an electric arc furnace, the source holder melts and the cesium becomes volatilized into the off-gas.

The available sizes of industrial gauge cesium sources are typically up to 5 Ci, though the most popular sizes in use are in the 50-200 mCi (millicurie) range.

2.3 Cesium Contamination from Incident

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The cesium source smelting incident at a North American stainless steel producer dispersed a small amount of radioactive cesium very finely throughout many tons of EAF dust. A quantity of this dust, amounting to 22.73 tons, was shipped to INMETCO. Processing of this shipment along with non-contaminated material at INMETCO resulted in accumulation of an estimated 220 tons of contaminated EAF dust, now being stored at INMETCO awaiting disposition. Because of the low resulting concentrations, the unit of picocurie is used throughout this report. A picocurie (pCi) is 1×10^{-12} Ci. This extremely small unit represents only 0.037 disintegration per second or 2.22 disintegrations per minute (DPM). Concentrations in picocuries per milliliter (pCi/ml) and picocuries per gram (pCi/g) are used.

The average concentration of Cs-137 and its variation within the stored incident-related material is uncertain. The cost of collecting samples from various zones in hundreds of containers and assaying the samples is prohibitive. There are several assay values and a number of radiation survey readings available which allow making estimates of concentration. Section 5.1 describes the storage configurations, and presents survey readings and calculation of implied concentrations. In addition, Appendix A also reviews the assay and survey values from earlier temporary storage in a pneumatic tanker and dump trucks. The data suggests that the average concentration is not over 30 pCi/g. Because of uncertainty and variation from uniformity, an average concentration of 50 pCi/g is used in this risk assessment study to be conservative. Also, regarding the quantity of stored dust, the alternative of continued storage uses the actual estimated quantity of 220 tons. The other alternatives considered involve the logistics of transportation and blending. To cover uncertainty in these alternatives, a conservative quantity of 300 tons is assumed for some calculations.

2.4.1 Radiation Characteristics

Radiation emitted by radioactive material falls into three types: $alpha(\alpha)$, beta (β), and gamma (γ). Alpha radiation is associated with some heavy metals, but is not encountered with cesium decay and will not be considered further. Beta radiation is emitted in the Cs-137 decay scheme described in Section 2.1. The maximum beta energy is 0.51 mev (94.6%) and 1.18 mev (5.4%). Any intervening material (shielding) reduces radiation intensity by absorption and scattering. The maximum range of this beta radiation is only 0.19 cm (0.072 in) in aluminum and 0.066 cm (0.026 in) in steel. A typical metal or tri-wall cardboard (with polyethylene liner) container for EAF dust will completely block this radiation. If there is spilled dust, much of the beta radiation is absorbed by self-shielding and most of the emissions from the surface have a maximum range in air of less than 2 m, with the higher energy portion reaching up to about 4 m. Therefore, the beta radiation from Cs-137 contamination is a negligible contributor to risk.

The 0.662 mev radiation (or X-ray) from Cs-137 decay is the penetrating radiation that must be considered in the risk analysis. Attenuation of intensity by absorption and scattering through 0.1 cm thickness of steel is about 7%, through 0.2 cm is about 13%, and through 0.3 cm is about 19%. Attenuation in air is only about 1% in 1 m and about 10% in 10 m. As shown in later Section 4, self-shielding in a thick body of EAF dust results in virtually all of the emitted radiation coming from the outer 0.5 m of dust depth.

Many radiation survey meters measure incident radiation in terms of roentgens, often expressed as microroentgens per hour (μ R/hr), as with the meter used for data furnished for this study. Other meters have plastic detectors that simulate body tissue and are calibrated in the absorbed dose unit, rem, such as μ rem/hr. It turns out that for the 0.662 mev emission from Cs-137, readings in the two units are almost equal. Therefore, in this report, measurements are reported in μ R/hr, and subsequent analysis of dose is in units of μ rem/hr, with no conversion needed.

2.4.2 Dose Conversion Factors

Absorbed dose in persons exposed to radiation is expressed in rems. The term "dose" in this report, expressed in mrem (millirem), refers to <u>effective dose equivalent</u> for external exposure, and <u>committed effective dose equivalent</u> for internal exposure. A "dose conversion factor" (DCF), for the pathways considered, is the ratio of either of these doses to the concentration of a radionuclide in a mass of contaminated material (for external exposure), or the quantity ingested (for internal exposure). A variation of the DCF used in this report for direct (external) exposure is the hourly dose rate and annual dose rate per unit concentration of Cs-137 in the EAF dust: µrem/h (microrem per hour) per pCi/g, and mrem/y per pCi/g, respectively. A DCF multiplied by the concentration, pCi/g, yields the corresponding dose rate resulting from that concentration.

2.4.3 Dose-Response Relationship

Regulations currently in place and guidelines for radiation protection are all based upon the linear no-threshold (LNT) dose-response relationship for low-level radiation exposure. The LNT model was adopted many years ago, and was believed to be conservative. It notes health effects encountered at high dose rates and assumes that effects occur linearly with doses and dose rates to lower values, all the way down to zero dose. Support is rapidly growing for replacing the LNT model with a threshold model. The threshold model recognizes repair and other mechanisms that limit net health effects to dose values above some threshold value. The Health Physics Society now recommends against quantitative estimation of health risks below an individual dose of 5 rem in one year or a lifetime dose of 10 rem in addition to background radiation. Logan reported on potential benefits from replacing the LNT model with a threshold model [1]. It may be several years before the threshold model gains acceptance by regulatory agencies. A detailed examination of the dose-response model is beyond the scope of this report, but the subject is mentioned because it can be expected that the trend toward lower dose limits may soon reverse. This report examines various conditions involving up to a few millirems per year and provides arguments for regulatory permission for these levels, but eventually it will be recognized that these dose rates have no real health effect consequences.

2.5 Regulations-General

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The EAF dust, contaminated with Cs-137, has a very low average level of radioactivity, but it is not zero. At the same time, it is much lower in activity than the category designated as "Low-Level Waste" (LLW). Also, the EAF dust contains the hazardous components: lead, cadmium, and chromium. Because of this, the dust is designated as U.S. EPA hazardous waste No. K061, and is regulated under RCRA (Resource Conservation and Recovery Act) [2]. Waste containing both radioactive and hazardous components is "mixed waste." Regulations are not generally in place for very low levels of radioactivity, and particularly are not in place for mixed waste. Therefore, in the absence of specific regulatory requirements, consideration of options following a cesium source meltdown incident is not simply a matter of evaluating compliance with such requirements.

In the following subsections, various regulations and regulatory agency actions are briefly described. It should be noted that the regulations all refer to radioactive concentrations much greater than in contaminated EAF dust. The annual dose to any member of the public is generally limited to either 100 mrem or 25 mrem, but in some EPA regulations, the limit is 15 mrem. For some items, only the parts that relate to cesium contamination are presented.

2.5.1 General Radiation Protection

"Standards for Radiation Protection" issued by the U.S. Nuclear Regulatory Commission (NRC) are contained in 10 CFR 20 [3]. Table 1 summarizes the regulations of interest in this study, expressed in units parallelling our use. The specified limits for release in effluents of Cs-137 to unrestricted areas were reduced in 1994 to the values listed: 1 pCi/ml in water and 0.2 pCi/L in air.

Table 1. Summary of 10 CFR 20 Limits

	Occupational	Public
Annual dose limit, rem/yr	5	0.1
Unrestricted area in any one hour (external sources), µrem/hr (mrem/h	hr)	2,000 (2.)
Cs-137:	~	
Annual Limits on Intake (AL Oral ingestion, μCi	1) 100	
Inhalation, μ Ci	200	
Derived Air Concentration (I pCi/L	DAC) 6	
Effluent Concentration	1 000	
Air, pCi/L	0.2	
Release to Sewer (monthly a concentration), pCi/L	vg. 10,000	

DOE Order No. 5400.5: "Radiation Protection of the Public and the Environment," [4] contains a Radiation Protection Standard of 100 mrem/y for the general public.

The "U.S. DOE Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites," as revised March 1987 [5], states that the basic limit for the annual dose received by an individual member of the general public is 100 mrem/y. It may be noted that a full-time dose of 100 mrem/y corresponds to 23 mrem/y for a 40 hour work week, 50 weeks per year, close to the 25 mrem/y specified for waste repository dose limits in some regulations.

2.5.2 Low-Level Wastes

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The NRC "Licensing Requirements for Land Disposal of Radioactive Waste" (applies to Low-Level Wastes) are contained in 10 CFR 61 [6]. The lowest concentration category of waste addressed is Class A. This class applies for Cs-137 content up to 1 Ci/m³, which is 10⁶ pCi/ml. The stored contaminated EAF dust has an estimated cesium content lower than the Class A limit by a factor of 20,000. Concentrations of radioactive materials released to the general environment in ground water, air, soil, etc., must not result in an annual dose exceeding 25 mrem whole body dose to any member of the public. Handling the EAF dust as LLW subjects it to excessively stringent repository requirements and high costs.

DOE policies and guidelines for radioactive waste management are covered in DOE Order 5820.2A [7]. Chapter III of this order is titled "Management of Low-Level Waste." It states:

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"Assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground water, soil, plants and animals results in an effective dose equivalent that does not exceed 25 mrem/y to any member of the public," and "Assure that the committed dose equivalents received by individuals who inadvertently may intrude into the facility after the loss of active institutional control (100 years) will not exceed 100 mrem/y for continuous exposure or 500 mrem for a single acute exposure."

The proposed EPA regulation for Low-Level Radioactive Waste management, storage and disposal is 40 CFR 193 [8]. Proposed limits are consistent with EPA approaches in 40 CFR 191 [9] drinking water standards in 40 CFR 141 [10]. The proposed limit for individual protection is 15 mrem annual committed effective dose.

2.5.3 High-Level Wastes

The NRC regulations "Disposal of High-Level Radioactive Waste in Geologic Repositories" are in 10 CFR 60 [11]. These regulations limit the total body dose equivalent to any member of the public outside of the controlled area to 25 mrem/y. Concentrations in ground water in the vicinity of a repository are limited to that which would produce a total body dose equivalent of 4 mrem/y for an individual consuming 2 L/d.

The corresponding EPA standards "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" are in 40 CFR 191 [9]. One section of this rule limits any member of the general public to 15 mrem/y "committed effective dose." Concentrations in ground water are limited to the Maximum Contaminant Levels (MCLs) in the National Primary Drinking Water Regulations (NPDWRs) in 40 CFR 141 [10]. For radionuclides such as Cs-137, the MCL is the concentration causing 4 mrem/y total body dose for an individual consuming 2 L/d (same as for NRC regulations). For a dose conversion factor of 5.0×10^{-5} mrem/pCi for Cs-137 intake, the corresponding MCL is 0.11 pCi/ml. While this concentration is lower than the 1 pCi/ml new limit for effluents in 10 CFR 20, it should be noted that the MCL applies to water specified as used for drinking and effluent is subject to treatment prior to use as drinking water.

2.5.4 Transportation

NRC regulations "Packaging and Transportation of Radioactive Material" in 10 CFR 71 [12] and DOT (Department of Transportation) regulations in 49 CFR 173 [13] apply to radioactive materials packaged in containers. However, regulation as "radioactive material" applies only if the specific activity is greater than 2,000 pCi/g, much greater than for the EAF dust considered here. Nevertheless, the least stringent packaging is "Type A". For Cs-137, the maximum quantity in each Type A package is 10 Ci, much larger than the total in the stored EAF dust. The maximum dose rate at the package <u>surface</u> is 200 mrem/h, and at a distance of 1 m from the surface is 10 mrem/h. The maximum dose rate for any normally occupied position of a transport vehicle is 2 mrem/h. "Low specific activity material" per 10 CFR 71.4 is material in which the average concentration does not exceed 0.3 mCi/g (3 x 10⁸ pCi/g), more than several million times higher than in the stored EAF dust!

2.6 NRC Staff Technical Position

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In March 1997, the NRC issued guidance, with their position coordinated with the EPA, in the form of a technical position, that may be used in case-by-case requests to dispose of incident-related EAF dust contaminated with Cs-137 [14]. This followed an earlier study by Logan in 1993 which was published in the Waste Management'93 Proceedings [15]. The conclusion in the position is "some significant volume of Cs-137 contaminated emission control dust and other incident-related materials from an inadvertent melting of a sealed source can be disposed of at a Subtitle C, RCRA-permitted facility with negligible impacts to public and worker health and safety and the environment." Prior to treatment for disposal in a RCRA landfill, the average concentration of Cs-137 is limited to 130 pCi/g if packaged, and 100 pCi/g if in unpackaged bulk form. Their analysis indicates less than 1 mrem/y dose rate or 1 mrem per incident to any worker or individual member of the public. These doses are much lower than any regulatory limits, and could be relaxed considerably without any harm to individual workers or members of the public. Disposal in a RCRA facility is an option reviewed in Section 8 of this report. The NRC position included only this option as a means to provide some regulatory relief to the steel industry quickly, instead of delaying for a broad recycle rulemaking. Recycle via High Temperature Metal Recovery (HTMR) is not covered in this staff position, but may be included in broad recycle rulemaking stated as being underway. Such HTMR treatment is examined in Sections 6 and 7 of this report.

3. ALTERNATIVES CONSIDERED

Four alternatives for disposition of the stored contaminated EAF dust are considered in this risk assessment study.

The first alternative is to simply continue the current storage indefinitely. This is the "do nothing" option, intended to wait until some future time when another more cost-effective option becomes available. It also serves as a reference for risk comparison with the other active alternatives.

The second alternative is to ship directly to HRD for recycle processing, without dilution by blending with other non-contaminated dust at INMETCO. This requires raising the allowable radioactivity level for acceptance and processing at HRD. The option can include blending of the stored material to obtain more uniformity while being loaded at INMETCO for shipment. Also, blending at HRD with other incoming material is typically involved.

The third alternative is to blend stored material with other non-contaminated material at INMETCO, to dilute the contamination concentration and to obtain more uniformity, prior to or while loading for shipment to HRD. This option also requires raising the allowable radioactivity level for acceptance and processing at HRD, but to a lesser extent than for the second alternative.

The fourth alternative is to ship the stored material to a Subtitle C, RCRA-permitted landfill facility for stabilization treatment and disposal. This is a no-recycle disposal option, allowed on a case-by-case basis under NRC guidance issued in March 1997.

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Each of these four alternatives are described and assessed in the following sections.

4. DIRECT RADIATION EXPOSURE

Radiation dose from direct exposure to masses of EAF dust contaminated with Cs-137 is a pathway associated with storage, transport to other facilities, and handling at the other facilities. In this section, a base case is developed and used to demonstrate the effect on direct exposure of cesium concentration, decay time, material density, depth dimension, and area and shape geometry factors. Subsequently, Sections 5 through 8 apply the direct exposure analysis to each of the options considered. In this and subsequent sections, a cesium concentration of 50 pCi/g is assumed as a normalized base. Results scale linearly up or down for other concentrations.

4.1 RESRAD Code

The RESRAD computer code [16,17] is a DOE code developed to implement compliance with DOE Residual Material Radioactive Material Guidelines. It is applied in this risk assessment for direct exposure pathways and also for drinking water pathways involved in disposal in a RCRA landfill (Sec. 8).

The starting point in the direct exposure pathway calculations is use of the RESRAD computer code (version 5.70) [16,17] to obtain the radiation dose at a distance of 1 m from the surface of a semi-infinite volume of EAF dust. This refers to a volume of infinite lateral extent and infinite depth, with uniform distribution of a radioactive contaminant. This condition is reached for practical purposes with an area of 10,000 m² (circular area radius of 56 m). The RESRAD code considers gamma radiation emission from each elemental volume throughout the semi-infinite mass, considers scattering and absorption in each direction in transport to the soil/air interface, and attenuation by scattering and absorption in air above the interface en route to a receptor. The receptor is taken as a point 1 m from the surface. The dose contributions from all elemental volumes are summed up and applied to an anthropomorphic phantom at that point to determine organ doses and the corresponding effective dose equivalent. Because of self-shielding effects, it is found that for Cs-137 contamination, the outer 0.5 m of material depth contributes almost all of the radiation dose.

For smaller and non-circular sources, a "shape/area factor", less than 1.0, is applied to the dose rate for a semi-infinite source to obtain the lower dose rate for a given finite source. To calculate a shape/area factor (we'll simply refer to this as the "area factor"), the code: 1) sets up 12 annular zones encompassing the area of interest and centered at the receptor location, 2) determines the contribution to dose of a unit area at each annular radius, 3) determines the area of each annulus and the fraction of that area covered by the contaminated area (and hence the fraction of the annular area contributing to dose), and 4) sums up the dose received from the 12 annuli. The ratio of this total dose from the area of interest to the dose from a semi-infinite mass is the area factor. The concept involved applies to any shape or size.

4.2 Application to EAF Dust

The density of EAF dust varies with the degree of settling and moisture content. As generated, dust at INMETCO is 28 to 40 lb/ft³, with a 32 lb/ft³ average. In storage, the dust settles and absorbs moisture from the air, increasing density up to more than double the original

value. Figure 1 is a plot of the Dose Conversion Factor (DCF), mrem/y per initial pCi/g concentration, versus time, for a semi-infinite mass of dust. Initially, the DCF is 3.192(mrem/y)/-(pCi/g), decreasing with time as radiodecay progresses. Dividing by 8.76 obtains the corresponding dose rate in µrem/hr. The 3.192 value is approximately two-thirds of the value obtained by Logan four years ago using an earlier version of RESRAD. Since then, the code has been updated with a data base incorporating more exact modeling in accordance with recommendations from the EPA Federal Guidance Report No. 12 [18]. The corresponding initial hourly dose rate is 0.364 (urem/hr)/(pCi/g). For contamination the assumed concentration of $C_c = 50$ pCi/g, this initial base dose rate for the semiinfinite mass becomes



Fig. 1. Dose Conversion factor vs. time for semi-infinite mass.

$$D_{\text{base}} = DCF \times C_{\text{c}} = 3.192 \times 50 = 156 \text{ mrem/y}$$

or = 0.364 x 50 = 18.2 µrem/hr. (1)

As density of the material is increased, the volume concentration of the contaminant increases, but the radiation absorbing shielding effect also increases, with the net effect that the DCF for concentrations based upon mass is found to remain constant with density changes. If volume concentrations are used, the corresponding DCF is inversely proportional to density.

For material with large depths, radiation from material at the greater depths is absorbed by intervening mass and does not contribute to the direct exposure dose. Radiation from material at shallower depths is progressively less absorbed as the depth decreases. Figure 2 shows the initial DCF versus depth for contaminated material. It may be seen that for depths greater than about 0.5 m, the curves approach the value for the semi-infinite source. For the pathways considered in this study, depths are generally equal to or greater than 1 m, but values shown for lesser depths are useful for evaluating spills or residual deposits.

Quantities of EAF dust we are considering do not cover large areas. The base dose rate for semi-infinite extent must be multiplied by an area/shape factor, F_a , to obtain the lower actual dose expected from a finite dimensioned source. The direct exposure dose to a finite source of EAF dust, such as a storage or shipping box or a pile of material being processed, becomes

$$D = D_{base} \times F_{a}$$

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(2)

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Combining Eqs. 1 and 2,

$$D = DCF \times C_c \times F_a$$
(3)

For example, from Eqns. 1 and 2, the dose rate for a person standing on the ground 1 m from the center of a pneumatic tanker (see later Sec. 6: area factor = 0.41), containing 50 pCi/g material becomes

$$D = D_{base} \times F_a = 18.2 \times 0.41 = 7.5 \text{ urem/hr.}$$
(4)

Area factors for the various shapes and sizes involved are determined later under each of the options considered.



Fig. 2. Dose conversion factor versus source thickness.

4.3 Other Considerations

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The analyses presented here are based upon a distance of 1 m from the closest surface of various packages or piles of contaminated material. At greater distances, the dose decreases. For a concentrated point source, the dose is simply proportional to the reciprocal of the distance squared (dose rate $\propto 1/d^2$), plus accounting for attenuation in air from scattering and absorption (see Section 2.4). For area sources, the calculations for various distances become complex. A set of plots in the NRC analysis related to disposal in a RCRA landfill [14] indicate that for distances from 1 m to 3 m from a typically-sized container, dose rate $\propto 1/d$, and for greater distances up to 10 m, dose rate $\propto 1/d^{1.5}$. At distances greater than 10 m, the $1/d^2$ relationship for a point source may be used.

The RESRAD code assumes soil constituents resembling the earth's crust, which is different than the EAF dust composition, which has much lower SiO_2 and much higher Zn content. The gamma mass attenuation factor was calculated for the element compositions for soil and INMETCO EAF dust, at the 0.662 mev Cs-137 emission energy level, and it was found that they are almost equal. This confirmed that the RESRAD code may be applied to the EAF dust without requiring a correction.

5. INDEFINITE STORAGE AT INMETCO

5.1 Storage Geometry and Survey Measurements

The estimated 220 tons of contaminated EAF dust were transferred from the pneumatic tanker and dump trailers and are now stored in approximately 260 tri-wall cardboard boxes, one cubic yard in size, with an 8 mil thick polyline (LLDPE) bag liner. Each box is on a $38" \times 38"$ (approximately 1 m x 1 m) pallet. The boxes are arranged in numerous groups to accommodate available storage areas in a warehouse building. The largest group has 92 boxes, arranged in one row of 4 boxes, 10 rows of 7 boxes each, and 3 rows of 6 boxes each. That is, this largest group is generally in a close-packed 14 x 7 single layer array. The other large group has 52 boxes, in a roughly 12 x 6 array, but not close-packed. The remaining 116 boxes are in small groups of 8 to 20 boxes each.

Radiation readings were made along accessible face rows of boxes in the largest groups using a Bicron Micro Analyst survey meter, set on Range X10 (0-50 μ R/hr). The detector in the meter is a NaI(Tl) 1" x 1" scintillator, which receives incoming radiation from the full surrounding sphere. Radiation from horizontal or vertical directions not directly ahead of the meter face are partly absorbed by material in the meter construction. Particularly, from the rear, meter batteries and other materials absorb about one-half of the incoming radiation. However, there remains a broad angle subtending the meter when scanning rows of boxes, with very little attenuation over the front 180°.

The boxes were surveyed first at a level of one foot above the bottom, at a distance of 6" from the center of each box in turn. Starting with the 14-box longest side of the largest group, the readings along the four sides, in μ R/hr (not corrected for background), were:

12-10-11-10-14-14-13-14-12-10-10-8-10-14 12-14-8-10-10-8-8 10-8-10-10-11-10-10-11-10-8-10-10-10-10 10-12-11-12-14-10

In this sequence, each of four corner boxes was measured on two faces. The 41 measurements, representing 37 boxes, averaged 10.7 μ R/hr, with a range of 8 to 14 μ R/hr. Subtracting the mean background of 7 μ R/hr obtains an average net value of 3.7 μ R/hr, with a range of 1 to 7 μ R/hr.

Measurements of the other large group (52 boxes) were 6 to 17, with an average of 10.3 μ R/hr, or 3.3 μ R/hr, corrected for background. The breakdown of these measurements is not available, but it is assumed that they represent about 30 readings and 30 boxes.

Next, we can estimate the implied concentration of Cs-137 in each storage group from the average radiation readings. From Eqs (1) and (2) in Section 4.2, the implied average concentration is

 $C_{c} = D/(DCF \times F_{a})$, pCi/g

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(5)

where D is the corrected measured dose rate for each group, DCF is the Dose Conversion Factor for a semi-infinite mass of EAF dust (0.364 µrem/hr per pCi/g), and F_a is the area factor, evaluated for a representative row length for each group, using the RESRAD code method described in Section 4.1. The area factor for a receptor 1 m from and centered on an area 0.73 m (average height of fill in boxes) x 10 m (row of 10 boxes) is 0.20. This value is insensitive to a variation of several boxes more or less. It is estimated that the effective area factor at the close measurement distance of 0.15 m is greater by a factor of 3, or 0.60. By Eqn. 5, the apparent cesium concentration for the large array is $3.7/(0.364 \times 0.60) = 16.9$ pCi/g.

One measurement was taken pointing down at the top center of the array from a distance of 1 ft, obtaining a mean corrected reading of 6.5 μ R/h. The relatively large area of the array top surface has an area factor of 0.80 at a distance of 1 m, estimated to be 0.90 at the measurement distance of 0.3 m. The corresponding calculated concentration is 19.8 pCi/g, not greatly different from the indicated perimeter value.

Survey meter readings for perimeter boxes in the other large group (52 boxes), corrected for background, averaged 3.3 μ R/h. The corresponding average concentration in this group, by Eqn. 5, is 15.1 pCi/g. The dose rate at our 0.662 mev energy level in μ rem/hr is very close to being equal to the indicated μ R/hr (see Sec. 2.4.1), and they are assumed here to be equal and interchangeable.

The 15 to 20 pCi/g average value obtained above should be tempered by a recognition of the uncertainty involved. Only accessible facing rows of boxes were scanned with the survey meter. Thus, only about 67 boxes out of the 260 total (14 %) were scanned. Because of self-shielding, only the outer 0.1 to 0.2 m in each box contributed to the readings and any rows behind the facing row were totally shielded from contributing. Also, the use of an average area factor for a given row, applied to all measured boxes in the row is an approximation. The characterization of stored material reviewed in Appendix A (see Table A-3) indicates average concentration values estimated from weight-averaged data from earlier phases of handling range from 15 to 33 pCi/g.

A group of measurements was also taken along the bottom of outside-perimeter boxes in the large (92-box) group. Readings were: "12 to 15 with 12 boxes reading between 18 to 22." Assuming this means 12 boxes averaged 20, and the 25-box balance of those measured averaged 13.5, the weighted average becomes 15.6 μ R/hr, or 8.6 μ R/hr corrected. The area factor along the bottom at 1 m distance is 0.18; the factor at 6" is estimated to be three times greater, or 0.54. The implied concentration (Eqn. 5) becomes 43.8 pCi/g. An explanation of the apparent higher value along the bottom is not known.

5.2 Risk Assessment

1.1.1

Average implied concentrations in the storage boxes from the analysis in the previous section are summarized in Table 2.

	$\mathbf{F}_{\mathbf{a}}$	D µR/hr	C _c pCi/g
92-box group			
mid-perimeter	0.60	3.7	16.9
top center	0.90	6.5	19.8
bottom perimeter	0.54	8.6	43.8
52-box group			
mid-perimeter	0.60	3.3	15.1

Table 2. Implied Average Concentrations in Boxes

The indicated concentrations are not uniformly at an average value. The survey measurements for the boxes entering into the averages indicate a variation over a range with a factor of almost three. Average concentrations estimated from previous measurements with a pneumatic tanker and dump trailers (Appendix A, Table A-3.) indicate a range of 15 to 33 pCi/g. This range weight-averaged the relatively high measurements related to the pneumatic tanker contents, which were later distributed among the boxes. The values in Table 2 (excepting the unexplained higher value for the bottom perimeter) are lower than those from the earlier tanker and trailer data. This may be due to the addition of moisture in the interim, as is in fact indicated by a density increase. Added moisture increases mass without adding Cs-137 and increases the self-shielding provided by the stored material. The effect would be to reduce radiation measurements and therefore imply a lower concentration. A lower concentration would be consistent with a fixed volume concentration of Cs-137 plus addition of water.

While the other active alternatives provide for some mixing and blending to obtain more uniformity, the continued storage option necessarily involves acceptance of the existing variations as stored. To compensate for the variations and uncertainty, including the effects of added moisture, it is assumed that all boxes contain an average Cs-137 concentration of 50 pCi/g, for purposes of calculating the potential dose rate and dose from possible worker exposure times. The value of 50 pCi/g encompasses the full range of implied concentration from the various categories of data, and includes the unexplained 44 pCi/g implied by bottom perimeter measurements.

A representative grouping of boxes has an area factor of about 0.20. Using an average concentration of 50 pCi/g, the calculated dose rate at a distance of 1 m, from Eqn. 3, becomes $0.364 \times 50 \times 0.20 = 3.64 \mu$ rem/hr. This value is larger than all of the average measured dose rates in Table 2, adjusted from the measurement distances of 6" and 12" to the 1 m (Table 2 values divided by approximately three) distance.

The building in which the stored boxes are located is not normally accessed by workers. The 3.6 μ rem/hr is lower than the 2,000 μ rem/hr limit for public unrestricted area in any one hour in 10 CFR 20 [3] by a factor of more than 500, and the continued storage therefore represents a miniscule risk.

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6. PROCESS DIRECTLY AT HORSEHEAD

This is a recycle alternative. Dust from electric arc furnaces (EAF dust) is processed at the Palmerton, PA plant of Horsehead Resource Development Co., Inc. to remove lead, zinc, copper, and cadmium. In addition to removing hazardous components, processing recovers valuable metals, particularly zinc. A residual material called "IRM" (Iron Rich Material) has had hazardous materials removed, and is released for unrestricted use in the construction industry. In the following, the process is first described, the modeling equations are developed, a base case for Cs-137-contaminated material with typical blending at HRD is defined, and the effects of other additional blending at INMETCO are then considered.

6.1 Description of Processing at Horsehead

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The processing sequence is shown in the schematic flow chart in Fig. 3. A more detailed flow diagram of the Palmerton Plant from HRD publications is in Fig. 4. The top box in Fig. 3: "Subject EAF Dust," refers to a load being tracked such as material contaminated with a radioisotope. An incoming load of Subject EAF dust for the Waelzing Plant is blended with material from other sources and conditioned with addition of water. The mixture is conveyed in enclosed transfer via the Feed Building to Waelzing rotary kilns, operated at temperatures up to 1,300°C. Zn, Pb, and Cd volatilize and with suspended dust in the off gas go to the bag room where the collected material is called "Crude ZnO," which then goes to a storage building. Heavy unreacted material in the off gas is collected in a settling chamber and recycled. Air flow to Waelzing kilns is 125,000-140,000 actual cfm for a plant capacity of 490 tons of EAF dust per day (typical kiln capacity is 275 TPD each). Solid material discharged from the kiln is the IRM, and air discharged from the bag room is released through a stack.

The Crude ZnO is routed from the storage building to the Calcining Kilns. It is blended with material from other incoming shipments and conditioned with addition of water. The mixture is conveyed in enclosed transfer to rotary calcining kilns, operated at temperatures up to 1,100°C. Pb and Cd volatilize along with 5-10% of the zinc, under oxidizing conditions, and go to the bag room where the collected material is called "lead chloride concentrate." Again, a settling chamber is used to collect unreacted material for recycling. The air flow rate to calcining kilns is 80,000-100,000 actual cfm for a plant capacity of 490 tons of Crude ZnO per day (typical kiln capacity is 240 TPD each). Most of the zinc is discharged from the kilns in the calcined material.

The lead chloride concentrate is packaged in "supersacks" (4 ft diameter by 8 ft tall) and shipped in covered gondola rail cars to the Lead/Cadmium Concentrate Processing Facility in Oklahoma for wet processing to recover $PbSO_4$, $ZnCo_4$, Cu sponge, and Cd sponge. A flow chart of this facility from HRD publications in Fig. 5 provides details. The remaining solution after removal of metals goes to a waste water tank at the plant waste water treatment facility. 2,200 gal of waste water are produced per ton of feed to wet processing. An incoming shipment of lead chloride concentrate is diluted by an undetermined amount of material from other sources.



Fig. 3. Horsehead Resource Development Co. schematic flow chart.

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Fig. 4. Schematic flow diagram of HRD Palmerton Plant.

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6.2 Fate of Cesium in EAF Dust

Cesium is a volatile metal, melting at 28.5° C and boiling at 670° C. The form of cesium in EAF dust is as one of the oxides, which decompose at temperatures between 360 and 600°C. It is because of the volatility that the cesium in the melting incident ended up in the EAF dust; there was none detected in slag or the steel product. The likely fate of the cesium during processing at Horsehead is to 1) volatilize in the Waelzing kiln and be collected in the Crude ZnO, 2) revolatilize in the calcining kiln and be collected in the lead chloride concentrate, and 3) dissolve into wet processing solutions, collect in the waste water tank, and 4) disposed of via deep well injection.

6.3 Pathways Considered

The pathways considered are:

1. Direct exposure to incoming contaminated EAF dust and to materials at stages during processing.

2. Release to atmosphere due to bagroom failure.

3 Release to waste water at Lead Concentrate Processing Facility.

It is expected that conditioning of the dust by addition of water, coupled with enclosed transfer and low Cs-137 concentrations, reduces ingestion and inhalation hazards to negligible levels. However, there are compelling practical reasons why these pathways need not be examined further. Ingestion and inhalation limits are specified in 10 CFR 20 for occupational exposure. The limits are based upon an allowable occupational dose of 5 rem/y. The Annual Limit on Intake (ALI) by ingestion for Cs-137 is 100 μ Ci/y. At 50 pCi/g, this represents eating 2 x 10⁶ g/y or 4,400 lb/y! The ALI by inhalation is double the quantity for ingestion (inhale 8,800 lb/y). The corresponding Derived Air Concentration (DAC) for Cs-137 is 6 x 10⁻⁸ μ Ci/ml. The DAC covers chronic exposure to both inhalation and direct immersion. At 50 pCi/g, this translates into 1.2 grams per liter of air, clearly an unexpected level of suspended material. Further, duration of exposure to the incident-related material while it is being processed is only a matter of days.

6.4 Modeling of Pathways

The applicable equations are developed first and applied later in Sec. 6.5.

Nomenclature:

. جانب مد DCF = direct exposure dose conversion factor, $(\mu rem/hr)/(pCi/g)$ D = direct exposure dose rate, $\mu rem/hr$ W_c = daily receipt of contaminated EAF dust, TPD W_w = daily total feed to Waelzing Kiln, TPD W_{z1} = daily total Crude ZnO from Waelzing, TPD W_z = daily total feed to Calcining Kiln, TPD W_{Pb} = daily total lead concentrate, TPD C_c = Cs-137 concentration in contaminated dust, pCi/g C_w = Cs-137 concentration in Waelzing Kiln feed, pCi/g C_{z1} = Cs-137 concentration in Crude ZnO from Waelzing, pCi/g C_z = Cs-137 concentration in ZnO Calcining Kiln feed, pCi/g C_p = Cs-137 concentration in lead concentrate, pCi/g

6.4.1. Direct Exposure to Contaminated Materials

The starting point in pathway calculations is to use the RESRAD computer code to obtain the radiation dose at a distance of 1 m from the surface of a semi-infinite volume of EAF dust containing Cs-137 contamination. This refers to a volume of infinite lateral extent and infinite depth. Because of self-shielding effects, the outer 0.5 m of material depth contributes almost all of the radiation dose. For smaller and non-circular sources, an area factor, F_a , less than 1.0, is applied to the base dose rate (for a semi-infinite source) to obtain the actual lower dose rate for a given finite source. The RESRAD code yields a dose conversion factor (DCF) for Cs-137 in a semi-infinite volume of 0.364 (µrem/hr)/(pCi/g). The base dose rate is simply the product of the DCF and contaminant concentration in the incoming EAF dust:

$$D_{\text{here}} = \text{DCF x } C_{\text{s}} = 0.364 \text{ x } C_{\text{s}} \text{, } \mu \text{rem/hr}$$
(6)

Applying an appropriate area factor for the incoming contaminated dust (truck, dumped pile, hopper, etc.) obtains the actual expected dose rate to workers in the vicinity at an average distance of 1 m:

$$D = 0.364 \text{ x C}_{\circ} \text{ x F}_{\circ}, \mu \text{rem/hr}$$
 (7)

Equation 7 is also applied later for calculating dose rates at other process points by replacing C_c with C_w , C_{z1} , C_z , or C_{Pb} , and adjusting F_a , if different. The concentration (Cs-137 content) of the feed at the Waelzing Plant is diluted by the blending ratio of the quantity of Total feed to contaminated EAF dust:

$$C = C_x \chi 1/(W_y/W_c), pCi/g$$
⁽⁸⁾

The dose rate for a larger accumulated mass of blended material, considering the <u>new</u> applicable area factor, becomes:

$$D = 0.364 \text{ x } C_w \text{ x } F_a$$
, $\mu \text{rem/hr}$ (9)

For each ton of EAF feed, 0.4 ton of Crude ZnO is produced, and this ZnO contains all of the Cs-137 content of the EAF feed. That is, the quantity of ZnO produced is

$$W_{zl} = 0.4 \times W_w, \text{ TPD}$$
(10)

And the concentration in the ZnO produced is

17

(0)

(0)

$$C_{z1} = C_w / 0.4 = 2.5 \text{ x } C_w \text{ , pCi/g}$$
 (11)

23

This ZnO is then diluted with ZnO from other sources, reducing the concentration of the total calcining kiln feed to

$$C_{z} = C_{z1} \times 1/(W_{z}/W_{z1}), pCi/g$$
 (12)

The trivial equation for Calcining Kiln total feed is

$$W_{z} = (W_{z}/W_{z}) \times W_{z}, \text{ TPD}$$
⁽¹³⁾

Finally, one ton of lead concentrate is produced from calcining, per 8 tons of Crude ZnO. Then, the quantity of lead concentrate is

$$W_{Pb} = W_z / 8 = 0.125 \text{ x } W_z$$
, TPD (14)

Again, the lead concentrate contains all of the initial Cs-137 and it's concentration is therefore

$$C_{\rm Pb} = 8 \times C_{\rm r} , \, \rm pCi/g \tag{15}$$

Thus, if contaminated EAF dust at incoming concentration C_c was processed with <u>no</u> blending for Waelzing Kiln feed and also <u>no</u> blending of the Crude ZnO product for calcining kiln feed, the concentration of Cs-137 would progressively increase. The increase factor for the Crude ZnO would be 2.5, with further increase by a factor of 8 for the lead concentrate, or a total net factor of 20.

However, normal operations at HRD must maintain full continuous feed to all operating kilns, and must accommodate other incoming material. The expected dilution by blending will more than offset the concentrating, with the result that Cs-137 concentrations will decrease as the material progresses through the plant. At each stage, various appropriate values of the shape/area factor, less than 1.0, apply. At each stage, the dose rate to a worker in the vicinity is as stated in Eqn. 7, except with the local concentration replacing the original incoming C_c , and using the local area factor, F_a .

6.4.2. Release to Atmosphere from Bagroom Failure

The Cs-137 volatilized in the Waelzing kiln is trapped in the dust collected in the bag room. As a severe case, assume that <u>none</u> of the cesium is trapped and <u>all</u> of it escapes up the stack to the atmosphere due to a complete failure of bags in the baghouse. The kiln air flow rate is 125-140,000 acfm for a process rate of 490 tons per day. The air concentration for this extreme case, conservatively using the lowest air flow rate, becomes

$$C_{airl} = (490/125,000) \times (2,000 \times 454)/(60 \times 24 \times 28.32) \times C_w$$

= 0.00392 x 22.27 x C_w = 0.0873 x C_w , pCi/L (16)

where unit conversion factors are: 2,000 = lb/ton

454 = g/lb 24 = hr/d (hours/day) $28.32 = L/ft^{3} (Liters/ft^{3})$ 3,785 = ml/gal (milliliter/gallon)

Next, assume <u>all</u> of the cesium is trapped in the dust from the Waelzing Kiln but subsequently <u>all</u> of it escapes up the stack to the atmosphere due to complete failure of bags in the Calcining Kiln baghouse. The kiln air flow rate is 80-100,000 acfm for a Crude ZnO process rate of 490 tons per day. The air concentration for this extreme case, conservatively using the lowest air flow rate, becomes

$$C_{air2} = (490/80,000) \times 22.27 \times C_z = 0.136 \times C_z , pCi/L$$
 (17)

A complete failure in either baghouse is not expected; any actual release from the failure of one or a few bags would be limited to a fraction of the above values.

6.4.3. Release to Waste Water

One ton of lead concentrate is produced from 8 tons of Crude ZnO (Eq. 14). The lead concentrate is shipped in covered rail gondolas, packed in bags, to the Lead/Cadmium Concentrate Processing Facility in Oklahoma. The Cs-137 contamination in the lead concentrate is expected to pass through in the wet processing and collect in the waste water tank. There are 2,200 gal of waste water produced per ton of lead concentrate processed. The concentration of Cs-137 in the waste water going to the waste water tank after removal of other metals is

$$C_{ww} = (1/2,200) \times (2,000 \times 454 / 3,785) \times C_{pb}$$

= 0.109 x C_{pb}, pCi/ml (18)

This calculation does not take credit for the dilution of the wet process feed with an unknown fraction of material from other sources, nor dilution of waste water going to the tank by water already in the tank or following the cesium-contaminated flow. Hence, C_{ww} represents the maximum possible concentration. The waste water, containing essentially the halogens removed in the process, and presumedly any Cs-137 contamination, is pumped to the site waste water treatment facility and then disposed of by deep well injection under permit.

6.5 Risk Assessment Base Case

The base case is intended to represent typical operation of the HRD facility. Also, the base case assumes that the contaminated material shipped from INMETCO is blended by itself for greater uniformity but is not diluted by blending with other non-contaminated material. Later, in Sec. 6.6, <u>lower</u> concentrations shipped from INMETCO, after additional blending, are evaluated. HRD has several Waelzing rotary kilns with capacity of up to 275 TPD each, and several calcining kilns with rated capacity of 240 TPD each. Plant capacity is about 490 TPD for both Waelzing and calcining phases. It is assumed here that Waelzing Kilns are used to process the contaminated EAF dust from INMETCO, <u>along with other material from other sources</u> at a typical blending ratio. As a separate operation, the Crude ZnO from the Waelzing Kilns is then assumed to go to the calcining kilns, <u>along with other ZnO from other sources</u> at

(1 **m**)

a typical blending ratio. The blending ratio for calcining must be about 2.5 to run at full capacity, because the ZnO product is only about 40% of the Waelz feed. For the base case, the Cs-137 concentration, C_c, is assumed to be 50 pCi/g (see Sec. 2.3). In Sec. 7, blending at INMETCO to lower concentrations is assessed. The Dose Conversion Factor (DCF) for exposure to a semi-infinite mass of contaminated material is given in Sec. 6.4.1 as 0.364 µrem/hr per pCi/g. Then, with a Waelz total feed rate, $W_w = 490$ TPD, the only other items of data input needed to evaluate concentrations in the equations in Sec. 6.4.1 are the two blend ratios, estimated to be 15 for the Waelz Kiln, and 2.5 for the calcining kiln. The ratio into the Waelz kilns for the average INMETCO shipping rate of 22 TPD is 490/22 = 22. But, the value of 15 (less dilution) is conservatively used here to allow for some variations in day-to-day deliveries. In addition, to calculate dose rates, appropriate area factors need to be evaluated, as discussed below. Calculation of direct radiation exposure then needs estimates of the number of exposure hours for a worker during the period INMETCO contaminated dust is processed, also discussed The releases to air and water pathways (Secs. 6.5.2 and 6.5.3 below) relate to below. concentrations compared to regulatory limits.

6.5.1 Assessment of Direct Exposure Pathway

<u>Area Factors</u>. The pneumatic tanker, used for EAF dust delivery to HRD, has a 6-sided trapezoidal shape as viewed from the side, shown in Fig. 6, with a person shown for scale. The approximation used in RESRAD to calculate area factors is a rectangle 8 m long by 3 m high, with triangular areas cut off of each end as shown by the shaded area in Fig. 6. Area factors were calculated by RESRAD for several receptor locations: center bottom (as for a person standing on the ground), $F_a = 0.41$, and standing at either end, 0.15. Higher up, at the center of



Fig. 6. Area factor model of pneumatic tanker.

the tank (as for seeking the greatest survey meter reading), 0.58 was obtained. For meter readings taken at very close distances, the effective area factor for the meter itself approaches unity.

Semi trailer dump trailers, also used for shipments to HRD, are 8' wide x 5'-6' high x 34'-40' long. The side of a typical trailer (not necessarily completely filled) is considered to be a rectangle 1.5 m x 11 m. The area factor for the center point of this rectangle is 0.33, calculated by RESRAD. The corresponding value at the center of the bottom edge (as for a person standing alongside) drops slightly to 0.30.

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. ج ک During processing at HRD, there are many configurations of the material, in piles, in conditioner, in kilns, in conveyors, etc. Details are not available to define all such areas. A worker at any location is in the vicinity of only a relatively small fraction of the total inventory in process. For assessment purposes, the simplifying assumption is that the mass to which workers are exposed at any point and at any time has face dimensions of 7 m x 2 m. The area factor for a receptor at the center of this area (or other equivalent combinations of dimensions) at a 1 m distance, is 0.45. This is the conservative value of F_a used for calculations throughout the processing sequence.

Exposure Duration. The term for this used by the NRC [14] is "worker time-integrated interactions with contaminated materials." As in the above discussion of area factors, details are not available to define the time-integrated interactions. The conservative assumption is therefore made that the potential exposure time for a worker, in hours, is the number of days for <u>input</u> of 300 tons (conservatively greater than the actual estimated 220 tons) of contaminated dust, plus the typical number of days for <u>completing</u> processing for any one batch, multiplied by eight hours. That is, it is assumed that a worker is exposed <u>full</u> shift time during the campaign to process the INMETCO contaminated dust. The shipping rate from INMETCO is about 22 TPD (8,000 TPY). At this rate, 300 tons (no additional blending for base case) requires 14 days. Six additional days are required at the end to complete processing, totalling 20 days. The maximum exposure time for any one worker becomes $20 \times 8 = 160$ hours (neglecting reduction for days off).

Base Case Direct Exposure Calculations. The dose rate for a worker standing alongside a pneumatic tanker containing 50 pCi/g dust, by Eqn. 3, is 7.5 μ rem/hr, and alongside a dump trailer is 5.5 μ rem/hr. Table 3 presents the base case calculation sequence for direct exposure after receival at HRD, applying the equations in Sec. 6.4.1. with F_a = 0.45. Input data items are listed in bold face. Recall that DCF = 0.364 μ rem/hr per pCi/g.

The maximum dose rate during the processing sequence in Table 3 is 8.2 μ rem/hr, occurring at the incoming pile of contaminated material before blending with other feed. Multiplying the dose rate by the total hours of exposure (160 hr) obtains a maximum total worker dose of only 1,310 μ rem (1.3 mrem). Note that the incoming material with Cs-137 concentration of 50 pCi/g is diluted 15:1 to 3.3 pCi/g as Waelzing feed. Concentration by 2.5:1 in the Waelzing kiln produces 8.3 pCi/g in the Crude ZnO product. This in turn is diluted 2.5:1 back down to 3.3 pCi/g as calcining kiln feed, and is reconcentrated by 8:1 to 26.6 pCi/g in the lead concentrate product during calcining. Thus, the concentrations during processing at HRD remain below the concentration in the material received from INMETCO, due to normal dilution with

feed materials from other sources. The indicated dose rates at all stages of processing are <u>far</u> below the regulatory limit of 2,000 μ rem/hr for a member of the public in an unrestricted area!

Table 3 Base Case Calculation Sequence

<u>Eqn. No.</u>	Item	Value	<u>Units</u>
	EAF dust Cs-137 conc.	$C_{c} = 50$	pCi/g
6	Base dose rate	$D_{base} = 18.2$	µrem/hr
0	Area Factor	$F_{a} = 0.45$	
7	Incoming EAF dust dose rate	D = 8.2	µrem/hr
,	Total Waelzing feed	$W_w = 490$	TPD
	Waelzing feed blend ratio	$W_{w}/W_{c} = 15$	
8	Waelzing feed Cs-137 conc.	$C_{w} = 3.33$	pCi/g
9	Blended material dose rate	D = 0.55	µrem/hr
10	Crude ZnO production	$W_{z1} = 196$	TPD
11	Crude ZnO Cs-137 conc.	$C_{z1} = 8.33$	pCi/g
7	Crude ZnO dose rate	D = 1.36	µrem/hr
1	Calcining blend ratio	$W_{z}/W_{z1} = 2.5$	
12	Calcining feed Cs-137 conc.	$C_{z} = 3.33$	pCi/g
7	Calcining feed dose rate	D = 0.55	µrem/hr
13	Calcining total feed	$W_{z} = 490$	TPD
14	Lead Concentrate production	$W_{Pb} = 61.3$	TPD
15	Lead Concentrate Cs-137 conc.	$C_{Pb} = 26.6$	pCi/g
7	Lead Concentrate dose rate	D = 4.36	µrem/hr

6.5.2 Assessment of Release to Air Pathway

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With $C_w = 3.33$ pCi/g from Table 3, and Eq. 16, the air concentration discharged from the Waelz stack following a complete failure of the bags in the Waelz baghouse is 0.29 pCi/L for the base case. The limit for unrestricted release of Cs-137 in air, per 10 CFR 20, is 0.2 pCi/L, somewhat lower than the calculated value. [Note: prior to 1994, the limit was a factor of 10 higher, at 2 pCi/L.]

With $C_z = 3.33$ pCi/g from Table 3, and Eqn. 17, the air concentration discharged from the calcining stack following a complete failure of the bags in the calcining baghouse is 0.45 pCi/L for the base case, about double the regulation limit.

6.5.3 Assessment of Release to Waste Water

With $C_{Pb} = 26.6 \text{ pCi/g}$ from Table 3, and Eq. 18, the concentration in waste water at the Lead/Cadmium Concentrate Processing Facility can reach 2.90 pCi/ml for the base case. The limit for unrestricted release of Cs-137 in water, per 10 CFR 20, is 1.0 pCi/ml, and for release to sewers is 10 pCi/ml. [Note: prior to 1994, the unrestricted limit was a factor of 20 higher, at

20 pCi/ml.] The calculated value is greater than the limit for unrestricted release, but is within the limit for release to sewers.

6.6 Assessment of Additional Blending at INMETCO

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The above base case considers treatment at HRD without diluting the stored contaminated material with non-contaminated material. Section 7 describes and assesses blending operations The other blending ratios applied at INMETCO (total blended mixture: at INMETCO. contaminated material) reduce the incoming Cs-137 concentration approximately inversely proportional to the blending ratio. For example, a blending ratio of 2.0 reduces the modeled Cs-137 concentration from 50 to about 25 pCi/g. The concentration does not decrease quite in proportion to the blend ratio because the added material is assumed to have an average environmentally occurring Cs-137 concentration of 1.5 pCi/g. Correspondingly, the concentration in product and the dose rate for exposure to a mass of product at each stage of processing, are approximately inversely proportional to blending ratio. Similarly, air concentrations with accidental stack releases, and the concentration in the eventual release to waste water decrease with an increase in the blending ratio. However, the volume and weight of material, and corresponding number of shipping days, increases in direct proportion to the blending ratio. The exposure hours and corresponding maximum worker dose increase at slightly less than in direct proportion due to the fixed 6-day trailing completion time. Because increased exposure time is offset by decreased Cs-137 concentration (decreases dose rate), the total worker dose of only about 1 mrem does not change greatly, but decreases slightly as blending ratio increases.

The affected values from Table 3 are given in Table 4 (on the following page) with the proportional adjustments listed for several blend ratios. The Blend Ratio = 1 represents the previously discussed base case. It may be noted that increasing the blend ratio to a value of three drops the calculated air concentration for an accidental release to either the Waelz or calcine stacks to less than the 0.2 pCi/L limit and drops the waste water concentration to about the 1.0 pCi/ml limit for unrestricted release (though the release to sewers limit was met with the base case unity blend ratio).

	1	2	3	4	8	10
Incoming						
C_c pCi/g	50	25.8	17.70	13.6	7.6	6.4
D _{base} µrem/hr	18.2	9.4	6.44	4.95	2.77	2.33
$(xF_a=0.45)$ D µrem/hr	8.2	4.2	2.90	2.23	1.24	1.05
Waelzing Feed						
C _w pCi/g	3.33	1.72	1.18	0.91	0.51	0.43
D µrem/hr	0.55	0.28	0.19	0.15	0.08	0.07 .
Crude ZnO Product						
C ₁ pCi/g	8.33	4.30	2.95	2.28	1.28	1.08
D µrem/hr	1.36	0.70	0.48	0.37	0.21	0.18
Calcining Feed						
C _z pCi/g	3.33	1.72	1.18	0.91	0.51	0.43
D µrem/hr	0.55	0.28	0.19	0.15	0.08	0.07
Pb Conc. Product						
C _{Pb} pCi/g	26.6	13.76	9.44	7.28	4.08	3.44
D µrem/hr	4.36	2.25	1.55	1.19	0.67	0.56
Waelz Stack pCi/L	0.29	0.15	0.10	0.08	0.05	0.04
Calcine Stack pCi/L	0.45	0.23	0.16	0.12	0.07	0.06
Waste Water pCi/ml	2.90	1.50	1.03	0.79	0.44	0.37
Receival Days	14	28	42	56	112	140
Completion Days	6	6	6	6	6	6
Exposure Hours	160	272	384	496	944	1168
Max. Worker Dose Rate						
urem/hr	8.2	4.2	2.9	2.2	1.2	1.1
Max. Worker Dose mre	m 1.31	1.14	1.11	1.11	1.17	1.23

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Blend Ratios

7. BLEND CONTAMINATED MATERIAL AT INMETCO

The third alternative is to "truck blend" contaminated stored material with other noncontaminated material at INMETCO, to dilute the Cs-137 contamination concentration and to obtain more uniformity, for shipment to HRD. For the base case in Sec. 6, "Process Directly at Horsehead," no dilution is assumed. Thus, the base case at INMETCO considers blending of only the stored material by itself to achieve more uniformity prior to shipping. This is followed by consideration of adding various multiples of non-contaminated new material to reduce the concentration in shipments to HRD.

7.1 Blending Methods

Ideally, all 260 boxes of stored material would be blended to uniformity as a first step. As this is not readily accomplished, the method used should draw from as many boxes as possible for any one shipment in order to approach uniformity.

One method being considered by INMETCO for the base case is to simply distribute the - contents of one storage box after another along the length of a dump trailer. If trailers are loaded to about the same extent as they were before transfer into the boxes, each trailer load can accommodate the equivalent of about 24 boxes. The degree of blending attained depends upon how much rotation among boxes and extent of spreading is done during loading. Ideally, only a portion of each box would be distributed into a trailer at a time, and loading of each trailer would draw partially from an inventory much larger than 24 boxes. A means for stirring to promote mixing may not be available. This method can also be applied to addition of non-contaminated materials, in which case a rotation sequence includes increments of the added material.

Another method appears to be preferred for blending with added materials. INMETCO has a way to feed the contaminated material into the dust handling line after the baghouse, as newly generated dust is being transported to the storage silo. In normal operations, 28-35 pounds of dust per minute (1,660-2,100 lb/hr) to the baghouse system is generated. Feeding in the contaminated material at some rate within the total handling rate capacity would promote mixing as well as dilution. Ideally, the feeding should rotate among many boxes to achieve the maximum uniformity.

Estimates of Cs-137 concentration, in Appendix A, suggest that the average concentration in the stored material is not greater than about 30 pCi/g, but 50 pCi/g is assumed to cover uncertainty and variations. The concentrations vary greatly within each box and from box-to-box. The more finely the incrementing and the greater the number of boxes drawn from during each loading operation, the more uniform will be the blending result.

7.2 Risk Assessment

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7.2.1 Area Factors and Dose Rates

It will be helpful to first define the applicable area factors, F_a (see Sec. 4.1), and corresponding calculated dose rates to be used. The handling of boxes will range from a single

box to rows of boxes. The area factor at a distance of 1 m from the center of a single box (assumed to be 80% full), calculated by RESRAD, is 0.096. As boxes are added in a row, the exposure increases. The area factor at the center of 3 boxes becomes 0.169, for 5 boxes is 0.196 and for 10 or more is 0.205. As one moves from the center of a row to the end of a row, the effective area factor decreases. For example, at the end box in a row of 5 boxes, the area factor decreases from 0.20 to 0.15. Details of the blending procedure to be used are not available to define the expected time-integrated worker interactions with contaminated materials. Therefore, for operations involving collections of boxes in a row, $F_a = 0.20$ is conservatively assumed. This value is the approximate maximum for a row of up to 10 or more boxes. If additional boxes are grouped into additional rows, they are shielded by the front row from increasing exposure. By Eqn. 7, for $C_c = 50$ pCi/g, the exposure rate during handling of boxes for the blending operation becomes 3.6 µrem/hr above background.

After transfer of blended material to a pneumatic tanker or dump-trailer, exposure to areas of increased masses are involved. From Sec. 6.5.1, and Fig. 6, The area factor for a worker standing alongside the center of a pneumatic tanker is 0.41, and for a typical dump-trailer is 0.30. The corresponding dose rates for an undiluted average concentration of 50 pCi/g become 7.5 and 5.5 μ rem/hr (above background). Corresponding meter readings taken close to the surface of either vehicle (e.g. a distance up to 0.15 m), with effective area factor of 1.0, are calculated to be 18 μ R/hr, plus estimated 7 μ R/hr background, or 25 μ R/hr indicated. For material blended with additional non-contaminated material, the dose rates and meter indications decrease approximately in proportion to the blend ratio.

7.2.2 Blending Operations

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It was estimated at INMETCO that blending in a dump trailer will require 1.5 to 2 hours per box handled. For blending the 260 boxes of stored material by themselves, without adding non-contaminated material, a total exposure time of 390 to 520 hours will be required. Using the longest estimated time and the previously discussed 3.6 μ rem/hr for box handling, the maximum individual worker exposure becomes 1.9 mrem (1,872 μ rem). This represents a worker exposed for the full duration of the operations. If the work is done continuously on a three shift basis, an individual worker would be exposed to one-third of the total or about 0.6 mrem, neglecting further reduction by days off during the three weeks of operations.

Blending with added materials by feeding the contaminated material into the dust handling line requires considering the normal handling rate of 1,660-2,100 lb/hr. This rate represents approximately one box per hour if no other material is added, assuming the system can handle the high-moisture-content stored material without addition of dry newly generated dust. Also, this full use of handling capacity necessarily would involve interruption of the normal operation flow. However, because of the estimate of up to two hours per box for handling, it appears that about 0.5 boxes per hour would be the maximum feed rate of contaminated material into the dust handling line. This contaminated feed rate would require 520 hours for the 260 boxes and would imply a blend ratio of 2:1. Also, it appears that this would still impact about one-half of the normal operation flow rate and may not be acceptable for the three week period involved. Going to higher blend ratios allows the contaminated material to merge with newly generated material within the total handling capacity and causes less to no impact on normal operations. Table 5 lists the Cs-137 concentrations in the blended product, the exposure time and corresponding dose

for a range of blending ratios. Dose is based upon the assumed 50 pCi/g material being handled in boxes, not the blended product. The concentration does not decrease quite in proportion to the blend ratio because the added material is assumed to have an average environmentally occurring Cs-137 concentration of 1.5 pCi/g. Worker dose, using 3.6 μ rem/hr from Sec. 7.2.1, is given for exposure to the full operations duration and for the more likely 40-hour week for an individual during continuous operations. Any rotation of workers would further reduce the already low individual dose.

Table 5. Blending Parameters

Blend	C,	Operatio	on Time	Dose, mrem	Dose, mrem
Ratio	pCi/g	hours	weeks	full time	40-hr wk
2.0	25.8	520	3.1	1.9	0.5
3.0	17.7	780	4.6	2.8	0.7
4.0	13.6	1040	6.2	3.8	0.9
6.0	9.6	1560	9.3	5.7	1.3
8.0	7.6	2080	12.4	7.6	1.8
10.0	6.4	2600	15.5	9.4	2.2

If we assume the average load transported to HRD in pneumatic tankers and dump trailers is 20 tons, the annual rate of 8,000 tons requires 400 loads, or an average of 7.7 per week. Table 6 lists the number of loads required and the equivalent number of boxes of stored material in each load corresponding to various blend ratios for the Blending/Loading/Transport campaign.

Table 6. Shipment Breakdown vs. Blend Ratio

Blend Ratio	Weeks Duration	No. Loads	Boxes/Load
2.0	3.1	24	10.8
3.0	4.6	35	7.4
4.0	6.2	48	5.4
4.0 6 0	9.3	72	3.6
8.0	12.4	96	2.7
10.0	15.5	119	2.2

In Table 6, the number of boxes per load represents the equivalent with portions taken from many more than the numbers shown, in an attempt to approach uniformity.

Table 7 lists the calculated dose rates after transfer of blended material to pneumatic tankers and dump trailers, assuming uniform Cs-137 concentrations at the indicated values. The column for meter readings, including an assumed background level of 7 μ R/hr, is for close-up (e.g. 0.15 m) readings, as seems to be the practice for inspectors attempting to "get good readings."

Dose Rate Above Background, urem/hr		Close-Up Meter Rdg., μR/h	
C _c pCi/g	Tanker $F_a=0.41$	Trailer $F_a=0.30$	Incl. Background $F_a=1.0$
50	7.5	5.5	25
25.8	3.9	2.8	16
17.7	2.6	1.9	13
13.6	2.0	1.5	12
96	1.4	1.1	10
7.6	1.1	0.8	10*
6.4	1.0	0.7	9*
	C _c pCi/g 50 25.8 17.7 13.6 9.6 7.6 6.4	$\begin{array}{c c} & \text{Dose Rate A} \\ \underline{Background} \\ C_c & Tanker \\ pCi/g & F_a=0.41 \\ \hline 50 & 7.5 \\ 25.8 & 3.9 \\ 17.7 & 2.6 \\ 13.6 & 2.0 \\ 9.6 & 1.4 \\ 7.6 & 1.1 \\ 6.4 & 1.0 \\ \hline \end{array}$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $

Table 7. Dose Rates for Loaded Tankers and Dump Trailers

* values of 10 and 9 are 3 and 2 μ R/hr above background, respectively.

The assessment of HRD operations in Sec. 6 indicated (Table 4) that blending with a ratio of 3.0 or greater at INMETCO would reduce the concentrations processed at HRD sufficiently to avoid exceeding allowable stack release to air in the event of a bag room failure, and also would reduce the concentration in waste water at the Lead/Cadmium Concentrate Processing Facility sufficiently to allow unrestricted general release in water as well as in the less restrictive release to sewers (met without dilution blending). A blend ratio of 3.0 (Tables 5 and 7) obtains an average concentration of less than 20 pCi/g for shipping.

It appears that blending at ratios of 4.0 or greater could be absorbed by the system capacity and would avoid interfering with normal operation flow in the dust handling line between the baghouse and storage silo.

The alarm level for acceptance at HRD is meter readings of 2-3 μ R/hr above background. Table 7 indicates that this would be marginally reached with blending ratios at INMETCO of 8.0 to 10.0. The corresponding indicated Cs-137 concentration would be 7.6 and 6.4 pCi/g, respectively. Uncertainties in these calculations and in the attainable degree of uniformity in blending make it marginal to depend upon meeting the current HRD acceptance criterion by blending at 10:1. Table 5 indicates that a blending ratio of 10 would require four months to complete the campaign.

A question was raised concerning reducing the Cs-137 concentration to the 2.5 pCi/g level. Considering that the "non-contaminated" material can be expected to itself have environmental Cs-137 at a level of about 1.5 pCi/g, it would require a blending ratio of almost 50:1 to achieve a reduction of the assumed 50 pCi/g material to an average of 2.5 pCi/g. This would require almost 600 shipping loads during continuous operation over a 1.5 year campaign. The equivalent of only one-half of a box per load would be involved.

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8. SEND TO RCRA LANDFILL

8.1 Description of Alternative

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This disposal alternative is to ship the stored material to a Subtitle C, RCRA-permitted landfill facility. After receival at the facility, EAF dust is treated with additives to stabilize the material to meet TCLP leaching requirements [19], followed by emplacement in a disposal trench. A trench is designed with a double liner and leachate collection system. A typical trench has a base of about 3 feet-thickness of low-permeability clay, covered by a 60-mil Flexible Membrane Liner (FML). Above this, in sequence, is a drain net (molded grill-like material), filter fabric, a second FML and another drain net, 12 inches of sand, and 6 inches of coarser filter material. Above this, waste is emplaced to a depth of 25-50 feet and covered with 9 feet of cover, consisting of layers of low-permeability fill, coarse filter material, fill, and top soil. Finally, the surface is contoured and grassed to promote runoff of precipitation and minimize erosion.

Emplacement typically is in narrow bands, up to 1 m wide, building up from the bottom and tamped as filling proceeds. Treatment before disposal introduces approximately 30 g of additives per 100 g of dust, and moisture as needed, in a mixer-blender. This dilutes Cs-137 contamination by a factor of 0.77, and increases volume by a factor of 1.3.

8.2 Risk Assessment

A 1993 study by Logan, summarized in a 1994 paper [15], applied the RESRAD computer code [16,17] and considered all of the potential exposure pathways associated with disposal in a RCRA facility, and eliminated those that are not credible. The remaining pathways were: 1) direct exposure during transportation, receival, treatment, and disposal emplacement, and 2) drawing drinking water from within or near the facility. Later, the NRC applied similar analysis and issued guidance for this disposal option in their staff technical position issued in March 1997 [14]. For assessment purposes here, both of these studies are utilized.

The NRC position [14] would allow disposal of up to 100 pCi/g Cs-137 contaminated EAF dust transported in bulk form. Their supporting analysis uses 2,000 tons of material containing 100 pCi/g. A typical handling rate of 500 tons per shift requires four shifts or 32 hours of worker exposure time for receival, treatment, and disposal. The emplacement is assumed to be a volume 20 ft wide, 100 ft long, and 20 ft deep. Their conclusions were that EPA drinking water standards would not be violated at any point in the ground water, and that worker exposure would be limited to less than 1 mrem per incident. In the INMETCO case, less than 300 tons of material are involved, and the contamination is estimated to be not over 30 pCi/g (Appendix A) but is conservatively assumed to be 50 pCi/g instead of 100 pCi/g. Therefore, identical analysis would indicate a worker exposure of less than 0.1 mrem.

The Logan study considered an extreme case in which contaminated material is <u>continuously</u> received, workers are exposed 2,000 hours per year, and a disposal trench is <u>completely</u> filled with 20 pCi/g contaminated material. For the unlikely case that drinking water is continuously drawn directly from the leachate collection zone after the 30-year post closure monitoring period, the dose rate obtained was less than the drinking water limit of 4 mrem/y.

For our present assessment, with a doubled 40 pCi/g concentration assumed $(0.77 \times 50 = 39 \text{ pCi/g after treatment})$, but filling less than 0.2% of the trench capacity, clearly leads to a much lower dose rate than in the earlier extreme case. For drinking water drawn from a well drilled to the underground aquifer (a depth of about 100 ft below the waste), it was found that downward migration is sufficiently slow that Cs-137 decays virtually to zero long before the aquifer is reached, plus subsequent further delay in retarded horizontal flow to a well.

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Finally, we can update estimates of direct radiation exposure. During shipment in a pneumatic tanker, the dose rate to a person standing along side, 1 m from the center of the trailer (area factor = 0.41), from Eqn. 4 is 18.2 x 0.41 = 7.5 µrem/hr. The corresponding dose rate for a person taking radiation measurements at a higher level (1 m distance) opposite the tank center (area factor = 0.58) becomes 10.5 µrem/hr. Expected meter readings, if taken very close to the tank surface (effective $F_a = 1.0$), would be 18.2 µR/hr plus 7 µR/hr background, or about 25 µR/hr total. Transportation regulations permit 10 mrem/hr at a distance of 1 m, a factor of 1,000 higher than with our shipment! At a handling rate of 500 tons of incoming material per shift, 300 tons would require 5 hours, but to be conservative, a full 8 hour shift is assumed. During treatment, assuming exposure to an average 8 m x 2 m area of material (area factor = 0.42), the dose rate is (Eq. 4) 18.2 x 0.42 = 7.6 µrem/hr and over 8 hours the dose becomes 61 µrem.

Treatment increases the 300 tons (also about 300 yd³) volume to $1.3 \times 300 = 390 \text{ yd}^3$, which happens to also be about 300 m³. Emplacement can be expected to be dispersed to several locations in a trench from load-to-load, and perhaps all placed in one vertical 1 m-wide band, but here it is assumed that a dedicated zone is used, either 5 m wide x 30 m long x 2 m deep (surface area factor = 0.76), or 10 m wide x 30 m long x 1 m deep (area factor = 0.88). The corresponding dose rates for the 40 pCi/g concentration after dilution by treatment, by Eq. 3, become 0.364 x 40 x 0.76 = 11.1 μ rem/hr, and 0.364 x 40 x 0.88 = 12.8 μ rem/hr, and over 8 hours the doses are 89 and 102 μ rem, respectively for these two alternate emplacement geometries.

As the cover is emplaced, the dose rate from emplaced waste material decreases virtually to zero. The indicated total dose to any of the workers from receival, treatment, or disposal emplacement of up to 300 tons of incident-related material is limited to less than about 100 μ rem (0.1 mrem). Independently, the quantity and Cs-137 concentration are well within the factors considered acceptable by the NRC [14].

9. DISCUSSION

Much of this report deals with characterizing the stored material in the absence of comprehensive assay and other properties data. The available data is examined in several ways leading to a conclusion that the average concentration of Cs-137 is not over 30 pCi/g. To allow for variations in concentrations remaining after further blending, and for other uncertainties, 50 pCi/g is assumed for risk assessment purposes. Ingestion and inhalation exposure pathways are shown to not be of concern. The direct exposure pathway is examined for all of the alternatives considered, but exposure levels are found to be low to minuscule. The final choice of the alternative to be used depends upon operational costs, appeasement of perceived risk by workers and at facilities, and upon revised regulatory provisions.

Baghouse dust with an environmental presence of up to 2 pCi/g Cs-137 is routinely processed at INMETCO and HRD. Radioactive material at very much higher radioactive concentrations than in the subject material, but without hazardous content, is routinely handled. But here, we have a mixed waste material, both slightly radioactive and with a hazardous content. While regulatory accommodation was recently obtained for disposal in a Subtitle C, RCRA-permitted landfill [14], the provision for recycle via High Temperature Metal Recovery, such as at HRD, is not yet available. Discussion of the risk assessment for each of the alternatives considered follows.

9.1 Indefinite Storage at INMETCO

The present storage in boxes in a warehouse presents very little risk. The dose rate calculated for direct exposure to a worker is $3.6 \,\mu$ rem/hr, and the presence of a worker in the vicinity is a rare occurrence. This dose rate is lower than the 2,000 μ rem/hr regulatory limit for a member of the public in an unrestricted area, by a factor of greater than 500. Continued storage is primarily a question of convenience versus the costs and continued annoyance.

9.2 Process Directly at Horsehead

ر. ویک The base case for processing at HRD assumes 50 pCi/g undiluted material shipped from INMETCO. Any cesium in the Waelzing feed is concentrated by a factor of 2.5 into the Crude ZnO product. And cesium in the calcining feed is concentrated by a factor of 8 into the lead/cadmium product. This concentration characteristic is more than offset by blending of the Waelz feed by 15:1 with material from other sources and by blending of the calcining feed by 2.5:1 with material from other sources. The maximum dose rate relates to a pile of incoming INMETCO material, prior to Waelz feed blending, and is calculated to be 8.2 µrem/hr. This decreases to 0.55 for Waelz feed, concentrates to 1.4 in the Crude ZnO product, is diluted to 0.55 for calcining feed, and concentrates to 4.4 µrem/hr for the lead/cadmium concentrate. Thus, the concentrations during processing at HRD at all times remain below the concentration in the material received from INMETCO. The total individual exposure time during processing is shown to be 160 hours. The corresponding maximum individual dose for exposure during the treatment campaign is 1.3 mrem. This is only about 2% of the annual direct exposure from background radiation and represents virtually no risk.

In the unlikely event of a total failure of bags in one or the other of the baghouses (still the base case with 50 pCi/g from INMETCO), the potential cesium concentration in air from the stack is calculated to be up to 0.29 pCi/L from the Waelz baghouse, or 0.45 pCi/L from the calcining baghouse. These represent factors of 1.5 and 2.3 over the 0.20 pCi/L regulatory limit. Release to waste water at the Lead/Cadmium Concentrate Processing Facility is calculated to be 2.9 pCi/ml, which is well within the 10 pCi/ml limit for release to sewers but above the limit of 1.0 pCi/ml limit for unrestricted release to water. Diluting the incoming material from INMETCO by 3:1 would bring both the accidental release to air and the release to waste water within all limits.

Additional blending at INMETCO reduces the concentration received at HRD, but increases the duration of the processing campaign. Table 4 provides parameter values for blending at ratios of 2:1 to 10:1. Blending at ratios of more than the 3:1 mentioned above do not appear to offer any advantage in HRD processing unless imposed to meet arbitrarily established acceptance criteria at HRD. For example, a 10:1 blending at INMETCO appears to marginally meet the present 2-3 μ R/hr above background acceptance level. Increasing acceptance to 6 μ R/hr (above background) would marginally accommodate the 3:1 dilution discussed above.

9.3 Blend Contaminated Material at INMETCO

Objectives for blending at INMETCO are: 1) blend existing material for greater uniformity, and 2) dilute with non-contaminated material as needed to meet any new acceptance criteria at HRD. Blending only the existing material is estimated to require 390 to 520 hours, with the exposure rate to a worker handling boxes of 3.6 μ rem/hr. The maximum individual worker exposure, for a worker exposed for the full duration of the operations, becomes 1.9 mrem. If pursued on a three-shift basis, the dose to an individual drops to about 0.6 mrem. After loading a pneumatic tanker with blended average 50 pCi/g material, the dose rate to an individual alongside is calculated to be 7.5 μ rem/hr. The corresponding dose rate alongside a dump trailer is 5.5 μ rem/hr. These low dose rates are below the transportation limits by a factor of more than 1,300!

Blending at various ratios of 2:1 to 10:1 (Tables 5-8) indicate worker dose for 40-hour work weeks of 0.5 mrem to 2.2 mrem, respectively. These are minimal dose levels. A ratio of 3:1 represents less than 20 pCi/g in the blended material and would avoid the potential for excessive release to air at HRD in the event of a bagroom failure. A ratio of at least 4:1 appears to avoid interfering with the normal flow of newly generated dust at INMETCO and may be desirable for that reason. Blending at 8:1 to 10:1, on average, appears to marginally meet the present 2-3 μ R/hr above background acceptance level at HRD. However, in the absence of completely uniform blending, this basis risks rejection of some loads.

As the blending ratio is increased, the duration of the processing campaign (up to four months for 10:1) increases with no risk reduction benefit beyond 3 or 4:1. The choice of blend ratio comes down to tradeoffs in operational costs, capacity in the transfer line, and the new level for acceptance at HRD.

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9.4 Send to RCRA Landfill

This disposal alternative is less preferred than recycle alternatives with HTMR processing at HRD. Shipment of the existing inventory of stored waste to a Subtitle C, RCRA-permitted landfill facility results in a calculated dose to a worker at the facility for soil stabilization treatment and emplacement of about 0.1 mrem. The 50 pCi/g assumed concentration is well within the NRC value of 100 to 130 pCi/g, deemed to meet risk requirements [14].

10. RECOMMENDATIONS

1. The low concentration of Cs-137 in the contaminated EAF dust currently being stored at INMETCO does not cause any significant risk for any of the alternatives considered. The only instance of approaching or exceeding a regulatory limit is the potential for exceeding the air concentration limit in the exhaust stacks at HRD in the unlikely event of a total baghouse failure, if undiluted 50 pCi/g material is shipped from INMETCO. Modest dilution by blending at INMETCO at 3:1 or greater avoids any such potential problem.

2. Continued storage at INMETCO presents no significant risk. However, this alternative only postpones the inevitable need to resolve the issue with appropriate disposition. Continued storage until relaxed conditions are obtained to permit recycling by HTMR is recommended.

3. Blending operations at INMETCO, whether blending only the existing material by itself or adding non-contaminated material, should strive for the maximum degree of uniformity by incrementing from individual boxes and drawing from as many boxes as possible for each blended load. The purpose here is to maximize the validity of the analyses in this study, and to avoid having a load rejected at HRD because of a "hot spot" detected upon receival of an otherwise acceptable average concentration.

4. Steps should be taken to establish a validated relationship between Cs-137 concentration and survey meter readings. Here again, the greater the uniformity achieved, the better will be this relationship, because survey readings only "see" the outer 0.1 to 0.2 m of dust in a tanker or trailer. During blending of each load, particularly the first load, frequent small samples should be dipped out (and if trailers, draw from several zones) and mixed for an average assay and moisture content sample for the load. After loading a tanker or trailer, survey meter readings should be taken in many locations over the surface, with distance controlled to that currently being used by the HRD inspection staff. The average corrected reading, D, and the associated assay value, C_{er} can then be used to establish the value of K in the following relationship:

$$D = K \times C_{c}$$
(19)

This is in the same form as Eqn. 3, in which DCF and the effective area factor, F_a , are incorporated in the constant K.

5. Operational capabilities and limitations should be reviewed at INMETCO to confirm or modify the conclusion that a blending ratio as low as 4:1 can be accommodated in the Dust handling system without interfering with normal new generation of dust. If so, this ratio, or if possible 3:1, appears to be preferred, to obtain less than 20 pCi/g in shipments to HRD.

6. Regulatory agencies should be requested to allow a relaxation in the acceptance criteria at HRD. Modest relaxation from 2-3 μ R/hr above background to 6 μ R/hr appears to marginally accommodate 3:1 blending (to about 18 pCi/g), but relaxation to as much as 20 μ R/hr is a preferred objective. The analysis method used in this report parallels the method used by the NRC in reaching their staff position approving disposal in a RCRA landfill.

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- 10. 40 CFR 141. Code of Federal Regulations, Title 40, Part 141, National Primary Drinking Water Regulations.
- 11. 10 CFR 60. Code of Federal Regulations, Title 10, Part 60, Disposal of High-Level Radioactive Waste in Geologic Repositories.
- 12. 10 CFR 71. Code of Federal Regulations, Title 10, Part 71, Packaging and Transportation of Radioactive Material.
- 13. 49 CFR 173. Code of Federal Regulations, Title 49, Part 173, Shippers--General Requirements for Shipments and Packagings, Par. 173.441: Radiation Level Limitations.
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APPENDIX A. CHARACTERIZATION OF STORED MATERIAL

At the present time, an estimated 220 tons of EAF dust, previously contaminated with Cs-137 and processed at INMETCO, is being stored at INMETCO. There are also an estimated 50 tons of filter cake from the INMETCO processing in storage. The sequence is tracked in following paragraphs.

A1. Source of Contaminated Material

An inadvertent smelting of an industrial Cs-137 source occurred at a North American stainless steel producer. An assay sample from the first pneumatic tanker load of EAF dust (22.73 tons of baghouse dust) following this incident indicated contamination with Cs-137 at 210 pCi/g. As this radioactive content was far below the 2,000 pCi/g allowable limit for transport, the load was transported to INMETCO for processing to recover nickel, chromium and iron. Further shipments of EAF dust from the smelting incident were not accepted at INMETCO. As an estimate of the Cs-137 content, assume the assayed 210 pCi/g was uniform throughout the load and/or represents the average level. This indicates a total of 4.3 mCi (millicuries), but the single assay sample involves a large uncertainty. Other information indicates that the concentration varied considerably.

A2. Processing at INMETCO

The load of incident material was off-loaded into one of the dust storage silos. Approximately 80% of this dust (17.7 to 18.7 tons) was fed through the INMETCO facility, along with a quantity of other dust and feed material. There are two elevated temperature steps in the processing where volatilization of cesium can occur: the Rotary Hearth Furnace and the submerged arc smelting furnace. Most of the cesium can be expected to be released into baghouse dust from the arc furnace. From the Rotary Hearth Furnace, the offgas treatment vents gas from the quencher through a cyclonic separator and scrubber. Solid material (plus water) goes through a clarifier and into a filter press. Any quantity of cesium that may have been vented through the stack or released in water from the clarifier is unknown, but the filter cake indicates a low Cs-137 content. A sample from the 50 tons of filter cake shows 4.2 pCi/g which, if uniform throughout, represents only 0.5 mCi total.

The total EAF dust collected after feeding approximately 18.2 tons of incident material, blended with an unknown amount of uncontaminated feed material, trailed by sufficient uncontaminated material to purge the system and reduce radiation levels to normal values, was isolated. The earliest portion of the resultant dust (17.2 tons) was loaded into a pneumatic tanker and the balance was loaded temporarily into ten dump trailers. When the pneumatic tanker was sent to Horsehead Resource Development Company (HRD), it was found that radiation measurements there greatly exceeded their acceptance value and the shipment was returned. Subsequently, the dust was transferred into 260 tri-wall cardboard boxes, one cubic yard in size, with an 8 mil thick polyline (LLDPE) bag liner, and placed into storage. The contents of the pneumatic tanker, apparently of higher Cs-137 concentration, was dispersed into the other material during the transfer into boxes. After the initial loading into the pneumatic tanker and dump trailers, the tanker and five of the trailers were weighed, indicating an estimated total material weight of 220 tons. If this was all "as generated" dry material, it indicates a ratio of blended material to contaminated material of 11:1. However, the baghouse dust is hygroscopic and moisture was absorbed during storage in trailers and during transfer to boxes. If a portion of the 220 tons represents subsequent moisture addition, the actual blending ratio when processed through the INMETCO facility would be less, perhaps as low as 8:1.

The 50 tons of filter cake are in storage. In order to simplify the risk analysis covered by this report, further consideration of the filter cakes and and any other unprocessed material is not done. It is expected that guidance resulting from this study can later be extended to disposition of any other stored material.

A3. Estimates of Contamination Concentration

Ideally, assay samples would be drawn from various zones in each of the 260 storage boxes and measured to obtain the average concentration and its variations from box-to-box. However, this would be prohibitively expensive. There are several categories of data that can be examined to arrive at estimates of the Cs-137 concentration in the stored dust.

A3.1 Initial Material Basis

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Assume the reported assay sample value of 210 pCi/g for the initial sample represented the average concentration. In the initial material processed at INMETCO, if all of the indicated 4.3 mCi of cesium was transferred into the 220 tons of EAF dust exiting the INMETCO process (and neglecting the indicated few percent showing up in the filter cake), the average becomes 21 pCi/g.

A3.2 Pneumatic Tanker and Dump Trailer Storage

A sample from the pneumatic tanker was assayed at 82 pCi/g. A sample from each of five of the ten dump trailers was assayed, showing 28, 20, 11, 5.8, and 4.7 pCi/g, averaging 11.9 pCi/g. It is not known whether the assay samples were single "grab samples" in each case or were blended from numerous locations. Radiation survey readings for the tanker are reported as 70 μ R/hr, and for the dump trailers ranging from 13 to 16 μ R/hr (average 15) for the five sampled trailers, and 9 to 33 μ R/hr (average 22) for the five other trailers that were not assayed. The tanker is reported to have received the first dust generated during the INMETCO processing. As later dust deposited in trailers included progressive dilution by purging the system with noncontaminated material, it can be expected that the Cs-137 concentration in the tanker was greater than at least in some of the trailers. The tanker and trailer data is summarized in Table A-1. The average concentration for the five not-assayed trailers is estimated (17.5 pCi/g) to be higher than for the assayed trailers in proportion to the respective average survey readings. The implied radioactivity in each storage unit, obtained from the weights and assay values, are shown in Table A-1. The 4.0 mCi total, derived from the assay values, is close to the previously mentioned 4.3 mCi. If assumed dispersed throughout the 220 tons, it represents 19.6 pCi/g. Because of varying measurement geometries, limited assay sampling, and due to self-shielding in the dust (survey readings result from only the outer 0.1-0.2 m of dust), the indicated concentrations must be regarded as approximate.

Table A-1. Survey and Assay Summary

Гуре	Volume lbs	Survey µR/hr *	Avg. Assay pCi/g	Activity mCi
Pneumatic Tanker	34,480	70	82	1.3
Dump Trailers (assayed)	200,000	15	11.9	1.1
Dump Trailers (not assayed)	206,120	22	17.5 est	1.6
TOTAL	440,600 (220) tons)		4.0

* Survey readings not corrected for background.

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An attempt to correlate the average assay values with the calculated concentrations corresponding to the reported survey readings (corrected for average 7 μ R/h background) is summarized in Table A-2. From Eqn. 5, for D in units of μ R/h,

$$C_a = D/(0.364 \times F_a), \ pCi/g$$
 (A-1)

Because the survey readings were reported to have been taken very close to the surfaces of the relatively large tanker and trailers, the area factor, F_a (defined and explained in Sec. 4), is assumed to be equal to unity.

Table A-2. Correlation of Concentration Indications.

	Net Survey	Calc.	Assay
	µR/h *	pCi/g	pCi/g
Pneumatic Tanker	63	173	82
Assayed dump trailers	8	22	11.9
Non-assayed dump trailers	15	41	17.5 est
Weight-based averages		33	15

* Net Survey values are corrected for 7 μ R/h background.

Reasons for the calculated concentrations being about twice the assay values are not apparent. Details regarding the assay sampling method are not available.

A3.3 Storage in Cubic Yard Boxes

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The contaminated material initially stored in a tanker and trailers was transferred to 260 boxes, each with a nominal capacity of one cubic yard. This transfer accomplished some blending of the tanker and trailer contents, partially leveling the large variation in concentrations. These boxes are currently stored in a warehouse in several groups. The largest group has 92 boxes, arranged in one row of 4 boxes, 10 rows of 7 boxes each, and 3 rows of 6 boxes each. That is, this largest group is generally in a close-packed 14 x 7 single layer array. The other large group has 52 boxes, in a roughly 12 x 6 array, but not close-packed. The remaining 116 boxes are in small groups of 8 to 20 boxes each. The geometry and survey meter readings for accessible boxes in the two larger groups are described in some detail in Section 5 (Indefinite Storage at INMETCO).

The average of 41 survey meter readings for perimeter boxes in the largest group was 10.7 μ R/h, with a range of 8 to 14 μ R/h. Subtracting the mean background of 7 μ R/h obtains an average net value of 3.7 μ R/h, with a range of 1 to 7 μ R/h. The area factor for a receptor 1 m from and centered on an area 0.73 m (average height of fill in boxes) x 10 m (row of 10 boxes) is 0.20. This value is insensitive to a variation of several boxes more or less. It is estimated that the effective area factor at the measurement distance of 0.15 m is larger by a factor of 3, or 0.60. By Eqn. A-1, the apparent cesium concentration is 16.9 pCi/g. One measurement was taken pointing down at the top center of the array, obtaining a mean corrected reading of 6.5 μ R/h. The relatively large area of the array top surface has an area factor of 0.80 at a distance of 1 m, estimated to be 0.90 at the measurement distance of 0.3 m. The corresponding calculated concentration is 19.8 pCi/g. Survey meter readings for perimeter boxes in the other large group (52 boxes), corrected for background, averaged 3.3 μ R/h, with a range of 0 to 10 μ R/h. The corresponding average concentration by Eqn. A-1 is 15.1 pCi/g.

The ranges of measurements along the central height zone extended to a maximum of 10 μ R/h, corrected for background, indicating local concentrations up to a maximum of 46 pCi/g. A group of measurements along the bottom of the large group averaged 8.6 μ R/h (corrected). The area factor along the bottom is estimated at 0.54 (3 x 0.18 at 1 m distance), yielding 43 pCi/g. An explanation for the higher average value along the bottom is not apparent.

A4. Assumed Cs-137 Concentration for Risk Assessment

The estimates of Cs-137 concentration previously discussed are summarized in Table A-3. Except for the pneumatic tanker, the average Cs-137 concentrations by assay and calculation from radiation survey measurements range from 12 to 41 pCi/g. The higher tanker values, when weight-averaged with the trailers indicate 15-33 pCi/g. It can be reasonably expected that the average Cs-137 concentration is not greater than about 30 pCi/g. However, because of uncertainties from several causes, the average concentration may be higher than indicated. In addition, in spite of efforts to blend the stored material for uniformity in some of the disposition options, some portions will have higher activity than the average. To account for uncertainty and variations, a concentration of 50 pCi/g is assumed for the risk assessment in this study.

Initial material basis:		21
Pneumatic tanker:	assay calculated	82 173
Dump trailers:	assay calculated	12 & 18* 22 & 41*
<u>Tanker & trailers average</u> :	assay calculated	15 33
Storage in boxes: 92 box 52 box	calculated group perimeter top group perimeter	17 20 15

Table A-3. Summary of Cs-137 Concentrations, pCi/g, by Various Data Categories.

* assayed and not assayed trailer groups, resprctively

A5. Density of The EAF Dust

The dry baghouse dust, as generated, has a density of 28-40 lb/ft³, with a 32 lb/ft³ average. This density is considerably lower than dust from the carbon steel industry due to extraction of iron, nickel, and chromium in the INMETCO process. During handling and storage, the dust settles and because it is hygroscopic, it absorbs moisture from the air. This can double the density. Weights reported for ten of the "cubic yard" storage boxes (actually 31.75 ft³) indicate an average net weight of box contents of 1,645 lb. The tare weight for a box and pallet is 85 lb. Assuming an average fill fraction of 0.8, the indicated apparent density of the currently stored material is about 65 lb/ft³. One box which was 99% full was re-weighed as 2,200 lb gross or 2115 lb net. The indicated density for this box becomes 67 lb/ft³. Because of uncertainty of density at various stages in storage, and other factors, a material weight and volume balance cannot be defined.