EASTERN MAINE MEDICAL CENTER
489 STATE STREET BANGOR, MAINE 04401-6674

October 15, 1987

Judith A. Joustra
Nuclear Materials Safety Section B.
Division of Radiation Safety and Safeguards
Nuclear Regulatory Commission Region I
631 Park Avenue
King of Prussia, PA 19406

Dear Mrs. Joustra:

In June of this year Eastern Maine Medical Center requested an amendment to our license (18-01577-01), which consisted of moving Nuclear Cardiology from one room into another.

Your response of June 30th requires a final closeout survey with results sent to the NRC for review.

I am writing to inform you that Nuclear Cardiology did not, and will not be moving out of it's present occupied room. In fact, when the Cardiac Surgery Unit is complete, the room in which Nuclear Cardiology was to move into will become a part of the Nuclear Cardiology Department.

I want to thank you for your efforts and timely response to EMMC's request for amendment to the license.

If you are in need of further information, please give me a call.

Sincerely,

Paul M. Scarpinato

Paul M. Scarpinato
Administrator for Diagnostic Services

cc:Radiation Safety Officer
Larry Alquist, PhD.

PMS:dmw

Larry Alquist, Ph.D.
Radiation Oncology
Eastern Maine Medical Center
489 State Street
Bangor, Maine 04401

18/AUG/87

Edwin McCullough, Ph.D.
Mayo Clinic/Foundation
Radiaiton Oncology
200 1st Street SW
Rochester, Minnesota 55905

Dear Dr. McCullough,

We are considering some **changes in the mould room** of our department, which led me to search for a paper addressing some safety concerns based upon measured data.

I was unable to find the paper or the reference, but seem to recall that you were the (co?)author. If I am correct, and you have a reprint, could you please send it to me?

Sincerely,

Larry

Larry Alquist, Ph.D.

Larry,

Someone from Wayne State called & said he got higher values which he thought were due to stirring the cerrobend. We didn't survey our pots during use, just over a weekend. I would ventilate room but probably not in special hoods unless in new construction

Airborne concentrations of toxic metals resulting from the use of low melting point lead alloys to construct radiotherapy shielding

Edwin C. McCullough and David H. Senjem

Mayo Clinic/Foundation, Rochester, Minnesota 55901

(Received 25 January 1980; accepted for publication 26 February 1980)

Determinations of airborne concentrations of lead, cadmium, bismuth, and tin were made above vessels containing a "fusible" lead alloy (158 °F melting point) commonly used for construction of radiotherapy blocks. Fume concentrations were determined by collection on a membrane filter and analysis by atomic absorption spectrophotometry. Samples were obtained for alloy temperatures of 200 °, 400 °, and 600 °F. In all instances, concentrations were much lower than the applicable occupational limits for continuous exposure. The results of this study indicate that the use of a vented hood as a means of reducing air concentrations of toxic metals above and near vessels containing low temperature melting point lead alloys commonly used in construction of radiotherapy shields appears unjustifiable. However, proper handling procedures should be observed to avoid entry into the body via alternate pathways (e.g., ingestion or skin absorption). Transmission data of a non-cadmium containing lead alloy with a melting point of 203 °F was ascertained and is reported on.

Key words: radiotherapy, technique; radiotherapy, hazards; radiotherapy, lead shields

Since an early report[1] on the use of low temperature melting point lead alloys (also called "fusible alloys") for the construction of blocks for radiation therapy treatments, this material has become widely used for this application. The term "fusible metal" or "fusible alloy" usually refers to alloys which owe their primary importance to the fact that they melt at relatively low temperature. Pure metals characteristically melt or solidify at a definite and constant temperature; alloys consisting of two or more metals usually melt and solidify over a range of temperatures. The temperature at which an alloy commences to melt is known as the solidus and the temperature at which it just becomes completely molten as the liquidus. In certain alloy systems there may be one composition, known as the *eutectic* alloy, which changes completely from solid to liquid at a definite temperature. This temperature is lower than that at which any other alloy composed of the same constituents is completely liquid.

Table I presents data for a variety of fusible alloys that might be used for constructing blocks for radiotherapy shielding. One group of alloys is based on a ternary eutectic,

TABLE I. Compositions and melting temperatures of some fusible alloys and eutectics of interest for construction of radiation therapy shielding*

Trade name or type of alloy	Composition, percent				Melting range	
	Sn	Bi	Pb	Cd	solidus (°F)	liquidus (°F)
Malottes	34.2	46.1	19.7	...	205	253
Roses	22.0	50.0	28.0	...	205	230
D'Arcets	25.0	50.0	25.0	...	205	208
Newtons	18.8	50.0	31.2	...	205	207
Ternary eutectic	15.5	52.5	32.0	...	205	205
Ternary eutectic	...	51.7	40.2	8.1	198	198
Lipowitzs (Cerrobend†, Ostalloy-158‡)	13.3	50.0	26.7	10.0	158	163
Woods	12.5	50.0	25.0	12.5	158	162
Quaternary eutectic	13.1	49.5	27.3	10.1	158	158
Cerrolow 147†	12.8	4[illegible]	25.6	9.6[a]	142	149
Cerrolow 136†	12.0	49.0	18.0	...[b]	136	136
Cerrolow 117†	8.3	44.7	22.6	5.3[c]	117	117

* from Ref. 2

† Trade name—Cerro Metal Products, Bellefonte, PA

‡ Trade name—Arconium Corporation of America, Providence, RI

[a] plus 4.0% indium

[b] plus 21.0% indium

[c] plus 19.1% indium

containing 15.5% tin, 52.5% bismuth, and 32% lead, which melts at 90°C (205°F). Newton's, D'Arcet's, and Rose's alloys approximate to this eutectic. A second group of alloys is based on a quaternary eutectic, containing 13.1% tin, 49.5% bismuth, 27.3% lead and 10.1% cadmium, which melts at 158°F (70°C). Wood's and Lipowitz's alloys are typical of this group. The quaternary eutectic alloys are the ones most frequently used in the United States, while one of the authors (E. C. McCullough) has noted that a particular ternary eutectic alloy (i.e. Rose's alloy) is utilized in some Scandinavian centers.

Since the above mentioned fusible alloys are a mixture of bismuth, lead, tin, and cadmium in the case of the quaternary eutectic alloys, one should observe handling procedures that ensure minimal ingestion (e.g. use of gloves, washing hands). However, the potential inhalation of fumes from open pots of this material may be more difficult to guard against and, in fact, one sees vented hoods being used in some radiotherapy departments. In spite of assurances from the manufacturers about the lack of toxic fumes when these alloys are used at temperatures normally employed in block making, we still found doubts in the minds of some of our technical staff. The scientific literature readily available to us and an inquiry to our State Department of Health provided no guidance on this topic. As a result, we have conducted and herein report on a series of measurements aimed at assessing inhalation hazards in the use of alloys based on the quaternary eutectic (e.g. Ostalloy-158, Cerrobend) in construction of blocks for shielding in radiation therapy beams.

METHOD

Air sampling was done using a calibrated personnel air flow sampler[3] with a rate (1.5 liters/min) and total volume consistent with recommendations contained in National Institute of Occupational Safety and Health (NIOSH) sampling data sheets.[4-6] Sampling for bismuth was carried out in a manner recommended by the commercial analysis laboratory used for these studies[7] since we are not aware of the NIOSH sampling data sheet for bismuth. Overall sampling times were on the order of 5–8 h and depended, in part, on the logistics of carrying out the sampling. No corrections for ambient temperature and pressure were applied, as these small effects will not alter any of our conclusions. During sampling, the air was immediately passed through a 0.8 μ pore size mixed cellulose ester membrane filter supported by a cellulose backup pad in a sampling chamber. At completion of the sampling, the chambers were sealed and sent to a commercial laboratory[7] for analysis by atomic absorption spectroscopy.

Samplings of airborne concentrations were carried out at two locations: the Mayo Clinic where sampling was done at a slightly elevated temperature (200°F) and at a commercial metallurgical laboratory[8] where sampling was done at extreme elevated temperatures (400° and 600°F). One impetus for investigating behavior at these elevated temperatures is the frequent use of soldering irons and even propane torches to patch or cut radiotherapy blocks. For each sampling at Mayo, two samples were taken: one for lead, cadmium, and bismuth, which can be analyzed together, and a separate one for tin which requires slightly different preparation prior to atomic absorption spectroscopy.

At the Mayo Clinic a thermostatically controlled alloy pot[9] containing roughly 1 gal of a quaternary eutectic (Ostalloy-158) is used in block making operations. The block making operation is contained in a room 9 × 20 ft with 8 ft ceilings and the alloy pot is left on continuously. The exposed surface area of the alloy is 250 cm^2 and the alloy temperature is usually 165°–170°F.

At Mayo three different sampling situations were investigated. The first sampling placed the filter and holding chambers about 2 in. above the rim of the uncovered pot containing the eutectic at a slightly elevated temperature of 200°F (representing a temperature that might be reached inadvertently). Prior measurements had indicated to us no significant difference in sampling concentrations between a pot at 165° and 210°F. A second sampling was carried out at a point directly across the room from the alloy pot. During the sampling periods, the pot contained at least 1 gal of alloy for at least 24 h prior to commencement of sampling and the pot was always uncovered. During the time of sampling all air flow through the room was stopped and the door shut in order to create a "worst case situation." A third sampling was done at a point well removed from the radiation therapy

TABLE II. Airborne concentrations measured for a fusible alloy (Ostalloy-158)

Site	Location	Alloy temperature	Sampled air volume (liters)	Concentrations ($\mu g/m^3$) Lead	Cadmium	Bismuth	Tin
Mayo	Above pot (2 in.)	200°F	525	4/3.8[a]	1/0.95	ND[b]/1.9	105/95
	Block room	200°F	707	ND/2.8	1/0.71	ND/1.4	92/71
	Outside air	...	300	ND/6.7	ND/1.7	ND/3.3	...
Arconium	Above pot (4 in.)	400°F	589	12/3.4	2/0.85	ND/1.7	...
	Above pot (10 in.)	600°F	450	16/4.4	1/1	ND/2.2	...
	Ambient air	600°F	725	ND/2.8	ND/0.69	ND/1.4	...
		OSHA threshold limit values[c]		50(30)[d]	100	None	2000

[a] Measured value/minimum detectable value based on the following detection limits: lead–2 μg/filter; bismuth–2 μg/filter; cadmium–0.5 μg/filter; tin–50 μg/filter (Note: The differences between rows are due to the different volumes of air sampled).
[b] ND = None Detected (i.e. below detection limit).
[c] Values thought to be acceptable for 40 h/week exposure.
[d] The value 30 $\mu g/m^3$ is the limit above which "action" must be taken (e.g. quarterly blood checks).

TABLE III. Additional data on airborne toxic metal concentrations ($\mu g/m^3$)

Site	Location	Alloy	Temperature	Sampling time	Sampled volume	Cadmium	Lead	Tin
1	Top of pot	Ostalloy-158	170°F	4 h	480 l	9	15	52
2	Block room	Ostalloy-158	?	?	?	7.1	6.5	...
	Adjacent office	Ostalloy-158	?	?	?	<0.7	7	...
3	Block room	?	?	?	?	0.3[a]	0.4[a]	...

[a] Average of two samples. At this site cadmium oxide was also sampled and showed a concentration comparable to the Cadmium concentrations.

center as an assessment of the quality of Rochester, Minnesota air.

In a commercial metallurgical laboratory[8] analogous sampling procedures were carried out with the alloy at 400° and 600°F. Sampling was done above a gas fired, thermostatically controlled pot containing 2000 pounds of Ostalloy-158. These samplings were done with Mayo supplied filter chambers and analyzed by the same laboratory used for the samples obtained at Mayo. The sample chambers for the measurements at 600°F were placed about 10 in. above the alloy-containing vessel because of the propensity of the plastic filter holding chamber to melt if placed any closer.

RESULTS AND DISCUSSION

Table II summarizes the results of all samplings taken during this study. The results are presented as measured concentrations followed by the detection limit concentrations. The detection limit concentration ($\mu g/m^3$) is calculated from the detection limits in μg/filter and the volume of air sampled using the formula:

$$\mathrm{DLC}(\mu g/m^3) = \frac{\mathrm{DL}(\mu g/\mathrm{filter})1000}{\text{Sample volume (liters)}}.$$

It is quite clear from the data shown in Table II that the majority of values are "none detected" and those values that are not reported as such are just above the minimum sensitivity levels. It is important to keep in mind that at the sensitivity level of the analysis, there may be a substantial standard deviation in the values reported. In terms of established threshold limits (based on 40 h per week exposure), all values reported fall short of these limits.

Based on the results reported in Table II it would be difficult to argue forcibly that ventilation is mandatory in areas where Lipowitz's metal is being melted and poured in the construction of blocks for radiotherapy. However, entry into the body via ingestion is a possible concern. In this regard, there may be some interest in eliminating the chance of accidental ingestion of the very toxic metal cadmium. As shown in Table I, there is available a ternary eutectic (and associated alloys) with melting points around 205°F. We have obtained a sample of Ostalloy-203 (15.5% tin, 52.5% bismuth, and 32.0% lead) from which we have constructed an 8-cm-thick block identical to one constructed from Ostalloy-158. Transmission for a 4 MV x-ray beam was measured to be 2.6% and 2.3% for Ostalloy-158 and Ostalloy-203, respectively. If one considers the measurement for the Ostalloy-203 significantly different than for the Ostalloy-158, it is presumably due to the higher portion of lead and bismuth which results in a slightly increased density (5%) of the 203 alloy.

With regard to ingestion of lead, we have carried out an analysis for lead in a 24-h urine specimen for a technologist who has been making lead alloy blocks for ten years. This assay showed 20 μg whereas the upper limit (2σ) in a series of normal volunteers is 80 μg. Samples from two additional technologists with about two years of "exposure" showed 24-h levels of 8 and 14 μg. The differences in the three levels cited might not be considered significant when one considers the difference in urine volumes obtained in a 24-h collection.

ACKNOWLEDGMENTS

The authors are indebted to Dr. Kenneth Green, metallurgist at Arconium Corporation for his assistance (and perserverance in obtaining the samples at 600°F!) and for providing other varied assistance.

Mr. Steven DeMoe, R.T. (T) provided considerable assistance for the studies carried out at Mayo Clinic.

APPENDIX

One of the authors (E. C. McCullough) issued a request[10] for "hard data" on the environmental safety aspects of fusible alloys employed in the construction of therapy shielding. Over a period of the last several months limited data has trickled in. With the gracious consent of the individuals involved, Table III summarizes as much of the information about the sampling that is available. It is clear that at all these sites, the sampled air concentrations are significantly below the recommended threshold limit values of 100, 50, 2000, and 100 $\mu g/m^3$ for cadmium, lead, tin, and cadmium oxide, respectively.

[1] W. E. Powers, J. J. Kinzie, A. J. Demidecki, J. S. Bradfield, and A. Feldman. Radiology **108**, 407 (1973).

[2] "Fusible Alloys Containing Tin," Publication No. 175 (Tin Research Institute, Columbus, Ohio, 1967).

[3] Monitaire Sampler, Model S, Mine Safety Appliances Company, 400 Penn Center Boulevard, Pittsburgh, PA 15235.

[4] Cadmium, Sampling Data Sheet S313, National Institute of Occupational Safety and Health (NIOSH), Washington, D.C.

[5] Lead and Inorganic Lead Compounds, Sampling Data Sheet S341,

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Paul
I penciled this in for you already
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To: MEMBERS OF RADIATION SAFETY/MEDICAL ISOTOPE COMMITTEE
From: Frank L. D'Amelio, M.D.
Date: August 11, 1987

There will be a meeting of the Medical Isotope/Radiation Safety Committee on September 9 at 12 noon in Conference Room 2E. Lunch will be served.

AGENDA

Letter to NRC

12:08 AM 1. Review of old minutes. D'Amelio

12:10 2. Quarterly film badge report. Buchanan

12:13 3. Quarterly misadministration report. Thompson

12:14 4. Results of recent NRC inspection. Alquist

12:26 5. Receipt of NRC amendment. Scarpinato

12:31 6. Arrival of Strontium-90 RA material. Alquist

12:33 7. Access by unauthorized personnel to restricted area.

8. New business.

~~- update on Nuc. Cardiology amendment~~

~~? Ed - letter from me~~

A.) Video ~~update~~

B.) thyroid uptake system

C.) ______ us in Genetics

D.) radiopharmaceuticals FDA (vs) NRC

Send Letter to NRC of current status

Adjourned 12:50