C. Mattsen

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 1, 1996

To: Donald A. Cool, Director
Division of Industrial and Medical Nuclear Safety, NMSS

From: Joel O. Lubenau
Senior Health Physicist

Re: Radiation Levels From Steel Contaminated With ^{60}Co: A Limited Study of Potential Regulatory Issues

Summary

A limited study was made of the potential external radiation levels from steel contaminated with ^{60}Co. Data on external radiation levels and specific activity for steel ingots contaminated with ^{60}Co provided by SEG, a company that smelts and makes products from contaminated steel, was used for the study. These data were then compared with radiation levels predicted by the RESRAD-RECYCLE and MICROSHIELD dose models. The results show that the current NRC exempt concentration limit of 500 pCi/g for ^{60}Co would lead to external radiation levels in the mrem/h range at contact and one foot from a thick, large surface area slab. The exemption and "clearance" levels recommended by the IAEA and the CEC are lower and would result in correspondingly lower external radiation levels. These radiation levels, however, could still be detected by radiation monitoring systems currently used by the metal scrap recycling industry and their detection could confound current metal recycling industry efforts to screen out unwanted radioactive sources mixed with metal scrap.

Definition of Terms

The IAEA now makes a distinction between "exemption levels" and "clearance levels."[1] Exemption levels apply to radiation sources which never enter the regulatory control regime, i.e., control is not imposed. Clearance levels apply to radiation sources that are released from regulatory control. The IAEA notes that this is a recent distinction and that the terms were used interchangeable in the past. In NRC space, Schedules A and B of 10 CFR 30.70 are examples of exemption levels and Reg Guide

[1]IAEA Draft Safety Series No. 111-G-1.51, "Clearance Levels for Radionuclides in Solid Materials" (1995).

1.86 is an example of NRC clearance levels. The IAEA notes that to avoid regulatory conflicts clearance levels should never be greater than exemption levels.

Clearance levels fall into two categories, unconditional and conditional clearances. The objective of the former category is to provide clearance levels for solid materials "irrespective of the use to which those materials are put or of their destination after control has been relinquished."[2] The IAEA specifically identifies the import and export of scrap metals in international trade as an intended application of this category. Conditional clearances apply to cases where unconditional clearance is not applicable.

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[2] Ibid.

For ^{60}Co in steel the applicable clearance levels are:

TABLE 1

Reference	Date	Bq/g	pCi/g
CEC[3]	1988	1	27
IAEA 111-P-1.1[4]	1993	0.1 - 1.0	2.7 - 27
IAEA 111-G-1.5[5]	1995	0.3	8

[3] CEC Radiation protection No. 43, "Radiological Protection Criteria for the Recycling of Materials for the Dismantling of Nuclear Installations."

[4] IAEA Safety Series No. 111-P-1.1, "Application of Exemption Principles to the Recycle and Reuse of materials from Nuclear Facilities." The most limiting level, 0.1 Bq/g, is based upon individual dose (Table VIII). Consideration of the collective dose leads to a level of 1.0 Bq/g (Table XIV).

[5] IAEA Draft Safety Series No. 111-G-1.5, op. cit. For ^{60}Co, the derived unconditional clearance level is a range, 0.1 - 1.0 Bq/g (Table I). However, in this document, IAEA states that, "[w]here a single value of the clearance level is required by regulators, the log-mean values for each category are proposed for use as representative clearance level values. The clearance levels are then 0.3, 3, 30, 300 and 3,000 Bq/g for the five classes."

Similarly, the applicable exemption levels are:

TABLE 2

Reference	Date	Bq/g	pCi/g
IAEA[6]	1994	10	270
NRC[7]	1970	18.5	500

Discussion

The study was initiated to answer questions raised by the metal recycling industry about the radiological consequences of regulatory exemption and clearance levels, particularly for ^{60}Co in steel. The NRC exemption level of 500 pCi/g is used by the steel industry as the maximum concentration of ^{60}Co in iron resulting from the use of ^{60}Co sources embedded in blast furnace refractory walls to measure wear of the walls.[8] Such use is authorized by specific licenses issued by the NRC or an Agreement State. According to limited data collected by me in 1984, ^{60}Co levels in iron made in such blast furnaces are ranged from 174 to 0.2 pCi/g.[9] These levels were calculated, not measured, and differences in calculational methods can affect outcomes, e.g., averaging the loss of the ^{60}Co sources in the furnace wall over the length of time of the operation of the furnace vs. over the last 30 days of operation or some other time span. The concentrations in steel products are further reduced because when the iron is refined into steel, such as in the basic oxygen

[6] IAEA Safety Series No. 115-1, "International Safety Standards for Radiation Protection Against Ionizing Radiation and for the Safety of Radiation Sources, Interim Edition."

[7] 10 CFR 30.14 and 30.70.

[8] NRC memorandum from J.R. Metzger to J.A. Pagliaro dated November 15, 1979 re "Steel Making in Co-60 Refractory Liners." According to recent communications with representatives of the steel making industry, this application of ^{60}Co is diminishing in the U.S. in favor of alternative technologies such as using lasers. Reportedly, only one U.S. steel maker is using ^{60}Co for this purpose.

[9] October 15, 1984 telephone conversations with A. LaMastra, RSO for Bethlehem Steel and A. Mammerelli, RSO for Republic Steel.

furnace (BOF), scrap metal is usually added to the charge of a BOF which has the effect of diluting the ^{60}Co. According to steel industry health physicists, standard portable radiation detection equipment would not detect any radiation from U.S. produced steel as a result of this use of ^{60}Co. The radiation from the ^{60}Co is detectable, however, when such steel is used as shielding for low background radiation detectors.[10]

Another item of interest has been the issuance of clearance levels by the CEC and the IAEA for the recycling of radiologically contaminated materials from nuclear facilities and th implications of the importing into and the recycling of such metals in the U.S.[11,12] There is a common understanding in the metals recycling industry that, under GATT, radiologically contaminated materials that meet European clearance or exemption criteria are acceptable for export to the U.S.[13,14] Metal recyclers and mill operators who have installed radiation detectors to protect themselves against unwanted radioactive materials mixed with metal scrap are concerned that such metals may cause their radiation detection systems to alarm and thus cause confusion about the acceptability of radioactive materials in metal scrap.

Scientific Ecology Group, Inc. (SEG) routinely smelts

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[10] Telephone conversations in 1984 with J. Rosen, University of Pittsburgh, R. Brisson, State of MD and F. Bronson, Canberra Industries.

[11] CEC, op. cit.

[12] IAEA, Safety Series No. 111-P-1.1, op. cit.

[13] 10 CFR 30.14(b) states that "This section shall not be deemed to authorize the import of byproduct material or products containing byproduct material." It is not clear what authorization is needed to import radiologically contaminated metal meeting CEC or IAEA criteria under GATT. In fact, foreign made steel imported into the U.S. is as likely as U.S. produced steel to contain ^{60}Co as a result of the use of ^{60}Co in foreign blast furnaces. As an example, in 1985 steel pipe imported from Brazil was found to contain detectable levels of ^{60}Co. The Brazilian authorities attributed it to the use of ^{60}Co sources in furnace walls (Lubenau and Nussbaumer, Health Physics 51:409-425 [1986]). At the time US officials disbelieved this explanation but in view of the results of this study it now seems plausible.

[14] At the recommendation of the author, the ISCORS Subcommittee on recycling agreed to include a discussion of the implication of GATT on recycling or radioactively contaminated metal in a future meeting.

radioactively contaminated steel at its plant in TN. Among its products are shielding blocks for accelerators. SEG staff provided examples of data for radiation levels measured from large surface area, relatively thick steel ingots contaminated primarily with ^{60}Co.[15] The ingot sizes in inches were 26x26x13 and 52x52x26. At contact with the surface of the ingots, the average value of $k_{(c)}$ is 170 μrem/h per Bq/g for the larger slab and 65 μrem/h for the smaller slab. At one foot from the slab surfaces, $k_{(f)}$ is about 57 μrem/hr per Bq/g for the larger slab and 32 μrem/h for the smaller slab. Details are provided in the attachment.

In response to a request, Shih-Ywe Chen, Argonne National Laboratory, used the RESRAD-RECYCLE model to predict the dose levels from a steel slab contaminated with a unit concentration of ^{60}Co having dimensions similar to the larger SEG slab (attachment B). The corresponding $k_{(c)}$ value is 62 μrem/h. The corresponding $k_{(f)}$ value is 35 μrem/h.

According to Shih-Yew Chen, the relationship between the k values and concentration is linear.

Sami Sherbini, NMSS provided a chart for the k values as a function of distance from the surface of a slan with the same dimensions as the SEG slab using the MICROSHIELD dose model (attachment C). The model dose not work well for distances close to contact. At one foot from the surface the $k_{(f)}$ value is 46 μrem/h per Bq/g which is comparable to the value of 57 μrem/h derived from SEG measurements.

Applying these k values and assuming a linear relationship between concentration and external radiation levels results in the following estimates of doses from a 52x52x26 inch slab of steel contaminated with ^{60}Co (the Bq/g values correspond to those listed in Table 1):

TABLE 3

Criterion	^{60}Co Bq/g	SEG Contact μrem/h	RESRAD Contact μrem/h	SEG 1 ft μrem/h	μSHIELD 1 ft μrem/h	RESRAD 1 ft μrem/h
Clearance	0.1	17	6.2	5.7	4.6	3.5
"	0.3	51	19	17	14	11
"	1	170	62	57	46	35

[15] December 5, 1995 fax from S. Sugerman, Health Physics Manager for Metal Melt Operations, SEG. See attachment.

Exemption	10	1,700	620	570	460	350
"	18.5	3,100	1,100	1100	8500	630

In a slab of this size a concentration of ^{60}Co equal to the either the NRC or IAEA exemption limits would result in radiation levels in mrem/h range at contact and at one foot. Further, contaminated steel released at the unconditional clearance levels would result in radiation levels of one to two orders of magnitude greater than typical background levels. Radiation levels from such steel could cause radiation monitors at scrapyards and mills to alarm depending upon the position of such metal in a scrap shipment, its distance from the detector and the sensitivity of the detection system. Steel plates having smaller cross-sections or smaller surface areas would, of course, produce lower dose rates. Nonetheless, it is apparent that the introduction of such steel into recycled metal scrap has the potential to confound existing radiation monitoring programs at scrapyards and mills.[16]

While these data are limited, another issue that arises is the discrepancies between the radiation levels measured by SEG and those predicted by the dose models. These discrepancies, however, do not detract from the conclusion that ^{60}Co contaminated steel meeting exemption or clearance criteria would produce radiation levels that could be detected by radiation monitoring systems currently in use by the metal scrap recycle industry.

Conclusions

The results of this limited study suggest that NRC should re-examine the application of the solid exemption concentration limit in 10 CFR 30.70 of 500 pCi/g for ^{60}Co. The NRC level is nearly twice the value recommended by the IAEA. Both the IAEA and NRC levels would result in radiation levels near or in contact with thick steel slabs in the mrem/h range. (The radiation levels would be greater for less dense materials, e.g. aluminum). Intuitively, radiation levels close to the surface in the mrem/h range would seem to be contradictory to one's expectations for materials that are exempted from regulatory controls such as steel containing radioactive material.

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[16] In 1995 finished steel plates that were imported from Bulgaria to a steel fabricator in MS caused the radiation detection system at the fabrication plant to alarm. The radiation levels from the 4'x8'x5/8" plates were reported to be from 30 to 70 μR/hr. The contaminant was ^{60}Co. (Lubenau & Yusko, Health Physics, 68:440-451 [1995]).

If, indeed, the 500 pCi/g value is not appropriate, then other solid concentration values in 10 CFR 30.70 may also merit review.

The results suggest there is a need to further compare radiation doses predicted by models with measured doses and to critically review the technical bases for both measurements and models.

Notwithstanding the question of the acceptability of the existing exemption and clearance levels from the point of view of radiation protection, there is a need to carefully consider the implications of the exemption and unconditional clearance levels for the metal recycling industry which is utilizing radiation monitoring systems as a means of protecting its plants from the hazards of radioactive sources that occasionally become mixed with metal scrap. The introduction of metal into metal scrap streams that could cause radiation detectors to alarm but which regulators have determined to be acceptable for recycle will certainly lead to confusion in the metal recycling industry.

Recommendations

The SEG data should be further examined and refined, e.g. obtain more details of the processes used to produce the data. If similar, additional data is available, it should be obtained and reviewed. Such data should be compared to predictions from dose models.

Sources of other measurement data should be looked into, e.g., Seimpelkamp Metal Works in Aachen, Germany.

Similarly, an examination should be made of how dose models were validated with respect to prediction of radiation levels as a function of concentration for given densities, masses and shapes of solids.

The derivation of the NRC exempt concentration limit should be re-examined with respect to the acceptability of external dose rates from a mass of steel containing ^{60}Co at the exemption concentration of 500 pCi/g. If there is a problem with this value, then, in addition to modifying the licenses authorizing activities under 10 CFR 30.14, examination should also be made of other solid exempt concentration values in 10 CFR 30.70.

With respect to the CEC and IAEA, clarification should be sought as to why different clearance criteria are recommended and which would be used by members of the European Community.

Clarification should be sought as to whether foreign radioactively contaminated metal that is approved for release for recycling by foreign regulatory authorities may be exported into

the U.S. and whether the import of such material into the U.S. requires licensing or other NRC approval.

Lastly, pending confirmation of the conclusions of this study and clarification of the role of GATT and the NRC, the metal recycling industry should be advised that it is possible that foreign radioactively contaminated metal approved for release for recycling may be detectable by their radiation detection systems.

Attachment: As stated

cc w/attachments:
R. Meck, RES
C. Mattsen, RES
C. Ryder, RES
R. Free, TX
J. Yusko, PA

Attachment A

Notes

1. SEG data provided by fax by Steve Sugarman, Health Physics Manager for Metal Melt Operations, SEG.

2. Ingot S2 - 52 1/4 x 52 1/4 x 25 3/4 inches
   Ingot S3 - 26 x 26 x 13 inches

3. Dates of measurements - not reported

4. External radiation levels measured with an energy compensated GM detector.

5. "Sucker" specific activity: The "sucker" is a small sample taken from the melt, solidified, weighed and subjected to a gamma spectrum analysis specific to ^{60}Co.

6. "Dissolved" specific activity: A solidified sample of the melt is dissolved and the dissolved sample is subjected to gamma spectrum analysis for gamma emitting radionuclides contributing to the activity of the sample.

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Oak Ridge, TN 37830
Telephone (423) 481-0222
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DATE: 12-5-95

FROM: Steve Sugarman

TO: Joel Lubenau

FAX: (301) 415-5369

MESSAGE

See attached

p. 2 of attachment A

Joel,

In order to save time I decided to "write out" the table (I'm not very quick on the computer). If you have any questions, or are unable to read the info. on the table, feel free to give me a call.

Steve Sugarman
phone: (615) 220-1348
fax: (615) 483-4706

p. 3 of attachment A

Size	Sucker Sample (uCi/gr) (All activity is Co-60)	Dissolved Metal (uCi/gr) (Co-60/total activity)	Contact (mrem/hr)	1 foot (mrem/hr)	Bkgd (mrem/hr)
S4	7.16 E-5	9.76 E-5 / 1.08 E-4	0.6	0.4	0.3
S4	7.09 E-5	8.66 E-5 / 9.85 E-5	0.4	0.3	0.3
S4	6.37 E-5	7.44 E-5 / ALL ACTIVITY Co-60	0.5	0.4	0.3
S4	1.35 E-4	1.82 E-4 / ALL ACTIVITY Co-60	0.8	0.5	0.3
S4	3.41 E-5	4.72 E-5 / 4.96 E-5	0.4	0.3	0.3
S2	2.62 E-4	2.90 E-4 / ALL ACTIVITY Co-60	1.4	1.0	0.3
S2	5.18 E-5	6.99 E-5 / ALL ACTIVITY Co-60	0.7	0.4	0.3
S2	3.26 E-5	5.05 E-5 / ALL ACTIVITY Co-60	0.6	0.3	0.3
S2	1.51 E-5	2.06 E-5 / ALL ACTIVITY Co-60	0.5	0.3	0.3
S2	3.61 E-5	5.46 E-5 / ALL ACTIVITY Co-60	0.5	0.3	0.3

S2 = 52¼" x 52¼" x 25¾"

S4 = 26" x 26" x 13"

Background dose rates have not been subtracted.

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Sample	Gross BG µrem/h	Gross Contact µrem/h	Gross 1 ft µrem/h	Net Contact µrem/h	Net 1 ft µrem/h	^{60}Co Sucker pCi/g	^{60}Co Diss pCi/g	Avg pCi/g	K(c) µrem/h/pCi/g	K(f) µrem/h/pCi/g
1	300	600	400	300	100	71.6	97.6	84.6	3.6	1.2
2	300	400	300	100	–	70.9	86.6	78.8	1.3	–
3	300	500	400	200	100	63.7	74.9	69.0	2.9	1.3
4	300	800	500	500	200	135	182	159	3.1	1.1
5	300	400	300	100	–	34.1	47.2	81.3	1.2	–
								Avg	2.4	1.2

Notes

1. Data for "S4" slabs, 26 × 26 × 13 inches
2. 2.4 $\frac{\mu rem/h}{pCi/g}$ = 65 $\frac{\mu rem/h}{Bq/g}$ @ contact
3. 1.2 $\frac{\mu rem/h}{pCi/g}$ = 32 $\frac{\mu rem/h}{Bq/g}$ @ contact

Attachment A

Sample	BG µrem/h	Gross Contact µrem/h	Gross 1 ft µrem/h	Net Contact µrem/h	Net 1 ft µrem/h	^{60}Co Sucker pCi/g	^{60}Co Diss. pCi/g	^{60}Co Avg pCi/g	K(c) µrem/h/pCi/g	K(ft) µrem/h/pCi/g
1	300	1400	1000	1100	700	262	290	276	4.0	2.5
2	300	700	400	400	100	51.8	69.9	60.9	6.6	1.6
3	300	500	300	200	–	32.6	50.5	41.6	4.8	–
4	300	500	300	200	–	15.1	20.6	17.9	11.1	–
5	300	500	300	200	–	36.1	54.6	45.4	4.4	–
								Avg	6.2	2.1

Notes

1. Data for "52" slabs, 52¼ × 52¼ × 25¾ inches

2. $6.2 \frac{\mu rem/h}{pCi/g} = 170 \frac{\mu rem/h}{Bq/g}$ @ contact

3. $2.1 \frac{\mu rem/h}{pCi/g} = 57 \frac{\mu rem/h}{Bq/g}$ @ 1 foot

Attachment A

From: Shih-Yew Chen <chens@smtplink.dis.anl.gov>
To: WND1.WNP1(jol)
Date: 3/1/96 1:20pm
Subject: Re: RESRAD-RECYCLE

Joel:

You are absolutely right! I made a blunder when I ran RESRAD-Recycle. I failed to save the file when I made changes to the default input. Therefore, the results I presented to you earlier did not correspond to the specs of your problem. I re-ran the case, and here are the new results:

on surface: 2.3 uRem/hr = 62.1 @ 1 Bq/g
at 1 ft : 1.3 uRem/hr = 35.1 @ "
at 2 ft : 0.7 uRem/hr

This is for the iron block 52"X52"x26"

MicroShield fails at surface, it peaks near surface and then drops off with distance. The higher MicroShield value (1.7 uR/hr) could be due to (1) conversion factor from R to Rem, and (2) peaking factor of MicroShield.

I apologize for the inconvenience. Hope this would settle the case for you. Please let me know if it is the case.

S.Y. Chen

______________________________ Reply Separator ______________________________

Subject: RESRAD-RECYCLE
Author: JOL@nrc.gov at SMTPlink-EID
Date: 2/26/96 4:42 PM

>Corrected Message:
Shih-Yew - Last November you used RESRAD-RECYCLE to answer a qiestion of mone about the radiation levels predicted at contact with and one foot away from the surface of a steel slab contaminated with 1 pCi/g of Co-60 having the dimensions in inches of 26x26x52*. The readings were for points above the center of the 26x26** surface. Since then, I had the same thing done using MICROSHIELD. That model breaks down at points near the surface but predicted an exposure level of 1.7 uR/h at 1 foot. This is roughly an order of magnitude less than that predicted by RESRAD-RECYCLE, 16.9 urem/hr. One possible explanation that occurred to me is that RESRAD may take into account a beta component which I assume, from the units that were used, MICROSHIELD did not. I'm also checking this out with my

p.1 d

MICROSHIELD source. Any comments? Thanks.

* Correction: This should be 52x52x26 ** Correction: This should be 52x52.

Sorry about the confusion.

Joel Lubenau
JOL@NRC.GOV

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November 17, 1955

Joel:

Many thanks for your package. It's going to be very useful for me.

Regarding your request, I have made a few RESRAD-Recycle runs. Here are the results:

1. For a 30"(L)x42"(W)x48"(H) block

   Dose rate at surface = 0.0289 mrem/hr
   Dose rate at 1 ft from surface = 0.0127 mrem/hr

2. For a 52"(L)x52"(W)x26"(H) block

   Dose rate at surface = 0.0292 mrem/hr = 790 µrem/h @ 1 Bq/g
   Dose rate at 1 ft from surface = 0.0169 mrem/hr = 460 µrem/h @ 1 Bq/g

All detectors are assumed at the center of (or at perpendicular distance to) the LxW surface. The blocks are assumed to be steel containing a density of 7.86 g/cc, with a uniform Co-60 concentration of 1 pCi/g.

Please let me know if you have any questions.

Best Regard,

S.Y. Chen

11/20 Telecon:
relationship is linear.
JR

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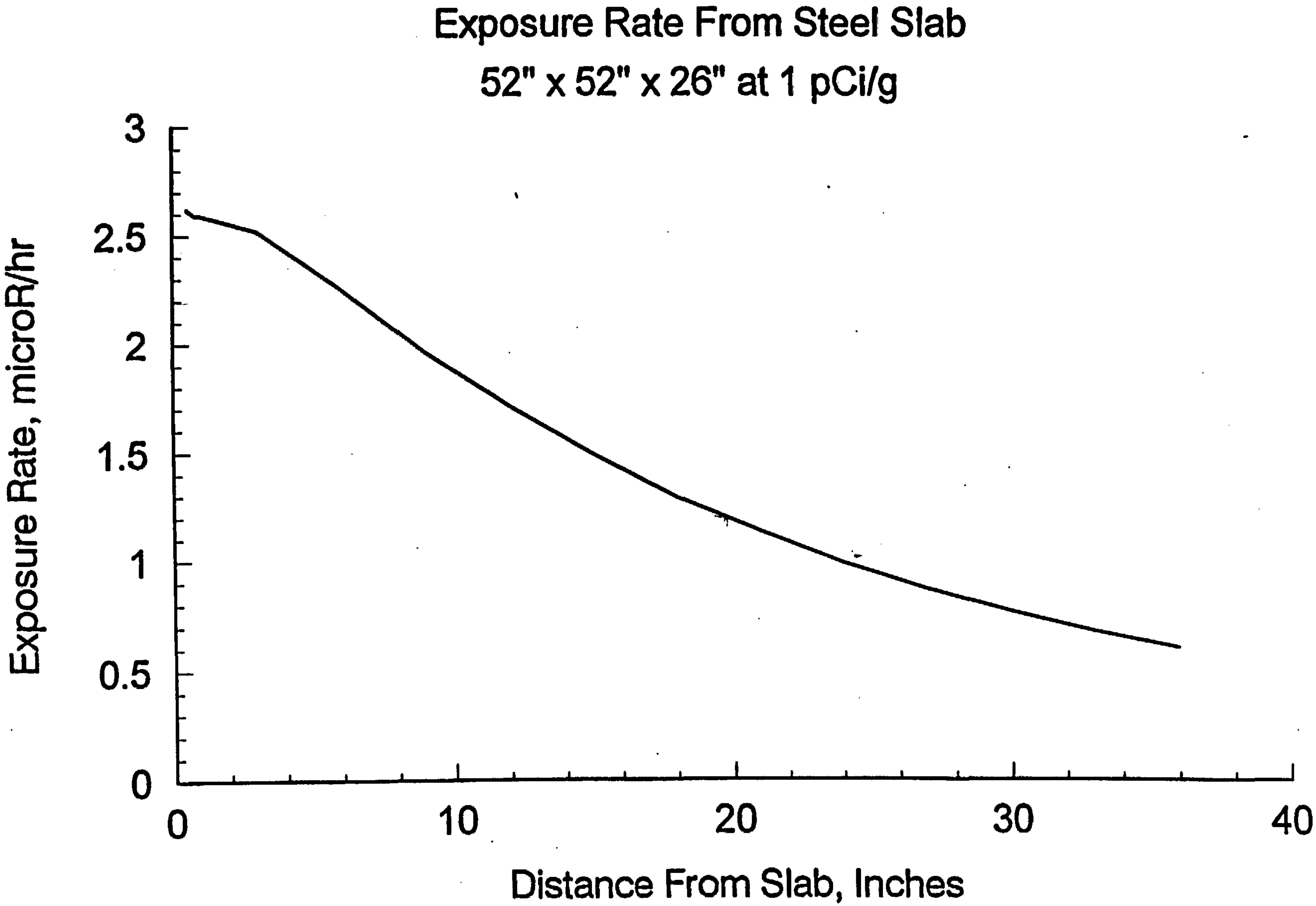
Exposure Rate From Steel Slab
52" x 52" x 26" at 1 pCi/g
Exposure Rate, microR/hr
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
Distance From Slab, Inches