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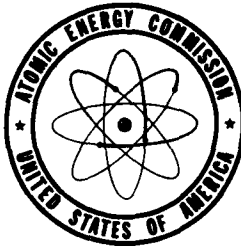
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**INVESTIGATION OF THE POTENTIAL HAZARD  
IN RELEASING SCRAP STEEL CONTAMINATED  
WITH URANIUM TO COMMERCIAL CHANNELS**

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#### ABSTRACT

Tests were conducted on a laboratory and semi-plant scale to determine the effect of permitting scrap grossly contaminated with uranium to be used in steel manufacture. It was found that most of the uranium is removed with the slag. Steel made with this scrap would have a uranium constituent so little above that made with uncontaminated scrap as to be hardly significant. The slag itself would not present any hazard in handling or normal use.

It is recommended, therefore, that in the future steel with only surface uranium contamination be released through normal scrap channels.

Note: All references to uranium in this report are to natural uranium only.

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INTRODUCTION:

It has been standard operative procedure to release no scrap material contaminated by radioactive materials. This contaminated waste scrap policy has been dictated in consideration of the welfare of the general public for two reasons, the possibility of harmful effects to health of any general increase in the radioactive content of any or all materials and the possible adverse effect of an increase in radioactive content of raw materials on industries such as the manufacture of instruments or photographic materials. The latter is often referred to as technical contamination.

As of May 1, 1951, there was on hand an estimated 1,000 tons\* of contaminated scrap steel at the Lake Ontario Ordnance Works (LOOW). During one year (October 1949-1950) freight records indicated a total of 503 tons of scrap, largely steel, transported from St. Louis (Missouri) Cleveland (Ohio) and Cononsburg (Pennsylvania) to the LOOW at a freight cost of \$6904.00 for the year in addition to a loss in over \$2,000.00 by not selling it. This represents only a fraction of the total contaminated scrap steel taken out of useful service each year by the AEC.

During the year of 1950, the entire domestic steel industry produced a total of 97 million tons of steel. This steel was made up of approximately 50% scrap steel, half of which scrap was purchased on the open market, the other half obtained from within the steel industry. The total scrap steel purchased on the open market was, therefore, approximately 25 million tons in the year 1950 as compared with perhaps several thousand tons retained by the Commission. The great cost of shipping and retaining contaminated scrap steel at centralized storage areas instead of selling it on the open market has prompted the study

\*All references to tonnage are in terms of gross tons (2240 lbs.)

of any possible disadvantages in doing so. In addition to this financial consideration it was believed advisable to inquire into the rationale of our present policy because of the possibility of a steel shortage hampering the national production effort. Any study of the effects of releasing contaminated materials to be salvaged and reworked into raw material for industrial consumption will depend greatly on the establishment of two bench marks. One is the normal concentration of the contaminant in the material being investigated and the other is the threshold concentration of contaminant beyond which scrap material is to be considered significantly contaminated.

#### NORMAL URANIUM CONTENT OF STEELS:

It was first necessary to estimate the normal uranium content of steels. Eight steel samples and a sample of cast iron, all produced prior to 1940, were obtained from the National Bureau of Standards and analyzed fluorometrically with the following results: From 14 samples of the steel an average of .06  $\mu\text{g}$  uranium per gram of steel (range <0.01 to 0.2  $\mu\text{g}/\text{g}$ ) was found and from a single sample of the cast iron 0.6  $\mu\text{g}$  of uranium per gram iron, as tabulated below:

Table I - Analysis of Old Steel

	<u>Sample</u>	<u>U-analysis</u> ( $\mu\text{g}$ U per g steel)
12 e	Basic Open Hearth	0.06, 0.1
16 e	" " "	0.05, 0.01
22 e	Bessemer	0.01, 0.02
10 e	"	0.04, 0.2
19 e	Acid Open Hearth	0.02, 0.02
21 d	" " "	0.07, —
150	Lead-Bearing Steel	0.07, 0.02
4g	Cast Iron	—, 0.6
56b	W., Cr., V Steel	0.1, —
	Mean (Steel only)	0.0622

## RADIATION FROM TRACE AMOUNTS OF URANIUM IN STEEL:

Since any effect uranium contamination in steel could have depends upon the alpha or beta emission from the surface of the manufactured steel, the relationship between surface emission and uranium content of steel was calculated. See Appendix A & B. The estimated alpha emission was compared with the measured values from steel having known uranium content (Figure 1). Considering the assumptions made in calculating the emission there was reasonably good agreement with the measured value of about .03 alpha particles per minute per square cm for a uranium content of 5  $\mu\text{g}/\text{gram}$  of steel.

## EXPERIMENTAL MELTING OF CONTAMINATED STEEL:

In order to measure the resultant uranium content after contaminated steel is melted, a laboratory experiment was set up in which several samples of grossly contaminated steel were first measured carefully as to surface contamination in terms of alpha count as well as total contamination in terms of micrograms of uranium per gram of steel through carefully planned sampling and analytical methods. The general method used is as follows: Steel drillings are prepared for the ether extraction of uranium. The residue which contains the uranium is then measured fluorometrically (1). Five such samples of contaminated steel were analyzed with the results given in Table II. It can be seen from these data that the original average contamination of the steel was 57.8 micrograms of uranium per gram of steel (standard deviation 32.0), but that after melting in an induction furnace, the melted steel was separated from the slag and the uranium contamination of the steel was reduced by a factor of approximately 40 to a level of 1.5 micrograms of uranium per gram of steel (range <0.1 to 5.5  $\mu\text{g}/\text{g}$ ). By throwing out one high sample suspected of containing slag this figure was reduced to 0.5  $\mu\text{g}$

uranium per gram of steel (standard deviation 0.59). This laboratory run was considered significant but it was decided that it would be necessary to verify these findings in a semi-plant run, on a scale closer to that used in actual production. Consequently, approximately 500 pounds of grossly contaminated steel was selected and cut up for shipment to a steel mill where it was melted down in a high frequency induction furnace without the use of any flux. Samples of this melt were prepared for analysis and found to contain 0.56 micrograms of uranium per gram of steel (range 0.39 to 0.8 ug/g). Table III shows the results of these analyses. The slag in each case was found to contain a high concentration of uranium as expected, the semi-plant run was considered more representative of industrial conditions and it should be noted that the specially selected contaminated steel was known to represent the highest degree of uranium surface contamination found in our operations. The mean uranium concentration of the samples of produced steel was found to be less than 10 times that of the old steel samples.

Table II - Laboratory Melt  
(Contaminated Sheet Steel)

<u>Sample</u>	<u>Alpha Count (a)</u> (Average-Each Side)	<u>U-Analysis (b)</u>		<u>Alpha Count (c)</u>
		<u>Before Melting</u>	<u>After Melting</u>	
1	7, 14	117, 87	5.5	0.38
2	38, 9	92, 36	1.2	0.06
4	250, 65	71, 12.8	0.7	<0.05
5	6, 0.4	141, 13.6	0.1	<0.05
7	11, 20	1.6, 5.6	<0.1	<0.05
Mean		57.8	1.50	
Mean (omitting sample 1)			0.47 (see note)	
Scale		8700		

- (a) - in units of 1000 c/m/100 cm<sup>2</sup>
- (b) - micrograms U per gram steel
- (c) - counts per minute (40% geometry)

Note: Sample 1 (after melting) was found to have small cavities in which there were inclusions of slag which could account for the higher uranium content.



Table III  
Semi-plant Melt in Steel Mill

<u>Sample</u>	<u>U-Analysis</u> (after melting)
1	0.8
2	0.6
3	0.45
4	0.39
Mean	0.56
5 (slag)	18
6 (slag)	140

It should be emphasized that in both runs scrap steel was carefully selected with the aid of an alpha survey meter so that it would have the maximum possible contamination resulting from the usual uranium operations. All of the scrap was either sheet metal or shapes. No containers or pipes that might contain caked materials were used.

**HEALTH ASPECTS:**

From the relationship shown in Figure 1 (extrapolated) even the slag with its relatively high uranium concentration could not present a health hazard and it would be highly improbable that any such material would reach an eventual destination where it could be technically objectionable. For example, the slag sample having the highest uranium content of 6.6 mg per gram of steel would emit something of the order of 30 to 40 alpha particles and about 200 beta particles per square cm. of surface per minute (equivalent to about one or two mrep/hr in contact). The steel on hand would certainly be diluted to the extent of one part contaminated steel to three parts uncontaminated, even if the entire scrap input of any plant were to be made up of this contaminated steel, and most likely would be considerably further diluted by being mixed with other uncontaminated scrap steel. By way of comparison, it is interesting to note that samples of widely used commercial fertilizers analyzed by the National Bureau of Standards showed an average uranium content of 55 micrograms per gram (Appendix C).

#### TECHNICAL CONTAMINATION - PHOTOGRAPHIC INDUSTRY:

A radioautograph was made with a steel sample from the first run (Table II - Sample 1), the sample having the highest uranium content being selected. After a one-week exposure in contact with a panchromatic photographic emulsion, no fogging could be observed. This sample gave a count of 0.38 per minute for the whole area (10 square centimeters) which would correspond to about  $0.5 \times 10^4$  alpha particles for the week. Webb (2) estimates that it requires about  $10^5$  beta particles per square mm to produce a pronounced darkening (density 0.3 to 0.6) on a fast x-ray film and he has also found that an equal number of alpha particles produces approximately the same photographic effect.

Extrapolating the ratio of 5.5  $\mu\text{g U/g}$  of steel to a surface count of 0.03 alpha particles per minute per square centimeter to Webb's figure of  $10^5$  alpha particles per square mm ( $10^7$  particles per square cm), it would therefore require a uranium content of 74  $\mu\text{g/g}$  steel in contact with x-ray film for six months to darken a film to the specified degree. This is a figure more than 10 times the highest we found and over 100 times the mean concentration in the resultant steel from the second (semi-plant) run. With the additional expected dilution in the steel industry there should be no possible harmful effect on the photographic industry.

#### TECHNICAL CONTAMINATION - INSTRUMENT INDUSTRY:

In the manufacture of Geiger-Muller tubes the background should be kept down to the order of 10 counts per minute. The contribution of the cylindrical electrode should be expected to contribute about one tenth of this or of the order of one count per minute. A 10 square inch area electrode should, therefore, be kept below 0.015 counts per square cm.

In the case of high sensitivity ionization chambers such as those for measuring radon background a limit of about 10 counts per hour per 125 square inches of surface should be met. This corresponds to .0002 counts per minute per square cm.

These figures would correspond to a uranium content in steel, if used for this purpose, of 2.0 and 0.03  $\mu\text{g}$  per gram of steel respectively. Reference to Table I shows that these are below the figures found for some of the samples of steel prepared before 1940, prior to the large scale processing of uranium.

For this reason it has always been necessary in the instrument industry to avoid the use of ordinary commercial steel for certain low level applications. Stainless steel (made from virgin iron ore only) and tungsten are ordinarily used in the electrodes for counters. Any slight increase in the uranium content of commercial steel could therefore have no effect on the manufacture of radiation instruments because the level of natural radioactivity in commercial materials is such that they have always been compelled to be discriminating in choosing materials for components.

Table IV  
Summary of Results

<u>Steel</u>	<u>No. of Samples</u>	<u>Mean Uranium Concentration</u> (micrograms per gram)
Old Samples	14	0.0522 (.0519)
<u>First Run (Laboratory Level)</u>		
Contaminated Steel *	10	57.8 (18.3)
Melted Steel	5	1.50 (2.28)
Slag	6	550 to 9900
<u>Second Run (Semi-Plant Level)</u>		
Melted Steel	5	0.56 (0.093)
Slag	2	79.0

\* Sample of scale measured 8700  $\mu\text{g}/\text{g}$   
Standard deviation is given in parentheses.

Radiation measurements indicated the contaminated steel used in the second run to have the same order of contamination as in the first run.

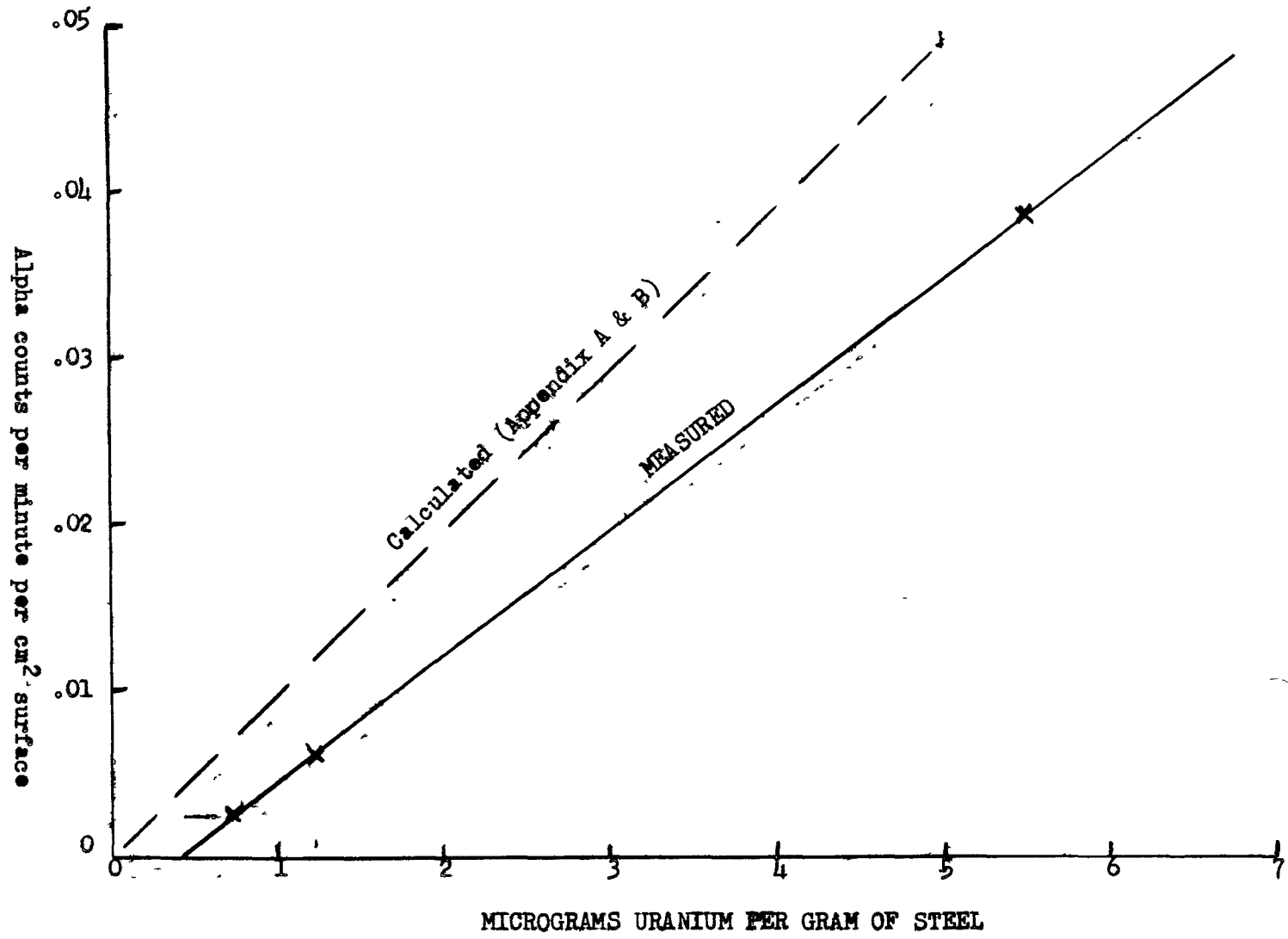


FIGURE 1

## CONCLUSION:

As a result of these studies the Health and Safety Division has recommended that within New York Operations scrap steel contaminated with uranium may be released for sale through the usual scrap channels with only the following two restrictions:

1. No containers, pipes, tubing or machinery be released in which gross quantities of uranium bearing materials such as caked sludges could be entrapped.
2. This lifting of existing restrictions applies to scrap metal known to be contaminated with uranium only and does not apply to other radioactive contamination."

Subsequent studies of other types of contamination are to be made and if results warrant, policies governing the disposition of scrap materials will be amended further.

A study of this nature could be successfully completed only through the cooperation of several groups. Acknowledgement is extended to S. A. Rothenberg for field work in selecting and preparing contaminated scrap for tests, as well as making radio-autographic exposures of some of the samples and to John Alercio who performed the uranium analyses. Mr. William Olson, Assistant Editor of Iron Age was helpful in obtaining statistics of the steel industry as was Joseph N. Cook of our Administrative Operations Division who compiled figures on tonnage and costs involved in shipping scrap in the past. Edward B. Meservey of the Division of Technical Advisers was responsible for Appendix B.

APPENDIX A

Alpha emission from Uranium 238 in equilibrium with Uranium 234

$$e = \frac{NuR}{4} \quad \text{from Nogani \& Hurley (3)}$$

$$N = 6.02 \times 10^{23} \times d \times \frac{\lambda_{uI}}{W_{uI}}$$

$$d = 18.68 \text{ (uranium) - range in air (cm)}$$

$$\lambda_{uI} = 4.83 \times 10^{-18} \quad \text{- uranium disintegration rate (sec}^{-1}\text{)}$$

$$W_{uI} = 238$$

$$u = \text{ratio of range in uranium to range in air}$$

$$N = \frac{6.02 \times 10^{23} \times d \times 4.83 \times 10^{-18}}{4 \times 238}$$

$$= 3.06 \text{ ud} \times 10^3 \text{ (}\Sigma R\text{)}$$

$$\Sigma R = 5.86 \text{ cm}$$

$$\text{ud} = \frac{.001226 \sqrt{238}}{3.84} = 4.92 \times 10^{-3} \quad \text{- range in uranium}$$

Therefore in pure uranium alpha particles would reach a surface from a depth of ud involving a volume of

$$\begin{aligned} v &= 5.07 \text{ cm}^2 \times 4.92 \times 10^3 \\ &= 24.9 \times 10^{-3} \text{ cc} \\ &\text{or } 0.466 \text{ grams} \end{aligned}$$

With a specific activity of  $2.5 \times 10^4$  alpha particles per gram per sec this would be equivalent to about  $7 \times 10^5$  alpha disintegrations per minute for this volume.

Experimental evidence indicates that from an alpha emitting sample of infinite thickness something of the order of one quarter of the alpha particles would be emitted from a surface. This would be a surface emission of the order of  $2 \times 10^5$  alpha particles per minute.

## APPENDIX B

### Surface Alpha and Beta Radiation from Iron Contaminated with Uranium.

#### Assumptions:

1. The thickness of metal is greater than the range of alpha particles, and the area of the metal is infinite compared with range of alpha particles.
2. The amount of uranium is small enough to have negligible effect on the density of the mixture.
3. The range of alpha particles is given approximately by:

$$L = K \frac{\sqrt{A}}{D} \quad (\text{Goodman - The Science and Engineering of Nuclear Power Vol. I, p. 60})$$

where:  $L$  = range (cm)  
 $D$  = density (gms/cm)  
 $A$  = atomic wt.  
 $K$  = an experimental constant

#### Dose from Contaminated Irons:

The approximate dose at the surface of a piece of iron containing some uranium can be calculated as follows. The ionization at the surface of uranium metal is caused by alpha particles produced in a surface layer of thickness equal to the range of alphas in uranium (assumption 1). The ionization at the surface of iron containing uranium will be caused by alpha particles produced in layer of thickness equal to the range of alphas in iron (assumption 2). The ratio of the intensities of ionization in the two cases is equal to the ratio of the number of alphas produced in the two surface layers having thicknesses equal respectively to the range of alphas in the two substances. The number of alphas produced will be proportional to the mass of uranium in the corresponding layer ( $\text{g/cm}^2$ ).

From assumption (3) the ranges (thickness of layer) for the two materials are:

$$\begin{aligned} L_1 &= K \frac{\sqrt{A_1}}{D_1} && \text{(uranium)} \\ L_2 &= K \frac{\sqrt{A_2}}{D_2} && \text{(iron)} \end{aligned} \quad (1)$$

The masses of uranium (per  $\text{cm}^2$ ) in the two layers are:

$$\begin{aligned} M_1 &= L_1 D_1 \\ M_2 &= L_2 C D_2 \end{aligned} \quad (2)$$

where  $C$  is the concentration of uranium in the iron.

The ratio of ionization intensities is equal to the ratio of masses of uranium:

$$\frac{I_2}{I_1} = \frac{M_2}{M_1} = \frac{L_2 C D_2}{L_1 D_1} = \frac{C \sqrt{A_2}}{\sqrt{A_1}} \quad (3)$$

For application to contaminated iron:

$$\begin{aligned} A_2 &= 55.9 \text{ (iron)} \\ A_1 &= 238 \text{ (uranium)} \\ \frac{I_2}{I_1} &= \frac{\sqrt{55.9}}{238} \quad C = .49 C \end{aligned} \quad (4)$$

Therefore the alpha count from contaminated steel is equal to:

$$0.49 \times \text{Alpha count from U x U concentration in steel}$$

Thus 1% by wt. uranium contamination in iron would give a dose at the surface equal to 1/200 times the surface dose from pure uranium.

In the case of beta radiation, the general method of calculation would be exactly the same, except that the range of beta particles in grams per square centimeter is the same approximately for all elements. This means that the equation (4) should be modified when applied to beta particles so as to read:

$$\frac{\beta\text{-dose from contaminated iron}}{\beta\text{-dose from pure uranium}} = \text{U-concentration in iron} \quad (5)$$

Thus 1% by weight uranium contamination in iron would give a beta dose at the surface equal to 1/100 times the surface dose from beta-



particles from pure uranium. It is also to be noted that the maximum range of uranium beta's is 1.1 grams per square centimeter and that therefore the above formula will apply when the thickness of iron is 1.5 millimeters or more.

For thicknesses of iron less than 1.5 millimeters, the dose decreases with thickness. The dose is not, however, directly proportional to thickness but decreases less rapidly because of the decreased self-absorption in the thinner sources.

APPENDIX C

Uranium analysis made by the National Bureau of Standards in 1948 of three samples of DuPont commercial fertilizer gave the following results. The identification refers to nitrogen-phosphorus-potassium ratios.

<u>Sample</u>	<u>Uranium</u>
3-12-5	61
5-10-5	53
5-10-10	50

Reference - Letter from C. J. Rodden (NBS) to F. M. Belmore (AEC-NYOO) dated September 20, 1948.

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