UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

IN REPLY REFER TO:
40-9008
LRL:ED

SOURCE MATERIAL LICENSE

License No. C-4960
Amendment # 1
Dated: APR 1 1960

The Carborundum Company
P. O. Box 32
Akron, New York

Attention: Mr. D. H. Sp[illegible]

Gentlemen:

Pursuant to the Atomic Energy Act of 1954 and Section 40.21 of the Code of Federal Regulations, Title 10 - Atomic Energy, Chapter 1, Part 40 - Control of Source Material, you are hereby licensed to receive possession of and title to nine hundred thousand (900,000) pounds of ore containing thorium for processing at your Parkersburg plant located at Washington, West Virginia.

You are further licensed to transfer and deliver possession of and title to refined source material to any person licensed by the Atomic Energy Commission, within the limits of his license.

As a condition of this license, you are required to maintain records of your inventories, receipts and transfers of refined source material.

This license is subject to all the provisions of the Atomic Energy Act of 1954 now or hereafter in effect and to all valid rules and regulations of the U. S. Atomic Energy Commission, including 10 CFR 20, "Standards For Protection Against Radiation."

Neither this license nor any right under this license shall be assigned or otherwise transferred in violation of the provisions of the Atomic Energy Act of 1954.

This license shall expire July 31, 1960.

CC: Docket Officer
Document Room
S/H
Insp. w/c appl

FOR THE ATOMIC ENERGY COMMISSION

J. C. Delaney
Chief, Nuclear Materials Section
Licensing Branch
Division of Licensing & Regulation

Originator: LW
Approved: JCD

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RADIATION SAFETY BR.
9/25/58

RADIATION SAFETY CHECK

Company The Carborundum Co. Docket No. 40-5001

References Letter of July 13, 1960 License Renewal of C-4960

Material Requested ore containing thorium Quantity 900,000 lbs.

Weight % ______ Form 3-6% Th Quantity on hand at any one time: ______

Intended Use Chemical Processing of Nigerian Zircon

FACILITIES Not Required ______ See Comments ______ Adequate ______

In Application:		Not Required:
	Hot cell	✓
✓	Vented area	
	Storage	

EQUIPMENT Not Required ______ See Comments ______ Adequate ______

In Application:		Not Required:
✓	Processing	
	Hood	
	Dry box	
	Filter	
✓	Resp.Prot.	
	Strge.Cont.	
	Handling	
✓	Clothing	

INSTRUMENTS Not Required ______ See Comments ______ Adequate ______

In Application:		Not Required:
✓	Beta gamma	
	Alpha	
	Neutron	
✓	Air samplers	
	Countg.(Scalers)	
	Fluorimeter	

ADMINISTRATIVE PROCEDURES — need

Not Required ______ See Comments ______ Adequate ______

RADIATION PROTECTION PROCEDURES

Not Required ______ See Comments ______ Adequate ______

In Application:		Not Required:
	Shipping	
	Handling	
	Processing	
	Emergency	

need.

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RADIATION SAFETY BR.
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RADIATION SAFETY CHECK

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RADIATION SURVEY PROCEDURES Not Required ______ See Comments ____ Adequate ✓

In Application:		Not Required:
✓	Rad. levels	
✓	Contamination	
✓	Air Sampling	
✓	Effluents	
	Leak testing	✓

PERSONNEL MONITORING Not Required _____ See Comments _____ Adequate ✓

In Application:		Not Required:
✓	Film badges	
	Dosimeters	
	Calculations	
✓	Urinalysis	

WASTE DISPOSAL No Waste ✓ See Comments _____ Adequate ✓

Estimated Quantity ________ Method:
Burial ________
Sewer ✓
Transfer ________
Incineration ____

O.K. with Part 20 __________
Requires approval __________

TRAINING & EXPERIENCE AVAILABLE Not Required _____ See Comments _____ Adequate ______

In Application:		Not Required
	Rad. safety officer	
	Supervision	
	Instruc. of Personnel	

} need for routine procedures after Whipple leaves.

ADDITIONAL INFORMATION REQUESTED ______________________________ (date)

Reviewed by CMF Date approved ______________

"GLC (4)

MEMORANDUM

January 24, 1961

TO: Dr. D.R. Spink
Carborundum Metals Co.
Akron, New York

FROM: D. E. Barber, C.A. Pelletier, and G. Hoyt Whipple
The University of Michigan

SUBJECT: Revisions of Atomic Energy Commission Standards for Protection Against Radiation, 10CFR20, that Pertain to the Operations of the Parkersburg Plant.

We have reviewed Title 10, Code of Federal Regulations, Part 20 as amended September 7, 1960 and December 30, 1960 and list below changes and additions to the regulations pertinent to operations at the Parkersburg plant. The numbers preceding each paragraph below refer to the section of 10CFR20 to which the comments apply. You will note that some of the revisions are helpful to Carborundum Metals Co., others are not.

20.5 (c) (1): "...a curie of natural thorium...means the sum of 3.7×10^{10} dis/sec from Th-232 plus 3.7×10^{10} dis/sec from Th-228."

This new definition of the curie for natural thorium means that all previously reported values of microcuries or microcuries/milliliter (μc/ml) are now to be multiplied by 0.5. Accordingly, the formulas given on page 11 of our July 25, 1960 memo should be changed to:

High Vol. Sampler:

$$\frac{\mu c}{ml\ (air)} = 1.1 \times 10^{-10} \times \frac{(\text{net 100 hr. c.p.m.})}{(\text{vol. in cu. ft.})}$$

Continuous 24. hr. Samplers:

$$\frac{\mu c}{ml\ (air)} = 1.38 \times 10^{-11} \times \frac{(\text{net 100 hr. c.p.m.})}{(\text{vol. in cu. ft.})}$$

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Liquid Samples:

$$\frac{\mu c}{ml\ (liquid)} = 2.25 \times 10^{-6} \times \frac{(net\ 100\ hr.\ c.p.m.)}{(vol.\ in\ ml.)}$$

No change is required in the maximum permissible urinary excretion rate of .015 dpm/ml recommended in our March 10, 1960 memo since the computation of that value assumed separation of Th-232 and Th-238 in urine samples before counting. This assumption forced the use of the new definition of the curie.

20.5 (c) (2): "...one curie of natural thorium...is equivalent to 9,000 kilograms or 19,850 pounds of natural thorium."

This specific activity is consistent with the new definition of a curie of natural thorium, and means that it will now be possible to have twice as much material in a container, room, or area as was previously reported. The new minimum quantities requiring labels are, therefore:

Label: "Caution Radioactive Material(s)"
+ radiation symbol

Rooms	containing	greater	than	5000 μc Th(nat.)
"	"	"	"	99.3 lb. Th(nat.)
"	"	"	"	1660 lb. ore
"	"	"	"	9930 lb. $ZrCl_4$
Containers	"	"	"	500 μc Th(nat.)
"	"	"	"	9.93 lb. Th(nat.)
"	"	"	"	166 lb. ore
"	"	"	"	993 lb. $ZrCl_4$

Airborne radioactivity area warning signs must still be posted at the entrances to ..s Carbide and Chlorination buildings.

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20.101 (a): This paragraph prescribes the maximum permissible γ radiation exposure doses which are to be observed.

If one is to avoid the determination of previously accumulated exposures from past records the maximum permissible exposure dose is 1/1/4 rem per calender quarter. This is the sum of continuous exposure, 40 hours per week, for one quarter of a year to 2.5 mrem/hr. to the whole body.

20.101 (b): The licensee may allow slightly greater exposures to the whole body than provided by paragraph 20.101 (a) provided: "...the licensee has determined the individual's accumulated occupational dose to the whole body on Form AEC-4..." or its equivalent.

The labor involved in compiling the past accumulated exposure outweighs any advantage of the higher dose limit provided by this paragraph. It is recommended that C.M.C. use the 1 1/4 rem/quarter dose as the whole body exposure dose limit.

20.103 (c)(1):. "Except as authorized by the Commission pursuant to this paragraph, no allowance shall be made for particle size or the use of protective clothing or equipment in determining whether an individual is exposed to an airborne concentration in excess of the limits specified...".

This means that respiratory protection factors, even the conservative factors we have used, may not be applied without specific approval from the A.E.C.

20.103 (c) (2) and (3): The Commission may authorize exposure to airborne concentrations in excess of those prescribed by regulation provided an application soliciting such permission demonstrates that the person exposed will not

inhale, ingest, or absorb quantities of radioactive material in excess of those otherwise permitted.

Your attention is called particularly to 20.103 (c) (3) (ii) which indicates the importance of a good fitting, maintenance and cleaning schedule for protective equipment. In addition, 20.103 (c) (3) (iii) states, "The proposed periods for use of the equipment by any individual should not be of such duration as would discourage observance by the individual of the proposed procedures...".

The implications of these paragraphs are two:

(1) Concentrations to which employees are exposed must be equal to or less than the MPC prescribed by 10CFR20 after occupancy factors are taken into consideration, or

(2) The plant must apply to the A.E.C. for permission to take advantage of protection afforded by respirators and protective clothing or the physical nature of the airborne contaminant.

If the latter course is chosen, studies must be undertaken to determine both the particle size distribution of the airborne contaminant and the protection efficiency of the protective clothing used in air having such a particle size distribution. Such studies will be expensive and time-consuming; the results they provide will be applicable only to a given set of operating conditions. A change in process will require a repetition of these studies.

These new paragraphs on protective clothing and equipment present problems. The major difficulties stem from carbiding operations, where it has not been possible to apply an occupancy factor less than 1.

20.104 (a): The total body exposure of persons under 18 years of age in the plant is limited to 10% of the exposures listed in 20.101 (a), i.e. limited to 125 millirem per calender quarter.

20.104 (b): In-plant air concentrations may be averaged over periods no greater than a week if persons under 18 years of age are to be exposed to airborne concentrations which are permissible for older persons.

If persons under 18 years of age are employed the provisions of 20.104 (a) and (b) and 20.202 (a) (2) will require that:

(1) more intensive sampling be done

(2) film badges be provided routinely to persons under 18 years of age.

We suggest that these provisions make the employment of persons under 18 years of age even during the summer months undesirable.

20.202 (a)(2): "Each individual under 18 years of age who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 5 percent of the applicable value..." shall be supplied with appropriate personnel monitoring equipment.

20.206 (a): All personnel frequenting a restricted area must be instructed in the appropriate radiation safety problems, procedures to minimize exposure, and in applicable provisions of Commission regulations and licenses. Employees must be advised of reports of radiation exposure which they may request.

This means that provision will have to be made to instruct all personnel, not just supervisors. We feel the instructor should be a company employee rather than a consultant. We shall, of course, be pleased to instruct the instructor.

20.206 (b): A copy of 10CFR20, a copy of your A.E.C. license, and a copy of operating procedures applicable to work under the license must be posted in

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accordance with this paragraph or be kept "available for employees' examination upon request."

We recommend the latter action.

20.206 (c): "Form AEC-3 "Notice to Employees", shall be conspicuously posted in a sufficient number of places in every establishment where employees are employed in activities licensed by the Commission to permit them to observe a copy on the way to or from their place of employment."

A posting at the main gate would suffice if other entrances are not used. Copies of Form AEC-3 may be obtained from:

Manager
Oak Ridge Operations Office
P.O.Box E
Oak Ridge, Tennessee

It is suggested that Form AEC-5 (see below) also be requested from this Office.

20.401 (a): Where personnel monitoring is used records of exposure shall be kept on Form AEC-5 or its equivalent. Doses recorded shall be for periods of time not exceeding 13 weeks.

It is unlikely that film badges will have to be used routinely unless individuals under 18 years of age are employed. If film badge monitoring is not used, we suggest you include as a part of this record the γ radiation measurements made with the Jordan survey meter.

20.401 (b) and (c): Radiation exposure records must be "preserved until

December 31, 1965 or until a date 5 years after termination of an individual's employment, whichever is later." Microfilms may be used.

These records include air and water concentration determinations and γ radiation measurements and film badge exposure results. Concentrations shall be recorded in terms of μc/ml and γ radiation exposure in terms of rem. We shall assume that the Jordan survey meter reads mrem/hr.

<u>20.404 (a):</u> A former employee may request a written report of his exposures as shown in the company records pursuant to 20.401 (a). Such a report must be furnished within 30 days after request and shall include the statement, "This report is furnished to you under the provisions of the Atomic Energy Commission regulations entitled, "Standards for Protection Against Radiation" (10CFR20). You should preserve this report for future reference". Bioassay data must be included if bioassays were required as a condition of licensing by the AEC pursuant to 20.108.

This means that C.M.C. must be prepared to issue exposure reports to individuals perhaps years after such exposure occurred. Herein lies one of the advantages of film badge monitoring even though the regulations may not directly require such monitoring. It will be difficult and time consuming to establish the exposure of an individual from γ radiation measurements made with a survey meter.

<u>20.405 (a):</u> When exposures or activity concentrations occur in the plant which exceed those recommended by 10CFR20 or which exceed 10 times the MPC's for the general population, a written report must be sent to the AEC within 30

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days of the occurrence. The individuals exposed must also be advised, in writing, of the nature and extent of their exposure. Consult these paragraphs for details.

This means that a report must be written to the A.E.C. and an individual every time a man is exposed to concentrations greater than the MPC. This has ridiculous, but real, implications for operations such as picking-belt operations in the Carbide building.

20.406: Any employee may request an annual exposure report. The company should be prepared to issue such reports.

Appendix B: Revised Maximum Permissible Concentrations in air and water:

	Old μc/ml		New μc/ml	
	Air	Water	Air	Water
Occupational levels	5×10^{-11}	1.5×10^{-6}(s)	3×10^{-11}(s)	3×10^{-5}(s)
for Th (nat.)	———	———	3×10^{-11}(I)	3×10^{-4}(I)
Public levels	1.7×10^{-12}	5×10^{-8}	1×10^{-12}(s)	1×10^{-6}(s)
for Th (nat.)			1×10^{-12}(I)	1×10^{-5}(I)

The letters "s" and "I" stand for soluble and insoluble respectively.

The occupational MPC in air for natural thorium is now 0.6 times its former value.

The public MPC in air for natural thorium is now 0.59 times its former value.

The public MPC (I) in water is 200 times its former value but the MPC (s) is only 20 times its former value. This change in water MPC's has solved the liquid effluent problem of the plant. It will probably not be necessary to perform the intensive effluent survey mentioned previously regardless of whether the contaminent is soluble or insoluble.

Reductions in MPC's plus the change in the definition of the curie for natural thorium (20.5 (c) (1)) require that "Average/MPC" values reported in memos dated March 10, April 20, May 31, and July 25, 1960 be multiplied by the following factors:

Samples	Correction Factor for Average/MPC
On-Site Air	(5/3)(1/2) = 0.83
Off Site Air	(1.7)(1/2) = 0.85
Water Effluent	(1/20)(1/2) = 0.025

Conclusions:

These changes mean that, except for water, the new regulations have been of little help to Carborundum Metals Co. Indeed, you have been presented with more problems, particularly with respect to protective clothing and reports. The reporting requirements in themselves would seem to make good ventilation mandatory if one is not to be plagued with writer's cramp.

D. E. Barber

D. E. Barber

C A Pelletier

C. A. Pelletier

G. Hoyt Whipple

G. Hoyt Whipple

DOCKET NO. 40-5001

File Copy

C. M. Memo, 3-10-60

MEMORANDUM

March 10, 1960

To: Dr. D. R. Spink
Carborundum Metals Co.
Akron, New York

From: R. J. Augustine, D. E. Barber and G. Hoyt Whipple
University of Michigan
Ann Arbor, Michigan

Subject: Report of the Radiological Survey of the Operations at the Parkersburg Plant, January 6 to February 19, 1960.

This report is arranged in the following sections.

1. Introduction
2. Maximum Permissible Concentrations
3. Air Samples
    a. Sampling and Counting Procedures
    b. Data Analysis
    c. Sampling Locations and Conditions
    d. Data Summary
4. Water Samples
5. Urinalysis
6. Film Badges
7. Gamma Measurements
8. Respirators
9. Plant Duty Cycle and Occupancy Factor
10. Recommendations
11. References

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1. Introduction. This memorandum reports the methods, results, and summary of radiological health surveys made at the Carborundum Metals Co. plant at Parkersburg, West Virginia, during the interval from January 6 to February 19, 1960. During this period Nigerian zircon ore containing up to 6% thorium was being processed under AEC Source Material License No. C-4960.

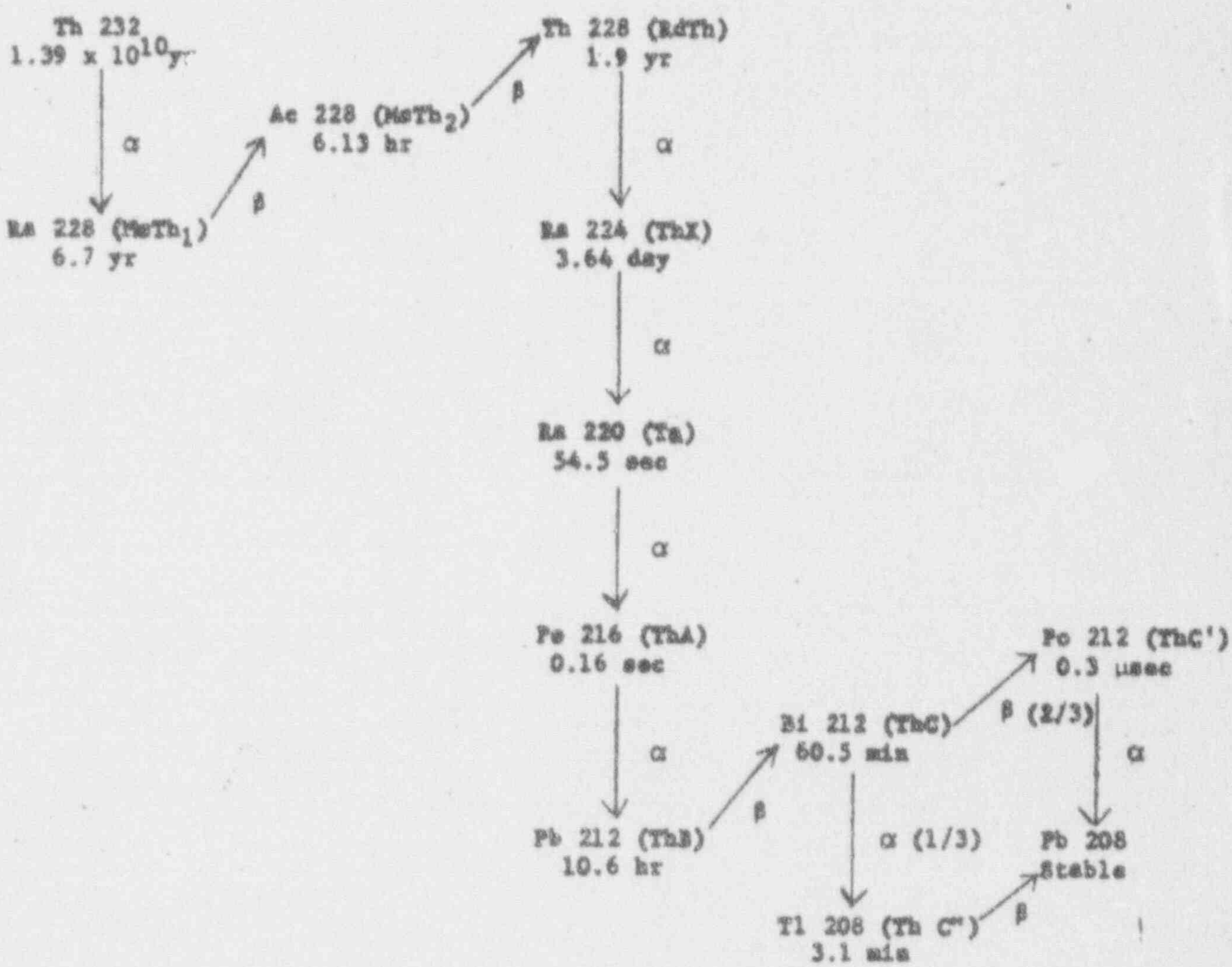
The plant and the processes carried out on this ore have been described in a letter dated November 27, 1959, from D. R. Spink, Assistant to the Manager, Technical Branch, Carborundum Metals Co. to Mr. Doules, Nuclear Materials Section, Licensing Branch, Division of Licensing and Regulations, U. S. Atomic Energy Commission. Further description of the plant and its operations seems unnecessary here.

Because everyone in this work has frequent occasion to consult the decay series of the thorium family, Table 1 has been included as a convenience for the reader, and, it should be admitted, for the authors as well.

2. Maximum permissible concentrations (MPC's) for natural thorium and for thoron in equilibrium with its daughter products are given in Table 1 from several sources, and in the last row the MPC's used for the purposes of this report. It is evident from Table 2 that there is considerable diversity of opinion on the proper MPC for natural thorium in air. The present legal limits are the 10CFR20 limits now in effect. The National Committee on Radiation Protection in giving the provisional values listed in Table 2, suggests that subsequent investigations may indicate the need for limits as low as those given for soluble and insoluble natural thorium in Table 2.

Table 1

The Thorium Decay Series



The MPC's for natural thorium in both 10CFR20 and Handbook 69 are given for the parent isotopes, thorium 232 and thorium 228. It is assumed that in natural thorium these two isotopes are in equilibrium. The fact that the parent isotopes decay to alpha emitting daughters is taken into account in calculating the MPC values. Thus, in comparing the activity of a sample to the MPC, only the activity due to the parents should be used.

The activity of natural thorium is defined in two ways. AEC Regulation 10CFR20, Section 20.5 c, gives the following definition, "the number of microcuries (of natural thorium) shall be determined by dividing the total rate, in dpm, of alpha emissions from the mixture by 2.2×10^6 dpm per µc." Handbook 69, on the other hand, gives on page 14 this definition, "a curie of recently extracted thorium is considered to correspond to the sum of 3.7×10^{10} dis/sec from Th 232 and 3.7×10^{10} dis/sec from Th 228." It appears that the term, recently extracted thorium, in the Handbook 69 definition, means the same thing as natural thorium in the 10CFR20, since the ICRP report defines natural thorium in this way. Thus a microcurie of natural thorium by the Handbook 69 definition has twice the alpha activity (4.4×10^6 dpm/µc) of a microcurie by the 10CFR20 definition (2.2×10^6 dpm/µc).

Comparison of the MPC's for natural thorium in Table 2 shows an apparent disparity. This disparity may be resolved by putting the activities in terms of alpha disintegration rates.

The Handbook 69 MPC for 40-hour per week occupational exposure:

$$3 \times 10^{-11} \text{ µc/ml} \times 4.4 \times 10^6 \text{ dpm/µc} = 1.3 \times 10^{-4} \text{ dpm/ml}$$

The corresponding MPC from 10CFR20:

$$5 \times 10^{-11} \text{ µc/ml} \times 2.2 \times 10^6 \text{ dpm/µc} = 1.1 \times 10^{-4} \text{ dpm/ml}$$

As used in this report the microcurie is that defined in 10CFR20, i.e. 2.2×10^6 dpm. The MPC's used for natural thorium are those given in 10CFR20, but the Handbook 69 MPC's have been used for thoron 220 + daughters and for Ra 228, since 10CFR20 gives no MPC's for these materials.

3. Air Samples

a. Sampling and Counting Procedures. Samples of airborne dust were taken with high volume sampling units manufactured by General Metal Works, Cleves, Ohio. These units draw a maximum of about 25 cfm of air through a 4-inch diameter Whatman No. 41 filter paper disk. Samples were obtained within the plant at locations most likely to be occupied by workers and at various times during the carbiding and car-pulling operations. The points at which samples were taken are described in Section 3c. A number of off-site samples of airborne dust were also collected.

After the filter samples were brought to the laboratory a section was cut out of the filter to fit the 2-inch stainless steel counting planchets. The samples were counted for alpha activity in a proportional counter, Model PC-3, manufactured by the Nuclear Measurements Corp., Indianapolis, Indiana. The first count was made 4 to 6 hours after the sample was collected and succeeding counts were made approximately 12, 24, 48 72 and 150 hours after collection.

b. Data Analysis. Theoretical alpha activity curves for Th 232 + Th 228, for Rn 220 (thoron), and for Ra 228 + Ra 224 are given in Figs. 1, 2 and 3, respectively. These curves have been redrawn from reference 2.

Table 2. Maximum Permissible Concentrations in Units of μc/ml

Source	Material	Air		Water
		40 hr/week occupational exposure	168 hr/week public exposure	Public Drinking
AEC Regulations 10-CFR-20 (in effect)	Natural thorium	5×10^{-11}	1.7×10^{-12}	5×10^{-8}
National Bureau of Standards Handbook 69	Natural thorium			
	Soluble	2×10^{-12}	6×10^{-14} (*)	2×10^{-5} (*)
	Insoluble	4×10^{-12}	1×10^{-13} (*)	1×10^{-5} (*)
	Provisional	3×10^{-11}	1×10^{-12} (*)	-----
	Thoron 220+daughters	3×10^{-7}	1×10^{-8} (*)	-----
	Radium 228	7×10^{-11}	2×10^{-12} (*)	-----
Used in This Report	Natural thorium	5×10^{-11}	1.7×10^{-12}	5×10^{-8}
	Thoron 220+daughters	3×10^{-7}	1×10^{-8}	-----
	Radium 228	7×10^{-11}	2×10^{-12}	-----

* Handbook 69 gives the 168 hr/week occupational exposure value. These figures are 1/10 of the Handbook 69 values, in order to apply them to the public exposure.

The activity of each sample, in net counts per minute, was plotted as a function of time after collection on log-log graph paper. Several representative sample curves are shown in Fig. 4. Comparison of the sample curves to the theoretical curves showed that to a greater or lesser degree all three components occurred in the collected samples.

The sample curves which showed only short lived daughter activity, e.g. the lowest curve in Fig. 4, were extrapolated back to obtain the activity one hour after collection and evaluated in terms of the MPC for thoron daughters. The MPC for Rn 220 in equilibrium with its daughters is some 10,000 times greater than the MPC for thorium, as shown in Table 2. No sample taken thus far has indicated the presence of Rn in amounts significant to health. So far, only the isotopes Th 232, Th 228, Ra 224 and Ra 228 contribute significantly to the health problems associated with the operation of the plant.

The majority of the sample curves show a minimum about 100 hours after collection; this minimum is followed by a slight increase and then by a decay that appears to be rapid on the logarithmic time scale. These features are illustrated in the middle curve of Fig. 4. The slight increase after 100 hours is attributed to the Th 232-228 component; the subsequent decay is believed to be due to the Ra 228-224 component.

It can be seen in Figs. 1 and 3 that the maximum activity attained by Th 232-228 and by Ra 228-224 are just about twice the activity at 100 hours after separation. Since it was quite impractical to take successive counts until each sample had attained its maximum activity, advantage has been taken of this relation by multiplying the activity observed at 100 hours after collection by two to obtain an estimate of the equilibrium activity.

C. M. Memo, 3-10-60

The ultimate alpha activity for a sample of thorium in equilibrium with all the daughter products is six alpha particles for each Th 232 disintegration: one alpha particle each from Th 232 and Th 228 and four alpha particles from other daughters. Multiplying the 100-hour alpha activity by two gives an estimate of the activity when this equilibrium has been reached. The MPC's, however, are given in terms of Th-232 and Th 228 activity, which constitute only 1/3 of the equilibrium activity. To obtain a value suitable for reference to the MPC, the 100-hour alpha activity is first multiplied by two to obtain an estimate of the equilibrium activity and then multiplied by 1/3 to obtain an estimate of the activity due to Th 232 and Th 228 alone. Thus the value to be compared to the MPC is 2/3 of the 100 hour activity.

The MPC for Ra 228 is only about twice as great as that used in this report for natural thorium, so the distinction between them does not seem worth the labor involved in extending the counting data long past 100 hours. The practice followed here of referring 2/3 of the activity observed at 100 hours to the MPC for natural thorium is conservative regardless of the shape of the activity curve beyond 100 hours.

The concentration was calculated from the following relation,

$$A = (2/3)(KC/fVE), \qquad (1)$$

where A = concentration of Th 232 + Th 228 in μc/ml

K = proportionality constant to justify the units = 1.6×10^{-11}

C = observed net count 100 hours after collection in cpm

f = fraction of the total filter paper counted = 0.25

V = volume of the air sample in cubic feet

E = efficiency of the counter = 0.40

Substitution of these values gives

$$A = 1.1 \times 10^{-10}\ C/V \qquad (2)$$

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c. Sampling locations and conditions. Samples of airborne dust were taken at many points throughout the plant. In order that the data may be reported in a convenient and understandable manner they have been grouped under the several general locations described below. The concentrations observed within these general locations all followed the same patterns and fell within reasonable limits, i.e. these are natural groupings.

Main Floor: This includes all samples taken on the main floor of the Carbide Building.

Control Room: This is the Carbide Building Office and is on the same level as the catwalk around the furnace.

Locker Room: This is the change room for the workers, located on the same level as the main floor, and separated from the main floor area by a door.

Catwalk: This is the walkway around the furnace, near the feed hoppers.

On-Site: These are samples taken at various places on plant property, but outside of the Carbide Building.

Off-Site: These are environmental air samples taken at locations outside of the plant property, and therefore in the public domain.

Ore and Coke Hole: This location is near the loading pit where ore and coke are dumped into the conveyor system. It is outside the Carbide Building.

Stack Samples: These were samples taken from the cyclone exhaust ducts leading to the main stack. Because of the high dust loading, it was not possible to sample accurately at this location. Hence, a comparison has not been made between the sample values and the MPC.

Calcinatory Stack: These were taken from the cyclone exhaust duct leading to the main stack from the calciner. High dust loading also prevented accurate sampling here.

The following sampling conditions designate the type of operation which was going on at the time samples were taken.

Furnace On: This means the carbide furnace was running, loaded with the Nigerian Ore.

Furnace Off: This means the carbide furnace was not running.

After Cleanup: After the carbiding of Nigerian Ore had been completed, the Carbide Building was cleaned up in prepara on for a run with normal zircon sand. These samples were taken after this cleanup.

Car Pulling: This includes all samples taken during the pulling of the furnace shells, cleaning off the carbide pigs, sorting carbide, the picking belt operation, loading of old mix fines, etc.

d. Data Summary. The sampling data are summarized in Table 3. The data are grouped according to the classifications of location and condition described above. The values given are (a) the average concentration, (b) the highest concentration obtained, and (c) the lowest concentration obtained, all in μc/ml as computed from equation 2. Also given in Table 3 are the number of samples taken under each classification and the observed average concentration divided by the appropriate MPC. Values greater than 1.0 in the last column indicate situations where and when the average concentration exceeded the appropriate MPC.

TABLE 3. SUMMARY OF AIR SAMPLE DATA

Location	Condition	Average μc/ml	Highest μc/ml	Lowest μc/ml	No. of Samples	Average/MPC
Main Floor	Furnace on	3.2×10^{-10}	1.3×10^{-10}	6.7×10^{-13}	24	0.65
	Furnace off	1.1×10^{-12}	5.3×10^{-12}	2.9×10^{-13}	14	0.02
	After Cleanup	4.8×10^{-12}	5.3×10^{-12}	4.3×10^{-12}	2	0.10
	Car Pulling	2.8×10^{-10}	4.0×10^{-9}	6.7×10^{-13}	70	5.5
Control Room	Furnace on	1.2×10^{-11}	6.0×10^{-11}	2.7×10^{-13}	14	0.24
	Furnace off	1.6×10^{-12}	8.0×10^{-12}	2.0×10^{-13}	9	0.03
	After Cleanup	2.2×10^{-12}	4.7×10^{-12}	2.1×10^{-12}	3	0.04
Locker Room	Furnace on	2.3×10^{-11}	6.7×10^{-11}	2.7×10^{-13}	6	0.47
	Furnace off	6.7×10^{-12}	3.3×10^{-11}	4.0×10^{-13}	7	0.13
	After Cleanup	2.4×10^{-12}	3.5×10^{-12}	1.3×10^{-12}	2	0.05
Catwalk	Furnace on	6.4×10^{-11}	1.3×10^{-10}	3.1×10^{-12}	14	1.2
	Furnace off	7.6×10^{-12}	1.8×10^{-11}	1.5×10^{-12}	5	0.15
On Site	Furnace	2.0×10^{-12}	6.0×10^{-11}	1.0×10^{-13}	10	0.04
	Car Pulling	9.99×10^{-13}	4.9×10^{-12}	2.2×10^{-13}	9	0.02
Ore & Coke Hole	Furnace on	3.5×10^{-11}	6.7×10^{-11}	2.7×10^{-12}	2	0.69
	Furnace off	7.7×10^{-11}	1.9×10^{-10}	9.4×10^{-12}	3	1.5
Stack Samples	Furnace on	2.6×10^{-8}	8.0×10^{-8}	1.3×10^{-8}	6	*
Calciner Stack	Furnace off	2.7×10^{-9}	4.0×10^{-9}	1.3×10^{-9}	2	*
Off Site	Furnace on	5.3×10^{-12}	9.3×10^{-12}	6.7×10^{-14}	24	3.1
	After Cleanup	No Detectable Activity			2	

*See discussion under "Sampling Locations"

4. Water Samples were taken at two locations before the use of the water tank at the cyclone discharge was discontinued. A sample taken directly from the water tank showed a concentration of 3×10^{-6} μc/ml for insoluble material alone. Subsequent samples taken at the plant sewer outfall on two occasions yielded concentrations of 3×10^{-7} μc/ml and 4×10^{-8} μc/ml for the total of soluble and insoluble material. The MPC for thorium in water in the public domain is 5×10^{-8} μc/ml. The plant effluent was, therefore, greater in one case than the MPC before its dilution by river water.

This section is included in the report as a matter of information even though it no longer applies. Since cyclone residues are now collected dry in 55 gallon drums and the residues are recycled through the furnace, no significant material should appear in the water effluent. Although there will probably be a very small amount that reaches the plant water effluent as a result of contamination of the furnace cooling water, routine counting of water samples is considered unnecessary.

5. Urinalysis. Very little seems to be known concerning the excretion of thorium taken into the body via the lung. The present concensus is that the excretion of thorium should be little different from that of uranium. Thorium activity that has been introduced into the body by inhalation may appear in the urine by two routes.

a. The material that is released from the critical organ, or organs, with a characteristic biological half life.

b. The material that is taken into the blood directly from the lung, but which is not sequestered in a critical organ.

The first contribution, that released from the material deposited in the critical organ, usually taken to be bone for thorium, may be estimated from the following assumptions:

a. The exposed individual has accumulated the maximum permissible body burden of 0.04 μc in bone (1).

b. The activity is excreted exponentially from the body with a biological half life of 200 years (1).

c. The worker excretes 1.5 liters of urine per day.

Using these assumptions one finds that the concentration of thorium activity in the urine is 0.0006 dpm/ml.

The second contribution, termed "unretained" thorium in this report, may be estimated from the following assumptions:

a. The exposed individual works for eight hours per day in an atmosphere containing the occupational MPC for natural thorium, 5×10^{-11} μc/ml.

b. The worker breathes a total volume of 10^7 ml. of air per eight hour day.

c. The thorium contained in the inhaled air is distributed as follows (3):

25% enters the blood.

75% is exhaled, retained by the lung, or removed from the lung and swallowed and excreted in the feces.

Of the thorium in the blood:

72% deposited in bone
4% deposited in kidney
4% deposited in liver

leaving 20% of the material in the blood to be excreted in the urine.

Therefore 20% x (25% of the inhaled thorium) = 5% of the inhaled thorium will appear in the urine.

d. The worker excretes 1.5 liters of urine per day. Using these assumptions one finds that the concentration of thorium activity in the urine is 0.037 dpm/ml. This is the "unretained" thorium.

For any practical situation one must have a concentration level in the urine that is regarded as indicating a significant inhalation hazard under the circumstances at hand. For workers who are exposed to thorium dust for the first time, or who are continuously exposed to this dust, the concentration of unretained thorium in the urine will be some 60 times that of retained thorium. The latter estimate would be more suitable in a home for the aged, i.e., for individuals no longer exposed.

Using the same urinary concentration for thorium as for uranium, i.e., 30 μg/liter, one obtains an activity level for thorium of 0.015 dpm/ml. The value of 30 μg/liter is used by at least one installation (5).

To summarize, there are three estimates of thorium concentration in urine that may be taken as indicating the need for action.

a. 0.0006 dpm/ml in the case of individuals no longer exposed to thorium dust.

b. 0.037 dpm/ml in the case of an individual breathing air containing 5×10^{-11} μc/ml of natural thorium activity.

c. 0.015 dpm/ml by analogy to uranium.

The first estimate is not applicable to the present case. The second and third estimates are in good agreement, considering the many uncertainties involved. For the purposes of the present study a urine thorium concentration

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of 0.015 dpm/ml is taken as indicating the need for corrective action.

The gross alpha activity in the urine of 22 individuals who work at the Carborundum Metals Plant was determined by Controls for Radiation, Inc. The specimen volume analyzed was 500 ml, and the group submitting samples included individuals exposed to thorium dust as well as individuals with no known exposure. The results are summarized below:

	dpm/ml
Lowest Concentration	0.00002
Highest Concentration	0.00149
Mean Concentration for group (22)	0.00057
Mean Concentration for exposed and potentially exposed group (18)	0.000525
Mean Concentration for unexposed group (4)	0.000795

The highest concentration obtained is only 10% of the action level developed above. These were gross alpha analyses, and hence may include alpha emitters from natural sources such as drinking water. It is concluded that no significant internal exposure has resulted from the inhalation of thorium dust during the carbiding operations covered by this report.

6. Film badges. The film badge service was provided by R. S. Landauer, Jr. and Co., Matteson, Illinois. Badges were worn by about 30 individuals in the plant. During the carbiding operation, badges were worn for a full week, involving about 50 hours of potential exposure, before being returned for exposure evaluation. During the unloading of the ore, badges were worn only eight hours at a time before being turned in for exposure evaluation. The latter practice is to be attributed to excess zeal on the part of the plant

security officer rather than to any belief that exposure rates were high.

All film badge readings were reported as "zero", save for the three discussed below. The minimum gamma ray dose that can be reliably indicated by a film badge is about 30 mr. The fact that all but three of the badges showed less than 30 mr. means that average exposure rates were less than 0.6 mr/hour in the carbiding operation, and less than 4 mr/hour in the ore unloading operation. These estimates of the upper limits of exposure rates compare favorably with the measured gamma dose rates in Table 4 of the following section.

Two film badges were reported to have densities corresponding to gamma ray exposures of 240 and 245 mr, but the report of these readings included the note that the densities were uniform over the film without trace of a window and the suggestion was made that these films had been exposed out of the badges. Investigation revealed that these two film badges, containing the films, had been inadvertently dropped into a bucket of water by the man who was washing respirators. It is concluded that the densities shown by these two films resulted from their getting wet and not from radiation exposure.

One film badge was placed directly on a bag of ore in a position where it was surrounded by other bags and allowed to remain in this position for eight hours. The reported exposure value for this badge was 90 mr, in excellent agreement with the gamma radiation measurement of 12 mr/hour, given in Table 4.

AEC regulation 10CFR20, Section 20.202 requires personnel monitoring for all individuals who are likely to receive more than 75 mr/week. These results lead to the conclusion that film badge monitoring is unnecessary for

carbiding and ore processing operations. A similar type of check will be made in the chlorination process to determine whether film badge monitoring is required in this operation. This will require careful use of control badges since the chemical fumes may darken the films and give a false indication of radiation exposure.

7. Gamma measurements were made with a Model AGB-10K-G-SR survey meter manufactured by Jordan Electronics, Inc., Alhambra, California. Samples of the ore had been run on a gamma ray spectrometer. The gamma spectrum obtained was such that this survey meter, calibrated with Cobalt 60 gamma radiation, gives valid dose rates. The measurements obtained are presented in Table 4.

Table 4

Gamma Ray Measurements

Location	Positions		Max. mr/hr
Catwalk	Feed hopper surface		2
	3 ft. from feed hopper		0.7
	Inside furnace		0.6
	All other	less than	2
Main floor	Blender surface		2.5
	Drums of old mix		4
	Carbide pig surface		2
Roof	Ore storage bin surface		5
Outside	Surface of bags of ore		12

8. Respirators. During the period covered by this report everyone who worked in the carbide building was supplied with a Welsh Manufacturing Co., Model No. 7100 respirator fitted with Model No. 7100-7 filter. This respirator covers

only the mouth and nose and bears the Bureau of Mines approval number 2175, which approves the respirator "for dusts and mists not significantly more toxic than lead." Thorium dusts are considered to be significantly more toxic than lead, but it is proper to point out that as yet the Bureau of Mines has no approval system for respirators to be used in atmospheres containing radioactive aerosols.

The limit of efficiency of a partial-face respirator, such as the Welsh No. 7100 is set not by the efficiency of the filter which it incorporates, but by the excellence of the fit between the respirator and the wearer's face. In an effort to estimate the overall effectiveness of these respirators in use, alpha counts were made of portions of the respirator filters that had been used for a single day during a complete carbiding run. The portions counted were cut from the center of the filter where most of the material appeared to collect. Alpha counts were taken on both the outside and inside surfaces of portions from 14 filters. The ratios of inside surface count to outside surface count ranged from 0.02 to 0.5 with a mean of 0.2.

This ratio provides only an admittedly crude estimate of the protection provided by these respirators, but on this basis it is considered conservative to assign a protection factor of 2 to this type of respirator in this application, provided that it is worn properly and that the filter is changed at eight hour intervals.

9. <u>Plant Duty Cycle and Worker Occupancy Factor</u>. During the conference at the plant on February 18, 1960 it was determined that a worker's actual furnace time is about 80 hours per month. The remainder of the time is spent working with old mix or ore. Since the data indicate that the old mix and

the ore itself constitute the major exposure hazard, one must adopt an occupancy factor of 1. Also, it was determined that a reasonable duty cycle for the plant is 0.7. This is a figure which may be properly applied directly to the estimate of the exposure to the general public.

10. Conclusions and Recommendations. The data and discussions presented in this report lead to the following conclusions:

a. Main Floor of the Carbide Building. Car-pulling results in air concentrations more than 5 times the MPC. The use of the Welsh respirator, with a protection factor of 2, does not alone remove this operation from the substandard category. Under a regular schedule, car-pulling will be carried out for something less than eight hours a week, i.e. a duty cycle for this operation of less than 0.2. This duty cycle, taken with respirator protection, gives reasonably satisfactory conditions, although it would seem that better dust control is desirable. All other conditions on the main floor appear to be satisfactory, particularly if the present practice of wearing respirators is continued. The closing of furnace leaks will improve conditions throughout the Carbide Building appreciably.

b. Control Room of the Carbide Building. Conditions in this room appear to be satisfactory even though respirators are not generally worn here. Closing furnace leaks will improve conditions.

c. Locker Room of the Carbide Building. Conditions in this room appear to be reasonably satisfactory. Closing furnace leaks and/or the pro-

vision of a filtered, forced air supply for this room will improve conditions.

d. Catwalk around the carbide furnace. During furnace operation air concentrations exceed the MPC somewhat. The use of respirators, which is general practice here, provides satisfactory protection in this location. It is unlikely that any individual spends more than 20 hours per week on the catwalk. The closing of furnace leaks will greatly improve conditions in this location.

e. On-site. Conditions on the plant site appear to be satisfactory.

f. Ore and coke hole. During the dumping of bags or drums of ore the use of respirators makes this a reasonably satisfactory operation. More care in the dumping process will reduce the air concentrations.

g. Off-site. The plant duty cycle of 0.7 does not reduce the average of the observed air concentrations to the public MPC. It is obvious that the 24 samples on which this average is based are insufficient to characterize off-site conditions through any typical span of meteorological and operating conditions. It is certain that the limited operations carried out with Nigerian zircon ore so far have not resulted in significant exposure to the public. Additional off-site data will be necessary to determine the need for more refined cleaning of the stack effluent.

h. General. No employee or member of the public has been exposed to more than a small fraction of the appropriate maximum permissible exposure

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from either external or internal sources as a consequence of the operations covered by this report.

Before it is reasonable to make final recommendations for the operation of the plant with Nigerian zircon ore, some further preliminary measurements are needed. It is recommended that among these measurements the following should be made:

a. continuous samples of off-site air concentrations

b. a series of periodic samples of the sewer outfall concentrations.

c. two sets of urinalyses, one after several weeks without work involving Nigerian ore, and the other at the end of the next period of work with this ore.

d. The chlorinating and reducing operations on the carbide produced from Nigerian zircon ore should be carried out and monitored in a manner comparable to that used in the carbiding process. The physical and chemical nature of these subsequent operations is such that the health problems are expected to be smaller than those associated with ore handling and carbiding.

e. air concentrations on the main floor of the carbide building, the locker room, the cat walk and at the ore and coke hole be measured at the time of the next carbiding run with Nigerian ore after all practicable improvements have been made.

Certain final recommendations are possible at this time:

a. The wearing of film badges may be discontinued in future ore handling and carbiding operations.

b. All entrances to the Carbide Building should be posted with the warning signs specified in 10CFR20, Section 20.203, (d), (1) and (2), and also with the warning signs specified in 10CFR20, Section 20.203, (e), (2). The present "radiation area" signs on the Carbide Building are unnecessary and should be removed.

c. The ore and coke hole area should be fenced off in some manner and posted with the same two warning signs specified above.

d. Containers holding more than 80 pounds of Nigerian zircon ore, or its equivalent in thorium content, should be labeled with the warning signs specified in 10CFR20, Section 20.203, (f), (2).

The bases for the sign recommendations are as follows:

a. The Nigerian zircon ore contains approximately 6% thorium.

b. The specific activity of natural thorium is 2×10^{-7} curies per gram, i.e. one pound of ore contains approximately 6 μc of thorium.

c. A room containing more than 5,000 μc must be posted. This is equivalent to 830 pounds of ore.

FIG. 4

REPRESENTATIVE SAMPLE DECAY CURVES