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

April 24, 1979

MEMORANDUM FOR: NRR Staff

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: RECORD OF ACTIONS, THREE MILE ISLAND ACCIDENT

During the early stages of the TMI accident, a great number of NRR personnel were actively involved in the NRC response to the situation, and in communicating with other agencies, national laboratories, industrial concerns, etc. As time progressed, and the primary focus of activity evolved at the TMI site, such actions and communications of significance were logged and a system of recordkeeping was established at the TMI site.

Many of the early actions and communications were logged in the Incident Response Center, with a large portion of the telephone traffic being recorded on the 20-channel recorder in the IRC.

While memories are relatively fresh, however, it is important that all NRR personnel engaged in the NRC response to the TMI accident put their recollections on paper, particularly for actions they were involved in during the period of March 28th through, at least, April 1st. Unless you are certain that such actions and/or communications are logged in the IRC, you should prepare a memorandum for the files describing to the best of your recollection the timing, substance, and parties involved.

These memoranda, along with the originals of any notes or logs that you may have in your possession should be sent, clearly marked to identify them as Three Mile Island documents, to Dennis Crutchfield, Program Support Staff, NRR, P-433, no later than Friday, ~~April 27,~~ MAY 4, 1979.

for Harold R. Denton, Director
Office of Nuclear Reactor Regulation

180 322

8130392

J. Read, involvement in TMI-2 response

28 March – telephoned questions from IRC concerning chemical kinetics of water radiolysis

30 March – at IRC, telephone calls to GPU, TMI, regarding coolant composition.

week of 2 April – attempts to calculate H_2-Fr balance, discussion with Bob Budnitz (RES) on possible borohydride formation, gas solubilities

Easter – telephone discussion with George Seeley at TMI regarding gas solubility

week of 9 April – discussions on telephone with radiochemists at Bettis, ORNL.

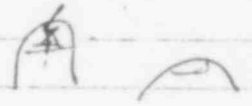
180 323

HENRY'S LAW $P_H = k X_H$ ~ mol

Partial pressure	H_2 (23°C) atm
1.18 atm	—
2.63	7.76 $\times 10^4$
3.95	7.77
5.26	7.81
6.58	7.89
7.90	8.00
9.20	8.16

55.6 mm/l

5.6×10^4 m/m



200 m^3

1.1×10^7 m H_2O in primary system

10^3 psi ≈ .70 atm

$.70 = 10^3 X$

7% mole fraction ~ 10^6 mol H_2

$\times .0224 = 2.2 \times 10^4$ m

180 324

18 April 1979

Calculations of Xe

The three main stable Xe isotopes are

^{131}Xe	2.79 %	of fission
^{132}Xe	4.16 %	"
^{134}Xe	7.51 %	"
	14.4 %	"

If 2.5×10^5 MWD of fission have occurred in core, at 3.2×10^{-11} J/fission, then 6.7×10^{26} fissions have occurred 9.7×10^{25} atoms of stable Xe, ie 160 moles. In addition there were initially 6 moles of ^{135}Xe.

If 300 tonnes of primary coolant received the Xe

$$\frac{166 \text{ moles}}{3\times10^5 \text{ Kg}} \frac{55 \text{ moles } H_2O}{\text{Kg}} = 1\times10^{-3} \text{ mole fraction}$$

Henry's Law for Xe is

$$P_{atm} = (2\times10^4)(\text{mole fraction})$$

$\therefore$ $P_{atm} = 0.2$ atmospheres.

Hence the partial pressure of Xe in the coolant was 3 psi. Total pressure was 900 psi $\therefore$ 0.3 % of reactor vessel gas is Xe.

ARMS plane said ~20 Ci/sec of ^{133}Xe lost

$$\frac{\text{atoms}}{\text{Ci}} = \frac{3.7\times10^{10} \text{ dps/Ci}}{1.52\times10^{-6} \text{ sec}^{-1}} = 2.43\times10^{16}$$

$$\therefore 20 \text{ Ci/sec} = \frac{(20)(2.43\times10^{16})}{6\times10^{23}} = 8.1\times10^{-7} \text{ moles/s}$$

$$\frac{166}{6} = 28$$

Absolute FY.

83 Kr	.518	4.5% plus Kr
84 "	1.01	
85 "	1.31	
86 "	2.04	

131 Xe	2.74	8d I → Xe
132	4.16	2h I → Xe
133	6.73 ←	21h I → 5d Xe → Cs
134	7.51	2y Cs → Xe e ← 52min I

TMI-2 has 6.7×10^{26} fissions

2.79
4.16
7.51
14.46

$(0.144)(6.7 \times 10^{26}) = 9.71 \times 10^{25}$ atoms Xe stable

= 161 moles stable Xe

160 moles stable Xe + 5.7 moles ^{133}Xe

3×10^5 kg H_2O $\quad \frac{160}{3 \times 10^5} = 1.5 \times 10^{-5}$

$(2 \times 10^4)(1.5 \times 10^{-5}) = 0.3$ atmospheres internal pressure

out of 60 atm $\therefore$ 0.2% Xe

28 March – 5 April

13×10^6 Ci ^{133}Xe

14 Ci ^{131}I

140×10^6 Ci = initial core inventory

From Fake Lovett's 12 April estimate

(24)(3600) = 86,400 sec/day

$\tau_2 = 5.29$ d.
$\lambda = 1.5166 \times 10^{-6}$ sec^{-1}
$= 0.131$ day^{-1}

	time	^{133}Xe	release rate	total core inventory	fraction/second	
1	3/28 - 3/29	4.2 MCi	31 hr 48.6 Ci/sec (150)	140 MCi	3.47×10^{-7}	3.
2	3/29 - 3/31	2.2 MCi	43 hr 12.7 (.769)	108	1.18×10^{-7}	1.0
3	3/31 - 4/1	2.1 MCi	22 hr 24.3 (.675)	94.5	2.57×10^{-7}	2.
4	4/1 - 4/2	0.4	4.63 (.592)	82.9	0.56 "	.45
5	4/2 - 4/3	1.1	12.7 (.519)	72.7	1.75 "	1.5
6	4/3 - 4/4	0.07	0.81 (.456)	63.8	0.13 "	.11
7	4/4 4/5	0.2	2.3 (.400)	55.9	0.41	.35%

900 mw
9×10^8

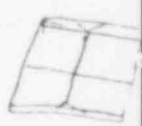
ARMS 20 - 50 Ci/sec CCC est

$$\frac{\text{atoms}}{\text{Ci}} = \frac{3.7 \times 10^{10} \text{ dps}}{1.52 \times 10^{-6} \text{ sec}^{-1}} = 2.43 \times 10^{16}$$

140×10^6 Ci $= 3.4 \times 10^{24}$ atoms

6.2.2

$= 5.66$ moles



2.5×10^5 MWD $= 2.5 \times 10^{11}$ WD

$= 2.5 \times 10^{11} \frac{J}{sec}$ 86,400 $\frac{sec}{day}$ $= 2.16 \times 10^{16}$ J

@ 200 MeV/fiss $\equiv (2.0 \times 10^8)(1.602 \times 10^{-19}) =$

3.20×10^{-11} J/fiss 3600 J =

$\therefore 6.74 \times 10^{26}$ fissions 1.8×10^{-4} m^3/K

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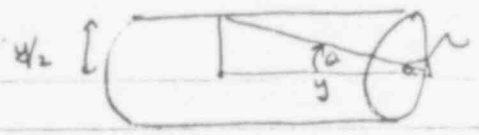


1.) counter is sphere of diameter d
2.) wall is t thick, $t\sec\theta$ is path in tank wall
3.) $y\cos\theta$ is distance between point and detector

area of detector $= \pi d^2$

area of sphere of radius $y\cos\theta = 4\pi y^2\cos^2\theta$

$\therefore$ fraction of decays at point (y,θ) getting to detector

$$= \frac{\pi d^2 \, e^{-\mu t\sec\theta}}{4\pi y^2\cos^2\theta}$$ integrate over ϕ $0\le\phi\le 2$

$$\frac{2\pi d^2}{4\pi}\int_\theta\int_y \frac{e^{-\mu t\sec\theta}}{y^2\cos^2\theta}\,dy\,d\theta$$

let $x = \sin\theta$

$\frac{dx}{d\theta} = \cos\theta$

$x^2 + \cos^2\theta = 1$

$\cos\theta = \sqrt{1-x^2}$

$$\int \frac{e^{-\mu t\sqrt{1-x^2}}}{\sqrt{1-x^2}}\,dx$$

let $q = \sqrt{1-x^2}$ $\quad \frac{dq}{dx} = \frac{-2x}{\sqrt{1-x^2}} = -2\sqrt{1-$

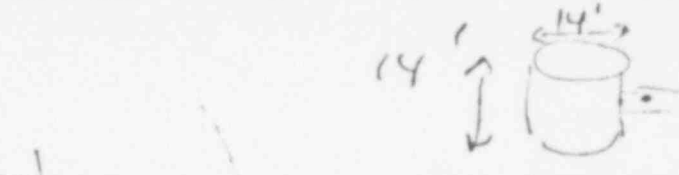
$q^2 = 1-x^2$

$x = \sqrt{1-q^2}$ $\qquad \sqrt{\frac{1}{q^4} - \frac{1}{q^2}}$

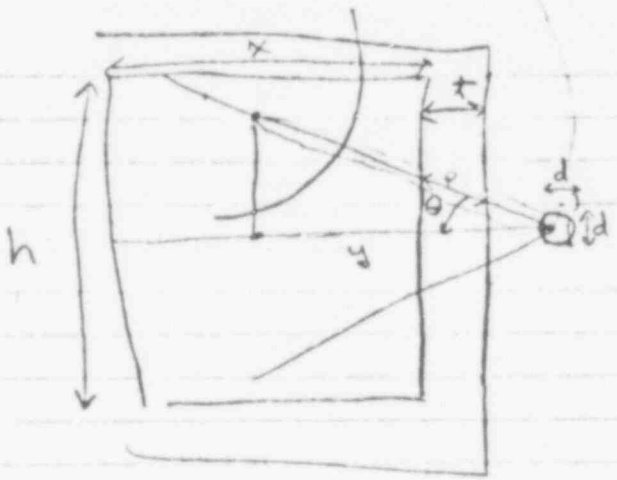
$$\int \frac{e^{-\mu t q}}{q}\left(-2\frac{\sqrt{1-q^2}}{q}\right)dq = -2\int e^{-\mu t q}\frac{\sqrt{1-q^2}}{q^2}\,dq$$

$\int uv\,dv = uV - \int V\,du$ $\qquad u = \frac{\sqrt{1-q^2}}{q^2}$ $\qquad dv = e^{-\mu t q}\,dq$

$du =$ $\qquad V = \frac{e^{-\mu t q}}{-\mu t}$



path length through tank wall = $p = t \sec\theta$



counter is sphere of diameter d

$\therefore$ area of counter $= \pi d^2$

$y\cos\theta$ = distance from point in tank to counter

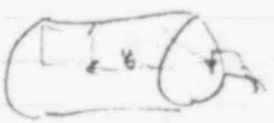
area of sphere of radius $y\cos\theta = 4\pi y^2 \cos^2\theta$

$\therefore$ fraction of counts at point in tank that would "get" to detector if no shielding

$$= \frac{\pi d^2}{4\pi y^2 \cos^2\theta}$$

$\therefore$ fraction with shielding

$$\frac{\pi d^2 B(\theta) e^{-\mu t \sec\theta}}{4\pi y^2 \cos^2\theta}$$



$$0 \le \phi \le 2\pi$$
$$0 \le \theta \le \sin^{-1}\left(\frac{7'}{y}\right)$$
$$0 \le y \le 14'$$

$u^2 + \sin^2\theta = 1$
$\sin\theta = \sqrt{1-u^2}$

Let $u = \cos\theta$ $\quad du = -\sin\theta\, d\theta$ $\quad d\theta = -\frac{\sin\theta}{du} = -\frac{\sqrt{1-u^2}}{du}$

$$\therefore \frac{d^2}{4y^2}\int \frac{e^{-\mu t \sec\theta}}{\cos^2\theta}\, d\theta = \frac{d^2}{4y^2}\int \frac{e^{-\mu t u}\sqrt{1-u^2}}{u^2}\, du$$

$$= -\frac{d^2}{4y^2}\int \frac{\sqrt{1-u^2}}{u^2} e^{-\mu t u}\, du$$

180 330

at time of SCRAM, total core had:

7.55×10^{24} atoms ^{140}Ba
1.04×10^{24} atoms ^{140}La

The amount of ^{140}La dissolved is equal to that fraction of ^{144}Ce which dissolved, i.e. at dissolution, one m^3 of coolant contained

3.69×10^{19} atoms ^{140}Ba

and $(1.09 \times 10^{-6})(1.04 \times 10^{24}) = 1.134 \times 10^{18}$ atoms ^{140}La

$$[^{140}La] = [^{140}La(t_0)]\, e^{-\lambda_2 \Delta t} + \frac{\lambda_1}{\lambda_2 - \lambda_1} [^{140}Ba(t_0)] \left[e^{-\lambda_1(\Delta t)} - e^{\lambda_2 \Delta t} \right]$$

where $\lambda_1 = 6.273 \times 10^{-7}$ sec^{-1}
$\lambda_2 = 4.786 \times 10^{-6}$ sec^{-1}
$\frac{\lambda_1}{\lambda_2 - \lambda_1} = 0.1508$

for $\Delta t = 340$ hours $e^{-\lambda_1 \Delta t} = 0.4640$
$e^{-\lambda_2 \Delta t} = 2.857 \times 10^{-3}$

$$[^{140}La]_{\text{at } 340 \text{ hrs}} = (1.134 \times 10^{18})(2.857 \times 10^{-3}) + (0.1508)\left(\frac{0.464 - 0.003}{0.461}\right)(3.69 \times 10^{19})$$

$$= 3.24 \times 10^{15} + 2.565 \times 10^{18} = 2.57 \times 10^{18}$$

$$\frac{\lambda_2 (2.57 \times 10^{18})}{3.7 \times 10^{10}} = 332 \text{ Ci}$$

Memo to: Jack Kudrick

Thru: Wayne Houston

From: J. Read

Not sent or typed

Subject: Noble Gas Releases

Xenon is somewhat more soluble in water than either hydrogen or nitrogen, and, as TMI-2 has demonstrated, is susceptible to transport in aqueous solutions. Lange's Handbook lists the Henry's Law constant for xenon in water as 2×10^4 atmospheres, and the standard atmosphere at sea level is 80 ppb xenon. It follows, therefore, that any solution containing a mole fraction of xenon isotopes greater than 4×10^{-12} will effervesce xenon until it descends to that concentration, after which it will undergo isotopic exchange. At present there is no method in place to contain rare gas releases to a building atmosphere other than total isolation, i.e., control by low exfiltration rate.

Xenon is a comparatively abundant fission product, being present in the 131, 132, 133, 134, 135, and 136 mass chains. In the 133 and 135 mass chains it is also present as the daughter of iodine isotopes of appreciable half-lives (8 days and 9 hours, respectively).

isotope	cumulative chain yield	half-life
^{131}Xe	2.91%	stable
^{132}Xe	4.26	"
^{133}Xe	6.69	5.27 days
^{134}Xe	7.8	stable
^{135}Xe	6.3	9.2 hours
^{136}Xe	6.46	stable

Stable xenon is produced at the rate of 21.4 atoms per 100 fissions, or 2.4×10^{19} atoms per watt-hour (thermal), or 2.2×10^{-5} m^3(STP) per megawatt day. TMI-2 had a core inventory of about 6 m^3 (STP) of xenon. The preliminary analyses by

EEB/DOR indicates that about 10% of this inventory (13 out of 140 megacuries of ^{133}Xe) was transported outside containment and released during the first two weeks of the accident, with the remainder still presumably in the reactor vessel and containment. The initial specific activity of this xenon was of the order of 23 MCi/m^3(

[illegible]

To understand this loss rate, assume that 30%, or 2 m^3, of xenon was released to containment prior to containment spray actuation. The containment volume, about 36,000 m^3, would then have a partial pressure of 6×10^{-5} atm. xenon. The containment sprays would bring the sump solution to equilibrium, which by Henry's Law would be a xenon mole fraction of 3×10^{-9}, or a dissolved xenon concentration of 4×10^{-9} m^3 (STP) per Kg of solution. If 10,000 gal. of this solution, i.e., 35,000 Kg were then purged into the auxiliary building floor, then 1.3×10^{-4} m^3 (STP) of xenon, or 3 kilocuries, would be released.

If the original 270 moles of xenon were initially dissolved in 3×10^5 Kg of primary coolant (1.7×10^7 moles of water), its mole fraction would be 1.6×10^{-5}, corresponding to a partial pressure of 0.3 atm within the reactor vessel. The primary coolant xenon concentration would then be 2×10^{-5} m^3 (STP)/Kg, or 460 Ci ^{133}Xe per Kg of primary coolant.

In addition, the initial core inventory contained about 850 MCi of ^{133}I, which, by decay into ^{133}Xe, was producing 1 cc/sec of ^{133}Xe, or 1.3 kilocuries/sec. Indeed, the release rates during the first few days of the accident strongly suggest the 20.8 hour half-life of ^{133}I. A 50 Ci/sec ^{133}Xe release rate corresponds to 33 MCi of decaying ^{133}I. ^{135}Xe would be similarly produced by the 6.58 hour ^{135}I, but its release rate would fall markedly with time. The EEB estimates for the first few days, therefore, suggest 3 to 4 % of the core iodine inventory was in the auxiliary building.

The only feasible method of controlling this xenon would have been cryogenic charcoal absorption. In theory, 1000 cubic feet per minute of auxiliary building air could be compressed isothermally to 300 atmospheres, expanded isoenthalpicly by the Joule-Kelvin effect, and vented through an insulated charcoal bed. The reversible thermodynamic energy requirement would be about 4 megawatts. A search of the Thomas catalogues indicates this would need a unit about an order of magnitude larger than offered for sale. The public safety benefits of such larger units in place at all potential rare gas fission product release points would, however, argue strongly in favor of promoting their development and production.

The handbook value of the Henry's Law constant for hydrogen solubility in water is 8×10^4 atm. The major source of H_2 is

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2$$

such that the oxidation by steam of 1 Kg of Zr yields 0.49 m^3 (STP) of H_2, or 21.9 moles. If 10^4 Kg of Zr were oxidized, 2.2×10^5 moles of H_2 would be produced. The mole fraction of dissolved H_2, given 10^3 psi, or 70 atm, of system pressure by Henry's Law would be of the order of 10^{-3}. Upon being let down to ambient pressures, the primary coolant would effervesce 1.2 times its volume of H_2 (STP).

Zirconium is chemically unique in that ZrO_2 is soluble in the metal, hence the oxidation is a homogeneous solid-state reaction in which a Zr object slowly swells and emits H_2 while oxidizing.

The appearance of a 28 psig pressure pulse due to hydrogen deflagration suggests the release of about 10^9 Joules of thermal energy. Since the oxidation of $1 mol H_2$ releases 2.4×10^5 J/mole, this pressure pulse argues for the combustion of $\geq 4.2 \times 10^3$ moles of H_2, which would, in turn, require the oxidation of about 200 Kg of Zr. It is, of course, extremely likely the deflagration did not produce the

pressure peak with 100% thermodynamic efficiency, in which case the H_2 consumed would be much greater. Hydrogen balance may summarized

28 psig pressure pulse	>	4×10^3 moles
2% of containment		3×10^4 "
dissolved in primary coolant		2×10^4 "
lost by diffusion		?

Hence an absolute minimum of 2 tonnes of Zr has been oxidized.

It should be noted that the radiolysis of water is greatly affected by the presence of dissolved gases. The high concentration of dissolved H_2 in the primary coolant will greatly reduce the concentration of hydroxyl radicals via

$$H_2 + \cdot OH \rightarrow H_2O + H\cdot$$

Since the hydroxyl radicals govern the path by which O_2 is generated, the O_2 evolution rate is undoubtedly negligible.

Several metals, notably titanium and platinum, form interstitial hydrides, i.e. H_2 is soluble in these metals and passes through them readily. In degassing the primary coolant, it is not necessary to reinject the H_2 into containment, since it may be totally separated from all radioisotopes (except tritium) by passage through titanium.

Jacques

At time of dissolution"

^{140}La of $(7.55\times10^{24})(1.09\times10^{-6}) = 8.23\times10^{18}$

$\lambda_1 = 6.273\times10^{-7}$

$\lambda_2 = 4.786\times10^{-6}$ $\quad \lambda_2-\lambda_1 = 4.159\times10^{-6}$

$$N(La) = 8.23\times10^{18}e^{-\lambda_1\Delta t} + \frac{6.273\times10^{-7}}{4.159\times10^{-6}}3.69\times10^{19}\left(e^{-\lambda_1\Delta t} - e^{-\lambda_2\Delta t}\right)$$

$$= \left(8.23\times10^{18} + 5.57\times10^{18}\right)e^{-\lambda_1\Delta t} - 5.57\times10^{18}e^{-\lambda_1\Delta t}$$

$\frac{1}{2.155}$ $\qquad$ $\frac{1}{350.0}$

$$= \frac{1.380\times10^{19}}{2155} - 1.59\times10^{16}$$

$6.40\times10^{18} - .02\times10^{18} = 6.38\times10^{18}$

$$\text{Ci at 340 hours} = \frac{(4.786\times10^{-6})(6.38\times10^{18})}{3.7\times10^{10}}$$

826 Ci ^{140}La

ORNL = 160 Ci = 1.237×10^{18} } ^{140}La at 340 hours

SRL 135 Ci = 1.044×10^{18} }

$N_2(1)$

$N_2(1) = 5.57\times10^{18}\ e^{-6.273\times10^{-7}\Delta t}$

ORNL = $0.222 = e^{-\lambda_1\Delta t}$, $\lambda_1\Delta t = 1.5047$ $\quad \Delta t = 2.399\times$

SRL = 0.1874 $\quad \lambda_1\Delta t = 1.674$ $\quad 2.67\times$

$^{140}Ba \xrightarrow{\lambda_1} {}^{140}La \xrightarrow{\lambda_2}$

$x_1 \qquad x_2$

$$x_1 = x_1(0)\, e^{-\lambda_1 (t - t_0)}$$

$$\frac{dx_2}{dt} = -\lambda_2 x_2 + \lambda_1 x_1(0)\, e^{-\lambda_1 (t - t_0)}$$

$$e^{\lambda_2 t}\, \frac{dx_2}{dt} = -\lambda_2 x_2 e^{\lambda_2 t} + \lambda_1 x_1(0)\, e^{\lambda_2 t - \lambda_1 (t - t_0)}$$

$$\frac{d(x_2 e^{\lambda_2 t})}{dt} = \lambda_1 x_1(0)\, e^{\lambda_2 t - \lambda_1 (t - t_0)}$$

$$x_2 = x_2(0)\, e^{-\lambda_2 (t - t_0)} + \frac{\lambda_1 x_1(0)}{\lambda_2 - \lambda_1} \left[e^{-\lambda_1 (t - t_0)} - e^{-\lambda_2 (t - t_0)} \right]$$

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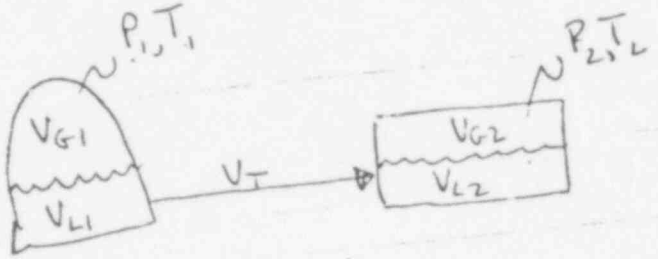

$V_1 = V_{G1} + V_{L1}$

$V_2 = V_{G2} + V_{L2}$

c_1, the concentration of gas G in V_T is the same as that in L1

$P_2 = P_a + P_{N_2}$, assuming letdown (or makeup) tank originally filled with N_2

amount of G in V_2 = X_{2a} (moles liquid) + $\frac{P_{a2}}{P_2}$ (moles gas)

and $P_{a2} = K_a X_{2a}$

amount of G in V_T = X_{1a} (moles liquid) = amt in V_2

but, initially $P_{a1} = K_a X_{1a}$

$\therefore X_{1a} = \frac{P_{a1}}{K_a}$

$\therefore c(V_T) = c(V_1) = \frac{M P_{a1}}{K_a} = M X_{2a} + \frac{P_{a2}}{P_2}$ (moles

$= X_{2a}\left(M + \frac{P_{a2}}{P_2}\right.$ mole

$\therefore P_{a1} = \frac{K_a}{M} X_{2a}\left(M + \frac{P_{a2}}{P_2} \frac{P_2(V_2 - V_{L2})}{R T_2}\right)$

MEMORANDUM
OF CALL

TO: Ford

☑ YOU WERE CALLED BY— ☐ YOU WERE VISITED BY—

Mr. Ford

OF (Organization)

☐ PLEASE CALL → PHONE NO. CODE/EXT. 7216527 ☒ FT

☐ WILL CALL AGAIN ☐ IS WAITING TO SEE YOU

☐ RETURNED YOUR CALL ☐ WISHES AN APPOINTMENT

MESSAGE

RECEIVED BY | DATE 11/15 | TIME 4:3

63-109

STANDARD FORM 63 (Rev. 8-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.6

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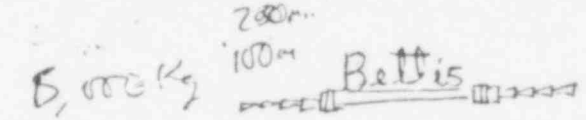


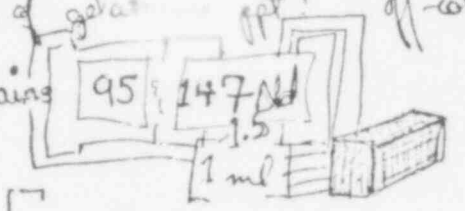
5,000 Kg 200m 100m Bettis TMI-2

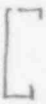
2.5-10^7 Fong 8-721-6527

95 & 147 chains

Any sign of gelat ppt? off-color?

Mass chains 95 & 147 Nd 1.5 1 ml





95 Zr

180 340

MEMORANDUM OF CALL

TO: G. Read

☒ YOU WERE CALLED BY— ☐ YOU WERE VISITED BY—

Bob Burnett

OF (Organization)

☒ PLEASE CALL → PHONE NO. CODE/EXT. 74335 ☐ FTS

☐ WILL CALL AGAIN ☐ IS WAITING TO SEE YOU

☒ RETURNED YOUR CALL ☐ WISHES AN APPOINTMENT

MESSAGE

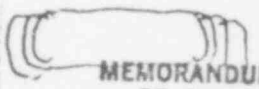
If you are in over the weekend & would like to talk to him about 3-Mile Island have the NRC operator give you his home phone #.

RECEIVED BY Jenny | DATE 4-6-79 | TIME 4:40

63-109

STANDARD FORM 63 (Rev. 8-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.6

*USGPO: 1978:281-184/13



MEMORANDUM OF CALL

TO: Reed

☐ YOU WERE CALLED BY— ☐ YOU WERE VISITED BY—

Budnitz

OF (Organization) Off. of Research

☐ PLEASE CALL → PHONE NO. CODE/EXT. X 74338 ☐ FTS

☐ WILL CALL AGAIN ☐ IS WAITING TO SEE YOU

☒ RETURNED YOUR CALL ☐ WISHES AN APPOINTMENT

MESSAGE

BO_3 $Zr(BH_4)_4$

RECEIVED BY	DATE	TIME
cnl	4-10	11:05

63-109

STANDARD FORM 63 (Rev. 8-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.6

*USGPO:1978:281-184/13

180 54

at IRC 30 March 1979

717-944-4067 - Elinor et al

Greg Gibson

~~SOS~~ water sample 16:00 3/29

3 ml to Bettis

licensee has rest

about 60 ml ?

$Zr \rightarrow Zr^{+3}$

$\frac{3}{2}$

Geo Knighton

El Zebroski EPRI chemist at site

GPU { Bob Cutler Dick Howard

N.J.

201-263-4900

X410/411

Bettis {

180 343

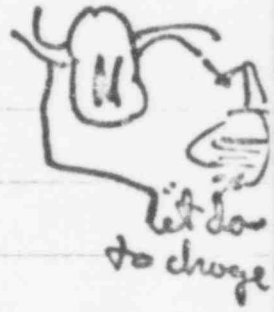
Primary coolant chemistry

11:30

201-263-4900

Bob Cutler

John Barton



or John Daniels

H_3BO_3?

redox protection? (N_2 Bowra) hot

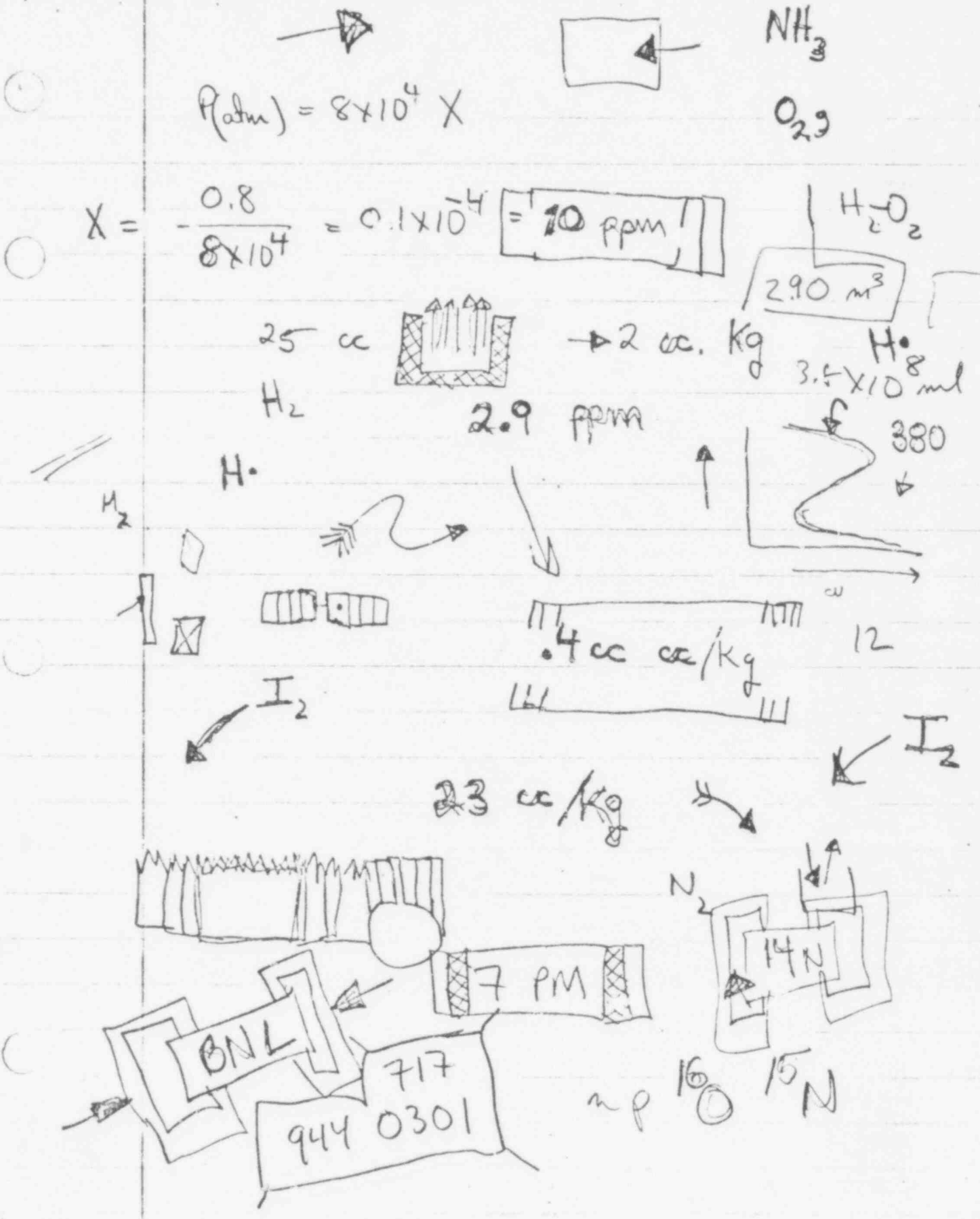
sampling bias?

no date yesterday

Radiochemist

SRL
Bob Overman
239-3559

J. Fong
J. Fong
721-6527
Bettis


NH3
O2
P(atm) = 8x10^4 X
X = 0.8 / 8x10^4 = 0.1x10^-4 = 10 ppm
H2O2
290 m3
25 cc
2 cc. Kg
H2
2.9 ppm
H•
3.5X10^8 ml
380
12
.4 cc cc/kg
I2
23 cc/kg
N2
14N
7 PM
BNL
717
944 0301
16O
15N

180 346

Geo Seely

0.4 cc/kg H_2

2.9 cc/kg O_2

Total 25 cc/kg

3.8×10^8 ml

$\therefore 3.8 \times 10^5$ kg

↓ per 1 cc/kg

3.8×10^5 cc (STP)

380 l.

$\times$ 25 cc = 9.5×10^3 cc

$\frac{9.5 \text{ l}/\ell}{380}$

$\frac{\frac{9.5}{22.4}}{55.5 \frac{380}{55.5}} = \frac{0.42}{21,000}$

$\therefore X_{gas} = 2 \times 10^{-5} \times 8 \times 10^{-4} =$ 1 atm

mass chain	% from Kgs, 10^3 MW-years	Kg 10^3 MW-years
85	1.33	Kr 0.75
6	1.94	Kr
7	2.56	Rb
8	3.7	Sr
9	4.8	Y
90	5.9	Sr 18
1	5.9	Zr, Y
2	6.0	Zr
3	6.4	Zr
4	6.5	Zr
5	6.5	Mo, Zr, Nb
6	6.3	Zr
7	5.9	Mo
8	5.8	Mo
9	6.1	Tc 27.5
100	6.3	Mo
1	5.1	Ru
2	4.2	Ru
3	3.1	Rh, Ru 14.8
4	1.83	Ru
5	.95	Rh
6	.39	Ru
7	.12	Pd
8	.07	Pd
9	.03	Ag
110	.02	Pd
1	.018	Cd, Ag
2	.013	Cd
3	.013	Cd
4	.013	Cd
5	.011	In, Cd
6	.011	Cd
7	.016	Sn
8	.015	Sn
9	.013	Sn

120	.013	Sr
1	.018	b
2	.015	Sn
3	.024	Sb, Sn
4	.02	Sn
5	.025	Te(Sb)
6	.05	~~Te~~ Sn
7	.014	I
8	.40	Te
9	.9	I
130	2.0	Te
1	2.77	Xe, I
2	4.13	Xe
3	6.77	Cs
4	7.19	Xe
5	6.7	Cs
6	6.12	Ba, Xe
7	6.23	Cs
8	6.7	Ba
9	6.6	La
140	6.3	Ce(La)(Ba)
1	5.9	Ce
2	6.0	Ce
3	6.0	Nd
4	5.45	Nd(Ce)
5	3.95	Nd
6	3.00	Nd
7	2.26	Pm(Nd)
8	1.69	Nd
9	1.07	Pm
150	.65	Nd
1	.423	Pm
2	.265	Sm
3	.16	Sm
4	.071	Sm
5	.033	Eu
6	.013	Gd, Eu

50.

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

APR 10 1979

MEMORANDUM FOR: Thomas E. Murley, Director
Division of Reactor Safety Research, RES

FROM: Robert J. Budnitz, Deputy Director
Office of Nuclear Regulatory Research

SUBJECT: CHEMISTRY OF BORIC ACID, BEHAVIOR AT THREE MILE ISLAND 2

I just received a telephone call from Jacques B. Read of NRR on the subject of the chemical behavior of the boric acid in the primary coolant system at TMI-2 during the recent transient. Jack's point is that, with fission products and significant hydrogen in the system, there is a very large number of boron compounds that one might find in the coolant besides the boric acid that is normally there; and that an understanding of this complex chemical system might be of some safety significance.

This looks like one of those (presumably numerous) topics where research might be required to upgrade NRC's understanding. Of course, for all I (or Jack) know, the whole thing might have been long since worked out, including understanding of not only how boric acid behaves under 1000 psi of hydrogen over-pressure, but its safety implications. If so, it might not be too hard to establish that; if not, perhaps we ought to initiate at least enough of a search of the literature and conventional wisdom to assist us in deciding whether we ought to do more. What do you think?

Bob

Robert J. Budnitz, Deputy Director
Office of Nuclear Regulatory Research

cc: S. Levine
J. Read, DSE
R. C. DeYoung, DSE

180 350

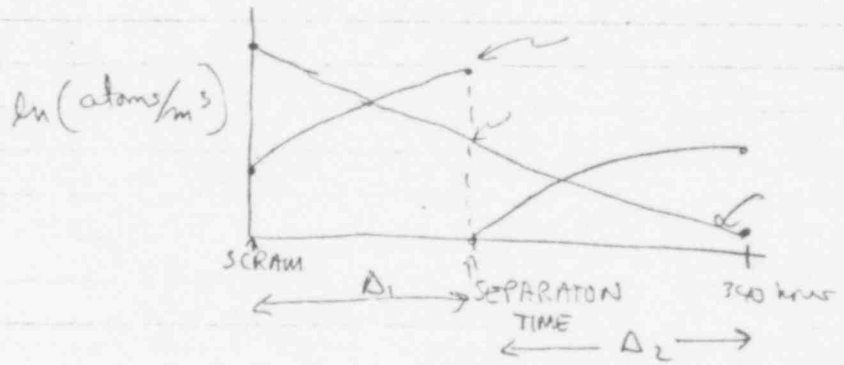
Reduced mass 140 data from TMI-2

According to ORIGEN, the core contained 7.55×10^{24} atoms of ^{140}Ba and 1.04×10^{24} atoms of ^{140}La at SCRAM. Shortly (compared to 40 hours) thereafter some of the fuel dissolved in the coolant. By measurement we know that 3.69×10^{19} atoms of ^{140}Ba dissolved per m^3. Since 1.09×10^{-6} of the ^{144}Ce is in a m^3 of solution, then

$$(1.09 \times 10^{-6})(1.04 \times 10^{24}) = 1.13 \times 10^{18} \text{ atoms } ^{140}La/m^3$$

was the initial concentration. In 340 hours, this would have decayed to 3.24×10^{15} atoms, while ^{140}Ba would have grown in ^{140}La. At 340 hours after SCRAM, the two analyses were, for ^{140}La

ORNL = 160 Ci = 1.237×10^{18} atoms
SRL = 135 Ci = 1.044×10^{18} atoms.



where: $\Delta_1 + \Delta_2 = 340$ hours

$$[Ba]_{ST} = e^{+\lambda_2 \Delta_2} [Ba]_{340}$$

$$[La]_{340} = [La]_{ST} e^{-\lambda_2 \Delta_2} + \frac{\lambda_1}{\lambda_2 - \lambda_1} [Ba]_{ST} \left[e^{-\lambda_1 \Delta_2} - e^{-\lambda_2 \Delta_2} \right]$$

$$[La]_{340} = [La]_{ST} e^{-\lambda_2 D_2} + \frac{\lambda_1}{\lambda_2 - \lambda_1} [Ba]_{340} e^{+\lambda_1 D_2} \left[e^{-\lambda_1 D_2} - e^{-\lambda_2 D_2} \right]$$

$$= [La]_{ST} e^{-\lambda_2 D_2} + \frac{\lambda_1}{\lambda_2 - \lambda_1} [Ba]_{340} \left(1 - e^{(\lambda_1 - \lambda_2) D_2} \right)$$

to ORNL Let $[La]_{ST} \approx 0$

$[La]_{340} = 1.237 \times 10^{18}$

$[Ba]_{340} = 1.71 \times 10^{19}$ $\Rightarrow (0.1508)(1.71 \times 10^{19}) = 2.579 \times 10^{18}$

$$\therefore \frac{1.237 \times 10^{18}}{2.579 \times 10^{18}} = 0.4797 = \left(1 - e^{(\lambda_1 - \lambda_2) D_2} \right)$$

$$\therefore e^{-(\lambda_2 - \lambda_1) D_2} = 0.5203$$

$$\therefore (\lambda_2 - \lambda_1) D_2 = 0.65335$$

$\lambda_2 - \lambda_1 = 4.159 \times 10^{-6}$ $\therefore D_2 = 1.571 \times 10^5$ sec

$= 43.6$ hours.

1 day, 18 hours.

hence septum at 2P.M on 9 April

B. A Németh Chemical Tables

H_2 2.14 ml abs N_2 2.33 ml 0°C.
0.85 ml 80°C 1.32 ml 60°C

Xe 24.1 ml 0°C
7.3 ml 50°C

ASME Steam Tables

500 psig = 514.7 psia 470°F 0.01978 ft³/lb
1000 psig = 1014.7 psia 0.90915 " "

enthalpy BTU/lbm			entropy BTU/lbm°R		
H_2O	evap	steam	H_2O	evap	steam
451.9	752.7	1204.6	0.6515	.8105	1.4620

Large: Xe at 20°C 10.81 cc in 100 cc.
N_2 " " 1.52 cc in 100 cc ✓
H_2 " 1.9 cc " ✓

at 40°C, 1.01×10^5 pa, according to Lange

H_2 1.384×10^{-4} g = gms / 100 gms 55.5 moles/l.
.01644 α vol. gms / vol. H_2O

N_2 .01184 volume
1.391×10^{-3} g gms/100 gms $p = 14.7 = k\,\cancel{X}\,c$

MW water = 18 gms / mole ∴ 100 gms = 5.56 moles

H_2 $\frac{1.384 \times 10^{-4}}{2} = 6.92 \times 10^{-5}$ ∴ $X = 1.25 \times 10^{-}$

1 atm = $k\ 1.25 \times 10^{-5}$
$k = 8.028 \times 10^{+4}$

N_2 $\frac{1.391 \times 10^{-3}}{28} = 4.97 \times 10^{-5}$ $X = 8.94 \times 10^{-}$

1 atm = $k\ 8.94 \times 10^{-6}$
$k = 11.2 \times 10^{4}$

Xe	T °C	ml/100 ml H_2O	X	k
MW=131	0	24.1	~~5.98×10^{-3}~~ 1.94×10^{-4}	0.51
ml × $\frac{1}{22,400}$ = moles/100 ml	20	10.81	8.69×10^{-5}	1.15
	50	7.3	$k = \frac{\text{ml}}{\text{mole}}$ $\frac{\text{mole}}{\text{mole}}$ 5.87×10^{-5}	1.70

$p = kX$ $p = k'V$ $p = kV_{\text{STP ratio}}$ $\frac{22.4\ l}{.018\ l}$

$\frac{k}{k'}$

Xe ~ 2×10^4 2.5×10^7

H_2 ~ 8×10^4 1.0×10^8

N_2 ~ 10×10^4 1.2×10^8 ^{10}B

NRC operations
S-717-944-3583 Sue Cagner PA

180 354

180 355