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Page 1

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TEST REPORT
GENERAL ELECTRIC COMPANY-HANFORD WORKS
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Verified By Jerri Maley,
7-27-94

VERNATHERM FUNCTIONAL TEST

TEST PROJECT NO. 1A

October 31, 1951

*Arg + Man
div Reactor
Test Section
Reports*

Prepared: J. L. Smith Date 10-31-51

MASTER

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VERNATHERM FUNCTIONAL TESTS

I. INTRODUCTION

The Vernatherm unit (see Figure I) is a temperature sensitive capsule which translates temperature change to mechanical movement of a brass plunger. A change in phase of a hydrocarbon contained in a cylinder caused by temperature change, causes movement of the brass plunger. The units are available for various temperature ranges.

The adaptation considered was to monitor the outlet water temperature from individual process tubes in the "G" pile.

II. PURPOSE OF TEST

To determine the magnitude of error, if any, that is induced in a standard Vernatherm unit of known calibration when subjected to:

- a. Gamma irradiation at an energy level of 6 MEV with an intensity of 5×10^3 mr/hr obtained by exposing the units to outlet process water. (See Section V. for method of intensity determination).
- b. Gamma irradiation from discharged slugs having an energy level of approximately 1.1 MEV and an estimated intensity of 5×10^4 mr/hr.

III. SUMMARY

1. The accuracy of the units prior to irradiation was $\pm 1.25^\circ\text{F}$. An examination of the calibration curves shows that a hysteresis effect in the hydrocarbon of the unit causes the curve of descending temperature to be displaced from the ascending temperature curve.
2. The effects of irradiation were to decrease the accuracy to $\pm 3.75^\circ\text{F}$. after a total exposure of $17,416 \times 10^4\text{R}$ at 1.1 MEV.

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The accuracy was within $\pm 2^{\circ}\text{F}$. up to a total exposure of $11,441 \times 10^4\text{R}$ at 6 MEV.

3. Since the exposure of $11,441 \times 10^4\text{R}$ is equivalent to approximately 2,000 months exposure in the pile at 250 MW we can conclude that the effect of radiation is not detrimental since the increase in inaccuracy is only $\pm 0.75^{\circ}\text{F}$.

IV. PROCEDURE

The tests were run in three parts:

Part A - Four Vernatherm units were calibrated in a temperature controlled water bath prior to exposure to radiation.

Curves were drawn for heating and cooling from 140°F . to 175°F . See pages 12, 13, 14, and 15.

Part B - Two units were installed in special tee fittings shown in Figure 3 which served as connectors between the pigtail and nozzle. These were installed on process tubes 1073 and 1079 in 105-F pile.

The units were removed for calibration at every available shutdown for a period of time and then inserted prior to start up. See calibration curves on pages 12 and 13.

Part C - Two units were installed in a special holder shown in Figure 2 and exposed to gamma radiation in a special slug bucket in the storage basin. This holder containing the Vernatherm unit was placed in the center of a circular pattern of six process slugs.

These units were removed periodically for a calibration check. These calibration curves are on pages 14 and 15.

V. METHOD OF DETERMINING RADIATION EXPOSURE

1. Slug Bucket Exposure

A totem pole instrument was used to periodically measure the intensity level of the 1.1 MEV gamma radiation and a curve was plotted of intensity level vs. time. The values of exposure given on the calibration curves were determined from this data, knowing also the total exposure time prior to the calibration.

2. Outlet Pigtail Exposure

Calculations of intensity made by R.E. Nather of Pile Technology Unit indicated approximately 5×10^4 mr/hr at the outlet pigtail connection to the nozzle.

The intensity was measured on two pigtails at 105F pile by mounting pieces of picture badge film on the pigtail adjacent to the nozzle during a pile shutdown. The film was to be removed during a poison push, but an emergency shut down occurred and in the excitement and rush the film was not removed until later and was badly over-exposed. By special methods, however, the intensity was obtained and the value is 5×10^3 mr/hr.

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This value of 5×10^3 mr/hr was used to present the total exposure given on the calibration curves.

VI. RESULTS AND CONCLUSIONS

For temperature range of 142.5°F . to 162.5°F . the units as received were accurate within limits of $\pm 1.25^\circ\text{F}$.

From the foregoing we can see that these units have inherent inaccuracies and any detrimental effects of irradiation will increase these inaccuracies.

The curves on pages 12, 13, 14, and 15 show the effects of radiation. The data on pages 5, 6, 7, 8, and 9 show the deviations from the original calibration. A study of these data and curves enables a determination of the inaccuracy existing after periods of exposure between calibrations.

CASE I

CASE II

CASE III

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These partial curves show how the increase of error and total error can be determined. The following table shows the maximum magnitude of these errors after each period of irradiation.

	Unit #1				Unit #2°			
	Cal. #1	2	3	4	Cal. #1	2	3	4
Δt_1	2.5	2.75	2.0	°	.15	1	.25	
Δt_2	1.5	1.27	2.5		°	1.88	3.0	
$\Delta t_1 \neq \Delta t_2$	4.0	4.02	4.5			2.88	3.25	
$\Delta t_1 \neq \Delta t_0$					2.65			

	Unit #3						
	Cal. #1	2	3	4	5	6	7
Δt_1	1.0	.88	0	0	2.75	1.0	
Δt_2			3.4	3.4°		2.4	6.62
$\Delta t_1 \neq \Delta t_2$		⊙	3.4	3.4		3.4	6.62
$\Delta t_1 \neq \Delta t_0$	3.5	2.98			3.25		

	Unit #4						
	Cal. #1	2	3	4	5	6	7
Δt_1	1	0.87	0	.25	.5	4	7.5
Δt_2	1.5	1.5		2.25	3.25		
$\Delta t_1 \neq \Delta t_2$	2.5	2.37		3.0	3.75		
$\Delta t_1 \neq \Delta t_0$			2.5				

Note that these tables are for the range from 150°F to 165°F.

Note that the variation is, of course, plus or minus one-half of the values given in the tables. These tables present the maximum variation of temperature at a given plunger displacement. We can see from inspection that the maximum error occurred with unit #4 on calibration #7 and was $\pm 3.75^\circ\text{F}$. in magnitude. This represents an increase in error of $\pm 2.5^\circ\text{F}$. due to gamma radiation in a slug bucket for an exposure of $17,416 \times 10^4\text{R}$.

Also evident is that for exposures of $11,441 \times 10^4\text{R}$ and less the increase in error is $\pm 0.75^\circ\text{F}$. and so on until the minimum exposure of $4.44 \times 10^3\text{R}$ which introduced $\pm 0.125^\circ\text{F}$ error on Unit #2 and $\pm 0.75^\circ\text{F}$ error on Unit #1.

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#1 VERNATHERM UNITASCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Orig. Cal.	.0196	.034	.056	.084	.123	.198	.261	.204
1st "	.0199	.034	.053	.078	.114	.199	.202	.204
2nd "	-	.032	.055	.083	.120	.178	.199	.202
3rd "	-	.031	.052	.078	.112	.170	.196	.201
4th "	-	.038	.064	.095	.137	.201	.204	.207
$\Delta 0,1$	$\cancel{f}.0003$	0	-.003	-.006	-.009	$\cancel{f}.001$	$\cancel{f}.001$	0
$\Delta 1,2$	-	-.002	$\cancel{f}.002$	$\cancel{f}.005$	$\cancel{f}.006$	-.021	-.003	-.002
$\Delta 2,3$	-	-.001	-.003	-.005	-.008	-.008	-.003	-.001
$\Delta 3,4$	-	$\cancel{f}.007$	$\cancel{f}.012$	$\cancel{f}.017$	$\cancel{f}.025$	$\cancel{f}.031$	$\cancel{f}.008$	$\cancel{f}.006$

DESCENDING TEMPERATURES

Temp. ° (°F)	140	145	150	155	160	165	170	175
Orig. Cal.	.026	.044	.068	.099	.145	.202	.203	.204
1st "	.028	.045	.066	.092	.135	.203	.203	.204
2nd "	.022	.041	.065	.094	.133	.201	.201	.202
3rd "	.030	.047	.069	.097	.140	.200	.200	.201
4th "	.023	.045	.072	.105	.150	.206	.206	.207
$\Delta 0,1$	$\cancel{f}.002$	$\cancel{f}.001$	-.002	-.007	-.010	$\cancel{f}.001$	0	0
$\Delta 1,2$	-.006	-.004	-.001	$\cancel{f}.002$	-.002	-.002	-.002	-.002
$\Delta 2,3$	$\cancel{f}.008$	$\cancel{f}.006$	$\cancel{f}.004$	$\cancel{f}.003$	$\cancel{f}.007$	-.001	-.001	-.001
$\Delta 3,4$	-.007	-.002	$\cancel{f}.003$	$\cancel{f}.008$	$\cancel{f}.010$	$\cancel{f}.005$	$\cancel{f}.005$	$\cancel{f}.006$

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#2 VERMATHERM UNIT

ASCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Orig. Cal.		.038	.059	.085	.119	.178	.204	.208
1st "		.035	.058	.086	.125	.197	.202	.206
2nd "		.031	.053	.080	.118	.187	.198	.200
3rd "		.034	.054	.080	.112	.158	.199	.202
4th " °		.030	.053	.083°	.129	.189	.197	.203
Δ0,1		-.003	-.001	+.001	+.006	+.019	-.002	-.002
Δ1,2		-.004	-.005	-.006	-.007	-.010	-.004	-.006
Δ2,3		+.003	+.001	0	-.006	-.029	+.001	+.002
Δ3,4		-.004	-.001	+.003	+.017	+.031	-.002	+.001

DESCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Orig. Cal.	.029	°.045	.065	.091	.126	.205	.207	.208
1st "	.024	.043	.068	.098	.140	.205	.206	.206
2nd "	.020	.038	.060	.090	.134	.201	.201	.200
3rd "	.023	.043	.066	.094	.132	.201	.201	.202
4th "	-	.034	.058	.089	.135	.201	.202	.203
Δ0,1	-.005	-.002	+.003	+.007	+.014	0	-.001	-.002
Δ1,2	-.004	-.005	-.008	-.008	-.006	-.004	-.005	-.006
Δ2,3	+.003	+.005	+.006	+.004	-.002	0	0	+.002
Δ3,4	-	-.009	-.008	-.005	+.003	0	+.001	+.001

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Temp. (°F)	140	145	150	155	160	165	170	175°
Ortg. Cal.	.020	.038	.060	.091	.136	.199	.201	.202
1st	.028	.047	.071	.100	.140	.202	.203	.204
2nd	.022	.042	.067	.099	.142	.198	.199	.200
3rd	.0198	.036	.058	.088	.130	.190	.191	.192
4th	.019	.032	.058	.088	.130	.186	.188	.188
5th	.019	.030	.055	.089	.135	.183	.185	.186
6th	.0198	.020	.055	.095	.145	.160	.160	.161
7th	.0195	.034	.059	.095	.137	.137	.137	.137
Δ0,1	f.008	f.009	f.011	f.009	f.004	f.003	f.002	f.002
Δ1,2	-.006	-.005	-.004	-.001	f.002	-.004	-.004	-.004
Δ2,3	-.0022	-.004	-.009	-.010	-.012	-.008	-.008	-.008
Δ3,4	-.0008	-.004	0	0	0	-.004	-.003	-.004
Δ4,5	0	-.002	-.003	f.001	f.005	-.003	-.003	-.002
Δ5,6	-.0008	f.010	f.011	f.009	f.010	-.023	-.025	-.025
Δ6,7	-.0003	-.006	-.007	-.003	-.008	-.023	-.023	-.024

DESCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Ortg. Cal.	.016	.032	.053	.080	.118	.192	.197	.202
1st	.0199	.037	.059	.086	.122	.176	.201	.204
2nd	-	.029	.053	.083	.121	.183	.196	.200
3rd	-	.031	.052	.079	.117	.180	.189	.192
4th	-	.032	.054	.082	.120	.178	.186	.188
5th	-	.0198	.043	.074	.116	.181	.183	.186
6th	-	.032	.052	.078	.112	.158	.159	.161
7th	-	.023	.042	.064	.091	.128	.137	.137
Δ0,1	f.0039	f.005	f.006	f.006	f.004	-.016	f.003	f.002
Δ1,2	-	-.008	-.006	-.003	-.001	f.007	-.005	-.004
Δ2,3	-	f.002	-.001	-.004	-.004	-.003	-.007	-.008
Δ3,4	-	f.001	f.002	f.003	f.003	-.002	-.003	-.004
Δ4,5	-	-.0122	-.011	-.008	-.004	f.003	-.003	-.002
Δ5,6	-	f.0122	f.009	f.004	-.004	-.023	-.024	-.025
Δ6,7	-	-.009	-.010	-.014	-.011	-.030	-.022	-.024

ASCENDING TEMPERATURES

#3 VERNATHERM UNIT

#4 VERNATHERM UNIT

ASCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Orig. Cal.	.020	.036	.057	.085	.123	.180	.198	.200
1st "	.024	.040	.060	.086	.122	.180	.202	.206
2nd "	.021	.036	.058	.085	.125	.191	.198	.201
3rd "	.021	.037	.057	.086	.127	.189	.192	.196
4th "	.0197	.033	.053	.079	.115	.176	.188	.191
5th "	-	.031	.049	.075	.114	.180	.188	.190
6th "	-	.035	.056	.083	.119	.170	.172	.175
7th "	-	.036	.055	.079	.110	.148	.155	.156

0,1	+.004	+.004	+.003	+.001	-.001	-	+.004	+.006
1,2	-.003	-.004	-.002	-.001	+.003	+.010	-.004	-.005
2,3	0	+.001	-.001	+.001	+.002	-.002	-.006	-.005
3,4	-.0013	-.004	-.004	-.007	-.012	-.013	-.004	-.005
4,5	-	-.002	-.004	-.004	-.001	+.004	0	-.001
5,6	-	+.004	+.007	+.008	+.005	-.010	-.016	-.015
6,7	-	+.001	-.001	-.004	-.009	-.022	-.017	-.019

DESCENDING TEMPERATURES

Temp. (°F)	140	145	150	155	160	165	170	175
Orig. Cal.	.025	.043	.065	.097	.145	.199	.200	.201
1st "	.028	.044	.066	.095	.138	.205	.206	.206
2nd "	.025	.042	.065	.096	.140	.200	.201	.201
3rd "	.025	.043	.066	.097	.142	.195	.195	.196
4th "	.020	.040	.065	.096	.140	.190	.190	.191
5th "	.026	.044	.068	.101	.149	.190	.190	.190
6th "	-	.051	.076	.109	.158	.175	.175	.175
7th "	.039	.058	.084	.118	.156	.156	.156	.156

0,1	+.003	+.001	+.001	-.002	-.007	+.006	+.006	+.005
1,2	-.003	-.002	-.001	+.001	+.002	-.005	-.005	-.005
2,3	0	+.001	+.001	+.001	+.002	-.005	-.006	-.005
3,4	-.005	-.003	-.001	-.001	-.002	-.005	-.005	-.005
4,5	+.006	+.004	+.003	+.004	+.009	0	0	-.001
5,6	-	+.007	+.008	+.008	+.009	-.015	-.015	-.015
6,7	-	+.007	+.008	+.009	-.002	-.019	-.019	-.019

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FIGURE -1

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FIGURE 2

FIGURE 3

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CALIBRATION CURVES FOR #1 VERNATHERM

UNIT INSTALLED IN A 'T' FITTING ON REAR FACE, PROCESS TUBE #1073

2ND CALIBRATION
EXPOSED TO A TOTAL OF $10.9 \times 10^3 R$

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$36.5 \times 10^3 R$

170
E F

CALIBRATION CURVES FOR #2 VENTHERM UNIT I

ORIGINAL CALIBRATION

NOT EXPOSED TO GAMMA IRRADIATION

1ST CALIBRATION

EXPOSED TO A TOTAL OF 4.4

3RD CALIBRATION

EXPOSED TO A TOTAL OF 24.5 $\times 10^3$ R

4TH CALIBRATION

EXPOSED TO A TOTAL OF

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INSTALLED IN A [REDACTED] FITTING ON REAR FACE, PROCESS TUB #1079 Page 13.

2ND CALIBRATION
EXPOSED TO A TOTAL OF $10.9 \times 10^3 R$ MOTION
 $36.5 \times 10^3 R$

o CALIBRATION CURVES FOR #3 VERNATHERM UNIT

EXPOSED TO GAMMA IRRADIATION IN A SLUG BUCKET

CALIBRATION CURVES FOR #4 VERNATHER

UNIT EXPOSED TO GAMMA IRRADIATION IN A SLUG BUCKET