OGDEN

Ogden Energy Group, Inc.
40 Lane Road
Fairfield, NJ 07007-2615
973 882 9000
Fax 973 882 4167

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BUREAU OF AIR REGULATION

November 16, 2000

Mr. Scott M. Sheplak, P.E., Administrator
Title V Section
Florida Department of Environmental Protection
Bureau of Air Regulation
111South Magnolia Drive, Suite 4
Tallahassee, FL 32301

Reference: Title V Air Operation Permit No. 1010056-002-AV
Pasco County Resource Recovery Facility

Dear Mr. Sheplak:

On behalf on Pasco County and pursuant to Specific Condition No. A.7.3.0, Operating Temperature in the Pasco County Resource Recovery Facility Title V Air Operation Permit No. 1010056-002-AV, please find enclosed for your review and approval, a copy of the roof/furnace temperature correlation report (dated May 24, 1991). This report has been previously provided to your Department in 1991 and has been the mechanism for demonstrating compliance with the furnace temperature conditions of the PSD permit (No. PSD-FL-127).

The attached "Demonstration of 1800 Degree Combustion Temperature and the Development of Furnace Roof Thermocouple Correlation" report has been stamped by a Florida professional engineer. The report indicates that a furnace roof temperature thermocouple reading of at least 1,167 degrees Fahrenheit (four-hour average) corresponds to a furnace temperature of 1,800 degrees F.

We are providing this report to your Department in response to the permitting note corresponding to Specific Condition A.7.3.0 of the Title V permit. The contents of this report demonstrates roof/furnace temperature correlation in accordance with good engineering practices. The Pasco County Resource Recovery Facility will continue to use this correlation report to satisfy the Operating Temperature condition, unless otherwise directed by your Department.

If you have any questions, or require further information, please let me know. I can be reached at (973) 882-7285.

Sincerely,

Leon Brasowski
Vice President, Permitting

CC: J. Gallagher (Pasco County)
J. Gorrie (CDM)
J. Milller (OMSP)
A. Nguyen (FDEP-Southwest District)
V. Ta (OMSP)

PASCO COUNTY SOLID WASTE RESOURCE RECOVERY FACILITY
DEMONSTRATION OF 1800 DEGREE COMBUSTION TEMPERATURE
and
DEVELOPMENT OF FURNACE ROOF THERMOCOUPLE CORRELATION

WM. R. CRELLIN, JR. P.E.
CERTIFICATE NO. 45574
STATE OF FLORIDA
REGISTERED ENGINEER

William R. Crellin, Jr.
11/1/00

SUBMITTED BY:

Z. Semanyshyn
Manager, Facility
Performance

APPROVED BY:

K.F. Stianche
Vice-President,
Technical Operations

OGDEN MARTIN SYSTEM OF PASCO
1387 HAYS ROAD
SPRING HILL, FL 34610

MAY 24, 1991

PASCO COUNTY SOLID WASTE RESOURCE RECOVERY FACILITY
DEMONSTRATION OF 1800 DEGREE COMBUSTION TEMPERATURE
and
DEVELOPMENT OF FURNACE ROOF THERMOCOUPLE CORRELATION

1.0 OBJECTIVE

The objective of the furnace temperature traverse was to obtain furnace gas temperature data to demonstrate the Florida Department of Environmental Regulation (DER) condition which requires the furnace mean temperature at the fully mixed zone of the combustor not to be less than 1800°F. The fully mixed zone of the combustor is viewed as the distance the combustion gas travels in one second above the grate (i.e. a one second residence time).

In addition the temperature traverse was performed to establish a monitoring method for insuring that the minimum 1800 degree temperature requirement is met on a continuous basis during long term facility operation by correlating the thermocouple readings at the top of the radiant pass ("rooftop") to the combustion zone temperature.

The three combustion units at the facility are of identical design and construction, therefore, per agreement with The Florida DER the traverse was performed in one of the three boilers (boiler 3) to demonstrate the permit condition.

2.0 BACKGROUND

The development of a correlation between the rooftop thermocouples and the actual combustion zone temperature is required since reliable and accurate combustion zone temperature measurement is not achievable on a long term basis using conventional "bare" type thermocouples. This is due to:

a) the high temperatures and harsh environment in and directly above the combustion zone, and

b) the radiation effect of the cooler furnace waterwalls on the thermocouple measurement.

The radiation effect stems from the exchange of radiant heat between the thermocouple and the cooler tempertures of the surrounding furnace waterwall surfaces . Due to this radiation effect the temperature indicated by a "bare" type thermocouple at the combustion zone and at the furnace roof will yield correspondingly lower temperatures than the true temperature of the gas. The general magnitude of temperature error observed in watercooled furnaces at 1800 degrees is 100 - 200 degrees (Refer to Tab 2 - Attachment 1).

To measure the true combustion gas temperature in the furnace a water cooled high velocity temperature thermocouple (HVT) is required. A HVT probe is the only reliable method of obtaining the true gas temperature since it eliminates the radiation effect on the measurement by shielding the thermocouple with a ceramic shield. For a detailed description of flue gas temperature measurement in boiler furnaces using HVT probes, refer to Tab 2 - Attachment 2).

3.0 DEMONSTRATION OF 1800 DEGREE F, 1 SECOND RESIDENCE TIME

A furnace temperature traverse, at full load operation, was performed on April 22, 1991. The traverse was performed at a boiler steam flow of 98,208 lbs/hr by Total Source Analysis Inc. using a 16 foot HVT, type K thermocouple, probe.

Due to the location of available boiler penetrations and constraints of HVT probe insertion into the furnace, the temperature traverse was performed at the 57.2 foot elevation or approximately 15 feet above the elevation where the minimum 1800 degree, one second residence time is required.

The traverse was performed by inserting the probe through a furnace sidewall observation port. The port was located at the approximate quarter point of the right sidewall. The average flue gas temperature at El. 57.2' was measured by traversing the furnace at one foot intervals for a total of 9 individual measurement points.

The average temperature measured was 1861 degrees. The raw data sheets and the averaged results of the traverse are included in Tab 1.

The furnace elevation where the minimum 1800 degree, 1 second residence point is required is determined as follows:

Flue gas flow rate (ACFM) measured at economizer outlet	=	93,050	(Refer to Tab 1, pgs. 9 & 10)
Flue gas temperature	=	450 F	

$$VOLUMETRIC\ FLOWRATE(ACFM) = 93{,}050\ x\ \frac{460+1861}{460+450} = 237{,}329$$

Furnace cross-sectional area = 13'6" X 17'10"
= 240.7 sq.ft.

Flue gas Velocity (V) in the Furnace

$$V = \frac{237329}{240.7 \times 60} = 16.4 \frac{ft}{sec}$$

Therefore, the minimum 1800 degrees for 1 second requirement exists 16.4 feet above the center of the combustion grate.

Grate elevation	=	28.4' EL.
Gas travel distance in 1 second	=	+16.4'
Elevation of 1800 degree, 1 second requirement	=	44.8' EL.

Since the furnace traverse was performed at the 57.2' elevation or 14.8 feet above the furnace elevation where a minimum 1800 degree flue gas temp must be demonstrated, the measured traverse temperature of 1861 must be adjusted to the 44.8' elevation. The temperature at the 44.8' elevation is approximated as follows:

Combustion temp on grate (Design-Theoretical) (EL. 28.4')	=	2012 F
HVT traverse temp. (EL. 57.2')	=	1861 F

The temperature drop of 151 degrees F (2012 minus 1861) between the combustion grate elevation and the traverse elevation (28.8 feet) yields a furnace absorption of 5.24 degrees per vertical foot.

The furnace temperature at the elevation where the 1800 degree, 1 second residence time is required:

$$TEMP._{1\ second} = 1861 + 12.4\ ft \times 5.24 \frac{degrees}{ft}$$

$$= 1925\ F$$

The furnace traverse yields a gas temperature of 1925 degrees F and therefore demonstrates the requirement of having a minimum combustion gas temperature of 1800 degrees at a residence time of 1 second.

4.0 DEVELOPMENT OF TEMPERATURE CORRELATION

In accordance with the permit requirement and recognizing the difficulty of accurately measuring combustion zone temperatures continuously, a correlation has been developed utilizing the furnace rooftop thermocouples as a surrogate temperature measurement for monitoring the 1800 degree minimum combustion zone temperature requirement.

Using the permanently installed thermocouples at the top of the first pass, temperature data was collected by the facility's Distributed Control System (DCS) and compared to data obtained simultaneously at the 57.2' furnace elevation using a HVT probe.

The temperature corresponding to the 1 second residence time point was demonstrated to average 1925 degrees F (refer to Section 3). During this period the rooftop thermocouple temperature averaged 1308 degrees F.

The individual rooftop temperature readings were grouped into a nominal temperature band of 24 degrees F about the average temperature, when firing refuse. This slight temperature variation is reflective of the process associated with the actual charging of waste fuel, i.e., there is a slight rise and fall in the furnace temperature as the feed ram pushes the fuel into the furnace and then retreats. One therefore needs to account for the inherent process variations characteristic of this cyclic feeding. Since the purpose of the correlation is to determine the minimum rooftop temperature corresponding to the 1800 degree requirement, the low end of the temperature bandwith has been applied to the average measured rooftop temperature measurement. An average bandwith of 24 degrees would thus yield a processing variation of ± 12° from the average temperature of 1308 degrees.

As previously noted in Section 3.0, during the test the unit exceeded the 1800°F by 125°F therefore, the minimum rooftop thermocouple temperature which will ensure a minimum 1800 degrees combustion zone temperature is (1308 - 125 -12) = 1167 degrees F.

5.0 ACKNOWLEDGEMENTS

The furnace traverses were conducted by Ogden Martin Systems of Pasco in conjunction with Total Source Analysis, Inc. The Ogden Martin test participants were:

S. Deduck
D. Porter

FIELD DATA SHEET

CLIENT Ogden Martin Systems - Pasco OPERATOR H. Stiles

PROJECT NO. 91-070-FL DATE April 22, 1991

PLANT SITE Pasco Co. Fla. - Unit 3 boiler

Time	samp. pt.		°F Hi	Lo
1502	10'		1846	1684
1506			1882.4	1680
1510	9'		1903.4	1742.8
1513			1865.2	1769
1517	8'		1930.4	1730.2
1519			1908.6	1741.6
~~1529~~ 1523	7'		2077.6	1718.8
~~1532~~ 1525			1924.6	1866.4
1529	6'		1993	1805
1532			1902	1812
1534	5'		1960	1846.4
1536			1894.4	1866
1540	4'		1978.4	1762.0
1544			2029.4	1749.4
1548	3'		1951	1754
1550			1959.6	1809.4
1554	2'		1998.2	1747
1556			2025	1787

TOTAL SOURCE ANALYSIS, INC.

TSA

Date 22-Apr-91

Furnace Gas Traverse
UNIT 3

Performed at burner elevation through rear-right side observatio

Time	MAX	MIN	
1502	1846.0	1684.0	
1506	1882.4	1680.0	
1510	1903.4	1742.8	
1513	1865.2	1769.0	
1517	1930.4	1730.2	
1519	1908.6	1741.6	
1523	2077.6	1718.8	
1525	1924.6	1866.4	
1529	1993.0	1805.0	
1532	1902.0	1812.0	
1534	1960.0	1846.4	
1536	1984.4	1866.0	
1540	1978.4	1762.0	
1544	2029.4	1749.4	
1548	1951.0	1754.0	
1550	1959.6	1809.4	
1554	1998.2	1747.0	
1556	2025.0	1787.0	
Averages	1951.1	1770.6	1860.8

BOILER 3 1-HR PERFORMANCE TEST LOG - PAGE 1 LOG 31 16:20:23 22-APR-91 MONDAY

1	3-FR-13	MAIN STEAM FLOW BLR C
2	3-FR-610	BFW TO BLR C FLOW
3	FR-606	BFW HEADER FLOW
4	3-FR-1460	OVERFIRE AIR FLOW-BLR C
5	3-FR-1426	UNDERGRATE AIR FLOW-BLR C
6	3-FR-2007	PROPANE TO BLR C FLOW
7	TR-609	BFW HEADER TEMP
8	3-TR-55	PRIMARY SUPERHTR INLET TEMP-BLR
9	3-TR-56	PRIMARY SUPERHTR EXIT TEMP-BLR C
10	3-TR-9	INT SUPERHTR INLET TEMP-BLR C
11	3-TR-8	FINAL SUPERHTR INLET TEMP-BLR C
12	3-TR-11	FINAL SUPERHTR INLET TEMP-BLR C
13	3-TR-13	MAIN STEAM TEMP BLR C

TIME	1 KLB/HR	2 KLB/HR	3 KLB/HR	4 ACFM	5 ACFM	6 LB/HR	7 DEG F	8 DEG F	9 DEG F	10 DEG F	11 DEG F	12 DEG F	13 DEG F
15:01	90.250	89.000	284.000	17216	31200	0	293	542	675	605	758	763	815
15:02	92.000	92.250	289.500	17504	31456	0	293	542	675	607	758	763	815
15:03	91.500	91.125	290.000	17536	31424	0	293	542	675	605	758	763	815
15:04	90.750	90.375	284.500	17088	30976	0	293	542	675	605	757	762	814
15:05	93.125	90.750	286.500	17216	31264	0	293	543	676	608	759	764	814
15:06	94.875	93.000	292.000	17664	31168	0	293	543	677	611	761	766	816
15:07	92.750	93.500	291.500	17472	30528	0	293	542	676	608	760	765	816
15:08	91.125	91.875	285.500	17248	32736	0	293	542	674	605	758	763	814
15:09	91.500	91.125	287.000	16896	30528	0	294	542	674	604	757	763	813
15:10	95.250	93.875	288.500	17344	30784	0	294	543	675	608	759	764	813
15:11	95.500	93.375	284.000	17760	30624	0	294	543	675	608	760	765	814
15:12	92.375	94.000	282.500	17632	30080	0	295	542	674	605	759	764	815
15:13	94.250	93.875	285.500	17568	30016	0	295	543	674	605	758	763	814
15:14	93.375	93.750	283.500	17440	29216	0	295	542	673	603	756	762	813
15:15	94.000	93.875	279.000	17344	28416	0	295	542	672	602	755	761	811
15:16	93.625	94.375	277.000	17824	28512	0	296	543	671	602	755	760	811
15:17	90.000	91.125	278.500	17952	28448	0	296	542	671	599	754	760	811
15:18	92.000	91.625	284.000	17600	28480	0	296	542	670	599	753	758	809
15:19	94.250	94.250	285.000	17856	28512	0	296	543	671	601	753	758	808
15:20	92.500	93.500	282.000	17824	28128	0	297	542	670	601	753	758	809
15:21	92.375	93.375	282.000	17568	27872	0	297	542	670	600	752	757	807
15:22	98.250	97.250	284.000	18240	28128	0	297	543	671	604	754	759	808
15:23	97.125	95.375	280.000	19008	28064	0	297	543	671	604	755	760	810
15:24	95.500	95.875	280.500	18656	27104	0	297	543	670	601	753	759	810
15:25	95.500	95.625	281.000	18752	26496	0	297	543	669	600	752	758	809
15:26	94.625	94.250	281.500	18304	25344	0	297	543	668	598	751	757	809
15:27	95.375	95.625	282.000	18464	24640	0	298	543	667	598	750	756	807
15:28	93.625	95.375	280.000	18528	23808	0	298	542	666	595	748	754	806
15:29	92.375	93.750	276.500	18560	23520	0	298	542	665	593	746	752	804
15:30	92.625	93.125	279.000	18624	23872	0	298	542	666	595	747	753	803
15:31	93.000	94.250	281.500	18368	23616	0	298	542	665	593	746	752	803
15:32	91.625	93.000	277.500	18336	24000	0	298	541	663	591	743	750	801
15:33	89.500	91.250	272.500	17696	24448	0	298	541	663	589	742	748	799
15:34	90.125	93.375	275.000	17888	25536	0	298	542	664	590	743	748	798
15:35	90.625	93.000	276.000	17856	26080	0	298	541	665	591	744	749	798
15:36	91.000	91.875	271.500	17760	26560	0	297	542	665	592	744	750	798
15:37	90.250	91.500	273.500	17856	27520	0	297	542	667	594	746	751	799
15:38	90.750	91.625	274.500	17632	27872	0	297	542	667	594	746	751	800
15:39	91.000	92.875	273.500	17312	29632	0	297	542	668	595	746	752	800

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15:40	92.250	92.375	274.500	17408	30112	0	297	542	670	597	749	754	801
15:41	93.000	93.250	277.000	17568	29632	0	297	542	670	598	750	755	803
15:42	92.000	93.500	275.500	17344	29664	0	297	542	670	598	750	756	803
15:43	91.750	92.625	277.000	17344	29984	0	297	542	671	599	752	757	804
15:44	90.750	91.875	280.500	16992	30048	0	297	542	670	597	751	756	805
15:45	90.875	92.125	280.000	16928	29856	0	297	542	669	596	749	755	804
15:46	92.000	92.000	278.000	17344	30432	0	297	542	669	598	750	756	803
15:47	90.875	91.875	281.500	17408	30528	0	297	542	670	597	751	757	805
15:48	91.125	91.875	280.500	17152	30432	0	297	542	670	598	751	756	804
15:49	95.125	95.125	284.000	17216	30112	0	297	543	671	602	753	758	805
15:50	94.375	95.625	283.000	17568	29888	0	297	543	671	602	754	759	807
15:51	92.875	93.000	279.500	17248	29536	0	298	542	670	599	752	757	807
15:52	93.625	94.375	280.000	17504	29600	0	298	542	669	599	752	757	806
15:53	93.375	92.500	283.500	17568	29248	0	298	542	669	599	752	757	807
15:54	93.625	93.625	285.000	17504	28512	0	298	542	669	600	752	757	807
15:55	95.875	96.375	288.500	17888	27968	0	298	543	670	602	753	758	807
15:56	94.250	93.750	285.500	17824	27232	0	298	542	669	600	752	757	808
15:57	94.125	94.500	283.500	17664	26400	0	298	542	668	598	750	756	807
15:58	96.000	96.000	282.500	18208	26272	0	298	543	668	600	750	756	806
15:59	94.625	95.375	285.500	18144	25152	0	298	543	667	599	750	755	807
16:00	95.375	94.875	285.000	18304	24480	0	298	543	666	598	749	754	806
AVERAGE	92.969	93.327	281.533	17725.332	28361.600	0.000	296.19	542.27	669.98	599.73	752.02	757.40	807.35
MINIMUM	89.500	89.000	271.500	16896.000	23520.000	0.000	292.50	541.00	663.00	589.00	742.00	743.00	793.00
MAXIMUM	98.250	97.250	292.000	19008.000	32736.000	0.000	298.00	543.00	677.00	611.00	761.00	766.00	816.00

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BOILER 3 1-HR PERFORMANCE TEST LOG - PAGE 2 LOG 32 16:10:32 22-APR-91 MONDAY

14	3-TR-1425	AIR PREHTR EXIT AIR TEMP-BLR C
15	3-TR-1401A	COMBUSTION ZONE TEMP-BLR C
16	3-TR-1401B	COMBUSTION ZONE TEMP-BLR C
17	3-TR-1404A	FURNACE ROOF TEMP-BLR C
18	3-TR-1404B	FURNACE ROOF TEMP-BLR C
19	3-TR-1404C	FURNACE ROOF TEMP-BLR C
20	3-TR-1407A	FURNACE SUPERHTR TEMP-BLR C
21	3-TR-1407B	FURNACE SUPERHTR TEMP-BLR C
22	3-TR-1407C	FURNACE SUPERHTR TEMP-BLR C
23	3-TR-1407D	FURNACE SUPERHTR TEMP-BLR C
24	3-TR-1407E	FURNACE SUPERHTR TEMP-BLR C
AA	3-TR-1411	FURN ECONOMIZER EXIT TEMP-BLR C
BB	3-TI-3867	SCRUBBER OUTLET TEMP
CC	3-TI-1437	BAGHS EXIT-BLR C FLUE GAS TEMP

TIME	14 DEG F	15 DEG F	16 DEG F	17 DEG F	18 DEG F	19 DEG F	20 DEG F	21 DEG F	22 DEG F	23 DEG F	24 DEG F	AA DEG F	BB DEG F	CC DEG F
15:01	229	1428	1420	1238	1340	1314	1036	925	789	729	729	461	303	298
15:02	229	1434	1422	1238	1340	1316	1038	927	790	730	729	461	302	298
15:03	229	1428	1418	1238	1340	1316	1036	926	790	730	729	461	302	299
15:04	229	1432	1420	1238	1340	1316	1036	925	789	730	729	461	303	298
15:05	229	1454	1424	1236	1340	1318	1044	931	793	732	730	462	305	299
15:06	229	1458	1420	1236	1340	1318	1050	935	796	734	731	462	304	299
15:07	229	1442	1412	1236	1340	1320	1046	933	793	733	731	462	302	299
15:08	229	1438	1412	1236	1340	1320	1042	930	791	731	731	462	302	299
15:09	229	1442	1430	1236	1340	1320	1042	929	791	731	731	461	303	299
15:10	229	1456	1470	1236	1340	1322	1046	932	793	732	731	461	304	299
15:11	229	1458	1486	1236	1340	1322	1048	935	796	734	731	462	304	299
15:12	229	1448	1486	1236	1340	1322	1046	933	794	733	731	462	304	299
15:13	229	1448	1482	1236	1340	1324	1044	931	792	732	731	462	303	299
15:14	228	1440	1472	1236	1340	1326	1042	927	789	730	731	461	301	299
15:15	228	1442	1476	1236	1340	1326	1040	925	788	729	731	461	301	299
15:16	228	1444	1478	1236	1342	1328	1040	925	788	729	732	460	301	298
15:17	227	1428	1466	1236	1342	1328	1036	922	786	727	731	460	301	299
15:18	227	1422	1462	1236	1342	1330	1032	921	786	727	730	460	302	298
15:19	227	1436	1462	1236	1342	1330	1036	924	788	728	730	460	301	299
15:20	227	1432	1454	1236	1342	1330	1036	923	786	727	731	460	300	298
15:21	227	1442	1462	1234	1342	1332	1036	922	785	727	731	460	301	298
15:22	227	1476	1484	1234	1344	1332	1046	928	789	729	732	460	301	298
15:23	227	1480	1478	1234	1344	1334	1050	930	789	730	733	460	301	298
15:24	227	1468	1474	1236	1344	1336	1048	929	788	729	733	460	301	298
15:25	227	1462	1484	1236	1344	1336	1046	928	787	729	733	460	300	297
15:26	227	1454	1492	1236	1346	1338	1044	925	785	727	733	459	299	297
15:27	228	1452	1492	1238	1346	1340	1040	921	783	726	733	459	298	297
15:28	228	1438	1482	1238	1348	1342	1034	916	779	723	732	458	298	296
15:29	229	1440	1494	1238	1348	1342	1032	913	778	722	731	458	298	296
15:30	229	1442	1502	1238	1348	1344	1034	913	778	722	731	457	297	296
15:31	230	1430	1496	1238	1350	1346	1028	909	775	720	730	457	295	296
15:32	230	1416	1492	1238	1350	1346	1022	903	771	718	729	456	294	295
15:33	230	1418	1492	1238	1350	1346	1018	900	770	716	726	455	295	294
15:34	231	1424	1490	1238	1350	1348	1020	901	771	717	728	455	296	294
15:35	231	1418	1484	1238	1350	1348	1020	901	771	717	727	455	296	294
15:36	231	1420	1492	1238	1352	1348	1022	904	773	718	727	456	296	293
15:37	231	1420	1496	1238	1352	1350	1024	906	774	719	727	456	296	293
15:38	231	1412	1500	1236	1352	1350	1022	904	773	718	727	456	296	293
15:39	231	1422	1506	1236	1352	1352	1023	906	775	720	727	456	297	293

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15:40	231	1444	1508	1236	1352	1352	1030	912	779	722	727	457	298	293
15:41	231	1446	1496	1236	1352	1354	1034	914	780	723	728	458	297	293
15:42	230	1444	1494	1234	1352	1354	1034	916	782	724	728	458	298	293
15:43	229	1442	1494	1234	1354	1354	1036	918	783	725	729	458	296	293
15:44	229	1426	1482	1234	1354	1356	1032	914	780	723	729	458	295	293
15:45	229	1424	1482	1234	1354	1356	1026	912	779	722	728	458	296	293
15:46	229	1442	1494	1234	1354	1356	1030	914	781	724	728	458	297	293
15:47	229	1436	1488	1234	1354	1356	1030	914	781	724	728	458	297	293
15:48	229	1432	1492	1234	1356	1356	1030	916	782	724	728	459	298	293
15:49	229	1450	1500	1234	1356	1356	1036	922	786	727	729	459	298	293
15:50	229	1448	1494	1234	1356	1358	1040	923	786	727	729	459	295	293
15:51	229	1442	1498	1234	1356	1358	1036	919	783	726	729	459	295	293
15:52	229	1446	1508	1234	1356	1358	1036	921	785	726	729	458	297	293
15:53	229	1442	1512	1234	1356	1360	1038	921	785	727	730	459	297	293
15:54	229	1442	1508	1234	1358	1360	1038	923	786	727	730	459	298	293
15:55	228	1450	1500	1234	1358	1360	1042	925	787	728	731	460	297	294
15:56	228	1440	1482	1234	1358	1362	1040	922	784	727	731	460	295	294
15:57	228	1444	1478	1236	1358	1362	1038	920	783	726	731	459	295	294
15:58	229	1460	1482	1236	1360	1362	1042	921	783	726	731	459	296	294
15:59	229	1454	1470	1236	1360	1364	1040	919	782	725	731	459	296	293
16:00	229	1452	1466	1238	1360	1364	1038	916	780	724	732	458	295	293
AVERAGE	228.833	1440.833	1476.533	1235.933	1348.267	1341.233	1036.183	920.000	783.983	726.033	729.967	458.86	298.55	295.57
MINIMUM	227.000	1412.000	1412.000	1234.000	1340.000	1314.000	1018.000	900.000	770.000	716.000	727.000	455.00	294.00	292.50
MAXIMUM	231.000	1480.000	1512.000	1238.000	1360.000	1364.000	1050.000	935.000	796.000	734.000	733.000	462.00	304.50	299.00

AVG. = 1308
MIN = 1296
MAX = 1320

BOILER 3 1-HR PERFORMANCE TEST LOG - PAGE 3   LOG 33   16:20:26 22-APR-91 MONDAY

25	3-PI-4	DRUM PRESSURE BLR C
2	3-PR-13	MAIN STEAM PRESS BLR C
27	3-PI-611	FEEDWATER PRESS BLR C
28	3-PI-1413	FURNACE-BLR C AVG PRESSURE
29	3-PI-1416	FURN ECON EXIT PRESSURE-BLR C
30	3-PI-1432	SCRBR EXIT-BLR C FLUE GAS PRESS
31	3-PI-1436	BAGHS EXIT-BLR C FLUE GAS PRESS
32	3-II-1445	ID FAN-BLR C MOTOR AMPS
33	3-II-1421	FD FAN-BLR C MOTOR AMPS
34	3-II-1450	OFA FAN-BLR C MOTOR AMPS
35	3-AI-1427	FLUE GAS-INSITU OXYGEN-BLR C
36	3-LR-41	DRUM LEVEL BLR C
37	3-AI-1443	FLUE GAS - BLR C OPACITY

TIME	25 PSIG	26 PSIG	27 PSIG	28 IN WC	29 IN WC	30 IN WC	31 IN WC	32 AMPS	33 AMPS	34 AMPS	35 PERCENT	36 INCHES	37 PERCENT
15:01	950.0	871.0	1040.0	-0.4	-1.9	-7.7	-16.4	50.2	145.0	88.9	8.3	5.1	1.0
15:02	950.0	871.0	1042.0	-0.5	-2.1	-7.9	-16.5	50.2	145.8	89.5	7.1	4.2	1.0
15:03	948.0	868.0	1038.0	-0.4	-1.8	-7.6	-16.4	50.2	146.0	89.3	8.6	5.0	1.0
15:04	951.0	871.0	1042.0	-0.2	-1.4	-7.5	-16.5	50.2	145.0	88.4	7.9	4.3	1.0
15:05	956.0	873.0	1046.0	-0.4	-1.9	-7.7	-16.7	50.1	145.0	88.9	5.9	5.4	1.0
15:06	954.0	871.0	1044.0	-0.4	-1.9	-7.6	-17.2	50.2	144.3	89.6	7.0	5.3	1.0
15:07	950.0	868.0	1040.0	-0.2	-1.4	-7.0	-17.5	50.2	145.0	89.1	8.6	5.5	1.0
15:08	950.0	871.0	1040.0	-0.0	-1.1	-6.7	-17.4	50.2	147.5	88.5	8.0	4.4	1.0
15:09	953.0	871.0	1044.0	-0.1	-1.2	-6.9	-17.3	50.2	144.0	88.1	7.5	4.7	1.0
15:10	956.0	870.0	1048.0	-0.4	-1.8	-7.8	-16.5	50.2	143.8	89.4	5.6	5.3	1.0
15:11	954.0	869.0	1044.0	-0.4	-1.9	-7.9	-16.7	50.2	142.8	90.0	7.0	5.9	1.0
15:12	954.0	872.0	1044.0	-0.4	-1.8	-7.7	-16.9	50.1	141.8	89.6	8.5	4.8	1.0
15:13	953.0	871.0	1044.0	-0.4	-1.8	-7.3	-17.6	50.0	140.8	89.6	7.5	4.5	1.0
15:14	951.0	868.0	1042.0	-0.2	-1.5	-7.1	-17.6	50.1	138.8	89.3	8.5	4.6	0.9
15:15	954.0	869.0	1044.0	-0.4	-1.9	-7.4	-17.5	50.1	136.8	89.4	7.4	4.6	1.0
15:16	953.0	871.0	1044.0	-0.9	-2.8	-8.6	-17.1	50.1	136.5	90.4	6.9	4.4	1.0
15:17	949.0	874.0	1040.0	-0.6	-2.3	-8.3	-17.0	50.1	136.3	89.8	8.9	4.7	1.0
15:18	952.0	870.0	1042.0	-0.7	-2.5	-8.3	-17.3	50.1	136.8	89.9	8.3	4.1	1.0
15:19	952.0	870.0	1042.0	-0.8	-2.5	-8.1	-18.0	50.1	136.5	90.1	6.8	3.8	0.9
15:20	950.0	870.0	1040.0	-0.6	-2.2	-7.8	-17.9	50.1	135.8	90.0	8.4	3.7	0.9
15:21	956.0	872.0	1046.0	-0.5	-2.0	-7.6	-17.9	50.1	135.0	89.8	8.1	3.4	0.9
15:22	961.0	870.0	1052.0	-1.0	-3.1	-8.9	-17.5	50.1	135.5	91.9	5.5	4.3	0.9
15:23	957.0	870.0	1048.0	-1.0	-3.0	-8.8	-17.4	50.1	134.0	92.5	7.4	5.2	0.9
15:24	957.0	871.0	1048.0	-1.1	-3.1	-8.9	-17.5	50.1	132.5	92.4	8.4	4.6	0.9
15:25	956.0	871.0	1046.0	-0.9	-2.8	-8.2	-18.0	50.1	130.0	92.3	7.6	4.6	0.9
15:26	955.0	871.0	1046.0	-0.9	-2.8	-8.1	-18.0	50.0	127.3	91.6	8.0	4.8	0.9
15:27	953.0	869.0	1044.0	-1.3	-3.6	-9.0	-17.4	49.1	125.9	92.4	7.2	4.6	0.9
15:28	950.0	867.0	1040.0	-1.1	-3.3	-8.8	-17.0	49.8	123.3	92.0	8.7	3.4	0.9
15:29	952.0	871.0	1044.0	-1.3	-3.5	-8.9	-17.0	48.6	123.0	92.1	7.2	3.6	0.9
15:30	952.0	873.0	1042.0	-1.3	-3.4	-8.5	-17.4	48.3	123.4	92.0	7.0	3.8	0.9
15:31	947.0	866.0	1038.0	-1.1	-3.1	-8.1	-17.5	48.1	123.1	91.6	8.3	3.3	0.9
15:32	944.0	866.0	1034.0	-0.9	-2.7	-7.9	-17.4	48.1	124.1	90.9	8.5	3.3	0.9
15:33	946.0	870.0	1036.0	-1.0	-3.0	-8.5	-16.5	48.5	126.3	90.4	7.8	3.0	0.8
15:34	947.0	871.0	1038.0	-1.1	-3.1	-8.5	-16.3	48.1	128.8	90.3	6.8	3.0	0.8
15:35	945.0	868.0	1036.0	-0.8	-2.7	-8.2	-16.3	49.0	129.8	90.0	8.0	3.0	0.8
15:36	948.0	870.0	1040.0	-0.9	-2.7	-8.1	-16.1	48.1	131.8	90.1	7.1	3.4	0.8
15:37	947.0	871.0	1040.0	-0.8	-2.5	-8.0	-16.2	48.1	133.8	89.9	7.5	3.8	0.8
15:38	947.0	869.0	1040.0	-0.6	-2.1	-7.8	-16.1	49.1	135.8	89.6	8.4	3.7	0.8
15:39	950.0	870.0	1044.0	-0.3	-1.6	-7.4	-15.9	49.8	141.3	89.0	7.7	3.7	0.8

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15:40	952.0	872.0	1046.0	-0.5	-2.0	-7.6	-16.1	48.9	140.0	89.4	6.6	3.4	0.8
15:41	948.0	868.0	1044.0	-0.4	-1.7	-7.4	-15.9	49.3	140.0	89.3	7.8	3.5	0.8
15:42	951.0	870.0	1048.0	-0.3	-1.6	-7.0	-16.5	48.8	140.3	88.9	8.1	4.0	0.8
15:43	950.0	873.0	1048.0	-0.3	-1.6	-6.8	-16.7	48.1	141.3	88.9	7.1	4.1	0.8
15:44	946.0	870.0	1044.0	-0.2	-1.4	-6.8	-16.9	49.0	141.3	88.3	9.0	3.3	0.8
15:45	948.0	868.0	1046.0	-0.2	-1.4	-6.9	-16.5	49.8	141.3	88.1	8.7	3.9	0.8
15:46	951.0	872.0	1050.0	-0.5	-2.1	-7.8	-16.1	49.4	142.5	89.3	6.4	4.3	0.8
15:47	948.0	871.0	1048.0	-0.3	-1.7	-7.5	-16.1	49.9	142.8	88.6	8.5	4.3	0.8
15:48	952.0	871.0	1052.0	-0.2	-1.4	-7.2	-16.5	49.9	142.3	88.5	8.3	3.7	0.8
15:49	955.0	871.0	1056.0	-0.3	-1.5	-6.8	-16.7	48.3	141.5	89.0	6.3	4.2	0.8
15:50	951.0	869.0	1052.0	-0.2	-1.4	-6.6	-16.7	48.7	140.0	88.9	7.6	3.8	0.8
15:51	953.0	870.0	1054.0	-0.3	-1.7	-7.0	-16.5	49.3	139.5	88.8	8.2	4.0	0.7
15:52	954.0	872.0	1056.0	-0.7	-2.3	-8.0	-16.3	49.8	139.8	89.4	7.1	3.9	0.8
15:53	952.0	871.0	1054.0	-0.6	-2.2	-7.8	-16.3	50.1	138.5	89.4	8.2	4.6	0.8
15:54	956.0	872.0	1053.0	-0.6	-2.2	-7.7	-16.7	49.6	136.8	89.5	8.1	4.1	0.8
15:55	955.0	872.0	1058.0	-0.7	-2.3	-7.5	-17.2	48.6	135.0	90.1	6.8	4.3	0.8
15:56	952.0	869.0	1054.0	-0.6	-2.2	-7.4	-17.3	49.2	133.0	90.0	8.9	4.7	0.8
15:57	955.0	870.0	1058.0	-0.7	-2.3	-7.5	-17.2	48.9	130.8	90.0	7.9	4.0	0.8
15:58	957.0	872.0	1060.0	-1.1	-3.1	-8.5	-16.6	48.1	130.0	91.1	6.5	4.4	0.8
15:59	954.0	871.0	1058.0	-1.0	-2.9	-8.4	-16.5	48.9	127.0	90.9	8.3	4.2	0.8
16:00	954.0	869.0	1058.0	-0.9	-2.8	-8.2	-16.5	48.4	124.8	91.1	7.8	4.5	0.8
AVERAGE	951.733	870.333	1045.900	-0.608	-2.233	-7.792	-16.886	49.443	136.433	89.925	7.666	4.200	0.871
MINIMUM	944.000	866.000	1034.000	-1.309	-3.578	-8.953	-18.031	48.063	123.000	88.125	5.477	2.984	0.747
MAXIMUM	961.000	874.000	1060.000	-0.037	-1.125	-6.625	-15.906	50.188	147.500	92.500	9.016	5.898	1.016

OGDEN MARTIN SYSTEMS, INC.
CAE Project No. 5661

Pasco County Resource Recovery Facility
Energy Tests

4/22/91
1500-1530

Run 15	Unit 1	Unit 2	Unit 3
Pbar	29.94	29.94	29.94
SRDp	0.775	0.813	0.815
Ts	436	456	450
St	-1.5	-2.0	-1.2
% CO2	10.1	9.9	9.7
% O2	10.0	10.2	10.3
% N2	79.9	79.9	80.0
Bwo	0.150	0.149	0.146
Md	30.02	29.99	29.96
Ms	28.22	28.21	28.22
Ps	29.83	29.79	29.85
Vs	57.4	61.0	60.8
acfm	89,000	94,500	94,300
dscfm	44,500	46,200	46,600
lb/hr	229,900	238,400	239,700

CAE

OGDEN MARTIN SYSTEMS, INC.
CAE Project No. 5661

Pasco County Resource Recovery Facility
Energy Tests

4/22/91
1530-1600

Run 16	Unit 1	Unit 2	Unit 3
Pbar	29.94	29.94	29.94
SRDp	0.796	0.803	0.794
Ts	434	457	449
St	-1.5	-2.0	-1.2
% CO2	10.1	9.9	9.7
% O2	10.0	10.2	10.3
% N2	79.9	79.9	80.0
Bwo	0.150	0.149	0.146
Md	30.02	29.99	29.96
Ms	28.22	28.21	28.22
Ps	29.83	29.79	29.85
Vs	58.9	60.2	59.2
acfm	91,300	93,400	91,800
dscfm	45,700	45,600	45,400
lb/hr	236,100	235,300	233,500

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SECTION 2
ATTACHMENT 1

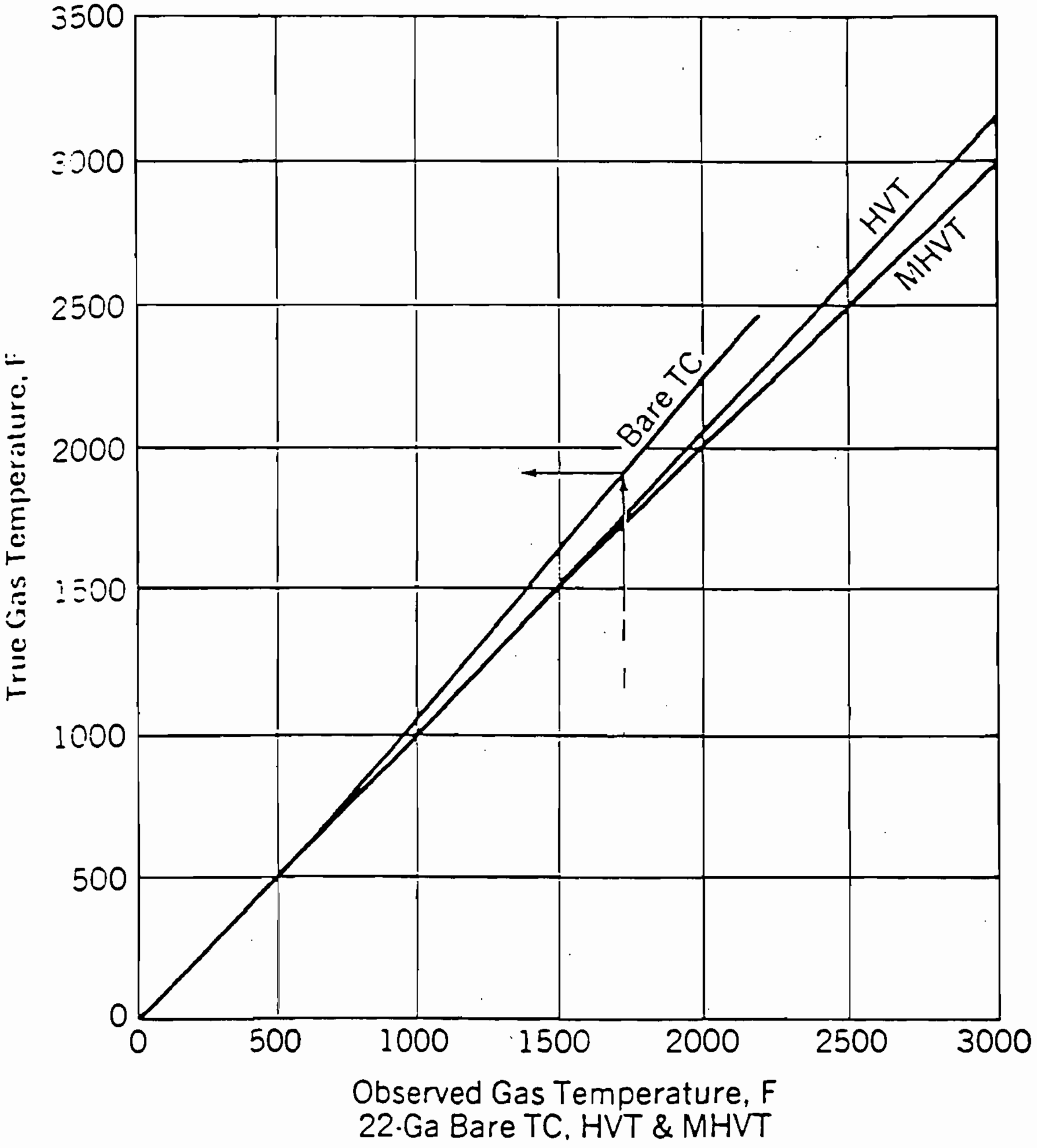

Fig. 28 General magnitude of error in observed readings when measuring gas temperature in boiler cavities with thermocouples.

REF. B & W STEAM BOOK

SECTION 2
ATTACHMENT 2

December 1983

MEASUREMENT OF GAS TEMPERATURE IN BOILER FURNACES

High Velocity Thermocouples

Babcock & Wilcox
a McDermott company

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Typical Orifice Gas Flow Curve .... Fig. 9

INTRODUCTION

Progressive design and operation of modern steam generating units depends, to an increasing extent, upon the critical evaluation of gas temperature conditions in the furnace and superheater sections of the equipment. Successful performance must take into account the limitations imposed by metal temperatures of superheater tubes, and by the fusing characteristics of ash and slag from the fuel in current or expected use.

While the over-all complexity of combustion and heat-transfer relationships prevents exact calculation, much valuable information can be obtained by taking direct and accurate measurement of the gas temperatures occurring in operating units, and making comparative studies of related factors.

Methods and equipment have been developed for this purpose and are described in this bulletin. They employ the portable, water-cooled high-velocity-thermocouple (HVT) for traversing various sections of the gas stream. Practical details for the construction and use of the equipment are included.

GENERAL PRINCIPLES

A simple exposed thermocouple, immersed in a hot gas stream, is affected not only by convection heat transfer from the gas to the thermocouple junction, but also by radiant heat exchange with surrounding surfaces which it can "see". If these surfaces are at the same temperature as the gas, the thermocouple junction will attain that temperature, and its reading will be the true gas temperature.

If the surrounding surfaces are at a temperature higher than that of the gas, heat exchange by radiation to the thermocouple junction will take place, resulting in a reading that is higher than the true gas temperature by an amount representing the equilibrium condition of the thermocouple in relation to its environment. On the other hand, if the surrounding surfaces are cooler than the gas, a net loss of heat from the thermocouple junction will result in readings that are lower than the true gas temperature.

The latter situation is more commonly encountered in boiler practice, because of the presence of water-cooled boiler and furnace wall tubes or steam-cooled superheater surfaces. Under some conditions the reading obtained from a bare exposed thermocouple in boiler passes may be several hundred degrees below the true temperature of the gas stream. For the sake of simplicity, in the descriptions which follow, it will be generally considered that the surrounding surfaces are cooler than the gas.

HIGH VELOCITY THERMOCOUPLE TYPES

HVT — (Single Shield)

Radiation error may be largely overcome by use of the high-velocity-thermocouple (HVT), which interposes a procelain radiation shield around the thermocouple junction, as shown in Figure 1. In this device, hot gas is aspirated over the thermocouple junction at a high velocity,

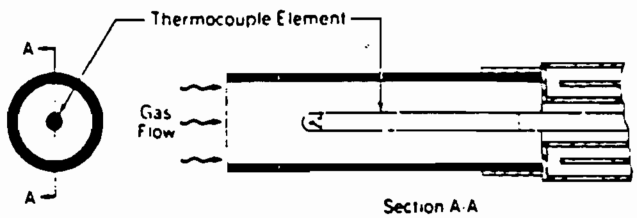

Fig. 1 High Velocity Thermocouple Shield Assembly

to increase the rate of heat transfer by convection from the gas to the thermocouple, and simultaneously impart heat to the radiation shield. The shield greatly reduces the amount of colder boiler surface which the thermocouple can "see", and substitutes surface at a temperature much closer to that of the gas, thereby reducing radiation loss from the thermocouple.

MHVT — (Multiple Shield)

By the use of multiple shields, all of which are heated by the aspirated gas stream, the radiation error may be further decreased, and the reading of the thermocouple caused to approach, very nearly, the true gas temperature. In such an arrangement the shielding surface nearest the thermocouple reaches higher temperatures, because its own heat losses are diminished by the outer shields.

One form of multiple shielding, (designated MHVT), which is widely adopted as a standard of reference in boiler testing, is shown in Figure 2. This assembly consists of an outer porcelain tube, connected to the aspirating source, and packed with smaller thin-wall porcelain tubes that surround the thermocouple element.

The MHVT can be used for traverse purposes in gas-fired or oil-fired units, where the products of combustion are relatively clean. Its small openings tend to clog rapidly if used in dust-laden gases from coal firing, and consequently require frequent cleaning or replacement. It can be operated for short periods, however, to serve as a standard of comparision in calibrating the more practical, though less effective, types of shielding.

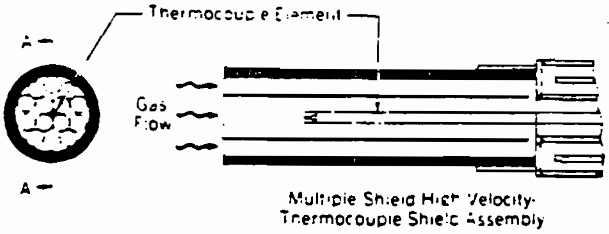

Fig. 2 Shield assemblies for high-velocity thermocouple (HVT) and multiple-shield high velocity thermocouple (MHVT).

TEMPERATURE CORRECTION

The amount of thermocouple radiation error will vary with many factors. These include the size of the thermocouple junction, its relation to the gas flow and surrounding boiler surfaces, the distribution and thickness of ash or slag as they affect the resultant surface temperature, the composition of the gases as well as the radiation characteristics of the active combustion zone, including its size and position. These factors vary with the design of the unit, rate of firing, and nature of the fuel.

Considering that the MHVT gives substantially accurate reading of true gas temperature, the general magnitude of error shown by a bare thermocouple and the single-shielded HVT, are indicated in Figure 3. It will be noted that the amount of error is greater in the high range of temperatures, and becomes negligible in the cooler range corresponding to economizer or air-heater gas passages.

The curves may be used for approximate correction of HVT readings taken in water-cooled furnaces and in cavity spaces of superheater and boiler convection banks. Inasmuch as they represent generalized data, obtained from a great many units, involving different fuels and operating rates, they should not be regarded as precise values. Where more exact corrections are desired, it may be necessary to run specific calibration by direct comparison of HVT and MHVT readings, taken under the particular conditions of the test.

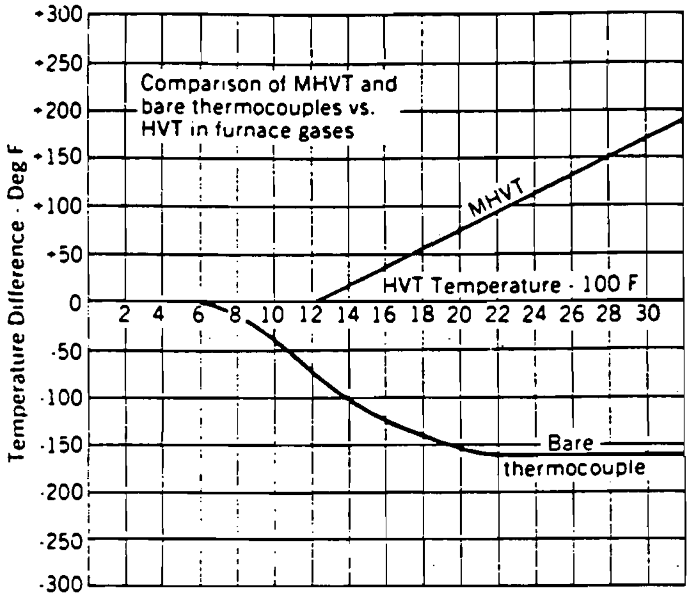

Fig. 3

CONSTRUCTION

General arrangement of the HVT test probe is shown in Figure 4. The assembly consists of a thermocouple element, supported by a water-cooled holder of sufficient length to span the traverse distance required for the boiler setting. Details of construction are such that it can be readily fabricated from stainless steel tubing and fittings. Certain features are provided to facilitate repair when it becomes necessary through normal use of the equipment.

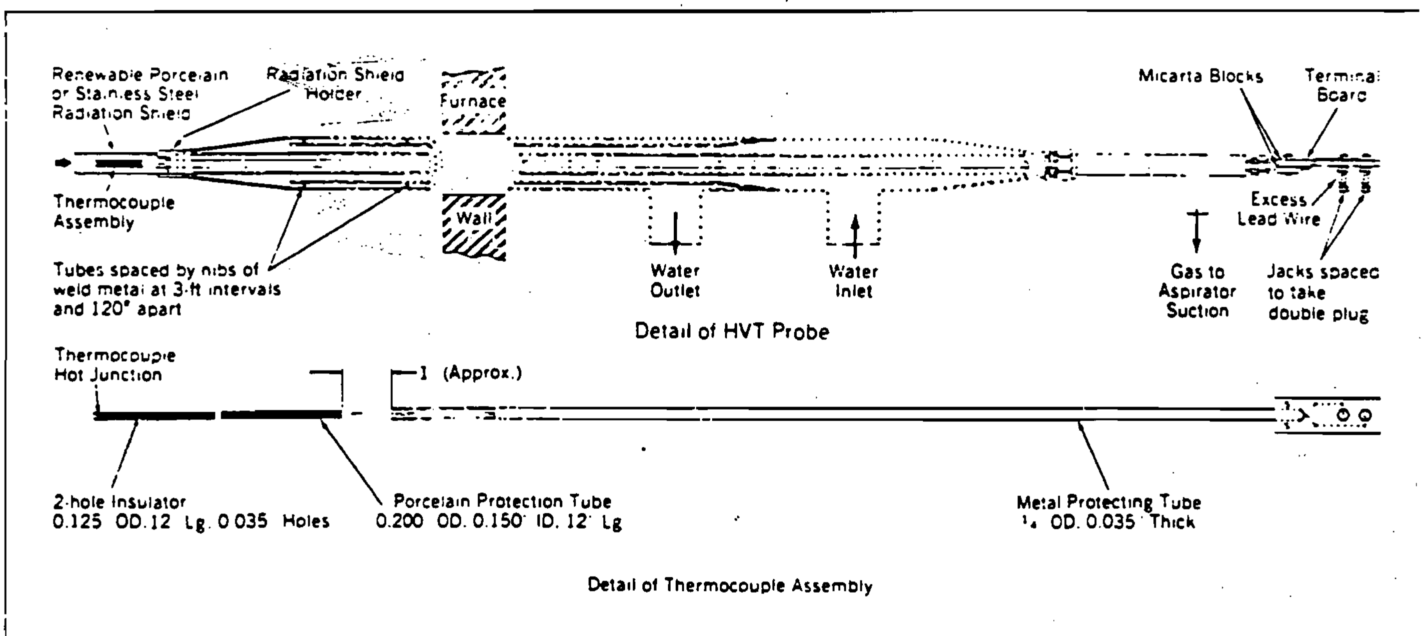

Fig. 4 Rugged water-cooled high-velocity thermocouple (HVT) for determination of high gas temperatures.

Water-Cooled Holder

The water-cooled holder consists of three concentric tubes. Cooling water flows through the two outer annuli and gases are drawn through the inner annulus by means of an aspirator operated by compressed air. At the furnace end, the thermocouple hot-junction projects beyond the water-cooled holder, and is surrounded by a porcelain radiation shield through which the gas is drawn at high velocity, simultaneously heating the thermocouple junction and the refractory shield.

Several factors must be considered in selecting the proper diameter and length of probe. Among these are the location and size of available doors, the traverse area to be covered, external clearances for access and manipulation as well as the probable range of the temperature of the gases and the available pressure of cooling water. Probes can be made in various lengths up to twenty feet. In the longer probes a larger diameter tubing is required to assure adequate water circulation for a given water supply pressure.

Two sizes are presently being fabricated with stainless steel tubing and fittings and should be considered standard. 1½" O.D. up to and including 15'-0 and 2" O.D. over 15'-0 up to and including 20'-0 in length.

The probes are normally made of straight tubing. For some special cases they may be made with a moderate degree of curvature in order to reach otherwise inaccessible areas. Brass, mild steel, or stainless steel tubes may be used in the construction . Stainless steel tubing is preferred because of its strength and corrosion resistance. It is desirable to have the outer tube of sufficient thickness to withstand physical damage in handling. The tubes are held in concentric position by the use of small spacing nibs of brazed metal shown in the detail.

Thermocouple Assembly

The thermocouple assembly is shown in Figure 4. The basic circuit consists of a paired length of 24 AWG platinum, and 90% platinum, 10% rhodium wire, joined to a suitable length of 22 AWG extension lead wire. The hot junction between the platinum and the platinum-rhodium wires can be made by twisting the ends together and fusing the twist into a small bead, by means of a portable electric welder, or acetylene torch. Welding flux should not be used. The copper and copper alloy lead wires should be given a polarity check, as outlined in Figure 5, before being permanently joined to the thermocouple wires by silver solder. For stainless steel tubing, welding or silver soldering should be used instead of brazing. Figure 6 shows the temperature and error limits for thermocouple wire.

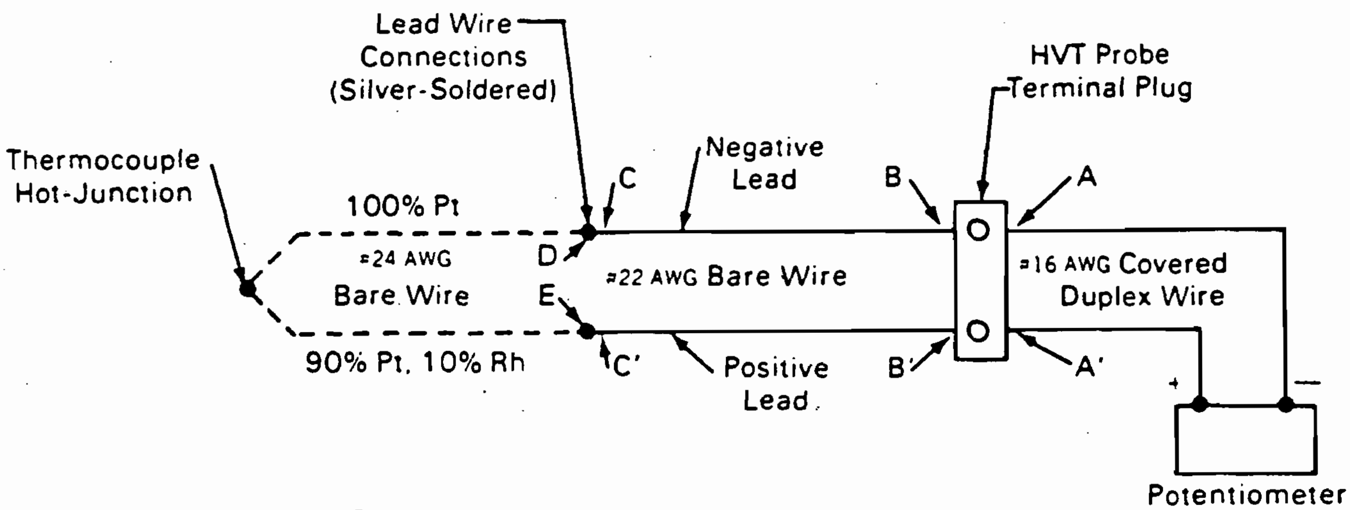

Fig. 5 Polarity check for thermoelement for high velocity thermocouple.

Temperature limits for standard thermocouples that are protected with a closed end protecting tube are shown. These limits are suggested for continuous temperature sensing where insulation is not a factor. For unprotected thermocouples where fast response is required these limits should be reduced for equivalent service life.

TEMPERATURE LIMITS FOR THERMOCOUPLE WIRE

Thermocouple	ISA Type	WIRE GAUGE (AWG) 8	14	20	24	28
Copper-Constantan	T	–	700°F	500°F	400°F	400°F
Iron-Constantan	J	1400°F	1100°F	900°F	700°F	700°F
Chromel-Constantan	E	1600°F	1200°F	1000°F	800°F	800°F
Chromel-Alumel*	K	2300°F	2000°F	1800°F	1600°F	1600°F
Platinum-Platinum Rhodium	R & S	–	–	–	2700°F	–
Platinum 6% Rhodium Platinum 30% Rhodium	B	–	–	–	3100°F	–
Tungsten Tungsten Rhenium	WR W5 W3	-		–	4200°F	–

THERMOCOUPLE WIRE LIMITS OF ERROR

WIRE ALLOYS	ANSI TYPE	TEMPERATURE RANGE (°F)	LIMITS OF ERROR STANDARD GRADE	SPECIAL GRADE
Copper(+) vs Constantan(–)	T	-300 to -75 -150 to -75 -75 to +200 +200 to +700	— ±2% ±1½°F ±¾%	±1% ±1% ±¾°F ±⅜%
*Iron(+) vs Constantan(–)	J	32 to 530 530 to 1400	±4°F ±¾%	±2°F ±⅜%
Chromel(+) vs Constantan(–)	E	32 to 600 600 to 1600	±3°F ±½%	±2¼°F ±⅜%
Chromel(+) vs *Alumel(–)	K	32 to 530 530 to 2300	±4°F ±¾%	±2°F ±⅜%
Platinum(–) vs Platinum Rhodium(+)	R & S	32 to 1000 1000 to 2700	±2½°F ±¼%	— ±1/10%
Platinum 6% Rhodium(–) Platinum 30% Rhodium(+)	B	1600 to 3100	±½%	–
Tungsten(+) vs Tungsten 26% Rhenium	WR*	to 800	±8°F	–
Tungsten 3% Rhenium(+) Tungsten 25% Rhenium(-)	W3*	800 to 4200	±1%	
Tungsten 5% Rhenium(+) Tungsten 26% Rhenium	W5*			

*Magnetic Conductor

Fig. 6 Temperature and error limits for thermocouple

Correction values thus obtained for the service thermocouple should be applied to the readings taken in the test traverses of the operating boiler unit. With repeated use, the service thermocouple may show progressively increasing deviation from the calibrating thermocouple, due to accumulating contamination effects. This tendency is more pronounced when the service thermocouple is used at temperatures above 2600F. A couple is considered usable if correction values at its highest operating temperature do not exceed approximately 40 to 50 degrees. If a greater deviation is shown, the contaminated portion should be cut off and a new hot junction made. A record should be kept of the amount cut off the service thermocouple to insure that it is not used after its length is reduced below 50 inches.

APPLICATION TO BOILER TESTING

The high velocity thermocouple described is primarily a tool for accurate measurement of high gas temperature under the difficult conditions encountered in steam boiler practice. Its application to boiler testing is, of course, quite varied, depending on the purpose of the test. In common practice it is used to explore the range and distribution of temperature in sections of the unit where information is needed relative to heat transfer rates, duty on pressure parts of superheater or other components of the equipment, and for investigating the behavior of ash and slag.

Graphical correlation is usually the most satisfactory method for appraising the data, and may be developed in the form of temperature-profile plots for individual traverse sections, or as area plots of isotherms, drawn in conformity with the readings obtained at local traverse points.

In any consideration of average temperature values, attention should be given to the nature and distribution of gas mass flow in the traverse area, which may require separate investigation by velocity traverse, using other test equipment.

Where the study requires a determination of gas composition, in conjunction with temperature data, the gases may be sampled from the line ahead of the aspirator, simultaneously with the progress of the temperature traverse. For separate traverse to determine gas composition, the water-cooled holder may be used conveniently as a sampling tube, after withdrawing the thermocouple element.

Progress and improvement in boiler design and operation depend very largely upon procuring more complete and accurate knowledge of the relationship of factors involved in the problem. Intelligent use of the HVT probe can yield data of primary significance to the resolution of this problem, and its extended application is encouraged.