VOLUME FLOW RESULTS

Flows

COMPANY: SOLAR TURBINES
DATE: 6-26-89
UNIT: TURBINE #1
REPORT #: 89-017

FIELD DATA @ 60'

Need → 60' and 60°

CONDITION:

RUN #:	1		3
TIME:	1230		40
Vm (dry gas sampled)	27.85		43
Y (meter calib. factor)	1.018627		27
P bar (Barometric pressure)	29.9	29.9	29.9
P static (stack pressure, " H20)	-0.55	-0.55	-0.55
Delta H (differential meter press, " H20)	1.3	1.4	1.46
Tm (meter temperature, R')	548	543	544
Vol H20 mls	30.8	43.8	31.4
Vm(std),dscf	26.99	27.89	26.79
Bws-H20 vapor	0.051	0.0688	0.0523
MF-moisture factor	0.949	0.9312	0.9477
% CO2	2.75	2.76	2.75
% O2	17.7	17.5	17.4
% N2	79.55	79.74	79.85
Md-MW stk gas,dry	29.15	29.14	29.14
Ms-MW stk gas,wet	28.58	28.37	28.56
Cp-pitot tube	0.84	0.84	0.84
Avg sq rt ^p	0.914	0.914	0.91
T stack, R'	1027	1026	1009
Stack area,ft2	4.91	4.91	4.91
Vs-fps	71.93	72.16	71.01
Qstd-dscfm	10162	10013	10197

COMPANY: SOLAR TURBINES
DATE: 6-27-89
UNIT: TURBINE #2
REPORT #:89-017

Need 68° and 60°

FIELD DATA @ 60'

SITE:

	OUTLET		
RUN #:	1		3
TIME:	930		3
Vm (dry gas sampled)	24.99	27.8	34.7
Y (meter calib. factor)	1.018627	1.018627	1.018627
P bar (Barometric pressure)	29.9	29.9	29.9
P static (stack pressure, " H2O)	-0.6	-0.6	-0.6
Delta H (differential meter press, " H2O)	1.15	1.4	1.11
Tm (meter temperature, R°)	540	541.5	543.6
Vol H2O mls	27.3	17.6	22.8
Vm(std),dscf	24.57	27.27	33.88
Bws-H2O vapor	0.0497	0.0295	0.0307
MF-moisture factor	0.9503	0.9705	0.9693
% CO2	2.68	2.8	2.75
% O2	17.7	17.63	17.61
% N2	79.62	79.57	79.64
Md-MW stk gas,dry	29.14	29.15	29.14
Ms-MW stk gas,wet	28.59	28.82	28.8
Cp-pitot tube	0.84	0.84	0.84
Avg sq rt ^p	0.947	0.985	0.92
T stack, R°	1032	1038	1026
Stack area,ft2	4.91	4.91	4.91
Vs-fps	74.78	77.69	72.17
Qstd-dscfm	10526	11104	10423

SAMPLING AND ANALTICAL PROCEDURES

REF: EPA code of Federal Regulations, Title 40, Part 60, Appendix A Methods 1, 2, 3, and 4.

SAMPLING PROCEDURE

The sampling apparatus consisted of a probe connected to a sample line, teflon. A series of impingers (see data sheet for type and contents) were connected in tandem and immersed in an ice bath. The absorption train was followed by a gas pump, dry test meter and a calibrated restriction orifice fitted with a magnehelic differential pressure gauge. A type "S" pitot tube and temperature probe was positioned along side the probe terminating at the sample nozzle for monitoring duct conditions throughout the test.

After a successful pre-test leak check is run, the probe is positioned in the stack and the pump engaged. A minimum of twenty (20) cubic feet is drawn through the impinger train. After a final meter volume is recorded a post-leak check is performed at the highest vacuum documented during the test.

EPA Method #1: Sampling and Velocity Traverses for Stationary Sources:

Prior to the source test a site acessment was performed in order to locate sample points for obtaining the best representative measurements of pollution concentrations and volumetric flow rates. EPA Method #1 takes into account duct area, straight run and cyclonic or stratified flow patterns.

EPA Method #2: Velocity and Volumetric Flow Rate:

A computer was used in selection of suitable sample/traverse points. The calibrated pitot tube was connected to a magnehelic gauge and leak checked. A temperature and delta-P was recorded at each traverse point and a duct static pressure was measured and recorded. A volume flow rate was calc the measured required traverse points.

EPA Method #3: %CO2, %O2, Dry Molecular Weight:

Concurrent with each particulate sampling, an intergrated gas sample was withdrawn from the summation of the traverse points through the train and collected at the outlet of the meter into a sample bag. The contents of the sample bag were analyzed by Orsat for fixed gas composition.

EPA Method #4: Percent Water:

Tare weights of the charged individual impingers were recorded. After sampling, the final weights were recorded. Percent water was calculated from the weight of water collected and the dry gas volume sampled.

Quality Control:

All sampling equipment, pitot tubes, dry gas meters and thermocouples, are calibrated in-house, on a quarterley basis. Calibration sheets can be found in the "Quality Control" section of the test report.

Not used - delete

Apparently ORSAT done for CO2 as it was used.

METHOD 2 STACK GAS VELOCITY AND VOLUMETRIC FLOWRATE

Average Stack Gas Velocity

$$Pg = \frac{\text{Static Pressure, "}H_2O\text{"}}{13.6}$$

$$Ps = P_{bar} + Pg \qquad \text{Eq. 2-6}$$

$$Vs = K_p C_p \left(\sqrt{\Delta p}\right)_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}} \qquad \text{Eq. 2-9}$$

Average Stack Gas Dry Volumetric Flow Rate

$$Q_{std} = 60\,(1-B_{ws})\,v_s A \left(\frac{T\ std}{Ts\ (avg)}\right) \left(\frac{Ps}{Pstd}\right) \qquad \text{Eq. 2-10}$$

$$\frac{Q_{std}}{MF} = SCFM_{wet}$$

METHOD 3 DRY MOLECULAR WEIGHT OF STACK GAS

$$Md = 0.440\,(\%CO_2) + 0.320\,(\%O_2) + 0.280\,(\%N_2 + \%CO) \qquad \text{Eq. 3-2}$$

Wet Molecular Weight of Stack Gas

$$M_s = Md\,(1-B_{ws}) + 18\,(B_{ws})$$

Meth
#
2
3
4
[redacted]
3
4

METHOD 4 DETERMINATION OF MOISTURE CONTENT IN STACK GASES

(Use when a moisture train is run separately from other pollutant measurements.)

Volume of Water Vapor Condensed

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w RT_{(std)}}{P_{std} M_w} = K_1 (V_f - V_i) \qquad \text{Eq. 4-1}$$

Where $K_1 = 0.04646\ ft^3/ml$ @ 520°R

Volume of Water Vapor Collected in Silica Gel

$$V_{wsg(std)} = \frac{(W_f - W_i)\ R\ Tstd}{P\ std\ M_w\ (453.6\ g/lb)} = K_2(W_f - W_i) \qquad \text{Eq. 4-2}$$

Where $K_2 = 0.04651\ ft^3/g$ @ 520°R

Sample Gas Volume

$$V_{m(std)} = V_m Y \frac{(Pm)\ (Tstd)}{(Pstd)\ (Tm)} = K_3 Y \frac{Vm\ Pm}{Tm}$$

Where $K_3 = 17.38$ °R/in Hg @ 520°R

← T is really 520°R

Moisture Content

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(stg)}}{V_{wc(std)} + V_{wsg(stg)} + V_{m(stg)}}$$

$B_{ws} \times 100 = \%H_2O$ in gas stream

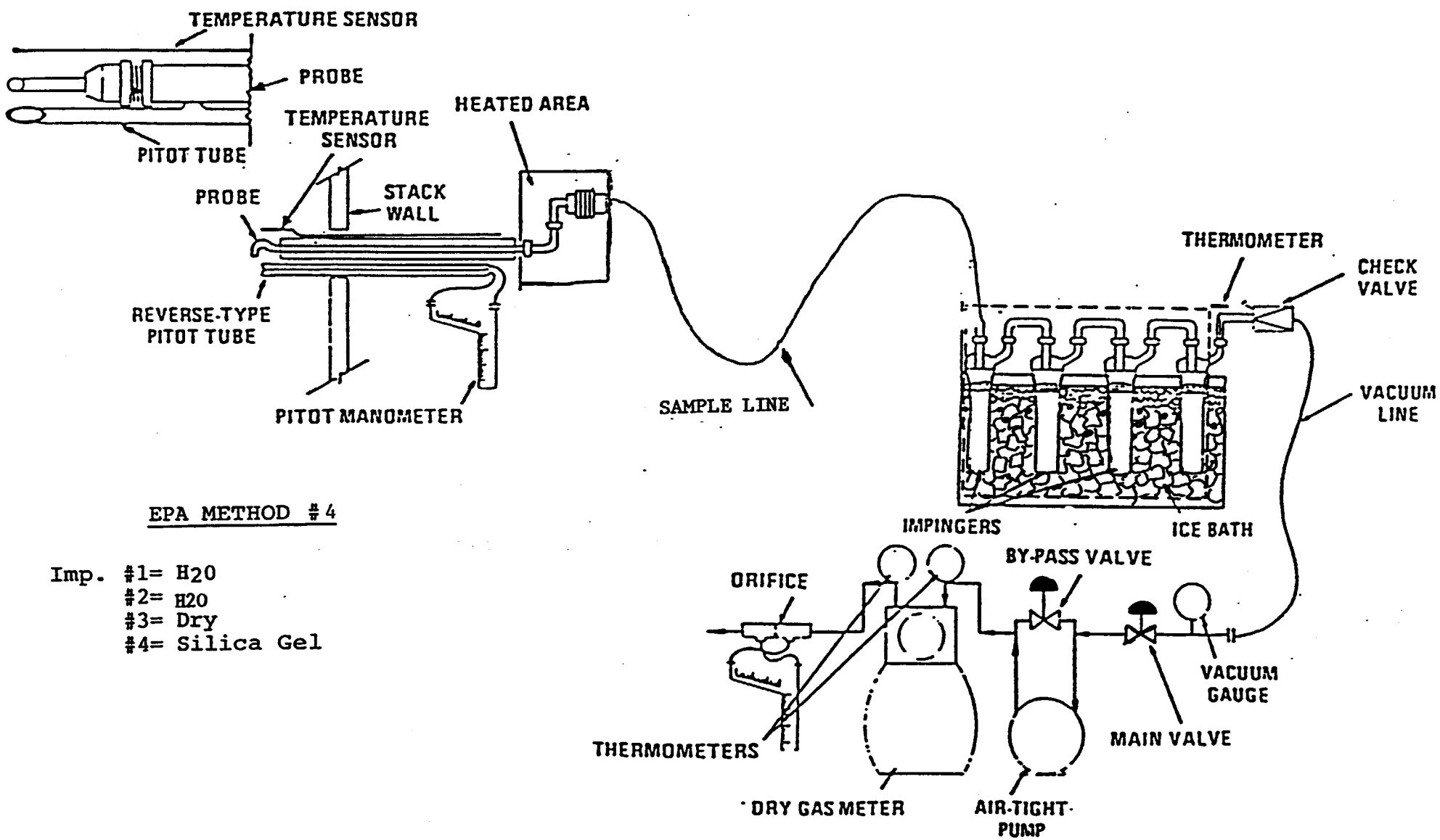
$MF = 1 - B_{ws}$

NOMECLATURE

A	=	Cross-sectional area of stack (ft^2)
A_n	=	Cross-sectional area of nozzle, (ft^2)
B_{ws}	=	Proportion of water vapor, by volume, in the gas stream
C_a	=	Acetone blank residue concentration, (mg/g)
C_p	=	Pitot tube coefficient, dimensionless
C_s	=	Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, (gr/dscf).
C_{SO_2}	=	Concentration of sulfur dioxide, dry basis corrected to standard conditions, (lb/dscf)
$C_{H_2SO_4}$	=	Sulfuric acid (including SO_3) concentration, corrected to standard conditions, (lb/dscf)
ΔH	=	Average pressure differential across the orifice meter, (in H_2O)
K_p	=	Pitot tube constant, $85.49 \frac{ft}{sec} \left[\frac{(lb/lb\text{-}mole)(in\ Hg)}{(°R)(in\ H_2O)}\right]^{\frac{1}{2}}$
L_p	=	Leakage rate observed during the post-test leak check, (cfm)
L_a	=	Maximum aceptable leakage rate, (0.02 cfm or 4% of average sampling rate, whichever is less)
L_i	=	Individual leakage rate observed during the leak check conducted prior to the "i^{th}" component change, (cfm)
m_a	=	Mass of residue of acetone after evaporation, mg.
M_d	=	Molecular weight of stack gas, dry basis, (lb/lb-mole)
m_n	=	Total weight of particulate matter collected, mg.
M_s	=	Molecular weight of stack gas, wet basis, (lb/lb-mole)
M_w	=	Molecular weight of water, 18 lb/lb-mole
N	=	Normality of barium perchlorate titrant, (milliequivalents/ml)
Δp	=	Velocity head of stack gas, (in H_2O)
P_{bar}	=	Barometric pressure at measurement site (in Hg)
P_g	=	Stack static pressure, (in Hg)
P_m	=	Absolute pressure at the dry gas meter
P_s	=	Absolute stack gas pressure, (in Hg)
$P_{std)}$	=	Standard absolute pressure, 29.92 in Hg
Q_{std}	=	Dry volumetric stack gas flow rate, standard conditions, (dscfm)
R	=	Ideal gas constant, 21.85 (in Hg) (ft^3)/(lb-mole)(°R)
t_s	=	Stack temperature, (°F)
T_m	=	Absolute temperature at meter, (°R)
T_{std}	=	Standard absolute temperature, (520°R)

T_s	=	Absolute stack temperature, (460° + t_s)
V_a	=	Volume of sample aliquot titrated, (ml)
V_{ab}	=	Volume of acetone blank, ml
V_m	=	Dry gas volume measured by dry gas meter, (dcf)
$V_{m(std)}$	=	Dry gas volume measured by dry gas meter, corrected to standard conditions, (dscf)
$V_{wc(std)}$	=	Volume of water vapor condensed corrected to standard conditions, (scf)
$V_{wsg(std)}$	=	Volume of water vapor collected in silica gel corrected to standard conditions (scf)
V_{lc}	=	Volume of water vapor condensed in impingers and silica gel, (ml)
V_f	=	Final volume of condensed water, ml
V_i	=	Initial volume of condensed water, ml
v_s	=	Average stack gas velocity, (ft/sec)
V_{soln}	=	Total volume of solution in which the sulfur dioxide sample is contained (ml)
V_t	=	Volume of barium perchlorate titrant used for the sample, (ml)
V_{tb}	=	Volume of barium perchlorate titrant used for the blank, (ml)
W_f	=	Final weight of silica gel or silica gel plus impinger, (g)
W_i	=	Initial weight of silica gel or silica gel plus impinger, (g)
Y	=	Dry gas meter calibration factor
ρ_w	=	Density of water, (0.002202 lb/ml @ 60°F)
ρ_a	=	Density of acetone, (g/ml)(see bottle label)
MF	=	Moisture factor
$\%CO_2$	=	Percent CO_2 by volume (dry basis)
$\%O_2$	=	Percent O_2 by volume (dry basis)
%CO	=	Percent CO by volume (dry basis)
$\%N_2$	=	Percent N_2 by volume (dry basis)

0.264	=	Ratio of O_2 to N_2 in air v/v
0.280	=	Molecular weight of N_2 or CO, divided by 100
0.320	=	Molecular weight of O_2, divided by 100
0.440	=	Molecular weight of CO_2, divided by 100
60	=	Conversion factor, (sec/min)
18.0	=	Molecular weight of water, (lb/lb-mole)
32.03	=	Equivalent weight of sulfur dioxide
0	=	Total sampling time (min)
O_i	=	Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, (min)
O_1	=	Sampling time interval, from the run beginning until first component change, (min)
O_p	=	Sampling time interval, from the final (n^{th}) component change until the end of the sampling run, (min)



EPA METHOD #4

Imp. #1= H_2O
#2= H_2O
#3= Dry
#4= Silica Gel