ATTACHMENT 3

Battelle
Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
Richland, Washington 99352
Telephone (509) 376-8552

September 6, 1991

Mr. K. Steven West
NRR/PMSB
Mailstop 12 H26
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: L-1866, Task 91-03, "Technical Assistance in the Support of the Determination of Particulate Sample Line-Loss at Browns Ferry, Unit 2"
NRC TAC:80018

Dear Mr. West:

This letter report constitutes the final report for Task Assignment 91-03. The objective of this task is to assist the NRC in assessing the adequacy of various systems for sampling particulates at Browns Ferry, Unit 2. Specifically, this task looked at the air sampling systems for the reactor building, turbine building and refuel floor ventilation exhausts.

BACKGROUND

A region II inspection of the Browns Ferry Nuclear Plant identified sample lines entering the constant air monitors of the reactor building, turbine building and refuel floor ventilation exhausts as having several new right angle bends prior to entering the sample collectors. These configurations raised questions as to whether the sample lines met the criteria of Appendix B of ANSI N13.1-1969, "Particle Deposition in sample Lines, Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities."

CONCLUSIONS

The air sample transport tubes installed by the licensee and furnished by the CAM vendor would appear to be adequate if one accepts the licensee's proposition that particle sizes under sampler operating conditions will remain no larger than a couple of microns. If the airborne particles include substantial mass on particles larger than a few microns, then the sampler transport tubing would significantly hinder sample delivery. The licensee has stated that fuel integrity is excellent and that maintenance work in the areas served by these ventilation systems is conducted in temporary enclosures with independent HEPA filter systems. The licensee also stated that attempts to

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collect particle size data have been frustrated by the low levels of activity. Therefore, the licensee's particle size assumption seems plausible, but remains unconfirmed.

It was further concluded that there was no data to rationalize the use of single nozzle sampling probes in the large ducts; however, the probes are scheduled for replacement with improved designs shortly. Suggestions for validating the performance of the new probes were given.

DISCUSSION

The details of this assessment will be discussed in three parts: Sample Transport Tubing; Sample Extraction Probe; and Eberline Model 250 CAM.

Sample Transport Tubing

The transport tubing is the part of the sampling system piping that conveys the sampled particles from the probe to the collection filter. Obtaining adequate information for this assessment required a plant trip to personally inspect and measure the system components.

Tables 1, 2, and 3 list the description of each tubing segment of each air sampler in order from the tip of the probe nozzle to the CAM filter holder. Figures 1 through 4 are simplified sketches of the systems. Sources of information included field observations and TVA Browns Ferry Special Tests ST-8701 (Mims 1987) and ST-8815 and Drawings: 47W600-80 for probe details; W1073-117 for details adjacent to the CAM; and 47W928 Sheets 1 through 5 for the elevations. Precise information on the wall thicknesses of the flexible tubes and the tubes in the CAM was lacking so values were assumed. The sags in the flexible tubes were considered of minor importance and are ignored. A 2-cm radius for the elbows was assumed (although the value is unnecessary for most models of bend losses) to subtract from the corner-to-corner length in calculating tube runs. Fittings, valves, and water traps were assumed to have the same inside diameter as the connecting tubes. Models for particle losses due to brief abrupt diameter changes are not available anyway.

Tables 4, 5 and 6 summarize the piping runs for each sampler to make model input simpler. The subtotal length of similar tube runs is given. Similar bends are grouped together. The total number of bends and the total run length of each group of bends is given. The total length of the entire sample transport route is estimated. Curths (1991) used longer tube runs and fewer bends in his analysis as shown at the end of each table.

Table 7 lists key operating parameters for each sampling system. References used for the data include TVA Browns Ferry Technical Instruction TI-15 Revision 6 (Nix 1991) and field observations. The sampler flows are based on field observations at the CAM which reads in mass units (scfm): 0.77, 1.77, 1.55 scfm for the turbine building, refuel floor and reactor building samplers

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respectively. Actual volumetric flow at the nozzle will vary in proportion to the absolute air temperature. The air temperature in the ducts probably ranges from 70°F to 110°F, so the volumetric flow at the nozzle could be about (570/530=) 1.08 times higher than the reading at the assumed maximum temperature. The data for air flow in the ducts were assumed to be in terms of actual volumetric flow. Duct flows at low fan speed are from TI-15 page 26. At high fan speed, duct flows are from TI-15, page 17, the column for actual measurements.

Table 8 shows the estimated fractional particle penetration through each sampler as a function of particle aerodynamic diameter (unity density spheres) using the model developed by Wong, et. al. (1991)[1]. The results are for particles of single size. Mixtures of sizes can also be run if desired. The conditions modelled were those listed in Table 7 for the low duct flow at 70°F. The other conditions can also be run if desired. At higher temperature, the disparity between intake and duct air velocity would be larger yielding worse penetration values. At higher duct flow, the disparity is reduced, yielding improved penetration.

The air sample transport tubes would appear to be adequate if one accepts the licensee's proposition that particle sizes under sampler operating conditions will remain no larger than a couple of microns. If the airborne particle included substantial mass on particles larger than a few microns, then the sampler transport tubing would significantly hinder sample delivery. The licensee has stated that fuel integrity is excellent and that maintenance work in the parts of the plant served by these ventilation systems is conducted in temporary enclosures with independent HEPA filter systems. They have also stated that attempts to collect particle size data have been frustrated by the low levels of activity.

Sample Extraction Probe

The probe locations, although not in keeping with ANSI N13.1 recommendations, are about as good as available with the existing ductwork. There is no particle concentration mapping data in the sampled cross sections of the ducts to rationalize the use of a single nozzle probe instead of several nozzles across the duct cross section. Perhaps with the small expected particle size, the particles are well mixed in the air flow. Generally, the probes are located too near a change in a direction flow. If contaminant comes mostly from one of the feeder ducts in the Reactor Building duct for example, it may not be well mixed with the bulk air flow by the time it reaches the sampling nozzle plane. This is a common failing of air sampling systems. Because particle

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[1] Wong F.S., N.K. Anand and A.R. McFarland. April 1991. Software Program for Characterizing Aerosol Penetration Through Transport Systems. NRC Contract Grant NRC-04-89-353 (monitored by Stephen A. McGuire), Texas A&M University.

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mapping data cannot be obtained and because the probe will be replaced with a multi-nozzle probe, further consideration is not given to this topic. It is suggested that the licensee conduct contaminant mapping when probe replacement provides the opportunity.

Eberline Model 250 CAM

The manufacturer did not provide data on particle penetration through their CAM piping. However, that piping has been modified by the licensee and particle penetration was estimated as detailed above. The liberal use of a variety of pipe fittings and size changes would seem to bode ill for particle penetration.

FINAL COMMENTS

The documentation available from the licensee was incomplete and should be updated, especially when the new probe is installed. Their assessment of the system adequacy, while in close agreement with this assessment for small particles, was deficient in terms of the equipment description. The system adequacy owes more to the small presumed size of the contaminant particles than to thoughtful design and implementation practices.

Sincerely,

John A. Glissmeyer

John A. Glissmeyer
Senior Research Engineer
Applied Meteorology
ATMOSPHERIC SCIENCES DEPARTMENT

JAG:rak

Enclosures

cc: Jack Hayes
Brian Thomas

REFERENCED TVA SUBMITTALS

Curths, D. W. January 3, 1991. "Browns Ferry Nuclear Plant (BFN) - Airborne Sample Line Interim Plateout Evaluation - Eberline Continuous Monitors and GE Stack Monitor." In Memorandum to J. W. Sabados, Chemistry Technical Support Supervisor, PMA 1E-BFN, Tennessee Valley Authority, Knoxville, Tennessee.

Mims, D. C. June 24, 1987. "Browns Ferry Nuclear Plant (BFN) - Duct Velocity and Probe Dimensions - Special Test 8701." In Memorandum to Plant Operations Review Committee, Tennessee Valley Authority, Knoxville, Tennessee.

Nix, D. June 27, 1991. "Radioactive Gaseous Effluent Engineering Calculations and Measurements, Procedure 0-TI-15, Rev 6." Browns Ferry Nuclear Plant, Tennessee Valley Authority, Knoxville, Tennessee.

ST-8815 Ventilation Flow Measurements 2

250 CAM Monitoring System Technical Manual, Eberline, Santa Fe, New Mexico.

Browns Ferry Drawings:

47W600-80, Mechanical Instruments and Controls
W1073-117, Powerhouse Unit 2 Mechanical Instruments and Controls
47W928 Sheets 1 - 5, Mechanical Heating and Ventilating Framing Details

Table 1. Reactor Sampler Tubing Details

Segment	Description	References (F.O. denotes field observation)	Material	Inside Diameter cm	Length or Radius cm
1	Nozzle Vertical	ST 8701 47W600-80	SST	0.673	9
2	Nozzle Vertical	""	1" OD SST 0.049 wall	2.29	14
3	Nozzle 90° Bend	""	""	""	30
4	Nozzle Horizontal	""	""	""	60
5	Horizontal	F.O.	""	""	25
6	90° Bend	""	""	""	30
7	Horizontal	""	""	""	28
8	90° Bend	""	""	""	30
9	Horizontal	""	""	""	99
10	90° Bend	""	""	""	30
11	Horizontal	""	""	""	168
12	90° Bend	""	""	""	30
13	Horizontal	""	""	""	325
14	Horizontal	W1073-117	""	""	69
15	90° Bend	F.O.	""	""	10
16	Horizontal	""	"" & Water Trap	""	55
17	3° to Horizontal	"" & W1073-117	1" SST Flex Tube & Fittings	""	97
18	90° Elbow	W1073-117	Elbow	""	2
19	Horizontal	""	1" OD SST Valve & Fittings	""	53
20	Horizontal in CAM	F.O. & Vendor Diagram	1" OD SST Valve & Fittings	""	38
21	Horizontal in CAM	""	½" OD SST 0.049 wall & Fittings	1.02	28

Table 2. Refuel Sampler Tubing Details

Segment	Description	References (F.D. denotes field observation)	Material	Inside Diameter cm	Length or Radius cm
1	Nozzle Vertical	ST 8701 47W600-80	SST	0.80	9
2	Nozzle Vertical	""	1" OD SST 0.049 wall	2.29	11
3	Nozzle 90° Bend	""	""	""	30
4	Nozzle Horizontal	""	""	""	46
5	Horizontal	F.D.	""	""	30
6	90° Bend	""	""	""	30
7	Vertical	F.D. & 47W928-5	""	""	618
8	90° Bend	F.D.	""	""	30
9	Horizontal	""	""	""	955
10	90° Bend	""	""	""	30
11	Vertical	""	""	""	659
12	90° Bend	""	""	""	30
13	Horizontal	""	""	""	152
14	Horizontal	W1073-117	""	""	75
15	90° Elbow	""	""	""	2
16	Horizontal	""	"" & Water Trap	""	37
17	90° Elbow	""	1" Fitting	""	2
18	25° to Horizontal	F.D.	1" SST Flex Tube & Fittings	""	110
19	90° Elbow	""	Elbow	""	2
20	Horizontal	""	1" OD SST Valve & Fittings	""	59
21	Horizontal in CAM	F.D. & Vendor Diagram	1" OD SST Valve & Fittings	""	23
22	Horizontal in CAM	""	½" OD SST 0.049 wall & Fittings	1.02	43

Table 3. Turbine Sampler Tubing Details

Segment	Description	References (F.O. denotes field observation)	Material	Inside Diameter cm	Length or Radius cm
1	Nozzle Vertical	ST 8701 47W600-80	SST	0.508	9
2	Nozzle Vertical	""	1" OD SST 0.049 wall	2.29	13
3	Nozzle 90° Bend	""	""	""	30
4	Nozzle Horizontal	""	""	""	46
5	Horizontal	F.O.	""	""	30
6	90° Bend	""	""	""	30
7	Vertical	""	""	""	618
8	90° Bend	""	""	""	30
9	Horizontal	""	""	""	315
10	90° Bend	""	""	""	30
11	Vertical	""	""	""	659
12	90° Bend	""	""	""	30
13	90° Bend	""	""	""	30
14	Horizontal	""	""	""	152
15	Horizontal	W1073-117	""	""	82
16	90° Elbow	""	1" Fitting	""	2
17	Horizontal	""	1" OD SST & Water Trap	""	62
18	90° Elbow	""	1" Fitting	""	2
19	31° to Horizontal	F.O.	1" SST Flex Tube & Fittings	""	98
20	90° Elbow	W1073-117	Elbow	""	2
21	Horizontal	""	1" OD SST Valve & Fittings	""	37
22	Horizontal in CAM	F.O. & Vendor Diagram	1" OD SST Valve & Fittings	""	18
23	Horizontal in CAM	""	½" OD SST 0.049 wall & Fittings	1.02	48

Table 4. Reactor Sampler Tubing Consolidated

Type	Segments	ID, cm	Length, cm	Radius, cm
Vertical	1	0.673	9	
Vertical	2	2.29	14	
Horizontal	4, 5, 7, 9, 11, 13, 14, 16, 19, 20	2.29	920	
Horizontal	21	1.02	28	
3° to Horizontal	17	2.29	97	
90°Bend	3, 6, 8, 10, 12	2.29	236	30
90°Bend	15	2.29	16	10
90°Bend	18	2.29	3	2
Approximate Total Length, cm			1,323	
Curths (1991) used 1616 cm horizontal, 5-90° bends, 2-45° bends, 2.29 cm ID				

Table 5. Refuel Sampler Tubing Consolidated

Type	Segments	ID, cm	Length, cm	Radius, cm
Vertical	1	0.80	9	
Vertical	2, 7, 11	2.29	1288	
Horizontal	4, 5, 9, 13, 14, 16, 20, 21	2.29	1377	
Horizontal	22	1.02	43	
25° to Horizontal	18	2.29	110	
90°Bend	3, 6, 8, 10, 12	2.29	236	30
90°Elbow	15, 17, 19	2.29	9	2
Approximate Total Length, cm			3,072	
Curths (1991) used 2012 cm horizontal, 1585 cm vertical, 6-90° bends, 1-45° bend, 2.29 cm ID				

Table 6. Turbine Sampler Tubing Consolidated

Type	Segments	ID, cm	Length, cm	Radius, cm
Vertical	1	0.508	9	
Vertical	2, 7, 11	2.29	1290	
Horizontal	4, 5, 9, 14, 15, 17, 21, 22	2.29	742	
Horizontal	23	1.02	48	
31° to Horizontal	19	2.29	98	
90°Bend	3, 6, 8, 10, 12, 13	2.29	283	30
90°Elbow	16, 18, 20	2.29	9	2
Approximate Total Length, cm			2,479	
Curths (1991) used 1372 cm horizontal, 1585 cm vertical, 7-90° bends, 1-45° bends				

Table 7. Sampler and Duct Flow Parameters

Parameter	Reactor	Refuel	Turbine
Sampler flow, slpm	43.9	50.1	21.8
Nozzle ID, cm	0.6731	0.8001	0.5080
Nozzle intake velocity, m/s	20.56	16.61	17.33
Duct cross section m^2	3.9019	2.3226	4.6451
Low flow m^3/s	20.469	9.3458	22.915
Low velocity m/s	5.25	4.02	4.93
High flow m^3/s	43.8	19.7	44.2
High velocity m/s	11.23	8.48	9.52

Table 8. Fractional Penetration of Particles Through Each Sampler Line as a Function of Particle Aerodynamic Diameter (microns)

REACTOR					
Penetration for Particle Aerodynamic Diameter, microns					
Tube ID	1	2	5	10	20
.673 cm	0.9960	0.9815	0.7583	0.4659	0.2883
2.29 cm	0.9803	0.9303	0.6509	0.1839	0.0011
1.02 cm	0.9998	0.9992	0.9856	0.7259	0.2466
Total	0.9762	0.9124	0.4865	0.0622	0.0001

REFUEL					
Penetration for Particle Aerodynamic Diameter, microns					
Tube ID	1	2	5	10	20
.673 cm	0.9975	0.9890	0.8638	0.5264	0.3612
2.29 cm	0.9734	0.9104	0.5744	0.1105	0.0001
1.02 cm	0.9997	0.9987	0.9653	0.5246	0.1785
Total	0.9707	0.8992	0.4790	0.0305	0.0000

TURBINE					
Penetration for Aerodynamic Particle Diameter, microns					
Tube ID	1	2	5	10	20
.673 cm	0.9952	0.9785	0.7314	0.2895	0.1987
2.29 cm	0.9752	0.9162	0.5969	0.1313	0.0003
1.02 cm	0.9995	0.9982	0.9885	0.9408	0.4945
Total	0.9700	0.8949	0.4316	0.0358	0.0000

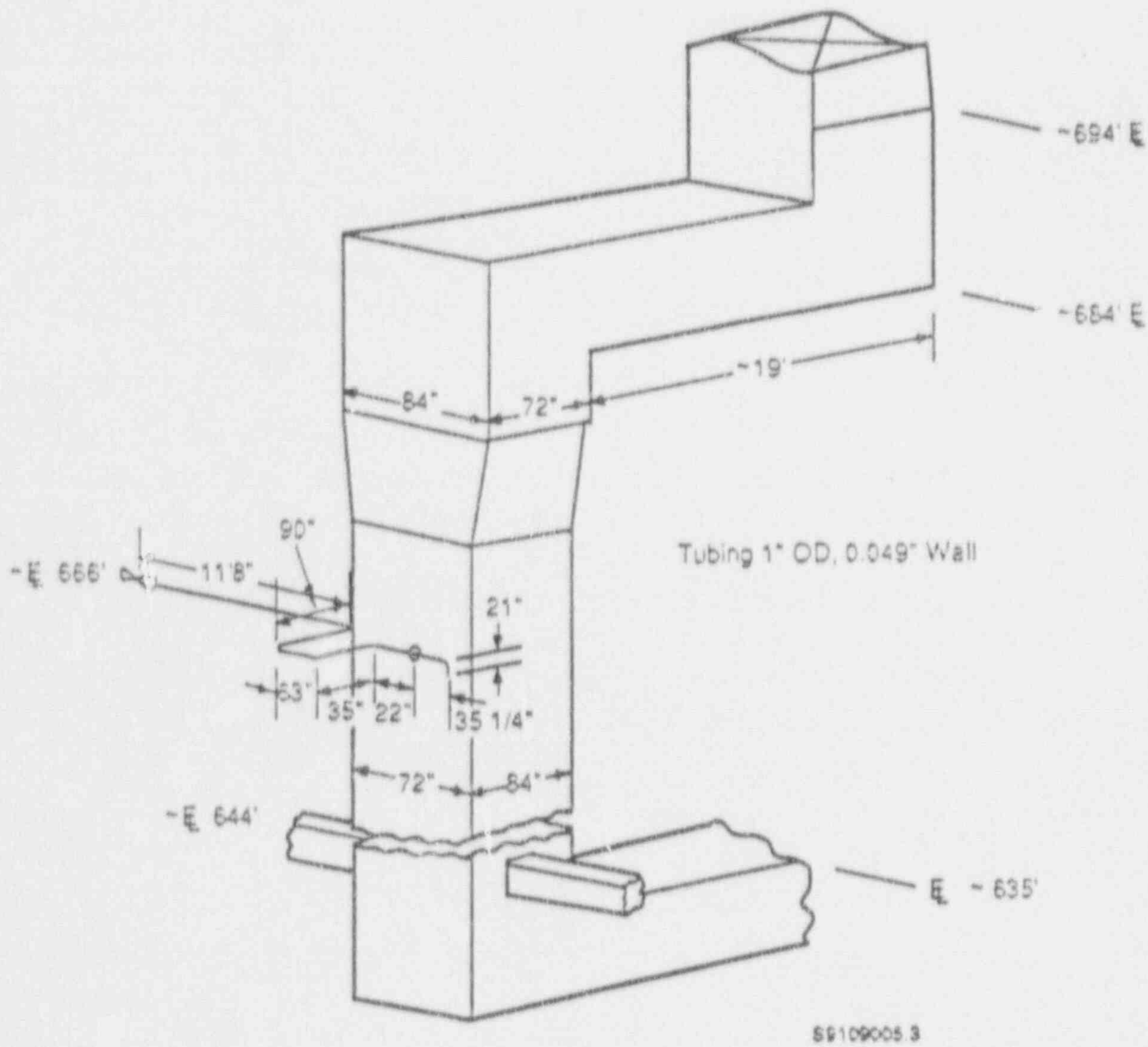

Figure 1. Sketch of Reactor Duct Air Sampling Tubing

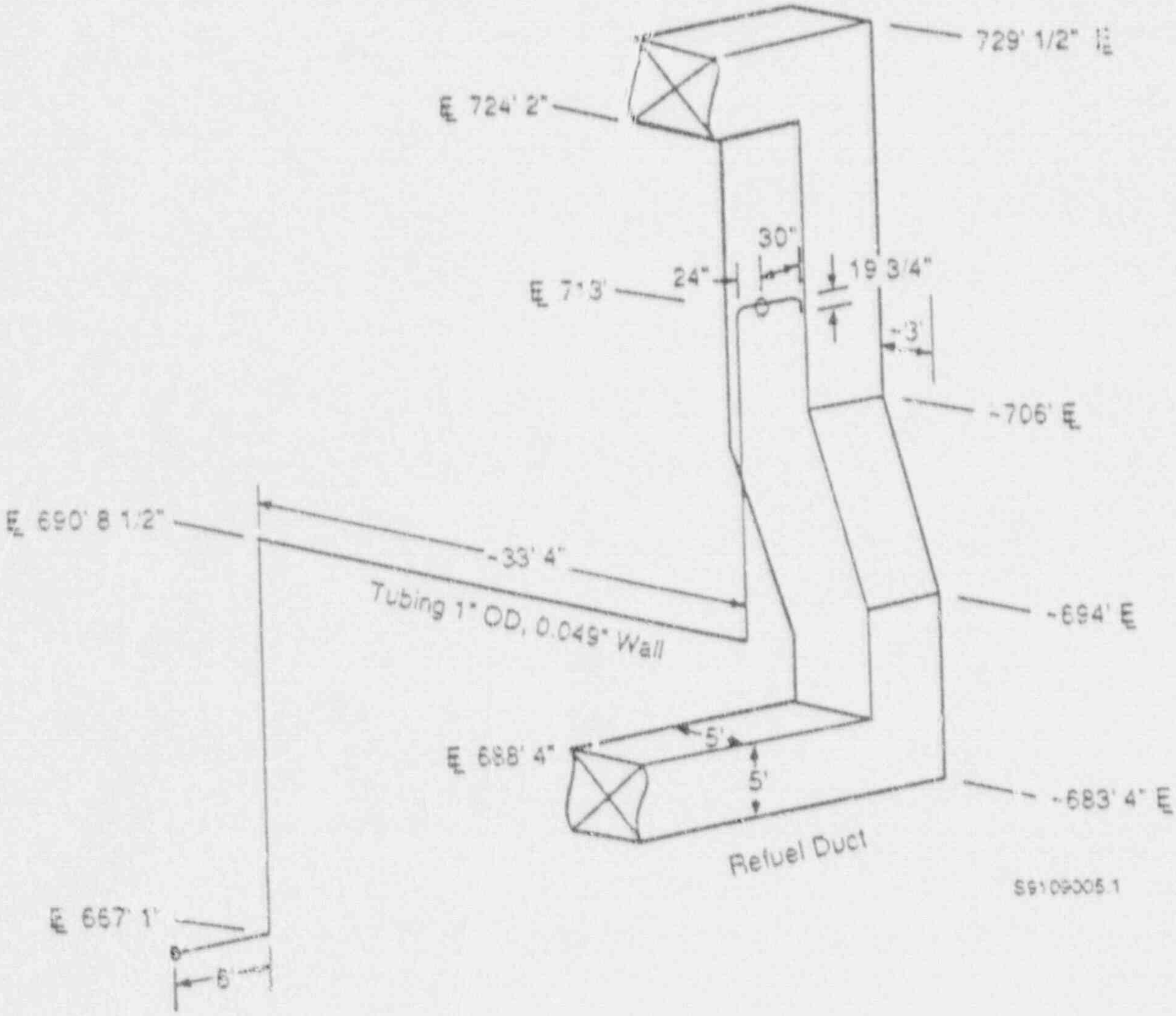

Figure 2. Sketch of Pefuel Duct Air Sampling Tubing

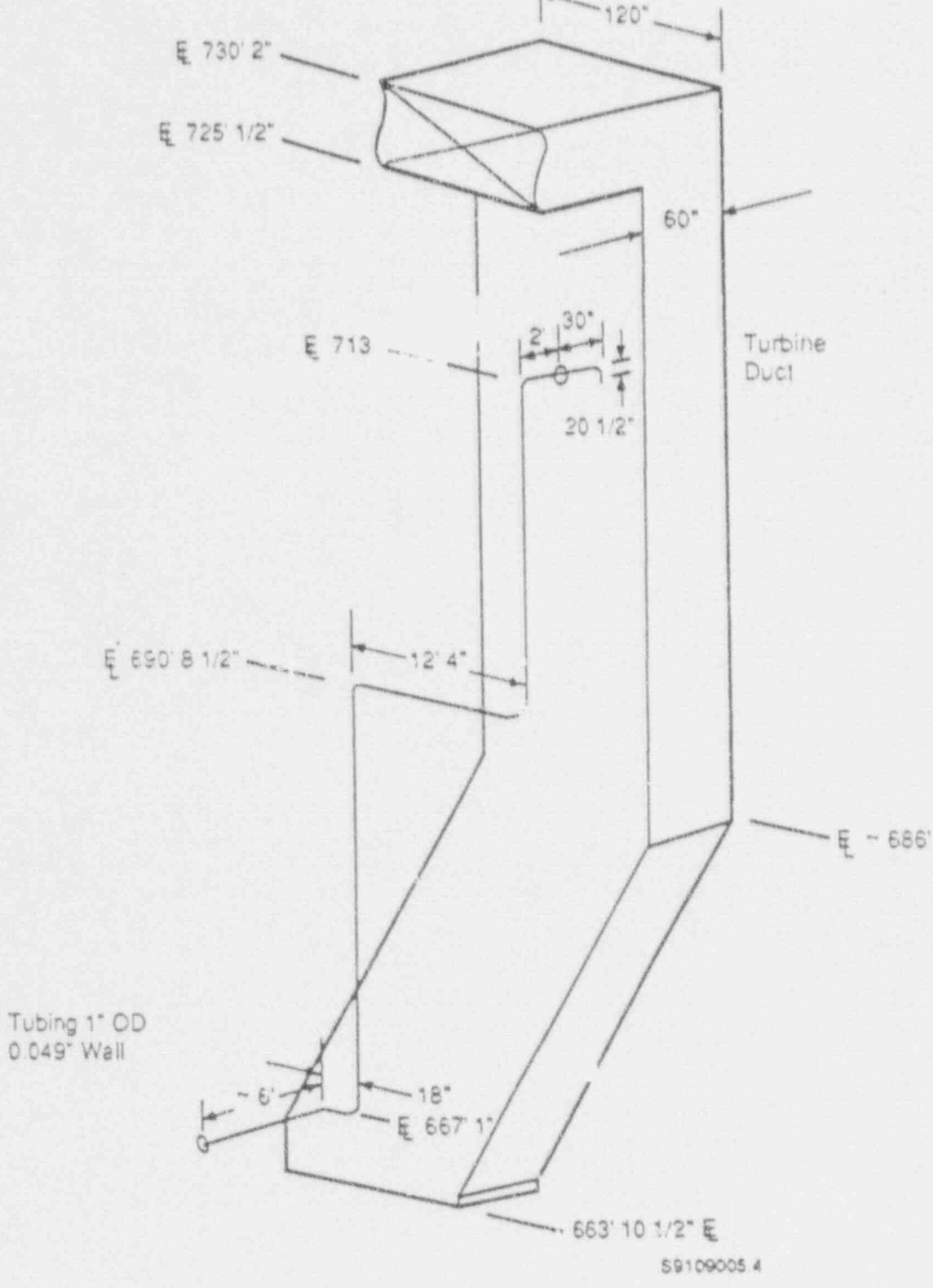

Figure 3. Sketch of Turbine Duct Air Sampling Tubing

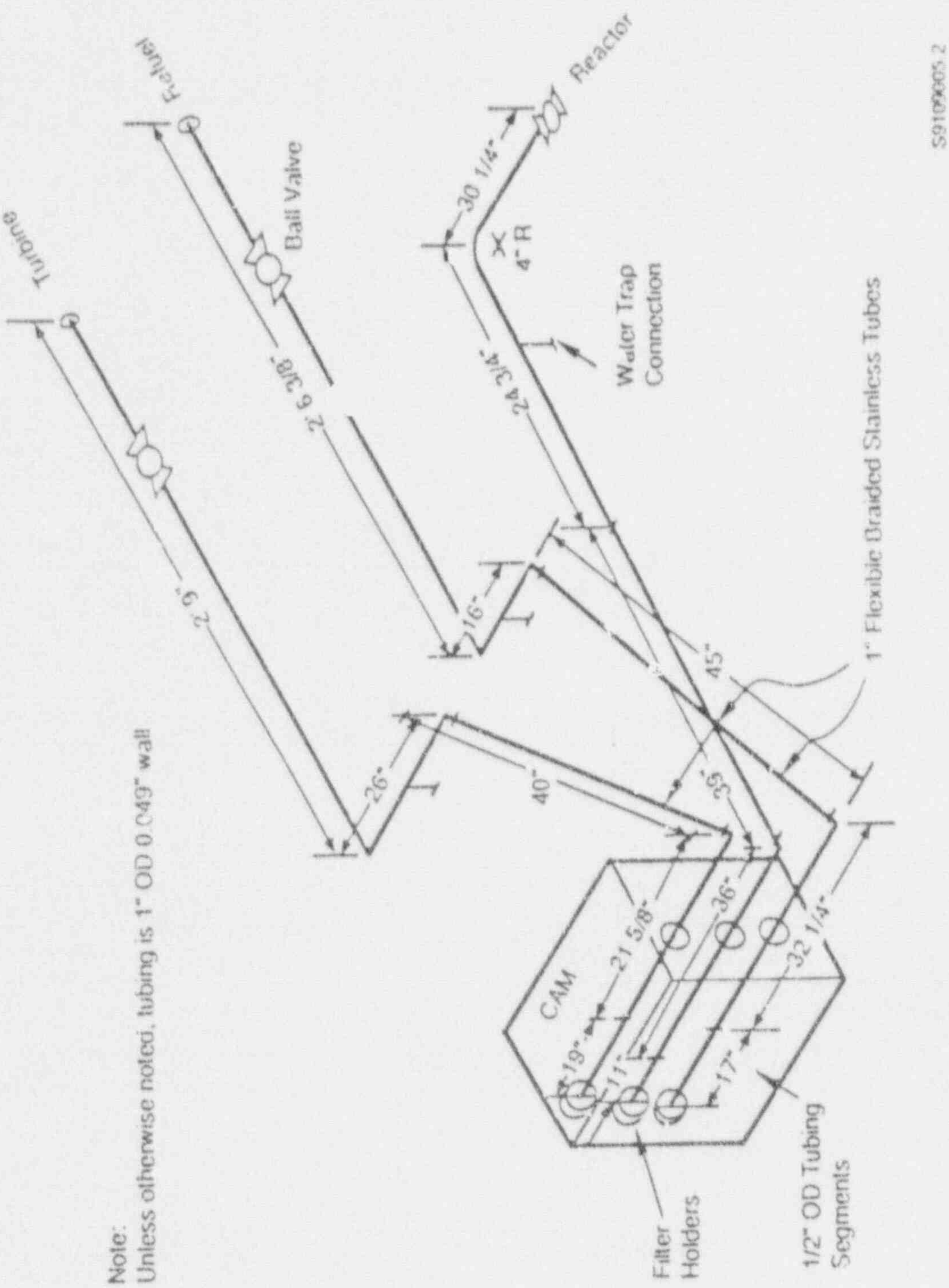

Figure 4. Sketch of Air Sampling Tubing Runs Near The CAM