United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

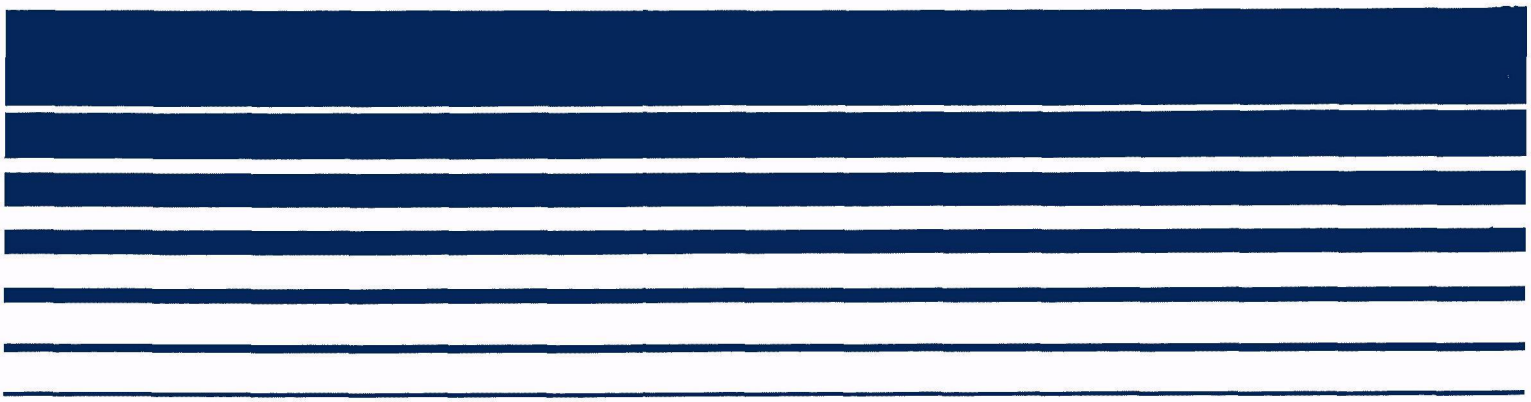
EMB Report 79-DRY-7
August 1979

Air

EPA

Material Balance Test Perchloroethylene Refrigerated Closed System-Coin Operated Dry Cleaners

Emission Test Report Plaza Cleaners Northville, New Jersey



MATERIAL BALANCE TEST PERCHLOROETHYLENE REFRIGERATED CLOSED SYSTEM

AT

PLAZA CLEANERS

NORTHVALE, NEW JERSEY

By

Robert F. Jongleux

TRW
ENVIRONMENTAL ENGINEERING DIVISION

P.O. Box 13000
Research Triangle Park, North Carolina 27709

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Emission Measurement Branch
Research Triangle Park, NC 27711

April 1980

SN. 95643.000
Contract No. 68-02-2812
Task Assignment #44

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES — Page

FIGURES

1. INTRODUCTION

During the week of June 4th, 1979, a two member test crew conducted a material balance test at Plaza Cleaners, Northvale, New Jersey. The material balance test was conducted on a commercial perchloroethylene machine and refrigerated condenser manufactured by Neil and Spencer Limited and distributed by Spencer America, Inc., of St. Louis, Missouri. The purpose of the testing was to establish the effectiveness of controlling perchloroethylene emissions by application of a refrigerated condenser reclaimer. This location had installed one of the few operational units of this type. The test request called for a material balance with process parameter recordings, 12 integrated bag samples at the inlet and outlet from the refrigerated condenser, flow and temperature measurements, and vapor leak detection.

Section 2.0 summarizes the testing results. Section 3.0 details equipment specification of the process investigated. Section 4.0 discusses the difficulties encountered pursuant to the testing objectives. Appendix A contains field data sheets utilized during the week of testing. Appendix B details the testing procedures utilized for testing.

2.0 SUMMARY OF RESULTS

Table 2.1 highlights the information collected for the purpose of a mass balance. The net usage of solvent for the duration of the test was 10.2 liters (2.7 gallons). The plant throughput was 427 kilograms (943 pounds). Based on these figures, the mass loss rate from the drycleaning unit was 3.85 pounds of perchloroethylene per hundred pounds of clothes cleaned.[1] The calculated mileage was 18162 pounds of clothes per 52-gallon drum of solvent. It should be understood that these figures are approximations based upon a limited input of data. The accuracy of this data is discussed more completely in Section 4.0 of this report.

Table 2.2 summarizes the analytical data collected from the integrated bag samples. The average removal efficiency for twelve (12) integrated bag sampling runs was 14.1%. This represents a removal efficiency, which was lower than the anticipated results.

Because the results were lower than anticipated, a theoretical estimation of removal efficiency was calculated in Section 4.0 (Discussion) based on a multiple pass system. Based on the information derived from the limited mass balance study, the calculated solvent mileage (18162) and mass loss rate (3.85) figures indicate a good overall performance for a commercial drycleaning machine at this location.

Based on this limited testing information and field observation, an application of a single pass refrigerated condenser reclaimer (similar to the Spencer Unit tested) to a coin-operated perchloroethylene drycleaning machine to control emissions would be inappropriate at this time. Application may be applicable upon redesign of the resolver, which would permit the resolver reclaimer system to attain an optional removal efficiency approaching the levels indicated by the theoretical estimate based on a multiple pass system (+99%).

[1] Weight of clothes measured as dirty clothes before cleaning.

Tables 2.3 and 2.4 summarizes velocity and temperature measurements, respectively. The velocity measurements tabulated in the appendix and summarized in Table 2.3 were consistent during the testing. The velocity averaged 6.5 meters per second (21.2 fps) which calculates to an average flowrate of 7.1 cubic meters per minute (250 cfm). Table 2.4 lists the temperature profile of the resolver for two sampling runs. The profile shows an approximate temperature drop of 15°C (59°F) at the start of the dry-cleaning machine-to-resolver venting cycle. This venting cycle is pre-programmed by means of an operations card and was a consistent five minutes in duration.

The only process parameter that varied from one drycleaning cycle to another was the weight of the clothes processed per load. Table 2.5 is a summary of the plant throughput data during the test period. The operator measured the weight of every load and logged this value on a tabulation record which is contained in the appendix of this report. (Table A.1)

Vapor leak detection was undertaken during the test program on a limited scale. Prior testing had indicated the effectiveness of a limited number of inexpensive leak detection monitors.[2] Based on this information, an HLD-440 manufactured by TIF Manufacturing was used to screen the drycleaning machine, the resolver, and associated ducting. The HLD-440 is a portable, battery-operated electronic halogen gas detector. The complete manufacturer's operating instructions are included in Appendix B for reference. The halogen leak detector provides a ticking signal, which accelerated in frequency as a vapor leak was encountered. The HLD-440 instrument indicated four significant solvent vapor leaks from the drycleaning machine. The vapor leaks were located at the muck drain valve, the water separator lid, the valve activated during the aeration cycle (which allows venting of the drycleaning machine to the resolver), and a liquid solvent leak located at the base of the dryer drum. Concentration measurements were not determined on any of the vapor leaks identified by the screening with the HLD-440 because such a determination was beyond the scope of task assignment. The sensitivity as a mass rate emission of the HLD-440 was specified by the manufacturer as one-half ounce per year.[3]

---

[2]Source Test Report "Kleen Kornor, Courtland, New York" - EMB Project #79-DRI-6, Dec. 1979.

[3]See Appendix B - HLD-440 - Operating Instructions.

		MONDAY		TUESDAY		WEDNESDAY		THURSDAY		TOTAL	
		(ml)	(oz)	(ml)	(oz)	(ml)	(oz)	(ml)	(oz)	(ml)	(oz)
LIQUID ADDITIONS	SOAP	237	8	710	24	710	24	946	32	2603	88
	WATER	237	8	237	8	237	8	473	16	1184	40
	SIZING	---	---	473	16	473	16	473	16	1419	48
	DEODORANT	---	---	---	---	118	4	---	---	118	4
										5324	80
										5.3 liters (1.4 gal.)	
SOLIDS ADDITIONS	CARBON	---	---	---	---	---	1/2 lb.	---	---	- - -	
	DIATOMACEOUS EARTH	---	---	---	---	---	4 lbs.	---	---	4.5 lbs.	
LOSS[4]											
		Gallons(1)						Gallons (2)			
LIQUID LEVEL MEASUREMENTS	BASE TANK	50.0						60.0			
	DISTILLATION TANK	23.9						12.8			
	SUADE TANK	25.1						24.9			
	TANK FULL	X						X			
										4.9 liters (13 gal.)	
NET USEAGE										10.2 liters (2.7 gal.)	
MILEAGE										18162[3]	

1) INITIAL MEASUREMENT - MACHINE CIRCULATING
2) FINAL MEASUREMENT - MACHINE CIRCULATING
3) CALCULATED FROM PLANT THROUGHPUT - UNITS ARE POUNDS OF CLOTHES CLEANED PER 52 GALLON DRUM OF SOLVENT.
4) PERC CONTENT OF MUCK NOT DETERMINED - NOT IN SCOPE OF WORK.

TABLE 2.1 - SUMMARY MASS BALANCE INFORMATION

RUN	CONCENTRATION		REMOVAL EFFICIENCY (1)	INSTRUMENT DRIFT		
	INLET (ppm)	OUTLET (ppm)	(%)	ZERO (2) (%)	STANDARD (3) (%)	TOTAL (2) (%)
1	5650	2350	+58.4	8.0	14.3	22.3
2	17750	15500	+12.7	0.0	26.5	26.5
3	13000	13750	-5.8	7.5	15.5	24.0
4	12250	11650	+4.9	5.5	13.0	18.5
5	10000	10250	-2.5	0.0	0.0	0.0
6	5750	4250	+26.1	1.5	10.0	11.5
7	8000	6300	+21.3	1.0	3.0	4.0
8	10000	10250	-2.5	1.0	5.5	6.5
9	9950	6490	+34.8	1.0	15.5	16.5
10	9400	8020	+14.9	2.0	5.5	7.5
11	8150	7550	+7.4	0.5	2.0	2.5
12	9450	9500	-.53	0.5	2.0	2.5
AVERAGE	9946	8822	14.1	2.38	9.36	11.9

(1) BASED ON INTEGRATED BAG SAMPLES OVER HALF OF THE AERATION VENTING CYCLE.
(2) PERCENT DRIFT OF FULL SCALE.
(3) 92 PPM PERCHLOROETHYLENE IN AIR.

TABLE 2.2 SUMMARY ANALYTICAL RESULTS

	INLET				OUTLET			
	VELOCITY		FLOWRATE		VELOCITY		FLOWRATE	
	mps	(fps)	ACCM	(ACFM)	mps	(fps)	ACCM	(ACFM)
RUN #1	6.66	(21.85)	7.08	256.96	6.40	(20.99)	6.97	246.27
RUN # 2	6.69	(21.94)	7.30	258.02	6.70	(21.97)	7.28	257.06
RUN # 3	6.63	(20.77)	6.91	244.24	5.95	(19.52)	6.50	229.50
RUN # 4	6.83	(22.39)	7.45	263.35	6.35	(20.82)	6.93	244.83
AVERAGE	6.70	(21.74)	7.185	(255.64)	6.35	(20.83)	6.92	(244.42)

TABLE 2.3 - SUMMARY - FLOWRATE DATA (RESOLVER)

	TIME	TEMPERATURE ^{o}C
RUN 1	1015:00	34^{o}
	1020:35	13^{o}
	1021:30	14^{o}
	1022:30	15^{o}
	1023:00	16^{o}
	1023:30	18^{o}
	1024:00	18^{o}
	1024:30	19^{o}
	1025:00	20^{o}
RUN 2	1107:00	35^{o}
	1115:46	16^{o}
	1116:30	15^{o}
	1117:30	14^{o}
	1118:00	16^{o}
	1119:15	18^{o}
	1119:30	19^{o}

TABLE 2.4 RESOLVER TEMPERATURE PROFILE-OUTLET

MONDAY			TUESDAY			WEDNESDAY			THURSDAY		
	WEIGHT			WEIGHT			WEIGHT			WEIGHT	
TIME	(kg)	(lbs)	TIME	(kg)	(lbs)	TIME	(kg)	(lbs)	TIME	(kg)	(lbs)
0912	17.2	38	0831	17.21	38	0816	8.6	19	0850	2.5	5.5
0950	16.8	37	(b)0916	15.4	34	0900	17.2	38	0950	17.7	39
(b) 1035	18.1	40	1004	11.3	25	0940	16.8	37	(b)1030	9.5	21
1105	14.9	33(b)	1042	8.6	19	1038	15.9	35	1130	18.1	40
1150	10.9	24	1127	18.1	40	(b)1120	12.2	27	1221	18.1	40
1230	6.8	15	1207	17.7	39	1210	18.1	40	1302	8.6	19
1400	17.7	39	1250	6.8	15	1300	10.0	22	1400	14.1	31
			1329	15.4	34	1340	12.7	28	1500	12.9	28.5
			(s)1405	1.4	3						
DAILY TOTAL-102.4		226		111.9	247		111.5	246		101.5	224.0
WEEKLY TOTAL-										427.3	943.0

b- BATCH LOAD

s - SUADE - SPECIAL LOAD

TABLE 2.5 SUMMARY - PLANT THROUGHPUT

3.0 PROCESS DESCRIPTION

This section details the equipment use in the drycleaning operation at Plaza Cleaners. The perchloroethylene drycleaning process consisted of two pieces of equipment; a commerical dry-to-dry perchloroethylene drycleaning machine and a refrigerated condenser reclaimer. The drycleaning machine had a rated capacity of 30 kg (65 lbs). General purpose drycleaning was processed by the subject machine at a yearly throughput note of 22220 kilograms per year (49036 lbs/yr). The subject machine was the only drycleaning unit at this plant location. The plant was estimated to be five (5) years old, while the drycleaning machine and resolver were six (6) months old at the time of the test period.

The refrigerated-condenser reclaimer, called a resolver by the manufacturer, was designed to serve the 30 kg (65 lb) machine. The resolver at this location was designated as a MAJOR, due to the fact that its refrigerated bed had twice the volume than its sister model, the MINOR.

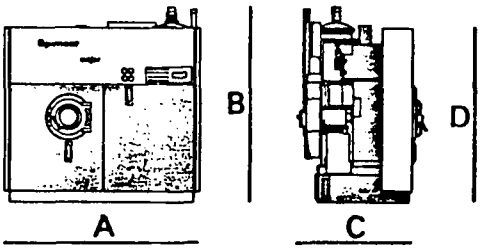
The specifications of the drycleaning machine are listed in Table 3.1 as supplied by the manufacturer. Table 3.2 lists the specifications for the resolver. Figure 3.3 illustrates the layout and configuration of the system. Sampling locations for flue gas, velocity and temperature measurements are indicated. Figures 3.4 and 3.5 are exterior and functional interior diagrams of the control equipment, respectively. All tables and figures utilized in this section were adapted from Spencer America supplied literature.

specification

Cylinder	
dryweight loading (max)	30 kg (65 lb)
diameter	104 cm (41 in)
depth	66 cm (26 in)
volume	561 l (19.8 ft³)
load factor	19 l/kg (3.3 lb/ft³)
wash speed	33 rpm
extract speed	360 rpm
Still	
max distillation rate	364 l/hr (80 imp gall/hr)
Filter	
filtration area	2.66 m² (28.6 ft²)
flow rate	8183 l/hr (1800 imp gall/hr)
Solvent capacities	
tank 1 main	590 l (130 imp gall)
tank 2 distilled	136 l (30 imp gall)
tank 3 treatment	168 l (37 imp gall)
tank 4 still feed	145 l (32 imp gall)

Services	
max steam consumption (based on max output 2½ loads per hour and max distillation rate)	114 kg/hr (250 lb/hr)
max water consumption	1360 l/hr (300 imp gall/hr)
compressed air pressure	6/7 kg/cm² (80/100 lb/in²)
compressed air volume	0.06 m³/min (2 ft³/min)
electric motors (total)	7.3 kW
average electrical consumption	3.3 kW hrs per hr

Dimensions	
A	2.63 m (8 ft 7¼ in)
B	2.62 m (8 ft 7 in)
C	1.63 m (5 ft 4 in)
D	2.33 m (7 ft 8 in)
required ceiling height	3.05 m (10 ft 0 in)
Weights	
empty	3150 kg (6950 lb)
with solvent	4320 kg (9530 lb)
floor loading	1550 kg/m² (320 lb/ft²)
Shipping data	
crate size	2.74 x 1.85 x 2.82 m (9 ft 0 in x 6 ft 1 in x 9 ft 3 in)
packed weight (approx)	3560 kg (3.5 ton)



Neil and Spencer Limited

Leatherhead, Surrey, KT22 7AJ
Telephone Leatherhead 75441
Telex 917010 Spencer Leahead

TABLE 3.1 SPECIFICATIONS - SPENCER DRYCLEANING MACHINE

TABLE 3.2

SPECIFICATIONS- SPENCER RESOLVER

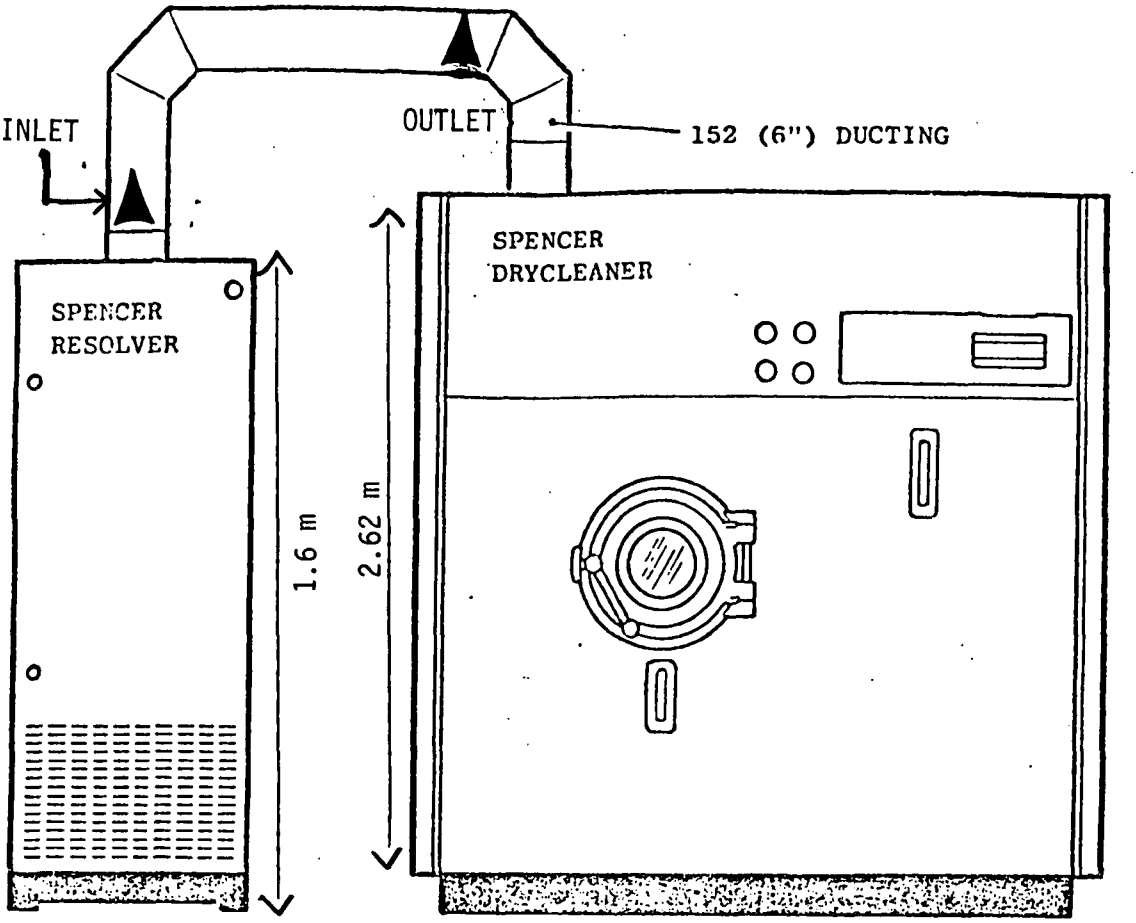
SPENCER AMERICA, INC.
2036 CONGRESSIONAL DRIVE ST. LOUIS, MO 63141 TELEPHONE: 314/569-0421
TELEX: 44-7377
SPENCER STL

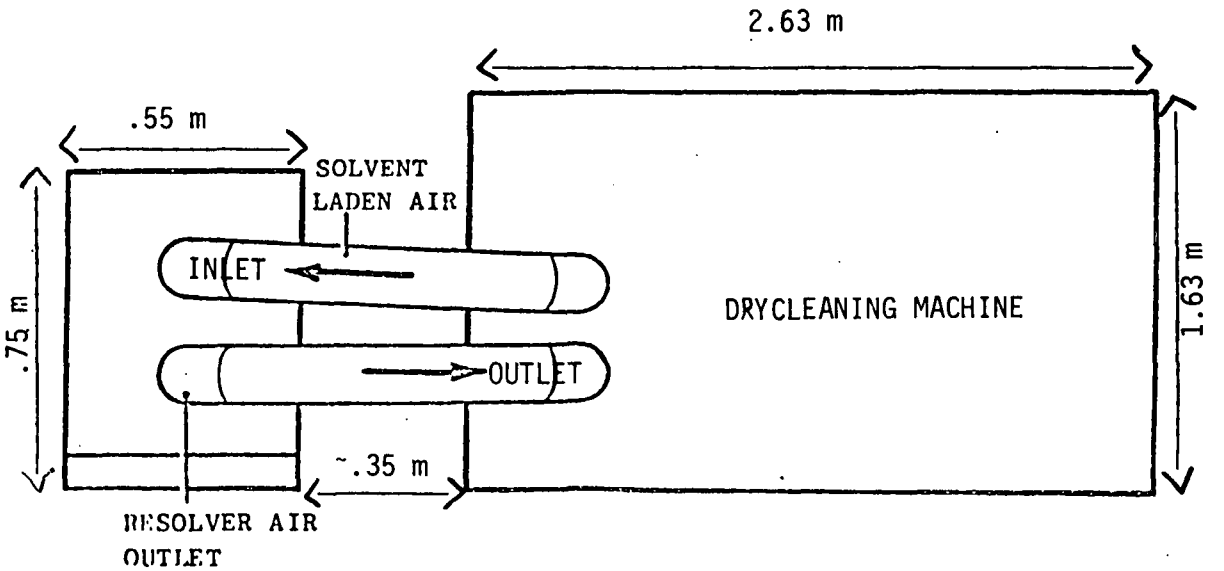
DATA FOR

SPENCER RESOLVER

SPENCER MINOR, JUNIOR AND MAJOR DRYCLEANING MACHINES
(30 lb) (45 lb) (65 lb)

	Minor/Junior	Major
Refrigeration Unit (Air Cooled)	0.55 Kw (0.75 HP)	0.55 Kw (0.75 HP)
REFRIGERATED BED		
Material	Stone Chips	Stone Chips
Coil (12 mm o/dia)	1 each	2 each
Volume of Bed	70 lt (2.5 cu.ft)	140 lt (5 cu.ft)
SEPARATOR		
Maximum Volume of Solvent	10.9 lt (2.9 U.S.gal)	10.9 lt (2.9 U.S.gal
Minimum Volume of Solvent	7.7 lt (2.04 U.S.gal)	7.7 lt (2.04 U.S.gal
VAPOUR CONNECTIONS		
Inlet and Outlet Ports	15.25 cm (6 in.)	15.25 cm (6 in.)
OVERALL DIMENSIONS		
Width	55 cm (21-1/2 in.)	55 cm (21-1/2 in.)
Depth	75 cm (29-1/2 in.)	75 cm (29-1/2 in.)
Height	160 cm (63 in.)	160 cm (63 in.)
WEIGHT		
Overall Weight - Empty	365 kg (800 lb)	430 kg (946 lb)
Overall Weight - Full	390 kg (860 lb)	457 kg (1006 lb)
Floor Loading - Full	0.095 kg/cm^2 (194 lb/ft^2)	0.11 kg/cm^2 (225 lb/ft^2)



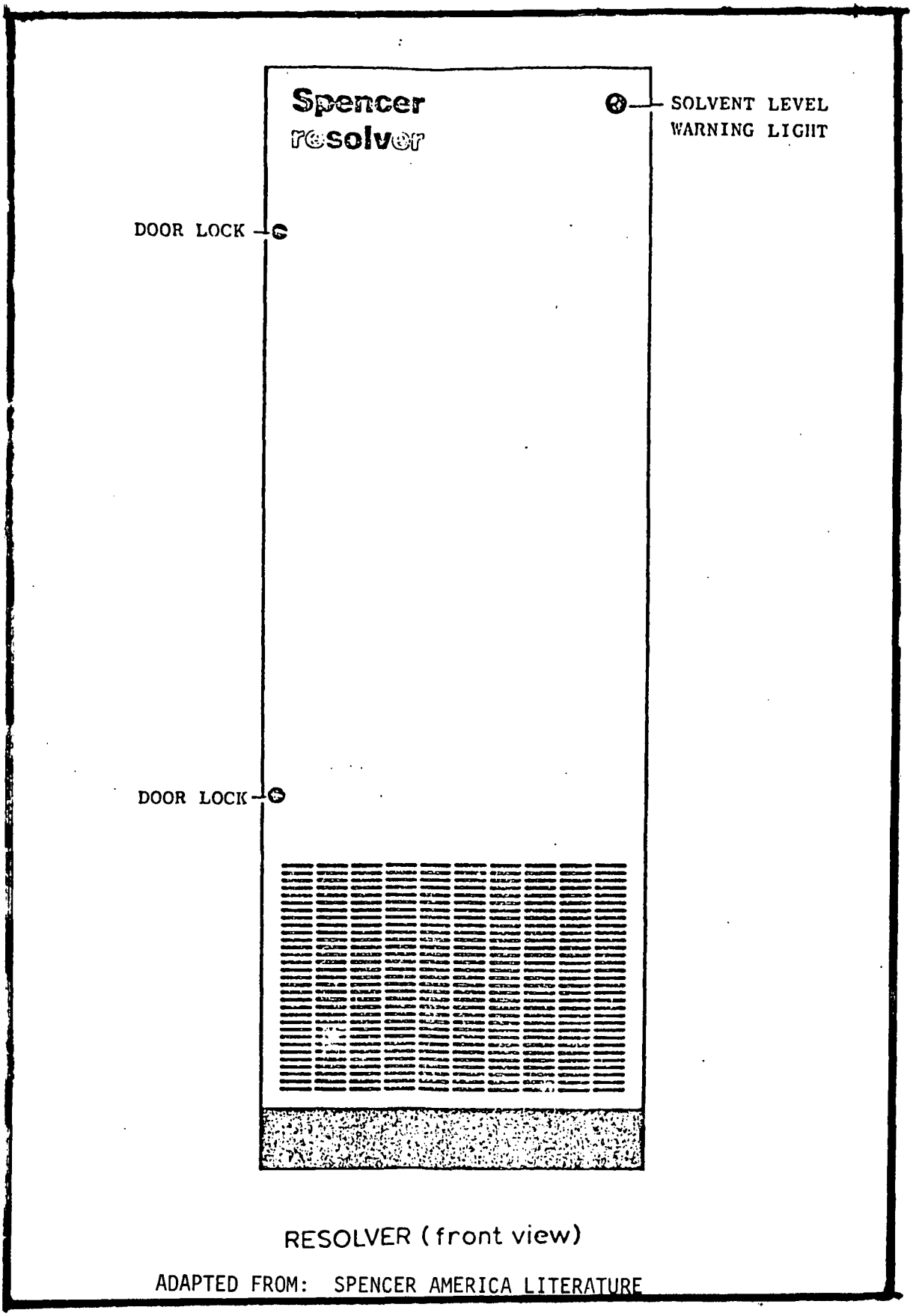


NOTE: DIMENSIONS FROM FIGURE 3.1 AND FIELD NOTES

FIGURE 3.3

LAYOUT OF RESOLVER AND DRYCLEANING MACHINE

ADAPTED FROM: SPENCER AMERICA LITERATURE



RESOLVER (front view)

ADAPTED FROM: SPENCER AMERICA LITERATURE

FIGURE 3.4

RESOLVER

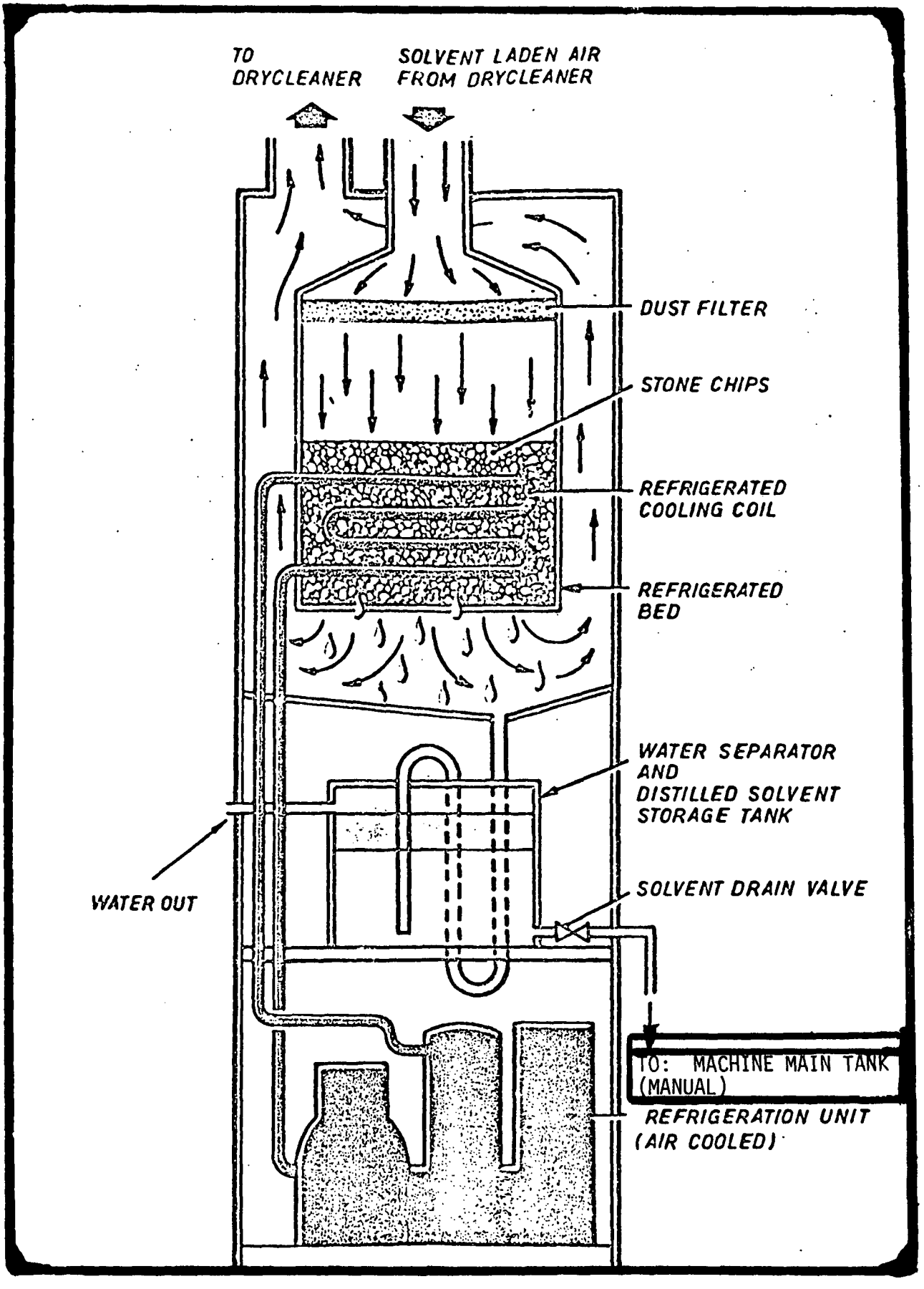


FIGURE 3.5

RESOLVER

functional diagram

4.0 DISCUSSION

Several areas of the test program require further elaboration. These areas include validity of the perchloroethylene concentration measurement, the accuracy of the measurements utilized for the mass balance summary, and the calculated efficiency of the resolver-reclaimer.

The analytical results summarized in Table 2.2 were measured with a Beckman 402 Hydrocarbon Analyzer. Due to the fact that perchloroethylene was by far the predominate constituent of the flue gas, no separation of constituents, by gas chromatography, was necessary. The instrument employs a flame ionization detector (FID) to measure the perchloroethylene concentration as total hydrocarbons. The instrument was calibrated with a certified standard of perchloroethylene in air (92 ppm). The standard certificate is contained in Appendix C.

The instrument drift in the field was considerable. The summary of the baseline drift and the standard drift were recorded for each sampling run and are recorded in Table 2.2. The instrument drift in total was expressed as a percentage of chart scale. The hydrocarbon analyzer was set on range selection of X10 for zeroing and standard spanning. All instrument drift readings were taken on this range setting. The integrated bag samples were analyzed on the X5000 range. Normal and preferred analytical procedure required either a higher concentration standard or dilution of the integrated bag sample with a known volume of nitrogen. The equipment necessary to implement either of these preferred procedures was not available on-site and was not anticipated from preliminary information. The drift of the instrument was greater than anticipated based upon previous testing experience. A contaminated detector was suspected. Subsequent post-field instrument diagnosis indicated no substantial problem with the detector. After adequate zeroing with instrument grade air, the hydrocarbon analyzer performed adequately. Therefore, the conclusion can be reached that the higher concentrations of perc (10,000 to 25,000 ppm) were the major factors in causing instrument

drift. Based upon the instrument drift and the variability of data as presented in Table 2.2, the validity of data as generated was definitely suspect. It is recommended that future testing plans consider appropriate testing alternatives.

The measurements associated with the mass balance portion of the test program were relatively basic. The weight of the clothes cleaned was measured to an estimated accuracy of ± five (5) kilograms (2.5 lbs). The liquid measurements were estimated to be accurate to ± 10 ml (1/3 oz). The scale utilized was not calibrated and its ability to weigh accurately the clothes according to generally accepted scientific norms was nominal. In order to increase the accuracy of the mass balance data, an unreasonable time and financial burden would have been incurred.

The measured efficiency of the resolver-reclaimer was less than anticipated. The efficiency reported in the summary represents a limited efficiency, (14%). The sample was taken over half of the aeration cycle. Due to the fact that the system was closed, the gas volume within the system was continuously circulated throughout the course of the aeration venting cycle. Therefore, it can be reasoned that the recovery efficiency of the resolver for perchloroethylene may have been slightly greater than reported on the basis of the actual testing data, but not significantly to invalidate the test results.

An estimated theoretical efficiency of the resolver, based on actual test measurements and equipment specifications from the manufacturer's literature, consequently is discussed below.

GIVEN the following information:

1) $V = 34.9\ ft^3$
2) $Q = 250$ cfm
3) $D_V = 5$ min

AND using the equation:

$$E_o = 1-(1 - X)^Y$$

WHERE:

Y = Single pass removal efficiency

X = Number of air changes during the venting cycle.

V = Volume of system in cubic feet (ft^3)

Q = Flowrate (average) through the system in cubic feet per minute (cfm)

D_V= Duration of venting cycle in minutes (min)

The upper limit of the theoretical efficiency of the resolver utilizing this limited and possibly biased set of inputs was calculated as 99.5% for the test period considering an average dryer aeration/cycle of five (5) minutes.

This estimate is in need of further justification by further testing and more accurate testing, exact measurements of the internal volume of the drycleaning machine and the resolver, and modification of the programmed duration of the aeration cycle to adequately gauge the influence of time upon removal efficiency of the resolver.

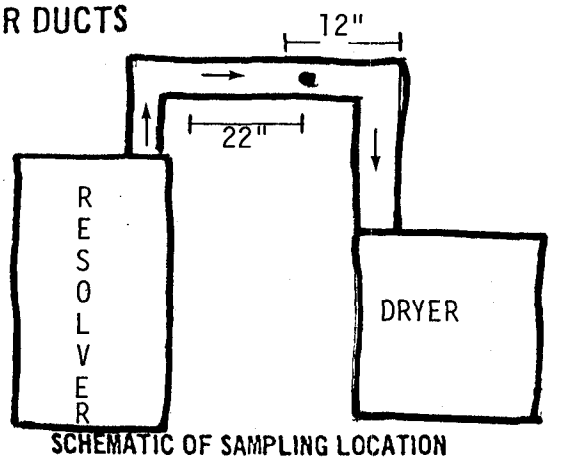
APPENDIX A

RAW TEST DATA

TRW / ENVIRONMENTAL ENGINEERING DIVISION

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

LANT PLAZA CLEANERS
DATE 6/5/79
SAMPLING LOCATION OUTLET FROM RESOLVER
INSIDE OF FAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE A) 6"
INSIDE OF NEAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE B) 0"
STACK I.D., (DISTANCE A - DISTANCE B) 6"
NEAREST UPSTREAM DISTURBANCE 3.6 E_0
NEAREST DOWNSTREAM DISTURBANCE 2.0 E_0
CALCULATOR JONGLEUX



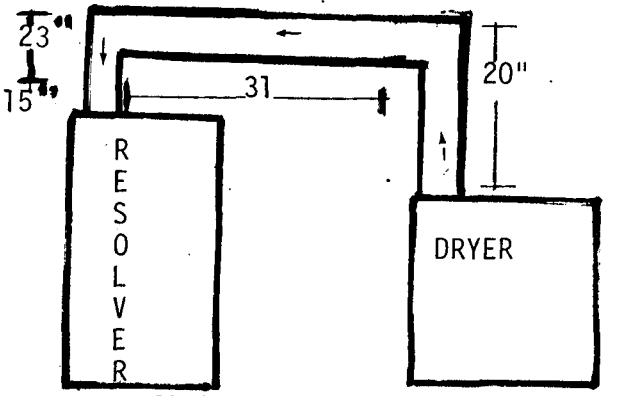
SCHEMATIC OF SAMPLING LOCATION

TRAVERSE POINT NUMBER	FRACTION OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	DISTANCE B	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	2.1	6"	.426	--	.5
2	6.7	6"	.402	--	.5
3	11.8	6"	.708	--	.75
4	17.7	6"	1.062	--	1.0
5	25.0	6"	1.50	--	1.5
6	35.6	6"	2.136	--	2.25
7	64.4	6"	3.864	--	3.8
8	75.0	6"	4.50	--	4.5
9	82.3	6"	4.938	--	4.9
10	88.2	6"	5.292	--	5.25
11	93.3	6"	5.593	--	5.5
12	97.9	6"	5.874	--	5.5

TRW / ENVIRONMENTAL ENGINEERING DIVISION

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

LANT PLAZA CLEANERS
ATE 6/5/79
SAMPLING LOCATION INLET TO RESOLVER
ISIDE OF FAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE A) 6"
INSIDE OF NEAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE B) 0"
ACK I.D., (DISTANCE A - DISTANCE B) 6"
NEAREST UPSTREAM DISTURBANCE 3.8 E.
NEAREST DOWNSTREAM DISTURBANCE 2.5 E.
ALCULATOR JONGLEUX

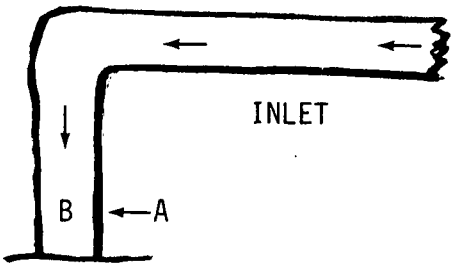


SCHEMATIC OF SAMPLING LOCATION

TRAVERSE POINT NUMBER	FRACTION OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	DISTANCE B	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	2.1	6"	.126	--	.5
2	6.7	6"	.402	--	.5
3	11.8	6"	.708	--	.75
4	17.7	6"	1.602	--	1.0
5	25.0	6"	1.5	--	1.5
6	35.6	6"	2.136	--	2.25
7	64.4	6"	3.864	--	3.8
8	75.0	6"	4.50	--	4.5
9	82.3	6"	4.938	--	4.9
10	88.2	6"	5.292	--	5.25
11	93.3	6"	5.598	--	5.5
12	97.9	6"	5.874	--	5.5

VELOCITY TRAVERSE

PLANT PLAZA CLEANERS.
DATE 6/5/29 (FROM -> 6/15)
LOCATION INLET
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg 29.75
STACK GAUGE PRESSURE, in. H_2O + 2.3
OPERATORS JONGLEUK / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

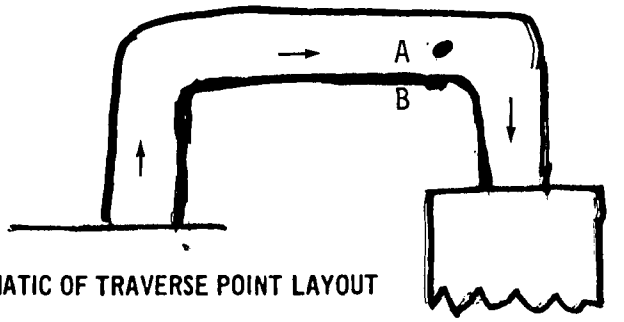
TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.145	24°C
A-2	.145	24°C
A-3	.14	24°C
A-4	.14	23°C
A-5	.135	23°C
A-6	.135	23°C
A-7	.15	23°C
A-8	.17	23°C
A-9	.175	23°C
A-10	.185	24°C
A-11	.145	24°C
A-12	.145	24°C
AVERAGE	.143	23.5°C

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
B-1	.1	24°C
B-2	.1	24°C
B-3	.115	23.5°C
B-4	.115	24°C
B-5	.125	23°C
B-6	.145	23°C
B-7	.17	23°C
B-8	.195	23°C
B-9	.195	23°C
B-10	.215	23°C
B-11	.218	23°C
B-12	.215	23°C
AVERAGE	.159	23.4°C

VELOCITY TRAVERSE

OUTLET

PLANT Plaza Cleaners
DATE 6/1/87 (Pre-Con / Con)
LOCATION Outlet
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg 29.96
STACK GAUGE PRESSURE, in. H_2O - 1.0
OPERATORS JONCEUX / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.135	10°C
A-2	.135	10°C
A-3	.140	10°C
A-4	.135	10°C
A-5	.125	11°C
A-6	.125	11°C
A-7	.130	11°C
A-8	.140	11°C
A-9	.145	12°C
A-10	.160	13°C
A-11	.175	14°C
A-12	.180	14°C
AVERAGE	.144	11.4°C

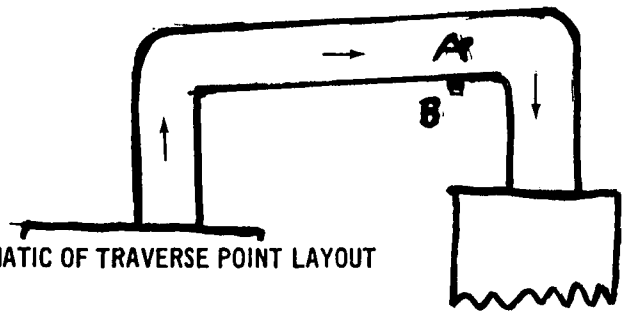
TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
AVERAGE		

ENVIRONMENTAL ENGINEERING DIVISION

VELOCITY TRAVERSE

OUTLET

PLANT Plasma Cleaner
DATE 6/5/22 (1500)
LOCATION Outlet
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg ~~29.05~~ 29.96
STACK GAUGE PRESSURE, in. H_2O -1.0
OPERATORS JONGLEUX / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

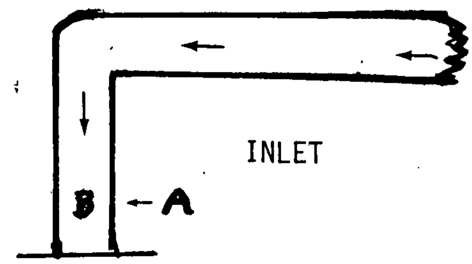
TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.129	23.4°C
A-2	.127	23.4°C
A-3	.145	23.4°C
A-4	.140	23.4°C
A-5	.137	23.4°C
A-6	.137	23.4°C
A-7	.141	23.4°C
A-8	.156	23.4°C
A-9	.180	23.4°C
A-10	.173	23.5°C
A-11	.173	23.5°C
A-12	.173	23.5°C
AVERAGE	.151	24.3°C

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
B-1	.132	23.4°C
B-2	.132	23.4°C
B-3	.137	23.4°C
B-4	.137	23.4°C
B-5	.131	23.4°C
B-6	.129	23.4°C
B-7	.132	23.4°C
B-8	.138	23.4°C
B-9	.157	23.5°C
B-10	.183	23.5°C
B-11	.183	23.5°C
B-12	.183	23.5°C
AVERAGE	.148	23.6°C

NOTE: (RESOLVER APPARENTLY NOT FUNCTIONING PROPERLY - NO TEMPERATURE CHANGE)

VELOCITY TRAVERSE

PLANT Plaza Cleaners
DATE 6/5/79 (1500)
LOCATION Inlet
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg 29.96
STACK GAUGE PRESSURE, in. H_2O +2.3
OPERATORS JONGLEUX / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

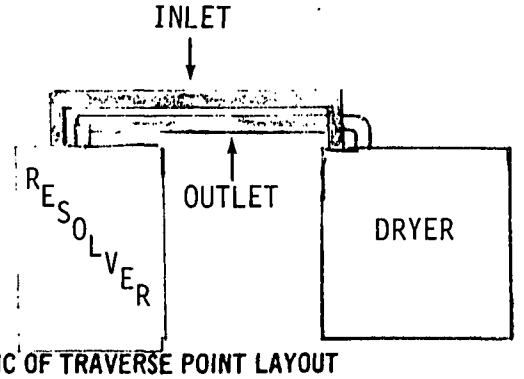
TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.098	25°C
A-2	.098	25°C
A-3	.101	26°C
A-4	.108	26°C
A-5	.108	25°C
A-6	.133	25°C
A-7	.156	25°C
A-8	.181	26°C
A-9	.171	26°C
A-10	.192	28°C
A-11	.192	28°C
A-12	.112	28°C
AVERAGE	.146	26.083°C

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
B-1	.144	26°C
B-2	.144	26°C
B-3	.160	25°C
B-4	.149	25°C
B-5	.148	25°C
B-6	.144	25°C
B-7	.145	25°C
B-8	.160	25°C
B-9	.170	26°C
B-10	.181	26°C
B-11	.185	26°C
B-12	.185	26°C
AVERAGE	.156	25.5°C

NOTE: (RESOLVER APPARENTLY NOT FUNCTIONING PROPERLY - NO TEMPERATURE CHANGE)

VELOCITY TRAVERSE

PLANT Plaza Cleaners
DATE 6/6/79 (Cross)
LOCATION Inlet & Outlet
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg 30.05
STACK GAUGE PRESSURE, in. H_2O
OPERATORS JONGLEUX / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

Inlet

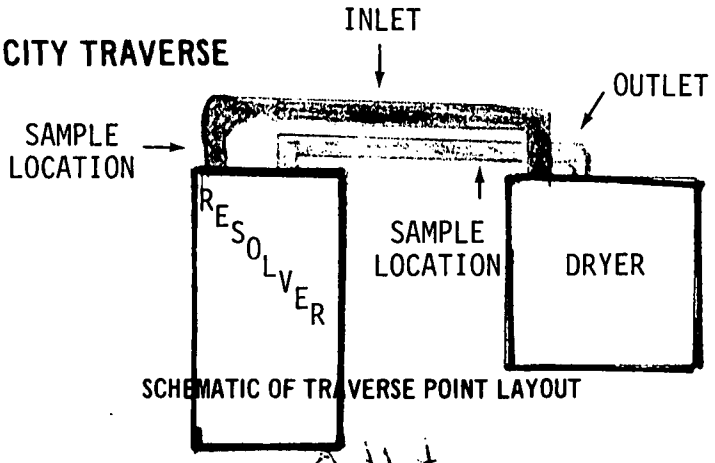
TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.089	25°C
A-2	.089	25°C
A-3	.010	26°C
A-4	.100	25°C
A-5	.100	25°C
A-6	.119	25°C
A-7	.140	24°C
A-8	.150	24°C
A-9	.121	24°C
A-10	.110	24°C
A-11	.113	24°C
A-12	.103	24°C
STATIC	+1.7	
AVERAGE	.136	24.6°C

Outlet

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A-1	.103	12°C
A-2	.103	12°C
A-3	.111	11°C
A-4	.120	11°C
A-5	.123	12°C
A-6	.122	12°C
A-7	.121	12°C
A-8	.127	13°C
A-9	.132	13°C
A-10	.139	15°C
A-11	.142	16°C
A-12	.148	16°C
STATIC	-1.0	
AVERAGE	.124	12.9°C

VELOCITY TRAVERSE

PLANT Plaza Cleaners
DATE 6/7/79 (1230)
LOCATION Inlet & Outlet
STACK I.D. 6"
BAROMETRIC PRESSURE, in. Hg 30.05
STACK GAUGE PRESSURE, in. H_2O +2.3
OPERATORS JONGLEUX / CONSTANTINE



SCHEMATIC OF TRAVERSE POINT LAYOUT

Inlet

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A 1	.135	83°F
A-2	.135	83° F
A-3	.135	83° F
A-4	.135	83° F
A-5	.134	83° F
A 6	.135	83° F
A-7	.181	82° F
A-8	.180	82° F
A 9	2.2	81° F
A 10	>2	81° F
A 11	>2	81° F
A 12	>2	81° F
STATIC	+2.3	
AVERAGE	.164	82.2° F

Outlet

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
A 1	.133	68°F
A-2	.133	66°F
A 3	.140	69°F
A-4	.142	69°F
A-5	.148	70°F
A-6	.149	70°F
A-7	.148	71°F
A 8	.148	71°F
A-9	.148	72°F
A-10	.148	72°F
A-11	.148	72°F
A-12	.148	72°F
STATIC	-1.0	
AVERAGE	.144	70.3°F

PADIKER INDUSTRIES
1010 CLIFTON AVENUE
CLIFTON, NJ 07013
201 472-9300

ParaLine Products

Week Beginning 6/4/79

Washer No. .....

Week Ending .....

	Monday		Tuesday		Wednesday		Thursday		Friday	
	FFA..... Det. .....%		FFA..... Det. .....%		FFA..... Det. .....%		FFA..... Det. .....%		FFA..... Det. .....%	
	Solvent Temp.		Solvent Temp.		Solvent Temp.		Solvent Temp.		Solvent Temp.	
	Filter Press. ..... lbs.		Filter Press. ..... lbs.		Filter Press. ..... lbs.		Filter Press. ..... lbs.		Filter Press. ..... lbs.	
	Det. Added ..... oz.		Det. Added ..... oz.		Det. Added ..... oz.		Det. Added ..... oz.		Det. Added ..... oz.	
	Misc. Prod. Added ..... oz.		Misc. Prod. Added ..... oz.		Misc. Prod. Added ..... oz.		Misc. Prod. Added ..... oz.		Misc. Prod. Added ..... oz.	
	Solvent Added		Solvent Added		Solvent Added		Solvent Added		Solvent Added	
	Pounds	TIME Classification	Pounds	TIME Classification	Pounds	TIME Classification	Pounds	TIME Classification	Pounds	TIME Classification
1	38	9 12	19	8.16	5[illegible]	8:[illegible]0				
2.	37	~~9:50~~	38	9:00	39	9:50				
3.	40	10:35	37		21					
4.	33	11:05	35	10:38	40	-				
5.	24	11:50	27B	11:20	40	12:21				
6.	15	12:30	40	12:10	19	1:02				
7.	39	2:00	22		B 31	:00				
8.	38	2:31	28		28½	B50				
9.	34	9:16								
10.	25	10:04								
11.	19	10:42								
12.	40	1:27								
13.	39	12:07								
14.	15	12:50								
15.	34	1:29								
16.	3	2:05								
17.	~~19~~	~~8:16~~								
18.										
19.										
20.										

Weekly Summary

DETERGENT

Det Used .....

Stock Used .....

SOLVENT

At Start ..... Gals.

Delivered ..... Gals.

Total ..... Gals.

At End ..... Gals.

Used ..... Gals.

COSTS

Gals. Solvent Per Cwt. .....

Detergent Per Cwt. .....

TOTAL POUNDS FOR WEEK

.....

TABLE A-1 LOAD TABULATION RECORD

APPENDIX A

STRIPCHART RECORDINGS

Beckman 402
Plaza Cleaners
June 1979

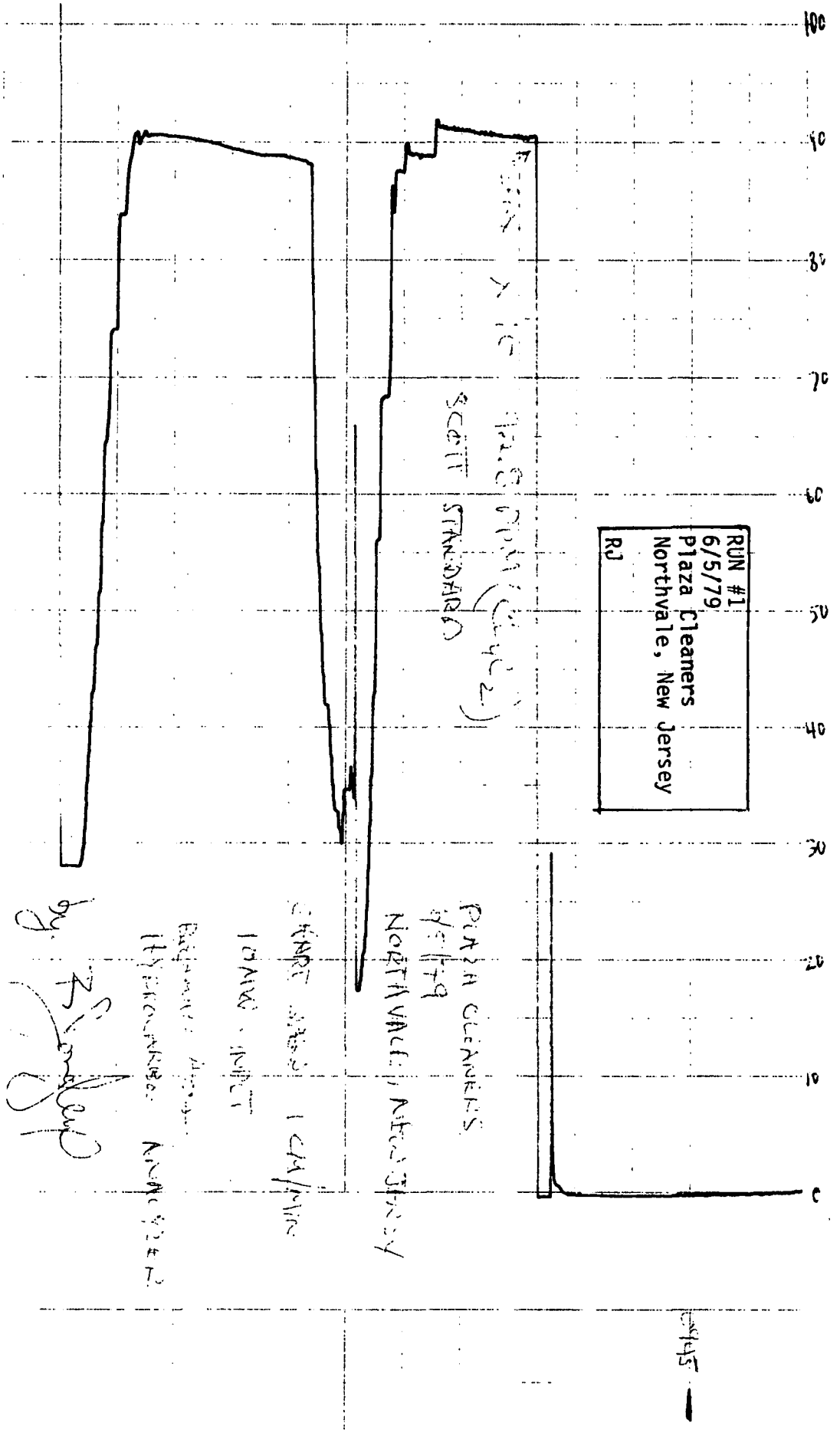


FIGURE A.2 RUN #1

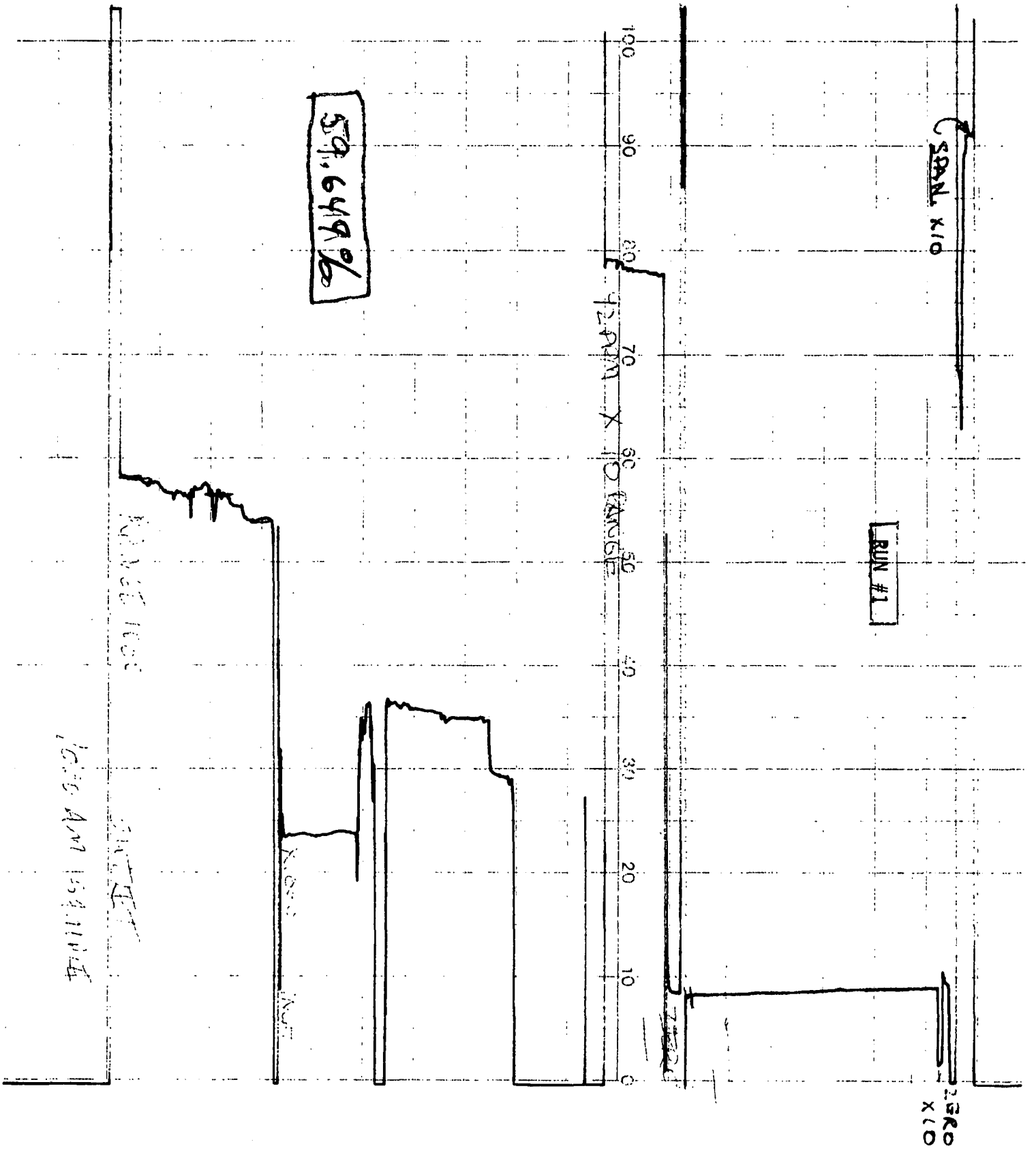


FIGURE A.3 RUN #1 (CONTINUED)

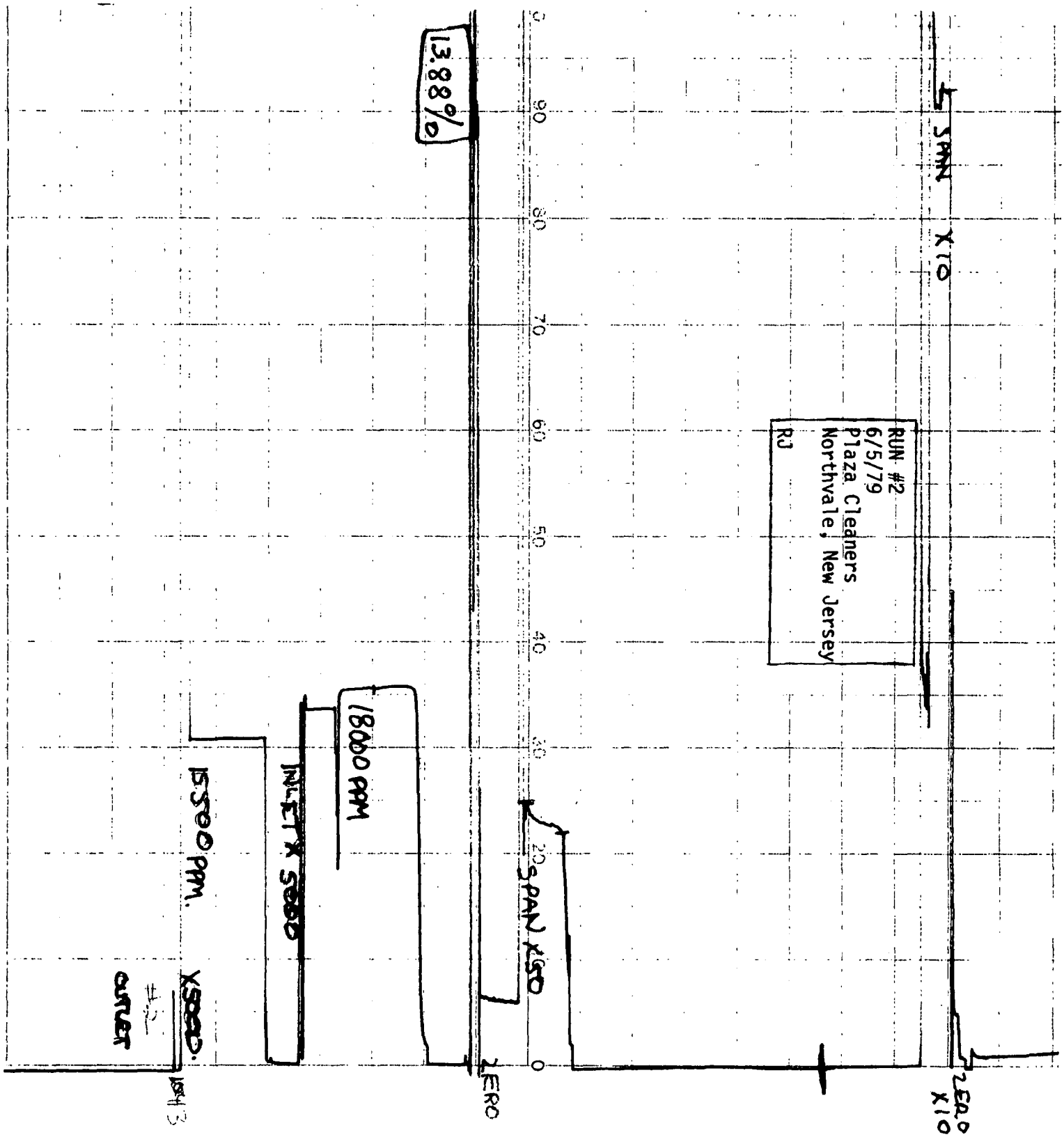


FIGURE A.4 RUN #2

FIGURE A.5 RUN #3

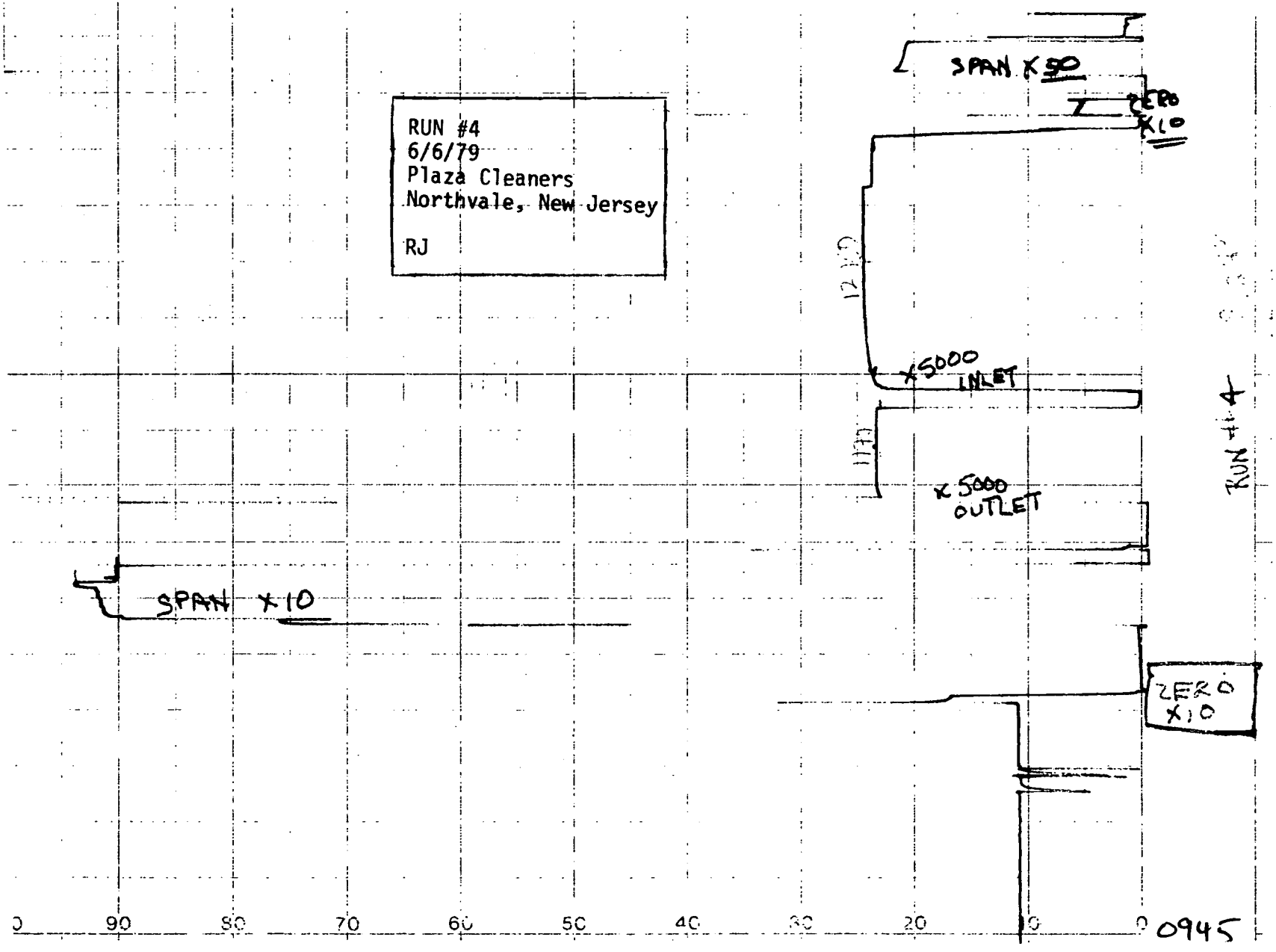


FIGURE A.6 RUN #4

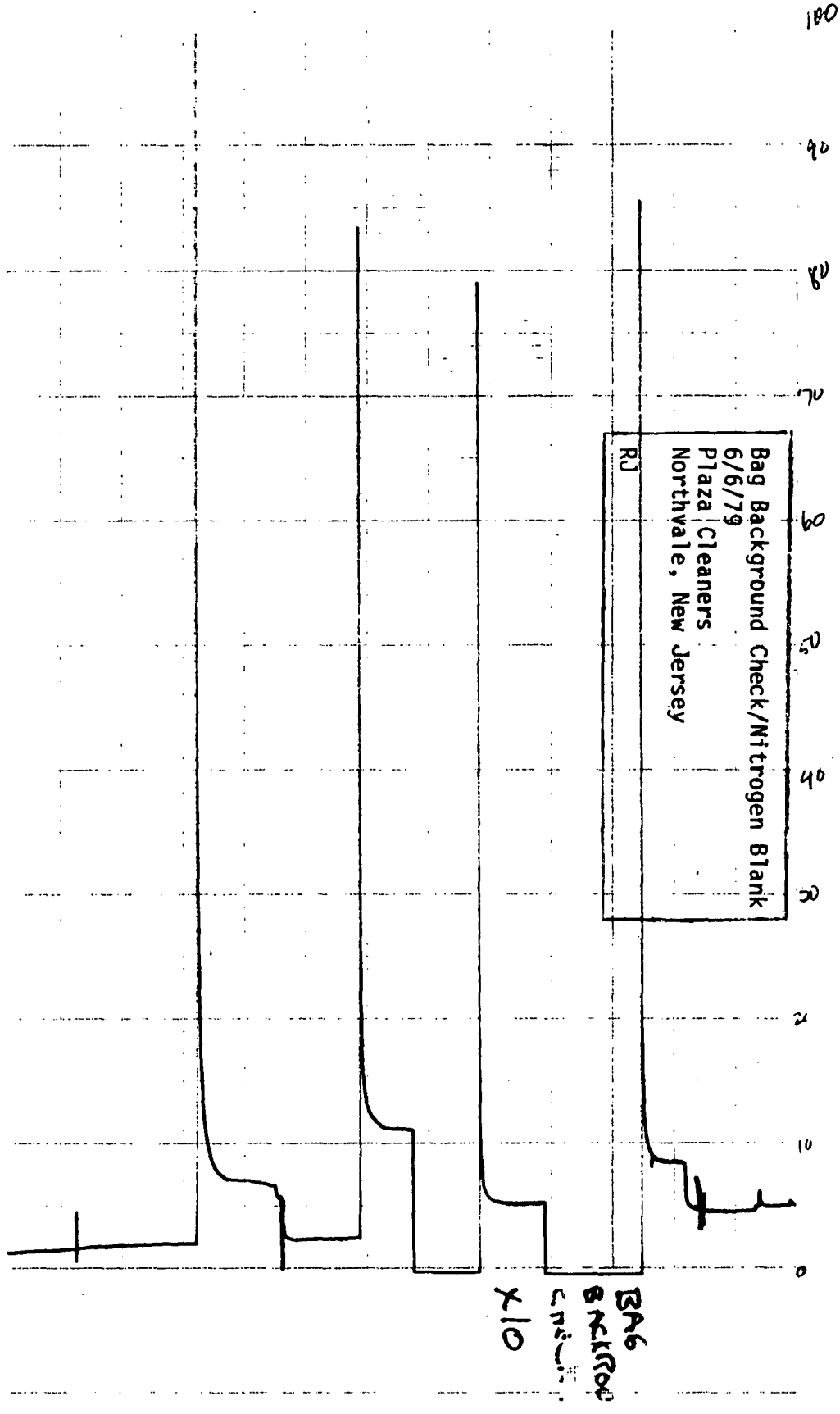

Bag Background Check/Nitrogen Blank
6/6/79
Plaza Cleaners
Northvale, New Jersey
RJ
100
90
80
70
60
50
40
30
20
10
0
X10
BA6

FIGURE A.7

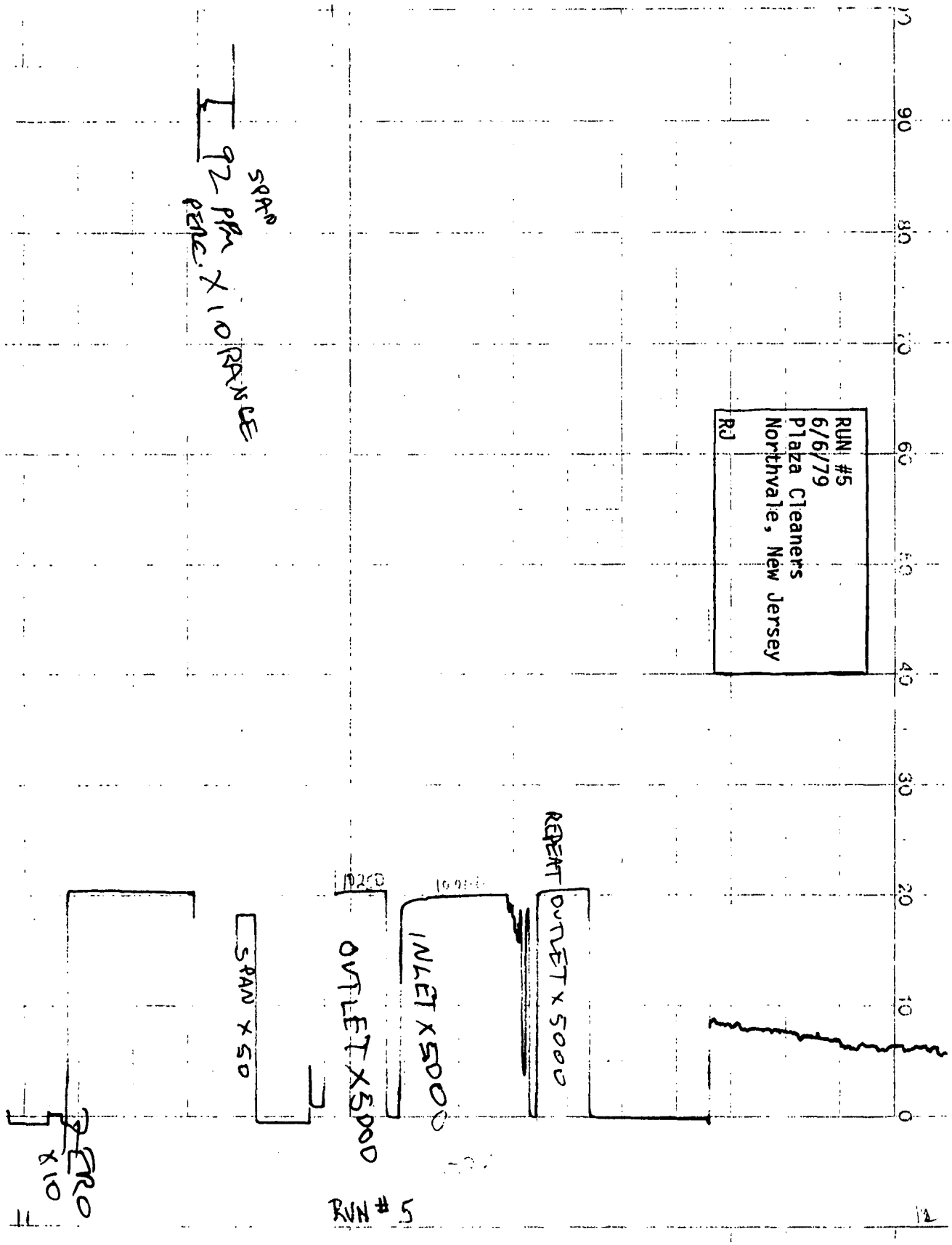
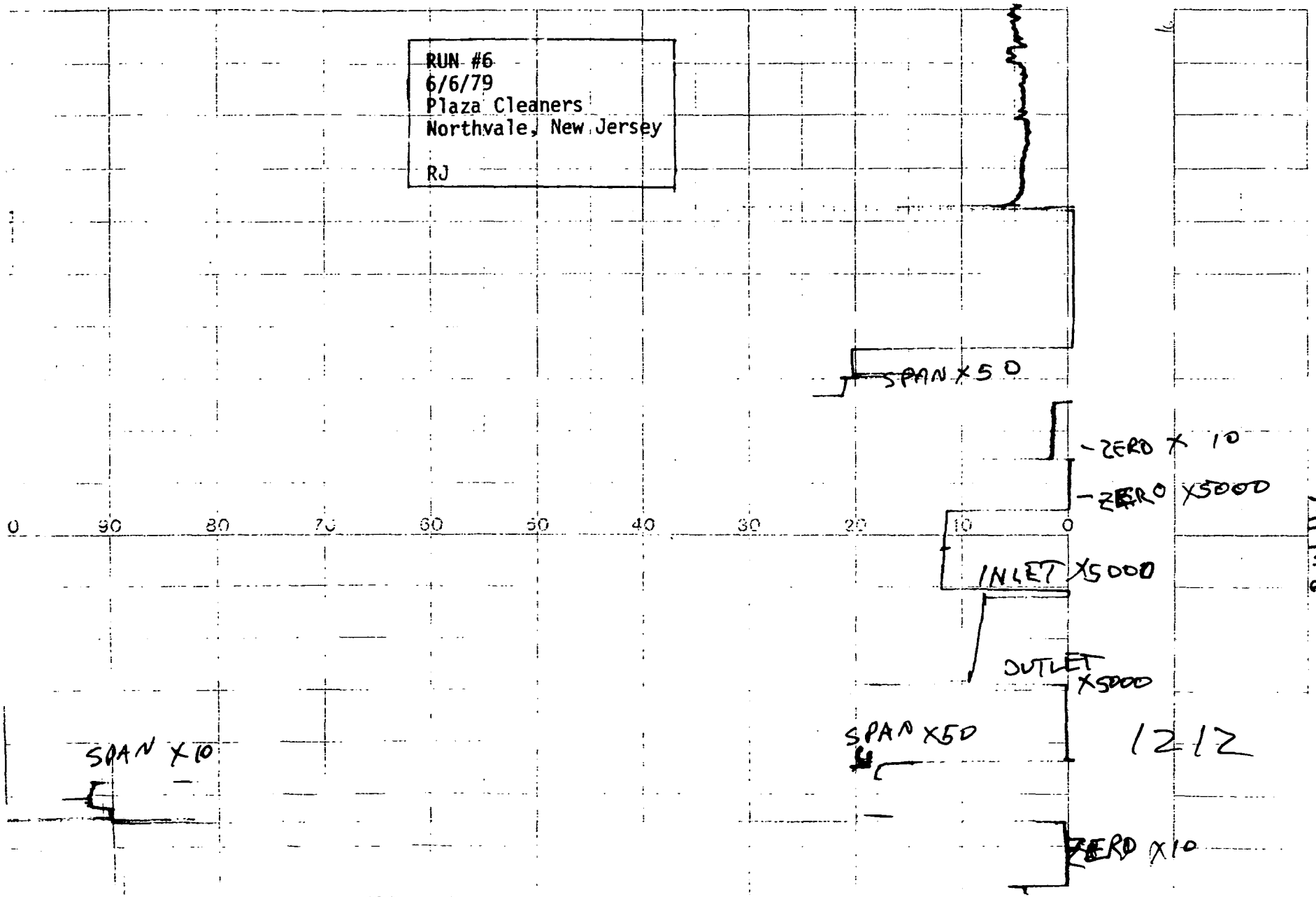


FIGURE A.8 RUN #5



RUN #6
FIGURE A.9 RUN #6

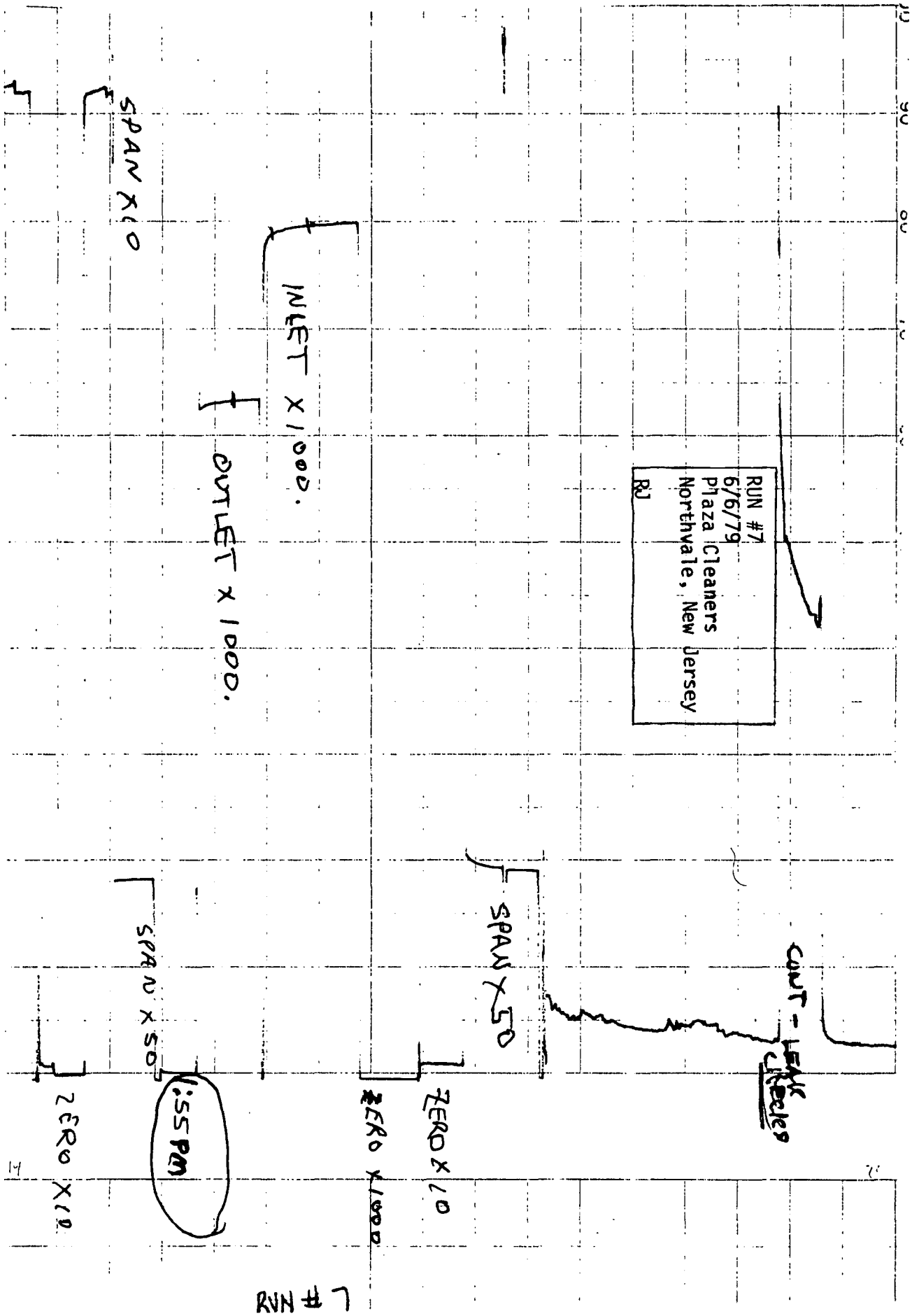


FIGURE A.10 RUN #7

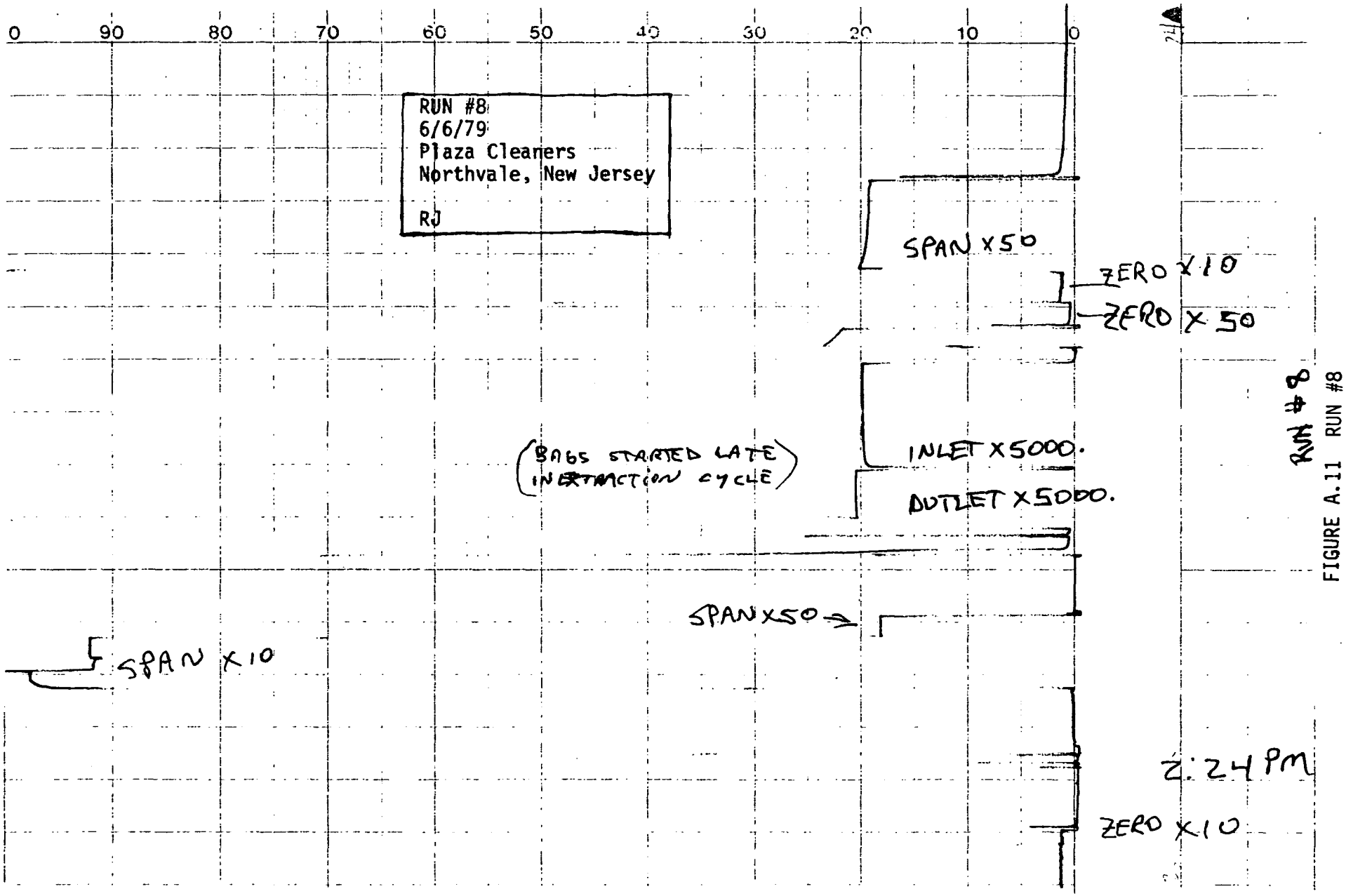


FIGURE A.11 RUN #8

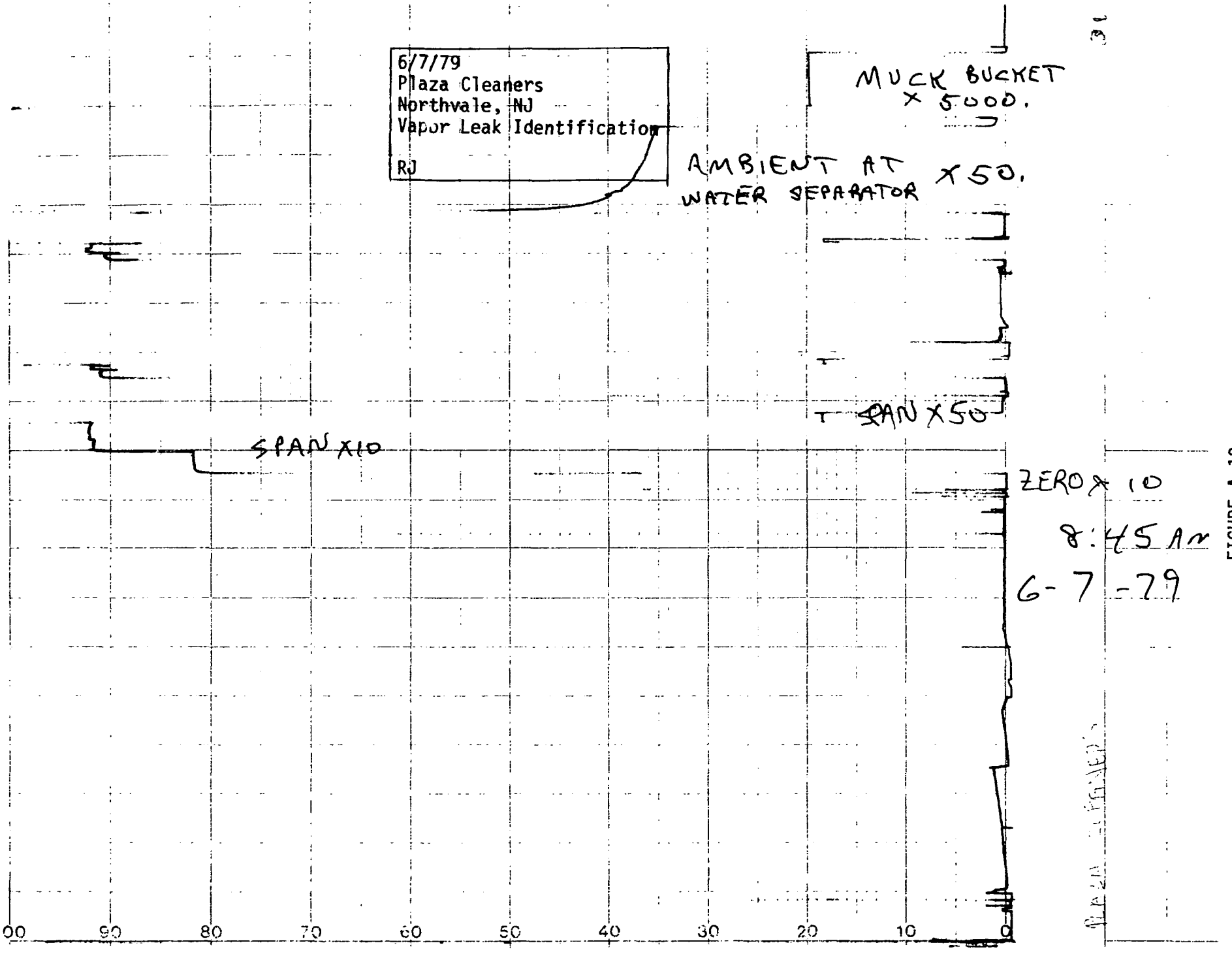

6/7/79
Plaza Cleaners
Northvale, NJ
Vapor Leak Identification
RJ
MUCK BUCKET
X 5000.
AMBIENT AT
WATER SEPARATOR
X50.
SPAN X50
SPAN X10
ZERO X 10
8:45 AM
6-7-79
100
90
80
70
60
50
40
30
20
10
0

FIGURE A.12

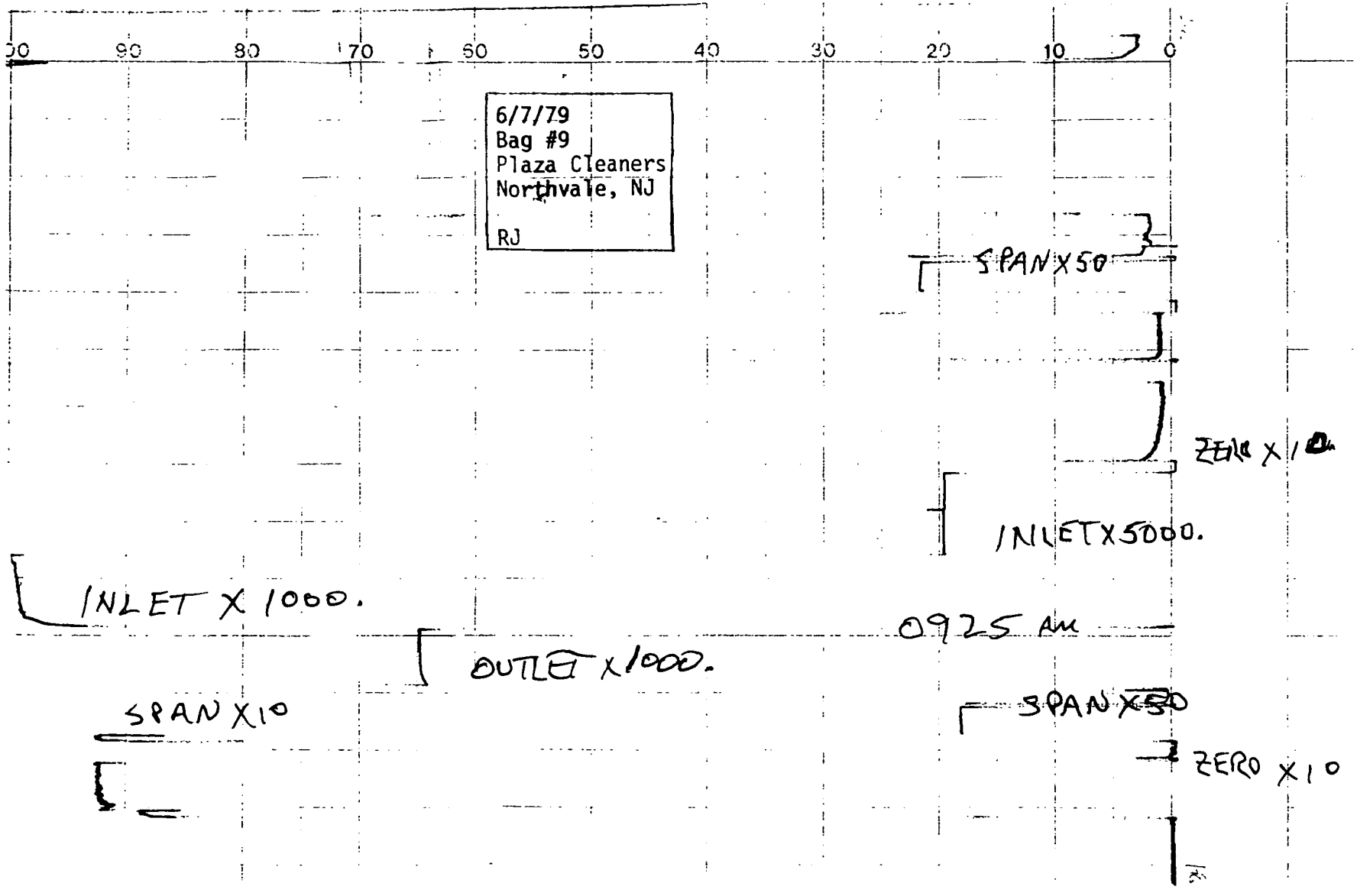


FIGURE A.13 BAG #9

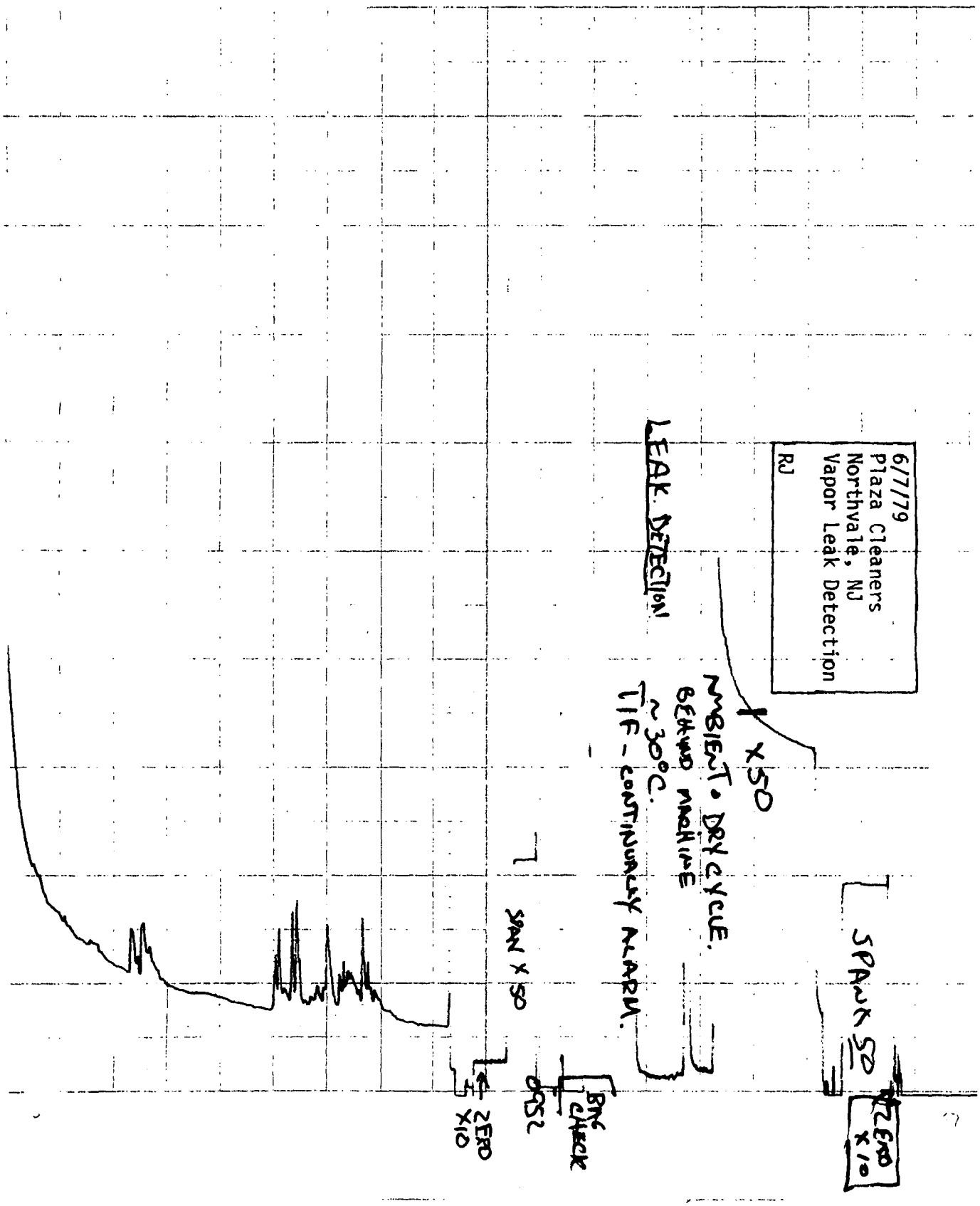

6/7/79
Plaza Cleaners
Northvale, NJ
Vapor Leak Detection
RJ
X50
AMBIENT • DRY CYCLE.
BEHIND MACHINE
~ 30°C.
T/F - CONTINUOUSLY ALARM.
LEAK DETECTION!
SPAN X50
SPAN X10
ZERO X10
ZERO
BTK CHECK
OCSL

FIGURE A.14

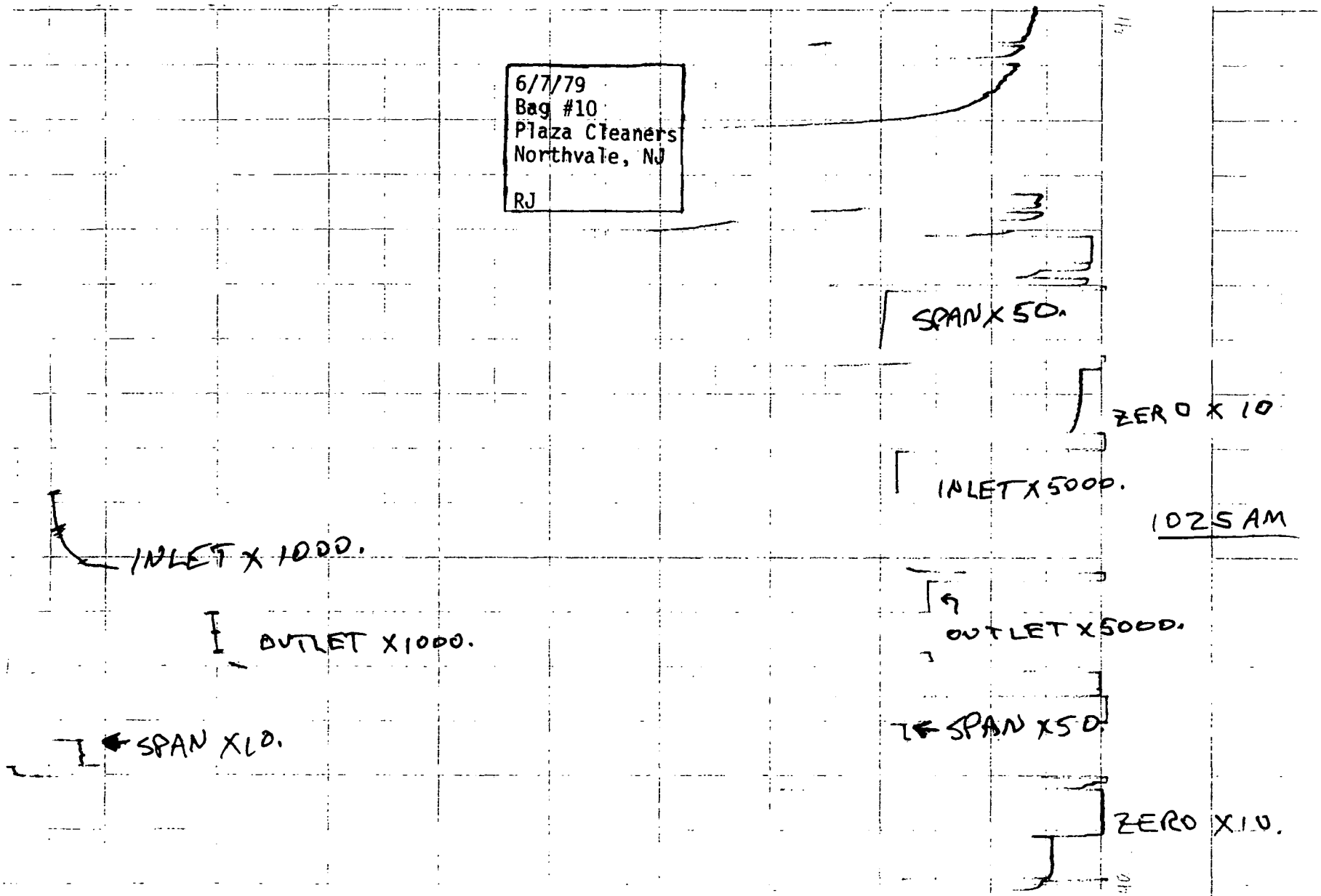


FIGURE A.15 BAG #10

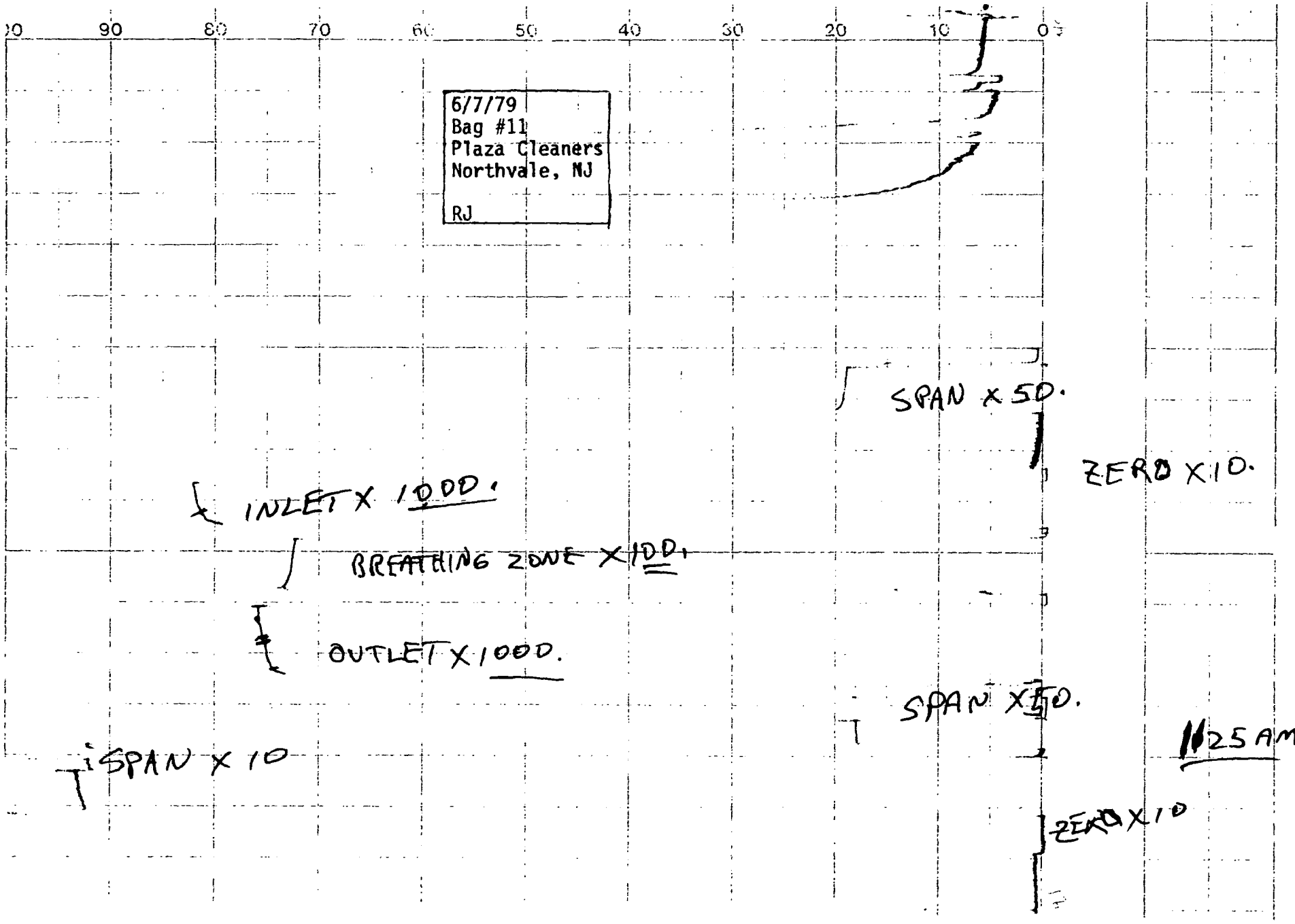


FIGURE A.16 BAG #11

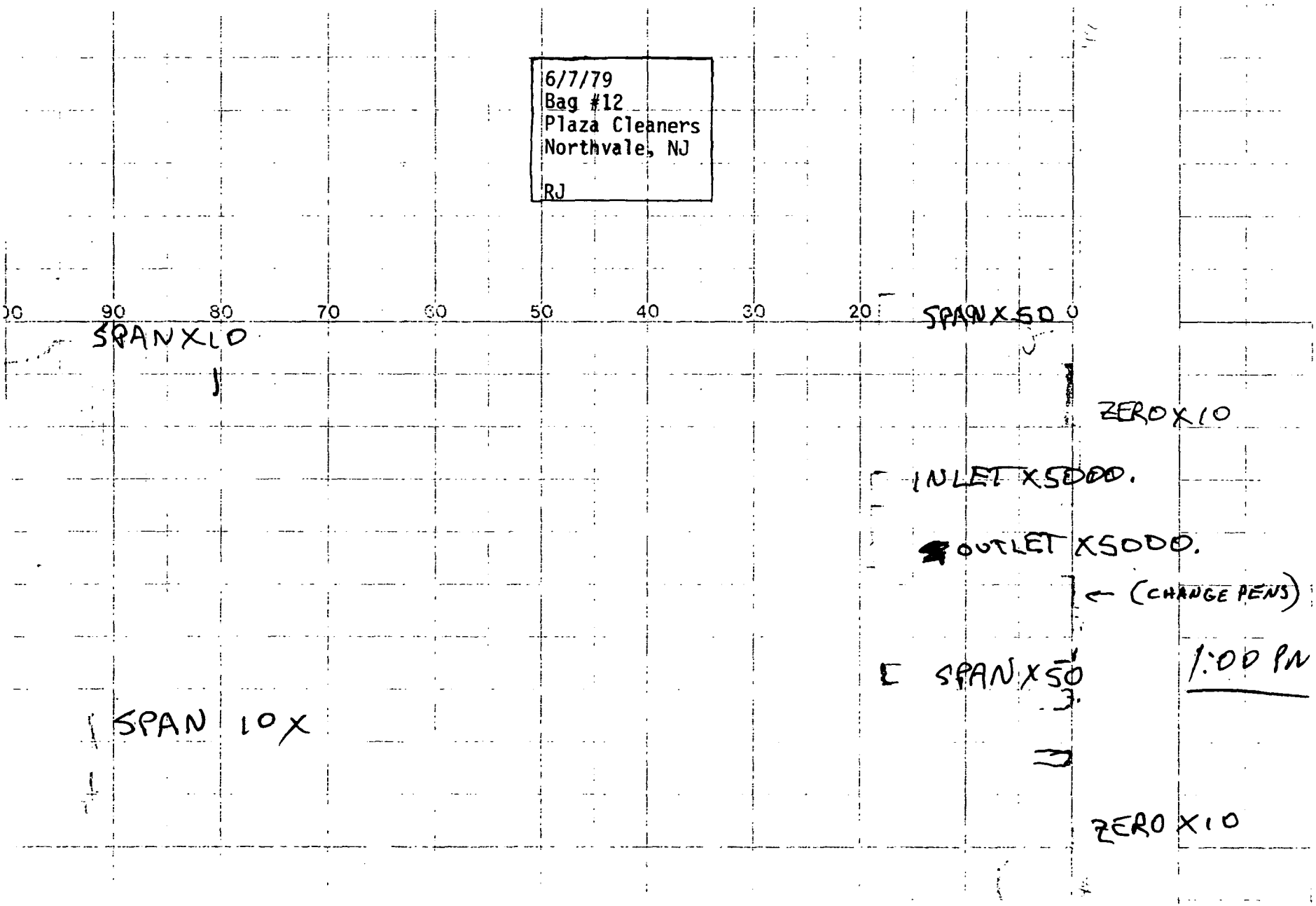


FIGURE A.17 BAG #12

APPENDIX B

DETAILED TEST PROCEDURES

ANALYTICAL PROCEDURE - PERCHLOROETHYLENE

The following procedure was used to analyze the inlet and outlet integrated bag samples at Plaza Cleaners test site. Figure B.1 is a schematic of the hydrocarbon analyzer. A Beckman 402 Hydrocarbon analyzer was used in the field van while on site. Aluminized gas sampling bags were transported to the van for analysis immediately after sampling. The hydrocarbon analyzer, which operates on the principle of flame ionization, was calibrated with a 92 ppm standard and a zero standard prior to and after every sample run. The range used for the calibration was X10 and the range used for analysis was X5000. The sample and standard were introduced to the FID analyzer by means of an auxiliary pump from a gas sampling bag. A 40% hydrogen in helium and THC-free air were the gases used to fuel the instrument. The sample, air, and fuel pressures were regulated at 2, 10, 20 pounds per square inch (psig), respectively.

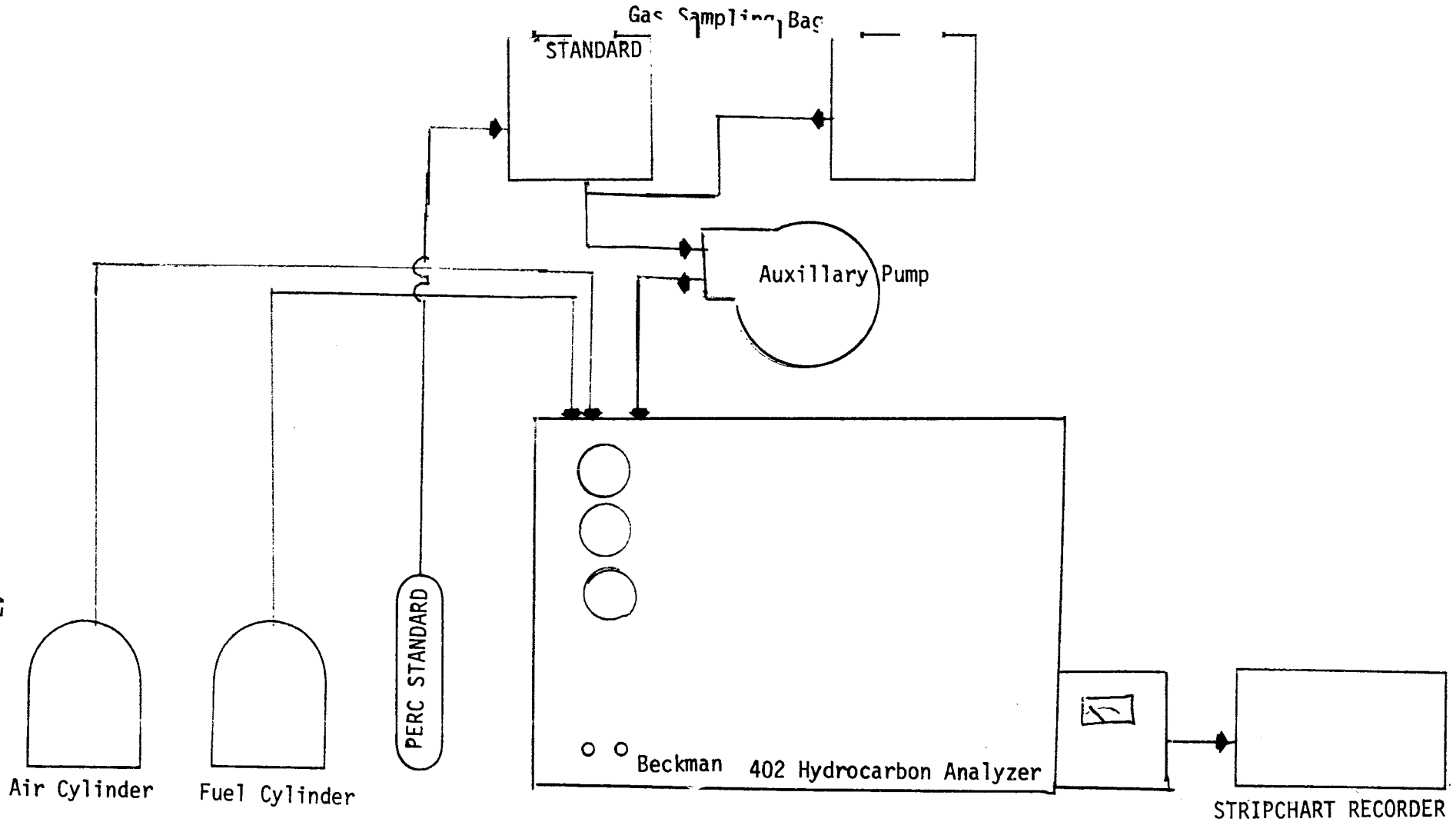


Figure B.1 Hydrocarbon Analyzer System

VELOCITY AND FLOWRATE DETERMINATION PROCEDURE

The velocity and flowrate determinations conducted on-site were performed in accordance to EPA reference Method 1 and Method 2, (text following) with modifications implemented to compensate for the small diameter (6-inch) duct where the velocity profile was taken. The modifications in the standard procedure included the use of a small (9-inch) S-type pitot tube and a separate thermocouple to measure the flue gas temperatures. These modifications were implemented in accordance with recommended protocol.[3]

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and flues. The method cannot be used when: (1) flow is cyclonic or swirling (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m^2 (113 $in.^2$) in cross-sectional area, or (3) the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured; failure to do so may require subsequent alterations to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. *Procedure*

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_e) shall be calculated from the following equation, to determine the upstream and downstream distances:

$$D_e = \frac{2LW}{L+W}$$

[3] "Recommended Procedure for Sample Traverses in Ducts Smaller Than 12 Inches in Diameter", STACK SAMPLING TECHNICAL INFORMATION - A Collection of Monographs and Papers; Volume IV - EPA-450/2-78-042d; October 1978.

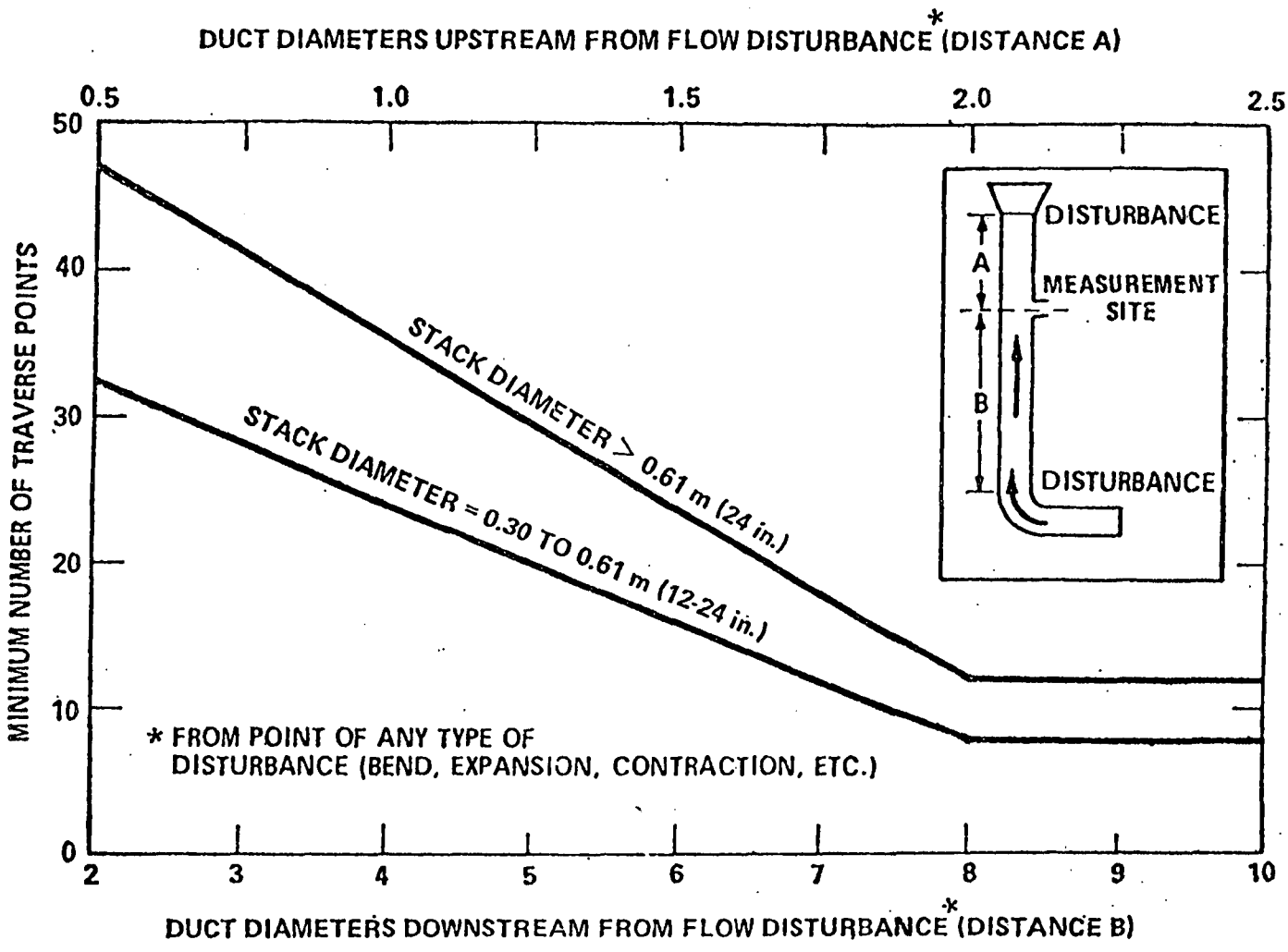


Figure 1-1. Minimum number of traverse points for particulate traverses.

where L=length and W=width.

2.2 Determining the Number of Traverse Points.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that corresponds: (1) to the number of duct diameters upstream; and (2) to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1-1.

TABLE 1-1. *Cross-sectional layout for rectangular stacks*

Number of traverse points:	*Matrix layout*
9	3x3
12	4x3
16	4x4
20	5x4
25	5x5
30	6x5
36	6x6
42	7x6
49	7x7

[Appendix A, Method 1]

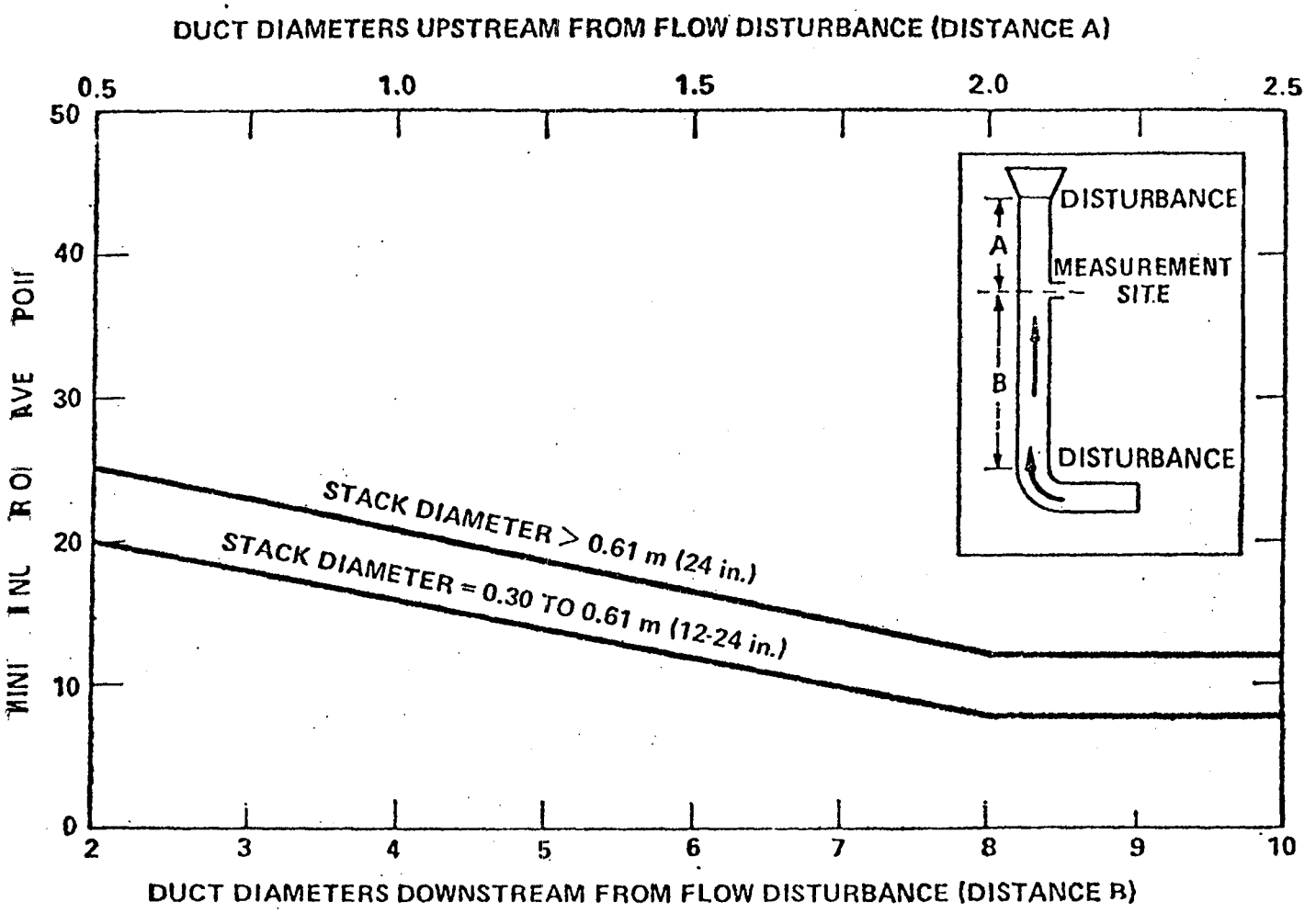


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

2.2.2 Velocity (Non-Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-2 may be used instead of Figure 1-1.

2.3 Cross-Sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used *in lieu of* Table 1-2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, *one diameter shall be in the* plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition, for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). When any of the traverse points as located in Section 2.3.1 fall within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.00 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as *two separate traverse points, both in the* sampling (or velocity measurement) procedure, and in recording the data.

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.7
3	29.5
4	70.5
5	85.3
6	95.6

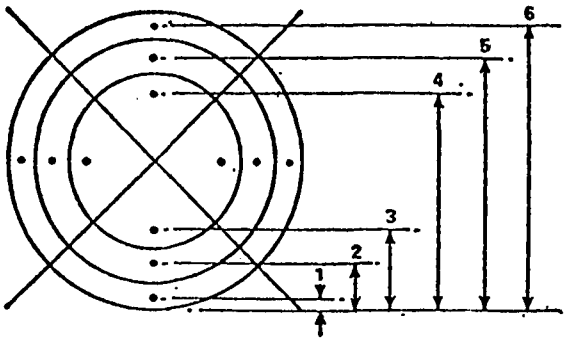


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

Table 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS
(Percent of stack diameter from inside wall to traverse point)

Traverse point number on a diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10					97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

2.3.1.2 Stacks With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4x3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9x4 or 12x3, and would not necessarily have to be 6x6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or

(2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

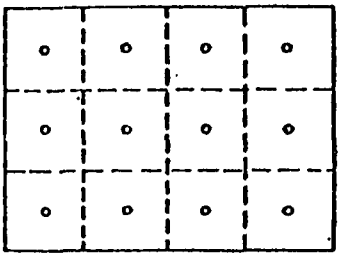


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α; assign α values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 10°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

3. *Bibliography*

1. Determining Dust Concentration in a Gas Stream. ASME. Performance Test Code No. 27. New York. 1957.

2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District. Los Angeles, CA. November 1963

3. Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co. Los Angeles, CA. Bulletin WP-50. 1968.

4. Standard Method for Sampling Stacks for Particulate Matter. In: 1971 Book of ASTM Standards, Part 23. ASTM Designation D-2928-71. Philadelphia, Pa. 1971.

5. Hanson, H. A., et al. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. USEPA, ORD, ESRL, Research Triangle Park, N.C. EPA-600/2-76-170. June 1976.

6. Entropy Environmentalists, Inc. Determination of the Optimum Number of Sampling Points: An Analysis of Method 1 Criteria. Environmental Protection Agency. Research Triangle Park, N.C. EPA Contract No. 68-01-3172, Task 7.

METHOD 2—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. *Principle and Applicability*

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

1.2 Applicability. This method is applicable for measurement of the average velocity of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1, Section 2.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams; Section 2.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, subject to the approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically, or (3) to move to another measurement site at which the flow is acceptable.

2. *Apparatus*

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

[Appendix A, Method 2]

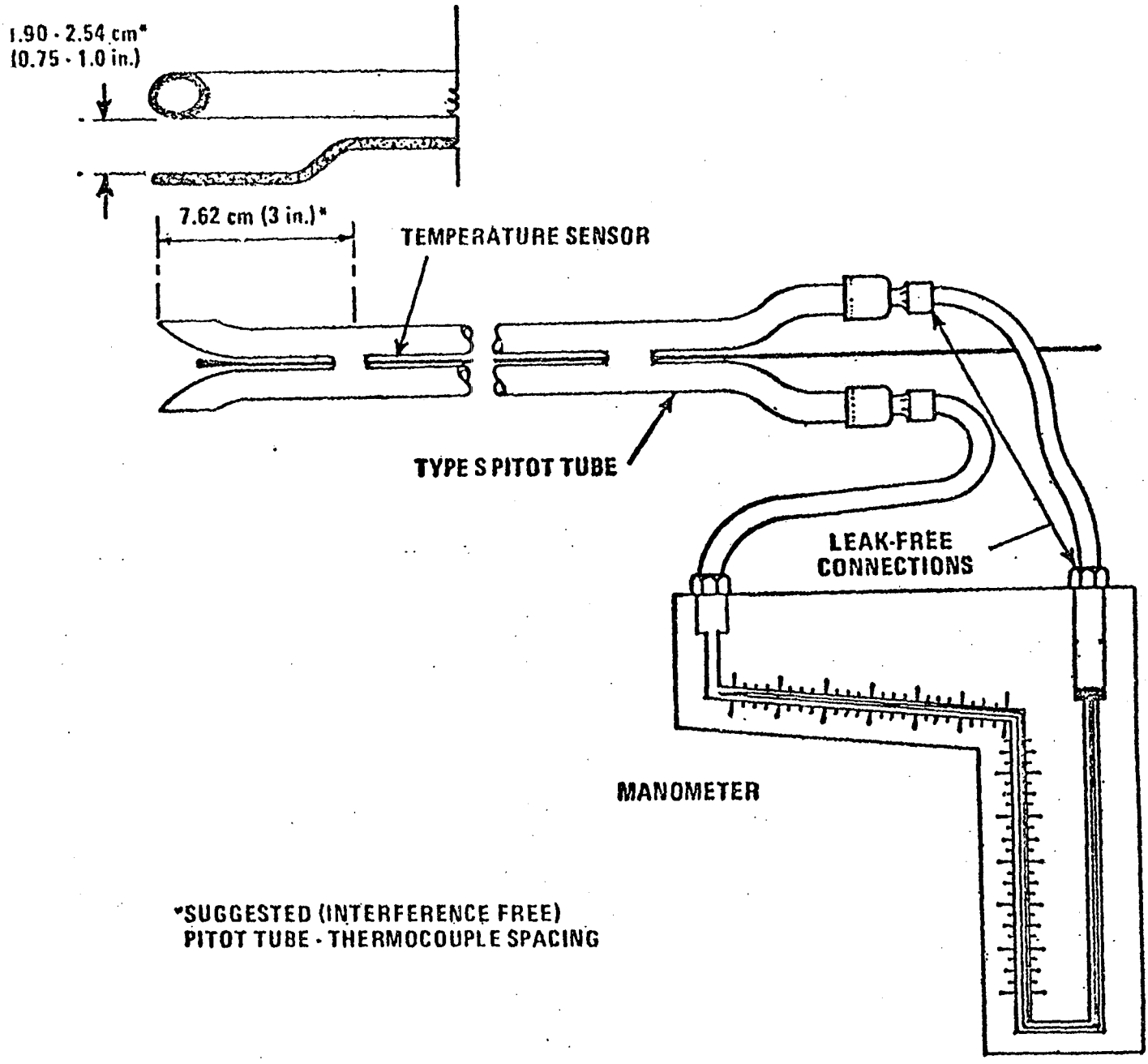


Figure 2-1. Type S pitot tube manometer assembly.

2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g., stainless steel). It is recommended that the external tubing diameter (dimension D_t, Figure 2-2b) be between 0.48 and 0.95 centimeters (3/16 and 3/8 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P_A and P_B, Figure 2-2b); it is recommended that this distance be between 1.05 and 1.50 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4. An identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

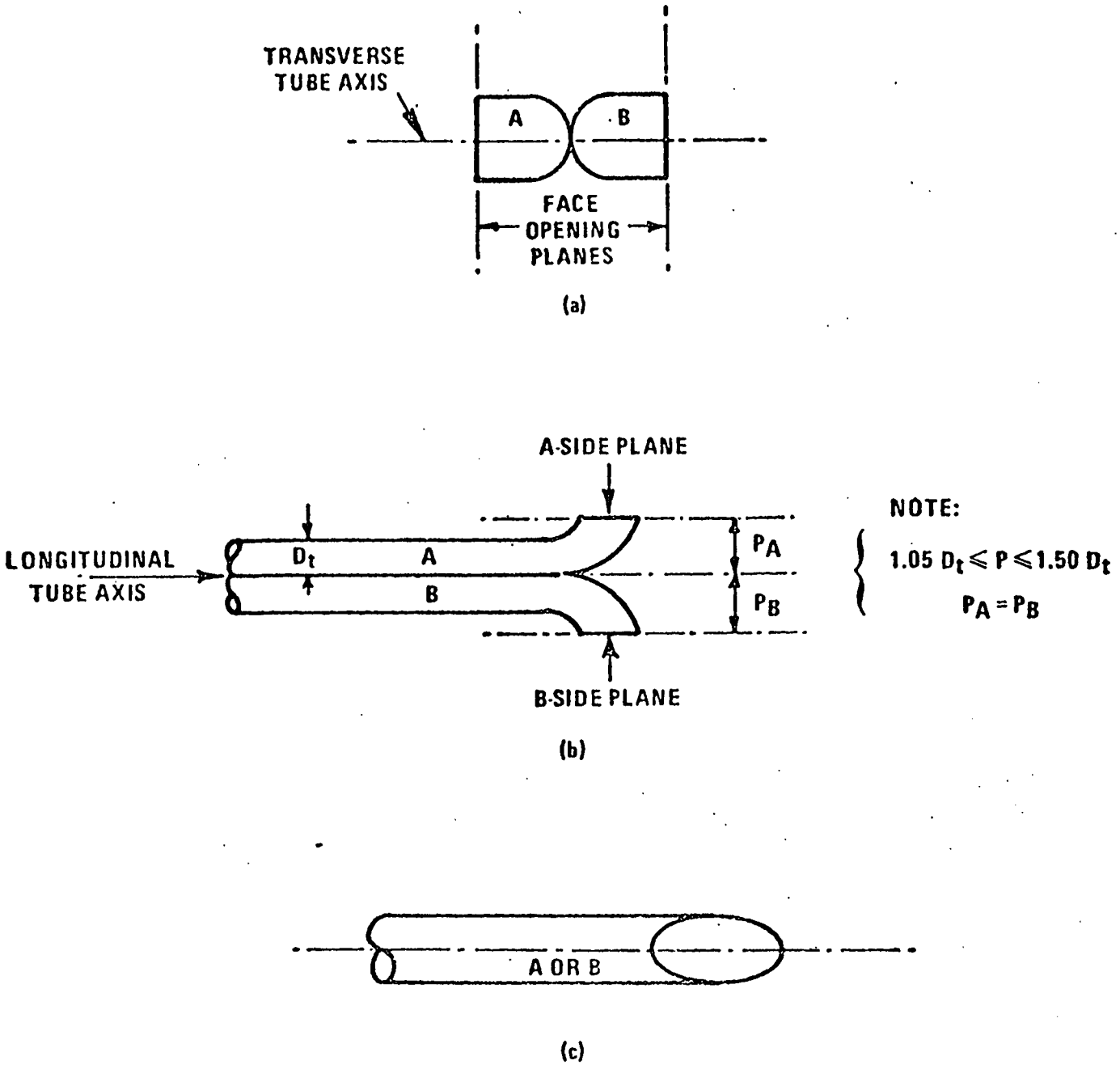


Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.

[Appendix A, Method 2]

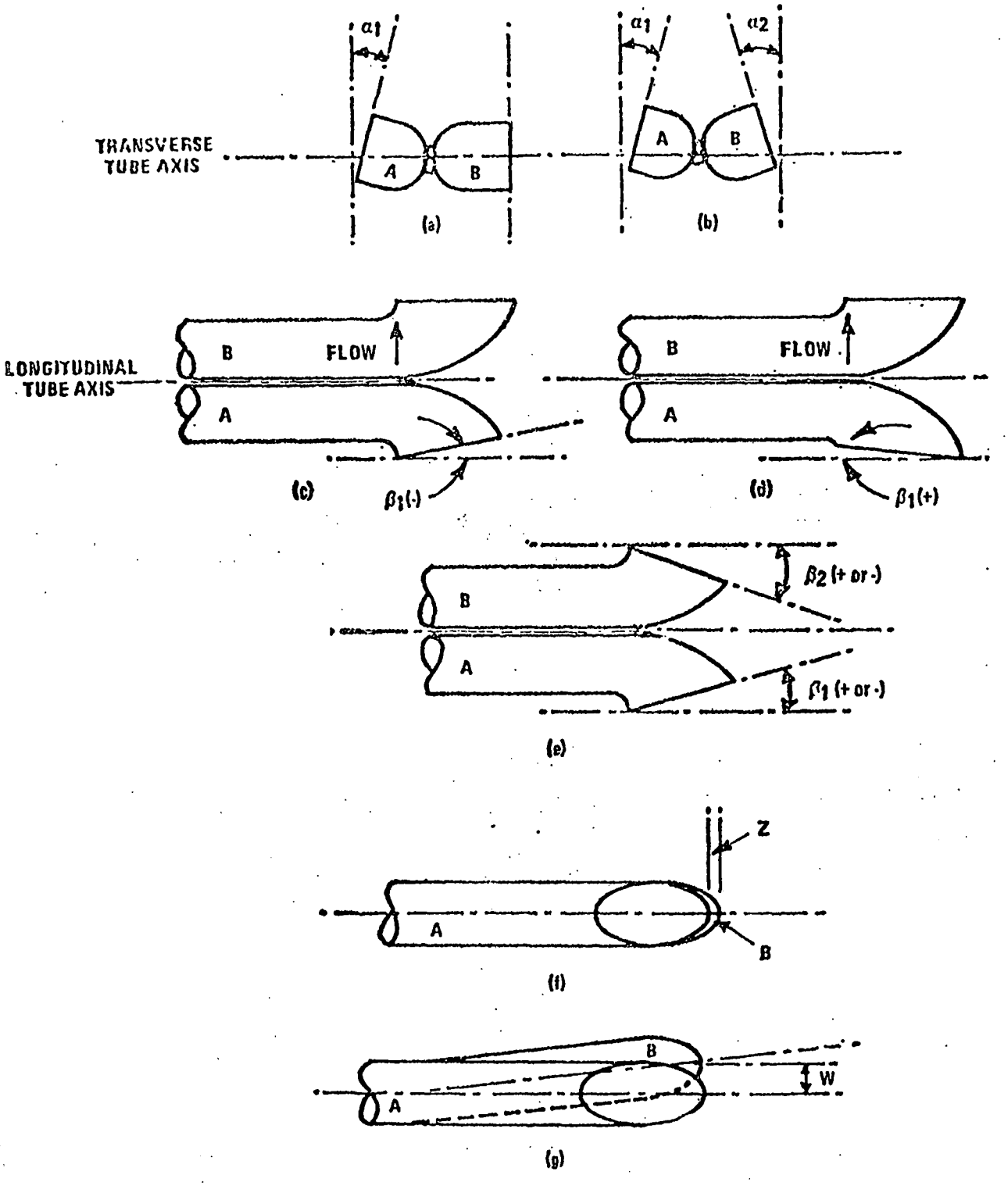


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of $\bar{C}p(s)$ so long as α_1 and $\alpha_2 < 10^o$, β_1 and $\beta_2 < 5^o$, $z < 0.32$ cm (1/8 in.) and $w < 0.08$ cm (1/32 in.) (citation 11 in Section 6).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same (+5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, having 0.01-in. H_2O divisions on the 0- to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm (0.05 in.) H_2O; (2) for traverses of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Section 6 describes commercially available instrumentation for the measurement of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gauge:

$$T = \frac{\sum_{i=1}^{n} \sqrt{\Delta p_i + K}}{\sum_{i=1}^{n} \sqrt{\Delta p_i}}$$

where:

Δp_i = Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).

n = Total number of traverse points.

K = 0.13 mm H_2O when metric units are used and 0.005 in H_2O when English units are used.

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gauge must be used.

NOTE.—If differential pressure gauges other than inclined manometers are used (e.g., magnehelic gauges), their calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare Δp readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing the range of Δp values in the stack. If, at each point, the values of Δp as read by the differential pressure gauge and gauge-oil manometer agree to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. Otherwise, the test series shall either be voided, or procedures to adjust the measured Δp values and final results shall be used, subject to the approval of the Administrator.

2.3 Temperature Gauge. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature shall be used. The temperature gauge shall be attached to the pitot tube such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the pitot tube face openings (see Figure 2-1 and also Figure 2-7 in Section 4). Alternate positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more than 1 percent in the average velocity measurement is introduced, the temperature gauge need not be attached to the pitot tube; this alternative is subject to the approval of the Administrator.

2.4 Pressure Probe and Gauge. A piezometer tube and mercury- or water-filled U-tube manometer capable of measuring stack pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard type pitot tube or one leg of a Type S pitot tube with the face opening planes positioned parallel to the gas flow may also be used as the pressure probe.

2.5 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 30-meter (100 foot) elevation increase, or vice-versa for elevation decrease.

2.6 Gas Density Determination Equipment. Method 3 equipment, if needed (see Section 3.6), to determine the stack gas dry molecular weight, and Reference Method 4 or Method 5 equipment for moisture content determination; other methods may be used subject to approval of the Administrator.

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, obtained either (1) directly from the National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.7.1 through 2.7.5 below and illustrated in Figure 2-4 (see also Citations 7, 8, and 17 in Section 6) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 Hemispherical (shown in Figure 2-4), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon D, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degree bend.

2.7.4 Static pressure holes of equal size (approximately 0.1 D), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 Differential Pressure Gauge for Type S Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For multivelocity calibrations, the gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm H_2O (1.0 in. H_2O). A special, more sensitive gauge will be required to read Δp values below 1.3 mm H_2O (0.05 in. H_2O) (see Citation 18 in Section 6).

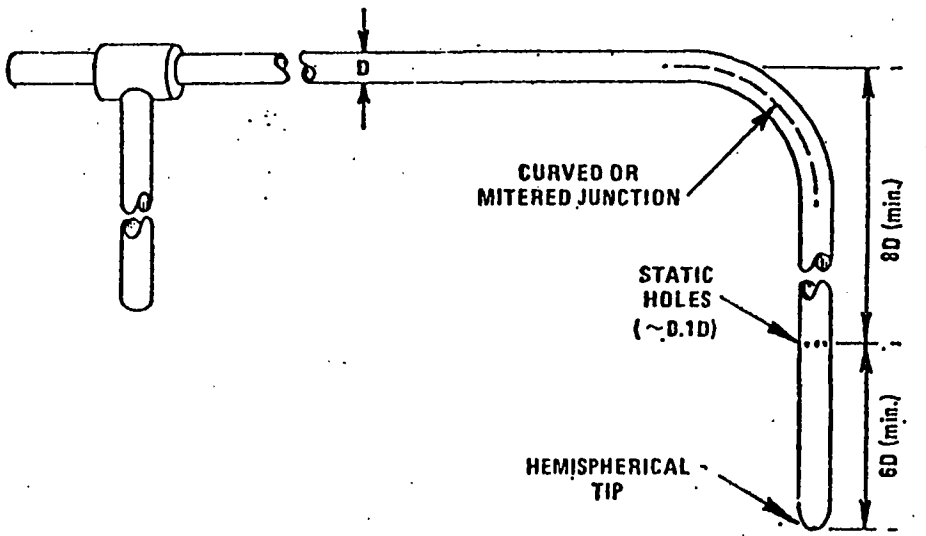


Figure 2-4. Standard pitot tube design specifications.

3. *Procedure*

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen Δp fluctuations. It is recommended, but not required, that a pretest leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 7.6 cm (3 in.) H_2O velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3 in.) H_2O. Other leak-check procedures, subject to the approval of the Administrator, may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-5).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of Δp values encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the Δp and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.

PLANT _____

DATE _____ RUN NO. _____

STACK DIAMETER OR DIMENSIONS, m(in.) _____

BAROMETRIC PRESSURE, mm Hg (in. Hg) _____

CROSS SECTIONAL AREA, $m^2(ft^2)$ _____

OPERATORS _____

PITOT TUBE I.D. NO. _____

AVG. COEFFICIENT, C_p = _____

LAST DATE CALIBRATED _____

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H_2O	Stack Temperature		P_g mm Hg (in.Hg)	$\sqrt{\Delta p}$
		t_s, °C (°F)	T_s, °K (°R)		
		Average			

Figure 2-5. Velocity traverse data.

3.6 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially CO_2, O_2, CO, and N_2, use Method 3. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 29.0. For other processes, other methods, subject to the approval of the Administrator, must be used.

3.7 Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 5.

3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.

4. *Calibration*

4.1 Type S Pitot Tube. Before its initial use, carefully examine the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment specifications.

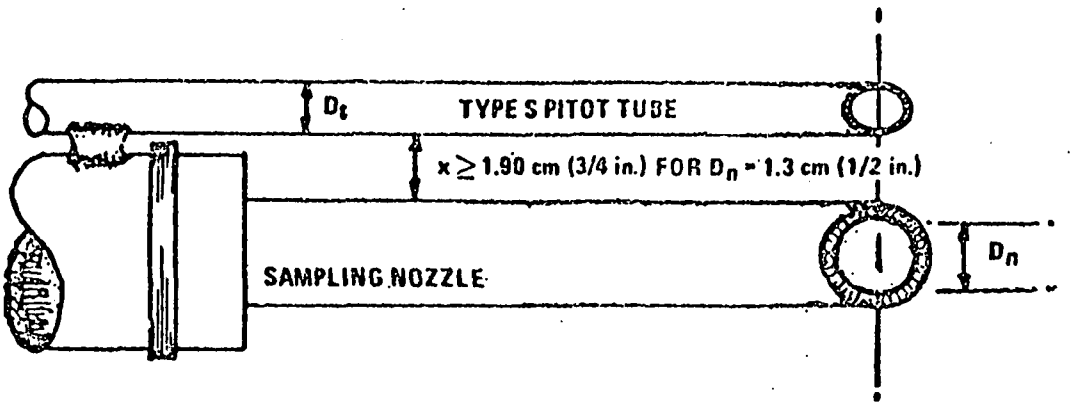
After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P_A and P_B are equal and between 1.05 and 1.50 D_t, there are two possible options: (1) the pitot tube may be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, or (2) a baseline (isolated tube) coefficient value of 0.84 may be assigned to the pitot tube. Note, however, that if the pitot tube is part of an assembly, calibration may still be required, despite knowledge of the baseline coefficient value (see Section 4.1.1).

If D_t, P_A, and P_B are outside the specified limits, the pitot tube must be calibrated as outlined in 4.1.2 through 4.1.5 below.

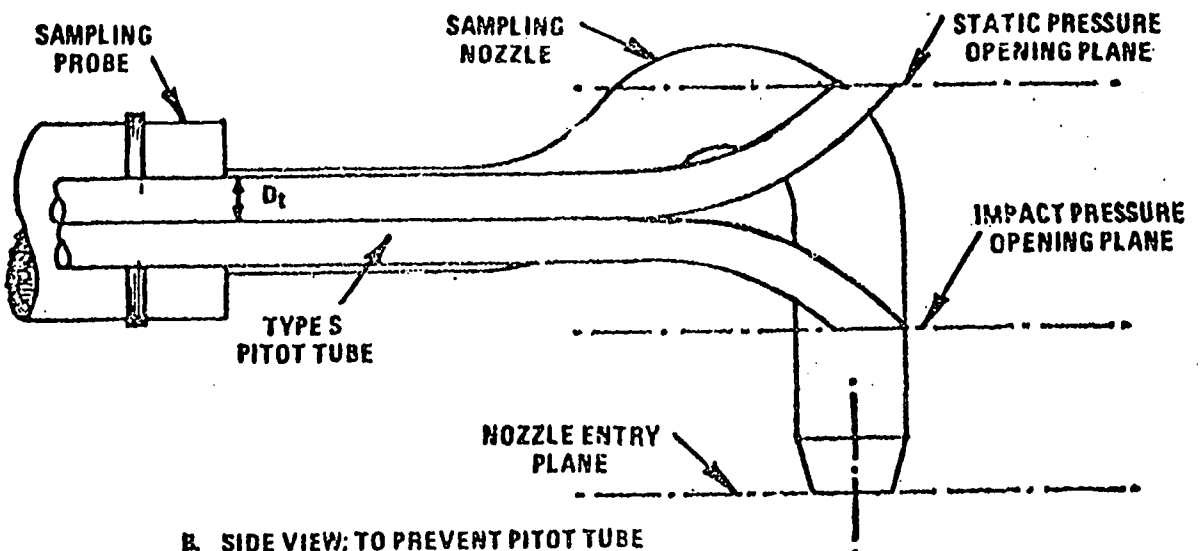
4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in Section 6); therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-6 through 2-8 illustrate interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

NOTE.—Do not use any Type S pitot tube assembly which is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the nozzle (see Figure 2-6b).

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A, and the other, B. Calibration shall be done in a flow system having the following essential design features:



A. BOTTOM VIEW; SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW; TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE, THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

Figure 2-6. Proper pitot tube - sampling nozzle configuration to prevent aerodynamic interference; buttonhook - type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

[Appendix A, Method 2]

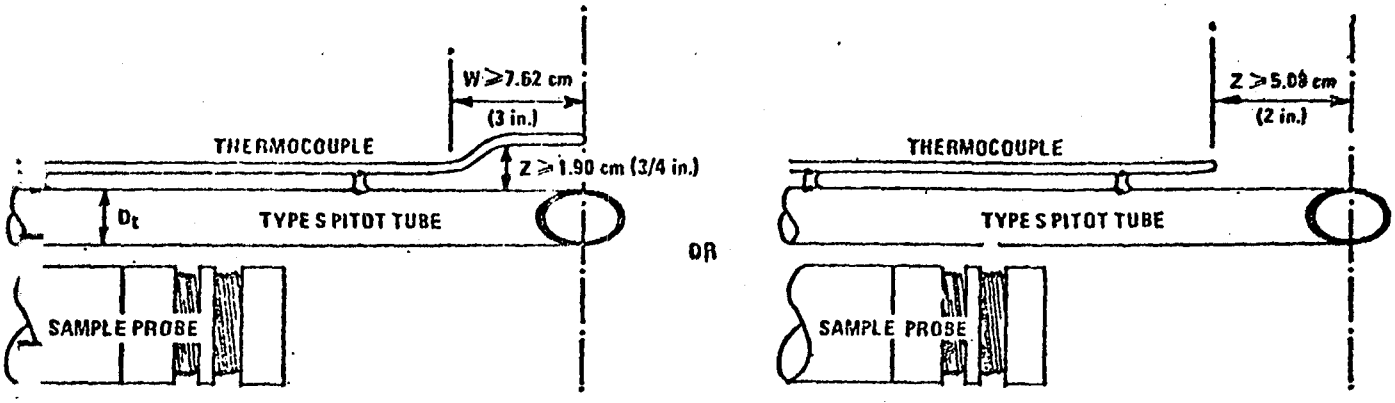


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

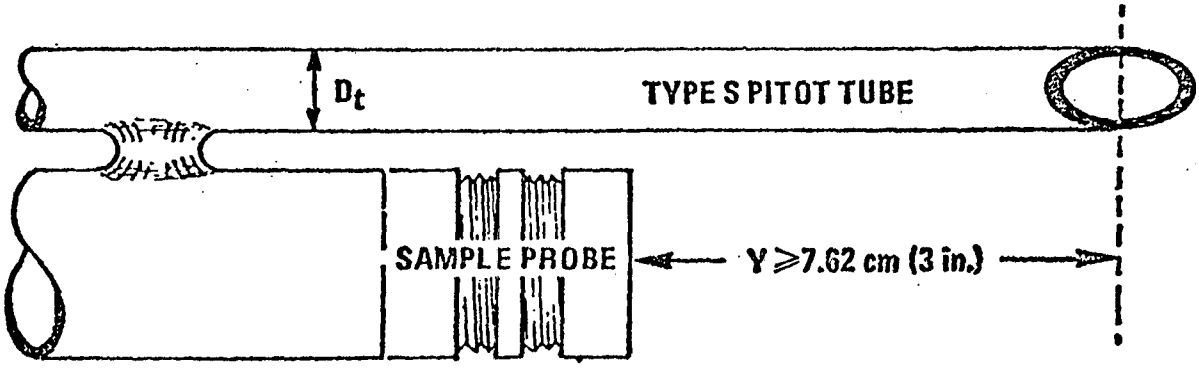


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, either circular or rectangular. For circular cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.); for rectangular cross-sections, the width (shorter side) shall be at least 25 cm (10 in.).

4.1.2.2 The cross-sectional area of the calibration duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

$$D_e = \frac{2LW}{(L+W)}$$

Equation 2-1

Where:
D_e = Equivalent diameter
L = Length
W = Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the sampling must be located at least eight diameters downstream and two diameters upstream from the nearest disturbances.

NOTE.—The eight- and two-diameter criteria are not absolute; other test section locations may be used (subject to approval of the Administrator), provided that the flow at the test site is stable and demonstrably parallel to the duct axis.

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 14 in Section 6 for details).

4.1.2.4 Two entry ports, one each for the standard and Type S pitot tubes, shall be cut in the test section; the standard pitot entry port shall be located slightly downstream of the Type S port, so that the standard and Type S impact openings will lie in the same cross-sectional plane during calibration. To facilitate alignment of the pitot tubes during calibration, it is advisable that the test section be constructed of plexiglas or some other transparent material.

4.1.3 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Make sure that the manometer is properly filled and that the oil is free from contamination and is of the proper density. Inspect and leak-check all pitot lines; repair or replace if necessary.

4.1.3.2 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.3 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.4 Read Δp_{std} and record its value in a data table similar to the one shown in Figure 2-9. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.5 Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the Type S pitot tube so that its A side impact opening is at the same point as was the standard pitot tube and is pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.6 Read Δp_A and enter its value in the data table. Remove the Type S pitot tube from the duct and disconnect it from the manometer.

4.1.3.7 Repeat steps 4.1.3.3 through 4.1.3.6 above until three pairs of Δp readings have been obtained.

4.1.3.8 Repeat steps 4.1.3.3 through 4.1.3.7 above for the B side of the Type S pitot tube.

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

4.1.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 4.1.3 above, calculate the value of the Type S pitot tube coefficient as follows:

PITOT TUBE IDENTIFICATION NUMBER: _____ DATE: _____

CALIBRATED BY: _____

	"A" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1				
2				
3				
		$\bar{C}_p$ (SIDE A)		

	"B" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1				
2				
3				
		$\bar{C}_p$ (SIDE B)		

$$\text{AVERAGE DEVIATION} = \sigma\,(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(\text{A OR B}) \right|}{3} \longleftarrow \text{MUST BE} \leq 0.01$$

$$\left| \bar{C}_p\,(\text{SIDE A}) - \bar{C}_p\,(\text{SIDE B}) \right| \longleftarrow \text{MUST BE} \leq 0.01$$

Figure 2-9. Pitot tube calibration data.

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\Delta p_{std}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tub coeficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in. H_2O)

4.1.4.2 Calculate $\bar{C}_p$ (side A), the mean A-side coefficient, and $\bar{C}_p$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\bar{C}_p$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\bar{C}_p$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \bar{C}_p(\text{A or B})$$

Equation 2-3

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(A \text{ or } B) \right|}{3}$$

Equation 2-4

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\bar{C}_p$ (A) and $\bar{C}_p$ (B) is 0.01 or less.

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

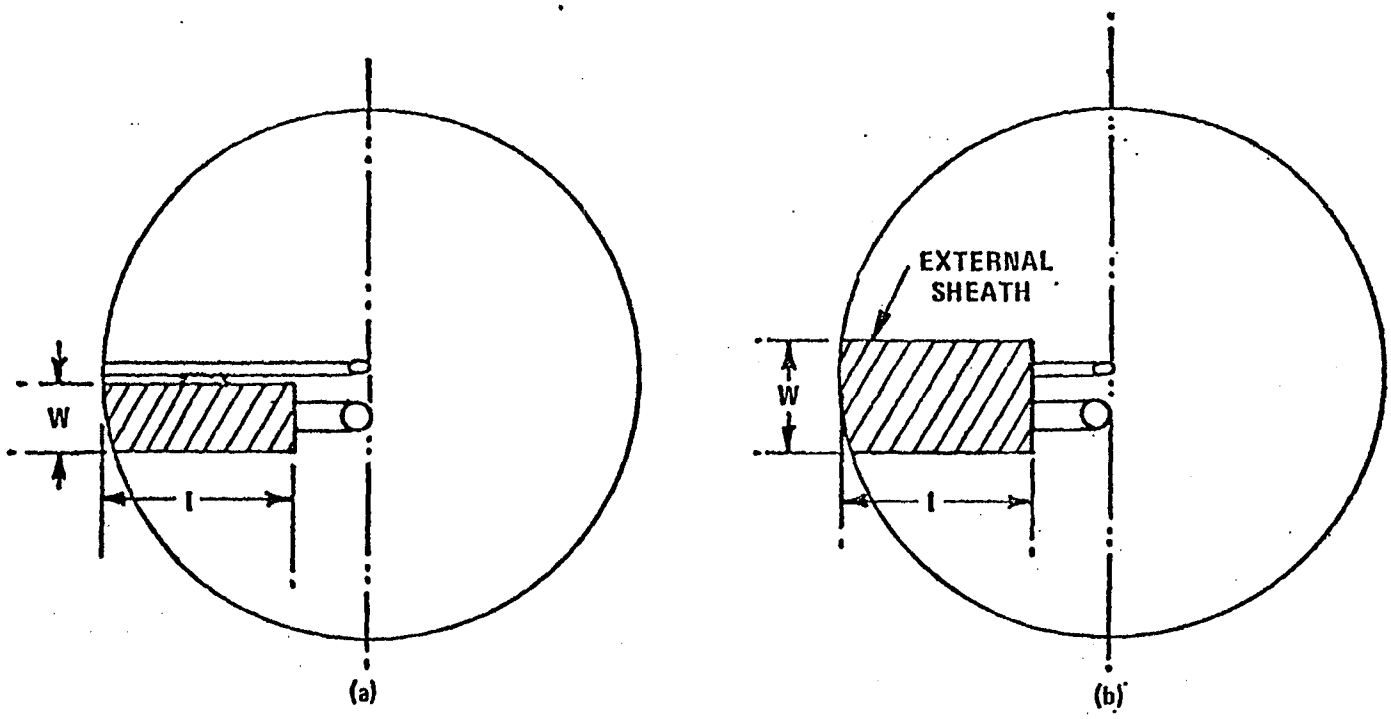
4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\bar{C}_p$ (side A) and $\bar{C}_p$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-8).

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6 and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).



$$\text{ESTIMATED SHEATH BLOCKAGE (\%)} = \left[\frac{l \times W}{\text{DUCT AREA}}\right] \times 100$$

Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

4.1.6.1.1 When a Type S pitot tube (isolated tube or assembly) is used in the field, the appropriate coefficient value (whether assigned or obtained by calibration) shall be used to perform velocity calculations. For calibrated Type S pitot tubes, the A side coefficient shall be used when the A side of the tube faces the flow, and the B side coefficient shall be used when the B side faces the flow; alternatively, the arithmetic average of the A and B side coefficient values may be used, irrespective of which side faces the flow.

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of C_p. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been damaged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

4.1.6.2.2 Pitot Tube Assemblies. After each field use, check the face opening alignment of the pitot tube, as in Section 4.1.6.2.1; also, remeasure the intercomponent spacings of the assembly. If the intercomponent spacings have not changed and the face opening alignment is acceptable, it can be assumed that the coefficient of the assembly has not changed. If the face opening alignment is no longer within the specifications of Figures 2-2 or 2-3, either repair the damage or replace the pitot tube (calibrating the new assembly, if necessary). If the intercomponent spacings have changed, restore the original spacings or recalibrate the assembly.

4.2 Standard pitot tube (if applicable). If a standard pitot tube is used for the velocity traverse, the tube shall be constructed according to the criteria of Section 2.7 and shall be assigned a baseline coefficient value of 0.99. If the standard pitot tube is used as part of an assembly, the tube shall be in an interference-free arrangement (subject to the approval of the Administrator).

4.3 Temperature Gauges. After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple-potentiometer systems, and other gauges at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405° C (761° F), use an ASTM mercury-in-glass reference thermometer, or equivalent, as a reference; alternatively, either a reference thermocouple and potentiometer (calibrated by NBS) or thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure) may be used. For temperatures above 405° C (761° F), use an NBS-calibrated reference thermocouple-potentiometer system or an alternate reference, subject to the approval of the Administrator.

If, during calibration, the absolute temperatures measured with the gauge being calibrated and the reference gauge agree within 1.5 percent, the temperature data taken in the field shall be considered valid. Otherwise, the pollutant emission test shall either be considered invalid or adjustments (if appropriate) of the test results shall be made, subject to the approval of the Administrator.

4.4 Barometer. Calibrate the barometer used against a mercury barometer.

5. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

5.1 Nomenclature.

A = Cross-sectional area of stack, m² (ft²).

B_{ws} = Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

$$34.97 \frac{\text{m}}{\text{sec}} \left[\frac{(g/g\text{-mole})(\text{mm Hg})}{(°\text{K})(\text{mm H}_2\text{O})}\right]^{1/2}$$

for the metric system and

$$85.49 \frac{\text{ft}}{\text{sec}} \left[\frac{(\text{lb/lb-mole})(\text{in. Hg})}{(°\text{R})(\text{in. H}_2\text{O})}\right]^{1/2}$$

for the English system.

M_d = Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).

M_s = Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

$$= M_d(1 - B_{ws}) + 18.0\, B_{ws} \qquad \text{Equation 2-5}$$

P_{bar} = Barometric pressure at measurement site, mm Hg (in. Hg).

P_g = Stack static pressure, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

$$= P_{bar} + P_g \qquad \text{Equation 2-6}$$

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

Q_{sd} = Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).

t_s = Stack temperature, °C (°F).

T_s = Absolute stack temperature, °K (°R).

$$= 273 + t_s \text{ for metric} \qquad \text{Equation 2-7}$$

$$= 460 + t_s \text{ for English} \qquad \text{Equation 2-8}$$

T_{std} = Standard absolute temperature, 293°K (528° R)

v_s = Average stack gas velocity, m/sec (ft/sec).

Δp = Velocity head of stack gas, mm H_2O (in. H_2O).

3,600 = Conversion factor, sec/hr.

18.0 = Molecular weight of water, g/g-mole (lb-lb-mole).

5.2 Average stack gas velocity.

$$v_s = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

$$Q_{sd} = 3{,}600(1 - B_{ws}) v_s A \left(\frac{T_{std}}{T_{s(avg)}}\right)\left(\frac{P_s}{P_{std}}\right)$$

Equation 2-10

6. *Bibliography*

1. Mark, L. S. Mechanical Engineers' Handbook. New York, McGraw-Hill Book Co., Inc. 1951.

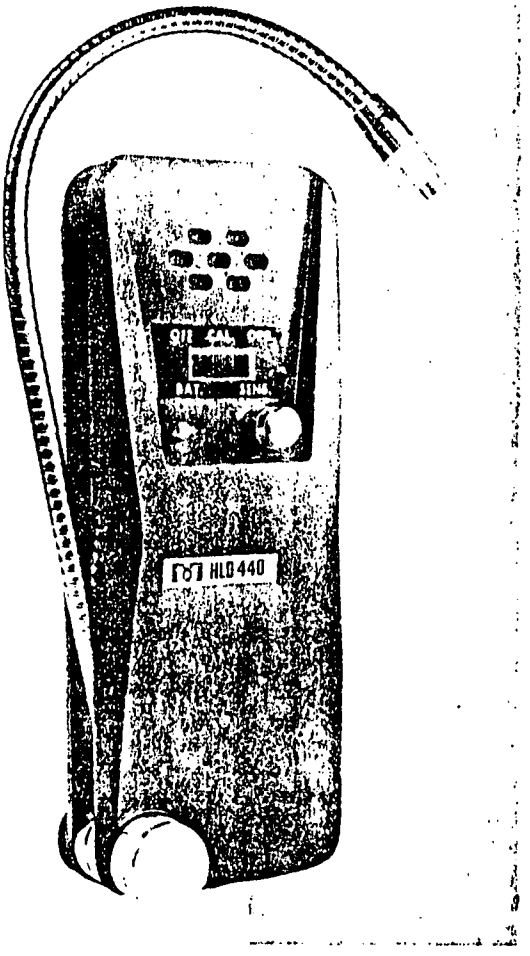
2. Perry, J. H. Chemical Engineers' Handbook. New York. McGraw-Hill Book Co., Inc. 1960.

MANUFACTURERS SUPPLIED

INFORMATION

HLD-440

HALOGEN LEAK DETECTOR



HLD 440
Halogen Leak Detector
operating instructions

GENERAL DESCRIPTION

This instrument is a portable, battery-operated, electronic halogen gas detector. It is capable of finding leaks as small as ½ ounce per year; as well as large leaks in areas where background contamination may be present.

The instrument provides a "Geiger Counter" ticking signal which increases as the leak is approached. When the leak has been found, a siren is sounded.

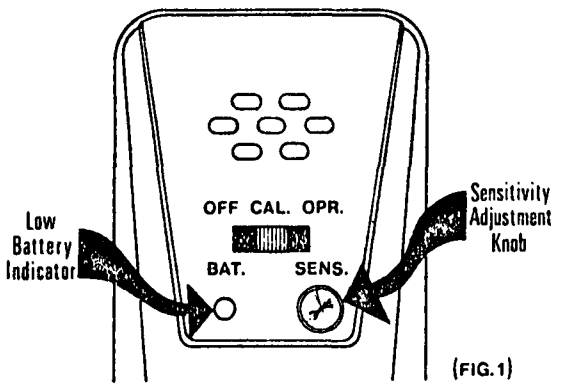
No danger exists when approaching a large refrigerant leak with the leak detector. Unlike a gas torch, dangerous or poisonous gases are not generated. The sensing tip is not affected by large amounts of refrigerants as are vacuum-type halogen gas detectors. Recovery time after the probe is removed from a contaminated area is instantaneous.

Requiring no warm-up period, the instrument is ready to use following a simple calibration procedure. It is equipped with a dual length flexible probe which can be bent to permit the sensing tip at the end of the probe to reach normally inaccessible leaks.

A low battery indicator light is also provided, so that your leak detector is kept in top working condition at all times.

HOW TO FIND LEAKS

1) Move slide switch to CALIBRATE position. ***(Figure 1)***
2) Calibrate by turning the knob until ticking signal is heard.
3) Move switch to OPERATE position.
4) Search for leaks.
5) When a small trace of halogen refrigerant enters the sensing tip, the "Geiger Counter" ticking signal quickens. As more gas enters the tip, the signal speeds up until it becomes a siren.



(FIG. 1)

SEARCHING FOR LARGE LEAKS OR IN CONTAMINATED AREAS

1) In areas of high background contamination and/or large leaks, if the siren alarm sounds before the leak source can be located, your leak detetor can be de-sensitized. Turn the control knob counter-clockwise slowly until the siren alarm returns to a ticking signal. Now a large leak can be located despite any background contamination which might be present.
2) In windy areas, a large leak can be extremely difficult to find, because the escaping gas is rapidly carried away from the leak source. Under these conditions, it may be necessary to shield the potential leak area.

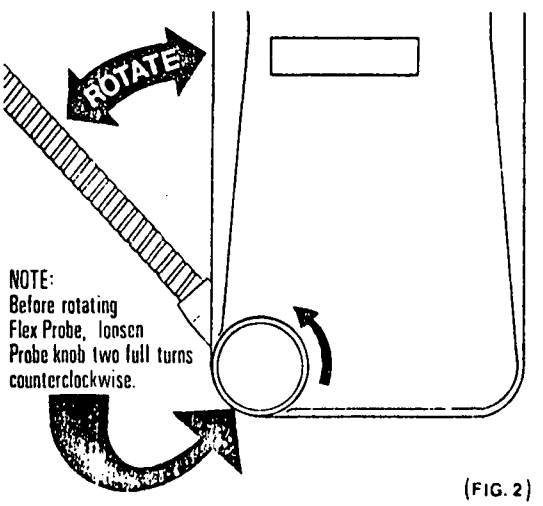
NOTE: It may **not** be necessary to readjust calibration knob each time the unit is turned on. Simply move switch directly to operate position.

SEARCHING FOR SMALL LEAKS

1) In a situation when large leaks mask the presence of very small leaks, locate and repair large leaks first. Finding the small leaks will then become an easy task.
2) When trying to locate a very "hard to find leak", first isolate potential leak area with a drop cloth, etc. Wait a few minutes and probe the shielded area. Continue this practice until all suspected areas have been checked.
3) When searching for ULTRA small leaks, you may wish to leave the instrument's slide switch in the CALIBRATE position. In this position, due to the extreme sensitivity, a slight variation in the ticking signal may be noticed.

OTHER LEAK DETECTION TECHNIQUES

1) When the knob (Figure 2) in the lower corner of the instrument is loosened, the flexible probe is free to move 180°. This is especially useful when searching in normally inaccessible areas.
2) In areas where background noise is a problem, you may want to use the earphone accessory available for your leak detector.
3) It is important to remember that halogen gases are heavier than air. The first indication of the presence of halogen gases may be slightly below the actual leak source.
4) When searching for leaks, the sensing probe should be moved at a rate of approximately one inch per second.



(FIG. 2)

MAINTENANCE HINTS

1) To install batteries, remove the battery cover on the back of the instrument. Be sure to install batteries as indicated in the battery compartment.
2) Batteries effect performance. When your leak detector is turned on, the red battery indicator should be lit. If the red light is not on, install fresh and/or tested Size "C" Alkaline batteries. Remember, cold temperatures will effect battery strength.
3) If the red light is on, and the unit fails to operate properly, turn instrument off and replace the sensing tip*. If the unit still does not function correctly, return it to the factory for repairs.
4) If the ticking signal is erratic or a continuous siren is heard, the sensing tip should be replaced.
5) Minimize tip contamination from dust and grease by utilizing the tip protector and filter cloth.
6) **Always be sure your instrument is off when changing tips.** To change the sensing tip, turn the tip counter-clockwise. Attach a new tip by turning clockwise on the connector. Do not operate your leak detector until the sensing tip is screwed on finger tight. Use care not to catch perspiration, or grease such as hand cleaner in the slots, while attaching the tip.

***NOTE: The battery voltage is amplified in the sensing tip. Failure to turn the instrument off when changing tips will result in a mild shock when the tip is touched.**

REMEMBER: This leak detector is an electronic instrument. If you treat it with care, it will provide you with years of trouble-free operation.

PARTS LIST

SENSING TIP	Part #HLD 441
SENSING TIP PROTECTOR	Part #HLD 442
REFERENCE LEAK BOTTLE	Part #HLD 443
FILTER CLOTHS	Part #HLD 444
MAINTENANCE KIT	Part #HLD 445

MAINTENANCE KIT CONTAINS:

2 SENSING TIPS
3 SENSING TIP PROTECTORS
12 FILTER CLOTHS

ACCESSORIES:

EARPHONE ACCESSORY	Part #HLD 446
CARRYING CASE	Part #HLD 447

SPECIFICATIONS

1.	POWER SUPPLY:	Two, Size "C" Alkaline Batteries
2.	SENSITIVITY:	One-half Ounce per year
3.	OPERATING TEMPERATURE RANGE:	33° - 100°F
4.	BATTERY LIFE:	Approximately 40 hours, normal usage
5.	DUTY CYCLE:	Continuous, no limitation
6.	RESPONSE TIME:	Instantaneous
7.	WARM-UP TIME:	Instantaneous
8.	WEIGHT:	28 ounces (with batteries)
9.	DIMENSIONS:	8" x 3" x 1.8"
10.	PROBE LENGTH:	12.5"

WARRANTY AND REPAIR/EXCHANGE POLICY

This instrument is designed and produced to provide unlimited service. Should the unit be inoperative after the user has performed the recommended maintenance*, a no-charge, repair or replacement will be made to the original purchaser. This applies to all repairable instruments which have not been tampered with or damaged. The claim must be made within one year from the date of purchase. Repairable instruments, out of warranty, will be repaired or replaced for a service charge not exceeding $20.00 plus transportation costs to and from our plant. An additional 90 day warranty will cover the repaired or replaced unit.

*Recommended maintenance: Failure to change batteries and sensing tip will result in an $8.00 maintenance charge.

APPENDIX C

GAS CALIBRATION CERTIFICATION

Scott Environmental Technology Inc.

Plumsteadville, PA 18949
(215) 766-8861

Madison Heights, MI 48071
(313) 544-0625

San Bernardino, CA 92411
(714) 887-2571

SPECIALTY GAS DIVISION

TRW
Attn: Bob Jangleau
800 Follin Lane
Vienna, VA 22180

Date: April 10, 1979
Our Project No.: 306601
Your P.O. No.: H 08503

Gentlemen:

Thank you for choosing Scott for your Specialty Gas needs. The analyses for the gases ordered, as reported by our laboratory, are listed below. Results are in volume percent, unless otherwise indicated.

ANALYTICAL REPORT

Cyl. No. C-1414 — Analytical Accuracy ±2%

Component	Concentration
TETRACHLORO ETHYLENE	45.7 ppm
AIR	BALANCE

Cyl. No. C-1682 — Analytical Accuracy ±2%

Component	Concentration
TETRACHLORO ETHYLENE	92.8 ppm
AIR	BALANCE

Cyl. No. C-1560 — Analytical Accuracy ±2%

Component	Concentration
TETRACHLORO ETHYLENE	473 ppm
AIR	BALANCE

Cyl. No. _____ — Analytical Accuracy _____

Component	Concentration

Analyst FRANCIS NEVILL

Approved By ROBERT DENYSZYN

The only liability of this Company for gas which fails to comply with this analysis shall be replacement thereof by the Company without extra cost.