AUG 07 1998

STATION 4 (25)

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 622241

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) TWRS Projects/SST Retrieval	4. Related EDT No.: n/a
5. Proj./Prog./Dept./Div.: D2991 W-320 TWRS/TCPN # ~~D2MA1~~	6. Design Authority/ Design Agent/Cog. Engr.: JW Bailey, NHC	7. Purchase Order No.: n/a
8. Originator Remarks: For approval and release of a new supporting document. This document has been generated to ensure retrievability of the Project W-320 "HVAC Calculations, Vol. 1".		9. Equip./Component No.: n/a 10. System/Bldg./Facility: 241-C-106
11. Receiver Remarks: 11A. Design Baseline Document? [X] Yes [] No		12. Major Assm. Dwg. No.: n/a 13. Permit/Permit Application No.: n/a 14. Required Response Date:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-2483	-	0	Project W-320, 241-C-106 Sluicing, HVAC Calculations, Vol. 1	NA			-

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
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(G) Reason	(H) Disp.	(J) Name (K) Signature (L) Date (M) MSIN	(G) Reason	(H) Disp.	(J) Name (K) Signature (L) Date (M) MSIN
2	1	Design Authority JW Bailey 7/25/98 S2-48			
		Design Agent MC Davenport 7/25/98			
2	1	Cog.Eng. ~~CE Graves~~ S2-48			
2	1	Cog. Mgr JW Bailey 7/25/98 S2-48			
		QA			
		Safety			
		Env.			

18. MC Davenport ~~C.E. Graves~~ ~~3/24/98~~ 7/25/98 Signature of EDT Originator Date	19. Authorized Representative Date for Receiving Organization	20. J.W. Bailey ~~3/24/98~~ 7/25/98 Design Authority/ Cognizant Manager Date	21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

BD-7400-172-1

S

Project W-320, 241-C-106 Sluicing HVAC Calculations, Vol. 1

John W. Bailey
Numatec Hanford Co., Richland, WA 99352
U.S. Department of Energy Contract DE-AC09-96RL13200

EDT/ECN: 622241 UC: 506
Org Code: 8C452 Charge Code: D2991/HANA0600
B&R Code: EW3130010 Total Pages: 153

Key Words: W-320, Sluicing, Tank 241-C-106, Tank 241-AY-102, WRSS, calculations, HVAC.

Abstract: This supporting document has been prepared to make the FDNW calculations for Project W-320, readily retrievable.

Kara M Broz 8/7/98
Release Approval Date

AUG 07 1998
DATE: HANFORD RELEASE
STA: 4 ID: 25
Release Stamp

Approved for Public Release

Cover sheet page 1 of 2

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Application approved by:

Name: Thomas P Hamilton **Date:** 7/30/98

Company Name: NEW YORK BLOWER **Signatory's Position:** NAT'L SALES MGR

Signature: Thomas P Hamilton **(on behalf of)** NYB

A-6000-237 (05/97) WEF220

HNF-2483, Rev 0
Cover Sheet
page 2 of 2

Project W-320, 241-C-106 Sluicing HVAC Calculations, Vol. 1

TABLE OF CONTENTS

W320-28-001

Exhaust Airflow Sizing for Tank 241-C-106

	CALCULATION IDENTIFICATION AND INDEX	Page i of i Date 3-28-95

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. W320-28-001

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item Exhaust Airflow Sizing for Tank 241-C-106

These calculations apply to:

Dwg. No. H-2-818468 HVAC Overall Flow Diagram C-106 Rev. No. draft 21, 3-17-95

Dwg. No. H-2-818479 HVAC Energy Balance Rev. No. draft 2, 3-21-94

Other (Study, CDR) N/A Rev. No. N/A

The status of these calculations is:

[] Preliminary Calculations

[x] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [x] No

This calculation verified by independent "check" calculations? [] Yes [x] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	superceeded by revision 1. 11/29/93 PH LANGOWSKI	PH Langowski 3-28-95	
Checked by	T.O. LOONEY 12/1/93	[signature] 3/31/95	
Approved by	RW DAVIDSON 12/8/93	PH Langowski 4-3-95	
Checked Against Approved Vendor Data		Charles T. Li 4/10/98	

INDEX

Design Analysis Page No.	Description
i	Calculation Identification and Index
1	Objective, Design Inputs
2-4	Calculations
5	Findings & Conclusions
A1-A10	Appendix A
B1-B8	Appendix B

KEH 0378.00 (06/92) KEF072

DESIGN ANALYSIS

		Calc. No. W320-28-001
		Revision 1
		Page No. 1 of 5
Client WHC	WO/Job No. ER4319	
Subject W-320 Exhaust Airflow Sizing for Tank 241-C-106	Date 3/28/95	By PH Langowski
	Checked 3/31/95	By R. Pina
Location 241-C Farm, 200 East	Revised	By

1.0 OBJECTIVE

The objective of this calculation is to determine the range of exhaust airflow design values required for Tank 241-C-106 during active sluicing retrieval operations.

2.0 DESIGN INPUTS

2.1 CRITERIA AND SOURCE

DOE General Order 6430.1A
Functional Design Criteria WHC-SD-W320-FDC-001, rev. 2, 1-18-94

2.2 GIVEN DATA

- none

2.3 ASSUMPTIONS

- Assumed C-106 tank minimum operating pressure of -2.00" water gauge (w.g.). This assumes that the operating pressure setpoint will be approximately -1.50" w.g. with a range of control that would limit the minimum pressure to -2.00" w.g. under normal operating conditions. Operating pressure setpoint is stated as -1.50" w.g. on ref. 6.

- Assumed the C-105 airspace temperature is equal to 80F and a vaporspace pressure of -1.00" water gauge due to continuing radiolytic heat input. C-105 was formerly designated a high-heat watchlist tank and is estimated to have between 20,000 and 25,000 Btu/h of radiolytic heat generation in January, 1991 per Figure 12 of ref. 3 (see Appendix A). The thermal analysis shows that the temperature in C-105 may reach 120F if the ventilation is ceased. With a C-105 ventilation rate of approximately 1,000 cfm at a tank pressure of -1.0" water gauge (similar to actual conditions on 2/5/91 data), the tank average annual air temperature should be approximately 80F.

- Assumed a maximum infiltration rate of 250 scfm into tank C-106 through the three existing pits with cover blocks and the additional riser flanges. Actual infiltration will be less with the installation of the sealing tape from the W-030 project and proper operating procedures. This assumes that the three cover blocks currently in place on C-106 are replaced with new cover blocks which will have covers for all penetrations (2" valve handle holes and others) through the cover blocks. The design of new, low-infiltration cover blocks is the current design assumption and design philosophy. Psychrometric data from DST's AW, AN, and AP (see Appendix A) shows that 250 scfm is a reasonable assumption for the maximum infiltration through the three existing cover blocks.

2.4 METHODS

Hand calculations and Excel spreadsheet using ASHRAE formulae.

DESIGN ANALYSIS

Client WHC
Subject W-320 Exhaust Airflow Sizing for Tank 241-C-106
Location 241-C Farm, 200 East

WO/Job No. ER4319
Date 3/28/95 By PH Langowski
Checked 3/31/95 By R. Pino
Revised By

2.5 REFERENCES

1. WHC-SD-WM-ANAL-012, Rev. 1, "Flow Analysis for Single Shell Tanks", p. 2
2. W320ER1.TD.395, "Tank 241-C-106 Sluicing Tank Farm Riser Usage and Pit Modifications," 9/93.
3. WHC-SD-WM-ER-189, Rev. 0, "Thermal Analysis of Tank 241-C-105 in Support of Process Test," Figure 12, January 1993.
4. WHC-EP-0651, Rev. 0, "Barometric Pressure Variations," June 1993.
5. W320-H-011, Rev. 0, "Exhaust Skid Stack Sizing and Fan Sizing"
6. H-2-818468, draft 21, 3-17-95, "Overall Flow Diagram C-106"
7. HW-72743, Rev. 19, "75'-0" Dia Storage Tanks Arrangements"
8. ASHRAE Fundamentals 1993

3.0 CALCULATIONS

The total airflow into Tank 241-C-106, and hence, the total exhaust flowrate from C-106 is estimated to be made of two components: 1) the infiltration through the three pit cover blocks and into the pit drains and infiltration through riser flanges outside of the pits on Tank C-106, and; 2) the inflow through the 3" cascade line which connects tank C-106 to tank C-105.

3.1 Infiltration

Riser Study ref. 2 (see Appendix A) details the current existing risers on Tank C-106. There are fourteen risers listed on the summary, seven of which are located inside the three pits. Of the remaining seven, one is covered with dirt and could be assumed sealed airtight. Of the remaining six, there are four 4" and two 12" risers. It is expected that all three existing pits on C-106 will have large openings into the tank and that the pit cover blocks will be the limiting infiltration path. No new risers are currently planned to be constructed under W-320. The existing 3" floor drains in the three existing pits are not planned to be used after W-320 construction. The risers through which the pumps are inserted are planned to have perforated spacer rings which will provide a large drain opening to the tank. This large opening is thought to be required based on the accident scenario of 350 gpm spilling into the pit.

A calculation of infiltration into the C-106 tank with the equipment installed in the risers is severely dependent on the crack width assumptions used on each riser flange and on the pit cover blocks. This calculation was not undertaken due to it's inherent low reliability. The maximum 250 scfm infiltration rate for a 75' diameter tank with three pits is based on psychrometric data from existing DST's (see Appendix A) which showed a wide range of airflows, generally in the 100 to 200 cfm range, but with a few big exceptions. DST's generally have at least twice as many risers as SST's. The high end of the general range of the DST infiltration data was used.

The W-320 design assumes that the pit cover blocks are sealed so that the size of the drains in the pits is unimportant. This would yield infiltration rates near zero with only the purge air used for the FIC, purge air for the pressure transmitter PIT-1361 at Hatchway Riser R-15, the CCTV purge air, and the infiltration through the riser flanges on risers located outside of the pits or through penetrations in the pit cover blocks as contributors. This is a partially unrealistic assumption. Even if the pits are

DESIGN ANALYSIS

Client WHC
Subject W-320 Exhaust Airflow Sizing for Tank 241-C-106
Location 241-C Farm, 200 East

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Checked 3/31/95 By R. Pina
Revised By

sealed there will be times when the seals are broken for maintenance of items in the pits, or infiltration due to lack of maintenance of the seals themselves. The 250 scfm maximum infiltration assumption should prove conservative. For calculations where a normal operating flow rate is specified, 170 scfm shall be used.

The ref. 1 flow analysis report (see Appendix A) discusses infiltration rates into single shell tanks for various combinations of risers, pit drains, and pressures. For 2" w.g. pressure drop, the following infiltration rates were calculated: 23 cfm for a tank with sealed pits; 425 cfm for a tank with cover blocks off and pit drains sealed 50%; 819 cfm for a tank with cover blocks off and pit drains 100% open; and, 2819 cfm for a tank with an open inlet filter and 100% open pit drains. Pit drains are the standard 3" drains in the flow analysis report. The 250 scfm maximum infiltration assumption is reasonable in this context.

3.2 Inflow Through Cascade Line

The airflow through the 3" (ref. HW-72743 see Appendix B) cascade line of approximately 30' length from C-105 is calculated by assuming a delta pressure drop along the cascade line. Thirty feet of pipe with a 2" w.g. delta pressure drop would require a pressure drop of approximately (2")(100'/30')=6.67" w.g. per 100' of pipe and require a substantial velocity. The entrance and exit losses should not be neglected at these high velocities.

The C-105 entrance is a 4" schedule 80 pipe on the OD with the 3" cascade line inside overhanging the sidewall of the tank by 12". The C-106 exit side is the 3" cascade line overhanging the tank by 4' (see ref. 7). ASHRAE Fundamentals 1993 fitting ED1-1 was assumed to model the entrance in C-105(See Appendix B). Using Schedule 80 pipe data (see Appendix B), For C-105: 2t=4.5"-2.9"=1.6", so t=0.8"; L=12"; D=2.9"; t/D=0.8/2.9=0.276; L/D=12/2.9=4.14; from the table C_o=0.50. The exit in C-106 can use C_o=1.00 since the airstream decelerates to zero velocity.

Appendix B contains a simple Excel spreadsheet which proved useful in iterating in on an airflow with a given delta pressure. ASHRAE Fundamentals (ref. 8) equations as listed on the spreadsheet were used to calculate friction factors and pressure loss through the piping. The entrance and exit losses which are dependent on velocity pressure are also included. The spreadsheet shows that a normally expected cascade airflow of 60 scfm of 80F air can be expected at 0.5" w.g. total pressure drop between the two tanks. The same spreadsheet yielded 103 scfm of 120F air and 108 scfm of 80F air at 1.5" w.g. total pressure drop simulating the case of C-105 not being ventilated. 110 scfm shall be used as the maximum cascade line airflow.

3.4 Minimum Airflow

DOE Order 6430.1A, para. 1550-99.0.3 "Offgas Systems", states that "the design of process confinement off-gas treatment systems shall preclude the accumulation of potentially flammable quantities of hydrogen generated by radiolysis or chemical reactions within process equipment." Review of SY-101 hydrogen generation was undertaken to investigate an assumed worst case. Scaling down an estimated 241-SY-101 steady-state hydrogen generation rate of 2.24 scfh based on total mass yields a C-106 steady-state hydrogen generation rate of 0.33 scfh. To operate safely below the lower

DESIGN ANALYSIS

Client WHC
Subject W-320 Exhaust Airflow Sizing for Tank 241-C-106
Location 241-C Farm, 200 East
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Checked 5/31/95 By T. Pina
Revised By

explosive limit only 1 scfm need be exhausted. The W-030 flammability calculations yielded a 3 scfm fresh air sweep requirement. The W-320 airstream characterization lists no flammable components.

Minimum airflow for infiltration should address the tank breathing rate due to changes in atmospheric pressure. Barometric Pressure Variation Report ref. 4 (see Appendix A) analyzes data for 1988-1991 as measured at the Hanford Weather Station located between 200E and 200W. The report presents the average breathing rate as 0.005639 inches of mercury per hour. It also presents hourly swing data. The largest value which occurred through the four year data collection is 0.12 inches of mercury per hour. The report presents annual average barometric pressures ranging from 29.22 to 29.26 inches mercury. The thirty year average for 1950 to 1980 is presented as 29.21 inches of mercury.

Assuming ideal conditions, the % volume change in one hour would be:

0.005639/29.21 = 0.0193% volume change per hour (average)
0.12/29.21 = 0.41% volume change per hour (maximum)

A 530,000 gallon single shell tank consists of a 75' diameter cylinder which is 18' tall, a 12' tall dome, and a 1' deep dished bottom. The total tank volume would be:

cylinder: (pi*75*75/4)(18) = 79,522 cubic feet
dish: approximately (pi*75*75/4)(0.5) = 2,209 cubic feet
dome: approximately pi*75*75*12/8 = 26,507 cubic feet (paraboloid)

The total tank volume (neglecting any waste in the tank) is approximately:

79,522 + 2,209 + 26,507 = 108,238 cubic feet

At the average hourly volume change this yields:

(0.000193 volume/hour)(108,238 cubic feet)(1 hour/60 minutes) = 0.35 cfm

At the maximum hourly volume change this yields:

(0.00411 volume/hour)(108,238 cubic feet)(1 hour/60 minutes) = 7.4 cfm

The maximum flowrate of 7.4 cfm is the most that could be expected through infiltration due to pressure variations.

The minimum airflow requirement to properly operate the high pressure blower exhaust fan may prove to be a concern when detailed selection of fan and controls is undertaken. Calculation ref. 5, lists a potential fan for consideration. The fan should be able to operate down at any reduced airflows below the 180 scfm minimum sizing range since a radial high pressure blower can function down to shut-off routinely.

KEH 0037.00 (06/92) KEF055

DESIGN ANALYSIS

Client WHC
Subject W-320 Exhaust Airflow Sizing for Tank 241-C-106
Location 241-C Farm, 200 East

WO/Job No. ER4319
Date 3/28/95 By PH Langowski
Checked 3/31/95 By R. Pim
Revised By

4.0 FINDINGS & CONCLUSIONS

The total maximum exhaust airflow is the sum of the 250 scfm infiltration airflow, and the 110 scfm cascade line flow. This yields a total maximum exhaust design airflow of 360 scfm. 360 scfm should be used for maximum exhaust design airflow purposes. Normal operating design airflow would be 60 scfm cascade flow, plus 170 scfm infiltration flow for a total of 230 scfm.

The proposed 360 scfm maximum exhaust air system can maintain the tank vapor space pressure at -1.50" water gauge under the worst case assumptions. 360 scfm should be used for maximum exhaust airflow sizing of equipment. The minimum absolute total exhaust airflow if Tank C-105 were actively ventilated to an equal or more negative pressure than C-106 (or the cascade line is plugged) and infiltration is extremely small should be considered to be 70 scfm infiltration (assumed). Neither of these two scenarios are deemed likely. For design purposes, the minimum exhaust airflow should be considered to be 60 scfm cascade flow (0.5" w.g. cascade line pressure drop) plus 120 scfm infiltration for 180 scfm total.

APPENDIX A

T. Pini 3/31/95
W320-28-001 rev 1 PHR
4-3-95

Figure 12. Calculated Temperatures to Year 2002.
(Level 3 —— Level 4 +++)

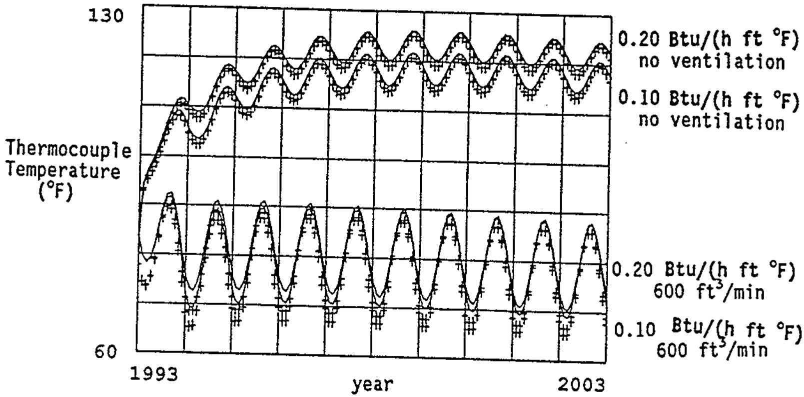

Table 1. Maximum Temperatures for Dry Out Transient.

	Ventilation ($600\ ft^3/min$)		Ventilation off	
Minimum Waste Conductivity (Btu/(h ft °F))	0.2	0.1	0.2	0.1
Maximum Waste Temperature (°F)	137	163	166	189
Maximum Concrete Temperature (°F)	133	151	162	175

R. Pint 3/31/95
W320-28-001 rev 1 PH
4-3-95

Vent & Balance Data

PSYCHROMETRIC SURVEY

DATE: 6-13-89

TO: ~~A. ALSTAD~~ Dan Baide R1-51
~~Jim~~ A

FROM: T. Johnson ~~H. Nichols~~
2101M bldg. Rm. 133
200 East (S2-70)
3-1657

Psychrometric Tank Farm Survey 241-AP , TANK EXH.

Taken by: RUGGLES, WARD KINZEL

The following airflow and temperature readings were taken on subject tank.

Date: 6-13-89

Weather Tower
Time: 9:00 Am Wet Bulb 63° °F Dry Bulb 77° °F

Ambient:
Time: 9:00 Am Wet Bulb 64° °F Dry Bulb 78° °F

Tank No.	Time	Temperature Wet °F	Temperature Dry °F	Flow CFM	Neg. Off Chart %	Exh Duct S/P IN. W.G.	Exh Damp Pos. % OPEN	Neg. Off Tank IN. W. G.
101	9:00 Am	68°	68°	100	18%	2.37" WG	25	-2.70" WG
102	9:10 Am	68°	68°	130	26%	2.07" W.G.	25	-2.40" WG
103	9:15 Am	68°	68°	130	18%	2.00" W.G.	25	-2.80" W.G.
104	9:20 Am	70°	74°	212	17%	2.45" WG	20	-2.60" W.G.
105	9:25 Am	61°	70°	264	10%	2.91" W.G.	100	-3.00" WG
106	9:30 Am	68°	68°	188	15%	2.55" WG	188	-2.70" WG

COMMENTS:
296-A-40 681 CFM

PRE FILTER .10" W.G. D/P
PRIMARY .80" W.G. D/P
SECONDARY .65" WG D/P
DEENTRAINER .68" WG D/P

INLET TEMP 68°
OUTLET TEMP 76°

CC. ~~H. N. ANDERSON~~
Betty Hanlin ~~R1-51~~

T. Ann 3/31/95
W320-28-001 rev1 PHR 4-

Vent & Balance Data

PSYCHROMETRIC SURVEY

DATE: 7/17/89

TO: ~~J. H. Cleavenger~~ Dan Baide R1-51

FROM: I. T. Johnson
2101M bldg. Rm. ~~XXXX~~ 141-D
200 East (S2-70)
3-1857

Psychrometric Tank Farm Survey 241 A.P. TANK EXH.

Taken by: KINZEL KNUTSON Deltjen

The following airflow and temperature readings were taken on subject tank.

Date: 7/17/89

Weather Tower
Time: 10:00 Wet Bulb 59 °F Dry Bulb 76 °F

Ambient:
Time: 10:00 Wet Bulb 60 °F Dry Bulb 75 °F

Tank No.	Time	Temperature Wet °F	Temperature Dry °F	Flow CFM	Neg. Off Chart %	Exh Duct S/P IN. W. G.	Exh Damp Pos. % OPEN	Neg. Off Tank IN. W. G.
101	9:18	66	73	110	-2.7" w.g.	2.61" w.g.	18	-2.60" w.g.
102	9:22	66	72	99	-2.1" w.g.	2.02" w.g.	25	-2.10" w.g.
103	9:27	66	73	99	-2.7" w.g.	2.00" w.g.	22	-2.70" w.g.
104	9:33	66	72	116	-2.7" w.g.	2.4[illegible]" w.g.	20	-2.60" w.g.
105	10:50	64	75	255	-2.2" w.g.	2.90" w.g.	95	-2.10" w.g.
106	10:00	71	73	153	-2.3" w.g.	2.60" w.g.	25	-2.60" w.g.
							Blanked off	
							Blanked off	

COMMENTS:
296-A-40 791 CFM

Pre Filter .10" w.g.
Primary .75" w.g.
Secondary .63" w.g.
Deentrainer .65" w.g.

Inlet Temp. 65°F
Outlet Temp. 72°F

CC.

Betty Hanlon R1-80
~~H. Ahrens~~

T. Pm. 3/31/95
70-28-001 rev 1 Ath 4-3-9

Vent & Balance Data

241-AN Tank Farm

DATE: 2-8-90

TO: ______

FROM: 2101-M RM. 200 E (S2-70) 3-1857

Instrument Type micro

Instrument Last Calibration Date 11-8-89

Instrument Code No. WHSL 702-28-09-013

Psychrometric Survey Tank 241, TANK EXH.

Taken By: Carrick, Tiffany + McLinse

The following airflow and temperature readings were taken on subject tank.

DATE: 2-8-90

Weather Tower:
Time: 9:00 AM Wet Bulb 31 °F Dry Bulb 33 °F

Ambient:
Time: N/A Wet Bulb N/A °F Dry Bulb N/A °F

TANK NO.	TIME	TEMPERATURE WET °F	TEMPERATURE DRY °F	FLOW CFM	NEG. OFF CHART %	EXHAUST DUCT S/P IN. W.G.	EXHAUST DAMP POSITION % OPEN	NEG. OFF TANK IN. W.G.
AN	AM							
101	10:10	61°F	66°F	.48	41%	-1.65"w.g.	100%	10/39 -2.0"w.g.
102	10:30	75°F	77°F	34	40%	-1.66"w.g.	100%	10/39 -1.50"w.g.
103	10:20	63°F	78°F	235	43%	-1.65"w.g.	100%	10/39 -1.50"w.g.
104	10:00	66°F	75°F	55	43%	-1.67"w.g.	100%	10/39 -2.0"w.g.
105	9:40	66°F	70°F	34	43%	-1.61"w.g.	60%	10/39 -2.0"w.g.
106	9:30	59°F	63°F	347	45%	-1.55"w.g.	75%	10/39 -1.50"w.g.
107	9:10	61°F	75°F	203	42%	-1.65"w.g.	80%	10/47 -1.90"w.g.

COMMENTS: No Ambient readings due to broken equipment.

Ira Johnson, Manager Ventilation Balance

TEST RECORD SHEET 3.

T. Pam 3/31/95
20-28-001 rev1 Att 4-3-9

Vent & Balance Data

241-AW Tank Farm

DATE: 2-9-90

TO:

FROM: 2101-M RM.
200 E (S2-70)
3-1857

Instrument Type micro

Instrument Last Calibration Date 11-8-89

Instrument Code No. WHSL 712-28-09-013

Psychrometric Survey Tank 241, TANK EXH.

Taken By: Carrick, McCuse + Tiffany

The following airflow and temperature readings were taken on subject tank.

DATE: 2-8-90

Weather Tower:
Time: 1:45 Wet Bulb 35 °F Dry Bulb 41 °F

Ambient:
Time: N/A Wet Bulb N/A °F Dry Bulb N/A °F

TANK NO.	TIME	TEMPERATURE WET °F	DRY °F	FLOW CFM	NEG. OFF CHART %	EXHAUST DUCT S/P IN. W.G.	EXHAUST DAMP POSITION % OPEN	NEG. OFF TANK IN. W.G.
AW	P.M.							
101	1:50	65°F	65°F	.59 X	55%	-1.30"w.g.	15%	9/39 -1.70"w.g.
102	2:30	66°F	66°F	339 X	60%	-1.19"w.g.	50%	9/39 -1.20"w.g.
103	2:00	65°F	65°F	106 X	59%	-.99"w.g.	25%	9/39 -1.20"w.g.
104	2:40	67°F	67°F	243 X	59%	-1.19"w.g.	25%	9/39 -1.30"w.g.
105	2:20	52°F	59°F	270 X	55%	-1.27"w.g.	100%	9/39 -1.40"w.g.
106	2:10	68°F	72°F	116 X	65%	-.89"w.g.	25%	9/39 -1.0"w.g.

COMMENTS: Ambient inst. broken K1-5-2 Fan inservice.

Ira Johnson, Manager Ventilation Balance

TEST RECORD SHEET 3.

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Riser	Existing Use	Proposed Modification
TANK 241-C-106		
R1 - 4 in.	FIC	
R2 - 12 in.	HVAC Outlet	HVAC Outlet
- 42 in. (36 in.)	Dirt Covered Construction Manhole	
TANK 241-C-106 SLUICE PIT		
R3 - 12 in.	Liquid Level Tape Riser blanked, H-2-73346	Install New Sluicer Risers empty and open
R4 - 4 in.	Recirc Dipleg Still there, H-2-73346 Sluice Pit Drain	Dipleg is laying in pit Riser is empty and open
TANK 241-C-106 HEEL PIT		
R13 - 26 in.	Heel Jet Pump Still there, H-2-73346 Heel Pit Drain	Install New Heel Pump Possibly Modify Riser dia. Remove Old Pump
TANK 241-C-106 PUMP PIT		
R5 - 4 in.	Recirc Dipleg Still there, H-2-73346 Pump Pit Drain	Riser is empty and open
R6 - 12 in.	Sluicing Access	New Sluicer
R7 - 12 in.	Observation Port In wall of Pit See H-2-93726 Blind Flange on Riser	Visual System Installation
R-9 - 42 in. (36 in.)	Sludge Pump Still there, H-2-73346	New Submersible Pump
TANK 241-C-106		
R8 - 4 in.	Temp Cont. Still there, H-2-73346 West of Pump Pit	
R11 - 4 in.	Southeast of Heel Pit (below grade)	
R14 - 4 in.	Thermocouple Tree	
TANK 241-C-106 HVAC INTAKE		
R15 - 12 in.	HVAC, HEPA Filtered Intake Intake, Riser plate could be made larger	HVAC Intake

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1.0 INTRODUCTION

The purpose of this document is to show the analytical results which were reached in determining the minimal flow rate for one air change per day from a single shell tank.[1] Also, what flow rate will be required to maintain a static pressure of -.3" wg to -5.9" wg in the tank (DOE Order 6430.1A page 11-4 paragraph 1161-4, and OSD #113). This flow may be used to size a exhauster for both, before and after stabilization. Please review all the assumptions made during this analysis very carefully. These assumptions are uncontrolled variables (ie.. drains being plugged by dirt and debris), therefore, close attention should be paid to these assumptions.

2.0 SCOPE

The flow rates and static pressures were determined by the following four scenarios:

- o 2 - 4" risers and 2 - 6" risers with a crack width of 1/64" each, 3 - 3" drains in the sluice pits (completely open free from debris), and 1 - 4" drain in the pump pit (completely open free from debris). In addition, 50 cfh or .833 cfm[2] is also added due to purge air used by the FIC.

- o 2 - 4" risers and 2 - 6" risers with a crack width of 1/64" each, 3 - 3" drains in the sluice pits (50% of the drain blocked due to dirt and debris), and 1 - 4" drain in the pump pit (50% of the drain blocked due to dirt and debris). In addition, 50 cfh or .833 cfm[2] is also added due to purge air used by the FIC.

- o 1 - inlet filter placed on a 12" riser with flow through both, the inlet filter, and flow going through the above mentioned cracks. In addition, 50 cfh or .833 cfm[2] is also added due to purge air used by the FIC.

- o 2 - 4" risers and 2 - 6" risers with a crack width of 1/64" each, and the sluice pits and pump pit are sealed up completely (no in-leakage through pits). In addition, 50 cfh or .833 cfm[2] is also added due to purge air used by the FIC.

The tank which was used for this analysis was 104-AX. This tank had the largest vapor space (gal.) due to the lowest liquid level (gal.) of all single shell tanks. This was determined by using the March 30, 1991 Tank Farm Facilities Chart (see appendix B).

1 = Internal Memo from J.D. Thomson and J.L. Deichman to M.A. Payne, 2-18-92, Single Shell Tank Ventillation Systems
2 = Information supplied by A.T. Alstad and V.D. Maupin

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3.0 RESULTS

All scenarios, which were mentioned above, were evaluated, labeled, and explained in Appendix A. The results were as follows:

PRESSURE DROP in. wg	SCENARIO #1[3] cfm	SCENARIO #2[3] cfm	SCENARIO #3[1,2,3] cfm	SCENARIO #4[3] cfm
.3" wg	317	165	300 + #1 or #2	9
1" wg	579	301	1000 + #1 or #2	16
2" wg	819	425	2000 + #1 or #2	23
3" wg	1003	521	3000 + #1 or #2	28
4" wg	1158	601	4000 + #1 or #2	33
5" wg	1333	672	5000 + #1 or #2	37
5.9" wg	1406	730	5900 + #1 or #2	40

1 = Based on damper being completely open
2 = See page 16 in Appendix A for reasoning of additive flows
3 = .83 cfm needs to be added to these values for the purge air off the FIC

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Table 4. Population of Pressure Changes Every Hour.

Press swing (inches of mercury)	Year			
	1988	1989	1990	1991
-0.13 or lower	0	0	0	0
-0.12	0	0	1	0
-0.11	3	1	1	3
-0.10	0	2	1	0
-0.09	2	0	1	0
-0.08	3	3	3	3
-0.07	1	2	4	4
-0.06	10	5	15	7
-0.05	26	10	27	16
-0.04	130	86	128	110
-0.03	344	238	294	302
-0.02	890	915	990	976
-0.01	1,446	1,583	1,435	1,473
0	2,838	2,934	2,785	2,825
0.01	1,772	1,806	1,674	1,703
0.02	930	888	995	958
0.03	266	181	252	231
0.04	76	71	99	89
0.05	17	14	31	33
0.06	13	8	14	13
0.07	3	2	0	7
0.08	1	0	4	2
0.09	3	2	1	0
0.10	1	0	2	1
0.11	1	3	0	1
0.12	2	1	1	0
0.13 or higher	0	0	1*	0

*One reading was 0.18 but is ascribed to an error, see discussion in Section 1.2, "Raw Data."

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Table 1. Annual Data.

Value	Year				
	1988	1989	1990	1991	1950 -1980*
Average (inches of mercury)	29.25	29.26	29.22	29.23	29.21
Standard deviation (inches of mercury)	0.211	0.197	0.193	0.210	-
Number	8779	8756	8760	8758	-
Maximum (inches of mercury)	29.94	29.96	30.02	29.83	30.23
Minimum (inches of mercury)	28.52	28.79	28.50	28.33	28.10
Total increases (inches of mercury)	49.98	46.04	51.46	49.97	-
Total decrease (inches of mercury)	50.50	46.20	51.28	49.78	-

* Source: Stone et al. (1983)

gross outliers. Some years have more storms than others. Further computations would show that the coupling of extremes with the average and standard deviations indicate a well-behaved and normal distribution of values. Finally, 1988 was a leap year.

The total yearly breathing is 49.40 inches of mercury (0.005639 inches of mercury per hour) or about 1.69 atmospheres, which is somewhat lower than previous rates of about 2.2 atmospheres used in other studies (Klem 1991; Garfield 1975). Note that the present data gave breathing rates approaching 3 atmospheres before the few erroneous entries were corrected. Therefore, we believe the 1.69 atmospheres (0.005639 inches of mercury per hour) annual breathing rate to be valid and the best available.

Note that the total hourly barometric movement (upward or downward changes being accumulated as separate accounts) are higher than would be determined from Stone et al. (1983). For example, Table 36 in Stone et al. (1983) gives the annual average station pressure for hours 1 through 24. From this, the average diurnal change from low to high is 0.04 inches of mercury, or about 30% of the movement determined by the present analysis from hourly changes. Although this is a natural rate, one needs to be aware that some tanks are actively being purged (through the Food Instrument Corporation level gauge or other instruments). These purges may be in excess of 0.71 m^3/h (25 ft^3/h), which is similar to the natural breathing rate.

The data were examined on a daily basis to see if variations could be seen that were similar to the sinusoidal temperatures seen during the day. Those results for 1990 are presented (other years are very similar) as Table 2. Figure 1 is a graphical representation of the same data. There really is no trend over the day; in this case, Figure 1 is more enlightening than Table 2. Therefore, it would be impossible to predict that tank pressure would be high or low for any given hour of the day at some time in the future.

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APPENDIX B

3/31/95
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KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM : Cascade Line from C-105 to C-106

PREPARED BY: P.H. LANGOWSKI
DATE: 3/27/95
CHECKED BY:

NOTES:
Calculation W320-28-001.
3" schedule 80, ID=2.90".
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
ASHRAE fitting ED1-1 1993 Fundamentals p.32.29.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

AIR STREAM	AIR FLOW	TEMP	AIR FLOW	AIR FLOW TAKEOFF	DUCTSIZE either round or rectangular			EQUIV DUCT LENGTH	DUCT AREA	PERI METER	HYDRAL DIA	REY	FPRIME	F	VEL.	VEL. PRESS. Vp	PRESS. LOSS
					WIDTH	HEIGHT	DIA.										
	SCFM	DEGREE F	ACFM	SCFM	IN.	IN.	IN.	FT.	SQ. IN.	IN.	IN.				FPM	IN. WG	IN. WG
	initial only							duct only									
C-106 gauge pressure																	-0.500
entrance in C-105	60	80	61				2.90		6.61	9.11	2.90	31,790	0.025	0.025	1,334	0.111	0.055
30' of 3" schedule 80	60	80	61				2.90	30	6.61	9.11	2.90	31,790	0.025	0.025	1,334	0.111	0.334
exit in C-106	60	80	61				2.90		6.61	9.11	2.90	31,790	0.025	0.025	1,334	0.111	0.111
																total	0.000

DATA USED ABOVE

roughness = 0.0001
density = 0.074 lbm/ft3 80F, dry air 13.602 ft3/lbm
kinematic viscosity = 0.000169 ft2/s

friction factors		
	galvanized	0.0003
	carbon steel	0.0001

kinematic viscosity	temp(F)	ft2/s
from Mechanical Engineering	0.00	0.000126
Reference Manual Eighth	20.00	0.000136
Edition, p.3-36.	40.00	0.000146
	60.00	0.000158
	68.00	0.000160
	80.00	0.000169
	100.00	0.000180
	120.00	0.000189
	250.00	0.000273

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM : Cascade Line from C-105 to C-106

PREPARED BY: P.H. LANGOWSKI
DATE: 3/28/95
CHECKED BY:

NOTES:
Calculation W320-28-001.
3" schedule 80, ID=2.90".
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
ASHRAE fitting ED1-1 1993 Fundamentals p.32.29.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

AIR STREAM	AIR FLOW	TEMP	AIR FLOW	AIR FLOW TAKEOFF	DUCTSIZE either round or rectangular WIDTH	HEIGHT	DIA.	EQUIV DUCT LENGTH	DUCT AREA	PERI METER	HYDRAL DIA	REY	FPRIME	F	VEL.	VEL. PRESS. Vp	PRESS. LOSS
	SCFM	DEGREE F	ACFM	SCFM	IN.	IN.	IN.	FT.	SQ. IN.	IN.	IN.				FPM	IN. WG	IN. WG
	Initial only							duct only									
C-106 gauge pressure																	-1.500
entrance in C-105	103	120	113				2.90		6.61	9.11	2.90	58,591	0.022	0.022	2,458	0.377	0.188
30' of 3" schedule 80	103	120	113				2.90	30	6.61	9.11	2.90	58,591	0.022	0.022	2,458	0.377	0.935
exit in C-106	103	120	113				2.90		6.61	9.11	2.90	58,591	0.022	0.022	2,458	0.377	0.377
																total	0.000

DATA USED ABOVE
roughness = 0.0001
density = 0.068 lbm/ft3 120F, dry ai 14.613 ft3/lbm
kinematic viscosity = 0.000189 ft2/s

friction factors		
	galvanized	0.0003
	carbon steel	0.0001

kinematic viscosity	temp(F)	ft2/s
from Mechanical Engineering	0.00	0.000126
Reference Manual Eighth	20.00	0.000136
Edition, p.3-36.	40.00	0.000146
	60.00	0.000158
	68.00	0.000160
	80.00	0.000169
	100.00	0.000180
	120.00	0.000189
	250.00	0.000273

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
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NOTES:
Calculation W320-28-001.
3" schedule 80, ID = 2.90".
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
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ASHRAE fitting ED1-1 1993 Fundamentals p.32.29.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

AIR STREAM	AIR FLOW	TEMP	AIR FLOW	AIR FLOW TAKEOFF	DUCTSIZE either round or rectangular			EQUIV DUCT LENGTH	DUCT AREA	PERI METER	HYDRAL DIA	REY	FPRIME	F	VEL.	VEL. PRESS. Vp	PRESS. LOSS
					WIDTH	HEIGHT	DIA.										
	SCFM	DEGREE F	ACFM	SCFM	IN.	IN.	IN.	FT.	SQ. IN.	IN.	IN.				FPM	IN. WG	IN. WG
	initial only							duct only									
C-106 gauge pressure																	-1.500
entrance in C-105	108	80	110				2.90		6.61	9.11	2.90	57,198	0.022	0.022	2,400	0.359	0.180
30' of 3" schedule 80	108	80	110				2.90	30	6.61	9.11	2.90	57,198	0.022	0.022	2,400	0.359	0.961
exit in C-106	108	80	110				2.90		6.61	9.11	2.90	57,198	0.022	0.022	2,400	0.359	0.359
																total	0.000

DATA USED ABOVE
roughness = 0.0001
density = 0.074 lbm/ft3 80F, dry air 13.602 ft3/lbm
kinematic viscosity = 0.000169 ft2/s

friction factors		
	galvanized	0.0003
	carbon steel	0.0001

kinematic viscosity	temp(F)	ft2/s
from Mechanical Engineering	0.00	0.000126
Reference Manual Eighth	20.00	0.000136
Edition, p.3-36.	40.00	0.000146
	60.00	0.000158
	68.00	0.000160
	80.00	0.000169
	100.00	0.000180
	120.00	0.000189
	250.00	0.000273

equals the difference between the upstream pressure, which is zero (atmospheric pressure), and the loss through the fitting. The static pressure of the ambient air is zero; several diameters downstream, static pressure is negative, algebraically equal to the total pressure (negative) and the velocity pressure (always positive).

System resistance to airflow is noted by the total pressure grade line in Figure 3. Sections 3 and 4 include fan system effect pressure losses. To obtain the fan static pressure requirement for fan selection where the fan total pressure is known, use:

$$P_s = P_t - p_{v,o} \tag{18}$$

where

P_s = fan static pressure, in. of water
P_t = fan total pressure, in. of water
$p_{v,o}$ = fan outlet velocity pressure, in. of water

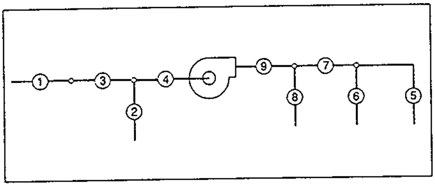

Fig. 2 Illustrative 6-Path, 9-Section System

FLUID RESISTANCE

Duct system losses are the irreversible transformation of mechanical energy into heat. The two types of losses are (1) frictional losses and (2) dynamic losses.

FRICTIONAL LOSSES

Frictional losses are due to fluid viscosity and are a result of momentum exchange between molecules in laminar flow and between particles moving at different velocities in turbulent flow. Frictional losses occur along the entire duct length.

Darcy, Colebrook, and Altshul Equations

For fluid flow in conduits, friction loss can be calculated by the Darcy equation:

$$\Delta p_f = f(12L/D_h)\,\rho\,(V/1097)^2 \tag{19}$$

where

Δp_f = friction losses in terms of total pressure, in. of water
f = friction factor, dimensionless
L = duct length, ft
D_h = hydraulic diameter [Equation (24)], in.
V = velocity, fpm
ρ = density, lb_m/ft^3

Within the region of laminar flow (Reynolds numbers less than 2000), the friction factor is a function of Reynolds number only.

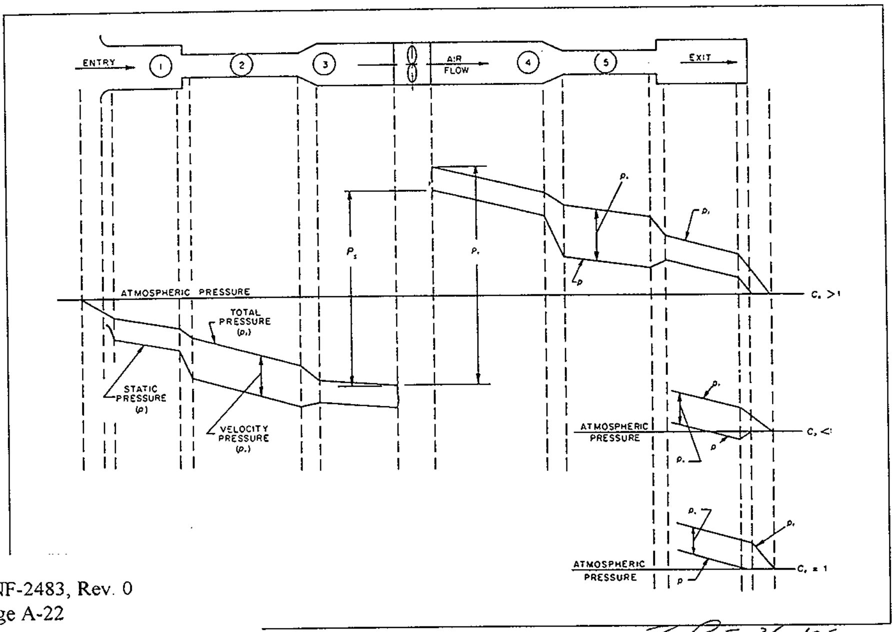

Fig. 3 Pressure Changes During Flow in Ducts

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For turbulent flow, the friction factor depends on Reynolds number, duct surface roughness, and internal protuberances such as joints. The traditional Moody chart depicts the behavior for round passages. For hydraulically smooth ducts, the friction factor again depends only on Reynolds number, but the dependence is markedly different from that for laminar flow. In general, for nonsmooth surfaces, the friction factor depends on roughness and Reynolds number; however, for a particular level of roughness beyond a sufficiently large Reynolds number, the friction factor becomes independent of Reynolds number, a flow condition considered as fully rough. Between the bounding limits of hydraulically smooth behavior and fully rough behavior, is a transitional roughness zone where the friction factor depends on both roughness and Reynolds number. In this transitionally rough, turbulent zone, where most cases of airflow occur in air-conditioning applications, the friction factor f is calculated by Colebrook's equation (1938-39). Since this equation cannot be solved explicitly for f, use iterative techniques (Behls 1971).

$$\frac{1}{f^{0.5}} = -2\log\left[\frac{12\epsilon}{3.7D_h} + \frac{2.51}{\mathrm{Re}\,f^{0.5}}\right] \qquad (20)$$

where

ϵ = material absolute roughness factor, ft
Re = Reynolds number

A simplified formula for calculating friction factor, developed by Altshul (1975) and modified by Tsal, is

$$f' = 0.11\left(\frac{12\epsilon}{D_h} + \frac{68}{\mathrm{Re}}\right)^{0.25}$$

$$\text{If } f' \geq 0.018: \quad f = f'$$

$$\text{If } f' < 0.018: \quad f = 0.85f' + 0.0028 \qquad (21)$$

Friction factors obtained from Altshul's modified equation are within 1.6% of those obtained by Colebrook's equation.

Reynolds number (Re) may be calculated by using Equation (22).

$$\mathrm{Re} = \frac{D_h V}{720\,\nu} \qquad (22)$$

where ν = kinematic viscosity, ft²/s.

For standard air, Re can be calculated by

$$\mathrm{Re} = 8.56\,D_h V \qquad (23)$$

Roughness Factors (ϵ)

The ϵ-values listed in Table 1 are recommended for use with the Colebrook or Altshul-Tsal equation. These values should be interpreted as representing a combination of material, duct construction, joint type, and joint spacing (Griggs and Khodabakhsh-Sharifabad 1992). Roughness factors for other materials are presented in Idelchik *et al.* (1986). Idelchik summarizes roughness factors for 80 materials including metal tubes; conduits made from concrete and cement; and wood, plywood, and glass tubes.

Swim (1978) conducted tests on duct liners of varying densities, surface treatments, transverse joints (workmanship), and methods of attachment to sheet metal ducts. As a result of these tests, Swim recommends for design 0.015 ft for spray-coated liners and 0.005 ft for liners with a facing material cemented onto the air side. In both cases, the roughness factor includes the resistance offered by mechanical fasteners and assumes good joints. Liners cut too long and fastened to the duct cause much more loss than a liner cut too short; therefore, any fabrication error in liner length should be on the short side. Liner density does not significantly influence flow resistance.

Manufacturers' data indicate that the absolute roughness for fully extended nonmetallic flexible ducts ranges from 0.0035 to 0.015 ft. For fully extended flexible metallic ducts, absolute roughness ranges from 0.0004 to 0.007 ft. This range covers flexible duct with the supporting wire exposed to flow or covered by the material. Figure 4 provides a pressure drop correction factor for straight flexible duct when less than fully extended.

Table 1 Duct Roughness Factors

Duct Material	Roughness Category	Absolute Roughness ϵ, ft
Uncoated carbon steel, clean (Moody 1944) (0.00015 ft)	Smooth	0.0001
PVC plastic pipe (Swim 1982) (0.00003 - 0.00015 ft)		
Aluminum (Hutchinson 1953) (0.000015 - 0.0002 ft)		
Galvanized steel, longitudinal seams, 4-ft joints (Griggs *et al.* 1987) (0.00016 - 0.00032 ft)	Medium smooth	0.0003
Galvanized steel, continuously rolled, spiral seams, 10-ft joints (Jones 1979) (0.0002 - 0.0004 ft)		
Galvanized steel, spiral seam with 1, 2, and 3 ribs, 12-ft joints (Griggs *et al.* 1987) (0.00029 - 0.00038 ft)		
Galvanized steel, longitudinal seams, 2.5-ft joints (Wright 1945) (0.0005 ft)	Average	0.0005
Fibrous glass duct, rigid	Medium	0.003
Fibrous glass duct liner, air side with facing material (Swim 1978) (0.005 ft)	Rough	
Fibrous glass duct liner, air side spray coated (Swim 1978) (0.015 ft)	Rough	0.01
Flexible duct, metallic (0.004 - 0.007 ft when fully extended)		
Flexible duct, all types of fabric and wire (0.0035 - 0.015 ft when fully extended)		
Concrete (Moody 1944) (0.001 - 0.01 ft)		

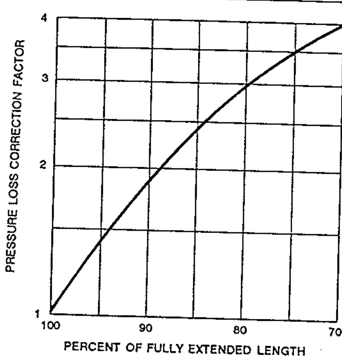

Fig. 4 Correction Factor for Unextended Flexible Duct

C. Phan 3/31/95

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Friction Chart

Fluid resistance caused by friction in round ducts can be determined by the Friction Chart (Figure 5). This chart is based on standard air flowing through round galvanized ducts with beaded slip couplings on 48-in. centers, equivalent to an absolute roughness of 0.0003 ft.

Changes in barometric pressure, temperature, and humidity affect air density, air viscosity, and Reynolds number. No corrections to the Friction Chart are needed for (1) duct materials with a medium smooth roughness factor, (2) temperature variations in the order of ±30°F from 70°F, (3) elevations to 1500 ft, and (4) duct pressures from −20 in. of water to +20 in. of water relative to the ambient pressure. These individual variations in temperature, elevation, and duct pressure result in duct losses within ±5% of the standard air friction chart.

For duct materials other than those categorized as medium smooth in Table 1, and for variations in temperature, barometric pressure (elevation), and duct pressures (outside the range listed), calculate the pressure loss in a duct due to friction by the Altshul-Tsal and Darcy equations [(21) and (19), respectively].

Noncircular Ducts

A momentum analysis can relate average wall shear stress to pressure drop per unit length for fully developed turbulent flow in a passage of arbitrary shape but of uniform longitudinal cross-sectional area. Combining the result with the definition of the Darcy friction factor leads to Equation (24), with the ratio $4A/P$ defined as hydraulic diameter:

$$D_h = 4A/P \tag{24}$$

where

D_h = hydraulic diameter, in.
A = duct area, in^2
P = perimeter of cross section, in.

While the hydraulic diameter is often used to correlate noncircular data, exact solutions for laminar flow in noncircular passages show that such practice causes some inconsistencies. No exact solutions exist for turbulent flow. Tests over a limited range of turbulent flow indicated that fluid resistance is the same for equal lengths of duct for equal mean velocities of flow if the ducts have the same ratio of cross-sectional area to perimeter. From a series of experiments using round, square, and rectangular ducts having essentially the same hydraulic diameter, Huebscher (1948) found that each, for most purposes, had the same flow resistance at equal mean velocities. Tests by Griggs and Khodabakhsh-Sharifabad (1992) also indicated that experimental rectangular duct data for airflow over the range typical of HVAC systems can be correlated satisfactorily using Equation (20) together with hydraulic diameter, particularly when a realistic experimental uncertainty is accepted. These tests support using hydraulic diameter to correlate noncircular duct data.

Rectangular ducts. Huebscher developed the relationship between rectangular and round ducts that is used to determine size equivalency based on equal flow, resistance, and length. This relationship, Equation (25), is the basis for Table 2.

$$D_e = 1.30\,\frac{(ab)^{0.625}}{(a+b)^{0.250}} \tag{25}$$

where

D_e = circular equivalent of rectangular duct for equal length, fluid resistance, and airflow, in.
a = length of one side of duct, in.
b = length of adjacent side of duct, in.

To size retangular ducts, determine the circular duct diameter by any design method, and use Table 2 to select the equivalent duct size as a function of aspect ratio. Equations (21) or (20) and (19) must be used to determine pressure loss.

Flat oval ducts. To convert round ducts to spiral flat oval sizes, use Table 3. Table 3 is based on Equation (26) (Heyt and Diaz 1975), the circular equivalent of a flat oval duct for equal airflow, resistance, and length. Equations (21) or (20) and (19) must be used to determine frictional pressure loss.

$$D_e = \frac{1.55\,A^{0.625}}{P^{0.250}} \tag{26}$$

where A is the cross-sectional area of flat oval duct defined as:

$$A = (\pi b^2/4) + b\,(a - b) \tag{27}$$

and the perimeter P is calculated by:

$$P = \pi b + 2(a - b) \tag{28}$$

where

P = perimeter of flat oval duct, in.
a = major dimension of flat oval duct, in.
b = minor dimension of flat oval duct, in.

DYNAMIC LOSSES

Dynamic losses result from flow disturbances caused by fittings that change the airflow path's direction and/or area. These fittings include entries, exits, transitions, and junctions. Idelchik (1986) discusses parameters affecting fluid resistance of fittings and presents loss coefficients in three forms: tables, curves, and equations.

Local Loss Coefficients

The following dimensionless coefficient is used for fluid resistance, since this coefficient has the same value in dynamically similar streams, *i.e.*, streams with geometrically similar stretches, equal values of Reynolds number, and equal values of other criteria necessary for dynamic similarity. The fluid resistance coefficient represents the ratio of total pressure loss to velocity pressure at the referenced cross section.

$$C = \frac{\Delta p_j}{\rho(V/1097)^2} = \frac{\Delta p_j}{p_v} \tag{29}$$

where

C = local loss coefficient, dimensionless
Δp_j = fitting total pressure loss, in. of water
ρ = density, lb$_m$/ft^3
V = velocity, fpm
p_v = velocity pressure, in. of water

Dynamic losses occur along a duct length and cannot be separated from frictional losses. For ease of calculation, dynamic losses are assumed to be concentrated at a section (local) and to exclude friction. Frictional losses must be considered only for relatively long fittings. Generally, fitting friction losses are accounted for by measuring duct lengths from the centerline of one fitting to that of the next fitting. For fittings closely coupled (less than six hydraulic diameters apart), the flow pattern entering subsequent fittings differs from the flow pattern used to determine loss coefficients. Adequate data for these situations are unavailable.

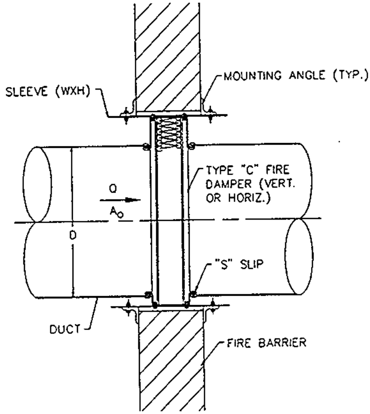
For all fittings, except junctions, calculate the total pressure loss Δp_j at a section by:

(30)

PHR 4-3-95

CD9-3 Fire Damper, Curtain Type, Type C

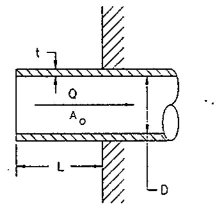
$C_o = 0.12$



ED1-1 Duct Mounted in Wall (Idelchik *et al.* 1986, Diagram 3-1)

C_o Values

	L/D								
t/D	0.000	0.002	0.010	0.050	0.100	0.200	0.300	0.500	10.000
0.00	0.50	0.57	0.68	0.80	0.86	0.92	0.97	1.00	1.00
0.02	0.50	0.51	0.52	0.55	0.60	0.66	0.69	0.72	0.72
0.05	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
10.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50



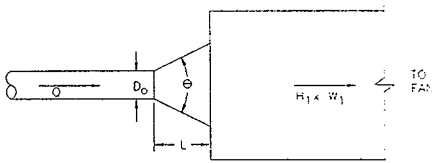
ED2-1 Conical Diffuser, Round to Plenum, Exhaust/Return Systems (Idelchik *et al.* 1986, Diagram 5-8)

C_o Values

	L/D_o										
A_1/A_o	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0
1.5	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.10	0.11	0.13
2.0	0.08	0.06	0.04	0.04	0.04	0.05	0.05	0.06	0.08	0.09	0.10
2.5	0.13	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.09
3.0	0.17	0.12	0.09	0.07	0.07	0.06	0.06	0.07	0.07	0.08	0.08
4.0	0.23	0.17	0.12	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08
6.0	0.30	0.22	0.16	0.13	0.12	0.10	0.10	0.09	0.09	0.09	0.08
8.0	0.34	0.26	0.18	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.09
10.0	0.36	0.28	0.20	0.16	0.14	0.13	0.12	0.11	0.10	0.09	0.09
14.0	0.39	0.30	0.22	0.18	0.16	0.14	0.13	0.12	0.10	0.10	0.10
20.0	0.41	0.32	0.24	0.20	0.17	0.15	0.14	0.12	0.11	0.11	0.10

Optimum Angle, θ

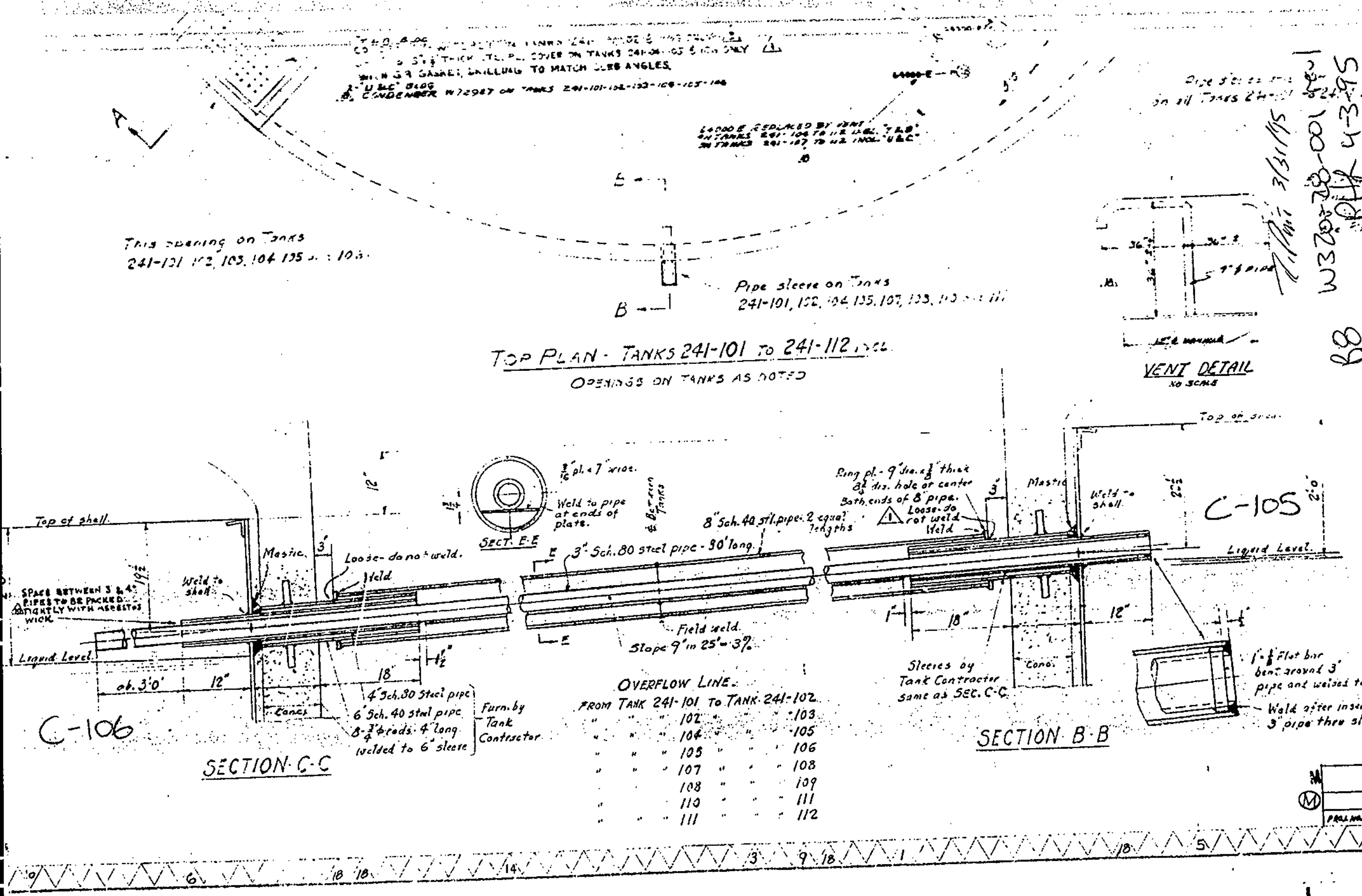
A_1/A_o	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0
1.5	34	20	13	9	7	6	4	3	2	2	2
2.0	42	28	17	12	10	9	8	6	5	4	3
2.5	50	32	20	15	12	11	10	8	7	6	5
3.0	54	34	22	17	14	12	11	10	8	8	6
4.0	58	40	26	20	16	14	13	12	10	10	9
6.0	62	42	28	22	19	16	15	12	11	10	9
8.0	64	44	30	24	20	18	16	13	12	11	10
10.0	66	46	30	24	22	19	17	14	12	11	10
14.0	66	48	32	26	22	19	17	14	13	11	11
20.0	68	48	32	26	22	20	18	15	13	12	11



B6

Appendix F
Dimensions of Welded and Seamless Steel Pipe

Nominal Diameter Inches	Schedule	Outside Diameter Inches	Wall Thickness Inches	Internal Diameter Inches	Internal Area Sq Inches	Internal Diameter Feet	Internal Area Sq Feet
1/8	40 (S)	0.405	0.068	0.269	0.0568	0.0224	0.00039
	80 (X)		0.095	0.215	0.0363	0.0179	0.00025
1/4	40 (S)	0.540	0.088	0.364	0.1041	0.0303	0.00072
	80 (X)		0.119	0.302	0.0716	0.0252	0.00050
3/8	40 (S)	0.675	0.091	0.493	0.1909	0.0411	0.00133
	80 (X)		0.126	0.423	0.1405	0.0353	0.00098
1/2	40 (S)	0.840	0.109	0.622	0.3039	0.0518	0.00211
	80 (X)		0.147	0.546	0.2341	0.0455	0.00163
	160		0.187	0.466	0.1706	0.0388	0.00118
	(XX)		0.294	0.252	0.499	0.0210	0.00035
3/4	40 (S)	1.050	0.113	0.824	0.5333	0.0687	0.00370
	80 (X)		0.154	0.742	0.4324	0.0618	0.00300
	160		0.219	0.612	0.2942	0.0510	0.00204
	(XX)		0.308	0.434	0.1479	0.0362	0.00103
1	40 (S)	1.315	0.133	1.049	0.8643	0.0874	0.00600
	80 (X)		0.179	0.957	0.7193	0.0798	0.00500
	160		0.250	0.815	0.5217	0.0679	0.00362
	(XX)		0.358	0.599	0.2818	0.0499	0.00196
1 1/4	40 (S)	1.660	0.140	1.380	1.496	0.1150	0.01039
	80 (X)		0.191	1.278	1.283	0.1065	0.00890
	160		0.250	1.160	1.057	0.0967	0.00734
	(XX)		0.382	0.896	0.6305	0.0747	0.00438
1 1/2	40 (S)	1.900	0.145	1.610	2.036	0.1342	0.01414
	80 (X)		0.200	1.500	1.767	0.1250	0.01227
	160		0.281	1.338	1.406	0.1115	0.00976
	(XX)		0.400	1.100	0.9503	0.0917	0.00660
2	40 (S)	2.375	0.154	2.067	3.356	0.1723	0.02330
	80 (X)		0.218	1.939	2.953	0.1616	0.02051
	160		0.344	1.687	2.235	0.1406	0.01552
	(XX)		0.436	1.503	1.774	0.1253	0.01232
2 1/2	40 (S)	2.875	0.203	2.469	4.788	0.2058	0.03325
	80 (X)		0.276	2.323	4.238	0.1936	0.02943
	160		0.375	2.125	3.547	0.1771	0.02463
	(XX)		0.552	1.771	2.464	0.1476	0.01711
3	40 (S)	3.500	0.216	3.068	7.393	0.2557	0.05134
	80 (X)		0.300	2.900	6.605	0.2417	0.04587
	160		0.438	2.624	5.408	0.2187	0.03755
	(XX)		0.600	2.300	4.155	0.1917	0.02885
3 1/2	40 (S)	4.000	0.226	3.548	9.887	0.2957	0.06866
	80 (X)		0.318	3.364	8.888	0.2803	0.06172
4	40 (S)	4.500	0.237	4.026	12.73	0.3355	0.08841
	80 (X)		0.337	3.826	11.50	0.3188	0.07984
	120		0.438	3.624	10.32	0.3020	0.07163
	160		0.531	3.438	9.283	0.2865	0.06447
	(XX)		0.674	3.152	7.803	0.2627	0.05419



TOP PLAN - TANKS 241-101 TO 241-112
OPENINGS ON TANKS AS NOTED
This opening on Tanks
Pipe sleeve on Tanks
VENT DETAIL
NO SCALE
C-105
C-106
SECTION C-C
SECTION B-B
SECT. E-E
Top of shell.
Liquid Level.
Mastic
Weld to shell
Loose- do not weld.
Weld
Weld to pipe at ends of plate.
3" Sch. 80 steel pipe - 30' long.
8" Sch. 40 stl. pipe: 2 equal lengths
Field weld.
Slope 9" in 25' = 3%
4" Sch. 80 Steel pipe
6" Sch. 40 steel pipe
Furn. by Tank Contractor
welded to 6" sleeve
Ring pl. - 9" dia. x 1/8" thick
Both ends of 8" pipe.
Loose - do not weld.
Sleeves by Tank Contractor same as Sec. C-C
Conc.
OVERFLOW LINE:
FROM TANK 241-101 TO TANK 241-102
102 103
104 105
105 106
107 108
108 109
110 111
111 112
SPACE BETWEEN 3" & 4" PIPES TO BE PACKED TIGHTLY WITH ASBESTOS WICK.

W320-28-001

Equipment Sizing & Selection
Recirculation Fan

CALCULATION IDENTIFICATION AND INDEX

Date 3-6-95

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. W320-~~H-003~~ 28-003

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item Equipment Sizing & Selection Recirculation Fan

These calculations apply to:

Dwg. No. N/A Rev. No. N/A

Dwg. No. N/A Rev. No. N/A

Other (Study, CDR) Procurement Specifications: W-320-P6 Recirculation fan Rev. No. 0

The status of these calculations is:

- [] Preliminary Calculations
- [x] Final Calculations
- [] Check Calculations (On Calculation Dated)
- [] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	PH Laugh 3-6-95		
Checked by	Paul Rice 3.8.95		
Approved by	PH Laugh 3-9-95		
Checked Against Approved Vendor Data	Charles T. Li 4/10/98		

INDEX

KEH 0378.00 (06/92) KEF072

Calc. No. W320-~~H~~-003
Revision 0
Page No. 1 of 2

DESIGN ANALYSIS

Client WHC
Subject Equipment Sizing & Selection, Recirculation Fan
Location 241-C/200 East

WO/Job No. ER4319
Date 3-6-95 By PH Langowski PHL
Checked 3.8.95 By Paul Rice
Revised By

1.0 OBJECTIVE

The objective of this calculation is to determine the performance requirements of the recirculation fan.

2.0 DESIGN INPUTS

2.1 CRITERIA AND SOURCE

DOE General Order 6430.1A
Functional Design Criteria WHC-SD-W320-FDC-001, rev. 2, 1/18/94

2.2 GIVEN DATA

1. Energy Balance drawing H-2-818479 which gives normal fan operation of 77F fan inlet air conditions.

2.3 ASSUMPTIONS

1. Pressure drop through the condenser is linear with reduced airflow.
2. Pressure drop through the moisture separator is governed by the square of the velocity ratio of the design airflow to the actual operating point airflow (based on Wright-Austin vendor data).

2.4 METHODS

Hand calculations, Excel spreadsheet, vendor information.

2.5 REFERENCES 28

W320-~~H~~-018, rev 1 Calculation, Pressure Drop Calculations for Exhaust Skid Sizing
W320-~~H~~-015, rev 0 Calculation, Moisture Separator Sizing
199~~3~~ 28 ASHRAE Fundamentals

See calc. on page 2 CTL 4/7/

3.0 CALCULATIONS 28

From W320-~~H~~-015 para 7.4, 5463 lb_{da}/h at a 40F saturated humidity ratio of 0.005216 lb_w/lb_{da} yields 28.49 lb_w/h (vapor) leaving the condenser. From the same calculation para 7.5 it is shown that 0.7 lb_w/min (mist) enters the moisture separator and 0.56 lb_w/min (mist) is removed by the moisture separator. Therefore, (0.14 lb_w/min)(60 min/h)=8.4 lb_w/h of mist is leaving the moisture separator.

The humidity ratio of the airstream is therefore (28.49 + 8.4)lb_w/h / 5463 lb_{da}/h = 0.006753 lb_w/lb_{da}. At the 77F temperature exiting the heating coil with a saturated humidity ratio of 0.020170 lb_w/lb_{da} for 77F, the relative humidity is 0.006753/0.020170=33%.

From the psychrometric chart (App A), at 77F and 33% RH, the specific volume is 13.569 ft^3/lb_{da} (0.0737 lb_{da}/ft^3). At 500 feet elevation the standard atmosphere is 14.430 psia which is equivalent to (14.430)(27.708)=399.83" water absolute [(14.696)(27.708) = 407.20" water absolute at sea level]. Using ideal gas laws, a density factor of 399.83/407.20 = 0.982 accounts for a 500 foot elevation difference and yields (0.982)(0.0737) = 0.0724 lb_{da}/ft^3. The specification P6 was completed with

DESIGN ANALYSIS

Client WHC
Subject Equipment Sizing & Selection, Recirculation Fan
Location 241-C/200 East

WO/Job No. ER4319
Date 3-6-95 By PH Langowski PHL
Checked 3-8-95 By Paul Rice
Revised By

an inlet air density of 0.0704 lb_{da}/ft^3, which is within three percent of that calculated at 500 foot elevation. At a slightly higher elevation the air density would be even closer to that listed in the specification.

An upset condition where the condenser is off line and the tank is at a 120F operating limit condition is based on FDC equipment operating limits for tank installed equipment. The assumed 100% saturation at this upset condition yields a 0.0605 lb/ft^3 density. The fan should be sized to be away from the top of it's curve between the normal and upset operating points so as to not induce pulsations. Using the W320-~~H~~28-018 spreadsheet with 120F saturated air and the airflows set at 600, 750, and 860 scfm for the recirculation fan yields a system curve for this temperature (App A spreadsheet printout results are plotted on top of vendor fan curve on page A4). Intersection of an upset system curve with the vendor fan curve at this upset condition shows that at 120F the fan will move approximately 850 acfm at a 16.8" w.g. pressure differential.

4.0 FINDINGS & CONCLUSIONS

The recirculation fan sizing design operating point will be: 860 scfm (916 acfm) @ 19.0" water gauge static pressure differential and a 77F inlet air density of 0.0704 lb/ft^3. The maximum assumed upset operating temperature is 120F (saturated) with an inlet air density of 0.0605 lb/ft^3. At the 120F upset condition, the fan will move approximately 850 acfm at a 16.8" w.g. pressure differential and operation should be stable.

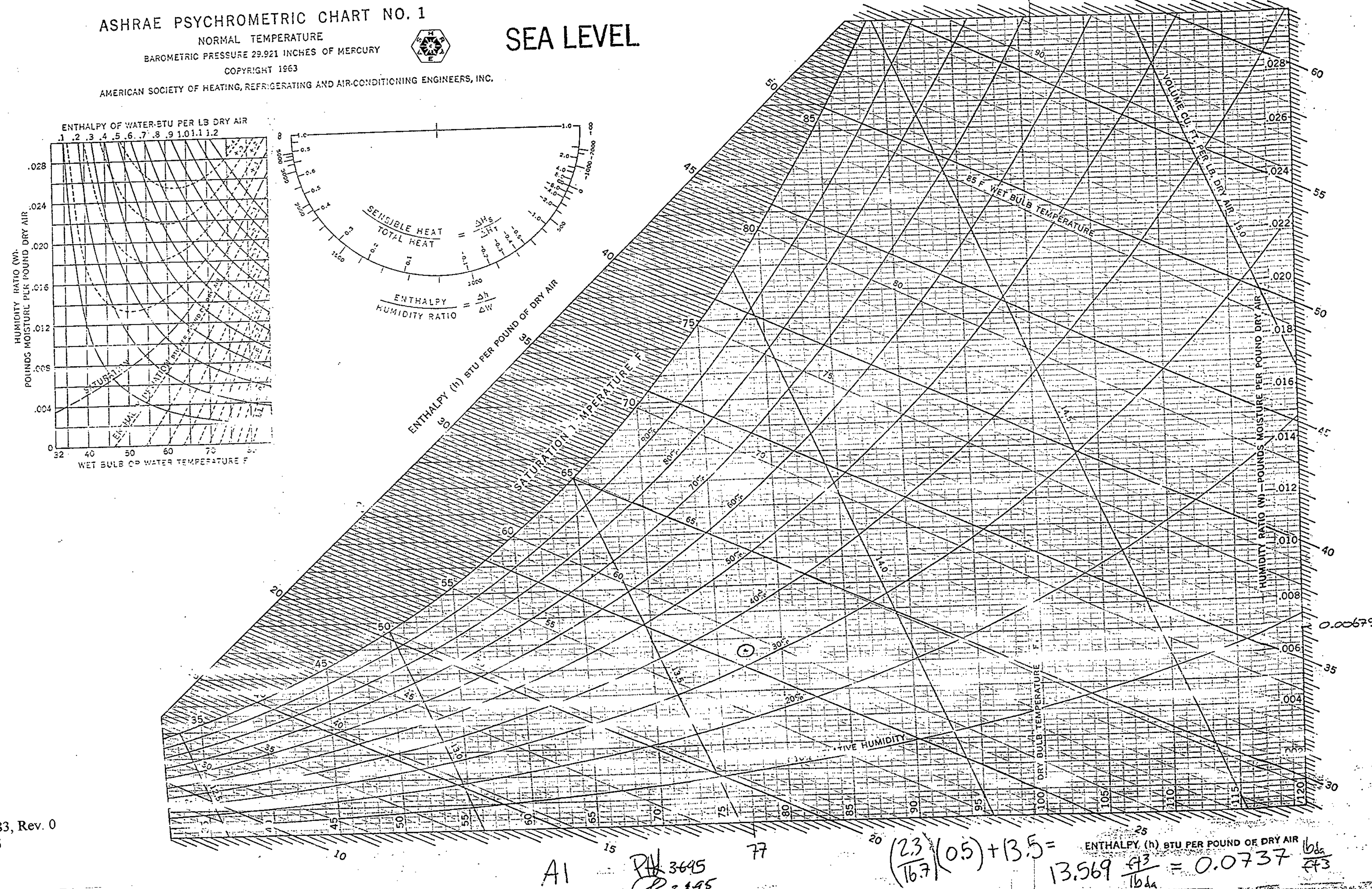
3.0 Calculation vapor leaving condenser = 28.49 lb/hr
wt. of air through condenser: 5463 lb da/hr } para. 7.4 of calc. W320-28-15
wt of air recirculated = 5463 × $\frac{860}{1200}$ = 3851 lb da/hr
wt. of water recontrainted to moisture separator = 0.7 lb/min] para. 7.5 of W320-28-15
wt. of water removed by moisture separator = 0.59 lb/min
wt of water leaving moisture separator (0.7-0.59) × 60 = 6.6 lb/hr.
Humidity ratio for air leaving heating coil
(28.49+6.6)/3851 = 0.0091 lbw/lbda
R.H. of air leaving heating coil = 0.0091/0.020170 = 45.18%
Specific volume = 13.72 ft³/lb da ; 0.0729 lbda/ft³
Corrected to 500' elevation 0.982 × 0.0729 = 0.0716 lb da/ft³

Volume of air to be handle by recirculation fan
3851 lb da/hr × 13.72 ft³/lb da = 52,840 ft³/hr. at heating coil outlet condition
or 880 ft³/min

ETL 4/7/98

KEH 0037.00 (06/92) KEF055

APPENDIX A


ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
COPYRIGHT 1963
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
ENTHALPY OF WATER-BTU PER LB DRY AIR
HUMIDITY RATIO (W)-POUNDS MOISTURE PER POUND DRY AIR
WET BULB OR WATER TEMPERATURE F
SENSIBLE HEAT / TOTAL HEAT = ΔHs / ΔHT
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE F
85 F WET BULB TEMPERATURE
VOLUME CU. FT. PER LB. DRY AIR
RELATIVE HUMIDITY
DRY BULB TEMPERATURE F
HUMIDITY RATIO (W)—POUNDS MOISTURE PER POUND DRY AIR
0.006753
77
A1
PH 3-6-95
GB 3-8-95
(2.3/16.7)(0.5) + 13.5 =
13.569 ft3/lbda = 0.0737 lbda/ft3

DAVID W. MCKENZIE, INC.
Air Handling Equipment

P.O. Box 728, Bellevue, WA 98009
Phone Number: 206-454-4666
Fax Number: 206-562-1169

Date: 02-09-95 *Number of Pages (Including Cover Page):* 3

To: PETER LANGOWSKI
KAISER ENGINEERS HANFORD *Fax Number:* 509-373-3343

RE:

RECIRCULATION & EXHAUST FANS
FAN ENGINEERING COMPANY

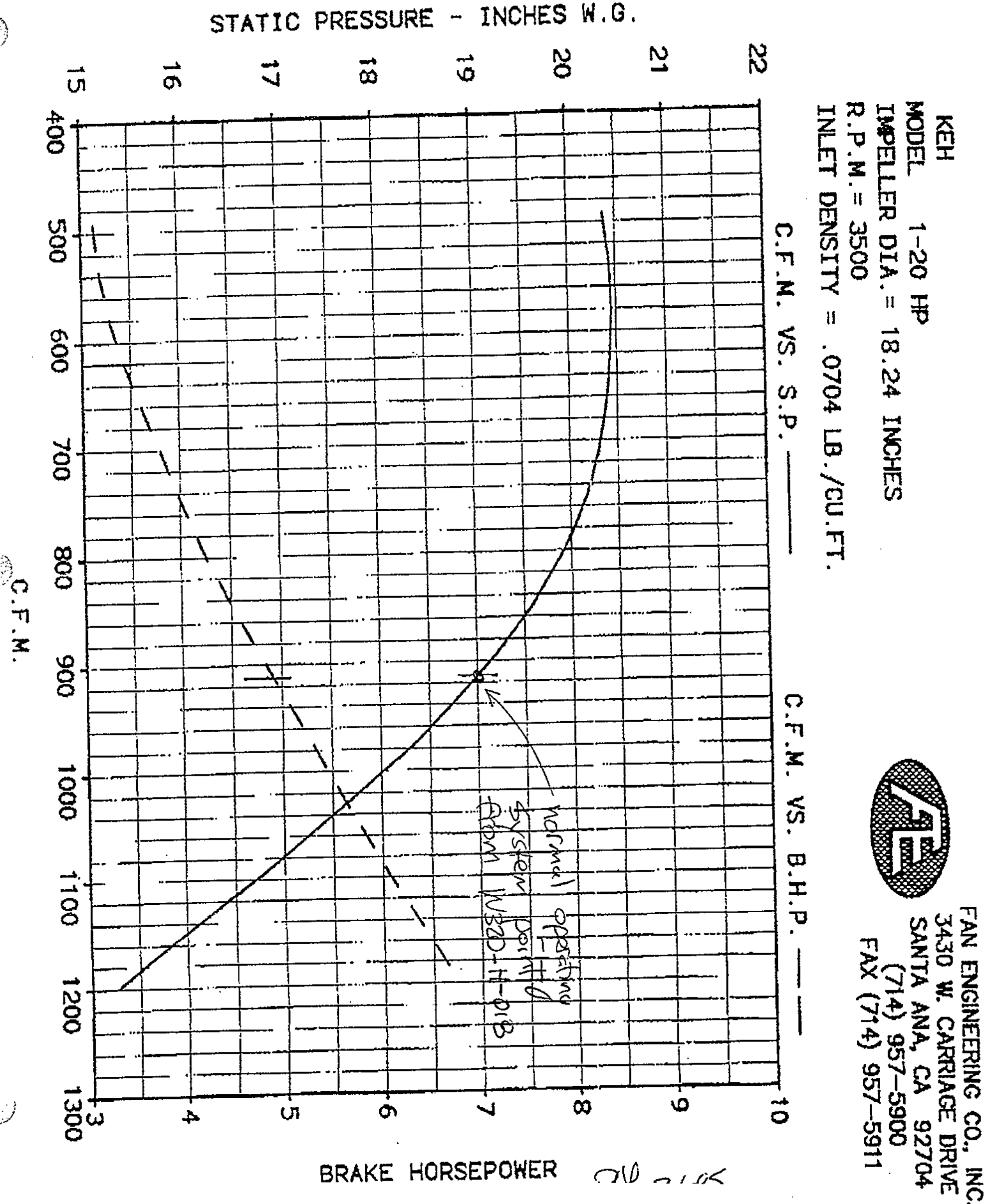
Message:

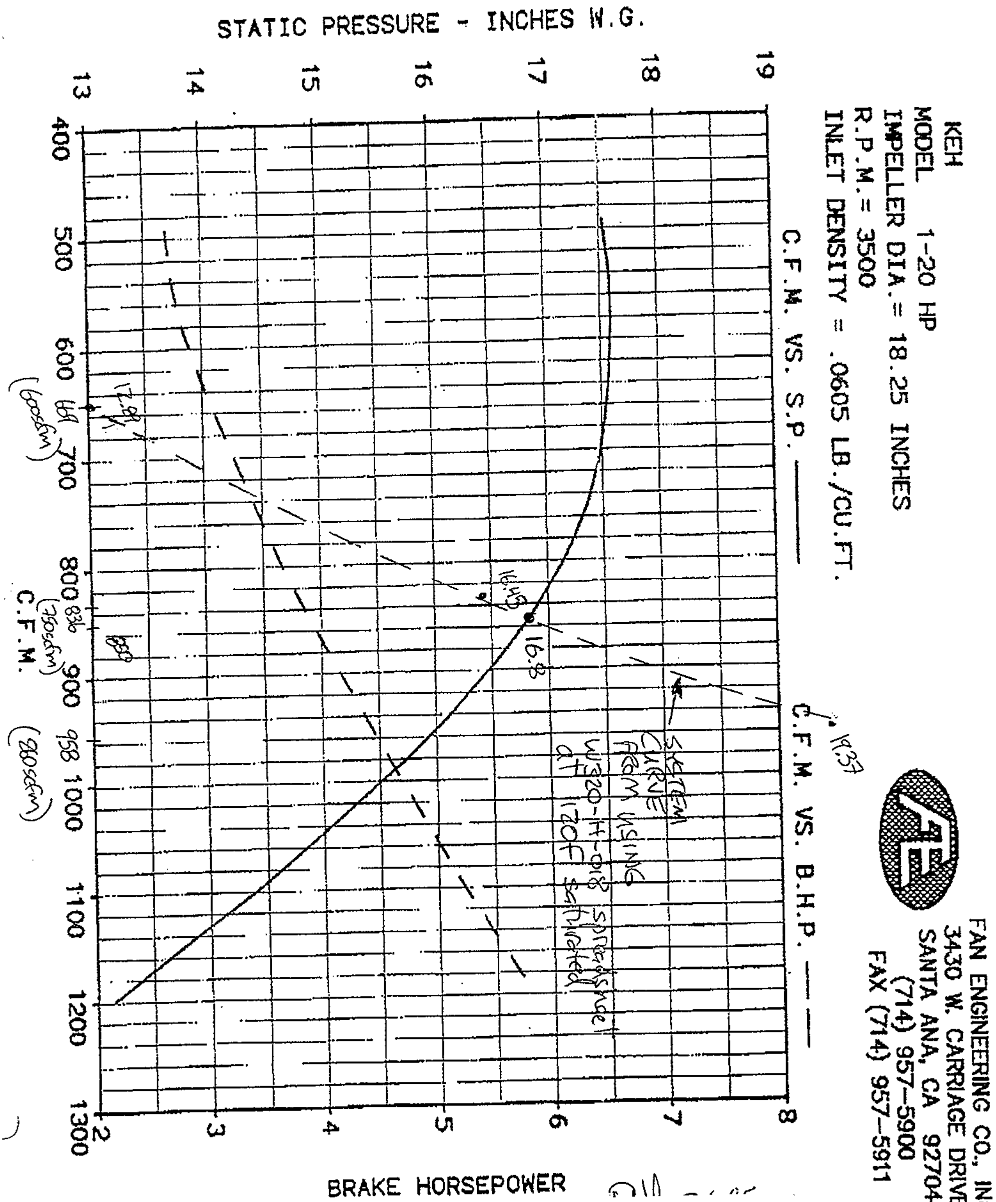
Enclosed are performance curves for the design density of 0.0704 lb/cu ft and the upset density of 0.0605 lb/cu ft.

As we discussed, the basic fan and motor size remains the same. The fan wheel diameter will increase from 17" to 18.25".

Information on the clutch for preventing backflow has been forwarded to the factory. It appears as though the overall length of the assembly will increase with the addition of this device. There will be no change in the fan centerline height or in the relationship between the inlet and discharge. I will advise you of any changes as soon as I hear from the factory.

Please call whenever I can be of assistance.


STATIC PRESSURE - INCHES W.G.
KEH
MODEL 1-20 HP
IMPELLER DIA. = 18.24 INCHES
R.P.M. = 3500
INLET DENSITY = .0704 LB./CU.FT.
C.F.M. VS. S.P.
C.F.M. VS. B.H.P.
FAN ENGINEERING CO., INC.
3430 W. CARRIAGE DRIVE
SANTA ANA, CA 92704
(714) 957-5900
FAX (714) 957-5911
Normal operating
system point
from W320-H-018
C.F.M.
BRAKE HORSEPOWER


STATIC PRESSURE - INCHES W.G.
KEH
MODEL 1-20 HP
IMPELLER DIA. = 18.25 INCHES
R.P.M. = 3500
INLET DENSITY = .0605 LB./CU.FT.
C.F.M. VS. S.P.
C.F.M. VS. B.H.P.
FAN ENGINEERING CO., INC.
3430 W. CARRIAGE DRIVE
SANTA ANA, CA 92704
(714) 957-5900
FAX (714) 957-5911
SYSTEM CURVE FROM USING W320-H-018 spreadsheet at 120F saturated
16.8
16.45
19.37
C.F.M.
BRAKE HORSEPOWER

120°F UPSET CONDITIONS FOR SYSTEM CURVE GENERATION

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation W320H018 rev 1~~
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D = 1.5, fitting loss = 0.15; Short Radius (SR) elbows: r/D = 1.0, fitting loss = 0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. B-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW SCFM	TEMP DEG F	AIR FLOW ACFM	AIR FLOW TAKEOFF SCFM	DUCTSIZE either round or rectangular: WIDTH IN.	HEIGHT IN.	DIA. IN.	PRESS. LOSS IN. WG	FITTING LOSS COEFF. Co	EQUIV DUCT LENGTH FT.	DUCT AREA SQ. IN.	PERI METER IN.	HYDRAL DIA IN.	REY	FPRIME	F	VEL. FPM	VEL. PRESS. Vp IN. WG	cum delta p (in w.g.) for seal pot calc
		initial only								fittings onl	duct only									
1	tank pressure	960	120	1070	0				1.500			0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.50
2	inlet to hatchway (ED1-1)	960	120	1070	0			24.375	0.003	0.50		466.64	76.58	24.38	76,552	0.019	0.019	330	0.007	1.50
3	hatchway elbow (CD3-12)	960	120	1070	0			24.375	0.003	0.42		466.64	76.58	24.38	76,552	0.019	0.019	330	0.007	1.51
4	hatchway pipe	960	120	1070	0			24.375	0.000		6	466.64	76.58	24.38	76,552	0.019	0.019	330	0.007	1.51
5	hatchway exit (SD4-1)	960	120	1070	0	69	39		0.005	25.00		2691.00	216.00	49.83	27,139	0.025	0.025	57	0.000	1.51
6	hatchway loss	960	120	1070	0	69	39		0.000		10	2691.00	216.00	49.83	27,139	0.025	0.025	57	0.000	1.51
10	inlet to piping (ED1-1)	960	120	1070	0			10.020	0.119	0.50		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.63
11	piping	960	120	1070	0			10.020	0.015		4	78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.65
12	elbow, 90 (LR)	960	120	1070	0			10.020	0.036	0.15		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.68
13	pipe section	960	120	1070	0			10.020	0.019		5	78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.70
14	elbow, 90 (LR)	960	120	1070	0			10.020	0.036	0.15		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.74
15	pipe section	960	120	1070	0			10.020	0.019		5	78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.75
16	elbow, 90 (LR), in Process Bldg	960	120	1070	0			10.020	0.036	0.15		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.79
20	pipe section	960	120	1070	0			10.020	0.004		1	78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.79
21	elbow, 90 (SR)	960	120	1070	0			10.020	0.052	0.22		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.85
22	shutoff valve (7-5) HV-136142	960	120	1070	0			10.020	0.119	0.50		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	1.97
23	heat exchanger HX-1361	960	120	1070	0			10.020	8.656			78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	10.62
24	shutoff valve (7-5) HV-13639	960	120	1070	0			10.020	0.119	0.50		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	10.74
25	elbow, 90 (SR)	960	120	1070	0			10.020	0.052	0.22		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	10.79
26A	tee, flow split, branch (6-3)	960	120	1070	600			10.020	0.145	0.61		78.85	31.48	10.02	186,222	0.016	0.017	1,954	0.238	10.94
30	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	10.95
31	pipe section	360	40	346	0			6.065	0.017		3	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	10.97
32	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.00
33	pipe section	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.02
34	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.02
35	bypass valve (7-5) HV-13649	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.11
36	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.15
37	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.18
38	elbow, 45 (LR)	360	40	346	0			6.065	0.020	0.11		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.20
39	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.21
40	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	11.23
41	HEME HME-1361	360	40	346	0			6.065	10.000			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.23
42	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.25
43	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.26
44	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.28
45	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.30
46	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.32
47	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.33
48	bypass valve (7-5) HV-13646	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.43
49	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.43
50	elbow, 90 (SR)	360	40	346	0			6.065	0.050	0.27		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.48
50A	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.51
51	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.52
52	elbow, 90 (SR)	360	40	346	0			6.065	0.041	0.22		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.56
53	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	21.66
54	HEMF HMF-1361	360	40	346	0			6.065	4.500			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.16
55	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.25
56	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.28
57	pipe section	360	40	346	0			6.065	0.022		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.30
58	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.33
59	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.33
60	tee (6-3)	360	40	346	0			6.065	0.204	1.10		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.53
70	pipe section/flange process bldg	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.55

SYSTEM CURVES CONT-

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation W-320-H-010 rev 1.~~
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D=1.5, fitting loss=0.15; Short Radius (SR) elbows: r/D=1.0, fitting loss=0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. 8-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW	TEMP	AIR FLOW	AIR FLOW TAKEOFF	DUCTSIZE either round or rectangular WIDTH	HEIGHT	DIA.	PRESS. LOSS	FITTING LOSS COEFF.	EQUIV DUCT LENGTH	DUCT AREA	PERI METER	HYDRAL DIA	REY	FPRIME	F	VEL.	VEL. PRESS. Vp	cum delta p (in w.g.) for seal pot calc
		SCFM	DEG F	ACFM	SCFM	IN.	IN.	IN.	IN. WG	Co	FT.	SQ. IN.	IN.	IN.				FPM	IN. WG	
		initial only								fittings onl	duct only									
1	tank pressure	1110	120	1237	0				1.500			0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.50
2	inlet to hatchway (ED1-1)	1110	120	1237	0			24.375	0.005	0.50		466.64	76.58	24.38	88,513	0.019	0.019	382	0.009	1.50
3	hatchway elbow (CD3-12)	1110	120	1237	0			24.375	0.004	0.42		466.64	76.58	24.38	88,513	0.019	0.019	382	0.009	1.51
4	hatchway pipe	1110	120	1237	0			24.375	0.000		6	466.64	76.58	24.38	88,513	0.019	0.019	382	0.009	1.51
5	hatchway exit (SD4-1)	1110	120	1237	0	69	39		0.007	25.00		2691.00	216.00	49.83	31,380	0.024	0.024	66	0.000	1.52
6	hatchway loss	1110	120	1237	0	69	39		0.000		10	2691.00	216.00	49.83	31,380	0.024	0.024	66	0.000	1.52
10	inlet to piping (ED1-1)	1110	120	1237	0			10.020	0.159	0.50		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.67
11	piping	1110	120	1237	0			10.020	0.020		4	78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.69
12	elbow, 90 (LR)	1110	120	1237	0			10.020	0.048	0.15		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.74
13	pipe section	1110	120	1237	0			10.020	0.025		5	78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.77
14	elbow, 90 (LR)	1110	120	1237	0			10.020	0.048	0.15		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.81
15	pipe section	1110	120	1237	0			10.020	0.025		5	78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.84
16	elbow, 90 (LR), in Process Bldg	1110	120	1237	0			10.020	0.048	0.15		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.89
20	pipe section	1110	120	1237	0			10.020	0.005		1	78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.89
21	elbow, 90 (SR)	1110	120	1237	0			10.020	0.070	0.22		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	1.96
22	shutoff valve (7-5) HV-136142	1110	120	1237	0			10.020	0.159	0.50		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	2.12
23	heat exchanger HX-1361	1110	120	1237	0			10.020	10.008			78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	12.13
24	shutoff valve (7-5) HV-13639	1110	120	1237	0			10.020	0.159	0.50		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	12.29
25	elbow, 90 (SR)	1110	120	1237	0			10.020	0.070	0.22		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	12.36
26A	tee, flow split, branch (6-3)	1110	120	1237	0			10.020	0.194	0.61		78.85	31.48	10.02	215,319	0.016	0.016	2,259	0.318	12.55
30	elbow, 45 (LR)	360	40	346	750			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.57
31	pipe section	360	40	346	0			6.065	0.017		3	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.59
32	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.61
33	pipe section	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.63
34	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.63
35	bypass valve (7-5) HV-13649	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.72
36	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.76
37	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.80
38	elbow, 45 (LR)	360	40	346	0			6.065	0.020	0.11		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.82
39	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.83
40	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	12.84
41	HEME HME-1361	360	40	346	0			6.065	10.000			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.84
42	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.86
43	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.87
44	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.90
45	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.91
46	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.94
47	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	22.95
48	bypass valve (7-5) HV-13646	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.04
49	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.04
50	elbow, 90 (SR)	360	40	346	0			6.065	0.050	0.27		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.09
50A	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.13
51	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.14
52	elbow, 90 (SR)	360	40	346	0			6.065	0.041	0.22		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.18
53	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	23.27
54	HEMF HMF-1361	360	40	346	0			6.065	4.500			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.77
55	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.86
56	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.89
57	pipe section	360	40	346	0			6.065	0.022		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.91
58	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.94
59	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	27.94
60	tee (6-3)	360	40	346	0			6.065	0.204	1.10		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.14
70	pipe section/flange process bldg	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.16

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation W320-H-018 rev~~ 1.
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D = 1.5, fitting loss = 0.15; Short Radius (SR) elbows: r/D = 1.0, fitting loss = 0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. B-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW	TEMP	AIR FLOW	AIR FLOW TAKEOFF	DUCTSIZE either round or rectangular WIDTH	HEIGHT	DIA.	PRESS. LOSS	FITTING LOSS COEFF.	EQUIV DUCT LENGTH	DUCT AREA	PERI METER	HYDRAL DIA	REY	FPRIME	F	VEL.	VEL. PRESS. Vp	cum delta p (in w.g.) for seal pot calc
		SCFM	DEG F	ACFM	SCFM	IN.	IN.	IN.	IN. WG	Co	FT.	SQ. IN.	IN.	IN.				FPM	IN. WG	
		initial only								fittings onl	duct only									
71	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.58
72	pipe section	360	40	346	0			6.065	0.094		17	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.67
73	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.70
74	pipe section/flange exhaust skid	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	26.71
							total to exhaust skid		26.71											
26A	tee, flow split, main (6-3)	600	120	669	0			10.020	0.035	0.38		78.85	31.48	10.02	116,389	0.018	0.018	1,221	0.093	10.83
80	reducer, contraction (5-1)	600	120	669	0			6.065	0.048	0.07		28.89	19.05	6.07	192,286	0.017	0.017	3,333	0.692	10.88
81	elbow, 90 (LR)	600	120	669	0			6.065	0.104	0.15		28.89	19.05	6.07	192,286	0.017	0.017	3,333	0.692	10.98
82	moisture separator MS-1361	600	120	669	0			6.065	2.677			28.89	19.05	6.07	192,286	0.017	0.017	3,333	0.692	13.66
83	reducer, expansion (4-1)	600	120	669	0			7.981	0.157	0.68		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	13.81
84	tee (6-3)	600	120	669	0			7.981	0.000	0.00		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	13.81
85	elbow, 90 (LR)	600	120	669	0			7.981	0.035	0.15		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	13.85
86	transition (4-3)	600	120	669	0			7.981	0.162	0.70		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.01
87	electric heating coil HC-1361	600	120	669	0			7.981	0.042	0.15		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.05
88	transition (5-1)	600	120	669	0			7.981	0.016	0.07		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.07
89	elbow, 90 (LR)	600	120	669	0			7.981	0.035	0.15		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.10
90	pipe section	600	120	669	0			7.981	0.019		4	50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.12
91	recirculation fan FN-1361	600	120	669	0			7.981	0.000	0.00		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.12
92	pipe section	600	120	669	0			7.981	0.019		4	50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.14
93	elbow, 45 (LR)	600	120	669	0			7.981	0.021	0.09		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.16
94	pipe section	600	120	669	0			7.981	0.014		3	50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.18
95	elbow, 45 (LR)	600	120	669	0			7.981	0.021	0.09		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.20
96	bypass valve (7-5) HV-13648	600	120	669	0			7.981	0.115	0.50		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.31
97	pipe section	600	120	669	0			7.981	0.063		13	50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.38
98	elbow, 90 (LR)	600	120	669	0			7.981	0.035	0.15		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.41
99	converging wye (6-2)	600	120	669	0			7.981	-0.035	-0.15		50.03	25.07	7.98	146,124	0.017	0.018	1,925	0.231	14.38
100	pipe section riser R-2	600	120	669	0			11.938	0.010		14	111.93	37.50	11.94	97,689	0.018	0.018	860	0.046	14.39
							up to flow split		9.29											12.89 check
							split back to tank		3.59											
							total for recirc fan		12.89											

DATA USED ABOVE

elevation density factor at 500 feet = 0.982
roughness = 0.0001
density (corrected for elevation) = 0.0594 lbm/ft3 120F saturated air 16.519 ft3/lbm 0.964 altitude correction
kinematic viscosity = 0.000146 ft2/s

120F saturated air: 16.519 ft3/lbm
40F saturated air: 12.696

friction factors			
galvanized	0.0003	medium smooth	
carbon steel	0.0001	smooth	

kinematic viscosity	temp(F)	ft2/s
Mechanical Engineering	0.00	1.26E-04
Reference Manual Eighth	20.00	1.36E-04
Edition, p.3-36.	40.00	1.46E-04
	60.00	1.58E-04
	68.00	1.60E-04
	80.00	1.69E-04

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation W320-H-010 rev 1~~
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D = 1.5, fitting loss = 0.15; Short Radius (SR) elbows: r/D = 1.0, fitting loss = 0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. B-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW SCFM	TEMP DEG F	AIR FLOW ACFM	AIR FLOW TAKEOFF SCFM	DUCTSIZE either round or rectangular WIDTH IN.	HEIGHT IN.	DIA. IN.	PRESS. LOSS IN. WG	FITTING LOSS COEFF. Co	EQUIV DUCT LENGTH FT.	DUCT AREA SQ. IN.	PERI METER IN.	HYDRAL DIA IN.	REY	FPRIME	F	VEL. FPM	VEL. PRESS. Vp IN. WG	cum delta p (in w.g.) for seal pot calc
		initial only								fittings only	duct only									
71	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.19
72	pipe section	360	40	346	0			6.065	0.094		17	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.29
73	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.31
74	pipe section/flange exhaust skid	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.32
								total to exhaust skid	28.32											
26A	tee, flow split, main (6-3)	750	120	836	0			10.020	0.055	0.38		78.85	31.48	10.02	145,486	0.017	0.017	1,526	0.145	12.41
80	reducer, contraction (5-1)	750	120	836	0			6.065	0.076	0.07		28.89	19.05	6.07	240,358	0.016	0.017	4,166	1.082	12.49
81	elbow, 90 (LR)	750	120	836	0			6.065	0.162	0.15		28.89	19.05	6.07	240,358	0.016	0.017	4,166	1.082	12.65
82	moisture separator MS-1361	750	120	836	0			6.065	4.183			28.89	19.05	6.07	240,358	0.016	0.017	4,166	1.082	16.83
83	reducer, expansion (4-1)	750	120	836	0			7.981	0.245	0.68		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.08
84	tee (6-3)	750	120	836	0			7.981	0.000	0.00		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.08
85	elbow, 90 (LR)	750	120	836	0			7.981	0.054	0.15		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.13
86	transition (4-3)	750	120	836	0			7.981	0.253	0.70		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.39
87	electric heating coil HC-1361	750	120	836	0			7.981	0.052	0.15		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.44
88	transition (5-1)	750	120	836	0			7.981	0.025	0.07		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.46
89	elbow, 90 (LR)	750	120	836	0			7.981	0.054	0.15		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.52
90	pipe section	750	120	836	0			7.981	0.029		4	50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.55
91	recirculation fan FN-1361	750	120	836	0			7.981	0.000	0.00		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.55
92	pipe section	750	120	836	0			7.981	0.029		4	50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.58
93	elbow, 45 (LR)	750	120	836	0			7.981	0.032	0.09		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.61
94	pipe section	750	120	836	0			7.981	0.022		3	50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.63
95	elbow, 45 (LR)	750	120	836	0			7.981	0.032	0.09		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.66
96	bypass valve (7-5) HV-13648	750	120	836	0			7.981	0.180	0.50		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.84
97	pipe section	750	120	836	0			7.981	0.095		13	50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.94
98	elbow, 90 (LR)	750	120	836	0			7.981	0.054	0.15		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.99
99	converging wye (6-2)	750	120	836	0			7.981	-0.054	-0.15		50.03	25.07	7.98	182,655	0.017	0.017	2,406	0.361	17.94
100	pipe section riser R-2	750	120	836	0			11.938	0.014		14	111.93	37.50	11.94	122,112	0.018	0.018	1,075	0.072	17.95
								up to flow split	10.86											16.45 check
								split back to tank	5.59											
								total for recirc fan	16.45											

DATA USED ABOVE

elevation density factor at 500 feet = 0.982
roughness = 0.0001
density (corrected for elevation) = 0.0594 lbm/ft3 120F saturated air 16.519 ft3/lbm 0.964 altitude correction
kinematic viscosity = 0.000146 ft2/s

120F saturated air: 16.519 ft3/lbm
40F saturated air: 12.696

friction factors			
galvanized	0.0003	medium smooth	
carbon steel	0.0001	smooth	

kinematic viscosity	temp(F)	ft2/s
Mechanical Engineering Reference Manual Eighth Edition, p.3-36.	0.00	1.26E-04
	20.00	1.36E-04
	40.00	1.46E-04
	60.00	1.58E-04
	68.00	1.60E-04
	80.00	1.69E-04

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SYSTEM CURVES CONT-

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation W320H-018 rev 1.~~
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D = 1.5, fitting loss = 0.15; Short Radius (SR) elbows: r/D = 1.0, fitting loss = 0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. B-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW SCFM	TEMP DEG F	AIR FLOW ACFM	AIR FLOW TAKEOFF SCFM	DUCTSIZE either round or rectangular WIDTH IN.	HEIGHT IN.	DIA. IN.	PRESS. LOSS IN. WG	FITTING LOSS COEFF. Co	EQUIV DUCT LENGTH FT.	DUCT AREA SQ. IN.	PERI METER IN.	HYDRAL DIA IN.	REY	FPRIME	F	VEL. FPM	VEL. PRESS. Vp IN. WG	cum delta p (in w.g.) for seal pot calc
		initial only								fittings only	duct only									
1	tank pressure	1220	120	1360	0				1.500			0.00	0.00	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.50
2	inlet to hatchway (ED1-1)	1220	120	1360	0			24.375	0.005	0.50		466.64	76.58	24.38	97,284	0.018	0.018	420	0.011	1.51
3	hatchway elbow (CD3-12)	1220	120	1360	0			24.375	0.005	0.42		466.64	76.58	24.38	97,284	0.018	0.018	420	0.011	1.51
4	hatchway pipe	1220	120	1360	0			24.375	0.000		6	466.64	76.58	24.38	97,284	0.018	0.018	420	0.011	1.51
5	hatchway exit (SD4-1)	1220	120	1360	0	69	39		0.008	25.00		2691.00	216.00	49.83	34,489	0.023	0.023	73	0.000	1.52
6	hatchway loss	1220	120	1360	0	69	39		0.000		10	2691.00	216.00	49.83	34,489	0.023	0.023	73	0.000	1.52
10	inlet to piping (ED1-1)	1220	120	1360	0			10.020	0.192	0.50		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.71
11	piping	1220	120	1360	0			10.020	0.023		4	78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.73
12	elbow, 90 (LR)	1220	120	1360	0			10.020	0.058	0.15		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.79
13	pipe section	1220	120	1360	0			10.020	0.029		5	78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.82
14	elbow, 90 (LR)	1220	120	1360	0			10.020	0.058	0.15		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.88
15	pipe section	1220	120	1360	0			10.020	0.029		5	78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.91
16	elbow, 90 (LR), in Process Bldg	1220	120	1360	0			10.020	0.058	0.15		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.97
20	pipe section	1220	120	1360	0			10.020	0.006		1	78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	1.97
21	elbow, 90 (SR)	1220	120	1360	0			10.020	0.085	0.22		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	2.06
22	shutoff valve (7-5) HV-136142	1220	120	1360	0			10.020	0.192	0.50		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	2.25
23	heat exchanger HX-1361	1220	120	1360	0			10.020	11.000			78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	13.25
24	shutoff valve (7-5) HV-13639	1220	120	1360	0			10.020	0.192	0.50		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	13.44
25	elbow, 90 (SR)	1220	120	1360	0			10.020	0.085	0.22		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	13.53
26A	tee, flow split, branch (6-3)	1220	120	1360	0			10.020	0.234	0.61		78.85	31.48	10.02	236,657	0.016	0.016	2,483	0.384	13.76
30	elbow, 45 (LR)	360	40	346	860			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.78
31	pipe section	360	40	346	0			6.065	0.017		3	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.79
32	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.82
33	pipe section	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.84
34	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.84
35	bypass valve (7-5) HV-13649	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.93
36	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	13.97
37	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	14.00
38	elbow, 45 (LR)	360	40	346	0			6.065	0.020	0.11		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	14.02
39	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	14.03
40	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	14.05
41	HEME HME-1361	360	40	346	0			6.065	10.000			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.05
42	elbow, 45 (LR)	360	40	346	0			6.065	0.017	0.09		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.07
43	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.08
44	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.11
45	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.12
46	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.15
47	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.16
48	bypass valve (7-5) HV-13646	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.25
49	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.25
50	elbow, 90 (SR)	360	40	346	0			6.065	0.050	0.27		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.30
50A	elbow, 90 (LR)	360	40	346	0			6.065	0.035	0.19		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.33
51	pipe section	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.35
52	elbow, 90 (SR)	360	40	346	0			6.065	0.041	0.22		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.39
53	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	24.48
54	HEMF HMF-1361	360	40	346	0			6.065	4.500			28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	28.98
55	bypass valve (7-5) HV-13648	360	40	346	0			6.065	0.093	0.50		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.07
56	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.10
57	pipe section	360	40	346	0			6.065	0.022		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.12
58	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.15
59	tee (6-3)	360	40	346	0			6.065	0.000	0.00		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.15
60	tee (6-3)	360	40	346	0			6.065	0.204	1.10		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.35
70	pipe section/flange process bldg	360	40	346	0			6.065	0.019		4	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.37

KAISER ENGINEERS HANFORD CO.
DUCT PRESSURE LOSS
CALCULATION SHEET

JOB NO./ W.O. NO. : W-320/ER4319
BLDG NO./ AREA : 241-C-106/200E
DUCT SYSTEM :

PREPARED BY: Peter H. Langowski
DATE: 2/15/95
CHECKED BY:

NOTES: ~~Calculation [illegible]~~
Pressure loss per 1993 Fundamentals p.32.4 Darcy Equation (19).
Hydraulic diameter per 1993 Fundamentals p.32.6 Equation (24).
Reynold's Number per 1993 Fundamentals p.32.5 Equation (22).
Alphanumeric ASHRAE fitting numbers from 1993 Fundamentals. Numeric fitting numbers from 1985 Fundamentals. Pipe sizes for schedule 40S.

Long Radius (LR) elbows: r/D=1.5, fitting loss=0.15; Short Radius (SR) elbows: r/D=1.0, fitting loss=0.22, losses per 1991 Applications, p. 27.9, Table 4. Combined elbow factor of 1.25 per p. B-14.

NOTE: COLUMNS UNDER SHADED AREAS REQUIRE USER INPUT

#	TYPE OF FITTING (ASHRAE #)	AIR FLOW SCFM	TEMP DEG F	AIR FLOW ACFM	AIR FLOW TAKEOFF SCFM	DUCTSIZE either round or rectangular WIDTH IN.	HEIGHT IN.	DIA. IN.	PRESS. LOSS IN. WG	FITTING LOSS COEFF. Co	EQUIV DUCT LENGTH FT.	DUCT AREA SQ. IN.	PERI METER IN.	HYDRAL DIA IN.	REY	FPRIME	F	VEL. FPM	VEL. PRESS. Vp IN. WG	cum delta p (in w.g.) for seal pot calc
		initial only								fittings only	duct only									
71	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.40
72	pipe section	360	40	346	0			6.065	0.094		17	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.49
73	elbow, 90 (LR)	360	40	346	0			6.065	0.028	0.15		28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.52
74	pipe section/flange exhaust skid	360	40	346	0			6.065	0.011		2	28.89	19.05	6.07	99,458	0.019	0.019	1,724	0.185	29.53
								total to exhaust skid	29.53											
26A	tee, flow split, main (6-3)	860	120	958	0			10.020	0.073	0.38		78.85	31.48	10.02	166,824	0.017	0.017	1,750	0.191	13.60
80	reducer, contraction (5-1)	860	120	958	0			6.065	0.100	0.07		28.89	19.05	6.07	275,610	0.016	0.016	4,777	1.423	13.70
81	elbow, 90 (LR)	860	120	958	0			6.065	0.213	0.15		28.89	19.05	6.07	275,610	0.016	0.016	4,777	1.423	13.91
82	moisture separator MS-1361	860	120	958	0			6.065	5.500			28.89	19.05	6.07	275,610	0.016	0.016	4,777	1.423	19.41
83	reducer, expansion (4-1)	860	120	958	0			7.981	0.323	0.68		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	19.73
84	tee (6-3)	860	120	958	0			7.981	0.000	0.00		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	19.73
85	elbow, 90 (LR)	860	120	958	0			7.981	0.071	0.15		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	19.80
86	transition (4-3)	860	120	958	0			7.981	0.332	0.70		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.14
87	electric heating coil HC-1361	860	120	958	0			7.981	0.060	0.15		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.20
88	transition (5-1)	860	120	958	0			7.981	0.033	0.07		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.23
89	elbow, 90 (LR)	860	120	958	0			7.981	0.071	0.15		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.30
90	pipe section	860	120	958	0			7.981	0.038		4	50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.34
91	recirculation fan FN-1361	860	120	958	0			7.981	0.000	0.00		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.34
92	pipe section	860	120	958	0			7.981	0.038		4	50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.38
93	elbow, 45 (LR)	860	120	958	0			7.981	0.043	0.09		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.42
94	pipe section	860	120	958	0			7.981	0.028		3	50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.45
95	elbow, 45 (LR)	860	120	958	0			7.981	0.043	0.09		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.49
96	bypass valve (7-5) HV-13648	860	120	958	0			7.981	0.237	0.50		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.73
97	pipe section	860	120	958	0			7.981	0.122		13	50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.85
98	elbow, 90 (LR)	860	120	958	0			7.981	0.071	0.15		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.92
99	converging wye (6-2)	860	120	958	0			7.981	-0.071	-0.15		50.03	25.07	7.98	209,445	0.016	0.017	2,759	0.474	20.85
100	pipe section riser R-2	860	120	958	0			11.938	0.018		14	111.93	37.50	11.94	140,022	0.017	0.017	1,233	0.095	20.87
								up to flow split	12.03											19.37 check
								split back to tank	7.34											
								total for recirc fan	19.37											

DATA USED ABOVE

elevation density factor at 500 foot = 0.982
roughness = 0.0001
density (corrected for elevation) = 0.0594 lbm/ft3 — 120F saturated air 16.519 ft3/lbm — 0.964 altitude correction
kinematic viscosity = 0.000146 ft2/s

120F saturated air: 16.519 ft3/lbm
40F saturated air: 12.696

friction factors			
	galvanized	0.0003	medium smooth
	carbon steel	0.0001	smooth

kinematic viscosity	temp(F)	ft2/s
Mechanical Engineering	0.00	1.26E-04
Reference Manual Eighth	20.00	1.36E-04
Edition, p.3-36.	40.00	1.46E-04
	60.00	1.58E-04
	68.00	1.60E-04
	80.00	1.69E-04

W320-28-004

Sizing High Efficiency Mist Eliminator

CALCULATION IDENTIFICATION AND INDEX

Date 11-3-94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. ~~W320-H-004~~ 28 W320-28-004

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item Sizing High Efficiency Mist Eliminator

These calculations apply to:

Dwg. No. N/A Rev. No. N/A

Dwg. No. N/A Rev. No. N/A

Other (Study, CDR)
Procurement Specification:
W-320-P5 High Efficiency Mist Eliminator Rev. No. ~~preliminary~~ 0

The status of these calculations is:

~~[X]~~ Preliminary Calculations

[X] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	F. Pinto 11/3/94	F. Pinto 4/3/95	
Checked by	B. Price 11/8/94	P.H. Laughlin 4-3-95	
Approved by	P.H. Laughlin 11-8-94	P.H. Laughlin 4-3-95	
Checked Against Approved Vendor Data		Charles T. Li 4/10/98	

INDEX

Design Analysis Page No.	Description
i-ii	Calculation Identification and Index
1	Objective, Criteria, Given Data
2	Assumptions & References
3-11	Findings, Conclusions & Calculations

KEH 0378.00 (06/92) KEF072

	CALCULATION IDENTIFICATION AND INDEX Continuation Sheet	Page ii of ii Date 11-3-94

Discipline 28/HVAC   WO/Job No. ER4319   Calculation No. W320-~~H~~ 28-004

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	R. Pirri 11/3/94	R. Pirri 4/3/95	
Checked by	B. Rice 11/8/94	P.H. Laughlin 4-3-95	

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Design Analysis Page No.	Description
~~Appx A~~ A1-A2	Sample Calculation

KEH 0378.01 (06/92) KEF072

DESIGN ANALYSIS

Client WHC	WO/Job No. ER4319/W320		
Subject Sizing of High Efficiency Mist Eliminator	Date 11-3-94	By R. Pina	
	Checked 11/8/94	By P. Rice	PHR 4-3-9
Location 241-C/200 East	Revised 4/3/95	By R. Pina	

Δ1

1.0 OBJECTIVE

To size a High Efficiency Mist Eliminator (HEME) for Project W-320.

2.0 CRITERIA

Δ1 The HEME will remove aerosols and condensed water vapor (mist) from the exhaust ventilation system of Tank 241-C-106. Criteria provided per reference (1) ~~and~~ (2), and (16).

3.0 GIVEN DATA

The tank airstream characterization, per Reference (~~2~~ 16), is as follows:

~~AMMONIA AND ORGANIC CONCENTRATIONS~~

Δ1

~~Component~~	~~Concentration (mg/m^3)~~
~~EDTA~~	~~0.03285~~
~~HEDTA~~	~~0.02664~~
~~Oxylates and formulate and citrate~~	~~0.50286~~
~~Ammonia~~	~~0.00765~~

TOTAL AEROSOL CONCENTRATION
~~(<10 micron)~~
(includes components above)

Component	Concentration (mg/m^3)
Water	~~80~~ 2.97E+02
Soluble solids ~~in water solution~~	~~10~~ 6.92E-01
Insoluble free solids	~~10~~ 1.49E+01
Total	~~100~~ 313

Air Flow Rates, per Reference (14), are as follows:
Range 180-360 scfm
nominal 230 scfm

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By P. Rice PHR 4-3-95
Revised 4/3/95 By R. Pina

4.0 ASSUMPTIONS

Review of references, standards, etc... indicates that there is no definitive process to size/select a HEME. As will be shown later there are varied recommendations by manufacturers, test labs and users of HEME's. Material from many sources were gathered to provide a basis for sizing and selection of a HEME for Project W-320. Assumptions are as stated within calculation.

5.0 REFERENCES

1) DOE 6430.1A, General Design Criteria
2) WHC-SD-W320-FDC-001, rev. 2, 1/18/94
3) IAEA-TELDOC-521, Retention of Iodine and Other Airborne Radionuclides in Nuclear Facilities During Abnormal and Accident Conditions, 1989
4) US Energy Research and Development Administration 76-21, 1976
5) Perry's Chemical Engineering Handbook, 6th Edition
6) PNL-7142, Hanford Waste Vitrification Program Pilot-Scale Ceramic Melter Test 23
7) PNL-7188, Performance Evaluation of the Pilot-Scale, Double-Shell Tank Ventilation System Using Simulated Aerosol Streams.
8) IAEA-TELDOC-325, Particulate Filtration in Nuclear Facilities, 1991
9) Industrial Ventilation, 2nd Edition
10) ASME N509-1989, Nuclear Power Plant Air Cleaning Units and Components
11) Monsanto Enviro-Chem Quote MCB-001-21390.00-000
12) KOCH Engineering Co. Quote 61921A00
13) CECO Filters Inc. Quote 2973-3
14) H-2-818470, HVAC Overall Flow Diagram, Rev. 0
15) Calculation W320-H-015, Rev. 0
16) LOI, ADDENDUM 7, 12/13/94

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By P. Rice PHR 4-3-95
Revised 4/3/95 By R. Pina

6.0 FINDINGS & CONCLUSIONS

The following specifications will provide a HEME suitable for the exhaust ventilation of Tank 241-C-106:

Face Velocity 12 fpm (maximum)
Nozzle Spray .29 ±.05 gpm at 40 ±10 psig
Spraying Frequency: 1 min./hr to provide .29 gph
Fiber Material: Polyester essentially 100%
Removal Efficiency: >3μm ~~99.99%~~
≤3μm 99~~.5%~~
Maximum Dimensions 10'-3" HT x 45" W
Gasket Material: EPR
Minimum Filter Surface Area = 31 sq ft

The mist concentration at the inlet of the HEME will be 13,049 mg/m^3, due to reentrained water at condenser.

7.0 CALCULATIONS

7.1 FACE VELOCITY

The removal efficiency of HEME's is dependent upon flow rate and the penetration maximum shifts towards smaller particle sizes with increased flow, per pg 56 of Ref. (3). In addition, higher face velocities have been shown to reentrain moisture. Typical HEME face velocities range from 5 to 50 fpm per Ref. (4). Per Ref. (5), pg 18-84, the operating characteristic for a high efficiency mist eliminator range from 15 fpm to 39 fpm. Per Reference (6), pg 10.57, "the HEME should be sized for a superficial gas velocity of 10 fpm" (in their application). A low face velocity would provide four critical HEME characteristics in any application. They are a high removal efficiency, reduced pressure drop, reduced risk of reentrainment and a greater capacity for loading. A face velocity not to exceed 12 fpm is recommended to maximize efficiency. Note, research has indicated that HEME's have an unlimited turndown ratio; therefore, it is not necessary to specify a lower limit face velocity. Although HEME's are essentially designed to be regenerated by spraying the filter, some particulate loading will likely occur. The lower face velocity provides a greater filter surface area for this likely occurrence. For example as the filter loads up the face velocity could increase while still providing a satisfactory removal efficiency. In addition, it maintains the high removal efficiency of the HEME over its lifetime, thus minimizing the risks of filter replacement. Note, specifying a high face velocity will minimize the removal efficiency as well as decrease the life of the filter.

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By P. Rice
Revised By

7.2 FILTER SURFACE AREA

With a face velocity of 12 ft/min the required surface area is as follows:

The maximum flow shall be utilized to size HEME filter area. $Flow := 360$ scfm

$Velocity := 12$ fpm

The actual maximum flow rate at 40F, 13.5psia is: $360\left(\frac{14.7}{14.7-1.2}\right)\cdot\left(\frac{460+40}{520}\right)=377$ acfm

Surface Area Required Min. $\frac{377}{12}=31$ ft^2

7.3 NOZZLE SPRAY RATE

The cases below are the best examples of water spray rates and will be used to determine the spray rate for Project W-320. The range of spray rates could be attributed to the different filter configurations, fiberbed packing density, manufacturer experience, flow conditions, flow rates, etc.... There are too many variables to determine why the spray rates vary so much; therefore, the most conservative option is to select a spray nozzle that can provide .086 to 10.5 gph.

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/3/94 By P. Rice
Revised By

TABLE 1

	Savannah River[1]	DWPF[2]	CECO[3]	PNL[4]	PNL[5]
Spray Rate (mg/ft^3)	15	50	51	1471	.25 (gph/ft^2)
Total gph required for W-320 using above rates at 360 scfm	.086	.286	.29	8.4	10.5
Rate Developed by	in-use	in-use	experience	scale study	scale study

see Appx A for sample calc

1) Per discussion with D. Miller, Westinghouse Savanna, 6/29/94
2) Para. 10.2.5, Ref. (6), Defense Waste Processing Facility (DWPF) at Savannah River
3) Quote No. 2973-2, CECO Filters
4) Pg 10.53-10.54, Ref. (6)
5) Pg 2.3, Ref. (7), note spray rate was rated per ft^2 of filter

Having determined the range of .086 to 10.5 gph the size of the spray nozzle can now be selected. The following flow rates utilize "FullJet" spray nozzles, Spraying Systems Co. to estimate the time required to achieve the gph range. A spray nozzle of .29 ±.05 gpm at 40 ±10 psig provides the gph range at reasonable spray durations and provides additional capacity if required.

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
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WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By P. Rice
Revised By

	Gallons per Hour					Maximum Flow in 1hr (gal)
	.086	.286	.29	8.4	10.5	
Nozzle at 40 psig (gpm)	Time to reach gph (minutes)					
.95	.09	.3	.3	9	11	57
.5	.17	.6	.6	17	21	30
.38	.32	.8	.8	22	28	22.8
.29	**.29**	**1.**	**1.**	**29**	**36**	**17.4**
.19	.45	1.5	1.5	44.2	55	11.4

see Appx A for sample calc

Note per Ref. (5), pg 18-84, "solid particulates are captured as readily as liquids in fiber beds but can rapidly plug the bed if they are insoluble." Solid particulate if not washed away from the fiberbed can become imbedded and impossible to wash off. Therefore, it is imperative that solids introduced into the HEME be minimized and spraying be done frequently to remove insolubles which have impacted the face of the fiberbed. Various studies, handbooks and manufacturers have concluded that intermittent washing of the HEME filter will remove collected aerosols and regenerate the filter (e.g., pg 6.31 of Ref. (7) and pg 37 of Ref. (8)). Findings per Ref. (3), paragraph 5.1.4, indicated "the pressure drop of the HEME filter intensively sprayed with regeneration liquid is dependent on regeneration cycles." Also manufacturers such as CECO recommend spraying intermittently.

Since the introduction of water into a contaminated stream should be minimized and frequent spraying is desired for regeneration, initially the spray should be operated at the low end providing .29 gal/hr and may be increase if necessary. Since the spray will operate for 1 min., it essentially provides .29 gpm. Note, this is significantly greater than .035 gpm of mist in the airstream (due to reentrained water at condenser) and should provide sufficient washing of the fiber, see paragraph 7.7. Monitoring of the differential pressure is recommended during initial operation and the spray rate shall be adjusted, as required. In addition, during any major changes in system operation (e.g, increased sluicing) the HEME should be monitored and adjusted (i.e., frequency & duration of spray) as required. It is not recommended that the HEME operate without intermittent spraying, since this is likely to reduce the life of the HEME.

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/3/94 By R. Rice PHK 4-3-95
Revised 4/3/95 By R. Pina

7.4 FIBER MATERIAL

Recommendations from manufacturers indicate that fiberglass is not resistant to ammonia vapors and polyester is more resistant. Polyester as indicated in Table 4-1 of Ref. (9) provides fair to excellent resistance to various chemicals (mineral acid, organic acid, alkalies, solvents & oxidizing). Without the ability to perform tests with the actual airstream and fiberbed, the recommendations of the manufacturers and Ref. (9), Table 4-1 will be relied upon.

7.4.1 GASKET MATERIAL

Based on the following, EPR (EPT (NORDEL) more commonly known as EPT or EPDM or EPR) gaskets shall be used in the HEME. Compatiability charts from Aeroquip and Pall Trinity Micro Corp. indicate that EPR is compatible with ammonia. Chicago Wilcox Mfg. Co. recommends EPR for chemicals, acids, alkalis. Klinger Inc. indicates that it is suitable for ammonia and has excellent aging properties. Grinell Saunders indicates that EPR has the best relative radiation resistance of their materials. Note, Viton and Buna-N were considered but eliminated due to unsatisfactory resistance to ammonia (anhydrous and aqueous) per AEROQUIP, AIRCO and PALL compatiability charts. Neoprene was not chosen since EPR provides better resistance to chemicals and radiation. Ref. (16) indicates that Ammonia is no longer a concern; however, material will not be changed since it will perform satisfactorily.

7.5 LIFE EXPECTANCY

Essentially the HEME can be regenerated if the airstream consists mostly of soluble aerosols and minimal amounts of insoluble solid particulate. Reference (7) attempted to predict the life of a HEME with a scale HEME; however, attempts to extrapolate this data were unsuccessful. Most references did not provide methods or estimates to predict the life of a HEME; however, I found agreement that the HEME will be regenerated with a water spray. Spraying frequently appears to be the key in extending the life of the HEME.

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By G. Rice AHK 4-3-95
Revised 4/3/95 By R. Pina

7.6 AEROSOL REMOVAL EFFICIENCY

HEME's have varying removal efficiencies dependent upon many variables, fiber density, fiber material, flow rates, airstream, etc... The ranges listed below provide some guidance as to what we can expect. Monsanto and KOCH guarantee that their removal efficiency will be obtained and their efficiencies appear to be in close agreement with the other data. Note, other studies have demonstrated that higher efficiencies are attainable: therefore, it is within reason that manufacturer estimates are attainable. Therefore, the HEME shall be specified to satisfy a removal efficiency of all particulates >3 μm essentially 100% and ≤3 μm 99~~.5~~%.

The following removal efficiencies were obtained from studies or references:

Ref. (3) ≥99.97%
aerosols sizes of 0.52 μm.

Ref. (4) 99.3%
0.3-0.5 μm.

Ref. (5), 5th ed., Table 18-29,
99.3%
≤3 μm inlet concentration of 2.12 mg/scfm of H_2SO_4.

Table 18-22, Ref (5)
>3 μm 100%
≤3 μm 95-99%

Para. 5.4 of Ref. (10),
99%
5-10 μm

The following quotes are manufacturer removal efficiencies for the airstream characterization at low face velocities for project W-320:

III Monsanto Enviro-Chem (Ref. 11)
>3 μm 100%
≤3 μm 99.5%

IV KOCH Engineering Co. (Ref. 12)
>3 μm 100%
≤3 μm 99.5%

V CECO Filters Inc. (Ref. 13)
≥0.5 μm 99%

7.7 Concentration of Reentrained Condenser Water at HEME

DESIGN ANALYSIS

Client WHC
Subject Sizing of High Efficiency Mist Eliminator
Location 241-C/200 East

WO/Job No. ER4319/W320
Date 11-3-94 By R. Pina
Checked 11/8/94 By R. Pina
Revised By

The following calculation determines the amount of water mist at the inlet to the HEME due to reentrained water at the condenser. See Calc W320-H-015 for additional information.

Volumetric flowrate of reentrained water at inlet to HEME:

$$m_w := 0.7 \cdot \frac{lb}{min}$$

In lieu of repeating Ref (15), paragraph 7.5 calc, the reentrained mist at the HEME is equal to a percentage of the mist originating from the condenser.

$$m_r := \frac{360 \cdot \frac{ft^3}{min}}{860 \cdot \frac{ft^3}{min}} \cdot m_w \qquad m_r = 0.293 \cdot \frac{lb_m}{min}$$

Concentration of reentrained water at inlet to HEME:

$$m_r \cdot 0.454 \cdot \frac{kg}{lb_m} \cdot \frac{1}{360} \cdot \frac{min}{ft^3} \cdot \left(3.281 \cdot \frac{ft}{m}\right)^3 \cdot 1 \cdot 10^6 \cdot \frac{mg}{kg} = 13052 \cdot \frac{mg}{m^3}$$

KEH 0037.00 (06/92) KEF055

KAISER ENGINEERS HANFORD

DESIGN ANALYSIS

Calc. No. W320-~~A~~-004
Revision 0

Client WHC
Subject SIZING OF HIGH EFFICIENCY MIST ELIMINATOR
Location 241-C/200 EAST

WO/Job No. ER 4319/W-320
Date 7/12/94 By R. PIÑA
Checked 11/8/94 By R. Rice
Revised By

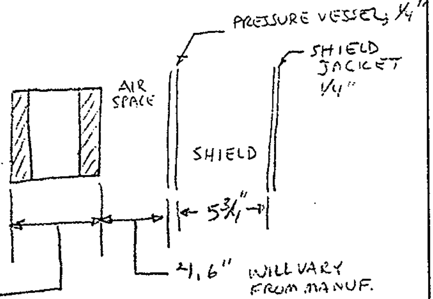
7.8 SPRAY WATER GENERATED OVER 2 YRS:

$$\left(1 \frac{min}{hr}\right)\left(24 \frac{hrs}{day}\right)\left(365 \frac{days}{yr}\right)\left(2\,yr\right)\left(.29 \frac{gal}{min}\right) = 5{,}081\ gal$$

BASED ON .29 gpm, OPERATING 1 min/hr FOR 2 yrs

7.9 MAXIMUM HEME DIMENSIONS

WIDTH OF HEME IS APPROXIMATED FROM QUOTES RECEIVED FROM VENDORS, EXCEPT FOR SHIELDING.



WIDTH = FILTER O.D. + (2)(4.6 + .5 + 5.75)

FOR 32" OD, W = 54"

FOR 24" OD, W = 46"

THE AVAILABLE SPACE IS ~49", TO THE WALL. VENDORS SHOULD BE ABLE TO PROVIDE A WIDTH OF ≤ 45". THIS WOULD ALLOW 4" CLEARANCE FOR WALL.

KAISER ENGINEERS HANFORD	Calc. No. W 320-M-004
	Revision 0
DESIGN ANALYSIS	Page No. 11 of 11
Client WHC	WO/Job No. ER4319 W-320
Subject SIZING OF HIGH. EFFICIENCY MIST ELIMINATOR	Date 7/12/94 By R. PINA
	Checked 11/8/94 By B. Rice
Location 241-C/200 EAST	Revised By

7.9 CONT.

ESTIMATED HEIGHT OF HEME IS APPROXIMATED FROM VENDOR QUOTES AS WELL AS UTILIZING REQUIRED FACE VELOCITY TO DETERMINE FILTER SURFACE AREA.

AREA REQUIRED IS 31 - 42 ft^2, SEE PARA 7.2

MINIMUM HEIGHT
(FOR "CECO")

32" OD
28" ID

HT OF FILTER IS, AT MIN. AREA

$$\frac{31\ ft^2}{2\pi(1.167\ ft)} = 4'$$

MAXIMUM HEIGHT
(FOR "MONSANTO")

24" OD
20" ID

AT MAX, AREA

$$\frac{42\ ft^2}{2\pi(.933\ ft)} = 8'$$

THE HT ESTIMATED IS

	MONSANTO	CECO
FILTER	8 (MAX)	4 (MIN)
HOUSING	3.5	3.5
SHIELDING	1	1
SUPPORT	1.5	1.5
	14'	10'

IT IS LIKELY A HEME CAN BE SIZED TO ACCOMODATE A 10'3" AVAILABLE HEIGHT. NOTE 11' IS ACTUALLY AVAILABLE SO THIS WOULD PROVIDE A 9" CLEARANCE.

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DESIGN ANALYSIS	Calc. No. W320-H-004
	Revision 0
	Page No. 1 of 2
Client WHC	WO/Job No. ER4319/W-320
Subject SIZING OF HIGH EFFICIENCY MIST ELIMINATOR	Date 7/12/94 By R. PIÑA
	Checked 11/8/94 By G. Rice
Location 241-C/200 EAST	Revised By

APPX A
SAMPLE CALC FOR TABLE 1

THE FOLLOW CALCULATIONS CONVERT THE RECOMMENDED SPRAY RATES TO mg/Ft^3, FOR TABLE 1.

FOR "CECO"
THEY RECOMMENDED .37 gal/hr AT MAX 460 SCFM

$$= \frac{(.37\ gal/hr)\left(\frac{1}{.1198}\ \frac{lb}{gal}\right)\left(\frac{1}{2.205\times10^{-3}}\ \frac{g}{lb}\right)\left(1000\ \frac{mg}{g}\right)}{\left(60\ \frac{min}{hr}\right)\left(460\ \frac{Ft^3}{min}\right)} = 51\ \frac{mg}{Ft^3}$$

FOR PNL[4]
THEY RECOMMENDED 15 L/hr, AT MAX 170 SCFM

$$= \frac{(15\ L/hr)\left(.2642\ \frac{gal}{L}\right)\left(\frac{1}{.1198}\ \frac{lb}{gal}\right)\left(\frac{1}{2.205\times10^{-3}}\ \frac{g}{lb}\right)\left(1000\ \frac{mg}{g}\right)}{\left(60\ \frac{min}{hr}\right)\left(170\ \frac{Ft^3}{min}\right)}$$

$$= 1471\ mg/Ft^3$$

SPRAY RATES FOR SAVANNAH, DWPF & PNL[5] NOT SHOWN SINCE THEY WERE GIVEN IN mg/Ft^3.

KEH 0037.00 (06/92) KEF055

KAISER ENGINEERS
HANFORD

DESIGN ANALYSIS

Client WHC		Calc. No. W320-A-004	
Subject SIZING OF HIGH EFFICIENCY MIST ELIMINATOR		Revision 0	
Location 241-C/200 EAST		Page No. 2 of 2	
		WO/Job No. ER4319 / W-320	
		Date 7/12/94	By R. PINA
		Checked 11/8/94	By G. Rice
		Revised	By

THE GPH REQUIRED AT RECOMMENDED SPRAY RATES AT 360SCFM ARE DETERMINED AS FOLLOWS: (FOR TABLE 1)

FROM VARIOUS RECOMMENDATIONS

$$GPH = \left(\square \frac{mg}{Ft^3}\right)\left(\frac{1}{1000}\frac{g}{mg}\right)\left(2.205\times10^{-3}\frac{lb}{g}\right)\left(.1198\frac{gal}{lb}\right)\left(60\frac{min}{hr}\right)\left(360\frac{Ft^3}{min}\right)$$

$$= \left(\square \frac{mg}{Ft^3}\right)\left(5.71\times10^{-3}\right)$$

FOR EXAMPLE AT 51 mg/Ft^3, CECO

$$GPH = 51(5.71\times10^{-3}) = .29\ gph$$

TIME FOR SPRAYING OBTAINED AS FOLLOWS: (FOR TABLE 2)

$$\frac{.29\ gph}{.29\ gpm} = 1\ \text{minute per hr}$$

spray rate → .29 gpm

TOTAL GPH FOR PNL^5 DETERMINED USING MAX AREA

$$.25\frac{gph}{Ft^2}\left(42\ Ft^2\right) = 10.5\ gph$$

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W320-28-005

Sizing Electric Heating Coil

KAISER ENGINEERS HANFORD

CALCULATION IDENTIFICATION AND INDEX

Date 5-10-94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline HVAC

WO/Job No. ER4319

Calculation No. ~~W320-H-005~~ 28 W320-28-005

Project No. & Name W-320 TANK 241-C-106

Calculation Item SIZING ELECTRIC HEATING COIL

These calculations apply to:

Dwg. No. Rev. No.

Dwg. No. Rev. No.

Other (Study, CDR) Rev. No.

The status of these calculations is:

[] Preliminary Calculations

[X] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	[illegible] 5/13/94	R. Pisani 4/6/95	
Checked by	K. [illegible] 5/18/94	P H Laughlin 4-6-95	
Approved by	P H Laughlin 5-18-94	P H Laughlin 4-6-95	
Checked Against Approved Vendor Data		Charles T. Li 4/14/98	

INDEX

KEH 0378.00 (06/92) KEF072

KAISER ENGINEERS
HANFORD

Calc. No. W320-~~H~~-005
Revision ~~0~~ 1
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DESIGN ANALYSIS

Client WHC
Subject SIZING ELECTRIC HEATING COIL
Location 241-C/200E

WO/Job No. ER4319
Date 5-10-94 By B. E. HURNEVICH
Checked By 5/18/94 4-6-95
Revised 4/4/95 By

OBJECTIVE: THE OBJECTIVE OF THIS CALCULATION IS TO SIZE THE ELECTRIC HEATING COIL REQUIRED FOR THE HVAC RECIRCULATION LOOP FOR PROJECT W-320.

CRITERIA AND SOURCE: FUNCTIONAL DESIGN CRITERIA, WHC-SD-W320-FDC-001, REVISION 2.

GIVEN DATA:

- AIR ENTERS COIL AT 40FDB (DRAWING H-2-8184~~70~~ 68, REV. 0)
- ~~15% CONDENSATE (DRAWING H-2-818478, REV.0) IS ENTRAINED IN THE AIRSTREAM. 15% OF THE CONDENSATES ENTERING THE CONDENSER UPSTREAM OF THE HEATER.~~
- DURING NORMAL OPERATION AIR WILL LEAVE THE COIL AT 77FDB. (DRAWING H-2-8184~~70~~ 68, REV.N 0)
- AIR VOLUME FLOWING ACROSS COIL WILL BE 860 SCFM (DRAWING H-2-8184~~70~~ 68 REV. 0).
- ASSUME HEATING COIL WILL BE SIZED TO HAVE THE CAPABILITY OF HEATING AIR UP TO 100FDB.

METHODS TO BE USED: HAND CALCULATIONS.

REFERENCES:

1 • CHROMALOX TECHNICAL P-120 CATALOG, PAGE 604 & 605.
2 • ASHRAE 93' FUNDAMENTAL.
3 • CRANE FLOW OF FLUIDS (TECHNICAL PAPER NO. 410).
4 • ASHRAE POCKET GUIDE FOR HVAC. (1989)
5 • FUNDAMENTAL OF ENGINEERING THERMODYNAMICS PAGE A-57. (ROBERSON/CROWE THIRD EDITION)
6 W320-~~H~~ 28-015, SIZING OF MOISTURE SEPARATOR, REV. 1

CALCULATION:

Sensible heating:

$$KW = \frac{Wt * Cp * (T2-T1) * S.F.}{3412}$$ (Chromalox page 604)

where:

Air Volume = 860 scfm

Air density = .0749 lb/ft^3 at 70F(Ashrae Pocket Guide for HVAC, PAGE 129)

Wt - Weight of Air per hr. (Mass Flow Rate)

Wt = Air volume * Air density * 60 min/hr
Wt = 860 scfm * .0749 lb/ft^3 * 60 min/hr = 3865 lb-air/hr.

Cp - Specific Heat of Air = .24 Btu/lb at 70F (Fund. of Eng. Thermodynamics PAGE A-57)

T2 - T1 - TEMPERATURE ACROSS COIL = 100F - 40F = 60 F

KEH 0037.00 (06/92) KEF055

DESIGN ANALYSIS

Client WHC
Subject SIZING ELECTRIC HEATING COIL
Location 241-C/200E

WO/Job No. ER4319
Date 5-10-94 By B. E. HURNEVICH
Checked 5-18-94 By [signature] AK 4-6-95
Revised 4/4/95 By [signature]

S. F. - Safety Factor 1.15 (15%)

3412 Btu/hr. = 1 KW

$$KW = \frac{3865 \text{ lb air/hr} * .24 \text{ Btu/lb} * (100F - 40F) * 1.15}{3412 \text{ Btu/hr}} = 18.75 \text{ KW}$$

Latent heat of Vaporization of ~~15%~~ 36% liquid condensate in airstream:

Entering the Condenser at 95F and 100%RH the Humidity Ratio(HR) = .036757 lb.moisture/lb.dry air (ASHRAE 93' Fundamentals Table 2 Page 6.4)

Mass Flow Rate(Wt) = Air Volume * Air Density * 60 min\hr.
Air Volume = 860 scfm, Air Density = .0749 lb./ft^3
Wt = 860 scfm * .0749 lb./ft^3 * 60 min\hr. = 3865 lb/hr

Amount of H20 in Airstream: Wt * HR
H20 = 3865 lb/hr * .036757 lb.moisture/lb.dry air = 142 lb.H20/hr

Exiting the Condenser at 40F and 100% RH Humidity Ratio (HR) = .005216 lb.moisture/lb.dry air.(ASHRAE 93' Fundamentals Table 2 Page 6.3)

Amount of H20 in airstream exiting condenser: 3865 lb/hr * .005216 lb.moisture/lb.dryair = 20.2 lb/hr

Amount of condensate = ~~142 lb.H20/hr - 20.2 lb.H20/hr = 121.8 lb.H20/hr~~
0.11 lb/min from Ref.(6), (.7 - .59), REPRESENTS 36% REENTRAINMENT

~~15% of the condensate = 18.3 lb.H20/hr~~

Heat of Vaporization of ~~18.3~~ 6.6 lb.H20/hr of condensate:

Latent Heat of Evaporization of H20 at .2 psig and 53F = 1053 Btu/lb. (Crane Flow of Fluids page A-12)

BTU = ~~18.3~~ 6.6 lb.H20/hr * 1053 Btu/lb = ~~19270~~ 6950 btu/hr

$$KW = \frac{\cancel{19270}\ 6950 \text{ btu/hr}}{3412} = \cancel{5.7}\ 2.0 \text{ KW}$$

TOTAL POWER REQUIRED ELECTRIC HEATING COIL = 18.75KW + ~~5.7~~ 2.0KW = ~~24.45~~ 20.75KW

<u>CONCLUSION:</u> An additional 15% safety factor was included in the sizing of this heating coil along with the heating coil having the capability of heating air up to 100FDB. With the presence of ~~15%~~ 36% liquid condensate in the airstream an additional ~~5.7~~ 2.0KW of power is needed to evaporate the condensate. The total power required to heat the airstream to the specified design conditions is ~~24.45~~KW, therefore a 30KW heating coil has been selected. The heating coil is slightly oversized to provide additional capacity for coil element failure. If a few coil elements fail, immediate replacement is not required to maintain the required load.

BEST AVAILABLE COPY

HNF-2483, Rev. 0
Page D-4

igh temperature air duct heaters

o 300 kW and above
tlet air temperatures 1200°F
0 volt 3 phase (voltages to 0 V available)
th .475 dia. tubular ements
pes ADH and ADHT

ne i
ming
g.

plications

- Heating air for various drying/curing erations up to 1200°F air temperature
- Heat treating
- Re-heating or dehumidification
- Other similar air heating applications

atures

gged construction. Sturdy 0.475 di-eter tubular elements mounted to a avy ½ or ⅜ inch thick steel flange. minal housing made of 18 ga. minized steel. Element support es of 16 ga. aluminized steel are in place by stainless steel support s. High temperature units have the ditional feature of stainless steel terial for the 3 inch insulation hous-g and element support plate — all of hich provides superior rigidity, ength and reliability.

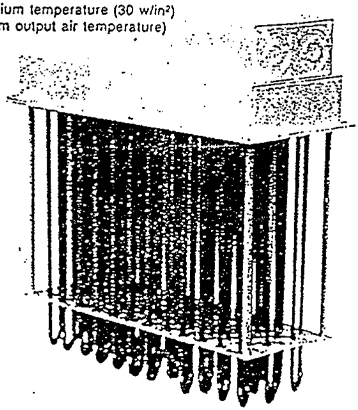
ong life metal sheath tubular ments—Corrosion/oxidation sistant sheath. High grade coloy® sheath material for excellent rosion/oxidation resistance at high erating temperatures.

gh purity magnesium oxide. The ements are filled with highest purity nds of magnesium oxide refractory GO) compacted to a rock hard den-y to insure maximum thermal conduc-y and electrical insulation resistance.

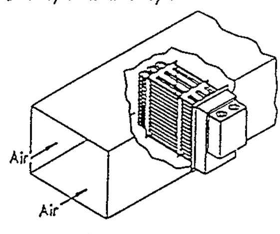
perior grade resistance wire. The art of each heating element is made 80% nickel-20% chromium resistance e for maximum long life.

w watt density resistor wire. Watt nsity on the heating coil is designed r low watt density operation by in-asing the coil diameter, gauge and gth of resistance wire to give maxi-m surface area and low operating l surface temperature — providing ger coil life.

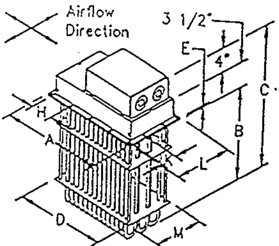
ADH—Low/medium temperature (30 w/in²)
(800°F maximum output air temperature)



Duct opening is
D + 1/4" x M + 1/4"



Typical Installation



Dimensions

ADH—Low/medium temperature (30 w/in²)

kW	A	B	C	D	E	H	K	L	M	No. Elem.	No. Circ.	Catalog No.	Status	PCN	Wt. Lbs.
	Dimensions—Inches														
5	5 5/8	20 3/4	28 1/4	4	1/4	2 1/2	3 1/2	11 1/8	9 1/2	3	1	ADH-005	S	210016	8
10	7 5/8	20 3/4	28 1/4	6	1/4	3 1/2	3 1/2	11 1/8	9 1/2	6	1	ADH-010	S	210024	15
15	9 5/8	20 3/4	28 1/4	8	1/4	3	3 1/2	11 1/8	9 1/2	9	1	ADH-015	S	210032	25
20	11 5/8	20 3/4	28 1/4	10	1/4	2 3/4	3 1/2	11 1/8	9 1/2	12	1	ADH-020	S	210040	35
25	13 5/8	20 3/4	28 1/4	12	1/4	3 1/4	3 1/2	11 1/8	9 1/2	15	1	ADH-025	S	210059	40
30	15 5/8	20 3/4	28 1/4	14	3/8	3 3/4	3 1/2	11 1/8	9 1/2	18	1	ADH-030	S	210067	55
35	17 5/8	20 3/4	28 1/4	16	3/8	4 1/4	3 1/2	11 1/8	9 1/2	21	1	ADH-035	S	210075	65
40	19 5/8	20 3/4	28 1/4	18	3/8	4 3/4	3 1/2	11 1/8	9 1/2	24	2	ADH-040	S	210083	70
45	21 5/8	20 3/4	28 1/4	20	3/8	5 1/4	3 1/2	11 1/8	9 1/2	27	2	ADH-045	S	210091	80
50	23 5/8	20 3/4	28 1/4	22	3/8	5 3/4	3 1/2	11 1/8	9 1/2	30	2	ADH-050	S	210104	90
60	27 5/8	20 3/4	28 1/4	26	3/8	4 1/2	3 1/2	11 1/8	9 1/2	36	2	ADH-060	S	210112	105
80	35 5/8	20 3/4	28 1/4	34	3/8	4 3/8	3 1/2	11 1/8	9 1/2	48	4	ADH-080	KS	210120	140
90	39 5/8	20 3/4	28 1/4	38	3/8	4 7/8	3 1/2	11 1/8	9 1/2	54	5	ADH-090	KS	210139	160
100	43 5/8	20 3/4	28 1/4	42	3/8	5 3/8	3 1/2	11 1/8	9 1/2	60	5	ADH-100	S	210147	175
144	35 5/8	35	42 7/8	34	3/8	4 3/8	3 1/2	11 1/8	9 1/2	48	4	ADH-144	KS	210155	165
162	39 5/8	35	42 7/8	38	3/8	4 7/8	3 1/2	11 1/8	9 1/2	54	5	ADH-162	S	210163	185
216	27 5/8	35	42 7/8	26	3/8	4 1/2	3 7/8	20	18 3/8	72	6	ADH-216F	S	210171	240
270	33 5/8	35	42 7/8	32	3/8	5 1/2	3 7/8	20	18 3/8	90	6	ADH-270F	S	210180	300

Specify: Quantity, catalog no., PCN, kW, air duct heaters.

Process Air

High temperature air duct heaters (con't.)

Superior performance at element bends. All elements bends are repressed in hydraulic presses after bending to assure recompaction of refractory material to eliminate hot spots and electrical insulation voids.

Sturdy metal sheath elements eliminate problems associated with open coil resistance wire units. Such as high operating temperatures resulting in shorter life, short circuits due to broken resistance wire or insulators, electrical shock hazard and flash fire hazard on start up due to dust and dirt accumulation.

Easy element replacement. Individual elements are mechanically fastened to the flange permitting convenient, easy replacement.

Low wiring compartment temperatures. Made possible by the addition of a one inch thick blanket of insulation in the terminal box—allows use of low temperature field wiring instead of expensive high temperature busbars and wire. High temperature units include additional three inches of insulation to help reduce duct heat losses.

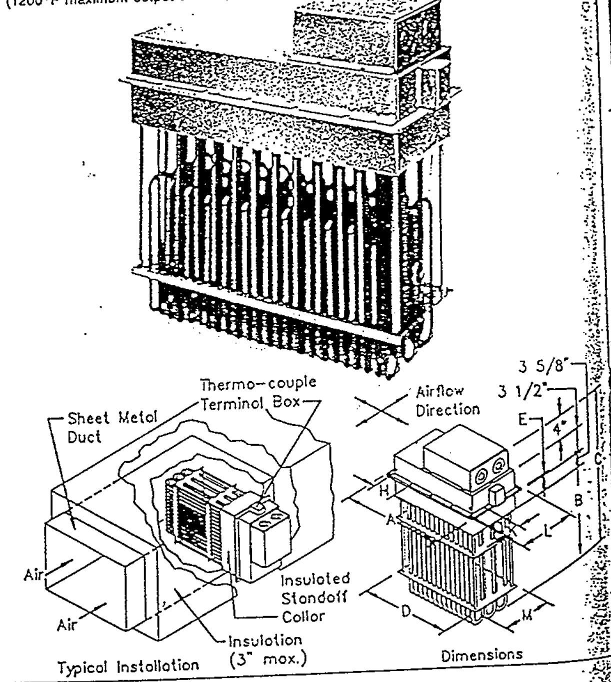
Meets NEC wiring requirements. Heaters are subdivided into 48 amp maximum circuits in compliance with the National Electrical Code (NEC).

Easy access to simplified field wiring terminals. Terminal housing is completely removable for maximum access to field wiring terminals. Individual terminal blocks with threaded stud type terminals are provided for each circuit to permit quick positive attachment of circuit wiring conductors.

Dirt/dust resistant terminal housing. Terminal housing made of solid heavy gauge aluminized steel rather than perforated metal to resist dirt and dust accumulation on the electrical connections and thus provide longer service life.

Flange mounting gasket. Packed separately with each duct heater to minimize air leakage between the flange and air duct.

ADHT—High temperature (20 w/in.²)
(1200°F maximum output air temperature)



ADHT—High temperature (20 w/in²)

kW	A	B	C	D	E	H	K	L	M	No. Elem.	No. Circ.	Catalog No.	Status	PCN
	Dimensions—Inches													
5	5⅝	20⅛	28⅛	4	¼	2½	3½	11⅛	9½	3	1	ADHT-005	S	210198
10	7⅝	20⅜	28⅛	6	¼	3½	3½	11⅛	9½	6	1	ADHT-010	NS	210200
15	9⅝	20⅜	28⅛	8	¼	3	3½	11⅛	9½	9	1	ADHT-015	NS	210219
20	11⅝	20⅜	28⅛	10	¼	2¾	3½	11⅛	9½	12	1	ADHT-020	S	210227
25	13⅝	20⅜	28⅛	12	¼	3¼	3½	11⅛	9½	15	1	ADHT-025	NS	210235
30	15⅝	20⅜	28¼	14	⅜	3¾	3½	11⅛	9½	18	1	ADHT-030	NS	210243
35	17⅝	20⅜	28¼	16	⅜	4¼	3½	11⅛	9½	21	1	ADHT-035	NS	210251
40	19⅝	20⅜	28¼	18	⅜	4¾	3½	11⅛	9½	24	2	ADHT-040	S	210250
45	21⅝	20⅜	28¼	20	⅜	5¼	3½	11⅛	9½	27	2	ADHT-045	NS	210278
50	23⅝	20⅜	28¼	22	⅜	5¾	3½	11⅛	9½	30	2	ADHT-050	NS	210285
60	27⅝	20⅜	28¼	26	⅜	4½	3½	11⅛	9½	36	2	ADHT-050	S	210294
80	35⅝	20⅜	28¼	34	⅜	4¾	3½	11⅛	9½	48	4	ADHT-080	NS	210307
90	39⅝	20⅜	28¼	38	⅜	4⅞	3½	11⅛	9½	54	5	ADHT-090	NS	210315
100	43⅝	20⅜	28¼	42	⅜	5⅜	3½	11⅛	9½	60	5	ADHT-100	NS	210323
120	27⅝	35	42⅞	26	⅜	4½	3½	11⅛	9½	36	4	ADHT-120	NS	210331
160	35⅝	35	42⅞	34	⅜	4¾	3½	11⅛	9½	48	8	ADHT-160	NS	210340
180	39⅝	35	42⅞	38	⅜	4⅞	3½	11⅛	9½	54	6	ADHT-180	NS	210358
240	27⅝	35	42⅞	26	⅜	4½	3⅞	20	18⅜	72	8	ADHT-240F	NS	210366
300	33⅝	35	42⅞	32	⅜	5½	3⅞	20	18⅜	90	10	ADHT-300F	NS	210374

High temperature air duct heaters (cont.)

Application Guide

Selecting heater size. Refer to Technical Section for examples on determining kW requirements. For quick estimating purposes, the following formula may be used for standard conditions:

kW = CFM x temp. diff/3000

Maximum work temperatures. Types ADH and ADHT process air heaters can generally be used at the following maximum temperatures shown, provided the minimum air velocity is maintained uniformly through the heater:

Air Velocity (ft/sec)	Max. Outlet Air Temp.°F	
	ADH	ADHT
4	800	1050
9	800	1100
16	800	1150
25	800	1200
36	800	1200

Application assistance. Chromalox sales/application engineers are available to assist you in the design or selection of equipment. Please contact your local Chromalox Sales Office if you need engineering assistance.

Installation mounting tips

Low temperature duct heaters can be fastened directly to the sheet metal duct work with bolts or sheet metal screws.

High temperature duct heaters are generally mounted to a field fabricated stand off collar from the ductwork to position the heater such that the 3" insulation housing is in the same plane as the duct insulation.

All heaters can be mounted in any position; top, side or bottom (preferred) entry. Minimum duct size is A or L dimension plus 3/8" and B dimension plus 1 5/8".

Provide adequate heater support. Consideration should be given to installing hangers or some other means of heater support whenever there is any question about the ability of the ductwork to support the heater weight.

Overtemperature protection. All heaters should include an overtemperature (overheat) control whose temperature sensing element is located on the air discharge side of the heater as close to the heater as practical. High temperature ADHT units include an overtemperature (Type K) thermocouple as standard.

Additional protection can be achieved by installing an air flow or pressure differential switch to protect the heater against low air flow conditions.

Operational controls. Selection of these controls, thermostat, SCR units, contactors and etc., depends on the degree of accuracy required, reliability, electrical rating of heater and economic considerations. Refer to Control Section.

Field power & control circuit wiring. Must be capable of carrying the electrical load and be protected by overcurrent protective devices, such as fusing, circuit breakers or ground fault detection in accordance with the requirements of the National Electrical Code and local codes as applicable.

Tandem mounting. Multiple heaters may be mounted in tandem with each other provided the maximum recommended outlet air temperature is not exceeded.

Pressure drop. Depends on the size of heater, its orientation with respect to air flow and the velocity of the air. Curve G-227-2 in Technical Section lists pressure drops for various heaters. Note, if pressure drop must be kept to a minimum, the heater should be mounted in the duct with the narrow width of the heater perpendicular to the air flow.

Options available

Gas tight design. Achieved by the use of threaded compression fittings with fiber washers to attach heating elements to flange—prevents leakage of ducted air into terminal housing.

Overtemperature protection. Thermocouple welded to the element sheath surface and wired to a terminal block can be provided for accurate overheat protection. Standard on high temperature units.

Moisture or explosion-resistant terminal housings are available for those applications requiring special terminal protection.

Special ratings or sizes. Chromalox can custom fabricate a duct heater to your particular needs whether it be rating, physical size or other specifications.

Contact your local Chromalox representative for assistance.

Process Air

Examples for heating air/gases

Heating air in ducts

Problem: A special drying process requires that we raise 450 cfm of air from 70° to 150°F. The existing ductwork which will be used for this purpose is insulated (negligible losses) and measures 2 ft. wide by 1 ft. high. Power available is 240 volts, 3 phase. Calculate the required kW and select a compatible heater for this application.

Solution: Under standard conditions air has a specific weight of .08 lbs./ft³ and a specific heat value of .24 Btu/lb/°F.

To find heating capacity in kW

$$kW = \frac{W_T \times C_p \times \Delta T \times 1.2}{3412}$$

Where:

W_T = Wt. of air/hr (450 x 60 x .08) = 2160

C_p = Spec. heat of air (.24)

ΔT = Temp. rise °F (80)

3412 = BTU to kWh conversion (for air at other than standard conditions refer to page T/37.)

1.2 = Safety factor.

$$kW = \frac{2160 \times .24 \times 80 \times 1.2}{3412}$$

$$= 14.85$$

For quick estimates, the following formula may be used where 3000 is a conversion factor in units of ft³—°F/min – kW.

$$kW \doteq \frac{\text{cfm} \times \text{temp. rise}}{3000}$$

$$= \frac{450 \times 80}{3000} = 12 \times 1.2 = 14.4$$

Or: When airflow (ft³/min) and temp. rise are known, curve G-176S (which shows 15 kW for this example) may be used. (This curve does not include contingency allowance).

To select the heater.

In this application there are a few choices to be explored. First, consider Chromalox type CAB heaters. Knowing the application required, 15 kW leads us to select either the CAB-1511 with chrome steel elements or the CAB-152 with iron sheath elements rated at 26 W/in². The maximum operating sheath temperatures are 750°F for iron and 950° for chrome steel.

Calculate air velocity through the heater to verify maximum operating sheath temperatures will not be exceeded.

$$V = \frac{F}{A \times 60}$$

Where:

V = Air velocity in ft/sec

F = Air flow in ft³/min (450 cfm)

A = Area of htr. ($15\frac{3}{8}'' \times 21\frac{5}{8}'' = 2.3$ ft²)

$$V = \frac{450}{2.3 \times 60}$$

$$= 3.3 \text{ ft/sec.}$$

Using curve G107S, page T/23, based on an outlet temperature of 150°F and a watt density of 26 W/in², a velocity in excess of 9 ft/sec is required to keep the sheath temperature at permissible levels for the CAB-152. This is well above the actual velocity and rules out the use of the CAB-152. By applying the watt density and outlet air temperature to curve G108S we see that we need a minimum of approximately 3 ft/sec air velocity to maintain a maximum of 900°F sheath temperature. Since this is lower than actual velocity, the use of CAB-1511 is acceptable.*

*Use of CAB-1511 will require a transition in the existing ductwork to accommodate the heater.

An alternative method to be considered would be mounting banks of Finstrip® heating elements in the ductwork. Knowing that 15 kW is required and that our duct measures 2 ft. wide x 1 ft. high and that a chrome steel sheath is required, we can select the proper Finstrip.

Using curve G108S, the maximum allowable watt density is 26 W/in². Elements with watt densities of 26 W/in² or less are suitable. Since the duct is 2 ft. wide, consider using OTF-210, 21 inches long, 240 volts, 1250 watts at 21 W/in².

$$\text{No. finstrips reqd.} = \frac{\text{Operating watts}}{\text{Rated W/elem.}}$$

$$= \frac{15{,}000}{1250}$$

$$= 12 \text{ Finstrips}$$

Use 12 OTF-210 Finstrips mounted sideways with narrow edge facing airstream. Total number of elements installed must be divisable by 3 so they can be connected in a 3 phase delta circuit.

For heating air ducts with tubular elements in a recirculating oven set at 975°F

Heating air in ducts may be accomplished by using standard tubular elements or by using packaged heater assemblies such as Type ADH.

Steel sheath may be used where the sheath temperature will not exceed 750°F; alloy sheath may be used for sheath temperatures up to 1600°F. Allowable watt densities should be determined by reference to curves G-151-1 through G-156-1, pg. T/24.

As an example, suppose it was determined that approaching air temperatures were to be 975°F at 4 ft/sec air velocity. The temperature is above 750°F so alloy sheath must be used. Using curve G-152-1 allowable watt densities would be 11 W/in² for a sheath temperature of 1200°F or 22 W/in² for a temperature of 1400°F. A standard ADH heater of proper kW rating, with 22 W/in² on the sheath, could be used.

Special ADH duct heaters, derated in directed proportion to the watt densities could be used where operating conditions require use of element ratings less than the standard 22 W/in².

Examples for heating air/gases

Oven heating

Problem: An oven with inside dimensions of 2 ft. H x 3 ft. W x 4 ft. D maintained at 350°F contains a steel tray weighing 40 lbs. This oven is charged with 250 lb. of steel parts which are to be raised from 70°F to 350°F in ¾ hour. Oven has 2 inches of wall insulation with 400 ft³ per hour of air ventilation. What kW capacity is required?

Weight of steel = 290 lbs.
Specific heat of steel = .12 Btu/lb/°F
Weight of air = .080 lb/ft³ at 70°F
Specific heat of air = .24 Btu/lb/°F
Temperature rise = 280°F
Heat loss/2 in. insul. = 18 W/ft²/hr @ 280°F temp. difference (curve G-126S), page T/22.
Surface area/oven = 52 ft²
Time = ¾ hr.
Airflow rate = 400 ft³/hr.

For oven applications add 30% to cover door losses and contingencies.

Solution:

1. Calculate kWh required to heat model.

$$kWh = \frac{W_T \times C_p \, \Delta T}{3412} = 2.86$$

Where:

W_T = Wt. steel/lbs (290)
C_p = Spec. ht. stl. (.12)
ΔT = Temp rise/°F (280)

2. Calculate kWh required to heat ventilated air

$$kWh = \frac{A_F \times H \times A_{WT} \times C_p \times \Delta T}{3412} = .47$$

Where:

A_{WT} = Wt. of air (.080)
C_p = Spec. ht. air (.24)
ΔT = Temp. rise (280)
H = Time/hr (.75)
A_F = Air flow rate (400)

3. Calculate surface losses

$$kWh = \frac{F \times E \times H}{1000} = .70$$

Where:

E = Heat loss W/ft²/hr (18)
F = Surface area ft² (52)
H = Time/hr (.75)

4. Combine steps 1, 2 and 3.

$$kWh = 2.86 + .47 + .70 = 4.03$$

$$kW = \frac{kWh}{H} = \frac{4.03}{.75} = 5.37$$

For oven applications, add 30% to cover door losses and contingencies. Therefore: required kW = 5.37 x 1.30 = 6.98 kW.

To select the heater
Chromalox type OV oven heaters would be suitable for this application. In this case you would use 2 standard OV-38 units rated at 3800 watts each.

Heating rooms

Although a complete analysis should be performed for room heating using the NOMA handbook or the ASHRAE guide, quick estimates of the kW capacity can be obtained using the following procedure.

Problem: A warehouse room measures 20 ft. long x 13 ft. wide x 9 ft. high. The building is poorly constructed and consists of corrugated metal sides with a plywood and tar paper roof. Determine the kW capacity required to maintain the warehouse at 70°F while the outside temperature is 0°F.

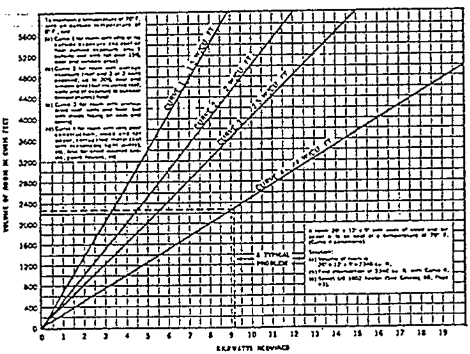
Solution:

1. Calculate the volume of the room. 20 x 13 x 9 = 2,340 ft³.
2. Refer to the curve chart shown. Use curve 4 which corresponds to the designated conditions.
3. If the volume of the room is larger than the chart values divide by 2, 3, 4 etc. until the trial volume fits the curve. (Does not apply in this case.) Then select heater from this volume. Multiply heaters selected by the number used to select the trial volume.

...nd intersection of 2340 ft³ with ... 4.

...m this we can see that 9.3 kW is re...ired. Select a 10 kW unit blower heater.

Heater selection: Depending on requirements, types UB, LUH or VUH heaters would be suitable for this application.



W320-28-006

Equipment Sizing & Selection
Recirculation Condenser

KAISER ENGINEERS HANFORD	CALCULATION IDENTIFICATION AND INDEX	Page 1 of 6 Date 5-4-94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline HVAC WO/Job No. ER 4319 Calculation No. ~~W320-28-006~~ H W320-28-006

Project No. & Name W-320 Tank 241 C106 Slucing

Calculation Item Equipment Sizing & Selection, Recirculation Condenser

These calculations apply to:

Dwg. No. H-2-818480 Rev. No.

Dwg. No. Rev. No.

Other (Study, CDR) Rev. No.

The status of these calculations is:

[] Preliminary Calculations

[X] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	Karl O'Neil 5/19/94		
Checked by	K. Merzonle 5/27/94		
Approved by	P. Haungh 5-27-94		
Checked Against Approved Vendor Data	Charles T. Li 4/14/98		

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KEH 0378.00 (06/92) KEF072

DESIGN ANALYSIS

Client Westinghouse
Subject Equipment Sizing & Selection, Recirculation Condenser
Location

WO/Job No. ER 4319
Date 04-06-94 By Charles O'Neill
Checked 5/27/94 By G. Reynolds
Revised By

OBJECTIVE: The objective of this analysis is to make a rough check of vendor proposals and to recommend a condenser for use in the W-320 tank ventilation system.

DESIGN INPUTS:

Criteria and Sources:

1.) Functional Design Criteria WHC-SD-W320-FDC-001 Rev 2.

2.) LOI 9359770 Rev 4.

Given or Known Data:

1.) 235,080 BTU/HR to be removed, from H-2-818479.

2.) Air inlet temperature - 95°F, saturated, from H-2-818479.

3.) Air outlet temperature - 40° F, saturated, from H-2-818479.

4.) Air flow 1090 ACFM @ 70° F, from H-2-818479.

5.) Air stream is supersaturated with 100 mg/m^3 of aerosols. The aerosol is composed of 10% solids and 90% liquids. The liquid portion is composed of 80% water and 20% solids in solution. All aerosols are less than 10μm in size, from LOI 9359770 Rev 4.

6.) Cooling fluid - 46% Propylene Glycol/Water Solution, from W320-H-007.

7.) Condenser will be skid mounted and located ~~outdoors~~ indoors. GR

8.) HVAC overall flow diagram as shown on H-2-818470.

Methods to be Used:

Standard heat transfer and psychometric equations.

References/Sources:

1.) ASHRAE Handbook of Fundamentals, 1993.

Client: Westinghouse Hanford Company	WO/Job No. ER4319		
Subject Equip. Sizing & Selection, Recirc. Conder	Date 04-06-94	By	Charles O'Neill
Selection	Checked 5/27/94	By	K. Meyer
Location:	Revised	By	

CALCULATION

Defining variables for Mathcad

$lb_a := lb$

$F := R - 460 \cdot R$

$Btu := 778.17 \cdot ft \cdot lb$

$lb_w := lb$

EXHAUST AIR STREAM

Inlet Conditions
95° F Saturated

$\rho := 0.072 \cdot \frac{lb_a}{ft^3}$

$C_p := 0.24 \cdot \frac{Btu}{(lb \cdot F)}$

$q_a := 1220 \cdot \frac{ft^3}{min}$ Maximum flow rate

$W_1 := 0.036 \cdot \frac{lb_w}{lb_a}$

$h_{s1} := 63.3 \cdot \frac{Btu}{lb_a}$

Outlet Conditions
40° F Saturated

$W_2 := 0.0052 \cdot \frac{lb_w}{lb_a}$

$h_{s2} := 15.2 \cdot \frac{Btu}{lb_a}$

PROPYLENE GLYCOL/WATER SOLUTION 46 %, 33 ° F

ASHRAE FUNDAMENTALS HANDBOOK 1993

$\rho_s := 65.5 \cdot \frac{lb}{ft^3}$

$C_{ps} := 0.845 \cdot \frac{Btu}{lb \cdot F}$

$\Delta T := 5 \cdot F$ Maximum temperature rise allowed. Exchanger Data Sheet

CALCULATION:

Exhaust Air

Mass flow rate of exhaust $m_a := q_a \cdot \rho \cdot 60 \cdot \frac{min}{hr}$ $m_a = 5.27 \cdot 10^3 \cdot \frac{lb_a}{hr}$

Heat Transfer $Q := m_a \cdot (h_{s1} - h_{s2})$ $Q = 2.535 \cdot 10^5 \cdot \frac{Btu}{hr}$

Water Condensed $LB_{h.2o} := m_a \cdot (W_1 - W_2)$ $LB_{h.2o} = 162.328 \cdot \frac{lb_w}{hr}$

Propylene Glycol

Heat Transfered to Glycol $Q_g := Q$ $Q_g = 2.535 \cdot 10^5 \cdot \frac{Btu}{hr}$

Glycol Flow Rate $M_g := \frac{Q_g}{\Delta T \cdot C_{ps}}$ $M_g = 6 \cdot 10^4 \cdot \frac{lb}{hr}$

$GPM := \frac{M_g}{\rho_s} \cdot 7.48 \cdot \frac{gal}{ft^3} \cdot \frac{hr}{60 \cdot min}$ $GPM = 114.201 \cdot \frac{gal}{min}$

ANALYSIS:

The proceeding calculations provide values to make a reasonable check of vendor proposals.

The design and manufacture of heat exchangers is a well developed process that is beyond this analysis. The ability of a shell and tube or a spiral heat exchanger to achieve the desired results is not in question. Instead this discussion will examine how the differences in design of shell and tube and spiral heat exchangers impact the W-320 ventilation system.

The air stream entering the heat exchanger is expected to be super saturated at 95°F. The heat exchanger is to be designed to lower the exiting air stream to 40°F saturated. Both heat exchangers as proposed will meet these conditions.

SHELL AND TUBE

The shell and tube heat exchanger is a four pass, U-tube unit with the air on the shell side. Air inlet and outlet flanges are mounted vertically on the top with a condensate drain on the bottom. The total length of the exchanger is 102 inches and the diameter is 23 inches including flanges.

Sealing
The shell and tube exchanger employs a fixed tubesheet at one end of the exchanger. The tubes are rolled into the sheet. This is a standard design and there is no reason to expect leaks at the tubes if the tube bundle is assembled properly.

Drainage/Contamination
The shell and tube exchanger will condense three tenths of a gallon per minute per the data sheet. The condensate will drain through a 3/4 inch outlet on the bottom of the shell. Inside the shell the tubes are supported by baffles that also act to direct the air across the tube bundle. These baffles will have a V notch at the bottom of the shell to allow the condensate to pass to the drain. The condenser can be sloped to promote condensate flow to the drain.

The joint where the tubes are rolled into the tubesheet is a likely spot for contamination to become lodged. Tight quality control will minimize gaps between the tubes and the tubesheet, but cannot eliminate them.

Cleaning/Decontamination
Fouling on the inside of the tubes is not a big concern. An inhibited glycol solution at these temperatures will not plate out on the inside of the tubes. The shell side may see some deposits from the insoluble

particles that are not washed from the exchanger by the condensate. Chemical cleaning will be required to remove any deposits on the shell side.

Decontamination of the shell and tube exchanger at completion of W-320 would probably be accomplished by chemically flushing the inside of the shell with a nitric acid solution. The tube bundle would have to be pulled to remove any remaining contamination.

Layout
The shell and Tube heat exchanger will require 13 sq. ft. of floor space. The ventilation skid layout provides adequate space for the shell and tube heat exchanger. The current layout would allow the exchanger to be mounted above the air heater while still providing room for removing the heater.The location of the air inlet on the top of the unit permits sloping the air duct down towards the tank for drainage of condensate back to the tank.

Cost
The cost of the shell and tube exchanger is $13,600. The vendor making this proposal is well known name in this field so this price is probably a good indicator of what a quality piece of equipment will cost.

SPIRAL

The spiral type heat exchanger consists of two sheets of stainless steel that are welded together at one end and then wound into a spiral with a fixed gap between the sheets. The sides of the spiraled sheets are then welded together in such a way as to form two separate channels. The spiral is installed inside a housing and end plates are fitted to each side to seal the channels.

The heat exchanger will be mounted with the spiral in the vertical axis. The air inlet would be on the bottom at the center and the air would spiral outward. The coolant would enter at the side of the housing and spiral inward and leave from the top at the center.

The total size of the unit is 45 inches in diameter and 88 inches tall. It will take 16 sq. ft. of floor space.

Sealing
The two channels are sealed from each other by welding the edges of the sheets at each end. The end plates utilize a full face gasket to prevent short circuiting of the fluids. The gasket material can be chosen to meet service conditions.

Drainage/Contamination

The spiral heat exchanger will condense four tenths of a gallon per minute per the data sheet. The condensate will drain through a two inch outlet on the bottom end plate. As the condensate forms it falls to the bottom of the exchanger and is pushed outward through the spiral to the drain by the air flow. The spiral exchanger cannot be sloped like the shell and tube to promote drainage.

The welded joint formed at each end of the channels provides a crack for radioactive material to enter. This problem will be minimized because the joint is located at the top of the air channel during fabrication.

Cleaning/Decontamination
Fouling of the coolant channel is not a concern. The air side channel may see some deposits from the insoluble particles that are not washed from the exchanger by the condensate. Chemical cleaning will be required to remove any deposits on the air side during operation.

Decontamination of the spiral exchanger would be accomplished by chemically washing with a nitric acid solution. If additional cleaning is required the end plates can be removed which exposes both channels for mechanical methods.

Layout
The major benefit of the spiral exchanger in this application is its compact size. However, the spiral heat exchanger requires the same floor space as the shell and tube unit. The spiral exchanger does not provide any benefits to the layout.

Cost
The cost of the proposed spiral exchanger is $38,000. This is twice the cost of the shell and tube. The cost may drop when other vendors are contacted but the spiral exchanger will probably still be more expensive than a shell and tube.

CONCLUSION

The shell and tube heat exchanger is the preferred choice for this application. The compact size of the spiral exchanger does not affect the size of the ventilation skid which is its major benefit. The shell and tube exchanger can be mounted to promote drainage and the nozzle orientation allows the inlet piping to be sloped to drain back to the tank.

W320-28-007

Chiller Skid System Sizing and Selection

CALCULATION IDENTIFICATION AND INDEX

Date 4-19-94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. W320-~~H~~-007 28 DCS

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item Chiller Skid System Sizing and Selection

These calculations apply to:

Dwg. No. H-2-818561 Rev. No. 0

Dwg. No. Rev. No.

Other (Study, CDR) N/A Rev. No. N/A

The status of these calculations is:

[ ] Preliminary Calculations

[X] Final Calculations

[ ] Check Calculations (On Calculation Dated)

[ ] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [ ] Yes [X] No

This calculation verified by independent "check" calculations? [ ] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	R Abiola 5/5/94 R Abiolwa		
Checked by	M. Mezak 5/11/94		
Approved by	PH Laugh 5-14-94		
Checked Against Approved Vendor Data	L Evans 6/10/98		

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Design Analysis Page No.	Description
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ii	Design Calculation Index (ICF KE Oakland)
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KEH 0578.00 (06/92) KEF072

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ICF KAISER ENGINEERS

DESIGN CALCULATION INDEX

CALC. NO.	SHT. NO.
HV-1	0

JOB NUMBER	AREA OR BUILDING	CALCULATION DESCRIPTION	DISCIPLINE
87059-553		PUMPS & EXPANSION TANKS	HVAC

JOB TITLE: TK. 241-C-106 HVAC - RECIRC. COND. C.S.

CALCULATIONS APPLY TO DRAWINGS AND REVISIONS SHOWN:

DRAWING	REV.	DRAWING	REV.	DRAWING	REV.	DRAWING	REV.

DESIGN ENGINEER [signature] (SIGNATURE) 3/15/94 (DATE)

DISCIPLINE SUPERVISOR ______ (SIGNATURE) (DATE)

CALCULATIONS CHECKED ______ (SIGNATURE) (DATE)

CHIEF DISCIPLINE ENGINEER/CHIEF ARCHITECT ______ (SIGNATURE) (DATE)

CALCULATIONS AGREE WITH DESIGN CRITERIA ______ (SIGNATURE) (DATE)

CALCULATIONS AGREE WITH APPVD. VENDOR DRAWINGS ______ (SIGNATURE) (DATE)

CALCULATION REVS.	△	DATES	△	DATES	△	DATES	△	DATES
REVISION DECRIPTION								
DESIGN ENGINEER								
CHECKED	K. Mayne 5/11/98							
CDS								

STATUS: PRELIMINARY | FINAL | CHECK | VOID | HOLD | OTHER

REASON FOR VOID OR HOLD:

INDEX

SHEET NO.	DESCRIPTION
1-1	REFERENCES
2	COOLANT FLOW
3-4	PIPE LOSS, 3"Φ PIPE
5-7	PIPE LOSS, 4"Φ PIPE
8-9	PUMP CALCULATIONS
10-11	PRICE COMPARISON & ENERGY SAVINGS
12-13	EXPANSION TANK SIZING
14	EXPANSION LOOP
15-23	REFERENCE DATA
24-34	VENDORS DATA

MISC/93060T 7
PC2

TK 241-C-106

HVAC - RECIRC. COND. COOLING SYS.

DESIGNED BY [signature] DATE 3/1

CHECKED BY [signature] DATE 5/11/9

REFERENCES:

1. PETER LANGOWSKI MEMO, DATED: 1/7/94
2. DOW CHEMICAL DATAS, DOWFROST HD
3. CRANE FLOW OF FLUIDS: LOSSES THROUGH FITTINGS & VALVES

GIVEN: 1, FROM REF. 1 : HEAT LOAD = 250,000 BTUH

2. FROM P. LANGOWSKY. (4/4/94) CONDENSER LOSSES = 14,251

3. FROM FEB. 18 MEETING AT RICHLAND WA. USE GLYCOL SOLUTION FOR -20°F AMBIENT TEMP. ≃ 46% GLYCOL

4. USE LIQUID TEMP. = 31°F

5. FROM DOW CHEMICAL DATA SHEET

a. DENSITY OF 46% PROPYLENE GLYCOL = 66.57 #S/ft^3

SPECIFIC HEAT = 0.811 BTU/# FT

CALCULATIONS KE Form No. E-6 Rev. 12-89

TO DETERMINE COOLANT FLOW

$Q = W c_p \Delta t$

WHERE: $Q = 250{,}000$ BTUH

$W = \#S/HR$

C_p = SPECIFIC HEAT = 0.811 *

$\Delta t = 36 - 31 = 5°F$

$$W = \frac{Q}{c_p \Delta t}$$

$$= \frac{250{,}000 \frac{BTU}{HR} \times 7.48 \frac{Gals}{FT^3}}{66.57 \frac{\#S}{FT^3} \times 0.811 \frac{BTU}{\#\cdot °F} \times 5°F \times 60 \frac{min}{HR}}$$

$= 115$ GPM

* HEAT EXCHANGER CAPACITY AT 14 PSI PRESSURE DROP = 110 GPM (PER PETER LANGOUSKY 4/4/94)

USE 110 GPM

$$\Delta t = \frac{250{,}000 \times 7.48}{66.57 \times .811 \times 110 \times 60} = 5.24°F \text{ OK}$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

* REF. 2

ICF KAISER ENGINEERS

SHEET 3 OF 27

TK 241-C-106

3"Ø PIPE

DESIGNED BY [signature] DATE 3-18-9

CHECKED BY [signature] DATE 5/11/9

TO DETERMINE PIPE LOSS THRU 3"Ø PIPE

1. GATE VALVE
   $L/D = 13$, FOR 7 VALVE $= \frac{3}{12} \times 13 \times 7 =$ 23

2. BUTTERFLY VALVE: $\frac{L}{D} = 40$
   FOR 4 BUTTERFLY VALVE $= 4 \times \frac{3}{12} \times 40 =$ 40

3. ANGLE VALVE
   $\frac{L}{D} = 145$; $L = \frac{3}{12} \times 145$ 36

4. CHECK VALVE
   $\frac{L}{D} = 135$; $L = \frac{3}{12} \times 135$ 34

5. 45° ELBOWS
   $\frac{L}{D} = 16$; FOR 12 EL $= 12 \times \frac{3}{12} \times 16 =$ 48

6. FOR 90° ELBOWS
   $\frac{L}{D} = 20$ FOR 30 EL $= 30 \times \frac{3}{12} \times 20$ 150

7. AIR SEPARATOR
   FROM B&G CAT. (W/O STRAINER = 9 elbows
   $= \frac{3}{12} \times 9 \times 20$ 45

SUB-TOTAL 376

8 PIPE LENGTH 638

TOTAL PIPE LENGTH 1014 FT

CALCULATIONS KE Form No. E-6 Rev. 12-89

TK 241-C-108

3"ϕ PIPE

DESIGNED BY ___ DATE 3-28-

CHECKED BY ___ DATE 5/11/

FROM DOWS DATA, REYNOLDS #, Re = 7757
FROM CRANE
FROM CRANE FLOW OF FLUID PAGE A-23
RELATIVE ROUGHNESS e/D for 3" PIPE = .0006

For Re = 7757 & e/D = .0006

$f = .033$

$$h_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2G}\right)$$

where:

h_L = PIPE LOSS, FT
f = friction factor = .033
L = pipe equivalent length = 1014 FT
D = diameter (FT) = $\frac{3}{12}$
V^2 = Velocity, ft/sec (3"ϕ & 110 Gpm) = 4.77
G = 32.2

$$h_L = 0.033\left(\frac{1014}{\frac{3}{12}}\right)\left(\frac{4.77^2}{2\times 32.2}\right)$$

$= 47.28$

II TO DETERMINE PUMP HEAD USING 4"ϕ PIPE

1 FROM REF. 1 TOTAL LENGTH OF PIPE = 638

2. # NO OF ELBOWS:

45° ——— 12

90° ——— 16

3. ADD'L ELBOWS FOR EXPN 8

ADD'L ELBOWS at SKID = 6

TOTAL 90° EL - 30

4. TEE ——— 1

FROM CRANE FLOW OF FLUID:
PAGE A-30, EQUIVALENT
LENGTH OF FITTINGS:

GATE VALVES: $\frac{L}{D} = 13$

BUTTERFLY VALVES $\frac{L}{D} = 40$

ANGLE VALVE $\cdot \frac{L}{D} = 145$

CHECK VALVES $= \frac{L}{D} = 135$

4"- 45° EL $= \frac{L}{D} = 16$

4"- 90° EL $: \frac{L}{D} = 20$

JOB NO. [illegible]

ICF KAISER ENGINEERS

SHEET 6 OF 27

TIC 241-C-106
HVAC - RECIRC. COND. COOLING SYS.
4" φ PIPE

DESIGNED BY [illegible] DATE 3/1/9[illegible]
CHECKED BY [illegible] DATE 5/11/9[illegible]

EQUIVALENT LENGTH:

1. GATE VALVE (FROM P&ID, 7 GATE VALVES)
$L/D = 13$ FOR 7; $L = \frac{4 \times 13}{12} \times 7 =$ 30.33

2. BUTTERFLY VALVES
$L/D = 40$; FOR 4 B.V.: $\frac{4 \times 40}{12} 4 =$ 53.33

3. ANGLE VALVE
$L/D = 145$; $L = \frac{4}{12} \times 145$ 48.33

4. CHECK VALVE:
$\frac{L}{D} = 135$; $L = \frac{4}{12} \times 135 =$ — 45.0

5. 45° ELBOWS
$\frac{L}{D} = 16$; FOR 12 EL; $L = \frac{4}{12} \times 16 \times 12$ = 64

6. 90° ELBOWS
$\frac{L}{D} = 20$; FOR 30 EL $= \frac{4}{12} \times 20 \times 30$ = 200

7. AIR SEPARATOR
FROM B&G CAT. (W/O STRAINER) = 9 ELBOWS
$= 9 \times \frac{4}{12} \times 20$ = 60

SUB-TOTAL 501.00

8. TOTAL PIPE LENGTH 638

1139

ICF KAISER
ENGINEERS

TK. 241-C-106
HVAC - RECIRC. COND. COOLING SYS.
4"Φ PIPE

JOB NO. [illegible]
SHEET 7 OF 27

DESIGNED BY [illegible] DATE 3/1/9[illegible]
CHECKED BY [illegible] DATE 5/11/9[illegible]

FROM DOWS DATA, REYNOLDS # 6445

FROM CRANE FLOW OF FLUID, PAGE A-23
RELATIVE ROUGHNESS FOR 4" STEEL PIPE = .00045
FROM A-24, FOR Re = 5911 & REL.
ROUGHNESS = .00045, FRICTION FACTOR = .035

FROM CRANE FLOW OF FLUIDS PAGE 3-4

$$h_L = f\left(\frac{L}{D}\right)\frac{V^2}{2g}$$

where: f = .035
L = 1139 FT
D = INTERNAL DIA. IN FEET
V = VELOCITY, FT/SEC :
G = 32.2 FT²/SEC²
hl = head loss, FT

$$h_L = 0.035\left(\frac{1139\,FT}{\left(\frac{4.026\,FT}{12}\right)}\right)\frac{(2.77)^2\ \frac{FT^2}{SEC^2}}{2\times 32.2\ \frac{FT}{SEC^2}}$$

$$= \frac{0.035\times 1139}{0.3355}\times .1416 = 16.85$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

COMPARISON OF PUMP HEAD

	3"φ	4"φ
1. PIPE, VALVES, SEPARATOR LOSS	47.28	14.15
2 CHILLER LOSS = 25FT × 1.46	36.5	36.5
3. CONDENSER LOSS $14 \times \frac{144}{66.57}$	30.28	30.28
4. STRAINER (CLEAN) $= .18 \frac{\#}{in^2} \times 1.46 \times 2.31$	.60	.60
5 CONTROL VALVE $= 10 \frac{\#}{in^2} \times \frac{144}{66.57}$	21.63	21.63
	136.29	103.16
10% FS	13.3	10.3
	149.59	113.46

$$HP = \frac{GPM \times HD \times SP.GR}{3960 \times EFF.}$$

$EFF_{3"} = 56\%$

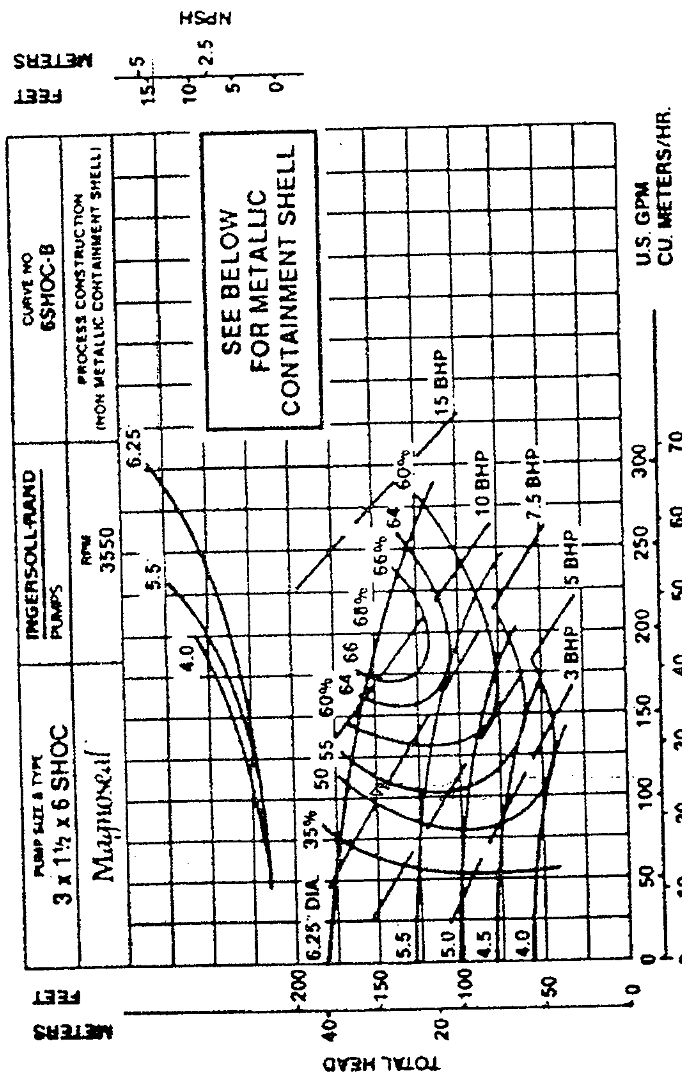
$EFF_{4} = 58\%$

$$HP_{3"} = \frac{110 \times 149.59 \times \frac{66.57}{62.4}}{3960 \times .53} = 8.36$$ 7½ HP

USE — 10 HP

$$HP_{4"} = \frac{110 \times 113.46 \times \frac{66.57}{62.4}}{3960 \times .53} = 6.34$$

USE 7½ HP


PUMP SIZE & TYPE
3 x 1½ x 6 SHOC
Magnosteal
INGERSOLL-RAND
PUMPS
RPM
3550
CURVE NO
6SHOC-B
PROCESS CONSTRUCTION
(NON METALLIC CONTAINMENT SHELL)
SEE BELOW
FOR METALLIC
CONTAINMENT SHELL
NPSH
METERS
FEET
TOTAL HEAD
CAPACITY
U.S. GPM
CU. METERS/HR.
6.25" DIA.
5.5
5.0
4.5
4.0
6.25
35%
50
55
60%
64
66
68%
66%
64
60%
15 BHP
10 BHP
7.5 BHP
5 BHP
3 BHP

PRICE COMPARISON
3"Φ PIPE VS 4"Φ PIPE

DESIGNED BY *ca* DATE 11/9/9

CHECKED BY *K. Munjak* DATE 5/11/98

PRICE COMPARISON 3"Φ PIPE VS 4"Φ PIPE	PIPE SIZE 3"	4Φ	
1. PIPE, RICKWILL 2.24 THICK INSULATION			
638 FT @ $17.00/FT	10,846		
638 FT @ 20.75/FT		13,239	
2. PUMPS 120 GPM, 150 FT. 10HP			
2 @ $6000	12,000		
120 GPM, 105 FT 7.5HP			
2 @ $5,500		11,100	
3. GATE VALVES			
7 @ $155	1085		
7 @ $225		1575	
4. CHECK VALVE			
2 @ $125	250		
2 @ $195		390	
5. ELBOWS			
30 @ $11	330		
30 @ $17		510	
	24,511	26,814	

PRICE DIFF = 26,814 − 24,511 = $2303

CALCULATIONS KE Form No. E-6 Rev. 12-89

ENERGY SAVINGS:

DIFFERENCE IN PUMP HP:

$$HP_{3''} - HP_{4''} = 8.36 - 6.34 = 2.02$$

AT \$.055/~~YR~~ KW-h

$$\text{SAVINGS/YR} = .055 \times 2.02\ HP \times .746\ \frac{KW}{HP} \times 24\ \frac{HRS}{day} \times 365\ \frac{day}{YR}$$

$$= \$\ 726.\sim$$

$$\text{PAYBACK PERIOD} = \frac{\$\ 2303}{\$726/YR} = 3.1 \text{ years}$$

YEARS of OPERATION = 2

USE: 3"⌀ pipe

10 Hp motor Pump

ICF KAISER ENGINEERS

JOB NO. [illegible]

SHEET 12 OF 27

TK 241-C-106

HVAC. RECIRC. COND. COOLING SYS.

DESIGNED BY [illegible] DATE 3/1/9[illegible]

CHECKED BY [illegible] DATE 5/11/9[illegible]

TO SIZE EXPANSION TANK

1. PIPE LENGTH - 638 FT (REF. 1)

SIZE 4"φ

$$VOLUME = \frac{\pi D^2}{4 \times 144} \times 638$$

$$= \frac{\pi (4)^2}{4 \times 144} \times 638 = 56 \text{ CUFT}$$

$$GALLONS = 56 \text{ CUFT} \times 7.5 \frac{GALS}{CUFT} = 420 \text{ GALLONS}$$

2. CHILLER ——— 14 GALS.

3. CONDENSER 14 GALS

448 GALS.

say 450 GALS.

RELATIVE ELEVATION OF SYSTEM AND PUMP = 646 - 633 = 13'-0" =

$$= 13 \times \frac{66.57}{144} = 6 \text{ PSI}$$

CALCULATIONS KE Form No. E-6 Rev. 12-89

PRESSURIZED TANK SIZING WORKSHEET

FIGURE 2

THINGS YOU MUST KNOW:

LINE	ITEM	Symbol	Reference Table Formula	ANSWER
1.	Total System Water Content	Vs	B, C, D	450s Gal.
2.	Average Design Water Temperature	t	-	325 °F.
3.	Minimum Fill Pressure (Pre-charge) 6.0 psig (Static) + 4 psig (top of sys)	Pf	A	10 psig
4.	Maximum Operating Pressure	Po	-	75 psig
5.	Tank Mounting	-	-	___ Horiz. ✓ Vert.
	TANK SIZING AND SELECTION			
6.	Net Water Expansion Factor	-	F	.004
7.	Correction Factor, if Glycol	-	E	1.8, Water = 1
8.	Expansion Volume, Multiply Line (1) 450 x (6) .004 x (7) 1.8	Ve	-	3.24 Gal.
9.	Acceptance Factor	Ae	G	0.725
10.	Minimum Tank Volume, Divide Line (8) 3.24 ÷ by (9) .725	Vt -	(6) H	2.35 Gal.

11. Select Tank - See Line (5)
Select Tank with Tank and Acceptance Volumes Equal or Greater Than Answers in Line (8) and (10).

12. Selection #1 : Model Sx-30V, Size 16 (Gal.), Ac 6 Gal.

12A. Alternate Selection: Model ______, Size ______ (Gal.), Ac ______ Gal.

With Two Tanks: Model ______, Size ______ (Gal.), Ac ______ Gal.

TOTAL:

JOB NAME ______

LOCATION ______

ENGINEER ______

CONTRACTOR ______

SALES REPRESENTATIVE ______

DATE ______

ICF KAISER ENGINEERS

JOB No. 8 ...

SHEET 14 OF 27

TK 241-C-106

PIPE EXPANSION

DESIGNED BY [signature] DATE 5-5...

CHECKED BY [signature] DATE 5/11/9...

ASSUME INSTALLATION TEMPERATURE OF PIPE = 85°F

WATER TEMP. = 31°F

$\Delta t = 85 - 31 = 54°F$

FROM RICKWIL CAT. (CAT. PAGE 16-E), SEE PAGE 22, PIPE THERMAL EXPANSION FOR 54°F ΔT IS CALCULATED AS FOLLOWS:

TABLE TEMP BASE IS -20°F

THERFORE USE THERMAL EXPANSION FOR TEMPERATURE = 54 - 20 = 34°F.

BY INTERPOLATION,

THERMAL EXPANSION = 0.389 inch/100 FT

PER PETE LANGOWSKI MEMO 1/7/94,

PIPE LENGTH = 279 FT.

NO. OF ELBOWS = 14

THERMAL EXPANSION FOR 279 FT =

$$279' \times \frac{.389''}{100'} = 1.08''$$

PIPE EXPANSION IS MINIMAL AND CAN BE HANDLED BY SYSTEM ELBOWS.

IF PIPING LOOP WILL BE USED, THE EXPANSION LOOP DIMENSION PER RICKWIL CAT. PAGE 18-E:

$2H + W = 9.5'$ WHERE: $W = \frac{H}{2}$

$2H + H/2 = 9.5;\ H = 4;\ W = 2$

CALCULATIONS KE Form No. E-6 Rev. 12-89

Heat Transfer Coefficient and Pressure Drop
DOWFROST HD Fluid (61.5 % Solution)
(At 46.3 Percent Weight Glycol)

ow Rate: 4.77 feet/second

Temperature: 31.0 F

Pipe or tube size: 3.068 inches

Density: 66.57 lb/ft^3

Specific Heat: 0.811 Btu/lb-F

Thermal Conductivity: 0.2095 Btu/hr-ft-F

Vapor Pressure: 0.08 psia

Viscosity: 37.77 lb/hr-ft

Prandtl No: 146.1

Reynolds No: 7,757

The correlation for film coefficient is not valid for Re<10,000.

RETURN	ESC	M	PrtSc	Q
Next	Prior	Main	Print	Quit
Menu	Screen	Menu	Screen	Now

Heat Transfer Coefficient and Pressure Drop
DOWFROST HD Fluid (61.5 % Solution)
(At 46.3 Percent Weight Glycol)

ow Rate: 2.77 feet/second

Temperature: 31.0 F

Pipe or tube size: 4.026 inches

Density: 66.57 lb/ft^3

Specific Heat: 0.811 Btu/lb-F

Thermal Conductivity: 0.2095 Btu/hr-ft-F

Vapor Pressure: 0.08 psia

Viscosity: 37.77 lb/hr-ft

Prandtl No: 146.1

Reynolds No: 5,911

The correlation for film coefficient is not valid for Re<10,000.

RETURN	ESC	M	PrtSc	Q
Next	Prior	Main	Print	Quit
Menu	Screen	Menu	Screen	Now

Schedule (Thickness) of Steel Pipe Used in Obtaining Resistance Of Valves and Fittings of Various Pressure Classes by Test*

Valve or Fitting ANSI Pressure Classification: Steam Rating		Valve or Fitting ANSI Pressure Classification: Cold Rating	Schedule No. of Pipe Thickness
250-Pound and Lower		500 psig	Schedule 40
300-Pound to 600-Pound		1440 psig	Schedule 80
900-Pound		2160 psig	Schedule 120
1500-Pound		3600 psig	Schedule 160
2500-Pound	½ to 6"	6000 psig	xx (Double Extra Strong)
	8" and larger	3600 psig	Schedule 160

*These schedule numbers have been arbitrarily selected only for the purpose of identifying the various pressure classes of valves and fittings with specific pipe dimensions for the interpretation of flow test data; they should not be construed as a recommendation for installation purposes.

Representative Equivalent Length‡ in Pipe Diameters (L/D) Of Various Valves and Fittings

Description of Product				Equivalent Length In Pipe Diameters (L/D)
Globe Valves	Stem Perpendicular to Run	With no obstruction in flat, bevel, or plug type seat	Fully open	340
		With wing or pin guided disc	Fully open	450
	Y-Pattern	(No obstruction in flat, bevel, or plug type seat)		
		– With stem 60 degrees from run of pipe line	Fully open	175
		– With stem 45 degrees from run of pipe line	Fully open	145
Angle Valves		With no obstruction in flat, bevel, or plug type seat	Fully open	145
		With wing or pin guided disc	Fully open	200
Gate Valves	Wedge, Disc, Double Disc, or Plug Disc		Fully open	13
			Three-quarters open	35
			One-half open	160
			One-quarter open	900
	Pulp Stock		Fully open	17
			Three-quarters open	50
			One-half open	260
			One-quarter open	1200
Conduit Pipe Line Gate, Ball, and Plug Valves			Fully open	3**
Check Valves	Conventional Swing		0.5†... Fully open	135
	Clearway Swing		0.5†... Fully open	50
	Globe Lift or Stop; Stem Perpendicular to Run or Y-Pattern		2.0†... Fully open	Same as Globe
	Angle Lift or Stop		2.0†... Fully open	Same as Angle
	In-Line Ball		2.5 vertical and 0.25 horizontal†... Fully open	150
Foot Valves with Strainer		With poppet lift-type disc	0.3†... Fully open	420
		With leather-hinged disc	0.4†... Fully open	75
Butterfly Valves (8-inch and larger)			Fully open	40
Cocks	Straight-Through	Rectangular plug port area equal to 100% of pipe area	Fully open	18
	Three-Way	Rectangular plug port area equal to 80% of pipe area (fully open)	Flow straight through	44
			Flow through branch	140
Fittings	90 Degree Standard Elbow			30
	45 Degree Standard Elbow			16
	90 Degree Long Radius Elbow			20
	90 Degree Street Elbow			50
	45 Degree Street Elbow			26
	Square Corner Elbow			57
	Standard Tee	With flow through run		20
		With flow through branch		60
	Close Pattern Return Bend			50
Pipe	90 Degree Pipe Bends			See Page A-27
	Miter Bends			See Page A-27
	Sudden Enlargements and Contractions			See Page A-26
	Entrance and Exit Losses			See Page A-26

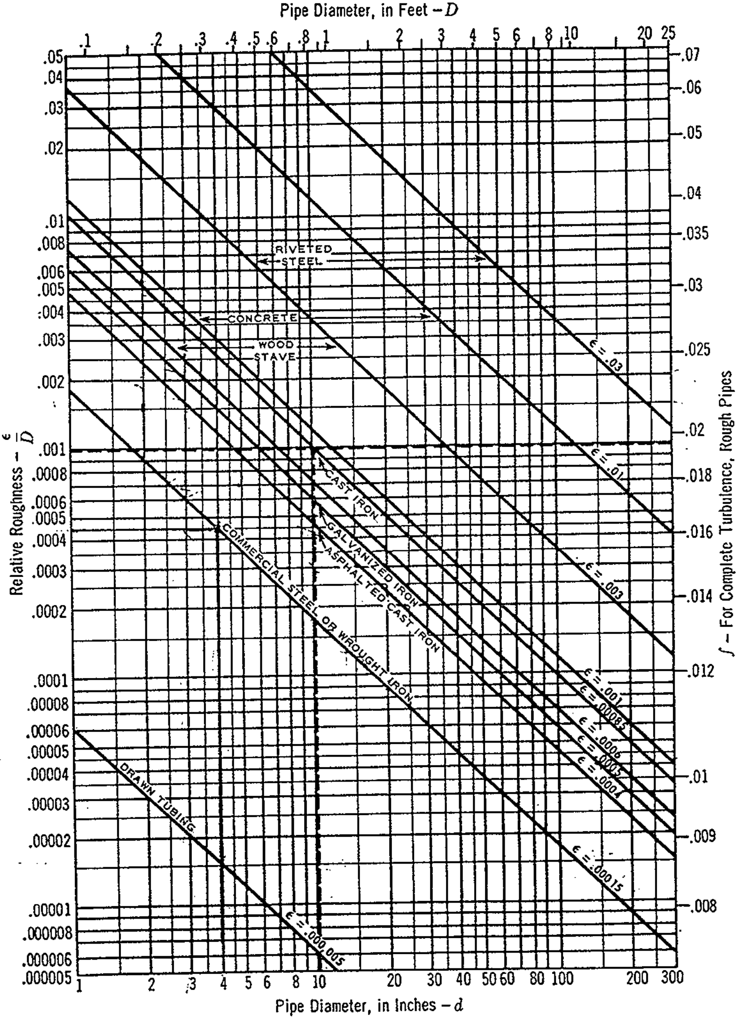
**Exact equivalent length is equal to the length between flange faces or welding ends.

†Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disc fully.

‡For limitations, see page 2-11. For effect of end connections, see page 2-10.

For resistance factor "K", equivalent length in feet of pipe, and equivalent flow coefficient "C_v", see pages A-31 and A-32.

Relative Roughness of Pipe Materials and Friction Factors For Complete Turbulence[18]

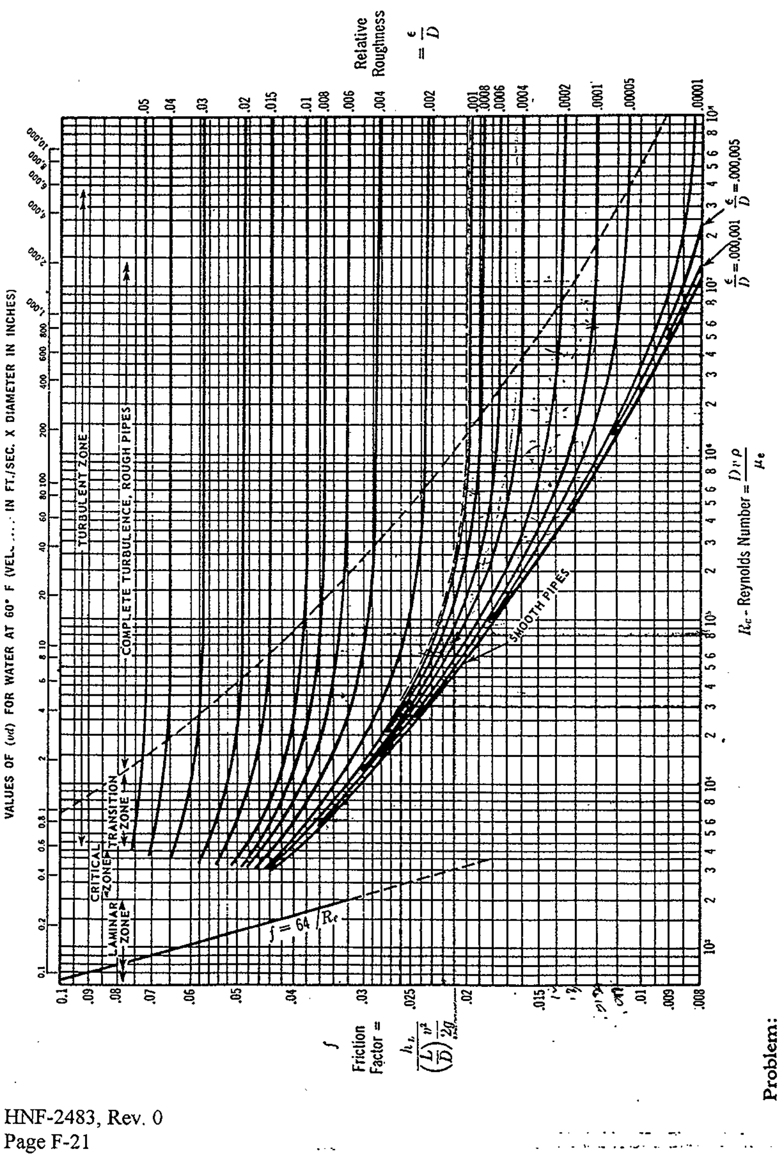


Data extracted from *Friction Factors for Pipe Flow* by L.F. Moody, with permission of the publisher, The American Society of Mechanical Engineers, 29 West 39th Street, New York.

Problem: Determine absolute and relative roughness, and friction factor, for fully turbulent flow in 10-inch cast iron pipe (I.D. = 10.16").

Solution: Absolute roughness (ϵ) = 0.00085 . . . . . Relative roughness (ϵ/D) = 0.001 . . . . . Friction factor at fully turbulent flow (f) = 0.0196.

Friction Factors for Any Type of Commercial Pipe[18]



For other forms of the R_e equation, see page 3-2.

Data extracted from *Friction Factors for Pipe Flow* by L. F. Moody, with permission of the publisher, The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y.

Problem: Determine the friction factor for 10-inch cast iron pipe (10.16" I.D.) at a Reynolds number flow of 30,000.

Solution: The relative roughness (see page A-23) is 0.001. Then, the friction factor (f) equals 0.026.

IDENTIFICATION CODE FOR ARMSTRONG STRAINERS

Strainer Codes are formed by using letter code for body, number code for screen specification followed by abbreviation for connection required. The code is completed by suffixing the connection size and, for flanged strainers, the flange rating. An AIFL-6-250 is a 6" cast iron strainer with .045" perf. stainless steel screen and 250 lb. flanged connections.

Code	Material
A	Cast Iron 30,000 Min. tensile (ASTM A-278 Cl. 30)or equal
B	Carbon Steel (ASTM A-216 WCB)
C	Chrome Moly Steel (1¼% Chrome, ½% Moly) ASTM A-217 WC6
D	Forged Steel (2¼% Chrome, 1% Moly) ASTM A-182 F22
E	Stainless Steel Type 316 (ASTM A-351 Grade CF8M)
F	Bronze (ASTM B-62)

Code	Screen
1	.045" perf. Stainless Steel (Type 304)
2	24x110 Type 316 Mesh Stainless Steel (.0056" opening)
3	.045" perforated Monel
4	.045" perforated Brass
5	20x20 Mesh Monel (.034" opening)
6	40x40 Mesh Monel (.015" opening)
7	.045" perforated Type 316 Stainless Steel
8	⅛" perforated Type 304 Stainless Steel
9	100x100 Mesh Stainless Steel (.0055" opening)
X	Any screen not number coded—specify screen requirement. See Table A-4.

Code	Connection
SC	Screwed
FL	Flanged
SW	Socket Weld
BW	Butt Weld

Chart A-3—Liquid Flow Capacities for all Armstrong Y-Type Strainers, in U.S. Gallons per minute (gpm).

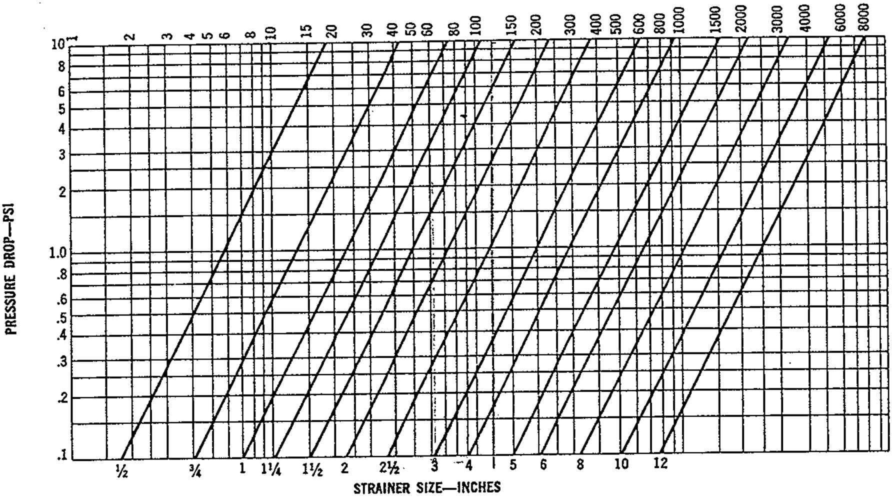


Table B-3—Ratio of Open Area of Screen to Inside Area of Pipe, Armstrong Y-Type Cast Iron Strainers. Color Background Indicates that Back-up Screens Are Employed.

Strainer Size	Total Screen Area, Sq. in.	Inside Area of Pipe, Sq. in.	RATIO—PERFORATED SCREENS							RATIO—WIRE MESH SCREENS				
			1/64"	1/32"	.045"	1/16"	1/8"	3/16"	1/4"	24x110	20x20	40x40	100x100	200x200
3/8"-1/2"	5.2	0.30	5.2	5.0	6.4	5.2	6.9	8.8	10.0	4.8	6.6	5.2	2.2	2.5
3/4"	7.2	0.53	4.0	3.9	5.0	4.0	5.4	6.9	7.8	3.8	5.3	4.1	1.8	2.0
1"	11.0	0.86	3.8	3.7	4.7	3.8	5.1	6.5	7.4	3.7	5.2	4.0	1.7	1.9
1¼"	15.9	1.49	3.2	3.0	3.9	3.2	4.2	5.4	6.1	3.2	4.4	3.4	1.5	1.6
1½"	23.6	2.03	3.4	3.3	4.3	3.4	4.6	5.9	6.7	3.5	4.8	2.8	1.6	1.8
2"	34.4	3.35	3.0	2.9	3.8	3.0	4.1	5.2	5.9	3.2	4.4	2.6	1.5	1.6
2½"	54.4	4.78	3.4	3.3	4.2	3.4	4.5	5.8	6.6	3.3	3.5	2.7	1.7	1.9
3" 125#	74	7.39	1.7	2.9	3.7	3.0	4.0	5.1	5.8	2.9	3.1	2.3	1.5	1.7
3" 250#	87	7.39	2.0	3.4	4.3	3.5	4.7	6.0	6.8	3.5	3.8	2.8	1.8	2.0
4" 125#	123	12.7	1.7	2.8	3.5	2.9	3.8	4.9	5.6	2.8	3.0	2.3	1.5	1.6
4" 250#	145	12.7	2.0	3.3	4.2	3.4	4.5	5.8	6.6	3.4	3.7	2.1	1.8	2.0
5" 125#	194	20.0	1.7	2.8	3.5	2.9	3.8	4.9	5.6	1.7	3.1	1.8	1.5	1.7
5" 250#	245	20.0	2.1	3.5	4.5	3.6	4.9	6.2	7.1	2.2	4.0	2.3	2.0	2.2
6" 125#	272	28.9	1.6	2.7	3.4	2.8	3.1	4.8	5.4	1.6	3.0	1.8	1.5	1.6
6" 250#	317	28.9	1.9	3.1	4.0	3.2	4.3	5.5	6.3	1.9	2.7	2.1	1.7	1.9
8" 125#	464	50.0	1.6	2.6	3.4	2.7	3.7	4.7	5.3	1.6	2.3	1.8	1.5	1.7
8" 250#	550	50.0	1.9	3.1	4.0	3.3	4.4	5.6	6.3	2.0	2.8	2.1	1.8	2.0
10" 125#	733	78.8	1.6	2.7	3.4	2.7	3.7	4.7	5.4	1.7	2.3	1.8	1.5	1.7
12" 125#	1050	113.1	1.6	2.6	3.4	2.7	3.7	4.7	5.3	1.7	2.3	1.8	1.5	1.7
Percentage Open Area			30%*	29%	37%	30%	40%	51%	58%	33.3%*	46.2%*	36%*		

Notes: Cast steel strainers have the same ratios as 250 lb. cast iron except for 150 lb. stainless steel which is the same as 125 lb. cast iron.

* For unbacked screens.

This table does not apply to forged steel strainers in table D-7.

Performance Adjustment Factors

Ross Abj…

Table 3-1 — Performance Data Adjustment Factors

Fouling Factor	Chilled Water ΔT	Sea Level CAP	Sea Level GPM	Sea Level KW	2000 Feet CAP	2000 Feet GPM	2000 Feet KW	4000 Feet CAP	4000 Feet GPM	4000 Feet KW	8000 Feet CAP	8000 Feet GPM	8000 Feet KW
0.00025	6	0.987	1.650	0.993	0.967	1.640	1.003	0.952	1.620	1.019	0.932	1.570	1.029
	8	0.993	1.250	0.997	0.973	1.240	1.007	0.956	1.220	1.025	0.936	1.190	1.035
	10	1.000	1.000	1.000	0.980	0.990	1.010	0.960	0.970	1.030	0.940	0.943	1.040
	12	1.007	0.820	1.003	0.987	0.810	1.013	0.966	0.800	1.035	0.945	0.780	1.045
	14	1.013	0.710	1.007	0.993	0.708	1.017	0.972	0.680	1.038	0.952	0.669	1.048
	16	1.020	0.640	1.010	1.000	0.630	1.020	0.980	0.620	1.040	0.960	0.600	1.050
0.00075	6	0.967	1.630	0.983	0.958	1.610	0.993	0.938	1.590	1.002	0.918	1.560	1.012
	8	0.973	1.230	0.987	0.964	1.220	0.997	0.944	1.200	1.006	0.925	1.180	1.016
	10	0.980	0.980	0.990	0.970	0.970	1.000	0.950	0.950	1.010	0.930	0.930	1.020
	12	0.987	0.800	0.993	0.975	0.800	1.003	0.955	0.780	1.015	0.934	0.770	1.026
	14	0.993	0.690	0.997	0.978	0.680	1.007	0.958	0.660	1.022	0.937	0.660	1.032
	16	1.000	0.620	1.000	0.980	0.610	1.010	0.960	0.600	1.030	0.940	0.580	1.040

Figure 3-1 — Ethylene Glycol Performance Adjustment Factors and Solution Freezing Points

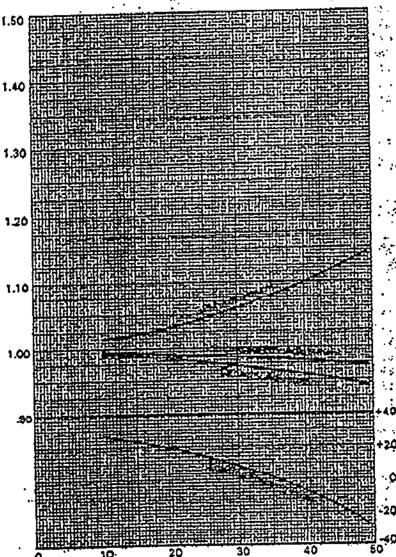


Figure 3-2 — Evaporator Water Pressure Drop

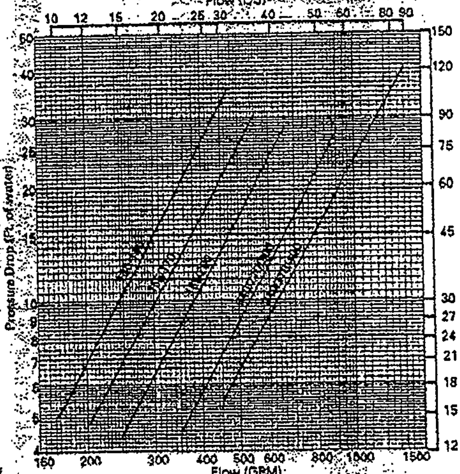


Table 3-2 — Ethylene Glycol Pressure Drop Adjustment Factors

LWT	Percent Of Ethylene Glycol 0	10	20	30	40	50
0	1.15	1.22	1.30	1.38	1.46	1.55
10	1.12	1.18	1.26	1.34	1.42	1.51
20	1.09	1.15	1.22	1.30	1.38	1.47
30	1.06	1.12	1.19	1.26	1.34	1.43
40	1.03	1.09	1.16	1.23	1.30	1.39
49	1.00	1.06	1.13	1.20	1.27	1.35

(Reference Only, see Proplyene Glycol properties in ASHRAE)

Pipe Expansion Table

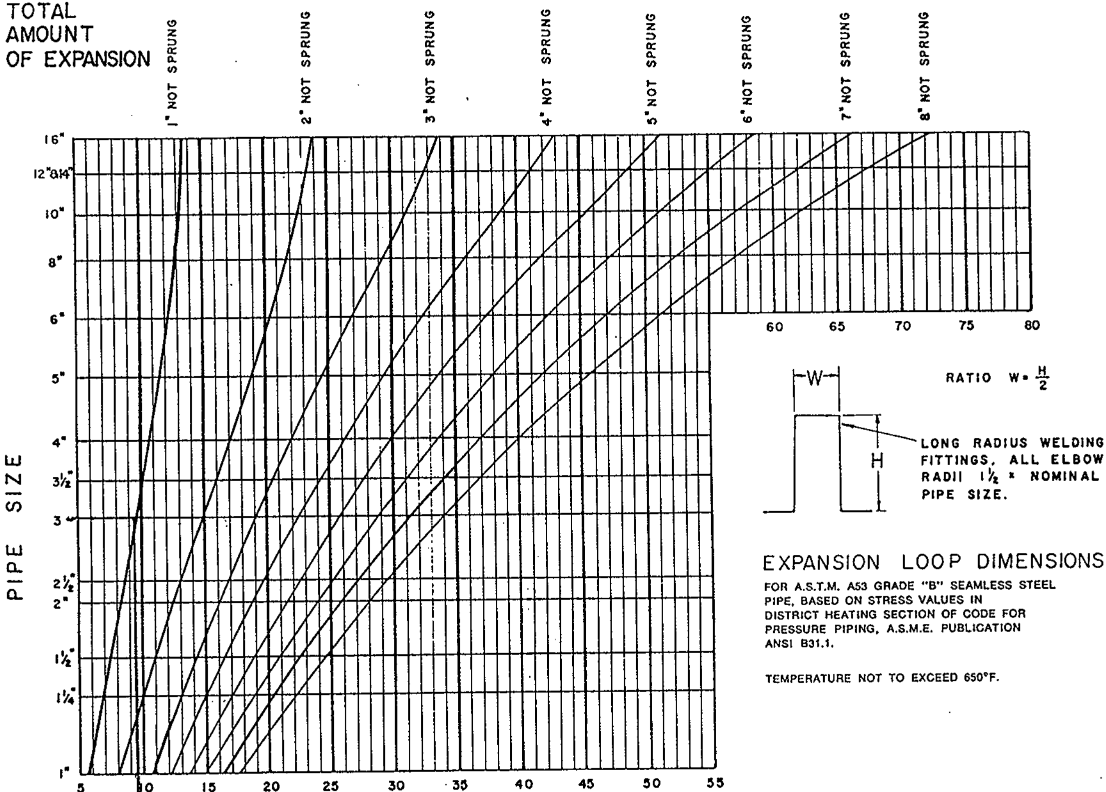
THERMAL EXPANSION OF PIPE IN INCHES PER 100 FEET

Pressure Psig	Temp. Degrees Fahr.	Steel Pipe	Stainless Steel 18CR-8NI	Copper Pipe	Pressure Psig	Temp. Degrees Fahr.	Steel Pipe	Stainless Steel 18CR-8NI	Copper Pipe
	—20	0	0	0	135	358	3.012	4.3272	4.356
	0	0.145	.2157	0.204	140	361	3.038	4.3632	4.381
	20	0.293	.4331	0.442	145	364	3.065	4.3992	4.430
	40	0.430	.6522	0.655	150	366	3.084	4.4232	4.454
	50	0.512	.7623	0.772	175	377	3.188	4.5555	4.595
	60	0.593	.8729	0.888	180.9	380	3.211	4.5917	4.628
	80	0.725	1.0953	1.110	200	387	3.272	4.6761	4.718
	100	0.898	1.3195	1.338	232.4	400	3.375	4.8334	4.870
	120	1.055	1.5454	1.570	250	406	3.435	4.9058	4.941
	140	1.209	1.7729	1.794	293.7	420	3.566	5.0751	5.118
	160	1.368	2.0022	2.008	366.1	440	3.740	5.3178	5.358
	180	1.528	2.2331	2.255	451.3	460	3.929	5.5619	5.612
	200	1.691	2.4658	2.500	550.3	480	4.100	5.8068	5.855
2.5	220	1.852	2.6974	2.720	664.3	500	4.296	6.0528	6.110
5	227	1.910	2.7788	2.804	795.3	520	4.487	6.3012	6.352
10	239	2.010	2.9186	2.828	945.3	540	4.670	6.5507	6.614
15	250	2.101	3.0472	3.075	1115.3	560	4.860	6.8013	6.850
20	260	2.183	3.1645	3.189	1308.3	580	5.051	7.0531	7.123
25	266	2.213	3.2349	3.259	1525.3	600	5.247	7.3061	7.388
30	274	2.299	3.3291	3.352	1768.3	620	5.437	7.5571	7.636
35	280	2.350	3.3998	3.422	2041.3	640	5.627	7.8091	7.893
40	286	2.401	3.4707	3.509	2346.3	660	5.831	8.0621	8.153
45	292	2.451	3.5417	3.576	2705	680	6.020	8.3160	8.400
50	297	2.494	3.6009	3.632	3080	700	6.229	8.5709	8.676
55	302	2.536	3.6601	3.689		720	6.425	8.8320	8.912
60	307	2.579	3.7193	3.747		740	6.635	9.0945	9.203
65	312	2.622	3.7786	3.806		760	6.833	9.3581	9.460
70	316	2.656	3.8261	3.853		780	7.046	9.6231	9.736
75	320	2.690	3.8736	3.900		800	7.250	9.8892	9.992
80	324	2.724	3.9211	3.949		820	7.464	10.1526	10.272
85	328	2.759	3.9687	3.998		840	7.662	10.4170	10.512
90	331	2.784	4.0044	4.035		860	7.888	10.6825	10.814
95	335	2.805	4.0521	4.084		880	8.098	10.9490	11.175
100	338	2.845	4.0879	4.121		900	8.313	11.2166	11.360
105	341	2.870	4.1238	4.169		920	8.545	11.4898	11.625
110	344	2.895	4.1596	4.192		940	8.755	11.7642	11.911
115	347	2.920	4.1954	4.227		960	8.975	12.0399	12.180
120	350	2.946	4.2313	4.263		980	9.196	12.3168	12.473
125	353	2.971	4.2672	4.298		1000	9.421	12.5950	12.747
130	355	2.987	4.2912	4.321					

TYPICAL INSULATION THICKNESSES

Temperature Ranges	Pipes ¾" thru 3"	Pipes 4" thru 6"	Pipes 8" thru 12"
100°F thru 200°F	1"	1"	1½"
200°F thru 300°F	1"	1½"	2"
300°F thru 400°F	1½"	2½"	3"
400°F thru 600°F	2"	3"	3½"

(V.S.) We recommend that temperature range 0°F thru 34°F be vapor sealed.
For recommendations on tempatures above 600°F and pipe sizes exceeding 12", contact Intergy, Inc. RICWIL® Piping Systems, 10100 Brecksville Rd., Brecksville, Ohio 44141



EXPANSION LOOP DIMENSIONS

FOR A.S.T.M. A53 GRADE "B" SEAMLESS STEEL PIPE, BASED ON STRESS VALUES IN DISTRICT HEATING SECTION OF CODE FOR PRESSURE PIPING, A.S.M.E. PUBLICATION ANSI B31.1.

TEMPERATURE NOT TO EXCEED 650°F.

FOR GRADE "B" STEEL PIPE

INTERGY, INC., RICWIL® Piping Systems BRECKSVILLE, OHIO 44141

23

POWER MACHINE CO.

FAX TRANSMITTA

COMPRESSORS, PUMPS and DRIVES • ENGINEERED SYSTEMS
KIPARY, INC. EXPORT TRANSACTIONS

TO: ROSS
COMPANY ICF KAISER ENG.
DATE: 3-28-94
FAX NO: 510-419-5355
FAX LOG NO: 94/408
SUBJECT:
FROM: JORDAN KAUFMAN
NO. OF PAGES 2 INCLUDING COVER SHEET REPLY TO FAX (510) 547-2007

ITEM 1 - COS: 120GPM @ 150FT
ONE (1) EACH INGERSOLL DRESSER PUMP MODEL 3X1.5X6 SHOC, MAGNOSEAL, BASEMOUNTED W/ COUPLING AND GUARD TO A 10HP, 3600 RPM MOTOR. (56% EFFICIANCY)
BUDGET PRICE EACH $6,000.00

ITEM 2 - COS: 120GPM @ 107FT
ONE (1) EACH INGERSOLL DRESSER PUMP MODEL 3X1.5X6 SHOC, MAGNOSEAL, BASEMOUNTED W/ COUPLING AND GUARD TO A 7.5HP, 3600 RPM MOTOR (58% EFFICIANCY)
BUDGET PRICE EACH $5,500.00

FOB FACTORY
DELIV. 4-6 WEEKS
TAX+FRT. EXTRA
QUOTE VALID 60 DAYS

INGERSOLL-RAND.
AIR COMPRESSORS

Ingersoll-Dresser. Pumps

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151 Bernal Road, Suite 5A, San Jose, California 95119 (408) 365-8700 • FAX (408) 365-0404
4003 Seaport Blvd., West Sacramento, California 95691 (916) 375-0075 • FAX (916) 375-8534

DON'T SAY IT --- *Write It!* DATE: January 7, 1994

TO: W.J. McGinley FROM: Peter H. Langowski PHL E6-21

Telephone: (509) 376-4226

cc (w/o att.): Ron Davidson, David Shrimpton, John Jurgilewicz, Charlie O'Neill

SUBJECT: Project W-320 Chiller Specification & Design Input

Please accept the following as the input you requested from KEH under Article I.B. of your Work Plan dated 12/30/93.

1. Length of coolant pipe between the chiller skid and condenser.

   Per HVAC Overall C-Farm Site Plan H-2-818469, revision 0 dated 1/7/94 (attached). A takeoff of this drawing yields the following (pipe lengths indicated for each supply line and return line; i.e. the total length of piping in the system is 638 feet):

   279 feet of pipe below grade (near horizontal)
   6 feet of pipe below grade (vertical risers)
   +34 feet of pipe above grade (total of both the condenser and the chiller ends)
   319 feet total for each supply and return

2. Number of elbows, (long or short radius).

   All chilled water piping elbows should be long radius ($r/D=1.5$). For sizing purposes use 14 elbows for each supply and return (i.e. 28 total elbows in the system between the condenser and the chiller skid): 8 @ 90°; and 6 @ 45°.

3. Heat transfer to coolant, Btu/hr.

   The Energy Balance drawing H-2-818479 states the heat transfer as being 235,080 Btu/h. Condenser sizing has been completed at 250,000 Btu/h. Use 250,000 Btu/h for calculation purposes.

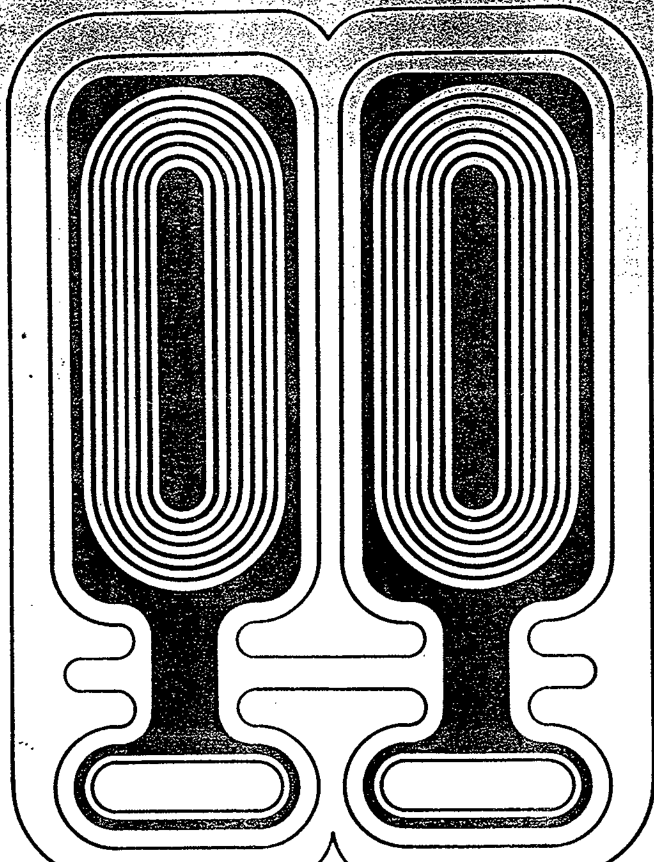
4. Coolant temperature entering and leaving condenser.

   Based on a preliminary selection of a condenser, the entering and leaving condenser temperatures shall be 33°F and 38°F, respectively. Preliminary coolant flow pressure drop through the condenser is 3 psig based on 120 gpm of 40% propylene glycol solution.

54-3000-101 (12/92) GEF014

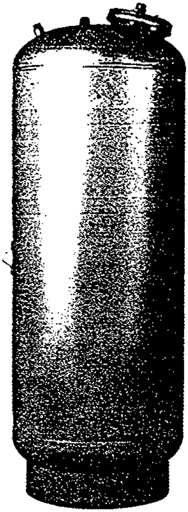
WESTROL SUPERTANKS

DIAPHRAGM, BLADDER AND PLAIN STEEL EXPANSION TANKS



HNF-2483, Rev. 0
Page F-28

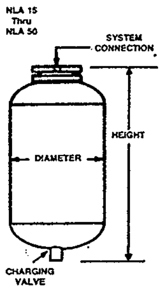
wessels company

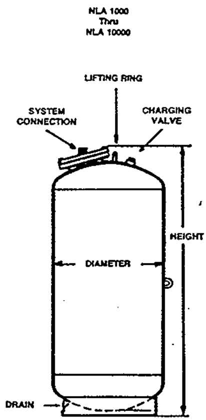


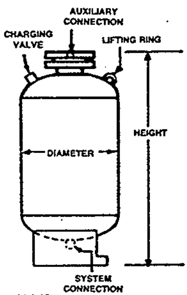
TYPE NLA EXPANSION TANKS

ASME replaceable bladder type expansion tanks for commercial and industrial heating/cooling systems. Space saving tank comes in sizes of 10 to 2640 gallons.

- ASME Section VIII Construction and Label
- Permanent separation of air and water
- Never waterlogs
- Water is "in the bag". Steel tank never touches water and is not subject to corrosion
- Replaceable Bladder
- Smaller sizes for easier handling, and saves space and installation costs
- Factory pre-charged and field adjustable







NLA 85
Thru
NLA 800

Model Number	Tank and Acceptance Volume Gallons	Tank Dia.	Tank Height	N.P.T. System Conn.	N.P.T. Aux. Conn.	Shipping Weight Pounds
*NLA 15	7.8	12"	19"	1/2"	-	47
*NLA 20	10.9	12"	25¾"	1/2"	-	60
NLA 35	10	12"	25½"	3/4"	-	40
NLA 50	13	14"	25½"	3/4"	-	50
NLA 85	23	16"	37"	1"	1/2"	90
NLA 130	35	20"	37"	1"	1/2"	125
NLA 185	48	20"	49"	1"	1/2"	160
NLA 250	66	24"	49"	1½"	1/2"	210
NLA 300	79	24"	54"	1½"	3/4"	225
NLA 400	106	28"	55"	1½"	3/4"	300
NLA 450	119	30"	54"	2"	3/4"	330
NLA 550	145	30"	67"	2"	3/4"	360
NLA 800	211	36"	66"	2"	3/4"	475
NLA 1000	264	36"	73¼"	1½"	-	710
NLA 1200	317	36"	86⅞"	1½"	-	720
NLA 1400	370	36"	98"	1½"	-	875
NLA 1600	422	48"	71"	1½"	-	1100
NLA 2000	528	48"	84¾"	1½"	-	1280
NLA 3000	792	48"	122"	2"	-	1550
NLA 4000	1056	54"	121"	2"	-	2230
NLA 5000	1320	54"	151"	2"	-	2570
NLA 7500	1980	72"	129"	3"	-	4005
NLA 10000	2640	72"	161"	3"	-	4845

125 P.S.I. operating pressure - 240°F maximum temperature at tank
Factory pre-charged 12 P.S.I.

Prime painted exterior finish

Saddles

Size	A	B	Weight
12	10	3	18
14	11	3	19
16	13	3	21
20	14	4	25
24	17	4	28
28	19	4	34
30	21	5	38
36	25	5	52

*Fixed diaphragm design with 2.5 gallons acceptance volume

POWER MACHINE CO.

FAX TRANSMITTAL

COMPRESSORS, PUMPS and DRIVES • ENGINEERED SYSTEMS
KIPARY, INC. EXPORT TRANSACTIONS

TO: Ross Abjelma

DATE: 2/22/94

FAX LOG NO:

FROM: Mike Ambrosi

COMPANY: Kaiser

FAX NO: 510-419-5355

SUBJECT: Pumps

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SHOC & SGRP PROCESS PUMPS

CAPABILITIES OF SHOC/SGRP ANSI PROCESS PUMPS

Viscosity (Max):	600 Centipoisie 2500 SSU
Temperature (Max):	250 Deg. F. for SGRP 250 Deg. F. for Process SHOC 500 Deg. F. for All Metal SHOC
Working Pressure:	375 psig max.
Entrained Gas (Max):	3% max. by volume
Particles (Max):	100 Micron, 1.5% by weight Contact SPD for Wash Flow Strainer Application
Minimum Flow:	See Back of page 7100.20, sheet 101

PRESSURE LIMITS, PSI

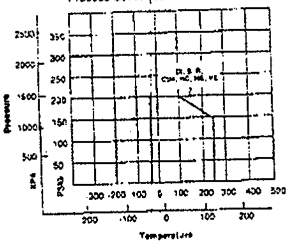
Refer to Pressure vs. Temperature charts below to determine pressure limits for specific operating conditions. The Maximum Suction Pressure equals the Maximum Working Pressure minus the Differential Pressure.

Category	Material Columns	Maximum Working Pressure: Process Construction	Maximum Working Pressure: All Metal Construction	Hydrotest Pressure
Standard 150# Flanges	DI S R CD4, HC, HB VE	200 200 200 200 200	290 275 235 295 N/A	See Note (2)
Optional 300# Flanges	S, R, CD4, HC, HB (1)	200	375	(2)

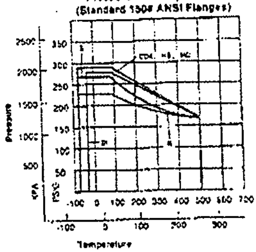
NOTES: (1) Ductile iron and VE pumps are not available with 300# Flanges.
(2) Hydrotest Pressure is a minimum of 1.5 times the Maximum Working Pressure for SHOC and 1.1 times the Maximum Working Pressure for SGRP.

PRESSURE VS. TEMPERATURE

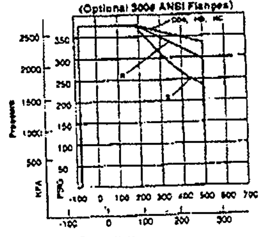
Pressure vs. Temperature
Process Construction (SHOC & SGRP)



All Metal Construction
Pressure vs. Temperature
(Standard 150# ANSI Flanges)



All Metal Construction
Pressure vs. Temperature
(Optional 300# ANSI Flanges)



Magnoseal™

SHOC & SGRP PROCESS PUMPS

STANDARD CONSTRUCTION

Category	Construction Features	Standard	Optional At Extra Price
Type	Horizontal, End Suction, Single Stage, Top Centerline Discharge, Foot Mounted Back Pullout, Flexible Coupling	X	
Drive	Permanent High Strength Magnet-to-Magnet	X	
Rotation	CW (Clockwise) facing pump coupling (per Hydraulic Institute)	X	
Casing	SHOC & SGRP are interchangeable with HOC2 & GRP respectively	X	
Nozzles	150# F.F. (Flat Face) Flanges	X	
	150# R.F. (Raised Face) Flanges (except Col. DI & VE) with grooved finish		X
	300# F.F. (Flat Face) Flanges (except Col. DI & VE)		X
	300# R.F. (Raised Face) Flanges (except Col. DI & VE) with grooved finish		X
Auxiliary Connections Casing	Material Col. DI and S—.50 inch NPT Casing Drain Tap, .38 inch NPT Discharge Gage Tap	X	
	—.38 inch NPT Suction Gage Tap		X
	—Casing with no Taps		X
	Material Col. CD4, R, HC, HB—No Taps	X	
	—.50 inch NPT Casing Drain Tap, .38 inch NPT Discharge Gage Tap		X
	—.38 inch NPT Suction Gage Tap		X
	Material Col. VE (SGRP)—No Taps	X	
	—.250 inch NPT Discharge Gage Tap and .250 inch NPT Casing Drain		X
	—.250 inch NPT Casing Drain Tap		X
Drain Plug	Machined Head Plug—Col. DI and S	X	
	Square Head Polypro—Col. VE		X
	Machined Head Plug—Col. CD4, R, HC, HS		X
	Round Head Plug		X
Impeller	Semi-Open, Balanced (1) SHOC & SGRP (except for 1-1/2x1x8 SGRP) are interchangeable with HOC2 & GRP respectively	X	
Cover	Non-wetted Casing to Cover fit, Flat Gasket—SHOC only	X	
	O-Ring Gasket at Cover to Casing fit—SGRP only	X	
	.25 inch NPT External Flush Tap—Plugged	X	
	Containment Shell drained internally to Casing	X	
	External containment shell drain		X
	Internal Flush Hole with .25 inch NPT—Not Plugged	X	
	Wash Flow Strainer—SHOC only		X
Gaskets & O-Rings	Gaskets—SHOC only (Group 2 includes casing and containment shell gaskets) —NTL/SYN	X	
	—Teflon		X
	—Graphite		X
	Containment Shell O-Ring—SHOC (Group I) —Viton-A	X	
	—Kalrez		X
	—Aflas		X
	O-Ring—SGRP (Includes all O-Rings) —Viton-A	X	
	—Aflas		X
Bearing Housing	Shroud Area—.38 inch NPT on top—Standard with Vent	X	
	—.38 inch NPT at bottom—Standard Plugged	X	
	Grease-for-life lubrication	X	
	Oil Bath Lubrication, Plastic Trico Oiler		X
	Oil Bath Lubrication, Guarded Glass Oiler		X
	Oil Mist Connections—(2) .375 inch NPT Taps		X
	Labyrinth Oil Seal—Outboard—Dura (bronze, viton)		X
	—INPRO (bronze, viton)		X
	.25 inch NPT Ball Bearing Temp. Probe Tap		X
Couplings	All Manufacturers and Types		X
Coupling Guard	OSHA, Steel		X
	Non-Sparking Aluminum		X
Bedplate	Fabricated Steel		X
	with 316SS Drip Pan		X
	with Drip Lip		X
	with Machined Pads		X
	with Stainless steel Stilts		X
	Fiberglass with built-in Drip Pan		X
	with Stainless Steel Stilts		X
Testing	Hydrostatic Test	X	
	Performance Test		X
	NPSH Test		X
	Witness Tests		X

NOTE: (1) SHOC Impellers are single plane spin balanced. Single shroud open impellers cannot be dynamically balanced because they do not have two shrouds on which to perform adjustments. SGRP Impellers, due to the high precision molding, do not require mechanical balancing.

Magnoseal™
SHOC & SGRP PROCESS PUMPS

STANDARD MATERIALS
ALL METAL CONSTRUCTION
SHOC ONLY

Material Column	DI	S	CD4	R	HC	HB
General Description	Ductile Iron	316 S.S.	CD4MCu	Alloy 20	Hastelloy C	Hastelloy B
Casing	Ductile Iron (Note 1)	316 S.S. (Cast)	CD4MCu	Alloy 20 (Cast)	Hastelloy C	Hastelloy B
Casing Gasket	Non-Asbestos					
Casing Bolting	Carbon Steel (Bolting)	304 S.S. (Bolting)				
Impeller	Carbon Steel (Cast)	316 S.S. (Cast)	CD4MCu	Alloy 20 (Cast)	Hastelloy C	Hastelloy B
Casing Cover	316 S.S. (Cast)			Alloy 20 (Cast) (Note 2)	Hastelloy C	Hastelloy B
Shaft-pump (internal)	316 S.S.			Alloy 20	Hastelloy C	Hastelloy B
Shaft-Brg Hsg (external)	Carbon Steel (Hot Rolled)					
Inner Magnet Carrier	316L S.S.			Alloy 20	Hastelloy C	Hastelloy B
Outer Magnet Carrier (4)	Ductile Iron					
Containment Shell	316 / Hastelloy C			Hastelloy (3)	Hastelloy C	Hastelloy B
Shell O-Ring	Viton					
Inner Magnet Cladding	316L S.S.			Alloy 20	Hastelloy C	Hastelloy B
Bearing Housing (4)	Ductile Iron					
Product Lube Bearings	Silicon Carbide					

NOTE 1: On 3x2x6K only the casing is investment cast carbon steel.
NOTE 2: Col. R Casing Covers may be provided in Alloy 20 or Hastelloy C at factory option
NOTE 3: Hastelloy C may be specified for specific application
NOTE 4: These parts may be supplied in carbon steel or steel at factory option

MATERIAL SPECIFICATIONS

General Description	Specification	General Description	Specification
Ductile Iron	ASTM A395	304 S.S. (Bolting)	ASTM A276 Type 304
316 S.S. (Cast)	ASTM A744 CF8M	316 S.S. (Wrought)	ASTM A276 Type 316
CD4MCu	ASTM A744 CD4MCu	Alloy 20 (Wrought)	ASTM B473
Alloy 20 (Cast)	ASTM A744 CN7M	Carbon Steel (Bolting)	ASTM A193 B7
Hastelloy C	ASTM A494 CW12MW	Carbon Steel (Hot Rolled)	AISI 4140
Hastelloy B	ASTM A494 N12MV	Carbon Steel (Key)	AISI C1018
Carbon Steel (Cast)	ASTM A216 WCB		

STANDARD MATERIALS
PROCESS CONSTRUCTION

Material Column	DI	S	CD4	R	HC	HB	VE (SGRP)
General Description	Ductile Iron	316 S.S.	CD4MCu	Alloy 20	Hastelloy C	Hastelloy B	Glass Reinforced Polymer
Casing	Ductile Iron (Note 1)	316 S.S. (Cast)	CD4MCu	Alloy 20 (Cast)	Hastelloy C	Hastelloy B	GRP
Casing Gasket (O-Ring on SGRP)	Non-Asbestos						Viton
Casing Bolting	Carbon Steel (Bolting)	304 S.S. (Bolting)					
Impeller	Carbon Steel (Cast)	316 S.S. (Cast)	CD4MCu	Alloy 20 (Cast)	Hastelloy C	Hastelloy B	GRP
Casing Cover	316 S.S. (Cast)			Alloy 20) (Cast) (Note 2)	Hastelloy C	Hastelloy B	GRP
Shaft-pump (internal)	316 S.S.			Alloy 20	Hastelloy C	Hastelloy B	Hastelloy C (3)
Shaft-Brg Hsg (external)	Carbon Steel (Hot Rolled)						
Inner Magnet Carrier	316L S.S.			Alloy 20	Hastelloy C	Hastelloy B	Hastelloy C (3)
Outer Magnet Carrier (4)	Ductile Iron						
Containment Shell	Reinforced Crystalline Polymer						
Shell O-Ring	Viton						
Inner Magnet Cladding	316L S.S.			Alloy 20	Hastelloy C	Hastelloy B	Hastelloy C (3)
Bearing Housing (4)	Ductile Iron						
Product Lube Bearings	Silicon Carbide						

NOTE 1: On 3x2x6K only the casing is investment cast carbon steel.
NOTE 2: Col. R Casing Covers may be provided in Alloy 20 or Hastelloy C at factory option
NOTE 3. Process fluid compatible materials will be provided.
NOTE 4. These parts may be provided in carbon steel or steel at factory option

MATERIAL SPECIFICATIONS

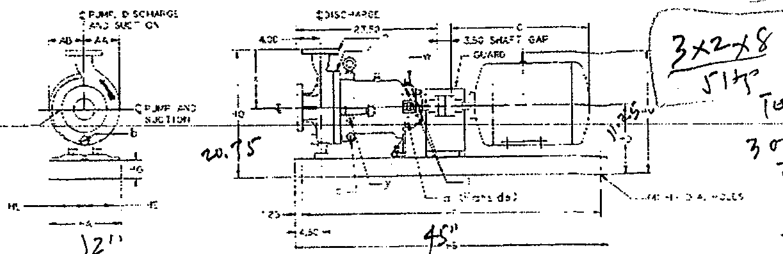
General Description	Specification	General Description	Specification
Ductile Iron	ASTM A395	304 S.S. (Bolting)	ASTM A276 Type 304
316 S.S. (Cast)	ASTM A744 CF8M	316 S.S. (Wrought)	ASTM A276 Type 316
CD4MCu	ASTM A744 CD4MCu	Alloy 20 (Wrought)	ASTM B473
Alloy 20 (Cast)	ASTM A744 CN7M	Carbon Steel (Bolting)	ASTM A193 B7
Hastelloy C	ASTM A494 CW12MW	Carbon Steel (Hot Rolled)	AISI 4140
Hastelloy B	ASTM A494 N12MV	Carbon Steel (Key)	AISI C1018
Carbon Steel (Cast)	ASTM A216 WCB	GRP	Glass Reinforced Vinyl Ester

Dom. Exp. Dist. on 50C

GENERAL ARRANGEMENT - SHOC GROUP 2 PUMPS

October 19[illegible]

INGERSOLL-RAND.
PUMPS



3x2x8 ✓
5 Hp
TEFC
300 P
80 m
80 DP
45°
20.75
12"
45"

GENERAL NOTES

1. CONSULT INSTRUCTION BOOK BEFORE INSTALLING PUMP
2. All dimensions given in inches and weights in pounds.
3. All pipe taps are standard NPT threads.
4. All holes in flanges straddle centerlines.
5. Allow .[illegible] for [illegible] of foundation bolt holes.
6. Foundation bolts and piping should not be set [illegible] until receipt of [illegible].
7. Allow [illegible] under baseplate for grouting.
8. Recheck alignment after unit reaches operating condition.
9. The design of piping system, foundations and other areas of system design is the responsibility of others. Ingersoll-Rand data and comments are offered as [illegible] but [illegible] cannot assume responsibility for the design [illegible] [illegible]. We recommend that the customer [illegible] [illegible] [illegible] in the design of foundations, piping, pumps and related systems so as to [illegible] and [illegible] Ingersoll-Rand Company [illegible] [illegible] a successful installation.

BEDPLATE DATA							
NO.	WT. [illegible]	HA	HB	HF	HP	[illegible]	[illegible]
[illegible]	80	2.25	45.00	4.50	42.50	[illegible]	[illegible]
2	4	3.25	52.50	6.50	49.50	3.38	[illegible]
3	[illegible]	[illegible]	58.50	[illegible]	55.50	[illegible]	[illegible]
4	[illegible]	[illegible]	60.00	[illegible]	57.50	[illegible]	[illegible]
5	[illegible]	3.50	67.00	[illegible]	64.50	[illegible]	[illegible]

PUMP, MOTOR, AND BEDPLATE DATA								
							FRAME	[illegible]
							C	[illegible]
ANSI	PUMP	SUCT	DISCH	AA	AB	X	WEIGHT	[illegible]
A50	3X1-1/2X[illegible]	3.00	1.50	6.50	4.50	8.50	275	[illegible]
A60	3X2X8	3.00	2.00	6.50	6.00	9.50	300	[illegible]
A60	4X3X8	4.00	3.00	7.00	6.00	11.50	315	[illegible]
A70	4X3X8H	4.00	3.00	7.00	6.00	11.50	320	[illegible]
A05	2X1X10	2.00	1.00	7.12	7.12	8.50	300	[illegible]
A[illegible]	3X1-1/2X10	3.00	1.50	7.12	7.12	10.50	315	[illegible]
A60	3X2X10	3.00	2.00	7.50	7.12	9.50	372	[illegible]
A70	4X3X10	4.00	3.00	7.88	7.12	11.50	345	[illegible]
A[illegible]	4X3X10L	4.00	3.00	8.00	7.62	11.50	345	[illegible]
A[illegible]	6X4X10	6.00	4.00	10.75	8.00	13.50	345	[illegible]
A70	3X1-1/2X13	3.00	1.50	9.50	8.38	10.50	365	[illegible]
A30	3X2X13	3.00	2.00	9.00	8.38	11.50	365	[illegible]
A40	4X3X13	4.00	3.00	10.00	8.50	11.50	395	[illegible]

PUMP, MOTOR, BEDPLATE SETTING AND OVERALL HEIGHT DATA										
MOTOR FRAMES	143-145	182-184	213-215	254-256	284-286	324-326	364-365	404-405	444-445	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FLANGE DATA												
150# ANSI DIMENSIONS - STEEL OR DI RF						300# ANSI DIMENSIONS - STEEL OR DI RF						
NOZZLE SIZE	OD FLANGE	THICK +.12/-.00	BOLTS NUMBER	BOLTS SIZE	DIA. BC		NOZZLE SIZE	OD FLANGE	THICK +.12/-.00	BOLTS NUMBER	BOLTS SIZE	DIA. BC
1	4.25	.56	4	.50	3.12		1	4.88	.69	4	.62	3.50
1-1/2	5.00	.69	4	.50	3.88		1-1/2	6.12	.81	4	.75	4.50
2	6.00	.75	4	.62	4.75		2	6.50	[illegible]	8	.62	5.00
3	7.50	.94	4	.62	6.00		3	8.25	1.12	8	.75	6.62
4	9.00	.94	8	.62	7.50		4	10.00	1.25	8	.75	7.88
6	11.00	1.00	8	.75	9.50		6	12.50	1.44	12	.75	10.62

BEARING HOUSING LUBRICATION

- ☐ GREASED-FOR-LIFE STANDARD
- ☐ OIL-LUBE & [illegible] FURNISHED
- ☐ OIL-LUBE & [illegible] [illegible] - OPTIONAL
- ☐ OIL-MIST [illegible] AND [illegible] CONNECTIONS

AUXILIARY CONNECTIONS (NPT)

- ● a 1/4" NPT - Bearing Housing Drain (plugged)
- b 1/2" NPT - Casing Drain (plugged)
- ● c 3/8" NPT - Leakage Detection (plugged or Standard)
- ● d 1/4" NPT - External Flush Connection (plugged as Standard)
- 3/8" NPT - Discharge Gage Connection (plugged)
- 3/8" NPT - Suction Gage Connection (plugged)
- 1/8" NPT - Oil Mist Vents (When Provided)
- ● w 3/8" NPT - Bearing Housing Vent (Standard) - Oil Mist Connection (When Provided)
- ● y 1/2" NPT - Manual Flush Connection (plugged as Standard) (1) Two Each Side

● Standard - Always Furnished

PRELIMINARY - DO NOT USE FOR CONSTRUCTION UNLESS ENDORSED BELOW								
CUSTOMER					CUSTOMER ORDER NO.			
PROJECT & LOCATION					CUSTOMER ITEM NO.			
I.R. ITEM NO.	PUMP	FRAME AND ENCLOSURE	HP / RPM	FLANGES	CASING DRAIN	GAGE CONNS.	COUPLING	
INGERSOLL RAND COMPANY ORDER NO.					CERTIFIED ONLY WHEN ENDORSED REP		DATE	

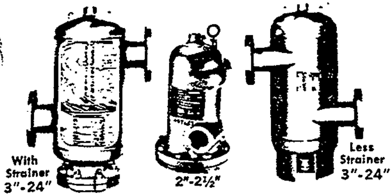
Dwg. No. [illegible]

33

BELL & GOSSETT

SUBMITTAL

A-326C



The ROLAIRTROL® Air Separator

Air Control

NOTE: 3" MODELS HAVE NPT NOZZLES.

JOB

B & G REPRESENTATIVE ______________________

UNIT TAG NO. ______________________

ENGINEER ______________________

CONTRACTOR ______________________

ORDER NO. ______________ DATE ________

SUBMITTED BY ______________ DATE ________

APPROVED BY ______________ DATE ________

DESCRIPTION

The Rolairtrol Air Separator is designed with tangential openings to create a low velocity vortex where air is separated and removed from the circulating water. As with all other air separators Airtrol Tank Fittings must be included in the system to properly direct and confine air inside the compression tank.

CONSTRUCTION

- Body — Models R-2, RL-2, R-2½ and RL-2½: Cast Iron
- Shell — All other models: Steel
- System Strainer ("R" Models only):
  Models R-2 and R-2½: Have stainless steel strainers with 5/32" diameter perforations and 63% open area.
  All other "R" models: Have galvanized steel strainers with 3/16" diameter perforations with 53% open area.
- Air Collector Tube: Stainless steel with 5/32" diameter perforations and 63% open area.
- Baffle/Collector Tube Support Assembly: Steel

SCHEDULE AND PERFORMANCE CHARACTERISTICS

MODEL NO. AND CAPACITY				SIZE OF TANGENTIAL OPENINGS INCHES		TAGGING INFORMATION	QUANTITY
WITH STRAINER		LESS STRAINER					
MODEL NO.	GPM*	MODEL NO.	GPM*				
R-2	56	RL-2	56	2	NPT		
R-2½	90	RL-2½	90	2½			
R-3	190	RL-3	190	3			
R-4	300	RL-4	300	4	FLANGED		
R-5	500	RL-5	530	5			
R-6	700	RL-6	850	6			
R-8	1300	RL-8	1900	8			
R-10	2000	RL-10	3600	10			
R-12	2750	RL-12	4800	12			
R-14	3400	RL-14	6100	14			
R-16	4400	RL-16	8000	16			
R-18	5200	RL-18	9700	18			
R-20	6300	RL-20	12000	20			
R-22	7400	RL-22	15000	22			
R-24	8500	RL-24	17000	24			

*PRESSURE DROP: With strainer—14 elbow equivalents Less strainer— 9 elbow equivalents

MAXIMUM DESIGN PRESSURE 125 P.S.I.G. MAXIMUM OPERATING TEMPERATURE 350°F

TYPICAL SPECIFICATION

Furnish and install, as show on plans, a centrifugal type air separator. The unit shall have _____ " (NPT/flanged) inlet and outlet connections tangential to the vessel shell. Vessel shell diameter to be three times the nominal inlet/outlet pipe diameter.

The unit shall have an internal stainless steel air collector tube with 5/32" diameter perforations and 63% open area designed to direct accumulated air to the compression tank via an NPT vent connection at top of unit.

The unit shall have a removable galvanized steel system strainer with 3/16" diameter perforations and a free area of not less than five times the cross-sectional area of the connecting pipe. A blowdown connection shall be provided to facilitate routine cleaning of the strainer. (Delete this paragraph if system strainer is not specified.)

Manufacturer to furnish data sheet specifying air collection efficiency and pressure drop at rated flow.

The air separator must be designed, constructed and stamped for 125 psig @ 350°F in accordance with Section VIII, Division I of the ASME Boiler and Pressure Vessel Code, and registered with the National Board of Boiler and Pressure Vessel Inspectors. The air separator(s) shall be painted with one shop coat of light gray air dry enamel.

A manufacturers' Data Report for Pressure Vessels, Form U-1 as required by the provisions of the ASME Boiler and Pressure Vessel Code shall be furnished for each air separator upon request.

Each air separator shall be ITT Bell & Gossett Model No. R-. . . . .(with system strainer) or RL- . . . .(less system strainer) Rolairtrol Air Separator for. . . . . .GPM.

ITT Bell & Gossett
ITT Fluid Technology Corporation

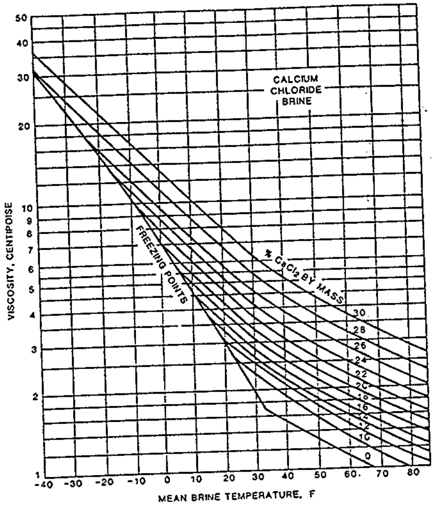


Fig. 4 Viscosity of Calcium Chloride Brine[1]

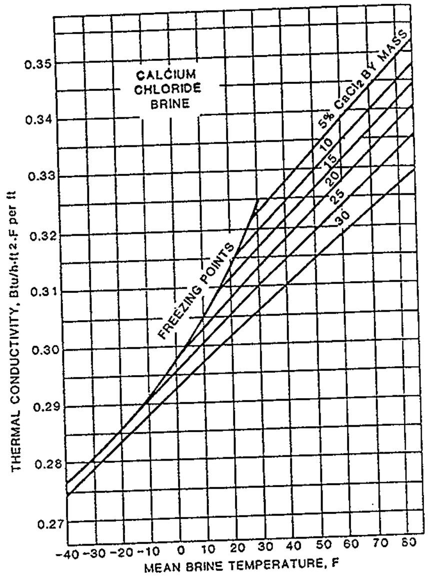


Fig. 5 Thermal Conductivity of Calcium Chloride Brine[1]

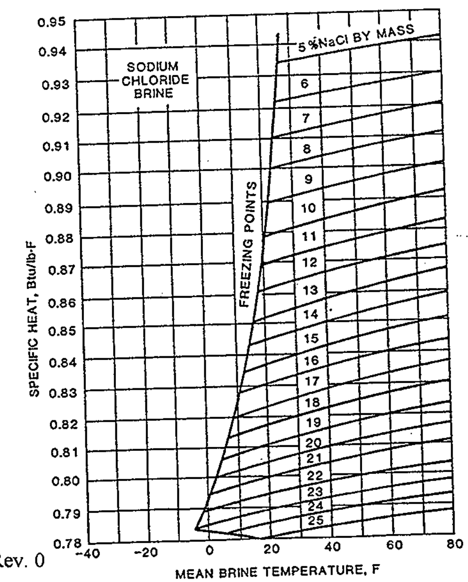


Fig. 6 Specific Heat of Sodium Chloride Brine[1]

INHIBITED GLYCOLS

Ethylene glycol and propylene glycol, inhibited for corrosion control, are used as aqueous freezing point depressants and heat transfer media in heating and cooling systems. Their chief attributes are the ability to lower the freezing point of water, and low volatility and relatively low corrosivity when properly inhibited. A monitoring schedule on glycol fluids helps prevent undesirable inhibitor depletion.

Inhibited ethylene glycol solutions have better physical properties than propylene glycol solutions, especially at lower temperatures. However, the less toxic propylene glycol is preferred for applications involving possible contact with food or beverages. Applications such as snow melting and ice rink systems are described in the 1982 APPLICATIONS and 1984 SYSTEMS VOLUMES.

Physical Properties[7]

Ethylene and propylene glycol are colorless, practically odorless liquids, completely miscible with water and many organic compounds. Table 3 shows important properties of the pure materials.

The freezing point vs. composition aqueous mixtures are given in Fig. 10. Pure ethylene glycol freezes at 9 F. The ethylene-glycol-water freezing point curve implies occurrence of a eutectic; but its exact composition and temperature are unknown, since solutions with freezing points in this range set to a viscous, glassy mass that makes it difficult to determine true freezing points. On the dilute side of the eutectic, ice forms on freezing; on the concentrated side, solid glycol separates from solution on freezing. Freezing velocity of such solutions is often quite slow; but, in time, they set to a hard, solid mass.

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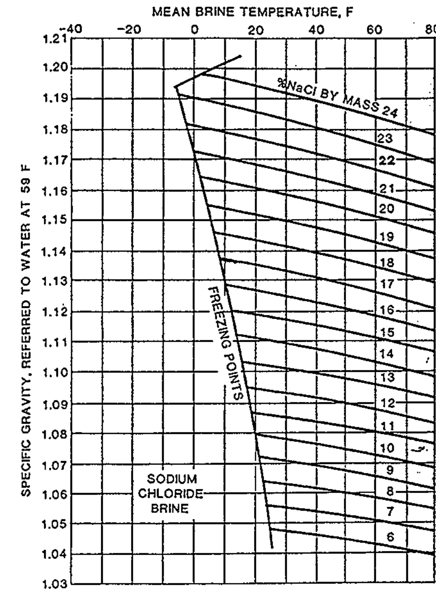


Fig. 7 Specific Gravity of Sodium Chloride Brine[1]

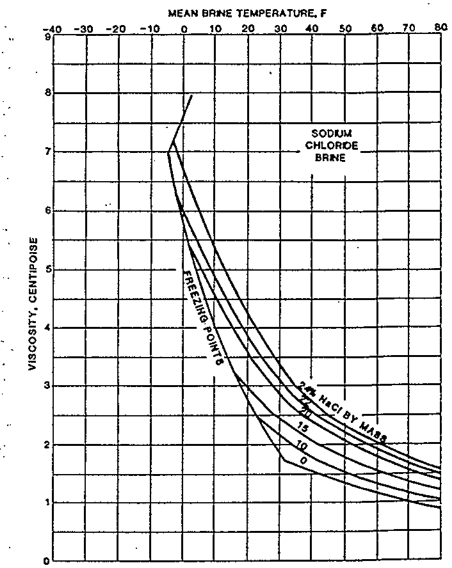


Fig. 8 Viscosity of Sodium Chloride Brine[1]

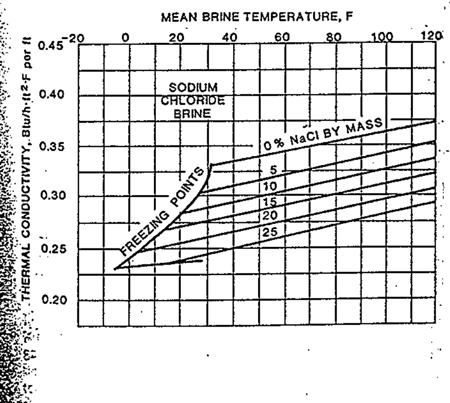


Fig. 9 Thermal Conductivity of Sodium Chloride Brine[1]

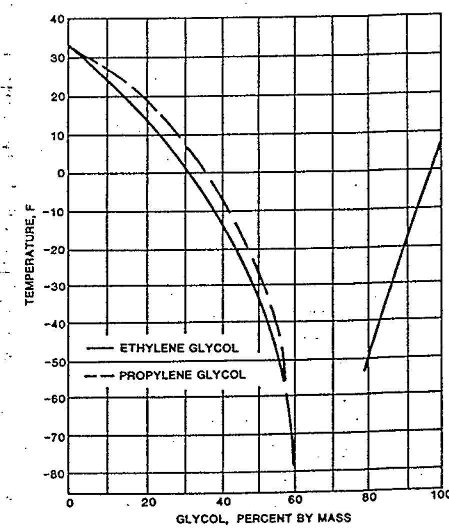


Fig. 10 Freezing Points of Aqueous Solutions of Ethylene Glycol and Propylene Glycol

boiling point and condensation ... for aqueous solutions of ethy- ... Note the relatively small increase in ... increase in glycol content over much ...ge. Vapor compositions above hot gly- ...mal dilutions (25 to 60%) are very low in ...nerefore, in open applications, significant ...f coolant is possible.

... and 14 give specific gravity vs. composition ... aqueous solutions of ethylene and propylene gly- ...e two important facts: (1) values for propylene glycol ...ose to those of water (when compared with ethylene gly- ... and (2) propylene glycol values are maximum at 70 to ...% concentration. This makes it difficult to ascertain propylene glycol content of solutions by specific gravity measurements. Control by refractive index measurement or Karl Fischer analysis for water are the preferred laboratory methods for determining composition of propylene glycol solutions.

To convert specific gravity to density, multiply the appropriate value from Fig. 13 or 14 by the water density at the reference temperature (62.37 lb/ft^3).

Figures 15 and 16 give viscosity for ethylene and propylene glycol-water systems. These plots show a significantly higher viscosity for the propylene glycol solutions, particularly at low temperatures.

Table 3 Summary of Physical Properties

Property	Ethylene Glycol	Propylene Glycol
Molecular Weight	62.07	76.10
Specify Gravity at 68/68 F	1.1155	1.0381
Mass per Unit Volume at 68 F		
lb/ft^3	69.50	64.68
lb/gal.	9.29	8.65
Boiling Point in F		
at 760 mm Hg	388	369
at 50 mm Hg	253	241
at 10 mm Hg	192	185
Vapor Pressure in mm Hg at 68 F	0.05	0.07
Freezing Point in F	9.1	Sets to glass below −76
Viscosity in centipoise		
at 32 F	57.4	243
at 68 F	20.9	60.5
at 104 F	9.5	18.0
Refractive Index, n_D, at 68 F	1.4319	1.4329
Specific Heat at 68 F in Btu/lb·F	0.561	0.593
Heat of Fusion at 9.1 F in Btu/lb	80.5	—
Heat of Vaporization at 1 atm in Btu/lb	364	296
Heat of Combustion at 68 F in Btu/lb	8280	10,312

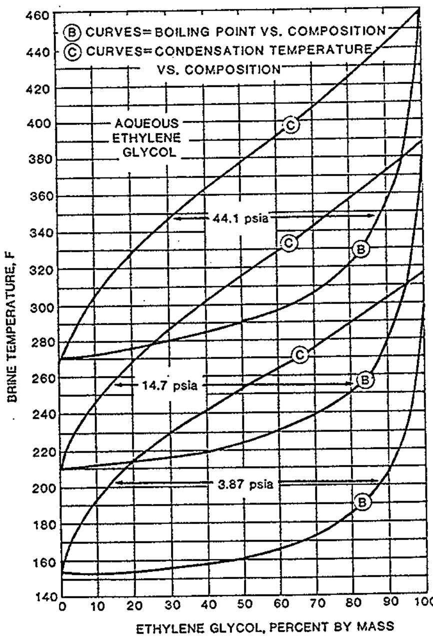


Fig. 11 Boiling Point and Condensation of Aqueous Solutions of Ethylene Glycol

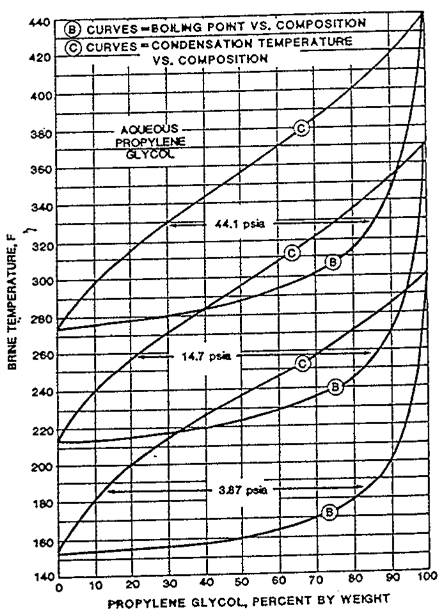


Fig. 12 Boiling Point and Condensation of Aqueous Solutions of Propylene Glycol

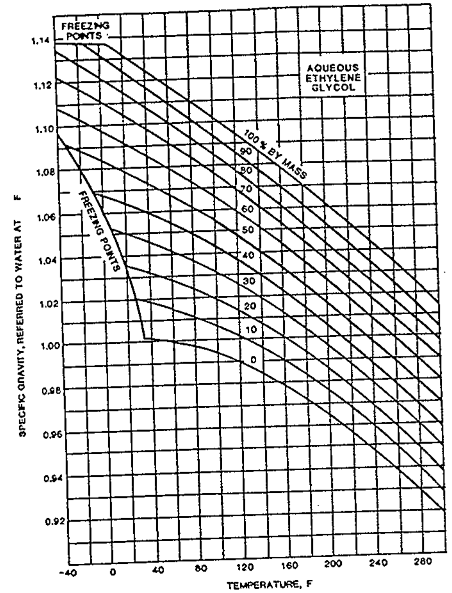


Fig. 13 Specific Gravity of Aqueous Solutions of Ethylene Glycol

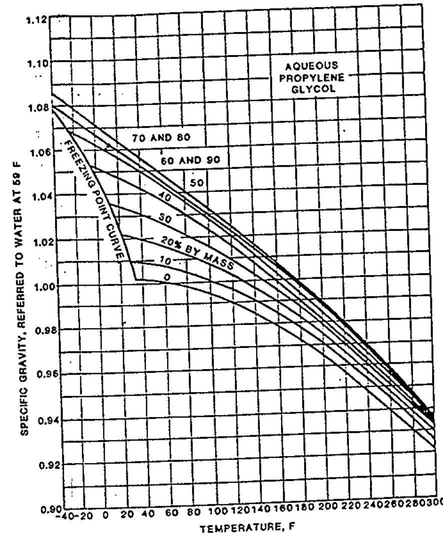


Fig. 14 Specific Gravity of Aqueous Solutions of Propylene Glycol

Figures 17 and 18 give specific heats for aqueous solutions of ethylene and propylene glycol. On an equivalent percent-by-mass basis, propylene glycol solutions have higher specific heat values than ethylene glycol solutions, though neither is as efficient as water alone for heat transfer applications.

Figures 19 and 20 give the thermal conductivity for aqueous ethylene glycol and propylene glycol solutions. Note that thermal conductivity of the glycols decreases with increasing temperature, but water dilution offsets this to some degree.

Additional physical property data is available from suppliers of ethylene and propylene glycol.

Corrosion Inhibition

Commercial ethylene or propylene glycol, when pure, is generally less corrosive than water to common metals used in construction. Aqueous solutions of these glycols, however, assume the corrosivity of the water from which they are prepared and can become increasingly corrosive with use if not properly inhibited. This is because glycols, like most other organic compounds, are oxidized by air into acidic end products. The amount of oxidation is influenced by such factors as temperature, degree of aeration and, to some extent, the particular combination of metal components to which the glycol solution is exposed.

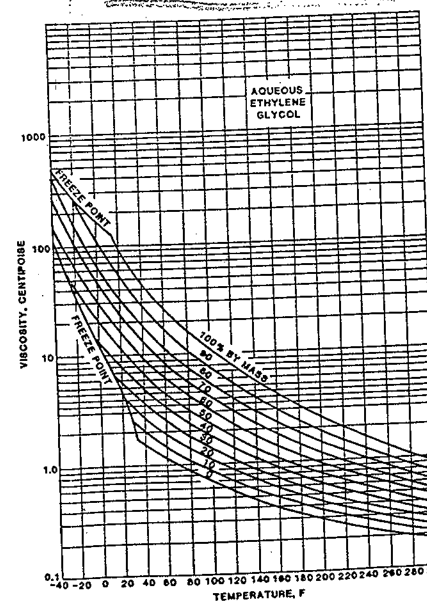


Fig. 15 Viscosity of Aqueous Solutions of Ethylene Glycol

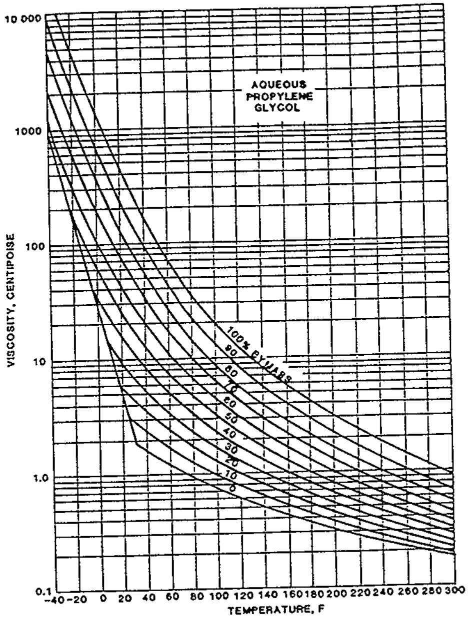


Fig. 16 Absolute Viscosity of Aqueous Solutions of Propylene Glycol

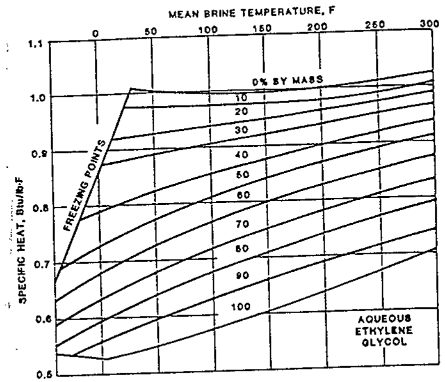


Fig. 17 Specific Heat of Aqueous Solutions of Ethylene Glycol

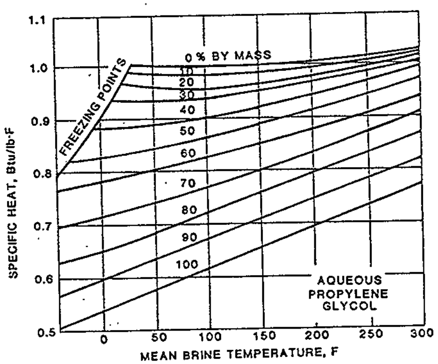


Fig. 18 Specific Heat of Aqueous Solutions of Propylene Glycol

Corrosion inhibition[8] is perhaps most easily understood by classifying additives either as: (1) corrosion inhibitors or (2) environmental stabilizers and adjusters. Corrosion inhibitors form a surface barrier that protects the metal from attack. These barriers are usually formed by mechanisms such as adsorption of the inhibitor by the metal, or by reaction of the inhibitor with the metal or perhaps the incipient reaction product. In most cases, metal surfaces are covered by films of their oxides that inhibitors reinforce.

Environmental stabilizers or adjusters, while not corrosion inhibitors in the strict sense, decrease corrosion by stabilizing or favorably altering the overall environment. An alkaline buffer such as borax is an example, since its prime purpose is to maintain an alkaline condition (*pH* above 7). Some chelating agents function as stabilizers by removing from the solution certain deleterious ions that accelerate the corrosion process or mechanism; however, exercise caution in their use.

Certain oxidants, such as sodium chromate, should not be used in conjunction with glycol solutions, because the glycol can oxidize prematurely. Generally, combinations of the two types of additives, inhibitors and stabilizers, offer the best corrosion resistance in a given system. Commercial, inhibited glycols are available from several suppliers.

Service Considerations

Storage and Handling. Inhibited glycol concentrates are stable, relatively noncorrosive materials with high flash points. Although they can be stored in mild steel, stainless steel or aluminum vessels, or even containers lined with a baked phenolic or vinyl resin coating, may be required. Since chemical properties of an inhibited glycol concentrate differ from those of its dilution, the effect of the concentrate on different containers should be known when selecting storage.

Choose transfer pumps only after considering temperature-viscosity data. Centrifugal pumps with electric motor drives are often recommended. Rubber-impregnated asbestos or its equivalent is a suitable pump packing material; a mechanical seal may also be satisfactory. Mild steel transfer piping with a minimum diameter is suggested. Welded construction is normally used in conjunction with the piping, although flanged and gasketed joints are also satisfactory.

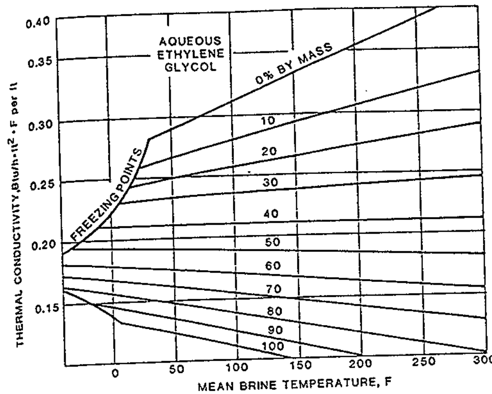


Fig. 19 Thermal Conductivity of Aqueous Solutions of Ethylene Glycol

Preparation Before Application. Before an inhibited glycol is charged into a system, remove residual contaminants such as sludge, rust, brine deposits and oil so the contained inhibitor functions properly. Avoid strong acid cleaners; if they are required, consider inhibited acids. Completely remove the cleaning agent before charging with inhibited glycol.

Water of dilution quality must be considered, because water from some sources contains corrosive elements that reduce effectiveness of the inhibited formulation. Surface waters classified as *soft* that are low in chloride and sulfate ion content (less than 100 ppm each) are preferred. Use distilled, deionized, or condensate water to avoid undesirable effects of poor quality water.

The decision to employ an inhibited glycol should be consistent with potential temperature factors. In systems with a high degree of aeration, a maximum bulk fluid temperature of 180 F is proposed, but up to 250 F is permissible in a pressurized system if air intake is kept to a minimum. Maximum skin temperatures should not exceed 300 to 325 F, and should be even lower if the hot wall surface area is large in proportion to the quantity of fluid circulated. Nitrogen blanketing often helps minimize oxidation when the system operates at elevated temperatures for extended periods.

Operation below −60 F is not recommended, although slightly lower temperatures are tolerable if the solution temperature is cycled periodically to a higher level.

Install suitable filters because the removal of active sludge and other contaminants is critical. If inhibitors are rapidly and completely adsorbed by such contamination, the fluid is ineffective for corrosion inhibition. Consider such adsorption in filter selections.

Inhibitor Maintenance. An important factor in maintaining a glycol solution in relatively noncorrosive condition for a long period is the inhibitor monitoring and maintenance schedule. This cannot be overemphasized. However, a specific schedule is not always easy to establish, since inhibitor depletion rate depends on the particular conditions of use. Analyses of samples immediately after installation, after two to three months, and after six months, should establish the pattern for the schedule. Visual inspection of the solution and filter residue can indicate active corrosion.

In corrosion protection, properly inhibited and maintained glycol solutions provide advantages over brine solutions in most systems. An indefinite service life, however, should not be expected. Avoid indiscriminate mixing of inhibited formulations. Exercise caution in replacing brine systems with inhibited glycols because brine components may be incompatible with glycol formulations.

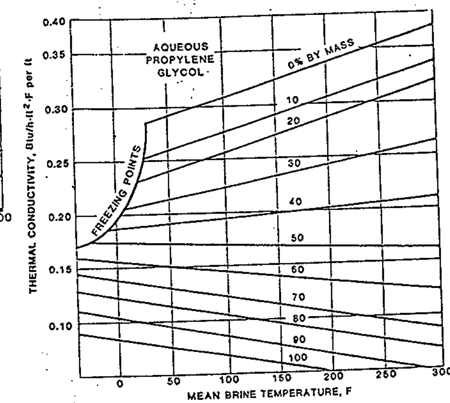


Fig. 20 Thermal Conductivity of Aqueous Solutions of Propylene Glycol

Table 4 Freezing and Boiling Points of Halocarbon Coolants

Refrigerant	Name	Freezing Point, F	Boiling Point, F
12	Dichlorodifluoromethane	−252	−21.6
11	Trichloromonofluoromethane	−168	74.8
30	Methylene Chloride	−142	103.6
1120	Trichloroethylene	−123	188.4

Table 5 Properties of Liquid Methylene Chloride

Temp F	Vapor Pressure psia	Specific Heat Btu/lb·F	Thermal Conductivity Btu/h·ft·F	Density lb/ft³	Viscosity Centipoise
140	25.4	0.296	0.074	78.3	0.32
122	19.9	0.293	0.076	79.4	0.34
104	14.5	0.289	0.079	80.5	0.37
86	10.2	0.286	0.081	81.6	0.40
68	6.82	0.284	0.083	82.7	0.44
50	4.39	0.282	0.085	83.8	0.48
32	2.73	0.280	0.087	84.9	0.53
14	1.64	0.278	0.089	86.0	0.59
−4	0.97	0.277	0.091	87.1	0.66
−22	0.55	0.275	0.093	88.2	0.76
−40	0.32	0.274	0.094	89.3	0.88
−58	0.18	0.273	0.096	90.4	1.05
−76	0.10	0.273	0.098	91.5	1.29
−94	0.06	0.273	0.099	92.6	1.68
−112	0.03	0.272	0.101	93.7	2.50

W320-28-008

High Efficiency Metal Filter Shielding Input and Flushing Frequency

CALCULATION IDENTIFICATION AND INDEX

Date 6-8-94

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. ~~W320-H-008~~ W320-28-008

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item High Efficiency Metal Filter shielding input and flushing frequency

These calculations apply to:

Dwg. No. H-2-818561 Rev. No. 0

Dwg. No. N/A Rev. No. N/A

Other (Study, CDR) W-320-P3 Rev. No. 0

The status of these calculations is:

~~[X]~~ Preliminary Calculations

[X] Final Calculations

[] Check Calculations (On Calculation Dated)

[] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	PH Lengyel / 6-10-94	R Pitt 2/15/96	
Checked by	Carl Rice 6/13/94	[illegible] 2/15/96	
Approved by	PH Lengyel 6-17-94	R Pitt 2/15/96	
Checked Against Approved Vendor Data		Charles T. Li 4/14/98	

INDEX

KEH 0378.00 (06/92) KEF072

Calc. No. W320-~~H~~-008
Revision ~~0~~ 1
Page No. 1 of 2

DESIGN ANALYSIS

Client WHC
Subject High Efficiency Metal Filter shielding input and flushing frequency
Location 241-C/200 East

WO/Job No. ER4319
Date 6-8-94 By PH Langowski
Checked 6/13/94 By B. Race
Revised 2/15/96 By Z Pita Danny Nguyen 2/15/96

1.0 OBJECTIVE

The objective of this calculation is to determine the shielding and flushing requirements for the High Efficiency Metal Filter (HEMF).

2.0 DESIGN INPUTS

2.1 CRITERIA AND SOURCE

DOE General Order 6430.1A
Functional Design Criteria WHC-SD-W320-FDC-001, rev. 2, 1/18/94

2.2 GIVEN DATA

The PSE values are "based on unit liter release source term values for laboratory data (conservative values) of C-106 solids" (ref. 1, p. B-3).

2.3 ASSUMPTIONS

none

2.4 METHODS

Hand calculations and Excel spreadsheet.

2.5 REFERENCES

1. Preliminary Safety Evaluation WHC-SD-WM-PSE-010, rev. 0
2. H-2-818478, rev. 0 -33-006
3. calculation W320-~~E-001~~, rev. 0
4. Functional Design Criteria, WHC-SD-W320-FDC-001, rev. 2

3.0 CALCULATIONS

3.1 Initial Shielding Design Inputs

Based on data gathered from reference 1, a source term was determined for an initial shielding calculation. Table A-3 from ref. 1 (see App A, p. A2), lists a value of 14.0 Rem/Liter equivalent dose to the onsite worker with plume meander. The onsite worker safety class 2 "trigger level" is 5 Rem. Therefore, 5 Rem/14 Rem/Liter = 0.357 Liter is the safety class 2 "trigger level" source term.

Table B-1 from ref. 1 (see App A, p. A3), lists the contribution to the source term from various radionuclides on a per Liter basis. Simple addition of these constituents yields an overall source term of 3.32 Curie/Liter. The values in Table B-1 are assumed to be listed for pure C-106 solids. The FDC states that the aerosol loading consists of 10% of C-106 solids and 90% AY-102 liquids. Therefore, every 3.57 Liter of aerosol entering the ventilation system contains the 0.357 Liter of C-106 solids in question.

Initial source term for shielding analysis is:

(0.357 Liter)(3.32 Curie/Liter) = 1.185 Curie

THIS CALCULATION IS SIMILAR TO REF. 1 EXCEPT FOR THE FOLLOWING: BECAUSE THE "TIME VOLUME" IN REF. 1 DID NOT INCLUDE THE REMOVAL EFFICIENCIES OF THE COMPONENTS UPSTEAM OF THE HEMF, IT WAS NOT USED. THE LIQUIDS IN REF. 1 ARE NOT USED, SINCE WE ARE ONLY INTERESTED IN THE SOLIDS THE HEMF WILL COLLECT.

DESIGN ANALYSIS

Client WHC
Subject High Efficiency Metal Filter shielding input and flushing frequency
Location 241-C/200 East
WO/Job No. ER4319
Date 6-8-94 By PH Langowski
Checked 6/13/94 By B. Bruce
Revised By

3.2 Flushing Frequency Based on Dose
Activity levels by radionuclide as used in ref. 3 along with the mass flow accumulated on the HEMF as shown in ref. 2 are repeated on an Excel spreadsheet in App. A. This spreadsheet then calculates the accumulated dose rate on the HEMF. As modeled, the HEMF will reach the 1.185 Curie level after 72 days of operation (2.4 months). The shielding is designed to mitigate the 1.185 Curie field to 10 mR/h as required by the FDC (ref. 4, p. E-3). Therefore, the HEMF will require flushing every 72 days so as to not exceed the FDC imposed limits. The nonradioactive components at this 1.185 Curie level will total 180 grams.

3.3 Flushing Frequency Based on Pressure

3.3.1 Clean Pressure Drop. Based on information from Pall (see App A), using a HEMF with the following dimensions (A=16", B=38", C=68", vessel volume=36 gallons) yields a 6" w.g. pressure drop at 500 acfm and a 3" w.g. pressure drop at 250 acfm. Pressure drop is known to be linear in clean filters (see Pall Brief in App A).

250 acfm/3" w.g. = 83 acfm/1" w.g.
180 acfm = 2.16" w.g.
230 acfm = 2.76" w.g.
360 acfm = 4.32" w.g.

3.3.2 Dirty Pressure Drop. Based on information from Pall (see App A) a prototype was run at 87 acfm and 7" w.g. clean and then loaded with 19.5 grams of dust and run to a final pressure of 10.5" w.g.

(360/87)(19.5 g) = 80.7 g on a unit scaled for 360 acfm at 10.5" w.g. instead of 87 acfm.

(7/4.5)(80.7 g) = 125.5 g on a unit scaled for a 4.5" clean pressure drop instead of 7" w.g. clean pressure drop.

(125.5/200)(4.5" w.g.) = 2.82" w.g. clean pressure drop if sized for 200 grams loading at 10.5" w.g.

Based on this information, the limiting sizing factor for a 360 acfm unit with 4.5" w.g. maximum clean pressure drop requirement and 10.5" w.g. dirty pressure drop with 200 grams loading will be the dust loading capability. Therefore, the HEMF will be sized by the manufacturer to meet the more stringent dust loading capability requirement.

4.0 FINDINGS & CONCLUSIONS

The HEMF will require flushing based on dose every 72 days. The HEMF pressure drop at this dose due to the nonradioactive components will be the limiting design constraint around which the HEMF specification (W-320-P3) is written.

APPENDIX A

P. A2

ckd B. Rice 6/23/94

Form 5007 (Rev. 4/93)

Raytheon Engineers & Constructors — A Consolidation of Badger and UE&C	GENERAL COMPUTATION SHEET	CALCULATION SET NO. 7362-H-005			REV.	COMP. BY	CHK'D BY
		PRELIM.	FINAL X	VOID	0	NTV DATE 1-11-94	DGH DATE 1-11-94
PROJECT 241-C-106 Waste Retrieval		SHEET 3 OF 38				DATE	DATE
SUBJECT Dose Consequences and EHSC Calculations for Determining Safety Classification		J.O. 7362.007					

Table A-2. Unit Liter Release Dose Calculation for Onsite Individual Without Plume Meander

Onsite	EDE, rem/liter (solids)	EDE, rem/liter (supernatant)
Inhalation	4.37E+1	3.42E-2

Table A-3. Unit Liter Release Dose Calculation for Onsite Individual With Plume Meander

Onsite	EDE, rem/liter (solids)	EDE, rem/liter (supernatant)
Inhalation	1.40E+1	1.10E-2

2. Per Section 4.2 of Onsite/Offsite Worker Definition (issued as draft for comment by Westinghouse Savannah River Company), a <u>two hour</u> evaluation period is recommended for all offsite calculations to the general public.

3. Per Items 9 and 10 of Section 4.2.1, Chapter 4.0 of *Nonreactor Facility Safety Analysis Manual*, WHC-CM-4-46 (Ref. 7), only inhalation and submersion pathways are considered for determining the offsite individual EDE values, as well as for onsite individual EDE values. Per *Safety Classification of Systems, Components, and Structures*, WHC-CM-5.46 (Ref. 8), only EDE values are needed to determine the safety classification of systems, equipment and components.

4. Design data for process systems that are considered for the accident analyses are taken from WHC-SD-W320-FDC-001, Rev. 2, Ref. 12.

5. It is assumed that the solids/sludge within the Tank AY-102 are not disturbed during sluicing from C-106 to AY-102.

6. A ground level point source release is assumed for all the accident scenarios.

7. The radioactive inventories included in Appendix B of Ref. 13 for C-106 and AY-102 (with AY-101 supernatant, see Criteria 1 and 14) are best available representative laboratory samples as stated in Appendix C of Ref. 13.

P. A3

chkd [signature] 6/13/44

Form 5007 (Rev. 4/93)

Raytheon Engineers & Constructors A Consolidation of Badger and UE&C	GENERAL COMPUTATION SHEET	CALCULATION SET NO. 7362-H-005			REV.	COMP. BY	CHK'D BY
		PRELIM.	FINAL X	VOID	0	[signature] DATE 1-11-94	[signature] DATE 1-11-94
PROJECT 241-C-106 Waste Retrieval		SHEET 32 OF 38				DATE	DATE
SUBJECT Dose Consequences and EHSC Calculations for Determining Safety Classification		J.O. 7362.007					

Table B-1 Radionuclide Source Term (Ref. 13)

ISOTOPE	C-106, SLUDGE (See Notes below)		AY-102, SUPERNATANT(See Notes Below)	
	Bq/L	CURIES/L	Bq/L	CURIES/L
Am-241	5.56E+7	1.50E-3		
C-14	1.23E+4	3.32E-7		
Co-60	4.50E+7	1.22E-3		
Cs-137	1.75E+10	4.73E-1	4.03E+9	1.09E-1
I-129	4.29E+3	1.16E-7		
Pu-239/240	1.42E+8	3.84E-3		
Sr-90	1.05E+11	2.84E+0		
Tc-99	1.16E+7	3.14E-4		
U-238	1.53E+4	4.14E-7		

3.32

Notes

1. Values are taken from Ref. 13. See Table C-7 for AY-102 (with AY-101 supernatant) and Table C-9 for C-106 solids
2. Per Criterion 14 on Sh. 5, C-106 will have supernatant from AY-101 via AY-102.
3. Curies/ L = (Bq/ L) / (3.7E + 10)

P. A4

Pall Advanced Separations Systems™

chk C. Rice 6/13/94

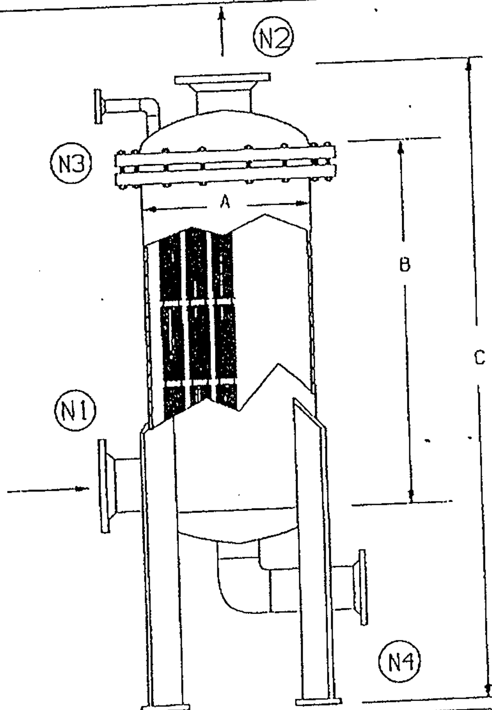
HEMF Sizing Matrix

Flow Rate (ACFM)

Dec-93

Pressure Drop (In. W.C.)	100 Dimensions	100 Nozzles	250 Dimensions	250 Nozzles	500 Dimensions	500 Nozzles
2	A: 8" B: 52" C: 78" Vessel Volume: 12	N1: 2" N2: 2" N3: 1" N4: 2"	A: 16" B: 38" C: 68" Vessel Volume: 35	N1: 3" N2: 3" N3: 1" N4: 2"	A: 18" B: 62" C: 93" Vessel Volume: 72	N1: 6" N2: 6" N3: 1" N4: 3"
3	A: 8" B: 36" C: 62" Vessel Volume: 8.5	N1: 2" N2: 2" N3: 1" N4: 2"	A: 16" B: 38" C: 68" Vessel Volume: 36	N1: 3" N2: 3" N3: 1" N4: 2"	A: 20" B: 47" C: 78 Vessel Volume: 67	N1: 6" N2: 6" N3: 1" N4: 3"
4	A: 8" B: 36" C: 62" Vessel Volume: 8.5	N1: 2" N2: 2" N3: 1" N4: 2"	A: 14" B: 37" C: 67" Vessel Volume: 26	N1: 3" N2: 3" N3: 1" N4: 2"	A: 18" B: 46" C: 77" Vessel Volume: 54	N1: 6" N2: 6" N3: 1" N4: 3"
5	A: 8" B: 36" C: 62" Vessel Volume: 8.5	N1: 2" N2: 2" N3: 1" N4: 2"	A: 14" B: 37" C: 67" Vessel Volume: 26	N1: 3" N2: 3" N3: 1" N4: 2"	A: 18" B: 46" C: 77" Vessel Volume: 55	N1: 6" N2: 6" N3: 1" N4: 3"
6	A: 8" B: 36" C: 62" Vessel Volume: 8.5	N1: 2" N2: 2" N3: 1" N4: 2"	A: 8" B: 52" C: 78" Vessel Volume: 12	N1: 3" N2: 3" N3: 1" N4: 2"	A: 16" B: 38" C: 68" Vessel Volume: 36	N1: 6" N2: 6" N3: 1" N4: 3"
7	A: 8" B: 20" C: 46" Vessel Volume: 5	N1: 2" N2: 2" N3: 1" N4: 2"	A: 8" B: 52" C: 78" Vessel Volume: 12	N1: 3" N2: 3" N3: 1" N4: 2"	A: 16" B: 38" C: 68" Vessel Volume: 36	N1: 6" N2: 6" N3: 1" N4: 3"

Vessel Volumes in Gallons
Note: Dimensions Refer To Drawing No. SKA-PASS-HEMF-012



Pall High Efficiency Metal Filter

REMOVAL EFFICIENCY: 99.97% 0.3 MICRONS

MATERIALS OF CONSTRUCTION:

HOUSING: 304 SS
ELEMENTS: 316L SS

NOZZLES:

N1: INLET
N2: OUTLET
N3 CLEANING INLET
N4: CLEANING DRAIN

REVISION	DATE

UNLESS OTHERWISE SPECIFIED

SURFACE FINISH ✓

DIMENSIONS ARE IN MM ☐ INCHES ☐

APPLICABLE SPECS

TOL.		
X.	±	±
.X	±	±
.XX	±	±
.XXX	±	±
FRACTIONS ANGLES	±	±

	NAME	DATE
DRAWN BY		
PROJ. ENG.		
CHECKER		
ENGR. MGR.		
RELEASED		

THIRD ANGLE PROJECTION

COMPANY CONFIDENTIAL

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SCALE: NONE

PALL
ADVANCED SEPARATION SYSTEMS

NAME: ASSY, HEMF

DWG NO. SKA-PASS HEMF-012

REV.

ckd G. Que 6/13/9?

ckd. P. Rice P.A6 6/13/94

BACKGROUND

Test of dust holding capacity and efficiency of a Pall metal HEPA grade filter per ASHRAE Standard 52-76 is summarized in a recent report, (see Technical Brief HEMF-IV which follows). Testing was carried out by Air Filter Testing Laboratories, Inc. (AFTL).

The tested filter was subsequently cleaned by backwash with water. It has been retested per ASHRAE Standard 52-76, and the results are reported herein.

FILTER REGENERATION

The contaminant laden filter was shipped from AFTL to Pall's facilities in Cortland, New York, for backwash cleaning. The outlet end of the filter was mounted to a tube sheet connected via 2" pipe to a pressure vessel. An in-line ball valve at the filter outlet was used to control (reverse) flow of water. The tube sheet was so positioned to suspend the filter into an open 55 gallon drum to facilitate visual inspection of the filter during cleaning procedures. Differential pressure across the filter in reverse flow was thus against atmosphere, and it was measured using a pressure gauge installed close to the tube sheet.

Backwash cleaning consisted of the following sequence.

1. Static soak 15 minutes in water.
2. Reverse flush with water at 2 psid for 50 seconds. Some loosening of contaminant was noted visually. An estimated 10% of the contaminant was dislodged.
3. Reverse flush with water at 8 psid for 10 seconds. Substantial majority of the contaminant remaining evident to visual inspection was dislodged.
4. Reverse flush with water at 7 psid for 15 seconds. Little further cleaning apparent to visual inspection.

RESULTS

After cleaning the filter as indicated above, Pall shipped it back to AFTL, where pressure drop vs. flow rate was measured prior to re-challenge in accordance with ASHRAE 52-76. Pressure drop as function of flow rate is given in Figure 1. At rated flow, pressure drop was 1.38" H_2O. This compares with 1.3" H_2O prior to initial challenge.

Re-challenge under conditions identical with those of cycle 1 showed an ingression of 371gm of ASHRAE test dust required post-backwash to produce terminal pressure differential of 10" H_2O, as shown in Figure 2.

This compares with 374gm in cycle 1. As in cycle 1, effluent quality was superior to the cleanest measurable per ASHRAE Standard 52-76. The shape of Figure 2 is in close analogy with the corresponding curve generated during cycle 1, indicating comparable dynamics of contaminant accumulation.

CONCLUSION

Backflush with water provided >99% regeneration of dust capacity, and near complete restoration of clean pressure drop. Excellent effluent quality was maintained, without measureable change resulting from backwash.

Figure 1. Clean Filter Device (After Cleaning)

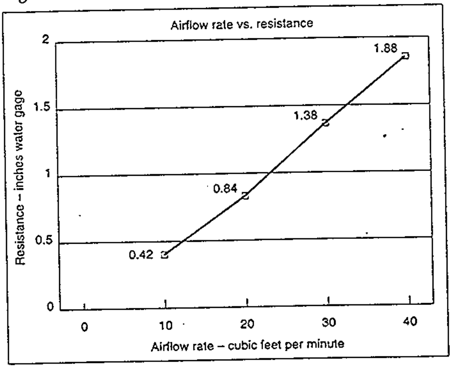
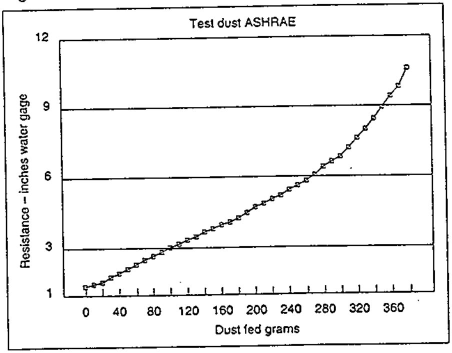


Figure 2. Dust Fed vs. Resistance



ckd G. Rice 6/13/94

ASHRAE TEST OF PALL METAL HEPA FILTERS

A test of dust holding capacity and filter efficiency of a Pall metal HEPA grade filter was performed per ASHRAE Standard 52-76, by the Air Filter Testing Laboratories, Inc. (AFTL), Crestwood, KY.

The following graphical data were provided directly to Pall's Scientific and Laboratory Services Department by AFTL. Testing was performed at rated flow, producing an initial pressure differential of 1.3" H_2O.

Pressure drop as a function of flow rate is given in Figure 3.

Figure 3. Clean Filter Device

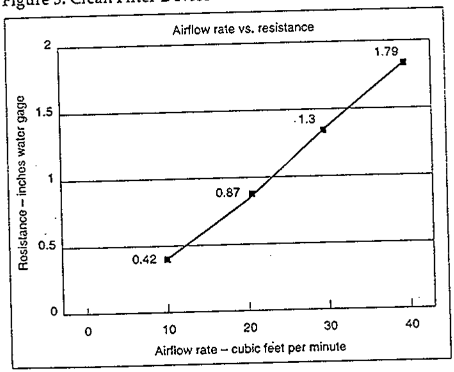
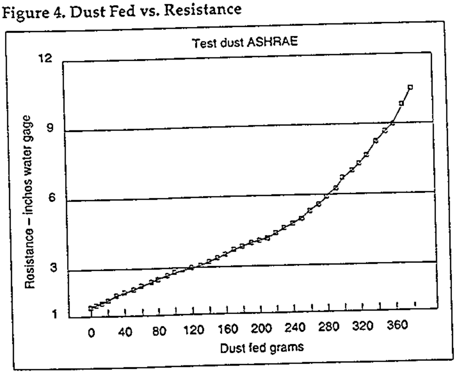


Figure 4. Dust Fed vs. Resistance



Pressure drop as a function of dust loading is given in Figure 4. Increase in differential is linear to approximately 4.3" H_2O, after which an increase in rate is evident. This is consistent with cake formation, a well characterized plugging mechanism for glass fiber HEPA filters. In the present test, pressure drop increase accelerates apparently starting from the point at which cake within the pleats is deep enough to reduce effective surface area, increasing face velocity. This interpretation is also consistent with post-test visual inspection.

Per AFTL's Mr. David J. Murphy, 20 gm of ASHRAE dust found at the housing bottom at termination of air flow may have resulted either from settling during challenge; or have fallen off the element with flow termination.

Also per Mr. Murphy, effluent quality was superior to the cleanest measurable per ASHRAE Standard 52-76. Arrestance was recorded at 100%.

ckd P. Rice 6/13/94

BACKGROUND

On December 2-3, 1992, a group comprised of Hanford, Kaiser Engineering, Lawrence Livermore, and Pall personnel met at facilities of Pall Land and Marine Division (PLM), New Port Richey, Florida, to witness efficiency and backwash test of Pall's stainless steel Melter Off-Gas filter assembly for Battelle. Reported in PASS Technical Report 7, the assembly was shown before and after vigorous backwash to provide filter efficiency equivalent to two stages of HEPA filter in series[1].

Also discussed were remaining test requirements for Pall's all stainless steel Zone 1 filter, to provide single stage HEPA equivalent efficiency. Revised test protocols for a "Fine Particle Dust Challenge," and "Moisture Challenge Test" were agreed to and circulated to all meeting participants. These are attached as Appendix 1. Pall agreed to undertake completion of these tests and to report by January 8, 1993.

Purpose of the Fine Particle test is to demonstrate dust holding capacity and filter regenerability without loss of integrity, following challenge using smaller diameter particles (more penetrating size distribution) than those found in ASHRAE Test Dust[2]. It should be noted that ASHRAE Test Dust is formulated to simulate ambient air-borne dust as encountered by filters in HVAC applications.

Present Tests of Pall metal filter technology to ASHRAE Standard 52.1-1992, performed by the Air Filter Test Laboratories, Inc., have been summarized[3]. The siliceous dust component of the ASHRAE contaminant is comprised of PTI SAE Fine Test Dust[4].

Pall's Scientific and Laboratory Services Department (SLS) has carried out the Fine Particle Dust Challenge, and the results are herein reported. The Moisture Challenge Test has also been completed by SLS, and the results are reported in reference[5].

TEST METHODS

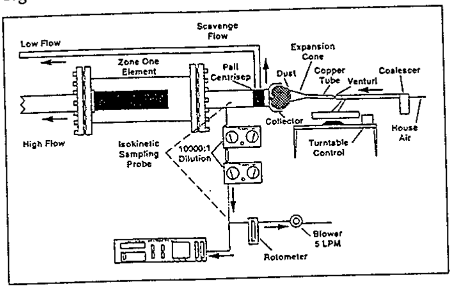
Test protocol is given in Appendix I, Section IIA, attached. Tests employed a Pall Zone 1 filter module, 6" OD by 15.75" in length. Note: The same filter was then tested by Moisture Challenge (Appendix I, Section IIB), without further cleaning or other treatment[5].

All DOP tests were carried out at 87 CFM, using methods previously reported[6].

1. Fine Dust Challenge.

   The Zone 1 module was housed downstream of a Pall Centrisep® unit designed to operate at 87 CFM plus 10% scavenge flow, in accordance with Appendix I. The test system is shown schematically in Figure 1.

Figure 1. Test Stand Configuration for Fine Dust Loading.



   Challenge was carried out by educting PTI SAE Fine Test Dust at approximately 260 gm per hour to the upstream Centrisep unit via a venturi at sonic throat conditions, and a difuser cone. Effluent of the Centrisep unit flowed directly to the Zone 1 filter. Pressure drop across the Zone 1 filter was monitored using a calibrated Magnehelic gauge.

   Photographic views of the test stand are given as Photos A and B.

2. Contaminant Particle Mass/Size Distribution.

   Mass distribution was monitored by isokinetic sampling in conjunction with a calibrated Particle Measuring Systems LAS-X laser spectrophotometer to measure particle counts influent to the Zone 1 filter (Figure 1).

   In separate tests using the Figure 1 configuration but without the Zone 1 filter, the LAS-X counter was found to demonstrate a sharp distinction between PTI SAE Fine Test Dust and Centrisep effluent of this contaminant.

   The LAS-X counter resolves particle diameter into 16 channels or "bins", to as small as 0.09 µm; the largest bin as >3.0 µm. Count in a given bin is reproducible to ±10%[1]. Two TSI Model 3302 diluters were used in series at a total 10,000 fold dilution, to prevent count sensor saturation.

Ckd S. Rue 6/13/94

3. PTI SAE Fine Test Dust removal efficiency of the Centrisep unit was measured at 88.1% by weight (11.9% transmission).

4. Particle counts with and without the Centrisep unit in place at equal dust aspiration rate are given in Table 2. Background counts prior to dust ingression were of the order of 10% in channels 1 - 3, and at ≤ 2% in higher channels.

Average counts per minute are virtually identical with and without Centrisep processing in the .09 µm – 2 µm ranges (bins 1 to 13), demonstrating 0% particle rejection. Between 2.5 and 3.0 µm, 35% rejection of counts is demonstrated; >3 µm the rejection rate is at 65%. These data indicate measureable efficiency for the Centrisep unit down into the 2.0 – 2.5 µm diameter range.

The count and gravimetric efficiency data are consistent. Mass distribution is a cubic function of particle radius, and larger particles strongly predominate mass even at lower count.

By Coulter counter test, PTI reports the volume (i.e. mass) of particles greater than 10 µm in diameter in PTI SAE Fine Test Dust as 43%. Reported fraction greater than 20 µm is 27%. This determination is made in liquid, under conditions to promote disagglomeration potentially more rigorous than the standard method in air (employed here) of transport through a converging/diverging nozzle under sonic conditions.

Thus, count data (Table 2) together with the substantial volume significance of particles >10 µm in untreated dust, confirm Centrisep effluent particle mass distribution to be highly skewed toward smaller diameters. Centrisep processed dust is expected to be substantially more penetrating than untreated PTI SAE Fine Test Dust.

5. Fine Particle Dust load on the Zone 1 filter to 10" H_2O differential was 19.5 gm. This is obtained by applying the gravimetric reduction factor measured for the upstream Centrisep unit to the total weight of dust aspirated.

Pressure drop vs. Fine Dust loading of the Zone 1 filter module is given as Figure 2. Linear trend of

Photo C. Representative Zone 1 module appearance at outset of Protocol IIA, Appendix I.

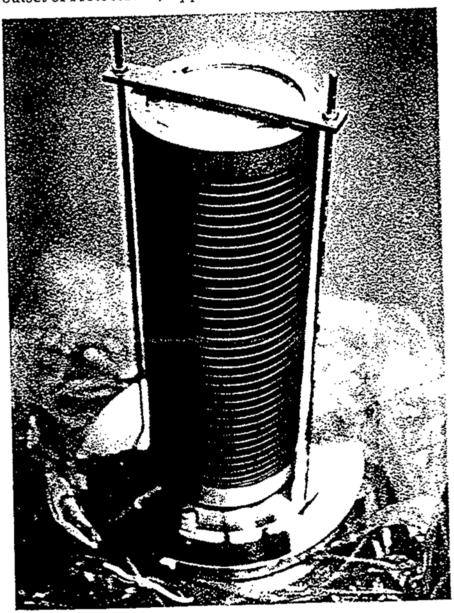


Photo D. Photographic record of appearance of tested element at conclusion of Protocol IIA, Appendix I.

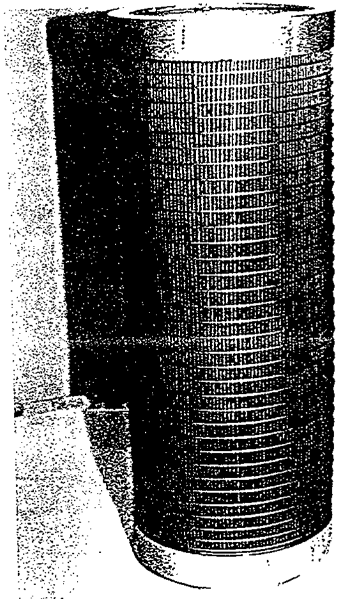
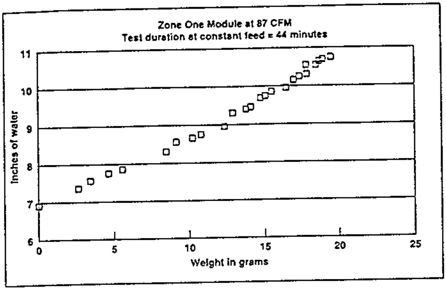


Figure 2. ΔP vs. Weight Loaded.



pressure drop increase at constant flow rate indicates a cake building mechanism of contaminant accumulation. Visual inspection of the element after dust loading showed a uniform color change consistent with that of the ingressed dust. However, no cake could be detected visually or at 10X magnification.

6. Particle counts taken during challenge are given in Table 3. Background counts prior to dust ingression were at a level comparable with that reported in section 4, above.

   Although total feed rate varied somewhat, % size (and therefore % mass) distribution (Table 3) was reproducible with that of Centrisep effluent in Table 2.

7. Maximum reverse pressure drop during backwashes is given in Table 1.

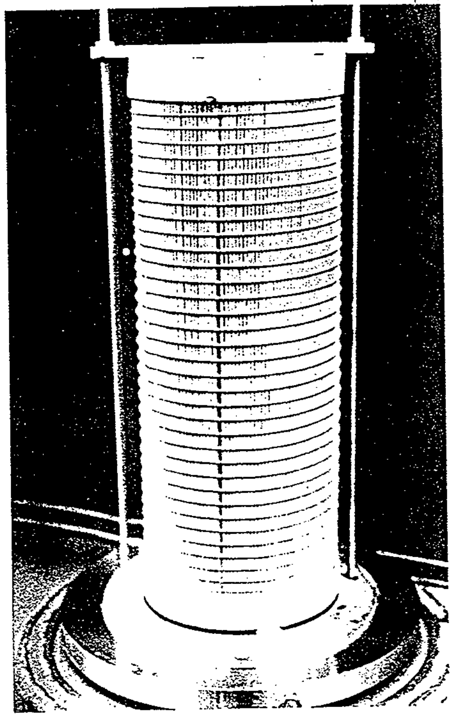


Photo E. Following dust loading to 10" H_2O over clean pressure drop per test Protocol IIA, Appendix 1, the photographic record of appearance of tested element was prepared.

Table 2. Particle size distribution PTI SAE fine test dust with and without stripping by a Pall Centricep.

With Centricep Channel Numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Channel range in µm	0.09-0.11	0.11-0.15	0.15-0.20	0.20-0.25	0.25-0.30	0.30-0.40	0.40-0.50	0.50-0.65	0.65-0.80	0.80-1.00	1.00-1.25	1.25-1.50	1.50-2.00	2.00-2.50	2.50-3.00	>3.0
Average count	73.17	190.3	372.3	384.7	323.2	526.1	390.3	356.8	209.5	156.8	112.2	68.83	74.5	34.58	20	34.58
% Total count	2.20	5.72	11.19	11.56	9.71	15.81	11.73	10.72	6.30	4.71	3.37	2.07	2.24	1.04	0.60	1.04
Without Centricep Channel Numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Channel range in µm	0.09-0.11	0.11-0.15	0.15-0.20	0.20-0.25	0.25-0.30	0.30-0.40	0.40-0.50	0.50-0.66	0.65-0.80	0.80-1.00	1.00-1.25	1.25-1.50	1.50-2.00	2.00-2.50	2.50-3.00	>3.0
Average count	76	200	393	385	319	511	369	347	194	147	113	72	87	48	31	99
% Total count	2.23	5.89	11.60	11.37	9.42	15.07	10.89	10.24	5.71	4.33	3.32	2.12	2.57	1.41	0.92	2.91

Note: With Centricep = An average of 12 one minute counts.
Without Centricep = An average of 11 one minute counts.

W320-H-008

Project W-320 Mass Balance Analysis (see ref. 2 and 3 for stream numbers,mass flows, and DF assumptions)

Stream 15 HEMF/seal pot

Radionuclide	activity (Ci/g)	flow (pCi/min)	flow (Ci/min)	flow (mg/min)	total Curie	total flow (mg)
C-14	4.46E+00	2.00E-01	2.00E-13	4.48E-11	2.07E-08	4.64E-06
Co-60	1.13E+03	2.00E+03	2.00E-09	1.77E-09	2.07E-04	1.83E-04
Sr-90	1.37E+02	4.20E+06	4.20E-06	3.07E-05	4.35E-01	3.17E+00
Y-90	5.45E+05	4.20E+06	4.20E-06	7.71E-09	4.35E-01	7.98E-04
Tc-99	1.70E-02	3.40E+02	3.40E-10	2.00E-05	3.52E-05	2.07E+00
Sb-125	1.04E+03	2.20E+04	2.20E-08	2.12E-08	2.28E-03	2.19E-03
I-129	1.73E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs-137	8.66E+01	1.30E+06	1.30E-06	1.50E-05	1.35E-01	1.55E+00
mBa-137	5.38E+08	1.60E+06	1.60E-06	2.97E-12	1.66E-01	3.08E-07
Ce-144	3.19E+03	9.30E+04	9.30E-08	2.92E-08	9.63E-03	3.02E-03
Eu-154	2.73E+02	2.30E+04	2.30E-08	8.42E-08	2.38E-03	8.72E-03
Pu-239	6.20E-02	4.00E+03	4.00E-09	6.45E-05	4.14E-04	6.68E+00
Pu-240	2.28E-01	6.30E+01	6.30E-11	2.76E-07	6.52E-06	2.86E-02
Am-241	3.43E+00	3.60E+03	3.60E-09	1.05E-06	3.73E-04	1.09E-01
				1.14E-05	1.18E+00	14 milligrams

total = 1.185 Curie safety class 2 "trigger level"

Stream 16 HEPA1
HEMF/DF=3000
0.000395 Curie

Radiation Shielding Study had 50 mRem/hr contact on housing after 0.0682 Curie collected. HEPA1 will be changed out after 173 flushes of the HEMF. HEPA1 will not require changing out until the end of the project.

Assume upstream components function properly (DF=1.25*3*20=75)

time = 103,511 minutes
1,725 hours
72 days
2.4 months

Flush every 2 and one half months and on final decon before removal.

Assuming no removal upstream of the HEMF

1,380 minutes
23 hours
1 days

Administrative radiation measurements every day to verify permanent rad monitor .
Administrative reading can be made on exterior of shielding. If less than 10 mR/h then criteria is met.

Ckd G. Bua 6/13/94

Stream 15 HEMF/seal pot

Contaminant	flow (mg/min)	total milligram
NH3	0.00E+00	0.00E+00
Al	9.00E-02	9.32E+03
Sb	5.80E-05	6.00E+00
As	2.20E-05	2.28E+00
Ba	4.30E-03	4.45E+02
Bi	4.70E-04	4.87E+01
B	3.00E-04	3.11E+01
Cd	3.00E-04	3.11E+01
Ca	1.60E-02	1.66E+03
Cr	2.40E-03	2.48E+02
Co	1.10E-05	1.14E+00
Cu	2.80E-04	2.90E+01
Fe	6.10E-02	6.31E+03
La	7.60E-03	7.87E+02
Pb	3.80E-03	3.93E+02
Mg	4.20E-03	4.35E+02
Mn	8.90E-03	9.21E+02
Hg	2.80E-04	2.90E+01
Ni	1.60E-03	1.66E+02
Pd	1.30E-04	1.35E+01
P	1.10E-02	1.14E+03
K	3.90E-03	4.04E+02
Se	8.70E-06	9.01E-01
Si	4.00E-02	4.14E+03
Ag	9.60E-04	9.94E+01
Na	5.10E-01	5.28E+04
Sr	1.30E-04	1.35E+01
U	7.50E-04	7.76E+01
Zn	2.50E-04	2.59E+01
Zr	2.20E-03	2.28E+02
CN	5.20E-05	5.38E+00
F	4.70E-03	4.87E+02
OH	5.90E-02	6.11E+03
PO3	1.20E-01	1.24E+04
SO3	6.50E-02	6.73E+03
NO3	4.10E-01	4.24E+04
NO4	1.10E-01	1.14E+04
ClO3	3.80E-03	3.93E+02
CO3	1.50E-01	1.55E+04
EDTA	2.90E-03	3.00E+02
HEDTA	2.30E-03	2.38E+02
O,F,C	4.40E-02	4.55E+03
C-14	4.48E-11	4.64E-06
Co-60	1.77E-09	1.83E-04
Sr-90	3.07E-05	3.17E+00
Y-90	7.71E-09	7.98E-04
Tc-99	2.00E-05	2.07E+00
Sb-125	2.12E-08	2.19E-03
I-129	0.00E+00	0.00E+00

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Project W-320 Mass Balance Analysis (ref. 2 3 for stream numbers, flows, DF inputs, etc.)

Cs-137	1.50E-05	1.55E+00
mBa-137	2.97E-12	3.08E-07
Ce-144	2.92E-08	3.02E-03
Eu-154	8.42E-08	8.72E-03
Pu-239	6.45E-05	6.68E+00
Pu-240	2.76E-07	2.86E-02
Am-241	1.05E-06	1.09E-01

total = 1.743 180393 milligrams
180 grams

4.96 pressure drop from loading " w.g.
9.46 total pressure drop " w.g.

Assume upstream components function properly

time = 103,511 minutes
1,725 hours
72 days
2.4 months

180393/103511 = 1.74 mg/min

Flush every 2 and one half months and on final decon before removal.

W320-28-011

Exhaust Skid Stack Sizing and Fan Sizing

CALCULATION IDENTIFICATION AND INDEX

Date 3-28-95

This sheet shows the status and description of the attached Design Analysis sheets.

Discipline 28/HVAC WO/Job No. ER4319 Calculation No. ~~W320-H-011~~ 28 W320-28-011

Project No. & Name W-320 Tank 241-C-106 Waste Retrieval

Calculation Item Exhaust Skid Stack Sizing and Fan Sizing

These calculations apply to:

Dwg. No. N/A Rev. No. N/A

Dwg. No. N/A Rev. No. N/A

Other (Study, CDR) Procurement Specifications:
W-320-P1 Exhaust Skid Rev. No. preliminary

The status of these calculations is:

- [] Preliminary Calculations
- [X] Final Calculations
- [] Check Calculations (On Calculation Dated)
- [] Void Calculation (Reason Voided)

Incorporated in Final Drawings? [] Yes [X] No

This calculation verified by independent "check" calculations? [] Yes [X] No

Original and Revised Calculation Approvals:

	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date
Originator	PH Langouk 3-28-95	Danny Nguyen 2/13/96	
Checked by	R Png 3/28/95	R. Pmt 2/13/96	
Approved by	PH Langouk 3-28-95	R Pmt 2/13/96	
Checked Against Approved Vendor Data		Charles T. Li 4/14/98	

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KEH 0378.00 (06/92) KEF072

DESIGN ANALYSIS

Client WHC
Subject Exhaust Skid Stack Sizing & Fan Sizing
Location 241-C/200 East

WO/Job No. ER4319
Date 3-28-95 By PH Langowski
Checked 3/28/95 By [signature]
Revised By

1.0 OBJECTIVE

The objective of this calculation is to determine the stack sizing required for input to the Exhaust Skid procurement specification. The calculation shall also size the pressure drop on the Exhaust Skid for fan sizing input to the Exhaust Skid procurement specification and estimate heating coil and exhaust fan power requirements.

2.0 DESIGN INPUTS

2.1 CRITERIA AND SOURCE

DOE General Order 6430.1A
Functional Design Criteria WHC-SD-W320-FDC-001, rev. 2, 1/18/94

2.2 GIVEN DATA

1. Upstream pressure drop information from W320-H-018, rev. 1

2.3 ASSUMPTIONS

no major assumptions, see text for minor assumptions.

2.4 METHODS

Hand calculations.

2.5 REFERENCES

1. W320-P1 rev. 0 (IFA draft date 3-29-95) Procurement Specification, Exhaust Skid Ventilation Air Cleanup Trains
2. W320-H-018 rev. 1 Calculation, Pressure Loss Upstream of the Exhaust Skid
3. 1993 ASHRAE Fundamentals
4. SDC 5.1 rev. 7
5. W320-P41 rev. 0 (IFA draft date March 1995) Procurement Specification, Isokinetic Air Sampler Stack Monitor
6. 1985 ASHRAE Fundamentals

3.0 CALCULATIONS

3.1 Stack Sizing

Stack sizing was originally performed by offsite author based on 4" diameter stack, modeling the Exhaust Skid as a 9' tall building. The stack size was changed to a 6" diameter stack to facilitate support of the relocated stack monitor instruments directly on the stack (see ref. 5, App. A). The 6" stack size will be examined with the same logic per ASHRAE Fundamentals (ref. 3) Chapter 14 information except a 6' tall building air intake assumption shall be used instead of 9' tall. The nearest building air intake is not close enough to warrant attention. The 6" stack has a 7" diameter stack head (ref. 5).

The larger diameter stack size drops us below the recommended ASHRAE limit of 2000 fpm since 180 cfm/[(pi)$(7/12)^2$/4]=674 fpm, and at 360 cfm yields 1347 fpm. With a

DESIGN ANALYSIS

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Revised By

7 mph wind speed (ref. 4) which equals (7)(5280)/60=616 fpm, we find that V_e is not 1.5 times as high as the wind speed U_H. Using equation 24, it is seen that the additional downwash height h_d, is equal to (2.0)(7/12)(1.5)(1)674/616=1.91 ft.

Using Equation 25, the plume rise, h_r, is calculated as (3.0)(674/616)(7/12)=1.91 ft. Equation 26 shows that h_r and h_d cancel each other out. The capped height of the stack above the fictional Exhaust Skid building, h_{sc}, is therefore determined using Equations 1 and 5 with the 1:5 slope. From Equation 1, $R=6.5^{0.67}26^{0.33}$ = 10.3 ft. From Equation 5, L_r=(1)(10.3) = 10.3 ft. For the 1:5 sloping plume to not enter the recirculation region of Figure 3, h_{sc} must be greater than (26.5+10.3)/5 = 7.4 ft. The total stack height must therefore be greater than the sum of the height of the building (6 ft.) and h_{sc}. Therefore, the total stack height must be greater than 6+7.4 = 13.4 ft. This minimum stack height will yield a suitable design. Ref. 5 shows a total stack and head height of 20'.

3.2 Exhaust fan sizing

From ref 2 calculation, the upstream pressure drops are as follows:

condition	minimum exhaust 180 scfm	maximum exhaust 360 scfm
clean & dry components	18.6" w.g.	24.4" w.g.
dirty & wet components	33.9" w.g.	34.5" w.g.

The pressure losses on the Exhaust Skid are estimated at 180 scfm as follows:

component	reference	loss in. w.g.
shutoff valve, 6"	ref. 6, 7-5, C_o=0.50 (180)/[(pi)(6/12)^2/4]=917 fpm, V_p=0.052	(0.50)(0.052) =0.026
electric heating coil	ref. 2, similar to recirculation heating coil	0.060
transition to square	use C_o=0.50	(0.50)(0.052) =0.026
inlet test section, 24"x24"	assumed negligible	0.000
HEPA filter, 24"x24"	(180/1000)(1)=0.18, assumes 1000 cfm size filter	0.18
combination test section, 24"x24"	assumed negligible	0.000

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Revised By

HEPA filter, 24"x24"	(180/1000)(1)=0.18, assumes 1000 cfm size filter	0.18
outlet test section, 24"x24"	assumed negligible	0.000
transition to round	assumed negligible	0.000
shutoff valve, 6"	ref. 6, 7-5, C_o=0.50 (180)/[(pi)(6/12)^2/4]=917 fpm, V_p=0.052	(0.50)(0.052) =0.026
stack & duct misc., 6"	20'(0.3" w.g./100')	0.060
stack head, 7"	ref. 3, SD2-6, C_o=1.00	0.052
		total 0.610

18.6 + 0.6 = 19.2" w.g. at 180 scfm (clean & dry). Round down to 19" for use in ref. 1.

The pressure losses on the Exhaust Skid are estimated at 360 scfm as follows:

component	reference	loss in. w.g.
shutoff valve, 6"	ref. 6, 7-5, C_o=0.50 (360)/[(pi)(6/12)^2/4]=1833 fpm, V_p=0.210	(0.50)(0.210) =0.105
electric heating coil	ref. 2, similar to recirculation heating coil, use 0.100 as heating coil sized for variable flow will probably have a higher pressure drop than normal at the high end.	0.100
transition to square	use C_o=0.50	(0.50)(0.210) =0.105
inlet test section, 24"x24"	assumed negligible	0.050
HEPA filter, 24"x24"	filter loaded to 4" w.g.	4.000
combination test section, 24"x24"	assumed negligible	0.050
HEPA filter, 24"x24"	filter loaded to 2" w.g. (note that the project documentation shows that the maximum allowable across both filters is 5.9" w.g.)	2.000
outlet test section, 24"x24"	assumed negligible	0.050

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Revised 2/13/96 By Danny Sayan R Pmi 2/13/96

transition to round	assumed negligible	0.000
shutoff valve, 6"	ref. 6, 7-5, C_o=0.50 (360)/[(pi)(6/12)^2/4]=1833 fpm, V_p=0.210	(0.50)(0.210) =0.105
stack & duct misc., 6"	20'(1.0" w.g./100')	0.200
stack head, 7"	ref. 3, SD2-6, C_o=1.00	0.210
		total 6.975

34.5 + 7.0 = 41.5" w.g. at 360 scfm (dirty, wet). Round up to 42" for use in ref. 1.

The brakehorspower required is estimated based on vendor data (App. A) of fan operating at 360 acfm at 40.8" w.g. at 140F & density=0.0644 (309 scfm at density=0.075). The 5.95 bhp with a 90% efficiency motor is equivalent to a 6.61 hp motor requirement. A 7.5 hp nameplate motor should be sufficient.

3.3 Exhaust heating coil sizing, 60% relative humidity

The normal maximum heating coil size would be required for the case of 360 scfm entering air at 40F saturated and the design exiting condition of 60% relative humidity at 53F (see psychrometric chart, App. A). The enthalpy change between these two states is 18.3 - 15.3 Btu/lb_{da} = 3.0 Btu/lb_{da}. At the entering density of 12.696 ft^3/lb_{da}, this yields (360 scfm)(3.0 Btu/lb_{da})/(12.696 ft^3/lb_{da}) = 85.07 Btu/min (5104 Btu/h, or 1.5 KW).

The maximum upset heating coil size would be required for the case of 360 scfm entering air at 120F saturated and the design exiting condition of 60% relative humidity at 139F (see psychrometric chart, App. A). The enthalpy change between these two states is ~~131~~ 125 - 119.5 Btu/lb_{da} = ~~11.5~~ 5.5 Btu/lb_{da}. At the entering density of 16.519 ft^3/lb_{da}, this yields (360 scfm)(~~11.5~~ 5.5 Btu/lb_{da})/(16.519 ft^3/lb_{da}) = ~~250.06~~ 119.86 Btu/min (~~15,037~~ 7,192 Btu/h, or ~~4.4~~ 2.1 KW).

DESIGN ANALYSIS

Client WHC
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Checked 3/28/95 By R. Pisco
Revised 2/13/96 By Danny Sorgen 2/13/96

4.0 FINDINGS & CONCLUSIONS

The Exhaust Skid stack sizing of 20' total (including stack head) will be adequate.

The Exhaust Skid fan will be required to be selected for the following pressure loss conditions. The fan motor will be required to be approximately 7.5 hp.

	minimum exhaust 180 scfm	maximum exhaust 360 scfm
design condition	19" w.g.	42" w.g.

The Exhaust Skid heating coil will be approximately 1.5 KW under normal operating conditions. In the upset condition, 2 ~~4.4~~ KW will be required. The heating coil with SCR control shall be capable of operating across a power range up to ~~4.4~~ KW.
2 KW

KEH 0037.00 (06/92) KEF055

APPENDIX A

RHL 3-28-95
RP 3/28/95

CHAPTER 14

AIRFLOW AROUND BUILDINGS

AIRFLOW around buildings affects worker safety, process and building equipment operation, weather and pollution protection at inlets, and the ability to control environmental factors of temperature, humidity, air motion, and contaminants. Wind causes surface pressures that vary around buildings, changing intake and exhaust system flow rates, natural ventilation, infiltration and exfiltration, and interior pressure. The mean flow patterns and turbulence of wind passing over a building can cause a recirculation of exhaust gases to air intakes. This chapter contains information for evaluating flow patterns, estimating wind pressures and air intake contamination, and solving problems caused by the effects of wind on intakes, exhausts, and equipment. Related information can be found in Chapters 11, 13, 23, and 24 of this volume; in Chapters 25, 27, and 47 of the 1991 Applications volume; and in Chapters 26, 31, 36, and 37 of the 1992 Systems and Equipment volume.

FLOW PATTERNS

Buildings of an even moderately complex shape, such as L- or U-shaped structures formed by two or three rectangular blocks, can generate flow patterns too complex to generalize for design. To determine flow conditions influenced by surrounding buildings or topography, a wind tunnel or water channel test of scale models or tests of existing buildings are required. However, if a building is oriented perpendicular to the wind, it can be considered as consisting of several independent rectangular blocks. Only isolated rectangular block buildings will be discussed here. Hosker (1984, 1985) reviews the effects of nearby buildings.

The mean speed of wind approaching a building increases with height above the ground (Figure 1). Both the upwind velocity profile shape and its turbulence level strongly influence flow patterns and surface pressures. A stagnation zone exists on the upwind wall. The flow separates at the sharp edges to generate recirculating flow zones that cover the downwind surfaces of the building (roof, sides, and leeward walls) and extend for some distance into the wake. If the building has sufficient length L in the windward direction, the flow will reattach to the building (Figure 2) and may generate two distinct regions of separated recirculating flow—on the building and in its wake.

Surface flow patterns on the upwind wall are largely influenced by approach wind characteristics. Higher wind speed at roof level causes a larger stagnation pressure on the upper part of the wall than near the ground, which leads to downwash on the lower one-half to two-thirds of the building (Figure 1). On the upper one-quarter to one-third of the building, the surface flow is directed upward over the roof. For a building whose height H is three or more times the width W of the upwind face, an intermediate zone can exist between the upwash and downwash regions, where the surface streamlines pass horizontally around the building. The downwash on the lower surface of the upwind face separates from the building before it reaches ground level and moves upwind to form a vortex that can generate high velocities close to the ground. This ground level upwind vortex is carried around the sides of the building in a U shape (Figure 1b) and is responsible for the suspension of dust and debris that can contaminate air intakes close to ground level.

Recirculation and High Turbulence Regions

For wind perpendicular to a building wall, the height H and width W of the upwind building face determine the flow patterns shown in Figure 3. According to Wilson (1979), the scaling length R which combines these dimensions is:

$$R = B_s^{0.67} B_L^{0.33} \tag{1}$$

where B_s is the smaller and B_L the larger of the dimensions H and W. When B_L is larger than $8B_s$, use $B_L = 8B_s$ in Equation (1). For buildings with varying roof levels or with wings separated by at least a distance B_s, only the height and width of the building face below the portion of the roof in question should be used to calculate R. Wilson (1976) indicates that for a flat-roofed building, the recirculation region maximum height H_c, at location X_c, and reattachment lengths L_c and L_r shown in Figures 3 and 17 are:

$$H_c = 0.22R \tag{2}$$

$$X_c = 0.5R \tag{3}$$

$$L_c = 0.9R \tag{4}$$

$$L_r = 1.0R \tag{5}$$

The downwind boundary of the rooftop recirculation region may be approximated by a straight line sloping downward from H_c to the roof at L_c. The dimensions of the recirculation zones are somewhat sensitive to the intensity and scale of turbulence in the approaching wind. High levels of turbulence from upwind obstacles may decrease the coefficients in Equations (2) through (5) by up to a factor of 2. Turbulence in the recirculation region and in the approaching wind also causes the reattachment locations on Figure 2 to fluctuate.

To account for changes in roof level, penthouses, and equipment housings and enclosures, the scaling length R of each of these obstacles should be calculated from Equation (1) using the dimensions of the upwind face of the obstacle. The recirculation region for each obstacle may be calculated from Equations (2), (3), and (4). The length L_r of the recirculation region downwind from the obstacle, or from the entire building, is given by Equation (5), with R based on the dimensions of the downwind face of the obstacle. The high turbulence region boundary Z_2 in Figure 17 follows a 1:10 (5.7°) downward slope from the top of the recirculation regions at X_c or L_r. When an obstacle is close to the

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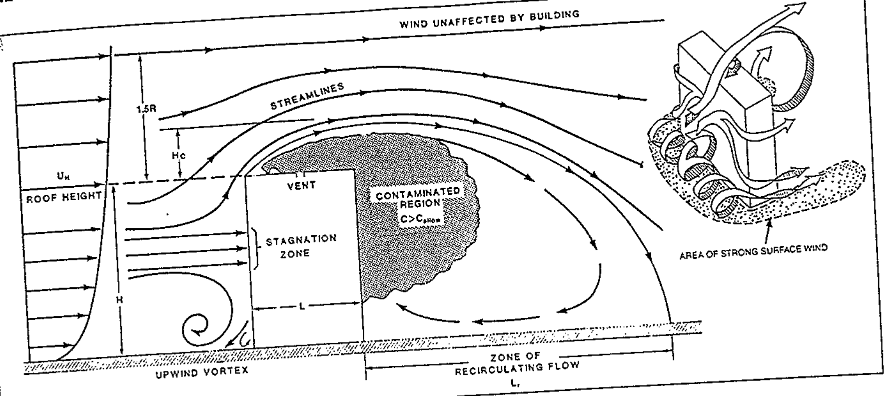

Fig. 1 Flow Patterns around Rectangular Building

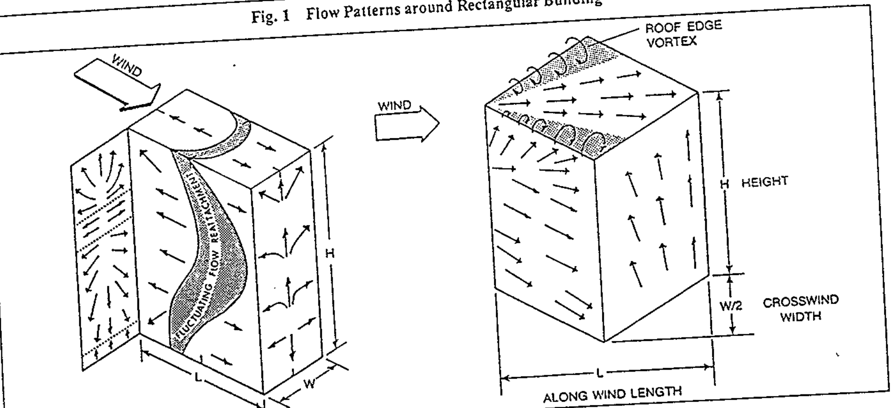

Fig. 2 Surface Flow Patterns and Building Dimensions

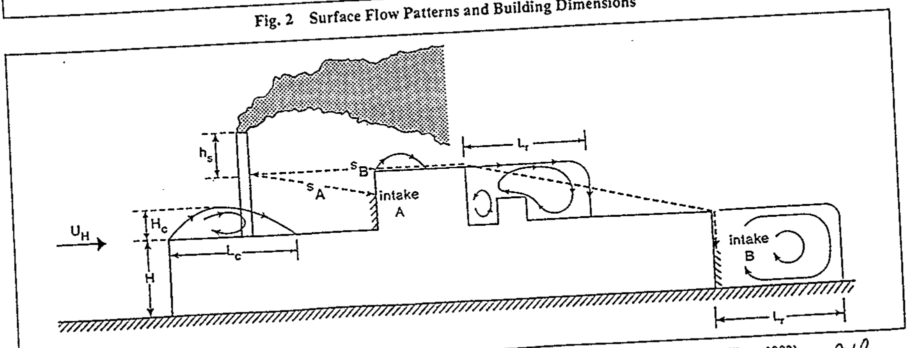

Fig. 3 Flow Recirculation Regions and Exhaust to Intake Stretched String Distances (Wilson 1982)

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wind directions, when the exhaust is uncapped ($\beta = 1$) and $V_e/U_H > 0.5$. A value of $B_1 = 0.0204$ should be used if V_e/U_H < 0.5 or the stack is capped ($\beta = 1$) and the wind is at 45° to the upwind wall, or if there is no significant atmospheric turbulence, for example, at roof level of high-rise buildings, or in flat rural surroundings [Wilson and Chui (1987), Chui and Wilson (1988)].

Equations (19), (20), and (21) imply that minimum dilution does not depend on the location of either the exhaust or intake, only on the distance S between them. This is true when exhaust and intake locations are on the same building wall or on the roof. The dilution may increase if the intake and exhaust are located on different faces, as indicated by the M factor in Equation (18). For roof exhausts with wall intakes, the results of Li and Meroney (1983) suggest that $B_1 \cong 0.20$ in Equation (21).

For buildings less than about 330 ft high and also less than twice as high as the surrounding buildings, atmospheric turbulence makes a significant contribution to exhaust gas dilution. Wilson (1976, 1977) gives surface concentration contours for flat-roofed buildings in a simulated approach wind typical of an urban area. Flush vents with small exhaust velocity make these results suitable for estimates for capped exhaust stacks or louvered exhaust vents.

The effect of atmospheric turbulence is relatively insignificant for high-rise buildings taller than 330 ft and also twice the average building height for 3000 ft upwind. On these high-rise buildings, where the effects of atmospheric turbulence are small, Wilson and Chui (1987) found that maximum surface concentrations for 10-min exposures were two to ten times higher than on an equivalent low-rise building. A dilution coefficient of $B_1 = 0.02$ should be used for high-rise buildings.

When exhaust from several collecting stations is combined in a single vent or in a tight cluster of stacks, the effective exhaust area A_e will increase, causing the minimum dilution in Equation (19) to decrease. To qualify as a cluster, the stacks must all lie within a two-stack diameter radius of the middle of the group. Stacks lined up in a row do not act as a single stack, as shown by Gregoric *et al.* (1982). However, the exhaust concentration C_e of each contaminant will decrease by mixing with other exhaust streams, and the plume rise will increase due to the higher momentum in the combined jets. For combined vertical exhaust jets, the roof level intake concentration C in Equation (12) will almost always be lower than the intake concentration caused by separate exhausts. Where possible, exhausts should be combined before release to take advantage of this increase in overall dilution.

Critical Wind Speed and Dilution

At very low wind speed, the exhaust jet from an uncapped stack will rise high above roof level, producing a large exhaust dilution D_{min} at a given intake location. Likewise, at high wind speed, the dilution will also be large because of the longitudinal stretching of the plume by the wind. Between these extremes, a critical wind speed exists at which the least dilution will occur for a given exhaust and intake location. This critical, absolute minimum dilution D_{crit} may be used to determine if an exhaust vent will be safe under all wind conditions. The critical wind speed for an uncapped vertical exhaust ($\beta = 1.0$) can be evaluated by finding the absolute minimum in Equations (19), (20), and (21). It is closely approximated by

$$U_{crit,o}/V_e = 2.9B_1^{-0.33}(S/A_e^{0.5})^{-0.67} \quad (22)$$

where $U_{crit,o}$ is the critical wind speed producing the smallest minimum dilution for an uncapped vertical exhaust with negligible stack height. This critical dilution $D_{crit,o}$ may be found by using Equation (22) in Equation (19). For $S/A_e^{0.5} > 5$, this minimum is closely approximated by

$$D_{crit,o} = 1 + 7.0B_1^{0.67}(S/A_e^{0.5})^{1.33} \quad (23)$$

The critical dilution in Equation (23) depends only on distance from the exhaust and not on the exhaust velocity V_e. However, increasing the exhaust velocity increases the critical wind speed in Equation (22), usually causing this worst-case critical dilution to occur less frequently.

To assess the severity of the hazard caused by intake contamination, it is useful to know how often the worst case D_{crit} is likely to occur. The number of hours per year during which the dilution is no more than a factor of 2 higher than the critical minimum value may be estimated from weather records by finding the fraction of time that the wind speed lies in the range from 0.5 $U_{crit,o}$ to 3.0 $U_{crit,o}$ (Wilson 1982, 1983). This fraction is then multiplied by the fraction of time the local wind direction lies in a sector ± 22.5° on each side of the line joining the exhaust and intake location.

EXHAUST STACK DESIGN

Before discharge, exhaust contamination should be reduced by filters, collectors, and scrubbers. Central exhaust systems that combine flows from many collecting stations should always be used where safe and practical. By combining several exhaust streams, central systems dilute intermittent bursts of contamination from a single station. However, in some cases, separate exhaust systems are mandatory. The nature of the contaminants to be combined, the recommended industrial hygiene practice, and the applicable safety codes need to be considered. Halitsky (1966) and Briggs (1984) present methods for estimating the trajectory of jets and the subsequent dispersion of jet plumes.

Separate exhaust stacks should be grouped in a tight cluster to take advantage of the larger plume rise of the resulting combined jet. In addition, a single stack from a central exhaust system or a tight cluster of stacks allows building air intakes to be placed as far as possible from the exhaust location. As shown in Figure 3, the effective stack height h_s is the portion of the exhaust stack that extends above local recirculation zones and upwind and downwind obstacles. Wilson and Winkel (1982) demonstrated that stacks terminating below the level of adjacent walls and architectural enclosures do not effectively reduce roof-level exhaust contamination. To take full advantage of their height, stacks should be located on the highest roof of a building. Where architectural enclosures are used to mask rooftop equipment, stacks must extend above the height H_c of the flow recirculation zone over the enclosure to prevent exhaust contamination of equipment within the enclosure.

Required Stack Exhaust Velocity

High stack discharge velocity and temperature increase plume rise and reduce intake contamination by increased jet dilution and by the elevated plume trajectory. However, high discharge velocity is a poor substitute for increased stack height.

As shown in Figure 15, stacks should have vertically directed uncapped exhaust jets. Stack caps which deflect the exhaust jet have a detrimental effect on both minimum dilution and critical wind speed. In any case, conical stack caps often do not eliminate rain, because rain does not usually fall straight down. Changnon (1966) shows that periods of heavy rainfall are often accompanied by high winds that deflect the raindrops under the cap and into the stack. A stack velocity of about 2500 fpm prevents condensed moisture from draining down the stack and keeps rain from entering the stack. Even when there are drains in the stack, the exhaust velocity should be maintained above 2000 fpm to provide adequate plume rise and jet dilution. Where stack condensate is corrosive, the body of the stack should be sized for a velocity of 1000 fpm.

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or less, and a drain provided for the condensate (Anonymous 1964). The stack tip should have a converging cone (Figure 15B) to provide the required high-velocity discharge of 2000 to 3000 fpm. For intermittently operated systems, protection from rain and snow should be provided by stack drains as shown in Figures 15F through 15J.

Stack Height to Avoid Exhaust Entrainment

To avoid entrainment of exhaust gases into the wake, stacks must terminate above the flow recirculation height H_c. Where stacks or exhaust vents discharge within this recirculation region, gases rapidly diffuse to the roof and may enter ventilation intakes or other openings. Figure 1 shows that this effluent will flow into the zone of recirculating flow behind the downwind face and will, in some cases, be brought back up onto the roof.

A high velocity exhaust with V_e at least 1.5 times as large as the wind speed U_H at roof height is essential not only to provide good initial dilution near the stack, but also to avoid stack wake downwash, which can reduce or eliminate plume rise. Downwash of the exhaust into the stack wake, shown in Figure 16, is caused by the low-pressure region which develops in the wake on the lee side of the stack. In situations where exhaust velocity cannot be maintained at a value larger than 1.5 times the wind speed, an additional downwash height h_d (see Figure 16) should be added to the stack height h_s. For a vertically directed jet from an uncapped stack ($\beta = 1.0$), Briggs (1973) recommends

$$h_d = 2.0d(1.5\beta V_e/U_H) \tag{24}$$

for $V_e/U < 1.5$, where $d = (4A_e/\pi)^{0.5}$ is the effective stack diameter. Rain caps are frequently used on stacks of gas-and oil-fired furnaces and package ventilation units. These units will have $\beta = 0$, so $h_d = 3.0d$, and this should be added to the nominal height h_s to avoid flue gas contamination of roof-mounted equipment and air intakes.

The design procedure for selecting an appropriate stack height starts by calculating the height h_{sc} of a stack with a rain cap and, therefore, no plume rise. For an uncapped vertical exhaust, the minimum rise h_r of the bent-over exhaust jet is estimated, and the

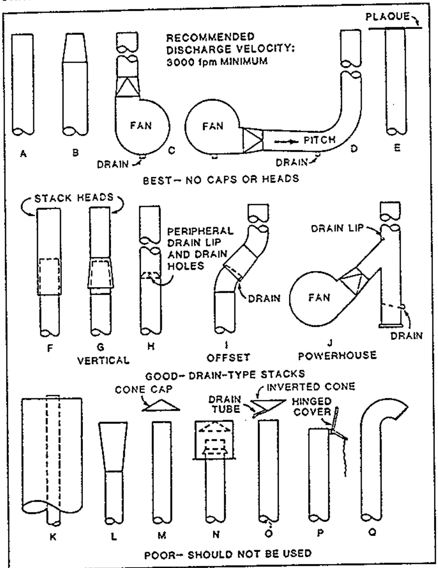

Fig. 15 Stack Designs Providing Vertical Discharge and Rain Protection

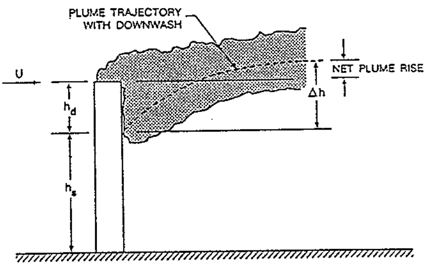

Fig. 16 Reduction of Effective Stack Height by Stack Wake Downwash

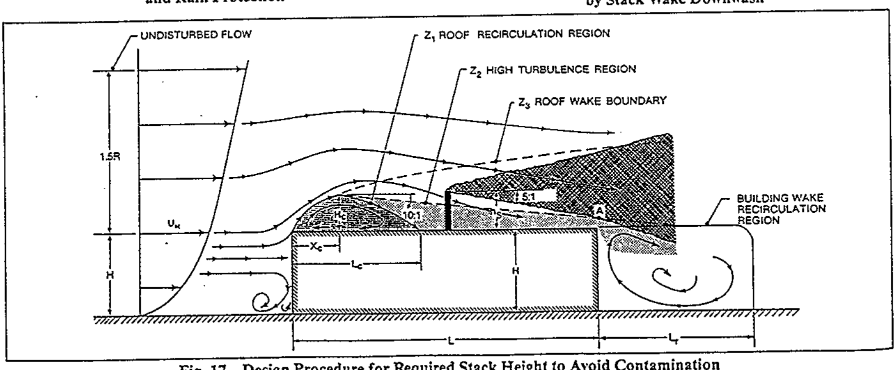

Fig. 17 Design Procedure for Required Stack Height to Avoid Contamination
(Wilson 1979)

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capped height h_{sc} is lowered by an amount h_r to give credit for plume rise (see Figure 16).

The capped stack height h_{sc} required to avoid excessive exhaust gas reentry is estimated by assuming that the plume spreads upward and downward from h_{sc} with a 1:5 slope (11.3°), as shown in Figure 17. The first step is to raise the capped height h_{sc} until the lower edge of the 1:5 sloping plume avoids contact with all recirculation (zone 1) boundaries on rooftop obstacles such as air intake housings, architectural screens, or penthouses. The size of these recirculation zones, shown in Figures 3 and 17, are calculated using Equations (2), (3), and (4).

If air intakes are located on the downwind wall, the lower edge of the plume, sloping down at 1:5, must lie above the downwind edge of the roof when a nontoxic exhaust contaminant, such as an odor or water vapor, is being dealt with. For a toxic contaminant that requires a large dilution factor at the wall intake, the lower edge of the plume should lie above the flow recirculation zone in the wake downwind of the building. The boundary of the building wake recirculation, shown in Figures 1, 3, and 17, is defined by a horizontal line extending a distance L_r from the downwind edge of the roof. The recirculation length L_r is calculated from Equation (5).

For an uncapped stack, the plume rise h_r due to the vertical momentum of the exhaust is estimated from Briggs (1984) as

$$h_r = 3.0(V_e/U_H)d \tag{25}$$

where the wind speed U_H is the maximum design wind speed for which air intake contamination must be avoided. The required height h_s of the uncapped stack extending above local recirculation zones and obstacles is

$$H_S = h_{SC} - h_r + h_d \tag{26}$$

If the minimum recommended exhaust velocity of $V_e = 1.5\ U_H$ is maintained, plume downwash $h_d = 0$, and $h_r = 4.5d$; thus, an uncapped stack can be made 4.5d shorter than a capped one.

The largest flow recirculation, high turbulence, and wake regions occur when wind is normal to the upwind wall of the building. Required stack heights should be the largest of the heights determined for all four directions for which the wind is normal to a building wall.

Estimating Critical Dilution for Exhaust Stacks

The geometric design for avoiding excessive contamination does not give any estimate of the worst case critical dilution factor D_{crit} between the stack and an air intake. In this section, D_{crit} will be estimated for a predetermined stack height.

An increase in stack height or in exhaust velocity ratio V_e/U_H reduces roof-level contamination by keeping the high concentrations on the plume centerline far enough above the roof so that the intakes see only intermittent concentrations in the fringes of the plume. In addition, stack height or high exhaust velocity increases the critical wind speed at which the absolute minimum dilution occurs. This higher critical wind speed often reduces significantly the number of hours per year that high intake contamination (*i.e.*, low dilution) will be observed.

Using a Gaussian plume dispersion equation, with a plume spread standard deviation of 0.14S, and an uncapped vertical exhaust jet with no buoyancy and with plume rise inversely proportional to wind speed, the critical wind speed U_{crit} at which the smallest minimum dilution D_{crit} observed is

$$\frac{U_{crit,o}}{U_{crit}} = (Y + 1)^{0.5} - Y^{0.5} \tag{27}$$

where $U_{crit,o}$ is the critical wind speed for a flush (zero stack height) vertical exhaust, computed from Equation (22). The influence of stack height on the worst case critical dilution for the standard 10-min exposure time may be calculated from

$$\frac{D_{crit}}{D_{crit,o}} = \frac{U_{crit}}{U_{crit,o}} \exp[Y + Y^{0.5}(Y + 1)^{0.5}] \tag{28}$$

where $Y = 12.6(h_s/S)^2$, and $D_{crit,o}$ is the dilution at critical wind speed for a flush vertical roof exhaust with no stack height, from Equation (23). Equations (27) and (28) are reliable only for $Y <$ 2.0. Close to the stack, where $Y > 2.0$, use $Y = 2.0$ in Equations (27) and (28). Because both wind speed and turbulence intensity vary strongly with height above the building roof, the plume rise of the exhaust jet may not be inversely proportional to wind speed; normally its behavior is between $\Delta h \propto U^{-0.4}$ and $U^{-1.0}$. Thus, Equations (27) and (28) are only approximations. Because buoyancy is not included, the added rise due to buoyancy provides a factor of safety, particularly at low wind speed.

Because Equations (27) and (28) give the effect of a stack relative to a flush exhaust with $h_s = 0$, they are useful for assessing the advantages of increasing stack height as a remedial measure. By comparing two different heights, this calculation allows the relative benefits of a stack to be estimated without knowing any details of the contaminant concentrations or exhaust velocity in the existing stack. For example, the stack height required using the simple geometrical design procedure in the following section will have h_s/S of at least 0.2. Equations (27) and (28) show that the critical wind speed U_{crit} for this stack height will be about a factor of 2 larger, and the critical dilution D_{crit}, about eight times more than for the vertical jet from an uncapped exhaust with zero effective stack height.

Example 1. The stack height h_s of the uncapped vertical exhaust on the building shown in Figure 3 must be specified to avoid excessive contamination of air intakes A and B by stack gases. The stack has a diameter d of 1.64 ft and an exhaust velocity V_e of 1770 fpm. It is located 52.5 ft from the upwind edge of the roof. The penthouse has its upwind wall (with intake A) located 98.4 ft from the upwind edge of the roof, a height of 13.1 ft, and a length of 23.0 ft in the wind direction. The top of intake A is 6.56 ft below the penthouse roof. The building has a height H of 49.2 ft and a length of 203 ft. The top of intake B is 19.7 ft below roof level. The width (measured into the page) of the building is 164 ft, and the penthouse is 29.5 ft wide. What are the required stack heights h_s for both nontoxic and highly toxic exhaust contaminants for a design wind speed specified at a factor of 2 higher than the annual average hourly wind speed of 9.32 mph at a nearby airport with anemometer height H_{ref} of 32.8 ft? The building is located in unshielded suburban terrain.

Solution: The first step is to set the height h_{sc} of a capped stack by projecting lines with 5:1 slopes upwind from points of potential plume impact. For intake A, the highest point of impact is the top of the recirculation zone on the roof of the penthouse. To find the height of this recirculation zone, start with Equation (1).

$$R = (13.1)^{0.67}(29.5)^{0.33} = 17.2 \text{ ft}$$

Then use Equations (2) and (3):

$$H_c = 0.22(17.2) = 3.77 \text{ ft}$$
$$X_c = 0.5(17.2) = 8.60 \text{ ft}$$

With the 5:1 slope of the lower plume boundary shown in Figure 17, the capped stack in Figure 3 must be

$$h_{sc} = 0.2(98.4 - 52.5 + 8.60) + 3.77 = 14.7 \text{ ft}$$

above the penthouse roof to avoid intake A. For intake B on the downwind wall, the plume boundary from the stack in Figure 3 must lie above the end of the roof for nontoxic exhaust gas or the end of the building flow recirculation zone for highly toxic exhaust gas. For this recirculation zone, from Equation (1):

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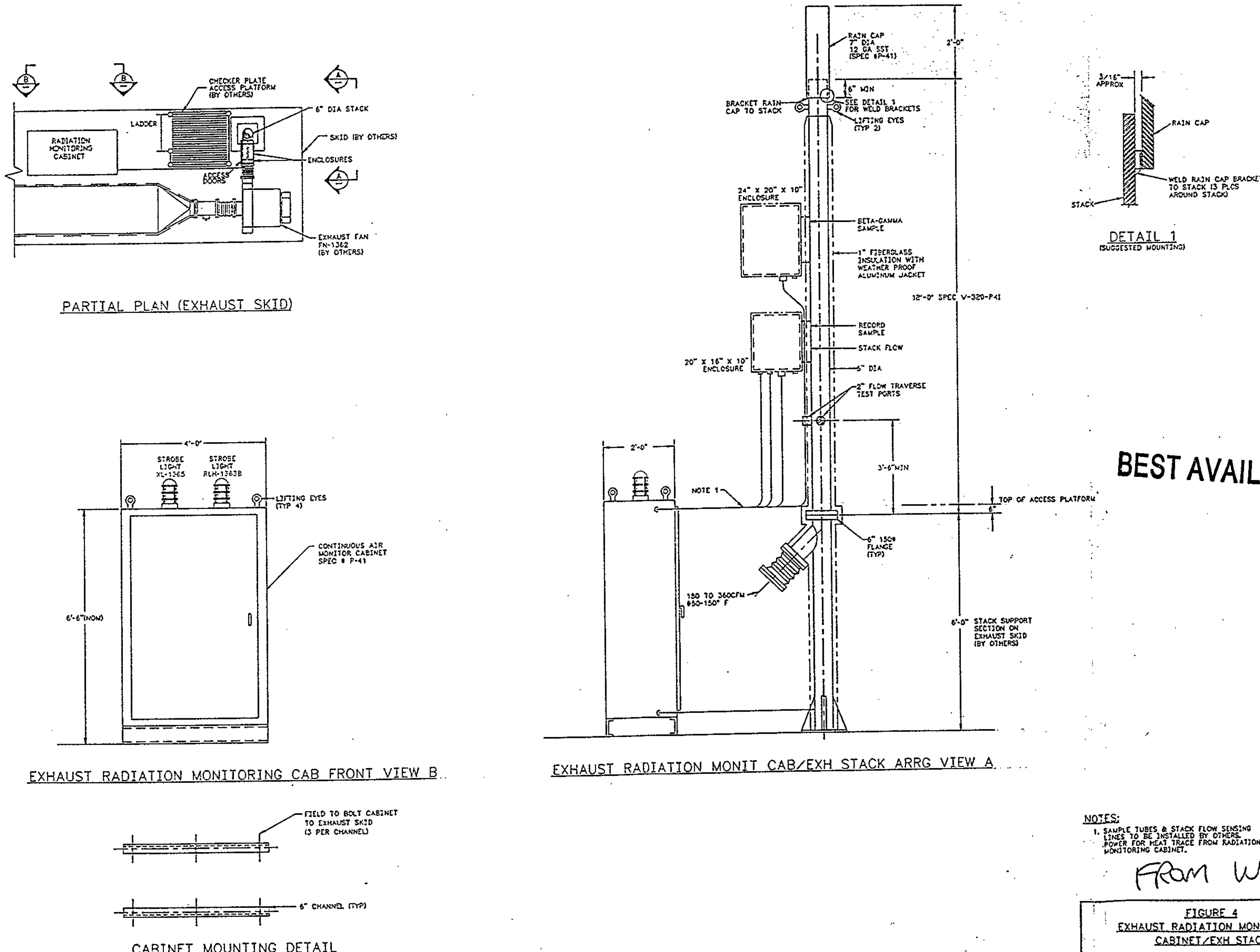

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FIGURE 4
EXHAUST RADIATION MONITORING
CABINET/EXH STACK

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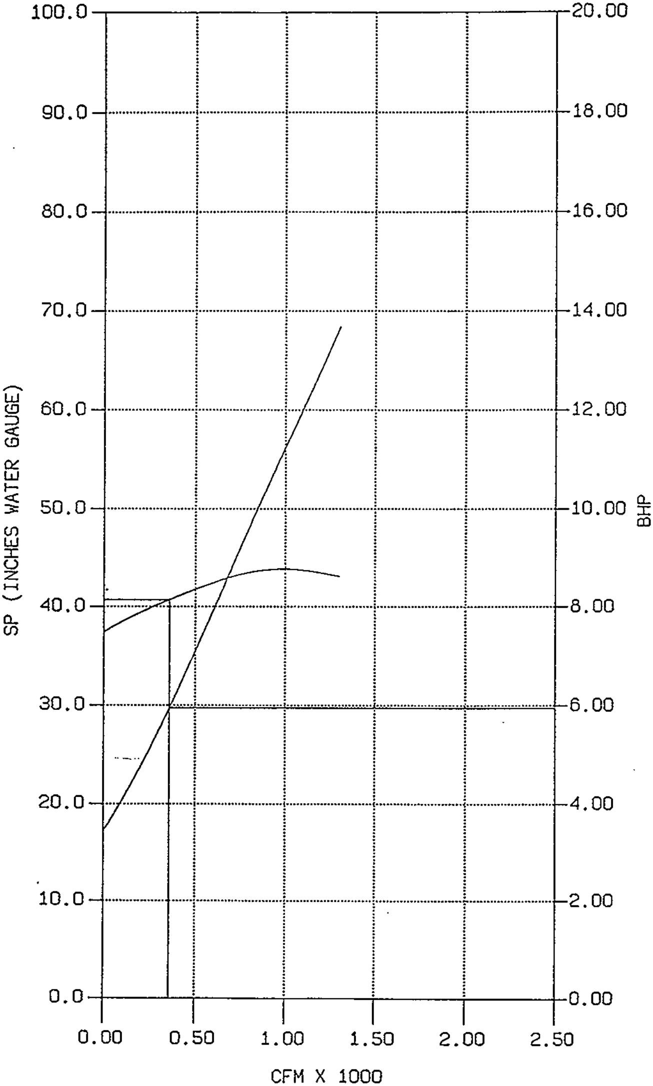

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RPM : 3406 BHP: 5.95
DEN : 0.0644
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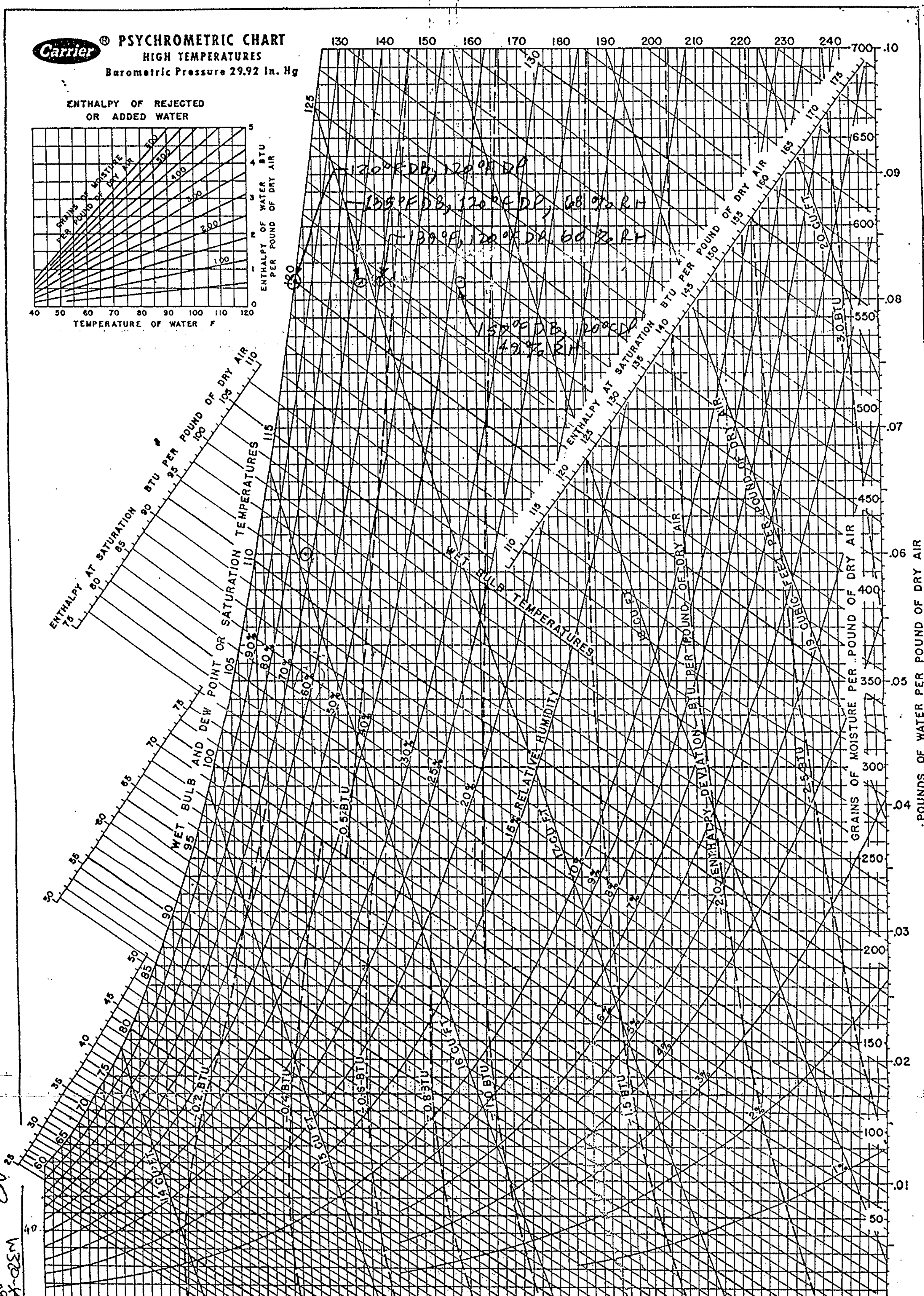

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ASHRAE PSYCHROMETRIC CHART NO. 1

SEA LEVEL

NORMAL TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

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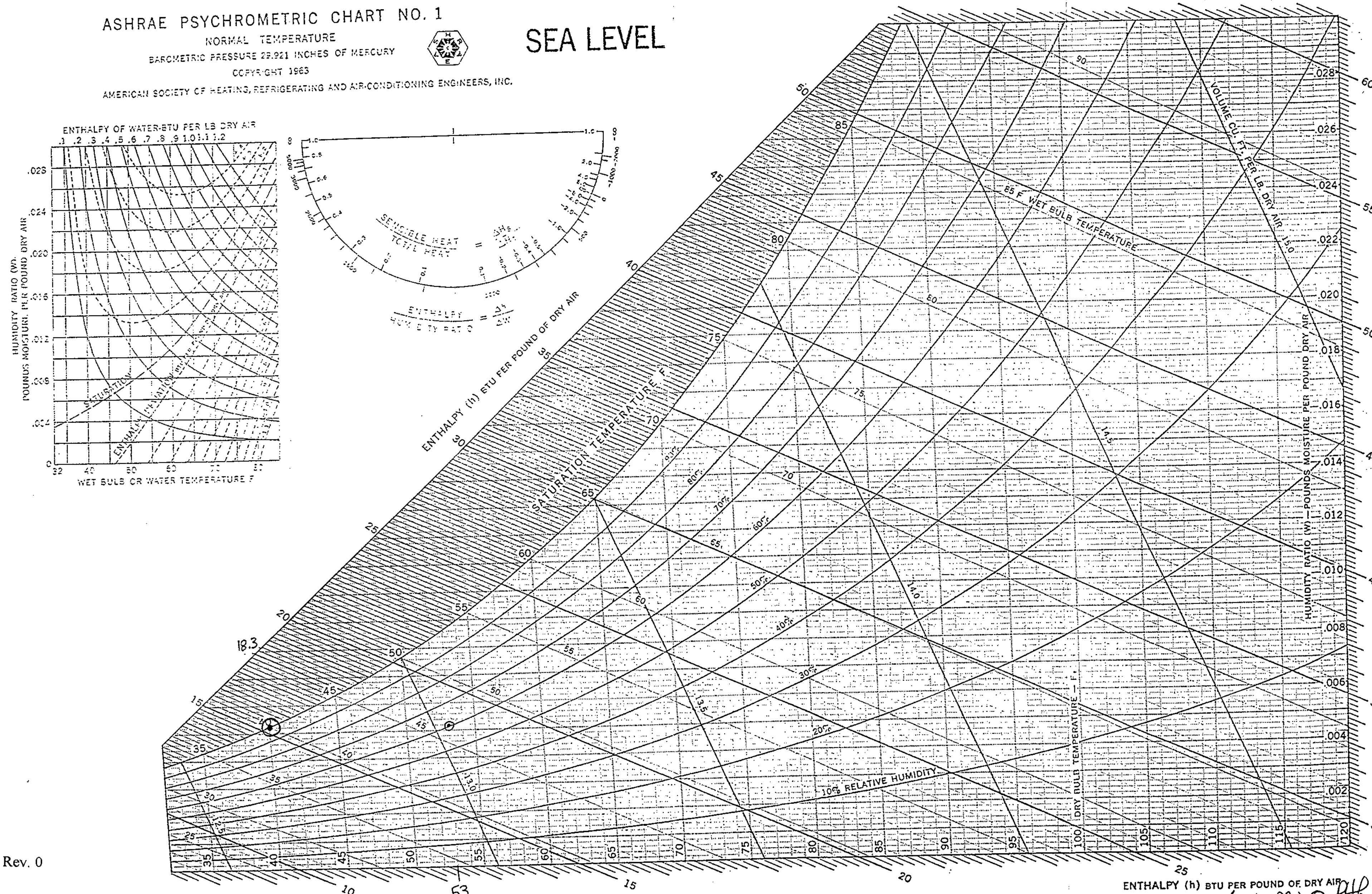

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ENTHALPY (h) BTU PER POUND OF DRY AIR

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