PB 198 349

SYSTEMS ANALYSIS OF EMISSIONS AND EMISSION CONTROL IN THE IRON FOUNDRY INDUSTRY. VOLUME II. EXHIBITS

A. T. Kearney and Company
Chicago, Illinois

February 1971

PB 198 349

APCO-DPCE

CONTRACT NO. CPA 22-69-106

SYSTEMS ANALYSIS OF EMISSIONS AND EMISSIONS CONTROL IN THE IRON FOUNDRY INDUSTRY

VOLUME II - EXHIBITS

FEBRUARY, 1971

A. T. KEARNEY & COMPANY, INC.

BIBLIOGRAPHIC DATA SHEET

1. Report No. APTD-0645

2.

3. Recipient's Accession No.

4. Title and Subtitle

Systems Analysis of Emissions and Emissions Control in the Iron Foundry Industry Volume II - Exhibits

5. Report Date February 1971

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

A. T. Kearney & Company, Inc.
100 South Wacker Drive
Chicago, Illinois 60606

10. Project/Task/Work Unit No.

11. Contract/Grant No. CPA 22-69-106

12. Sponsoring Organization Name and Address

EPA, Air Pollution Control Office
Technical Center, Box 12055
Research Triangle Park, N. C. 27709

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

One of three volumes of a study which was conducted for the purpose of defining the air pollution problems of the iron foundry industry and of setting priorities for research and development activities that will lead to improved emission control capabilities at reduced cost. This volume contains a list of exhibits which are coordinated with the text in Volume I. Volume III consists of six appendices. The study includes the following basic facilities and operations: 1. raw material storage, preparation and charging, 2. Metal melting, 3. Molding, pouring and shake out, 4. Sand conditioning and reclamation, 5. Cleaning, heat treating and finishing, 6. Coremaking

17. Key Words and Document Analysis. 17a. Descriptors

Foundries
Foundry practices
Airborne wastes
Air pollution control equipment
Cost analysis

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13/B

18. Availability Statement
Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages ~~124~~ 175

22. Price $3.00

FORM NTIS-35 (10-70) USCOMM-DC 403

This report was furnished to the
Air Pollution Control Office by
the A. T. Kearney Company in ful-
fillment of Contract No. CPA 22-69-106.

SYSTEMS ANALYSIS OF EMISSIONS AND EMISSIONS CONTROL IN THE IRON FOUNDRY INDUSTRY

VOLUME II EXHIBITS

FEBRUARY, 1971

FOR

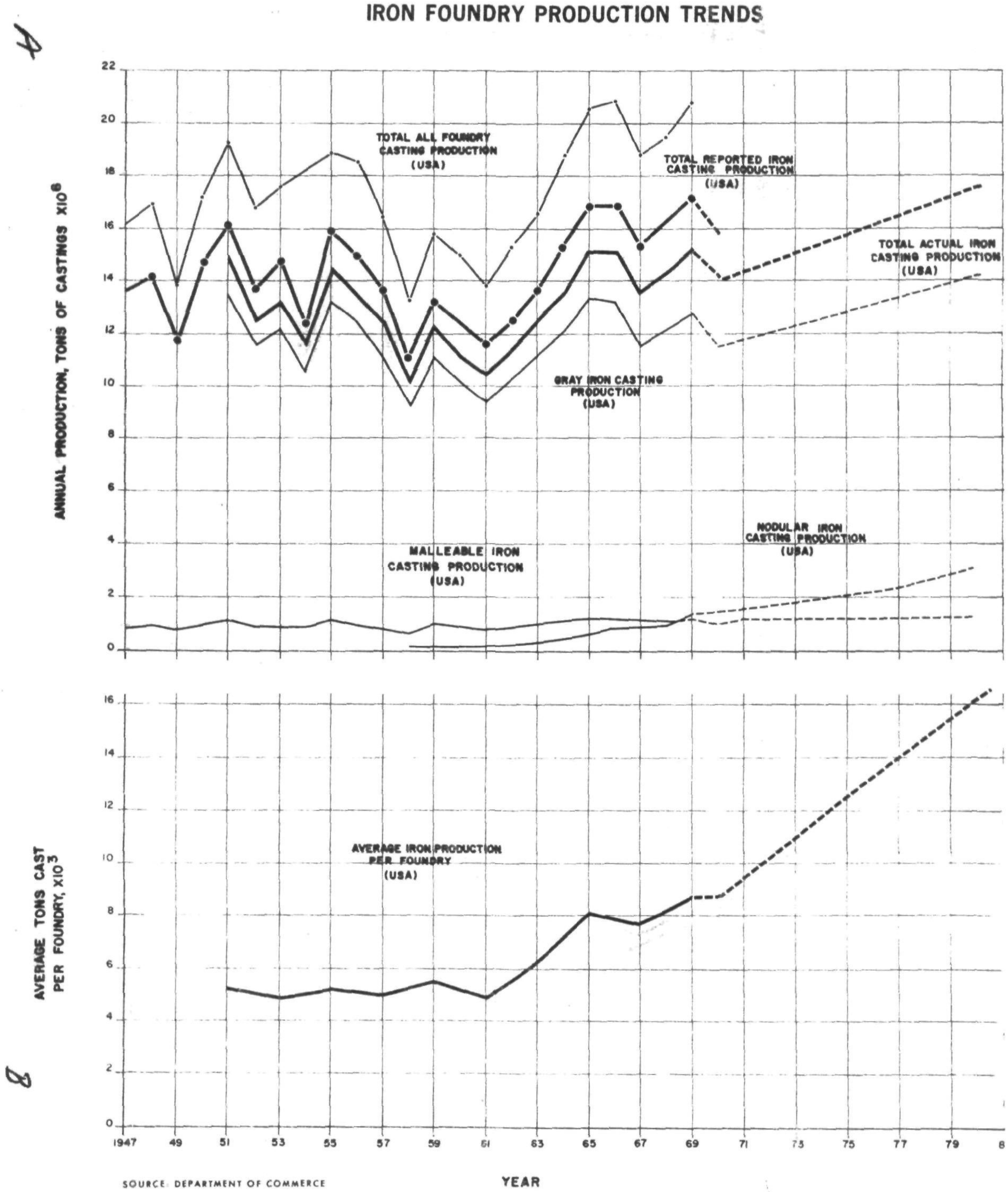
Division of Process Control Engineering
Air Pollution Control Office
Environmental Protection Agency
Contract No. CPA 22-69-106

Prepared by
A. T. Kearney & Company, Inc.
Chicago, Illinois

VOLUME II - LIST OF EXHIBITS

Number	Title
VIII-34	Capital and Operating Costs per Ton vs Operating Hours per Year for Hot Blast Cupola with Wet Scrubber (Alternate No.2)
VIII-35	Capital and Operating Costs per Ton vs Operating Hours per Year for Electric Arc Furnace with Fabric Filter (Alternate No. 3)
VIII-36	Capital and Operating Costs per Ton vs Operating Hours per Year for Coreless Induction Furnace with Afterburner on Preheater (Alternate No. 4)
IX-1	Modifications to Cupola Melting Practices to Reduce Emissions
XI-1	Inventory of Iron Foundry Emissions from Melting Operations, 1969
XI-2	Inventory of Iron Foundry Emissions from Non-Melting Operations, 1969
XI-3	Priority Rating Chart
XII-1	Proposed Research and Development Projects

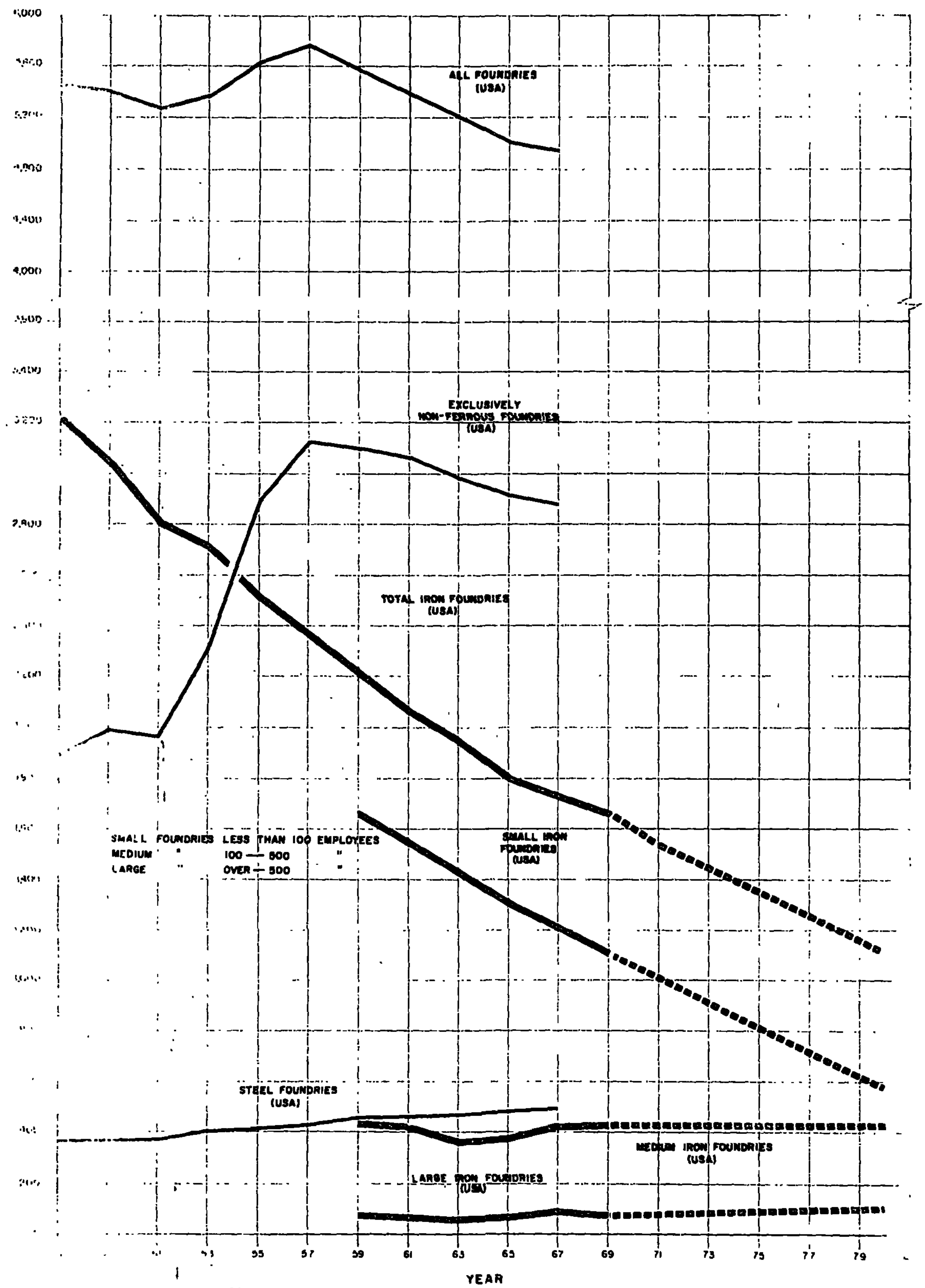
IRON FOUNDRY PRODUCTION TRENDS



SOURCE: DEPARTMENT OF COMMERCE

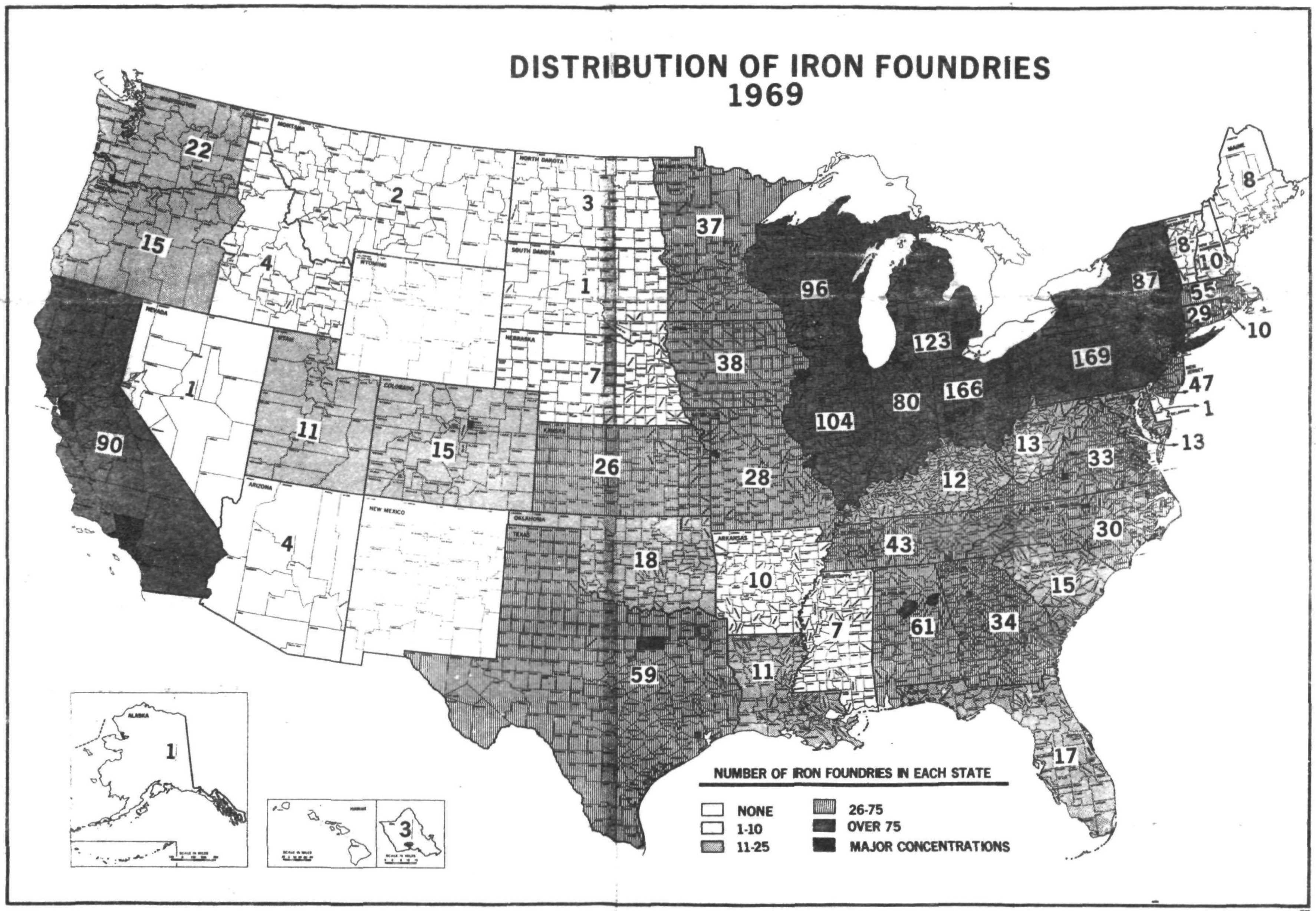
EXHIBIT III-1

POPULATION TRENDS IN THE FOUNDRY INDUSTRY



PUBLISHING CO

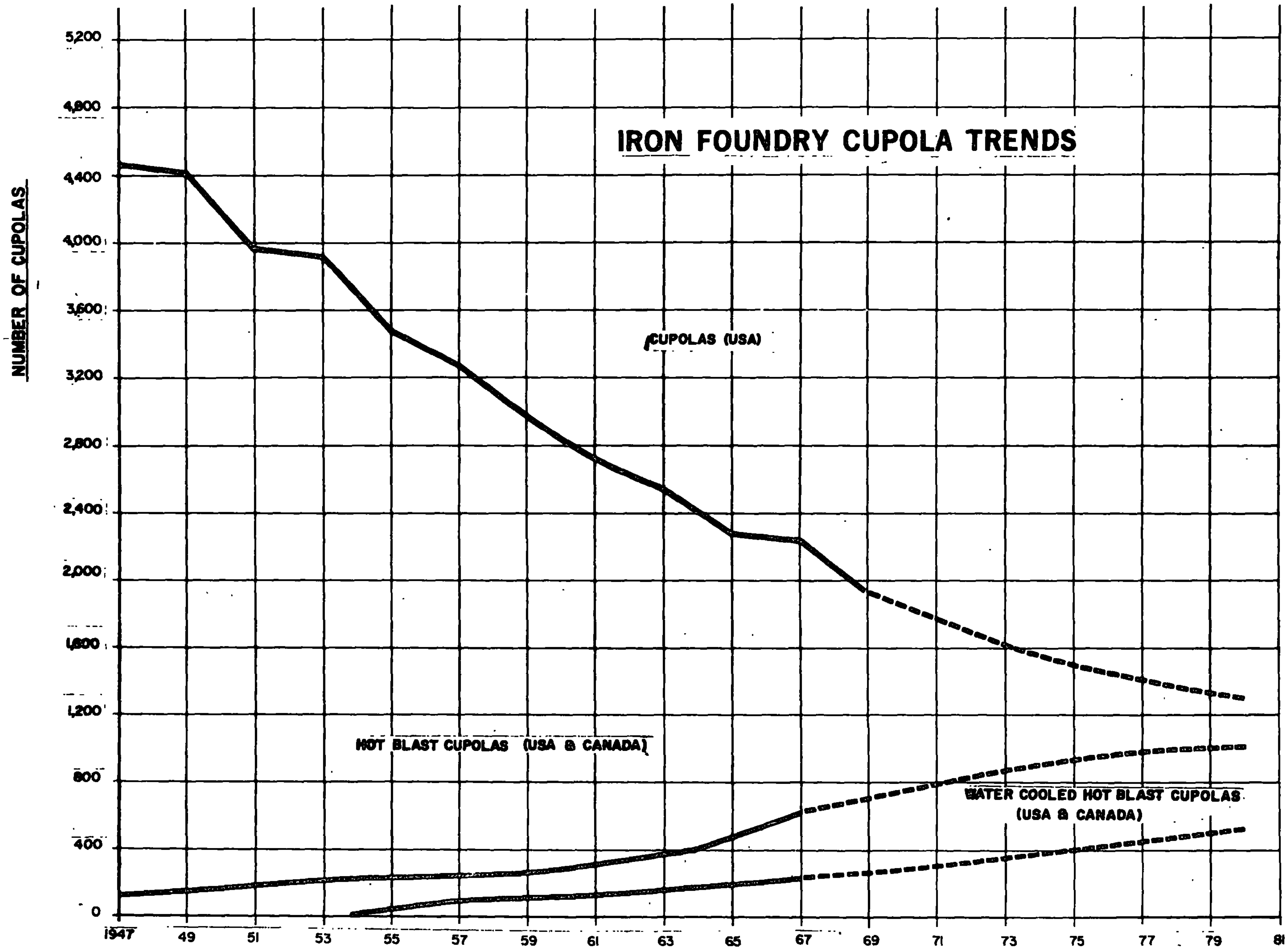
EXHIBIT II-2



SOURCE: PENTON PUBLISHING CO.

A

B



SOURCE: PENTON PUBLISHING CO.

EXHIBIT III-5

GEOGRAPHICAL DISTRIBUTION OF IRON FOUNDRIES

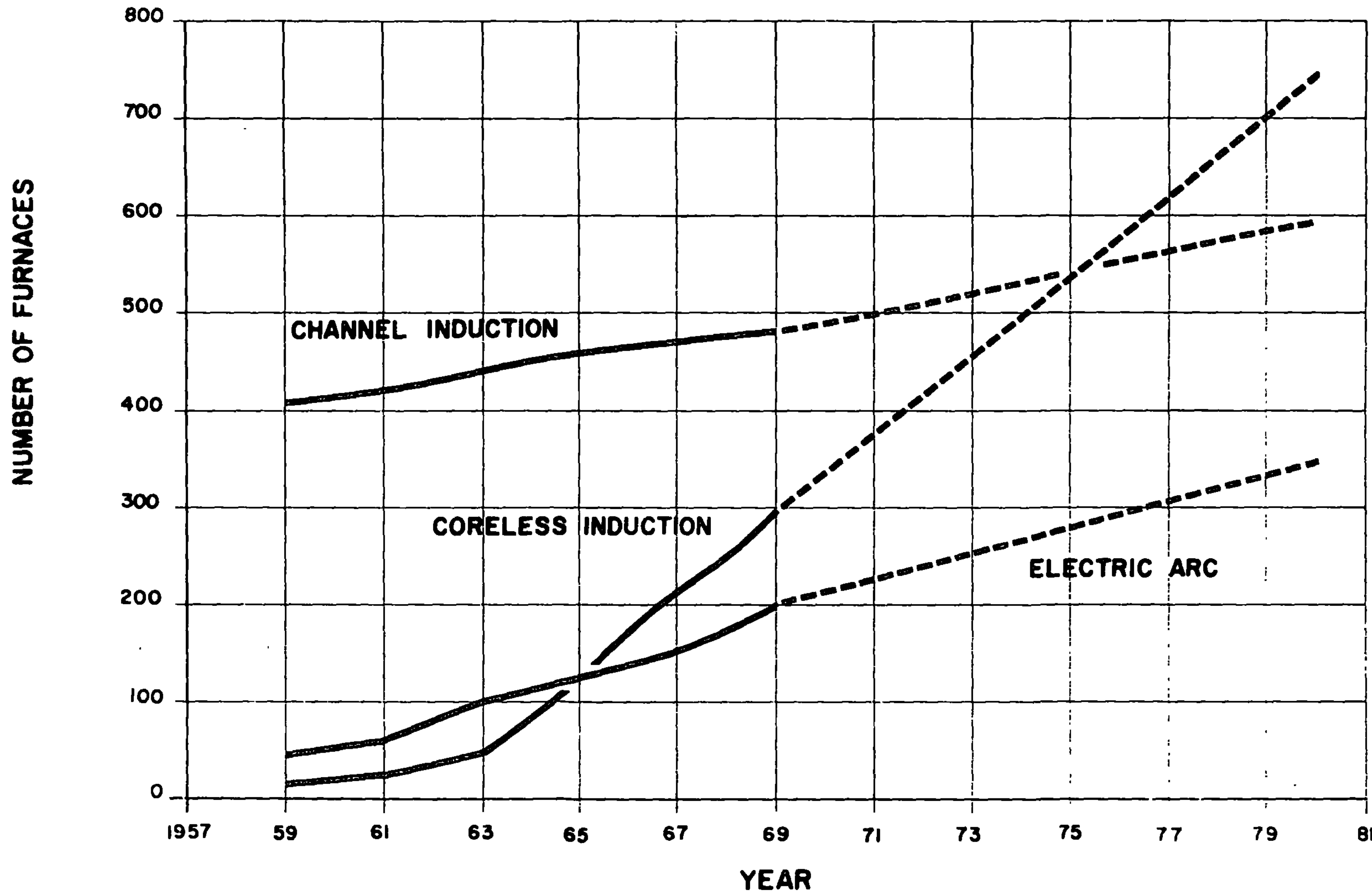
	Gray Iron				Ductile Iron				Malleable			
	1969	1967	1965	1963	1969	1967	1965	1963	1969	1967	1965	1963
Alabama	56	56	59	65	17	16	17	12	2	3	2	2
Alaska	1	-	-	-	-	-	-	-	-	-	-	-
Arizona	4	3	3	4	1	-	-	-	-	-	-	-
Arkansas	10	11	10	10	1	1	1	1	-	-	-	-
California	88	86	95	102	29	23	24	23	1	1	1	4
Colorado	15	17	18	20	4	3	4	3	-	-	-	1
Connecticut	24	23	24	29	7	6	6	5	4	5	5	5
Delaware	1	2	2	2	-	-	-	-	-	-	-	-
District of Columbia	-	-	1	1	-	-	1	1	-	-	-	-
Florida	17	19	19	20	3	3	2	2	-	-	-	-
Georgia	32	29	32	35	8	6	6	7	-	-	-	-
Hawaii	3	4	3	3	-	-	-	-	-	-	-	-
Idaho	4	4	4	4	1	1	1	1	-	-	-	-
Illinois	97	104	107	113	32	31	29	28	9	10	11	11
Indiana	75	81	75	84	16	12	12	11	4	4	4	5
Iowa	36	37	38	43	8	6	5	5	1	2	1	2
Kansas	24	22	22	23	9	6	7	7	-	-	-	-
Kentucky	11	15	16	16	2	1	-	-	-	-	-	-
Louisiana	10	10	16	13	2	2	2	1	-	-	-	-
Maine	8	8	8	9	1	-	-	-	-	-	-	-
Maryland	13	12	13	14	5	3	2	2	1	1	1	1
Massachusetts	53	56	57	67	13	9	9	7	3	3	5	3
Michigan	114	122	127	133	36	32	28	28	7	8	6	6
Minnesota	36	35	35	38	8	5	4	3	2	1	1	1
Mississippi	7	7	8	8	-	-	-	-	-	-	-	1
Missouri	28	30	29	33	6	5	3	4	-	-	1	2
Montana	2	2	2	4	-	-	-	-	-	-	-	-
Nebraska	7	8	8	8	1	-	-	-	-	-	-	-
Nevada	1	1	1	1	-	-	-	-	-	-	-	-
New Hampshire	8	5	4	8	2	1	-	-	1	1	1	1
New Jersey	45	44	48	56	12	10	10	9	2	1	1	2
New Mexico	-	1	2	1	-	-	-	-	-	-	-	-
New York	82	88	97	103	17	16	19	17	9	7	10	7
North Carolina	30	33	36	41	7	5	4	6	-	-	-	-
North Dakota	3	2	2	2	-	-	-	-	-	-	-	-
Ohio	151	162	159	163	61	52	46	46	16	18	16	18
Oklahoma	17	14	14	17	12	6	6	5	-	-	-	-
Oregon	13	16	17	16	5	7	7	6	-	-	-	1
Pennsylvania	155	183	189	198	48	43	41	34	16	14	13	14
Rhode Island	8	9	9	10	2	1	1	2	1	1	1	1
South Carolina	15	16	15	17	4	5	5	2	-	-	-	-
South Dakota	1	2	2	3	-	-	-	-	-	-	-	-
Tennessee	41	45	48	52	7	8	7	5	1	-	-	-
Texas	56	63	61	68	18	17	11	8	1	1	1	2
Utah	11	9	10	10	5	4	5	5	-	-	1	-
Vermont	8	8	10	10	1	-	-	-	-	-	-	1
Virginia	33	34	37	37	7	5	5	3	-	-	-	-
Washington	21	21	23	23	8	7	6	5	1	1	1	1
West Virginia	12	12	12	13	5	4	2	2	1	1	1	1
Wisconsin	84	82	85	87	28	25	23	22	10	10	11	11
Wyoming	-	-	-	-	-	-	-	-	-	-	-	-
Total United States	1,571	1,653	1,712	1,837	459	387	361	328	93	93	95	104

Source: Foundry Magazine Census of Foundries.

EXHIBIT III-4

EXHIBIT III-6

IRON FOUNDRY ELECTRIC FURNACE TRENDS



SOURCE : DATA PROVIDED BY FURNACE MANUFACTURERS

A

B

CHARACTERISTICS AND SOURCES OF EMISSIONS IN VARIOUS FOUNDRY DEPARTMENTS

DEPARTMENT	OPERATION	EMISSIONS: TYPE	EMISSIONS: CONCENTRATION	EMISSIONS: PARTICLE SIZE (Microns)	RELATIVE CONTROL-LABILITY	RELATIVE COST
RAW MATERIAL STORAGE AND CHARGE MAKEUP	Store metal scrap, coke, limestone, dolomite, fluorspar, silica sand	Dust: Coke, limestone and sand.	3 to 5gr./cu.ft. Moderate	Fine to coarse 30 to 1,000	Moderate to Difficult	Medium
	Centrifuge or heat metal borings and turnings to remove cutting oil	Oil vapors Smoke Unburned hydrocarbons	Light Light Light	.03 to 1 .01 to .4		
	Weigh charge materials	Coke dust Limestone dust	3 to 5gr./cu.ft. Moderate	Fine to coarse 30 to 1,000		
MELTING	Cupola furnace melting	Fly ash, dust Coke breeze Smoke Metallic oxides Sulfur compounds Oil vapors Carbon monoxide	.2 to 5gr./cu.ft. 5gr./cu.ft. & up Heavy Moderate to heavy Light Light Heavy	8 to 20 Fine to coarse .01 to .4 To .7 .03 to 1 -	Moderate to Difficult	High
	Electric furnace melting	Smoke Metallic oxides Oil vapors	Heavy Moderate Heavy	.01 to .4 To .7 .03 to 1	Moderate	Medium to high
	Induction furnace melting	Oil vapors, metallic oxides			Easy	Little or none
	Reverberatory (Air) furnace	Smoke Oil vapors Metallic oxides Fly ash, sulfur compounds	Moderate Moderate Moderate .2 to 5gr./cu.ft.	.01 to .4 .03 to 1 To .7 8 to 20	Difficult	High
	Furnace charge preheating or drying	Smoke, dust Oil vapors Metallic oxides Metallic oxides	Light to heavy Light to heavy 1.24#/ton .41#/ton	.01 to .4 .03 to 1 75%-5 to 60 bottom fired 0 to 20 top fired	Easy	Low
	Holding furnaces	Iron oxide Oil vapor	Light Light	Fine to medium .03 to 1	Easy to moderate	Low
	Duplexing furnaces	Oil vapor Metallic oxides	Light Light	.03 to 1 To .7	Easy	None to medium
	Inoculation	Metallic oxides	Heavy	To 0.7	Moderate	Medium
MOLDING, POURING AND SHAKEOUT	Molding	Dust, mist Vapor	Light	Coarse	Easy	Low

A B

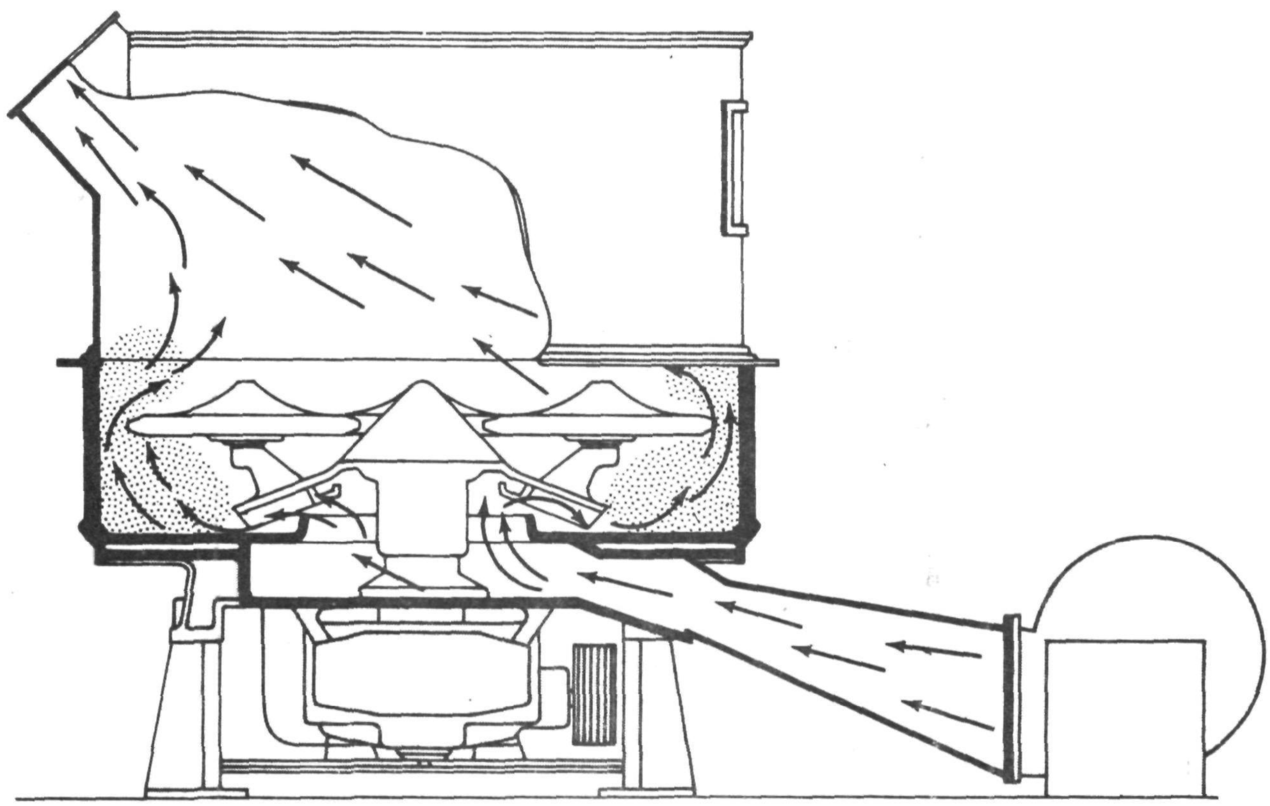
CHARACTERISTICS AND SOURCES OF EMISSIONS IN VARIOUS FOUNDRY DEPARTMENTS

DEPARTMENT	OPERATION	EMISSIONS TYPE	EMISSIONS CONCENTRATION	EMISSIONS PARTICLE SIZE (Microns)	RELATIVE CONTROL-LABILITY	RELATIVE COST
MOLDING, POURING AND SHAKEOUT (Cont'd)	Pouring				Moderate	Medium
	Gray and ductile iron	Core gases	Heavy			
	Malleable	Facing fumes	Heavy			
		Metallic oxides	Light	Fine to medium		
		Fluoride fumes	Heavy			
		Magnesium oxide fumes	Heavy	.01 to .4		
		Synthetic binder Smoke and fumes	Moderate to heavy			
	Shakeout	Dust	3 to 5gr./cu.ft.	50%-2 to 15	Moderate	Medium
		Smoke	Heavy	.01 to .4		
		Steam	Heavy			
CLEANING AND FINISHING	Abrasive cleaning	Dust	3gr./cu.ft.& up	50%-2 to 15	Easy	Low
	Grinding	Metal dust	5gr./cu.ft.& up	Above 7	Medium	Low
		Sand dust	3 to 5gr./cu.ft.	Fine to medium		
		Abrasive dust	.5 to 2gr./cu.ft.	50%-2 to 7		
		Wheel bond material	Light	Fine		
		Vitrified resins	Light	50%-2 to 15		
	Annealing and heat treating	Oil vapors, gas products of combustion		.03 to 1	Moderate	Low
	Painting	Solvent vapors			Easy	Low
	Spray and dip	Paint spray carry-over	.5 to 2gr./cu.ft.	50%-2 to 7		
		Water spray carry-over				
SAND CONDITIONING	New sand storage	Dust	3 to 5gr./cu.ft.	50%-2 to 15	Moderate	High
	Sand handling system	Dust	3 to 5gr./cu.ft.	50%-2 to 15	Moderate	Medium
		Steam				
	Screening	Dust	3 to 5gr./cu.ft.	50%-2 to 15	Easy	Low
	Mixing	Dust	3 to 5gr./cu.ft.	50%-2 to 15	Easy	Medium
		Flour	Moderate	Fine to medium		
		Bentonites	Moderate	Fine to medium		
		Sea coal	Moderate	Fine to medium		
		Cellulose	Moderate	Fine to medium		
	Drying and reclamation	Dust	1/2 to 2gr./cu.ft.	50%-7 to 15	Easy	Medium
		Core gases		.03 to 1		

A

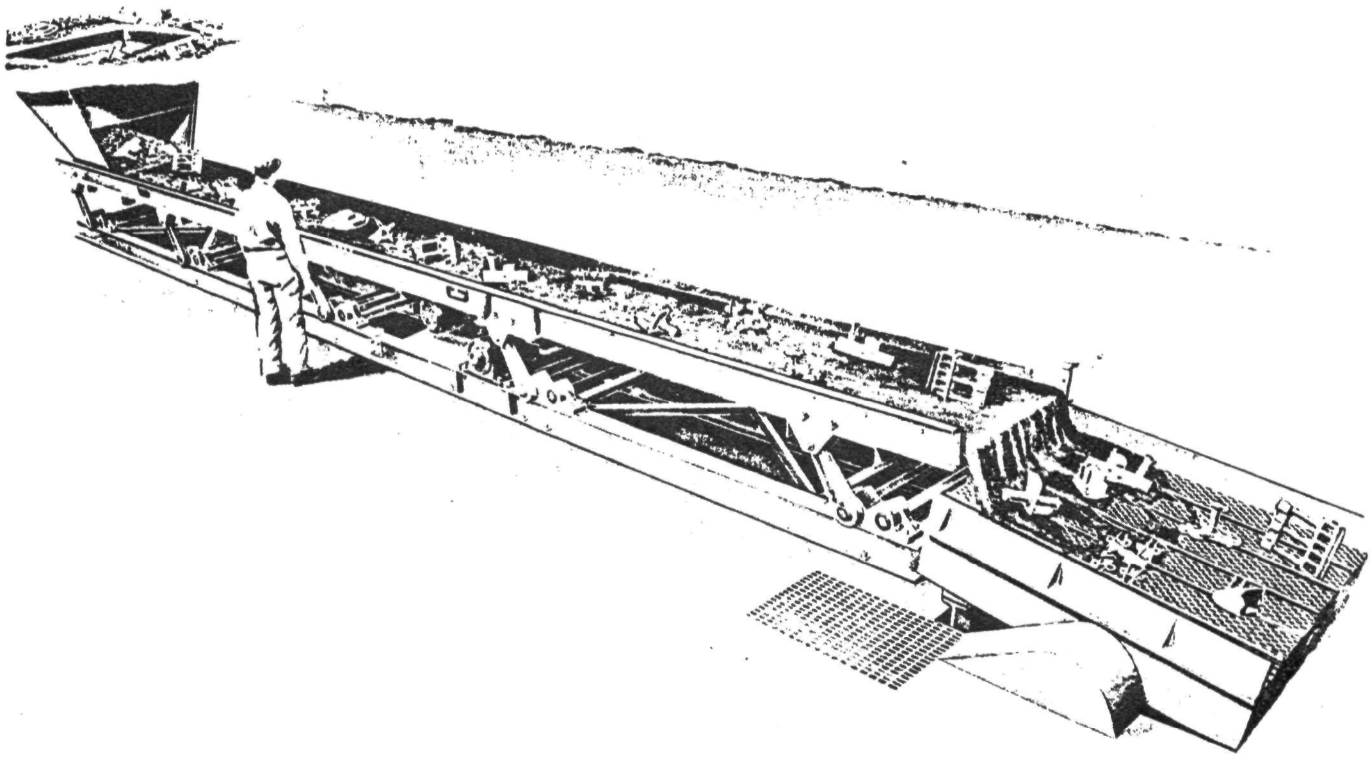
B

ILLUSTRATION OF SAND MULLER



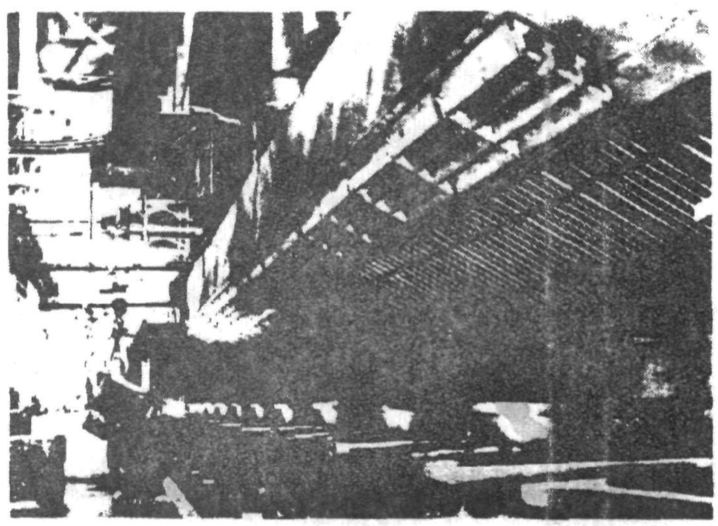
Source: Beardsley & Piper.

ILLUSTRATION OF SHAKEOUT STATION



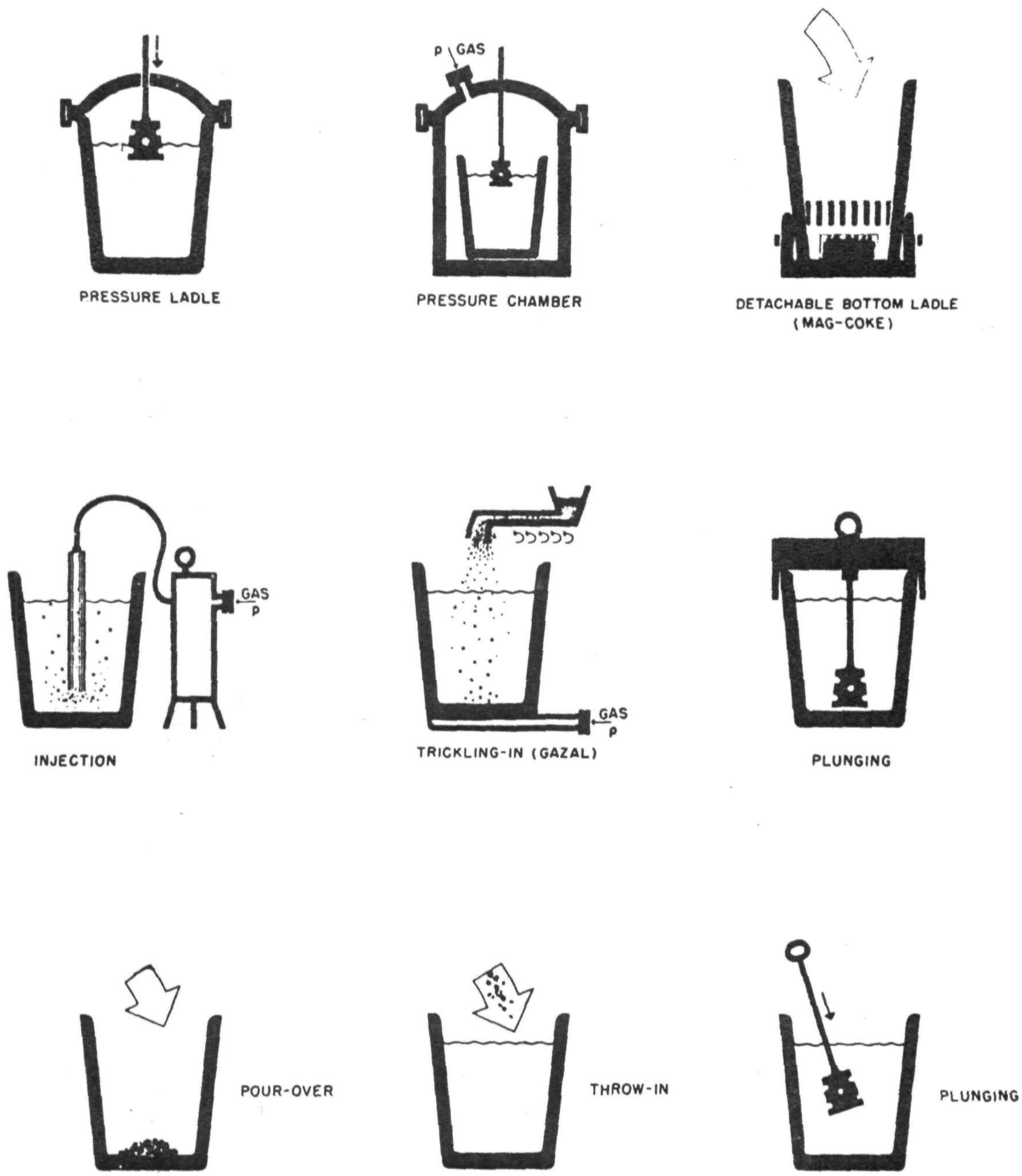
Source: Molding Methods and Materials;
Published by the American
Foundrymen's Society, 1962, p. 205.

ILLUSTRATION OF POURING STATION WITH HORIZONTAL DRAFT, CANTILEVERED HOOD



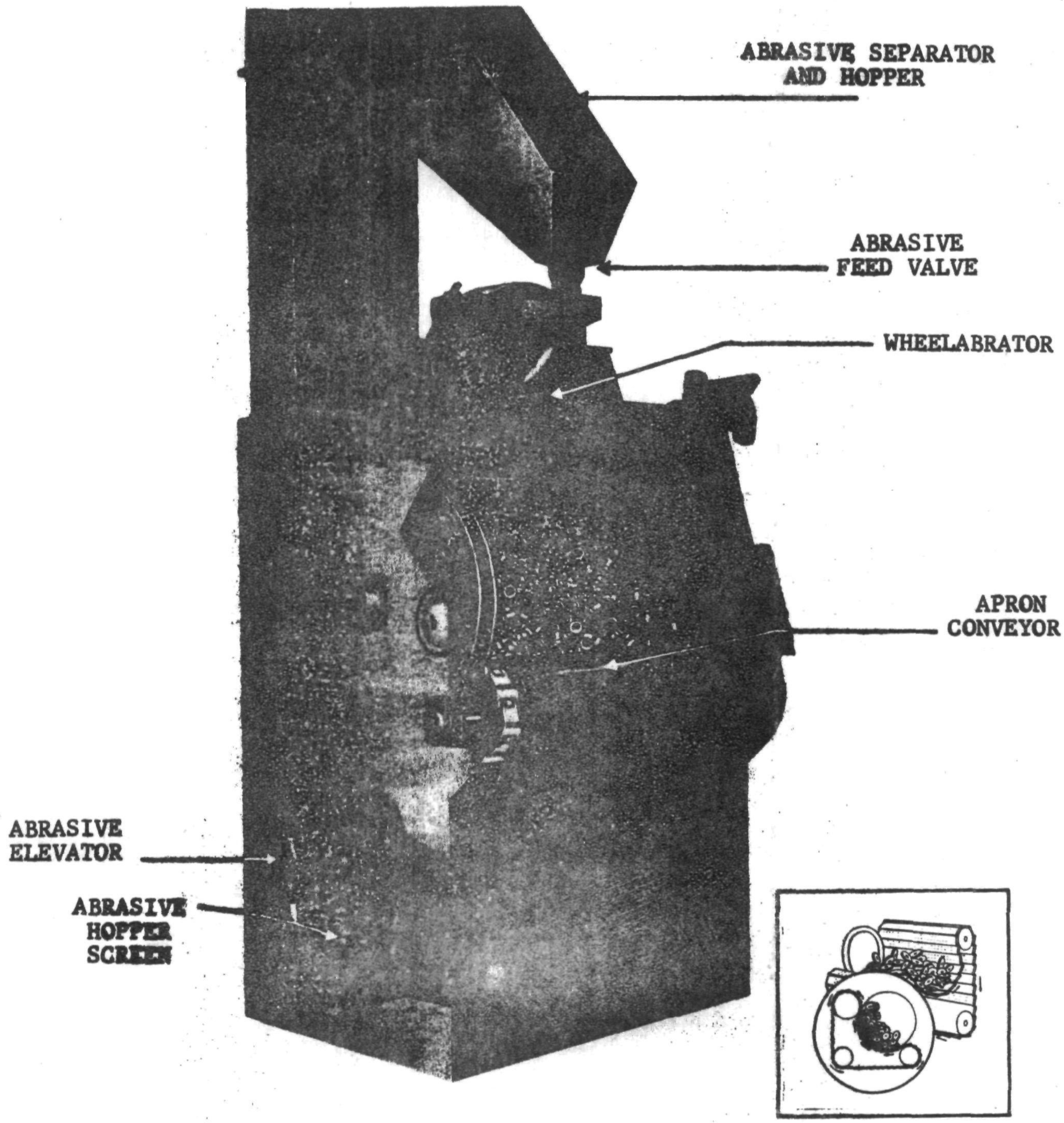
Source: Modern Casting, published by the American Foundrymen's Society, Inc., November, 1970, p. 83.

ILLUSTRATION OF MAGNESIUM TREATMENT METHODS FOR PRODUCING DUCTILE IRON



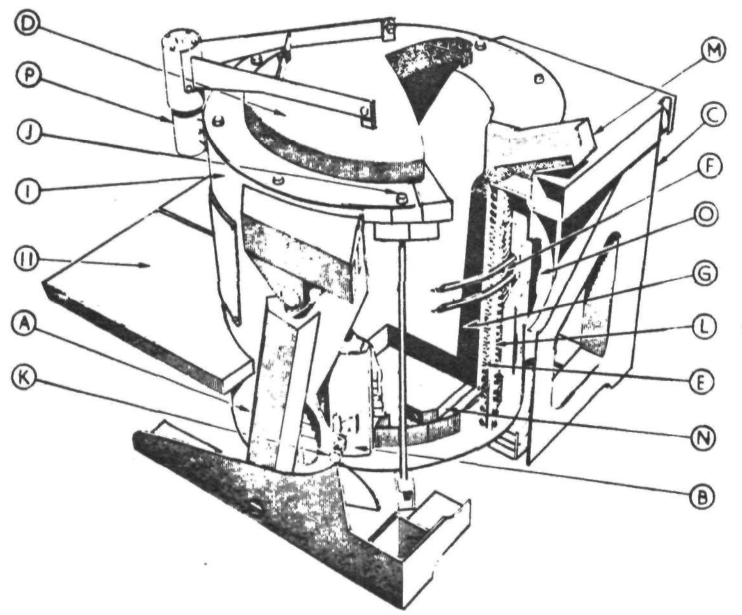
Source: "Comparing Processes for Making Ductile Iron," E. Modl, FOUNDRY, July, 1970, pp. 44-46.

ILLUSTRATION OF REVERBERATORY FURNACE



Source: Eclipse Fuel Engineering Company.

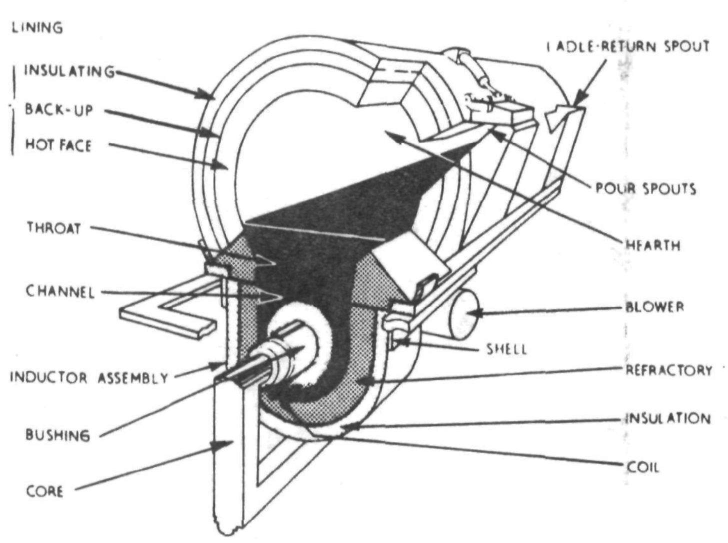
ILLUSTRATION OF CORELESS INDUCTION FURNACE



A. HYDRAULIC TILT CYLINDERS
B. SHUNTS
C. STANCHION
D. COVER
E. COIL
F. LEADS
G. WORKING REFRACTORY
H. OPERATOR'S PLATFORM
I. STEEL SHELL
J. TIE RODS
K. CLAMPING BOLTS
L. COIL SUPPORT
M. SPOUT
N. REFRACTORY BRICK
O. ACCESS PORT
P. LID HOIST MECHANISM

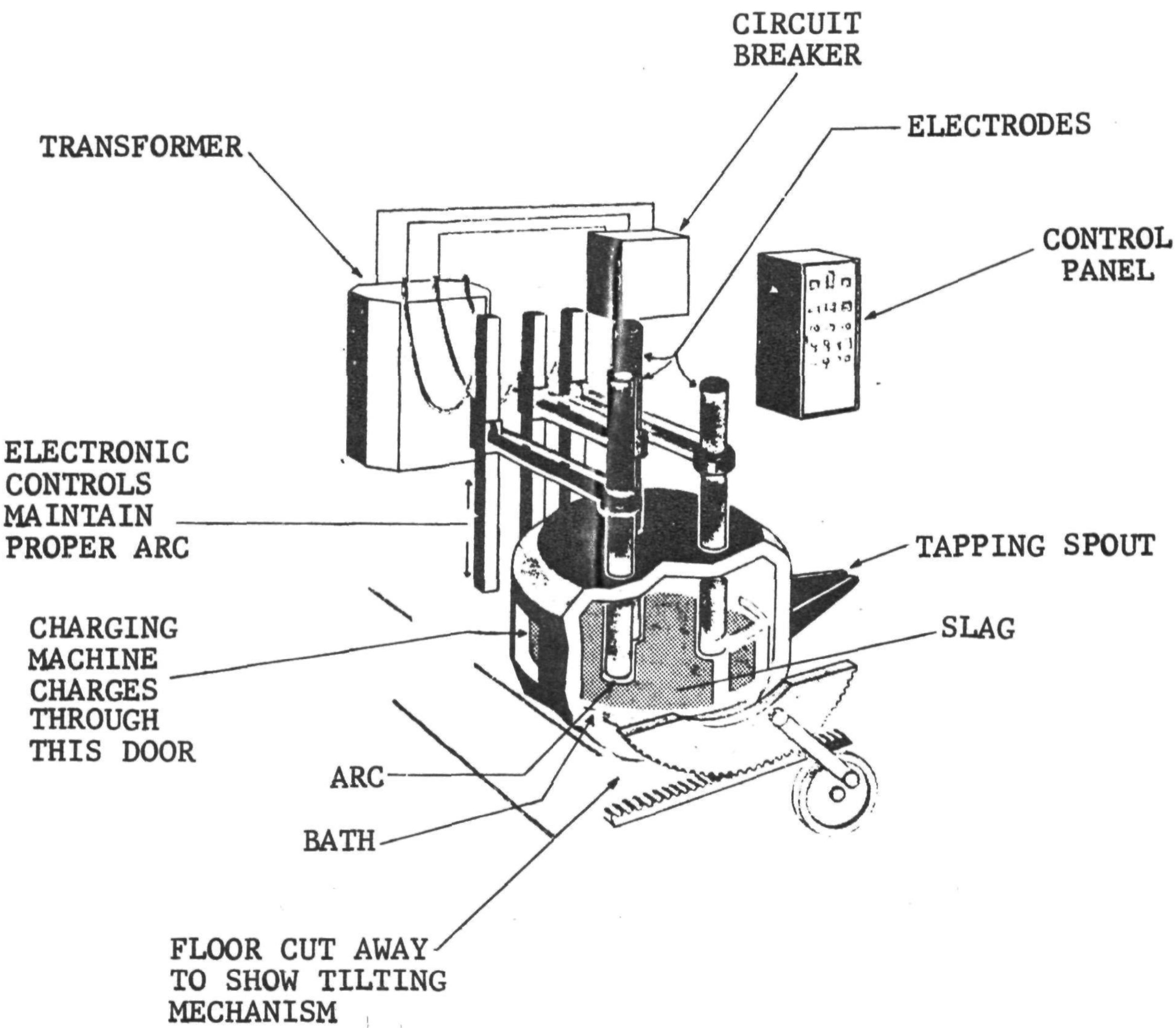
Source: "Electric Melting for Mass Production in U.S. Iron Foundries," Modern Casting, July, 1968, p. 47.

ILLUSTRATION OF CHANNEL INDUCTION FURNACE



Source: "Electric Melting for Mass Production in U.S. Iron Foundries," Modern Casting, July, 1968, p. 47.

ILLUSTRATION OF ELECTRIC ARC FURNACE



Source: The Picture Story of Steel, published by the American Iron and Steel Institute, 1952, p. 18.

ILLUSTRATION OF CUPOLA REACTION AREA

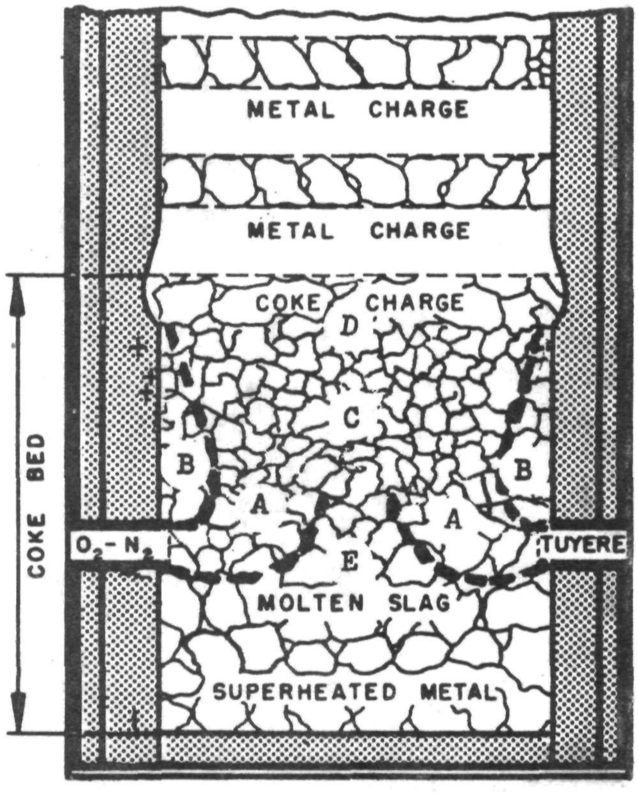
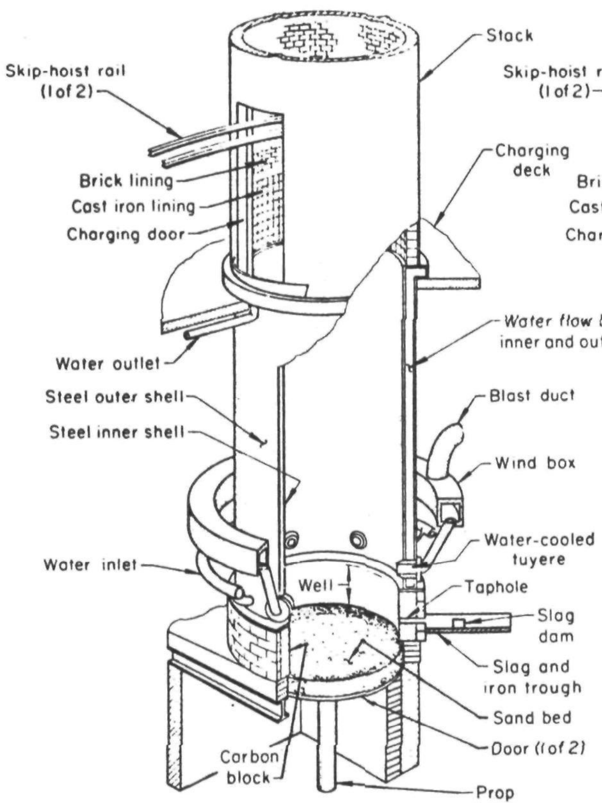


Fig. 3.3. Cross-section of cupola showing reaction areas.

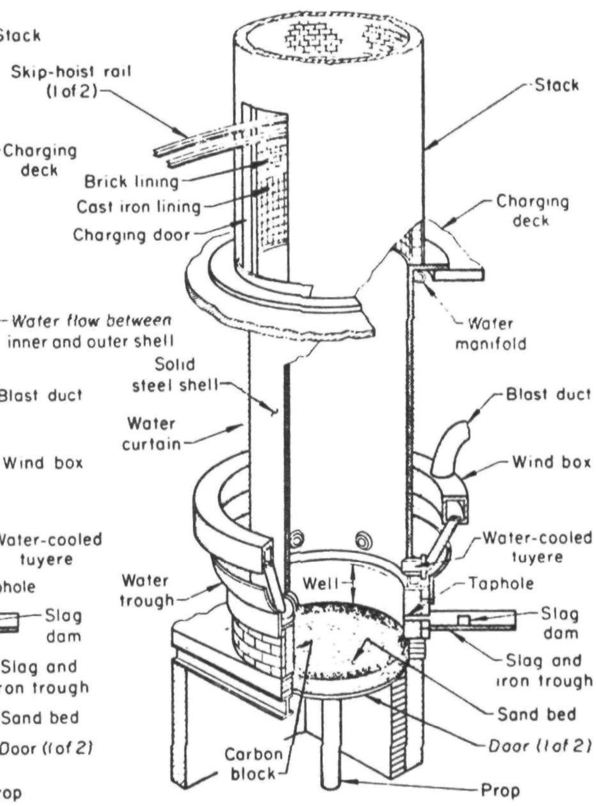
A — $O_2 + CO_2$
B — Area high in O_2
C — $CO + CO_2$
D — High $CO: CO_2$ ratio
E — High $CO: CO_2$ ratio

Source: The Cupola and Its Operation; published by the American Foundrymen's Society, Third Edition, 1965, p. 26.

ILLUSTRATION OF WATER-COOLED CUPOLA



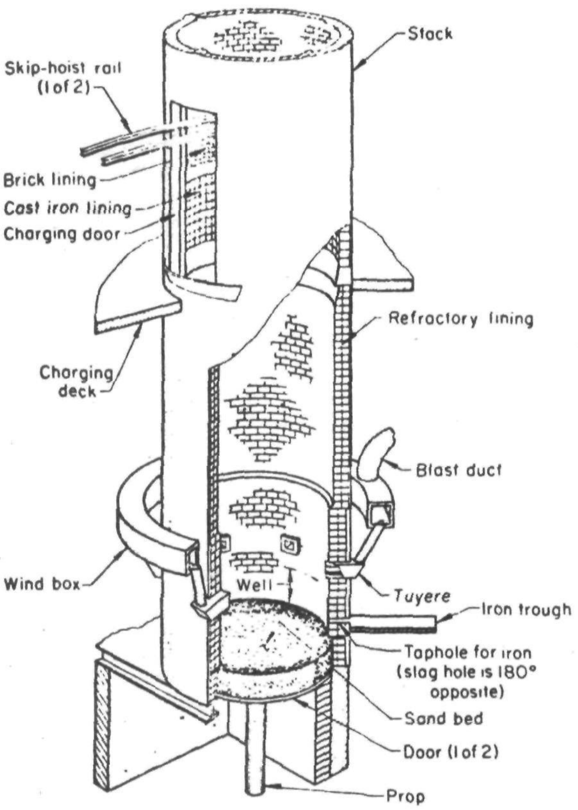
Water-cooled cupola (water-wall)



Water-cooled cupola (flood cooled)

Source: Metals Handbook, 8th Edition, Vol. 5, Forging and Casting, American Society for Metals, 1970, p. 337.

ILLUSTRATION OF CONVENTIONAL LINED CUPOLA

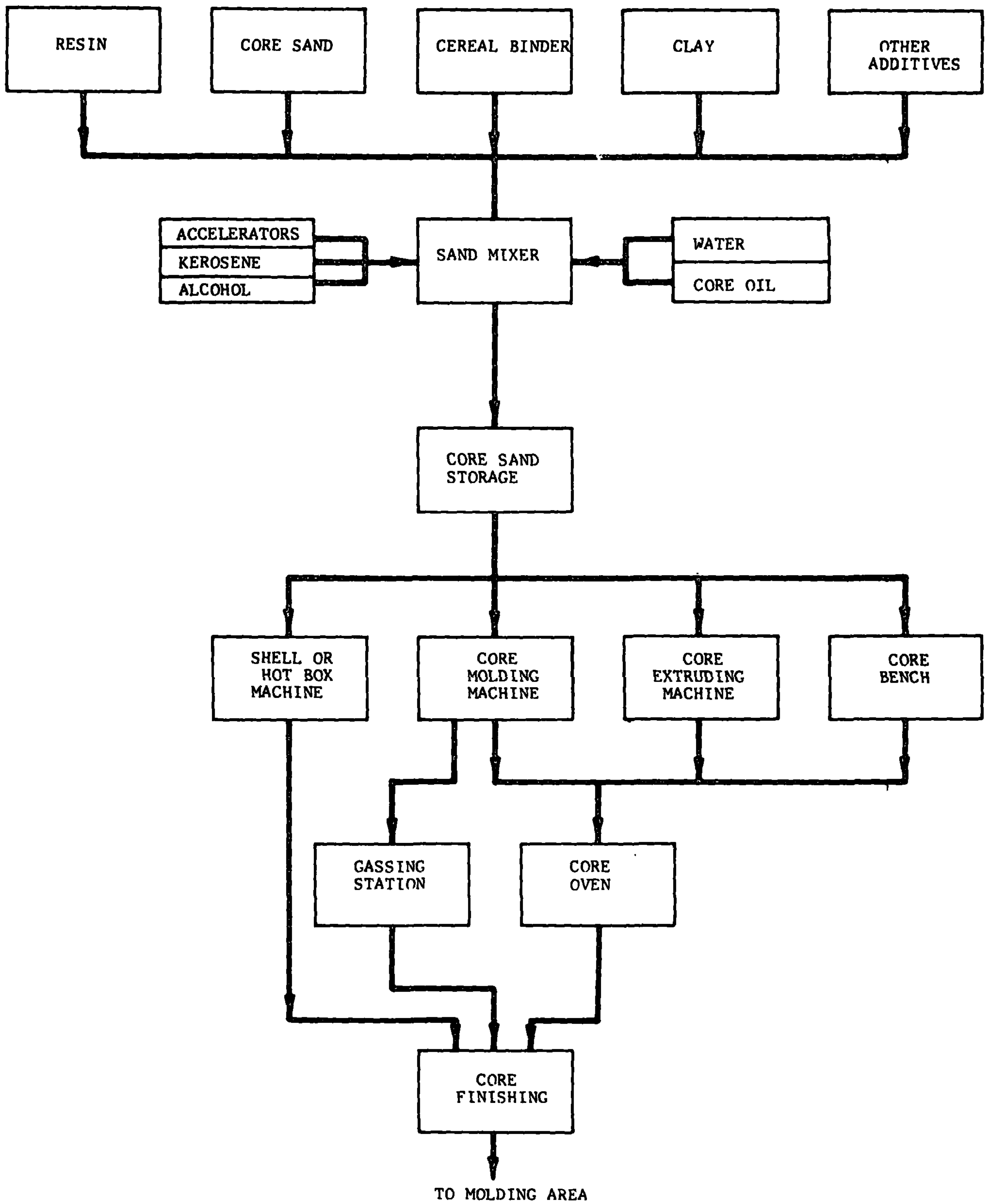


Conventional cupola

Source: Metals Handbook, 8th Edition, Vol. 5, Forging and Casting, American Society for Metals, 1970, p. 337.

PROCESS FLOW DIAGRAM

CORE MAKING



PROCESS FLOW DIAGRAM

SAND CONDITIONING

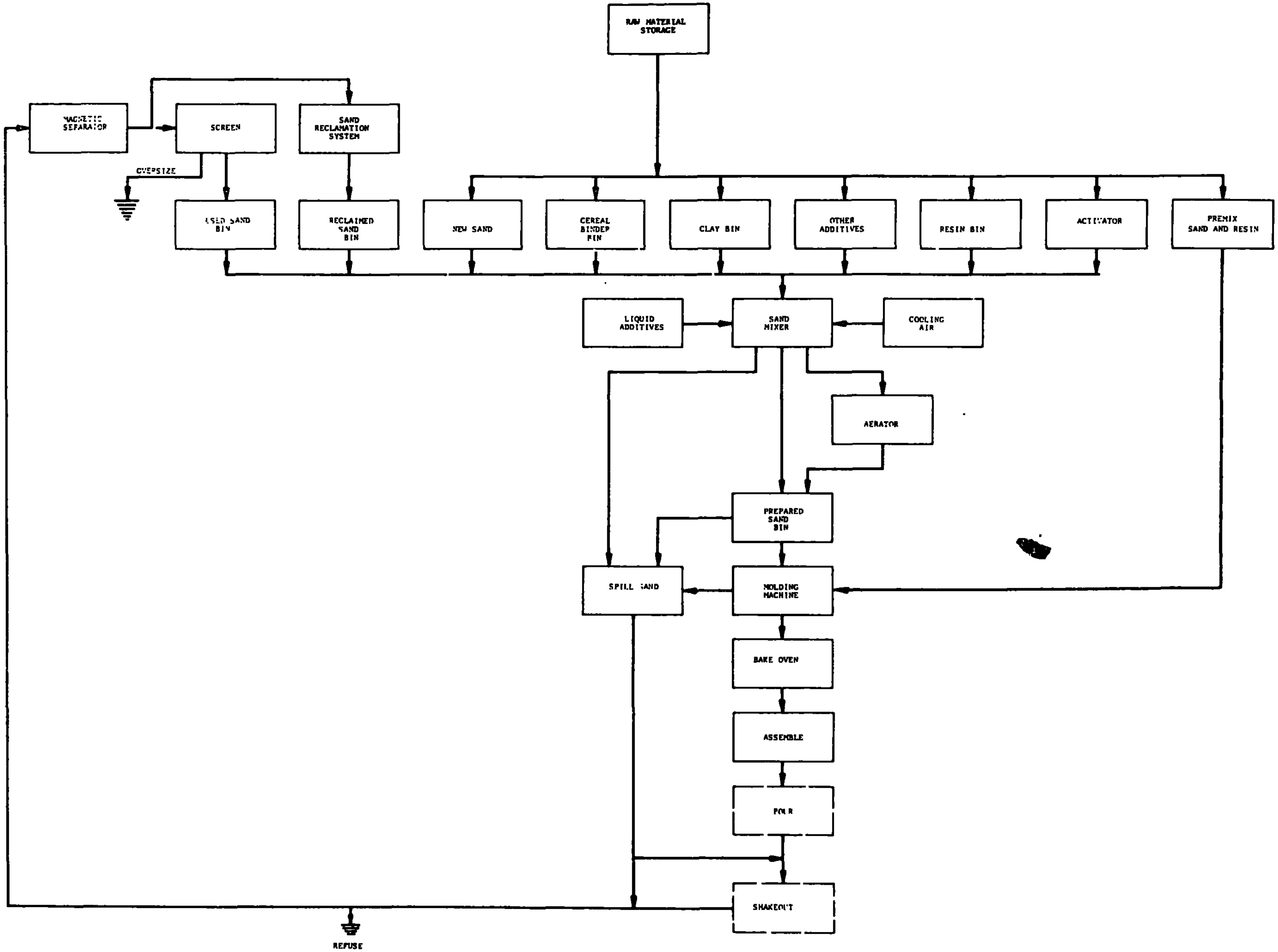
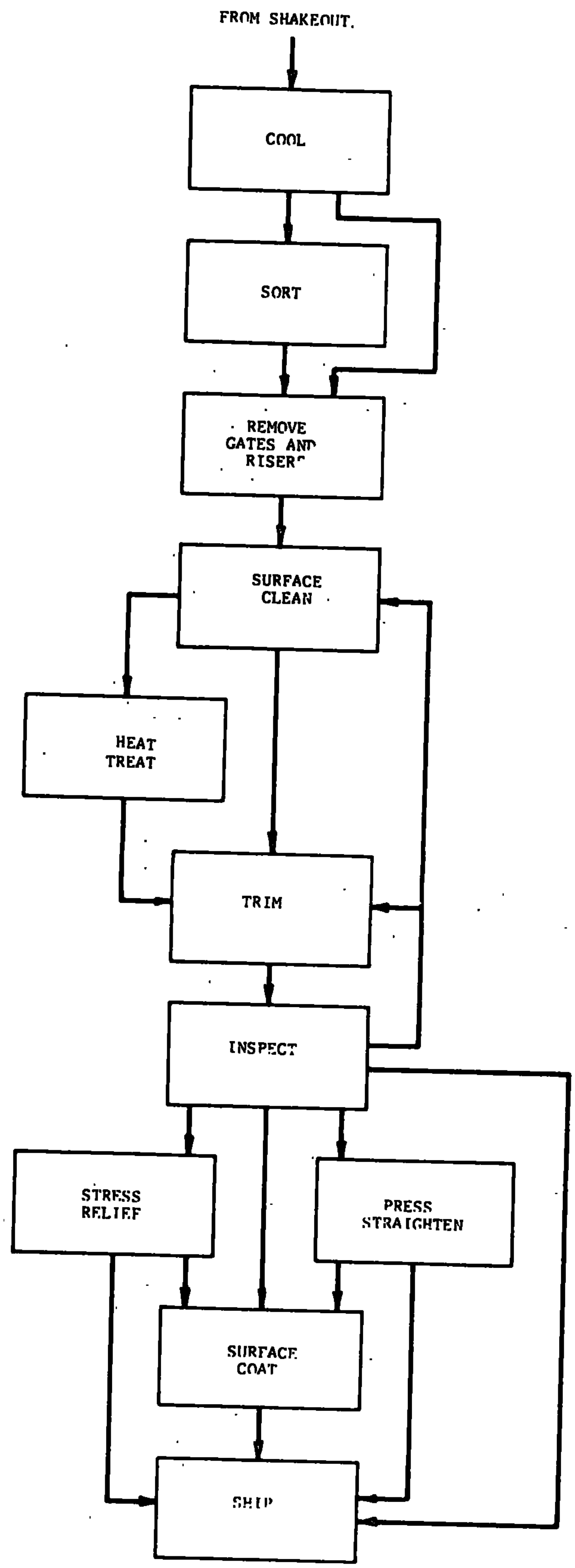


EXHIBIT IV-14

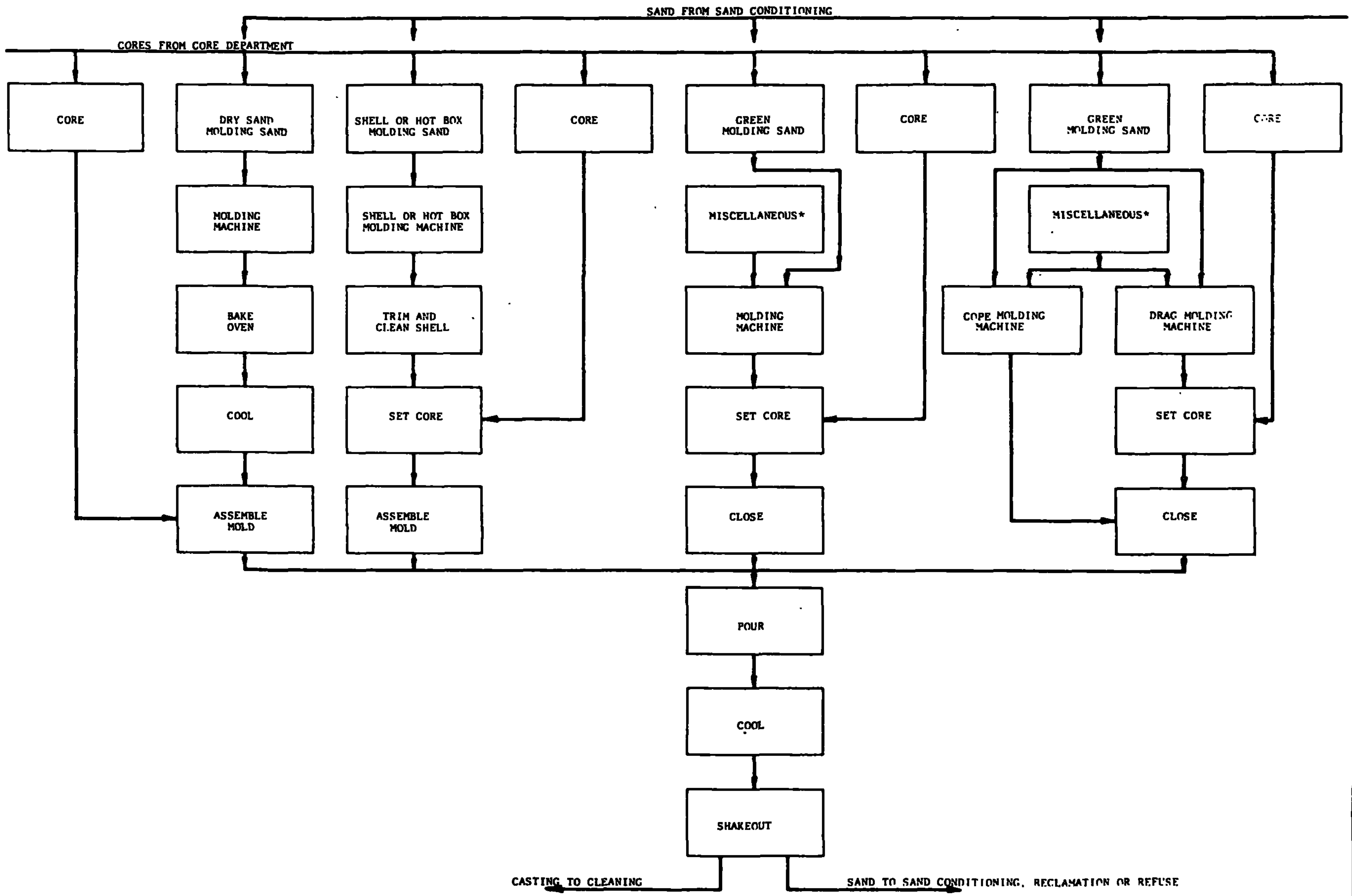
PROCESS FLOW DIAGRAM

CLEANING & FINISHING



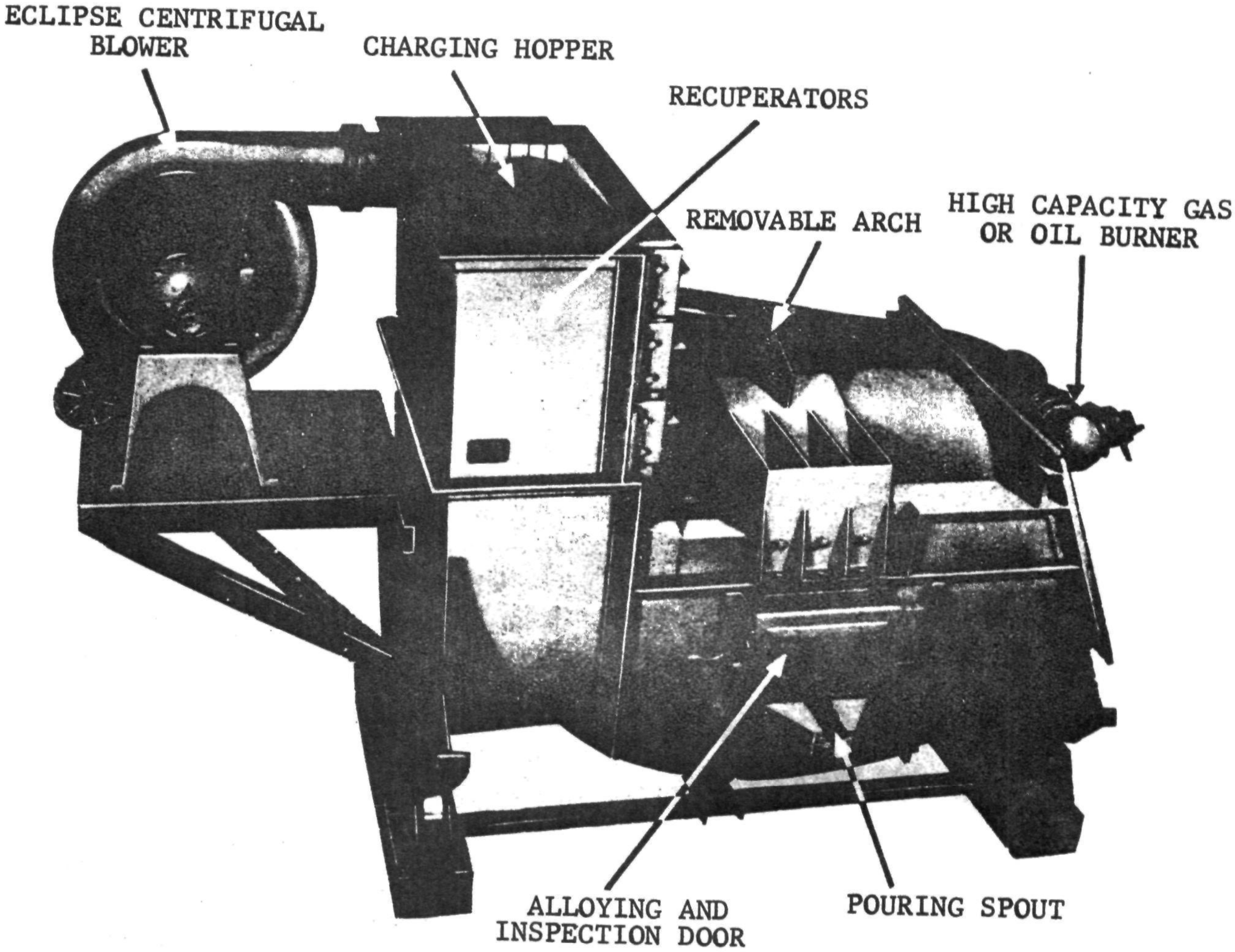
PROCESS FLOW DIAGRAM

MOLDING, POURING & SHAKEOUT



* MISCELLANEOUS - PARTING COMPOUND, WASH, CHAPLETS, ETC.

ILLUSTRATION OF REVERBERATORY FURNACE

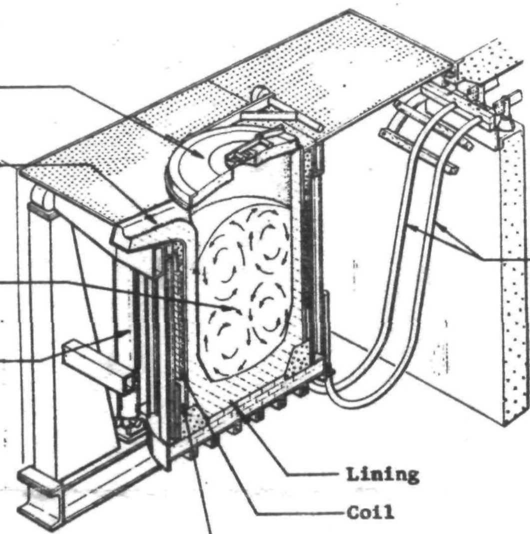


Source: The Wheelabrator Corporation.

HEAT BALANCE	BTU/TON (x 000)	PERCENT
INPUT HEAT		
ELECTRICAL ENERGY	1,669	100.0
OUTPUT HEAT		
MELTING AND SUPER-HEATING IRON	1,131	68.4
ELECTIRCAL LOSSES	325	19.1
TRANSMISSION LOSSES	81	4.7
HEAT LOSS	132	7.8
TOTAL	1,669	100.0

NOTE: ENERGY QUANTITIES INCLUDE ONLY THEORETICAL REQUIREMENTS FOR HEATING, MELTING, AND SUPERHEATING TO 2800° F, AND NORMAL ELECTRICAL, TRANSMISSION AND HEAT LOSSES. THE TOTAL IS LESS THAN THE AVERAGE USED IN NORMAL PRACTICE SINCE IT DOES NOT INCLUDE ALLOWANCES FOR HOLDING, OR NORMAL OPERATING DELAYS.

MATERIAL BALANCE	POUNDS	PERCENT
INPUT MATERIALS		
RETURNS	378	18.6
STEEL SCRAP	1,351	66.7
IRON CHIPS	188	9.3
FERROALLOYS	43	2.1
LINING	6	.3
CARBO-COKE	61	3.0
TOTAL	2,027	100.0
OUTPUT MATERIALS		
MOLTEN IRON	2,000.0	98.7
SLAG	10.0	.5
EMISSIONS		
GASEOUS	15.5	.7
PARTICULATE	1.5	.1
TOTAL	2,027.0	100.0



CORELESS INDUCTION FURNACE - HEAT AND MATERIAL BALANCE

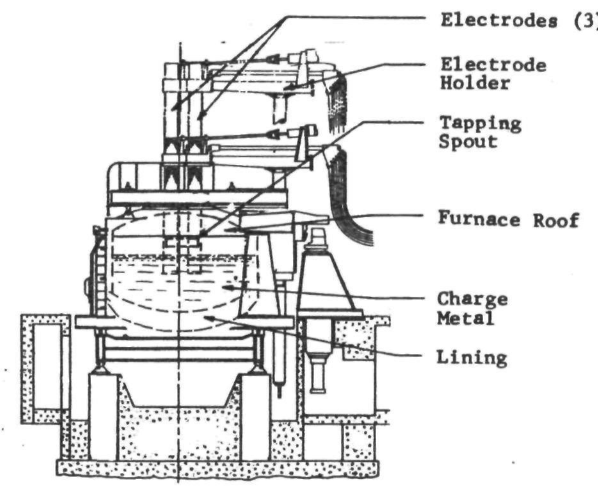
HEAT BALANCE

	BTU/Ton (x1000)	Percent
Input Heat		
Electrical Energy	1,907	100.0
Output Heat		
Melting and Superheating Iron	1,132	59.3
Heat Content of Slag	81	4.3
Decomposition of Water	9	.5
Gases		
Sensible Heat	231	12.1
Latent Heat	-138	- 7.2
Heat, Electrical and Cooling Losses	592	31.0
Total	1,407	100.0

NOTE: Energy quantities include only theoretical requirements for heating, melting, and superheating to 2800° F, and normal electrical, transmission and heat losses. The total is less than the average used in normal practice since it does not include allowances for holding, or normal operating delays.

MATERIAL BALANCE

	Pounds	Percent
Input Material		
Returns	1,388	56.9
Steel Scrap	630	25.8
Ferroalloys	17	.7
Carbo-Coke	31	1.3
Electrodes	10	.4
Air	318	13.0
Moisture	8	.3
Lining	38	1.6
Total	2,440	100.0
Output Material		
Molten Iron	1,997	81.8
Slag	93	3.8
Particulate Emissions	14	.6
Gaseous Emissions	336	13.8
Total	2,440	100.0



ELECTRIC ARC FURNACE - HEAT AND MATERIAL BALANCE

EXHIBIT IV-10

PROCESS FLOW DIAGRAM

MELTING DEPARTMENT

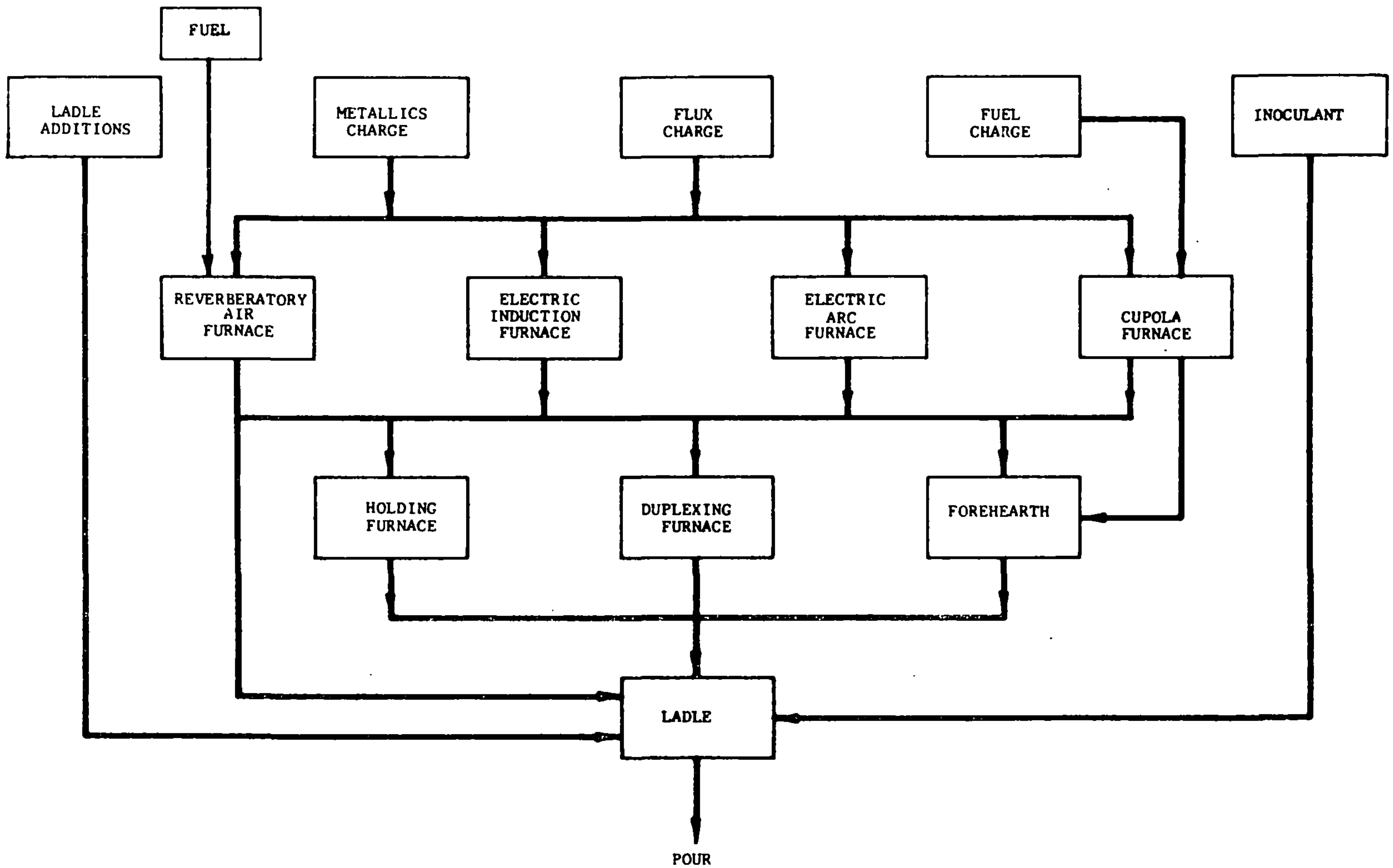
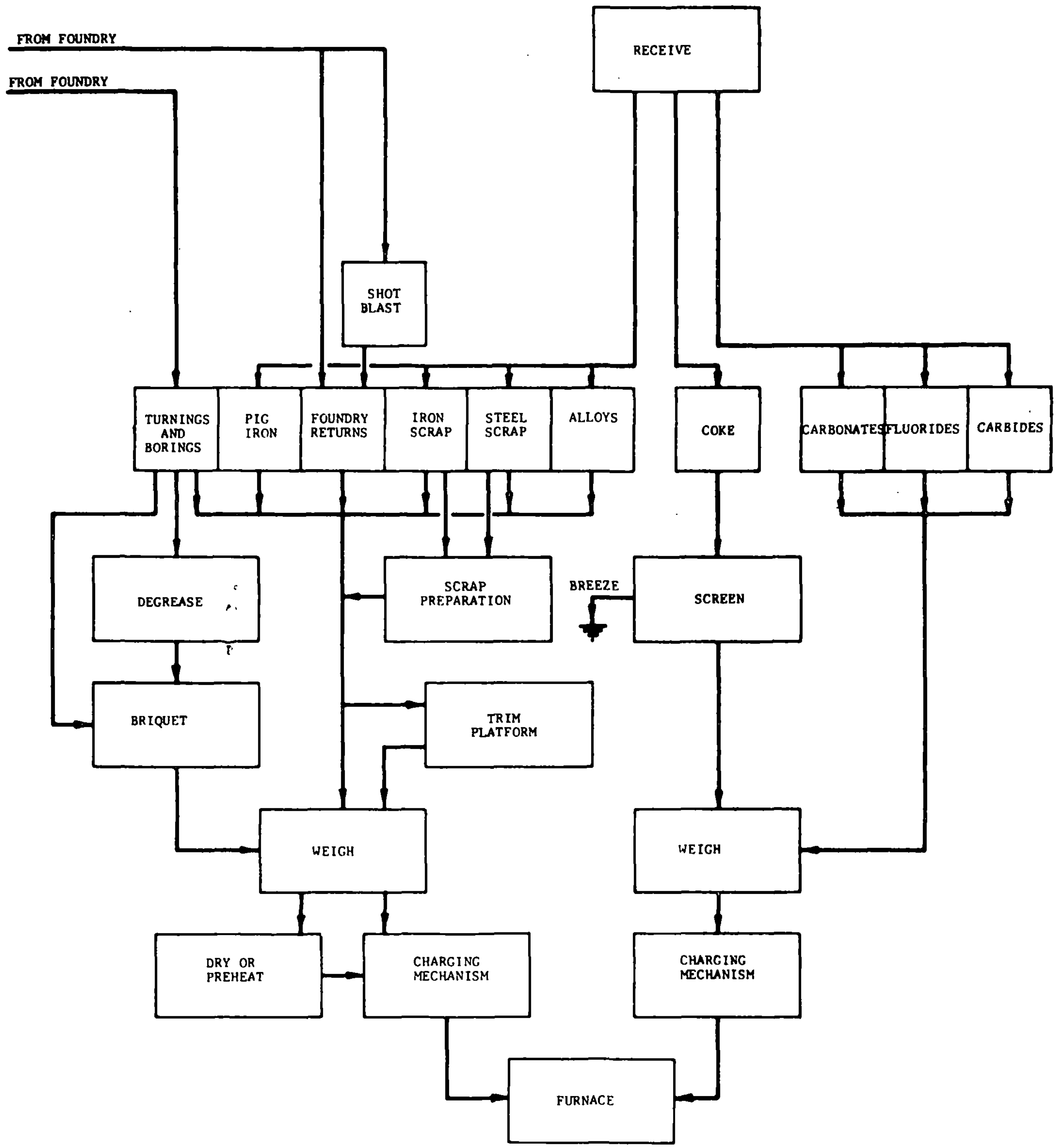


EXHIBIT IV-9

EXHIBIT IV-8

PROCESS FLOW DIAGRAM

RAW MATERIAL STORAGE AND FURNACE CHARGE MAKEUP



PIG IRON AND FERROALLOY SPECIFICATIONS

Designation	Silicon Percent	Sulfur Max. Percent	Phosphorus Percent	Manganese Percent	Carbon Percent
Fl - Foundry, low Phosphorus	1.75 - 3.50	.05	.30 - .50	.50 - 1.25	-
Fh - Foundry, high phosphorus	1.75 - 3.50	.05	.501 - .700	.50 - 1.25	-
Fs - Foundry, Southern	1.75 - 3.50	.05	.70 - .90	.40 - .75	-
S - Silvery	5.0 - 17.0	.05	.30 Max.	1.0 - 2.00 Max.	-
Ferromanganese	1.25 Max.	.05	.10 - .35 Max.	.78 - .85	Up to 7.50
Ferrophosphorus	1.50 - 1.75	.05	17.0 - 25.0 Max.	.07 - .50	1.1 - 2.0
Spiegeleisen	1.0 Max.	.05	.25 Max.	16.0 - 28.0	6.5 Max.
Ferrosilicon	8.0 - 18.0	.04 - .06	.05 - .15	-	.15 - 1.50

Source: The Modern Blast Furnace, Iron and Steel Engineers, April, 1946.

EXHIBIT IV-7

IRON FOUNDRY SCRAP SPECIFICATIONS

Source	Carbon Percent	Silicon Percent	Sulfur Percent	Phosphorus Percent	Manganese Percent
Agricultural and Stove Scrap	3.25 - 3.60	2.35 - 2.55	.08 - .13	.50 - .70	.50 - .70
Soil Pipe	3.25 - 3.60	2.35 - 2.50	.12 Max.	.65 - .90	.50 - .70
Automotive Blocks	3.10 - 3.45	2.10 - 2.50	.12 Max.	.15 - .30	.50 - .70
Malleable Iron	2.25 - 2.65	1.20 Max.	.05 Max.	.05 Max.	.40 Max.
Machinery Castings					
Light	3.35 - 3.55	2.25 - 2.55	.10 Max.	.20 Max.	.55 - .70
Medium	3.25 - 3.45	2.20 - 2.25	.12 Max.	.12 - .18	.55 - .70
Heavy	3.15 - 3.30	1.80 - 2.10	.12 Max.	.12 - .20	.65 - .75
Cast Iron Car Wheels	3.40 - 3.60	.60 - .80	.09 - .15	.15 - .25	.55 - .65
Ductile Iron	3.35 - 3.55	2.25 - 2.55	.04 Max.	.08 Max.	.50 Max.

Source: Adapted from "Maximum Limits for Specified Elements in Foundry Grade Scrap." Data collected by American Foundrymen's Society.

SUMMARY OF MALLEABLE IRON SPECIFICATIONS

TYPICAL COMPOSITION RANGES

Type	Grade	Carbon Percent Min.	Carbon Percent Max.	Silicon Percent Min.	Silicon Percent Max.	Manganese Percent Min.	Manganese Percent Max.	Sulfur Percent Min.	Sulfur Percent Max.	Phosphorus Percent Min.	Phosphorus Percent Max.
Ferritic Malleable Iron	32510	2.30	2.65	.90	1.65	.25	.55	.05	.18	-	.18
	35018	2.00	2.45	.95	1.35	.25	.55	.05	.18	-	.18
Pearlitic Malleable Iron	-	2.00	2.65	.90	1.65	.25	1.25	.05	.18	-	.18

Source: American Society for Metals Handbook, Vol. 1, 1961.

SUMMARY OF DUCTILE IRON SPECIFICATIONS

Specifying Body and Number	Use	Class or Grade	Tensile Strength Minimum PSI	Yield Strength Minimum PSI	Total Carbon Percent Min.	Total Carbon Percent Max.	Silicon Percent Min.	Silicon Percent Max.	Manganese Percent Min.	Manganese Percent Max.	Phosphorus Percent Min.	Phosphorus Percent Max.	Nickel Percent Min.	Nickel Percent Max.	Chromium Percent Min.	Chromium Percent Max.	Brinell Hardness Min.	Brinell Hardness Max.
American Society for Testing and Materials A439-62	Austenitic Ductile Iron Castings	D-2	58,000	30,000	-	3.00	1.50	3.00	.70	1.25	-	.08	18.00	22.00	1.75	2.75	139	202
		D-2B	58,000	30,000	-	3.00	1.50	3.00	.70	1.25	-	.08	18.00	22.00	2.75	4.00	148	211
		D-2C	58,000	28,000	-	2.90	1.00	3.00	1.80	2.40	-	.08	21.00	24.00	-	.50	121	171
		D-3	55,000	30,000	-	2.60	1.00	2.80	-	1.00	-	.08	28.00	32.00	2.50	3.50	139	202
		D-3A	55,000	30,000	-	2.60	1.00	2.80	-	1.00	-	.08	28.00	32.00	1.00	1.50	131	193
		D-4	60,000	-	-	2.60	5.00	6.00	-	1.00	-	.08	28.00	32.00	4.50	5.50	202	273
		D-5	55,000	30,000	-	2.40	1.00	2.80	-	1.00	-	.08	34.00	36.00	-	.10	131	185
		D-5B	55,000	30,000	-	2.40	1.00	2.80	-	1.00	-	.08	34.00	36.00	2.00	3.00	139	193
American Society for Testing and Materials A445-63T	Ferritic Ductile Iron Castings for Valves, Flanges, Pipe Flanges, Pipe Fittings and Other Piping Components	60-45-15	60,000	45,000	3.00	-	-	2.50	-	-	-	.08	-	-	-	-	149	201

Source: Gray and Ductile Iron Founders' Society, Inc.

EXHIBIT IV-4

SUMMARY OF GRAY IRON SPECIFICATIONS

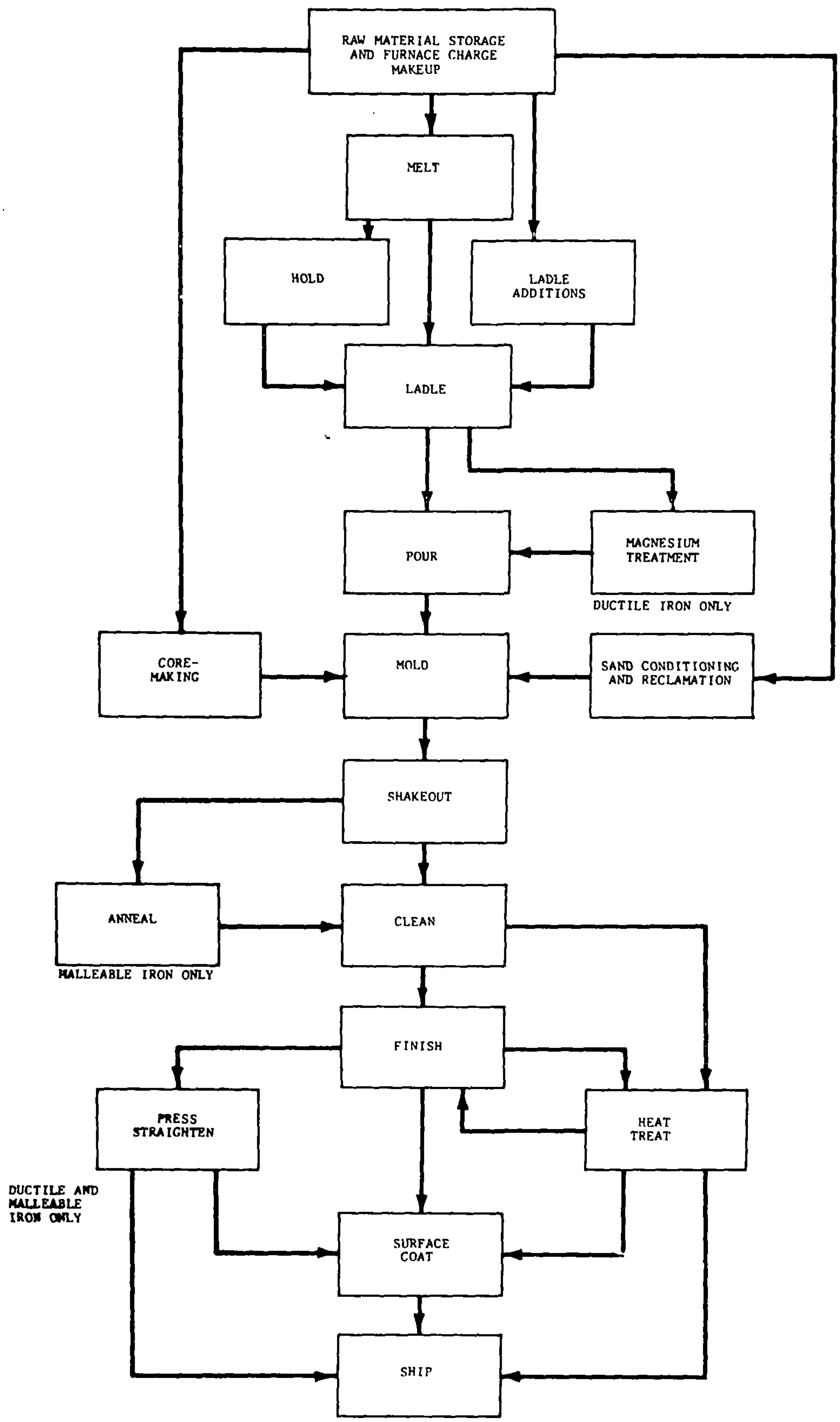
Specifying Body	Specifying Number	Class	Tensile Strength Minimum PSI	Brinell Hardness Minimum	Brinell Hardness Maximum	Total Carbon Percent Minimum	Total Carbon Percent Maximum	Silicon Percent Minimum	Silicon Percent Maximum
American Society for Testing and Materials	A159-62T	G2000(110)	20,000	-	187	3.40	3.70	2.30	2.80
		G3000(111)	30,000	170	223	3.20	3.50	2.00	2.30
		G3000a(113)	30,000	179	229	3.40	-	1.10	2.10
		G4000b(114)	40,000	207	269	3.40	-	1.10	1.80
Society of Automotive Engineers	J431a	G3500c(115)	35,000	187	241	3.50	-	1.10	1.80
		G3500(120)	35,000	187	241	3.10	3.40	1.90	2.20
		G4000(121)	40,000	202	255	3.00	3.30	1.80	2.10
General Services Administration	QQ-1-653	G4500(122)	45,000	217	269	3.00	3.30	1.80	2.10
		G4000d(123A)	40,000	248	311	3.10	3.40	2.10	2.40
		G4000e(123B)	40,000	248	311	3.10	3.45	2.10	2.40
		G4000f(123C)	40,000	248	311	3.40	3.75	2.10	2.35

Source: Gray and Ductile Iron Founders' Society, Inc.

EXHIBIT IV-2

PROCESS FLOW DIAGRAM

GRAY, DUCTILE AND MALLEABLE IRON



NOTE: ALL OPERATIONS APPLY TO GRAY, DUCTILE AND MALLEABLE IRON UNLESS OTHERWISE NOTED.

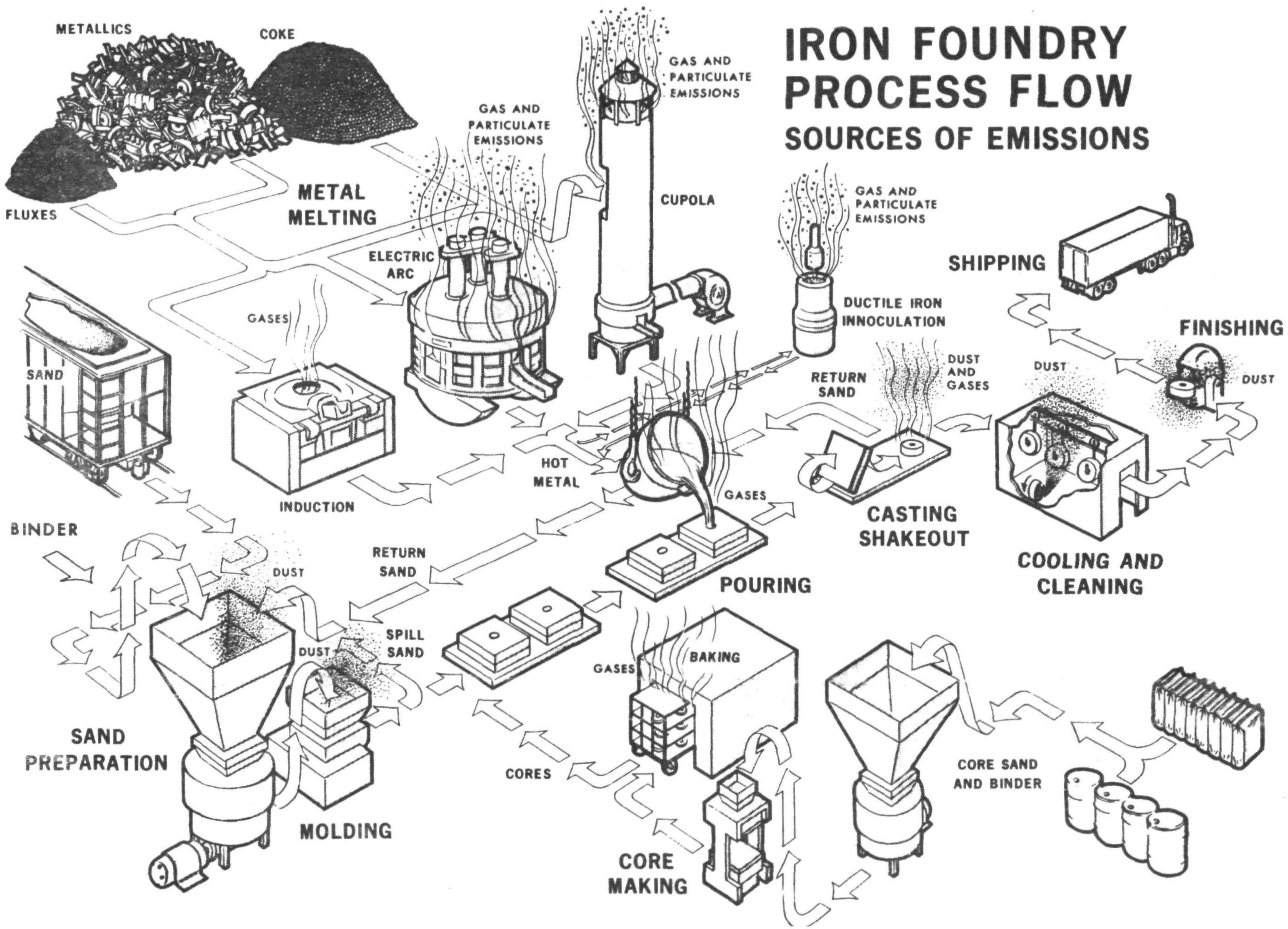

IRON FOUNDRY
PROCESS FLOW
SOURCES OF EMISSIONS
METALLICS
COKE
FLUXES
METAL
MELTING
GAS AND
PARTICULATE
EMISSIONS
GAS AND
PARTICULATE
EMISSIONS
CUPOLA
ELECTRIC
ARC
GASES
INDUCTION
SAND
GAS AND
PARTICULATE
EMISSIONS
DUCTILE IRON
INNOCULATION
SHIPPING
FINISHING
DUST
DUST
RETURN
SAND
DUST
AND
GASES
HOT
METAL
GASES
CASTING
SHAKEOUT
COOLING AND
CLEANING
POURING
BINDER
DUST
RETURN
SAND
SPILL
SAND
DUST
SAND
PREPARATION
MOLDING
GASES
BAKING
CORES
CORE
MAKING
CORE SAND
AND BINDER

EXHIBIT IV-1

CHARACTERISTICS AND SOURCES OF EMISSIONS IN VARIOUS FOUNDRY DEPARTMENTS

DEPARTMENT	OPERATION	EMISSIONS			RELATIVE CONTROL-LABILITY	RELATIVE COST
		TYPE	CONCENTRATION	PARTICLE SIZE (Microns)		
COREMAKING	Sand storage	Dust Flour Binders	Heavy 3 to 5gr./cu.ft.	Fine 50%-7 to 15	Moderate	High
	Coremaking	Resin dust Sand dust	Heavy Light	Fine to medium Fine to medium	Moderate	Medium
	Baking	Vapors, gases Smoke	-	-	Easy	Medium

A B

TEST METHODS

Method A. This method is based on the determination of the average dust concentration at the inlet of the separator and at the outlet of the separator. From these data the efficiency can be computed in accordance with the equations given in Section 5 of reference, which are based on the assumption that no change in the mass of gas flowing takes place between the two sampling locations. It is not necessary to know the gas flow rate or total quantity passing through the separator for the duration of each run, nor is it necessary to weigh or sample the dust caught by the separator.

Method B. This method is based on the quantity of dust caught, the dust concentration at the outlet of the separator, and the total quantity of gas passing through the separator. Obviously, this method can be applied only to those installations where the dust can be removed from the hopper in the dry state for the period of each test run. Also, it is necessary to measure the total quantity of gas passing through the separator with reasonable accuracy in order to correlate the average outlet dust concentration with the total quantity of dust caught. For method of computation see Section 5 of reference.

Method C. This method is based on the quantity of dust caught, the dust concentration at the inlet of the separator, and the total quantity of gas passing through the separator. The other factors relative to measurement by this method apply as in Method B. [4]

PERTINENT ASME ITEMS WHICH MUST BE CONFORMED TO BY PARTIES CONDUCTING A STACK SAMPLING TEST

(a) The object or objects of the test.

(b) Time of making the test.

(c) That the dust separator is in a satisfactory condition for testing at the time selected.

(d) Whether the test is to be made by Method A, Method B, or Method C.

(e) The number, type, and location of dust samplers and other instruments to be employed where alternatives are permitted.

(f) Method of maintaining constancy of test conditions.

(g) Gas flow rates or boiler loads at which runs are to be made.

(h) Method of determining gas flow through separator, i.e., by Pitot tube.

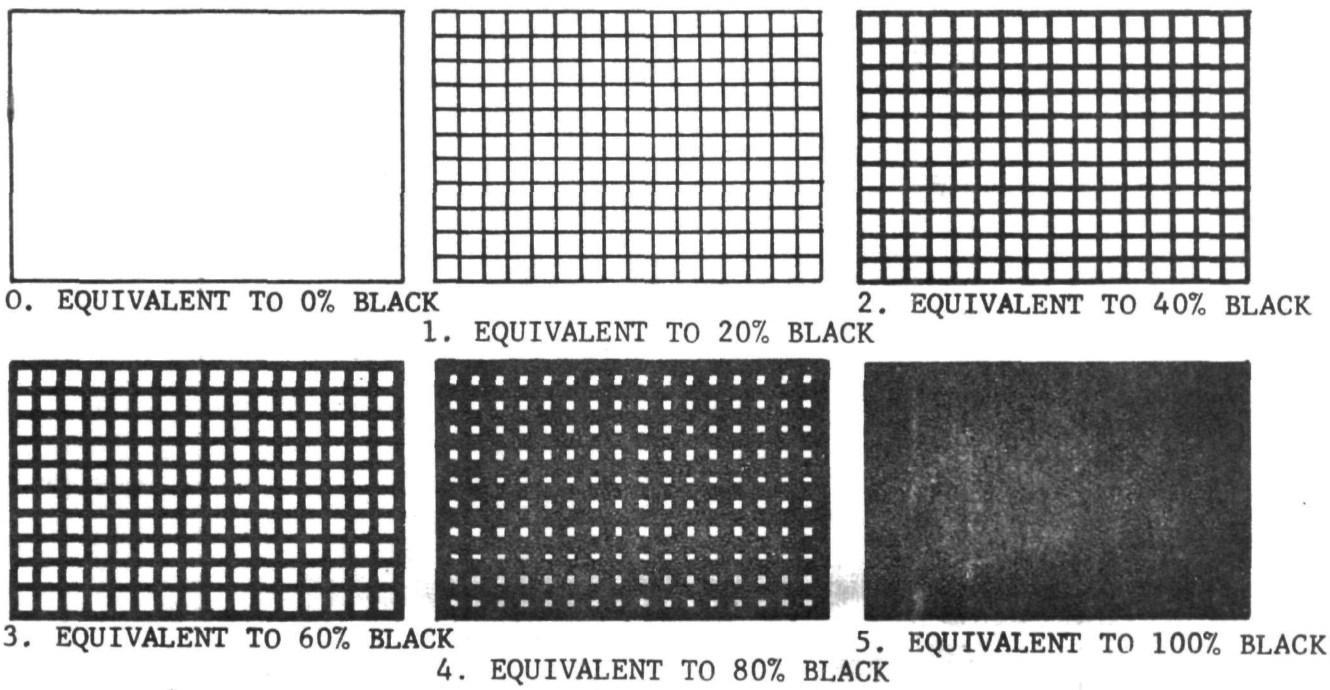
(i) Number and duration of runs.

(j) Duration of operation at each test load before sampling is commenced.

(k) Selection of laboratory for making equipment calibrations, weighing, size analysis and combustible content determinations of the dust samples if equipment and trained personnel for this work are not available at the plant.

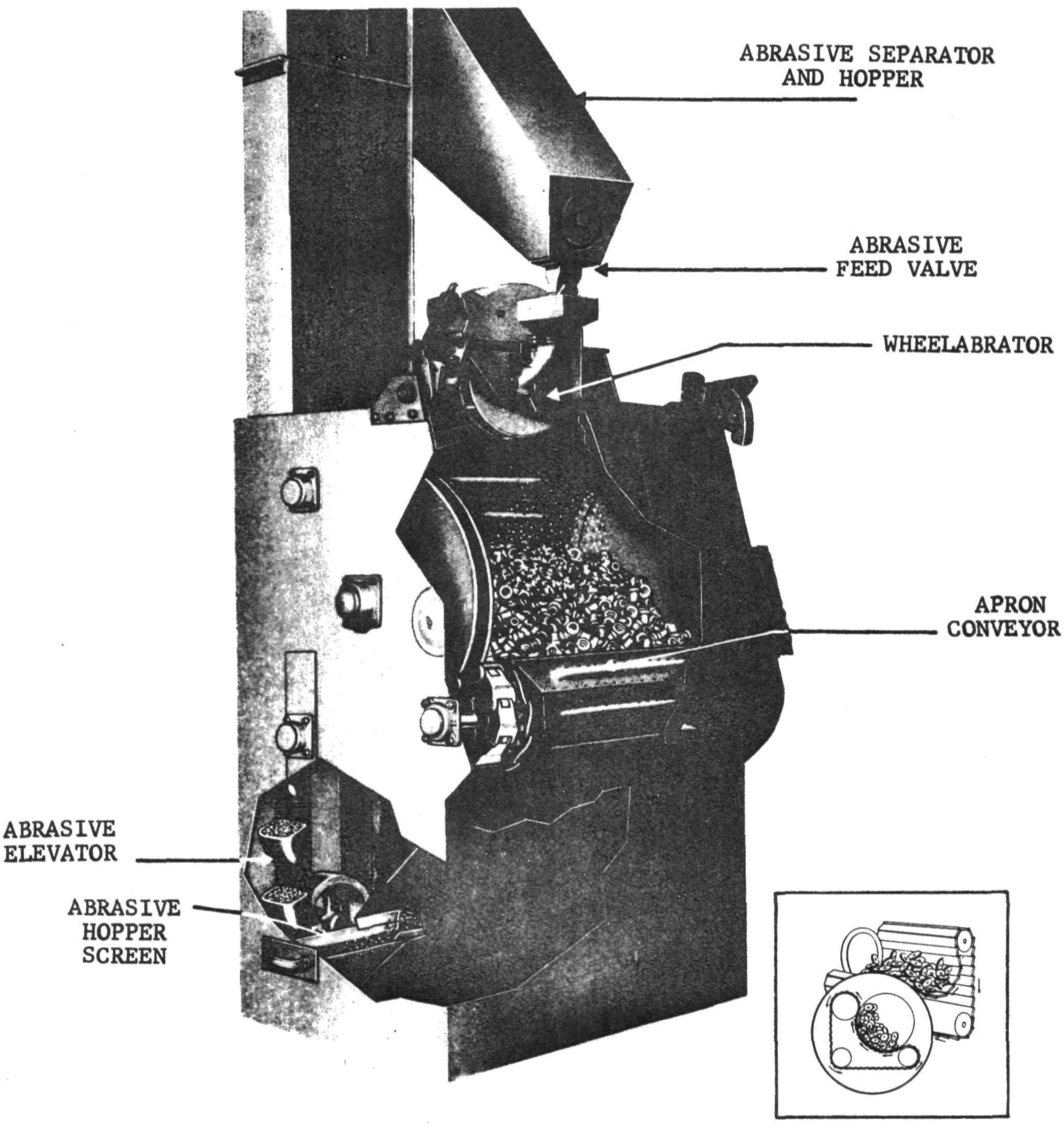
(l) Tolerances or margins, if any, to be applied.

RINGELMANN SCALE FOR GRADING DENSITY OF SMOKE



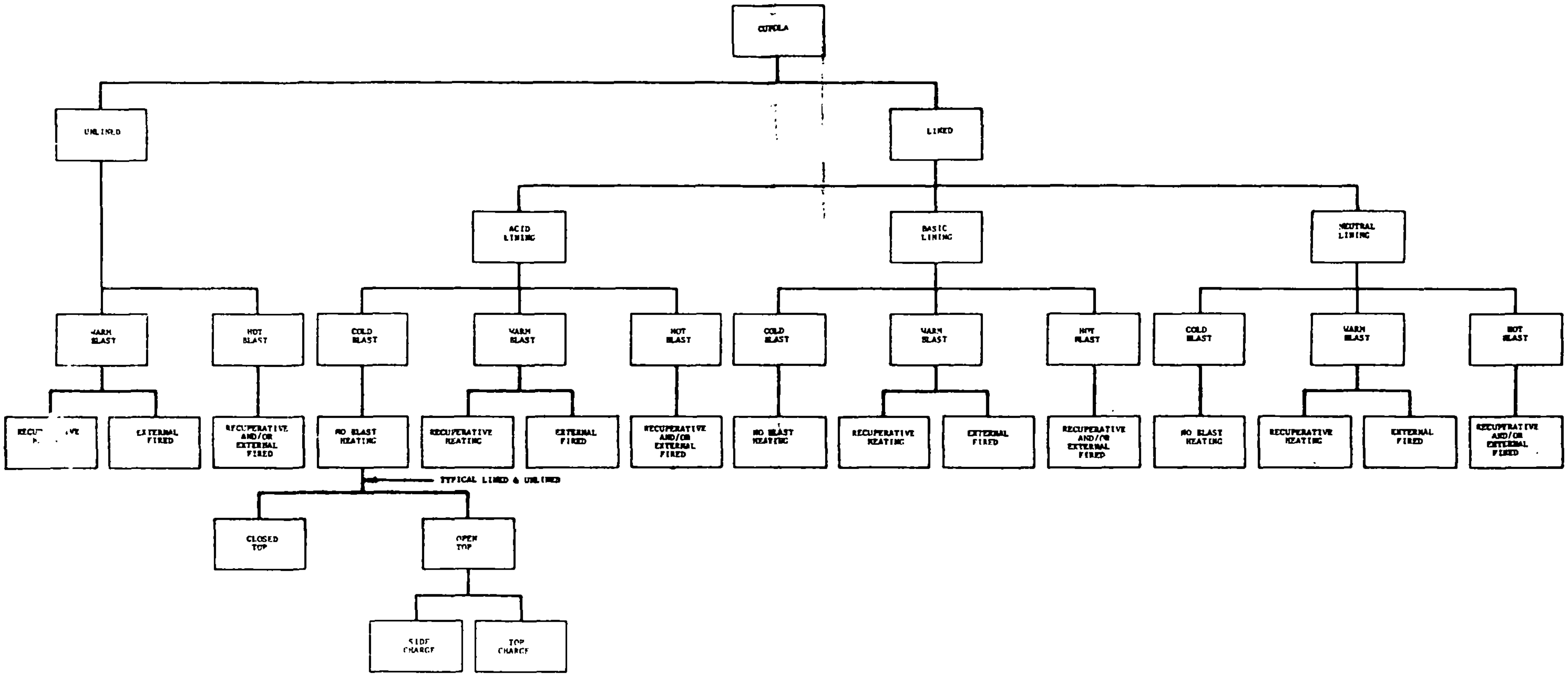
Source: Control of Emissions from Metal Melting Operations, American Foundrymen's Society.

ILLUSTRATION OF BLAST CLEANING UNIT



Source: Eclipse Fuel Engineering Company.

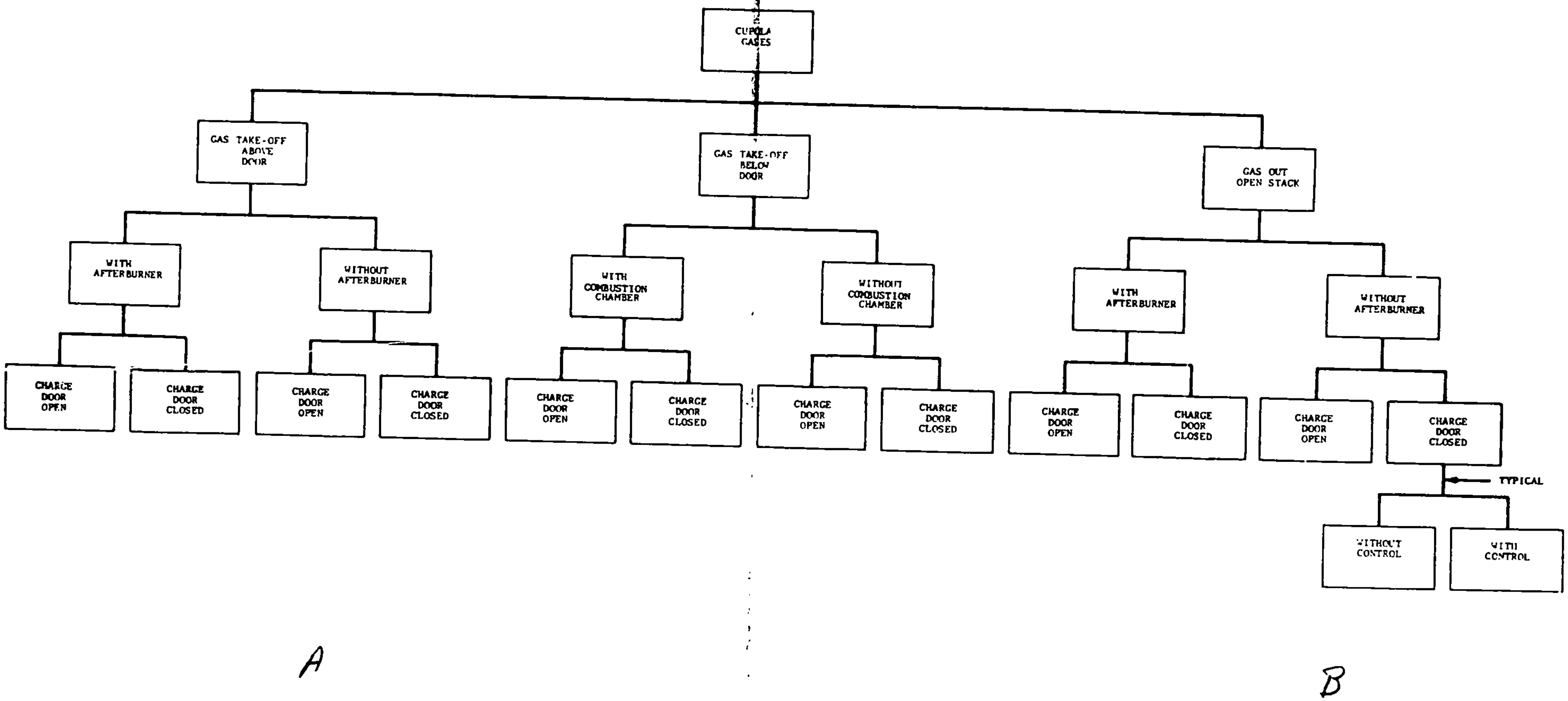
DESIGN FEATURES OF THE CUPOLA
LINING, BLAST & BLAST HEATING



A

B

DESIGN FEATURES OF THE CUPOLA GAS TAKE-OFF, AFTERBURNER, COMBUSTION CHAMBER, AND CHARGE DOOR



DESIGN FEATURE OF THE CUPOLA

FUEL INJECTION, OXYGEN ENRICHMENT AND TUYERE DESIGN

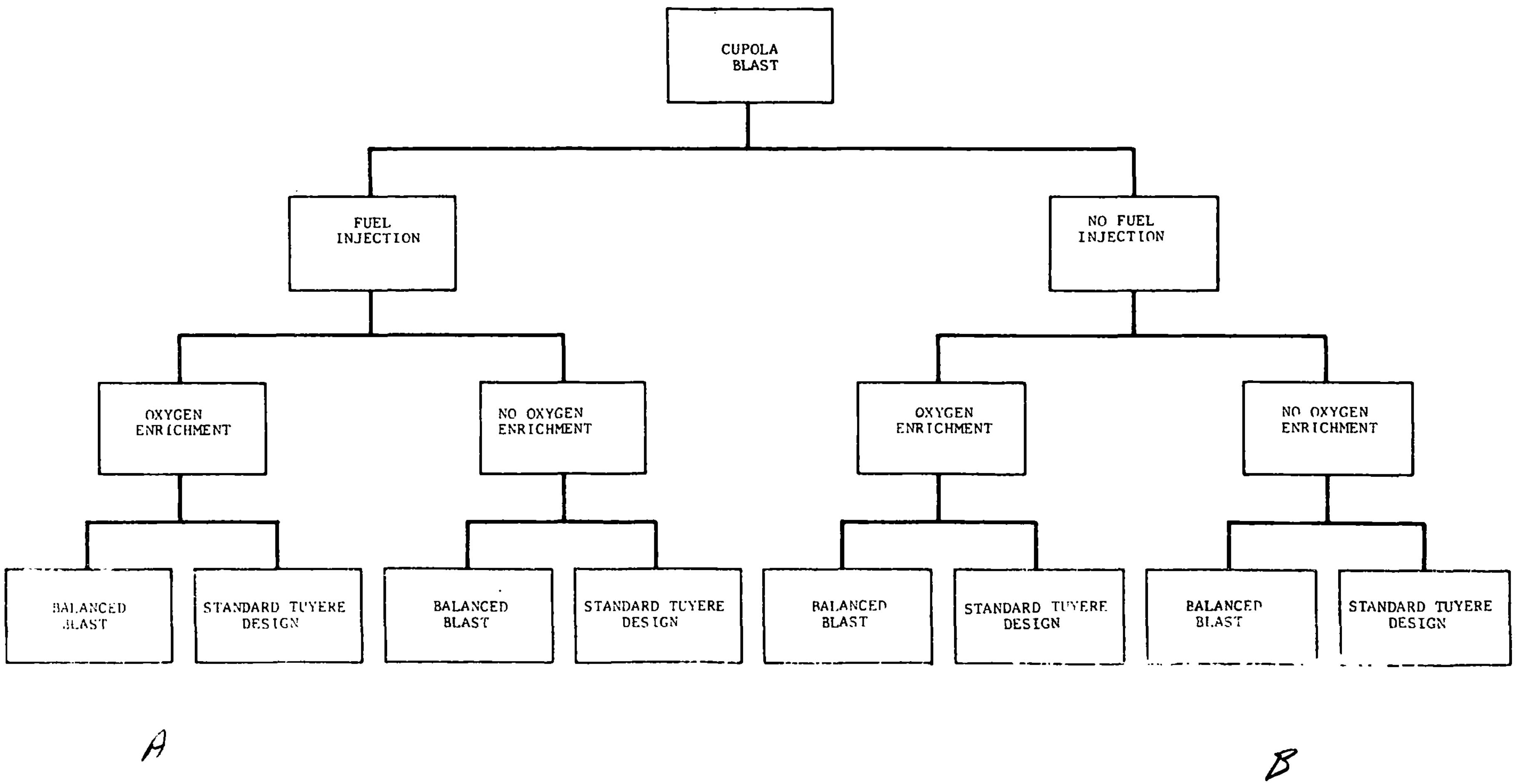


EXHIBIT VI-4

DESIGN FEATURES OF THE ELECTRIC ARC

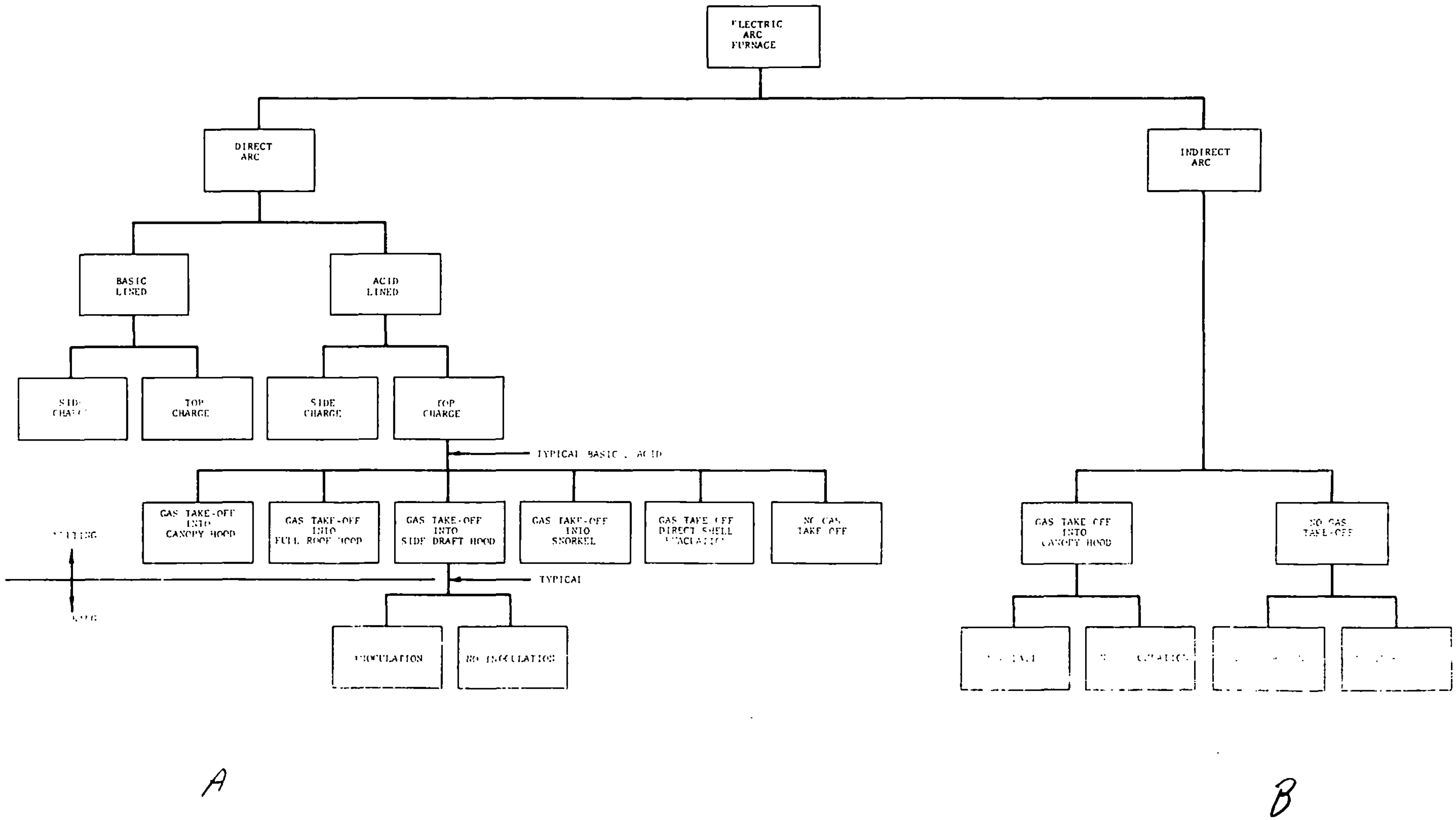
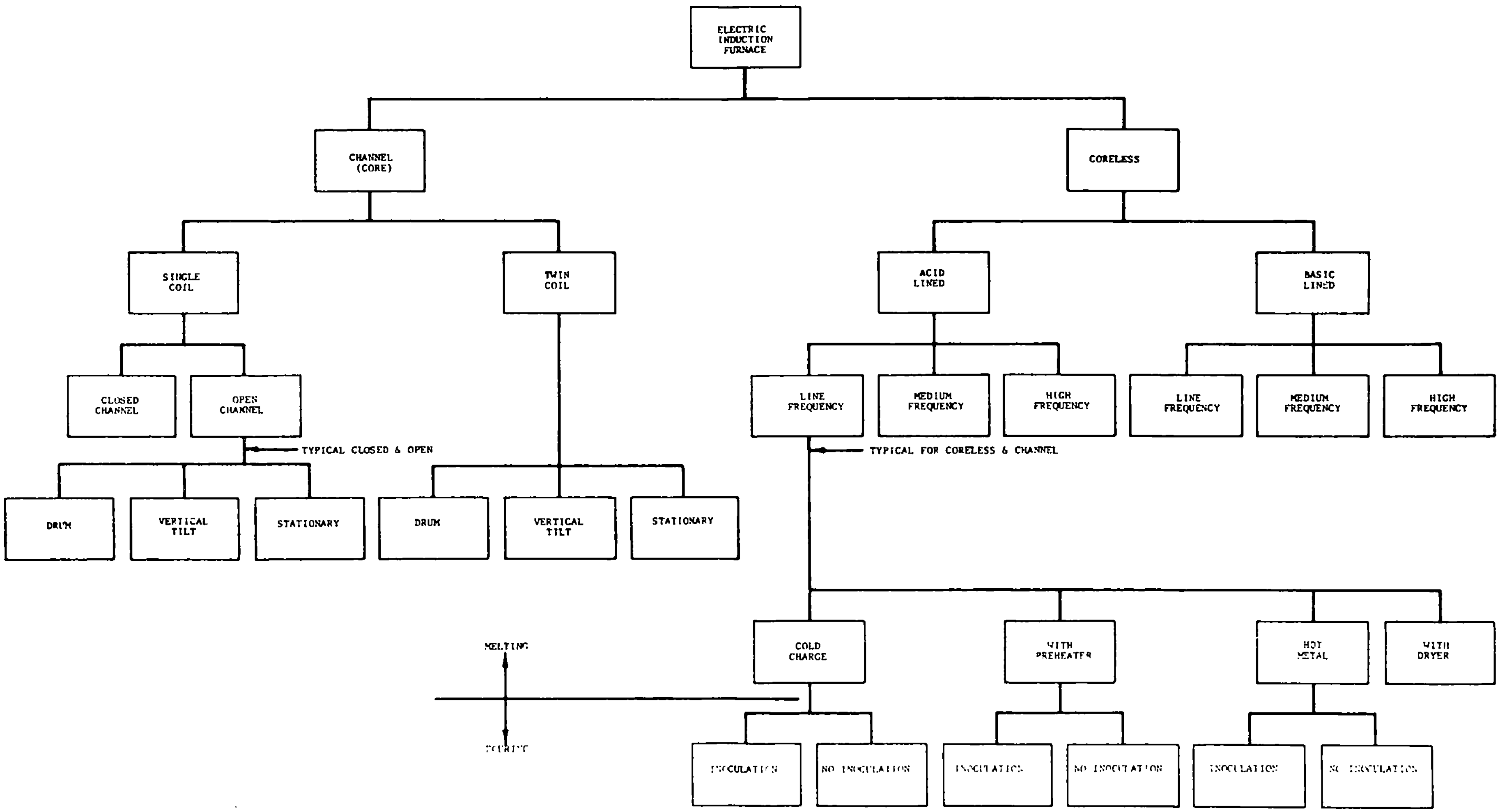
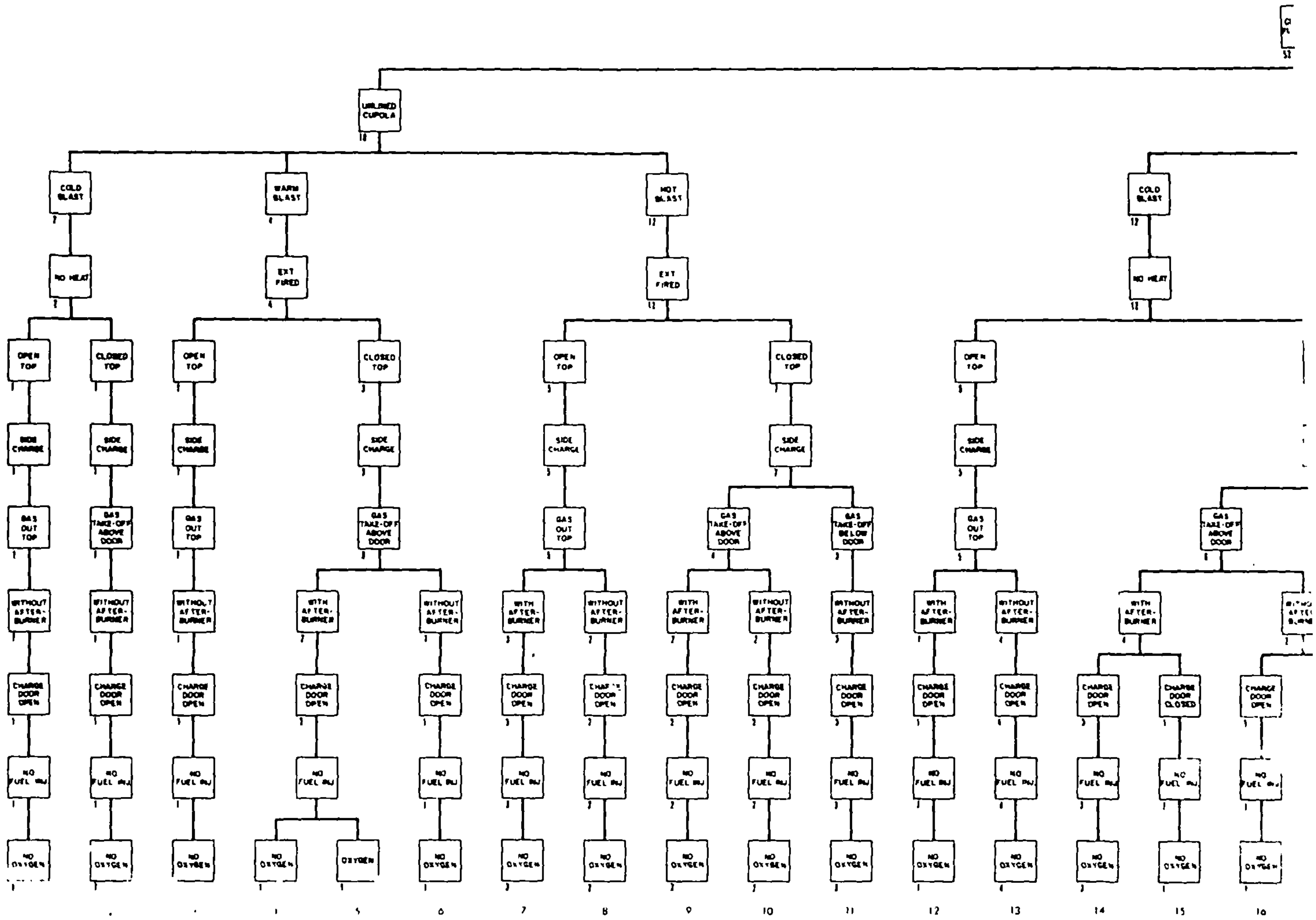


EXHIBIT VI-5

DESIGN FEATURES OF THE INDUCTION FURNACE



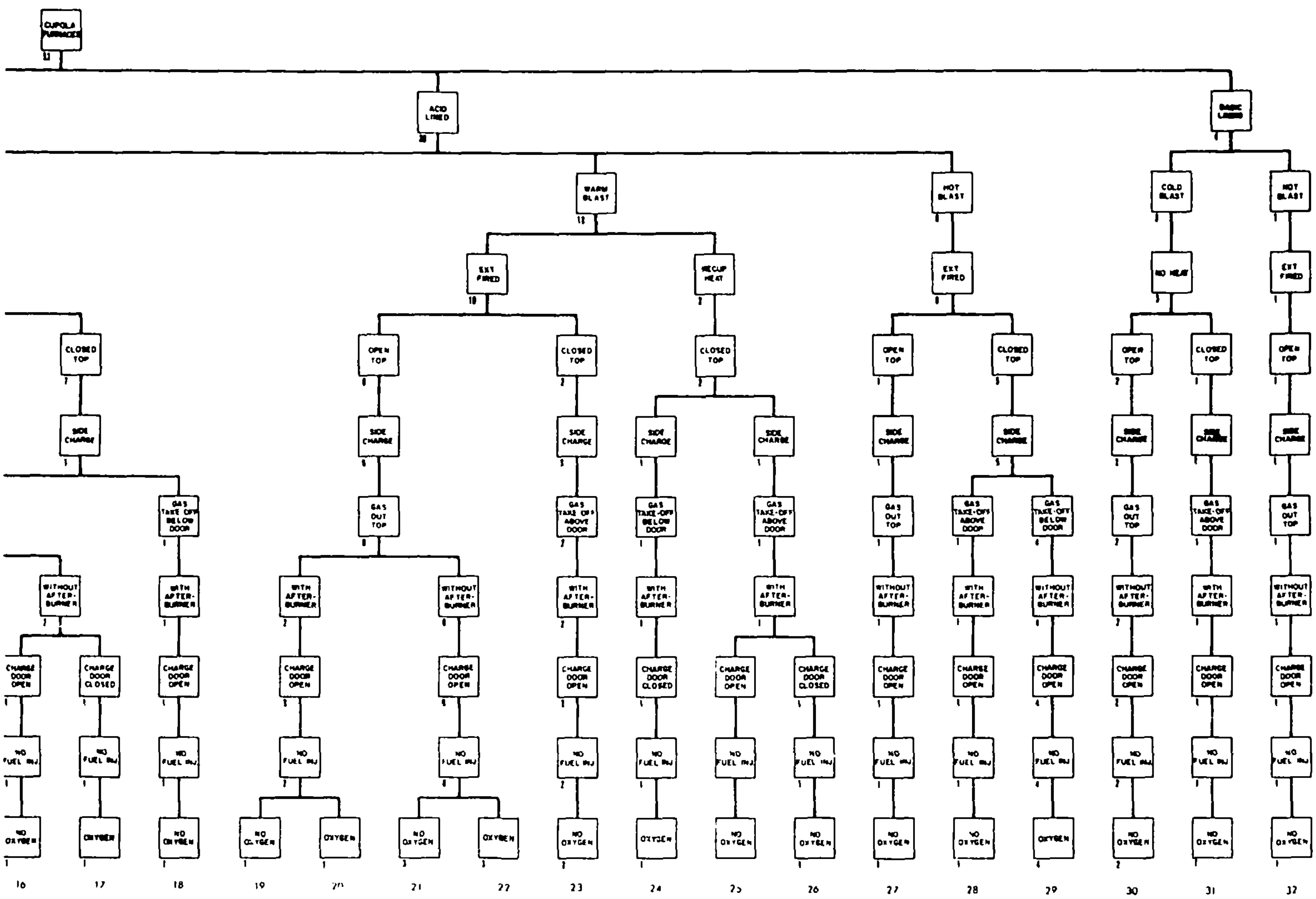
CUPOLA FURNACE



A

EXHIBIT VI-6

IACES FOUND IN PRACTICE



B

PARTICLE SIZE DISTRIBUTION-CUPOLA EMISSIONS

Foundry	Cumulative Percent by Weight							
	Diameter in Microns							
	-1	-2	-5	-10	-20	-50	-100	-200
9		30%	50%	65%	82%	90%	99%	
14		64	82	98	99			
18			2	12	34	92	99	99%
26		13	28	45	55	60		
32			54	86	98	99	99	99
67			14	15	15	21	99	
67					19	25	99	
146						99	99	
151		0.6	2	3	8	99	99	
A[1]			4	5.5	7	13.7	75	80
B[1]			11	13	32	53	75	94
C[1]			8	12	17	28	69	89
1[2]			18	25	38	62		
2[2]			17	26	36	53		
3[2]			24	28	23	42		
4[2]			26	30	32	44		
A[2]	0	7	25	32	34	41	56	61
B[2]	0	7	24	41	47	32	69	81

Sources: 1. The Cupola and Its Operation, Third Edition, 1965, American Foundrymen's Society, p. 82.

2. Air Pollution Engineering Manual, Public Health Service Publication, No.999-AP-40, 1967 Department of Health, Education, and Welfare.

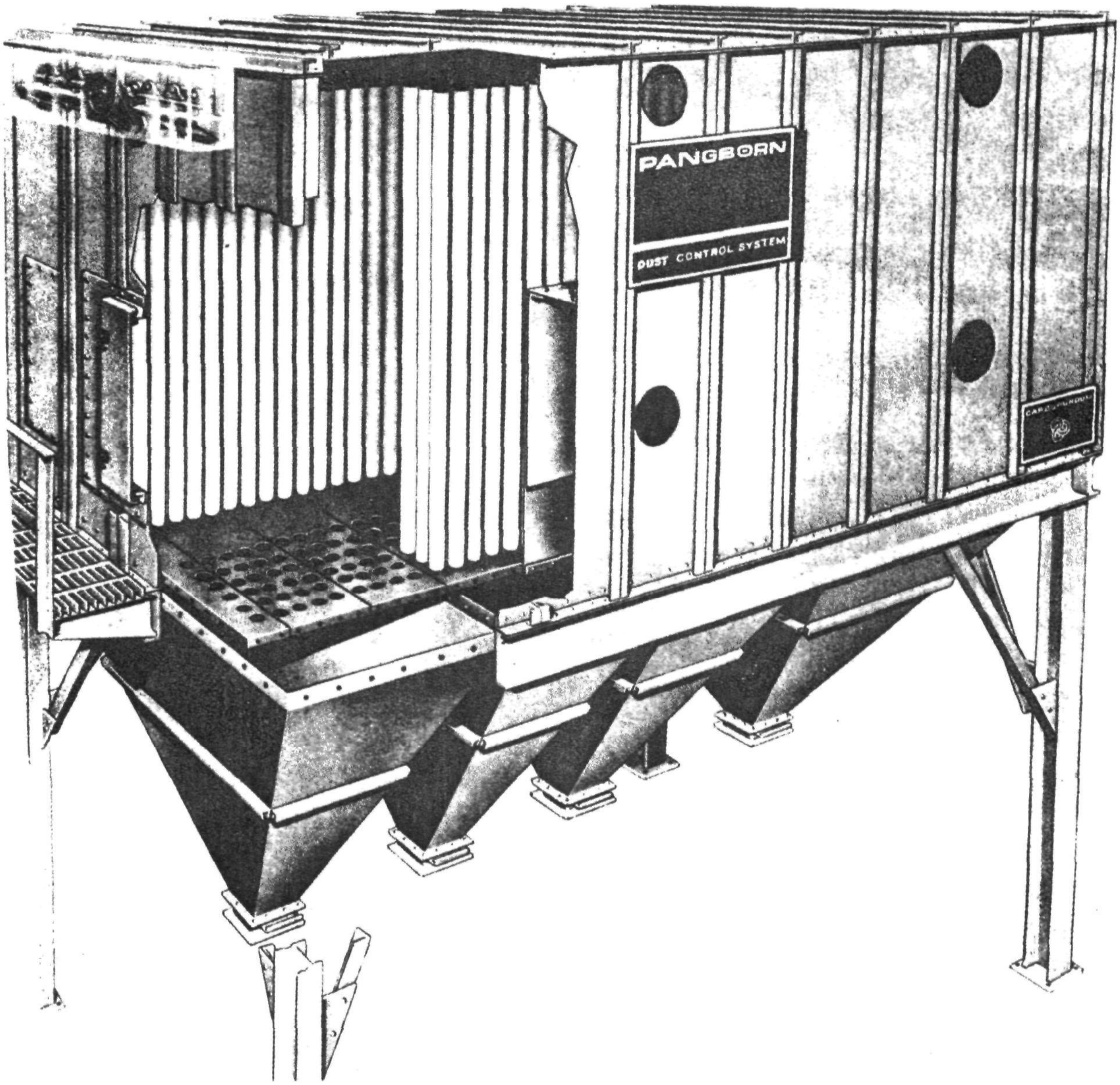
CHEMICAL COMPOSITION OF CUPOLA PARTICULATE EMISSIONS

	Percent by Weight in Cupola Effluent								
Foundry Number	Iron Oxide	Magnesium Oxide	Manganese Oxide	Lead Oxide	Aluminum Oxide	Zinc Oxide	Silicon Dioxide	Calcium Oxide	Combustibles
66	11.1%						12.3%		
85	14.7	1.3%		1.4%			28.7		24.0%
90							56.3	42.0%	0.9
113	8.6		3.7%		.05%		31.8	3.1	27.0
116	10.0	5.0	10.0		5.0	1.0%	10.0	3.0	5.0
146	33.0		1.0	5.0		38.0	20.0	1.0	
150	11.6	1.0	5.5	20.0	1.4	14.7	30.1	1.1	

Note: Quantities as reported. They do not add up to 100%.

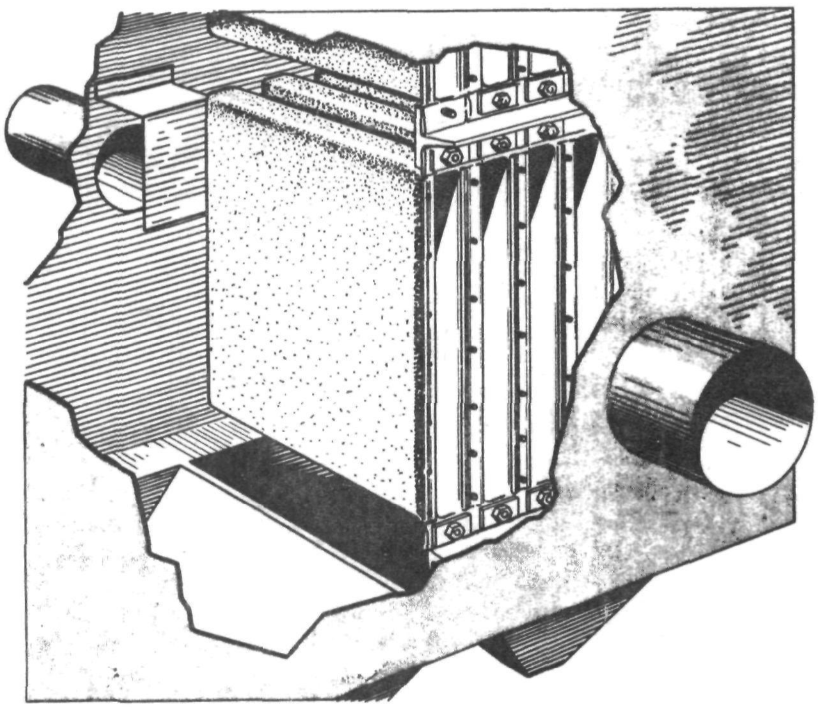
EXHIBIT VI-7

CUTAWAY VIEW SHOWING
FABRIC FILTER TUBULAR-TYPE BAGS



Source: Pangborn Division, Carborundum Company.

CUTAWAY VIEW SHOWING
FABRIC FILTER, FLAT- OR
SCREEN-TYPE BAG



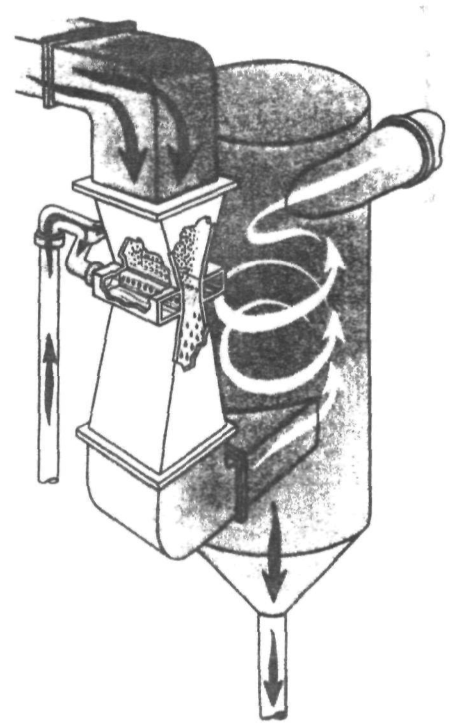
Source: Sly Manufacturing Company.

WET COLLECTOR PARTICLE COLLECTION LIMITATIONS AND DESIGN CAPACITIES

Control Equipment Type	Relative Comparison of Smallest Particle Collected (Microns)	Range of Capacities Available in Cubic Feet/Minute	
		Low	High
Static Washer	10	500	100,000
Dynamic Precipitator	2 to 3	1,000	50,000
Centrifugal	2 to 5	575	108,000
Orifice	2	400	50,000
Centrifugal Spray	2	300	50,000
Flooded Bed	2	1,000	500,000
Venturi	0.5	5,000	50,000

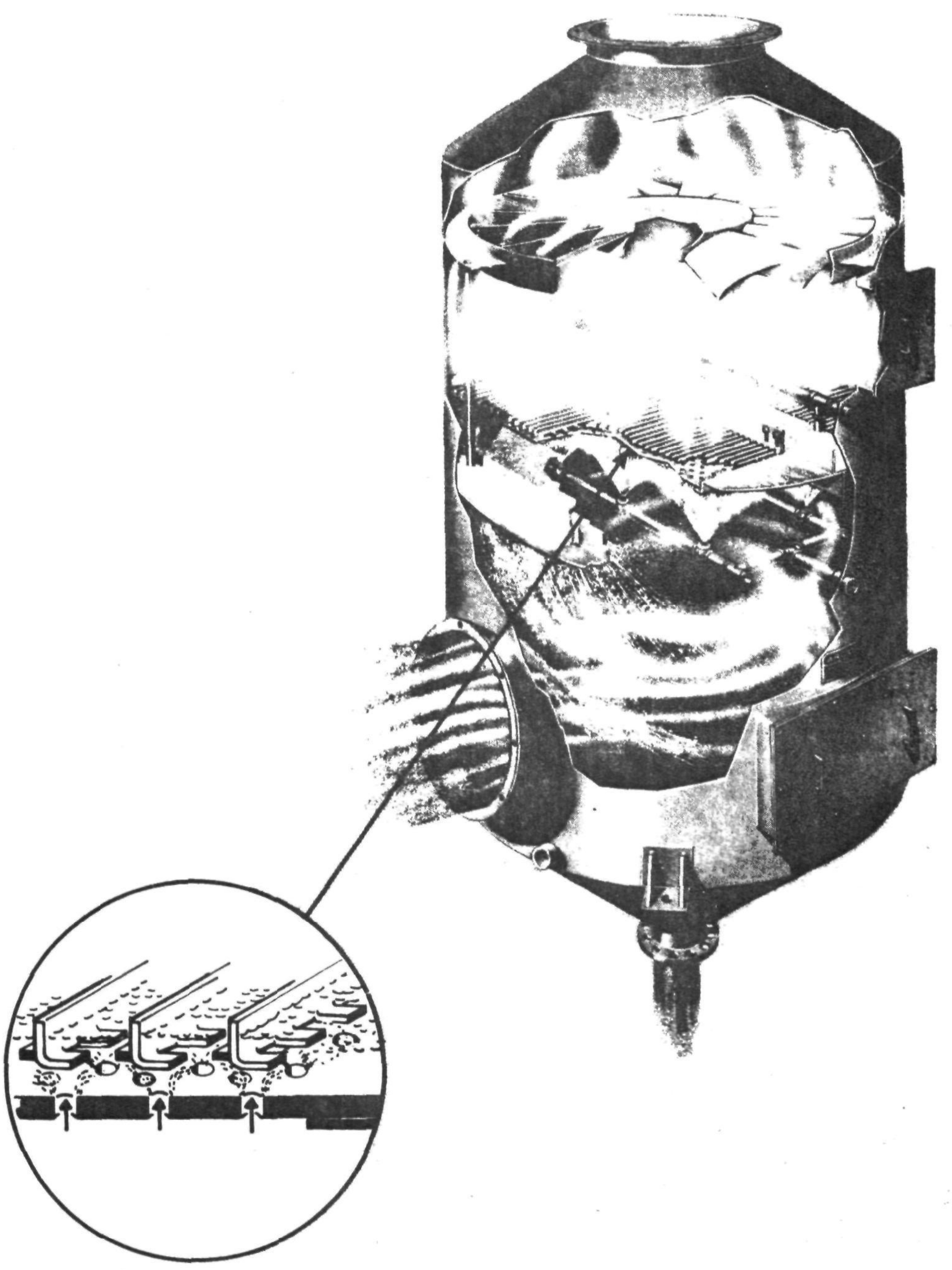
Source: Dust Collectors, American Foundrymen's Society.

VENTURI COLLECTOR



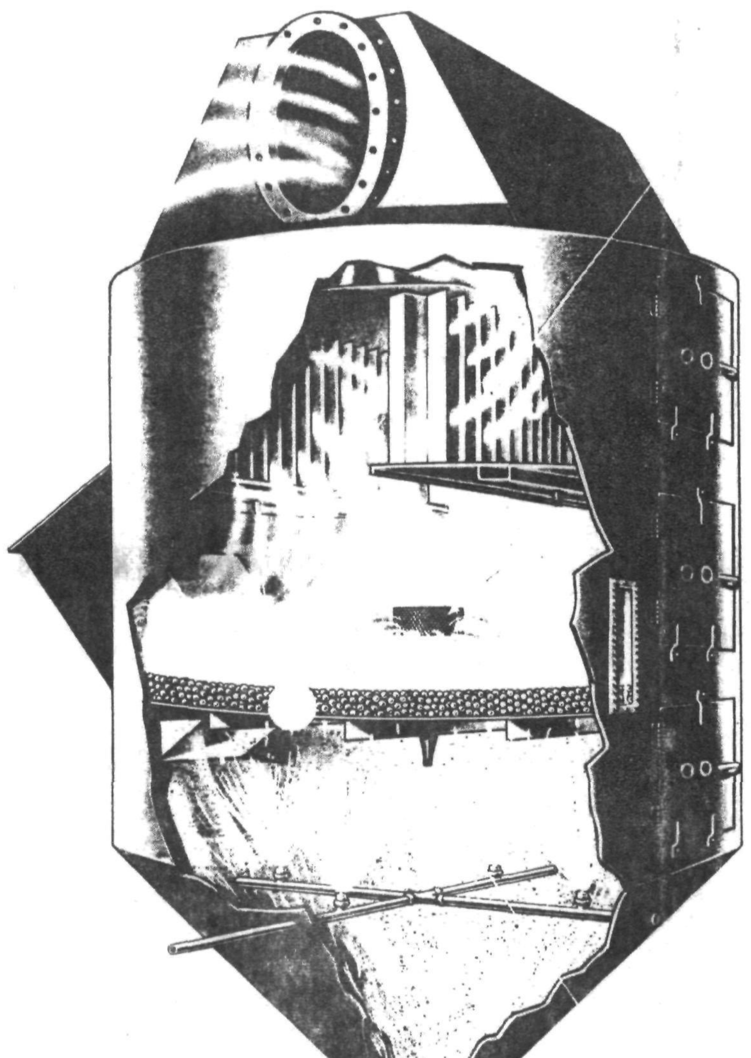
Source: Chemical Construction Co.

IMPINGEMENT BAFFLE GRID-TYPE WET COLLECTOR



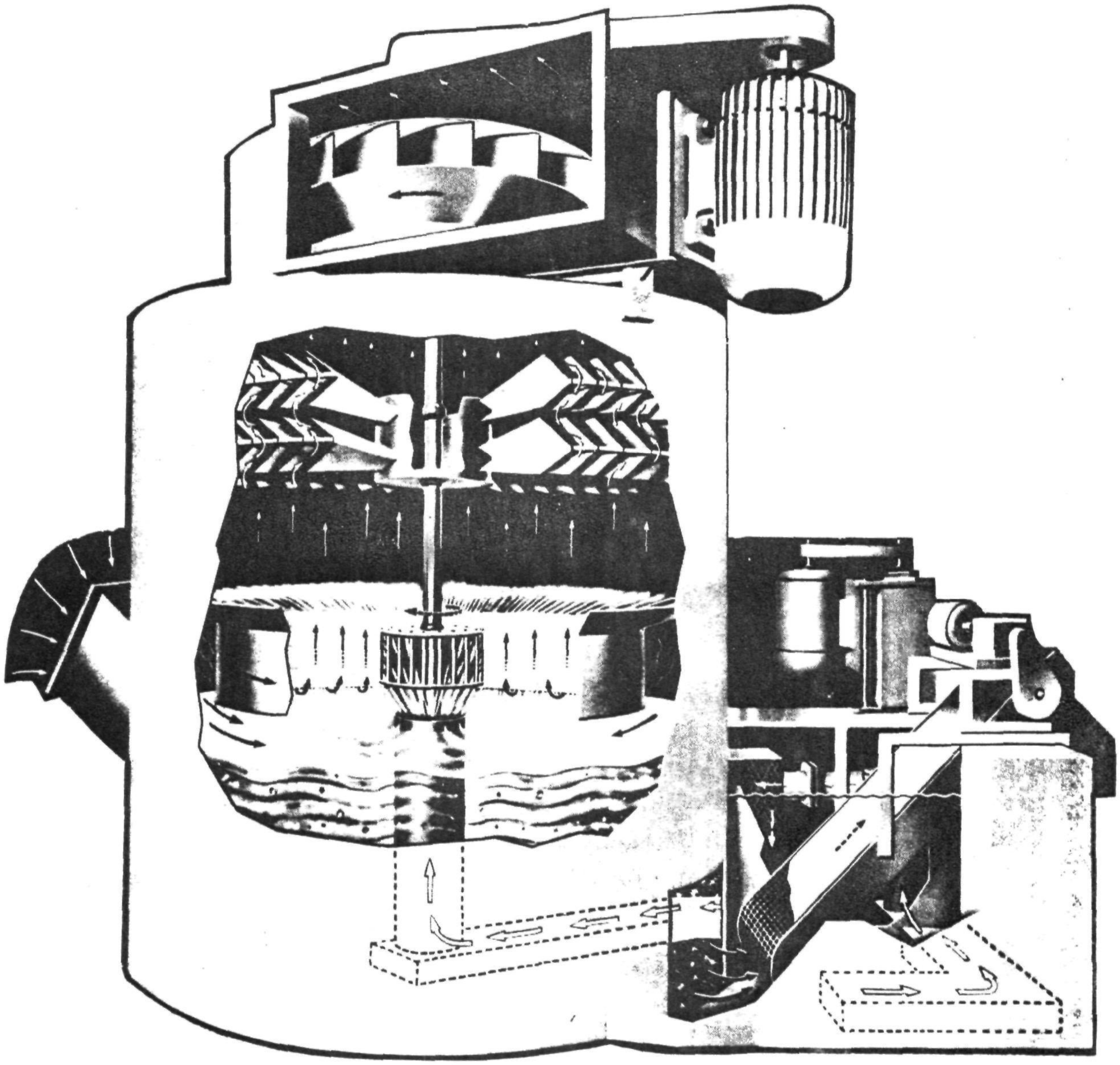
Source: Arco Ind.

MARBLE BED-TYPE WET COLLECTOR



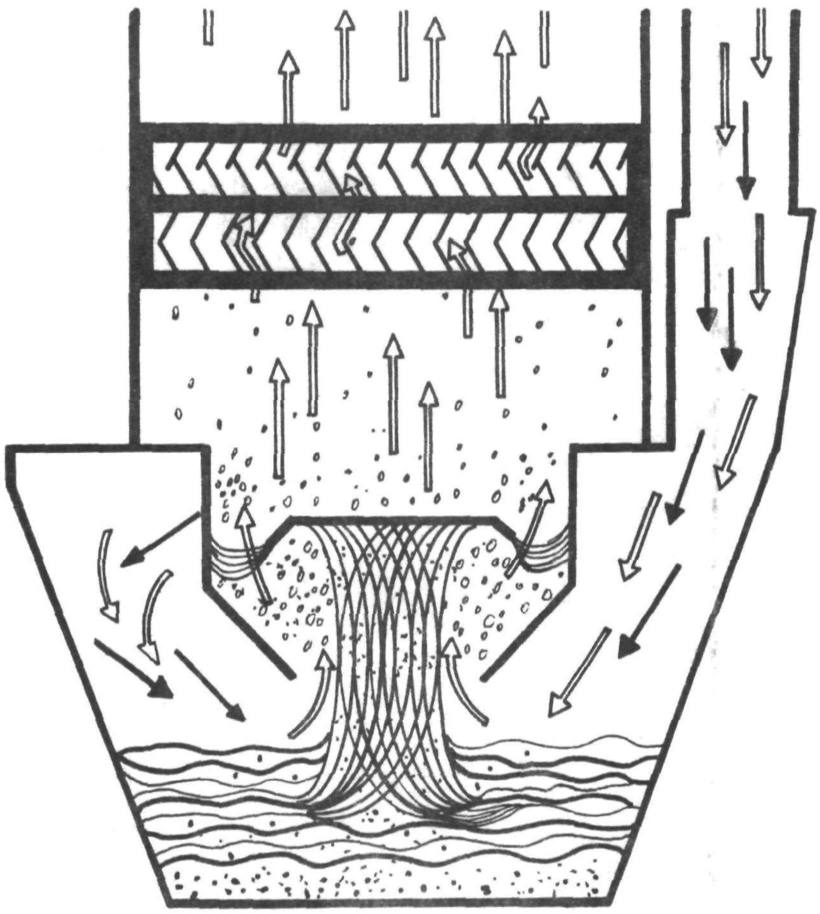
Source: National Dust Collector Corporation.

CENTRIFUGAL SPRAY WET COLLECTOR



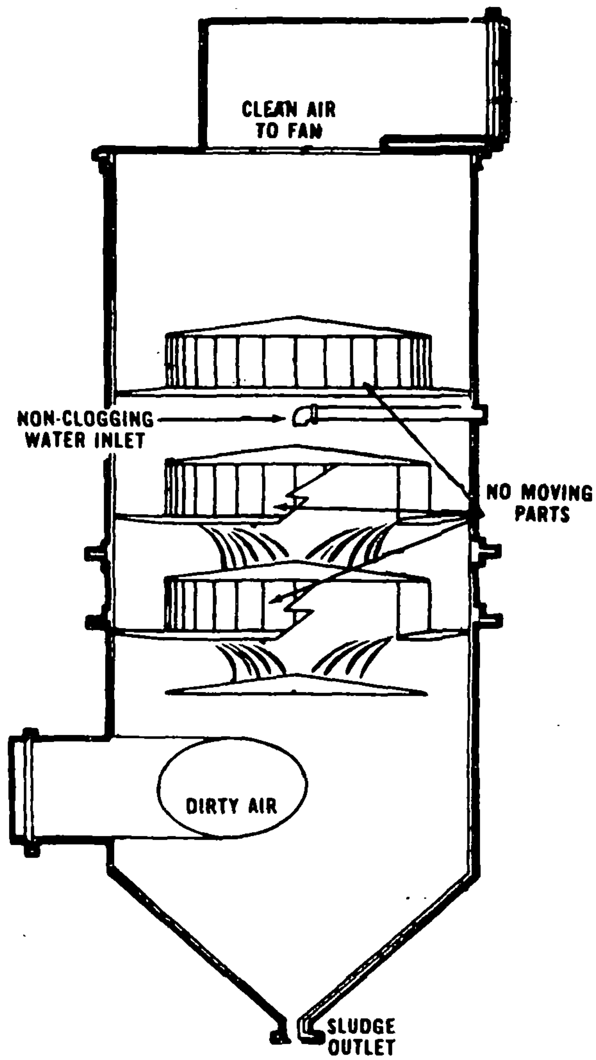
Source: Centri-Spray Corporation.

ORIFICE-TYPE WET COLLECTOR



Source: The De Vilbiss Company.

MULTIPLE TUBE-TYPE CENTRIFUGAL
WET COLLECTOR

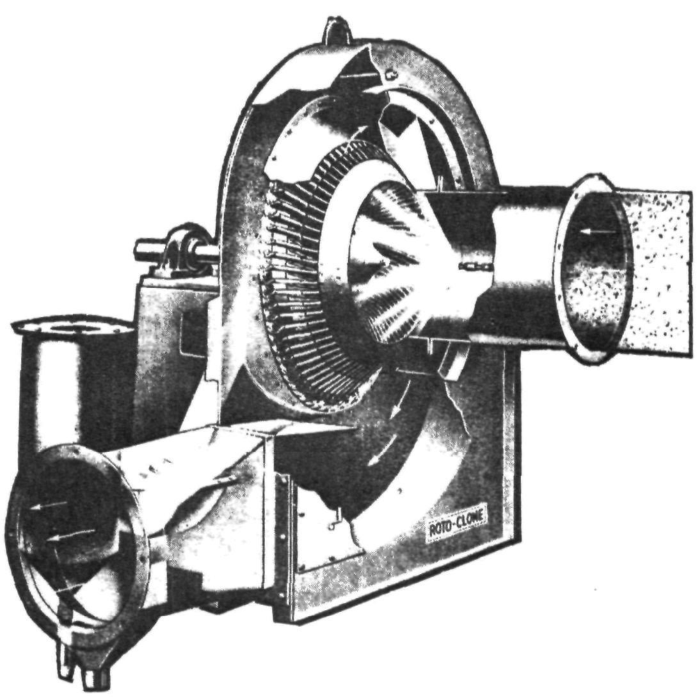


Source: American Air Flow Corporation.

VANE-TYPE CENTRIFUGAL
WET COLLECTOR

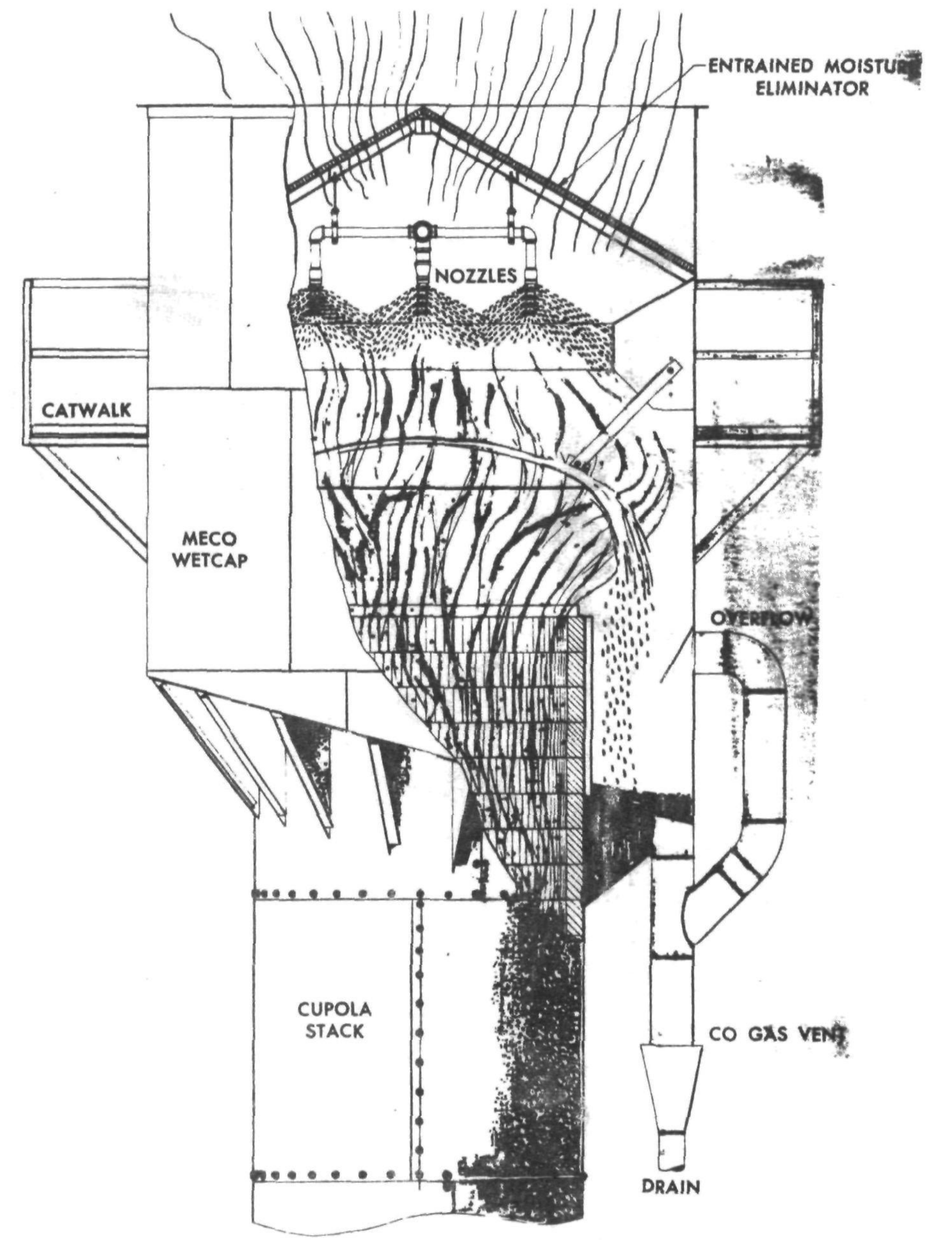
Source: Dust Collectors, American Foundrymen's Society.

WET DYNAMIC PRECIPITATOR COLLECTOR



Source: American Air Filter.

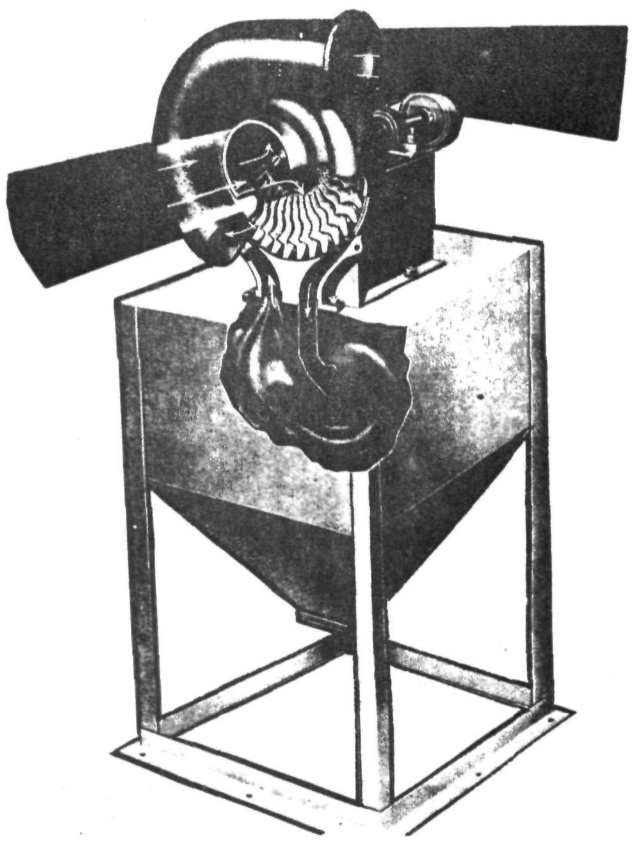
WET CAP COLLECTOR



Source: Modern Equipment Company.

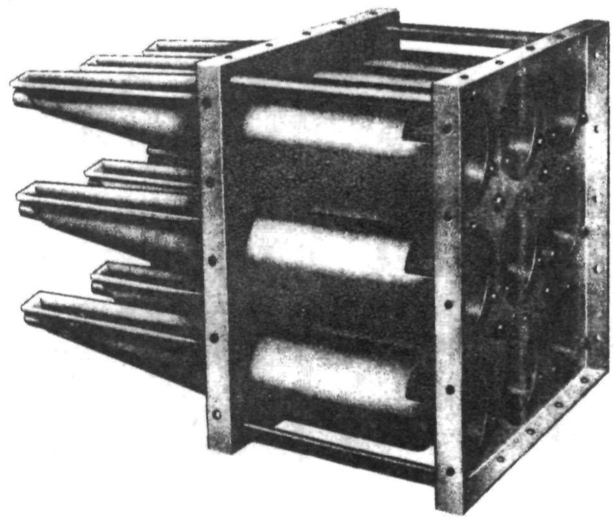
EXHIBIT VII-3

DRY DYNAMIC PRECIPITATOR COLLECTOR



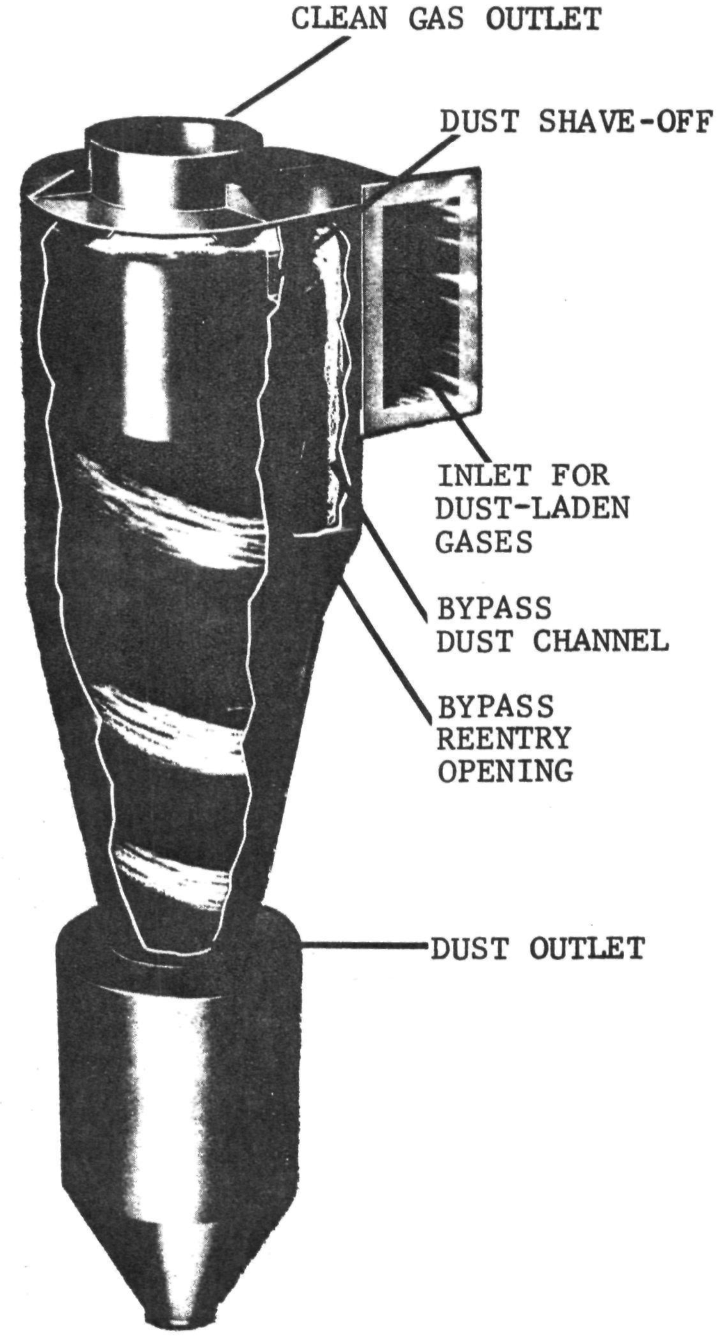
Source: American Air Filter.

HIGH EFFICIENCY CENTRIFUGAL COLLECTOR

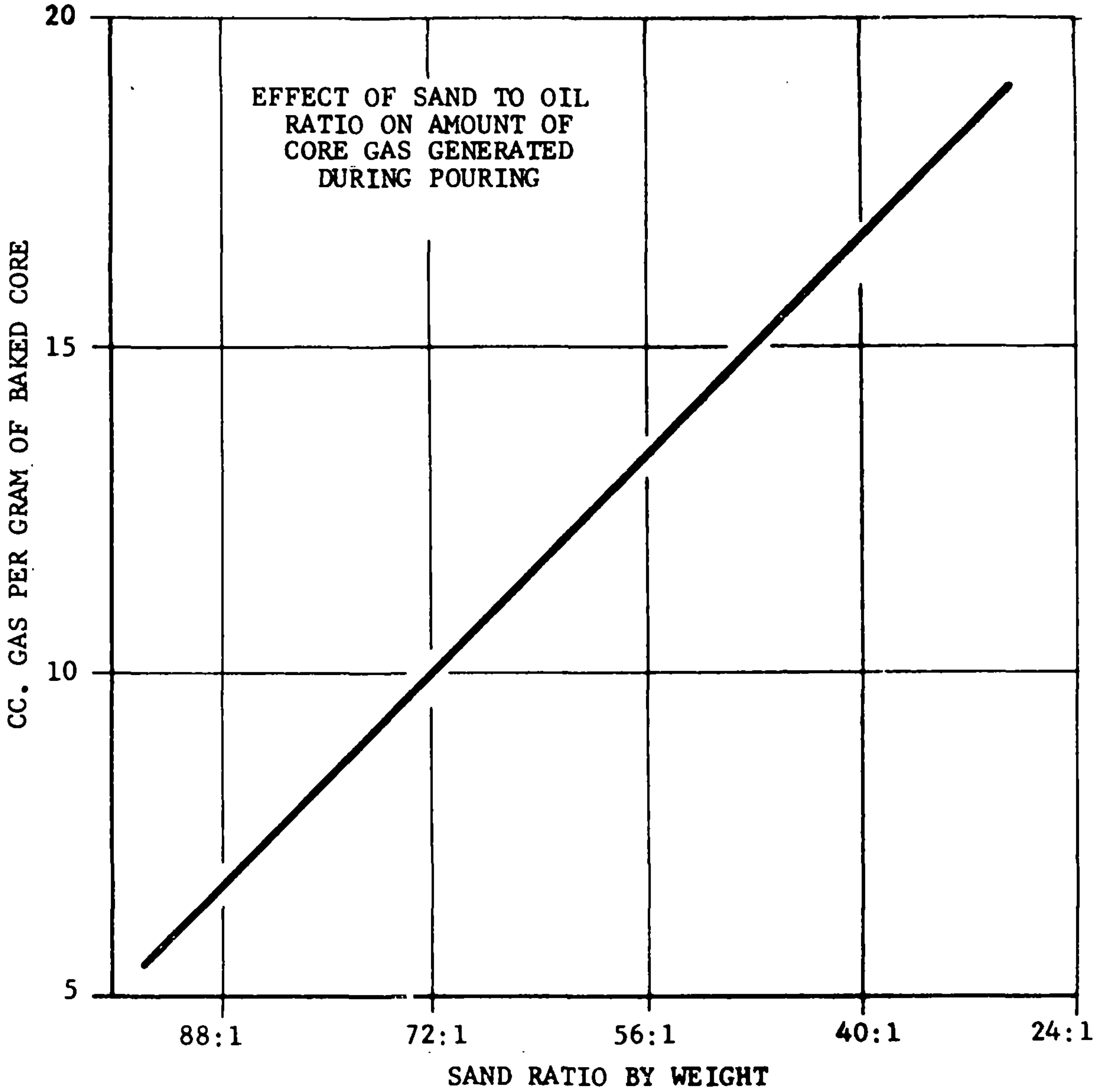


Source: American Air Filter.

CYCLONE COLLECTOR

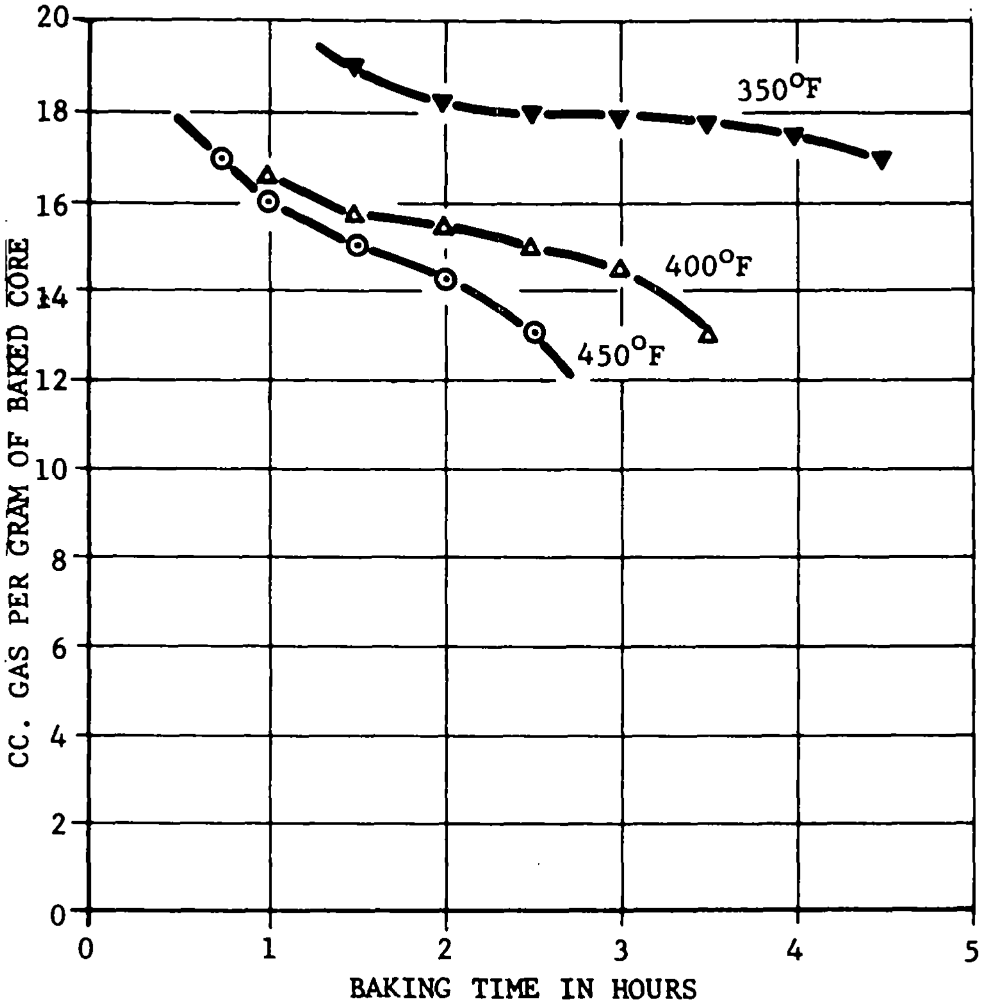


Source: Buell Engineering Company.



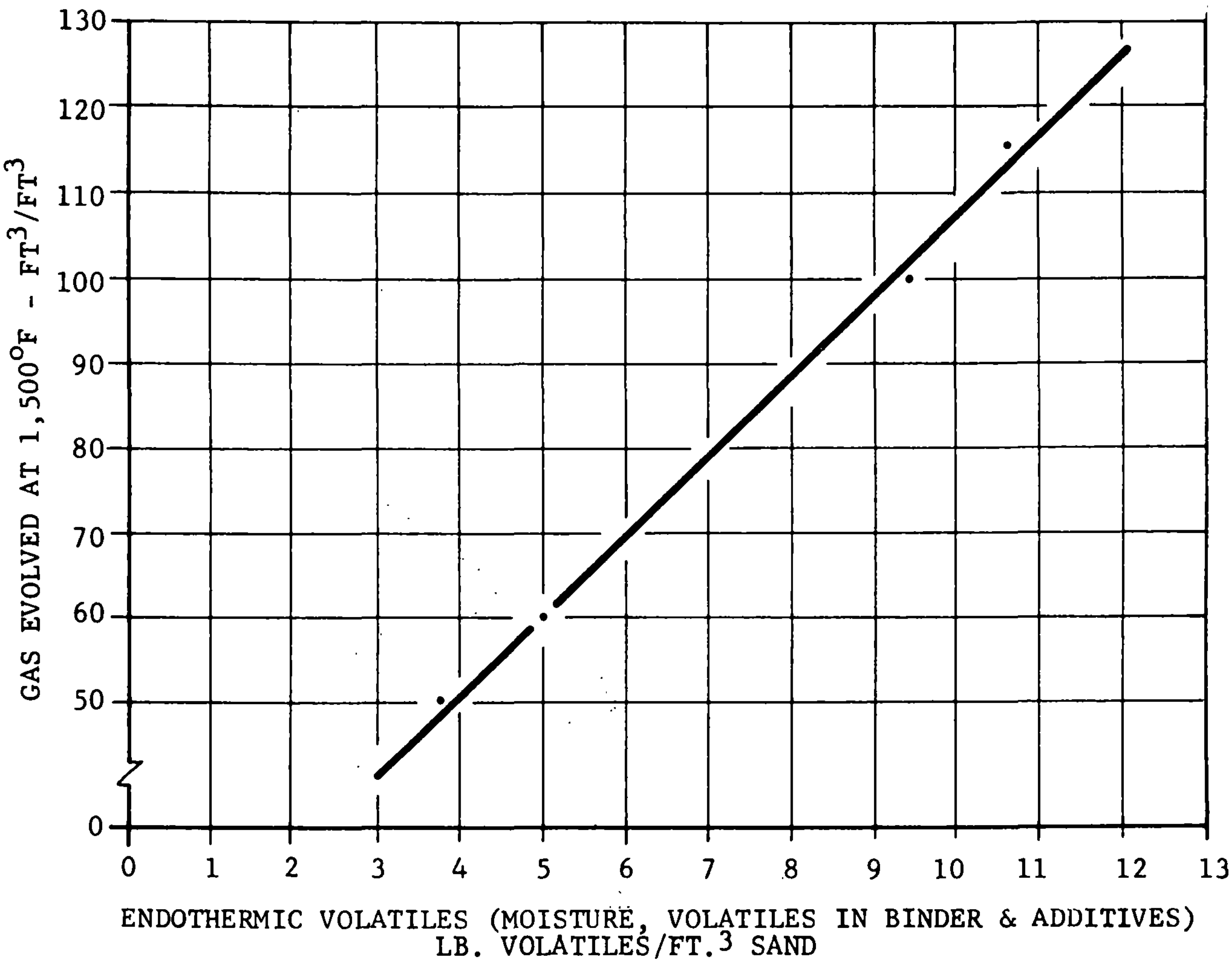
Source: Foundry Core Practice, H. Dietert, 1966.

EFFECT OF BAKING TIME ON
GAS GENERATED DURING POURING
FOR VARIOUS BAKING TEMPERATURES



Note: Adapted from Foundry Core Practice by H. Dietert, 1966, p. 172.

GAS VOLUME EVOLVED AS A FUNCTION OF VOLATILES CONTAINED IN MOLDING SAND



Note: Adapted from an article by F. Hoffman, "Property Changes and Conditioning of Repeatedly Circulating Foundry Sand Systems," Modern Casting, October, 1967.

MOLDING SAND
GAS EVOLUTION AND HOT PERMEABILITY

Bond Clay Added	Percent Tempering Water	CC Gas Evolved per Gram of Sand: Gas from Dried Specimen 1/2 Minute	3 Minutes	7 Minutes	Steam 0 212° F.	Total Gas 212° F.	1,800° F.	Cubic Feet Gas at 1,800° F. per Cubic Foot of Sand
Washed and Dried Silica Sand plus Bond Clays								
5% Western Bentonite	2.5	.50	2.50	2.50	40.0	43.3	145.2	233.8
4% Southern Bentonite	2.5	3.50	3.50	3.50	41.5	46.1	154.9	247.8
11% Ohio fireclay	3.5	3.00	3.00	3.00	56.5	60.3	203.0	824.8
Silica Sand Bonded with 5 Percent Western Bentonite and Other Binders								
1-10 Sea Coal (Vol.)	3.0	9.00	19.50	19.75	49.8	76.2	256.0	409.6
1-35 Pitch (Vol.)	2.9	4.25	7.50	7.50	48.2	58.2	195.5	312.8
1% Cereal Binder	3.4	7.25	9.50	9.50	56.5	69.0	231.8	370.9
1% Resin Binder	3.4	5.25	7.00	7.00	56.5	65.4	219.7	351.5
1% Special Binder A	3.5	4.25	7.00	7.00	58.0	67.3	220.0	381.6
1% Special Binder B	2.0	2.25	3.75	3.75	33.2	87.7	126.7	202.7
1% Dextrine	3.5	8.00	8.75	8.75	58.0	69.6	234.0	74.4
Silica Sands Bonded with 5 Percent Western Bentonite and 1-10 Sea Coal Volume								
Washed and dried Ottawa	8.0	9.00	19.50	19.75	49.8	76.2	256.0	409.6
Western Michigan core sand	2.9	5.00	15.25	15.25	48.2	68.4	229.8	367.7
Michigan bank sand	2.8	10.25	25.00	25.50	46.5	80.3	270.0	432.0
Gas Evolution from Sands in Actual Use								
Steel foundry-old sand	2.0	4.50	5.25	5.25	33.2	40.1	134.7	215.5
Steel foundry-facing sand	3.1	12.25	13.25	13.25	51.4	69.1	232.0	371.2
Malleable foundry-system sand	3.7	9.75	18.00	18.25	61.5	85.5	288.0	460.8
Malleable foundry-facing sand	3.8	18.25	27.75	27.75	63.0	99.4	334.0	534.4
Gray iron foundry-system sand	3.8	11.25	28.75	33.00	63.0	106.5	358.0	572.8
Synthetic Sand vs. Naturally Bonded Sand								
95% Washed and dried Ottawa 5% Western Bentonite	2.5	.50	2.50	2.50	40.0	43.3	145.2	232.3
New Albany sand	4.8	9.00	11.00	11.00	78.0	93.3	314.0	502.4
New Ohio sand	7.8	11.00	15.25	15.25	124.8	145.0	480.5	778.3

Source: "Gas Developed in Molds," Dunbeck, Foundry, September, 1944.

Molding Sand Gas Analyses

Sand Composition	A 4% Bentonite Oven Dried	B 4% Bentonite 2.5% H_2O	C 4% Bentonite 5% Water	D 4% Bentonite 1% Cereal Dried	E 4% Bentonite 1% Cereal 3.4% H_2O	F 1.5% Cereal Core Oil 1.0% Kerosene 1.0% Dried
CO_2	4.9	3.3	2.0	6.5	2.8	5.0
O_2	9.2	6.2	2.9	7.4	1.7	5.2
CO	2.4	6.3	11.3	10.8	11.5	30.4
H_2	0.9	33.0	46.1	2.5	50.3	25.6
Paraffins	0	1.2	0	0.4	2.9	2.2
N_2	82.6	49.7	37.7	72.4	30.8	31.6
Percent O_2 of O_2+N_2	15.7	20.2	21.7	21.0	25.0	44.5
CO/CO_2	0.49	1.91	5.7	1.66	4.10	6.08
Percent C	7.3	9.6	13.3	17.3	14.3	35.4

Sand Composition	G 4% Cereal 4% Bentonite 4% Water	H 4% Cereal 4% Bentonite Dry	I Oil Drag	J Oil Check	K Oil Cope	L Steel Cavity & Sprue
CO_2	2.5	2.3	6.4	6.4	6.8	5.0
O_2	3.0	6.2	4.3	5.5	8.9	9.4
CO	30.5	28.7	7.9	11.1	2.5	4.1
H_2	46.0	24.8	2.6	7.5	0.6	0.5
Paraffins	4.6	0.6	0.1	0	0	0.2
N_2	13.2	37.4	78.7	69.5	81.2	80.8
Percent O_2 of O_2+N_2	63.0	39.0	15.7	17.4	17.2	16.9
CO/CO_2	12.2	12.5	1.23	1.73	.37	0.82
Percent C	33.0	31.0	14.3	17.5	9.3	9.1

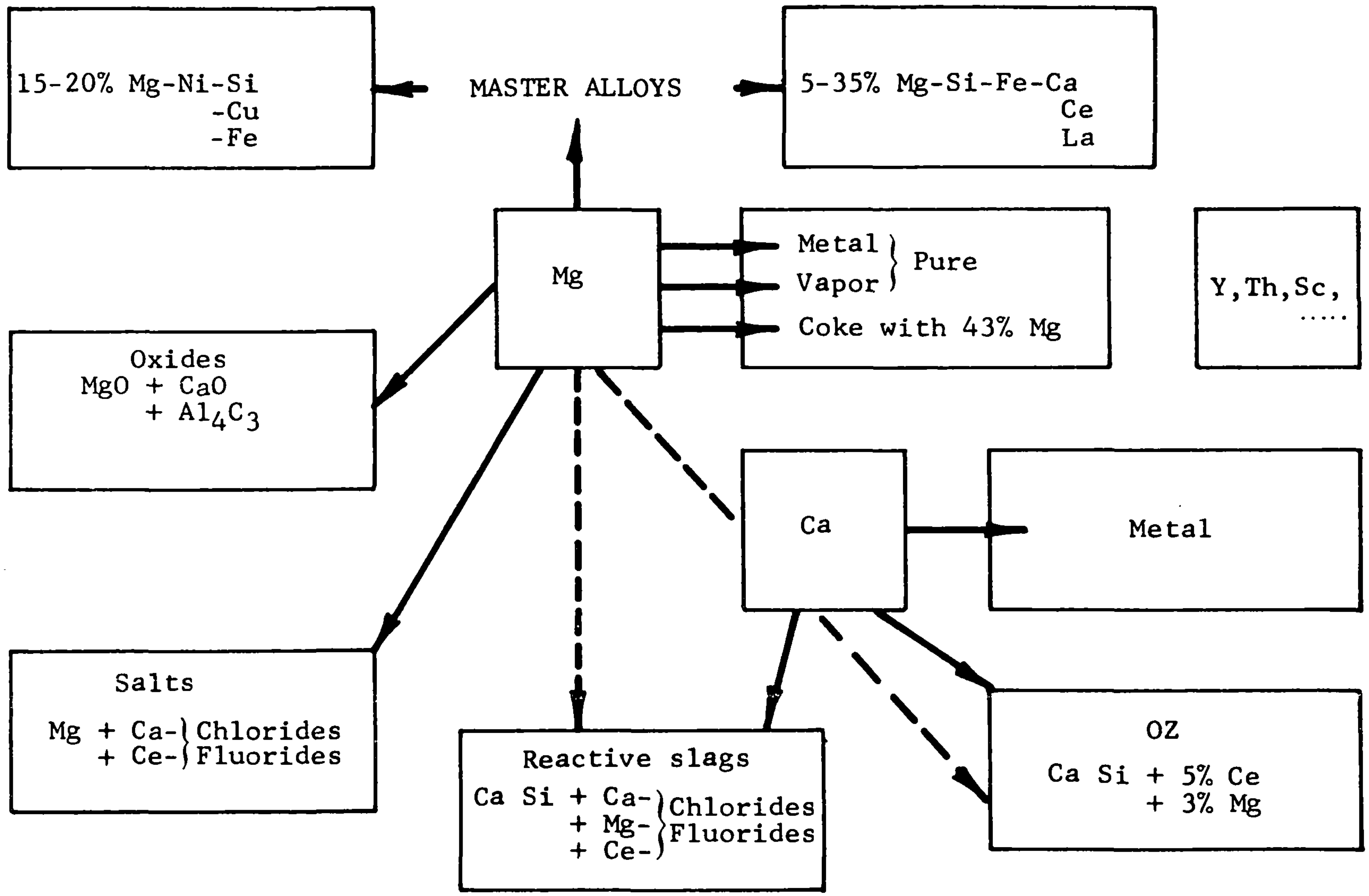
Source: "Nature of Mold Cavity Gases," Locke & Ashbrook, AFS Transactions, 1950.

MAGNESIUM TREATMENT SYSTEMS EMISSIONS REPORT FOR DUCTILE IRON PRODUCTION AND GRAY IRON DESULFURIZATION

Iron Treated - 30 Tons per Hour
Inoculant Added - 20-22 Pounds per Ton Iron
Inoculants Used - Soda Ash; MgFeSi-(10% Mg); 75% Fe
Emissions Produced - 100 Pounds per Hour
3.3 Pounds per Ton Iron
Emissions Analysis - 32% MgO
18.7% Fe_2O_3
9.5% CO_2
4.2% SiO_2
2.5% S
1.1% C
0.6% CaO
Balance Na_2O

Source: Foundry Visitations, Foundry Number 0150.

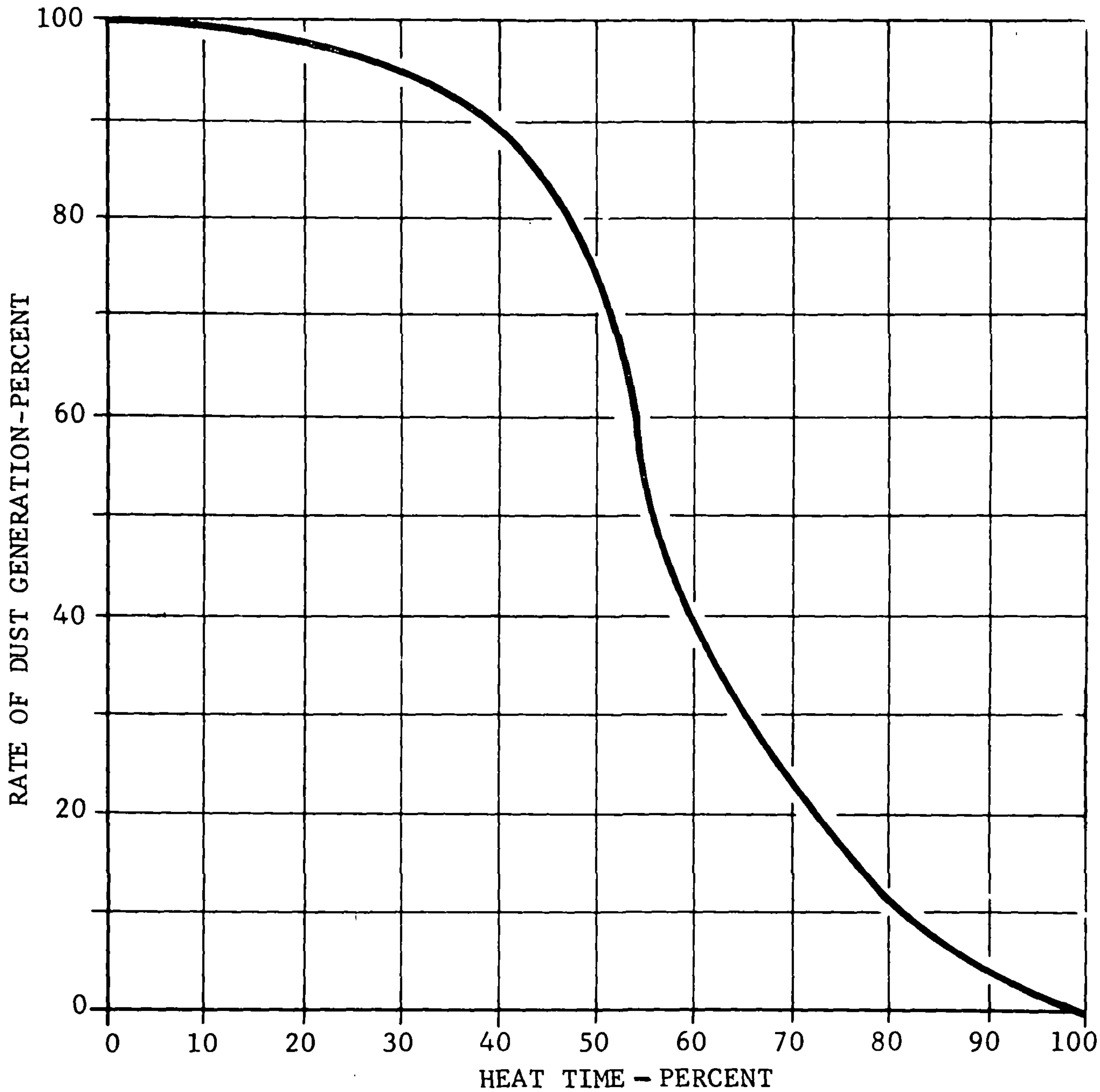
TREATMENT AGENTS FOR PRODUCING DUCTILE IRON



Source: Modl, Comparing Processes for Making Ductile Iron, Foundry, July, 1970.

EXHIBIT VI-18

RELATIONSHIP BETWEEN RATE OF EMISSIONS
AND HEAT CYCLE FOR ELECTRIC ARC MELTING



Source: Coulter, 1954, Los Angeles Air Pollution Manual.

EMISSIONS DATA FROM ELECTRIC ARC MELTING FURNACES

Number	Furnace Shell Diameter Feet	Furnace Charge Tons	Furnace Cycle Hours	Emissions Produced Lb/Ton Charge	Emissions Control System	
					Per Furnace Capacity-CFM	Gas Temp- °F
1	11.0	15	1.15	12.0(Est.)	50,000	250
2	12.0	20	1.5	6.0	65,000	120
3	8.0	5	1.0	20.0	17,000	120
4	12.0	20	2.5	18.3	32,000	250
5	7.0	3	1.75	10.0	26,000	225
6	12.0	25	4.0	4.0	63,000	200
7	8.0	5	1.0	40.0	20,000	150
8	7.0	3	1.75	12.7	10,000	220
9	7.0	2	2.0	10.7	19,000	
10	7.0	2	1.3	13.4		
11	7.0	3	2.0	5.3		
12	9.0	6	2.3	15.3		
13	9.0	6	2.0	12.8		
14	11.0	18	3.0	6.1		
15	9.0	6	1.2	29.4		
16	9.0	6	1.75	12.7		
17	8.0	4	2.0	11.0	13,000	130
18	11.0	14	1.75	7.5	19,000	190
19	12.0	19	1.7	15.0	42,000	170

Sources:
- 1- 4 Foundry Visits
- 5- 9 AFS Foundry Air Pollution Manual
- 10-19 Los Angeles Air Pollution Manual

CHEMICAL ANALYSIS OF ELECTRIC ARC EMISSIONS

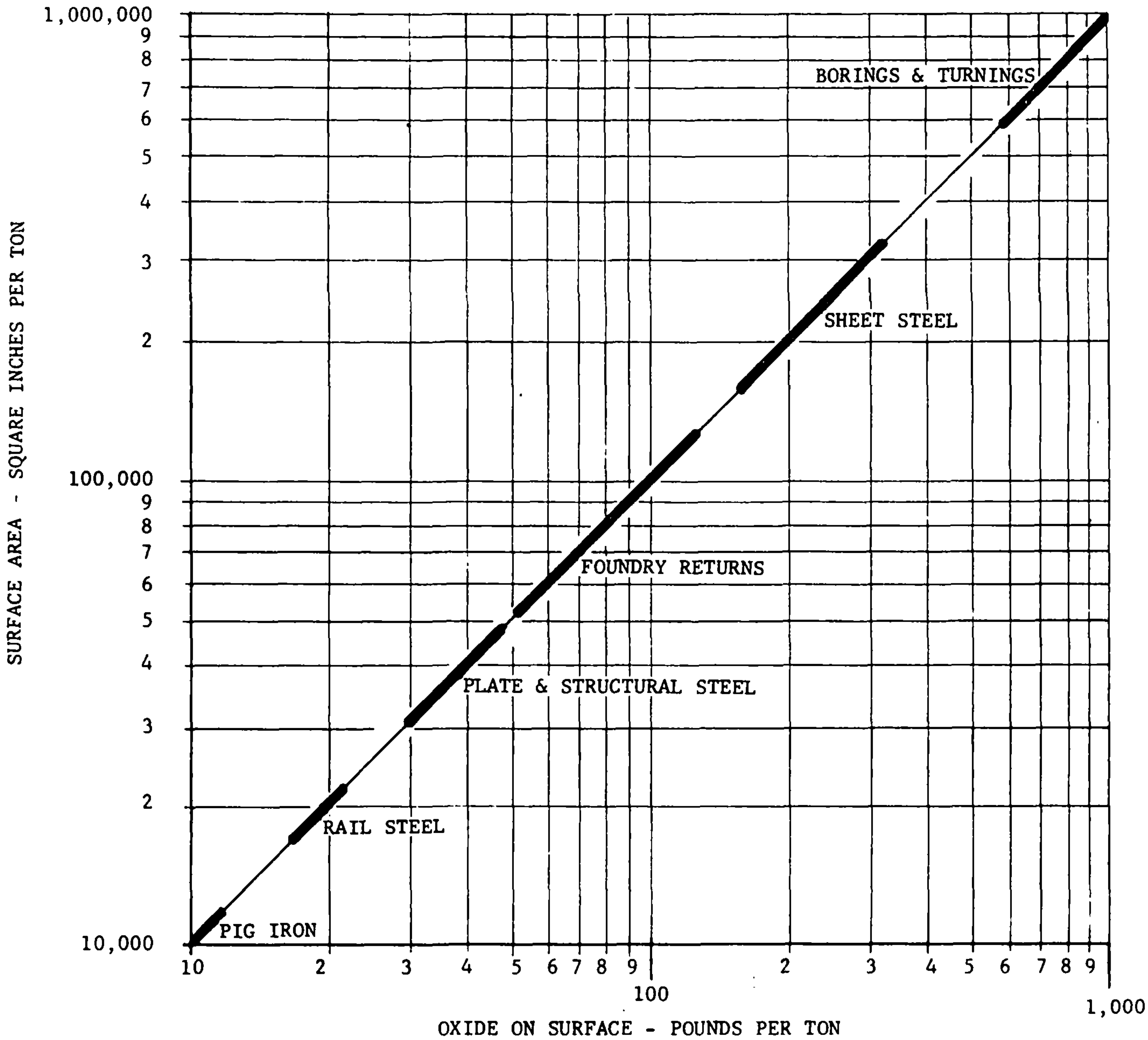
Oxides	Foundry A	Foundry B	Foundry C
Iron	75%-85%	75%-85%	75%-85%
Silicon	10	10	10
Magnesium	2	0.8	1
Manganese	2	2	2
Lead	1	2	0.5
Aluminum	0.5	1	0.5
Calcium	0.3	0.2	0.8
Zinc	0.2	2.	0.3
Copper	0.04	0.03	0.01
Lithium	0.03	0.03	0.03
Tin	0.03	0.3	0.02
Nickel	0.02	0.03	0.01
Chromium	0.02	0.07	0.02
Barium	0.02	0.07	0.01
Loss on Ignition	8.87	3.1	0
Ash	91.93	96.9	100

SIZE DISTRIBUTION FOR THREE ELECTRIC ARC INSTALLATIONS

Particle Size Distribution, Microns	Foundry A*	Foundry B	Foundry C
Less than 1	5%	8%	18%
Less than 2	15	54	61
Less than 5	28	80	84
Less than 10	41	89	91
Less than 15	55	93	94
Less than 20	68	96	96
Less than 50	98	99	99

Note: *Foundry A provided an agglomerated sample and is, therefore, less representative.

EFFECT OF TYPE OF SCRAP
ON AMOUNT OF IRON OXIDE PRESENT



EFFECT OF SPECIFIC BLAST RATE AND COKE RATE ON PARTICULATE EMISSIONS FROM UNLINED CUPOLAS

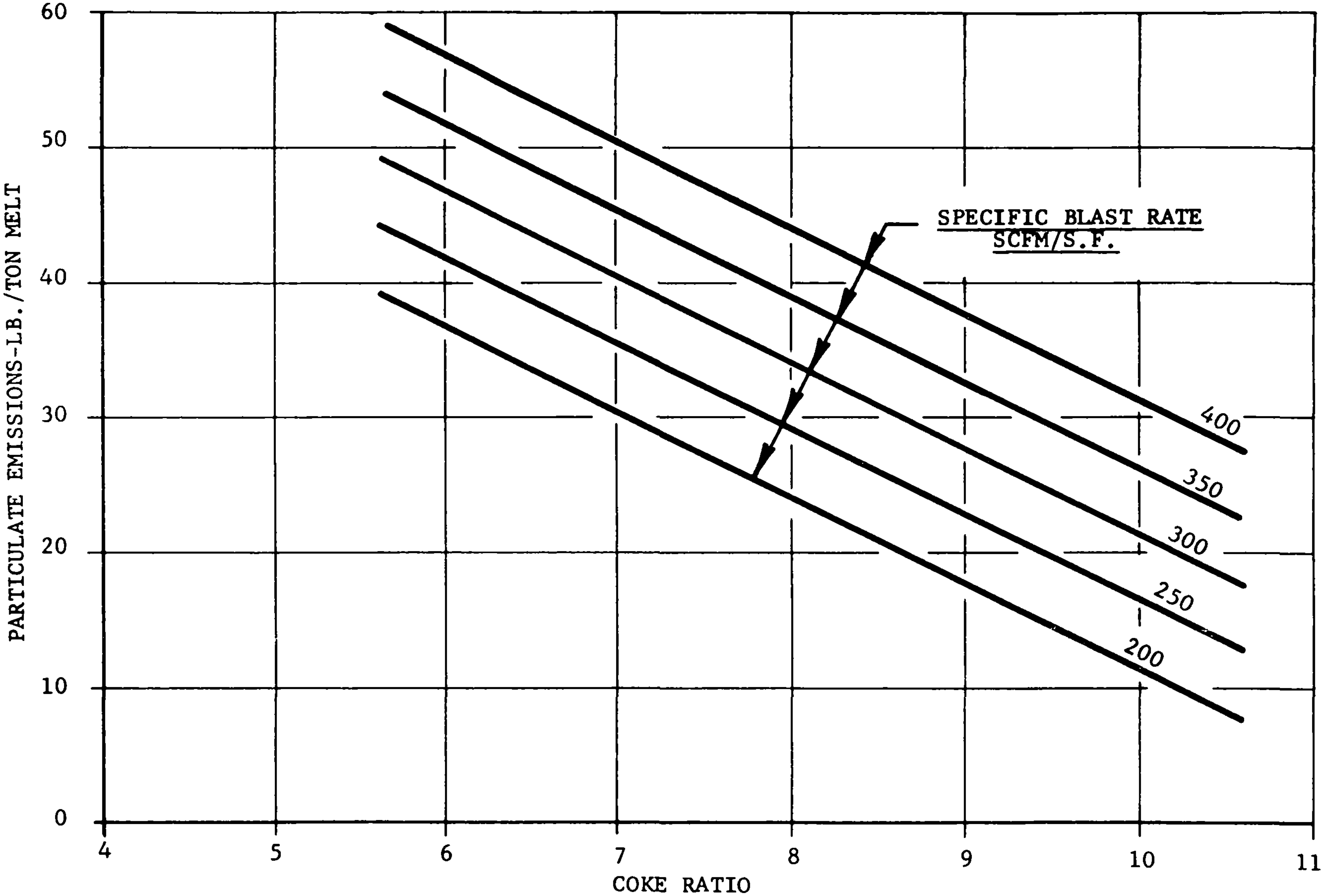


EXHIBIT VI-13

PARTICULATE EMISSIONS
VS. SPECIFIC BLAST RATE
FOR ACID LINED CUPOLAS

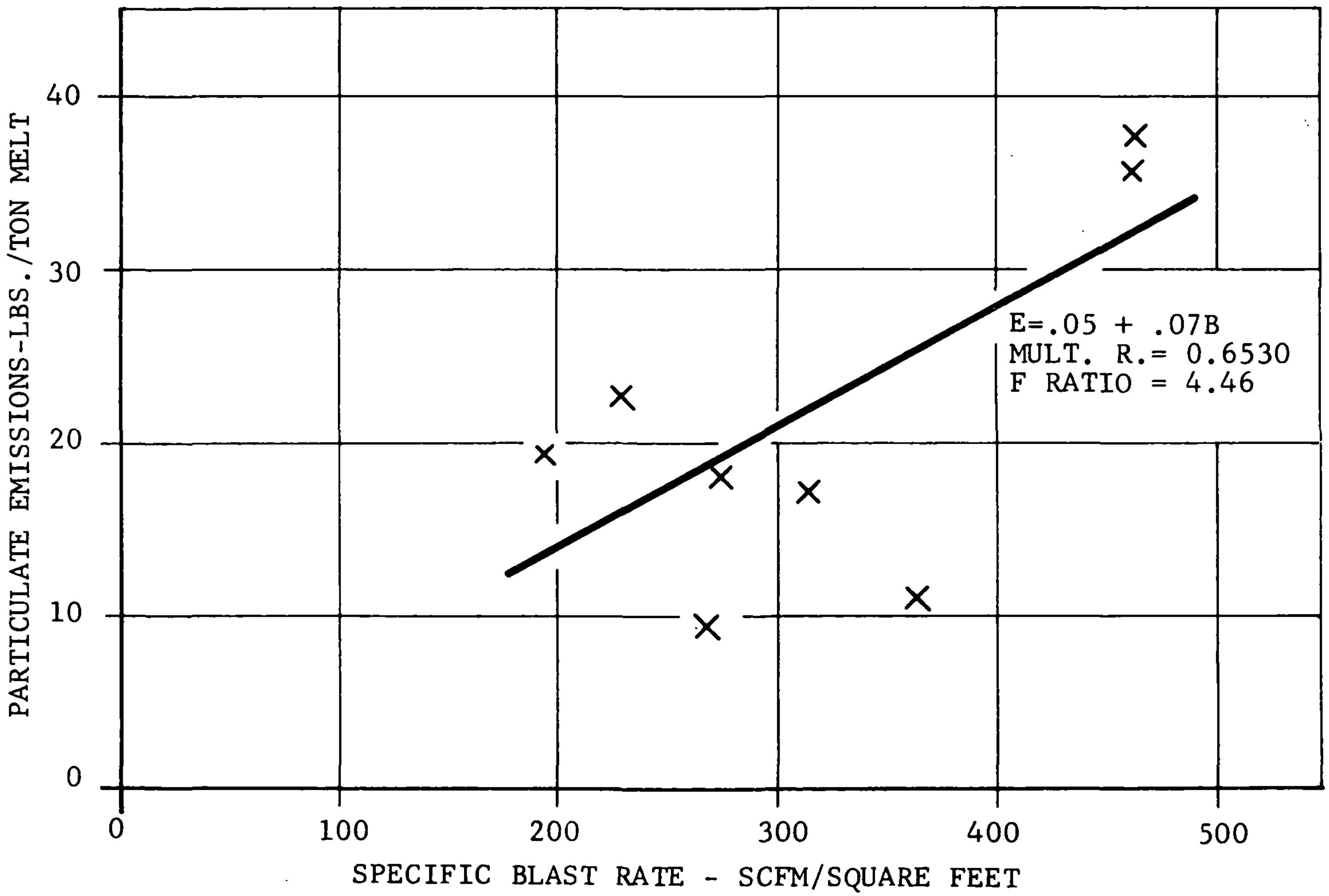


EXHIBIT VI-12

LINEAR REGRESSION ANALYSIS OBSERVATIONS

Foundry Number	Cupola Classification	Particulate Emissions Lb./Ton	Specific Melt Rate T/Hr./S.F.	Specific Blast Rate SCFM/S.F.	Metal to Coke Ratio	Temperature °F
Acid Lined Cupolas						
12	27	9.5	0.56	269	11.5	1,100
5	14	11.4	.73	364	8	70
37	14	17.4	.64	317	6	70
26	14	18.3	.63	274	8	70
7	18	19.9	.71	194	9	700
150	24	22.9	.78	231	10.5	750
9	23	36.0	.57	462	10	750
9	14	37.0	.57	462	10	
Basic Lined Cupola						
18	30	48.5	0.48	357	6	70
Unlined Cupolas						
151	10	7.5	0.50	248	9	1,000
45	10	20.4	.52	238	9	1,400
35	4	40.4	.76	324	8	600
125	9	40.4	.55	244	10	1,000
160	2	40.5	.36	317	8	1,000
84	9	45.7	.60	238	7	1,000
29	4	46.6	.31	252	6	750
67	9	66.3	.63	352	6	1,200
67	9	50.0	.70	352	7	1,400

MULTIPLE LINEAR REGRESSION CORRELATION MATRICES

CORRELATION MATRIX FOR ACID LINED CUPOLAS

Particulate Emissions Lb./Ton	Specific Melt Rate T/Hr./S.F.	Specific Blast Rate SCFM/S.F.	Metal to Coke Ratio	Blast Temperature °F
1.000	-0.330	0.653	0.223	0.294
-0.330	1.000	-0.561	-0.215	-0.473
0.653	-0.561	1.000	0.026	0.268
0.223	-0.215	0.026	1.000	0.874
0.294	-0.473	0.268	0.874	1.000

CORRELATION MATRIX FOR UNLINED CUPOLAS

Particulate Emissions Lb./Ton	Specific Melt Rate T/Hr./S.F.	Specific Blast Rate SCFM/S.F.	Metal to Coke Ratio	Blast Temperature °F
1.000	0.226	0.600	-0.703	-0.008
0.226	1.000	0.448	0.022	0.130
0.600	0.448	1.000	-0.454	0.131
-0.703	0.022	-0.450	1.000	0.060
-0.008	0.130	0.131	0.060	1.000

PARAMETERS OF CUPOLA FURNACES - LINEAR REGRESSION ANALYSES OF EMISSIONS AFFECTED BY FURNACE DESIGN FACTORS

		Cupola Furnace Parameters										
Foundry Number	Furnace Classification	Lining Type	Blast Design	Blast Heating	Top Open or Closed	Charging Top or Side	Gas Takeoff	After-burner	Charging Door Open or Closed	Fuel Injection	Oxygen Enrichment	Emissions Lb./Ton Melt
151	10	4	1	3	1	2	1	0	1	0	0	7.5
12	27	1	1	3	2	2	8	0	1	0	0	9.6
5	14	1	3	1	1	2	1	2	1	0	0	11.4
146	17	1	3	1	1	2	1	0	2	0	1	12.1
12	32	2	1	3	2	2	8	0	1	0	0	12.4
50	16	1	3	1	1	2	1	-1	1	0	0	15.1
37	14	1	3	1	1	2	1	2	1	0	0	17.4
26	14	1	3	1	1	2	1	2	1	0	0	18.3
152	16	1	3	1	1	2	1	-1	1	0	0	19.5
7	18	1	3	1	1	2	2	2	1	0	0	19.9
45	10	4	1	3	1	2	1	0	1	0	0	20.4
-69	29	1	1	3	1	2	2	0	1	0	1	20.6
134	6	4	1	3	1	2	1	-1	1	0	0	20.8
150	24	1	2	2	1	1	2	1	2	0	1	22.9
9	23	1	2	3	1	2	1	2	1	0	0	36.0
9	14	1	3	1	1	2	1	2	1	0	0	37.6
35	4	4	2	3	1	2	1	2	1	0	0	40.4
125	9	4	1	3	1	2	1	2	1	0	0	40.4
160	2	4	3	1	1	2	1	0	1	0	0	40.5
-71	11	4	1	3	1	2	2	0	1	0	0	44.7
84	9	4	1	3	1	2	1	2	1	0	0	45.7
29	4	4	2	3	1	2	1	6	1	0	0	46.6
18	30	2	3	1	2	2	8	-1	1	0	0	48.5
67	9	4	1	3	1	2	1	1	1	0	0	50.0
69	13	1	3	1	2	2	8	0	1	0	0	53.4
67	9	4	1	3	1	2	1	1	1	0	0	66.3

Note: See Appendix B, Exhibit 2 for description of cupola furnace parameter codes.

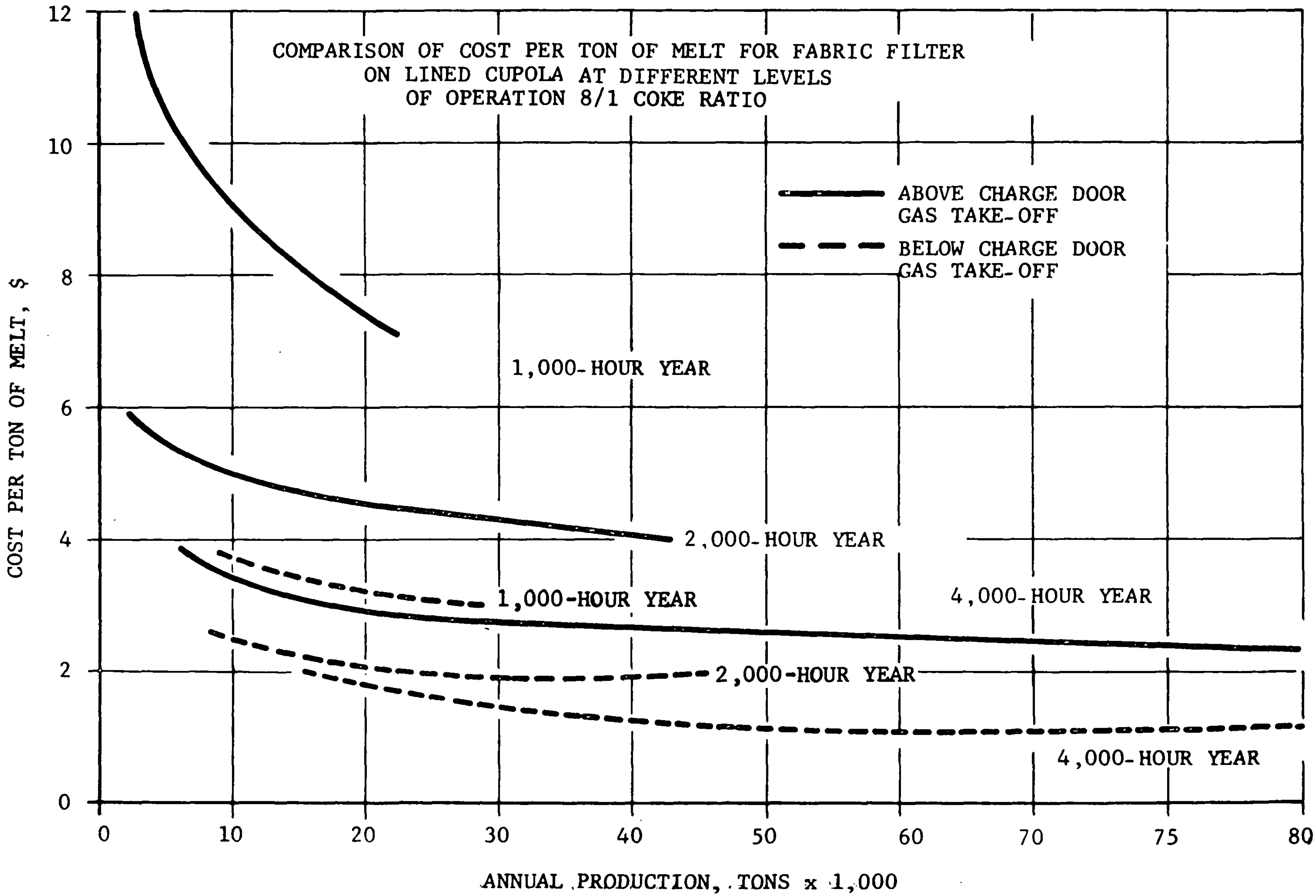
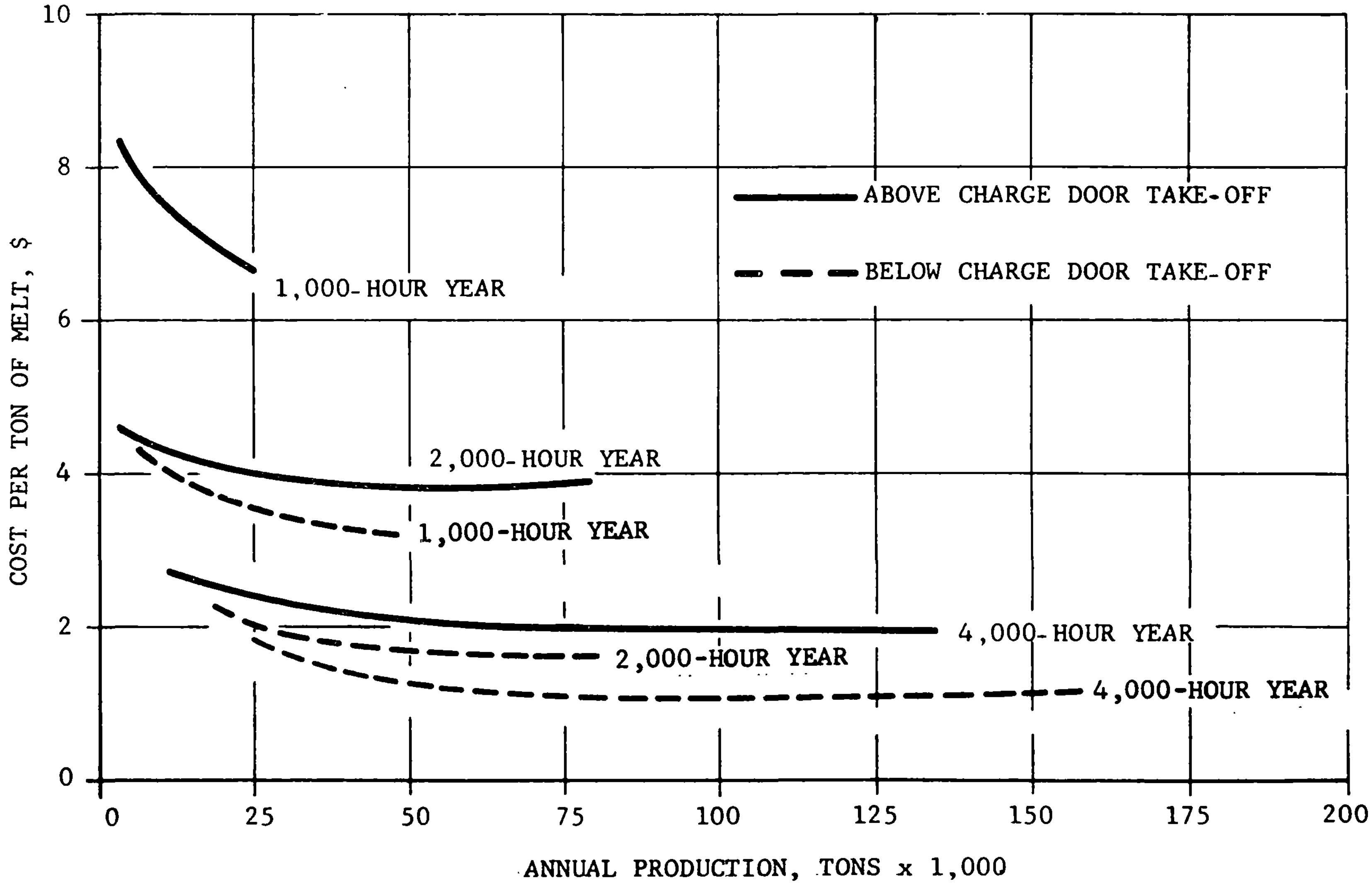


EXHIBIT VIII-30

COMPARISON OF COST PER TON OF MELT
FOR FABRIC FILTER ON UNLINED CUPOLA
AT DIFFERENT LEVELS OF OPERATION
5/1 COKE RATIO



COMPARISON OF COST PER TON OF MELT FOR LOW ENERGY WET SCRUBBER ON LINED CUPOLA AT DIFFERENT LEVELS OF OPERATION. 8/1 COKE RATIO

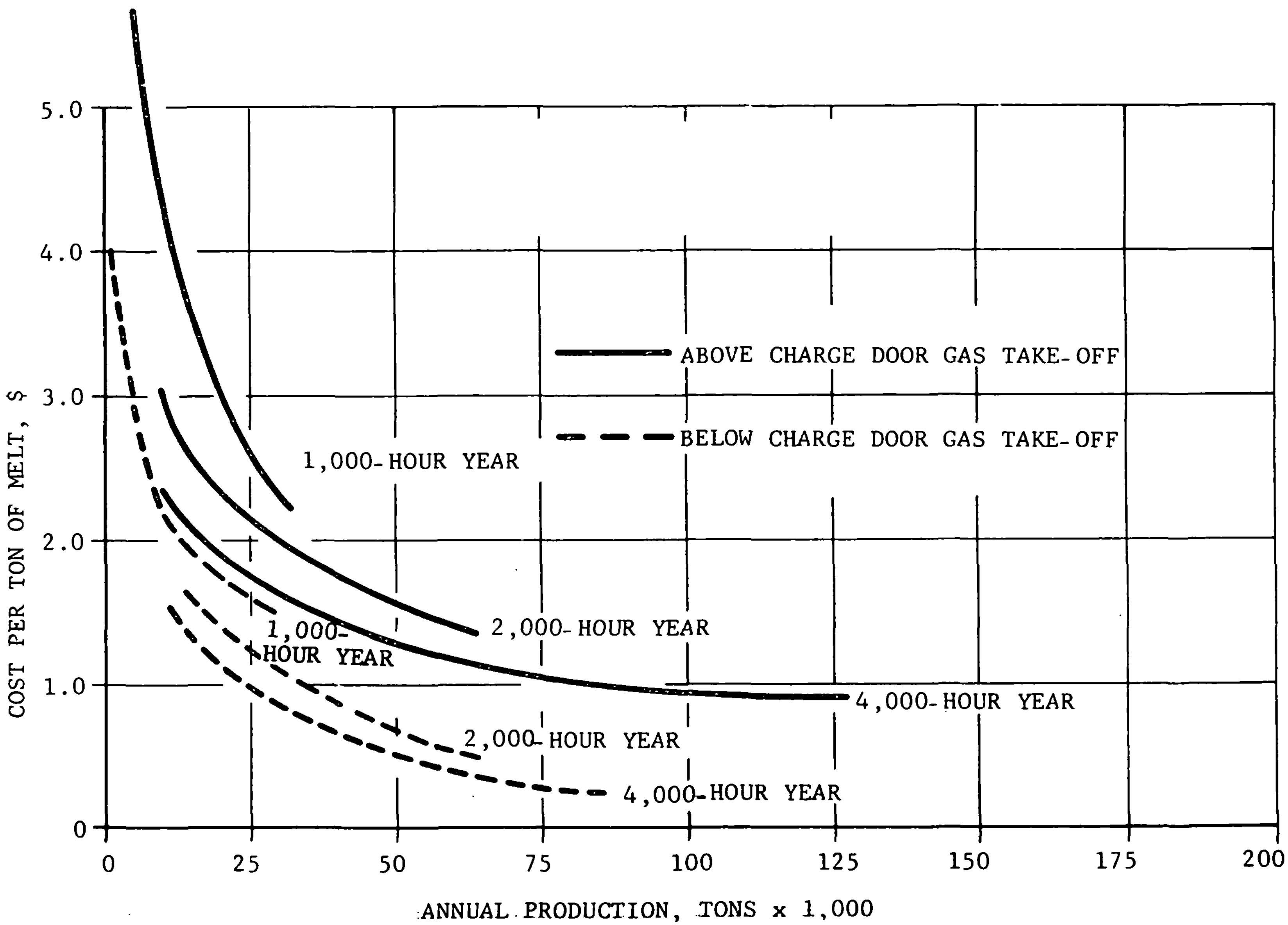


EXHIBIT VIII-28

COMPARISON OF COST PER TON OF MELT FOR LOW ENERGY WET SCRUBBER ON UNLINED CUPOLA AT DIFFERENT LEVELS OF OPERATION 5/1 COKE RATIO

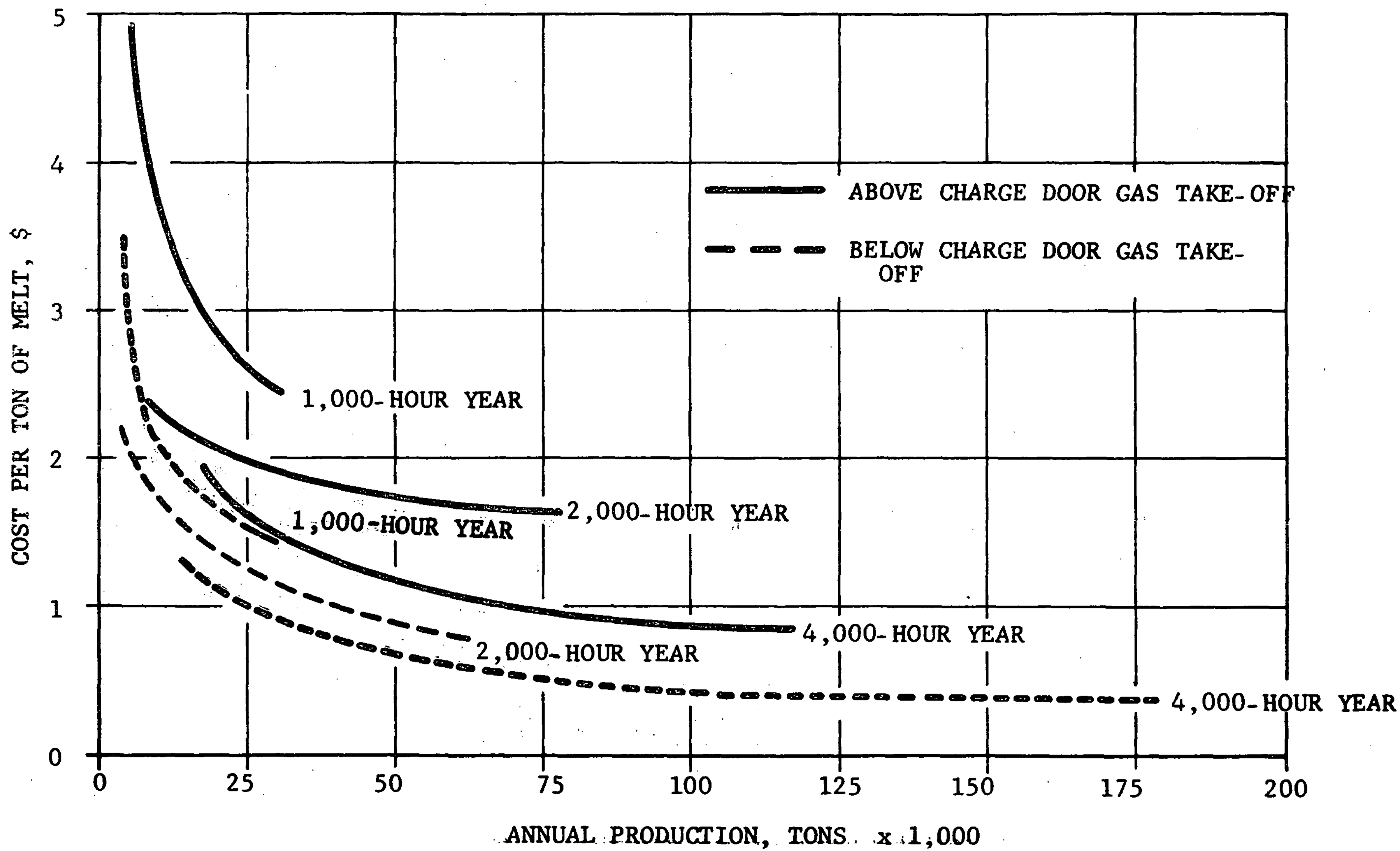


EXHIBIT VIII-27

COMPARISON OF COST PER TON OF MELT FOR HIGH ENERGY WET SCRUBBER ON LINED CUPOLA AT DIFFERENT LEVELS OF OPERATION. 8/1 COKE RATIO

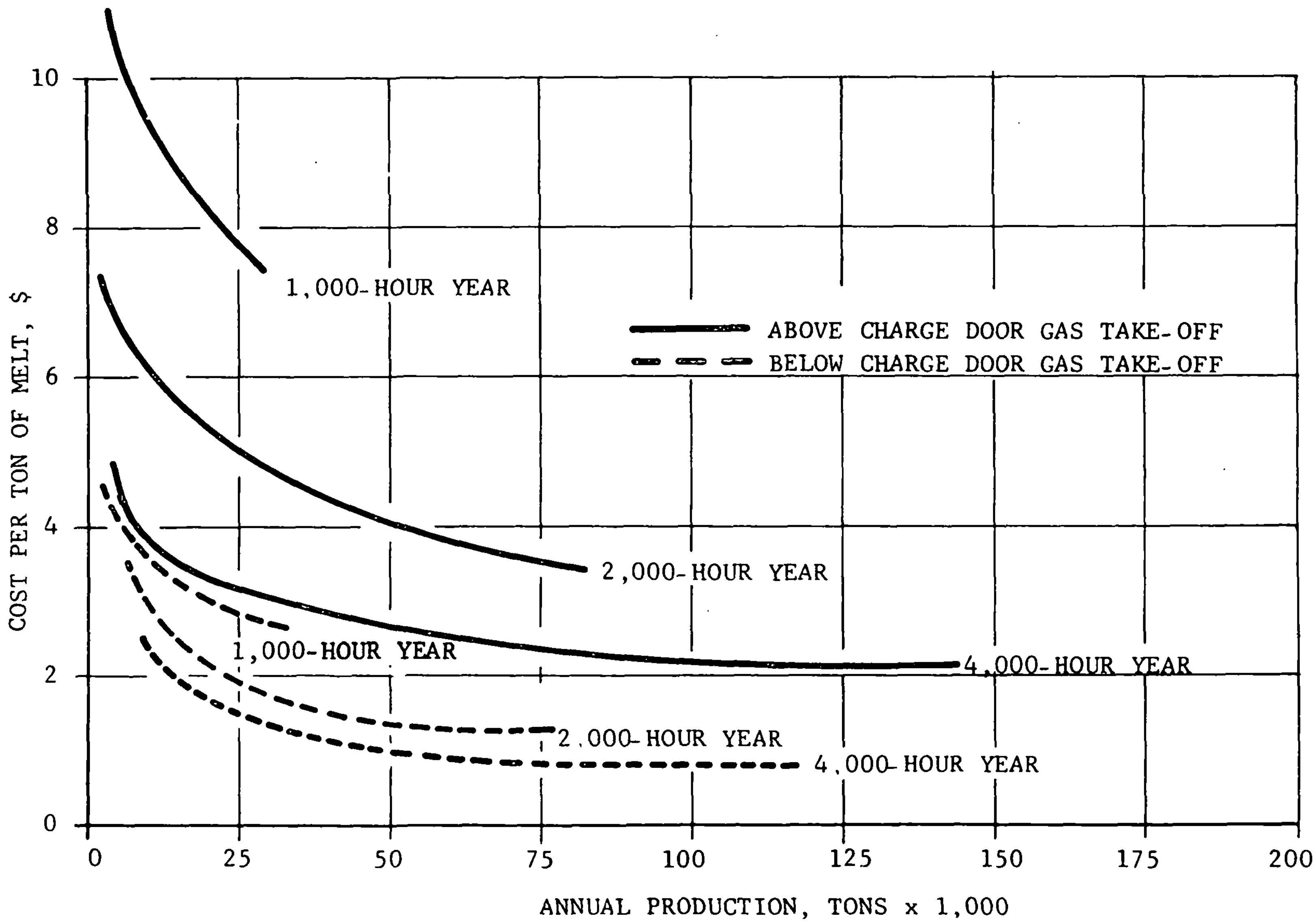
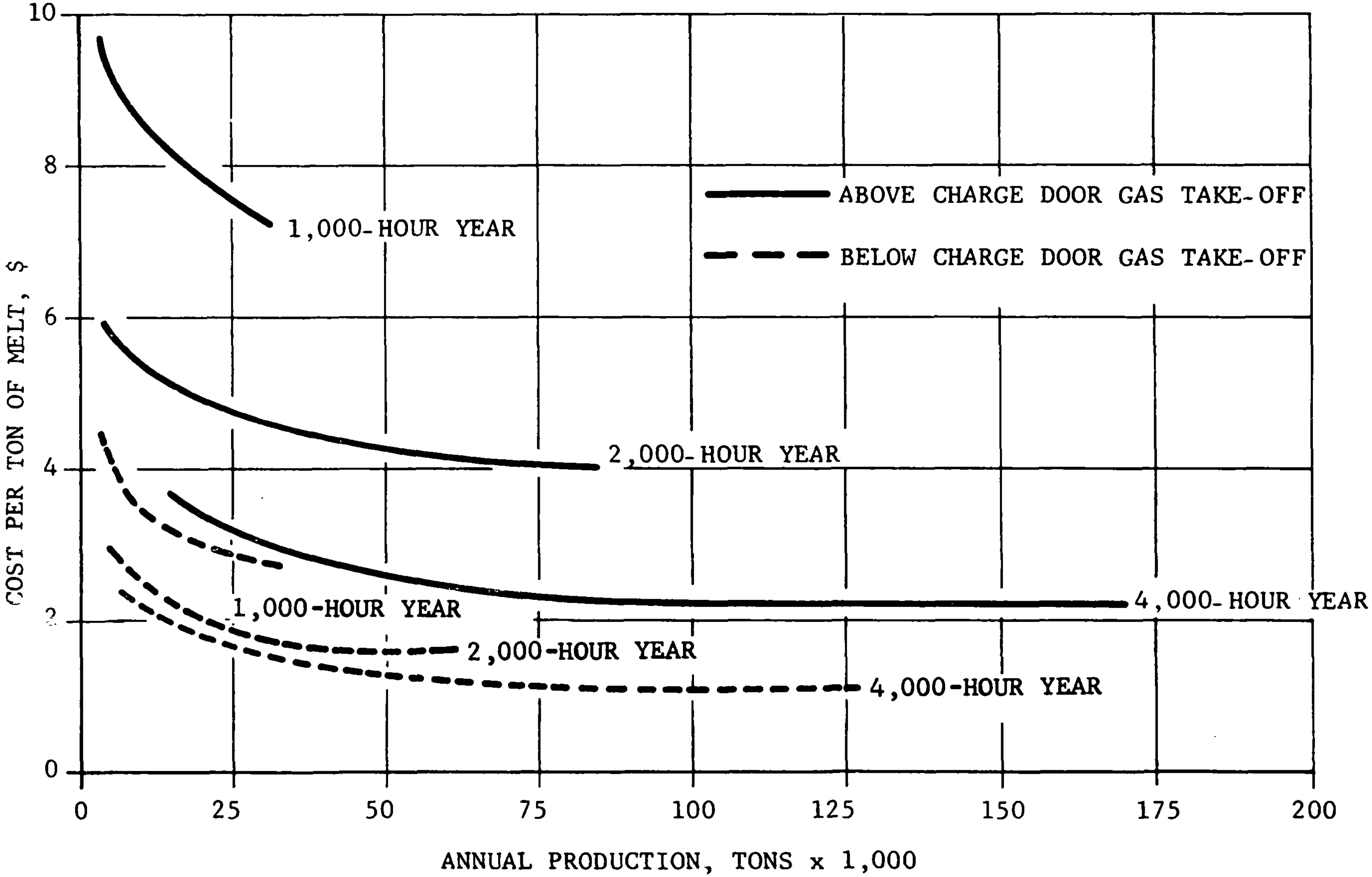


EXHIBIT VIII-26

COMPARISON OF COST PER TON OF MELT FOR HIGH ENERGY WET SCRUBBER ON UNLINED CUPOLA AT DIFFERENT LEVELS OF OPERATION 5/1 COKE RATIO



TOTAL ANNUAL COST
FOR FABRIC FILTERS ON
ELECTRIC ARC

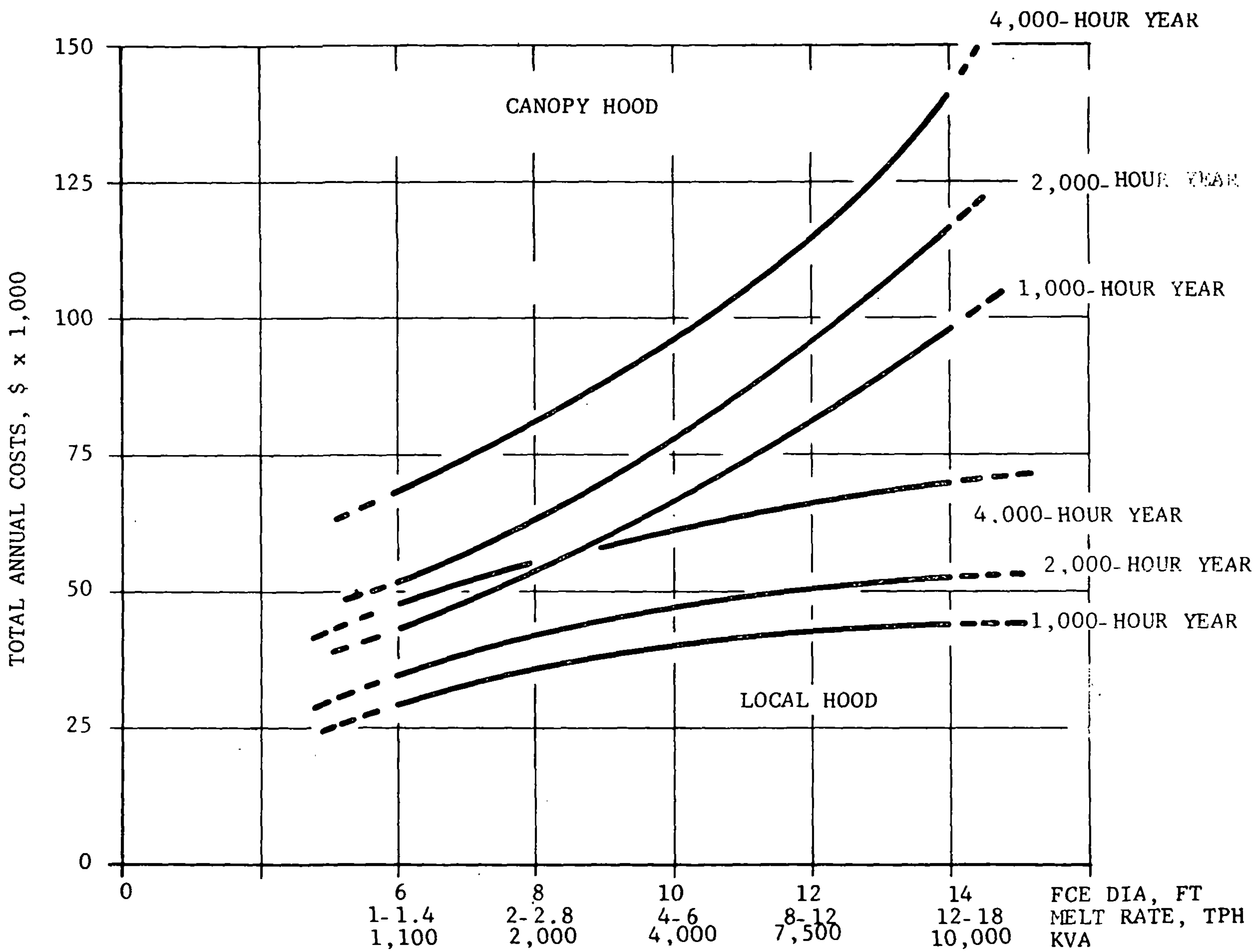
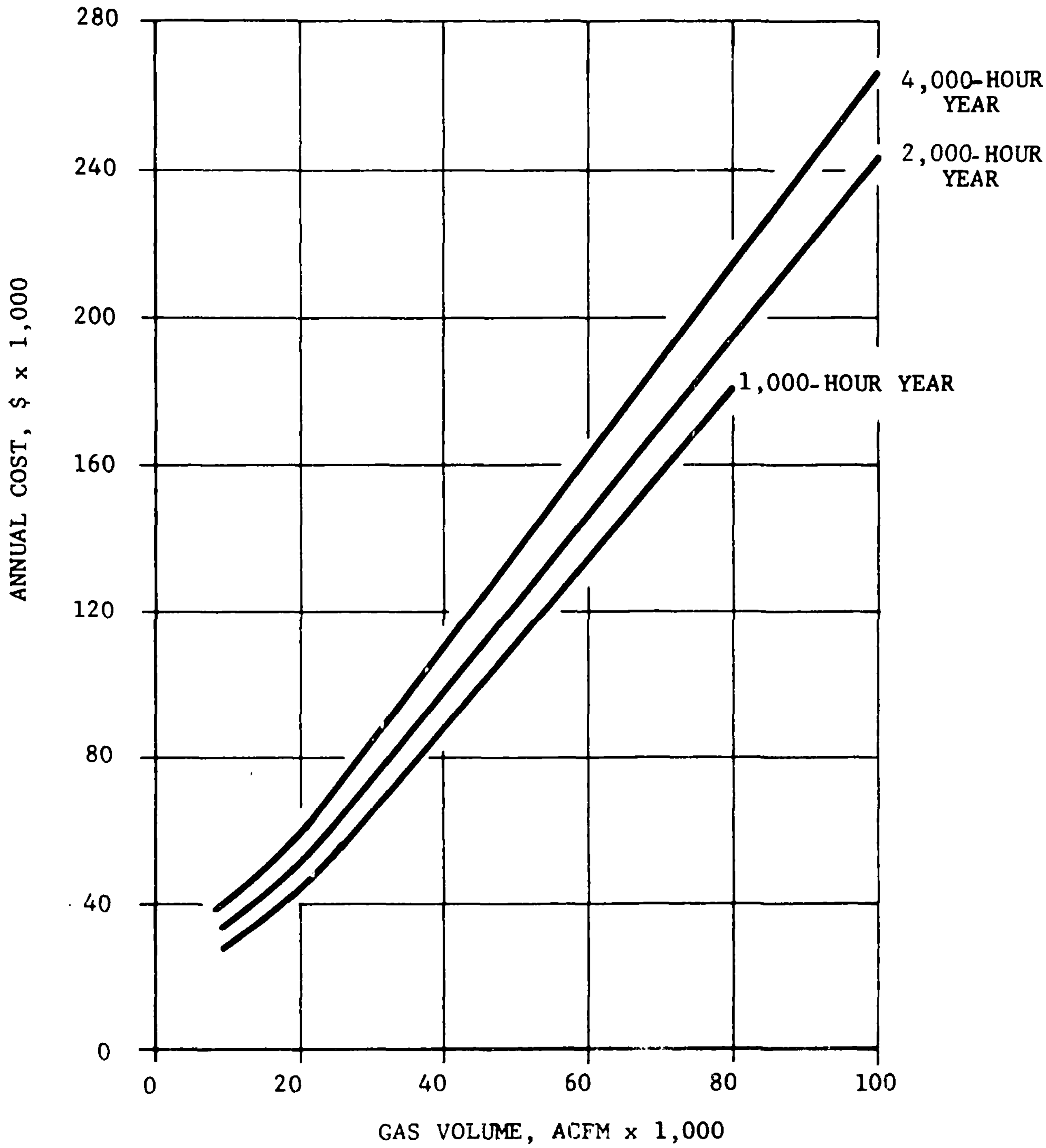
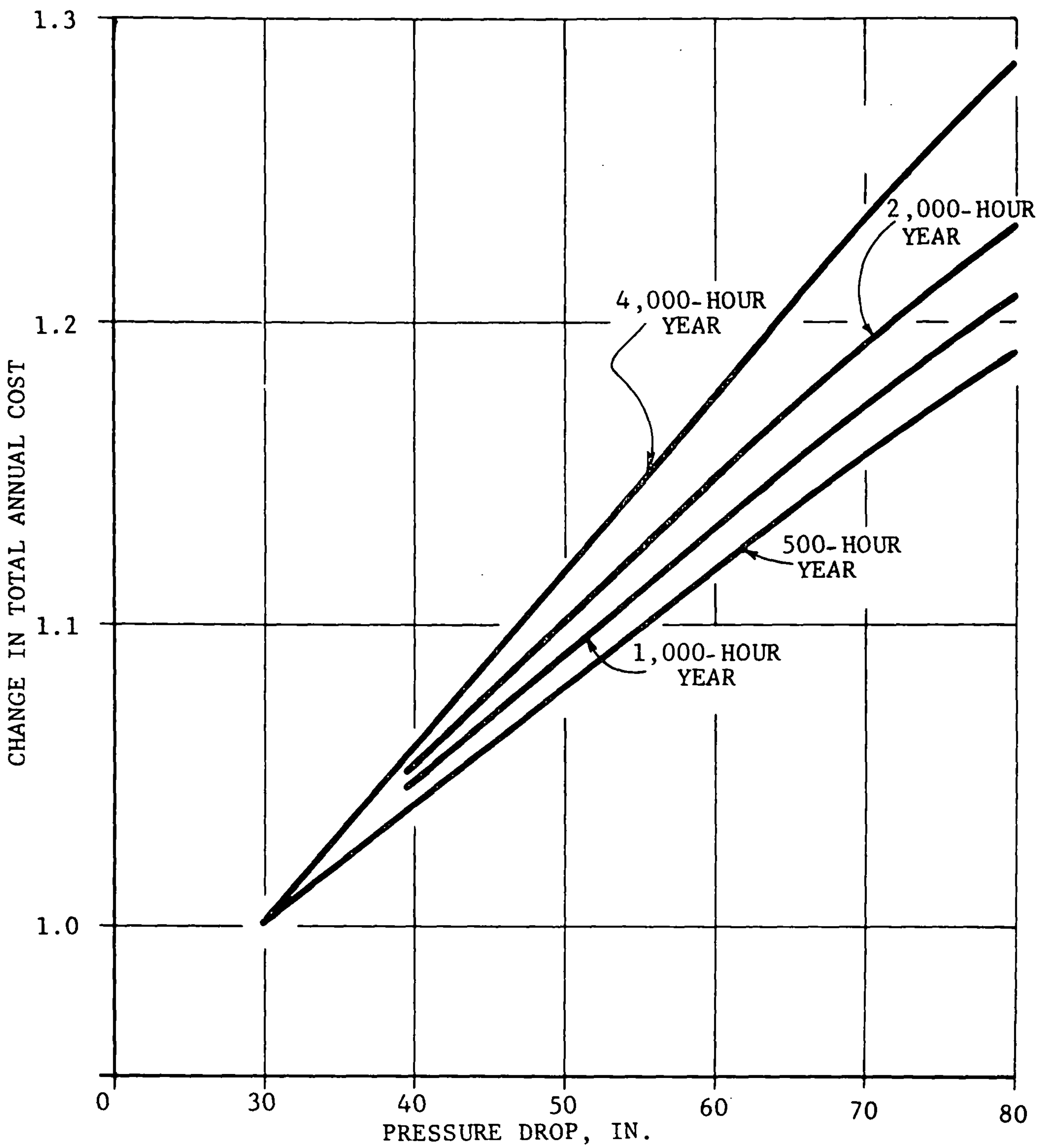


EXHIBIT VIII-24

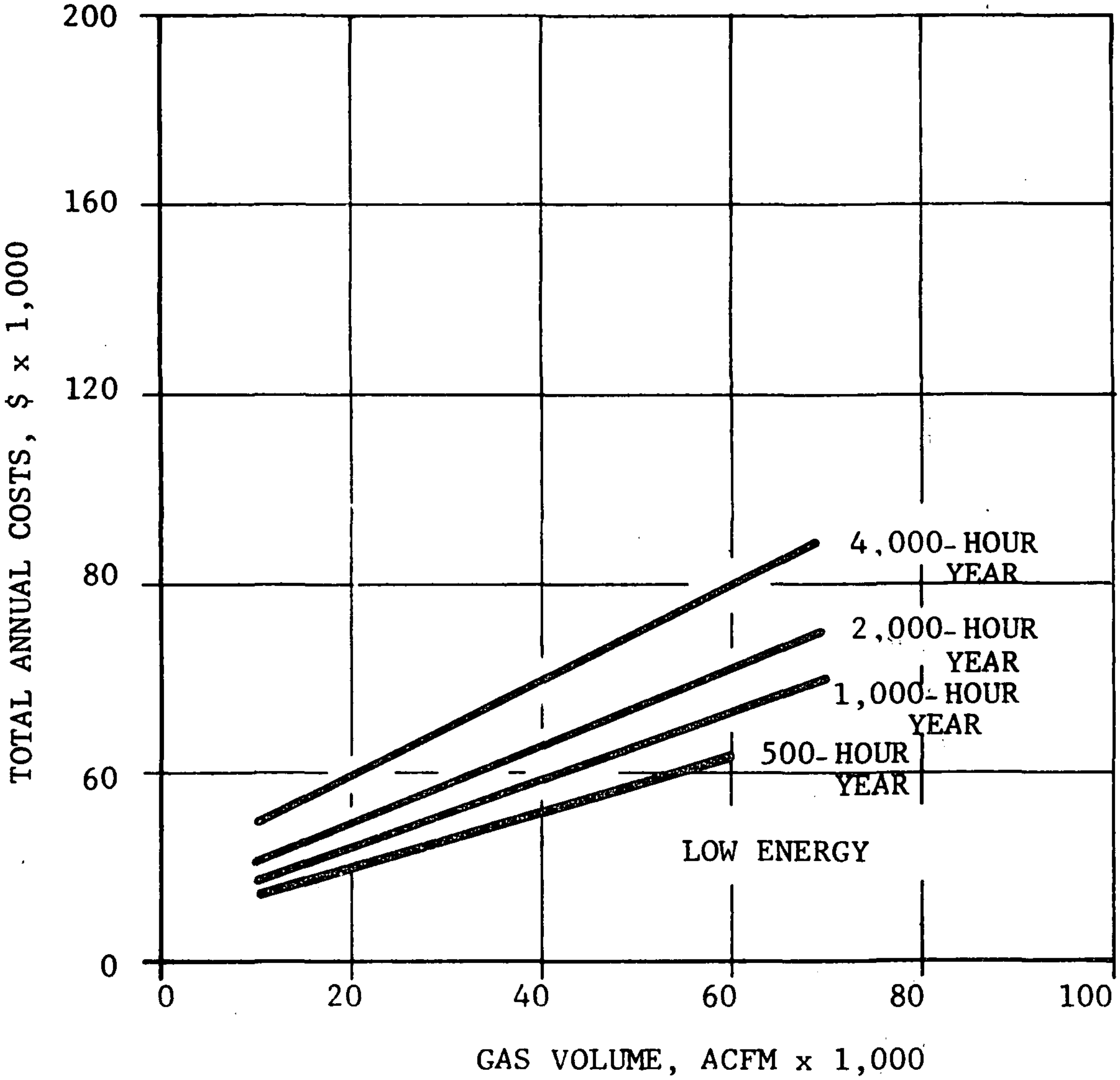
TOTAL ANNUAL COST FOR
FABRIC FILTERS ON CUPOLAS
(Air Cooling of Gas)



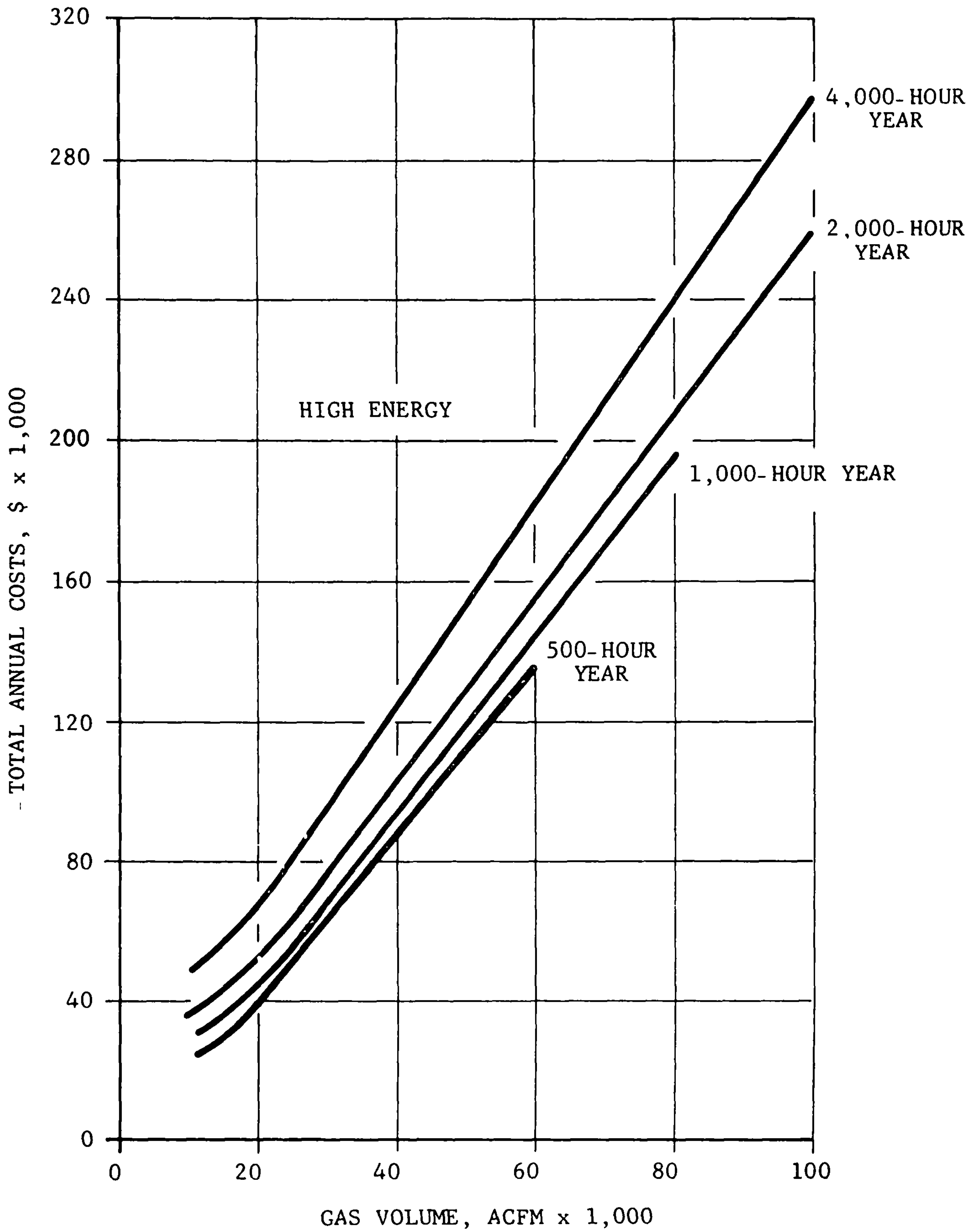
RELATIVE CHANGE IN TOTAL ANNUAL COSTS VS. PRESSURE DROP FOR WET SCRUBBERS



TOTAL ANNUAL COSTS
FOR LOW
ENERGY WET SCRUBBERS
ON CUPOLAS



TOTAL ANNUAL COSTS
FOR HIGH
ENERGY WET SCRUBBERS
ON CUPOLAS



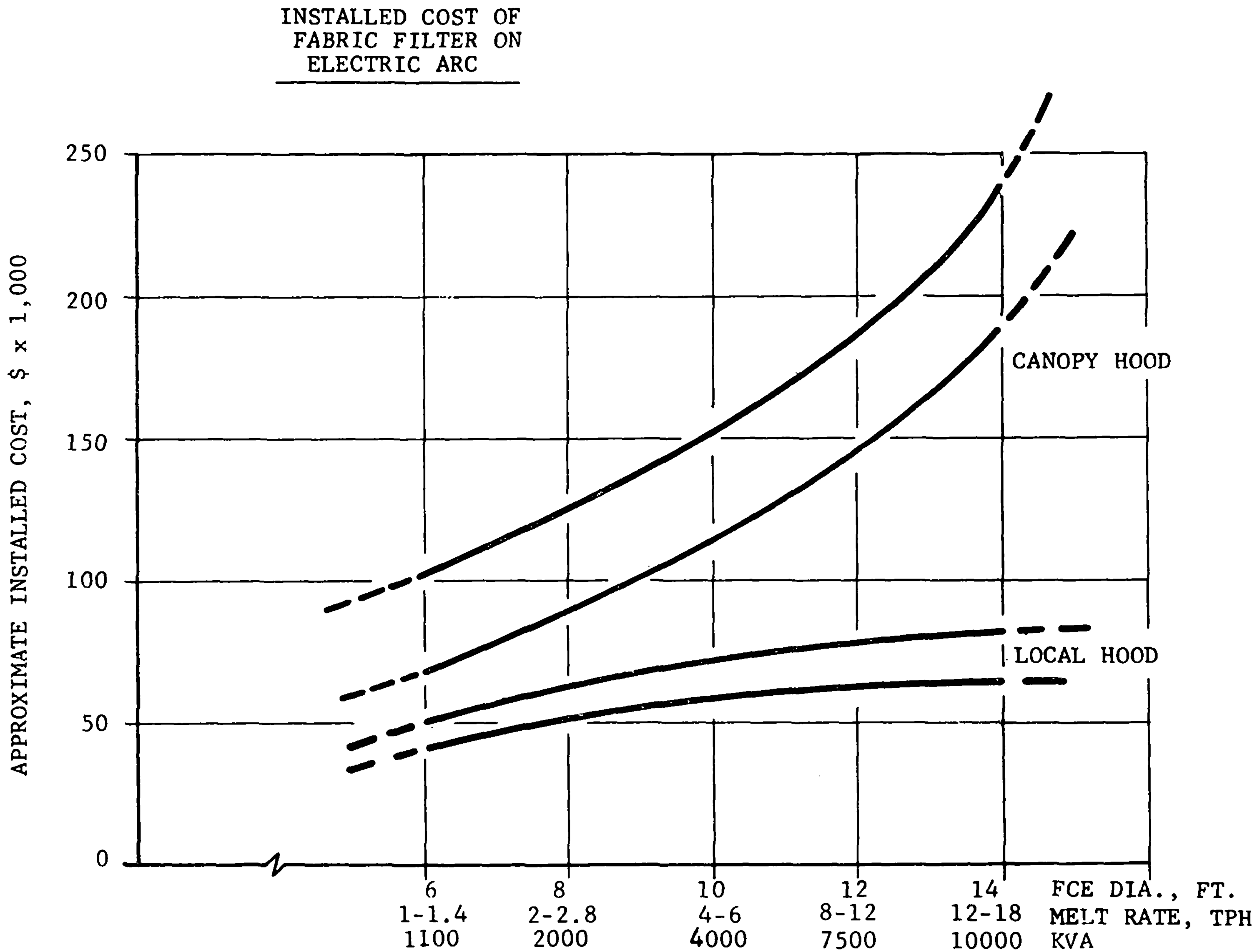


EXHIBIT VIII-19

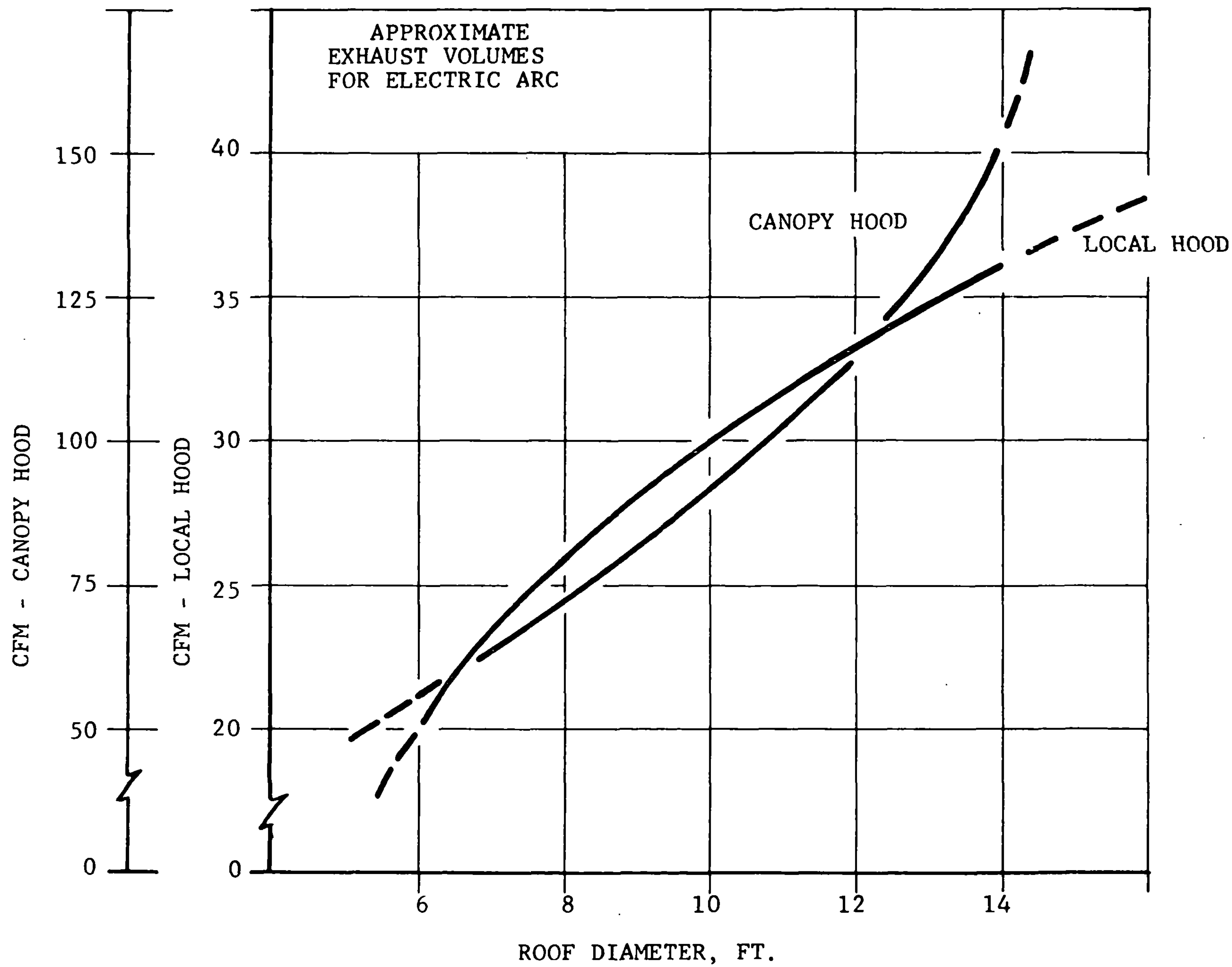
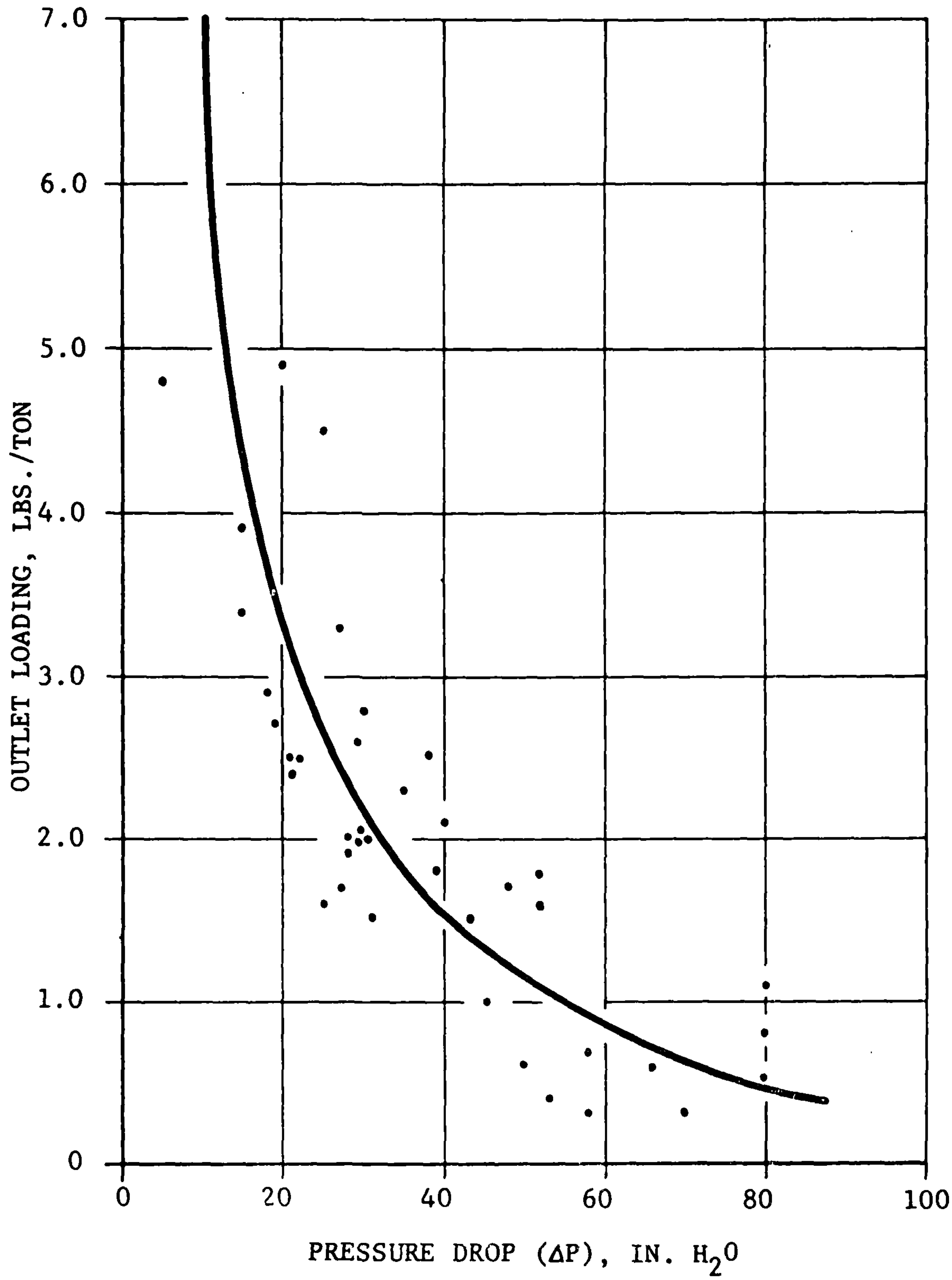


EXHIBIT VIII-18

COMPARISON OF CUPOLA OUTLET DUST LOADING AND PRESSURE DROP FOR WET SCRUBBERS



CALCULATION OF WET SCRUBBER EFFICIENCY FOR VARIOUS PRESSURE DROPS

Size of Particles, Microns	Percent of Particles(1)		Efficiency at Mean Size of Particles, Percent(2)						Overall Collection Efficiency, Percent											
									Cold Blast						Hot Blast					
	Cold Blast	Hot Blast	5"	10"	20"	30"	40"	60"	5"	10"	20"	30"	40"	60"	5"	10"	20"	30"	40"	60"
Over 200	15%	5%	100%	100%	100%	100%	100%	100%	15%	15%	15%	15%	15%	15%	5%	5%	5%	5%	5%	5%
100-200	10	15	100	100	100	100	100	100	10	10	10	10	10	10	15	15	15	15	15	15
50-100	15	20	99.9	100	100	100	100	100	14.9	15	15	15	15	15	19.9	20	20	20	20	20
20-50	15	20	99.9	99.9	99.9	99.9	100	100	14.9	14.9	14.9	14.9	15	15	19.9	19.9	19.9	19.9	20	20
10-20	20	5	99.5	99.9	99.9	99.9	99.9	100	19.9	19.9	19.9	19.9	19.9	20	4.9	4.9	4.9	4.9	4.9	5
5-10	5	5	97.5	99.4	99.9	99.9	99.9	100	4.8	4.9	4.9	4.9	4.9	5	4.8	4.9	4.9	4.9	4.9	5
2-5	5	10	95	98.5	99.7	99.9	99.9	99.9	4.7	4.9	4.9	4.9	4.9	4.9	9.5	9.8	9.9	9.9	9.9	9.9
0-2	15	20	82	93	98.3	99.4	99.7	99.9	12.3	13.9	14.7	14.9	14.9	14.9	16.4	18.6	19.6	19.8	19.8	19.9
Total	100%	100%							96.5%	98.5%	99.3%	99.5%	99.6%	99.8%	95.4%	98.1%	99.2%	99.4%	99.5%	99.8%

Notes: (1) Engels & Weber, "Cupola Emission Control"
(2) From Exhibit VII-28.

TOTAL INVESTMENT COSTS FOR WET CAPS

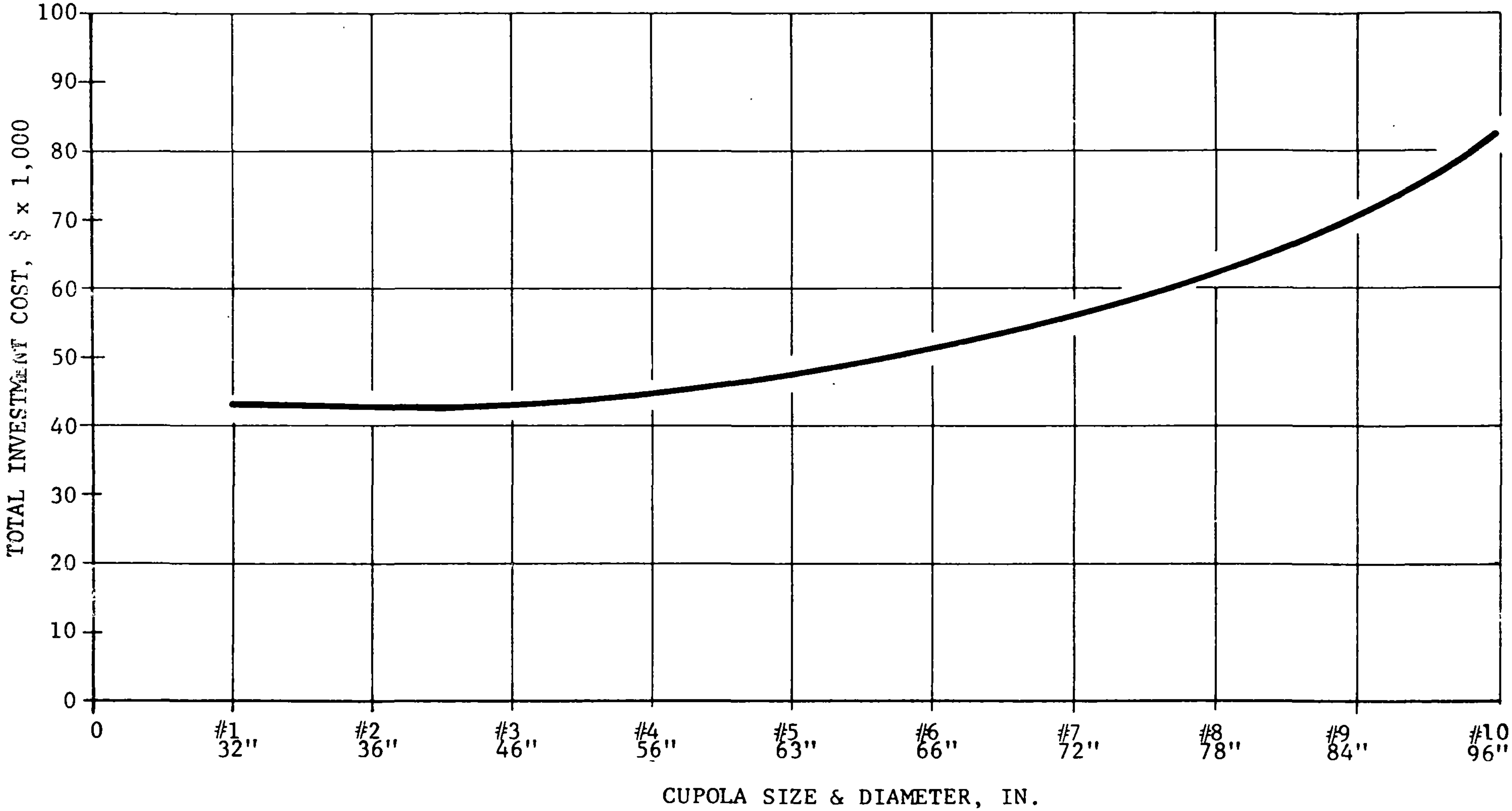
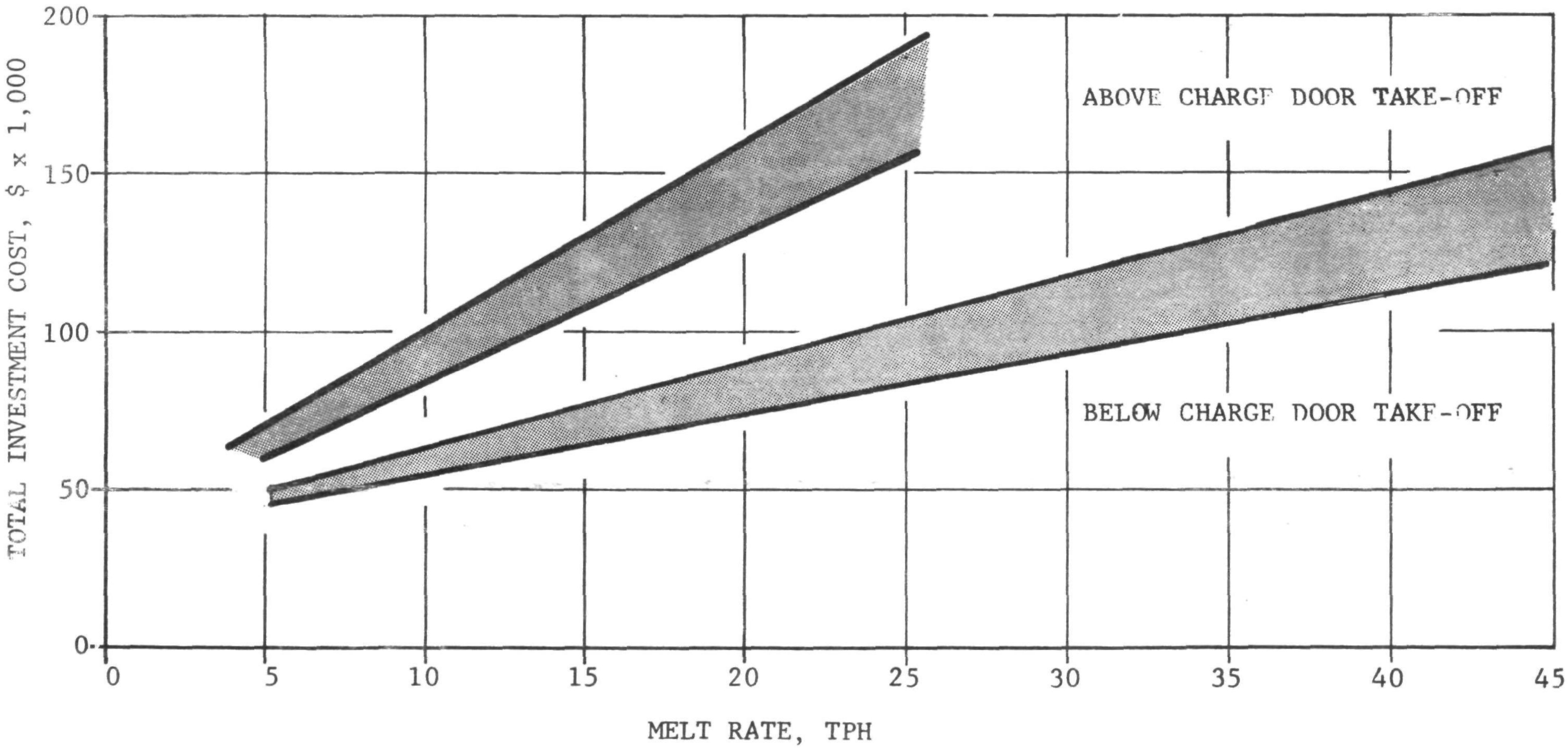


EXHIBIT VIII-15

LOW ENERGY WET SCRUBBER
TOTAL INVESTMENT COST
VS. MELT RATE FOR UNLINED
CUPOLA 8/1 COKE RATIO



LOW ENERGY WET SCRUBBER
TOTAL INVESTMENT COST
VS. MELT RATE FOR LINED
CUPOLA 8/1 COKE RATIO

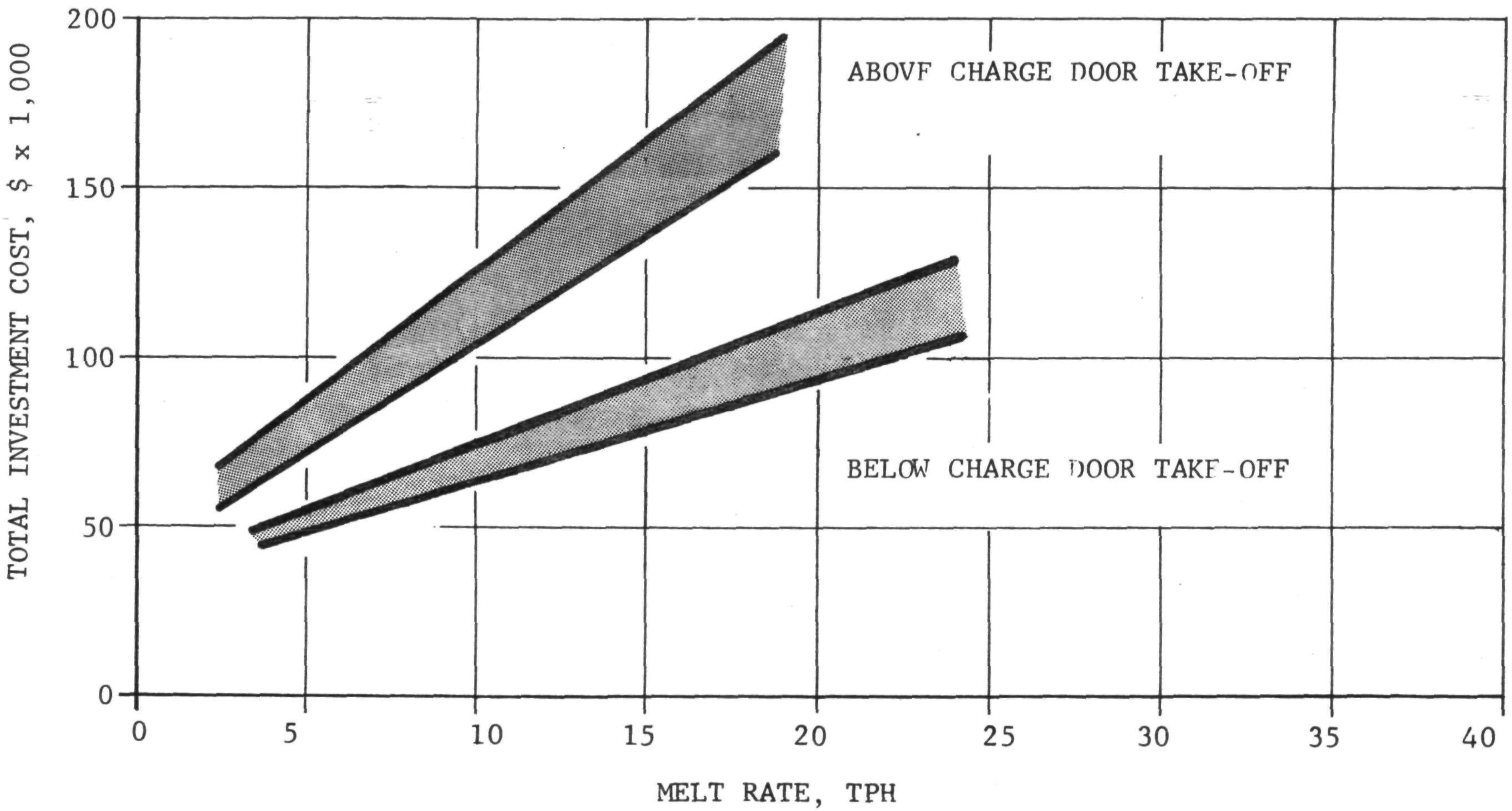


EXHIBIT VIII-12

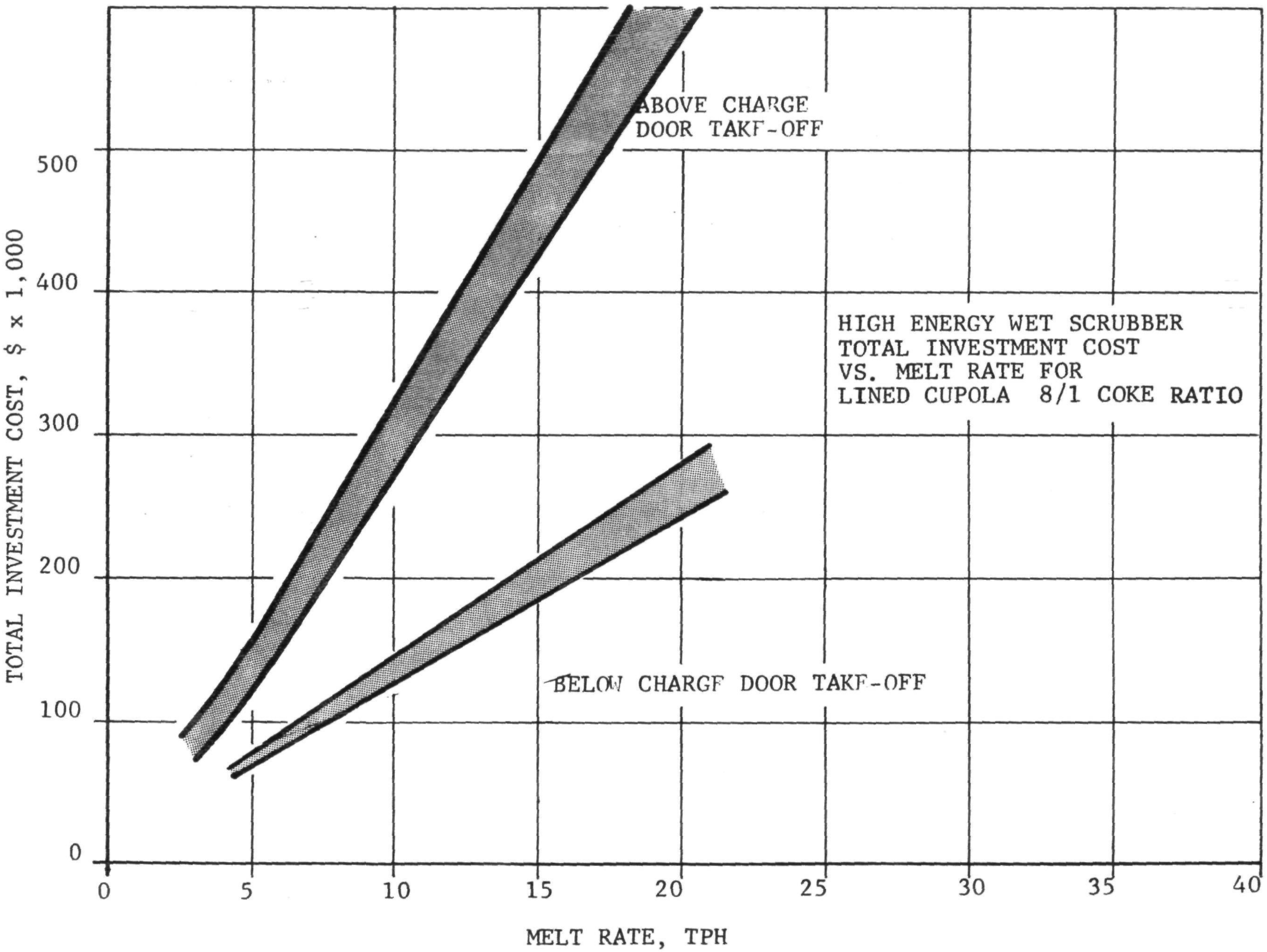
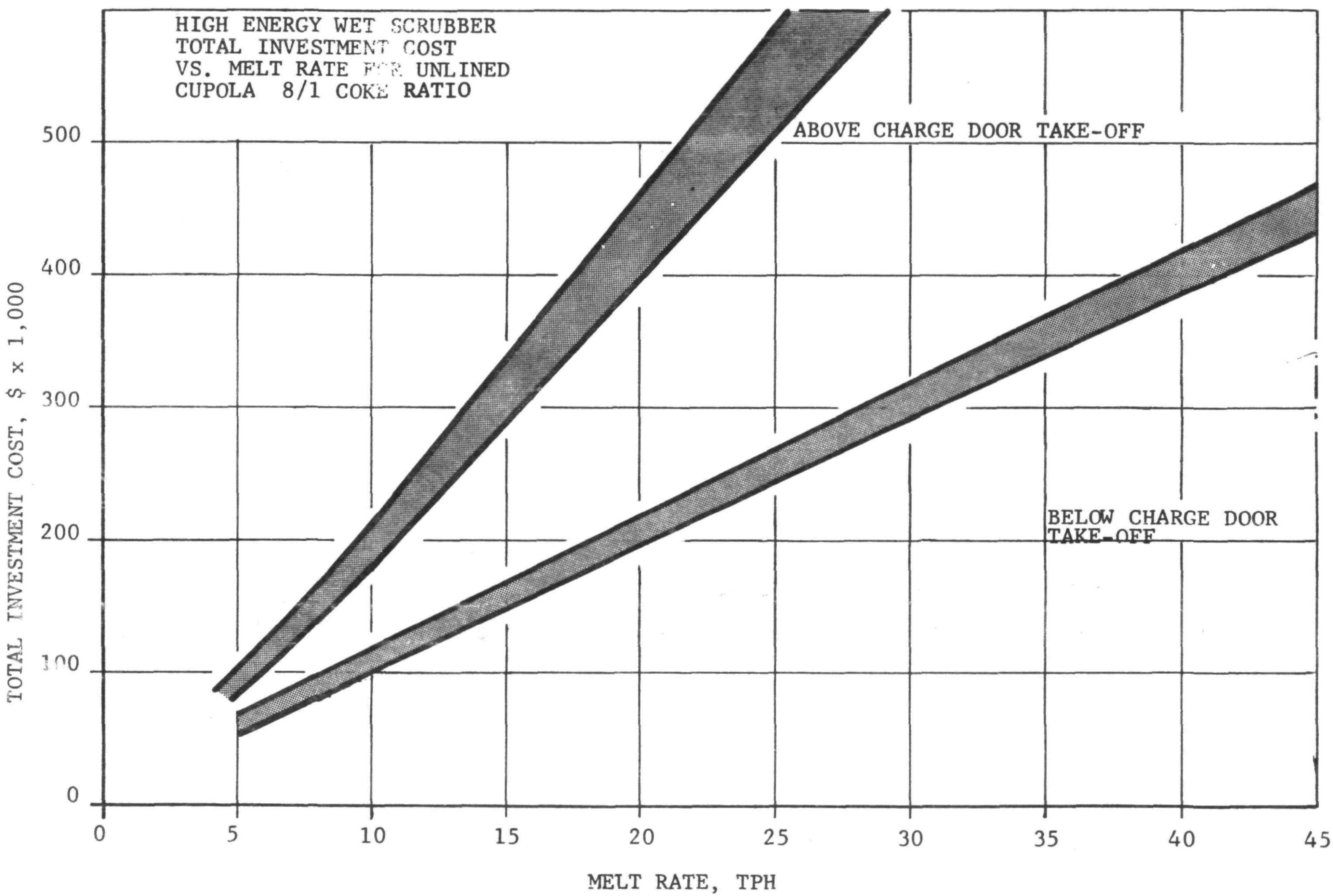


EXHIBIT VIII-10



HIGH ENERGY WET SCRUBBER
TOTAL INVESTMENT COST
VS. MELT RATE FOR UNLINED
CUPOLA 8/1 COKE RATIO
ABOVE CHARGE DOOR TAKE-OFF
BELOW CHARGE DOOR TAKE-OFF
TOTAL INVESTMENT COST, $ x 1,000
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
45
MELT RATE, TPH

COMPARISON OF GAS TAKE-OFF
ABOVE CHARGE DOOR AND BELOW
CHARGE DOOR. LINED CUPOLA
COKE RATIO 8/1

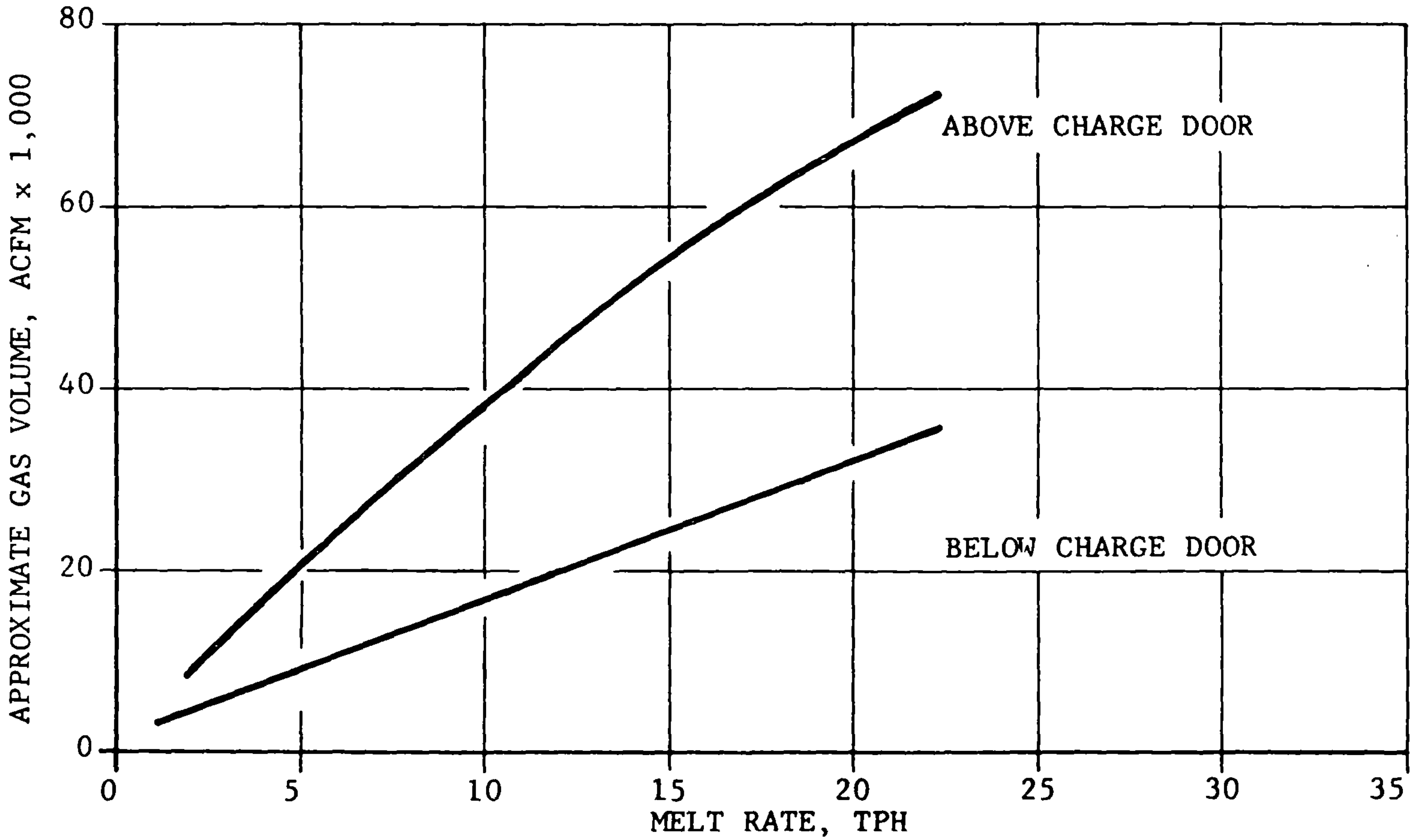
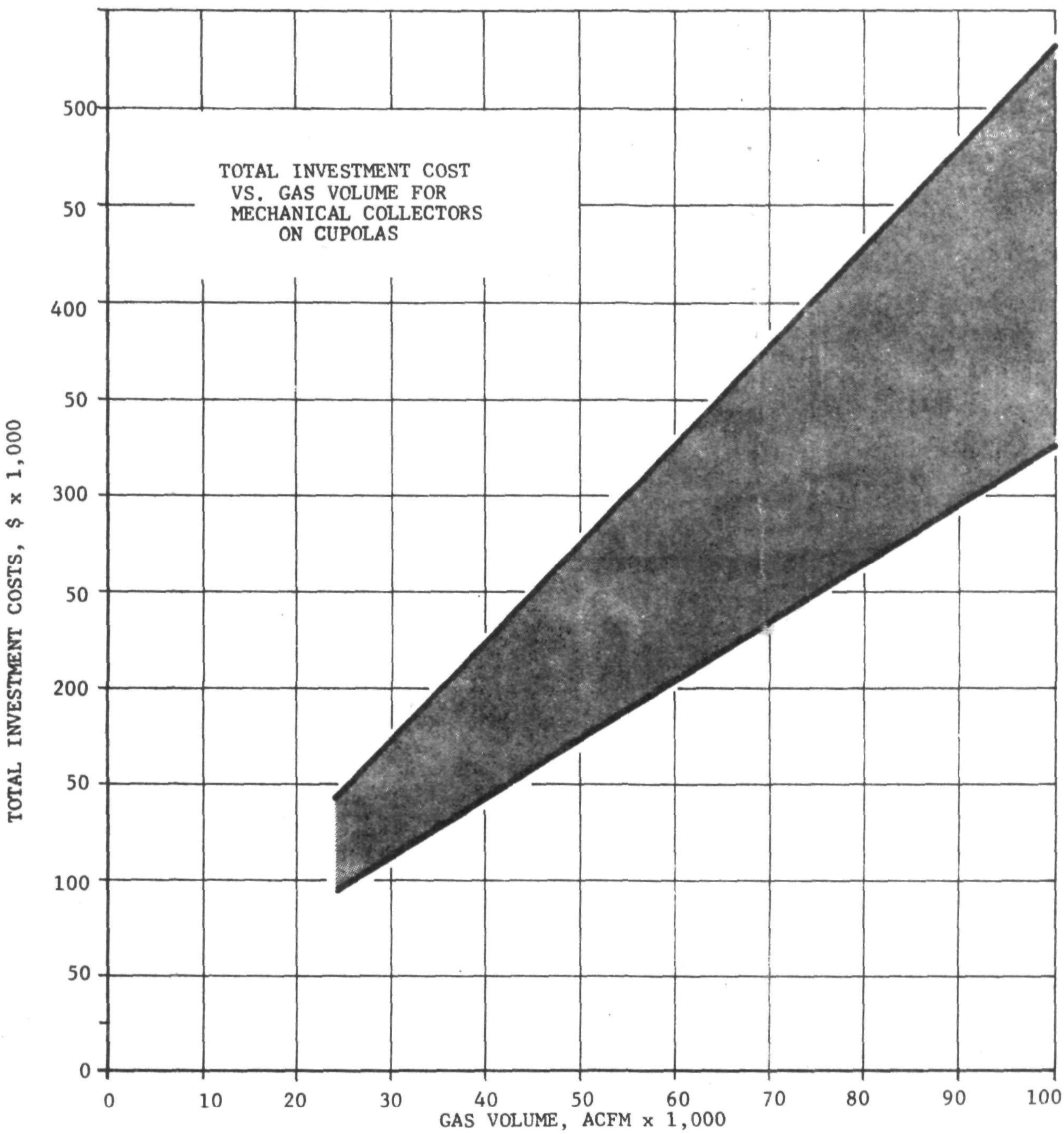
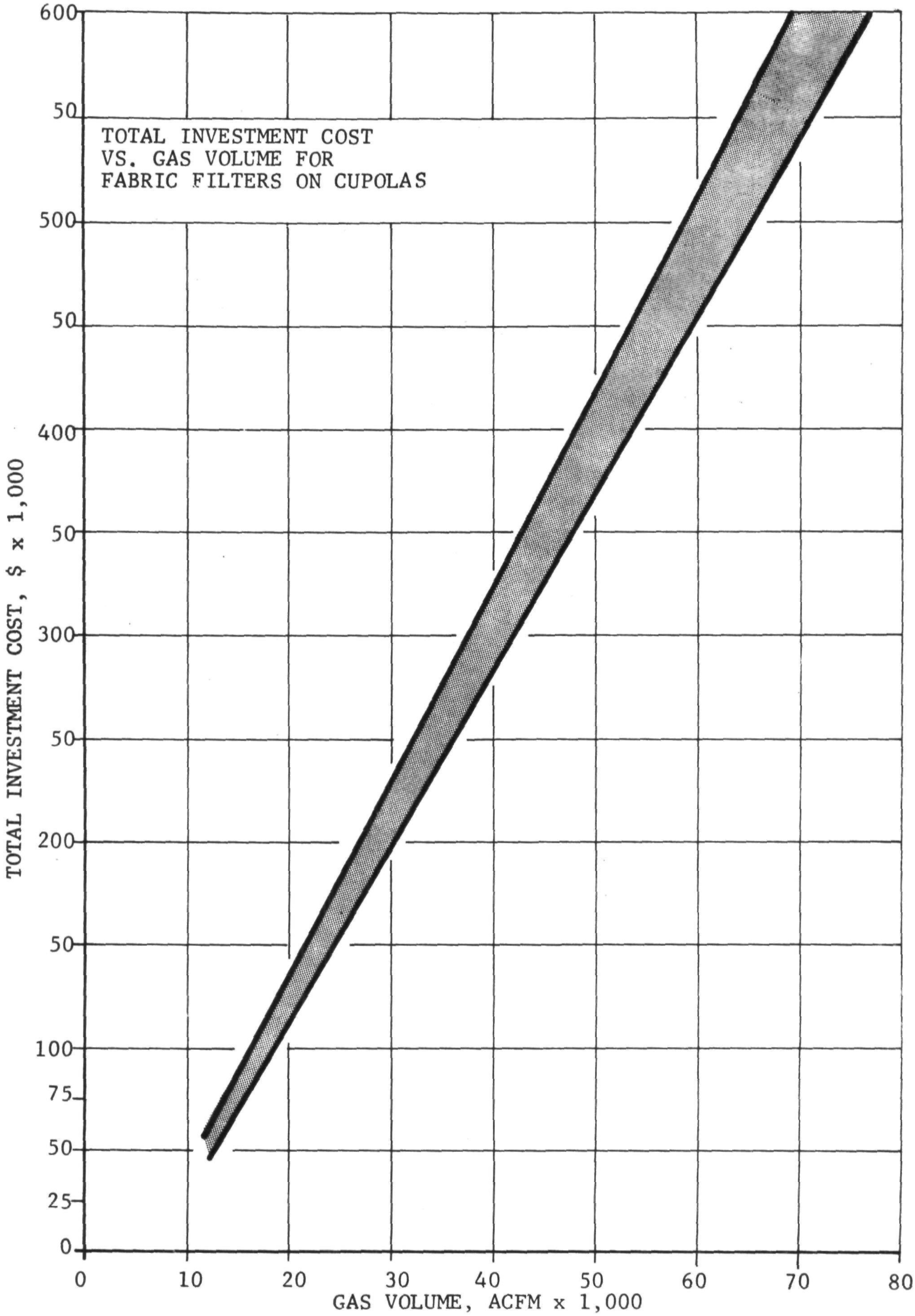
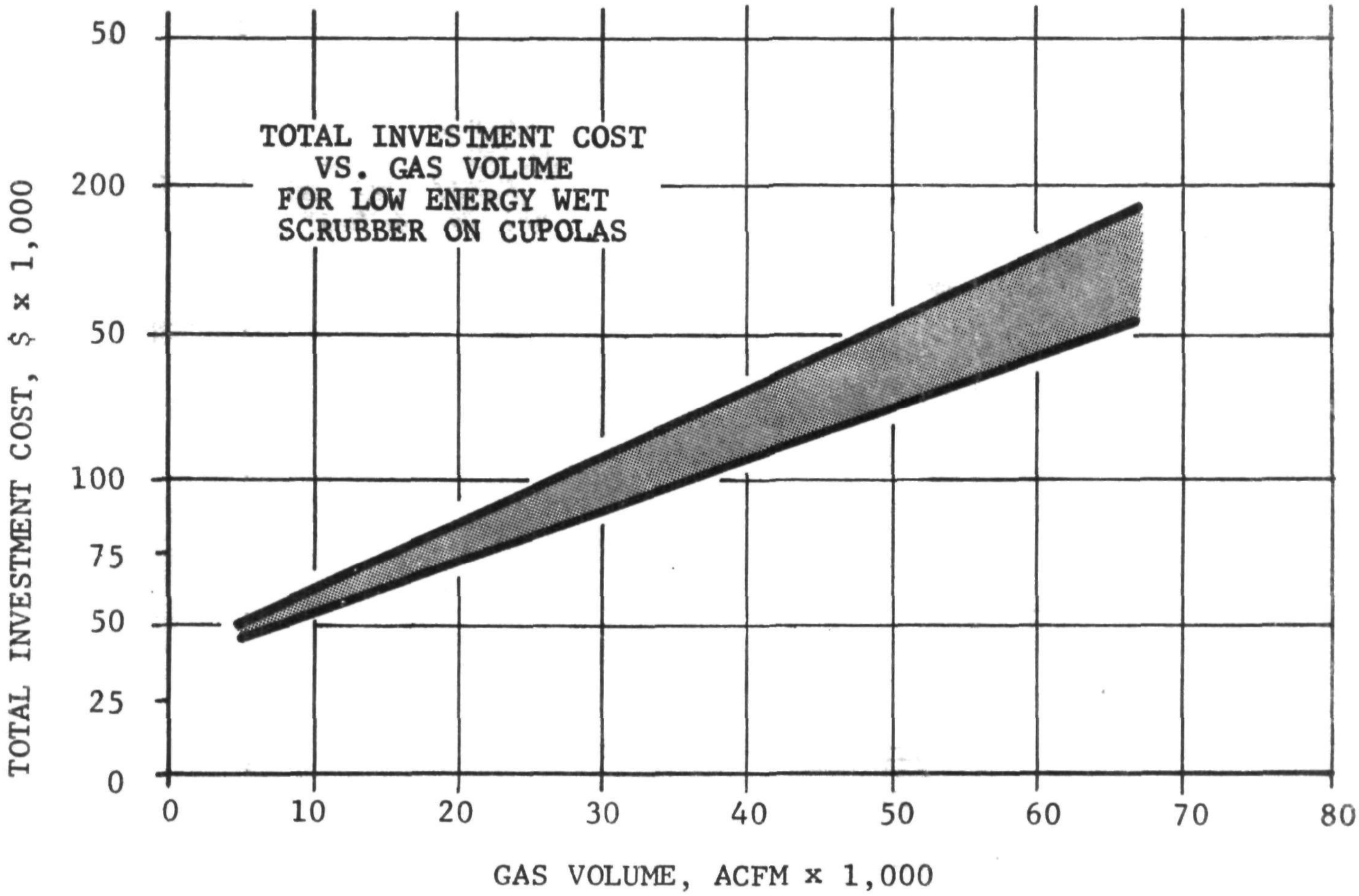
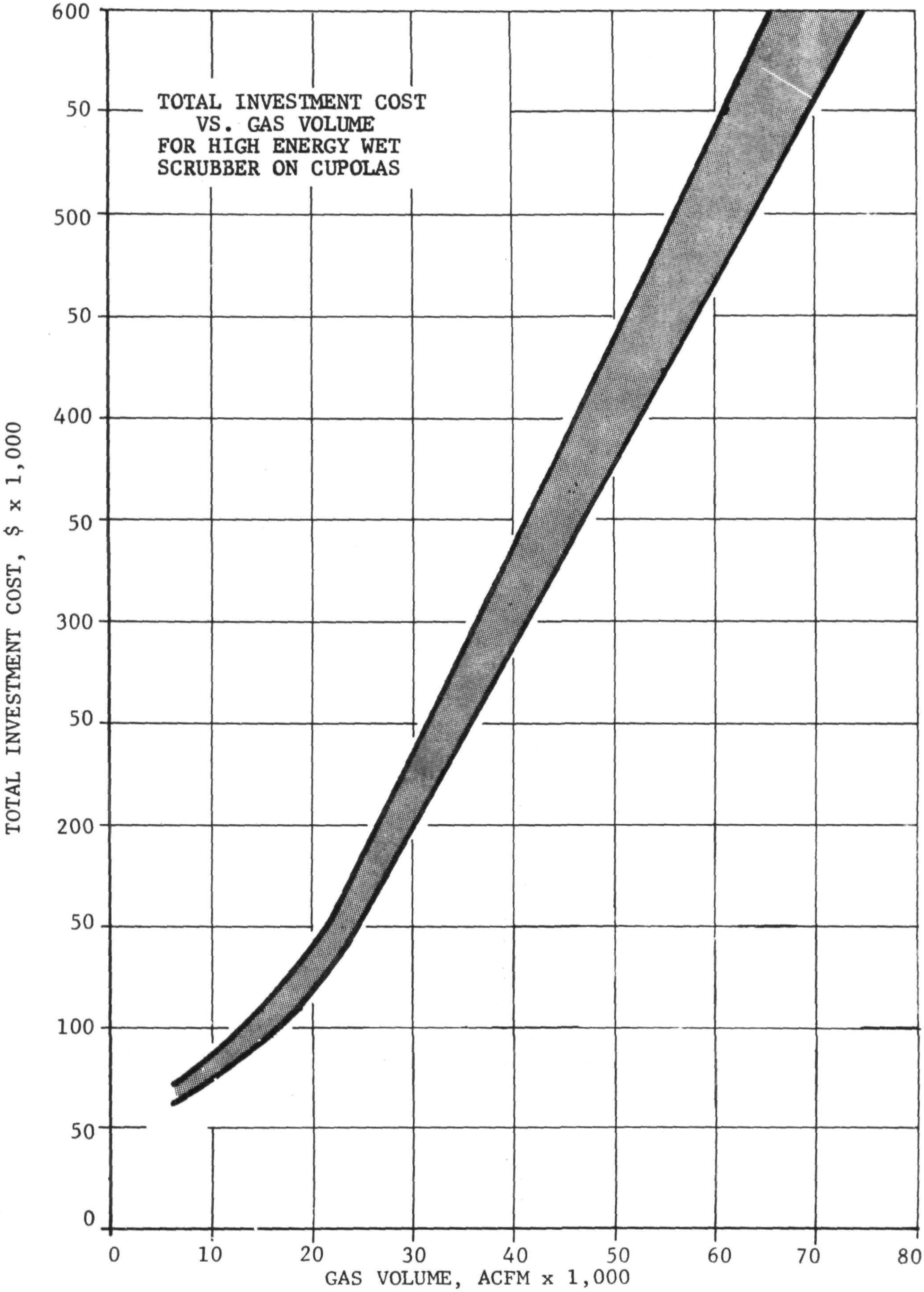


EXHIBIT VIII-8


TOTAL INVESTMENT COST
VS. GAS VOLUME FOR
MECHANICAL COLLECTORS
ON CUPOLAS
TOTAL INVESTMENT COSTS, $ x 1,000
0
50
100
50
200
50
300
50
400
50
500
GAS VOLUME, ACFM x 1,000
0
10
20
30
40
50
60
70
80
90
100


TOTAL INVESTMENT COST
VS. GAS VOLUME FOR
FABRIC FILTERS ON CUPOLAS
TOTAL INVESTMENT COST, $ x 1,000
600
50
500
50
400
50
300
50
200
50
100
75
50
25
0
0
10
20
30
40
50
60
70
80
GAS VOLUME, ACFM x 1,000


TOTAL INVESTMENT COST
VS. GAS VOLUME
FOR LOW ENERGY WET
SCRUBBER ON CUPOLAS
TOTAL INVESTMENT COST, $ x 1,000
50
200
50
100
75
50
25
0
0
10
20
30
40
50
60
70
80
GAS VOLUME, ACFM x 1,000


TOTAL INVESTMENT COST
VS. GAS VOLUME
FOR HIGH ENERGY WET
SCRUBBER ON CUPOLAS
TOTAL INVESTMENT COST, $ x 1,000
600
50
500
50
400
50
300
50
200
50
100
50
0
0
10
20
30
40
50
60
70
80
GAS VOLUME, ACFM x 1,000

INVESTMENT COST EQUATIONS FOR EQUIPMENT INSTALLED ON CUPOLAS

EQUIPMENT TYPE	INVESTMENT COST EQUATION	LIMITS OF OBSERVATION	CORREL. COEF.	REGRESSION PARAMETERS		DATA POINTS
				F RATIO	STD. ERROR	
High Energy Wet Scrubber	I= 49,519 + 2.84 x Gas Vol. I= -43,519 + 8.97 x Gas Vol.	6,000 ≤ Gas Vol. ≤ 20,000 20,000 ≤ Gas Vol. ≤ 92,000	.82 .99	25 139	16,000 29,000	25
Low Energy Wet Scrubber	I= 38,744 + 2.05 x Gas Vol.	4,500 ≤ Gas Vol. ≤ 67,000	.84	55	22,000	34
Fabric Filter	I= -55,000 + 8.95 x Gas Vol.	10,800 ≤ Gas Vol. ≤ 100,000	.98	321	48,000	19
Mechanical Collector	I= 20,192 + 4.07 x Gas Vol.	24,000 ≤ Gas Vol. ≤ 104,000	.87	16	70,000	15

CONDITIONS AFFECTING INSTALLATION COST OF CONTROL DEVICES

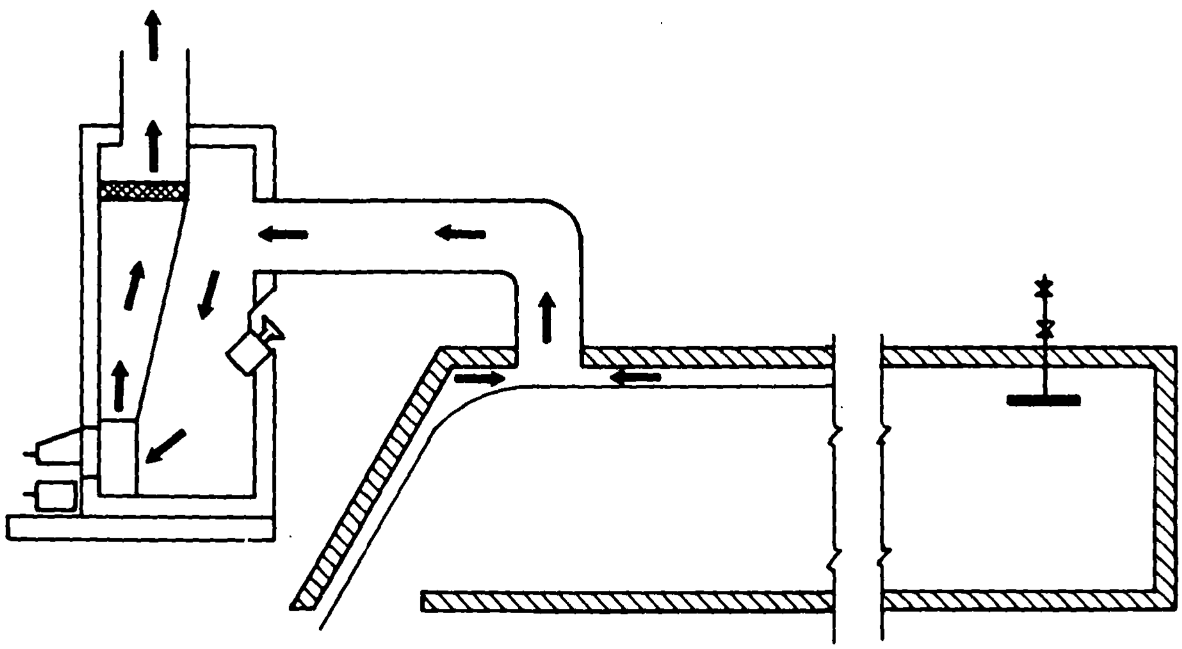
Cost Category	Low Cost	High Cost
Utilities	Electricity, water waste disposal facilities readily available.	Electrical and waste treatment facilities must be expanded, water supply must be developed or expanded
Collected waste material handling	No special treatment facilities or handling required	Special treatment facilities and/or handling required
Labor	Low wages in geographical area	Overtime and/or high wages in geographical area

Source: U. S. Department of Health, Education, and Welfare, National Air Pollution Control Administration, Control Techniques for Particulate Air Pollutants, Washington, D. C., 1969.

CONDITIONS AFFECTING INSTALLATION COST OF CONTROL DEVICES

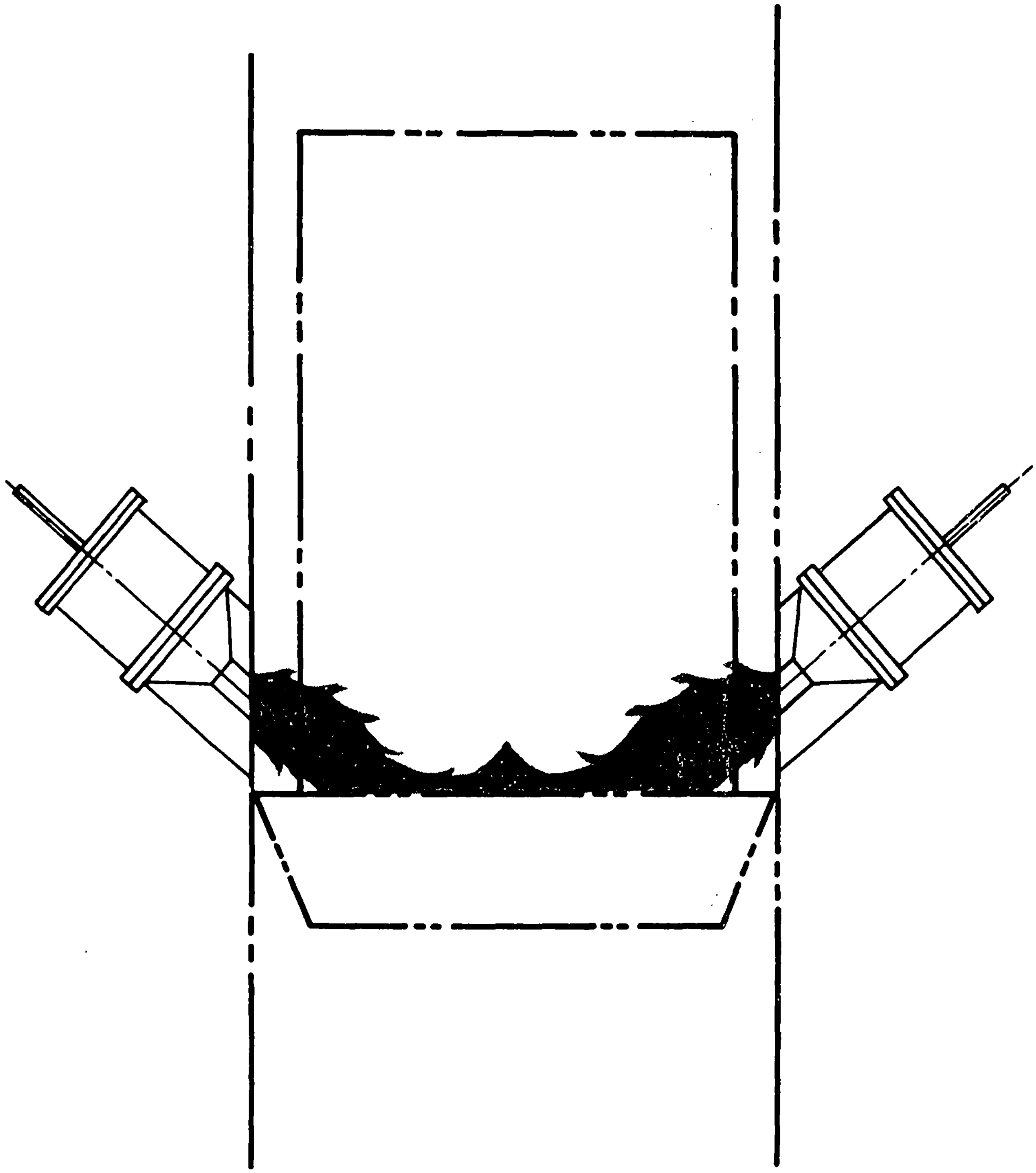
Cost Category	Low Cost	High Cost
Equipment Transportation	Minimum distance; simple loading and unloading procedure	Long distance; complex procedure for loading and unloading
Plant Age	Hardware designed as an integral part of new plant	Hardware installed into confines of old plant requiring structural or process modification or alternation
Available space	Vacant area for location of control system	Little vacant space requires extensive steel support construction and site preparation
Corrosiveness of gas	Noncorrosive gas	Acidic emissions requiring high alloy accessory equipment using special handling and construction techniques
Complexity of start-up	Simple start-up no extensive adjustment required.	Requires extensive adjustment; testing considerable downtime
Instrumentation	Little required	Complex instrumentation required to assure reliability of control or constant monitoring of gas stream
Guarantee on performance	None needed	Required to assure designed control efficiency
Degree of assembly	Control hardware shipped completely assembled	Control hardware to be assembled and erected in the field
Degree of engineering	Autonomous "package" control system	Control System requiring extensive integration into process, insulation to correct temperature problem and noise abatement

CATALYTIC AFTERBURNER APPLIED
TO CORE BAKE OVEN PROCESS



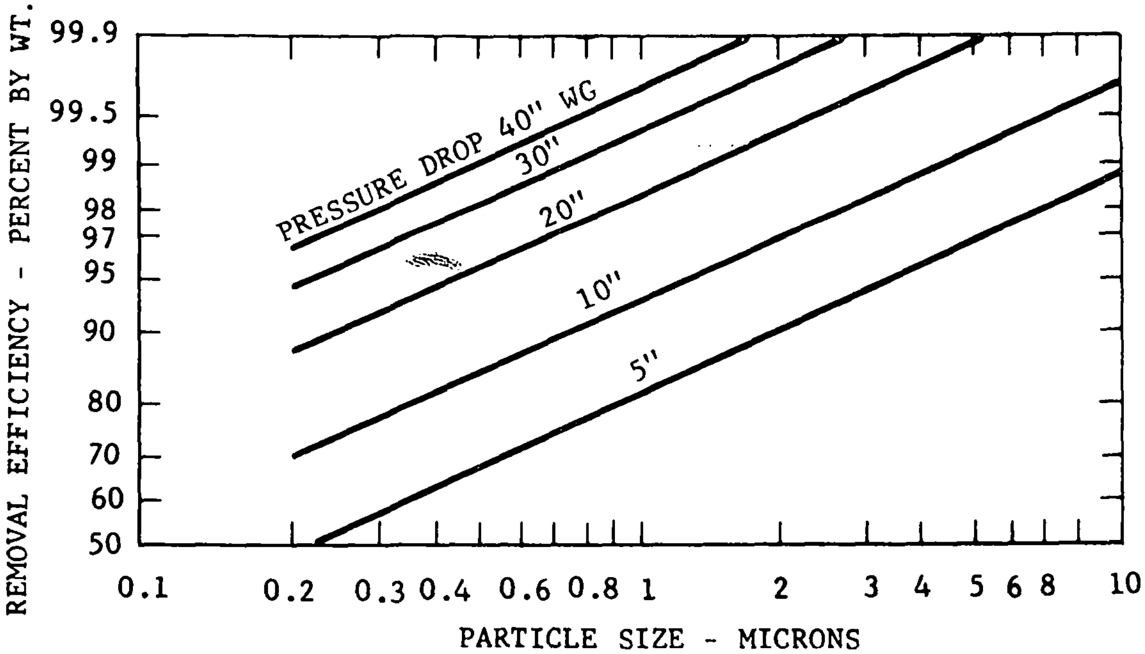
Source: Air Pollution Engineering Manual, U.S. Department of Health, Education and Welfare, #999-AP-40.

CUPOLA AFTERBURNER



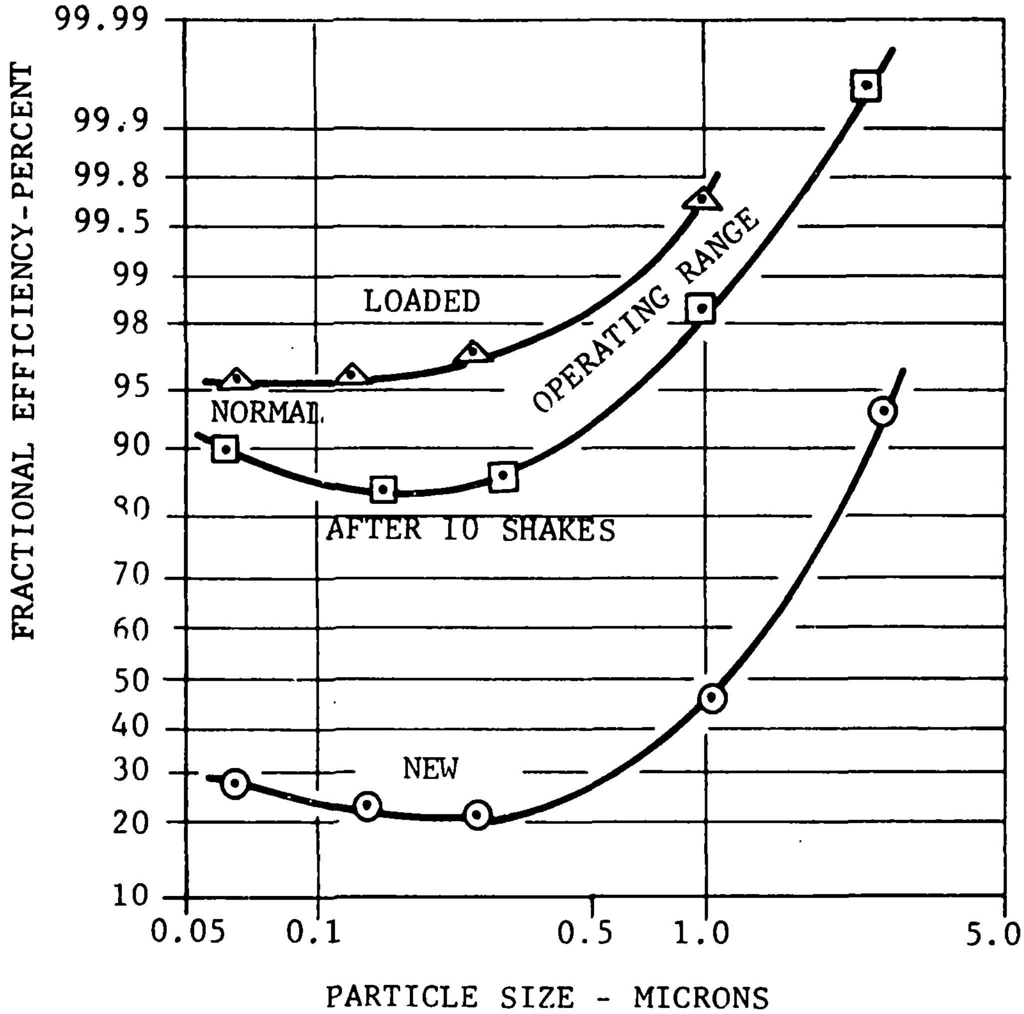
Source: Foundry Air Pollution Control Manual, AFS.

RELATIONSHIP BETWEEN COLLECTION EFFICIENCY, PARTICLE SIZE AND PRESSURE DROP FOR VENTURI SCRUBBERS



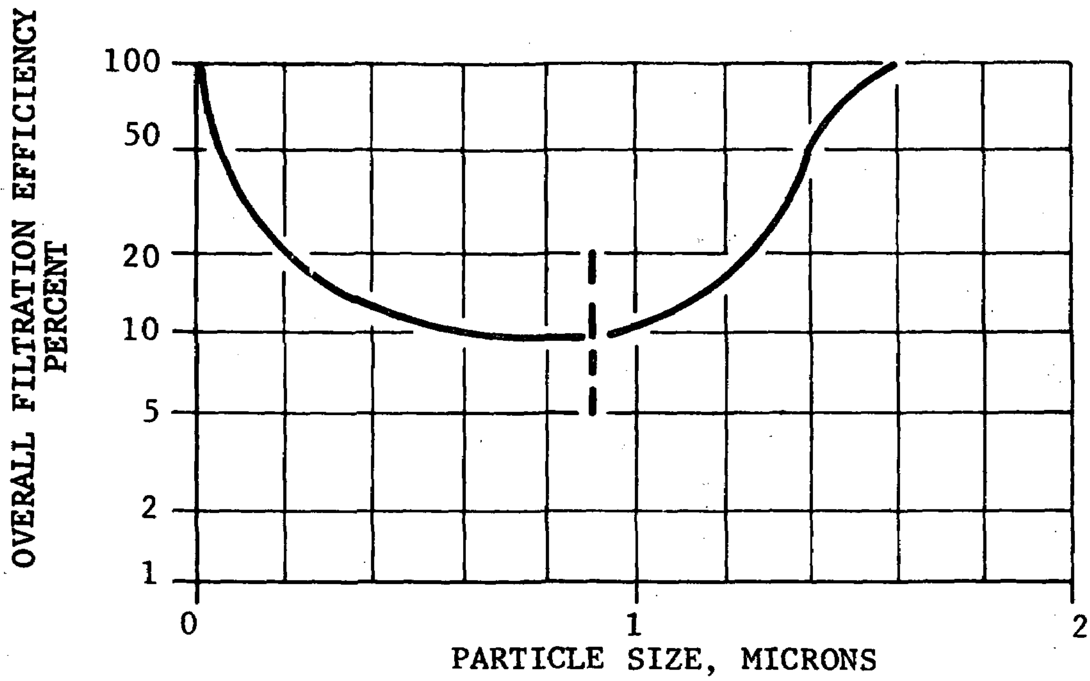
Source: Air Pollution Manual, American Industrial Hygiene Association.

EFFECT OF PARTICLE SIZE AND LENGTH OF BAG IN SERVICE ON FABRIC FILTER EFFICIENCY



Source: Torit, Dust Collectors, January, 1966.

GRADE EFFICIENCY CURVE
FOR FABRIC FILTER



Source: Design and Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

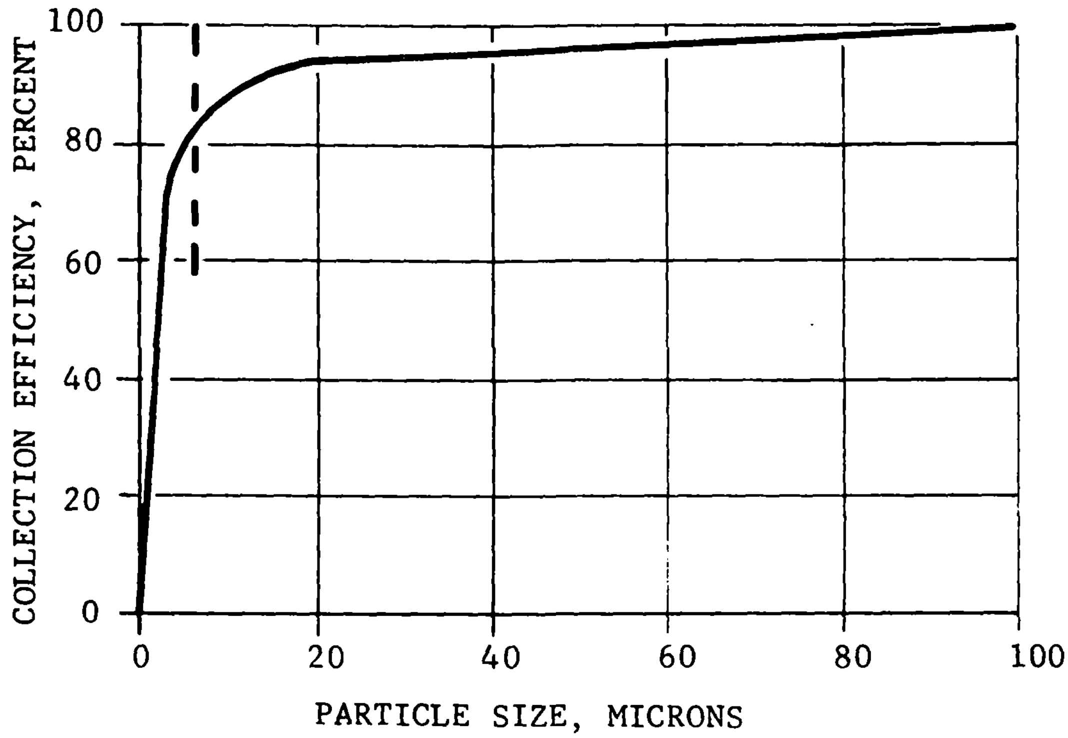
CALCULATION OF COLLECTOR EFFICIENCY

Cyclone				Electrostatic Precipitator			
Size of Grade, Microns	Percent in Grade at Inlet	Efficiency at Mean Size of Grade, Percent	Overall Collection, Percent	Size of Grade, Microns	Percent in Grade at Inlet	Efficiency at Mean Size of Grade, Percent	Overall Collection, Percent
104-150	3%	100.0%	3.0%	104-150	-	-	-
75-104	7	99.1	6.9	75-104	0.6%	99.2%	0.6%
60-75	10	98.5	9.9	60-75	0.6	98.7	0.6
40-60	15	97.3	14.6	40-60	2.5	97.7	2.4
30-40	10	96.0	9.6	30-40	2.5	96.8	2.4
20-30	10	94.3	9.4	20-30	3.8	96.5	3.7
15-20	7	92.0	6.4	15-20	3.8	96.0	3.7
10-15	8	89.3	7.1	10-15	5.7	95.5	5.4
7½-10	4	84.2	3.4	7½-10	3.8	95	3.6
5-7½	6	76.7	4.6	5-7½	8.8	94	8.3
2½-5	8	64.5	5.2	2½-5	17.6	90.5	16.0
0-2	12	33.5	4.0	0-2½	50.3	77.0	38.7
		Total	84.1%			Total	85.4%

Source: Design and Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

GRADE EFFICIENCY CURVE

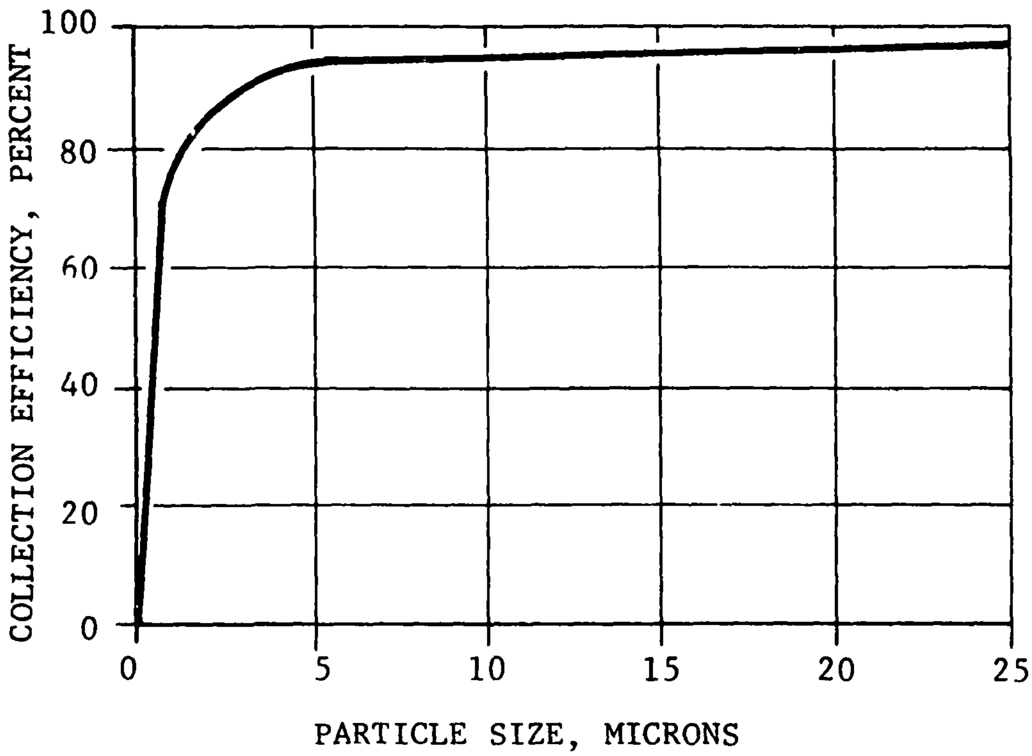
HIGH EFFICIENCY CYCLONE



Source: Design and Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

GRADE EFFICIENCY CURVE

DRY
ELECTROSTATIC
PRECIPITATOR



Source: Design and Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

CHEMICAL COMPOSITION OF CUPOLA DUST BY WEIGHT

	Mean Range	Scatter Values
SiO_2	20%-40%	10%-45%
CaO	3-6	2-18
Al_2O_3	2-4	0.5-25
MgO	1-3	0.5-5
FeO (Fe_2O_3, Fe)	12-16	5-26
Mno	1-2	0.5-9
Ignition Loss (C, S, CO_2)	20-50	10-64

Source: Cupola Emission Control, Gray & Ductile Iron Founders' Society, Inc.

OVERALL COLLECTION EFFICIENCY ON TEST DUST

Apparatus	Overall Efficiency Percent	Efficiency at 5 Microns Percent	Efficiency at 2 Microns Percent	Efficiency at 1 Micron Percent
Medium efficiency cyclone	65.3%	27%	14%	8%
High efficiency cyclone	84.2	73	46	27
Fabric filter	99.9	>99.9	99.9	99
Spray tower	96.3	94	87	55
Wet impingement scrubber	97.9	97	92	80
Self-induced spray deduster	93.5	93	75	40
Venturi scrubber	99.7	99.6	99	97
Electrostatic precipitator	94.1	92	85	70

Source: Design & Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

GRADING OF TEST DUST

Size of Grade, Microns	Percentage by Weight in Grade	Percentage by Weight Smaller Than Top Size of Grade
104-150	3%	100
75-104	7	97
60-75	10	90
40-60	15	80
30-40	10	65
20-30	10	55
15-20	7	45
10-15	8	38
7½-10	4	30
5-7½	6	26
2½-5	8	20
Under 2½	12	12
Total	100%	

Source: Design & Performance of Modern Gas Cleaning Equipment, Journal of the Institute of Fuel, February, 1956.

COLLECTION EFFICIENCY OF EMISSION CONTROL EQUIPMENT SYSTEMS

Foundry Application	Particle Size	Typical Inlet Loading Gr/SCF	Typical Outlet Loading Gr/SCF					
			Wet Cap	Wet Scrubber 6"-30"	Wet Scrubber 30"-70"	Low Efficiency Cyclone	Fabric Filter	Electrostati Precipitator
Melting								
Gray Iron Cupola	Coarse to Fine	1/2-10	0.4	0.3	0.05	0.4	0.01	0.036
Electric Arc	Fine	1/2-2	X	0.2	0.02	X	0.01	X
Screens and Transfer Points	Medium	1/2-3	X	0.005-0.01	X	X	0.01	X
Dry Sand Reclaimer	Coarse to Fine	10-40	X	0.1	0.02-0.05	X	0.01	X
Sand Cooler	Medium	1-20	X	0.01-0.05	X	X	X	X
Abrasive Cleaning	Fine to Coarse	1/2-5	X	0.01-0.05	X	X	0.01	X
Grinding	Coarse to Medium	1/2-2	X	0.01	X	0.1	0.01	X
Shakeout	Fine to Medium	1/2-1	X	0.01	X	X	X	X

Note: Particle Size

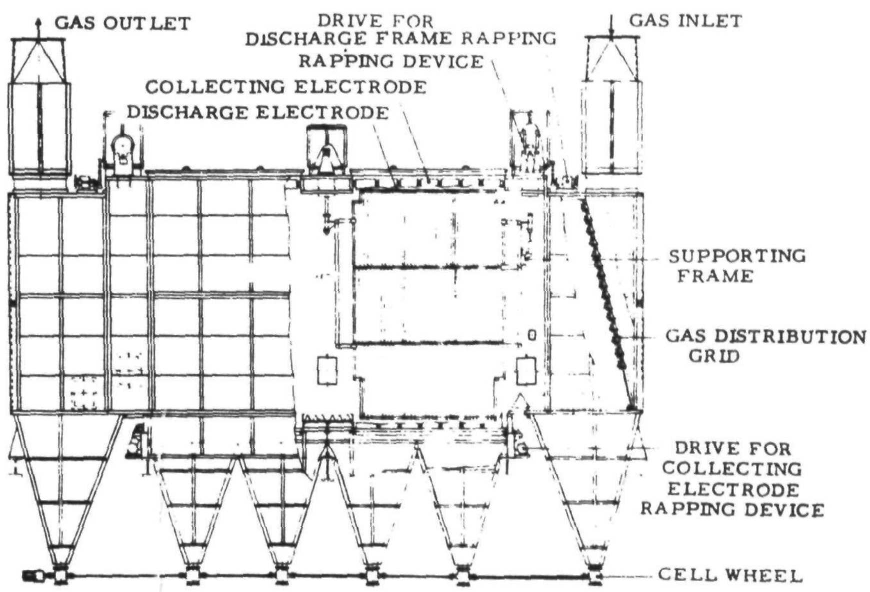
Coarse +20 Microns
Medium 2-20 Microns
Fine -2 Microns

X = Not applicable or rarely used.

Underlined outlet loading is lowest for that application.

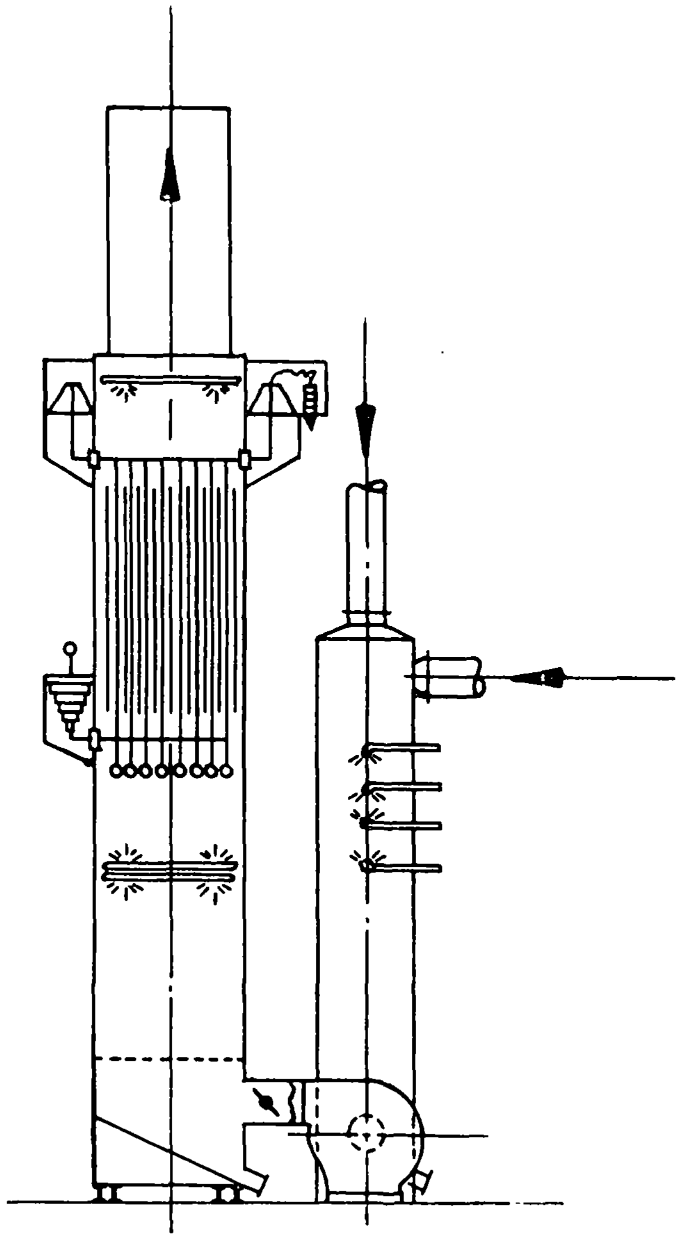
Sources: Foundry Air Pollution Control Manual, American Foundrymen's Society;
Air Pollution Engineering Manual, U.S. Department of Health, Education and Welfare, #999-AP-40.

DRY-TYPE ELECTROSTATIC PRECIPITATOR EFFLUENT CLEANING SYSTEM



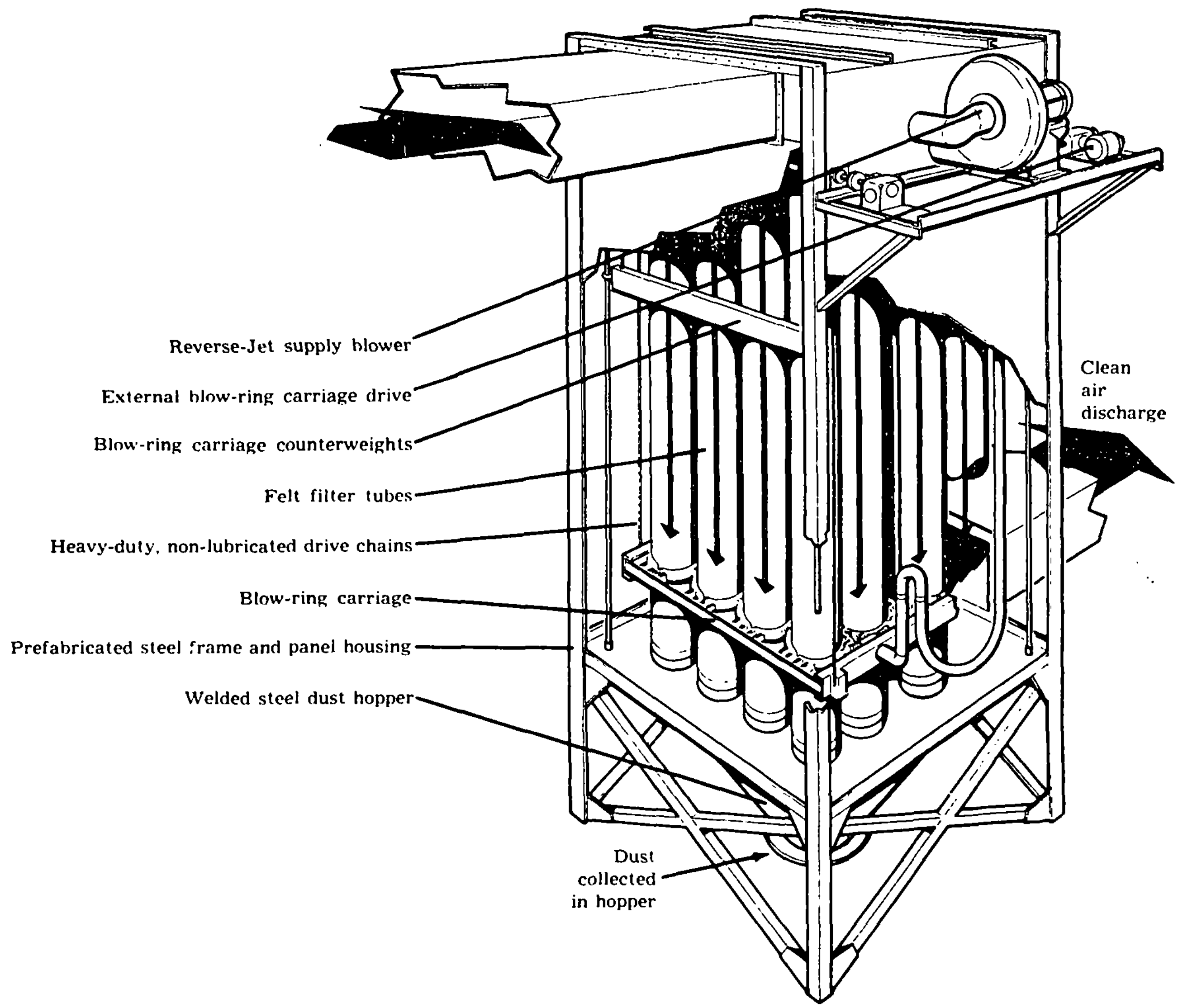
Source: Cupola Emission Control, Gray & Ductile Iron Society.

WET-TYPE ELECTROSTATIC PRECIPITATOR EFFLUENT CLEANING SYSTEM



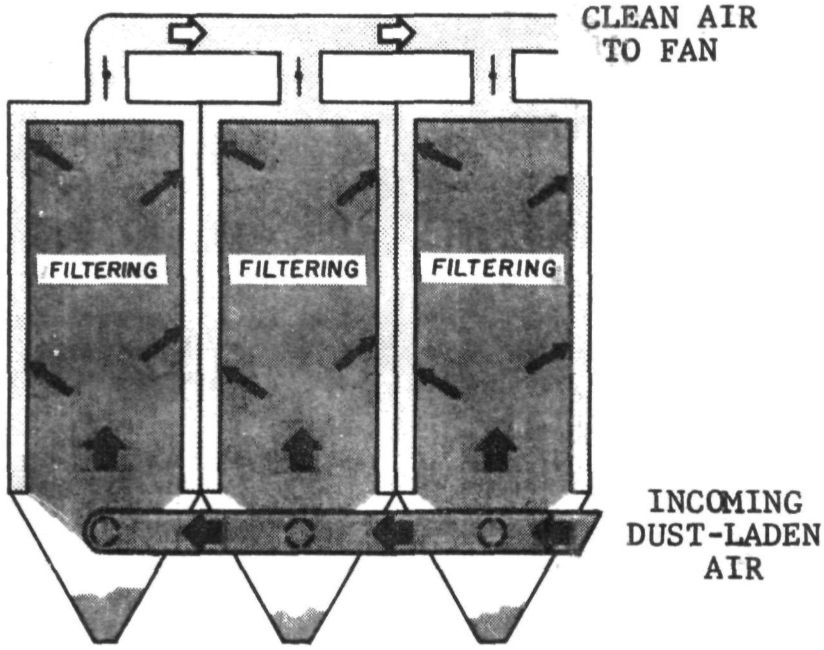
Source: Cupola Emission Control, Gray & Ductile Iron Society.

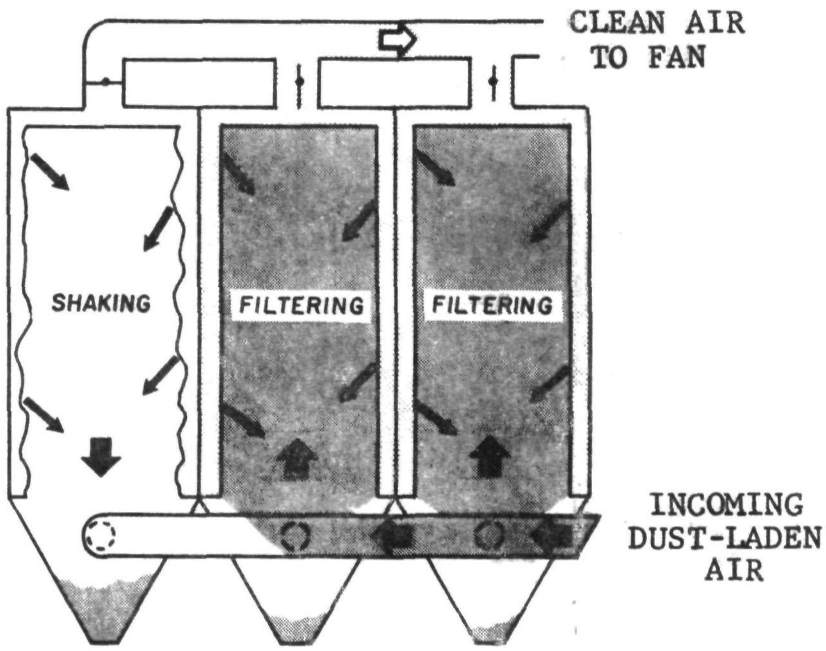
REVERSE JET CONTINUOUS FABRIC FILTER COLLECTOR



Source: Buffalo Forge Company.

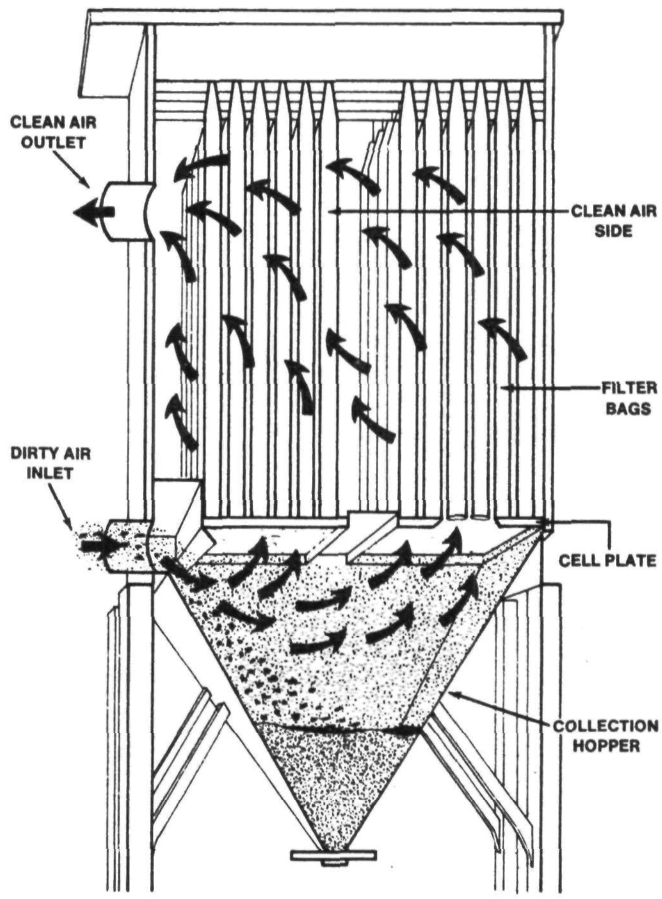
CONTINUOUS AUTOMATIC FABRIC FILTER COLLECTOR





Source: Fuller Company.

INTERMITTENT FABRIC FILTER COLLECTOR



Source: Burlington Glass Fabrics.

APPLICATION OF EMISSION CONTROL EQUIPMENT SYSTEMS TO FOUNDRY PROCESSES

Foundry Process	Dry Mechanical: Low Pressure Loss Cyclone	Dry Mechanical: Medium Pressure Loss	Wet Scrubber: Low Pressure Loss (Wet Cap)	Wet Scrubber: Medium Pressure Loss "4-8"	Wet Scrubber: Intermediate Pressure Loss "9-20"	Wet Scrubber: High Pressure Loss "21-80"	Fabric Filter: Cotton or Wool	Fabric Filter: Orlon or Dacron	Fabric Filter: Nomex	Fabric Filter: Glass	Electrostatic Precipitator: Dry	Electrostatic Precipitator: Wet	Catalytic Combustion
Raw Material Handling and Preparation	No	Rare	No	Rare	No	No	Rare	No	No	No	No	No	No
Melting Processes													
Cupola	Rare	Frequently	Frequently	Frequently	Frequently	Frequently	No	Rare	Occasionally	Frequently	Rare	No	No
Electric Arc	No	No	No	No	Rare	Occasionally	Rare	Usual	Rare	No	Rare	No	No
Electric Induction	No	No	No	No	No	No	No	No	No	No	No	No	No
Inoculation	No	No	No	Rare	Rare	Rare	Occasionally	Rare	Rare	No	No	No	No
Mold Pouring & Cooling	No	No	No	Rare	No	No	No	No	No	No	No	No	No
Shakeout													
Enclosed Hood	Rare	Occasionally	No	Usual	Occasionally	No	Occasionally	No	No	No	No	No	No
Side Hood	No	Rare	No	Usual	Occasionally	No	Occasionally	No	No	No	No	No	No
Sand Preparation & Handling													
Shakeout Molding Sand	Rare	Occasionally	No	Usual	Rare	No	Rare	No	No	No	No	No	No
New Sand	Rare	Occasionally	No	Usual	Rare	No	Occasionally	No	No	No	No	No	No
Core Sand	Rare	Occasionally	No	Usual	Rare	No	Occasionally	No	No	No	No	No	No
Coremaking													
Mechanical Material Handling	Rare	Rare	No	Frequently	No	No	Frequently	No	No	No	No	No	No
Pneumatic	No	No	No	Rare	No	No	Usual	No	No	No	No	No	No
Bake Oven	No	No	No	No	No	No	No	No	No	No	No	No	Frequently
Grinding	Rare	Occasionally	No	Frequently	No	No	Frequently	No	No	No	No	No	No
Casting Cleaning													
Airless Abrasive	No	Rare	No	Frequently	No	No	Usual	No	No	No	No	No	No
Blast Rooms	No	Rare	No	Usual	?	No	Usual	No	No	No	No	No	No
Tumbling Mills	No	Rare	No	Usual	-	No	Usual	No	No	No	No	No	No
Sprue	No	Occasionally	No	Usual	?	No	Usual	No	No	No	No	No	No
Grinding													
Snagging	Frequently	Frequently	No	Frequently	No	No	Frequently	No	No	No	No	No	No
Swing Frame	Rare	Frequently	No	Frequently	No	No	Frequently	No	No	No	No	No	No
Portable	Rare	Frequently	No	Usual	No	No	Usual	No	No	No	No	No	No
Boiler Fly Ash													
Chain Grate	No	Occasionally	No	No	No	No	No	No	No	No	No	No	No
Spreader Stoker	No	Usual	No	No	No	No	No	No	No	No	No	No	No
Pulverizer	No	Usual	No	No	No	No	No	No	No	No	Frequently	No	No
Paint Ovens	No	No	No	No	No	No	No	No	No	No	No	No	Frequently
Oil Burn-off Furnaces	No	No	No	Rare	No	No	No	No	No	No	No	No	Frequently
Pattern Shop													
Wood	Usual	Rare	No	Rare	No	No	Occasionally	No	No	No	No	No	No
Metal	Frequently	Usual	No	Rare	No	No	Occasionally	No	No	No	No	No	No

Sources: Foundry Air Pollution Control Manual, American Foundrymen's Society, 1967.
American Air Filter, Dust Collector Selection Guide, Bulletin 265-A, October, 1966.
Personal notes of [illegible].

A

B

APPROXIMATE MELTING RATES AND GAS VOLUMES FOR LINED CUPOLAS

FCE Lined Dia.	Melt Rate TPH Metal to Coke Ratio				Blast Air (SCFM)	Av. Chg. Door (Sq. Ft.)	Indraft (CFM)	Above-Door Total (SCFM)	Below-Door Total (SCFM)	Above Door (ACFM)	Below Door @ 850° F (ACFM)
	6/1	8/1	10/1	12/1							
18	3/4	1	-	-	570				650		2,000
23	1	1-1/2	-	-	940	10	3,000	3,940	1,050	7,700	3,000
27	1-3/4	2-1/4	-	-	1,290	10	3,000	4,290	1,450	8,500	4,000
32	2-1/2	3-1/4	4	-	1,810	10	3,000	4,810	2,000	10,800	5,000
37	3-1/4	4-1/4	5-1/4	-	2,420	11-1/4	3,380	5,800	2,700	13,100	7,000
42	4	5-1/2	7	-	3,100	16-1/2	4,950	8,050	3,500	18,100	9,000
45	4-1/2	6-1/4	8	-	3,600	22	6,600	10,200	4,000	23,000	12,000
48	5-1/2	7-1/4	9	10-3/4	4,100	45	13,500	17,600	4,600	34,500	16,000
54	7	9-1/4	11-1/2	13-3/4	5,200	50	15,000	20,200	5,800	39,500	18,000
60	9	11-1/4	14	17	6,400	50	15,000	21,400	7,100	42,500	20,000
66	10-1/2	13-3/4	17	20-1/2	7,700	52	15,600	23,300	8,500	51,000	23,000
72	12-1/4	16-1/4	20-1/4	24-1/2	9,200	52	15,600	24,800	10,500	56,000	28,000
78	15	19	23-3/4	28-3/4	10,700	60	18,000	28,700	12,000	65,000	32,000
84	17	22-1/4	27-3/4	33-1/4	12,500	63	18,900	31,400	14,000	71,000	37,000

Adapted from Useful Information for Foundrymen published by Whiting Corporation.

Assumptions:
1. No door closure
2. No oxygen enrichment
3. No fuel injection
4. Indraft at 300 FPM

APPROXIMATE MELTING RATES AND GAS VOLUMES FOR UNLINED CUPOLAS

FCE Dia.	Melt Rate TPH Metal to Coke Ratio (1000° F Hot Blast)						Blast Air (SCFM)	Av. Chg. Door (Sq. Ft.)	Indraft (CFM)	Above-Door Total (SCFM)	Below-Door Total (SCFM)	Above Door (ACFM)	Below Door @ 850° F (ACFM)
	5/1	6/1	7/1	8/1	9/1	10/1							
36	4-1/2	4-3/4	5	5-1/2	5-3/4	6-1/4	2,300	12	3,600	5,900	2,600	13,300	7,000
42	6-1/4	6-1/2	6-3/4	7-1/4	7-3/4	8-1/4	3,100	16-1/2	4,950	8,050	3,500	18,100	9,000
48	8	8-1/4	9	9-3/4	10-1/2	11-1/4	4,100	45	13,500	17,600	4,600	34,500	16,000
54	10	10-1/2	11-1/2	12-1/4	13-1/4	14-1/4	5,200	50	15,000	20,200	5,800	39,500	18,000
60	12-1/2	13	13-1/2	15-1/4	16-1/4	17-1/4	6,400	50	15,000	21,400	7,100	41,500	20,000
66	15	15-1/2	17	18-1/4	19-3/4	20-3/4	7,700	52	15,600	23,300	8,500	51,000	23,000
72	17-3/4	18-1/2	20	22	23-1/4	25	9,200	60	18,000	27,200	10,500	59,200	28,000
78	20-3/4	21-3/4	23-1/4	25-1/2	27-1/4	29	10,700	60	18,000	28,700	12,000	65,000	32,000
84	24-1/4	25-1/4	27-1/4	29-1/4	32	34	12,500	63	18,900	31,400	14,000	71,000	37,000
90	27-3/4	29	31-1/2	34-1/4	36-1/4	39	14,300	95	28,500	42,800	16,000	93,000	42,000
96	31-3/4	33	34-1/2	39	41-1/2	44	16,300	110	33,000	49,300	18,000	105,000	48,000
102	36	37-1/4	40-1/2	44	47	50	18,400	120	36,000	54,400	21,000	115,000	56,000
108	40	41-1/2	45	49	52-1/2	56	20,600	128	38,400	59,000	23,000	128,000	62,000

Adapted from Useful Information for Foundrymen published by Whiting Corporation.

Assumptions:
1. No door closure
2. No oxygen enrichment
3. No fuel injection
4. Indraft at 300 FPM

SUMMARY OF CAPITAL COSTS TO PRODUCE IRON UNDER VARIOUS PRODUCTION AND OPERATING CONDITIONS

Alternate Number	Melt Rate Tons/Hour	5				15			30		50	
	Operating Hours/Year	500	1,000	2,000	4,000	1,000	2,000	4,000	2,000	4,000	2,000	4,000
1	Cupola-Lined Cold Blast No Holding Furnace											
	Buildings and Melting Department Equipment	$ 395,000	$ 395,000	$ 497,000		$1,012,000	$1,221,000	$1,221,000	$2,099,000	$2,099,000	$2,869,000	$2,869,000
	Emission Control Equipment (Fabric Filter)	60,000	60,000	65,000		210,000	220,000	220,000	440,000	440,000	690,000	690 000
	Total	$ 455,000	$ 455,000	$ 562,000		$1,222,000	$1,441,000	$1,441,000	$2,539,000	$2,539,000	$3,559,000	$3,559,000
	Emission Control as Percent of Total Cost	13.2%	13.2%	11.6%		17.2%	15.3%	15.3%	17.3%	17.3%	19.4%	19.4%
2	Cupola-Hot Blast-Induction Holding Furnace											
	Buildings and Melting Department Equipment			$ 507,000	$ 507,000		$1,329,000	$1,329,000	$2,159,000	$2,159,000	$3,244,000	$3,244,000
	Emission Control Equipment (Wet Scrubber)			70,000	70,000		190,000	190,000	390,000	390,000	630,000	630,000
	Total			$ 577,000	$ 577,000		$1,519,000	$1,519,000	$2,549,000	$2,549,000	$3,874,000	$3,874,000
	Emission Control As Percent of Total Cost			12.1%	12.1%		12.5%	12.5%	15.3%	15.3%	16.3%	16.3%
3	Electric Arc-Induction Holding Furnace											
	Buildings and Melting Department Equipment	$ 826,000	$ 826,000	$ 826,000		$2,352,000	$2,352,000	$2,352,000	$3,765,000	$3,765,000	$5,174,000	$5,174,000
	Emission Control Equipment (Fabric Filter)	120,000	120,000	120,000		163,000	163,000	163,000	245,000	245,000	326,000	326,000
	Total	$ 946,000	$ 946,000	$ 946,000		$2,515,000	$2,515,000	$2,515,000	$4,010,000	$4,010,000	$5,500,000	$5,500,000
	Emission Control as Percent of Total Cost	12.7%	12.7%	12.7%		6.5%	6.5%	6.5%	6.1%	6.1%	5.9%	5.9%
4	Coreless Induction-No Holding Furnace											
	Buildings and Melting Department Equipment	$ 813,000	$ 813,000	$ 813,000		$1,670,000	$1,670,000	$1,670,000	$2,963,000	$2,963,000	$4,039,000	$4,039,000
	Emission Control Equipment (Afterburner)	5,000	5,000	5,000		10,000	10,000	10,000	15,000	15,000	19,000	19,000
	Total	$ 818,000	$ 818,000	$ 818,000		$1,680,000	$1,680,000	$1,680,000	$2,978,000	$2,978,000	$4,058,000	$4,058,000
	Emission Control as Percent of Total Cost	0.6%	0.6%	0.6%		0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%

Note: The assumptions made in the development of these figures are included in the text discussion.

A

B

SUMMARY OF OPERATING COSTS FOR PRODUCING IRON UNDER VARIOUS PRODUCTION AND OPERATING CONDITIONS

Alternate Number	Melt Rate Tons/Hour	5				15			30		50	
	Operating Hours/Year	500	1,000	2,000	4,000	1,000	2,000	4,000	2,000	4,000	2,000	4,000
1	Cold Blast, Lined Cupola Without Holding Furnace Using Fabric Filter Collector											
	Costs Per Ton											
	Direct Material	$ 51.09	$ 51.09	$ 51.09		$ 51.09	$ 51.09	$ 51.09	$ 51.09	$ 51.09	$ 51.09	$ 51.09
	Conversion Cost	65.84	44.90	35.47		33.22	25.70	19.56	21.92	16.40	18.55	14.16
	Subtotal	$116.93	$ 95.99	$ 86.56		$ 84.31	$ 76.79	$ 70.65	$ 73.01	$ 67.49	$ 69.64	$ 65.25
	Emission Control	10.00	6.00	3.50		4.00	2.33	1.33	2.33	1.33	1.80	1.00
	Total	$126.93	$101.99	$ 90.06		$ 88.31	$ 79.12	$ 71.98	$ 75.34	$ 68.82	$ 71.44	$ 66.25
	Emission Control as Percent of Total	7.9%	5.9%	3.9%		4.5%	2.9%	1.9%	3.1%	1.9%	2.5%	1.5%
2	Hot Blast, Water-Cooled, Unlined Cupola with Channel Induction Holding Furnace Using High Energy Wet Scrubber											
	Costs Per Ton											
	Direct Material			$ 47.14	$ 47.14		$ 47.14	$ 47.14	$ 47.14	$ 47.14	$ 47.14	$ 47.14
	Conversion Cost			38.04	29.48		26.51	19.22	21.71	16.05	18.83	14.00
	Subtotal			$ 85.18	$ 76.62		$ 73.65	$ 66.36	$ 68.85	$ 63.19	$ 65.97	$ 61.14
	Emission Control			3.50	2.50		2.00	1.25	1.83	1.17	1.65	.98
	Total			$ 88.68	$ 79.12		$ 75.65	$ 67.61	$ 70.68	$ 65.36	$ 67.62	$ 62.12
	Emission Control as Percent of Total			3.9%	3.2%		2.6%	1.8%	2.6%	1.8%	2.4%	1.6%
3	Electric Arc Furnace with Channel Induction Holding Furnace Using Fabric Filter Collector											
	Costs Per Ton											
	Direct Material	$ 44.69	$ 44.69	$ 44.69		$ 44.69	$ 44.69	$ 44.69	$ 44.69	$ 44.69	$ 44.69	$ 44.69
	Conversion Cost	143.72	84.95	55.09		74.78	47.94	33.33	41.44	29.47	37.14	26.79
	Subtotal	$188.41	$129.64	$ 99.78		$119.47	$ 92.63	$ 78.02	$ 86.13	$ 74.16	$ 81.83	$ 71.48
	Emission Control	22.40	12.40	6.50		5.47	3.27	2.13	2.45	1.60	1.96	1.28
	Total	$210.81	$142.04	$106.28		$124.94	$ 95.90	$ 80.15	$ 88.58	$ 75.76	$ 83.79	$ 72.76
	Emission Control as Percent of Total	10.6%	8.7%	6.1%		4.4%	3.4%	2.7%	2.8%	2.1%	2.3%	1.8%
4	Coreless Induction Furnace with Charge Preheater, Without Holding Furnace, Without Emission Control Except on Preheater											
	Costs Per Ton											
	Direct Material	$ 47.06	$ 47.06	$ 47.06		$ 47.06	$ 47.06	$ 47.06	$ 47.06	$ 47.06	$ 47.06	$ 47.06
	Conversion Cost	134.14	80.47	53.77		51.01	35.12	26.52	33.05	24.12	28.81	21.62
	Subtotal	$181.20	$127.53	$100.83		$ 98.07	$ 82.18	$ 73.58	$ 80.11	$ 71.18	$ 75.87	$ 68.68
	Emission Control	.46	.27	.17		.20	.14	.11	.12	.10	.11	.09
	Total	$181.66	$127.80	$101.00		$ 98.27	$ 82.32	$ 73.69	$ 80.23	$ 71.28	$ 75.98	$ 68.77
	Emission Control as Percent of Total	.3%	.2%	.2%		.2%	.2%	.2%	.2%	.1%	.1%	.1%

Note: The assumptions made in the development of these figures are included in the text discussion.

A

MODIFICATIONS TO CUPOLA MELTING PRACTICES TO REDUCE EMISSIONS

	Modification	Effect of Modification	Decrease in Emissions	Savings: Equipment Percent	Savings: Operation	Savings: Total Annual Percent	Cost of Modification/Ton Metal Melted
	Decrease Stack Gas Volume						
1.	Decrease area of charging door and use vibrating feeder or chute.	Decrease air infiltration up to 85%. Decrease volume of gas to be cleaned up to 60%.	None	7%	-	33%	
2.	Locate gas take-off below top of charge	Decrease total gas to be cleaned up to 74%	None	30%	-	40%	
3.	Locate gas take-off at charging door	Decrease total gas volume 45%	None	-	-	43%	
	Decrease Coke Charge						
4.	Hot blast	Reduce coke requirement by heating blast air using natural gas fuel.	Moderate - Estimated to be -4% for constant melting rate.		$1.00 per million BTU		
5.	Oxygen enrichment	Add O_2 to blast air to increase O_2 content of blast from 21% to 25% permitting coke reduction.	Moderate - Estimated to be 5% to 10% for constant melting rate		$1.25/ton of metal melted		
6.	Natural gas injection	Inject natural gas and air in stoichiometric ratio to replace up to 40% of coke	Moderate - 15%		$1.22/ton for 30% coke replacement $2.01/ton for 40% coke replacement		
	Preparation of Charge Materials						
7.	Screen coke and limestone	Remove coke breeze and limestone dust from charge	Depends upon degradation of coke and limestone. Estimated range of decrease 5%-20% consisting principally of +44 micron particles.	Nominal cost		Nominal Savings	
8.	Shot blast foundry returns	Removes embedded molding and core sand	Depends upon amount of sand on returns. Estimated range of decrease 2%-8%.				$2.00-$2.50/ton
9.	Incineration or detergent washing broken motor blocks or shredded automotive steel scrap	Remove oil, grease and other combustibles	Depends upon amount of combustibles in scrap. Estimated range of decrease 2%-25%	-	-	-	$3.50 - $4.00
10.	Remove nonferrous contaminants	Reduces nonferrous metallic oxides in cupola emissions	Depends upon amount of nonferrous material in scrap. Estimated range of decrease 1%-2%	-	-	-	

EXHIBIT IX-1
(Revised)

CAPITAL AND OPERATING COSTS PER TON VS. OPERATING HOURS PER YEAR FOR CORELESS INDUCTION FURNACE WITH AFTERBURNER ON PREHEATER (ALTERNATE NO. 4)

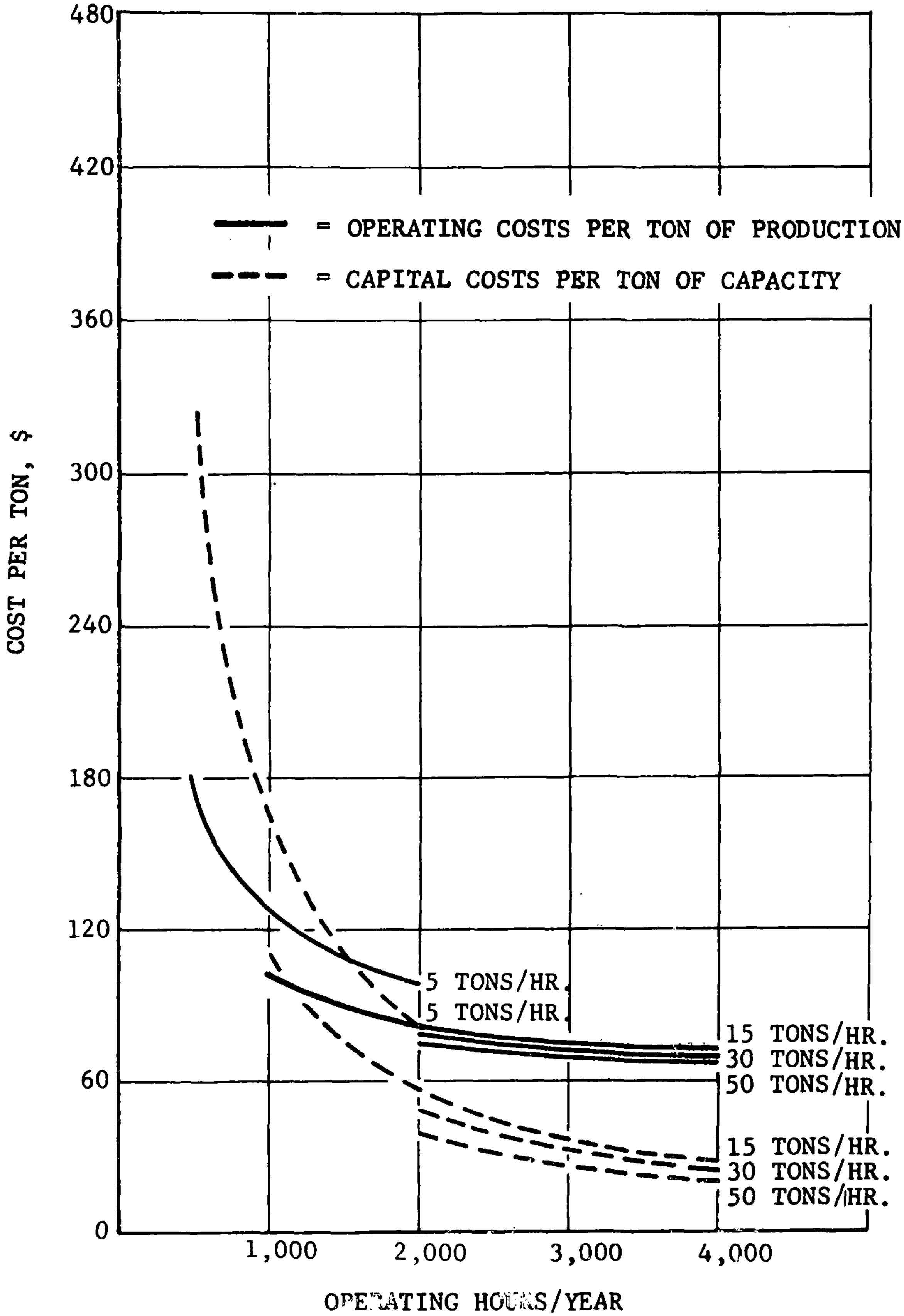
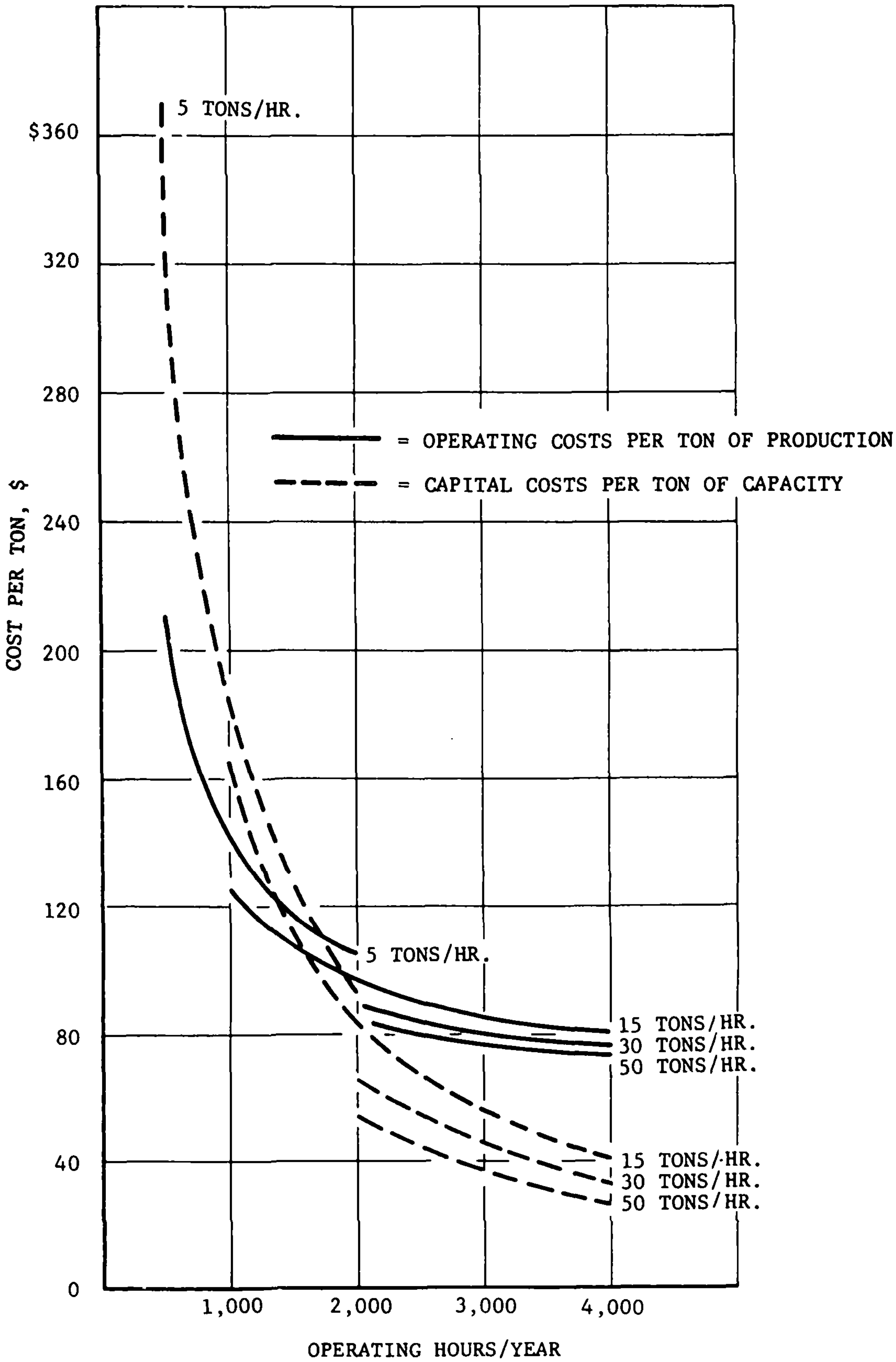
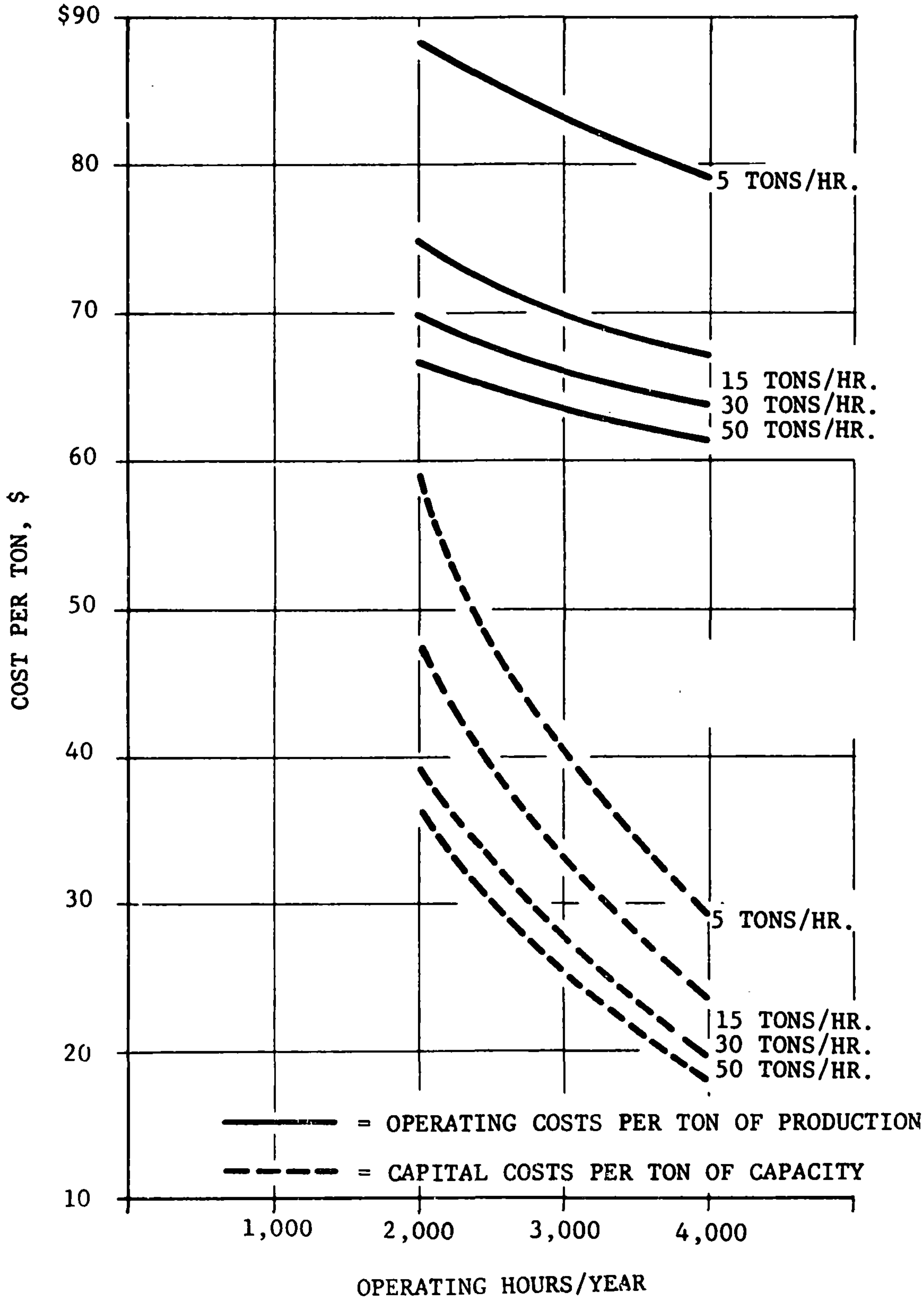


EXHIBIT VIII-35

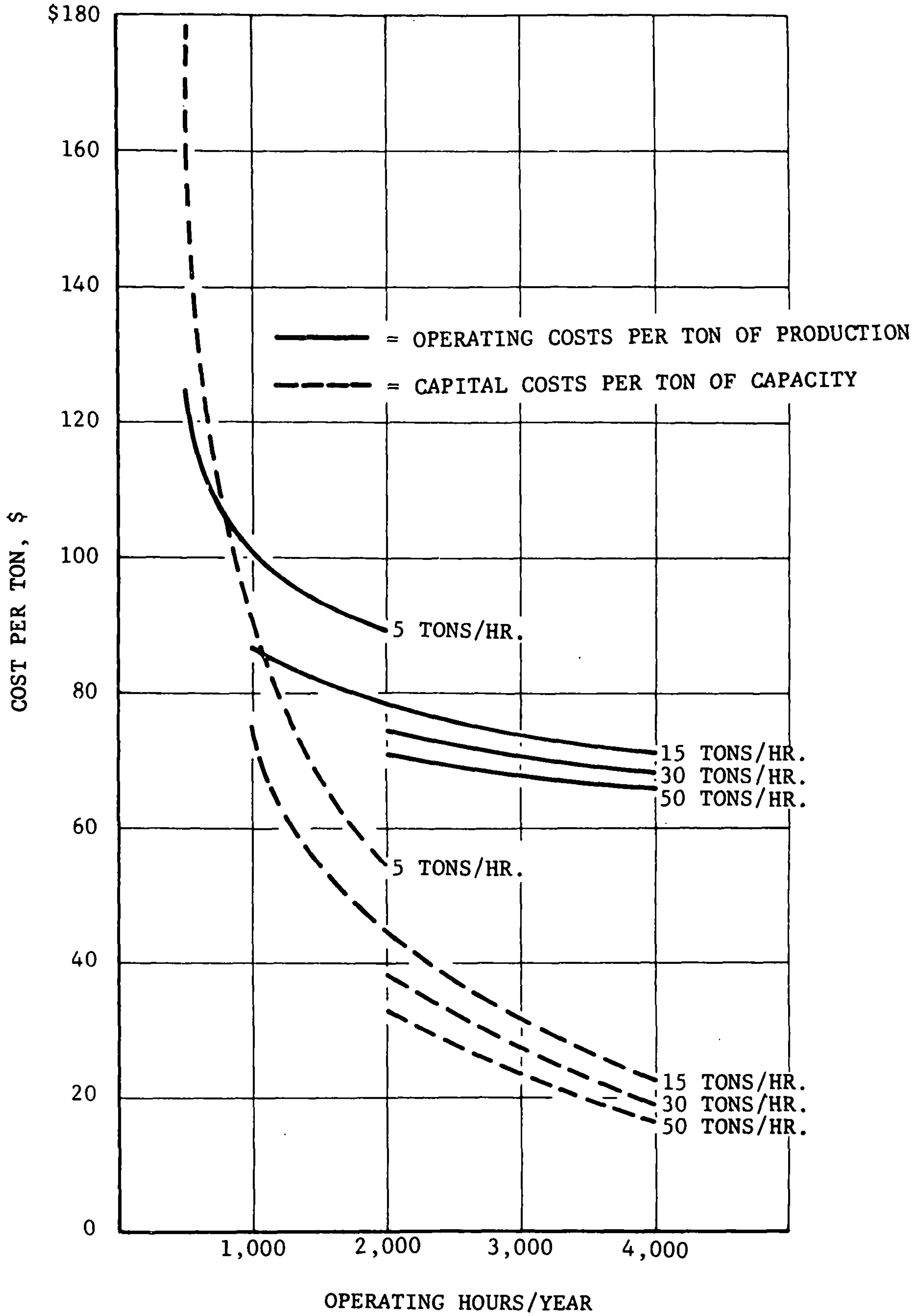
CAPITAL AND OPERATING COSTS PER TON VS. OPERATING HOURS PER YEAR FOR ELECTRIC ARC FURNACE WITH FABRIC FILTER (ALTERNATE NO. 3)



CAPITAL AND OPERATING COSTS PER TON VS. OPERATING HOURS PER YEAR FOR HOT BLAST CUPOLA WITH WET SCRUBBER (ALTERNATE NO. 2)



CAPITAL AND OPERATING COSTS PER TON VS. OPERATING HOURS PER YEAR FOR COLD BLAST CUPOLA WITH FABRIC FILTER (ALTERNATE NO. 1)



INVENTORY OF IRON FOUNDRY EMISSIONS FROM MELTING OPERATIONS, 1969

Region	Castings Production Tons (1)	Molten Iron Production Tons (1)	Total Particulate Emissions Generated, Tons (3)	Carbon Monoxide Generated, Tons (3)	Particulate Emissions Emitted, Tons (4)	Carbon Monoxide Emitted, Tons (5)
New England Maine New Hampshire Vermont Massachusetts Rhode Island Connecticut	235,000	362,000	3,800	49,000	2,800	24,500
Middle Atlantic New York New Jersey Pennsylvania	3,501,000	5,143,000	51,000	594,000	38,000	297,000
East N. Central Ohio Indiana Illinois Michigan Wisconsin	8,225,000	12,613,000	126,000	1,541,000	94,500	770,500
West N. Central Minnesota Iowa Missouri Nebraska Kansas N. Dakota S. Dakota	607,000	881,000	9,100	115,000	6,800	57,500
South Atlantic Delaware Maryland Virginia W. Virginia N. Carolina S. Carolina Georgia Florida	473,000	662,000	6,800	88,000	5,100	44,000
East S. Central Kentucky Mississippi Alabama Tennessee	2,300,000	2,887,000	27,700	304,000	20,800	152,000
West S. Central Arkansas Louisiana Oklahoma Texas	531,000	748,000	7,700	100,000	5,800	50,000
Mountain Montana Colorado Arizona Nevada (2) Idaho New Mexico (2) Wyoming (2)	243,000	332,000	3,300	38,000	2,500	19,000
Pacific Washington Oregon California Hawaii Alaska	499,000	739,000	7,600	95,000	5,700	47,500
Total	16,614,000	24,367,000	243,000	2,924,000	182,000	1,462,000

Notes:
(1) Castings and molten iron production quantities from cupolas and electric arc furnaces only.

(2) No iron foundries are located in Nevada, New Mexico, and Wyoming.

(3) Particulate emissions and carbon monoxide generated are the estimated maximum produced.

(4) Particulate emissions emitted are estimated at 75% of maximum produced, with an average 25% being collected.

(5) Carbon monoxide emitted is estimated at 50% being burned and 50% released to the atmosphere.

RATING CODE

IRON FOUNDRY EMISSION CONTROL

CLASSIFICATION	RATING NUMBER 1-5	6-10	11-15	16-20
Amount of Emissions Comparison of emission rates from all sources.	Low	Moderate	High	Very High
Particle Size Based on particle size distribution. Maximum diameter of finest 20% by weight.	Coarse	Medium	Fine	Very Fine
Difficulty of Capture Based on degree of confinement of emissions at source.	Easy	Moderate	Difficult	Extremely Difficult
Difficulty of Separation Comparison of particle size distribution and other characteristics of emissions affecting difficulty of separation.	Easy	Moderate	Difficult	Extremely Difficult
Cost of Control Systems Relative cost of separation equipment only, as affected by type of system and pressure drop.	Low	Medium	High	Extremely High
Cost of Auxiliary Equipment Based on complexity of ductwork, cost of motors, blowers and other auxiliary equipment.	Low	Medium	High	Extremely High
Availability of Control Equipment Based on whether equipment is standard and mass-produced, requires detailed engineering, or complete design engineering.	Readily Available	Available	Difficult to Find	Experimental or Pilot Plant Systems Only
Capability of Control Equipment Ability of existing control devices to perform satisfactorily.	Very Capable	Moderately Capable	Capable	Not Capable
Priority Rating-		7-80	80-110	110-160
Priority		Low	Medium	High

INVENTORY OF IRON FOUNDRY EMISSIONS FROM NON-MELTING OPERATIONS, 1969

Region	Castings Production Tons	Molten Iron Production Tons	Total Particulate Emissions Generated Tons	Particulate Emissions Emitted Tons
New England Maine New Hampshire Vermont Massachusetts Connecticut	239,000	368,000	21,000	1,100
Middle Atlantic New York New Jersey Pennsylvania	3,643,000	5,603,000	319,400	16,200
East North Central Ohio Indiana Illinois Michigan Wisconsin	8,453,000	13,001,000	741,100	37,700
West North Central Minnesota Iowa Missouri Nebraska North Dakota South Dakota	677,000	1,041,000	59,300	3,000
South Atlantic Delaware Maryland Virginia West Virginia North Carolina South Carolina Georgia Florida	485,000	746,000	42,500	2,200
East South Central Kentucky Mississippi Alabama Tennessee	2,327,000	3,579,000	204,000	10,400
West South Central Arkansas Louisiana Oklahoma Texas	551,000	847,000	48,300	2,500
Mountain Montana Colorado Arizona Nevada (1) Idaho New Mexico (1) Wyoming (1)	249,000	383,000	21,800	1,100
Pacific Washington Oregon California Hawaii Alaska	531,000	817,000	46,600	2,400
Total	17,155,000	26,385,000	1,504,000	76,600

Note: (1) No iron foundries are located in Nevada, New Mexico, and Wyoming.