



Dust Recovery Practice at Blast Furnaces

An evaluation of settleable solids formation and recovery at mills in the Ohio Valley and a suggested procedure for defining performance of wastewater clarifiers.

Reference Data Publication compiled by

Steel Industry Action Committee

**OHIO RIVER VALLEY
WATER SANITATION COMMISSION**



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Reference data publication prepared by

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CONTENTS

INTRODUCTION AND SUMMARY	4
BLAST FURNACE DUST SURVEY	6
Size and Composition of Dust	6
Washwater Requirements	7
Sampling Technique	7
Performance Index	9
Survey Questionnaire	9
Charts 1-6	13
Charts 7-11.	14
APPENDIX I - IRON MANUFACTURE	16
The Blast Furnace.	18
The Auxiliaries	18
Furnace Operation.	25
APPENDIX II - OCCURRENCE AND NATURE OF BLAST FURNACE DUST	29
Charging Practice.	29
Stock Movement.	29
Gas Velocity	30
Ore Quality.	30
High Top-pressure.	30
APPENDIX III - PROCEDURE USED IN SURVEY FOR DETERMINING SETTLEABLE SOLIDS IN BLAST FURNACE GAS WASHER WATER	31

FOREWORD

This is one of a series of manuals of practice relating to operations of the steel industry with specific reference to the control of water pollution. It was prepared under the direction of the Steel Industry Action Committee, which was organized by invitation of the Commission on April 13, 1950. Since that time the committee has promoted a critical examination of its problems -- and those of the Commission -- as related to water use and the public interest.

Because the membership of the committee includes all the major steel industries in the Ohio River Valley, a unique opportunity is afforded to draw upon a wide variety of resources and conduct studies of a nature far more comprehensive than heretofore has been possible. The findings developed for this manual are a case in point. They represent an evaluation of data from 23 mills that operate 81 blast furnaces.

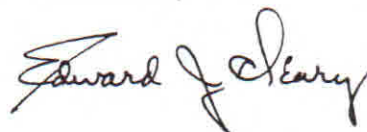
Planning and development of the study on blast-furnace dust formation and recovery is one of the projects of a subcommittee on settleable solids whose members include:

C. A. Bishop	United States Steel Corporation
* G. M. Dreher	Jones and Laughlin Steel Corporation
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G. A. Howell	United States Steel Corporation
G. A. Pettit	Armco Steel Corporation
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De Yarman Wallace	Youngstown Sheet & Tube Corp. (Co-Chairman)

* deceased

Execution of the project was assigned to Richard D. Hoak. Dr. Hoak is Senior Fellow of the American Iron and Steel Institute Fellowship at the Mellon Institute of Industrial Research.

It is with appreciation that the Ohio River Valley Water Sanitation Commission acknowledges this contribution to a better understanding of industrial-waste control practice.



Executive Director
and Chief Engineer

Cincinnati, Ohio
January, 1958

INTRODUCTION AND SUMMARY

The Ohio River Valley Water Sanitation Commission (ORSANCO) has fostered a genuinely cooperative approach to stream pollution control by inviting the formation of industry committees to participate in the regional program initiated by eight states in 1948. Over the years this policy has resulted in a degree of mutual understanding rarely achieved heretofore. The Steel Industry Action Committee appointed a number of subcommittees to deal with specific aspects of water pollution. One of these was the Subcommittee on Settleable Solids.

The major sources of settleable solids in steel manufacture are blast furnaces and rolling mills. These kinds of settleable material are similar in some respects, but methods of handling them differ considerably. As a first step in its assignment the subcommittee undertook an investigation of the current status of recovery of blast-furnace flue dust; the results are given in this report. A similar study of rolling-mill scale is in progress.

This report includes a brief description (Appendix I) of the blast furnace and its auxiliaries. Furnace operation is explained (Appendix II) to outline the many factors that influence dust formation, and dust recovery practice is described.

The subcommittee made a comprehensive survey of the 23 steel mills operating blast furnaces in the Ohio River Compact Area. The survey was based on a questionnaire that included detailed instructions and the analytical procedure to be used. Thus, all data were collected as nearly as possible in the same manner at each mill.

For purposes of the survey, settleable solids in blast furnace gas-washer water were defined as material that will settle in one hour under prescribed laboratory conditions. The performance of washwater clarifiers was defined by an index of the removal of settleable solids. Thus, if a one-hour laboratory test is arbitrarily adopted as a measure of complete removal of settleable solids, a performance index of 10 on a clarifier defines complete removal for that installation.

There are 81 furnaces in the drainage basin of which 79, with a combined rated capacity of 75,184 tons of pig iron per day, were in operation during the survey. The data showed that an average of 7,525 tons of dust was produced daily, and that 94 percent of it was being recovered. Of this, 70 per-

cent was collected in dry dustcatchers and 24 percent was separated in wash-water clarification equipment. Of the average 224 pounds of dust made per ton of pig-iron manufactured, only 10 pounds was discharged to streams.

The efficiency of flue-dust recovery devices is affected by many variables, especially the quantity and fineness of the dust as well as fluctuations in its concentration. These factors are governed by the physical characteristics of the materials charged to the furnace and the individual peculiarities of furnace operation. The average performance index of wash-water clarifiers was 8.8, with 29 of the 39 units above 9.0.

The survey disclosed considerable variation in the amount of dust produced and recovered from mill to mill, and from furnace to furnace at the same mill. These variations can be attributed to the many interdependent variables which differ among furnaces; no two blast furnaces ever operated exactly alike. (It is necessary to emphasize the fact that the manufacture of pig iron is more an art than a science; this in itself accounts for considerable variation in blast furnace operation.) Installations for wash-water clarification also differ, largely as a result of local conditions.

This survey has provided quantitative data on flue-dust recovery, but it cannot yield the kind of information required to determine the degree of waste treatment necessary for a given set of local conditions. Since basic research is needed to provide data not yet available, the American Iron and Steel Institute has requested its Fellowship at Mellon Institute to undertake a study of the effects clarifier effluents may have on river water quality.

BLAST FURNACE DUST SURVEY

For the assembly of pertinent information, the Subcommittee on Settleable solids sent a comprehensive questionnaire to each company operating blast furnaces in the Ohio River Compact Area. The questionnaire was designed to insure that the data would be collected and reported in the same manner by each company.

Several related factors influence the production of dust. The most important of these are: (1) charging practice; (2) movement of stock in the furnace; (3) physical properties of the charge; (4) blowing rate. These variables are discussed in Appendix II.

Size and Composition of Dust

Gas leaving the top of the furnace may contain 10 to 15 grains of dust per cubic foot. The dust consists of particles of ore, coke, and limestone. With smooth operation the particles will range in size from a quarter-inch to a few millionths of an inch in diameter. The range of particle size in a number of samples of dust leaving a dry dust catcher is given in Table I.

Table I. Range of Particle Size in Dry Dust

Tyler Mesh	Screen Opening, in.	Percent
+ 20	0.0328	2.5 - 20.2
+ 28	0.0232	3.9 - 10.6
+ 35	0.0164	7.0 - 11.7
+ 48	0.0116	10.7 - 12.4
+ 65	0.0082	10.0 - 15.0
+100	0.0058	10.2 - 16.8
+150	0.0041	7.7 - 12.5
+200	0.0029	5.3 - 8.8
-200	-	15.4 - 22.6

The range of chemical composition of a large number of dust samples is given in Table II.

Table II. Range of Chemical Composition of Dry Dust

Component	Percent (dry basis)
Iron, as Fe	36.5 - 50.3
Phosphorus, as P	0.1 - 0.2
Manganese, as Mn	0.5 - 0.9
Silica, as SiO ₂	8.9 - 13.4
Alumina, as Al ₂ O ₃	2.2 - 5.3
Lime, as CaO	3.8 - 4.5
Magnesia, as MgO	0.9 - 1.6
Sulfur, as S	0.2 - 0.4
Carbon, as C	3.7 - 13.9

Washwater Requirements

The volume of water required to clean blast furnace gas ranges from 10 to 40 gallons per 1,000 cubic feet of gas. Water consumption varies with the design and efficiency of gas washers, and with the furnace burden. Since furnaces may produce from 50,000 to 140,000 cfm of gas, the water consumption may be 500 to 5,600 gpm. Water is conserved in furnace operation by using water from the steam condensers of the turbo blowers to cool the shell and tuyeres of the furnace, and then to supply the wet gas washers. Water leaving the gas washers may contain from 50 to more than 200 grains of dust per gallon.

Sampling Technique

Faulty conclusions result from analysis of samples that do not represent the actual composition of the material sampled. Rapid changes in concentration of suspended solids in gas-washer water make it somewhat difficult to collect representative samples. The variation in concentration pointed to the need for averaging the results of a series of analyses, but there was no guide to the number of samples to be collected nor to the appropriate length of the sampling period. An intensive study was therefore made by the American Iron and Steel Institute Fellowship at a typical clarifier installation to establish a proper sampling program.

Samples of influent and effluent were collected at 20-minute intervals for two hours on each of 23 days over a period of two months. Influent samples were analyzed for non-settleable and total suspended solids; effluent samples were analyzed for total suspended solids. Statistical analysis of results from these 161 individual samples each of influent and effluent gave the following mean values and confidence intervals.

Table III. Influent and Effluent Solids Concentrations

Variable	Mean, ppm	95% Confidence, ppm
Influent, total suspended solids	1,216	1,047 - 1,385
Influent, nonsettleable solids	79	65 - 93
Effluent, total suspended solids	99	90 - 107

The above figures were compared with those from samples collected over a single 24-hour period. Samples were taken hourly as above and analyzed individually. In addition, influent samples collected at 15-minute and 60-minute intervals were composited over the 24-hour period. The results are shown in Table IV.

Table IV. Analyses of Composited Samples

Variable	Sample	Solids Conc., ppm	95% Confidence, ppm
Influent, total	15-min. composite	1020	
suspended solids	60-min. composite	1330	
Influent, non-	15-min. composite	63	
settleable solids	60-min. composite	64	
	Hourly, mean	73	65 - 82
Effluent, total	Hourly, mean	104	82 - 126
suspended solids			

Comparison of the data in Tables III and IV shows that the averages of individual samples collected over a single 24-hour period fall within the confidence intervals of samples taken over a much longer period of clarifier operation. The two pairs of composite samples show more deviation from the long-term averages, but not enough to make them invalid. In the opinion of the subcommittee, the small loss in accuracy which occurs when samples are composited does not justify the time required to make individual analyses. Therefore, the survey was based on the analysis of influent and effluent samples that were composited hourly for 24 hours.

Analytical Procedure

The analytical procedure developed by the Steel Industry Action Committee and accepted September 29, 1954 by the Engineering Committee of ORSANCO as suitable for purposes of the survey will be found in Appendix III.

Performance Index

It was necessary to have a method for comparing the efficiency of clarification devices. The effectiveness with which a clarifier removes settleable solids is its most important feature, and efficiencies were therefore evaluated on that basis. The following expression, which is part of the procedure developed in Appendix III, defines the Performance Index:

$$P.I. = \frac{(\text{Total Suspended Solids in}) \text{ minus } (\text{Total Suspended Solids out})}{(\text{Settleable Solids in})} \quad \text{times } 10$$

It will be noted in the tabulation of the survey data that several performance indexes are greater than 10. This simply means that the amount of suspended solids removed by the clarifier is greater than the amount of suspended solids removed in a laboratory sample in a settling time of one hour. In general, the greater the concentration of suspended solids in gas washer water the greater the tendency for increased settling efficiency in the field; that is, the greater the probability for a clarifier to show a performance index greater than 10.

Survey Questionnaire

The survey form and the instructions that accompanied it are shown on Page 10. The data collected are given in Table V. Inspection of this table shows that 23 of the units had performance indexes of 9.5 or better, 29 of 9.0 or better, and 32 of 8.5 or better. Seven had indexes of 8.0 or less, and four had no clarification equipment.

Important aspects of the survey findings have been shown graphically in a series of eleven histograms. The operating variables have been computed in terms of "units." A unit is defined as a blast furnace and its associated gas washing and dust recovery equipment, or a group of furnaces and associated equipment when such equipment is used in common. There were 43 units in service in the Compact Area during the survey.

The histograms were constructed as follows: For each variable the data were arranged in order of magnitude. They were then grouped in equal intervals and the frequency of occurrence was plotted against the chosen parameter. For example, in the histogram (Chart No. 1) representing the pounds of dust made per ton of iron, the data were grouped by hundreds. Thus three units

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[illegible]

9. Give the total number of wet washers within the unit, their total discharge rates and state the immediate destination of the discharge, i.e., sewer to river, clarifier, etc.
10. State the type of clarifier. Give the dimensions, i.e., length and width for rectangular basins or lagoons or diameter for circular clarifiers. Give the normal working depth. Give the number of trays for thickeners. State the source of the influent. State the overflow rate and the destination of the overflow.
11. The concentrations reported here will be those of the wet washer effluents and clarifier influents. In cases where the combined effluents of the gas washers flow through a common channel, the concentrations of solids may be determined from a single sample taken at a point where the concentration is assumed. It is necessary to sample at a point where the concentration is uniform. The concentrations should be reported in weight per volume; for example, if there are two washers having discharges of 1000 and 2000 gpm and effluent solids concentrations of 1000 and 1200 ppm, respectively, the weighted average will be
$$\frac{(1000 \times 1000) + (2000 \times 1200)}{3000}$$
 or 1133 ppm. The concentrations in clarifier influents may be determined from a single sample provided all influent streams are well mixed before the point of sampling. Where the streams are not mixed, each influent stream should be sampled and weighted average concentrations reported. The concentration of solids in the clarifier effluent should be determined from samples taken from the total discharge stream before it is mixed with other streams. Samples should only be taken from the launder or thickener in cases where the total effluent stream is inaccessible.
12. Calculate the performance index as shown in the analytical procedure.

TABLE V. Summary of Data from Blast Furnace Flue-Dust Survey

Abbreviations:

- | | | |
|-----------------------|---------|---|
| DC - Dorr clarifier | Note 1. | Underflow from three clarifiers settled in sump. |
| WC - Walker clarifier | Note 2. | Clarifier at sinter plant receives underflow from three clarifiers. |
| SB - Settling basin | Note 3. | Clarifier at sinter plant receives sinter dust. |
| L - Lazoon | Note 4. | Clarifier at boiler house receives flow from precipitator. |
| | Note 5. | Clarifier at sinter plant receives underflow from three clarifiers. |

Plant No.	1	2	3	4	5	5	5	5	5	5	6	7	8	9	10	10	10	10	10	11	11	12	13	13
Unit No.	1	1	1	2	1	1	2	3	4	5	6	1	1	1	1	1	2	3	4	4	1	1	1	1
Description	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. of Blast Furnaces	4	4	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2
Rated Capacity	1700	4500	1745	2625	1600	750	750	750	750	840	-	675	1470	675	1523	1952	2496	2098	-	1300	-	1533	881	1025
Dry Dust Recovered	49.0	250	55	420	108.0	43.8	47.5	22.5	30.0	18.8	-	165	105	67.0	57.5	81.5	222.8	74.4	-	81.4	-	78.0	79.3	126.6
Wet Dust Produced	22.0	150	31	58.0	15.4	8.2	33.3	11	32	42.4	-	77.1	44.5	34.5	31.6	36.1	79.6	58.2	-	113	-	52.3	26.0	28.7
Wet Dust Treated	-	-	-	-	-	-	-	-	-	-	82.2	-	-	-	-	-	-	-	161	-	26.7	-	-	-
Wet Dust Recovered	19.2	0	0	0	14.8	0	16.2	10.2	30.4	41.6	65.5	74.2	39.2	34.1	25.9	34.7	74.4	53.4	160.8	110.6	25	51.1	22.4	20.1
Wet Dust to Stream	2.8	150	31.1	58.0	0.6	8.2	17	0.7	1.6	0.8	16.7	2.8	5.3	0.5	5.7	1.4	5.2	4.8	0.2	2.3	1.7	1.3	3.6	8.6
Dust in Washer Water	85.6	100	90.4	116	180	35.4	142	61.9	149	236	384	404	144	231	55.7	207.7	204.7	286.7	6440	275	376	232	105	75.0
Dust to Stream	10.9	100	90.4	116	6.7	35.4	72.9	6.02	11.4	8.2	77.9	14.9	17.1	3.1	10.1	8.1	13.3	23.8	6.4	5.6	23.8	5.6	14.6	22.5
Discharge to Stream	3600	21000	4820	7010	1200	3237	3269	1652	1994	1352	2998	2668	4320	2016	7883	2440	5440	2840	350	5760	994	3150	3468	5350
Primary Washer Water	Yes	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Secondary Washer Water	None	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Type of Clarifier	DC	None	None	None	DC	None	Sump	DC	DC	DC	Sump	DC	DC	DC	SB	DC	DC	DC	DC	DC	SB	SB	SB	SB
Size of Clarifier	70'd.	-	-	-	60'd.	-	11x24	35'd.	35'd.	35'd.	35'd.	60'd.	42'd.	60'd.	Two- 27x136	40'd.	55'd.	60'd.	50'd.	90'd.	110'd.	110'd.	110'd.	110'd.
Performance Index	9.4	-	-	-	10.0	-	5.0	10.0	9.6	9.9	8.3	9.8	9.0	9.9	9.5	9.9	9.7	9.4	10.0	10.0	9.5	10.0	8.9	7.4
Wet Dust Produced	25.9	66.7	35.6	44.2	19.2	21.8	88.7	29.3	85.3	101	-	228	60.58	102	41.5	36.99	63.76	57.10	-	174	-	68.23	59.0	55.9
Dust to Stream	3.3	66.7	35.6	44.2	0.7	21.8	45.4	1.9	4.4	1.9	-	8.4	7.2	1.3	7.5	1.4	4.1	4.7	-	3.6	-	1.6	8.2	16.8
Dust Catcher	69.0	62.5	63.9	87.9	87.5	84.3	58.8	67.2	48.4	30.7	-	68.2	70.2	66.0	64.6	69.3	73.7	56.1	-	41.9	-	59.9	75.3	81.5
Efficiency, %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Plant No.	13	13	13	13	13	14	14	14	14	15	15	16	16	16	16	17*	18	19	19	19	19	20	20	21	21	21	21	21	22	23	23	23	
Unit No.	4	5	6	7	7	1	1	2	2	1	1	1	1	1	1	1	1	1	2	2	3	3	1	2	3	4	5	5	5	5	5	5	5
Description	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. of Blast Furnaces	1	1	1	1	1	5	2	2	2	1	2	1	2	1	1	1	2	1	1	1	1	2	2	2	1	4	-	-	-	-	-	-	-
Rated Capacity	950	1013	746	-	2781	931	5675	1584	1892	1837	1200	1600	500	500	1200	1990	2260	2660	1189	3696	-	2500	4000	1400	600	73.0	33.2	-	-	-	-	-	-
Dry Dust Recovered	28.0	89.6	Down	-	306.7	Down	267.0	131.7	157.4	152.9	137.0	93.2	50.0	50.0	150.0	95.0	126.0	163.0	110.0	268.0	-	139.0	262.0	135.0	73.0	-	-	-	-	-	-	-	-
Wet Dust Produced	63.9	77.6	-	-	81.7	-	156	62.3	27.6	35.5	8.0	28.5	0.3	10.0	181.0	46.0	61.9	110.5	39.7	77.9	-	38.1	68.3	8.2	33.2	-	-	-	-	-	-	-	-
Wet Dust Treated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wet Dust Recovered	58.9	71.9	-	0.6	76.6	-	146.1	61.3	26.0	32.0	8.0	27.9	0.1	3.2	178.0	40.2	45.1	106.3	37.8	74.7	232.1	36.2	5.4	1.9	36.7	-	-	-	-	-	-	-	-
Wet Dust to Stream	5.0	5.7	-	0.6	5.1	-	10.0	1	1.5	2.5	P	0.6	0.2	6.8	2.1	5.8	16.8	4.2	1.9	3.2	5.5	1.9	63.0	6.3	0.5	-	-	-	-	-	-	-	-
Dust in Washer Water	331	476	-	27.8	108	-	121	358	174	94.8	25.1	63.6	2.3	42.3	367	90	105	130	125	92.4	2310	56.0	96.6	62.9	146	-	-	-	-	-	-	-	-
Dust to Stream	25.7	34.8	-	14.0	7.30	-	7.7	6.0	9.7	6.7	0	1.3	1.9	28.7	4.3	11.4	28.4	5.0	6.0	3.8	53.5	2.8	36.8	29.3	2.0	-	-	-	-	-	-	-	-
Discharge to Stream	2704	2280	-	640	10601	-	18000	2440	2215	5240	0	6278	1728	3312	6912	7128	8280	11880	4464	11868	1440	9518	23976	3027	3111	-	-	-	-	-	-	-	-
Primary Washer Water	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Secondary Washer Water	None	Yes	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of Clarifier	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB	SB
Size of Clarifier	Two- 13x116	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128	Two- 14x128
Performance Index	9.3	9.4	-	7.4	9.7	-	9.6	9.9	9.6	9.6	10.0	10.9	2.8	3.5	10.0	8.9	7.7	10.1	10.2	10.2	9.8	10.3	0.8	3.0	10.2	-	-	-	-	-	-	-	-
Wet Dust Produced	134.5	153.1	-	-	58.8	-	55.0	78.7	29.1	38.6	13.3	35.7	1.12	40.0	302	46.2	54.8	83.1	66.8	42.2	-	30.5	34.2	11.7	110.5	-	-	-	-	-	-	-	-
Dust to Stream	10.4	11.2	-	-	3.7	-	3.5	1.3	1.6	2.7	0	0.8	0.9	27.1	3.5	5.9	14.9	3.2	3.2	1.7	-	1.5	31.5	9.0	1.5	-	-	-	-	-	-	-	-
Dust Catcher	30.5	53.6	-	-	79.0	-	63.1	67.9	85.1	81.2	94.5	76.5	99.4	83.3	45.3	67.4	67.1	59.6	73.5	77.5	-	78.5	79.3	94.3	68.8	-	-	-	-	-	-	-	-
Efficiency, %	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* A closed system - overflow from clarifier returns to washer.

made 100 lb. per ton or less, 17 made between 100 and 200, 15 between 200 and 300, 6 between 300 and 400, one between 500 and 600, and one between 700 and 800. These frequencies were then shown as vertical bars on a uniform scale along the base of the plot. The median value of the variable (half of the values larger, half smaller than the figure shown) is indicated on each histogram. Variables were computed from the data wherever they are not given directly in Table V.

Chart No. 1. Total Dust Made

A majority of the units produced between 100 and 300 pounds of dust per ton of iron manufactured. The median value was 202; the average 208. It will be noted that three units made much less dust than the average, while eight made much more.

Chart No. 2. Dustcatcher Efficiency

There was a rather wide spread in efficiencies of dry dustcatchers, ranging from 31 to 99 percent, with most installations in the range 55 to 85 percent. The median efficiency was 69 percent.

Charts No. 3 and 4. Wet Dust Made

These two charts show the amount of wet dust made in terms of tons per day and pounds per ton of iron produced. Total wet dust made is the sum of the amount recovered and the amount discharged to sewers. The wide range of this variable (0.3 to 181 tons per day; 11 to 302 lb. per ton of iron) is a function of furnace operation and dry dustcatcher efficiency. The median values were 40 tons per day and 55 pounds per ton of iron.

Chart No. 5. Wet Dust Recovery

Most of the wet dust recovery equipment was very efficient, as shown by the median value of 94 percent. Four units had no provision for recovery of wet dust.

Chart No. 6. Overall Dust Recovery

This chart illustrates the combined result of dry and wet dust recovery. A relatively inefficient dustcatcher combined with an efficient wash water clarifier (or vice versa) may be entirely satisfactory. Thirty-two of the 43 units showed overall dust recoveries in excess of 95 percent, and the median value was 98 percent.

CHART 1

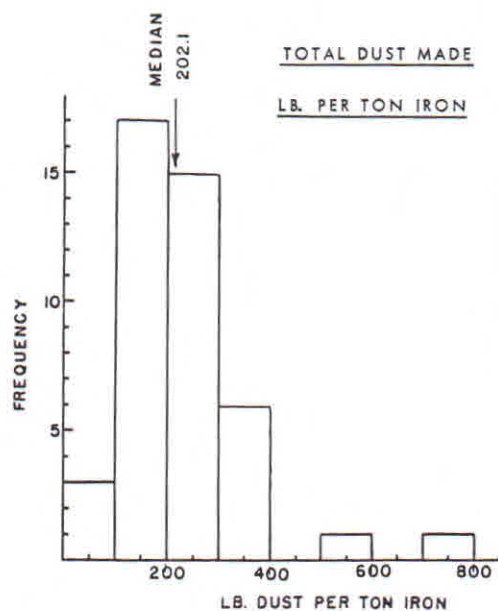


CHART 4

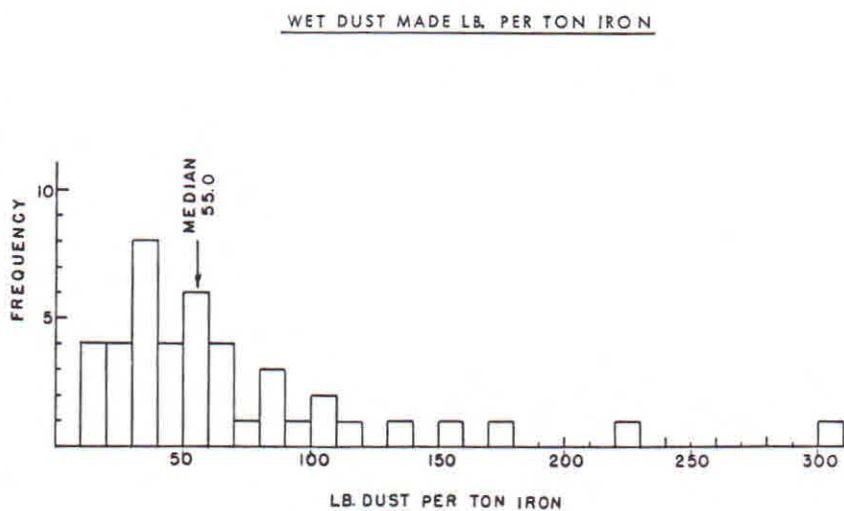


CHART 2

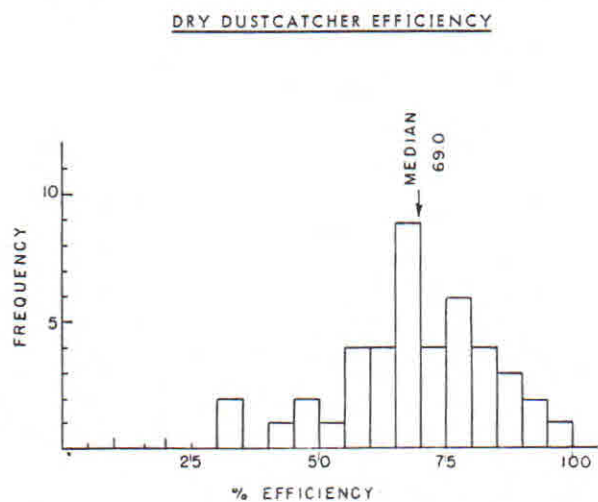


CHART 5

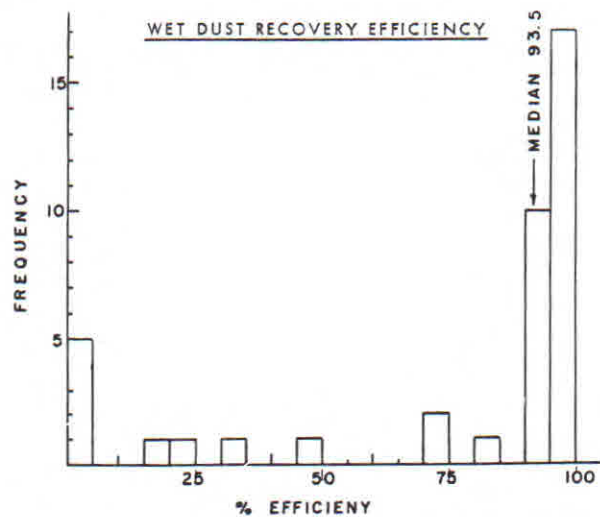


CHART 3

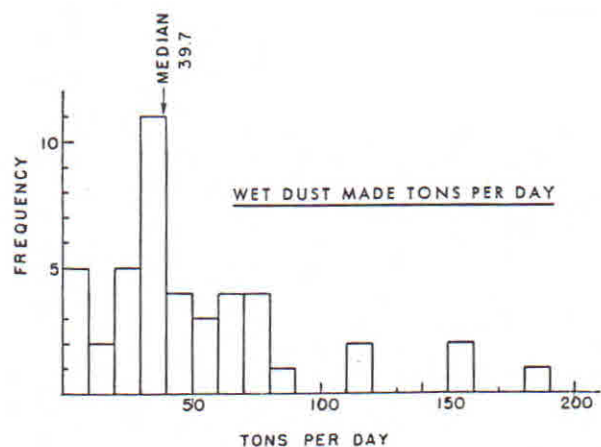


CHART 6

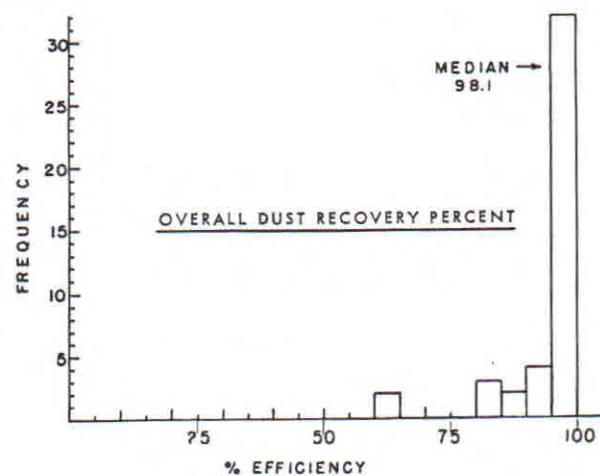


CHART 7

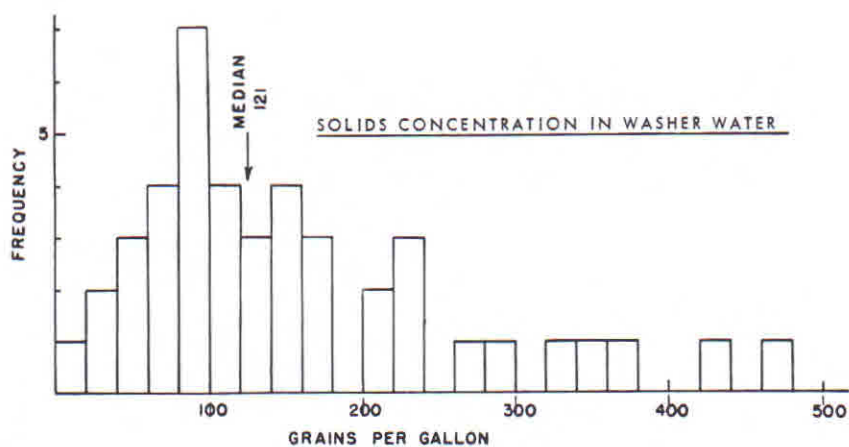


CHART 8

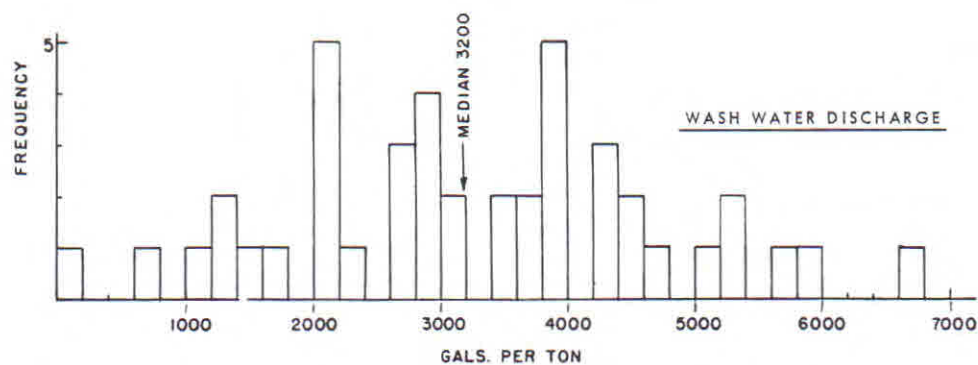


CHART 9

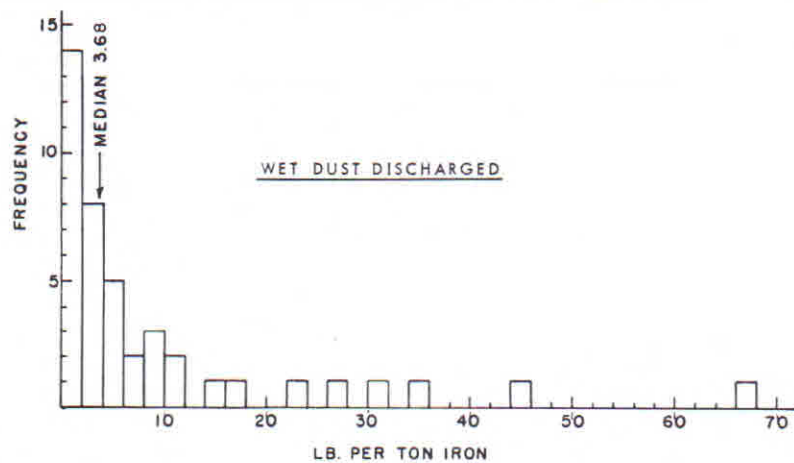


CHART 10

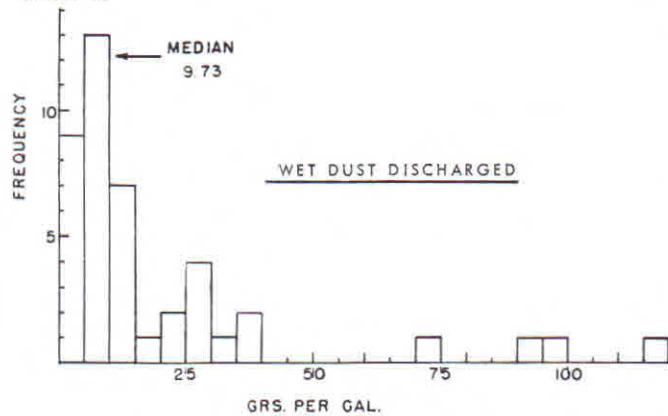


CHART 11

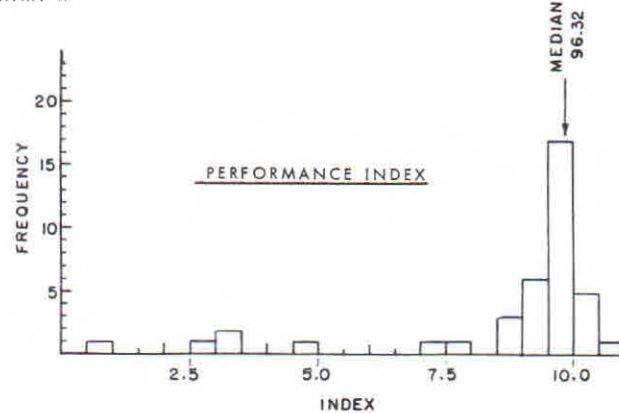


Chart No. 7. Suspended Solids Concentration in Washer Water

The concentration of suspended solids in washer water is governed largely by dustcatcher efficiency and volume of water supplied to the washer. The concentrations ranged from 2.3 to 476 grains per gallon, with a median value of 121.

Chart No. 8. Washer Water Discharge

The volume of washer water discharged generally depends on the amount of dust that must be scrubbed from the gas. The volume of water wasted varied from zero (one unit operates a closed system) to 6,620 gallons per ton of iron made; the median value was 3,200.

Charts No. 9 and 10. Wet Dust to Stream

These charts show that 29 of the 43 units discharged less than eight pounds of dust per ton of iron produced at a concentration of less than 15 grains per gallon. The median values are 3.7 pounds per ton and 9.7 grains per gallon.

Chart No. 11. Performance Indexes

Of the 39 units with clarification equipment, 29 had indexes of 9 or better.

Appendix I

IRON MANUFACTURE

Iron has been used by mankind for about four thousand years, but furnaces for producing it in large quantity are a comparatively recent development. Furnaces in use only a century ago were quite crude; rapid advancement in design of blast furnaces and appurtenant equipment dates from about 1880. But iron smelting is still rather more an art than a science, and innovations in design have been slow in gaining acceptance. The high cost of blast furnace installations and the length of time a furnace is in service deter the industry from adopting untried ideas for improvements. There has been steady progress, however, both in design of the furnace itself and of the complex of auxiliaries required for proper operation.

Smelting iron ore would appear to be a relatively simple process, because it is just a reduction of iron oxide to metal by well-known reactions. In practice, the operation is a complicated one which demands a high degree of skill. A variety of chemical reactions takes place in the furnace stack. The rate of these reactions, the degree to which they approach completion, and the extent of their reversibility, are largely governed by temperature and the ratio of carbon monoxide to dioxide. Also, the rate of iron production depends upon the rate at which air is blown into the furnace.

Manufacture of iron is a continuous process; once a furnace is "blown in" it is rarely shut down except for relining, usually six to eight years later. The furnace stack is kept full of burden, and a constant blast of preheated air is supplied. This means that iron ore, coke, and limestone in correct proportion must be charged to the stack at a regular rate, and that gas must be available to preheat the blast.

Blast furnace performance can be very temperamental; in spite of modern controls the furnace often behaves in unpredictable ways. Furnacemen must be alert to anticipate trouble and plan corrective measures, for few industrial operations require more forethought, experience, and promptness in action.

Blast Furnace Products

The principal product of the blast furnaces is pig iron, but special furnaces manufacture various ferroalloys. There are many kinds of pig iron, and they differ considerably in chemical analysis. The recognized commercial grades, and the range of certain important constituents, are listed in Table VI. The type of dust and the quantity made per ton of product will necessarily vary as furnaces are operated to produce these different kinds of material.

Table VI. Varieties of Blast Furnace Iron

Range in Composition -- percent

	Silicon	Sulfur	Phosphorus	Manganese	Carbon
Foundry Pig Irons	1.00 to 4.00	0.04 to 0.10	0.10 to 2.00	0.20 to 1.50	3.00 to 4.50
Graded in steps of	0.50	0.01	0.20	0.20	-
Malleable Pig, Standard	1.25 to 2.25	0.05	0.1 to 0.19	0.4 to 1.00	3.75 to 4.30
Graded in steps of	0.25	-	0.05	0.20	-
Gray Forge	1.20 to 1.75	Under 0.05	0.1 to 0.35	0.5 to 1.00	4.15 to 4.40
Puddling Iron	0.75 to 2.50	Under 0.05	0.1 to 0.50	0.5 to 1.00	4.10 to 4.40
Acid Pig, Bessemer	1.00 to 2.25	Under 0.045	0.04 to 0.1	0.5 to 1.00	4.15 to 4.40
Acid Pig, Open Hearth	1.0 to 1.50	Under 0.045	Under 0.05	0.5 to 2.50	4.15 to 4.40
Basic Pig, Bessemer	0.5 to 1.00	Under 0.20	1.9 to 2.5	1.5 to 2.5	3.50 to 4.0
Basic Pig, Open Hearth	Under 1.50	Under 0.05	0.11 to 0.90	0.4 to 2.0	4.10 to 4.40
Duplex Iron	1.2 to 1.75	Under 0.06	0.7 to 1.5	0.4 to 0.90	4.00 to 4.20
Special Low Phosphorus Spiegel	Under 2.00	Under 0.035	Under 0.035	Under 2.00	-
(3 grades)	Under 1.25	0.03 to 0.05	0.14 to 0.25	16 to 30	5.0 to 6.5
Silicospiegel	8.0 to 1.500	Under 0.02	Under 0.15	15 to 20	-
Ferromanganese	0.5 to 1.00	Under 0.05	0.2 to 0.35	78 to 82	6.5 to 7.5
Silvery Pig	6.00 to 17.00	Under 0.05	0.10 to 0.40	0.30 to 2.00	0.75 to 1.0
Ferrophosphorus	1.5 to 1.75	Under 0.05	15 to 24	0.07 to 0.50	1.10 to 2.0

Pig iron may be used directly for making castings, but most of it is refined to steel in open hearth furnaces or Bessemer converters. Ferroalloys are added to molten steel to adjust its final composition to pre-determined specifications. Data on pig iron production in the United States are given in Table VII.

Table VII. Production of Pig Iron

Year	Net Tons*	Year	Net Tons*
1956	75,068,489	1951	70,274,278
1955	76,857,417	1950	64,586,907
1954	57,965,548	1945	53,223,169
1953	74,901,429	1940	56,071,666
1952	61,312,938	1935	23,274,451

* Excluding ferroalloys.

THE BLAST FURNACE

The blast furnace comprises a hearth, surmounted by a relatively short inverted frustrum of a cone known as the bosh, upon which rests a much taller truncated cone, topped by a double-bell charging hopper. The hearth and furnace stack are heavily lined with refractory brick. The bosh is surrounded by a bustle pipe, which serves as a manifold to deliver preheated air to the charge in the furnace stack through a number of evenly spaced openings called tuyeres. The number and size of the tuyeres are important factors in smooth furnace operation. Air enters the furnace at pressures of 15 to 30 pounds per square inch gauge, and temperatures of 1000 to 1,500 deg. F. It passes through the charge in the furnace and leaves at the top under a pressure of about 2 pounds per square inch (up to 10 psi for high-pressure operation) and temperatures normally ranging between 400 and 600 deg. F.

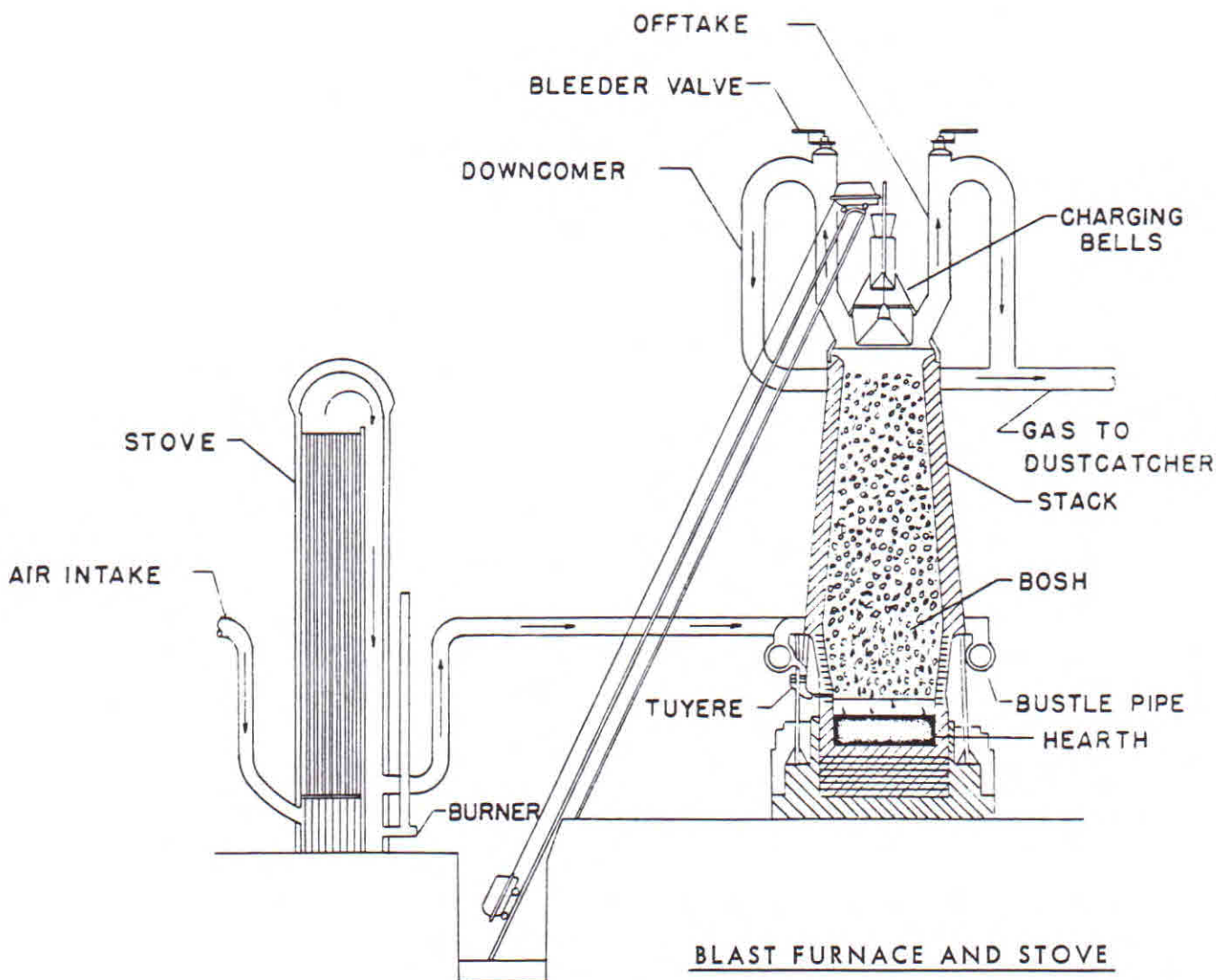
Iron ore, flux and coke are fed to the furnace through a double bell and hopper which serves the dual function of distributing the charge uniformly in the stack, and preventing emission of dust and gas during charging. Blast furnace gas leaves through oftakes opening into the stack above the stock level. Each cubic foot of air entering the furnace makes about 1.35 cubic feet of blast furnace gas as a result of chemical and physical reactions. The vertical oftakes are equipped with bleeders which open automatically to relieve excessive pressure. The oftakes lead to a downcomer which carries the gas to a dry dustcatcher. The essential parts of a blast furnace are shown diagrammatically on Page 19.

THE AUXILIARIES

The auxiliaries of a blast furnace installation may include a stockhouse for storing ore, limestone, and coke; weighing and transfer equipment for proportioning the components of the charge; a skip hoist for delivering the charge to the furnace hopper; stoves for preheating the air blast; gas cleaning equipment; wash water clarifiers; turbo blowers for compressing air for the hot blast; flue-dust sintering machinery; ladles for handling hot metal and slag; and a pig-casting machine.

Stockhouse

The stockhouse consists of a series of bins for storing the several varieties of ore that may be blended in the charge, the flux (limestone), and coke. The bins discharge to a weigh-car which moves the components of the charge to the skip hoist. Two counterbalanced skips carry the charge up an



incline to the charging hopper. The components of the charge are weighed to maintain correct proportions in the furnace. Ore and flux charged per ton of coke comprise the "burden" of the furnace; the fuel supply is held constant while changes are made by altering the burden. Coke is screened to remove fine material before charging; this decreases the amount of dust leaving the furnace stack.

Stoves

The air blast to the furnace is preheated in regenerative stoves, of which there are usually three per furnace. A stove is a cylindrical steel shell, 20 to 28 ft. in diameter and 90 to 120 ft. high, containing brick checkerwork which is heated by blast furnace gas. Gas, plus air for combustion, enters the bottom of the stove and burns in a vertical combustion chamber. The hot gases then pass downward through the checkerwork and out

to a stack common to all the stoves. When a stove is hot enough the gas supply is shut off, and air from a turbo blower is admitted below the checkerwork. The air passes through the stove countercurrent to the path of the burner gas and is heated to a temperature of 1000 to 1500 deg. F. It flows from the stove directly to the bustle pipe of the furnace. The three stoves of a set are operated in rotation; one stove preheats air while the other two are being gas fired. The purpose of preheating the air blast is to increase and control the temperature at the tuyeres and thereby reduce the amount of coke required; the saving in coke is greater than the equivalent sensible heat in the blast. A typical stove is shown on Page 19.

Dust Formation

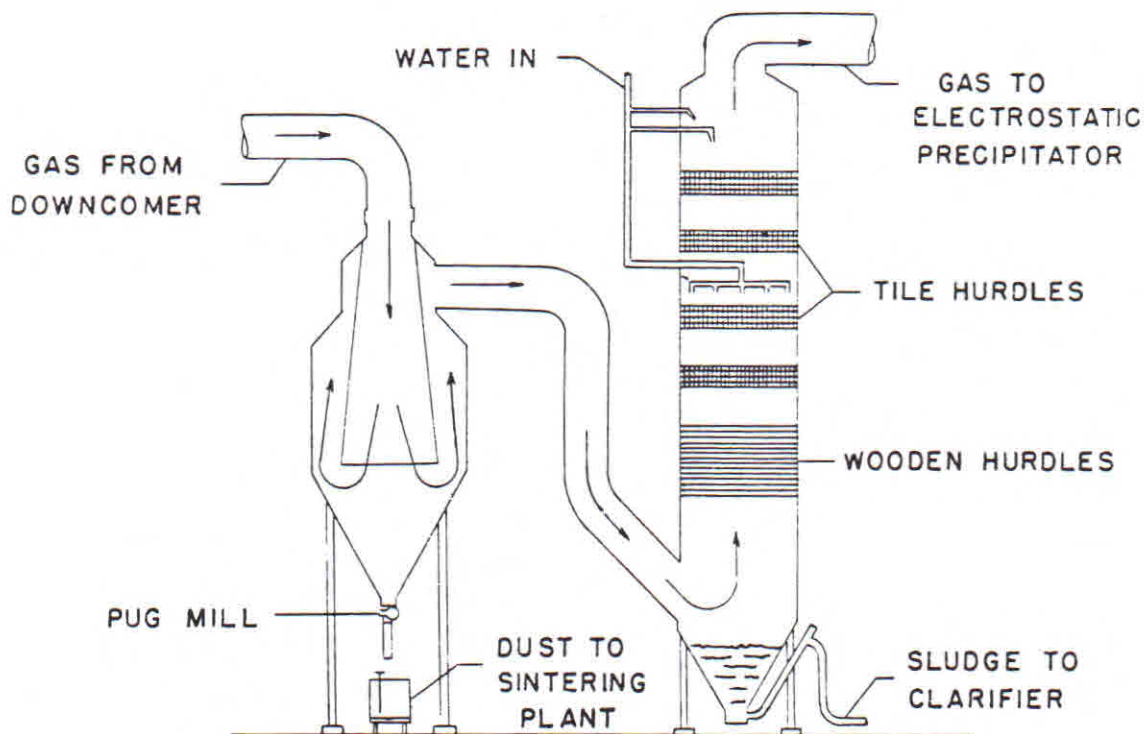
Dust in blast furnace gas arises primarily from passage of the reaction gases through the porous charge in the furnace stack. The voids in the charge constantly change in size as the stock descends. This movement abrades the lumpy material and forms smaller particles. The amount of dust entrained is proportional to the size and density of the particles, and to the gas velocity. Where the voids in the charge are of about the same size in successive cross sections, the gases pass upward at a uniform rate through any cross section and the furnace operates smoothly. But channeling in the stock occurs frequently, and this provides relatively large passages for the gas. As a result, a large proportion of the gas passes through such channels in preference to small passages where resistance to flow is high. This causes a variation in the amount of dust leaving the furnace, since the passages continually vary as the stock moves down the furnace.

It is not uncommon for the charge to form a bridge in the stack. When this happens the stock settles under the bridge and the gas pressure increases. When the bridge opens or slips, a volume of gas passes rapidly to the rest of the furnace system and takes with it great quantities of dust and lighter particles of the burden. The sudden release of gas, which sometimes occurs with violence, often causes the bleeders on the oftakes to open momentarily to relieve the increased pressure.

Gas Cleaning

Blast furnace gas should be cleaned before it is used as a fuel. As it leaves the furnace it will carry from 10 to 15 grains (0.0014 to 0.0021 lb.) of dust per cubic foot, on the average. Gas from the furnace is carried by the downcomer to a dry dustcatcher. The dustcatcher is a cylindrical steel shell, 20 to 40 ft. in diameter, with conical top and bottom. It is insulated with brick to prevent condensation of water vapor in the gas. The downcomer enters the conical top, and the gas passes down through a flared pipe extending almost to the bottom cone of the shell, reverses its direction, and passes upward in the annular space between the entrance pipe and the shell wall. Expansion of the gas, and reversal of its direction of flow, cause 60 to 70 percent of its dust content to drop out. Dust is removed from the

catcher by a pug mill attached to the bottom conical section; provision is made for moistening the dust before it drops into a railroad car. A dust-catcher is shown below.



DUSTCATCHER AND GAS WASHER

Practically all the dust in the gas leaving the dustcatcher is finer than 20 mesh (33 thousandths of an inch), and much of it has a particle size of only a few microns or less (1 micron = 39 millionths of an inch). The difficulty of cleaning gas increases inversely with the size of the dust particles it contains. For this reason, the gas is usually cleaned in two stages; a primary cleaner removes 90 to 95 percent of the dust in the gas from the dustcatcher, and a secondary cleaner removes 90 to 95 percent of the dust remaining from the primary stage. Primary cleaners are generally water scrubbers. As the gas is washed, it is cooled to the temperature of the water; this condenses moisture in excess of saturation at the water temperature.

The effectiveness of a gas scrubber depends upon the thoroughness with which the dust particles can be wetted. A variety of scrubbers have been designed and used to improve the efficiency of primary gas cleaners. Formerly, the revolving-spray scrubber was popular. This consists of a cylindrical steel shell containing a number of inverted frustrums of cones mounted on a

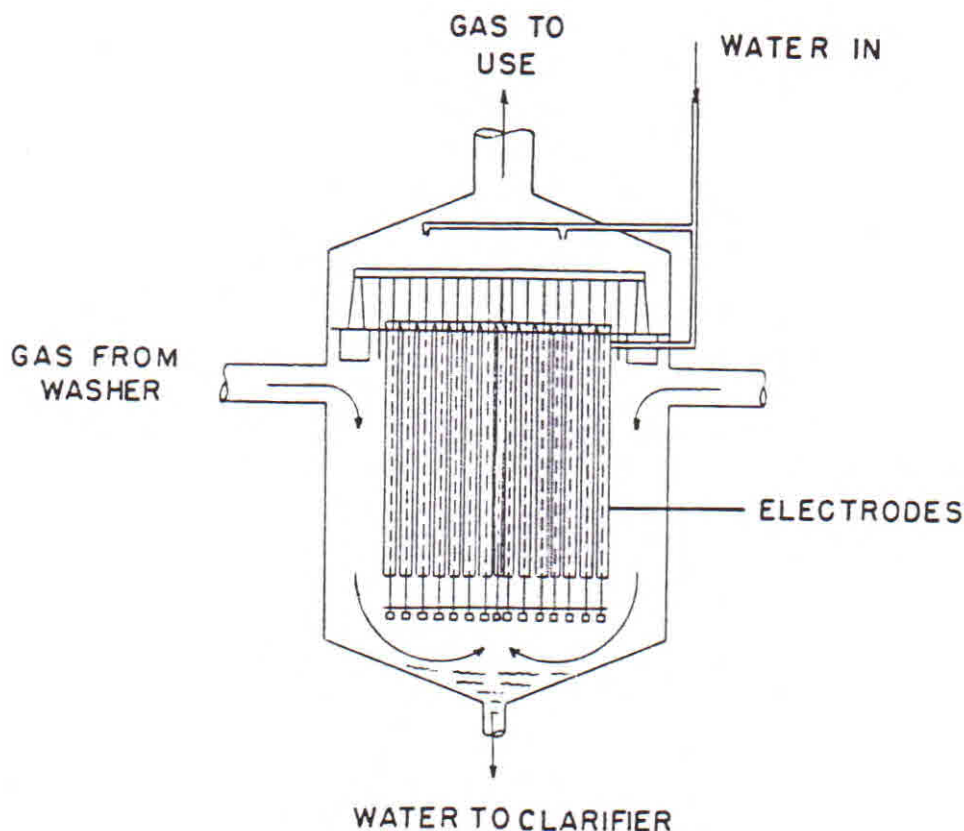
central drive-shaft. The rotating cones dip into trays of water, and centrifugal force picks up the water and throws it outward as a spray through which the rising stream of gas must pass. Baffles guide the water back to the trays, and the excess spills over into the tray below. Clean gas leaves the scrubber through an entrainment separator, and dirty water is discharged through a seal.

This washer has now largely given way to the stationary-spray type. This is a steel cylinder packed with assorted tile or hurdles or both which splits the gas into many small streams and offers a large surface to be wetted by sprays of water. As dirty gas passes up through the tower it meets a uniform rain of water droplets which wash out the dust. Gas leaves the scrubber through a cyclone separator to remove entrained water. Such a washer will reduce the dust content of the gas to 0.1 to 0.2 grains per cubic foot. Dirty water leaves through a seal in the bottom of a scrubber and flows to a clarifier or a lagoon. Some stationary-spray scrubbers have one or more revolving cones mounted below the fixed hurdles. These washers require 10 to 40 gallons of water per thousand cubic feet of gas. Since blast furnaces may produce up to 140,000 cubic feet of gas per minute, it is apparent that this operation uses a great deal of water. As a conservation measure, the effluent from a clarifier is sometimes used to replace a portion of the fresh water needed. A conventional scrubber is sketched on Page 21.

Secondary gas cleaners are usually either wet or dry electrostatic precipitators, or disintegrators. The electrostatic precipitator is a device comprising a duct or series of channels across which a high tension electric field is maintained, and through which the gas passes. The high-voltage discharge ionizes the gas molecules which then become part of the electric circuit. This places a like charge on the dust particles which causes them to move toward the electrode of opposite polarity. Although there are a number of designs of such precipitators, the principle is the same in each. For example, in a common type, an electrode is mounted centrally in a vertical tube and the charge carries the particles to the tube wall. In the wet method, a film of water flushes the collected dust from the tube wall; in the dry method, the cleaner is shut down from time to time to allow the dust to fall into a hopper, or suspended chains may be used as scrapers. In some installations an electrostatic precipitator is mounted directly above the primary scrubber. One precipitator design is shown on Page 23.

The disintegrator creates a fine mist by directing small jets of water against a revolving fan. Gas from the primary cleaner passes through the mist which reduces its dust content to 0.02 grains per cubic foot, or less. These machines have capacities up to 40,000 cfm and may require 500 horsepower to drive them.

Bag filters of various designs have been used as secondary dry cleaners but mechanical problems have created serious difficulties. Fabrics that have been tried tend to break at the temperature of the gas, and, if moisture in the gas condenses, the bags quickly clog.



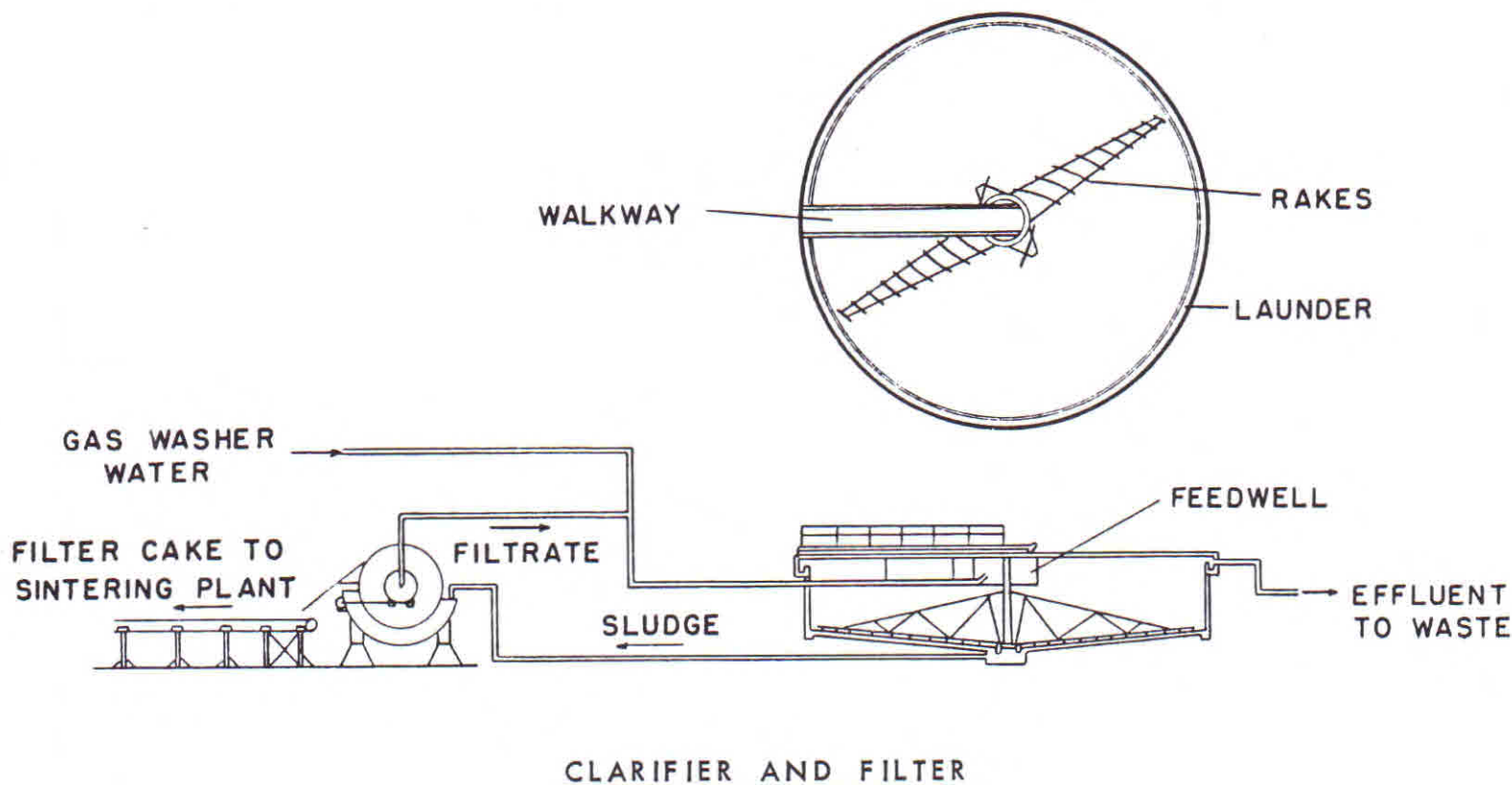
ELECTROSTATIC PRECIPITATOR

Washwater Clarification

Dirty water from the wet washers was formerly stored in lagoons with provision for discharging a clear supernatant. The high value of land at most steel mills has been forcing abandonment of this method in favor of mechanical clarifiers which occupy much less space per unit volume. There are a number of clarifier designs, ranging from plain sedimentation to chemical flocculation. The simplest embodiment of the clarifier is a circular tank to which dirty water is admitted through a central standpipe. The water flows radially to a peripheral launder over which clear water flows to the sewer. As the water flows through the clarifier its content of solid matter settles to the bottom of the tank. A number of slowly rotating arms equipped with scrapers gently move the settled material to a center well from which it is pumped to a vacuum filter which dewateres it to a moisture content of about 25 percent. Filter cake goes to a sintering machine and the filtrate is returned to the clarifier. One design of a clarifier and filter is shown on Page 24.

Clarifiers are normally designed to provide one to two hours detention of wash water for an average concentration of suspended solids. But furnace

operation is so variable that clarifiers cannot be built to operate with constant efficiency over the whole range of operating conditions. In spite of wide variations in load, however, this kind of equipment is highly effective in removing finely divided solids from water.



Uses of Blast Furnace Gas

Blast furnace gas has a heating value of about 90 Btu per cf and it has many uses in a steel mill. Its use as a fuel for preheating the air blast to the furnace has been mentioned. The gas was formerly used widely as fuel to drive internal-combustion engines for compressing air for the hot blast. These units have been almost completely supplanted by turbo blowers; the gas is now used to fire boilers to provide steam to drive the blowers. In addition, it is used to underfire coke ovens, to heat soaking pits, and for other purposes that do not need a rich fuel.

Dust Agglomeration

Sintering plants were installed originally to convert blast furnace dust into an aggregate suitable for charging to the blast furnace. But these plants are being used more and more to agglomerate finely divided ore, and

such ore is combined with dust at many mills. Dry dust, wet filter cake, and ore are blended in a pug mill with a small amount of water. If the proportion of fine ore is fairly large, coke dust or crushed coal must be added to supplement the fuel in the blast furnace dust.

The mixture is spread evenly on the moving grate of the sintering machine. The grate passes under an ignition furnace which brings the fuel in the charge to its kindling temperature. The grate then passes over a series of wind boxes which create a strong downdraft through the burning bed. As the fuel burns out, the mixture becomes a pasty mass in which the iron oxide has been partially reduced.

The sinter finally discharges to a large rotating apron containing louvres through which air is blown for slow cooling. The principle of sintering is to supply just enough fuel to produce a sticky mass, but not so much that the metal will melt and run. For this reason the proportion of the components of the mixture is quite important.

Tapping Iron and Slag

Iron and slag are tapped from the furnace several times a day. Hot metal flows from the iron notch, which is kept plugged with clay except when the furnace is casting, into ladles in which it is hauled to the open hearth shop or to the Bessemer plant. There it is held in hot metal mixers until needed in the steel-making process. When all the iron produced by the furnaces cannot be used while molten, it is cast into pigs by a machine carrying a series of molds on an endless chain. Iron flows from the ladle into a small basin from which it runs into the molds as they pass under a spout.

Slag is tapped into cinder ladles in which it is hauled to a dump. In some cases it flows directly from the furnace into a granulation pit where it is sprayed with water, in others it is converted into a lightweight aggregate for concrete or insulation. Blast furnace slag has a number of uses, more than 20,000,000 tons of various sizes being produced annually by slag processing plants; this is roughly half of the amount made by the furnaces.

FURNACE OPERATION

The blast furnace is an efficient device for continuously smelting iron ore in large quantity. But several other iron-bearing materials are regularly converted to pig iron in the furnace. Mill-scale, which is largely magnetic

iron oxide, Fe_3O_4 , flakes from the surface of steel while it is being hot rolled. Sinter is agglomerated flue dust or fine ore. Open hearth and Bessmer slags are by-products of the steel-making process; up to 10 percent of open hearth slag can be used in the burden. Scrap accumulates in casting the furnace; it may also be brought in from external sources to increase production. The proportions of various components in the charge will naturally vary, but for furnaces operating on ores from the Mesabi range, for example, input and output would be about as follows:

<u>Input, tons</u>		<u>Output, tons</u>	
Ore	2.0	Iron	1.0
Coke	0.9	Slag	0.6
Stone	0.4	Dust	0.1
Air	3.5	Gas	5.1
	<u>6.8</u>		<u>6.8</u>

Furnace Functions

The blast furnace performs two principal functions. It provides the high temperature and the reducing agent necessary to smelt iron ore, and it supplies a flux which combines with impurities in the ore and ash from the coke to yield a slag that can be readily separated from the metal. Chemical reaction in the furnace is rather complex, not only by reason of the number of reactions that occur, but because they are nearly all reversible and their equilibria depend upon where they take place.

Pure iron is a soft, ductile metal with poor tensile strength. It will not melt at blast furnace temperature (3,000 deg. F.) but, as iron ore is reduced, it forms sponge iron which picks up carbon as an alloying element; this reduces its melting point. Pig iron contains 3.5 to 4.5 percent of carbon, and, in this range, it is fluid at 2,500 deg. F.

Fluxing

The limestone flux which forms part of the blast furnace charge has two important functions. The impurities in iron ore are mainly silica and alumina. These acidic oxides will not melt in the furnace but, in reaction with a basic flux, they fuse and form a fluid slag which passes down through the furnace and collects on top of the molten iron on the hearth. The other function of the flux is to remove sulfur from the iron. Sulfur makes steel brittle, and it is difficult to remove in steel-making processes. By careful control of temperature and slag basicity, sulfur can be held to a low level in pig iron, provided excessive amounts are not introduced with the charge.

Impurities

Manganese is a common impurity in iron ore, but often a desirable one. Manganese, whose oxides are partly reduced to metal in the furnace, dissolves in iron to form a solid solution. It aids in removing sulfur from iron, increases its strength, and aids in refining iron to steel. Silicon also dissolves in iron, and, in small percentages, increases its strength; above about 3.5 percent it makes iron very brittle. Phosphorus is a highly undesirable impurity in iron ore. In the furnace it forms a phosphide with iron which dissolves in the pig and makes it brittle. Since it cannot be removed by the furnace it must be controlled by proper selection of materials for the charge.

Furnace Reaction Zones

Four separate reaction zones can be distinguished in a blast furnace, but they do not have definite boundaries. The zones change in extent with changes in operating conditions, and various reactions are not confined to a definite region in the furnace. Nevertheless, consideration of what happens in different parts of the stack helps in understanding furnace operation.

At the top of the stack there is a region extending perhaps 10 feet below the stock line where the temperature ranges from 350 to 600 deg. F. Moisture is driven from the stock in this zone and ore reduction begins at a low rate.

Extending some 20 feet below this is a zone in which temperatures range from 600 to 1,650 deg. F. Reduction of ore with carbon or carbon monoxide proceeds more rapidly here, and considerable ore is completely reduced. Limestone in the charge is calcined to lime and magnesia in this region.

Oxide reduction occurs at a high rate in the next zone, which extends to the top of the bosh. Temperatures are between 1,650 and 2,200 deg. F. Manganese oxides and silica are partially reduced and slag begins to form.

From the top of the bosh to the bottom of the hearth reduction of oxides is completed. Carbon, manganese and silicon dissolve in the molten iron, and the basic slag absorbs sulfur. Opposite the tuyeres carbon is burned to carbon dioxide which, in turn, is reduced to carbon monoxide. In this region the temperature is about 3,000 deg. F.

Unpredictable Furnace Behavior

The performance of a furnace is affected by the composition and characteristics of its burden. The operator can vary the volume and temperature of

the wind blown into the stack, and he can alter the burden. Changes in stock, however, do not show their effect for about eight hours after a change has been made. Appreciation of the skill and foresight a furnace operator needs to make pig iron to narrow specifications can be obtained by considering the complex chemical and physical conditions he must cope with constantly. In spite of everything an experienced operator can do, furnace stock sometimes bridges in the stack. When a bridge is forced to collapse the dust output increases tremendously, and this sudden surge of dust immediately overloads gas washers and clarifiers, even where generous safety factors were included in the design.

Appendix II

OCCURRENCE AND NATURE OF BLAST FURNACE DUST

Several related factors influence the production of dust. The most important of these are: (1) charging practice; (2) movement of stock in the furnace; (3) physical properties of the charge and (4) blowing rate.

Charging Practice

It is generally believed that uniform distribution of gas in the stack can best be achieved by adding successive layers of the several components of the charge in a definite order. It is desirable to control the particle sizes of the components to segregate coarse and fine material in successive layers. This ideal method of building a charge is approached by the double-bell charging mechanism. Rotation of the small bell between loads distributes the stock fairly well, but differences in particle size and weight cause the heavier lumps to roll farther than the lighter ones. This results in a circular ridge somewhat larger than the diameter of the large bell; it can be prevented to some extent by close sizing of the stock and careful operation of the charging mechanism.

Stock Movement

When the stock moves down the furnace stack smoothly and uniformly, fresh charge can be added at regular intervals and the blowing rate can be held constant. Such operating conditions are ideal, and the furnace produces a minimum of dust. But the stock sometimes tends to hang, and its movement then becomes quite erratic. When the charge has bridged in the stack, dust production is very low, but when the stock slips, the amount of dust produced is enormous. Under such conditions the average production of dust per ton of pig is high.

An important factor in dust production is the size, uniformity and strength of the charge. If the components of the charge consist of fairly large, strong lumps, and there is very little fine material, dust production will be low. This results from the small amounts of fines present initially, and the fact that a hard, uniform charge resists abrasion as it moves down the stack. Where ores that are rather fine or soft must be charged, a large proportion of the finest material is blown out of the stack as the charge is introduced. Such stock is often watered generously to hold down dust formation.

Gas Velocity

The higher the velocity with which gas leaves the furnace, the greater will be the amount of dust it carries. During periods when demand for steel is high, furnaces are blown at the maximum allowable rate, and dust production is high in consequence. High blowing rates also increase the tendency for erratic stock movement and thereby further increase the amount of dust made.

Ore Quality

Fifty years ago, iron ore from the Lake Superior region averaged 55 percent iron; today these ores contain little more than 50 percent iron. During the same period, silica increased from about 6 to nearly 10 percent. Ore, as mined, varies considerably in composition, but different qualities of ore are blended to provide a product of relatively constant analysis. During the war the high-quality ores were prodigally stripped away to increase steel production as much as possible, and, as these ores are no longer available in quantity to upgrade poor ore, the average quality of shipping ore must decrease.

Recognizing this situation, the steel industry has for a number of years been energetically studying ways in which poor ore can be upgraded by mechanical removal of impurities at the ore site. The taconites, which occur in extensive deposits adjacent to present ore mines, contain from 25 to 35 percent of iron intimately mixed with silica. Methods are being developed to beneficiate taconites and other low-grade material.

High Top-Pressure

A number of furnaces are being operated with high top-pressure, which means a top pressure in excess of 5 pounds per square inch. By a controlled restriction of the gas leaving the top of a blast furnace, its pressure is elevated. This reduces the volume of gas, which means that it leaves the furnace at a decreased velocity and carries less dust with it.

Appendix III

PROCEDURE USED IN SURVEY FOR DETERMINING SETTLEABLE SOLIDS IN BLAST FURNACE GAS WASHER WATER

1.0 Introduction

- 1.1 These definitions describe the terms used in the Steel Industry in the applications of the methods herein described. The methods described are procedures for the determination and differentiation of nonsettleable, total suspended and settleable solids in blast furnace gas washer water and the blast furnace water discharged to the stream. These methods are not intended for sanitary sewage.
- 1.2 This method for the determination of settleable solids deviates from the American Public Health Association "Standard Methods for the Examination of Water and Sewage" 9th edition in that the determinations of total suspended solids and nonsettleable solids are made on the same portion. This procedure is followed to eliminate any question of the results obtained. The nature of the solids is such that they settle out rapidly and make it difficult to portion the sample, thus if the determinations are made on separate portions the results are open to question.

2.0 Definitions

- 2.1 Nonsettleable Solids - Those solids which do not settle in a quiescent state for one hour by the method described herein.
- 2.2 Total Suspended Solids - Those solids which can be separated from the sample by filtration by the method described herein.
- 2.3 Settleable Solids - Those solids which can be separated by quiescent sedimentation for one hour by the method described herein.

3.0 Sampling

- 3.1 Normal variations in processes and in equipment from plant to plant preclude the possibility of specifying standard methods of sampling

that are applicable in all cases. Definite principles have, however, been established as a basis for the formation or formulation of procedures for sampling which are applicable in general and probably apply in most specific cases. Where modification of the sampling procedure is necessary, it may be made by the exercise of trained judgment in each individual case.

- 3.2 The samples must represent the conditions existing at the point taken.
- 3.3 The samples should be taken at a point of turbulence.
- 3.4 Care should be taken not to scrape the sides and bottom of the channel.
- 3.5 The samples must be of sufficient volume and must be taken frequently enough to permit an accuracy of testing requisite for the desired objective, as conditioned by the methods of analysis to be employed.
- 3.6 It is recommended for this work that a small sample (approximately 60 ml.) be taken from each source every hour for a 24-hour cumulative sample.
- 3.7 The 60 ml. sample taken should be poured quickly into the sample container of an approximate volume of 2500 ml. (5 pint acid bottle or more).
- 3.8 Analysis should be started at the close of 24-hour period.

4.0 Determinations

- 4.1 Blast furnace gas washer water.
 - 4.1.1 Flow rate - gallons per day.
 - 4.1.2 Nonsettleable solids - tons per day.
 - 4.1.3 Total suspended solids - tons per day.
 - 4.1.4 Settleable solids - tons per day.

4.2 Effluent from clarifier (thickener, basin, or lagoon) - to river.

4.2.1 Flow rate - gallons per day.

4.2.2 Total suspended solids - tons per day.

4.3 Calculations

4.3.1 Tons per day = $\frac{\text{gallons per day} \times \text{ppm} \times 8.34}{1,000,000 \times 2,000}$

4.3.2 Tons settleable solids to river = (4.2.2) - (4.1.2) =
total suspended solids in effluent from clarifier minus
nonsettleable solids in blast furnace gas washer water.

4.3.3 Performance index = $\frac{(4.1.3) - (4.2.2)}{(4.1.4)} \times 10 =$

10 times the difference between the total suspended solids
in blast furnace gas washer water and total suspended
solids in effluent from clarifier divided by settleable
solids in blast furnace gas washer water.

= 10 times the ratio of total suspended solids removed
by clarifier and settleable solids by definition.

NOTE: Dissolved solids are not considered.

5.0 Procedure

5.1 Non-settleable solids, Section (4.1.2) (Blast Furnace Gas Washer Water).

5.1.1 The container should be well shaken for 15 seconds.

5.1.2 Immediately after mixing, invert the sample container and
fill a Griffin liter beaker (standard form) with one liter
of the sample.

5.1.3 Note the time when beaker was filled and allow it to remain
quiescent for 45 minutes, then gently stir, moving in the
same direction, giving a very gentle swirling motion, but
do not disturb that material which has settled to the

bottom. Then allow the mixture to remain quiet until a total time of 60 minutes has elapsed from the time of filling the beaker.

- 5.1.4 At the end of one hour quiescent settling, without disturbing the settled material or that which is suspended on the sides of the beaker, remove 250 ml. of the sample from the center of the beaker at a point approximately half-way between surface of settled sludge and liquid surface. 250 ml. of the sample is most conveniently removed by a syphon. The syphon may be started by gentle suction.
- 5.1.5 After removing 250 ml. of the material from the beaker, return the material in the syphon to the beaker. Save the remaining contents of the beaker for total suspended solids determination.
- 5.1.6 Determine the nonsettleable solids in the 250 ml. sample withdrawn from the center of the beaker by filtering through a weighed filtering crucible, such as a Gooch crucible with a prepared mat of asbestos fiber from 3 to 5 mm. thick or its equivalent such as a fritted glass Gooch type of medium porosity, using suction. Wash twice with distilled water.
- 5.1.7 Dry the crucible and its contents at 103°C , cool and weigh in the same manner as was done for the crucible alone. See Note (6.1)
- 5.1.8 Record the weight of residue as "weight of nonsettleable solids" in 250 ml. of the mixture.
- 5.2 Total suspended solids. Section (4.1.3) (Blast Furnace Gas Washer Water).
 - 5.2.1 Take the material remaining in the beaker (Section 5.1.5) and determine the remaining solids in the sample.
 - 5.2.2 Filter the remaining material through a weighed filtering crucible and proceed as in Section (5.1.6).
 - 5.2.3 Dry the crucible as in Section (5.1.7).

- 5.2.4 Record the weight of solids in 750 ml. of mixture. The weight of solids in 750 ml. of mixture plus the weight of nonsettleable solids in 250 ml. of mixture (5.1.8) is recorded as the "weight of total suspended solids" in 1000 ml. of the sample.
- 5.3 Settleable solids. Section (4.1.4) (Blast Furnace Gas Washer Water).
- 5.3.1 The total suspended solids minus the nonsettleable solids equals the settleable solids.
- 5.4 Total suspended solids. Section (4.2.2) (Clarifier Effluent).
- 5.4.1 The container should be well shaken for 15 seconds.
- 5.4.2 Immediately after mixing, invert the sample container and remove one liter of the sample into a liter beaker.
- 5.4.3 Filter the liter of material through a weighed filtering crucible as in Section (5.1.6)
- 5.4.4 Dry the crucible as in Section (5.1.7).
- 5.4.5 Record the weight of solids as "weight of total suspended solids in effluent in 1000 ml. of sample."
- 5.5 Calculations.
- 5.5.1 Calculate the concentration of the solids in parts per million, as follows:

$$\text{ppm} = \frac{A}{W} \times 1000$$

Where:

A = Weight in grams of solids

W = Volume of sample in liters.

6.0 Notes

- 6.1 Care should be taken to insure that all of the moisture has been removed from the residue. Some dried residues readily absorb moisture. Rapid weighing is essential to this method.
- 6.2 When reporting results, state any deviation from the prescribed method.

7.0 Precision and Accuracy

- 7.1 Precision is limited primarily by sampling, temperature of sample during determination, balance reproducibility, drying temperature, technique and nature of residue.
- 7.2 It is impossible to determine the accuracy of this method. Because of the type of suspended solids present, the losses or gains will cause the accuracy of the results to range from the limits of precision to wide deviations from the "true" values.



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