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COKE OVEN WALLS DAMAGED BY CARBONIZATION PRESSURES

INTRODUCTION

From the files of the Operating Department of the Engineering and Construction Division and the Research Department of Koppers Company, Inc., a list of coke ovens with brick walls mechanically damaged by the carbonization of "expanding" coals was compiled. The exact dates when the trouble occurred were seldom known, but data for ovens thus injured since 1930 are included. Additional information in regard to these plants or any others would be valuable.

SUMMARY

Pertinent history, design, and operating data for 26 coke plants where oven walls have been damaged by carbonization pressure are presented. Tabulations are included on Oven Design, Age of Ovens, Coal Bulk Density, Coal Mixing and Segregation, Foundry Coke, Pushing Systems and Carbonization Pressures. An interpretation of these factors is given. Another list of plants with ovens possible injured by carbonization pressures is appended.

ONCLUSIONS

From these assembled data, it may be concluded that coal mixtures developing 1.5 Psig or more in the Koppers movable wall test ovens are unsafe for use in full-scale coke ovens. Silica oven walls of any reasonable thickness built into vertical flue ovens of any reasonable capacity are apparently subject to injury by such coals. No type of wall construction developed to date, and no oven taper used to date has prevented such damage.

The average bulk density of the coal charged to the injured ovens compared reasonably well with that of the prepared samples used in the test ovens, but the plant variations were wide. Two of the three plants that experienced damage from a nominal coal mix testing less than 1.5 Psig also had high bulk density charges. In these same two plants there were definite indications of segregations of the components of the coal mix. Thus, results of tests made with a niminal coal mix should be interpreted with caution.

Some 40% of the plants listed were producing foundry coke from which it is concluded that coal mixtures used for this purpose should be very carefully tested, blended, handled and heated at slow coking rates.

The theoretical disadvantages of the old 1-4-7 oven pushing sequence are confirmed by the majority of the injured ovens being thus pushed. However, the use of better pushing systems did not insure freedom from damage by carbonization pressures.

OVEN DESIGN

In the list are included ovens from 9 feet, 5-7/8 inches to 14 feet, 0 inches high, 13-1/2 inches to 19-3/4 inches average width; and with taper of from 1/2 to 4 inches. Many combinations of wall thickness are represented. Ovens are shown with walls constructed with "Bottle-nose", "Hammer-head", and "Saddle" bricks, and with Koppers patented top oven chamber flare.

Of the 32 designs tabulated, 4 are the saddle brick with flared oven top, one saddle brick without the flare, 7 hammer-head brick, and 20 bottle brick and liner construction. The patented top oven flare was first used in the year 1945, the saddle brick in 1944, and the hammer-head in 1935. Thus it seems reasonable that a greater number of the older bottle and liner walls are represented. (This is further discussed under "Age of Ovens"). The fact that some walls of the newer designs have been injured shows that none of the designs are foolproof.

The average height, width, and taper of the injured ovens are 12.0 feet, 17.5 inches and 2.6 inches. The respective averages for all other operating ovens built by Koppers Company, Inc. since 1930, (not tabulated), are 12.0 feet, 16.1 inches and 2.8 inches.

Since at least three of the injured batteries were built with 5-inch and thicker wall brick only, it is apparent that thicker oven walls, at least up to 5 inches, cannot safely be subjected to the action of "expanding" coal mixtures.

C[illegible] DESIGN

	Plant	Height Feet	Width Inches	Taper Inches	Wall Construct	Wall Thickness Height (Inches), thickness (inches)		
1.	A.B.C.	13.50	16.00	3.0	H	16.8" @ 5-1/2"	41.9" @ 5"	41.9" @ 4"
2.	Johns.	12.25	15.00	2.0	B	10.9" @ 6"	38.1" @ 5"	59.8" @ 4"
3.	Sp. Pt.	12.00	19.75	4.0	H	16.8" @ 5-1/2"	92.5" @ 5"	41.9" @ 4"
3.	Sp. Pt.	12.00	19.75	3.0	S&F	21" @ 5-1/2"	37.7" @ 5"	41.9" @ 4"
4.	Steelton	9.89	18.25	2.5	B	10.9" @ 6"	32.6" @ 5"	38.1" @ 4"
5.	Gary	11.00	19.0	4.0	B	16.3" @ 6"	43.5" @ 5"	27.2" @ 4"
6.	Indian.	9.49	17.75	2.5	B	----	----	----
7.	Nev. Is.	13.50	16.00	2.0	B	16.3" @ 5-1/2"	43.5" @ 5"	54.4" @ 4"
8.	Pains.	12.50	16.00	2.0	B	16.3" @ 5-1/2"	43.5" @ 5"	54.4" @ 4"
8.	Pains.	12.50	18.00	2.0	B	16.3" @ 5-1/2"	43.5" @ 5"	48.9" @ 4"
8.	Pains.	12.50	15.75	2.5	H	16.8" @ 5-1/2"	41.9" @ 5"	37.7" @ 4"
9.	Fairmont	9.89	16.00	2.0	B	10.9" @ 6"	32.6" @ 5"	27.2" @ 4"
10.	Dofasco	13.00	17.00	3.5	S, F.	21.0" @ 5-1/2"	37.7" @ 5"	50.3" @ 4"
11.	Ford	13.25	17.50	3.0	H	16.8" @ 5-1/2"	41.9" @ 5"	54.5" @ 4"
12.	Terre H.	11.69	16.00	2.0	B	10.9" @ 6"	31.8" @ 5"	43.5" @ 4"
13.	Inland	12.00	16.00	2.0	B	16.3" @ 5-1/2"	43.5" @ 5"	43.5" @ 4"
14.	Daing.	12.00	19.75	4.0	H	16.8" @ 5-1/2"	88" @ 5"	----
15.	Wyan.	12.50	17.25	2.5	B	16.3" @ 5-1/2"	43.5" @ 5"	48.9" @ 4"
16.	Montreal	13.00	17.25	2.5	B	16.3" @ 5-1/2"	43.5" @ 5"	48.9" @ 4"

OVEN DESIGN

	Plant	Height Feet	Width Inches	Taper Inches	Wall Construct	Wall Thickness Height (Inches), thickness (inches)		
17.	Everett	12.83	18.25	2.5	B	16.3" @ 5-1/2"	43.5" @ 5"	48.9" @ 4"
18.	Rep.Clev.	13.00	18.25	3.0	H	8.4" @ 5-1/2"	8.4" @ 5"	92.2" @ 4"
19.	Rep.War.	10 plus	18.00	-	B	-----	----	----
20.	Rep.Young	9.89	19.75	2.5	B	10.9" @ 6"	32.6" @ 5"	27.2" @ 4"
20.	Rep.Young	13.00	17.00	3.0	H	16.8" @ 5-1/2"	41.9" @ 5"	58.7" @ 4"
21.	Chatanoo.	12.13	18.00	3.5	B	----	----	----
22.	Clairton	14.00	18.00	3.0	S	12.6" @ 5-1/2"	41.9" @ 5"	50.3" @ 4"
22.	Clairton	14.00	18.00	3.0	S, F	12.6" @ 5-1/2"	41.9" @ 5"	50.3" @ 4"
23.	Weirton	13.00	17.00	3.5	S, F	21.0" @ 5-1/2"	37.7" @ 5"	37.7" @ 4"
24.	Wheeling	9.89	18.25	2.5	B	10.9" @ 6"	32.6" @ 5"	38.1" @ 4"
24.	Wheeling	9.89	18.25	1.5	B	10.9" @ 5-1/2"	32.6" @ 5"	32.6" @ 4"
24.	Wheeling	13.00	18.00	3.0	S, F	21.0" @ 5-1/2"	37.7" @ 5"	46.1" @ 4"
25.	Winnipeg	10.83	13.50	0.5	B	16.3" @ 5-1/2"	43.5" @ 5"	38.1" @ 4"
26.	Woodward	9.89	19.75	2.5	B	43.5" @ 6"	21.8" @ 5"	----
	Ave.	12.02	17.50	2.6	Ave. B	15.7" @ 5-3/4"	38.4" @ 5"	42.4" @ 4"
	High	14.00	19.75	4.0	Ave. H, S, SF	16.7" @ 5-1/2"	45.5" @ 5"	43.2" @ 4"
	Low	9.49	13.50	0.5				

B = bottle nose, H = hammer-head, S = saddle brick

SF = saddle brick with

AGE OF OVENS

Some of the least reliable information in this compilation is that in regard to the dates when the damage occurred. Bearing in mind this inaccuracy of data, it appears that the average age of the bottle brick walls may have been about two-and-one-half times that of the other types of walls when each was injured. Quite possibly the use of different coals by coke plants during and since World War II and/or recent thorough inspections of many ovens, have more significance in regard to damage dates and reported dates of damage than do design or age itself.

AGE OF OVEN WHEN DAMAGE WAS REPORTED

	Plant	Wall Construction	YEARS B	YEARS H, S, SF
1.	A.B.C.	B	20.0, 27.0 (1947)	
1.	A.B.C.	H		10.0 (1951)
2.	Johnstown	B	8.0, 5.0 (1935)	
3.	Sparrows Pt.	H		11.0 (1952)
3.	Sparrows Pt.	SF		4.0 (1952)
4.	Steelton	B	22.0 (1940)	
5.	Gary	B	0.5 (1936)	
6.	Indianapolis	B	10.0, 8.0 (1937)	
7.	Neville Island	B	5.0 (1934)	
8,	Painesville	B	11.0, 10.0 (1938)	
8.	Painesville	H		2.0 (1938)
10.	Dofasco	SF		1.0 (1952)
11.	Ford	H		13.0, 11.0 (1951)
12.	Terre Haute	B	22.0, 15.0 (1941)	
13.	Inland	B	23.0, 20.0 (1949)	
14.	Daingerfield	H		8.0 (1952)
15.	Wyandotte	B	14.0 (1941)	
16.	Montreal	B	23.0 (1951)	

COAL BULK DENSITY

The bulk density in the plant ovens as charged is known to be a major factor in the safe or unsafe use of coking coals. In the tabulation, the reported coal charging weight before the ovens were damaged was used when available. The average variation shown in pounds per cubic foot, in the ovens, is over 3 pounds. The charging weights used are necessarily 24-hour averages. If individual oven charge records were available for study, considerably wider variation would probably be found. Also the bulk density in various parts of each oven, even with best modern charging practice is known to vary.

The preparation of coal samples for testing in the movable wall oven is described in "Proposed Method for Measurement of Pressures Developed During Carbonization", in the A.S.T.M. Coal and Coke Standards for 1951. Air drying of the sample as described results in a bulk density in the test oven of over 50 pounds per cubic foot.

COAL BULK DENSITY

	Plant	Year	Oven Vol. To Coal Line cu. feet	Charging Weight M lbs.	Bulk Density In Ovens Lbs. Per cu. ft.	Variations
1.	A.B.C.	1951	706	34.8 - 35.4	49.3 - 50.0	0.7
2.	Johnstown	1930	555	29.8 - 30.0	53.6 - 54.0	0.4
3.	Sparrows Pt.	1941	732	37.6 - 40.7	51.4 - 55.5**	4.1
4.	Steelton	1943	610	30.6 - 32.7	50.0 - 53.6	3.6
5.	Gary	1941	586	27.0 - 29.2	46.0 - 49.8	3.8
6.	Citizens	1941	527	24.2 - 25.1	46.0 - 47.5	1.5
7.	Neville Is.	1950	790	40.0 - 40.0	50.5 - 50.5	0.0 (?)
8.	Painesville	1936	614	28.1 - 33.0	45.8 - 53.8	8.0
9.	Fairmont		435			
10.	Dofasco	1952	690	28.0 - 33.6	40.5* - 48.6	8.1
11.	Ford	1939	720	33.5 - 36.0	46.5 - 50.0	3.5
12.	Terre Haute		510			
13.	Inland	1937	628	26.6 - 31.9	42.4 - 50.7	8.3
14.	Daingerfield	1944	732	36.0 - 36.6	49.2 - 50.0	0.8
15.	Wyandotte	1927	672	33.1 - 36.0	49.2 - 53.6	4.4
16.	Montreal	1937	686	33.0 - 34.5	48.0 - 50.2	2.2
17.	Everett	1930	716	35.0 - 37.3	49.0 - 52.0	3.0

COAL BULK DENSITY

	Plant	Year	Oven Vol. To Coal Line cu. feet	Charging Weight M lbs.	Bulk Density In Ovens Lbs. Per cu. ft.	Variations
18.	Rep. Clev.	1943	738	35.5 - 35.6	48.1 - 48.3	0.2
19.	Rep. Warren	1949	656	28.9 - 33.9	44.0 - 51.6	7.6
20.	Rep. Young.	1949	656	32.8 - 32.8	50.0 - 50.0	0.0 (?)
21.	Chatanooga		670		high	
22.	Clariton	1951	831	42.9 - 44.8	51.6 - 53.9	2.3
23.	Weirton	1947	690	35.1 - 38.3	51.0 - 55.5**	4.5
24.	Follansbee	1948	734	36.5 - 37.9	49.8 - 51.6	1.8
25.	Winnipeg		267			
26.	Woodward	1952	492	24.0 - 24.5	48.8 - 49.8	1.0
			Ave.	48.3 - 91.6	Ave. 48.3 - 51.6	3.3
					** High 55.5	8.3
					* Low 40.5	0.0 (?)

AL MIXING AND SEGREGATION

In three of the plants listed, the damage occurred when carbonizing a single coal. Although the use of a coal from one source does not insure constant physical or chemical properties of the raw material, and although stocking, crushing, and handling of the coal in the plant may change its properties and/or aggravate variations in them, the control of the nature of the coal charged into the ovens, when from one mine, is comparatively simple. The majority of coke plants blend two or more coals.

The mixing of coals on a plant scale and keeping them mixed into the ovens is not a precise operation. In seven of the 23 plants damaged by coal mixtures, there is evidence that there had been improper mixing and/or segregation of the coals prior to the damage. There is no evidence that this is not true in some degree in all of the plants. In four of the seven plants above, the nominal coal mix showed carbonization pressure in movable wall oven over two pounds per square inch in two of the plants under one pound per square inch. (One was investigated before development of the test oven.)

The size consists of two or more coals, and their moistures, markedly affect their mixing and tendency to segregate after mixing, as well as the bulk density of the blend. With a few exceptions the 26 plants listed reported reasonably fine average pulverization on samples of the blend. High and low volatile coals are known to differ considerably in their grindability. Moisture control in most of the listed plants at the time of the trouble was poor.

COAL MIXING AND SEGREGATION

	Plant	No. of Components In Mix	Ave. Coal Pulverization % thru 1/8" Screen	Ave. Coal Moisture %	Definite Indication of Poor Mixing or Segregation
1.	A.B.C.	4	85	7.0	
2.	Johnstown	2	55	6.0	yes
3.	Sparrows Pt.	2	80	5.0	
4.	Steelton	2	70	4.0	
5.	Gary	2	61	3.0	yes
6.	Citizens	2	90	3.5	
7.	Neville Is.	2	under 80	5.0	yes
8.	Painesville	2	90	3.5	
9.	Fairmont	3	--	--	
10.	Dofasco	3	65	8.0	
11.	Ford	2	82	6.0	
12.	Terre Haute	2	--	--	
13.	Inland	2	80	7.0	
14.	Lone Star	3	80	6.5	
15.	Wyandotte	2	83	2.0	
16.	Montreal	4	75	5.0	
17.	Everett	3	70	5.0	yes
18.	Rep.Cleve.	2	74	3.5	yes
19.	Rep.Warren	2	76	6.0	
20.	Rep.Young.	3	80	5.0	
21.	Chatanooga	1	68	1.7	

furnace or water gas coke mixtures and rates, then back again, rapidly. Such operations require good supervision to avoid charging of the foundry mix into ovens intended (or inadvertently heated) for safer mixtures. In any case, if the switch is made too rapidly both the ovens and the quality of the foundry coke may suffer from overheating.

Most of the movable wall oven tests on foundry coke coal mixtures, as noted, were made with low test oven flue temperatures, similar to those used in the respective plant.

FOUNDRY COKE

	Plant	Damage to Battery or Part Battery on Foundry Coke	Foundry Coal Mix in Use in the Plant at the Time, but the Damage Occurred in Battery or Part Battery Not on Foundry Coke
1.	A.B.C.	X	
6.	Citizens	X	
8.	Painesville	X	
9.	Fairmont	X	
11.	Ford		X
12.	Terre Haute	X	
14.	Lone Star	X	
15.	Wyandotte	X	
16.	Montreal	X	
21.	Tennessee Products		X

USHING SYSTEMS

Four different pushing systems are represented in the list of ovens damaged. The most common one in use was the 1, 4, 7 system (pushing by threes), used in 17 plants. In all cases where the direction of movement of the walls of the ovens from carbonization pressure was established, this primary movement was toward the older (coking time) adjacent oven.

In seven plants, the 9 series pushing system was used. No direction of movement of walls was established.

'n one plant the 1, 5, 9 system was used. No direction of movement was established. One series only was damaged most. Pushing was not regular.

In one plant the 29 oven group system was used. No direction of movement that could be correlated with age of ovens was established.

PUSHING SYSTEMS

	Plant	Pushing System	Direction of Wall Movement	Severity of Damage
1.	A.B.C.	1, 4, 7	to older oven	Deep spalls - some bowing
2.	Johnstown	1, 4, 7	-----	Bottle nose spalls
3.	Sparrows Pt.	9 series	-----	Step cracks and spalls
4.	Steelton	1, 4, 7	to older oven	Serious bows and spalls
5.	Gary	1, 5, 9.	-----	One series badly spalled
6.	Citizens	9 series	-----	Spalled walls
7.	Neville Is.	1, 4, 7	-----	Serious spalls
8.	Painesville	1, 4, 7	-----	Spalled walls
9.	Fairmont	1, 4, 7	-----	Serious spalls
10.	Dofasco	9 series	-----	Some spalls - possible bows
11.	Ford	1, 4, 7	to older oven	Serious bows - some spalls
12.	Terre Haute	1, 4, 7	-----	Spalled walls
13.	Inland	1, 4, 7	to older oven	Bowed walls - spalled bottles
14.	Lone Star	1, 4, 7	to older oven	Bowed walls - spalls
15.	Wyandotte	1, 4, 7	to older oven	Bowed walls - deep spalls
16.	Montreal	9 series	-----	Some bowed walls - some spalls
17.	Everett	9 series	-----	Bad spalls - especially bottles
18.	Rep.Cleve.	1, 4, 7	to older oven	Serious bowing and spalls

PUSHING SYSTEMS

	Plant	Pushing System	Direction of Wall Movement	Severity of Damage
19.	Rep.Warren	9 series	-----	Serious spalling-especially bottles
20.	Rep.Young.	1, 4, 7	-----	Serious bows and spalls
21.	Chatanooga	1, 4, 7	-----	Serious spalling
22.	Clairton	Marquard*	-----	Serious bowing - some spalls
23.	Weirton	9 series	-----	Serious spalling-some bowed walls
24.	Follansbee	1, 4, 7	to older oven	Some bowed walls-some spalls
25.	Winnipeg	1, 4, 7	-----	Serious spalling
26.	Woodward	1, 4, 7	to older oven	Serious bows - serious spalls

* The major incidence of bowing in these ovens was from every other oven starting with oven A-2, into every other oven starting with A-3. This pattern has no correlation with age of adjacent ovens. It is further evidence of segregation of low volatile coal from the mix.

1, 4, 7 SYSTEM (10-3 System)

The ovens are nubmered consecutively. They are pushed in the following order: 1, 11, 21, 31, etc., then 4, 14, 24, 34, etc. then numbers ending in 7, then 10's, 3's, 6's, 9's, 2's, 5's, 8's, and 1's again. The adjacent lower number oven is always older in coking time than the adjacent higher number oven in the ratio of 70 to 30.

9 SERIES SYSTEM (Minus Ten) (9-2 System)

The ovens are numbered consecutively, but with the tens omitted, as, 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, etc. They are pushed in the following order: 1, 11, 21, 31, etc., then 3, 13, 23, 33, etc. then 5's, 7's, 9's, 2's, 4's, 6's, 8's, and 1's again. The adjacent lower number oven is always older in coking time than the adjacent higher number in the ratio of 55.6 to 44.4.

1, 5, 9 SYSTEM (10-4 System)

The ovens are numbered consecutively. They are pushed in the following order: 1's, 5's, 9's, 7's, 2's, 4's, 10's, 6's, 8's, 3's, then 1's again. In each ten oven group two ovens have both adjacent ovens of the same age, 4 higher number adjacent ovens are older and 4 lower number adjacent ovens are older, in ratio of 59 to 41.

MARQUARD (29-OVEN GROUP) SYSTEM

The ovens are numbered consecutively, A-1 to A-29, B-1 to B-29, C-1 to C-29. They are pushed in the following order: A-1, B-1, B-1, A-3, B-3, C-3 then 5's, 7's, etc. through 29's, then A-2, B-2, C-2 and all even numbers through C-28, then A-1 again. The adjacent lower number oven is always older in coking time than the adjacent higher number oven in the ratio 15 to 14, or 52 to 48.5.

CARBONIZATION PRESSURES

In 21 of the plants listed, carbonization pressures as measured in the Russell movable wall test oven are available. In 19 of these cases, the pressure shown by the nominal mix used in the plant at the time of oven damage was over 1.5 pounds per square inch measured at bulk density of 50 pounds per cubis foot or more.

One of the remaining plants used a "blend" of very coarse high volatile coal and fine low volatile coal. Segregation under these conditions is virtually certain to occur. When a sample of the plant mix with the plus 1/2 inch material screened out was tested, a pressure of 2.85 pounds per square inch was found.

In the last case 1.27 pounds per square inch was found, at 54.3 pounds per cubic feet. This single test was made on a sample made up in the laboratory like the nominal mix supposedly used in the plant at the

CARBONIZATION PRESSURES (Cont'd.)

No general correlation between oven height or wall thickness and safe carbonization pressure could be developed from the data, although the last two plants mentioned above happen to have ovens 13 feet high or more. No ovens under 10 feet high were injured by less than two pounds per square inch, but then only five coal mixtures tested showed pressures under 2-Psig.

CARBONIZATION PRESSURES

	Plant	Ave. Wall Thickness Inches	Oven Height Ft., Inches	Calculated Maximum Bulk Density in Ovens, Lbs. Per Cu. Ft.	Movable Wa Test Oven Pressure Psig
1.	A.B.C.	4.65	13 - 6	50.0	1.66
2.	Johnstown	4.56	12 - 3	54.0	approach 8.0
3.	Sparrows Pt.	5.06	12 - 0	55.5	4.6
4.	Steelton	4.66	9 - 10-5/8	53.6	2.6
5.	Gary	4.87	11 - 0	49.8	4.9
6.	Citizens	--	9 - 5-7/8	47.54	---
7.	Neville Is.	4.58	13 - 6	50.5	4.3
8.	Painesville	4.69	12 - 6	53.8	---
9.	Fairmont	4.76	9 - 10-5/8	---	---
10.	Dofasco	4.64	13 - 0	48.6	1.84
11.	Ford	4.62	13 - 3	50.0	2.0 plus
12.	Terre Haute	4.65	11 - 8-1/4	---	3.5 plus
13.	Inland	4.65	12 - 0	50.7	3.27
14.	Daingerfield	5.08	12 - 0	50.0	4.66
15.	Wyandotte	4.63	12 - 6	53.6	1.99
16.	Montreal	4.63	13 - 0	50.2	4.40
17.	Everett	4.63	12 - 10	52.0	---
18.	Rep.Cleve.	4.19	13 - 0	48.3	2.04
[illegible]	Rep.Warren	---	10 plus	51.6	4.30
20.	Rep.Young.	4.76-4.56	9 - 10-5/8 & 13 - 0	50.0	2.01

CARBONIZATION PRESSURES

	Plant	Ave. Wall Thickness Inches	Oven Height Ft., Inches	Calculated Maximum Bulk Density in Ovens, Lbs. Per Cu. Ft.	Movable Test Ove Pressure Psig
21.	Chatanooga	---	12 - 1-1/2	---	2.17
22.	Clairton	4.57	14 - 0	53.9 *	0.80
23.	Weirton	4.71	13 - 0	55.5 *	0.85
24.	Follansbee	4.66	9 - 10-5/8	---	4.8
24.	Follansbee	4.64	9 - 10-5/8	---	4.8
24.	Follansbee	4.66	13 - 0	51.6	1.27
25.	Winnipeg	4.69	10 - 10	---	---
26.	Woodward	5.66	9 - 10-5/8	49.8	4.0
	Average	4.67	12 - 0	51.6	3.2

* These plants using very coarse coal.

OTHER PLANTS POSSIBLY DAMAGED BY CARBONIZATION PRESSURES

Coke oven walls are known to have been bowed, spalled, and/or cracked in several ways in addition to the action of "expanding" coals. Among these are:

1. Discharging of "hard pushes" by holding in the pusher ram motor overload relay, or by repeatedly "hitting" the coke with the ram.

2. Pushing "out of series" next to an empty oven.

3. Using a bent pusher ram, allowing ram or carbon cutter to hit the oven roof, using ram shoe that wedges coke at the bottom.

4. Using bent or improperly designed level bar.

5. Air leakage into ovens, usually at floor or jambs.

6. Fluxing of brick from heating flue side of the walls.

7. Spalling of walls by flushing liquor or water.

8. Cracking of walls by cooling the silica brick to low temperature.

9. Improper support for the brickwork from the oven faces or at the pinion walls.

10. Slagging of walls by certain coal constituents.

11. Improper oven repair work, or improper maintenance and/or operation after repairs.

12. Settlement of battery foundations.

None of the above are believed to be factors in the cases of the 26 plants cited. In order to invite comments on this paper, and for the sake of completeness, 19 additional plants are listed here. The information available to date in regard to these is meagre or contradictory.

APPENDIX

OTHER PLANTS WITH OVEN WALLS POSSIBLY DAMAGED BY CARBONIZATION PRESSURE

	Plant	Contract Number
1.	Consolidated Edison, Hunts Pt., NY	#322, #453
2.	Peoples Gas, Chicago, IL	#217
3.	Bethlehem Steel, Bethlehem, PA	#119
4.	Jones & Laughlin, Hazelwood, PA	#773
5.	Granite City Steel, Granite City, IL	#646
6.	Republic Steel, Gadsden, AL	#136
7.	Interlake Iron, So. Chicago, IL	#287
8.	Republic Steel, Canton, OH	#129, #338
9.	Republic Steel, Massillon, OH	#334
10.	National Tube, Lorain, OH	#147, Wilputtes built in 1947
11.	Interlake Iron, Erie, PA	Wilputte built in 1925
12.	Donner-Hanna, Buffalo, NY	#199, #436
13.	Tennessee Coal & Iron, Fairfield, AL	Batteries 5, 6 built 1919-20
14.	Bethlehem Steel, Lackawanna, NY	#669, new Wilputte Battery 1953
15.	Du Pont, Belle, WV	Wilputte, built 1930, 1937
16.	Steel Co. of Canada, Hamilton, Ont.	Wilputte, built 1918
17.	Brooklyn Union Gas, Brookly, NY	#348
18.	Koppers-Seaboard, Kearny, NJ	#140, #168, #677
19.	Republic Steel, Warren, OH	#266

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A[illegible]t 21, 1953