author prefers to use instead of that of combustible, because the fuel free from ash and moisture contains oxygen and nitrogen, which are not combustibles. The capacities were lower than those in Table No. 1, because the coal used was a less favorable size. This latter test shows the effect of the difference in efficiency of the two boilers in ordinary service.

The author prefers to recognize a steam generating apparatus as being composed of separate features as follows: As boiler and grate, with this combination, the gases flow in contact with the heating surface immediately as they leave the fire. Also, as boiler, grate and furnace, the latter feature consisting of a refractory roof over the fire which extends back a considerable distance, its presence making it possible for the gases to be mixed together a sufficient extent while at high temperature, so that no combustible escapes oxidation. Such feature here designated as a furnace, if of a length of about 14 ft., will produce an ideal mixture of the gases if the coal is supplied to the grate at a uniform rate, but, if not, its ability to effect mixture of the gases is not sufficient for complete combustion. With the thick fire of a chain grate stoker feeding bituminous coals, a considerable amount of combustible gas escapes from the front of the fire, such a quantity, in fact, that an ignition arch alone, although 5 ft. in length, does not cause sufficient mixture of the gas and air to produce complete combustion, therefore, if the maximum requirement of the furnace is to thoroughly mix together the gases from a chain grate fire, then the efficiency of such furnace feature as fitted under boilers *A* and *B* is ideal, because proper regulation of the quantities of air and fuel supplied by the grate resulted in the production of 18 per cent. CO_2 with complete combustion and no smoke.

The performance of the chain grate stokers under boilers *A* and *B* are unsatisfactory in two respects: First, that with desirable strength of draft the available thickness of fuel bed does not supply sufficient combustible to satisfy the air supply. Second, fuel is wasted by passing over the end of the grate with the ash. This latter fault may be remedied by running the grate at a speed which will allow the fuel to burn away before it reaches the end, but this results in increased excess of air, therefore the chain grate stoker, in combination with the above described furnace feature, is inefficient to the extent by which it fails to supply a sufficient thickness of fire or quantity of combustible, and the loss of fuel with the ash is not a fault of the stoker, because if the supply of combustible was sufficient to satisfy the air the grate could be run at a speed which would insure that the fuel all be burned.

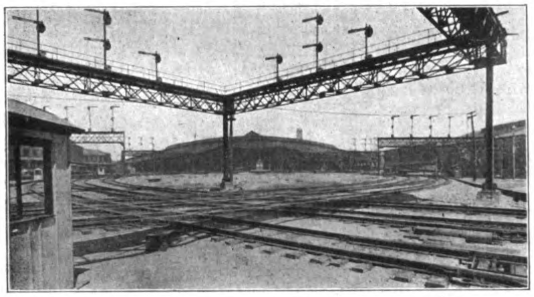

Fig. 1. Grand Crossing under Signal Bridge No. 8. Three tracks leading to each throat.

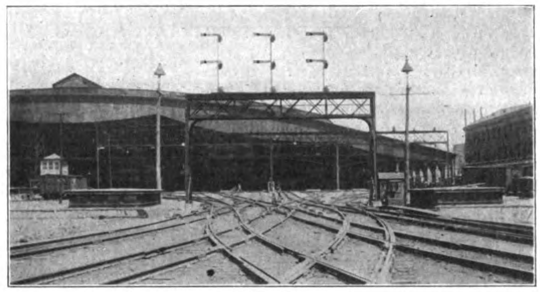

Fig. 4. East Throat, showing Three Double Slips and Bridge No. 4.

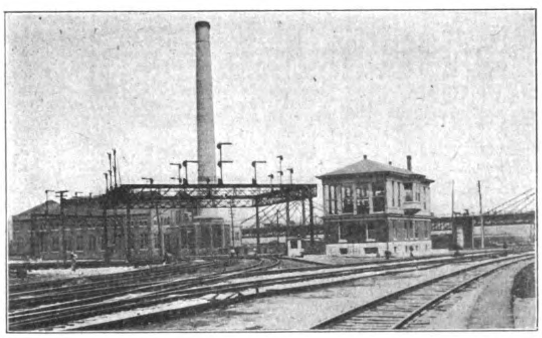

Fig. 2. Tower No. 1 and Bridge No. 8. New power house beyond Bridge.

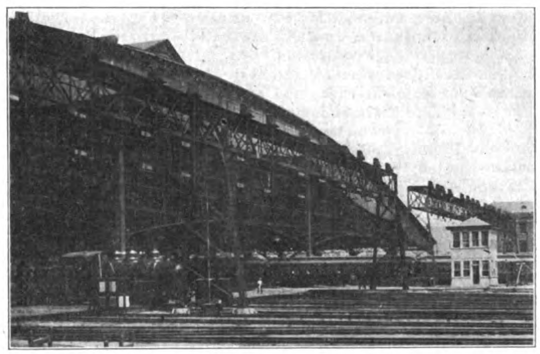

Fig. 3. Signal Bridges carrying Starting Signals for Outward Trains.

Electro-Pneumatic Signals at Union Station, St. Louis.

Signals at St. Louis Union Station.

The accompanying illustrations, Figs. 1, 2, 3 and 4, show the more interesting outward features of the extensive electro-pneumatic interlocking erected at the Union Station, St. Louis, by the Union Switch and Signal Company this year as a part of the elaborate enlargement which was made necessary at that city to accommodate the great increase of traffic in connection with the World's Fair. From the plan heretofore printed in the *Railroad Gaette* (March 20, 1903, page 212), the reader will recall that the tracks in the great train shed, which is 600 ft. wide, are divided into two groups of 16 each, with a separate throat for each group. Each "throat" has three tracks. Going out from the shed (southward), after reaching the narrowest point in the throat, which is about 400 ft. from the outer ends of the platforms, each throat is divided; three tracks turn to the west and three tracks to the east. The three eastern tracks from the western throat cross the three western tracks from the eastern throat at the "grand crossing," shown in Fig. 1. The four signal bridges required at this crossing are combined in a single rectangular structure, 75 ft. square, shown in the illustration.

The starting signal for outward trains are all "suspended signals"; the signal arms are at the lower end of the tubular post which contains the vertical operating rods, and the pneumatic valve is at the top of the post. Some of these are shown in Fig. 3. The combined length of the two bridges in this view is 488 ft.

Tower No. 1, which is just south of the rectangular signal bridge and between that and the east and west main tracks, controls all of the tracks leading to the station and all of the tracks eastward and westward in each direction from the tower for about 1,200 ft. Beyond this limit on the west is tower No. 2, and on the east is tower No. 3. The functions worked at the different towers are as follows:

Tower No. 1.—One-arm home signals, 9; two-arm home signals, 1; one-arm bridge signals, 21; two-arm bridge signals, 37; three-arm bridge signals, 2; one-arm suspended signals, 20; two-arm suspended signals, 12; dwarf signals, 37; single switches, 35; cross-overs, 15; double slips with m. p. f., 48. One hundred and three levers work 35 single switches, 15 cross-overs and 48 double slips with m. p. frogs. Seventy-eight levers work 194 signals. Total number of working levers, 181; spare spaces, 34; capacity of frame, 215 levers.

Tower No. 2.—One-arm bridge signals, 14; two-arm bridge signals, 18; dwarf signals, 3; single switches, 11; cross-over, 1; movable point frogs, 2; double slips with m. p. f., 9. Nineteen levers work 11 single switches, 1 cross-over, 2 movable point frogs and 9 double slips with m. p. f. Twenty-five levers work 53 signals. Capacity of frame, 59 levers (44 working levers, 15 spare).

Tower No. 3.—One-arm bridge signals, 10; two-arm bridge signals, 9; dwarf signals, 3; three-arm bridge signals, 2; single switches, 10; cross-over, 1; double slips with m. p. f., 8. Fourteen levers work 10 single switches, 1 cross-over and 8 double slips with m. p. f. Twenty-one levers work 37 signals. Total working levers, 35; spare spaces, 12.

Road Tests of Brooks Passenger Locomotives.*

As the Hocking Valley desired to draw comparisons between the two types of engines used at the time in their passenger service between Columbus and Toledo, it was decided to conduct at least four trials under as near as possible identical conditions, two on each locomotive.

The locomotives were built by the Brooks works of the American Locomotive Company, the dimensions of which are given in the following pages, the greatest difference, however, being the Belpaire type of boiler, with 72-in. drivers on No. 73, and the wagon top boiler, with 66-in. drivers, on No. 80. No. 73 had been in service several years, but was thoroughly overhauled nine months previous to the trials, and had been in continuous service from that time, while No. 80 was practically new, having been in service only two months before the trial. In each case, however, where needed, the engines were given new piston rings, the valve seats were put in good condition and valves reset so that each engine worked "square."

Apparatus and Preparation.

The apparatus used was as follows: A gage glass and scale on each side of each tank for determining the amount of feed water. A Barrus calorimeter connected to the dome. A Hohmann and Maurer mercury pyrometer inserted in the front-end. Draft gages in the cab to indicate fire drafts at front-end, fire-box and ash pan. The same flue gas-sampling and collecting apparatus was used as in the previous year, and also the same combustible collector at the stack. A continuous counter was driven from the reducing motion, and also an indicator tachometer from the forward truck axle. Two indicators were used on each cylinder, with ¾-in. pipes, 9 in. long, well lagged, connecting to each end of each cylinder. The indicators used were American Thomson and Star brass outside spring. Slotted pendulum reducing motion was used, with exception of on one side of No. 80, where a pantograph was substituted on account of the air tank interfering with the other form of reducing motion, this tank being located underneath the running board. A continuous stroke counter connected with the air pump, received its motion from a small plunger working in a brass cylinder.

Method of Conducting Trials.

Since these trials extended over the whole division, a distance of 124 miles, the total amount of coal used from the time the fires were first started in raising steam until the end of the run was easily obtained. The thickness of the fire was noted at the commencement of the trial, and also the amount of coal used up to that time, when at end of trial the fire was left as near as possible in same condition. It was then allowed to burn out, then dumped and the ash pan thoroughly cleaned, so that the refuse obtained in the ash pan was from the total coal burned. The sack method was used for determining accurately the amount of coal used.

The number of injector applications was noted, so as to make correction for loss at overflow, also the number of times and length of popping of safety valve, the loss of steam in this direction being determined from a test of the pop valve while in place on the engine. The steam used by the air pump was computed from the data furnished by the New York Air-Brake Company. All readings and indicator cards were taken at intervals of four minutes, with the exception of the sample of flue gas, which was taken practically every eight minutes. On account of the risk involved, it was considered advisable to attempt to read the calorimeter only when going into the station or in pulling out; so that, probably, there would be some variation between the amount of moisture determined and the true average.

The stack-refuse sampling apparatus was constructed so that the collecting pipe could be fastened at three different points on a radius of the stack. It was clamped in each of those positions for practically one-third of the run.

*From a paper by E. A. Hitchcock, read before the American Society of Mechanical Engineers, December, 1904.

GENERAL DIMENSIONS.

Hocking Valley Passenger Locomotive.

	No. 73.	No. 80.
Weight on drivers, lbs	84,000	87,000
Weight on truck wheels, lbs	44,000	46,000
Total weight, lbs	128,000	133,000
Weight of tender, lbs	95,000	102,000
Wheelbase, rigid	8′ 9″	8′ 9″
Wheelbase, total of engine	24′ 1½″	24′ 0″
Length of engine	36′ 1½″	36′ 0½″
Length of eng. and tender	59′ 3½″	59′ 4″
Height, cen. of boiler abv rails	8′ 7½″	8′ 4½″
Height, top stack above rails	14′ 11″	14′ 8″
Heating, surf., fire-box, sq. ft.	161	170
" " tubes	1,813	1,776
" " total	1,974	1,946
Grate area, sq. ft.	30.8	29
Drivers, diameter	72-in.	66-in.
Drivers, material of centers	Cast-steel.	Cast-steel.
Main wheel fit	8⅜-in.	8⅜-in.
Truck wheels, diameter	36-in.	30-in.
Journals, driving axle, diam	8½x11 in.	8½x11 in.
Journals, truck axle, diam	5½x12 in.	5½x12 in.
Main crank-pin, diameter	5½-in.	5½-in.
Main crank-pin, length	5½ in.	5½ in.
Cylinder, diameter	$18\frac{15}{32}$-in.	18-in.
Piston stroke	26 in.	26 in.
Piston rod, diameter	3½-in.	3½-in.
Kind piston-rod packing	Jerome.	Downing.
Length, main rod, c. to c.	7 ft. 9 in.	7 ft. 9 in.
Steam ports, length	17 in.	17 in.
Steam ports, width	1¾ in.	1¾ in.
Exhaust ports, length	17 in.	17 in.
Exhaust ports, width	3 in.	3 in.
Bridge, width	1¾ in.	1¾ in.
Valves, kind	American.	Richards'n
Valves, greatest travel	6¼ in.	6¼ in.
Valves, outside lap	1 in.	1 in.
Valves, inside lap	0 in.	0 in.
Boiler, type	Belpaire.	Wagon top
Material in barrel	Carbn st'l.	Otis steel
Thickness of material	9/16, ⅝, 9/16 & ½″	⅝, ⅝, 9/16, and ½″.
Barrel, outside diameters	62-in.	62⅛-in.
Kind of seams, longitudinal	Quintuple lap.	Sextuple butt.
Kind of seams, circumferentl	Double lap	Double lap
Tube sheet, thickness	¾ in.	⅝ in.
Kind of crown sheet stays	Tenn. iron.	Tenn. iron.
Dome, diameter outside	31⅛ in.	31¼ in.
Fire-box, length	108 in.	107½ in.
" width	42 "	39½ "
" depth, front	75 "	75 "
" depth, back	57 "	62 "
" material	Carbn st'l.	Otis steel
" thickness of sheets	⅜, 7/16, 5/16, 5/16″	⅜, 7/16, 5/16, 5/16″
" width of water space:	4″ front, sides & back 3½″	4″ all around
Grate, length	107 in.	106¾ in.
" width	34 "	34 "
" kind	Rocking finger.	
" No. of bars	10	10
Tubes, No.	301	295
" material	Shelby st'l	Shelby st'l
" outside diameter	2-in.	2-in.
" length over sheets	11 ft. 7 in.	11′ 7 1/16″
Smoke-box, outside diameter	65 in.	65 in.
Smoke-box, length	60 in.	60 in.
Exhaust nozzle:		
Single or double	Single.	Single.
Fixed or variable	Fixed.	Fixed.
Diameter	4⅝-in.	5-in.
Dist., tip from c. of boiler	2½″ abv.	7 in. belw.
Netting, size of mesh	¼x1¼-in.	¼x1½-in.
Stack, kind	Tank steel	C. I., taper
Stack, diameter in.	12½, 15⅞	14½, 17⅜
Stack, height abv smoke-box	43 in.	43 in.
Ratio, air space to grate area	45%	45%
Width of air space	⅝-in.	⅝-in.
Tender, type	8-wheeled.	8-wheeled.
Wheels, diameter	33 in.	33 in.
Journals, diameter	5 "	5 "
Journals, length	9 "	9 "
Distance between centers	76 "	76 "
Diameter of center of axle	5¾ "	5¾ "
Length, tndr. over bumper bar	22′ 10¾″	23 ft.
Tank capacity, gal.	5,000	5,000
Kind of material	Steel.	Steel.
Length of tank	19 ft. 6 in.	19 ft. 6 in.
Width of tank	9 " 10 "	9 " 10 "
Height of tank to collar	4 " 6 "	4 " 6 "
Tires, make	Midvale.	S. St'l Co.
Sight feed lubricator	Michigan triple.	
Front and back couplers:		
Buckeye; shank	Short	Long.
Safety valve (each 3-in.)	Coale.	Hayden.
Sanding devices	Leach "D" 2 double.	Leach "A" double.
Injectors, two each	Ohio No. 8.	Ohio No. 9.
Air-brake equipment	New York.	New York.
Tender brake-beam	Monarch.	Simplex.
Tender brake shoe	Brooks.	A. L. Co.'s
Steam gages	Ashcroft.	Star.

GENERAL RESULTS.

Boiler Performance.

	No. 80.	No. 80.
1. No. of trial	2	3
2. Date of trials	May 3, '04	May 6, '04
3. Duration trials, total, hrs.	2.96	2.64
4. Running time	2.58	2.36
5. Steaming time	2.31	2.09
6. Number of stops	13	11
7. Kind of fuel	Hocking.	Hocking.
8. State of weather	Clear.	Clear.
9. Direction of wind	E. & S.	E. & S.
10. Velocity wind, miles pr hr	8	6
Average Pressures.		
11. Steam press. at dome, lbs.	166	157
12. Barometer, in.	28.07	29.21
13. Absolute steam press., lbs	180	171
Force of draft:		
14. Front end, in.	2.05	2.31
15. Fire-box, in.	1.19	1.5
16. Ash-pan, in.	0.11	0.1
Average Temperatures.	Degs. Fahr.	
17. External air	65	75
18. Escaping gases	728.3	753
19. Feed-water in tank	58	62
Fuel:		
20. Size	Lump.	Lump.
21. Thickness of fire, in.	11 to 14	11 to 14
Weight of coal:		
22. Fired, lbs.	7,568	7,508
23. Before start, lbs	1,164	1,067
24. During run, lbs.	6,404	6,441
26. Percentage of moisture in coal by analysis, per. ct.	7.20	7.28
26. Weight dry coal fired, lbs	5,943	5,972
27. Weight, refuse in pan, lbs.	715	769
28. Percentage of refuse in pan to coal, per cent	9.45	10.22
29. Combustible in refuse, lbs.	309	371
30. Total combustible minus comb. in pan, lbs.	6,131	5,786
31. Total ash by analysis, lbs.	583	655
32. W't. ash passing flues, lbs.	177	257
33. T'l refuse pass'g flues, lbs.	730	959
Percentage:		
34. Ash lost to total ash, p.c.	30.4	39.25
35. Refuse through stock to coal, per cent	9.65	12.78
36. Equivalent coal actually burned, lbs.	5,743	5,566
37. Net dry coal burned, lbs.	5,320	5,160
38. Net combustible burned, lbs	4,890	4,565
Fuel Analysis—Proximate Analysis.	Per cent.	
39. Fixed carbon	49.24	49.70
40. Volatile matter	35.86	34.30
41. Moisture	7.20	7.28
42. Ash	7.70	8.72
Ultimate Analysis.	Per cent.	
43. Carbon	68.9	68.58
44. Hydrogen	5.45	5.45
45. Oxygen	16.0	15.0
46. Nitrogen	1.2	1.2
47. Sulphur	0.75	1.05
48. Ash	7.70	8.72
Analysis of Pan Refuse.	Per cent.	
49. Combustible	43.28	48.18
50. Ash	56.72	51.82
Analysis of Stack Refuse.	Per cent.	
51. Combustible	75.77	73.20
52. Ash	24.23	26.80
Fuel per Hour Steaming Time.		
53. Actual coal fired, lbs.	2,772	3,081
54. Equiv. coal burned, lbs.	2,486	2,663
55. Combustible burned, lbs.	2,112	2,187
56. Actual coal fired, per sq. ft. grate	95.6	106.2
57. Equivalent coal burned, per sq. ft. grate	85.7	91.8
58. Combustible burned per sq. ft. grate	72.7	75.4
59. Combustible burned per sq. ft. heating surface	1.08	1.12
Calorific Value of Fuel.		
Calorific value per pound:		
60. Of actual coal by Mahler Calorimeter	12,135	12,184
61. Of dry coal	13,080	13,120
62. Of combustible	14,265	14,854
63. Of stack refuse	10,750	10,390
Quality of Steam.		
64. At dome, dry steam-unity	0.9774	0.983
65. Quality correction	0.9843	0.988
Water.		
66. Actual weight, water fed to boiler, lbs	38,580	40,785
67. Equiv. weight of water actually evaporated into dry steam, lbs.	37,963	40,275