

AIR ZONING  
IN  
STOKER OPERATION

by

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## INTRODUCTION

This study was made on a 347 H. P. Walsh and Weidner water tube boiler, that had been in almost continuous operation for five years. This boiler is equipped with a Taylor four-retort, underfeed stoker.

The analysis of flue gas from this boiler has never showed anything near what would be expected of such an installation. For this reason a study was made on the air zoning in the boiler setting in hope of finding the defects in the installation and making changes that would remedy the trouble.

This thesis is written for the operating engineer in plants where coal is burned on stokers. It is written in such a way that the average operating engineer can understand all that is said. Much of the writing on this subject cannot be easily understood by the man without technical training. The purpose of this study is to help the operating engineer understand what is expected of him when burning coal, and to help him make his coal pile last longer.

When coal is burned, the carbon in the coal combines with the oxygen in the air and forms  $\text{CO}_2$ . When the carbon in the coal unites with the oxygen in the air, heat is given off. It is easily seen that to get the most heat from the coal all the carbon in the coal must unite with the oxygen in the air. It is not difficult to get this result if plenty of air is used. All the air that passes through the fire box must be heated and if more air than is needed to burn the coal is allowed to pass through, it carries away heat with it. All this heat is lost. Much of the heat from the coal is used to heat this excess air instead of making steam.

For the very best results just enough air would be added to furnish the exact amount of oxygen to unite with the carbon of the coal. Air contains about 21 percent oxygen by volume. If just the proper amount of air was added, the flue gas would contain 21 percent  $\text{CO}_2$  by volume. It is impossible to add just the exact amount of air needed and have all the oxygen unite with the carbon. Some excess air must be added to insure thorough mixing with the gases given off by the coal. It is possible to operate with 50 percent excess air. With 50 percent excess air the flue gas should show from 12 to 14 percent  $\text{CO}_2$  by volume.\*

\*Handbook Steam Engineering. Biggs and Woolrich

If too little air is added, or if the air is not thoroughly mixed with the gases from the coal, instead of forming  $\text{CO}_2$ , CO will be made. In this case the carbon is not thoroughly oxidized and the heat given off is less than it should be. It is necessary that the proper amount of air be added and that it be added so as to thoroughly mix with the gases from the coal.

The direct purpose of this work was to get a better percentage of  $\text{CO}_2$  in the flue gas from a boiler installed in the central power plant at the University of Tennessee.

A test was made on the boiler before any change had been made in the setting. The change was made and another test was made. It is proposed to show that the boiler is more efficient when the  $\text{CO}_2$  in the flue gas is higher.

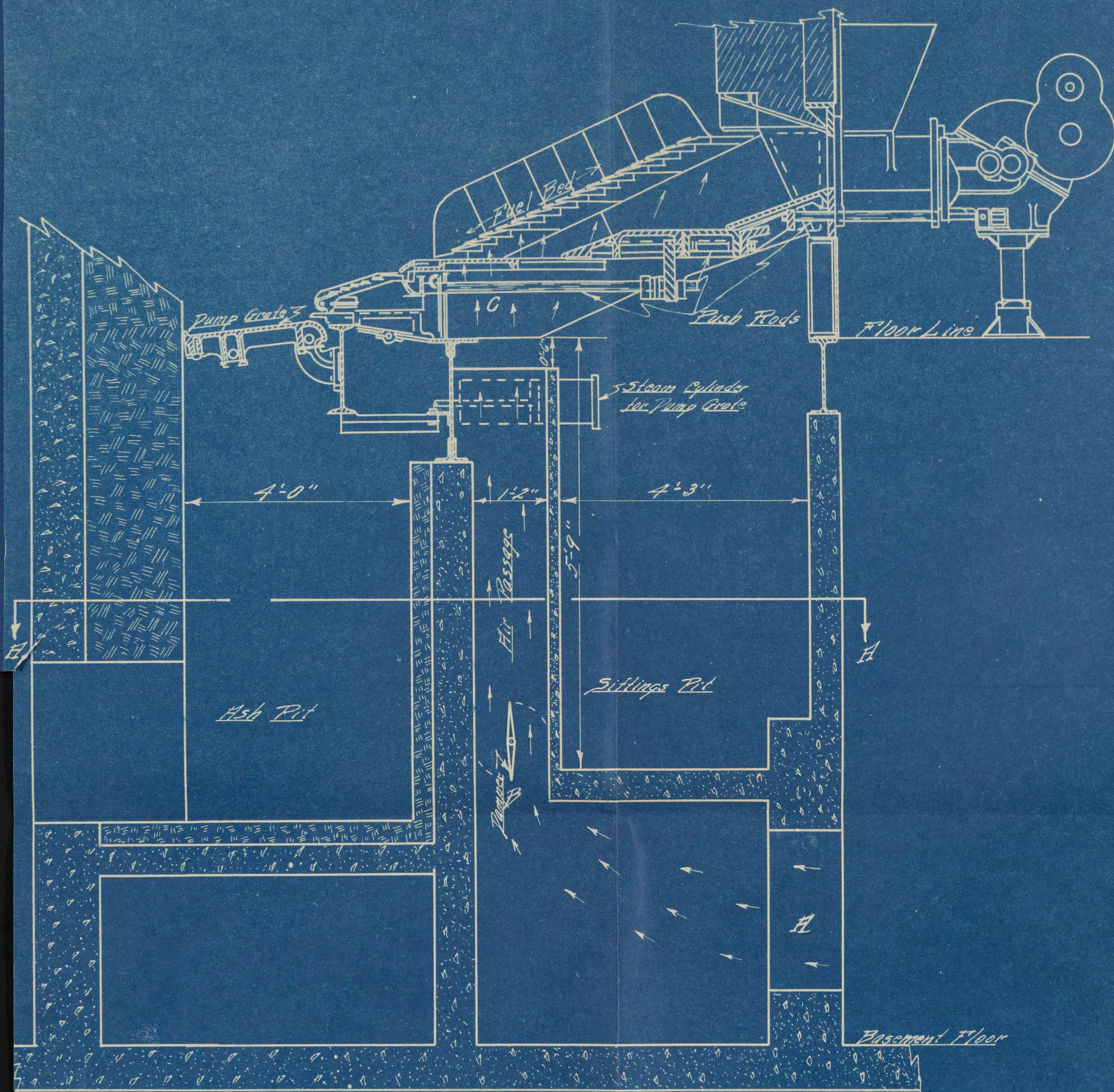


FIG. 1

SECTION THROUGH STOKER  
AND SETTING

Note that the air is forced up near  
the toe of the stoker. The pusher  
rods and steam cylinder would be  
in the way of dampers to shut  
off air from the toe of the stoker.

Scale -  $\frac{3}{4}$ " = 1'-0"  
Date May. 13, 1929

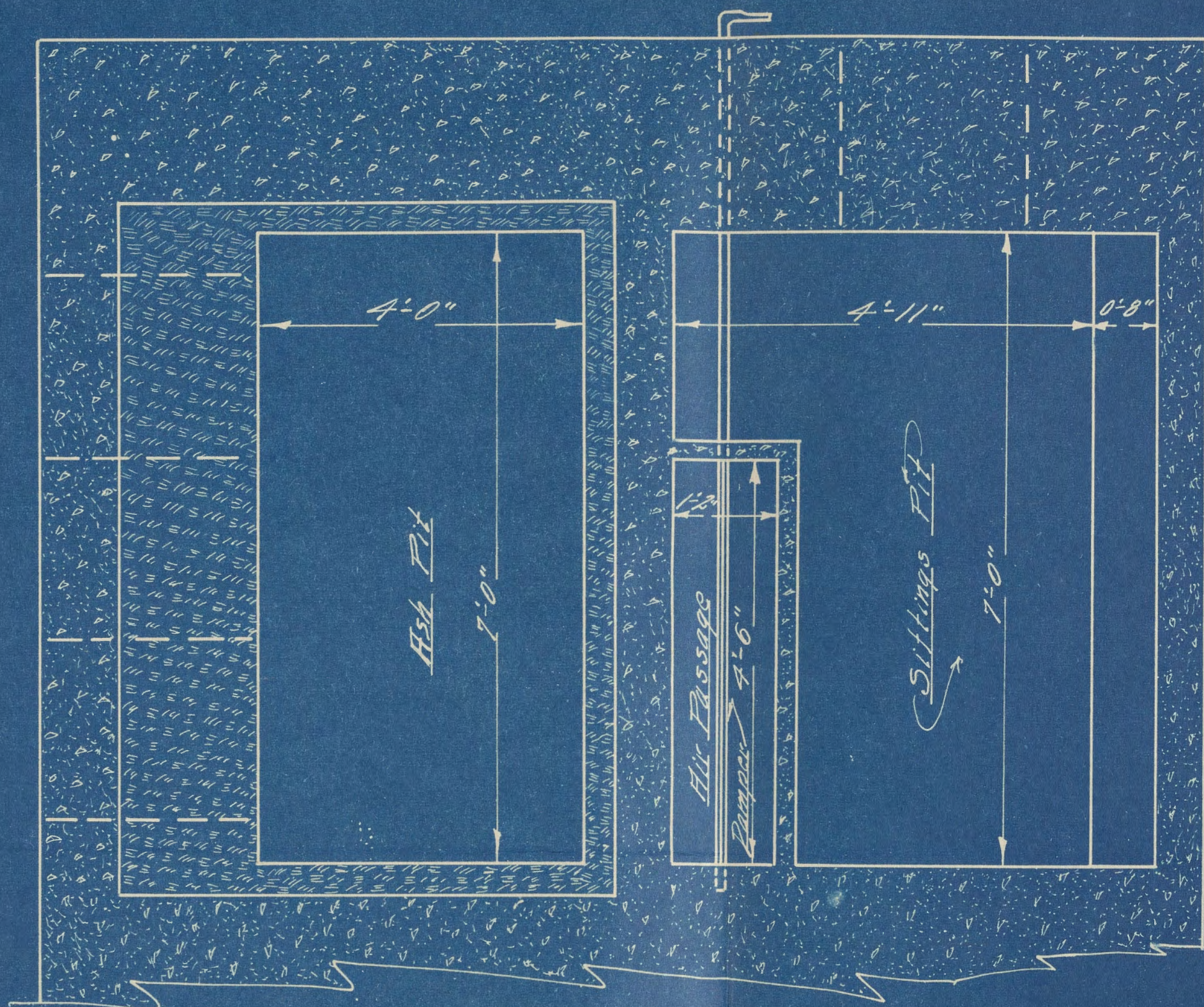
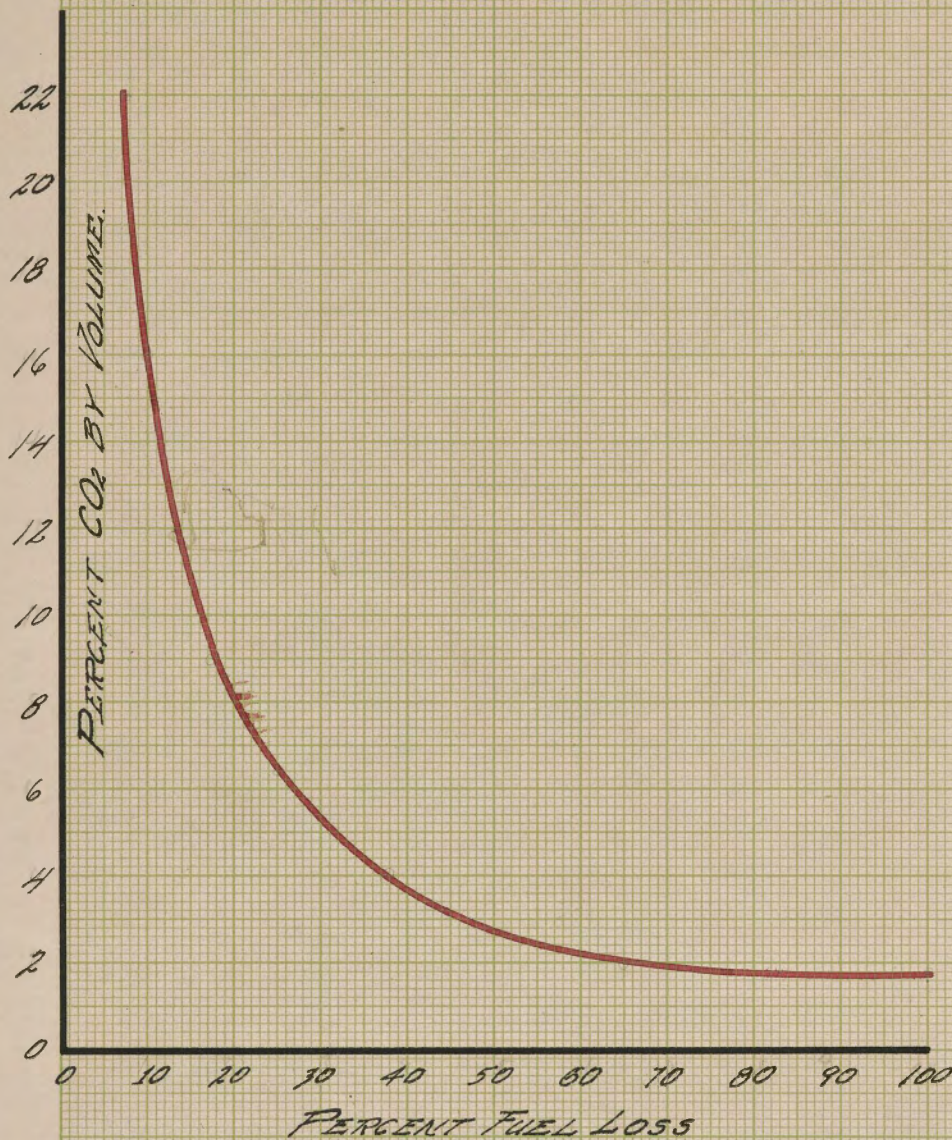


FIG. 2

SECTION A-A

Note that the air passage does not extend the full length of the stoker. This caused the coal to burn faster on one side of the stoker.

Scale -  $\frac{3}{4}" = 1'-0"$   
Date. May. 13, 1929.



Curve showing the relative fuel loss to percent CO<sub>2</sub> by volume in flue gas. Difference between temperatures of entering air and exhaust gas 400° F.

Chart by Westinghouse.

Published by The H. Cole Co., Columbus, Ohio, No. 290 G.

CHART NO. 1

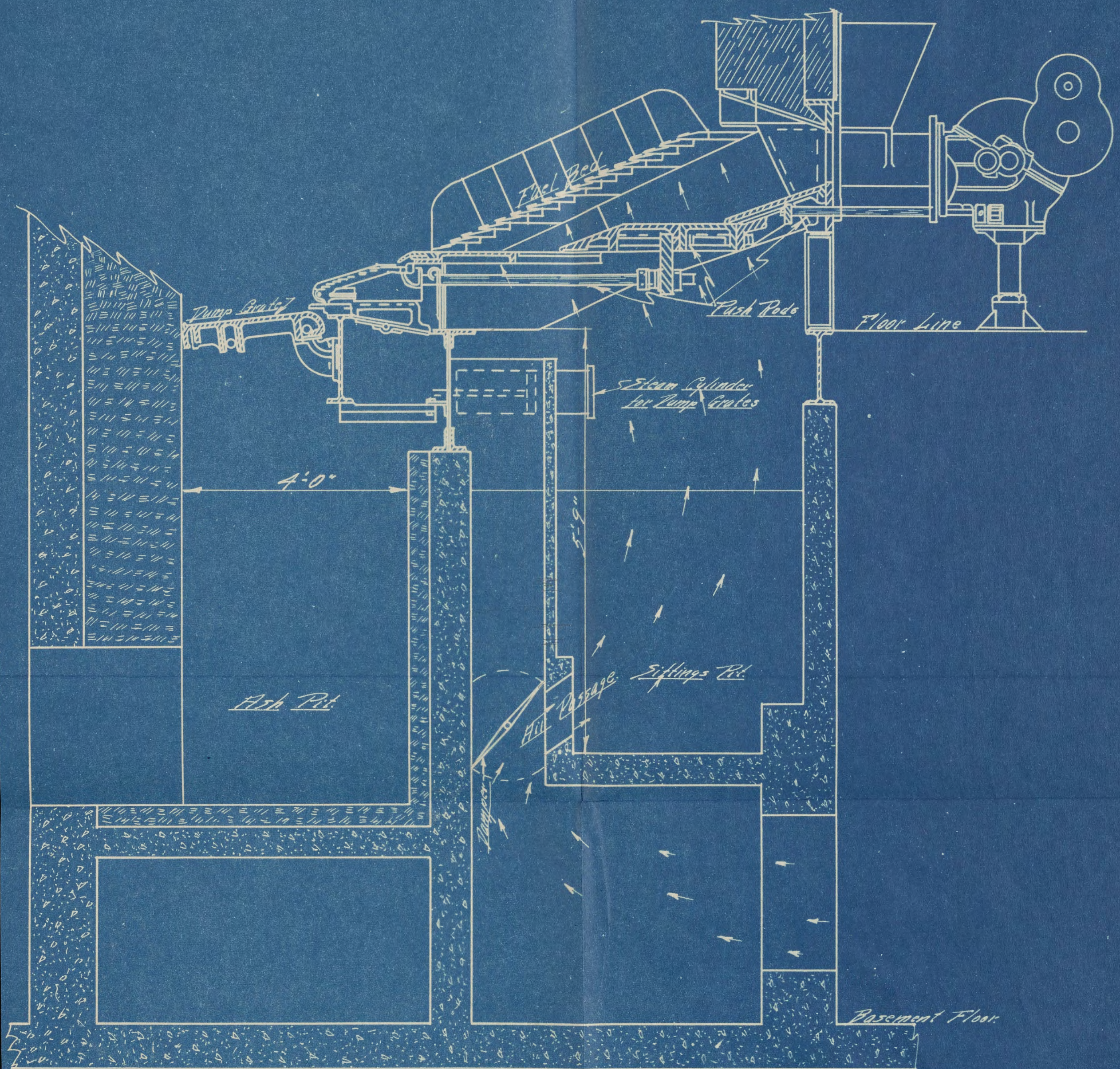


Fig. 3.

SECTION THROUGH STOKER  
AND SETTING AFTER THE  
DIRECTION OF AIR HAD  
BEEN CHANGED

*Note that the air is distributed over the entire  
surface of the grate. The damper can be ad-  
justed to throw most of the air to the  
top when needed.*

*Scale,  $\frac{3}{4}" = 1'-0"$   
Date, May. 13, 1928*

A flue gas analysis was made each day from October 15, 1928 to April 15, 1929. No definite time was set to take these samples. In this way the firemen had no chance to get their fire in good shape. The readings are very low. The highest CO<sub>2</sub> obtained over the entire period was 6.6 percent. This sample was taken December 10, 1928. The average for the entire period was 4.89 percent.

| Date                    | Average Percent CO <sub>2</sub> |
|-------------------------|---------------------------------|
| Oct. 15th to 31st, 1928 | 4.53%                           |
| Nov. 1st to 15th, 1928  | 4.47%                           |
| Nov. 15th to 30th, 1928 | 4.46%                           |
| Dec. 1st to 15th, 1928  | 4.66%                           |
| Dec. 15th to 31st, 1928 | 4.6%                            |
| Jan. 1st to 15th, 1929  | 4.92%                           |
| Jan. 15th to 31st, 1929 | 4.95%                           |
| Feb. 1st to 15th, 1929  | 5.37%                           |
| Feb. 15th to 28th, 1929 | 5.32%                           |
| Mar. 1st to 15th, 1929  | 5.21%                           |
| Mar. 15th to 31st, 1929 | 5.07%                           |
| Apr. 1st to 15th, 1929  | 5.2%                            |

From chart No. 1 it is seen that with 5 percent CO<sub>2</sub>, 31 percent of the fuel burned is lost. With 8 percent CO<sub>2</sub>, 20 percent of the fuel burned is lost. With 12 percent CO<sub>2</sub>, 10.3 percent of the fuel burned is lost.\*

\*Chart by Westinghouse Electric Company.

Since the average  $\text{CO}_2$  had been less than 5 percent it was evident from the above figures that a great saving in the coal could be made if this average could be raised.

Figure 1 shows a cross-section of the stoker and setting. The air was supplied with a centrifugal fan, driven by a steam engine. This engine is equipped with a Kielholtz regulator equipped with a Mason valve. The air enters through a steel conduit at A, passes under a fake floor and enters the vertical air passage at B. This vertical air passage is equipped with a damper. The air is forced through this passage and strikes the bottom of the toe of the stoker at C. This stoker is equipped with tuyeres between the retorts. From Figure 2, which shows a section A-A, it is noticed that the vertical air passage does not extend the entire length of the setting.

The air has considerable velocity and more air will pass through the tuyeres directly over the passage than will pass through the other tuyeres. This would happen if the resistance were the same all over the fuel bed. Since most of the coal is burned when it reaches the toe of the grate, especially when the load is light, the fuel bed is thin near the toe and the resistance is less. This causes more air to pass through near the toe of the stoker. In order to get enough air through the coal near the back of the stoker the pressure under the grate must be high. This causes a great excess of air and hence low  $\text{CO}_2$ . It was noticed that the coal directly over the air passage burned faster than on the other side. This caused the fire to be uneven and required the fireman to

keep this part covered up by pushing coal over it with a rake.

Most of the volatile matter is given off as soon as the coal begins to burn. This takes place near the back of the grate. Most of the coal burns by the time it reaches the middle of the grate. Since this is the case, most of the air is needed near the back of the grate and not at the toe.

The ideal arrangement would be to have dampers arranged so that nearly all the air could be cut off from the toe of the grate and let it pass through at the middle and back of the grate. The damper at the toe could be opened just before dumping and the coal that was in that section could all be burned.

After examining this stoker it was found that it was not practical to try to install a damper near the toe. The stoker is assembled in sections and ribs sixteen inches deep extend from the bottom of the grate. The spaces between these ribs are filled with pusher rods that work back and forth. It would be almost impossible to make a damper that could be adjusted and still cut the air off from the toe of the stoker.

An air passage 12" X 48" was cut in the vertical air passage as shown in Figure 3. The damper was made wider and by changing its position all the air can be forced through the new passage, or most of it can be made to go through the old passage, or it can be cut off entirely. It was not expected that this would entirely remedy the trouble. It does keep the air from striking the toe of the grate hardest and keeps the coal from burning over the air passage first. This eliminates

pulling new coal over this portion with a rake. With this arrangement the air pressure under the stoker is about the same at all points. There is no way to cut the air away from the toe but less should go through there than did formerly.

A ten-hour test was run on the boiler without any change in the air passage. The place cut in the side of the vertical passage was covered with a piece of sheet metal and fastened there. The next day this piece of sheet metal was taken out and the damper set to turn the air through this new passage. The results of these tests are shown, as follows:

Data from Test Before Direction of Air Had  
Been Changed. April 30, 1929

| Time     | Boiler<br>Pressure | Feed Water<br>Temperature | Quality<br>Temperature | Pressure |
|----------|--------------------|---------------------------|------------------------|----------|
| A.M.8:45 | 170                | 195                       | 232                    | 170      |
| 9:00     | 167                | 199                       |                        |          |
| 9:15     | 156                | 196                       | 262                    | 156      |
| 9:30     | 166                | 200                       |                        |          |
| 9:45     | 160                | 198                       | 282                    | 160      |
| 10:00    | 162                | 201                       |                        |          |
| 10:15    | 145                | 204                       | 284                    | 145      |
| 10:30    | 150                | 202                       |                        |          |
| 10:45    | 150                | 204                       | 275                    | 150      |
| 11:00    | 160                | 206                       |                        |          |
| 11:15    | 158                | 202                       | 276                    | 158      |
| 11:30    | 170                | 202                       |                        |          |
| 11:45    | 165                | 202                       | 277                    | 165      |
| 12:00    | 162                | 200                       |                        |          |
| 12:15    | 156                | 202                       | 262                    | 156      |
| 12:30    | 161                | 202                       |                        |          |
| 12:45    | 170                | 202                       | 280                    | 170      |
| P.M.1:00 | 163                | 202                       |                        |          |
| 1:15     | 168                | 200                       | 264                    | 168      |
| 1:30     | 169                | 200                       |                        |          |
| 1:45     | 170                | 198                       | 275                    | 170      |

| Time      | Boiler<br>Pressure | Feed Water<br>Temperature | Quality<br>Temperature Pressure |     |
|-----------|--------------------|---------------------------|---------------------------------|-----|
| P.M. 2:00 | 166                | 200                       |                                 |     |
| 2:15      | 168                | 198                       | 280                             | 168 |
| 2:30      | 165                | 202                       | 275                             | 165 |
| 2:45      | 167                | 202                       |                                 |     |
| 3:00      | 157                | 201                       | 264                             | 157 |
| 3:15      | 160                | 202                       |                                 |     |
| 3:30      | 166                | 197                       | 270                             | 166 |
| 3:45      | 169                | 200                       |                                 |     |
| 4:00      | 170                | 200                       | 276                             | 170 |
| 4:15      | 166                | 198                       |                                 |     |
| 4:30      | 170                | 198                       | 266                             | 170 |
| 4:45      | 167                | 197                       |                                 |     |
| 5:00      | 168                | 196                       | 270                             | 168 |
| 5:15      | 169                | 195                       |                                 |     |
| 5:30      | 171                | 196                       | 268                             | 171 |
| 5:45      | 170                | 199                       |                                 |     |
| 6:00      | 168                | 198                       | 270                             | 168 |
| 6:15      | 157                | 198                       |                                 |     |
| 6:30      | 166                | 197                       | 268                             | 166 |
| 6:45      | 163                | 197                       |                                 |     |
| Average   | 164                | 200                       | 98%                             |     |

| Time      | Flow Meter<br>Reading | CO <sub>2</sub><br>Flue Gas | Stack<br>Temperature | Draft<br>in Water |
|-----------|-----------------------|-----------------------------|----------------------|-------------------|
| A.M. 8:45 | 14740                 | 3.8%                        | 280                  |                   |
| 9:00      | 14745                 |                             |                      |                   |
| 9:15      | 14755                 | 5.6                         | 330                  |                   |
| 9:30      | 14766                 |                             |                      |                   |
| 9:45      | 14777                 | 4.0                         | 330                  |                   |
| 10:00     | 14787                 |                             |                      | 1.1               |
| 10:15     | 14799                 | 5.8                         | 325                  | 1.1               |
| 10:30     | 14810                 |                             |                      | 1.1               |
| 10:45     | 14824                 | 5.9                         | 315                  | 1.1               |
| 11:00     | 14838                 |                             |                      | 1.1               |
| 11:15     | 14856                 | 5.8                         | 320                  | 1.1               |
| 11:30     | 14874                 |                             |                      | 1.0               |
| 11:45     | 14890                 | 5.8                         | 335                  | 1.0               |
| 12:00     | 14911                 |                             |                      | 0.8               |
| 12:15     | 14921                 | 7.0                         | 332                  | 1.0               |
| 12:30     | 14938                 |                             |                      | 1.0               |
| 12:45     | 14953                 | 7.0                         | 320                  | 0.6               |
| P.M. 1:00 | 14968                 |                             |                      | 1.0               |
| 1:15      | 14983                 | 7.0                         | 355                  | 1.0               |
| 1:30      | 15000                 |                             |                      | 0.5               |
| 1:45      | 15016                 | 7.6                         | 370                  | 1.0               |
| 2:00      | 15032                 |                             |                      | 1.0               |
| 2:15      | 15048                 | 6.4                         | 335                  | 0.6               |

| Time      | Flow Meter<br>Reading | CO <sub>2</sub><br>Flue Gas | Stack<br>Temperature | Draft<br>in Water |
|-----------|-----------------------|-----------------------------|----------------------|-------------------|
| P.M. 2:30 | 15063                 |                             | 350                  | 0.6               |
| 2:45      | 15078                 | 4.8                         |                      | 0.8               |
| 3:00      | 15093                 |                             | 348                  | 1.0               |
| 3:15      | 15108                 | 5.8                         |                      | 1.0               |
| 3:30      | 15123                 |                             | 338                  | 0.6               |
| 3:45      | 15137                 | 8.4                         |                      | 0.6               |
| 4:00      | 15152                 |                             | 326                  | 0.6               |
| 4:15      | 15167                 | 7.3                         |                      | 1.0               |
| 4:30      | 15182                 |                             | 350                  | 0.6               |
| 4:45      | 15196                 | 8.2                         |                      | 0.8               |
| 5:00      | 15211                 |                             | 352                  | 0.8               |
| 5:15      | 15226                 | 7.0                         |                      | 0.5               |
| 5:30      | 15240                 |                             | 342                  | 0.5               |
| 5:45      | 15254                 | 7.8                         |                      | 0.5               |
| 6:00      | 15268                 |                             | 338                  | 0.6               |
| 6:15      | 15282                 | 6.2                         |                      | 0.9               |
| 6:30      | 15296                 |                             | 347                  | 0.5               |
| 6:45      | 15310                 | 6.2                         |                      | 0.8               |
| Average   |                       | 6.35                        | 335                  | 0.83              |

Boiler Test Before Direction of Air Had Been  
Changed. April 30, 1929

Dimensions

|                                  |               |
|----------------------------------|---------------|
| Boiler Heating Surface - - - - - | 3,470 sq. ft. |
| Grate Area projected - - - - -   | 66 sq. ft.    |

Fuel Analysis

|                              |                 |
|------------------------------|-----------------|
| Ash - - - - -                | 7.9%            |
| Moisture - - - - -           | 2.8%            |
| Heat Value, B. t. u. per lb: |                 |
| As fired - - - - -           | 13,041 B. t. u. |
| Dry - - - - -                | 13,417 B. t. u. |
| Combustible - - - - -        | 14,567 B. t. u. |

General Data

|                                          |                           |
|------------------------------------------|---------------------------|
| Average boiler pressure - - - - -        | 164 lbs. sq. in.          |
| Average feed water temperature - - - - - | 200° F.                   |
| Coal as fired - - - - -                  | 18,000 lbs.               |
| Ash from pit (dry) - - - - -             | 1,460 lbs.                |
| Feed Water - - - - -                     | 136,800 lbs.              |
| Average stack temperature - - - - -      | 335° F.                   |
| Average draft under fuel bed - - - - -   | 0.83 in. H <sub>2</sub> O |
| Quality of steam - - - - -               | 98%                       |

Hourly Quantities

|                                                                                |          |
|--------------------------------------------------------------------------------|----------|
| 1. Duration of test, hr.                                                       | 10       |
| 2. Fuel as fired, lb. per hr. = $18,000 \div 10 =$                             | 1,800    |
| 3. Dry fuel, lbs. per hr. = $17,496 \div 10 =$                                 | 1,749.6  |
| 4. Fuel as fired, lb. per sq. ft. grate surface<br>per hr. = $1,800 \div 66 =$ | 27.3     |
| 5. Dry fuel, lb. per sq. ft. grate surface per<br>hr. = $1,749.6 \div 66 =$    | 26.5     |
| 6. Actual Evaporation lbs. per hr.<br>$136,800 \div 10 =$                      | 13,680   |
| 7. Factor of evaporation = $\frac{1179.8 - 168}{970.4}$                        | 1.042    |
| 8. Equivalent evaporation lb. per hr. =<br>$13,680 \times 1.042 =$             | 14,254.6 |
| 9. Boiler horsepower developed $14,254.6 \div$<br>$34.5 =$                     | 401      |
| 10. Rated capacity (10 sq. ft. h.s. = 1 hp) =<br>$3470 \div 10 =$              | 347      |
| 11. Percent builders rating 100 ( $401 \div 347$ ) =                           | 115.8%   |

Evaporation

|                                                                                 |      |
|---------------------------------------------------------------------------------|------|
| 12. Actual evaporation, lb. per lb. of coal as<br>fired $13,680 \div 1,800 =$   | 7.6  |
| 13. Actual evaporation, lb. per lb. dry coal<br>$13,680 \div 1749.6 =$          | 7.83 |
| 14. Equivalent evaporation lb. per lb. coal as<br>fired $14,254.6 \div 1,800 =$ | 7.92 |

15. Equivalent evaporation, lb. per lb. dry  
 coal  $14,254.6 \div 1,749.6 =$  8.15
16. Equivalent evaporation, lb. per lb. of  
 combustible burned  $7.92 \div (1 - (0.0293 -$   
 $0.0803) ) =$  8.90
17. Equivalent evaporation per sq. ft. heating  
 surfact per hr.  $14,254.6 \div 3,470 =$  4.11

Efficiencies

18. Efficiency of boiler, furnace and grate  
 $100 (7.92 \times 970.4) \div 13,041 =$  58.8
19. Efficiency on combustible basis  
 $100 \times (8.90 \times 970.4) \div 14,567 =$  59.3

## Data from Test After Direction of Air

Had Been Changed. May 1, 1929

| Time       | Boiler<br>Pressure | Feed Water<br>Temperature | Quality<br>Temperature | Pressure |
|------------|--------------------|---------------------------|------------------------|----------|
| A.M. 10:00 | 141                | 194                       |                        |          |
| 10:15      | 139                | 192                       | 268                    | 139      |
| 10:30      | 160                | 196                       |                        |          |
| 10:45      | 146                | 192                       |                        |          |
| 11:00      | 143                | 190                       |                        |          |
| 11:15      | 146                | 192                       |                        |          |
| 11:30      | 165                | 192                       |                        |          |
| 11:45      | 147                | 192                       |                        |          |
| 12:00      | 165                | 190                       | 282                    | 165      |
| 12:15      | 152                | 195                       |                        |          |
| 12:30      | 153                | 194                       | 278                    | 153      |
| 12:45      | 120                | 178                       |                        |          |
| P.M. 1:00  | 170                | 185                       | 272                    | 170      |
| 1:15       | 140                | 191                       |                        |          |
| 1:30       | 170                | 194                       | 278                    | 170      |
| 1:45       | 132                | 200                       |                        |          |
| 2:00       | 170                | 190                       | 278                    | 170      |
| 2:15       | 139                | 184                       |                        |          |

| Time    | Boiler<br>Pressure | Feed Water<br>Temperature | Quality<br>Temperature | Pressure |
|---------|--------------------|---------------------------|------------------------|----------|
| 2:30    | 158                | 186                       | 278                    | 158      |
| 2:45    | 167                | 190                       |                        |          |
| 3:00    | 156                | 194                       | 276                    | 156      |
| 3:15    | 169                | 194                       |                        |          |
| 3:30    | 165                | 196                       | 274                    | 165      |
| 3:45    | 171                | 194                       |                        |          |
| 4:00    | 170                | 196                       | 276                    | 170      |
| 4:15    | 167                | 196                       |                        |          |
| 4:30    | 166                | 195                       | 272                    | 166      |
| 4:45    | 170                | 197                       |                        |          |
| 5:00    | 167                | 196                       | 276                    | 167      |
| 5:15    | 167                | 197                       |                        |          |
| 5:30    | 167                | 198                       | 277                    | 167      |
| 5:45    | 167                | 199                       |                        |          |
| 6:00    | 170                | 202                       | 278                    | 170      |
| 6:15    | 170                | 203                       |                        |          |
| 6:30    | 168                | 202                       | 276                    | 168      |
| 6:45    | 169                | 202                       |                        |          |
| 7:00    | 168                | 200                       | 270                    | 168      |
| 7:15    | 169                | 200                       |                        |          |
| 7:30    | 162                | 200                       | 268                    | 162      |
| 7:45    | 162                | 200                       |                        |          |
| 8:00    | 160                | 200                       | 266                    | 160      |
| Average | 159                | 195                       | 98%                    |          |

| Time     | Flow Meter<br>Reading | CO <sub>2</sub> in<br>Flue Gas | Stack<br>Temperature | Draft<br>in Water |
|----------|-----------------------|--------------------------------|----------------------|-------------------|
| AM.10:00 | 16039                 | 8.6                            | 356                  | 0.8               |
| 10:15    | 16051                 |                                |                      | 0.8               |
| 10:30    | 16076                 | 6.2                            |                      | 0.8               |
| 10:45    | 16096                 |                                |                      | 0.9               |
| 11:00    | 16114                 | 6.6                            |                      | 0.8               |
| 11:15    | 16132                 |                                |                      | 0.8               |
| 11:30    | 16152                 | 7.2                            |                      | 0.6               |
| 11:45    | 16170                 |                                |                      | 0.8               |
| 12:00    | 16188                 | 7.6                            | 426                  | 0.6               |
| 12:15    | 16210                 |                                |                      | 0.6               |
| 12:30    | 16225                 | 7.2                            | 428                  | 0.6               |
| 12:45    | 16236                 |                                |                      | 0.6               |
| P.M.1:00 | 16255                 | 6.4                            | 418                  | 0.4               |
| 1:15     | 16266                 |                                |                      | 0.6               |
| 1:30     | 16283                 | 7.4                            | 396                  | 0.6               |
| 1:45     | 16304                 |                                |                      | 0.6               |
| 2:00     | 16318                 | 8.2                            | 410                  | 0.4               |
| 2:15     | 16336                 |                                |                      | 0.6               |
| 2:30     | 16351                 | 9.8                            | 412                  | 0.8               |
| 2:45     | 16368                 |                                |                      | 0.6               |
| 3:00     | 16382                 | 8.4                            | 390                  | 0.6               |
| 3:15     | 16400                 |                                |                      | 0.4               |
| 3:30     | 16413                 | 10.2                           | 420                  | 0.6               |

| Time    | Flow Meter<br>Reading | CO <sub>2</sub> in<br>Flue Gas | Stack<br>Temperature | Draft<br>in Water |
|---------|-----------------------|--------------------------------|----------------------|-------------------|
| 3:45    | 16428                 |                                |                      | 0.4               |
| 4:00    | 16443                 | 9.0                            | 410                  | 0.4               |
| 4:15    | 16458                 |                                |                      | 0.6               |
| 4:30    | 16475                 | 7.6                            | 422                  | 0.6               |
| 4:45    | 16488                 |                                |                      | 0.4               |
| 5:00    | 16504                 | 8.4                            | 424                  | 0.6               |
| 5:15    | 16518                 |                                |                      | 0.6               |
| 5:30    | 16532                 | 8.6                            | 418                  | 0.4               |
| 5:45    | 16457                 |                                |                      | 0.4               |
| 6:00    | 16558                 | 8.4                            | 420                  | 0.4               |
| 6:15    | 16570                 |                                |                      | 0.4               |
| 6:30    | 16583                 | 8.0                            | 400                  | 0.5               |
| 6:45    | 16598                 |                                |                      | 0.5               |
| 7:00    | 16610                 | 8.8                            | 360                  | 0.5               |
| 7:15    | 16626                 |                                |                      | 0.6               |
| 7:30    | 16638                 | 7.6                            | 320                  | 0.6               |
| 7:45    | 16655                 |                                |                      | 0.6               |
| 8:00    | 16665                 | 8.4                            | 330                  | 0.6               |
| Average |                       | 8.04                           | 398                  | 0.58              |

Boiler Test After Direction of Air Had  
Been Changed.    May 1, 1929

Dimensions

|                                 |               |
|---------------------------------|---------------|
| Boiler Heating Surface- - - - - | 3,470 sq. ft. |
| Grate Area projected - - - - -  | 66 sq. ft.    |

Fuel Analysis

|                                     |               |
|-------------------------------------|---------------|
| Ash - - - - -                       | 7.32%         |
| Moisture - - - - -                  | 3.25%         |
| Heat Value B.t.u. per lb.-- - - - - |               |
| As Fired - - - - -                  | 13,191 B.t.u. |
| Dry - - - - -                       | 13,634 B.t.u. |
| Combustible - - - - -               | 14,707 B.t.u. |

General Data

|                                          |                          |
|------------------------------------------|--------------------------|
| Average boiler pressure - - - - -        | 159 lbs.sq.in.           |
| Average feed water temperature - - - - - | 195°F.                   |
| Coal as fired - - - - -                  | 19,000 lbs.              |
| As from pit (dry) - - - - -              | 1,530 lbs.               |
| Feed water - - - - -                     | 150,240 lbs.             |
| Average stack temperature - - - - -      | 398°F.                   |
| Average draft under fuel bed - - - - -   | 0.59 in.H <sub>2</sub> O |
| Quality of steam - - - - -               | 98%                      |

### Hourly Quantities

1. Duration of test, hr. 10
2. Fuel as fired, lb. per hr. =  $19,000 \div 10 = 1,900$
3. Dry fuel, lb. per hr. =  $18,382 \div 10 = 1,838$
4. Fuel as fired, lb. per sq.ft. grate  
surface per hr.  $1,900 \div 66 = 28.8$
5. Dry fuel, lb. per sq. ft. grate surface  
per hr.  $1,838 \div 66 = 27.8$
6. Actual evaporation lb. per hr. 150,240  
 $\div 10 = 15,024$
7. Factor of evaporation =  $(1181.7 - 163) \div 970.4 = 1.049$
8. Equivalent evaporation, lb. per hr.  
 $15,024 \times 1.049 = 15,780$
9. Boiler horsepower developed  $15,780 \div 34.5 = 457$
10. Rated capacity (10 sq.ft.h.s = 1 h.p.) =  
 $3,470 \div 10 = 347$
11. Percent builders rating  $100(457 \div 347) = 132$

### Evaporation

12. Actual evaporation, lb. per lb. of coal  
as fired  $15,024 \div 1,900 = 7.91$
13. Actual evaporation, lb. per lb. of dry coal  
 $15,024 \div 1,838 = 8.19$
14. Equivalent evaporation lb. per lb. of coal  
as fired  $15,780 \div 1,900 = 8.30$

15. Equivalent evaporation lb. per lb. dry coal  
 $15,780 \div 1,838 = 8.58$
16. Equivalent evaporation lb. per lb. of combustible burned  $8.30 \div (1 - (0.0293 - 0.0803)) = 9.33$
17. Equivalent evaporation per. sq.ft. of heating surface per hr.  $15,780 \div 3,470 = 4.55$

#### Efficiencies

18. Efficiency of boiler, furnace and grate  
 $100(8.30 \times 970.4) \div 13,191 = 61.2$
19. Efficiency on combustible basis  
 $100(9.33 \times 970.4) \div 14,707 = 61.5$



Legend—

— Before change had been made in setting.

— After change had been made in setting.

Log of  $\text{CO}_2$  readings from flue gas before and after a change had been made in the boiler setting.

CHART No. 2.

It will be noticed that the first test showed an average of 6.35% CO<sub>2</sub>. This was higher than had been anticipated. This was due to the fact that the firemen kept the coal fairly evenly distributed by using a rake. This had not been done so faithfully before. This is not expected of a fireman in stoker operation. The second test showed an average of 8.04% CO<sub>2</sub>, or a gain of 1.69%. It was not necessary to level the fire off as frequently the second day as the first.

The efficiency of the boiler, furnace and grate for the first test was 58.8%, and for the second test 61.2%. This is a gain of 2.4%.

The highest CO<sub>2</sub> reading for the two tests was 10.2%, made on the second test. The fire at this time was the thickest and most evenly distributed at any time during the test. With a heavy load and correspondingly heavy fire fairly good results can be obtained on this boiler. It is recommended that this boiler be used only for fairly heavy loads. The new boilers in the plant are equipped with excellent apparatus for zoning the air and can be operated efficiently at low loads.

## APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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