TABLE 1 CAUSES OF SMOKE AS SHOWN ON SECOND SMOKE CHART, FIG. 11

Time	Cause	
9:38	Hooked fire boiler No. 5.	Not shown on chart (9:38–10:28)
9:42	Hooked fire boiler No. 5.	
10:03	Hooked fire boiler No. 6.	
10:22	Hooked fire boiler No. 5.	
10:25	Cleaned fire No. 5.	
10:28	Cleaned fire No. 6.	
10:30	Green coal entered.	
10:31	Speeding up stoker No. 6.	
10:32	Speeding up stoker No. 6.	
10:33	Speeding up stoker No. 5.	
10:35	Cleaned fire No. 4.	
10:40	Cleaned fire No. 3.	
10:42	Cleaned fire No. 3.	
10:43	Cleaned fire No. 2.	
10:45	Cleaned fire No. 2.	
10:48	Green coal entered No. 3 and No. 4.	
10:49	Green coal entered No. 2.	
10:50, 10:52, 10:54	Green coal entering recently cleaned fires.	
10:58	Hooked fire No. 4.	
11:00	Hooked fire No. 3.	
11:01	Hooked fire No. 2.	
11:08	Banked coal falling on fire.	
11:11	Hooked fire No. 2 and No. 3.	
11:12	Hooked fire No. 2 and No. 3.	
11:16	Banked coal falling on fire.	
11:19	Banked coal falling on fire.	
11:21	Hooked fire No. 3.	
11:25	Hooked fire No. 5.	
11:28	Banked coal falling on fire.	

Time	Cause
11:30	Banked coal falling on fire.
11:37	Banked coal falling on fire.
11:40	Banked coal falling on fire.
11:46	Banked coal falling on fire.
11:50	Hooked fire No. 4.
11:55	Hooked fire No. 5.
12:02	Banked coal falling on fire.
12:08	Banked coal falling on fire.
12:13	Forced draft fan put on.
12:22	Banked coal falling on fire.
12:25	Speeded up No. 3 stoker.
12:26	Speeded up No. 4 stoker.
12:37	Banked coal falling.
12:40	Banked coal falling.
12:54	Hooked fire No. 2.
1:25	Hooked fire No. 2 and No. 6.
1:28	Hooked fire No. 3.
1:43	Hooked fire No. 2.
1:45	Hooked fire No. 3.
1:50	Hooked fire No. 6.
1:53	Stoker No. 6 speeded up.
2:15	Speed up No. 2 stoker.
2:20	Hooked fire No. 3.
2:25	Hooked fire No. 2.
2:35	Speeded up stoker No. 4.
2:47	Hooked fire No. 2.
3:10	Hooked fire No. 6. Load reduced at 2:30 p.m. accounting for no peaks from 3:10 to 4:25.
4.27	Speeded up stoker No. 5

will have to be made only about once a month. Long life is obtained from the light source, amplifier tube, rectifier tube, and photo-electric cell by extremely conservative design of the circuit and apparatus, as well as by the use of specially designed tubes. All of these are operated considerably under their rating in order that rapid deterioration will not result. The lenses will need to be cleaned only about once each week or ten days, depending on the weather.

Operating Results

The first installation of this smoke recorder was made on a pulverized-fuel boiler. Previously to this, visional inspection of the stack by means of a mirror located outside the building had been resorted to at this plant. Shortly after the installation of the recorder, a marked improvement was evident as revealed by the chart records, in decreasing the density of the smoke produced, particularly at night, when ocular inspection of the stack was impossible.

Photographs of this installation are shown in Figs. 3 and 4. The light-source unit, photo-electric amplifier, and control unit are mounted to the breeching near the point where the latter joins the stack. The breeching is 18 ft. wide at this point. In the boiler room are located the graphic instrument, the indicating light, and the alarm relay, as shown in Fig. 7 (see top portion of panel).

A smoke density chart of the above installation is reproduced in the first chart of Fig. 11. The boiler control is very effective, and therefore there is very little increase in smoke density due to load changes. Most of the smoke shown on the chart is caused by blowing soot, and comes at relatively infrequent intervals. This chart shows how the emission of smoke can be kept to a minimum in a well-designed and properly operated plant.

The smoke-recorder installation shown in Figs. 12 and 13 was made in another plant, and is on a stack to which are connected six-600 hp. boilers equipped with underfeed stokers. The second section of the chart shown in Fig. 11 is for an average day's operation except that soot was not blown from the tubes during this period. However, the first chart in Fig. 11 shows this effect very clearly for another installation, and it would be the same here. Table 1 explains in detail what caused the various periods of high smoke density in the second chart of Fig. 11, and the cause for this smoke. Such a study should help in reducing the amount of smoke produced.

There is considerable difference between various boiler installations in the quantity and duration of smoke emitted. The first chart in Fig. 11 is taken from a plant burning pulverized fuel, and consists of a very jagged line, at low smoke density most of the time. The very jagged line is caused by slight puffs of smoke emitted by the flames in the various burners and is quite regular. The chart from the stoker-fired plant in the second section of Fig. 11 shows a more regular low limit, but shows greater tendency to smoke. The peaks as shown in the tabulation are nearly all caused by firing methods incident to stoker firing such as hooking and green coal falling down in chunks, cleaning fires, etc. Blowing soot is of course incidental to both methods of firing.

Fig. 14 shows a smoke-recorder installation in a smaller industrial power plant, using underfeed stokers. The stack is four feet in diameter. The third and fourth charts in Fig. 11 show that there are frequent peaks of long duration of dense smoke, which should call for improvements in operating methods or improvements in the boiler installation itself.

Conclusions

As mentioned previously, there is a direct loss of fuel concomitant with the coloring of the stack gases with finely divided carbon particles, the extent of the loss varying with the color density of the smoke. No specific value can be assigned to the losses encountered that will cover all conditions, but the production of smoke and loss are synonymous.

The elimination of smoke is not only conducive to economy, but also contributes to the intangible good-will of the surrounding territory. It can, and should be avoided by the use of properly designed equipment and by the adoption of satisfactory operating methods.

Discussion

P. Nicholls.[13] Measurements of the products emitted from a chimney which are based on appearance or on absorption of light are at best crude, and their numerical values are not dependable as a relative measure for different conditions of the same chimney, and still less as a true comparison of the undesirable emissions from different chimneys. To be really just, different chimneys should be compared on the basis of their area, and the length of smoke viewed, that is, the length of the slot in the pipe of the instrument, should be some fixed numerical value multiplied by the product of the area of the flue or chimney and the velocity of the gases.

An instrument such as described is, however, sufficiently satisfactory for present purposes, and the more important requirements are that it should be reliable without constant attention, and should be of reasonable price. A price that would put it within the reach of the smaller plants would make it a great boon. If there should come a day when inspectors could visit a plant periodically and inspect smoke charts in the same way as a fire-insurance inspector calls for the watchman's clock cards, then their life would be easier. It is to be hoped that this new instrument will be manufactured soon on a production basis, and simplified to reduce its cost rather than complicated for greater normal accuracy.

Everett H. Bickley.[14] While the writer believes the photo-electric smoke recorder to be the best method of recording smoke

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at the present time, there are certain conditions under which the readings would not check with the Ringelmann density standards. White or yellow smoke, as generated by oil burners, ore smelters, or zinc roasters, would be recorded as black (as it should be), but the color would not check by visual observation.

A. S. Langsdorf.[15] This paper is of great interest since it makes use of an apparatus somewhat similar to a device that has been planned to yield measurements in a related field of smoke-abatement work. The particular instrument described in the paper is intended to produce a record of smoke issuing from an individual stack; however, in smoke-abatement work there is great need of a device which will give a more reliable indication than can now be obtained of the amount of solid material in suspension in the atmosphere over considerable areas. In measuring such suspended material, present practice has to be content with the weighing of deposits collected in containers of various types, or else with dust counts made with some such device as the Owens' dust counter. In both cases the results are subject to the errors common to all sampling, these errors being aggravated in this instance because of the fact that the samples are necessarily very minute in comparison with the total quantity to be determined. It was hoped that a new device, for the measurement of suspended material in a large area, might be ready for presentation at this meeting, but circumstances prevented the completion of the work. It may be in order at this time to report that the device makes use of a photo-electric cell upon which is projected a beam of light from a projector at a considerable distance, thereby making it possible to measure the amount of absorption of the light due to scattering caused by suspended material between the two stations. Many difficulties have been encountered, chief among which has been the elimination of the effect of daylight upon the photo-electric cell, but a way has been found to get around this difficulty. It is apparent that an observation which bears a quantitative relation to the condition of the atmosphere over a considerable distance, say a quarter of a mile, will be a measure of average conditions far more representative than that of a very small sample. It is expected that difficulties will be encountered in calibrating the device, since these readings will be dependent upon all kinds of floating particles, such as limestone dust, and not upon smoke and soot alone. In any case, the work thus briefly described will be presented for publication at a later date.

J. H. Walker.[16] This device will be welcomed by every enterprising power-plant operator. It fills a long-felt want.

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In Detroit at various times several devices have been experimented with for observing smoke. Periscopes and mirrors have been tried and an observer has been stationed to watch continuously the appearance of the stacks during certain periods when trouble was being experienced from excessive smoke. Now automatic cameras are trained on the stacks of central heating plants which take pictures at ten-minute intervals and record the date and time. All of these devices are more or less makeshifts. What is really needed is a continuous and instantaneous record right in front of the fireman.

Two important objections appear to the apparatus which has just been demonstrated. One is that the cost is very high. An instrument of this kind should be on each boiler if it is used at all. The purpose is not entirely accomplished if only one is installed for the entire plant, for it is necessary to know not only that there is smoke, but which boiler is the offender. If installed in this manner the total cost is a rather large figure.

The second objection that might be raised is that the instrument as now designed is hardly what one would call appropriate for a boiler room where there is exposure to coal dust. No doubt both of these objections will be remedied as the instrument becomes perfected and more of them are manufactured.

Author's Closure

The Ringelmann chart is based on the assumption that an area 60 per cent white for instance can be compared accurately with a sample of smoke in such a way that smoke which will transmit 60 per cent of the light will look the same to the eye as the mottled chart when held at a distance. The smoke recorder operates absolutely on quantity of light transmitted. The Ringelmann chart is in error, however, as soon as smoke is emitted which will reflect light, such as is the case with white smoke from various unusual fuels. The light reflected makes the smoke appear to be transmitting light even when such is not the case.

It is believed that considerable difficulty will be encountered in the development of apparatus to measure density of smoke, etc. over long distances due particularly to such things as fog, rain, etc. which it would not be desirable to measure.

The cost of the smoke recorder will decrease as the device is produced in quantities with tools, and in more or less continuous production.

The apparatus outside of the recording meter is very serviceable in any location, and is not affected by coal dust and water such as is obtained in ordinary weather outdoors. The recording meter is a standard instrument which is satisfactory in most cases for boiler-room installation. If exceptionally dirty conditions are encountered, a special case can be designed with the same meter parts which would be exceedingly rugged for severe conditions.