Laboratory and field experience with various metals applied to steel as protective coatings has produced promising results, and it is hoped to have enough confirmatory data for publication in the near future. Engineering changes in the burner arrangement of several furnaces to provide better distribution of coal and air have been responsible for the prevention of further attack and notable reduction of attack in many cases.

Smoke Abatement

At the annual meeting of the American Society of Mechanical Engineers at New York City in November, a report was presented, "Example Sections for a Smoke-Regulation Ordinance," prepared as a summary of the work for the past 5 years of the A.S.M.E. Model Smoke Law Committee, of which a Bureau of Mines representative is chairman. Nineteen written discussions were received. A special meeting of the Committee was held at Pittsburgh, Pa., in May. The 19 discussions were studied, and certain changes were made in the report. It is estimated that the report will reach its final form in the near future. At the request of the A.S.M.E., a representative of the Bureau of Mines served as chairman and prepared questions for a panel discussion of smoke abatement at the semiannual meeting at Detroit, Mich., in June. At the request of the City of Los Angeles, Calif., a meeting to discuss the abatement of smoke and noxious gases was called in Washington and was attended by representatives of the National Research Council, the Public Health Service, the National Academy of Science, the Bureau of Mines, and the mayor of Los Angeles; as a result of this conference the mayor decided upon certain administrative moves in connection with the problem. Consulting service was later given the Los Angeles area on carrying out this work. Conferences with the editorial staff of the Chicago Sun and representatives of the Bureau of Mines were held regarding a smoke-abatement campaign in Chicago. At the request of the District of Columbia government, a representative of the Bureau of Mines served as a member of a committee of three to hold hearings on the practicability of changing certain smoke-abatement regulations of the District of Columbia. Consulting service was given the cities of Wilmington, Del., and Niagara Falls, N. Y., on the establishment of smoke-abatement ordinances. Since the cessation of the war, requests for Bureau of Mines publications on smoke abatement have increased substantially.

Packaged Fuel Containing Anthracite Fines

Packaged fuels made from mixtures of anthracite fines and bituminous coals with an asphaltic binder have been investigated as a means of utilizing the smaller sizes of anthracite and of supplementing the supplies of domestic fuel.[52] In cooperation with a large industrial-equipment manufacturer, 29 experimental lots of widely varying composition, including several consisting only of anthracite and binder, were prepared on commercial coal-packaging equipment. Physical tests made to simulate the effects

[52] Schmidt, L. D., Reid, W. T., Seymour, William, and Myers, J. W., Physical and Combustion Characteristics of Packaged Fuel Containing Anthracite Fines: Bureau of Mines Rept. of Investigations 3882, 1946, 35 pp.

of handling and storage indicated that adequate cold strength was obtained in packaged fuel made entirely from anthracite fines with moderate quantities of asphaltic binder, as shown in figure 17. Other lots made from a wide variety of blends of anthracite fines and high- or low-volatile bituminous coal with the binder also possessed adequate cold strength. The compressive strength was shown to increase as the percentage of binder increased and also as the absolute size of the coal increased. The physical stability or resistance to abrasion and spalling was found to increase with increasing binder content within the limits studied. The compressive strength decreased, however, if coal of a relatively uniform size was used, as this increased the percentage of voids in the blocks.

The burning tests were conducted with equipment and firing techniques similar to those used for household heating. Packaged fuel made entirely from anthracite with reasonable quantities of asphalt binder crumbled excessively while burning, with the result that the grates became clogged, and adequate burning rates could not be maintained with the natural draft normally available from domestic chimneys. This crumbling, resulting from the lack of adequate caking properties of the fuel mixture, also caused excessive loss of unburned combustible matter in the ashpit. The addition of sufficient bituminous coal to the mixtures resulted in the manufacture of packaged fuels with satisfactory combustion characteristics. It was found that the production of smoke from these lots of packaged fuel tested depended primarily upon the quantity of binder used and only secondarily upon the volatile content and quantity of the bituminous coal used in the mixture. The effect of increased binder content upon the quantity of smoke produced is shown in figure 18. The asphaltic binder was found to produce about eight times as much smoke as the same quantity of high-volatile bituminous coal. Packaged fuel containing anthracite fines has been produced commercially by the company that cooperated in these tests.

Utilization of Mixtures of Bituminous Coal and Anthracite

Calculations and summaries were completed of many tests at a number of plants on various types of industrial stokers of mixtures of slack bituminous and fine anthracite.[53] These field tests show that the use of such mixtures is very practicable and that it is possible to change and usually to adjust to an improved condition the characteristics of a fuel bed of eastern bituminous slack coal by the addition of proper amounts of anthracite. The improved uniformity of the fuel bed of single-retort stokers makes possible less manual attention to the bed. Air flow through the fuel bed is affected. Smoke is decreased. In general, the fly ash as well as the unburned combustible in the fly ash and refuse are increased. Clinkering in the fuel bed is generally lessened. The peak-load carrying capacity of the stoker is definitely affected, usually adversely for the higher percentages of anthracite. In general, the efficiencies obtained on single-retorn stokers with the lower percentages of anthracite in the mixtures are

53/ Barkley, J. F., Burdick, L. R., and Wiggers, R., Tests of Bituminous-Anthracite Mixtures on Industrial Stokers: Bureau of Mines Rept. of Investigations 3916, 1946, 16 pp.

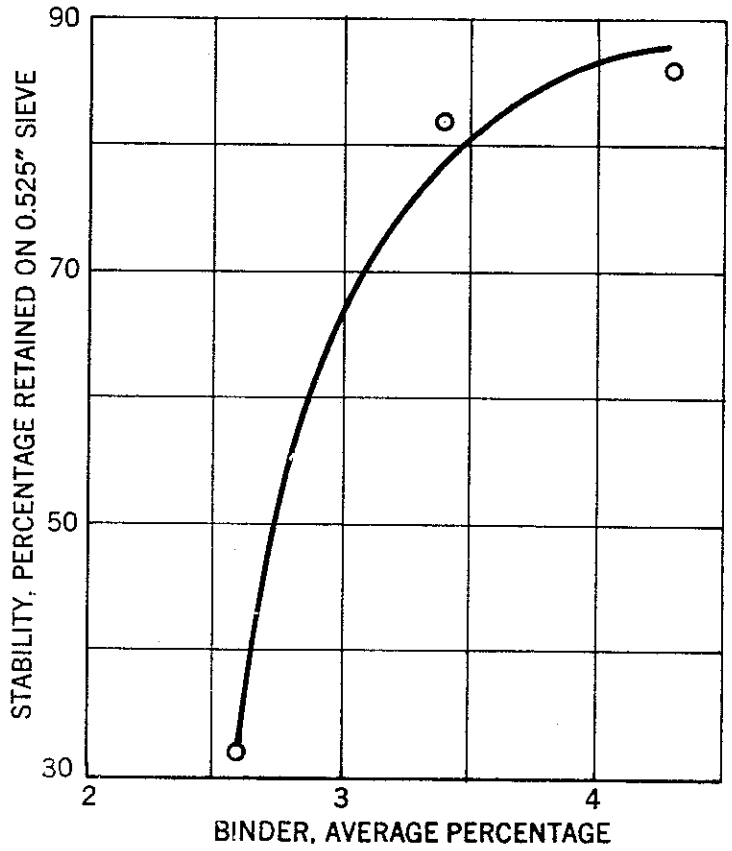


Figure 17. - Effect of binder content upon stability for packaged fuel containing only anthracite.

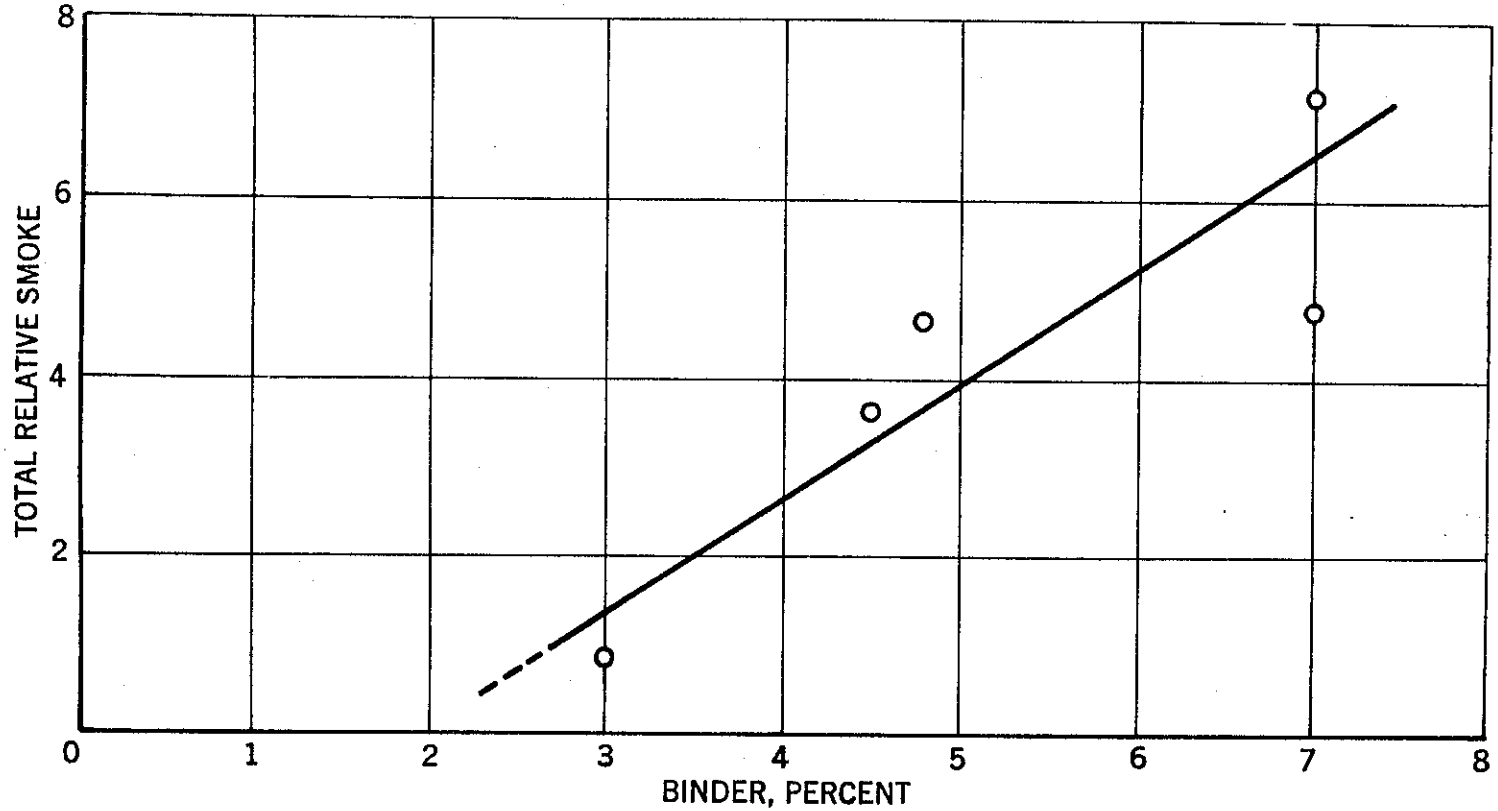


Figure 18. - Effect of binder content upon total smoke produced for packaged fuel containing only anthracite.

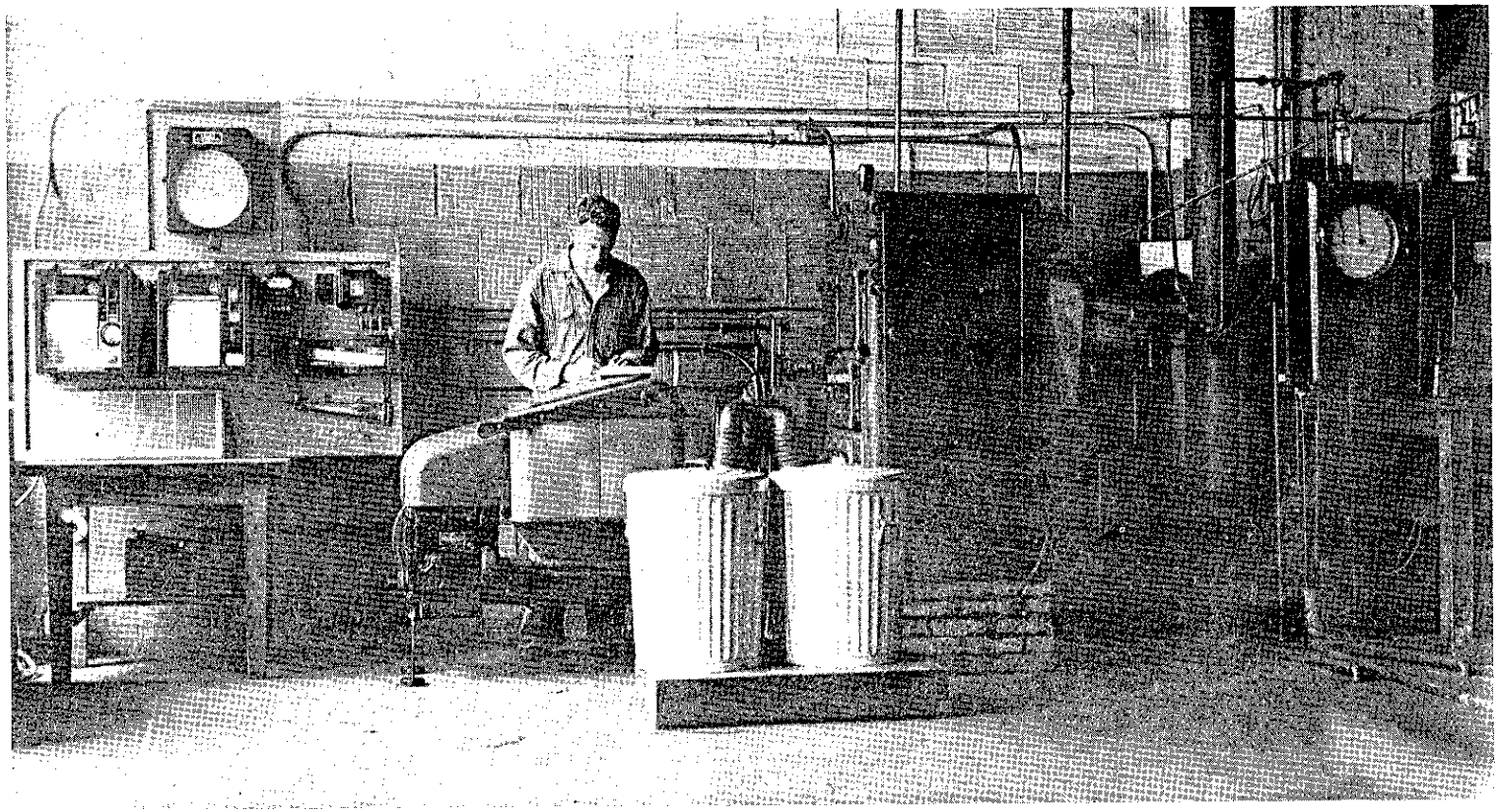


Figure 19. - Anthracite ash-removal-type stoker, hot-water boiler, and equipment used for burning trials.

about the same as with bituminous coal only. With the higher percentages of anthracite, the over-all efficiencies were found to be somewhat lower. The best percentage of anthracite to use at a given installation depends on many factors, such as the size consist, the volatile and ash content and ash fusion of the fuels to be used, the load conditions, the smoke production, and the type of equipment. It must be determined by trial for each installation. Usually, relatively simple mixing schemes can be devised at each plant to obtain a satisfactory fuel mixture for stoker use.

Ash-Removal, Domestic-Stoker Tests

Coals vary so widely in their burning characteristics that all coals prepared for domestic stoker use cannot be burned efficiently on every type of stoker. The overfeed stoker operates satisfactorily when burning low- to high-ash, noncaking, bituminous or subbituminous coals; whereas, on the clinkering-type, underfeed, bituminous stoker, both caking and noncaking bituminous and subbituminous coals are burned. Generally, these coals have ash contents below 12 percent and ash-softening temperatures between 1,800° and about 2,600° F.

Bituminous and subbituminous coals with high ash-softening temperatures and high-ash contents have not been able to enter the domestic stoker-coal market in the Pacific Northwest, because clinkers are not formed readily on clinker-type underfeed stokers, especially in mild weather. The labor required and attendant inconvenience entailed in handling the large volume of ash are particularly undesirable. Accordingly, an investigation was undertaken to enable mines producing coals of the kind described to enter the stoker-coal market. An anthracite stoker that conveys the refuse from the ash pit of the furnace and deposits it in dust-tight disposal cans was selected for the burning trials.54/

It is thought that home owners in the East who already have such stokers will wish to learn how successfully bituminous caking coals can be burned, in case of an anthracite shortage.

Eight representative Washington coals were selected with respect to their caking properties and ash-softening temperatures, and eighteen heat-balance trials on these coals were made to determine their relative suitability for use on this type of stoker. All the coals were burned at low and medium feed rates, and, in addition, two of the coals were burned at a high feed rate.

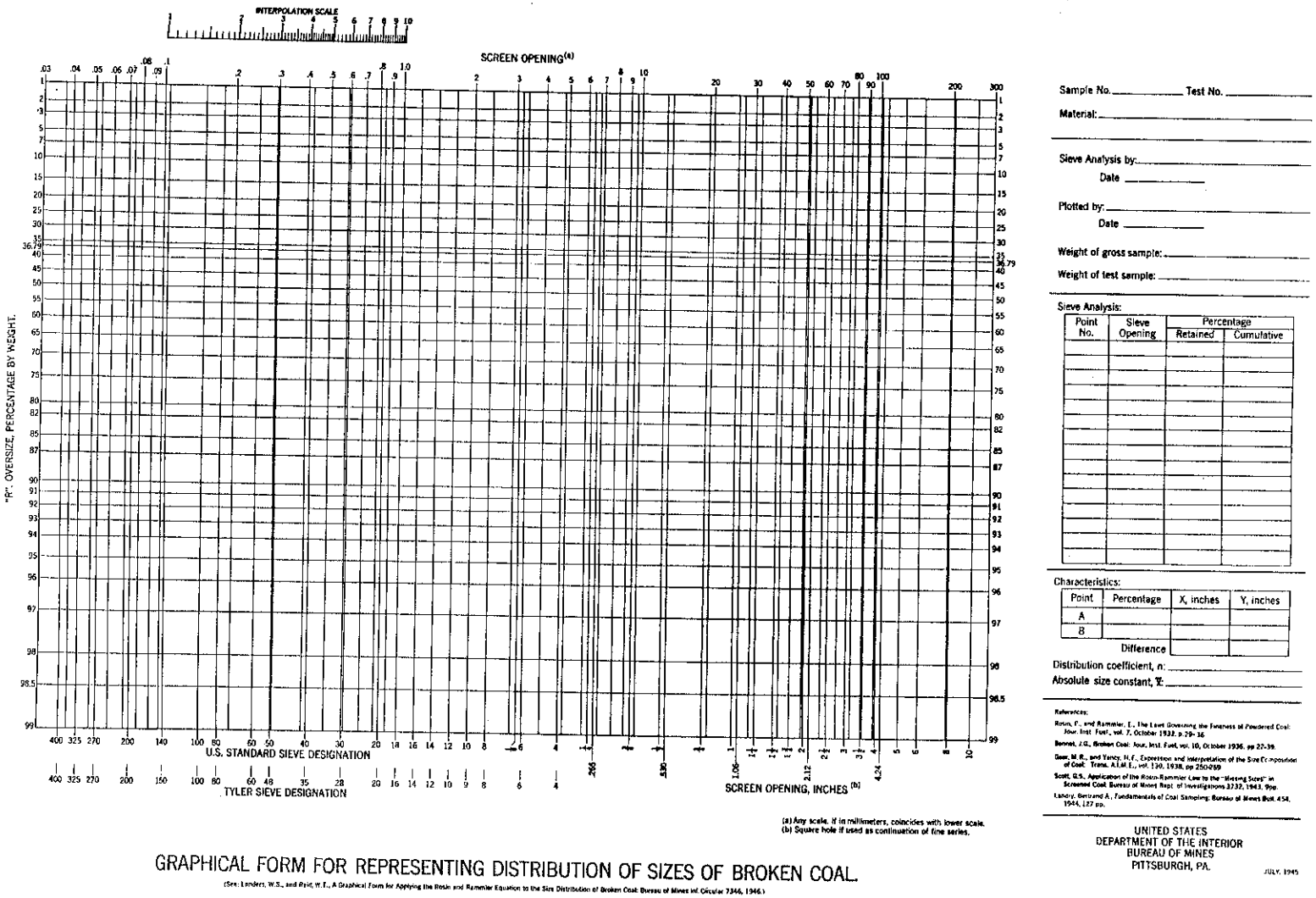
Figure 19 shows the stoker, the hot-water boiler, and the accessory equipment, and table 9 shows the principal results of the burning trials.

54/ Yancey, H. F., and Johnson, K. A., Burning Bituminous and Subbituminous Coals on an Anthracite, Ash-Removal-Type, Domestic Stoker: Bureau of Mines Rept. of Investigations 3849, 1945, 14 pp.

TABLE 9. - Principal results of stoker-burning trials on coals selected to show effect of caking properties and ash-softening temperatures

	Feed rate per hour, pounds	Heat balance, percent		
		Efficiency, heat to water	Ashes	Dry flue gases
Coal and caking properties:				
Roslyn-Cascade 1 and 4, fair caking	10.0	66.0	11.3	10.4
	17.7	63.0	17.8	9.2
Roslyn 5, fair caking	9.5	64.5	13.9	13.3
	15.3	64.6	11.5	14.1
Elk, poor caking	11.4	72.8	6.7	14.0
	17.2	65.0	12.0	14.1
Bellingham, noncoherent	10.1	79.4	.8	10.4
	16.1	75.1	.7	15.3
	22.1	73.2	1.1	15.6
Coal Creek, noncoherent	9.8	75.9	.9	11.5
	16.1	72.8	.6	16.0
	21.5	71.5	.7	17.9
Coal and ash-softening temperatures:				
Harris, 2,910+° F.	10.2	74.5	1.6	11.5
	16.4	73.7	1.4	13.6
Coal Creek, 2,780° F.	9.8	75.9	.9	11.5
	16.1	72.8	.6	16.0
	21.5	71.5	.7	17.9
Bellingham, 2,620° F.	10.1	79.4	.8	10.4
	16.1	75.1	.7	15.3
	22.1	73.2	1.1	15.6
Tono, 2,380° F.	10.0	77.8	1.2	8.5
	16.4	76.5	1.2	10.8
McKay, 2,280° F.	9.6	67.9	1.0	20.4
	14.9	67.7	1.1	21.8

It will be observed that caking coals are generally unsuitable for this type of stoker, but those caking only slightly may be used at some sacrifice in efficiency occasioned by the loss of unburned coke in the refuse. Thus, when emergency substitution of coal becomes necessary, weakly caking coals could be burned in anthracite ash-removal-type stokers with a reduction in efficiency of only 10 to 15 percent.



GRAPHICAL FORM FOR REPRESENTING DISTRIBUTION OF SIZES OF BROKEN COAL.

(See: Landers, W.S., and Reid, W.T., A Graphical Form for Applying the Rosin and Rammler Equation to the Size Distribution of Broken Coal: Bureau of Mines Inf. Circular 7346, 1946.)

Figure 20. - Form for applying Rosin and Rammler relationship to size consist.

Noncaking bituminous and subbituminous coals whose ash-softening temperatures are above 2,600° F. were burned with high efficiency, showing the practicability of using anthracite stokers to burn this type of coal for house heating. Coals with ash-softening temperatures as low as 2,380° F. also were burned with high efficiency, but the noise made by the ash-removal mechanism in crushing clinkers might be undesirable in a home. Stokers of this general type are especially desirable for burning high-ash coals, because the labor and inconvenience of handling the ashes are minimized.

Analysis of Size Distribution in Broken Coal

The Rosin and Rammler equation for expressing the distribution of sizes in crushed material is finding wide application in research and industrial problems relating to the utilization of coal and coke. It can be used to estimate the quantities of material that have been removed by screening from run of mine, crushed, or slack coal; in comparing different lots of coal, coke, or other materials; and in evaluating certain physical properties of coal. As the mathematical application of this relation to size consist data is cumbersome, a convenient and accurate graphical method has been in use for this purpose. The ruling and preparation of the special form required is tedious, and a printed form has been made available in order to extend the use of this valuable means of expressing size consist, particularly in industrial control.[55/] Figure 20 shows the form together with provisions for recording the tabular data and computations required for the application of the Rosin and Rammler relationship. In analyzing size consist data by this method, cumulative percentages retained on each sieve used in the sieve analysis are plotted against the corresponding sieve size or opening. For coal, coke, or other materials that have been shown to follow the Rosin and Rammler relationship, these points will lie on a straight line if the size consist resulting from mining or crushing has not been altered by the removal or loss of any of the material. If these points lie on a curve, it is possible to calculate the quantities of material that have been removed. When these points lie upon a straight line, the location and slope of this line provide an easy means of evaluating and describing the size distribution of the sample.

The Measurement of Heat Absorption in the Primary Furnace of a Central Station Boiler

In order to obtain the operating and design data required for the most efficient utilization of fuel in central station power plants fired with pulverized coal, the Bureau of Mines is cooperating with the American Society of Mechanical Engineers in a study of the efficiency of heat absorption in the primary furnace of a large central-station boiler. The tests are being conducted on a dry-bottom, tangentially fired, pulverized-fuel unit with a rated load of 475,000 pounds of steam per hour at 1,525 pounds per square inch gage pressure. This unit, operated by a large distributor

55/ Landers, W. S., and Reid, W. T., A Graphical Form for Applying the Rosin and Rammler Equation to the Size Distribution of Broken Coal: Bureau of Mines Inf. Circ. 7346, 1946, 5 pp.

of electrical energy, was put on the line in September 1945 and has undergone three series of tests since that time. Heat absorption in the primary furnace of this unit is being studied with respect to the following variables: (1) Age of the unit; (2) cleanliness of the walls; (3) load; (4) excess air, and (5) inclination and arrangement of the adjustable burners. The Bureau is determining the heat content of the gases leaving the furnace from measurements on the temperature, composition, and velocity of the gases at the furnace outlet. Results of these tests are then correlated with those obtained by other members of the cooperating group on the furnace-heat absorption calculated from the density of the steam-water mixture along a selected wall tube, and from the thermal gradient through the fire side of the furnace tubes, as determined by a large number of thermocouples around the furnace.

The techniques of test and the methods of calculation developed for these tests have been shown to be accurate and will be used in similar tests on other types of boilers after completion of the present series.

Automatic Water Heater

An automatic stoker-fired heating system using low-rank fuels was developed and used successfully by the Bureau of Mines.56/

The report presents practical performance data on the service water-heating system utilizing subbituminous coal and describes the development of an improved double-tank system for heating water for domestic purposes. Over a period of about 2-1/2 years, the two systems were used to supply hot water for a small laboratory using about 50 gallons a day, and observations were made periodically to find ways to heat water automatically at maximum efficiency and at the lowest cost.

A small commercial stoker originally designed for heating service water with anthracite was improved, with slight modifications to adapt it for burning subbituminous coal. The system employed a single storage tank and a combustion dome to extract heat from the coal-burning stoker. It performed satisfactorily on subbituminous coal, but the electric-power consumption was disproportionately high, because the stoker and blower unit operated continuously.

A double-tank heating system was designed to provide additional hot-water storage capacity and to increase the available heating surface, which would extract more of the heat from products of combustion discarded in the single-tank system. The stoker-operating mechanism was changed to allow it to operate intermittently and thus take advantage of the reactivity of subbituminous coal. This improved system was operated for about 18 months and was tested periodically to determine its performance under actual conditions developed during normal use.

56/ Parry, V. F., Landers, W. S., and Goodman, J. B., Automatic Water Heating Utilizing Subbituminous Coal: Bureau of Mines Rept. of Investigations 3890, 1946, 11 pp.

The following table compares the performance of the single- and double-tank heating systems when operating under practical conditions with subbituminous coal having a heating value of about 9,500 B.t.u. per pound:

	Single-tank system	Double-tank system
Coal burned per day ..... pounds	13.5	8.1
Service water used per day ..... gallons	47.3	37.0
Coal used per gallon of water ..... pound	.28	.22
Refuse ..... percent of coal burned	6.1	4.6
Ash in refuse ..... percent	69.0	81.5
Electric power consumed ..... kw.-hr. per day	2.0	.21
Temperature of service water ..... °F	150	165
Operating costs per month ..... dollars		
Coal at $6.00 per ton	3.62	.98
Power at 4 cents per kw.-hr.	1.22	.73
Cost per 100 gallons of service water heated ..... dollars	2.40	.25
	.26	.08

For several months the improved system furnished hot water at a rate of about 50 gallons a day for a total operating cost of about $1 per month, including the cost of coal and electric power. The cost of water from the single-tank system was about $3 per month owing to the disproportionately higher cost of electric power.

The improved system as operated used about 100,000 B.t.u. per day and operated at an efficiency of 71 to 72 percent. The electric power required was cut from 2.0 to 0.21 kilowatt per day by making the stoker operate intermittently. The final design of the improved system provided for a coal hopper containing 8.0 cubic feet, which was enough fuel for 1 month's operation without recharging. The ash receiver was 0.2 cubic-foot capacity and retained the ash from 300 pounds of coal.

Performance tests on the improved system revealed that water could be heated from 40° F. to 130° F. at a rate of 16 gallons an hour. Various grades of subbituminous slack coal were used in the stoker, but it was observed that the unit performed best when coal 1/16 by 1/2 inch in size was used. When using 1/2- by 0-inch slack coal, some troubles were experienced with fly ash. The stoker and heating system were designed for subbituminous coals, and the particular system employed is not suitable for higher-rank fuels because they are not reactive enough to maintain a live fuel bed unless provisions are made for frequent blowing of the bed. Subbituminous coal and lignite will remain kindled in the fuel bed for 200 minutes.

Mineral Wool from Rhode Island Anthracite

Studies are being conducted in cooperation with Rhode Island State College to determine if a slag suitable for the manufacture of mineral wool can be produced from Rhode Island anthracite. The fuel, containing more than 30 percent of high-silica ash, is mixed with local limestone and gasified