between frogs has unfortunately been mislaid, but, being on a particular layout, is of no general importance.

The frog-board used at the time was a rough affair of three pieces of siding and three nails, knocked together with an axe. An adjustable one is shown in Fig. 8, the holes on the base being bored for the different angles. This will be found very useful in laying out frogs in difficult places, especially in conjunction with switches already in.

Although in the foregoing calculations the decimals run into two and three figures, this was done to avoid cumulative errors, and were by no means used on the ground, the nearest ½-tenth being accurate enough. If the track has to be laid on rough rock grade, as happened in this case, the engineer is lucky if he can get the resultant frogs and switches within a couple of tenths, and in case of doubt it is better to have the foreman err on the side of having the point of frog moved towards the toe instead of vice-versa.

THE RELATION OF THE CHARACTER OF COALS TO THE PREVENTION OF SMOKE.

By D. T. Randall.†

The semi-bituminous and bituminous coals are the most extensively used of all the fuels which are available for generating steam. Containing as they do a considerable quantity of volatile matter which is given off when the coals are heated in the furnace, it is difficult to burn them under boilers so as to secure perfect combustion and freedom from smoke. Specially designed furnaces and careful operation are required to get good results.

The difference in the character of coals is only partly shown by the proximate analyses which are commonly used, but to one familiar with coals these analyses indicate in a general way the leading characteristics of the coals.

To show the difference in fuels the following table has been prepared:—

Table I.—Analyses of Fuels as Delivered and Used.

	Coke	Anthracite pea coal	Pocahontas coal	Pittsburg coal	Indiana coal
Moisture	4.67	4.75	1.12	2.48	9.62
Volatile matter	2.82	2.90	17.24	38.74	36.14
Fixed carbon	82.61	77.15	74.84	49.18	41.22
Ash	9.90	15.20	6.80	9.60	13.02
	100.00	100.00	100.00	100.00	100.00
Sulphur	.....	0.80	0.71	1.85	4.43
B.t.u.	12206	11886	14530	13172	11122

It will be noted that coals vary both in their composition and in their heating values (B.t.u.) and in consequenee they are more or less valuable as fuel, depending on these variations.

Other things being equal, a fuel high in fixed carbon is more easily burned in a common furnace without loss of heat and without smoke than those of lower percentages. Coke and anthracite coals are examples of this class of fuels.

The percentage of moisture is not of great importance except in cases in which the coal is naturally high in moisture, or in which the coal is very wet as a result of washing or exposure to storms. Moisture in small percentages seems to aid combustion, but in larger amounts it retards the ignition of the gases and lowers the furnace temperature. It may or may not increase the smoke, depending on the character of the fuel.

The percentage of ash and especially the character of the ash is of importance in connection with the smoke problem. Ash which is fusible and runs down on to the grate bars may cause smoke by shutting off the flow of air through the fuel, and by increasing the poking which is necessary to keep the grates free. Coals which clinker badly require more attention from the firemen and poking the fire is a common cause of smoke.

There is a great difference in the behaviour of the same coals when burned under different furnace conditions, and in different furnaces. Some grates and stokers are adapted to handle coals which are burned with great difficulty on other equipment.

The rate of burning per square foot of grate is often the deciding factor as to whether a given coal may be used or not. This is principally due to the higher temperatures which are obtained with high rates of combustion, and its effect on the fusible portion of the ash of the coal. Investigations are now being made to determine the characteristics of the ash of representative coals as related to the clinker formed at various temperatures.

So far as smoke is concerned the volatile matter is of the greatest importance. The quantity of volatile matter is not a true measure of the difficulty of burning a coal, but to one familiar with the various coal fields it is of great assistance in choosing a suitable coal or in designing a furnace suited to the given coal.

Investigations relating to the nature of volatile matter in representative coal have been carried on at the Government Fuel Testing Plant, at the University of Ohio and at the University of Illinois.

The results show that the differences in the gases given off from coals may be due to the composition of the coal and to the temperatures to which the coal is subjected when placed in the furnace. The higher temperatures tend to distill the volatile matter more rapidly and drive off the heavy hydrocarbon in forms which are difficult to burn without smoke.

Table II.—Absolute Quantities of Smoking Products in Ten Minutes Heating at Different Temperatures.*

* See paper by Porter & Ovitz in Journal of American Chemical Society, vol. xxx.

	Temperature Degrees C		Smoking Products	
Coal	Furnace	Coal	Tar per cent.	C_6H_6 – c.c.
3 Connellsville	600	441	4.9	61
1 Ziegler, Ill.	600	440	6.8	51
3 Connellsville	700	562	11.0	145
1 Ziegler	700	545	7.8	24
16 Pocahontas	700	599	4.2	138

The above table gives some idea of the complicated relation between the temperature of the coals in the furnace and the compositions of the various gases to be burned. Investigations of this character are necessary to determine the characteristics of coals from each of the representative beds.

The combustion of coke or other fuels high in fixed carbon is comparatively simple. The greater portion of the fuel is burned on the grate; the remainder in the form of gas burns at a short distance above the bed of fuel. This may readily be observed on a fire of anthracite coal in which there is only a small percentage of volatile matter.

In burning bituminous coals, however, the difficulties are much greater and for the reasons given above. The volatile matter from some coals is set free more readily than from others, and with some coals the nature of the volatile

* Presented at the Syracuse meeting of the International Association for the prevention of smoke, June 24-26, 1909.

† Engineer in charge of Fuel Engineering Department, Arthur D. Little, Inc. Laboratory of Engineering Chemistry, Boston, Mass.