The most practicable plan is to arrange a definite course of instruction as a unified graduate course based on the assumption that the technical graduates enrolled for the Master's Degree will hold undergraduate degrees in civil engineering. If the graduate instruction is to be given in the period from about December 1st to about April 1st it will be possible for practicing highway engineers, especially first, second, and third year graduates, to use the winter period advantageously in acquiring advanced knowledge under favorable circumstances.

It is gratifying to the highway engineering profession and that portion of the public interested in the development of good roads and streets throughout the United States that Columbia University should have decided to establish graduate courses in highway engineering based upon a most comprehensive plan and the principles enunciated above.

The new graduate courses to be offered at Columbia next year will cover the field of subjects referred to previously in this paper, and will in amount be sufficient to satisfy the requirements for the Master's Degree. As the period of attendance will be from December to March inclusive, two periods of residence will be required to fulfill the requirements for the Degree.

## First Year.

Process of Industrial Chemistry.

Dynamical and Structural Geology.

Advanced Highway Engineering.

Materials of Highway Engineering.

Seminary in Current Highway Engineering Literature.

Lectures by Highway Engineers, Chemists and Other Experts.

Mechanical Appliances Used in Highway Engineering. Highway Bridges and Culverts. Road Surveying, Drafting and Designing.

## Second Year.

Industrial Chemical Laboratory.

Lithology, Petrology and Petrography.

Advanced Highway Engineering.

Highway Laws and Systems of Administration.

Seminary in Current Highway Engineering Literature. Lectures by Highway Engineers, Chemists and Other

Experts.

Road Material Laboratory.

Management Engineering.

Street Surveying, Drafting and Designing.

As the special staff of instructors has been appointed and as the various laboratories required will be completely equipped in the near future all the advanced courses in highway engineering and allied subjects as outlined in the above schedule will be open to properly qualified persons next December.

It is of interest to note that this plan has the enthusiastic support of many of the foremost highway officials and engineers in the United States. All emphasize the feasibility of granting four months leave of absence to practically all the young civil engineers who wish to take graduate courses in highway engineering. It is the hope of those interested in the higher education of highway engineers in the United States that it will be possible in the near future to lay the foundation for the establishment of a corps of highway engineers comparable to that admirable body of trained men who have graduated from l'Ecole Nationale des Ponts et Chaussées of France.

## FLUE SHEET CINDER FORMATION IN LOCOMOTIVES.\*

## Robert Job.

Flue sheet cinder is the technical name for a growth which forms, as the name implies, on the flue sheets of locomotive boilers, gradually covering the ends of the flues, unless laboriously removed by the fireman, and ultimately choking the draught. Under some conditions this formation never occurs, and an engine may run year in and year out without difficulty due to this source, but with certain changes the same locomotive may suddenly find a normal rate of steaming out of the question. The composition of these clinkers varies decidedly, and the following analyses of some taken from engines using different types of fuel, will give a general idea of the range which may be found:

	No. 1	No. 2
	Anthracite	Bituminous
	Coal.	Coal.
	Per Cent.	Per Cent.
Silica	52.15	28.54
Alumina	34.51	12.30
Total Iron (figured as Fe <sub>2</sub> O <sub>3</sub> )	10.29	52.00
Total Sulphur (figured as SO <sub>3</sub> )	0.81	4.30
Lime (CaO)	2.68	2.75
Magnesia (MgO)	0.27	0.40
	100.71	100.30

in these analyses the total iron has been figured for convenience to the sesquioxide, although a part existed in the ferrous state. Clinker No. 1 was of greenish color, while the other was of a deep red due to the higher proportion of iron and to its more complete oxidation. It is interesting to note that in most cases relatively little sulphur was presented in these clinkers, or "sulphur lumps," as they are often called, and the proportion of alkalis was usually low. The cinders were generally of a characteristic structure and examination under the microscope showed that they were built up of small dark-colored particles which had fused together, resulting in a dense though somewhat porous form. Under service conditions it may be almost impossible to remove these cinders from the flue sheet owing to the more or less plastic state caused by the high temperature of the firebox. When cool they are, however, rather brittle and break with a vitreous fracture.

It was evident that the quality of the coal was of great importance, and a large number of analyses were made of a representative sample of the coal used and of the cinder found on the same run when the formation occurred. On making a comparison it was found, in general, that the composition of the coal-ash corresponded with that of the cinder, but the percentage of iron in the cinder was always higher than in the ash from which the latter was composed. Moreover, the fact was generally developed that when the proportion of iron in the coal-ash was low, say, below about I per cent., or when the color of the ash was white or gray, no formation of cinder, or only a slight one, appeared upon the flue sheets, regardless of the proportion of ash present in the coal. In fact, no formation was observed with coal of this character even when the proportion of ash in the coal averaged over 25 per cent. Under these latter conditions the flues themselves became more or less choked with the light powdery white ash "sulphur dust," as the deposit is

\* Abstract of a paper read before the American Society For Testing Materials at Atlantic City, June 27 to July 1, 1911.