E. F. BANKER,
DIRECTOR

J. B. FINK,
ASSISTANT DIRECTOR

DIVISION OF RECLAMATION
DIVISION OF FORESTRY
DIVISION OF HYDRAULICS
DIVISION OF GEOLOGY, PULLMAN
COLUMBIA BASIN COMMISSION, SPOKANE
DIVISION OF NATURAL RESOURCES

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
OLYMPIA

January 30, 1934.

CWA-S-C&D-GS-34A.

Mr. J. D. Hull, Supervisor,
Seattle, Washington.

SUBJECT: Colloidal Fuel.

Dear Sir:

This report will complete our investigation of this form of fuel; the words "disperse" and "oil-coal" are used by various writers to mean the same thing.

Essentials for a colloidal mixture are:

1st - A coal relatively low in ash and moisture
2nd - Fine grinding
3rd - Highly viscous oil
4th - A peptising agent to assist in keeping the coal particles in suspension and prevent agglomerating masses or "sludging".

PROCESS

The table following will show the necessity for fine grinding to avoid settling out of the coal in the combined mixture.

Settling Test - Fairfax, Washington Coal.

	100 Mesh			200 Mesh			325 Mesh		
Weeks	Oil Coal Settled Grams	Coal Settled Grams	Oil Coal Settled Percent	Oil Coal Settled Grams	Coal Settled Grams	Oil Coal Settled Percent	Oil Coal Settled Grams	Coal Settled Grams	Oil Coal Settled Percent
1	73.5	38.0	95.0	27.5	13.5	33.8	13.5	5.7	14.6
2	74.5	38.6	96.5	58.5	30.5	75.8	15.5	6.1	15.3
3	77.0	39.8	99.5	73.5	38.8	97.0	17.0	6.9	17.3
4	76.5	40.0	100.00	74.0	38.8	97.0	15.5	6.8	17.0
5	77.5	40.0	100.00	76.0	40.0	100.00	23.3	10.0	25.00

E. F. BANKER,
DIRECTOR

J. B. FINK,
ASSISTANT DIRECTOR

DIVISION OF RECLAMATION
DIVISION OF FORESTRY
DIVISION OF HYDRAULICS
DIVISION OF GEOLOGY, PULLMAN
COLUMBIA BASIN COMMISSION, SPOKANE
DIVISION OF NATURAL RESOURCES

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT
OLYMPIA

The finely pulverized coal and oil are thoroughly mixed, in the same method of paint mixing, stirred until the maximum dispersion is attained and the mixture free from moisture; oil at about 180° F. during stirring. The Cunard liner Scythia used a mixture of 40% coal and 60% oil and it burned satisfactorily. Creosote obtained in the carbonization of lignites of Germany seem to be the best peptising agent. The finished mixture is then burned the same as oil, gas or powdered fuel.

I am attaching a copy of a report by Dr. Schultze, December 24, 1932, which covers the experimentations in Germany. Also, a resume of the important papers and discussions at the World Petroleum Congress, July, 1933, as it covers the best collection of thought and facts to date and shows the interest being taken by coal and oil engineers.

The following publications have interesting articles:

The Engineer, July 15, 1932, refers to the work being done by the British Coal Producers.

The Engineer, July 22, 1932, has some "fine grinding" figures that are an important item in preparing the coal.

- CONCLUSIONS -

Apparently, this subject has passed the theory stage and threats of another war will bring colloidal fuel to the commercial stage on account of its many advantages.

Yours truly,

M. C. Butler

M. C. Butler,
Engineer in Charge
Coal Division.

February 3, 1933.

SUBJECT: Experiments on Firing with Colloidal Fuel, by Dr.-Ing. W. Schultes, Essen, Glückauff, vol. 68, No. 52, December 24, 1932, pp. 1198-1203.

The above interesting article describes experiments conducted at the Balcke Machine Works in Bochum, Germany, and the tests that were made by the Association for Improvement of Fuel and Power Economy in the Ruhr Collieries at Essen. Dr. Schultes, author of the article, refers to the recent experiments on the steamship "Scythia" and to the publicity given these experiments. He deprecates the apparent impression that these experiments accomplished anything new or novel and refers to the earlier experiments by Bates during the war, and by Professor Franke of the School of Technology, Hanover, in 1922-24. He says these earlier attempts to use colloidal fuel were unsuccessful because it was not possible to keep the coal in suspension for any length of time; that they had not yet found a suitable stabilizer.

But in 1931, this problem was solved at the Balcke Machine Works. By adding anthracene oil as a stabilizer, they were able to stabilize suspensions for several months. (The article does not give complete information on the stabilizer, but, in general terms, refers to it as anthracene oil. A.C.F.) A test of 100 c.c. in a glass stoppered cylinder kept at 20°C. in a place free from vibration showed only the barest beginning of separation at the end of three weeks. But even after nine months, there was no appreciable degree of separation, only about 10 c.c. of clear oil showed at that time on the surface of the suspension. It is claimed that this slight separation was due to the fact that the powdered coal used contained 4 per cent of mine moisture.

Boiler tests were made with this mixture in an internally fired boiler using the usual type of oil burner. The results were satisfactory from an operating standpoint and the thermal efficiency obtained ranged from 70 to 75 per cent, which the author considers very good. It was easy to operate without the production of smoke, although the stack showed a thin, gray smoke due to particles of ash. The article gives test data. The author observes that the colloidal fuel was easy to handle in transfer from one vessel to another.

WORLD PETROLEUM CONGRESS
July 19th-25th 1933

Section: OIL-COAL FUELS
July 24th - 2:30 p.m.

Chairman: Professor G. T. Morgan, O.B.E., D.Sc., F.I.C., F.R.S.

General Reporter: R. Lessing, Ph.D., F.I.C., F.Inst.F., M.I.Chem.E., M.Inst.P.T.

GENERAL REPORTER'S SUMMARY

The problem of using solid and liquid fuels in intimate admixture for general industrial purposes is not new. Tentative proposals were made from time to time which did not lead to commercial or technical application.

The exigencies of the War directed attention to the possibilities of substituting indigenous coal for imported fuel oils, particularly for naval purposes. Towards the end of 1917, Capstaff and Sheppard began work on preparing collodial mixtures of coal and oil, and this work led to intensive investigation by the American Submarine Defense Association, under the direction of Lindon W. Bates. At about the same time, and without knowledge of the work begun in America, R. Lessing studied the problem on behalf of the Fuel Oil Section of the Admiralty. (Samples of oil-coal mixtures prepared at the beginning of 1918, i.e., 15½ years ago, were exhibited at the meeting.)

The exploitation of the preparation of "colloidal" fuels was prosecuted by L. W. Bates after the War, but without leading to successful commercial application.

Experiments carried out in England about 1922 by the Great Central Railway, with mixtures of Yorkshire coal or coke breeze, and creosote oil or

fuel oil on locomotives gave satisfactory results, but were not followed by the use of such mixtures under regular service conditions.

The general adoption of oil fuel for naval purposes had shown the great advantages, the saving in stokehold personnel and the general convenience of liquid fuels, and rapid advances were made during the last decade in the use of oil for the propulsion of ships of the Mercantile Marine, both in the furnaces of steam-driven vessels and in Diesel engines of motor ships.

Although an immense amount of literature was published, particularly in the immediate post-War period, on the subject, much of which was based on somewhat inadequate scientific evidence or interpretation, general interest in the problem showed signs of flagging, until it was revived in the Summer of 1932 by the announcement that so important an undertaking as the Cunard Steam Ship Company had fitted out one boiler of S.S. "Scythia" for burning a 60/40 mixture of oil and coal, and that this vessel had made a voyage from Liverpool to New York during which 150 tons of this fuel were fired. The results were stated to be satisfactory although the burners required more frequent cleaning than when oil alone is used.

Interest was further stimulated by the news that experiments with mixtures of tar oil and coal on land boilers in Germany gave promising results.

The advantages of firing a coal in admixture with oil are obvious:

(1) Coal can be stored in bunkers without interstitial air spaces. The bulk weight of an oil-coal mixture is higher than that of either coal or oil, and the calorific value per unit volume is also superior to either fuel by itself.

(2) It can be pumped from distant and inaccessible bunkers or double bottoms, without manual labor.

(3) Coal in such a combination can be fired through burners like gas, oil or powdered fuel, with the efficiency peculiar to this type of combustion.

(4) The use of coal in Diesel engines in this form appears more easily accomplished than that of a dry coal powder.

(5) Ignition, both in burners or in high compression engines is usually effected at a lower temperature or compression than when oil alone is used.

(6) The density of the mixture is higher than that of water. The fire hazard is therefore lower than with oil, as bunkers can be drowned, nor is the mixture liable to spontaneous combustion like coal.

(7) The high density tends to reduce the risk of pollution of harbours and coast lines with oil, provided the mixture is resistant towards the electrolytes in salt water.

(8) The use of oil-coal mixtures permits home-produced solid fuels to be substituted for at least some of that portion of the fuel requirements of a country which for technical or other reasons must be supplied in fluid form.

There are hardly any disadvantages to be put against these advantages, provided technical perfection of the method of preparation is attained, whereby a homogeneous mixture is produced which remains stable in regard to the ratio of oil to coal throughout a bulk of commercial magnitude. The problem of effecting this stability, i.e., the prevention of separation into the components over a lengthy period of time has not yet been solved with absolute certainty, and nearly all work done in this branch or technology is directed towards this end.

The necessity of reduction to a fine particle size of the coal to be used need not constitute a disadvantage, seeing that the pulverisation of coal is now practiced on a very large scale. It merely means a certain expense which must be low enough not to affect unfavorably the economic side of the question.

A disadvantage which must be borne in mind is the ash content of the coal. It is not likely that this fuel will ever be generally acceptable, if high-ash coal slacks are used as raw material as is sometimes recommended by its protagonists. The first condition of success is the selection of coals of minimum ash content. If this requirement is not complied with, a fly-ash nuisance will be created which will militate against the adoption of oil-coal mixtures for most purposes.

Terminology:

In the past the term "colloidal fuel" has been widely applied to the material under discussion, whilst "Fliesskohle" (fluid coal" is used in Germany. There are objections to both terms. The mixture cannot claim a monopoly of the attribute "colloidal" since its two components, oil and coal, are themselves of colloidal nature and each might be justly described as colloidal fuel. The appellation "fluid coal" is hardly justivied when, as is usually the case, the greater portion of the material does not consist of coal. It is therefore to be preferred, at this stage of development, to de-

fine these products by the generic term "oil-coal fuels."

Previous Work.

The published literature dealing with the preparation of oil-coal mixtures is very voluminous. It describes the potentialities of the application of the teachings of modern colloid chemistry to the problem, rather than gives practical results substantiated by scientific evidence. The scientific or quasi-scientific papers published on the subject are largely concerned with stabilizers, fixateurs, protective colloids, and in many cases suffer from the element of secrecy apparently introduced not to avoid disclosure of knowledge, but to hide ignorance. What seems to be a vital question, the suitability of specific types of coal and oil and their compatibility has barely been touched upon. Many papers and articles in the technical press are concerned with comparisons of monetary values of coal, oil and their mixtures. Such discussions must be considered premature, so long as the technical problem of the preparation of these fuels, satisfactory in every respect, and applicable on a very large scale, has not been definitely solved.

Papers before the Meeting.

The papers to be discussed at this meeting, though small in number, cover the ground to a remarkable degree. They have the merit of touching fundamental points and of shedding the light of scientific evidence upon them.

A. B. Manning describes work carried out at H. M. Fuel Research Station on the stability of suspensions of coal in oil. He found that petroleum oils, such as paraffin oil and raw fuel oil, whose viscosity, as is well known, does not increase sufficiently with decreasing rate of shear to confer the required stability on coal suspensions therein, can be made to support pulverised coal (85% through 200-mesh I.M.M. screen) by previously dispersing 0.1 to 0.5% of sodium stearate in the oil. The viscosity of the oil under normal conditions of flow is thereby increased, but not unduly. The viscosity at small rates of shear, however, increases rapidly as the rate of shear diminishes, and indeed becomes infinite under the shearing forces involved in supporting small particles of coal. In other words, towards such particles of coal, the dilute gel behaves as an elastic solid and will support them indefinitely. It is not essential that the oil should have a gel structure in order to confer on the coal-in-oil suspension the relative stability requisite for practical purposes (e.g. no appreciable settling in six months). This degree of stability may be given by any treatment which affects the viscous properties of the oil in such a manner that its viscosity under low rates of shear has a sufficiently high value, whilst its viscosity at the rates of shear involved in normal flow remains low enough to give suspensions which can be readily pumped, etc. He concludes that the variation of the viscosity of an oil at low rates of shear is the determining factor from the point of view of the stability of suspensions of pulverized coal therein.

(Samples of a treated oil supporting coal particles in suspension and of a 60/40 mixture of Persian fuel oil and coal were exhibited.)

G. Benthin in his paper on "Fluid coal from brown coal" attacks the problem primarily from a different angle. He recognizes, as others have done before, that peptisation of coal can be effected by treatment with swelling agents, such as creosote or pyridine prior to its incorporation with the oil. In view of the more active character of the humic acids (ulmins) of lignite as compared with those of bituminous coal, Benthin regards brown coal as particularly suitable for preparing oil-coal fuels. He considers the creosote obtained in the carbonization of brown coal as a most suitable peptising agent because it contains constituents with CH- and COOH- groups polar to the same groups in the brown coal ulmins. The more concentrated the creosote is employed the better is the peptising power. Apart from this pretreatment of the coal which he prefers to give after the coal has been dried to a moisture content not exceeding 10-12%, Benthin suggests, as does Manning, gel formation in the oil by the addition of soaps or of alkali which can combine with the acidic constituents of the coal to soap-like substances. He considers that the ash content of the coal could be reduced by centrifuging the mixture, if it were possible to peptise the coal residuum, i.e., that portion insoluble in organic solvents and sodium hydroxide.

W. Schultes in his paper "Experiences with fluid coal in Germany" deals with the practical application of an oil-coal fuel in the actual firing of a steam boiler of Cornish type. He carried out a boiler test on behalf of the Verein zur Ueberwachung der Kraftwirtschaft der Ruhrzechen in Essen with the care and thoroughness customary with this Institution. The fuel was supplied by Messrs. Balcke of Bochum, but neither the composition nor the mode of preparation were given by that firm. The coal usedwas a slack from the Friedrich Ernestine pit of which the usual characteristics were ascertained. The oil on analysis was found to be the ordinary anthracene oil fraction of coal tar. The ratio of components was estimated to be 54.64% of coal and 45.36% of anthracene oil.

Stripped of experimental details the work showed that after the boiler, which had been heated up by gas prior to firing the oil-coal mixture, had attained normal running conditions, the fuel gave a steaming efficiency of 81.5%. The mixture was sufficiently fluid to be pumped and led from pressure vessels to the burners. No sedimentation of coal was observed during the two tests, which, however, were of only 6 hours duration.

The tests are interesting in that only coal and a coal product were employed in the preparation of the fuel. It must also be recognized that the dispersion of coal in a coal tar oil does not present the same difficulties as the use of a petroleum oil as the carrying medium.

Schultes discusses in detail the economics of oil-coal mixtures and gives a formula and a graphical demonstration for the calculation of their monetary value. He fixes a limit for the cost price of oil of R.M.36.35/ton below which the use of oil-coal fuels shows no advantage.

Schultes also refers briefly to experiments with oil-coal mixtures in the Rupa-Diesel engine of the Kosmos-G.m.b.h., originally designed for solid

fuel. According to a private communication from the designer, Mr. R. Pawlikowski, these trials gave promising results. The mixtures used had also been made with tar oil; the fact that they showed an appreciable tendency to separation makes it desirable to have them repeated with more stable mixtures and with such as contain petroleum oils.

On reviewing the present position of this phase of fuel technology, it must be conceded that whilst commercial success on an appreciable scale has not yet been attained, the technical and economic features of the problem of preparing and using oil-coal mistures in substitution of neat oil fuel, show sufficient promise to warrant intensive study of the questions involved, some of which are of a somewhat complex nature. In view of the common interest in this matter, of the producers of coal and oil, one might venture the suggestion that this is a case for joint research and whilst the difficulties of such an enterprise are fully recognized, the chances of success of such collaboration might be worthy of discussion.