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Alternative Carrying Media and Agglomeration Processes for Transportation of Coal

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Alternative Trägermedien und Agglomerationsverfahren für Kohletransport
Milieux porteurs alternatifs et procédés d'agglomération pour le transport du charbon
Agentes portantes alternativos y proceso de aglomeración en el transporte del carbón
石炭輸送用代替運搬手段およびアグロメレーションプロセス
煤炭运输中一种可取的承载介质和凝聚工艺
الأوساط الحاملة البديلة وعمليات التجميع الخاصة بنقل الفحم

Alternative Trägermedien und Agglomerationsverfahren für Kohletransport

Begriffe wie Colloil, COM (Coal in Oil Mixtures) und Methacoal sind in der Literatur gebräuchlich geworden.

Nicht zuletzt infolge der Knappheit oder Nichtverfügbarkeit von Süßwasser als Trägermedium für Kohle beim Pipelinetransport weisen neuere Überlegungen, Untersuchungen und Veröffentlichungen — auch zu aktuellen Projekten — immer mehr auf alternative Trägermedien wie Öl und Methanol hin.

Eine zukünftige wirtschaftliche Technologie der Kohleverflüssigung und -vergasung vorausgesetzt, hätten diese alternativen Trägermedien gegenüber Wasser den großen Vorteil, zum Teil aus der Kohle selbst hergestellt werden zu können, bei tiefen Temperaturen nicht zu gefrieren — d. h., die Rohrleitungen müßten nicht eingeerdet werden — und für den Transport selbst Wertstoff und keinen Ballast darzustellen.

Daneben wird auch die Verwendung von Äthanol und Flüssiggas (LNG-slurries) diskutiert.

Nicht zu verwechseln damit sind Methoden, sehr feinkörnigen, tonhaltigen Kokskohlen vor dem hydraulischen Transport bis zu 10 % Öl zuzugeben, wodurch ein Agglomeriereffekt für die Kohle, ein Separiereffekt für die tonigen Bestandteile nach dem Verlassen der Pipeline und eine Verbesserung der Verkokungseigenschaften der Kohle erzielt werden.

Der Aufsatz beschreibt den Stand obengenannter Techniken.

Milieux porteurs alternatifs et procédés d'agglomération alternatifs pour le transport du charbon

Des termes tels que Colloil, COM (Coal in Oil Mixtures) et Methacoal sont devenus des termes courants en littérature.

Non seulement par suite du manque ou de la non-disponibilité d'eau douce à titre de milieu porteur pour le charbon lors du transport par pipelines, des réflexions, recherches et des parutions plus récentes — portant également sur des projets à l'ordre du jour — visent de plus en plus à des milieux porteurs alternatifs comme le sont l'huile et le méthanol.

Présumant une technologie d'avenir économique de la fluidification et de la gazéification du charbon, ces milieux porteurs alternatifs présenteraient par rapport à l'eau, un avantage considérable, puisqu'ils peuvent en partie être réalisés à partir du charbon même, qu'ils ne gèlent pas à de basses températures — c'est-à-dire qu'il n'est pas nécessaire d'enterrer les conduites —, tout en représentant pour le transport même une substance utile et non pas un lest.

A part ceci, les discussions portent également sur l'emploi d'éthanol et de gaz liquéfié (LNG-slurries).

Il ne faut cependant pas confondre avec ceci les méthodes qui consistent à ajouter à du charbon à coke à grain très fin et à teneur d'argile, avant son transport hydraulique, jusqu'à 10 % d'huile, pour obtenir par là un effet d'agglomeration du charbon, un effet séparateur des composants argileux après que le mélange a quitté la pipeline, ainsi qu'une amélioration des propriétés de cokéfaction du charbon.

Le traité décrit l'état actuel des techniques susmentionnées.

Agentes portantes alternativos y proceso de aglomeración en el transporte del carbón

En las publicaciones se han popularizado los términos Colloil, COM (Coal in Oil Mixtures) y Methacoal.

Debido a la escasez o falta de disponibilidad de agua dulce como agente portante para el carbón en el sistema de transporte por pipelines, en recientes estudios y publicaciones — relacionados también con proyectos de actualidad — se hace alusión cada vez más a los agentes portantes alternativos como son aceites minerales y Metanol.

Presuponiendo el empleo en el futuro de una tecnología rentable para la licuefacción y gasificación del carbón, dichos agentes portantes alternativos ofrecerían frente al agua la enorme ventaja de en parte poder ser obtenidos a partir del mismo carbón, de no congelarse a bajas temperaturas, con lo que se podría prescindir de enterrar las pipelines, y de constituir en el transporte no un simple medio o agente sino un producto aprovechable.

A la vez se encuentra en discusión el empleo de etanol y de gas licuado (LNG-slurries).

No hay que confundir con ello aquellos métodos que preconizan la adición de hasta un 10 % de aceite a los carbones de coque de muy fina granulometría y componentes arcillosos, antes del transporte hidráulico, con lo que se consigue un efecto aglomerante para el carbón, una separación de los componentes arcillosos tras el transporte, y una mejora de las propiedades de coquización del carbón.

El artículo describe el estado actual de las citadas técnicas.

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Summary

Such terms as Colloil, COM (Coal in Oil Mixtures) and Methacoal have become a common feature in the literature.

More recent deliberations, examinations, and publications — also in respect of contemporary projects — have been tending towards alternative carrying media such as oil and methanol to an ever-increasing extent. One of the main reasons for this trend is the shortage or non-availability of fresh water as the carrying medium for coal in pipeline transportation.

Pressupposing an economic coal liquefaction and gasification technology in the future, these alternative carrying media would have the great advantage over water that they can be produced in part from the coal itself, do not freeze at subzero temperatures — i.e. the pipelines need not be buried — and represent in themselves substances of value for transportation and not ballast.

In addition, the use of ethanol and LNG slurries is discussed.

This should not be confused with methods whereby up to 10% oil is added to ultra-fine grained argillaceous coking coals before hydraulic handling whereby an agglomeration effect is obtained for the coal, a separating effect for the clay components upon leaving the pipeline and an improvement in the coking properties of the coal.

This paper describes the state of the art of the above mentioned methods.

1. Introduction

Water is a suitable carrying medium for the transportation of coal through pipelines but not, however, for later consumption because the water has to be removed at great cost before the coal can be used for firing purposes in a power station. In addition, water is either not available or not available in sufficient quantities in many locations where pipelines for coal transportation will begin in future for use as the carrying medium.

This is one of the main reasons why recent deliberations, investigations, and publications — also on the subject of present-day projects — more and more often are oriented towards alternative carrying media such as oil and methanol [1, 2, 3, 4]. Such terms as Colloil, COM (Coal in Oil Mixtures) and Methacoal have established themselves in the literature.

In view of the fact that the appropriate amounts of oil and solids will only rarely be present at one and the same area over a period of 20—30 years, it is said that these alternative carrying media would have the advantage over water in that they could also be produced from the coal itself. For transportation proper, they represent substances of value and not ballast. In addition, there is no risk of freezing at subzero temperatures so that the pipelines do not have to be buried.

The use of ethanol and liquefied gas (liquefied natural gas; LNG-slurries) is also being discussed.

Not to be confused with the complete substitution of water by another carrying medium are methods whereby up to 10% oil is added to ultra-fine-grain argillaceous coking coals before hydraulic handling. The result is an agglomeration effect for the coal, a separating effect for the argillaceous components upon leaving the pipeline, and an improvement of the coking properties of the coal [5].

2. Alternative Carrying Media

2.1 Coal and Oil Mixtures

At a very early stage, the oil companies had considered the problem as to how pipelines, laid for oil transportation, could be utilized in future and what was to be burned in power stations when the supplies of petroleum begin to fail. Under the name "Colloil", Shell developed a new type of fuel which can be fed to the user in the form of a coal-in-oil suspension through pipelines although more for the sake of securing their own existence than in the quest for a new carrying medium for coal pipeline. Finely ground coal is mixed with heavy heating oil and thus allows more simple and more economical handling. After many years of development work and experiments in a pilot plant in the British Shell Research Laboratory at Thornton, Chester, a larger demonstration plant for the production and use of "Colloil" went into service in the Scottish town of Renfrew in cooperation with Babcock & Wilcox. Here, "Colloil" in concentrations up to 50% by weight was charged into a boiler installation producing 27 t/h steam at a Colloil consumption of 4 t/h. It was demonstrated that Colloil is pumpable and can be continuously charged into atomizing burners. By adding additives or by selecting a production process which ensures uniform distribution of the variously sized coal particles in the heating oil, it is brought about that the suspension remains stable even after longer periods in storage or when the pipeline is out of operation.

At approximately the same time, SHELPAC, a jointly owned subsidiary of SHELL CANADA and CANADIAN PACIFIC, developed a similar system. INTERPROVINCIAL PIPELINE Co. (IPL) in Canada thereafter investigated the possibility of pumping low-sulphur coal from Alberta through an existing 48 inch crude oil pipeline in the form of a mixture consisting of oil with up to 35% coal to the power stations of Ontario or to other industrial concerns located en route.

In the autumn of 1979, there were reports from Japan and the USA on a new fuel mixture of coal and oil [6]. Under the name COM (Coal in Oil Mixtures), the Japanese Dengen Kaihatsu Electric Power Development produced a mixture of finely ground coal and heavy oil which could be transported through pipelines and which can be used for firing in power stations instead of oil. A surface-active additive prevents the coal particles from settling. A long-term experiment to convert oilfired power station boilers to a fuel mixture of oil and coal dust began in the 80 MW Salem Harbour power station in the USA. At first 10% and then, later 30% coal is added to the oil. It is reported that 50,000 t coal can replace more than 200,000 barrels of oil.

A completely new fuel under the designation "CoaLiquid" has been developed by Messrs. CoaLiquid Inc., of Louisville, Ky., USA, to replace oil. It consists of 50% pulverized coal, up to 40% oil, and 10 to 20% water. A patented ultrasonic process to mix the coal, oil and water, prevents subsequent sedimentation [7]. This process is reminiscent of the Cottel process [8] which became known in 1974 where a mixture of finely ground coal, oil, and water in the ratio 60:20:20 is so treated by ultrasonics that the water is dispersed ultrafine and results in a highly effective but at the same time, environmentally acceptable, combustible mixture. Fig. 1 shows a diagram of a transportation and heating system for the combustion of a coal — oil — water emulsion as the main fuel.

The information provided by all the examples quoted as to the suitability of oil as the carrying medium for coal in pipeline transportation is inadequate. With a specific density of approx. 0.8 g/cm³, the carrying properties of oil are, in the first place, lower than those of water. Giving the

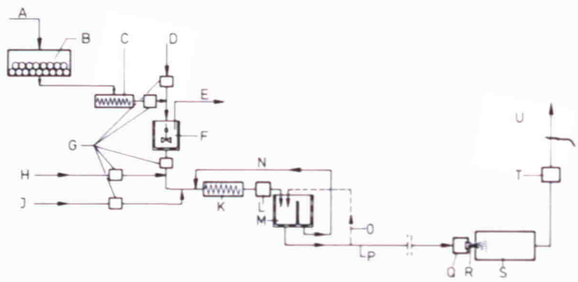

Fig. 1: Diagram of a transportation and industrial heating system for combustion of a coal-oil-water emulsion as main fuel

A = Coal	L = Ultrasonics
B = Ball mill	M = Supply tank
C = Vibratory trough	N = Oil return
D = Water	O = By pass
E = Air bleed	P = Pipeline
F = Mixing tank	Q = Ultrasonic reactor
G = Control equipment	R = Feed air
H = Oil	S = Combustion chamber
J = Lime slurry	T = Dryer
K = Premixer	U = Waste gas

concentration of coal in the mixture by weight provides no useful information if the grain size distribution of the coal, the type of coal, and the type of oil are not given at the same time. The flow behaviour of coal and oil mixtures has been investigated amongst others in [9] and [10]. Here, it was established that there is a high degree of dependence of the viscosity on the grain size of the coal particles and, above all, on the coal content and temperature. Fig. 2 from

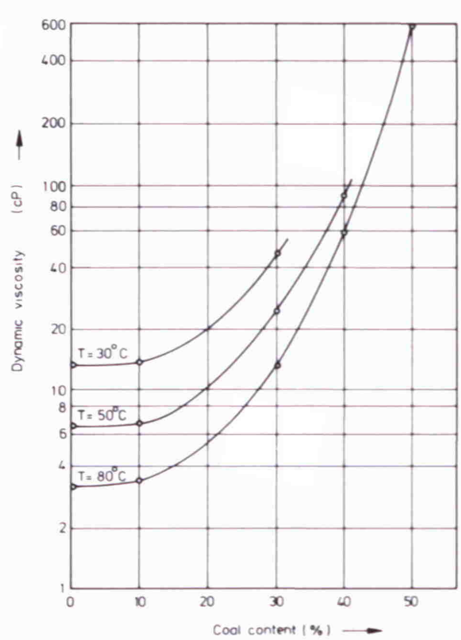

Fig. 2: Relationship between viscosity of a coal and oil suspension on the coal content and temperature

[9] shows that a maximum coal content of 30% can be attained in the coal-tar oil in the temperature range of T < 30 °C which is of technical interest for pipeline transportation because the viscosity rises steeply as a function of the physical properties of the partner-constituents of the mix at a 10—30% coal content ($d_s < 40\,\mu m$). It does not make sense to exceed the value of 30% coal at T = 30 °C because these suspensions could neither be pumped nor subsequently atomized. In consequence, the transportation of coal using oil as the carrying medium would not really be of any economic interest because the percentage of solid coal components is strictly limited.

2.2 Coal and Methanol Mixtures

In the first instance, the same considerations apply for the use of methanol as the carrying medium in the pipeline transportation of coal as for the use of oil although methanol can already be produced commercially at present from natural gas or oil and would thus reduce the dependence upon petroleum. For this reason, various research groups in the Federal Republic of Germany investigated alternative fuels for vehicles as long ago as 1974 on behalf of the Federal German Ministry for Research and Technology and discovered that the gradual introduction of methanol is the most sensible method [11]. The amounts of methanol present in coal transportation in pipelines using methanol can be used to such useful effects that, where the methanol cannot be returned to the head station of the pipeline, it could conceivably be subjected to further processing in the chemical industry.

The production of methanol from natural gas can be described as practicable and inexpensive, from coal as practicable but expensive and from coal in conjunction with the waste heat from nuclear reactors as not yet practicable but relatively inexpensive. However, since nuclear reactor heat is not available in sufficient quantities and since natural gas and coal are certainly only available in large quantities simultaneously at few locations in the world, only the production of methanol from coal itself, following on from a gasification process, e.g. the Koppers-Totzek-coal gasification process [12], remains.

In contrast to petroleum and natural gas, coal is available in quantities which are still virtually unlimited so that a certain autarchy can only be achieved in this method although methanol can also be produced from agricultural and forestry waste, inter alia.

With regard to the carrying properties for coal, methanol is shown to be less favourable than water with a specific density of 0.795 g/cm³ at 20 °C, also, from the energy aspect, there are no immediately visible advantages because 1.46 t coal or 5.37 t lignite have to be used to produce 1 t methanol. The calorific value obtained is then even less than that of the coal previously used although, admittedly, the application form after transformation is more favourable.

The Keller Corporation of Dallas, Texas, USA, have dealt with the use of methanol as the carrying medium for coal in pipelines with great intensity. They have developed and patented what is known as the "Methacoal" process, in which primarily American lignite coal is used although any other coal could also be used. After converting part of the coal to methanol, the methanol is mixed with coal dried to 8% humidity in the ratio 1:1. The system by which the coal is dried to obtain the requisite qualitatively high-value methacoal takes place as shown in Fig. 3 where the coal fines are used to produce the hot air.

A desirable reduction in grain size is produced when the heated coal is mixed with cold methanol. The suspension is given tixotropic properties by a specific grain composition which is also obtained by subsequent comminution.

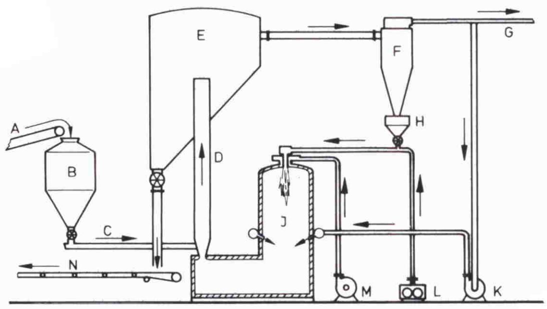

Fig. 3: Coal drying system

A = Coal supply
B = Coal supply container
C = Feed device
D = Hot air dryer
E = Coarse grain separator
F = Dust separator
G = To gas cleaning
H = Fuel tank
J = Combustion chamber
K = Blower
L = Feed air blower
M = Combustion air blower
N = Dry coal

Fig. 4 shows a diagram of a methacoal plant in which the methacoal mixture is burned at the end or can be separated again into its constituents, coal and methanol.

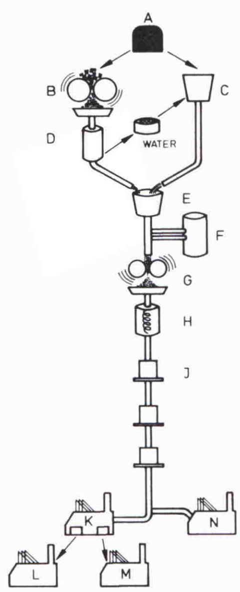

Fig. 4: Diagram of a methacoal plant

A = Coal mine
B = Crushing station
C = Methanol production
D = Coal drying
E = Mixing tank with agitator
F = Mixture reservoir
G = Fine grinding
H = Methacoal production
J = Pipeline with pump stations
K = Separating station
L = Coal power station
M = Chemical works for methanol
N = Methacoal power station

The flow properties of methacoal with 5 % moisture content are shown in Fig. 5. It can be seen that the strength decreases with increasing shear velocity and reaches a minimum at a specific diameter grain size percentage $< 30\,\mu m$, called ϕ 30, approximately 20 to 35 % volume of the entire solid. At very low shear velocities or low velocities in the pipe, the strength is very high so that sedimentation of the solids is even prevented when the system is shut down.

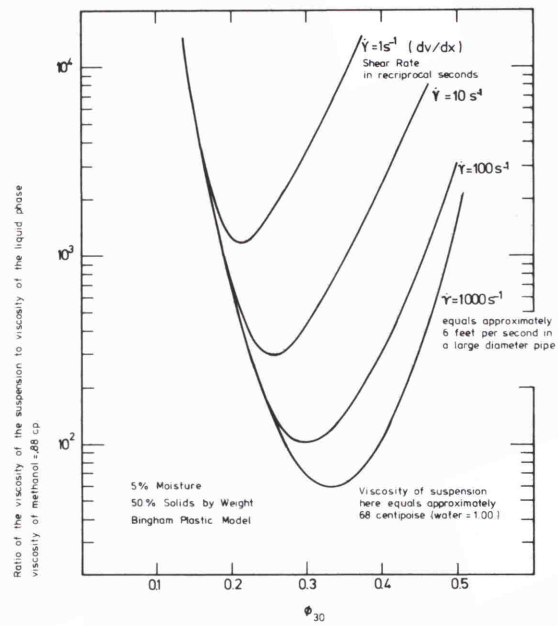

Fig. 5: Flow properties of methacoal produced from Texas lignite

One or two special features ought to be pointed out:

Methanol has the concealed risk for humans through contact or oral inhalation and is also highly explosive when mixed with air. However, these risks cannot be regarded as being higher than those for oil and gas pipelines.

3. Economic Considerations

In the first instance, an economic comparison between coal and water, coal and oil, and coal and methanol slurries [4] shows that the transportation of coal and oil mixtures is more economical in any case than coal and methanol mixtures if regarded from the point of view of the energy content of the coal (Fig. 6). In addition, it is also clear that the transportation costs increase with increasing velocity and at concentrations above 50 % by weight. If the energy content of the transportation medium is then also taken into account, the absolute costs per MBTU diminish but remain more favourable for oil than for methanol (Fig. 7), where the tendency for growing concentration and velocities remains the same.

If the product costs for methanol are estimated at US$ 7.50 per MBTU and those for oil at US$ 5.00 per MBTU, the result, as shown in Table 1, is that the transportation costs for methanol and oil pipelines are in fact slightly higher than for water pipelines if only the transportation of coal is considered. Where the energy content of the carrying media, methanol and oil, are also considered, the result, in comparison with coal and water mixtures, is high transportation cost advantages. Admittedly, the costs of transportation and carrying medium in coal and methanol and coal and oil pipelines are higher than for coal and water pipelines

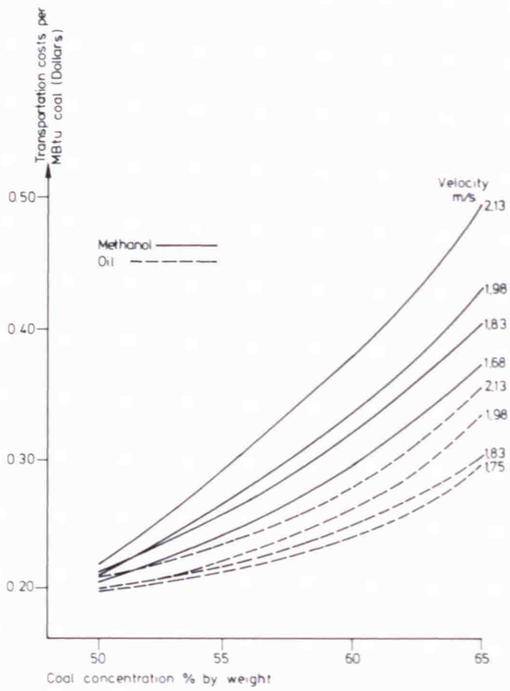

Fig. 6: Transportation costs per MBTU for coal

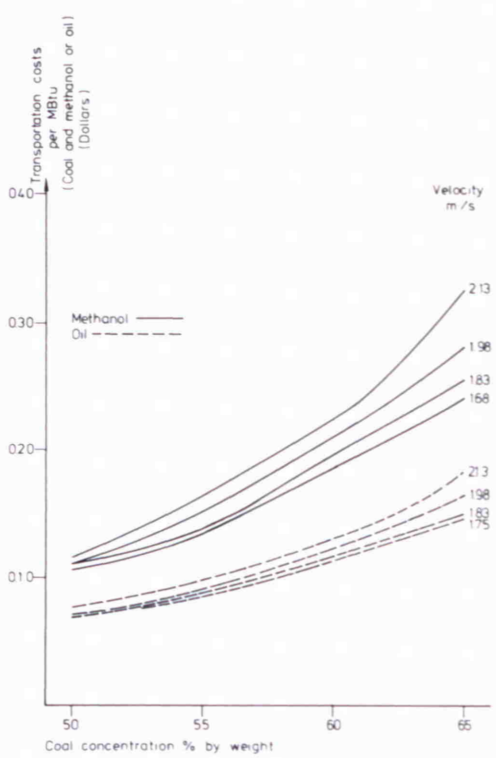

Fig. 7: Transportation costs per MBTU for coal and methanol or oil

Table 1:
Cost comparison

Type of slurry	Transportation costs per MBTU coal	Compared with water slurry
Water	US$ 0.1739	1.00
Methanol	US$ 0.2032	1.168
Oil	US$ 0.1974	1.135
	Transportation costs per MBTU coal plus methanol or oil	
Water	US$ 0.1739	1.00
Methanol	US$ 0.1066	0.613
Oil	US$ 0.0726	0.417
	Transportation plus product costs per MBTU	
Water	US$ 1.1739	1.00
Methanol	US$ 4.1962	3.575
Oil	US$ 3.6020	3.068

although this table does not reflect the savings in dehydration costs nor the further use of methanol or oil at the end of the pipeline.

This proves that the use of alternative carrying media can be of interest especially where water is scarce. Messr. Williams Brothers of the USA arrive at similar conclusions; [3] reports on their investigations. A 55 to 45 ratio of coal to methanol is described as ideal; large savings in capital investment and operating costs are reputedly the result of the lower tonnage required to transport the same amount of energy.

Because of the great potential in this technology, the suitability of methanol as the carrying fluid for coal in pipelines is being investigated all over the world. In the United States of America, the Energy Transition Corporation (ETCO) has been founded under the leadership of Charles Robinson, formerly vice-president of the financing company, Blyth Eastman Dillon & Co. together with several leading personages with the object of advancing coal as energy carrier in the United States of America and further development of the methacoal technology. In the meantime, ETCO have purchased rights in the Methacoal Corporation. The Texas A & M University, the South West Research Institute in San Antonio, Texas, USA, and also Messrs. Fried. Krupp GmbH in collaboration with Messrs. Mannesmann Anlagenbau AG, are attempting to estimate the profitability of a coal and methanol pipeline system based upon experimental data. A great many further investigations are still required.

4. Other Carrying Media

Ethanol is also quoted as an additional carrying medium but will merely be mentioned here in brief. Physically, ethanol has approximately the same properties as methanol but is less hazardous toxicologically.

In conclusion, coal could also be transported just as safely in liquefied natural gas as has been proposed for the pipeline transportation of frozen oil in LNG [13].

5. Oil Agglomeration of Coal in Pipeline Transportation

Messrs. Broken Hill Pty. Co. Ltd. (BHP) and British Petroleum Australia (BP) Ltd. have been operating a coal pipeline, 1.6 km in length, for the transportation of 30 t argillaceous coking coal per hour in the BHP coal mine of Stockton Borehole Colliery near Newcastle in New South Wales for some time. Before transportation, up to 10% oil, related to the solid, is added to the mixture. The addition of oil has a selective agglomeration effect on the fine coal particles. Upon leaving the pipeline, a layer of tailings, a layer of coal, and a layer of clear water form in settling lagoons. The coking properties of the coal do not suffer any impairment because the coal grains are coated with an oil film. This effect should be utilized to the end that no more dressing facilities need be built in future but only crushing and wetting facilities. The solid to water ratio is given as 50:50. After the initial tests in a test loop 100 m in length, the long-term target of a project 100 km in length is being planned. A diagram showing the integrated dressing, transportation, storage, and recovery facilities is shown in Fig. 8 as per [5].

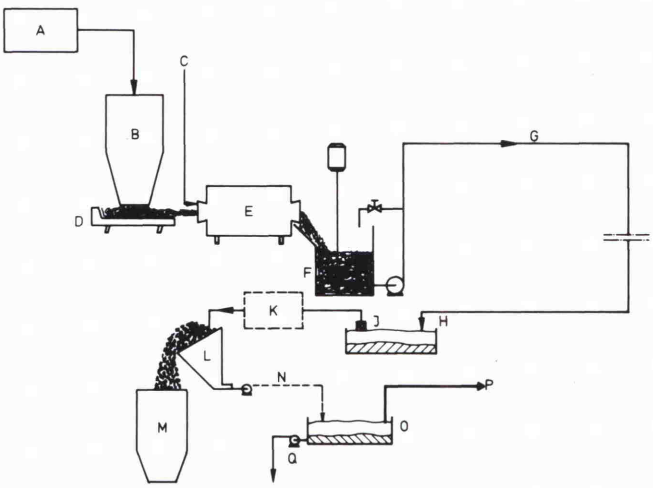

Fig. 8: Diagram showing a combined dressing, transportation, storage, and recovery plant for coal

A = Crude coal
B = Coal container
C = Oil and water emulsion
D = Feed device
E = Rod/ball mill
F = Pump sump or supply tank
G = Pipeline
H = Supply and mixing basins
J = Recovery suction head
K = Product preparation
L = Screen
M = Coking coal supply container
N = Waste water
O = Settling lagoons
P = Clear water
Q = Sediment

These companies have to open up broad application possibilities for the transportation of Australian coal from the mines to the shipping ports by means of this process which can also be applied to power station coal and thus offer a genuine alternative to the conventional means of transportation. This process can be compared with the Olifloc process developed at Ruhrkohle AG where, also by the addition of oil, it is brought about that coal particles of the grain sizes < 0.5 mm agglomerate to particles of 1.0 to 1.5 mm. This provides an improvement in the flotation and filter effect for the fine slurries [14].

Nevertheless, these processes must be regarded with some reservations from the current point of view because of the increases in price for crude oil.

6. Conclusion

Coal and water pipelines have been investigated in many examples. Alternative carrying media offer many advantages but also contain concealed risks; a great deal of fundamental information is still required before a final, definitive economic assessment can be made.

As is so often the case, no universally applicable statement can be made. Each transportation instance has to be regarded on its individual merits.

The above report provides an overview of the most frequently discussed non-water carrying media.

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