The Pipeline Revolution

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THE INCREASING USE OF PIPELINES in recent years represents one of the most notable revolutions in the history of transport, and especially in the transport of energy. In the United States, the country which has utilized this means of transport on a massive scale, the ton-mileage of oil transported through pipes makes up one-sixth of the total inter-city commodity movement, and the mileage of natural gas pipelines now exceeds that of the railways. In Europe, the arrival of oil and gas pipelines on a large scale has been delayed largely as a result of competition from alternative and cheaper water transport, and the late discovery of natural gas deposits. But now they are spreading rapidly across the map. Pipes, in the form of the regional gas grids, have transformed the geography of British gas production by allowing the concentration of production at larger markets and on the coalfields[1]; in the near future they will transform it even further when the new methane distribution system allows the transmission of imported natural gas to at least seven of the twelve Area Boards (see Fig. 1).[2] They have permitted the emergence of a new French gas industry which is concerned largely with the transport of natural and coke oven gases rather than with town gas production.[3] Vast schemes for the movement of hydrocarbons are being conceived and completed in the U.S.S.R.,[4] and the pipeline is as much a pioneer of transport facilities in the underdeveloped countries as are roads, or railways, or aircraft.

It is also significant that pipelines are being used to transport an increasing range of commodities. Besides their use for the movement of water, of oil and of gas, pipelines are now being used for the long-distance transport of chemicals; for example, the petrochemical feed-stock of the new I.C.I. Severnside works will be pumped from the Esso refinery at Fawley. Even more important as far as the future is concerned is the use of pipelines for the long-distance transport of coal. This has been successfully pioneered in the U.S.A. where in Ohio there is a 10-inch coal pipeline from Georgetown to Cleveland, a distance of 120 miles; through it a mixture of crushed coal and an equal quantity of water is pumped as a slurry from a mine to a power station at a substantial saving of costs over rail transport. More recently techniques have been developed to produce a "stabilized slurry" of 65 per cent coal and 35 per cent water which will make this method of coal transport even more advantageous; with it the coal remains in suspension and can be stored, the pipe carries 30 per cent more coal than the

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existing method of transmission, and the slurry can be burnt as a liquid fuel and thus requires no de-watering plant. As a result of this development there is now serious discussion of the possibility of pumping larger quantities of coal over even greater distances, and three pipes in

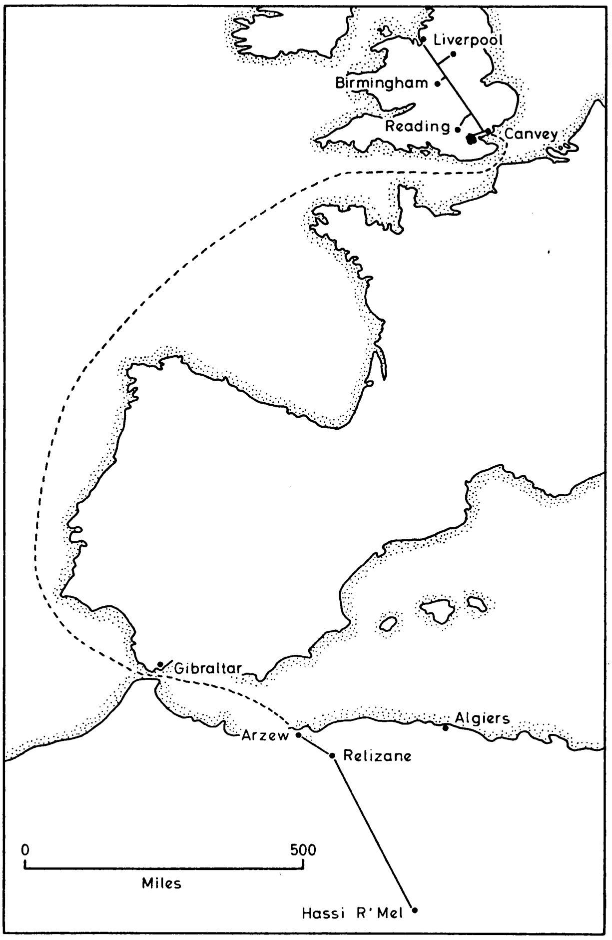

Fig. 1.—Proposed routes and pipelines for the transmission of Saharan gas to and within Britain.

particular have been proposed. One would carry 4 million tons of coal each year from southern Ohio to Detroit (250 miles), another would transport 6 million tons each year from southwestern Pennsylvania to the Atlantic seaboard (400 miles), and a third would carry the same quantity of coal from Utah to Los Angeles, a distance of over 600 miles.[5] On a much smaller scale, but still illustrating the theme of an increasing range of uses, pipelines have been successfully used to transport milk in the Alpine parts of Switzerland.

This new and rapidly increasing role of the pipeline in transport geography has been made possible by many technological advances.

In particular, it has been facilitated by the development of techniques which allow the production of relatively inexpensive pipes on a large scale, and by the advent of electric welding. But advances in the methods and economics of pipelaying and improvements in the means of transmission have played their part too.

Pipeline transport has quite distinctive characteristics. In the first place, in contrast to all other forms of transport (with the single exception of the transmission of electricity by wire) it provides for the continuous movement of a commodity at a constant rate, rather than for the movement of variable amounts at irregular intervals. As a consequence, the transport opportunities offered by pipelines are somewhat rigid. Not only is there a limitation to the range of commodities which can be successfully moved, but also the capacity of a pipe can be increased only marginally and this by the installation of additional pumping capacity. Pipelines are also rigid in the routes which they serve, for once they are laid down, there is no possibility of transferring part of the investment to serve an alternative route, even if conditions change and different patterns of transport are required. In these matters, the contrast of pipelines with tankers is acute, for the latter are a highly flexible form of transport. They can be transferred easily from one route to another, even during the course of a voyage, and, since the provision of additional carrying capacity can be made in relatively small increments, they are ideally suited to a gradual growth of demand.[6]

Table I

AVERAGE COST OF TRANSPORTING A BARREL OF OIL OVER 100 MILES IN THE U.S.A. (1954)

Tanker	1·5 to 1·8 cents
Barges	1·75 ,,
Pipeline (16-inch)	1·9 ,,
Rail	11·0 to 16·0 ,,
Road	80 ,,

Source: R. J. Lindsey, "The Location of Oil Refining in the United States", Unpublished Ph.D. Thesis, Harvard University, 1954, p. 193.

The "rigidities" of pipeline transport—in effect, disadvantages—are offset by the fact that under optimum conditions, and with appropriate commodities, pipelines offer a much cheaper form of transport than their competitors. Given a large and steady market (the need for this will be seen later) pipelines can be more economic than all other forms of land transport, and occasionally prove to be cheaper than sea transport. The actual costs of pipeline transport vary, of course, with the size of the pipe, the pressure of transmission, and the efficiency with which they are used; they also vary with the cost of capital, with the nature of the terrain over which they pass, with the costs of way-leave, and, if a fluid is being transported, with its viscosity. As a generalization, however, recent average American figures for the alternative costs of oil transport by different media will serve to illustrate the competitive nature of pipeline transport.

These general relationships of the alternative transport costs for oil have been confirmed by the Petroleum Information Bureau[7] and by Hubbard[8] for European conditions; they are illustrated in Fig. 2. From this logarithmic graph it is easy to appreciate why the availability of cheap water transport—both inland and by sea—prevented for so long the economic use of pipelines for oil in Europe. As will be shown later, it was only when sufficiently large markets grew inland that pipes with large diameters and capacities could offer lower transport costs than barges on inland waterways, and that pipelines came to be an economic proposition.

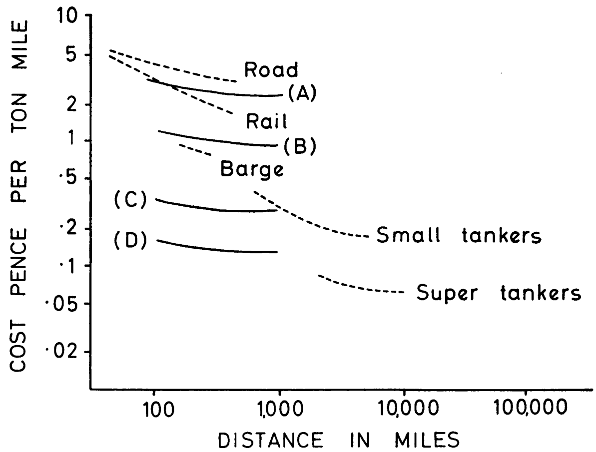

Fig. 2.—Alternative costs of transporting oil in Europe (*c.* 1960). Pipeline costs: A—0·5 million tons per year; B—1 million tons per year; C—5 million tons per year; D—20 million tons per year. Source: M. E. Hubbard, "Pipelines in relation to other forms of transport", p. 13.

Pipelines have been constructed in preference to the use of an alternative sea route under certain circumstances. In the Middle East, for example, the voyage from the Gulf of Aden to the Eastern Mediterranean is approximately 3000 miles; but the longest pipeline from Saudi Arabia is only about 1000 miles in length. In this situation it was considered economic to lay pipelines across the desert to compete with the alternative tanker route. When the pipes were first laid they were certainly competitive; but since 1957 the "Tapline" has never been used to full capacity, and it is currently pumping about one-half of the quantity of oil which could be transported through it. Although there are obvious political undertones to this situation, there is also an economic explanation for it. The increasing size of tankers and their economies of scale, plus surplus tanker capacity, have led to much lower sea freight rates for oil in recent years; and as a consequence the future of the trans-desert pipelines is now in doubt.[9] Whilst pipelines cannot generally compete with supertankers, the largest have become competitive with the smaller "conventional" tankers; and it has been argued that a 30-inch pipeline would be economic for the transport of oil from Texas to New York and the Middle Atlantic seaboard.[10] In this case, too, the pipeline has the advantage of having to transport the oil over a shorter physical distance than its competitors, as can be seen in the following table.

Table II

DISTANCE BETWEEN ATRECO (PORT ARTHUR, TEXAS) AND PHILADELPHIA BY VARIOUS MEANS OF TRANSPORT

Straight-line	1225 miles
Pipeline	1400
Rail	1512
Sea	2120

Source: Atlantic Refining Company, *The Transportation Story*, Philadelphia, 1951.

Vested interests in the coastal tanker trade, however, have been primarily responsible for preventing such a development. Oil pipelines were built between Texas and the Middle Atlantic seaboard during the war years, but the motive was strategic rather than economic. The submarine menace in the North Atlantic did not leave the American tanker fleet unmolested, and pipes were laid in order to ensure the availability of oil supplies in such cities as New York and Philadelphia. (These pipelines, incidentally, provided a basis for the post-war expansion of the natural gas industry, for they were built for the Federal Government and subsequently sold to natural gas transport companies.) Although strategic motives are not unknown elsewhere,[11] most pipelines have an economic justification; and the basic economics of pipeline transport rest upon three principles.[12]

Table III

FIXED AND VARIABLE COSTS OF OIL TRANSPORT MEDIA (per cent)

	Fixed	*Variable*
Ocean tanker	20	80
Barge	30	70
Product pipeline	75	25
Crude pipeline	65	35
Railway tank car	5	95
Lorry	15	85

Source: H. N. Emerson, "Oil Transportation Preferences—Their Bases", *Proceedings, American Petroleum Institute*, Section V, New York, 1957, p. 22.

The first principle is that capital costs make up between 65 and 75 per cent and—in contrast to other transport media—completely dominate the total costs of pipeline transport (see Table III). This means in turn that the costs of transport increase almost directly with distance. With the discontinuous transport media generally—ships, railways, lorries and the like—costs per ton-mile tend to fall with increasing distance since loading costs are spread over a greater mileage and there are certain running economies which follow from the long haul. But there is little or no such variable with pipelines, and graphically their cost–distance relationship is arithmetically represented by a straight line in contrast to the curved line of the discontinuous means of transport. The dominance of capital costs also means that a decline in the use of a pipeline below its maximum capacity results in a considerable increase in the ton-mile costs, since the greater part of expenses involved in the transport operation—that is, the capital costs—are still incurred. Thus, a regular market is essential for a commodity before a pipeline can be regarded as economic to transport it. If, therefore, there are considerable fluctuations in demand for a product, there is every advantage to be gained from the storage of the product either at its source or at its market in order to ensure an even flow through the pipe. If this is not possible, then an alternative, discontinuous form of transport will in all probability be more economic. In the United States, where the demand for natural gas fluctuates with the seasons and the weather as a result of its use for home and factory heating, the practice of some pipeline companies is to store gas near their markets in exhausted gas fields, or in suitable geological strata, during the summer months. There are over 250 of these underground gas stores in the United States, and the technique is also used in Europe where there are underground stores in the Federal Republic of Germany near Hanover, in France near Versailles, and in the United Kingdom (on a small scale) near Edinburgh and in north Yorkshire. With the prospect of importing large quantities of natural gas, the Gas Council is investigating the possibility of large-scale underground gas storage in southern England. An alternative solution to the load problems of the U.S. gas industry is to offer gas at very low rates at those times when demand is low. By selling gas even as cheaply as its field value plus some small contribution towards its transport costs, pipeline operations are more profitable than if considerable fluctuations were to be allowed in the use of the transport facilities.[13]

The second principle of pipeline transport is that, with increasing pipe diameter, the capacity of a pipeline increases more rapidly than do the costs of laying, installing and transmitting through it. Thus, within the technological limitations of the size of pipe which can be manufactured and through which products can be pumped, the larger the diameter of a pipeline the lower will be the ton-mile costs of transport. In this respect pipelines have an advantage over other transport media, for the economies of scale in road, rail and tanker transport are of a much smaller magnitude. The importance and the size of these scale economies of pipelines can be seen in Table IV and from the fact that a 24-inch diameter pipe for natural gas has about three times the capacity of a 16-inch pipe, and the costs of pumping gas through it are almost 35 per cent lower per therm-mile. It is because of this characteristic that the market must be large as well as regular before the use of a pipeline can be economic, especially if alternative forms of transport are available.

Table IV

Optimum Crude Oil Pipeline Size and Costs in the United States, 1953
(cents/barrel/100 miles)

	Pipeline	*Cents*
25,000 barrels/day	10¾-inch	3·9
50,000	14-inch	2·5
100,000	20-inch	1·8
200,000	26-inch	1·2
400,000	30-inch	0·9

Source: L. Cookenboo, Jnr., "Economies of Scale in the Operation of Crude Oil Pipelines", Unpublished Ph.D. Thesis, Massachusetts Institute of Technology, 1953, p. 188.

The final principle is that the costs of pipeline transport are affected by the nature of the commodity being moved. Thus, the more viscous the oil to be carried, the greater are the costs of pumping and hence the costs per ton-mile. It has been estimated, for example, that the costs of pumping residual fuel oil through a pipeline are four to five times the costs of pumping crude oil through a pipeline of similar diameter.[14]

These three principles provide the economic foundations upon which most modern pipelines are built. The Italian natural gas pipelines, the new 750-mile Indian crude-oil pipe from Assam to the Ganges, the German coke-oven gas pipelines,[15] and the link between the mainland of British Columbia and Vancouver Island for the transport of Prairie natural gas are all influenced by these three considerations. The operation of these principles can be more fully understood, perhaps, with the help of a brief survey of European oil pipeline developments. In spite of the rapid growth of Europe's oil market in the post-war years, there were few individual markets large or regular enough to warrant the installation of pipeline facilities which were at the same time without good water transport facilities. London has the Thames, and the Ruhr adjoins the Rhine. Paris proved to be an early and the only exception, and in 1953 the "Trapil" pipeline was laid to connect the refineries of the lower Seine with the capital. In more recent years, however, there has been a growth of large inland markets for oil and the location of new refineries in such places as Vienna, Cologne and Milan. The total capacity of these inland refineries was 25 million tons in 1960 and it is planned to increase this figure to 45 million by 1963.[16] These new developments have justified the plans for the construction of a considerable mileage of crude-oil pipelines to serve the inland markets (see Fig. 3), and soon the chief means of moving crude oil from the major terminals to them will be by this method. Already pipelines are laid from both Rotterdam and Hamburg to the Ruhr; a pipeline is under construction between Marseilles, Strasbourg and Karlsruhe. There are, in addition, plans for pipelines from Karlsruhe to Bavaria, from Genoa to Bavaria via Milan, Cremona and Aigle and from Trieste to Vienna. It is significant that all these and other European pipelines, with the exception of "Trapil" and a proposed pipe between Ravenna and Milan, are for the movement of crude oil rather than refined products. The reason is that the markets for individual refined products are not yet large or regular enough to justify the provision of pipeline facilities, being much more dispersed geographically than the refineries to which crude oil goes.[17] In addition, it is important that the largest item in European oil product demand is fuel oil, and this is one of the refinery products which it is very expensive to transport by pipeline.

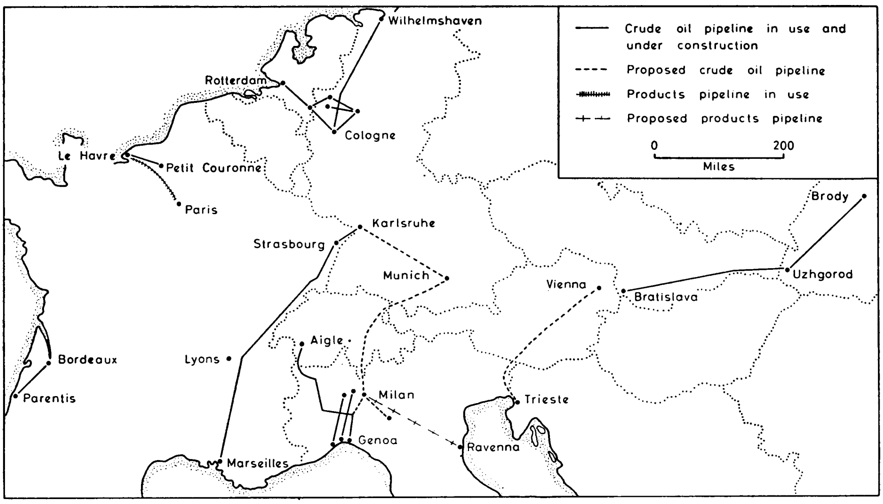

Fig. 3.—Oil pipelines in Europe.

This Continental pattern stands in strong contrast to the situation in Great Britain (see Fig. 4), where most of the pipelines, albeit limited in extent, are for the movement of oil products. In this country, crude oil can be most economically moved by tankers since all the major refineries have a coastal (or near-coastal) location, and it is only where a refinery does not have access to deep-water facilities capable of dealing with large modern tankers that crude-oil pipelines are being used. Thus there are pipes from Milford Haven to Llandarcy, from Tranmere to Stanlow, and from Finnart to Grangemouth. There are in addition a number of product pipelines. In the first place, there are the 1200 miles of pipe laid down during the war years to supply airfields in the east and southeast of the country from the ports and refineries of the west and south.[18] These are still used to supply military airfields. Since the war, pipelines between the refinery at the Isle of Grain and London Airport (Heathrow), and between Stanlow and Partington, have been laid. Pipes are now being installed between Fawley and

Severnside, and between Fawley and the west London market (including London Airport).[19] There are also plans to lay a "common carrier" product pipeline[20] from Essex to north London, which would be subsequently extended to Birmingham and southeast Lancashire.

Fig. 4.—Oil pipelines in Britain.

The contrast between the British and the Continental experiences seems to resolve itself around two points which admirably illustrate the possibilities of pipelines as a transport media. On the one hand, the absence of inland refineries in Britain, and the superiority of tanker transport for serving coastal refineries, have limited crude-oil pipeline development in this country. But for the supply of the inland markets on the Continent there is no competition from tanker transport, and, as a result, long-distance crude-oil pipelines are economically attractive. On the other hand, with the exceptions of Paris and the markets for fuel oil, the absence of large and regular markets for refined products on the Continent has temporarily inhibited the development of product pipelines, a contrast with Britain where the product pipeline is becoming increasingly important. The advent of further oil pipelines in Europe will continue to reflect the distinctive and relative economics of pipeline transport *vis-à-vis* alternative media, the size and nature of the markets being served, and the nature of the products being transported.

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[9] *Petroleum Press Service*, vol. xxviii, No. 1, January 1961, p. 267.
[10] R. J. Lindsey, "The location of oil refining in the United States", Unpublished Ph.D. Thesis, Harvard University, 1954.
[11] For example, the route of the Canadian natural gas pipeline from the Prairie to Ontario passes to the north of the Great Lakes and remains entirely in Canadian territory; it would have been more economic to take it to the south of the lakes via the U.S.A.
[12] See K. B. Nagler, "Transportation and storage of gaseous fuels", *World Power Conference*, Madrid, 1960, Section III, A/5.
[13] See G. Manners, "Natural gas in the U.S.A.", *Coke and Gas*, vol. 23, May 1961, pp. 181–5.
[14] R. J. Lindsey, *op. cit.*, p. 331.
[15] For a discussion of gas pipelines in Europe see G. Manners, "The gas industry in Europe", *The Canadian Geographer*, vol. 5, No. 4, 1961, pp. 30–6.
[16] *The Economist*, vol. 195, No. 6095, 18th June, 1960, p. 1228.
[17] It should be noted that, in addition, N.A.T.O. has a very extensive oil products pipeline network throughout western Europe.
[18] *The Economist*, vol. 194, No. 6073, 16th January, 1960, p. 237.
[19] Alongside this oil pipeline is another carrying liquefied petroleum gas for the London market; see *The Economist*, vol. 201, No. 6169, 18th November, 1961, p. 690.
[20] Common carrier pipeline companies offer, indeed are required by law to offer, their facilities for general use. Most pipelines in the U.S.A. are common carriers.