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Capsule Pipelining – Potential Applications

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ABSTRACT

A brief account of the concept of capsule pipelining is given and a complete capsule pipeline system outlined. Commodities amenable to transportation in the system are listed and the attendant problems peculiar to some of them are mentioned. Two potential applications of immediate interest are discussed in some detail. One concerns the transportation of solid waste and the other deals with transportation of Arctic crude oil in liquefied natural gas (LNG).

INTRODUCTION

THE STORY of capsule pipelining from its inception in 1958 to the present has been recorded in numerous publications (Ref. 1, 2). It may, nevertheless, be in order at this point to very briefly recount the essentials of this commercially untried transportation concept, pioneered by staff members of the Research Council of Alberta.

Capsule pipelining is a transportation system in which the solid materials in the form of trains of cylinders or spheres are moved in a pipeline filled with a carrier liquid. The solid bodies have diameters slightly less than the pipe and cylinders are 5 to 7 diameters long. The carrier liquid can be water, hydrocarbons or anything that can be pumped. It has from the outset been found that transmission energy requirements are very favorable. Detailed studies since then have substantiated this finding for cylindrical capsules of specific gravities up to 1.5, while solids with higher densities most advantageously are moved in the form of spheres. It has also been found that substantial pressure reductions relative to those observed for plain cylinders can be achieved by placing a thin band towards the front end of the capsules (Ref. 3).

According to the way they are manufactured, capsules can be divided into three categories:

(a) rigid capsules, examples of which are steel, aluminum, sulphur and crude oil in liquefied natural gas (LNG). Characteristically, these materials are cast into spheres or cylinders from the molten state and transported with or without a protective coating, depending on whether the solid contaminates the carrier liquid or not. Rigid containers filled with the solid also belong in this category.

(b) semi-rigid capsules, comprising almost anything that can be packaged. These capsules consist of a flexible container filled with the solid

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to be transported. The container can be plastic or metal and should ideally be a material that can be sold or disposed of at the terminal end of the pipeline, or at the destination for the solid.

(c) paste slugs, which are made by mixing the comminuted solid with a liquid immiscible with the carrier liquid. The doughlike paste is formed into cylinders in extruders and inserted into the pipeline without a protective skin. Examples are coal pasted with water and flowing in an oil-filled line, and potash pasted with potash brine and flowing in either oil or brine. Sulphur may be pasted with oil and moved in a water-filled line.

The work on capsule pipelining at the Research Council of Alberta has been underwritten by the Government of Alberta on a continuous basis. Outside financial assistance was obtained on two occasions. In 1967-68 the Solids Pipeline Research and Development Association (SPRDA) sponsored a feasibility study jointly with the Government of Alberta and the Federal Department of Industry, and in 1971 the Federal Ministry of Transport, through the Transportation Development Agency, granted a three-year contract for the purpose of developing reliable design equations based on hydrodynamic studies in experimental pipelines ranging in diameter from one-half to ten inches. Much valuable help has also been received from companies with an interest in transportation.

While most of the work has centered on the hydrodynamic aspects of capsule pipelining, some bench scale development work has also taken place on injection devices, by-pass and diverter system (Ref. 4, 5, 6), as well as on the movement of real commodities (Ref. 7).

THE CAPSULE PIPELINE SYSTEM

As the end of the current contractual work on hydrodynamics draws near and since it is already apparent that a fair degree of success in this very important area is in sight, it seems reasonable to take a closer look at other parts of the total capsule pipeline system, especially those problem areas which require solutions before the first commercial installation can be designed and built.

A complete capsule pipeline system comprises the following major components and operations:

(a) Capsule manufacture;
(b) Capsule treatment before injection;
(c) Injection machinery;
(d) Pipeline hydrodynamics including determination of pipe size and specifications;
(e) Pipeline pumps;
(f) Booster stations and by-pass systems;
(g) Terminal retrieval systems;
(h) Terminal liquid-solid separation and recovery;
(i) Instrumentation and control systems including safety devices and trouble-shooting equipment.

Availability and detailed knowledge of all these components are necessary before a capsule pipeline system can be designed and its viability assessed. On the basis of technological solutions to these problems, it will be possible to establish a computer model that accommodates all the parameters and variables peculiar to capsule pipelining. The model will reduce all factors involved to economic terms and provide answers related to the technical and economic aspects of the capsule pipeline. It will thus be possible to evaluate a specific potential application before detailed development work on it is commissioned.

POTENTIAL APPLICATIONS

Assuming then that a technologically viable pipeline system is available—and the validity of this assumption is only dependent upon completion of the necessary development work—it may be useful to take a closer look at the solids that can be considered potential candidates in Canada. Using technological criteria only, a reasonably complete list looks like this (no significance should be attached to the order in which the commodities appear):

Coal	Lead/zinc concentrates
Sulphur	Copper concentrates
Potash	Other ore concentrates
Gypsum	Asbestos
Iron Ore	Aluminum
Grain	Wood
Solid Waste	Crude Oil in LNG

It should be noted that with a few notable exceptions, most of these solids lend themselves to transportation in both slurry and capsule form. The fact that slurry pipelining has been proven commercially should not prevent the consideration of capsule pipelining in particular cases. An evaluation of the comparative merits of slurry and capsule pipelining is, in any event, outside the scope of this discussion.

Whether the capsule pipeline transportation of a solid is economically attractive proposition depends in large measure on the physical characteristics of the solid and the circumstances pertaining to its production (quantity, location of production and distance from market or tidewater, as well as long-range marketability and market value).

Grain

Applying economic and market criteria to the list above limit the number of commodity candidates to some extent. Grain, for instance, can only be pipelined if it is protected from the carrier liquid. Economic considerations dictate that the encapsulating material must be non-returnable, i.e. either cheap enough to be discarded at the destination or usable as a basis for further processing. Plastics of various kinds have been suggested but they are too expensive to dispose of and the volume involved is too large for any one market to absorb.

It is, however, technologically feasible to suggest a system where grain is delivered to the pipeline in non-returnable aluminum capsules, which can be produced at a cost very little higher than the cost of aluminum metal. It may even be possible to persuade farmers to accept this system. The capsules are delivered to the farm, filled in the field and then travel intact all the way to the consumer of the grain, where they are used as aluminum raw material. One obvious advantage is that grain is delivered as clean as it is harvested. The storage problems that now plague the movement of export grains are also eliminated since the water-tight capsules can be stored in the open at the origin or terminal of the line. But there are obvious flaws in the scheme. The most devastating drawback is perhaps that Canada does not have a steady market for grain and that there is only one market that also buys quantities of aluminum. Unless a long-term contract can be negotiated with this customer to accept fixed amounts of grain and aluminum on a year-round basis it does not appear very promising to delve further into the details of a grain capsule pipeline.

Minerals

The volume of production from producing mines of the minerals mentioned and the steady markets for them make these commodities prime candidates for capsule pipelining (Ref. 1). But capsule pipelining may also provide solutions to the transportation problems of minerals from known small, short-lived deposits that cannot be exploited economically at the present because of the prohibitive cost of building and operating roads or railways to them. In these cases portable, insulated pipelines, laid on the surface from the mine to the nearest existing transportation system in the same manner World War II supply pipelines were constructed and made movable at low cost, may make these deposits economically attractive.

Supply Pipelines

Similar portable capsule pipelines can be used to supply contaminated areas in case of emergencies. Canned food and medical supplies can in this manner be brought in with a minimum of personnel involved.

Permanent, buried pipelines, carrying standardized cans filled with a variety of necessities can be employed to supply large metropolitan areas and will serve to alleviate truck traffic on the increasingly congested streets and highways.

Solid Waste

Even though it appears possible to make a case for the application of capsule pipelining for each of the listed commodities, two particularly promising and timely examples have been chosen for more detailed consideration in this paper.

The first provides improvement in the transportation of solid waste. Concern for better environmental control has in recent years focused attention on the handling and disposal of solid wastes. Improvements, it is said, must be introduced in order to reduce or eliminate waste in a rapidly growing urban society faced with increased demands on finite amounts of raw materials, and new collecting and especially disposal techniques are required. To improve this situation it is suggested (Ref. 8) that currently used surface transportation means—trucks or trains—can be replaced with a buried or mobile pipeline which carries the compressed solid waste from a transfer station to a centrally located treatment facility or to an incinerator or land-fill site located some distance from densely inhabited areas. A flow diagram of the proposal is shown in Figure 1.

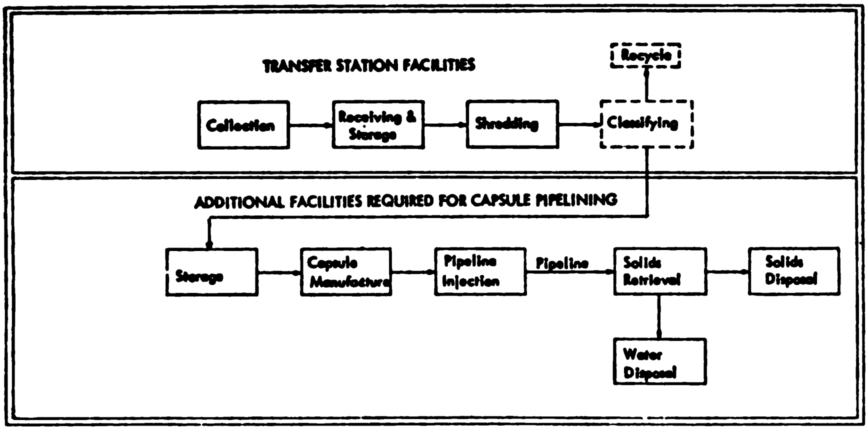

FIGURE 1

Solid Waste Capsule Pipeline Flow Diagram

It should be noted that the proposed change initially only involves the replacement of trucks or railroads. A cost analysis (Ref. 8) has shown that this can be done competitively. An additional bonus of this aesthetically pleasing system is to eliminate the line-haul trucks from the streets.

This system is not dependent on—but can work with—changes that may be introduced in the collection system. An example is the vacuum collection of solid waste generated in households. This system, which has been perfected in Sweden, is uneconomical over long distances, but it can readily be combined with a capsule pipeline.

The Swedish proposal is especially suitable in densely populated high-rise apartment buildings and institutions. But it is not readily applicable to already finished buildings and it might take a change in the building codes to allow for it. A wide-spread adoption of the complete system is therefore not likely in the near future, but the replacement of surface transportation with a buried pipeline can be implemented at any time.

Crude Oil in L.N.G.

The other suggested application that deserves immediate attention is concerned with the transportation of crude oil and natural gas from the deposits in the Arctic. Much public attention has been focused on the transportation of hydrocarbons from the Arctic to the South, and grave concerns have been voiced on the effect pipelines, and especially oil pipelines, may have on the ecology of the North. Aside from the ecological effect of an oil pipeline there is also concern about the technical problems arising if heat dissipating from the relatively warm pipeline melts the surrounding permafrost with the attendant risk that the foundation of the pipeline erodes and the line consequently breaks.

Many other transportation schemes, encompassing just about every mode of transport available to man, have been proposed, but it is interesting to note that the companies engaged in proving up the hydrocarbons in the Arctic so far have limited development work to full-scale pipeline testing. Published results of this work suggest that not only is pipelining capable of meeting the ecological demands, but it is also the most economical overland means of moving the reserves to market.

Capsule pipelining may enhance the economic claim. As applied to crude oil and natural gas from the Arctic it entails liquefaction of the natural gas and solidification of the crude oil in LNG and consequent simultaneous transportation of the two commodities with solid crude oil moving as capsules (or, if it is preferred, as a slurry) in one pipeline where LNG serves as the carrier liquid.

Liquefaction of natural gas is an established technology and work on LNG pipelines is well advanced though not yet commercially used on a large scale. (Ref. 9.) The idea of applying capsule pipeline techniques to this situation is feasible because of the very low solubility of crude oil in LNG.

If it is correct that two 48 inch pipelines are required to transport 1.8 million barrels of oil and 3.5 billion cu. ft. of gas per day (Ref. 10), then this amount of hydrocarbons—assuming the natural gas is liquefied—can be moved simultaneously in one 60 inch diameter pipeline. The volumetric ratio of oil to LNG is 2:1. The attendant savings in pipeline capital cost, based on the costs published for the proposed two pipelines, will be of the order of $3 billion. This saving is offset by the capital cost of liquefaction and oil freezing facilities, estimated at $1 billion. Another benefit is the preservation of the permafrost since the temperature at which this pipeline must operate is between —115°F and —260°F.

Details still have to be worked out but the immediately apparent advantages are obvious. If it is true that pipelining of Arctic oil and gas is the most economical means of moving this much needed energy to market, then a thorough assessment of this single pipeline proposal should be pursued as soon as possible.

CONCLUDING REMARKS

These few examples hopefully will serve to illustrate the potential and promise of capsule pipelining. Much costly development work admittedly is required before this potential can be realized. And since prevailing business philosophy requires even a risk venture to show promise of a reasonable return on investment, the initial parts of the work will have to be carried out by the organizations presently engaged in capsule pipeline investigations.

Consequently, as has been the case with most of the pioneering work in this field, financing for some time to come must be provided by institutions set up to support research and development work. Competition for these funds is keen but the possibility of adding a much needed new dimension to the Canadian transportation system is challenging.

Without generous support for this work, Canada stands to lose yet another first.

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