

Robert R. Faddick²INTRODUCTION

Slurry pipelining involves the transportation of particulate solids in a liquid carrier through a pipe under pressure. The liquid most commonly used is water, although liquors, brines and hydrocarbons (fuel oil, methanol, crude oil) have been used. The solids are usually products of the mineral industry, although agricultural and food products are also pipelined in slurry form. The mineral solids may be raw ores, beneficiated ores, or wastes such as tailings. Some examples are coal in oil, salt in brine, iron concentrates in water, and fly ash in water.

Generally, most slurries are inert, that is, non-reactive. Occasionally, reactive slurries are encountered where some or all of the solids can be partially dissolved in the liquid carrier, e.g., trona in water, or salt in water. The saturation level of such slurries is temperature-dependent. For purposes of throughput determination, the ratio of undissolved solids to dissolved solids is of concern when the brine carrier is separated from the solids and is recirculated. Otherwise, the total delivered solids, both undissolved and dissolved, contribute to the pay load.

There are mineral slurries which are inherently inert until made reactive by chemical treatment. For example, power plant scrubber sludge (calcium sulfate or sulfite) can be treated with a hardening agent which increases the slurry viscosity with time until it eventually sets up like concrete. Obviously, the slurry residence time of transportation in a pipe is minimal compared to the time for stabilization in a waste area.

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While the emphasis here is on mineral slurries, many unusual slurries have been pipelined. These include many kinds of waste products - sewerage sludges, bagasse (waste sugar products), and household garbage. Other interesting mixtures that have been pumped are peas in water for food processing (without being damaged by pumps), one-meter long pulpwood logs, live fish pumped past hydro-electric turbines, and grass seeds mixed with wood-fiber mulch for hydraulic revegetation of mountains. Appendix A lists numerous slurries which have been pumped.

Long distance pipelines have several advantages:

- 1) They have low operating costs which are relatively immune to cost escalation. However, their capital costs can be high. The major cost of a long distance pipeline is the steel pipe.
- 2) Pipelines have high reliability. Some water pipelines are over 100 years old and are still operating. Many of the long distance slurry pipelines are available well over 95% of the time. Some use factors are nearly 100%.
- 3) By their nature of being pressurized containers, pipelines require little manpower and are conducive to automation. The economics of long-distance pipelines are enhanced by high volumes of steady throughput which are also conducive to automation.
- 4) Overland pipelines are normally buried in trenches below the frost level. Consequently, they are out of sight, allowing for an aesthetic right of way which can be restored quickly to its original appearance. Of all the transportation modes, buried pipelines are probably the

least harmful to the environment.

- 5) The health and safety aspects of slurry pipelines, particularly buried pipelines, are noteworthy because the slurry is totally contained. This type of transportation mode is relatively quiet; few slurries emit toxic fumes, and the slurries do not come into contact with the general public where accidents can occur. Furthermore, many pipelines have an enviable record of longevity.
- 6) For the most part, slurry pipelines use water as the carrier liquid. It is generally the most abundant and inexpensive liquid although there can be exceptions depending on the source of solids being transported, their market destination, and the end use or process.

THE PAST

The earliest known slurry pipeline transported a gold bearing gravel-water slurry in a California placer mining operation in the late 1850's. In 1889, a patent claim was filed by W.C. Andrews for a slurry system although no record exists of its application. In 1904, coal pipelines were mentioned in a patent application by W.T. Donnelly of Brooklyn, N.Y.

The earliest working coal slurry pipeline was operated in England in 1914 by G.G. Bell. It transported 50 tph of 50% coal by weight at 1.2m/s in a 200-mm diameter pipe a distance of 600 m from barges in the Thames River to a power house. In the U.S., an anthracite sludge line was built in the late 1920's near Mt. Carmel, Pennsylvania. The pipeline was 1.6 km long and carried solids at 40 to 65% by weight.

Today's list of slurry pipelines is extensive, whether one considers long distance pipelines only, or whether one includes every slurry pipeline over one kilometer in length. Appendix A gives an idea of the range of commodities, solids throughput and pipeline diameters and length. The list is by no means complete but does show a preponderance of mineral commodities. Although this section will emphasize mineral solids, it does recognize the application of slurry pipeline technology to the transportation of food products, agricultural products, encapsulated solids, and three-phase (solids-liquid-gas) mixtures.

The mineral slurries, the transported product, may be a raw ore, a beneficiated ore, or a waste, called tailings. The tailings may be discharged into a settling pond, returned to a mine as backfill for ground support, or developed into a useful product such as landfill by the addition of a stabilizer. Several companies have found certain stabilizers which produce a landfill with fairly high load bearing capacities. For example, the Synearth process developed by the Dravo Corporation (Ref. 1) in the United States adds a cement-like stabilizer to a power plant wet scrubber sludge containing fly ash and sulfur dioxide compounds.

THE PRESENT

It is obvious from Appendix A that slurry pipeline technology is well established. This means that the technology is sufficiently well understood so that a systems approach to slurry pipelining can be applied. Adequate information can be obtained for each element of the system. For example, most slurry pipeline systems involve preparation of the slurry at the commodity source, pipeline transportation from source to market, and, possibly, solids

separation (dewatering) at the user point. Dewatering is not always necessary ; some examples being the calcining of a limestone-water slurry, or direct combustion of a coal-oil slurry or a highly-concentrated coal-water slurry.

Preparation of a slurry usually involves crushing and grinding of the solids, perhaps some cleaning and sorting, all followed by a mixing of the solids with water. Crushing and grinding are expensive. Therefore, reduction in particle size should be minimized wherever possible. Figure 1 shows a typical relationship between the cost of slurry preparation and the degree of reduction of particle size for coal. The particle size is represented by a weighted mean particle size (Ref. 2) for convenience.

There are two possible constraints in minimizing solids reduction: market requirements, and a solid size amenable to pipeline transportation. The first constraint tends to be nebulous at times. Rigid market specifications for particle size are not always dictated by product end use (e.g., combustion of coal) but by past experience and preference in materials handling. Lump solids are preferred because they are less dusty and handle more easily than powders, even though the end use may require a powder.

On the other hand, the pipeline transportation constraint is more explicit. It is a well known fact that fine solids are easier to pipeline in slurry form than coarse solids. Energy requirements to pump a slurry are high for coarse solids but decrease rapidly to some minimum value as solids size is reduced. Furthermore, pipe wear by erosion can be severe with large

particles. If the solids are made too small however, (approaching near-micron sizes) the energy requirements for pipeline transport climb rapidly because a thick paste-like slurry develops. Fig. 2 shows such a cost-particle size relationship for the pipeline transportation of coal (Ref. 2). Slurries of fine particles are said to be homogeneous or slow-settling whereas slurries of coarse, heavy particles are said to be heterogeneous or rapid settling. Most mineral slurries are composite in size distribution which is why their evaluation for pumpability is often complex.

At the terminal, the system contains dewatering equipment such as screens, centrifuges, filters, and dryers. Homogeneous slurries are much more difficult and costly to dewater than heterogeneous slurries. Figure 3 shows a typical cost-particle size relationship for the dewatering of coal (Ref. 2).

Regardless of the commodity, if such cost curves can be prepared, as shown above, for preparation, pipeline transportation, and separation, a slurry pipeline system can be optimized with respect to particle size, to give the lowest total cost. See Figure 4.

As with any technology, there are certain problem areas that require special attention. There are three major ones with slurries: flow and pressure requirements, particle size degradation, and wear of pumps and pipes. Depending on the commodity to be transported and the topography to be traversed by the pipeline, the ranking of the problem areas may be interchanged. For example, a gravity line is not concerned with pump wear but with pipe wear. Hoisting coarse solids upward in a pipe must overcome the static lift but pipewall friction itself is small (Ref. 3).

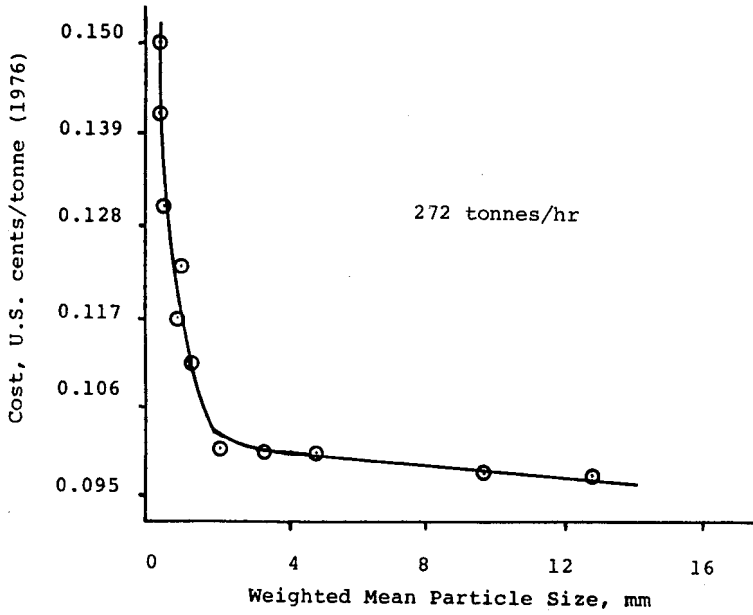


Fig. 1 - Cost Curve for Coal Slurry Preparation

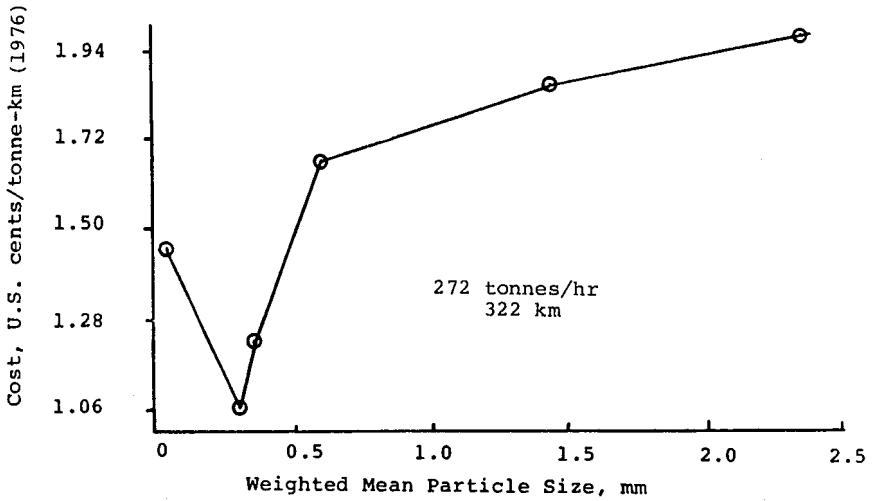


Fig. 2 - Cost Curve for Coal Slurry Pipeline Transportation.

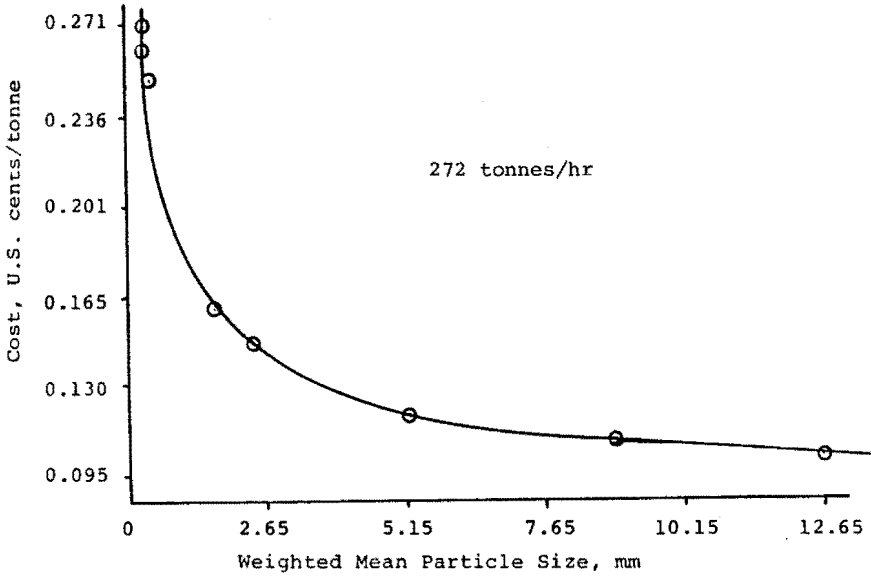


Fig. 3 - Cost Curve for Coal Slurry Separation.

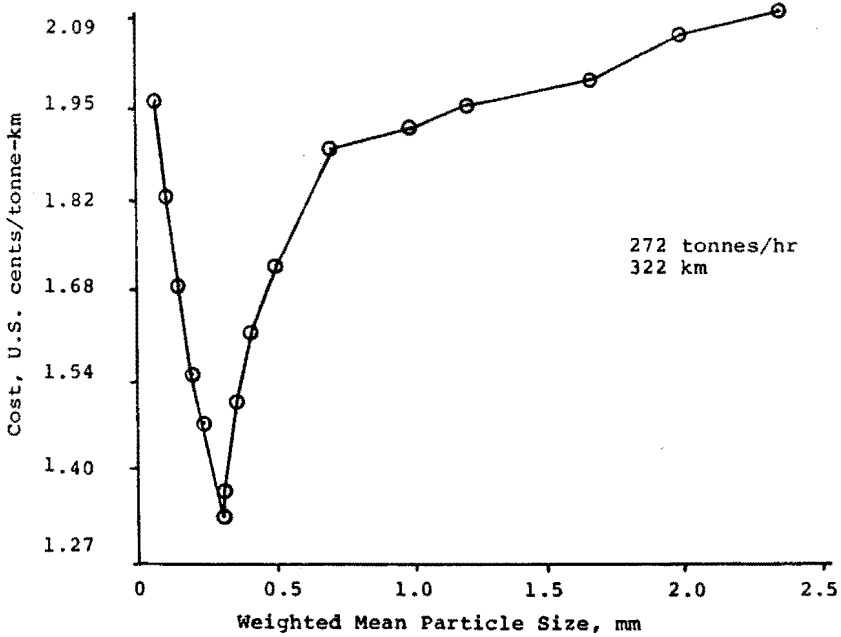


Fig. 4 - Total Cost of Coal Slurry Pipeline System

Generally, it can be said that energy requirements, particle degradation, and pipe wear are proportional to slurry velocity raised to some power, (2 to 3). Therefore, it is desirable to keep the velocity to a minimum such that deposition of solids doesn't cause cessation of flow. While there is an optimum operating point from the viewpoint of fluid mechanics it must be compromised with the economic optimum discussed previously.

The environmental impact of slurry pipelines is probably least of all the transportation modes. It will not be discussed herein except for highlighting one point, that of water contamination. There can be no slurry pipeline without water. If water availability is marginal, extensive water treatment may be necessary and recirculation of the water carrier may have to be considered (Refs. 4, 5). Coal slurries produce black water consisting of minute particles smaller than 50 microns. Removal is difficult and expensive. Woodchip slurries have the potential of imparting high chemical oxygen demand, biochemical oxygen demand, total organic carbon, turbidity levels and color to the water. In addition, pH can be lowered to about 5 (Ref. 6). In comparing the economics of various transportation modes, therefore, slurry water treatment may have to be included.

THE FUTURE

In looking to the future, the growth of slurry pipelines is excellent. In 1960, there were fewer than a dozen commercial slurry test facilities in the world. In 1980, a recent count showed over twelve test facilities in the U.S., over three dozen in Japan, as well as numerous facilities in Europe and the Soviet Union. A number of recent studies are described briefly where slurry pipeline technology shows promise of advances.

The U.S. Department of Energy has recently completed the construction of a Hydraulic Transport Research Facility, the largest in the world. It is a once-through or non-recirculating system capable of handling an initial load of 300 tonnes of coal. Three separate pipelines of 150-, 300-, and 430-mm diameter extend horizontally, declined at 45 degrees, and vertically for a total length of 230 meters. A filtration and clarification system permits dewatering of the coal slurry. The facility was constructed to generate design data and equipment for underground coal mining. Operation of the facility, located in Bruceston, Pennsylvania commenced in late 1980 (Ref. 7).

Pumps

1. The Electric Power Research Institute and the U.S. Department of Energy (DOE) have funded a study to develop a high capacity/pressure/temperature (315 L/s), (20.7 MPa), 290 C) centrifugal pump to discharge coal-oil slurries into liquefaction reactors (Ref. 8). The pump is concurrently being tested at the Colorado School of Mines Research Institute for Rockwell International under DOE sponsorship. Six modules of double-staged impellers constitute a pump set producing all the rated pressure and half the flowrate. Two sets in parallel achieve the total rated flowrate. The module being tested is designed to produce half the total flowrate and one-sixth the total discharge pressure at the rated temperature.
2. The U.S. Department of Energy has funded two studies to develop a high capacity, medium pressure, low profile coal-feeder pump to inject coal into a pipeline in an underground coal mining application (Ref. 9). In 1968, there were 14 hydraulic mines and four hydraulic complexes in operation in the Soviet Union with a total planned capacity of 14 million tonnes of coal per year (Ref. 10). The three largest hydraulic mines include surface pipelines of 10 km each. In North

America, private enterprise has been slow to adapt slurry pipelines both to hydraulic mining and underground coal mining transport. At present, there is only one hydraulic mine in Canada and one underground coal mine slurry transport system in the U.S. The Hydraulic Transport Research Facility operated for the Department of Energy is expected to accelerate interest in underground coal mining transportation by pipeline.

Pipes

1. The future will probably see an increased use of lined pipes, those containing ceramic (both chips and tiles epoxied in fiber-glass), polyurethane, and rubber, to resist erosive wear and corrosive wear in short distance pipelines. Long distance steel pipelines may perhaps be inner coated with plastics to reduce oxygen corrosion and improve hydraulic efficiency provided the joining of steel pipe by welding does not deform the plastic.
2. Work continues on the use of internal spiral ribs in steel pipe to improve the reliability of low flows of slurries. The turbulence created by the ribs re-suspends the solids and offsets the increased headloss normally associated with ribs (Ref. 11).
3. Another scheme is to install a segmented pipe. A horizontal plate is welded to the inner perimeter in the lower part of the pipe. The plate provides a wide, flat base for the solids to flow over and at the same time functions as a wear plate. It has been shown (Ref. 12) that such a segmented pipe reduces the minimum required flow velocity and the power requirements for the same solids throughput compared to a pipe without a plate.

The last two special pipes described above are installed as low-cost short sections of pipe where flow stability is hampered by bedload formation.

Instrumentation

1. Numerous manufacturers have improved the design of an ultrasonic velocity meter which is cemented to the outer wall of the pipe and connected to a digital recorder for a quick and inexpensive velocity measurement (Ref. 13).
2. A three-component sensor is under development by Science Applications, Inc., for the U.S. Department of Energy to measure coal-refuse-water concentration in a hydraulic pipeline. The sensor measures slurry conductivity, transmitted single-energy gamma rays, and transmitted neutrons (Ref. 14).

Slurry Technology and the Oceans

1. The U.S. Marconaflow system (Ref. 15) and the Japanese MIKS Flow system (Ref. 16) have been demonstrated successfully for slurring iron ore aboard ship and off ship. Coal and woodchips are receiving attention as the next potential candidates for application of slurry pipeline technology to maritime shipping. Research is progressing on four fronts: a test facility is currently under construction in New Zealand to test the pumping aboard ship and dewatering of coarse coal slurries; Marconaflow in the U.S. has been testing the slurring of coal off-board ship by their Dynajet system; and the Dutch are also studying port facilities for the off-loading of coal from ships. The Japanese have modified a ship for coal slurries and are studying dewatering characteristics.

2. Retrieval of manganese modules from 5 km below the ocean's surface and their hoisting to the mother ship via slurry pipeline will probably be the zenith of slurry pipelining. Several commercial ventures have been struggling with the technology for many years and to date slurry pipelines appear to be the leading contender for the transportation mode (Ref. 17).

Slurry Technology and Energy

1. Coal-oil slurries are seen as a possible means of reducing U.S. dependence on foreign oil by as much as 50 percent. Replacement of half the oil used to fuel furnaces, with coal, would achieve this goal. The U.S. Dept. of Energy has funded several programs to retrofit oil furnaces for coal-oil slurries. These include industrial and electric utility furnaces as well as kilns (Ref. 18).
2. In the process of making clean fuel (solvent-refined coal) from coal, slurries of coal and coal solvent are fed to high pressure and temperature reactors. The properties of the slurries are not well understood and represent an interesting challenge to slurry pipeline technology (Ref. 19).
3. The application of slurry pipeline technology to the transportation of raw and spent oil shales is gaining attention. Both types of shales are amenable to pipeline transportation but the shortage of water in the shale-rich areas may preclude slurry transport (Ref. 20).
4. The transportation of coal in a hydrocarbon liquid carrier over long distances to be fired by direct combustion in a power plant is being considered. This is discussed in more detail in the following section.

Energy Slurries

If direct combustion looks desirable and feasible in the immediate future, the logical extension of this thinking for the long term is to consider a total energy coal delivered in a hydrocarbon liquid carrier. The carrier would be crude oil, synthetic crude oil (Syn crude, Synthoil) or a member of the alcohol family such as methanol.

Crude oil is unlikely to be available where coal is mined. It would have to be pipelined to the coal source and mixed there for slurry transport to market. Possible customers would be utility plants which are presently burning oil and which must convert to coal as oil supplies dwindle or become excessively expensive. Retrofitting, or the modification of nozzles in oil burners to coal-oil slurry burners may be justifiable economically rather than total conversion to coal. Alaskan crude oil and Montana coal or Dakota lignite might be potential candidates for future consideration by U.S. mid-Western or Southern markets. Because of the widely different calorific content and market price of coal and oil, some proprietary research is directed at investigating the separation of coal and oil at the terminus of a pipeline but previous research (Ref. 21) suggests this may be expensive. Therefore, direct combustion of the total slurry may be the best approach.

The concept of creating a liquid hydrocarbon carrier from coal at the mine site is appealing provided more water is not used in the process than that required by coal-water slurry pipeline. Coal liquefaction has the same chemical basis as coal gasification. Only the ratio of carbon to hydrogen in the end product is different. Coal is reacted with hydrogen and oxygen by the application of heat and pressure in the presence of catalysts or chemical solvents to produce a volatile gas or synthetic crude oil. Both end products can be used either directly for combustion

or as a refinery feedstock. Coal can be liquefied by four basic methods:

- a) direct catalytic hydrogenation
- b) solvent extraction
- c) pyrolysis
- d) liquid hydrocarbon synthesis

Liquefaction consumes from 0.11 to 0.72 liters of water per million Joules. By contrast a coal-fired power plant consumes 3.1 liters/million Joules and a slurry pipeline requires a little over 0.36 liters/million Joules (Ref. 22). The economics of liquefaction are poorly understood pending further research. Consequently, the economics of producing a liquid hydrocarbon such as synthetic oil or methanol are vague. However, some preliminary work has been done which appears encouraging (Refs. 23, 24, 25).

Where pipeline transportation of energy slurries is involved the transport energy ratio may be defined as the ratio of energy required for transport to the total usable energy delivered. In terms of energy slurries, this can be simplified as the ratio of energy requirement to overcome pipewall frictional resistance, to the calorific content of the slurry transported. Thus, a common assumption inferred is that pump-motor efficiencies, and pipeline minor losses are similar for most energy slurries and are therefore, ignored. Another assumption is that the market use in each case will be combustion of fossil-derived fuel in thermal-electric generation stations. While the water that is separated from a coal-water slurry is used for cooling purposes, it has little energy value for combustion. The transport energy ratio per kilometer is:

$$\frac{\text{specific power} \times \text{throughput of solids}}{\text{calorific content delivery rate}}$$

$$\text{kw-hr/tonne-km} \times \text{tonnes/hr} \quad / \quad \text{Joules/hr} - \text{kw-hr/Joule-km}$$

where tonnes refer to the weight of dry combustible solids delivered. The specific power is the power required to overcome pipewall resistance in delivering one tonne of dry solids per hour a distance of one kilometer. The smaller the transport energy ratio, the more efficient is the energy slurry for pipeline transportation.

While a minimum ratio is desirable, it is obvious that this is achieved by increasing the concentration of the solids or liquid phase with the higher calorific content. Because the alternate fuels (oil and alcohol) are more valuable than coal, it is apparent that the choice of energy slurry for transport must be optimized in conjunction with its preparation. The availability or processing of the higher priced carrier liquid will be critical. If the oil or alcohol is derived directly from coal, it is probable that processing economics of the refining quality of the carrier will dictate a high coal-low liquid carrier mixture. On the other hand, a low coal-high liquid mix may be preferable where oil-burning power plants are retrofitted for coal-oil slurries.

For combustion purposes, no dewatering costs will be incurred, so effectively this cost can be transferred to the front of the pipeline for grinding the coal to a finer size. Since pulverization of coal to about 85 percent minus 75 microns is necessary for power plant combustion, this grinding cost is not attributable to pipeline transportation. The finely ground coal may allow higher stable slurry concentrations to be produced thus minimizing the amount of carrier liquid. Also, the affinity that coal has for hydrocarbon liquids enables easier

slurry mixing, avoiding the often-encountered hydrophobic tendencies of coal in water.

The disadvantage is that if the coal is ground too finely, the slurry becomes paste-like with a high viscosity and a high energy requirement for pipelining. However, the elimination of dewatering costs means that additional costs can be allocated for increased pipeline transportation costs. Furthermore, some proprietary work on chemical additives for coal-oil slurries looks promising for developing slurry viscosity thinners.

Preliminary work suggests a strong potential for energy slurries to become an alternate power plant fuel of the future. If burned directly, this fuel, besides being higher in calorific value, would probably ameliorate the materials handling problems associated with rail-delivered coal or coal-water slurry coal. It is strongly recommended that coal-liquid hydrocarbon slurries be researched at the preparation stage, pipeline transportation stage, and combustion stage to evaluate their economics.

Because energy slurries are combustible, unlike coal-water slurries, their transportation by pipeline would probably present the same environmental and pollution consequences as oil pipelines.

Novel Coal Slurries

Several different types of slurries have been proposed recently:

1. Enlightened slurries consist of froth flotation reagents (alcohol and oil) along with air to cause bubbles of air crusted with fine particles to attach themselves to coarser coal particles thereby effecting a reduced density.

This allows easier suspension of the coarse coal resulting in higher solids concentrations being pumped with less energy. These have been tested by the writer at the Colorado School of Mines Research Institute and results will be published soon.

2. Coal-liquid carbon dioxide slurries are under study by W.R. Grace and A.D. Little, Inc. These slurries are said to offer reduced pumping requirements and easy separation of the coal by depressurizing the slurry to allow the CO₂ to vaporize.

3. Aquatrain is a system proposed by W.R. Grace and Co. to take western coal encapsulated in plastic bags and propelled by western saline water through pipelines to the west coast. There the coal would be easily recaptured while the saline water would be dumped into the ocean.

It is evident that slurry pipelines are an active technology and will continue to attract strong interest.

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APPENDIX A

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - HORIZONTAL

SLURRY CODE	LOCATION/OWNER	SPECIFIC GRAV. OF SOLIDS	PSD #+-MM	OD X WALL THICKNESS MM	VEL M/S	L KM	CAPACITY TONNES PER (SEE NOTE)	OPERATION DATES	PUMP TYPE	NO. OPER. PUMPS-- STA	OPER. STANDBY REF	
ASH-T	SUNBURY PA, USA / PA, POWER & LIGHT	2.25	--	254.0	10.0	4.39	2,408	39.00 H	CSE	--	5	1
ASH-T	SAFE HARBOR PA, USA/PA, POWER	2.4	--	152.4	17.0	1.62	1,372	20.62 H	CSE	--	6	1
ASH-T	KAZINGBARKA, HUNGARY/BORSOD POWER	---	---	200.0	---	---	8,000	70 H	---	---	---	---
ASH-T	BUNA WERKE, GDR / IAI	---	---	400.0	---	---	12,000	320 H	---	---	---	---
ASH-T	NOVAKY, CZECH. / ELEKTRAREN, NOVAKY	---	---	250.0	---	---	7,200	300 H	---	---	---	---
AU-T	KOLAR, KARNATAKA, IND/KOLAR AU FIELDS	---	---	---	---	---	---	---	---	---	---	6
BAU-T	KORBA, MADHYA PRADESH, IND/BHARAT AL CO	---	---	---	---	---	---	---	---	---	---	6
BO-T	BORDON, CA, USA/US, BORAX & CHEM CORP	2.6	--	127.0	16-26	1.46-3.66	1,326	---	CSE	0	2-2	1
CE		3.15	--	203.2	---	---	0.152	---	---	7	---	1-1
CO-C	BLACK MESA, AZ, USA/SOUTHERN PACIFIC	1.41	99-1.19	457.2	48.0	1.768	439	599 H	DAPD	4	3	9-4
CO-C	CADIZ, OH, USA / CONS. COAL	1.4	--	273.0	50.0	1.52	173.8	1,186 Y	DAPD	2	3	13
CO-C	SAFE HARBOR, PA, USA / PA, POWER	1.85	--	323.8	---	---	0.49	57-63	C	---	---	16
CO-C	CHESTCK, PA, USA / HANNA COAL CO	1.5	--	152.4	52.5	2.44	0.792	1,456 Y	C	---	0	17
CO-C	POLAND	---	---	554.0	---	---	203.8	---	---	---	---	1
CO-C	CARLING, FRANCE	---	---	381.0	25.0	2.59	8651	1,586 Y	---	---	---	17
CO-C	MOROVLYANSKAYA MINES, USSR	---	---	304.8	38.0	1.463	61.16	199.6 H	---	---	---	14
CO-C	LONDON, ENG / HAMERSMITH BOROUGH	---	---	203.0	50.0	1.200	0.540	28 Y	C	---	1	17
CO-C	WESTFIELD COLLIERY, UK	---	---	175.0	---	---	1.700	28 Y	---	---	---	17
CO-C	WALTON COLLIERY, UK / N.E.	---	---	177.0	34.0	2.59	2.010	600 D	CE	---	1	3
CO-C	MARKHAM COLLIERY, UK	---	---	150.0	---	---	0.100	286 Y	---	---	---	17
CO-O	SAFE HARBOR, USA/PA POWER & LIGHT	1.85	--	288.5	13.3	4.63	488	154,256 Y	CSE	0	3-3	1
CO-O	ROBINSON, RON MINE, WA, USA/CONS. COAL	---	---	554.0	38.0	4.27	925	60,056 Y	C	---	2	---
CO-O	LOPERLUG, WA, USA / CONS. COAL CO	---	---	504.8	---	---	---	---	---	---	---	12
CO-O	SOKAGAWA MINE, JAPAN/MIITSUI COAL CO.	1.56	100-100	300.0	3.1	4.100	2,200	339 D	C	---	---	---
CO-O	LOHRKATZEK	---	---	345.0(5)	---	---	3.50	358 Y	---	---	---	---
CO-O	LOHRKATZEK	---	---	366.0	---	---	9.70	386 Y	---	---	---	---
CO-O	BURGHEIS, GFR	---	---	136.0	---	---	7.80	386 Y	---	---	---	---
CO-O	PERNOMAJSK, USSR	---	---	200.0	---	---	3.30	---	---	---	---	---

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - HORIZONTAL

SLURRY CODE	LOCATION/OWNER	SPECIFIC GRAV. OF SOLIDS	PSD #*-MW	OD X WALL THICKNESS MM	CONC WT.	VEL M/S	L KM	CAPACITY TONNES PER (SEE NOTE)	OPERATION DATES	PUMP TYPE	NO. OPER. OF PUMPS- STA	NO. OPER. STANDBY REF
CO-0	MORVNIEN, USSR	---	100-6	300.0	---	1.00	61.0	.356 Y	----	----	---	11
CO-T	FAIRMOUNT, WA, USA / CONS. COAL CO	---	---	101.6	40.0	2.13	.823	---	1953	CSE	0	3-0
CO-T	NORTHERN WA, USA	1.4	---	101.6	4.0	3.26	.549	2.344 H	1957	CSE	0	3-1
CO-T	DEHDE WA, USA / YOUNGSTOWN MINES CO	1.43	---	103.1	10.0	1.23	.533	7.312 H	1957	CSE	0	4-0
CO-T	CHESTICK, PA, USA / HARMAR COAL CO	1.50-	---	152.4	50-55	2.438	.792	110.6 H	1957	CSE	0	3-1
CO-T	CANADA	1.55	---	330.2	45.0	1.829	7.242	9090.9 D	---	---	---	3
CO-T	LIMBURG, ME	---	100-1	200.0	---	---	2.0	.566 Y	----	----	---	11
CO-T	SARGEBELT, GFR	---	100-1	150.0	---	---	1.10	.566 Y	----	----	---	11
CO-T	SARGEBELT, GFR	---	100-1	150.0	---	---	3.80	.566 Y	----	----	---	11
CO-T	SARGEBELT, GFR	---	100-1	150.0	---	---	3.80	.566 Y	----	----	---	11
CU-C	KOI TURKEY	---	---	127.0	---	---	61.16	0.9156 Y	----	----	---	---
CU-C	BOGLIVILLE	---	---	152.4	---	---	27.3	0.9156 Y	1972	WPL 3	---	2
CU-C	ARBITER PLANT, USA	---	---	181.6	---	---	---	0.1856 Y	1974	---	---	---
CU-C	MIRA / IRIAN JAYA FREEPORF IND. INC	---	---	88.9	65.0	1.22	111.0	0.653 D	1974	WPL 3	---	1-1
CU-C	PINTO VALLEY, AZ, USA/CITIES SERVICE CO	---	---	101.6	28.0	---	17.7	0.3656 Y	1974	FL 3	---	2
CU-C	ELSD-LIANTOCHLE / ANACONDA	---	---	152.4	---	---	22.93	721.3 D	1959	---	---	---
CU-C	HAYDEN/AZ, USA / KENNECOTT COPPER CO	4.2	---	152.4	26.0	1.28	0.853	---	1958	CSE RU 0	0	2-2
CU-S	GHATSILA, BIHAR, IND/HINDUSTAN COPPER	---	---	---	---	---	---	---	----	----	---	6
CU-T	JAPAN	---	---	304.8	---	---	70.81	0.566 Y	1968	DAPI 2	---	3
CU-T	WHITE PINE, MI, USA/WHITE PINE COPPER	2.7	---	587.38	17.5	3.22	1.897	14783.5 D	1953	CSE	0	4-0
CU-T	BUTTE, MT, USA / ANACONDA	2.7	---	508.0	30.0	2.844	5.632	25493.5 D	---	CSE	---	7
CU-T	W. VIRGINIA, USA	1.4	---	101.6	---	---	---	---	1957	C	---	3
CU-T	W. VIRGINIA, USA	1.4	---	102.1	---	---	---	---	1957	C	---	4
CU-T	CANADA / U.S. BORAX	2.6	---	127.0	---	---	---	---	1957	C	---	4
CU-T	MONTANA, USA / ANACONDA	---	---	508.0	---	---	---	18181.8 D	1964	C	---	3
CU-T	GHATSILA, BIHAR, IND/HINDUSTAN CU LTD	2.80	100-295	219x	35-40	1.70-	1.0	96-129 H	1974	C RU	---	6
CU-T	50-074	7.14	---	---	---	---	---	---	---	---	---	---
CU-T	KHETRI, RAJASTHAN, IND/HINDUST. CU LTD	2.80	100-220	355.6x	50.0	1.63	1.60	9200 D	----	C	---	6
CU-T	100-074	7.92	60-074	7.92	---	---	---	5000 D	---	---	---	---
CU-T	MALANJKHAND, MADHYAPRADESH, IND/HIN. CU	2.86	100-589	273x	25-25	2.5(2)	2.5	252 H	1982	CSE RU 5	---	6
CU-T	52-074	7.09	---	---	---	---	---	---	---	---	---	---
CU-T	HIGHLAND VALLEY, CA, USA/LORNEX MINING	2.60	---	915.0	36.0	2.00	8.00	19000 D	1975	C	---	---
CU-T	TUSCON, AZ, USA / ANAMEX	2.70	---	500.0	30.0	2.00	---	10	1979	C	---	---
CU-T	IDAHO, USA / ASARCO	2.70	---	203.0	27.0	2.80	---	---	1978	C	---	---

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - HORIZONTAL

SLURRY CODE	LOCATION/OWNER	GRAV. OF SOLIDS	PSD \$-MM	OD X WALL THICKNESS MM	CONC WT.	VEL M/S	L KM	CAPACITY TONNES PER (SEE NOTE)	OPERATION DATES	PUMP TYPE	NO. OF STA	OPER. STANDEY REF
FE-C	WAIPPI(LAND) / MARCONA	4.9	---	203.2	45.0	4.88	1.829	323 H	1971	CSE RU	10	3
FE-C	WAIPPI(OFFSHORE) / MARCONA	4.9	---	304.8	45.0	5.79	2.896	1800 H	1971	CSE	6	3
FE-C	CHONGIN,N. KOREA	---	---	---	---	---	98.17	4.1E6 V	1975	---	4	4
FE-C	SAWAGE RIVER,TASMANIA	5.0	---	228.6	55.0	---	83.30	2.3E6 V	1974	PL	3	4
FE-C	PENA,COLORADA-MEXICO	5.0	---	203.2	---	---	45.06	1.8E6 V	1974	PL	3	4
FE-C	SIERRA GRANDE,AGTI	5.0	---	203.2	---	---	27.36	1.8E6 V	1974	PL	3	4
FE-C	LAS TRUCHAS,MEXICO	5.0	---	203.2	---	---	400.3	1.4E6 V	1975	PL	3	4
FE-C	SAMARCO,BRAZIL	5.0	---	508.0	---	---	402.3	10.9E6 V	1977	PL	3	2
FE-C	CANADA / ANACONDA	---	---	---	---	---	225.3	2.1E6 V	---	---	---	---
FE-C	LARRADOR-PT. MARQUETE,CAN	---	---	203.2	---	---	482.8	40.9E6 V	1974	---	---	---
FE-C	KUDREMNK,KARNATAK,IND/KUDR. FE LTD	4.90	100-104	457/406	60-70	1.80-2.80	65.0	7.5E6 Y	1979	CSE RU	5	1-1
FE-T	HUNNER PLANT, USA / M.A. HANNA	3.2	---	406.4	16.0	2.92	5.364	---	1955	C	1	8-0
FE-T	STAR LAKE,NV,USA / LAUGHLIN STEEL	2.7	---	298.5	20.0	3.66	1.524	---	1957	C	0	14
FE-T	CLUREY,MI,USA / LAUGHLIN STEEL	2.8	---	458.4	17.8	2.36	2.921	---	1958	C	0	1
FE-T	CLEVELAND,OH,USA / CLEVELAND STEEL	2.8	---	457.2	17.5	2.68	0.923	---	1958	C	0	2
FE-T	CRANDRIDGE,MI,USA / LAUGHLIN STEEL	3.0	---	488.95	17.5	2.65	1.633	---	1958	C	0	2
FE-T	HIBBING,MI,USA / M.A. HANNA	3.2	---	408.4	16.5	2.69	3.252	---	1958	C RU	0	2
FE-T	KEENEVA,MI,USA / M.A. HANNA	3.0	---	388.4	16.5	2.69	3.252	---	1958	C RU	0	2
FE-T	KEPWIN,MI,USA / M.A. HANNA	3.0	---	324.1	43.0	3.572	3.219	---	1957	C	0	5
FE-T	SELWICK,ONTARIO,CAN/LEHIGH ORS/LTD	3.0	---	523.0	35.0	2.20	0.488	---	1957	C	0	6
FE-T	CORNING,PA,USA/BETHLEHEM CORNWALL	3.0	---	523.0	35.0	2.10	2.937	---	1957	C	0	4
FE-T	CLUREY,MI,USA / LAUGHLIN STEEL	3.0	---	493.6	6.0	2.40	1.937	---	1954	CRA	0	2
FE-T	KUDREMNK,KARNATAK,IND/KUDR. FE LTD	3.04	100-147	457X	40.0	4.20	2.50(2)	---	1979	CSE RU	5	2-1
FE-T	BAILADILLA,MAHARA PRADESH,IND / NATIONAL MINERAL DEVELOP CORP.	---	84-043	---	---	---	---	---	---	---	---	---
GIL-D	UTAH-COLORADO,USA/AMER. GILSONIE CO	1.04	---	152.4	46.0	1.19	115.9	997.9 D	57-75	PL	1	2-1
G-T	LORRAINE MINE-FREDDIE,NSA / LORRAINE GOLD MINES	2.7	---	228.6	50.0	1.33	9.449	150.4 H	1963	CSE	0	4-4
G-T	NSA	2.7	---	228.6	45.0	1.49	9.144	136.9 H	1957	CSE	0	4-4
G-T	LEAD, SD, USA / HOBSTAKE	3.1	---	303.0	47.0	1.85	4.67	1.3	1978	CSE	0	16
G-T	LEADVILLE,CO,USA / ASARCO	3.0	---	300.0	30.0	2.00	3.00	---	1975	---	---	---
GS-T	CREIGHTON,PA,USA/PITTSBG. PLATE GLASS	2.5	---	101.6	31.0	1.95	1.707	23.45 H	1949	CSE	2	6-6

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - HORIZONTAL

SLURRY CODE	LOCATION/OWNER	SPECIFIC GRAV. OF SOLIDS	PSD %+-MM	OD X WALL THICKNESS MM	CONC WT.	VEL M/S	L KM	CAPACITY TONNES PER (SEE NOTE)	OPERATION DATES	PUMP TYPE	NO. OPER. OF PUMPS-STA	OPER. STANDBY REF
HM-C	AUSTRALIA/TITANIUM & ZIRCONIUM LTD.	1.3	---	152.4	---	---	5.633	21.8 H	---	---	---	---
HM-C	FLORIDA, USA / E. I. DUPONT	3.4	---	101.6	---	---	---	40.9 H	1955	C	2	---
HM-C	LAMSEY FL, USA / E. I. DUPONT	3.4	---	101.6	40.0	2.47	4.828	41.30 H	1955	C	8	16-0 1
KC-O	GEORGIA, USA / PHILLIPP CORP.	2.6	---	203.2	25.0	1.22	17.70	41.12 H	1951	C	1	2-0 1
KC-O	GEORGIA, USA / PHILLIPP CORP.	2.6	---	203.2	33.0	1.22	25.75	86.31 H	1959	C	0	3-1 1
KC-O	GEORGIA, USA / PHILLIPP CORP.	2.6	---	304.8	25.0	1.22	8.047	137.0 H	1940	C	0	2-0 1
LI-O	CALAVERAS	---	---	177.8	---	---	27.3	1.486 Y	1971	DAPI	2	---
LI-O	RUGBY, ENGLAND	---	---	254.0	---	---	91.7	1.866 Y	1964	DAPI	2	---
LI-O	TRINIDAD	---	---	203.2	---	---	9.6	0.866 Y	1959	DAPI	2	---
LI-O	COLUMBIA	---	---	177.8	---	---	---	0.3666 Y	1944	---	---	---
NA	SZENTEGAT, HUNG/SZENTEGATI STATE FARMS	---	---	150.0	---	---	8.000	---	1973	---	---	---
NA	RABAFUZES, HUNG/SZOMBATHELY STATE FARMS	---	---	200.0	---	---	4.000	---	1974	---	---	---
NA	VAROSFOLD, HUNG/VAROSFOLDI STATE FARMS	---	---	150.00	---	---	3.000	---	1975	---	---	---
NA	PIROSKA, HUNG/SZOLNOKI STATE FARMS	---	---	150.00	---	---	4.500	---	1976	---	---	---
NI-C	CANADA	---	---	203.2	28.0	1.829	12.07	1818.2 D	---	---	---	2
NI-T	WEST MINNESOTA, USA / WESTERN MINING	---	---	101.6	---	---	6.920	.091E6 Y	1970	---	---	---
ORE	HUNGARY / ERCBANYA VALLALAT	---	---	250.00	---	---	7.000	---	1979	---	---	---
PHM-O	BARTON, FL, USA/ARMOUR AGRIC. CHEM. CO	2.75	---	406.4	25.0	3.658	3.200	544.31 H	1960	C	3	4-0 1
PHM-O	FLORIDA, USA / SMITH-DOUGLAS CO INC	2.7	---	406.4	25.0	3.658	3.200	---	1955	C	4	---
PHM-O	KOSZALV MINE, FL, USA/INT. MINICHEN CO	2.6	---	457.2	35.0	5.029	7.62	---	1974	C	7	---
PHM-O	NORALV MINE, FL, USA/INT. MINICHEN CO	2.6	---	508.0	35.0	5.029	7.62	6.260E6 Y	1974	C	7	2 2
PHM-O	NICHOLS FL, USA / MOBIL CHEMICAL CO.	2.7	---	457.2	35.0	3.658	2.743	1056.1 H	1971	C	5	3-1 2
PHM-O	LEE CREEK, NC, USA / TEXASGULF	2.7	---	457.2	35.0	3.392	4.420	4.754E6 Y	1966	C	5	2-3 2
PHM-O	WHITE SPRINGS, FL, USA/OCCIDENTAL CO.	---	---	508.0	37.0	5.030	5.273	1674.7 H	1965	C	4	4-0 2
PHM-O	BOONY LAKE MINE, USA / W. R. GRACE	2.6	---	457.2	32.5	4.572	8.230	5.823E6 Y	1948	C	10	10-0 2
PHM-O	FURT MEADE, FL, USA / USS AGRICHEM. CO.	2.65	---	508.0	30.0	4.724	3.658	1373.8 H	1968	GIN	4	4-0 2

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - HORIZONTAL

SLURRY CODE	LOCATION/OWNER	SPECIFIC GRAV. OF SOLIDS	PSD %MM	OD X WALL THICKNESS MM	CONC WT.	VEL M/S	L KM	CAPACITY TONNES PER DAY (SEE NOTE)	OPERATION TYPE	NO. OF PUMPS-STA	OPER. STANDBY REF
PHM-0	TAPIRA-UBERABA, BRAZIL / VALEP	3.2	--	244.5	61.0	1.658	119.0	2,056 Y	REPL 3	--	2-1
PHM-0	TEMOROC MINE, FL, USA/SMITH-DOUGLAS CO.	2.7	--	406.4	35.0	3.962	3.962	792.1 H	CSE	4	4-0
PHM-0	COLUMBIA, TN, USA / MONSANTO CHEM. CO.	---	--	254.0	25.0	3.719	0.137	12,076 Y	C	2	2-2
PHM-0	SILVER CITY, FL, USA/SWIFT AGRI CHEM CO	2.5	--	508.0	30.0	4.511	2.164	---	C	---	3
PHM-0	WATSON MINE, FL, USA/SWIFT AGRI CHEM CO	2.5	--	406.4	30.0	4.267	8.717	734.7 H	C	---	7-7
PHM-0	MANATSE CO., FL, USA/BECKER PHOSPHATE CO	2.65	--	635.0	34.0	5.500	3.962	15,426 Y	C	---	5-0
PHP-0	CONDA, ID, USA / JR. SIMPLOT CO.	2.95	--	127.0	50.0	5.014	2.295	191.9 H	CRU	0	1-1
PHP-0	CONDA, ID, USA / JR. SIMPLOT CO.	2.95	--	203.2	50.0	5.014	2.295	---	CRU	0	1-1
PHP-0	SYDNEY MINE, FL, USA/AMER. CYANAMID CO	2.65	--	406.4	35.0	3.63	6.096	787.2 H	CSE	1	7-3
PHP-0	ACHANGARALVN MINE, FL, USA / INT. MIN & CHEM CO.	2.7	--	508.0	40.0	3.66	6.437	---	C	9	9-5
PHD-C	MATON, RAJASTHAN, IND/HINDUSTAN ZN LTD	2.95	100-30	73x	58-68	1.25-	10.5	15 H	1982 V PL 3	1	1-1
			90-053	7.14		1.9	5				6
PHO-T	MATON, INDIA / HINDUSTAN ZN LTD.	2.8	--	127.0	40.0	0.488	1.500	8,913 H	WSP	1	1-1
PHO-T	FLORIDA, USA / CHEMICAL CO.	2.6	--	406.4	---	---	---	---	C	---	5
PHO-T	FLORIDA, USA / CHEMICAL CO.	2.6	--	355.6	---	---	---	---	C	---	7
PHO-T	FLORIDA, USA / PAL POWER & LIGHT	2.1	--	254.0	---	---	---	---	C	---	2
PHO-T	SULLIVAN WD, USA, NERAMEC MINING CO.	4.2	--	101.6	15.0	---	0.274	---	CRU	---	1-0
PHO-T	NICHOLS, FL, USA, VI-CAROL CHEM. CORP.	2.65	--	355.6	35.0	2.696	7.724	610.8 H	C	0	7-0
PHO-T	NICHOLS, FL, USA, VI-CAROL CHEM. CORP.	2.65	--	406.4	25.0	4.237	6.287	596.9 H	C	0	5-0
PHO-T	CAPT. PROV., RSA / CHEMFOS LTD.	2.8	--	152.4	30.0	1.890	3.060	46.79 H	C	5	9-9
PHO-T	WHITE SPRINGS, FL, USA/OCCIDENTAL CO.	2.72	--	508.0	25.0	5.243	2.967	1070.4 H	C	3	3-0
PHO-T	KINGSFORD MN-FL, USA/INT. MIN&CHEM. CO	2.65	--	457.2	32.0	4.511	4.267	6,325 Y	C	4	4-1
PHY-C	GWCL, RSA	3.0	--	127.0	---	---	---	181.8 D	C	---	4
SI-T	BLACKBIRD, ID, USA / CALERA MINING CO	2.7	--	152.4	45.0	1.387	2.262	52.28 H	CSE	9	18-0
SI-T	BRALORNE, BC, CAN / BRALORNE PIONEER MI	2.7	--	76.2	28.0	1.646	1.841	9,749 H	CSE	0	3-0
SI-T	KELLOGG, ID, USA / SUNKER HILL CO.	2.75	--	127.0	40.0	1.661	2.865	40.41 H	CSE	0	4-0
SI-T	TATABANYA, HUNG / COAL MINE TATABANYA	---	--	200.0	---	---	8.500	240 H	---	---	1
SI-T	--- / QUEBEC CARTIER MIN. CO	---	--	298.5	40.0	4.267	2.092	1814 H	C	---	4

SUMMARY OF MAJOR PIPELINE INSTALLATIONS - VERTICAL

SLURRY CODE	LOCATION/OWNER	SPECIFIC GRAV. OF SOLIDS	PSD §+-MM	OD X WALL THICKNESS MM	VEL M/S	L KM	CAPACITY TUNNES PER (SEE NOTE)	OPERATION DATES	PUMP TYPE	NO. OPER. OF PUMPS- STA	OPER. STANDBY REF
CO-C	GREISENAU, DORTMUND, GER	---	---	200.0	---	0.700	156 Y	1971	----	---	17
CO-0	EGERCSEHI, HUNGARY / COAL MINE BORSOD	---	---	150.0	---	.212	60 H	1966	----	---	---
CO-0	GWEISENAU, W. GERMANY / BERGBAU AG	---	---	150.0	---	.670	150 H	1971	----	---	---
CO-0	HANSA, W. GERMANY / BERGBAU AG	---	---	250.0	---	.850	250 H	1977	----	---	---
CO-0	DEBESKO MINE, POLAND	---	---	250.0	---	.309	100 H	1957	----	---	---
CO-0	SIERZA MINE, POLAND	---	---	---	---	.110	---	1958	----	---	---
CO-0	ANDALUZA MINE, POLAND	---	---	---	---	.300	120 H	1958	----	---	---
CO-0	SUTOGAN MINE, USSR	---	---	---	---	.400	41 H	1959	----	---	---
CO-0	SELIDVUGOL MINE, USSR	---	---	---	---	.130	21 H	1959	----	---	---
CO-0	ST. ETIENNE, FRANCE	---	---	200.0	---	.178	50 H	1960	----	---	---
CO-0	MITSUI-SUNAGAWA MINE, JAPAN	---	---	190.0	---	.515	100 H	1965	----	---	---
CO-0	YOSHIDA MINE, JAPAN	---	---	165.0	---	.253	110 H	1970	----	---	---
CO-0	LU-CHA-TO MINE, CHINA	---	---	400.0	---	.473	41 H	1974	----	---	---
CO-0	ROBINSON RUN MINE, USA	---	---	250.0	---	.035	270 H	1974	----	---	---
CO-0	KARL FUNK MINE, W. GER.	---	---	140.0	---	.762	73 H	1974	----	---	---
CO-0	GWEISENAU, W. GER.	---	---	200.0	---	.700	127 H	1974	----	---	---
CO-0	HANSA, W. GER.	---	---	240.0	---	.840	209 H	1976	----	---	---
CO-0	LOVERIDGE MINE, USA	---	---	300.0	---	.274	---	1979	----	---	---
CU-0	BANGCROFT MINE, RHODESIA	---	---	200.0	---	.400	143	1961	----	---	2
G-T	BAAL REEFS KLERKSDORF MINE, RSA	---	---	150.0	---	2.200	50	1970	----	---	4
ZN-0	SHULLSBURG-WI, USA / CAI UMET & HELCA CONS. COPPER	---	---	250.0	---	.111	220	1952	----	---	---

NOMENCLATURE

SLURRY CODE: C=CONCENTRATES,T=TAILS/REFUSE,U=ORE

ASH-T = FLY ASH;T
 AU-T = GOLD TAILS
 BAU-T = BAUXITE TAILS
 BO-T = BOKSAX;T
 CE = CEMENT
 CO-C = COAL;C
 CO-D = COPPER;C
 CU-C = COPPER;C
 CU-T = COPPER;T
 FE-C = IRON;C
 FE-T = IRON ORE;T
 GIL-O = GILSONITE;O
 GS-TD = GLASS TAILINGS;T,O
 G-T = GOLD;T
 HM-C = HEAVY MINERAL CONCENTRATES;C
 KC-O = KAOLIN CLAY;O
 LI = LIMESTONE
 MA = MANURE
 ML-T = MILL TAILINGS;T
 NI-C = NICKEL;C
 NI-T = NICKEL;T
 ORE = STERILE ORE
 PHM-O = PHOSPHATE MATRIX;O
 PHP-O = PHOSPHATE PEBBLES;O
 PHO-C = PHOSPHATE CONCENTRATES
 PHO-T = PHOSPHATE TAILINGS;T
 PY-C = PYRITE CONCENTRATES;C
 SI-T = SAND TAILINGS;T
 SR-T = SULFIDE ORE FLOTATION;T
 SS-T = SMELTER SLAG;T
 UP-C = URANIUM PYRITE CONCENTRATES;C
 UR-TD = URANIUM SLIME;T,O
 URN-T = URANIUM TAILS
 ZN-O = ZINC ORE
 ZN-T = ZINC TAILS

LOCATION: STATES

THE STATES ARE CODED USING THE
 US POSTAL SERVICE SYSTEM CODES

E6 = ONE MILLION

S = SECONDS

M = MINUTES

H = HOUR

D = DAY

Y = YEAR

PUMP TYPE:

C = CENTRIFUGAL
 DA = DOUBLE ACTING
 G = GRAVITY
 H = HORIZONTAL
 ME = METAL
 PA = PARALLELS
 PD = POSITIVE DISPLACEMENT
 PI = PISTON
 PL = PLUNGER
 RE = RECIPROCAL
 RU = RUBBER
 SA = SINGLE ACTING
 SE = SERIES
 V = VERTICAL
 2 = DUPLEX
 3 = TRIPLEX
 4 = QUADRAPLEX
 5 = QUINTUPLEX

LOCATION: COUNTRY

ARG = ARGENTINA
 AUS = AUSTRALIA
 BRAZIL = BRAZIL
 CAN = CANADA
 CHILE = CHILE
 COL = COLUMBIA
 ELSAL = EL SALVADOR
 ENG = ENGLAND
 GDR = EAST GERMANY
 GFR = WEST GERMANY
 HUNG = HUNGARY
 IND = INDIA
 INDO = INDONESIA
 JAPAN = JAPAN
 MEX = MEXICO
 NKOR = NORTH KOREA
 NL = NETHERLANDS
 POL = POLAND
 RSA = REPUBLIC OF SOUTH AFRICA
 TAS = TASMANIA
 TRIN = TRINIDAD
 USA = UNITED STATES
 USSR = USSR
 WIRA = WEST IRIAN

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