# A TECHNICAL COMPARISON OF COAL PIPELINE OPTIONS

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Long distance transportation of coal was commercially proven in the highly successful 440 km Black Mesa Coal Pipeline commissioned in 1970. The economic pumping of coal in water over long distances requires the coal to be reduced to a fine size consist. At the power station the de-watered coal is further reduced to pulverised fuel (pf) size. Another option is to reduce the coal to pf size before transport and pump as a coal-water mixture. For long distance transport of minus 50 mm export size coal, the only viable option is to use a unique Special Vehicle Slurry (SVS) system. The paper compares the technical issues involved in all coal pipeline options.

## 1. INTRODUCTION

The transportation of coal over long distances was commercially proven in the highly successful 440 km Black Mesa Coal Pipeline commissioned Aug. 14, 1970. The Black Mesa pipeline fed the captive Mohave Power Station for over 35 years. Although the use of coal for energy may slowly decrease in the long term, coking coal will still require transportation.

The economic pumping of coal in water over long distances requires the particle size of the coal to be reduced to a fine size consist with the Black Mesa pipeline having a top size of 1.4 mm and 18 to 20% minus 45 microns to ensure optimum slurry properties. At the power station the de-watered coal is further reduced to pulverised fuel (pf) size. Another option is to reduce the coal to pf size before transport and pump as a coal-water mixture.

Australia is the largest coal exporter in the world. The coal exported, both energy coal and coking coal, is generally minus 50 mm and such coal can only be pumped over distances of a few kilometres as a coal-water slurry because of high pump pressures required. For long distance transport over a few hundred kilometres the only viable option for export size coal transport is to use a unique Special Vehicle Slurry (SVS) system which extends the hydraulic fundamentals of the successful fine coal in water technology to create a slurry for commercial transportation of conventional minus 50 mm export coal.

The paper compares the technical issues involved in all coal pipeline options. Issues concerning the Russian, Bielovo-Novosibirsk coal-water mixture pipeline and experience with other European coal pipelines are discussed. The hydraulics of the SVS system are discussed in detail. The SVS vehicle slurry consists of a mixture of magnetite and fine coal of ratio and total concentration such that the density of the vehicle slurry is similar to the density of the lump coal. The technical issues are discussed including prediction of SVS slurry hydraulics from sample test data. The predictions were confirmed by pipe loop testing and Wheelstand tests with results presented.

## 2. LONG DISTANCE TRANSPORTATION OF COAL BY SLURRY PIPELINE - A REVIEW OF DEVELOPMENT

### 2.1 Background

The transportation of coal has conventionally been by rail for long distance and conveyor for shorter distances. The major users of coal are thermal coal for power generation and metallurgical coal for coke production in the steel industry. Mined coal is normally upgraded, at the minesite, in a coal preparation process to enhance the product and separate inert partings from the mine. The final product has low ash and low moisture content with a particle size of 50mm x 0.

The end user will subject the product coal to a finer size consist for final processing. For example the thermal coal feed to the burners in the power station is reduced to pf size of 300 μm x 0 and metallurgical coal to a coking plant is 6mm x 0.

The transportation of coal over long distances by slurry pipeline was established in 1957 with the opening of a 108 mile Consolidation (Consol) Pipeline in Ohio. The Consol pipeline was created to provide an economic alternative to rail. The driving commercial incentive for developing the slurry pipeline alternate was to reduce the price the railroad company levied for rail freighting coal on several of Consol Mines. The Ohio system was technically proven, however, the system was mothballed once an agreement was reached that the railroad company reduced the rail freight price on the five mines.

The transportation of coal by slurry pipeline technology languished for 20 years, until the installation of the Black Mesa pipeline in Arizona in 1970. The Black Mesa pipeline was a grassroots system. There was no existing railroad to transport the Black Mesa coal. Black Mesa coal was fed to the captive Mohave Power Plant. The Mohave Power Station was located near the electrical load at Las Vegas and was adjacent to cooling water on the Colorado River, Nevada, USA.

At Mohave the pumped (2mm x 0) coal slurry is stored as slurry and the final dewatering process occurs above pulverisers in the Mohave Power Station. The Black Mesa pipeline transported coal to the 1500 MW Mohave Power Station at the rate of $4.5 \times 10^6$ tpa of coal.

The Black Mesa coal slurry pipeline was both a technical and commercial success with a 38 year history. The following extracts are from EJ Wasp's paper [1] presented in 1975 at the Mining Convention of the American Mining Congress, San Francisco, Calif. Sept 28-Oct 1. On reliability:

> "The reliability of the coal slurry pipeline supplying the Mohave Plant has been excellent. Since the coal slurry pipeline is the sole source of coal for the Mohave Plant, the reliability and ninety-nine percent (99%) availability of the slurry pipeline has been of utmost importance to the Project Participants".

And on economics, their statement was:

> "Our experience to date indicates that the Black Mesa Pipeline has transported coal to the Mohave Plant at a cost benefit of nearly 50% below that of alternate transportation costs."

With the proven success of Black Mesa coal pipeline, the mid 1970's ushered in a period in the USA when a number of potential pipelines with project throughputs of 25 x $10^6$ tpa were promoted. Each system was capable of feeding up to 5 x 1500 MW power stations. Energy Transportation Systems Inc (ETSI) was the principal proponent.

### 2.2 Essentials for Producing a Fine Coal Slurry

Coal slurry preparation is a key to producing a slurry suited to long distance pumping. The essential requirement is to produce a slurry with the size consist summarised in Table 1. The process is a once through crushing process.

**TABLE 1**
**FINE COAL SIZE TO SUIT SLURRY TRANSPORT**

| Tyler Mesh | % Retained |
|---|---|
| +14 (1.19mm) | 1.5 |
| +20 (840µm) | 4 |
| +28 (590µm) | 11 |
| +48 (297µm) | 32.5 |
| +100 (145µm) | 55.0 |
| -32.5 (44 µm) | 19.5 Passing |
| J.G.Montford, 5th Int. Tech. Conf. on Slurry Transportation March 1980. | |

The typical preparation plant facility diagram is presented in Figure 1.

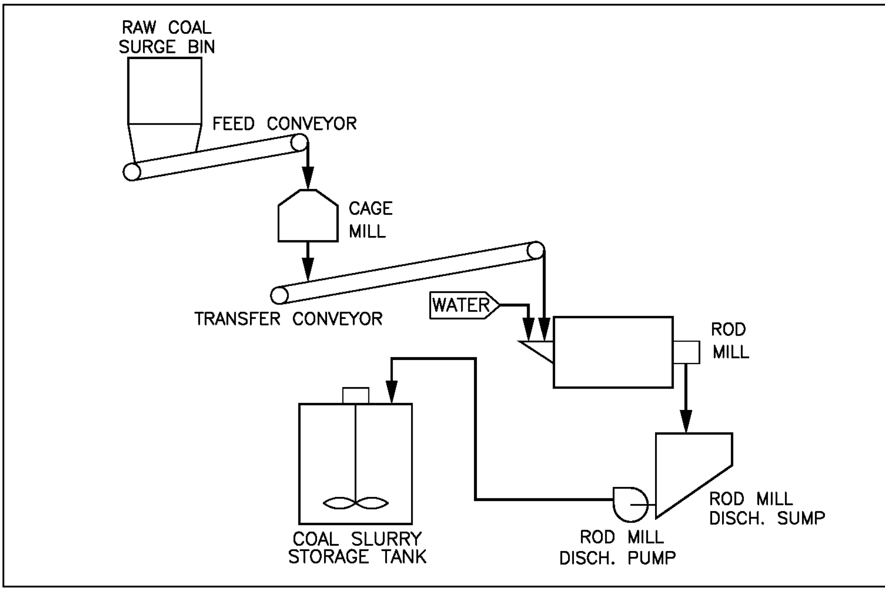



Figure 1
Typical Coal Slurry Preparation – Facilities Diagram

**2.3 Coal Slurry Utilisation – Power Generating Industry**
The electrical power generating industry required a high operating availability which fostered a conservative production and maintenance philosophy. The power generating industry is based on storage and handling coal with 50mm X 0 size consist. At Mohave the coal was received and stored as a (2mm X 0) coal slurry which was new technology to the power station personnel. Initially, the slurry storage and dewatering system at the Mohave power station experienced some processing problems. Of particular concern was the mechanical performance of the solid bowl centrifuges. These units wore out and required relining in less than 1,500 hours and centrifuge solids recovery of 95% meant 5% superfine coal carried over in the centrate. The superfine centrate coal slurry proved extremely difficult to recover. The centrate required concentration in large settling ponds. The low density settled centrate was eventually burnt direct into the furnace as a slurry.

The close coupling of the slurry pipeline system into the power station created technical and power plant operating issues that were perceived as a major problem for the conservative power generating industry. The slurry pipeline proponents initiated the concept of delivering the pipelined coal as a dewatered coal fuel as a similar product to current power station practice. The dewatered coal concept minimised the impact of new technology on the power industry.

ETSI developed and operated a large scale coal slurry dewatering demonstration plant. The ETSI demonstration Plant not only proved up the dewatering process , but also, produced product coal for conventional power generating processing. The key technical issues in dewatering of the slurry and the handling of the dewatered fine pipelined coal product were determined, including:

1. Slurry preheating prior to centrifuging.
2. Use of more efficient screen bowl centrifuges.

3. Determination of power station bunker configuration.
4. Covered conveyors and limited conveyor speeds and slopes.

The significant effort to promote coal slurry pipeline transportation systems in the USA was opposed by railroad interests and, even though coal slurry transport was cheaper and more environmentally friendly than rail transport, the pipeliners failed to obtain pipeline right-of-way across railroad property. An anti trust legal case against the railroads by the pipeliners was settled for $US600 Million.

Consequently the commercial rail road interests have successfully halted the technically and economically proven fine coal slurry pipeline technology for 26 years.

## 3. THERMAL COAL MARKET AND COAL SLURRY TRANSPORT

### 3.1 Background

2mm X 0 slurried pipelined coal size consist is significantly finer than the current specification size of 30mm x 0 for the power generating industry. The processing of the dewatered pipeline product in a conventional bunker feed power station has been proven. However, the power station storage, handling conveyors and bunker configurations and design require modification to suit a finer coal product. These modification include:

1. Covered stockpiles.
2. Covered and slower transfer conveyors.
3. Increased bunker discharge angles including stainless steel lining.

An alternative is to agglomerate the fine pipelined coal product by briquetting or other processes.

### 3.2 Pipelining Lump Coal without Particle Size Reduction ("Brute Force System")

The "Brute Force" approach has been available for decades, dating back to early dredging practice. A "Brute Force" system involves pumping lump coal at a low concentration in water. Consol, USA installed a relatively short distance system to hoist and transport raw coal from the Loveridge underground mine to a central coal washing facility.

"Brute Force" pumping is characterised by transporting the coarse coal particles in a high flowing water stream. The coal is moved by drag forces and supported by turbulence. A very high flow velocity is required to prevent deposition of the coal particles in the pipeline causing a blockage. The high velocity results in high headloss (headloss is proportional to the square of velocity). The high velocity causes high wear and bare steel pipes have a short life requiring pipelines to be laid above ground for ease of turning for maintenance.

"Brute Force" systems, although proven, are suited only for short pumping distances up to 10km. A number of technical issues arise:

- The pipeline wall is subject to erosion requiring a wear resistant lined pipe.
- The pumping units are restricted to centrifugal or special lock hopper units. Conventional high pressure positive displacement pumps are restricted to 6mm particle top size limit of poppet valves.
- The passage of the coal particles through multi stages of centrifugal pumps causes particle attrition.

### 3.3 Research into Stabilised Coarse Coal Pipeline

Research into the economical transportation of product coal (50mm x 0) over long distance by slurry pipeline, increased in the late 1970's, driven by the first oil shock. The research was innovative and was backed by pipe loop testing. These efforts focussed on pumping the coal at high % solids – low water, as an extension of the pumping of concrete in the construction industry. The efforts are summarised under various terminology, including "Stabflow" – stabilised flow and "ASEA technology" pumping coal at high concentrations. ASEA was part of the ABB Asea Brown Boveri Group. A brief overview of the research efforts follows.

#### *3.3.1 "Stabflow" Technology*

Over thirty six years ago, in early 1974, the concept of pumping coarse coal in a fine coal slurry of sufficient consistence to support the coarse coal particles in static conditions was instigated. This system was termed "Stabflow" (flow of stabilised coarse coal suspension). Early pilot plant tests showed great promise for the Stabflow concept.

About 4 years later, in 1978, the "Stabflow" technology was taken up by the Australian Commonwealth Scientific Industry Research Organisation (CSIRO). They concluded that 40 to 50% of the coal mixture was required to be fine coal less than 0.5mm size. The high fines level was unacceptable for market requirements. In addition, full scale pressure drops were higher than expected and pipe wear was still undefined.

The "Stabflow" technology is characterised by laminar flow of coarse particles supported by dense fine coal slurry. Although the coarse coal is supported by fine slurry in static conditions, laminar flow destroys the yield stress support mechanism since there is no turbulence to assist in suspending the coarse particle [2], the particles are dragged along the bottom of the pipeline and can cause pipeline blockage.

Headlosses are high as a result of the viscous slurry properties needed to support the coarse coal particles and to prevent deposition occurring. Some pipe wear does occur as the coarse coal is dragged along the bottom of the pipeline. The pipe wear is less than in a "Brute Force" system.

#### *3.3.2 "A.S.E.A. Technology"*

In 1982 ASEA continued the development of a unique "gattling gun" pump invented by Bede Boyle in Newcastle, Australia. The pump was created to pump export coal at very high solids concentrations.

The ASEA technology is characterised by packing the pipeline with coal particles at high concentration. The packed coal is transported as a sliding bed. The velocity is low. However, the headloss created by sliding friction is high.

The solids sliding along the invert of the pipe causes pipe wear and the pipeline system is susceptible to operability problems.

## 4. COAL-WATER MIXTURE PIPELINING

### 4.1 General

In the report "Energy strategy of Russia to 2020" it is said that most of electrical energy in Russia will come from thermal power plants and it is assessed at the level of 68-69%. Despite devising in Russia modern methods of combusting coal (EKOVOT) and despite the fact that the coal fuel produced in this way is 3 – 4 times cheaper than oil, these methods are not widely used in practice. Pipeline transport provides important support for thermal power industry based on coal-water mixtures. The cost of pipeline transport is lower or significantly lower in comparison to the alternative transport costs depending on the length of transport route. In Russian conditions the cost can be about 12% lower at the transport distance of 100km, from 22% to 32% lower at the route of 1000km and in case of the route length of 4000 km it can be lower from 47% to 65% [3].

In Russian conditions, where coal deposits are located in areas without technical infrastructure, it can be assumed that the pipe transport is preferred. **This also applies to a potential pipeline in Borneo.** Therefore, conditions indicate, pipeline transport has better development prospects in Russia than alternative means of transport.

Moreover, it is important that pipeline transport has significantly smaller influence on natural environment than other means of transport (for example road transport). Prospects for using pipeline hydrotransport in other countries seem also good, considering that energy production based on coal is dominant in many countries, for example in USA – 52%, Germany –54%, China-72%, Poland – 94% [3].

### 4.2 Belovo-Novosibirsk CWM Slurry Pipeline Experience

One of the most important pipeline installations for transporting coal was Belovo-Novosibirsk pipeline in Siberia, launched in 1989. With its length of 258 km and its diameter of 530 mm the Belovo-Novosibirsk pipeline was the first pipeline in the world which transported CWM(Coal-Water Mixture) from the mine directly to the boiler. Three pump stations were used for pumping CWM. The basic parameters of the pipe and coal slurry of Belovo-Novosibirsk pipeline are presented in Table 2.

**Table 2**
**Pipe and CWM Slurry Parameters of Belovo-Novosibirsk pipeline**

| Parameters of pipeline and coal slurry | Coal pipeline Belovo-Novosibirsk |
|---|---|
| Length, km | 258 |
| Diameter of main pipeline, mm | 530 (outside diameter) |
| Flow rate of coal slurry, m/s | 0.7-0.9 |
| Capacity, tons/yr | 3,000,000 |
| Number of intermediate pumping station | 2 |
| Type of pump | reciprocating |
| Effective head of pumps, MPa | 13.93-31.38 |
| Pump capacity at the following pressure, $m^3/s$ | |
| minimal | 0.0509 |
| maximal | 0.0227 |
| Weight concentration of slurry, % | 61 |
| Maximal particle dimension, mm | 0.5 |
| Viscosity of slurry μ, Pa s | 0.9-1.4 |
| Yield strength, Pa | 11-13 |

Snamprogretti Company used an internal technology called “Reocarb” [4] for preparing coal slurry. The biggest difficulty in developing the pipeline technology was to reconcile optimal characteristics of the slurry which suited pipeline transport requirements with characteristics of the slurry which met requirements of combustion process. Apart from meeting the mentioned requirements of transport and combustion, the slurry also had to meet assumed sedimentation requirements because it had been stored in storage tanks for some time prior to transport.

In the initial period of pipeline operation under the supervision of Snamprogretti 300,000 tons of stable slurry of the concentration 60-63% [4] were transported. During further operation stoppages in the installation happened frequently, the pipeline got blocked, rheological characteristics of the slurry delivered to the pipeline changed, also on the route of the pipeline. According to the paper by Shalaurov V.A. et al [5], one of basic reasons of problems with operation was significantly smaller flow velocity than critical velocity. In the last period of operation the daily capacity of the installation was 1,993 $m^3$ and the average capacity for 10 days was 16,213 m.$^3$ On the assumption the mixture flows through the whole cross section of the pipeline, the average flow velocity for the mentioned daily capacity was 0.12 m/s, and for the period of 10 days - 0.09 m/s. Comparing to the planned rate (Table No.5.1), these velocities are from 5 to 10 times smaller.

Problems with operation led to closing the pipeline in the second half of the year 1993.

Snamprogretti also designed a technology of creating coal-water slurry for Porto Torres Company in Sardinia. The slurry of the following parameters was transported from the Storage tank to the boiler over a relatively short distance: weight concentration of 63-65%, viscosity of 1,000-1,200 mPa s at $20^{o}$C, granulation below 250 µm at contents of 80% grains below 74 µm. The yearly capacity of the installation is 500,000 tons.

## 5. SPECIAL VEHICLE SLURRY CONCEPT

### 5.1 Fundamentals

Pipeline transport of conventional product coal (50mm x 0) over long distances was conceived as an extension of the use of heavy media in coal preparation processes. Heavy media is a fine magnetite in water slurry of solids concentrations sufficient to achieve a slurry specific gravity equivalent to the coal particle solids specific gravity of 1.36 – 1.4. A heavy media magnetite slurry has a magnetite concentration of 36% solids. On static settling, the settled magnetite concentration is 80% solids.

The mix of heavy media plus water plus coarse coal is acceptable for short distance in-plant pumping. However, for long distance transport the mix causes problems in the advent of a shutdown with slurry in the pipeline. On restart, the slurry will breakup increasing the potential for pipeline plugging.

Both the “Stabflow” and ASEA concepts were based on unstable pumping at high concentrations in laminar flow. Slurry Systems’ Special Vehicle Slurry Concept centred on pumping the coarse coal in turbulent flow where turbulent eddies are present to support the coarse coal particles.

The “SVS” technology evolved from Slurry Systems’ experience with operating slurry pipeline systems and in depth understanding of slurry transport mechanisms. Slurry Systems married the tried and commercially proven fine coal transport mechanism to transport of coarse coal at optimum flow velocity (See Figure 2). The coarse coal particle settling tendency is minimised by employing a vehicle **(or carrier)** slurry of a similar density as the coal. The special vehicle slurry has unique viscosity properties for minimising headloss and improving operability. The vehicle slurry contains a portion of magnetite and does not contaminate the coal.

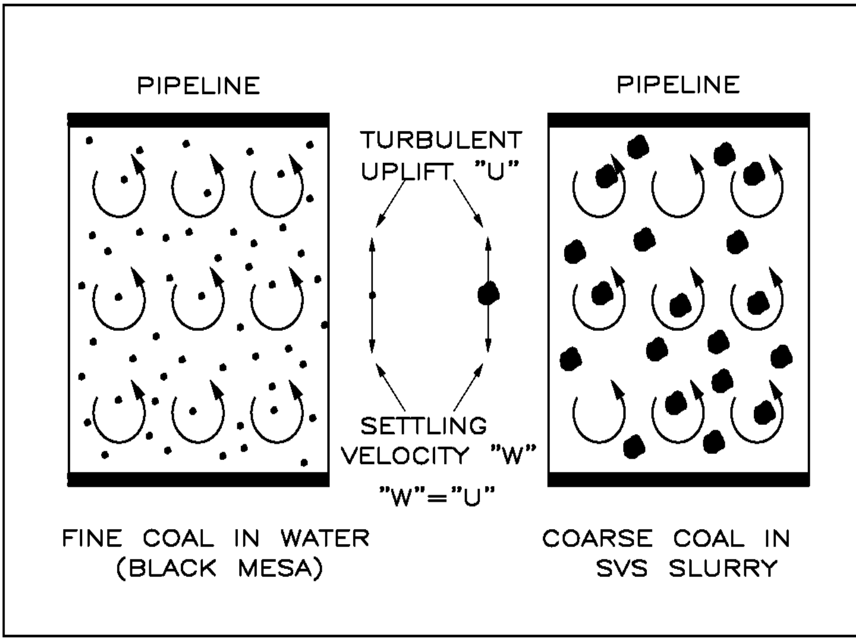


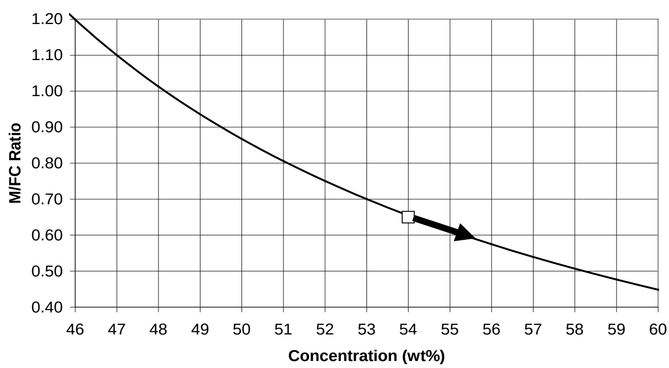

Figure 2
SVS-Fine Coal Pipelining – Technical Equivalency

**5.2 Special Vehicle Slurry (SVS)**
The SVS system utilises a vehicle slurry composed of magnetite and fine coal with the magnetite to fine coal ratio (M/FC) and combined solids concentration such that the density of the vehicle slurry is similar to the average density of the lump coal. The neutral buoyancy of the average lump coal particle means the pipeline hydraulics are similar to the successful fine coal Black Mesa pipeline. Required pumping velocity is moderate with resulting pressure gradients and pipe wear rates similar to a fine coal pipeline.

**5.3 SVS Vehicle Properties**
The SVS system is based on creating a vehicle slurry composed of magnetite (solids SG 5.0) and fine coal of SG equal to the lump coal. Suppose lump coal of SG 1.34 is to be transported. A vehicle slurry SG of 1.34 can be achieved by a range of vehicle concentrations and Magnetite to Fine Coal (M/FC) ratios. However an additional requirement relates to the stability of the vehicle slurry. The role of the fine coal is to provide a stable vehicle slurry which on shutdown settles homogeneously. The homogeneous settling criteria requires a certain minimum vehicle Yield Stress, typically around 1 Pa. In addition there is an upper Yield Stress limit, typically about 7 Pa, imposed by the requirement to ensure turbulent, rather than laminar, flow prevails at the normal pipeline operating velocity.

The stability and hydraulic considerations are important in selecting the M/FC ratio and the slurry vehicle concentration. Suppose the initial SVS vehicle slurry is at 54% concentration with a M/FC ratio of 0.65 to give the required vehicle SG of 1.34. During passage through the pumps and pipeline, the coarse coal suffers a degree of attrition and additional fine coal reports to the vehicle slurry. Attrition in the pipeline in particular results in production of very fine coal from rounding of the coarse particles. The fine coal attrition products are an ideal addition to the vehicle slurry. Attrition causes the concentration of solids in the vehicle to increase and the M/FC ratio to decrease. However, because the attrition products are of SG 1.34, the same as the vehicle, the vehicle SG remains constant at 1.34 as illustrated in Figure 3 where the M/FC versus concentration relationship follows the SG 1.34 curve down to higher concentrations and lower M/FC ratios.

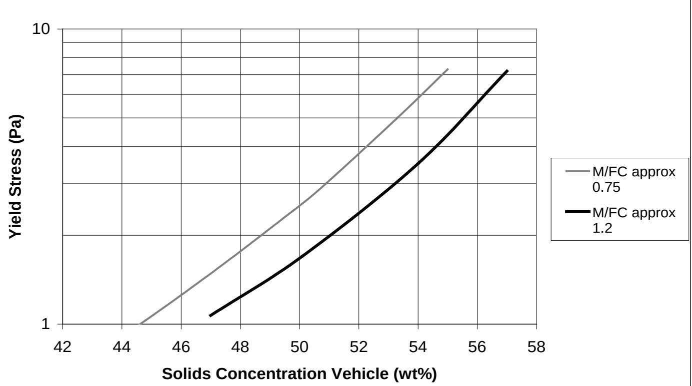
**Figure 3 M/FC Ratio versus Concentration Vehicle SG 1.34**




Attrition of the coarse coal provides a degree of self compensation for variations in coarse coal SG. Suppose the system normally transports coarse coal of average SG 1.34. If for some reason the coarse coal SG increases to say 1.38, the attrition products reporting into the vehicle are of higher SG than the initial vehicle and so the vehicle SG increases above 1.34 towards 1.38.

As the vehicle concentration and M/FC ratio vary, the slurry rheology changes. Figure 4 shows vehicle yield stress versus concentration for two M/FC ratios for a particular coal vehicle. The variation in plastic viscosity is of similar order.

**Figure 4 Variation in Yield Stress with Concentration and M/FC Ratio**



**5.4 SVS Technology – Wheelstand Tests**

SVS coarse coal tests have been conducted in a 200 mm NPS pipe Wheelstand test rig for a number of different coals. The degree of attrition depends on the hardness of the coarse coal. For one relatively soft coal with a Hardgrove Index (HI) around 80, the percent passing 125 microns increased by about seven percent after a simulated 100 kms pumping distance. The increase in fines results from coarse particle rounding rather than breakage of the coarse particles. The attrition resulted in an increase in the SVS vehicle slurry concentration of about one percentage point and a reduction in the M/FC ratio of about 0.05. Figure 6.2 indicates a small 0.5 change in concentration and M/FC ratio results in only a minor increase in yield stress, which as noted previously, can be within the range 1 to 7 Pa.

Pipe wear measurements were included in the Wheelstand tests using Corrosometer probes to measure wear rate at the top and bottom of the pipe. In unlined steel pipelines corrosion is controlled by maintaining slurry pH above 10. Wheelstand tests have been conducted both at normal and at high pH with a reduction in wear rate observed as the pH is raised. With pH maintained above 10 the measured wear rate is around 0.2 mm/y. A similar rate was observed for the vehicle slurry alone, which, given that the existing Black Mesa fine coal pipeline and the Savage River magnetite pipelines experience metal loss rates less than 0.1 mm/y, suggests that Wheelstand wear rates could be twice pipeline rates. On the basis of the Wheelstand double actual pipeline rates, the expected wear rate in a coarse coal SVS pipeline is expected to be around 0.1 mm/y although a design allowance of 0.2 mm/y is used.

**5.5 SVS Technology – Pipe Loop Tests**

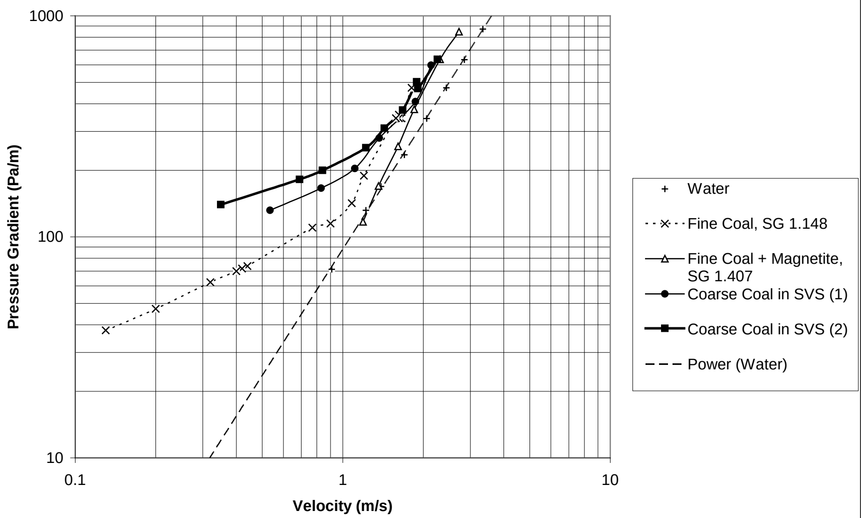
Pilot Plant pipe loop tests were conducted in a 105 mm diameter test loop with minus 40 mm coarse coal ($p_{80}$ 15 mm) in a SVS vehicle slurry. The coarse coal was SG 1.44. The fine coal was minus 300 microns with $p_{80}$ 50 microns and the magnetite was minus 100 microns with $p_{80}$ 35 microns.

Loop tests were first conducted on the fine coal alone, then on SVS fine coal and magnetite vehicle slurries at a number of slurry densities and then on coarse coal in SVS vehicle slurries at a number of coarse coal concentrations. Figure 5 summarises some typical results.

The fine coal test results (slurry SG 1.148, yield stress 2 Pa, plastic viscosity 19 mPas) show transition to laminar flow at around 1.1 m/s with laminar flow without deposition almost down to 0.1 m/s. The SVS fine coal-magnetite slurry (slurry SG 1.407, yield stress 2 Pa, plastic viscosity 8.4 mPas) exhibits a turbulent flow pressure gradient 1.45 times that of water for velocities above 2 m/s. Below 2 m/s the the vehicle slurry pressure gradient curves down towards the water line, indicating typical homogeneous non-Newtonian flow until deposition was observed at around 1.1 m/s.

Two coarse coal in SVS vehicle tests results are shown. SVS (1) is for vehicle SG 1.370 and coarse coal volume concentration 13.8%. SVS (2) is for vehicle concentration of 1.370 and coarse coal volume concentration 21.7%. In both cases laminar flow without deposition was possible down to the lowest data point shown. At the lowest data point the coarse coal was still moving but some magnetite was starting to deposit. Although the Figure 5 tests data showed laminar flow was possible, the SVS system is based on turbulent flow operation.

**Figure 5 SVS Coarse Coal 105 mm Loop Tests**




When flow is stopped the coarse coal SVS slurry settles homogeneously. During the test program, the loop, which included a vertical pipe section and a number of right angle bends, was shutdown for one week and was easily restarted.

### 5.6 SVS Technology Summary

The SVS System hydraulics have been confirmed by loop testing. The SVS system is suited for transporting export coal over long distances. The SVS system hydraulics can be predicted based on laboratory testing of representative samples of slurry components.

The SVS System is soundly based on the hydraulic mechanism commercially proven in the Black Mesa pipeline. The SVS system is an extension of Black Mesa pipeline technology to transport coarse coal over long distances by slurry pipeline. The flow velocity is low, the headloss is low and pipe wear is minimal. Coarse coal is maintained in suspension by turbulence. Coarse coal particle settling velocity is similar to 1mm fine coal settling velocity in water as is the case with Black Mesa.

Pilot Plant loop tests **(**July 1-8, 1985 includes restart after 5 days shutdown with slurry left in loop**)** and Wheelstand tests have confirmed:

- Low headloss in the pipeline
- Technical feasibility can be established based on sample testing and computer prediction of SVS pipeline hydraulics
- Low pipe wear
- Low capital cost
- Low operating cost

### 5.7 Typical SVS System Description

The SVS System involves two pipelines. A main pipeline to transport the coal in the special vehicle slurry and recycle pipeline to return the vehicle slurry. Apart from initial filling the system does not use water.

Typical facilities incorporated in a SVS system are illustrated in Figure 6 Facilities Diagram.

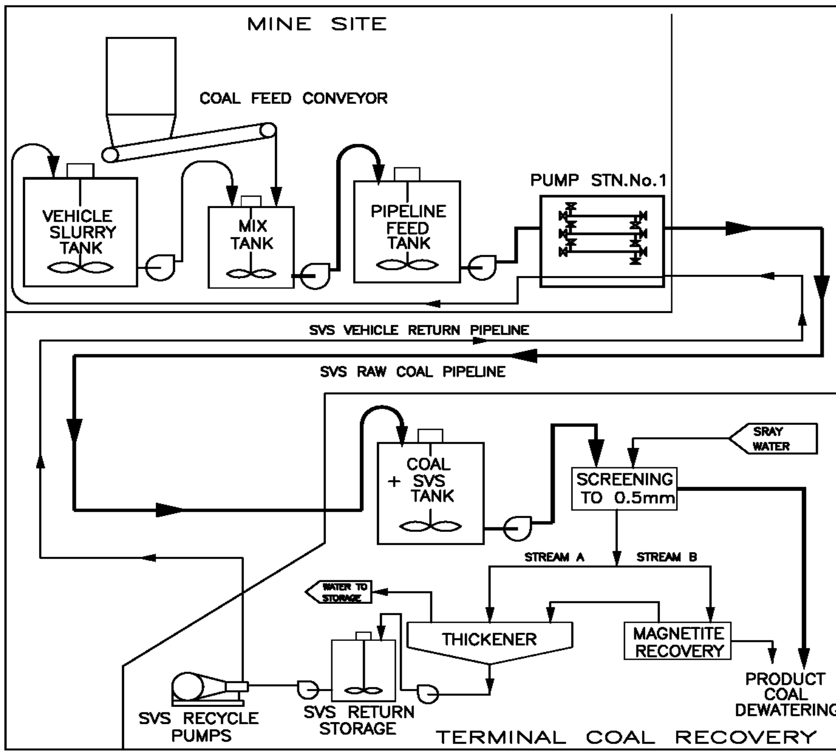



Figure 6
SVS- Product Coal Pipeline System – Facilities Diagram

Washed coal from the minesite coal preparation plant is received into the pipeline feed bunker at the minesite pump station. The bunker underflow feed rate is controlled by a belt feeder. The belt feeder discharges the coal into a coarse coal/SVS slurry mix tank. The proportion of SVS vehicle slurry to coal is controlled.

The coarse coal/SVS mix is transferred into one of four pipeline feed tanks. Each tank typically contains sufficient slurry for four hours of pipeline throughput. The mix is maintained in suspension by a downward thrusting turbine agitator. The coal/SVS slurry is then pumped by a centrifugal booster pump to feed the main line pumping unit (See Section 5.8). For long transport distances (typically in excess of 100 plus km), remote online booster pump stations are installed to maintain flow.

At the pipeline terminal the combined slurry is received into agitated slurry storage tanks. The coal recovery process involves coarse coal separation by screening followed by dewatering in basket centrifuges. The minus 0.5mm coal is recovered in screen bowl centrifuges and superfines are dewatered in a filter press. A substream of the SVS slurry component is processed through magnetic separators to recover coal fines from coal attrition. The SVS slurry is thickened and recycled in a separate pumping and pipeline system.

**5.8 Lock Hopper Pumps**

Conventional high pressure (20 MPa+) positive displacement piston diaphragm pumps installed in long distance slurry pipelines are equipped with poppet suction and discharge valves. These valves are limited to 6mm particle size. For the SV/coarse coal system the conventional PD pump is not suitable.

The use of multi-stages of high case pressure centrifugal pumps is limited to 7,000 kPa pressure and, in addition, the multiple passages through the stages of centrifugal slurry pumps can result in a break up of the coal particles.

One solution is to adopt a three leg lock hopper pump. A typical lock hopper pump is illustrated in Figure 7. The lock hopper arrangement allows the transfer of the required flow and pressure to inject the SVS/coarse coal slurry into the pipeline. The motivating pump can be a multi-stage high pressure water pump. Clean water supply to feed to the motivating pump is an essential requirement.

In operation, one leg of the hopper is filling with coarse coal/SVS slurry, the second leg is feeding the pipeline with high pressure SVS/coarse coal slurry and the third leg is filled ready for injection into the pipeline.

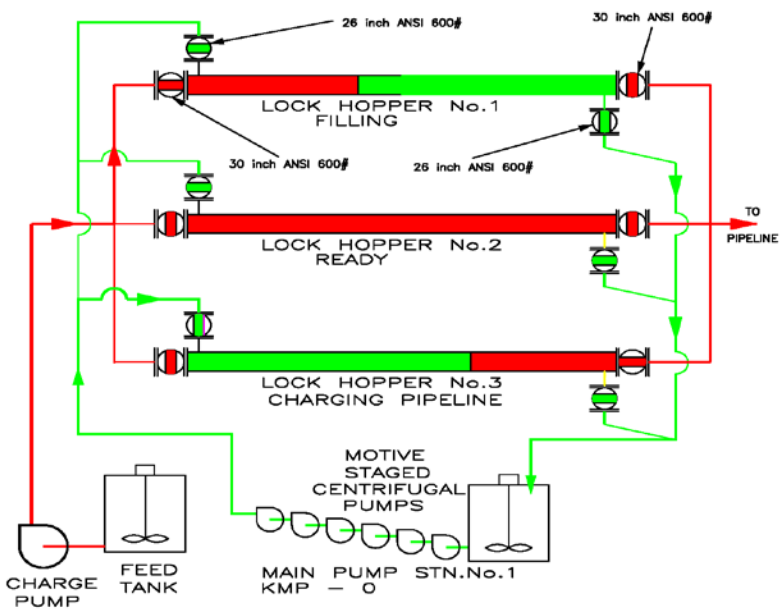



Figure 7
SVS – Product Coal Pipeline System – Typical Lock Hopper Pump

The attractiveness of an SVS pipeline system, both environmentally and politically, is summarised as follows:

- Aesthetically attractive as the pipelines are buried.
- No noisy exhaust as the pipeline is noiseless, peaceful and hidden.
- No diesel fumes or coal dust and the pipeline is clean, dustless and smokeless.
- No impact injuries – pipelines have good safety records.
- After the initial fill, SVS system will not consume water. Water is recycled in the SVS vehicle slurry.

Internal studies determine the SVS pipeline system offers cost and environmental advantages over alternative modes of transportation. The system is an advancement in coal pipeline technology evolving from Slurry Systems' four decades of slurry pipeline experience.

## 6. REFERENCES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