PNEUMATIC CAPSULE PIPELINE (PCP)

Pneumatic Capsule Pipeline (PCP) is the transport of freight (bulk or packaged materials) by capsules (wheeled vehicles) moving through large pipe of either round or rectangular cross section (Figure 1), with the capsules blown through the pipe by air. PCP is based on the same principle as “pneumatic tubes,” which use non-wheeled capsules and whose use is limited to small and lightweight cargoes. By having wheels, the capsules in PCP carry heavy cargo – more than a ton in each capsule. While PCP has been studied extensively in the US, England, and the Former Soviet Union since around 1970, successful commercial use has been achieved so far only in Japan. In 1980, the Sumitomo Metal Industries (SMI) in Japan designed and built a 3.2 km PCP in Kuzuu, Japan, for transporting 2 million metric tons of limestone to a cement plant (see Figure 2). The pipeline uses 1 m diameter steel pipe buried under an abandoned railroad previously used to transport limestone for the plant.

This PCP has an interesting history. Decision to abandon the railroad and replace it with an underground PCP was made mainly to alleviate safety and noise problems caused by trains passing through a village. SMI investigated several alternatives to solve the problem -- including an underground rail, a conveyor belt system and PCP. Trucking was not considered for it would cause even greater problems than the existing rail. The study found that the PCP was not only the most acceptable solution to the villagers’ concern but also the least costly solution. Operation of this highly successful PCP continued today, having accumulated a perfect safety record, and a high availability rate of over 95%. Another highly successful PCP project, also accomplished by SMI, was using a PCP of 1m x 1m cross section for transporting construction materials during the construction of a major rail tunnel in Japan for bullet trains – the Akima Rail Tunnel. The conduit of this PCP (see Figure 3) was made of prestress concrete panels so that they could be easily assembled in the field during tunnel excavation, and easily dismantled upon completion of the tunnel. This PCP transported excavated materials out the tunnel for disposal, and transported pre-mixed concrete into the tunnel for tunnel lining, using the same capsules. In addition to cost effectiveness, use of PCP in this case also greatly enhanced the safety in constructing this tunnel, and avoided air pollution in and near the tunnel that would otherwise have been caused by trucks or other diesel-powered vehicles.

Contemporary PCP systems, including those in Japan cited above, use blowers to blow air, which in turn causes the capsules to move through the pipe. Because capsules cannot pass through blowers, such systems utilize complex mechanisms for capsules to bypass the blowers intermittently. This not only increases the complexity of the system, but also great limits the system capacity – cargo throughput. It also makes it difficult to use booster pumps to enhance pipe length. These problems have been solved by researchers at University of Missouri – Columbia, under a National Science Foundation supported research center – Capsule Pipeline Research Center (CPRC). CPRC developed an electromagnetic capsule pump (see Figure 4) based on the principle of linear induction motor. Because the pump is non-intrusive, it allows free passage of capsules -- making it possible for PCPs to achieve high throughputs, and long lengths (practically any length) by using booster pumps. This greatly enhanced the capability of PCP. Based on this new technology, in 2003 Freight Pipeline Company planned, designed and assessed the feasibility of using PCP for underground freight transport in New York City.

Of the six potential applications investigated -- ranging from using 1m square PCP for tunnel construction to using 4.5 m diameter PCPs for transporting 40-ft containers from and to seaports -- all six were found to be technically feasible, and five of the six were found to be also cost-effective – less costly than using current transportation means. Moreover, using PCP will benefit the City greatly in reducing traffic jam and air pollution problems caused by trucks. A study was also completed in 2004 for the U.S. Department of Energy, to design an energy-efficient PCP system driven by linear induction motor for transporting minerals and mine waste. Future use of PCP technology in the US and the world is expected to bring major economic and environmental benefits to the nation and the world. It will also greatly benefit the construction industry. Implementing the new PCP technology remains a challenge to the construction industry.

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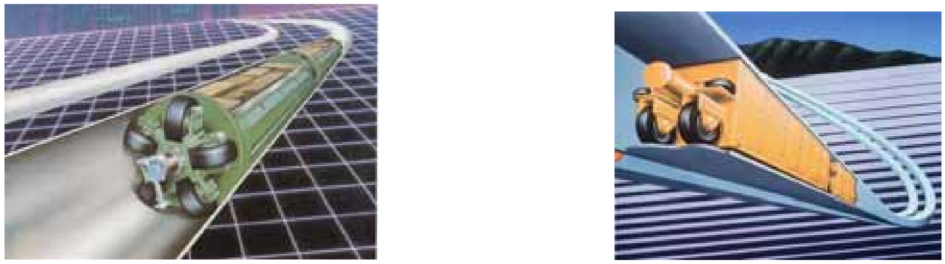
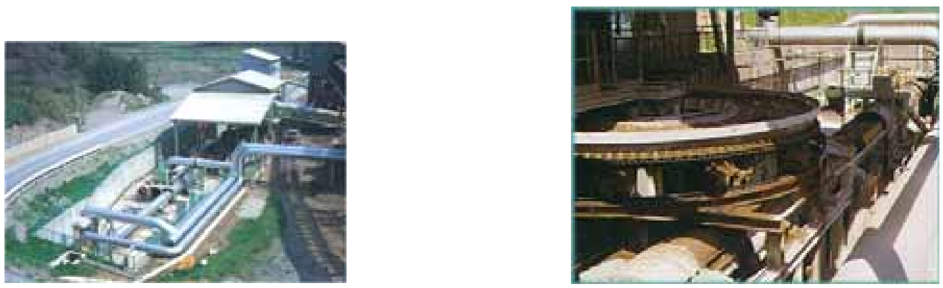


(a) Round type (b) Rectangular type

Figure 1. Two types of PCP used in Japan by Sumitomo Metal Industries (SMI)



(a) Bird-eye view of the Inlet station (b) Materials loading into capsules at inlet

Figure 2. Inlet loading system of PCP transport of limestone in Kuzzu, Japan

(a) PCP entering the tunnel (b) Capsule used (c) PCP transport of spoil to landfill

Figure 3. The Akima Rail Tunnel in Japan during construction

1 m × 1 m PCP

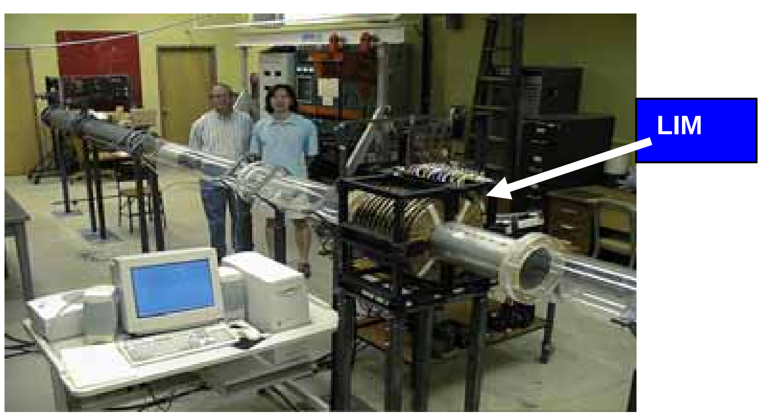


Figure 4. Testing a LIM-powered PCP at University of Misso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