
QUALIFICATIONS AND EXPERIENCE PROFILE

SOLIDS HYDRAULIC TRANSPORTATION SYSTEMS DESIGN



PIPELINE SYSTEMS ENGINEERING INC.
1501 N. Broadway, Walnut Creek
California, 94596 U.S.A.
Phone: 925-478-9190
Web Site: www.psei.co



TABLE OF CONTENTS

1.0	CORPORATE PROFILE	1
2.0	SCOPE OF SERVICES	3
3.0	PROJECT EXPERIENCE	8
4.0	DESIGN ALTERNATIVES/INNOVATIONS	10
5.0	LABORATORY TESTING FACILITIES.....	11
6.0	COMPUTER SOFTWARE SUPPORT.....	12



1.0 CORPORATE PROFILE

Pipeline Systems Engineering, Inc. (PSEI) is a medium-sized, multi-disciplinary engineering firm servicing the international mining and mineral processing industries from its headquarters in Walnut Creek, California, USA, as well as from offices in China, Chile. Formed in 2012 by a group of solids pipeline transportation pioneers, PSEI is a recognized leader, specializing in the design of pipeline systems for transport of solids and specialty products of all kinds around the world. Personnel from PSEI have participated in the engineering of the majority of all slurry pipelines installed in the past four decades. PSEI specializes in services for pipeline transportation system development, from testing in PSEI's laboratory, design audits, trade-off studies, feasibility studies, basic engineering, detailed engineering, construction management, system start-up/commissioning, contract operation.

Engineering services are available for design of cross-country pipelines for coal, mineral concentrates, mineral ores, phosphate, potash, oil sands, limestone, and various other industrial minerals, PLS/raffinate, water and tailings disposal systems. PSEI is also an expert at Supervisory Control And Data Acquisition (SCADA) and telecommunications systems design services. The following is a summary of the services that can be provided:

- Pipeline Engineering - design of slurry, paste, liquid, and gas pipeline systems including design audits, system optimization studies, conceptual, basic, and detailed engineering level work.
- Project Services - procurement assistance, construction management, commissioning, start-up, troubleshooting, and operations assistance.
- Transient Analysis, Dynamic Modeling and Pipeline Operation Simulation - for design, surge analysis, leak detection, and operator training.
- Solution of Complex Hydraulic Problems - involving fluid flow for slurries and other rheologically complex fluids, such as thickened tailings, pastes and high-density mineral concentrates, laterites & clays.
- Pipeline Controls and Telecommunications - complete SCADA systems, from conceptual design through assembly and start-up. Fiber optic, radio, and satellite systems from design to start-up. Supply of pipeline SCADA systems ensures proper integration of process design in the control system.

PSEI personnel combine four decades of professional experience in slurry and pipeline applications. Prior to the formation of PSEI, several key personnel were part of the pioneering group that developed slurry pipeline technology. For example, Mr. Tom Aude was one of key process design members for the 432 km long and 5 million tons per annum (MTA) coal slurry pipeline known as Black Mesa coal slurry pipeline, feeding to the Mojave Power Plant in USA. He was the commissioning manager at the time and was rewarded by the client for its outstanding services to the successful operation of the Black Mesa coal slurry pipeline. Since then PSEI has extended that fundamental technology to its present state-of-art. See the Certificate of Recognition from Black Mesa Pipeline, Inc. below.



PSEI can bring multi-discipline, in-depth pipeline experience to your next project. Common elements with other pipeline projects can be used to avoid redundant efforts. PSEI personnel have unsurpassed expertise and experience in the slurry pipeline design field. We place special emphasis on staff training in fields related to hydraulics and the hydrotransport industry.

2.0 SCOPE OF SERVICES

Larger, longer and more complex pipeline systems require sophisticated design methods. PSEI has the practical experience and technical background to provide the appropriate design approach. PSEI is an innovative engineering services company specializing in pipeline transport systems. Diversified services are available for design of cross-country slurry pipelines for coal and mineral concentrates; designs for tailings disposal systems (high density and paste transport), and water are also a specialized line offered.

Professional services and specialized expertise are available for a full range of customer requirements, from feasibility evaluation through start-up of a completed installation. While process and mechanical design are the focus of pipeline engineering, PSEI also offers complete multi-discipline services to permit fully integrated designs, which include civil/structural, electrical, instrumentation, controls, telecommunications and construction services.

Feasibility Studies

Evaluations of the technical and/or economic feasibility of specific applications are made using in-house experience and technology.

Laboratory and Pilot Scale (Loop) Testing

Laboratory or pilot plant (including loop testing) program design and execution provide project requirements from basic design data through flow sheet development. PSEI has the equipment and procedures to perform bench scale rheological tests, which provide data necessary for most applications.

Transient Pressure Analysis

Computer analysis, together with practical experience, have led to development of a proven model for analysis of steady static and transient pressures in piping systems. The flowing medium may be any combination of gas and liquid with entrained solids. Models also assist as design and operator training tools.

Conceptual Design

Development of the system design using PSEI's computerized hydraulic model and optimization techniques results in the most economic selection of basic pipe size and pumping horsepower variables for each specific application. The conceptual design is incorporated in a design manual, which specifies system parameters and key equipment.

Project Execution

PSEI can perform the detailed design, construction supervision and management activity for most projects. For large projects, PSEI will provide key personnel to ensure that the basic system concepts are carried through to the completed project.



Commissioning and Start-up

Preparation of operating and maintenance instructions, the commissioning program, operator training and system start-up by PSEI result in as-designed system performance.

Technical Services

Technical support of system operations is available for internal corrosion control, operations reviews, and problem solving.

SLURRY PIPELINE CHECKLIST OF SERVICES

The following checklist demonstrates the broad range of services offered by PSEI. Computer and proprietary programs assist in the design and engineering of all phases of services offered by PSEI.

Conceptual Design

- Feasibility Studies
- Economic Evaluations
- Trade-Off Studies
- Project Schedules
- Laboratory Test Work (Rheological Characterization of the slurry)

Preliminary Engineering

- Project Development Plans and Schedules
- Optimization Studies
- Project Specifications and Design Bases
- Capital Cost Estimates
- Operating Cost Estimates
- Pipeline Route Reconnaissance

Basic Engineering

- P&IDs
- Flow Sheets (PFDs)
- Basic Drawings and Layouts
- Detailed Design Specification
- Equipment List
- Major Equipment Specifications
- Route Location Surveys and Mapping
- Pipeline Alignment Sheets
- Control Systems and Instrumentation Design

Detailed Engineering

- Transient Analysis and Pipeline Models
- Leak Detection Systems

- Drawings, Specifications and Requisitions
- Equipment and Material Indices/Controls
- Vendor Bid Evaluations
- Approval of Design Changes
- Construction Specifications
- Cathodic Protection Surveys and Design

Procurement

- Equipment and Material Requisitions
- Recommended Vendor Lists
- Technical Qualification of Vendors
- Contract Placement
- Inspection and Expediting of Key Equipment
- Acceptance Test Witnessing

Construction

- Construction Planning and Management
- Technical Assistance
- Key Point Inspection
- Test Supervision
- Control System Construction
- Hydrotest Diagrams and Witnessing
- As-built Drawings

Commissioning & Start-up

- Operating Manuals
- Maintenance Manuals
- Pre-Operational Testing and Checklists
- Start-up
- Operator Training

Operations & Maintenance

- On-Going Service Programs
- Periodic Inspection
- Telephone/On-line Computer Support
- Modifications Design/Engineering
- Operations and Capacity Audits



TYPES OF PROJECTS

The following list demonstrates the broad range of projects performed by PSEI's personnel.

Coal Slurry Systems

These systems require slurry preparation and dewatering processes at the pipeline terminals. These processes must reflect a technical and economic balance between the pipeline operating requirements and the terminal costs. PSEI offers extensive experience in the testing and evaluation necessary for coal slurry pipeline system design.

Tailings Disposal Systems

Tailings disposal systems often require specialized designs for gravity flow, open channel flow, energy dissipation (drop boxes, drop tanks, orifices, cascades, etc.), multiple pumps in series, cycloned tailings, tailings distribution and sub-aqueous tailings disposal. PSEI offers a high level of experience to provide innovative approaches to the specialized tailings designs required by our clients.

Hydraulic/Paste Backfill Systems

PSEI has developed unique specialist expertise in the design and implementation of hydraulic and paste backfill systems for underground mines. Our service capabilities include:

- backfill plant design
- hydraulic design
- laboratory and onsite loop tests, backfill mix specification
- material and equipment selection
- specification for operating procedures

Surface Disposal of Thickened/Paste Tailings

Much has been said about thickened/paste tailings in the past few years, but it is only recently, through advances in thickener and pumping technology, that such systems are now possible.

Water is a scarce resource, particularly in arid regions such as Western and South Western USA, Northern China, Northern Chile, Southern Africa, Western Australia, and many additional mining regions around the world, and there is increasing pressure to reduce water consumption by mines in these areas. The part of the present process responsible for the greatest loss of water is the tailings system transporting slurry to the waste dam. At most, only thirty percent of this water is reclaimed; the balance is lost to evaporation and seepage.

Thickening problems appear to have been overcome by using coagulants and flocculant to increase particle-settling rates and reliable process equipment now exists to produce high-density tailings consistently. Developments in pump technology now make it feasible to pump such slurries reliably.



The key to design and implementing thickened tailings systems is being able to understand the slurry flow behavior and how it affects the thickening, process and placement requirements. Slurry flow behavior at high solids concentrations is complex and PSEI is at the forefront of developing this technology.

Hydraulic Ore Hoisting Systems

Hydraulic hoisting has the potential to be one of the most cost-effective methods of transporting ore from the underground to the surface. PSEI has been involved in the analysis of a number of proposed hydraulic hoisting systems.

Control Systems

The control system selected for any process plays an important role in the success of a pipeline project. Reliability, ease of use, and cost effectiveness contribute to a good process design. PSEI performs "systems house" engineering, software programming and assembly of computer-based SCADA systems. Color graphic CRTs act as human-machine interfaces (HMI), mini-microcomputers provide the master station operations framework and programmable logic controller-based (PLC) remote terminal units control collect information from the field devices. PSEI provides control systems for plant facilities, as well as pipeline systems.



3.0 PROJECT EXPERIENCE

PSEI brings a high-quality, experienced team with appropriate worldwide slurry transportation pipeline systems expertise to your next project. PSEI's principals and senior engineers, as a major specialty pipeline and slurry technology group, have worked on hundreds of slurry pipeline systems around the world. A few of the significant and relevant examples are:

Mineral Concentrate & Ore Pipeline Systems

- MBP Bauxite Ore Pipeline, 248 km Brazil
- Bauxite Ore Pipeline Study (110km) Jamaica
- Minera Antamina Copper/Zinc Concentrate P/L EPCM (303 km) Peru
- Collahuasi Copper Concentrate Pipeline EPCM (200 km) Chile
- Alumbreira Copper Concentrate Pipeline (314 km) Argentina
- Batu Hijau Copper Concentrate P/L's (17.6 km) Indonesia
- Escondida Copper Concentrate Pipeline (166 km) Chile
- Century Zinc/Lead Concentrate Pipeline System (303 Km) Australia
- Los Bronces Copper Ore Pipeline (57 km) Chile
- Jian Shan Iron Concentrate Pipeline (102 km) China
- Rio Capim Kaolin Slurry Pipeline System (178 km) Brazil
- JR Simplot Phosphate Pipeline System (138 km) Idaho, USA
- Weng Fu Phosphate Pipeline System (45 km) China
- Al Jalamid Phosphate Pipeline System (1150 km) Saudi Arabia
- IMC Agrico Phosphate Ore Pipeline System Study (64 km) Florida, USA
- Yichang Phosphate Pipeline System Study (120 km) China
- Confidential Potash Pipeline System Study (630 km) Argentina
- La Perla Iron Concentrate Pipeline (381 km) Mexico
- Essar Steel Iron Concentrate Pipeline System (268 km) India
- SAMARCO Iron Concentrate Pipeline (400 km) Brazil
- El Pachon S.A. Copper Concentrate Pipeline (164 km) Argentina
- La Granja Copper Concentrate P/L's (280 km) Peru
- Quellaveco Copper Ore & Concentrate Pipeline Studies (55 km) Peru
- Yu Wei Qing Coal Slurry Pipeline System (~1000 km) China
- Nickel Laterite Ore Slurry Pipeline (220 km) Madagascar
- Ramu River Nickel Ore Pipeline Study (134km) Papua New Guinea
- Nickel Laterite Ore Pipeline Study (500km) Ivory Coast
- Da Hong Shan Iron Concentrate Slurry Pipeline (171km/143km) China
- Pan Zhi Hua Iron Concentrate Slurry Pipeline (100 km, 3MTA) China
- Bai Yun Ebo Iron Concentrate Slurry Pipeline (154 km, 6 MTA) China
- Yuan Jia Chun Iron Concentrate Slurry Pipeline (28km, 7.4 MTA) China
- Citic Pacific Mining Iron Concentrate Pipeline(30km,33MTA) Australia

Prior to the formation of PSEI, our personnel had significant involvement in the design, construction management, and start-up of the pipelines featured in the list below:

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- Black Mesa Coal Slurry Pipeline, 432 km, 5 MTA USA
 - ETSI Coal Slurry Pipeline Study, 30 MTA, 1200 km USA
 - SAMARCO Hematite Concentrate Pipeline (405 km) Brazil
 - Pena Colorada Magnetite Concentrate Pipeline (47 km) Mexico
 - Las Truchas Magnetite Concentrate Pipeline (28 km) Mexico
 - Kudremukh Magnetite/Hematite Concentrate Pipeline (71 km) India
 - Waipipi Magnetite Sands Pipeline (10 km) New Zealand
 - Savage River Magnetite Concentrate Pipeline (86 km) Tasmania
 - JR Simplot Phosphate Concentrate Pipeline (140 km) Idaho, USA
 - SF Phosphate Concentrate Pipeline (153 km) Utah, USA
 - VALEP Phosphate Concentrate Pipeline (81 km) Brazil
 - Freeport Indonesia Copper Concentrate Pipeline (112 km) Indonesia
 - Bougainville Copper Concentrate Pipeline (28 km) Papua New Guinea
 - Pinto Valley Copper Concentrate Pipeline (18 km) Arizona, USA

PSEI is currently working on the following slurry pipeline projects (Feasibility Study, Basic Design and Detailed Design, Construction Management, Start-up and Commissioning):

- Eruu Gol River Iron Ore Project, Mongolia – Mining, Process Plant, 880 km Iron Concentrate (30 MTA) Slurry Pipeline EPCM, since 2016 to date.
- Congo Resources Inc. , Iron Ore Project, Republic of Congo - Feasibility study for the entire project, including mining, beneficiation, pipeline transportation (250 km long and 20 MTA), harbor and hydropower stations.
- Glengore's Zanaga Iron Ore Project, Republic of Congo – Bankable Feasibility Study for the pipeline transportation (350 km long and 30 MTA).
- Aluminum Corporation of China (Chinalco) Laos Bauxite Project, - 20 MTA, Laos – Feasibility study of pipeline transportation system (250 km).
- Madagascar Bauxite Project - Feasibility study of pipeline transportation system (170 km long and 8 MTA).
- China National Electric Investment Corp's Guinea Bauxite Project - Feasibility study of pipeline transportation system (12/34 MTA and 160 km).
- Yunnan Tin Datun Process Plant Expansion (8000 tpd) Project - EPCM
- Kunming Iron & Steel Co. Ltd. Yuhezhai Project – Feasibility, basic and detailed designs for mining, process plant, concentrate slurry pipeline, tailings dry storage. Equipment procurement. Construction services, 15 MTA Ore Processing Capability.
- Tian Bao Mining Inc.'s Tie Tai Iron Ore Mine project, Cheng De, China, 45 MTA Ore Processing Capacity, EPCM, including Mining, Crushing, Dry Process Plant, Waste Landfill/Tailings Disposal, 30 km long and 4 MTA Iron Concentrate slurry Project.
- Alumina Development Inc., Cambodia, 12 MTA Bauxite Project, feasibility study including mining, process plant, 453 km long Bauxite slurry pipeline.
- Confidential Client, Thermal Coal Slurry pipeline pre-feasibility study, 420 km, 5 MTA, Kyrgyz Republic/China.
- Si Chun Provincial Development Corp's Tai Rui Phosphate Concentrate Slurry Pipeline – EPCM, 2 MTA, 70 km slurry pipeline and 70 km return water pipeline.

4.0 DESIGN ALTERNATIVES/INNOVATIONS

PSEI has been involved in a number of innovative solutions to project problems. Some examples are:

- The pressure system concepts were applied by PSEI to the conceptual design of the Bougainville tailings pipeline system design with the addition of a tall tank to provide the control variation between choke steps. It was also applied by PSEI to the conceptual design of the Los Bronces copper ore pipeline in Chile, where four choking stations are used to achieve the required flow variability while keeping system pressures within limits both upper and lower (to insure against high wear if open channel flow occurs).
- At Kennecott's Utah copper operation, the issue was distribution of tailings around the perimeter of a large impoundment area with a gravity flow system. The multiple discharge point requirement resulted in a system tuned to provide the necessary resistance to control flow velocity within defined limits when discharging at any point in the system.
- A variation of the concept at Minahasa, Indonesia, used a variable speed centrifugal pump to hold level in the system feed tank while a choke system kept the system packed with slurry.
- PSEI's integration of a gravity driven tailings transport system into the design and operation of the concentrator at Newmont's Batu Hijau mine resulted in a simpler system and a +\$US 5 Million savings over the previously selected tailings system designed by others.
- PSEI's integration of a gravity driven concentrate transport system into the design and operation of the concentrator at Kunming Steel's Baozipu mine resulted in a gravity drop pipeline system without a choke station, successfully transporting 1 MTA of the iron concentrate by dropping 2000 meters to the terminal by a 10 km long pipeline and 168 drop pipe spools (each 7 meter tall).
- PSEI's innovations for the high pressure pump stations (ANSI 1500# Class rating) running in a "tight" line mood (5 ANSI 1500# Class pump stations in series over 171 km and vertical lift more than 1500 meters) has demonstrated that the high pressure boosting station systems can be designed and operated safely for the complex pipeline route. This has proven that the transporting of the solids in large quantity over complex remote areas are technically and economically feasible.

5.0 LABORATORY TESTING FACILITIES

The bench scale laboratory testing of slurry and water samples is performed at PSEI's Beijing laboratory facility. PSEI has the equipment and procedures to perform bench scale tests that provide data necessary for most applications. PSEI's personnel have been performing the laboratory testing necessary for its slurry pipeline designs for the past twenty years and has established a comprehensive data base. Results for the PSEI slurry laboratory have been the basis for design of all the major concentrate slurry and tailings pipeline systems designed by PSEI's personnel.

Some of the noteworthy tests that are routinely performed on slurry samples are:

1. Solids Characterization - screen analysis, solids specific gravity, and particle shape factor of the sample.
2. Slurry Characterization - rheology of each sample at different solids concentrations and the expected pH.
3. Operability – Settling test, angle of slide/angle of repose tests, and penetration test to determine the restartability of the pipeline with the settled slurry for each sample at selected solids concentration.
4. Corrosion/erosion - Corrosion/erosion test of a selected sample (this assumption has to be verified based on a knowledge of the chemistry of the concentrate). Water samples are tested for corrosiveness and standard water chemistry.
5. Abrasivity - ASTM Miller Number test will be sent out to White Rock Engineering. This is an index of the abrasiveness of the slurry relative to application of positive displacement pumps. The coarse sample will be tested.

SLURRIES EVALUATED

Bauxite slurry	Gold ore	Nickel laterite ore
Bastnasite tailings	Gold tailings	Nickel smelter slag
Bioleached gold slurry	Gypsum tailings	Oil sands
Bottom ash	Heavy mineral sands tailings	Phosphate concentrate
Cement slurry	Iron concentrate	Potash brine slurry
Chromite tailings	Iron sands	Red mud tailings
Coal plant refuse slurry	Iron/titanium tailings	Rutile tailings
Coal slurry	Jarosite tailings	Saprolite tailings
Coarse coal slurry	Kaolin slurry	Salt brine slurry
Copper concentrate	Kimberlite tailings	Silica sand
Copper ore	Lead/Zinc concentrate	Sinter feed
Copper smelter slag	Lead zinc tailings	Smelter Slag
Copper tailings	Limestone slurry	Soda ash tailings
Copper/molybdenum	Magnetite concentrate	Sulfide & oxide ore slurry
Drilling fluids	Manganese ore slurry	Titanium tailings
Fly ash	Methanol/coal	Zinc concentrate
Glacial till slurry	Milk of lime slurry	Zinc leach residue slurry

6.0 COMPUTER SOFTWARE SUPPORT

PSEI has adopted the following programs:

- PSEI 001 – Slurry Rheology Model, which is for slurry rheology analysis
- PSEI 002 - Hydraulic Models (Evaluating transition and deposition velocity)
- PSEI 003 - Steady State Slurry Hydraulic Model, which is based on WASP's theory
- PSEI 004 - High Density Slurry/Paste Hydraulic Model (Bingham Plastic Model)
- PSEI 005 – Pipeline Operating Simulator
- PSEI 006 – Pipeline Hydraulic Transient Model (P/L transient analysis)
- PSEI 007 – Pipeline Operation Monitor (Leak Detection)
- PSEI 008 – Gravity Flow Analyzer (orifice/drop spool sizing)
- CAESAR II – Pipe Stress Analysis
- SURGE – Simple System Surge Analysis
- AUTOCADtm Current Release
- Current Microsoft Officetm (MS Word, Access, Excel, Project)
- Microsoft Compliant Server System
- Primavera SureTraktm Project Manager