POLYPHENYLENE SULFIDE (PPS) PROCESS
POLYPHENYLENE SULFIDE PROCESS

Chemistry

$$\text{NaSH} + \text{NaOH} \rightarrow \text{Na}_2\text{S} + \text{H}_2\text{O}$$

Sodium Hydrosulfide  Sodium Hydroxide  Sodium Sulfide

$$\text{n Cl}_2\text{C}_{6}\text{H}_3\text{Cl} + \text{n Na}_2\text{S} \rightarrow \left[\begin{array}{c} \text{S} \\ \text{n} \end{array}\right] + 2\text{n NaCl}$$

Dichlorobenzene  Sodium Sulfide  Polyphenylene Sulfide Polymer

Overall

$$\text{Cl}_2\text{C}_{6}\text{H}_3\text{Cl} + \text{NaSH} + \text{NaOH} \rightarrow \left[\begin{array}{c} \text{S} \\ \text{n} \end{array}\right] + 2\text{NaCl} + \text{H}_2\text{O}$$
GENERAL:

1. PPS BACKGROUND
   Development History ---- To Present
   First Plant on-Stream
   Construction of Second Plant

2. ENEX PROCESS
   Secure in Enex Design Confidence
   Improved Performance Over Earlier Plants

3. FLASH & QUENCH PROCESS - INDEPENDENTLY OR IN PARALLEL

4. SPECIAL REQUIREMENTS - RAW MATERIALS OR EQUIPMENT
   Special raw Materials or Equipment Would Depend on Desired Use / Application

5. OUR SERVICES:
   We work with Clients from Conceptual to Detail Engineering, support in Procurement, Construction, Commissioning and start-up of the plant.
COMPARISON – PPS PROCESS – ‘flash’ vs ‘quench’

EACH PROCESS HAS ADVANTAGES / DISADVANTAGES

FLASH PROCESS
Higher yield efficiency (92 + %)
Polymer MW 18,000 – 22,000
(Further increase MW to 45,000 + by post heat treatment)
Operational Stability / Ease – Best Control Practices
Better quality control

QUENCH PROCESS
Higher MW Directly ~50,000 + mw (MFR Low as 75)
Lower yield efficiency (~88%)
Longer Batch Cycle Time (Reactors)
Temperamental Operation – Slightly More Complicated Than Flash
The global polyphenylene sulfide market size is expected to reach at USD 2.14 billion

- **Electronic industry:** Connectors, contact rails, heat shields, contact pressure discs and special types for semiconductor production
- **Automotive industry:** “under the hood”, fuel and brake and Turbo charger components
- **Medical industry:** Parts for surgical instruments sterilizable medical, dental, and laboratory equipment.
- **Mechanical engineering:** Compressor and pump-parts, gears, valves, slide bearings, chain guides and base plates
- **Chemical industry:** Valves, taps, bushings, pumps, nozzles, tubes and rollers
- **Thermal Power Plants:** Coal Thermal Power Stations Filter bag Application.
- **Aerospace and Defense:** Replacement of Metal in Military Equipment for weight reduction
- **Coatings:** Corrosion protection of ferrous metals in Chemical and Construction Industries.
- **Infrastructural Projects:** Subway Insulators, PPS Compounds in Bridge Construction.
Figure 1
PPS PROCESS SCHEMATIC - FLASH PROCESS
Figure 4
PPS PROCESS SCHEMATIC - QUENCH PROCESS
POLYPHENYLENE SULFIDE - Combined Flash & Quench Processes

Shared Processes
- Na2S Preparation
- Reactor Systems
- Solvent Feed System and Recovery
- Wastewater Treatment
- Vent Gas Treatment
- DCB Receiving / Distributing
- Deionized Water System
- Warehouse / Utility Systems

POLYMERIZATION
- Flash
- Quench

DEHYDRATION
- Na2S Preparation
- NaSH
- NaOH
- Solvent Make-up
- Acetic Anhydride

WASTE WATER
- Treatment
- Recovery
- Condenser
- Vent Gas Treatment
- Solvent Recovery
- Water Separation
- Filtration
- Waste Water Treatment
- Flash
- Quench
- Polymer Wash
- Polymer Drying
- Pelletization Packaging
- Filtration
- Cake
- Deionized Water
- Dichlorobenzene

DESIRABLE INDEPENDENT PROCESSES
- Acetic Anhydride
- Na2S / Solvent
- Heavies
- Condenser
- Vent
- Flash Polymerization
- Quench Polymerization
The triangle in Figure 2 provides an overview of the thermoplastic's world for amorphous and semi-crystalline materials in the different price/performance sectors.

In 2009, world consumption of these thermoplastic materials was approximately 150 million metric tons.

Commodity thermoplastics accounted for 174 million metric tons.

Engineering thermoplastic compounds (with ABS compounds included) for 10 million metric tons and high-performance thermoplastics for only 0.1 million metric tons.
When an application requires resistance to high temperature and combustion or chemical resistance, PPS is the material of choice in various industries.

On a price/performance basis, PPS is most often selected.

High performance thermoplastics are going to replace Metals.

Asia Pacific is anticipated to witness a substantial growth on automotive, oil and gas, paints and coatings, and medical sectors. This will fuel the PPS industry expansion over the next few years.
OTHER WASTES – 10 kta Plant

Organics:

A small amount of heavy organics, 4-5 kg/hr, from solvent recovery, will require incineration disposal.

If an incinerator is not already on site, one may be included in the design.

Solids:

Solid off-specification PPS would vary in the range of 30 to 90 kg/hr depending on the molecular weight of PPS being produced at the time.

A good approximation would be ~ 50 kg/hr.

Market may be gained for this off-spec PPS. If not, it may be safely disposed to landfill.
PLOT SIZE – 10 KTA PLANT

If offices, control room, shipping, receiving, raw material storage, warehousing, etc. is to be included, an area **300M x 100 M** may considered. However, if this is at an existing site, perhaps no storage of DCB is required, perhaps no offices, etc. and plot size could be reduced.

The basic process will preferably take place in a seven-level structure with downward gravity flow, for energy conservation, and reduced land space.
POLYPHENYLENE SULFIDE - FLASH PROCESS
Yield & Energy

Raw Materials
- Dichlorobenzene
- Sodium Hydrosulfide
- Acetic Anhydride
- Sodium Hydroxide

By-Products
- Sodium Chloride / Sodium Acetate
- Water
- $H_2S$ (Contained in RX Vent Gas)
- Heavy Waste Products

Other
- Nitrogen required for inert blanket & purge
- Deionized water for product washing
- Solvent - Initial charge + make-up

Energy Requirement ~ 1380 – 1530 Kcal/kg PPS
Depends on design parameters
ENEX - PPS - Basic Engineering Design (BED) - Deliverables

Process Information
   Full disclosure of production technology
   Plant operating parameters and methods
      Plant start-up procedure
      Plant shutdown procedure
      Emergency procedures
      Safety and operation practices

Process Flow Diagrams
Process and Instrumentation Drawings (P&IDs)
Material Balance - detailed
Utility Summary
   Flow diagrams
   Consumptions & Requirements

Heat (Energy) Balance
Chemicals & Catalyst(s) requirements
Preliminary Plot Plan
Equipment List
Equipment Sheets – Vessels, Exchangers, Distillation Columns
   Special Equipment
      Dimensions
      Internals
      Design and operating temperatures and pressures
      Surface areas (Exchangers)
      Metallurgy – Required / recommended materials of construction
      Special design / construction considerations

(Continued)
Instrumentation Index
  Inline Instrument Data Sheets
  Instrumentation Data sheets, control loops, logical interlocks

Relief loads and primary relief devices sizing
Material Safety Data Sheets
Environmental considerations
  Preliminary Hazard Overview
  Process and WasteWater – Treatment requirement / methods

Electrical Drawing and Loading
ENEX - Post BED Support

Following delivery of the Plant BED and until the final normalization of the UNIT operations, ENEX personnel will be available if and as (within prudent reasoning) requested to meet with the Client or their appointed Detail Design, procurement or construction companies for discussions and/or further assistance. An allowance of 100 man days assistance is normally included. Such support options, as chosen, may include, but not be limited to:

- Equipment Readiness for Service
- Construction scheduling and oversight
- Operator training
- Start-up assistance
- Product Optimization
- Product Development
- Quality Control
- Economic Evaluations

Other programs as defined

Product Development Support

ENEX will work with the Client to jointly evolve project definitions, Commercial Plant objectives and goals; ENEX main goal is the best progression and protection of the Client’s interests in development of quality products to achieve ultimate competitive, advantageous entry into PPS manufacture and sales.

ENEX will keep as confidential all technical, commercial or other information and data developed or supplied by its Client, its affiliates or associated partner companies.
THANK YOU