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Cyclotech

PRODUCED WATER TREATMENT TECHNOLOGIES SPECIAL SESSION – OFFSHORE AND OTHER

PRODUCED WATER TREATMENT USING HYDROCYCLONES: THEORY AND PRACTICAL APPLICATION

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History

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- First Patent for a Cyclone: 1891, Bretney, Dedusting technology for saw mills
- Solid Liquid cyclones used for decades in paper & mining industries
- Deoiling Hydrocyclone developed at Southampton Uni (UK) - Thew & Coleman
- First Patent Filing – 1978 by BTG
- First commercial Deoiling installation: 1982 in Bass Straight, Australia
- Revolutionised offshore Produced Water Treatment
- Introduction of Desanding Cyclone systems – late 80s
- Technology has improved & matured over last 25 years
- Deoiling HCs still the state of the art PRIMARY stage Produced Water Treatment technology

Cyclone Applications in Upstream Processing

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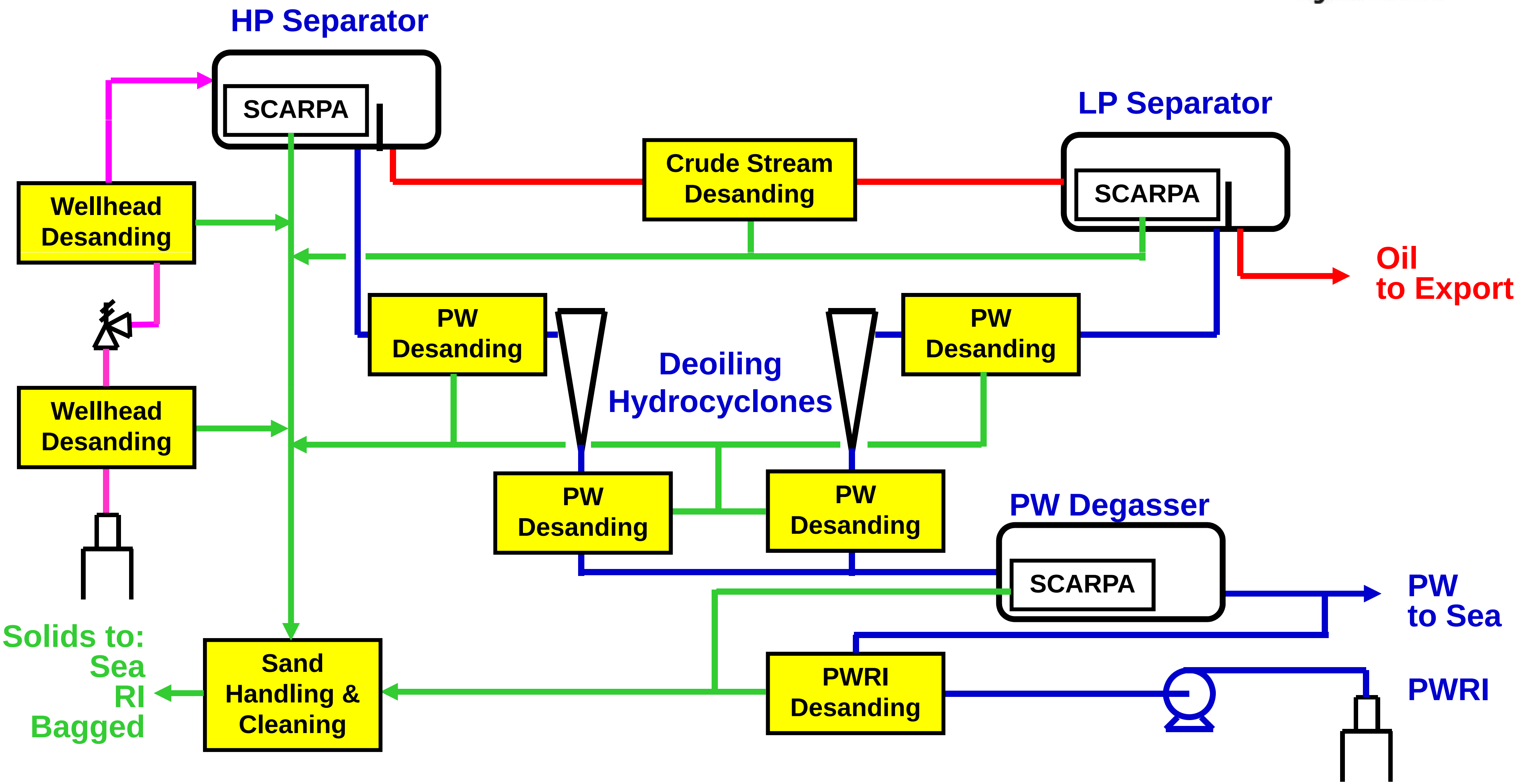
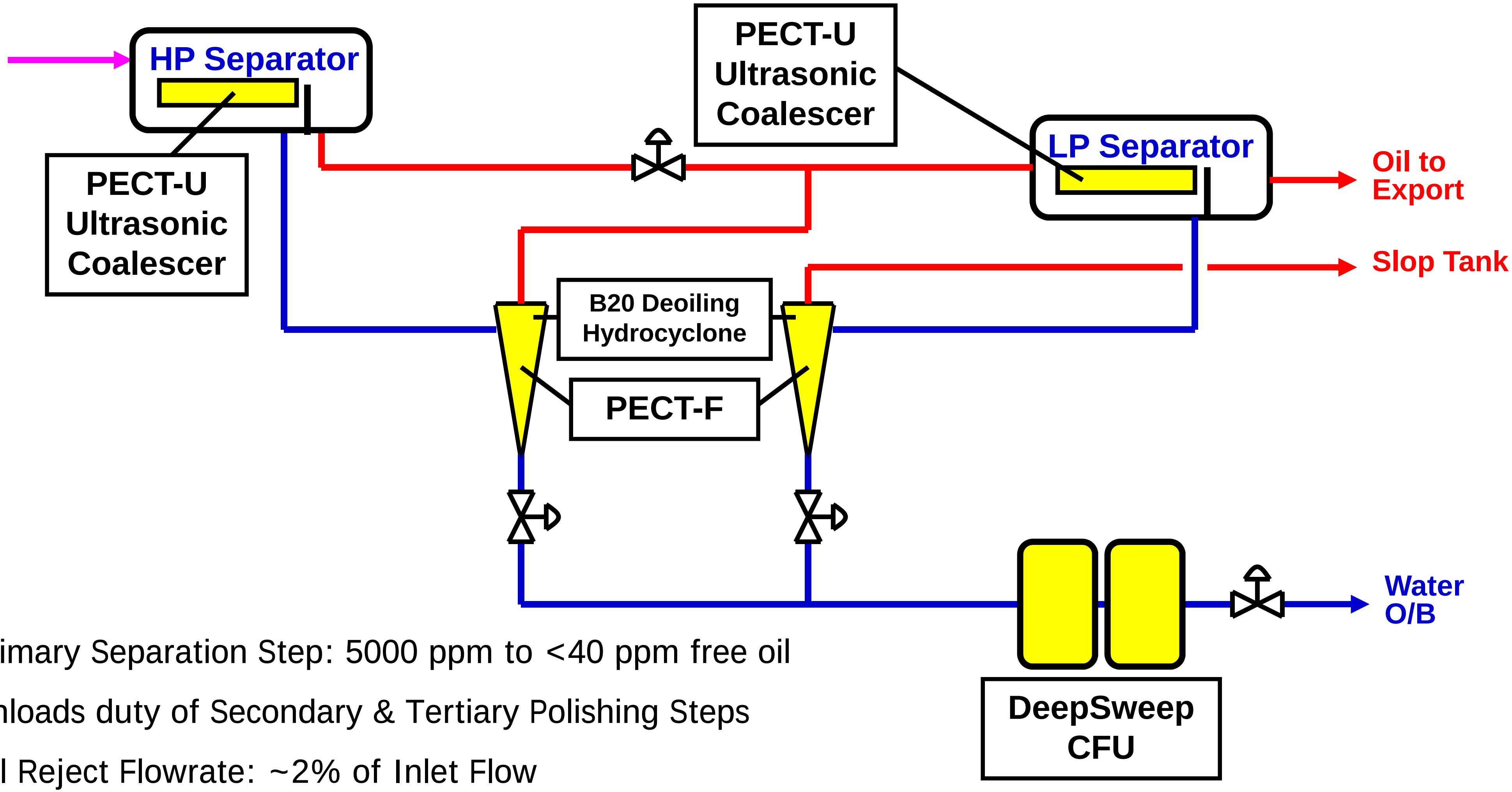


Cyclotech PWT System (Deoiling)



- Primary Separation Step: 5000 ppm to <40 ppm free oil
- Unloads duty of Secondary & Tertiary Polishing Steps
- Oil Reject Flowrate: ~2% of Inlet Flow

Hydrocyclone Operating Principle

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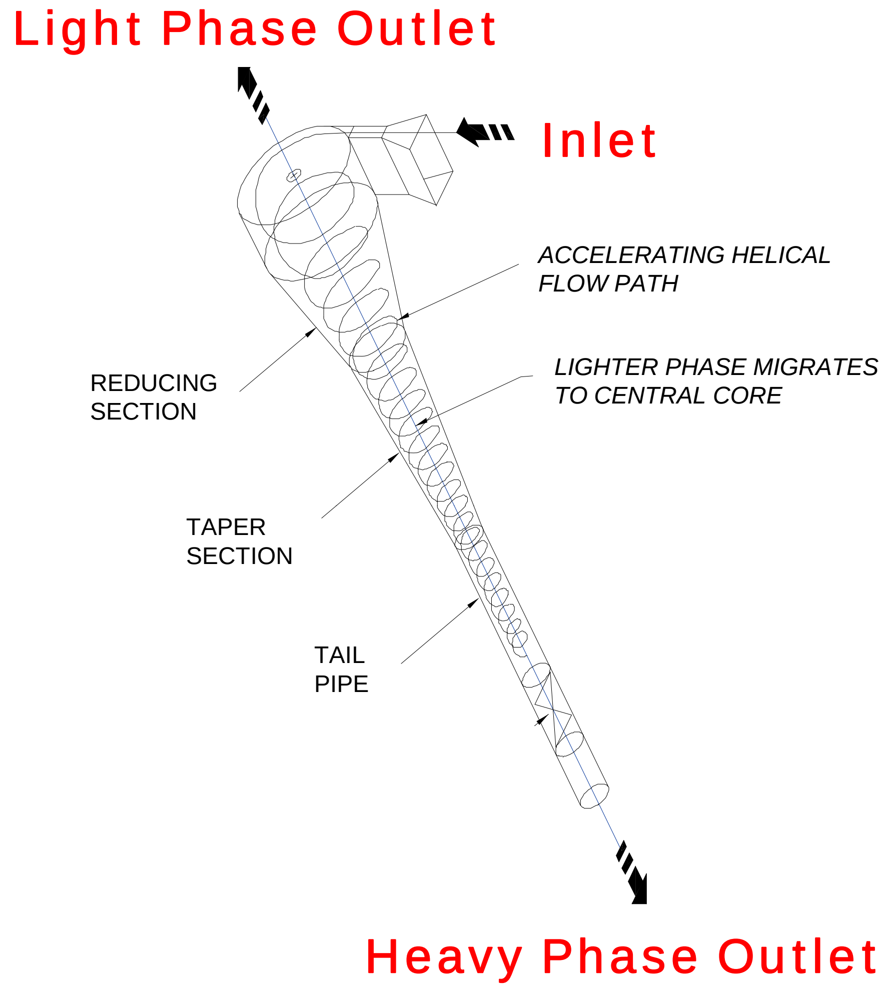

- Flow forced into tangential inlet under pressure causing flow to spin
- Spinning flow causes radial accelerations >1000g within hydrocyclone
- Density difference between oil and water causes oil to collect at axial core
- Pressure gradients within cyclone create two vortices, one inside the other, spinning in same direction but with opposite axial direction
- Dense phase exits at “underflow” & light phase exits at “overflow” adjacent to inlet
- External back pressure and outlet port diameters control split ratio - balance of outlet flowrates

Unique Deoiling Hydrocyclone Features

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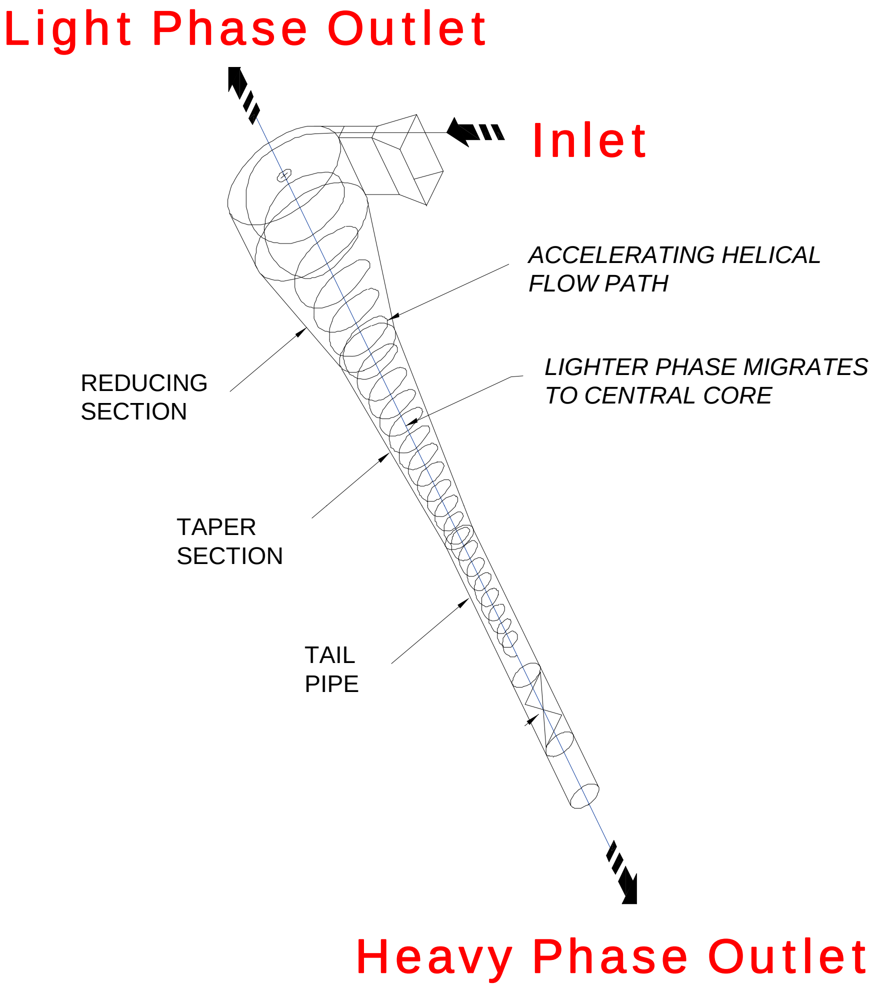

- **Long and thin compared to traditional cyclone design**
  - Small radial distance for oil drop to migrate to axial core
  - Maximises Residence Time
- **Oil reject diameter only ~2.0 mm**
  - High Du/Do Ratio
  - Low inlet oil concentration ~2000 mg/l
  - Small reject flowrate required
- **Underflow Backpressure Requirement**
  - No flow through reject unless water outlet is back pressured

Deoiling Hydrocyclone Packaging

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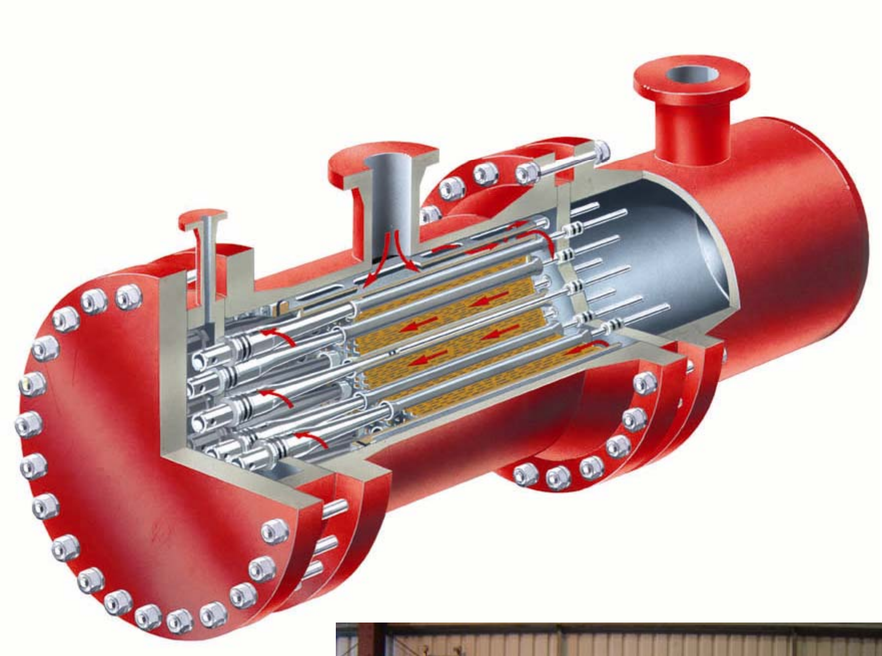

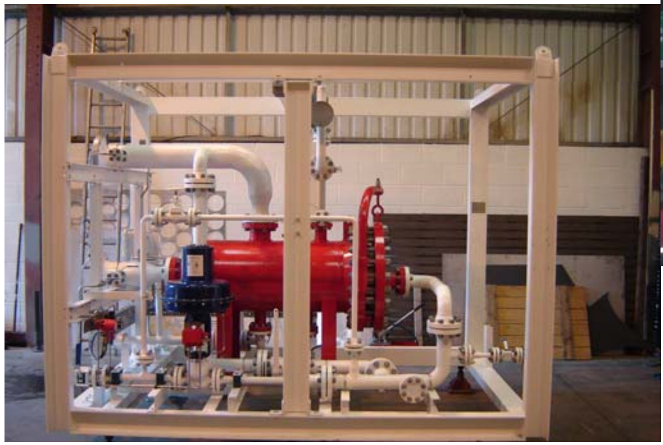

ConocoPhillips Ekofisk 2/4J – 340,000 BPD
Deoiling Hydrocyclone Package

Typical Deoiling Hydrocyclone Control Scheme

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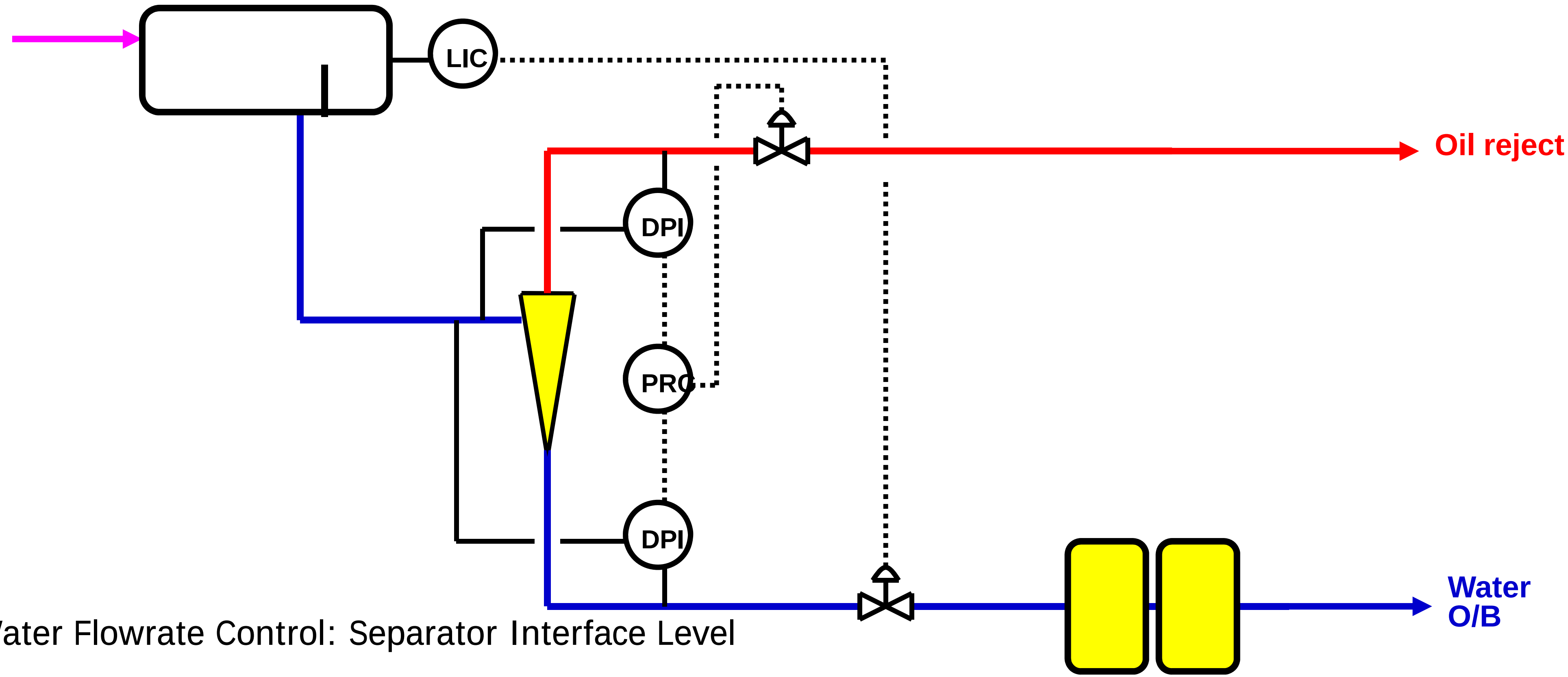

- Water Flowrate Control: Separator Interface Level
- Oil Reject Flow Control: Hydrocyclone PDR

Factors which Influence Separation Performance

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- **Bulk Property Parameters**
  - Phase Density Difference
  - Operating Temperature (Affects Water Viscosity & Interfacial Chemistry)
- **Operating Parameters**
  - Pressure Drop (max & min pressure drop envelope)
  - Pressure Difference Ratio Control (min critical PDR)
  - Inlet Droplet Size (critical droplet size)
- **Interfacial Chemistry Parameters**
  - Interfacial Tension (Coalescence Efficiency)
  - Third Party Additives
  - Naturally Occurring Surfactants
- **Mechanical Parameters**
  - Blocked Rejects
  - Mechanical Wear (Erosion, Corrosion)

Factors which Effect Performance Bulk Property Parameters

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- **Phase Density Difference**
  - The greater the density Difference between Oil & Water, the better the separation performance
  - Due to higher velocity attained by droplets to reach core
  - Deoiling of lighter oil an easier task
- **Operating Temperature**
  - Typically, the higher the temperature, the better the separation performance
  - Decrease in water viscosity – Higher droplet settling velocity
  - Destabilises processes on interface that inhibit coalescence – increase in coalescence activity

Factors which Effect Performance Operating Parameters

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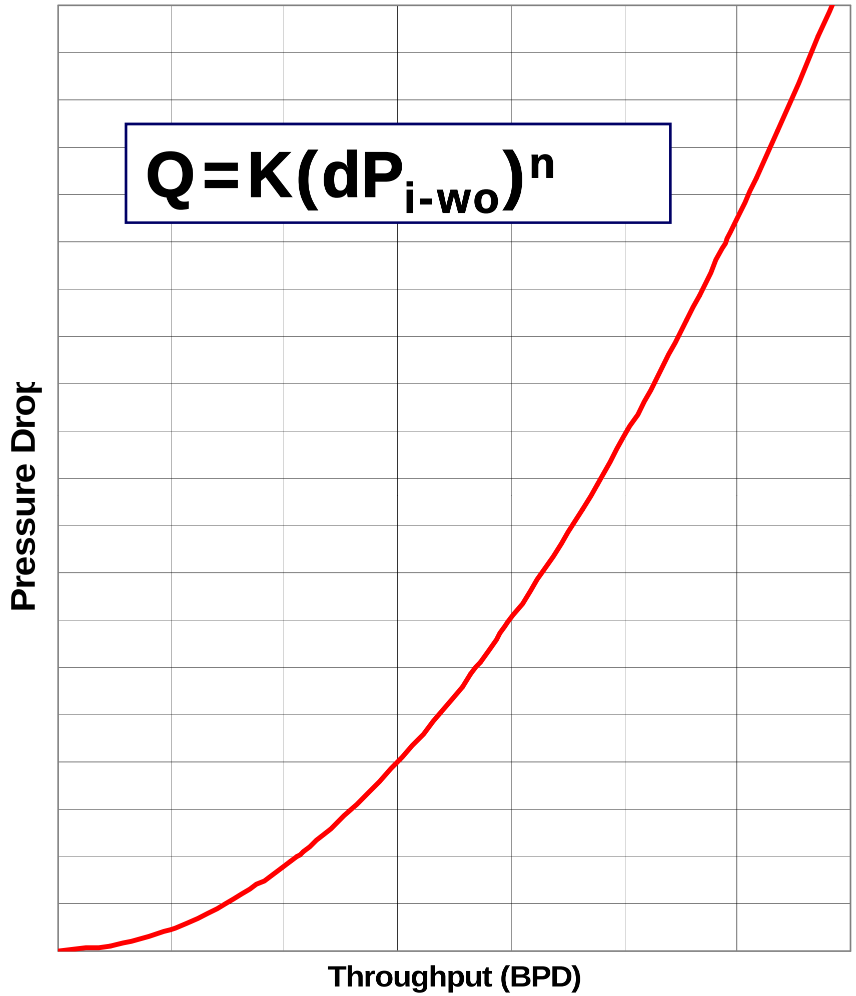
- **Pressure Drop : Flowrate**
  - Square Root Function
  - Typically Smaller capacity, better Separation Performance
- **Pressure Drop : Separation Performance**
  - Performance Envelope:
  - Typically higher pressure drop, higher tangential velocity, higher "g" field, better performance

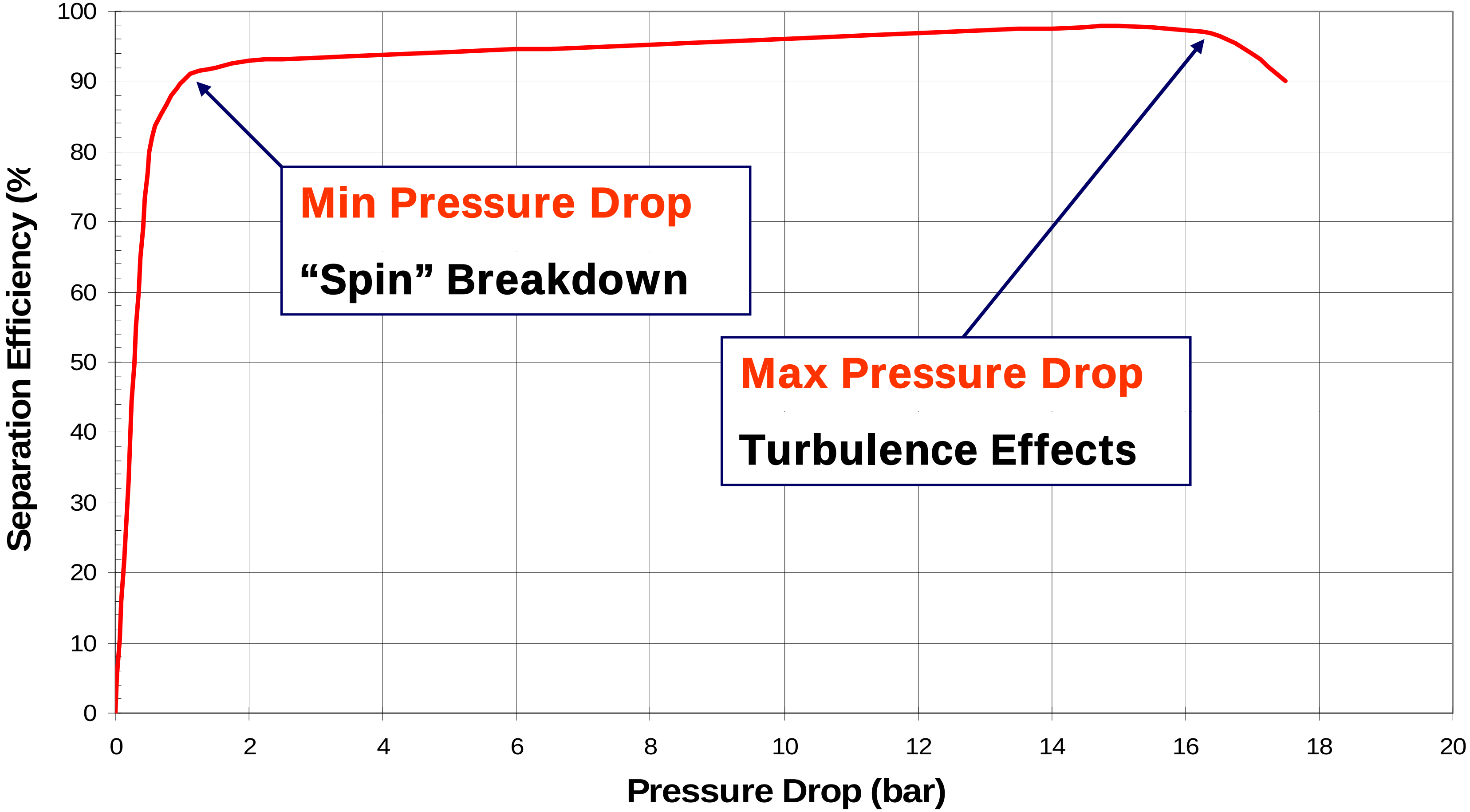
B U T

  - Minimum Flowrate : Breakdown of Spinning Flow
  - Maximum Flowrate : Remixing & Droplet Break up due to high turbulence levels



Factors which Effect Performance
Operating Parameters

- **Pressure Drop : Separation Performance**



Factors which Effect Performance Operating Parameters

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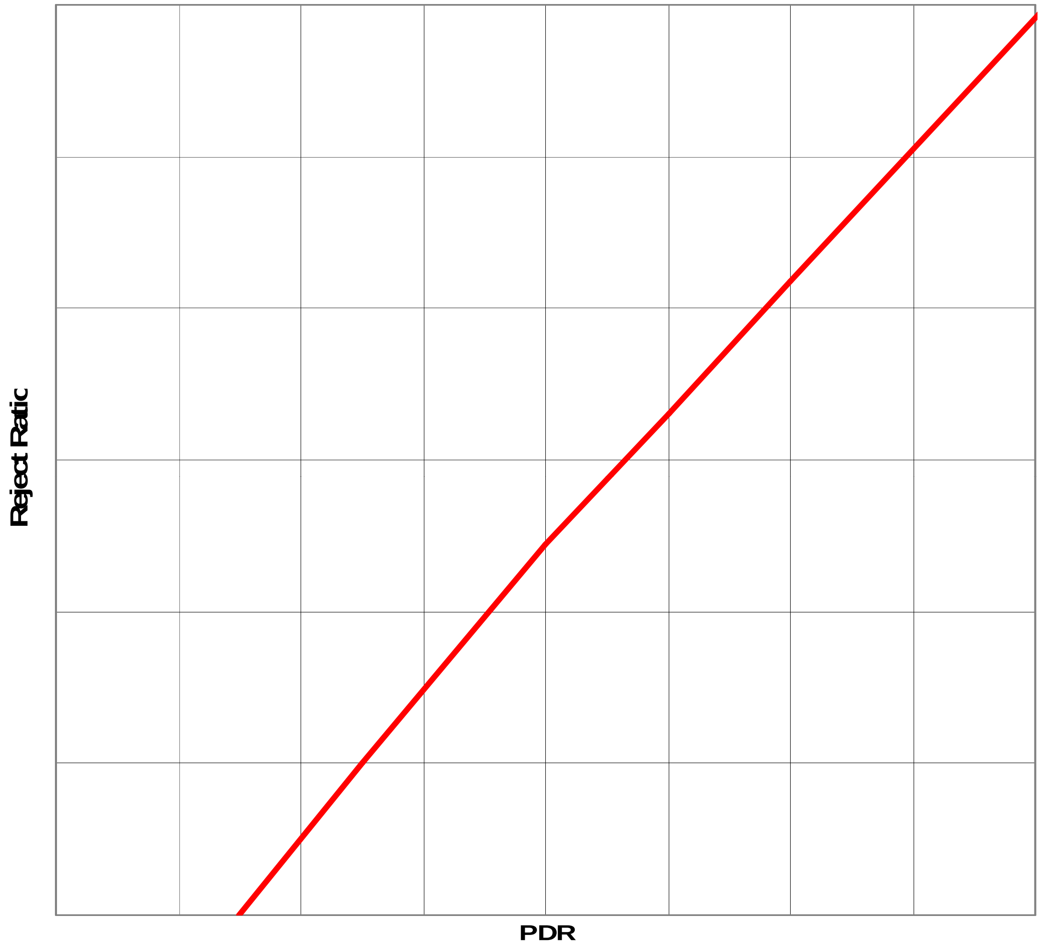
- **Pressure Drop Ratio : Reject Ratio**
  - Critical Controlling Parameter:

$$PDR = \frac{Pin - Por}{Pin - Pwo} > 1.6$$

  - The PDR controls the proportion of inlet Flow that exits through the oil reject
  - To ensure that sufficient flow exits at the oil reject, the PDR **MUST** be greater than critical PDR (1.6)
  - PDR >1.6 implies that pressure drop inlet to oil reject is at least 1.6 x pressure drop inlet to water outlet
  - If PDR < 1.6, insufficient reject flow, oil core will backflow & exit with water outlet = poor separation



Factors which Effect Performance Operating Parameters

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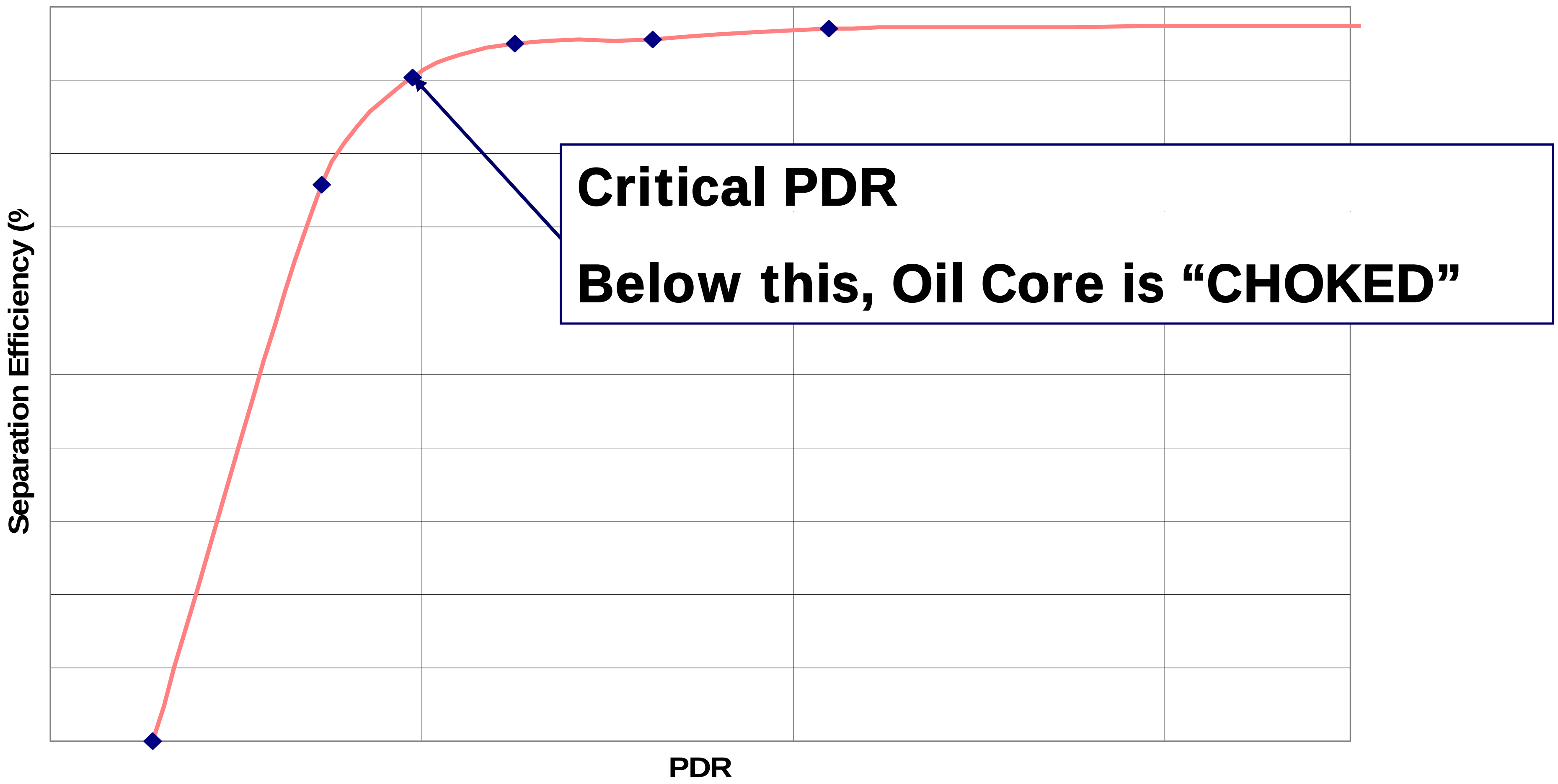
- **Pressure Drop Ratio : Separation Performance**



Factors which Effect Performance Operating Parameters

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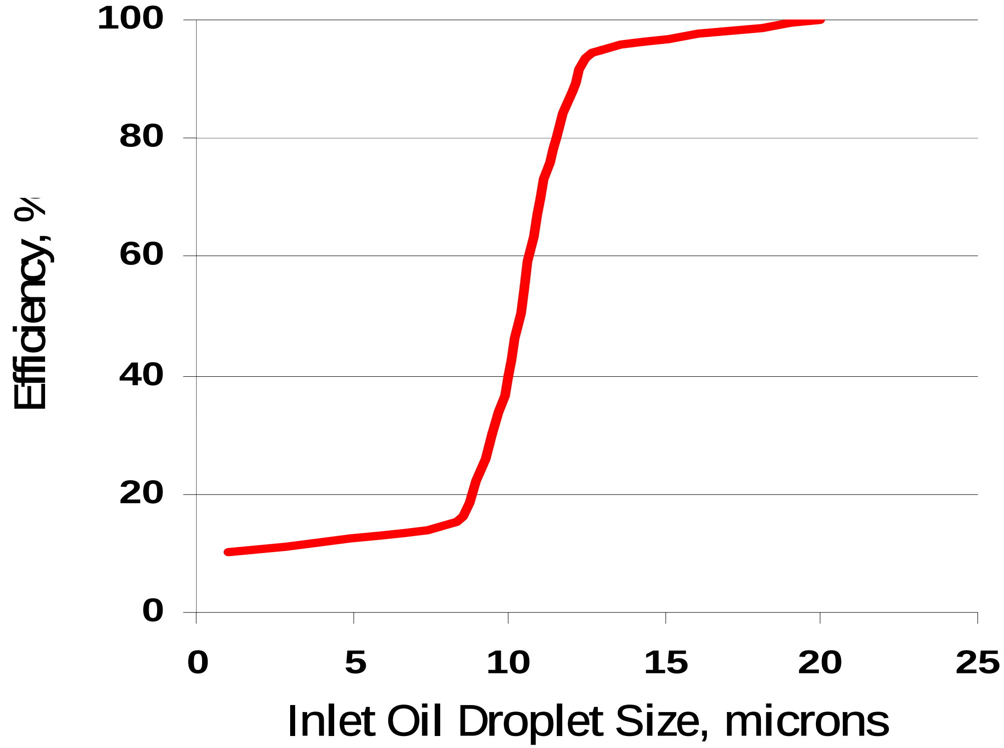
Inlet Droplet Size : Separation Eff.

- Very Defined Critical Droplet Size below which performance falls away markedly
- Critical Drop Size ~10/15 mics
- Actual value will vary with application since it will depend on bulk properties, operating & interfacial parameters
- Pre-Coalescers can enhance Performance – e.g. PECT-F



Factors which Effect Performance
Interfacial Chemistry Parameters

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- **High Interfacial Tension**
  - High resistance to droplet breakup
  - High capacity for coalescence
  - Therefore high interfacial tension = good separation performance
- **Third Party Additives**
  - Naturally Occurring Surfactants – asphaltenes, resins etc
  - Production Chemicals – Corrosion, Scale inhibitors, Demulsifiers
  - All could lower interfacial tension & inhibit deoiling performance OR
  - Increase interfacial viscosity = increase film drainage times = inhibit deoiling performance

Factors which Effect Performance Mechanical Parameters

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- **Blocked Oil Reject Ports**
  - Small oil reject ports (~2.0 mm) can suffer build up of wax/hydrocarbon desposits
  - Causes oil core to reverse & exit with water outlet = poor performance
  - SOLUTION: Backflush rejects

- **Mechanical Wear**
  - If solids present, can erode cyclone liner inlets & cause rifling of tail pipe = performance restriction
  - Solids can block inlet chamber of cyclone vessel = capacity restriction
  - Scale can sometimes form on inside of liner = capacity & performance restriction
  - SOLUTION: High Wear Materials – Stellite, Tungsten Carbide, RBSC

Performance Verification
Single Liner Field Trial

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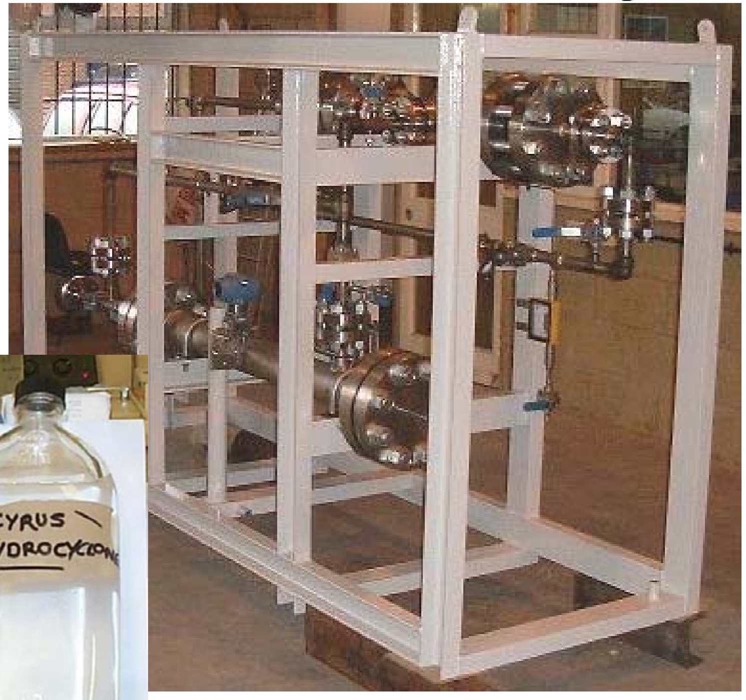

300#   Field Test Units   900#

Assessment - Hydrocyclone FTU, Oil-in-Water analysis, Drop sizing analysis

No Scale up Problems – "if 1 liner works, 100 liners will work"

Conclusions

Cyclotech

- **Benefits**
  - Compact for throughput processed
  - No moving parts
  - No power requirements – utilises natural pressure energy
  - Simple Control requirements
  - Minimal Maintenance Requirements (in most cases) – dependent on CAPEX spend
  - No consumables – Liners will last if correctly specified
  - Limited by-product - Reject Stream ~ 2% of total flow – returned to process
  - Cost effective: Typically $5 to 20$ (CAPEX + OPEX) per bpd processed
- **Ultimate Primary PWT step**
  - Unloads duty for second and third polishing steps