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TESTING OF A COMPACT GAS/LIQUID SEPARATOR AT HIGH PRESSURES

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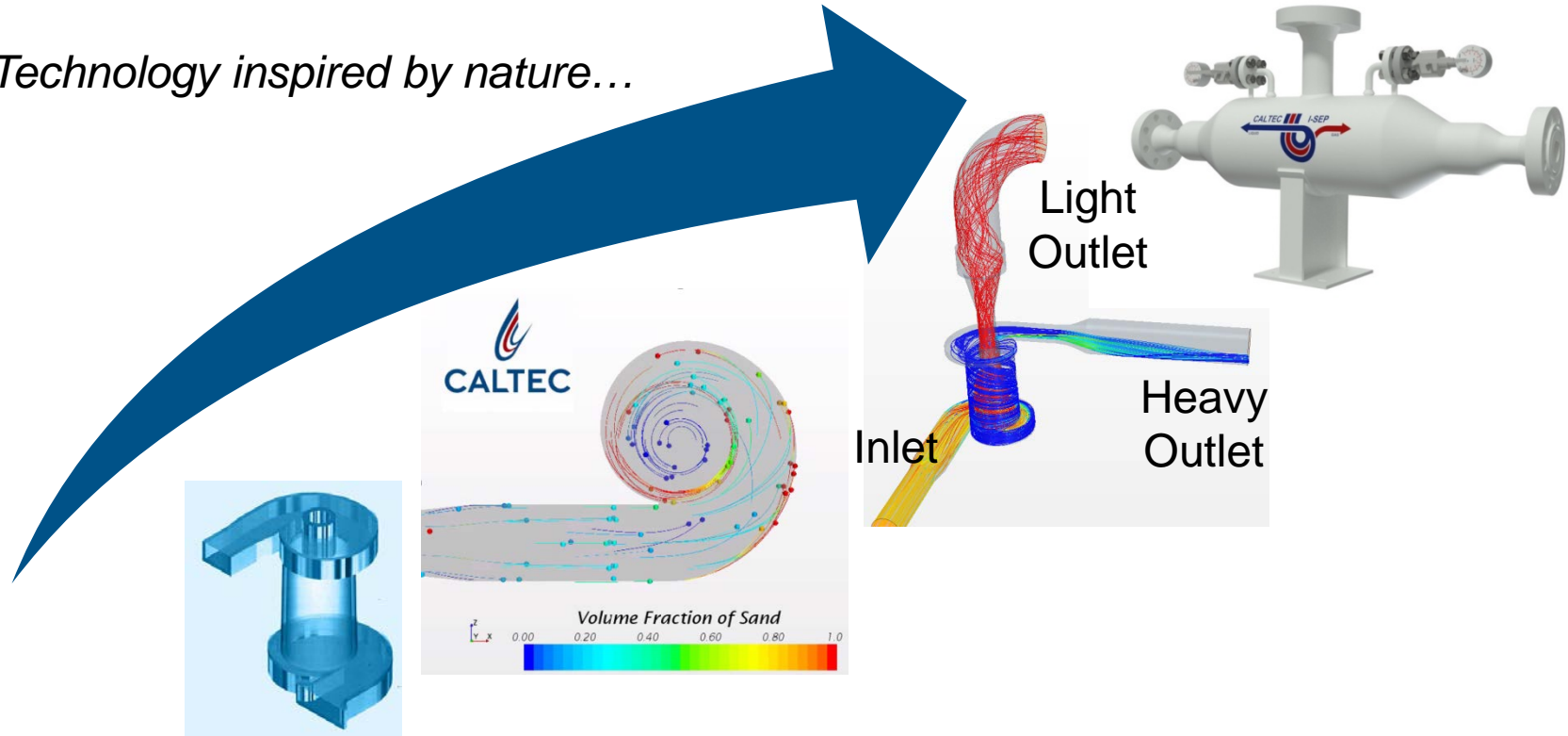
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1. Introduction to Caltec's I-SEP Technology
2. Operating Principal of I-SEP
3. Features and Applications
4. Chevron Performance Testing at Southwest Research Institute
 - a) Flow Ranges covered
 - b) Flow Loop
 - c) Performance Graphs
 - d) Performance with Slugging Conditions
5. Case histories
6. Summary

Compact Cyclonic Separator – Caltec's I-SEP[®]

Technology inspired by nature...

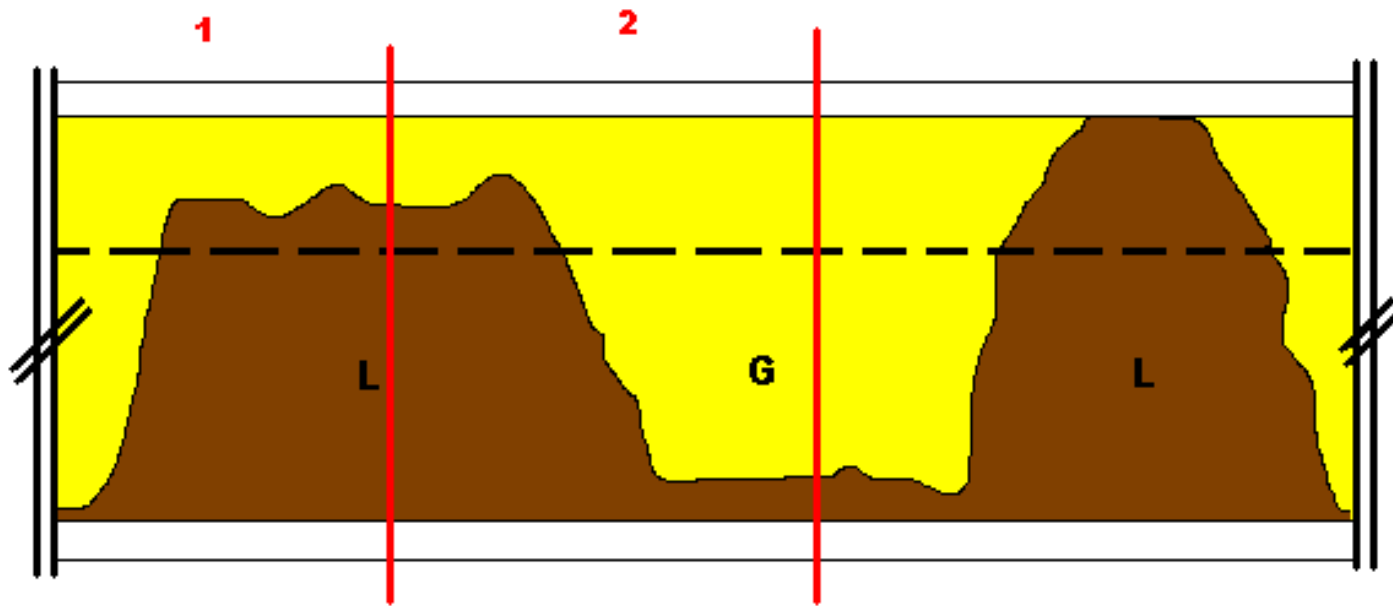


High 'g' forces are generated from the inlet flow stream's momentum by accelerating the flow through an involute to achieve rapid:

- Coalescence
- Phase separation

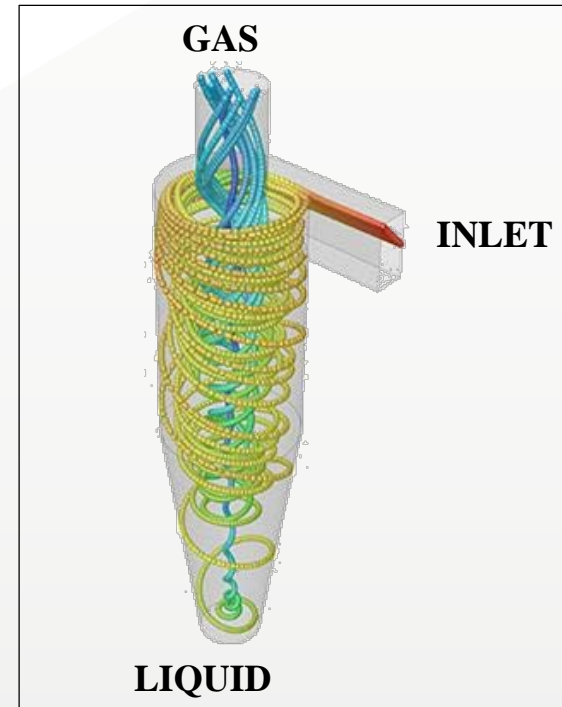
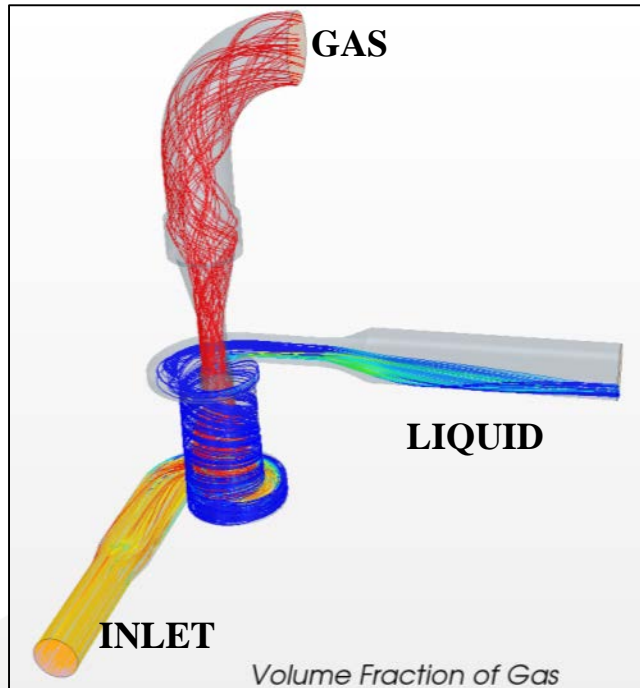


Typical Instantaneous Flow Regime Associated With Multiphase Flow



TYPICAL TWO-PHASE FLOW REGIME IN A PIPE

I-SEP vs. Conventional Cyclone



I-SEP

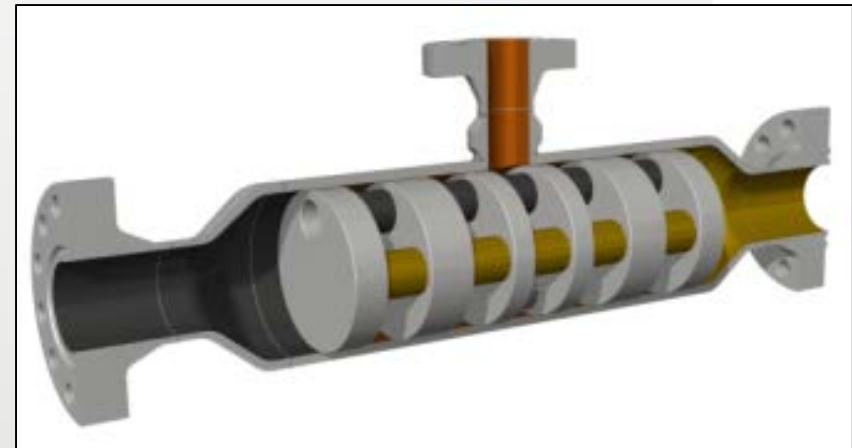
- Co-axial flow
- Low pressure drop
- High throughput
- Bulk separation
- Tolerant to inlet flow fluctuations
- Bigger internal diameter

Conventional Cyclone

- Counter-current flow
- Higher pressure drop
- Lower throughput
- Targeting high efficiency separation
- Very sensitive to inlet flow fluctuations
- Small internal diameter – prone to plugging

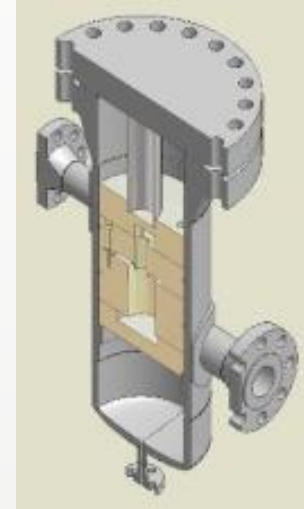
Features and Benefits of I-SEP®

- Uni-axial flow
- Low pressure loss
- High pressure rating
- Small footprint
- Light weight
- No moving parts
- Passive operation
- Minimal fluid inventory
- Easy to install (allows easy retrofiting)
- Modular
- Designed pipeline component code (ASME B31.3)



Typical I-SEP Applications

- Gas-liquid separation
- Knock-out liquid from wet gas
- Solid (sand) separation
- De-bottleneck gravity separators
- Multiphase metering/ test separator
- Well clean-out/well testing
- Underbalanced drilling (UBD)
- De-gassing liquids
- Slug management
- Bulk oil-water separation



Skid mounted system

I-SEP Full-Scale Trials at SwRI®

Undertaken by **Chevron Energy Technology Company (ETC)** at Southwest Research Institute (SwRI®) in San Antonio, TX USA

Aim of Trials

- To test Caltec's Compact Separation 'I-SEP' for bulk gas/liquid separation over a wide range of operating conditions:
 - Varying inlet pressure
 - Inlet range of GVF's (10%– 90%)
 - Testing with hydrocarbons with and without MEG
 - **Exxsol® D110 and Methane**
 - I-SEP's ability to handle slugs
 - Pressure drop at turn-down

Operating Conditions and Flowrates

- Operating pressure **250 psi - 3000 psi**
 - Surface Tension **23 – 7.8 dyne/cm**
- Temperature ~ **80 °F**
- Liquid flow rates up to **12,000 BPD**
- Gas flow rates up to **26 MMscfd**
- Inlet GVF varied **10% - 90%**



SwRI Multiphase Flow Facility

Simulates a high-pressure pipeline environment using "live" fluids - hydrocarbon liquid (crude or condensate), natural gas, and water.

I-SEP setup in SwRI Flow Loop

Unit Details

- Capacity: up to 8,000 bbl/d (*depending on inlet GVF*)
- Unit body size: 12"
- Inlet connection: 4"
- Water outlet connection: 4"
- Gas outlet connection: 3"
- Material of construction: CS
- Pressure rating: 1500# ANSI

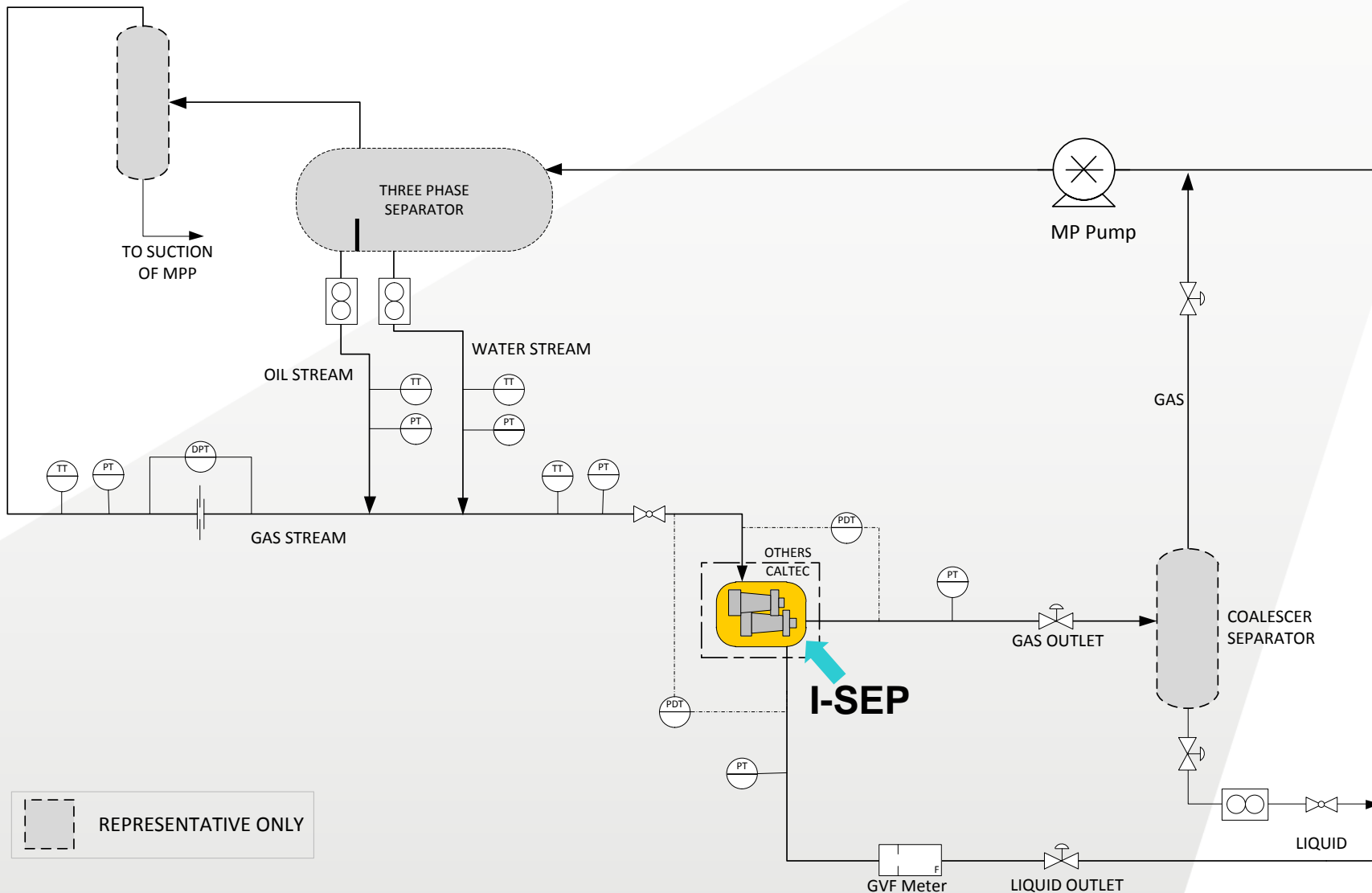


I-SEP before packaging for shipment

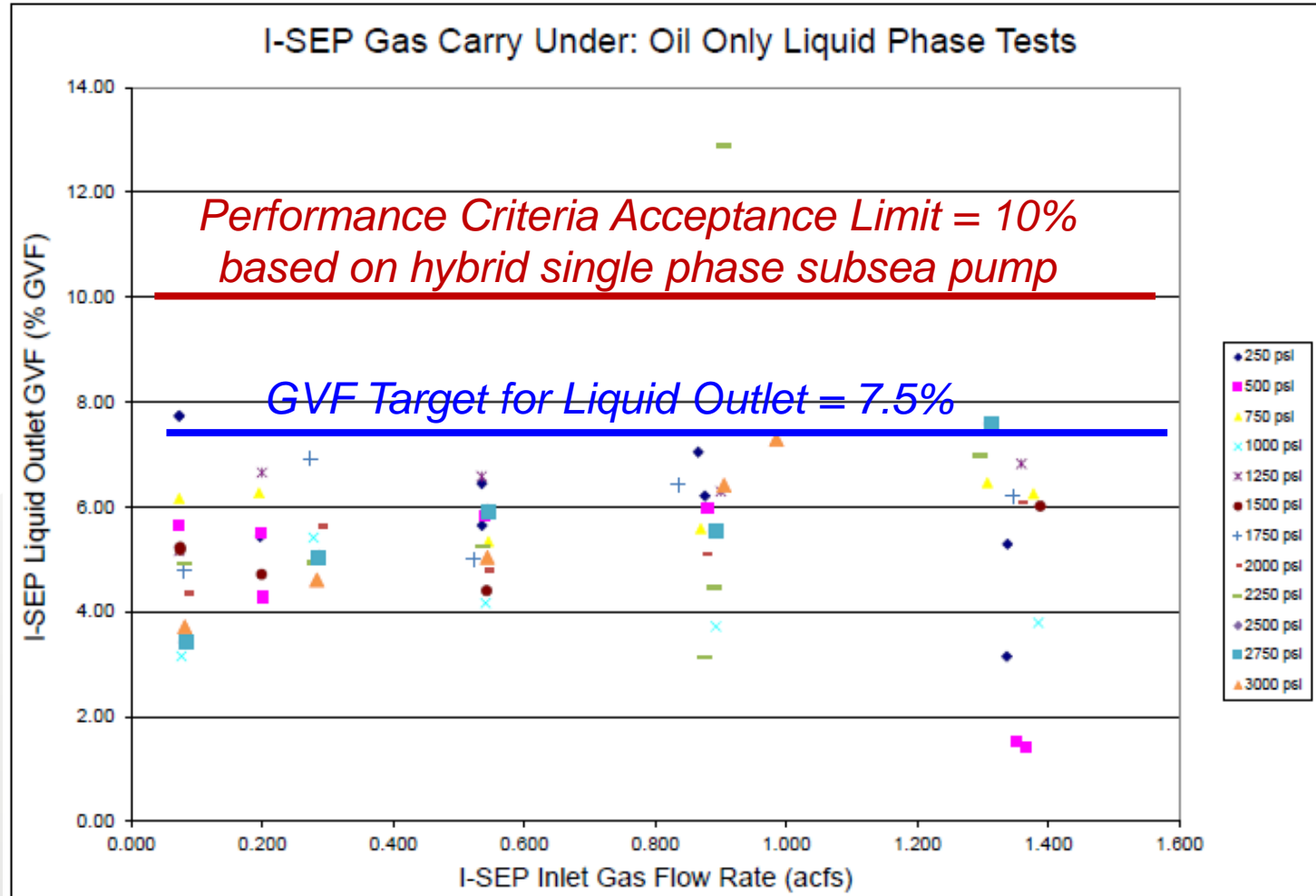


I-SEP in the Test Loop

Simplified Process Flow Schematic of I-SEP installation at SwRI

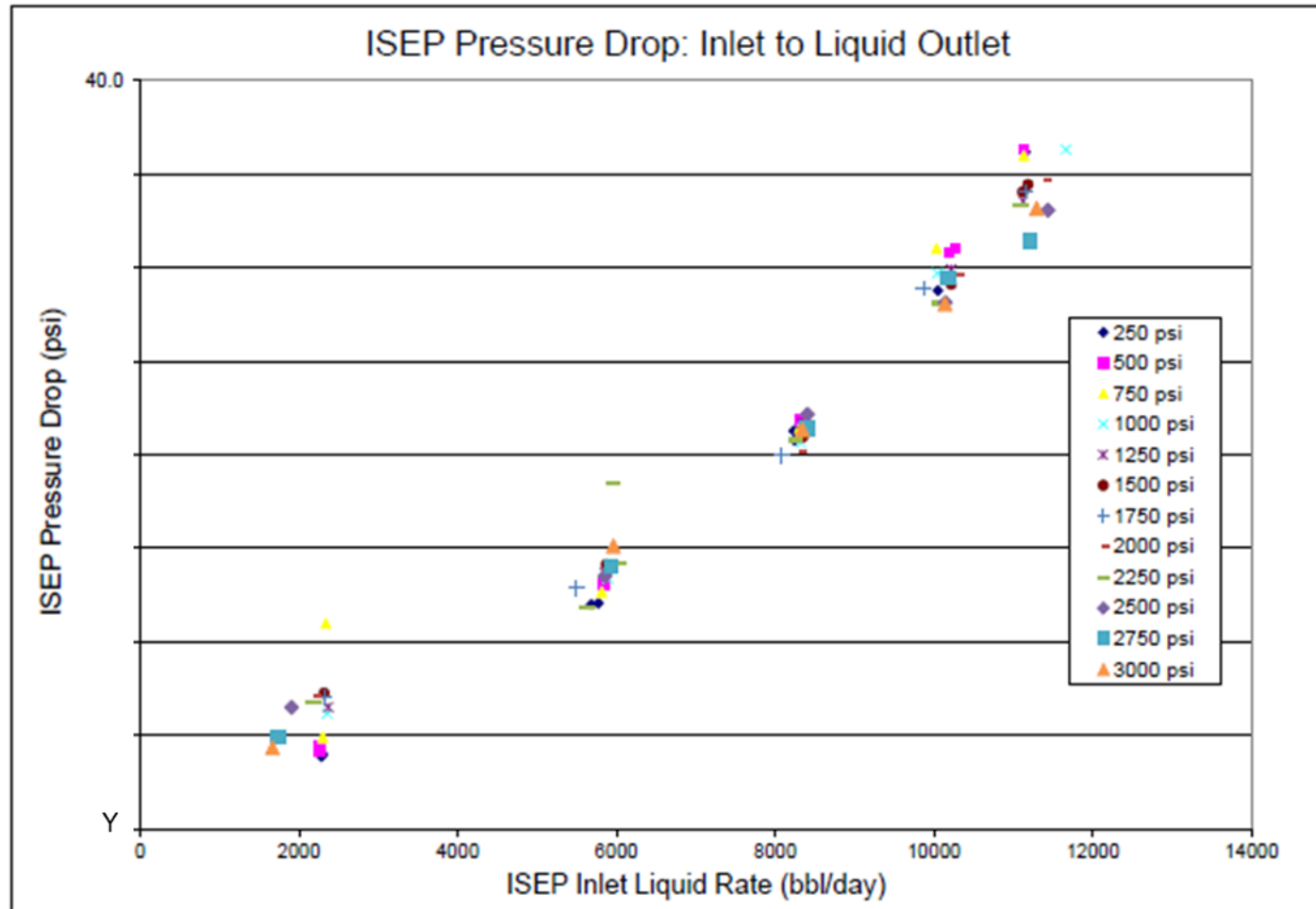


Chevron ETC Testing at SwRI Gas Carry Under for Oil only Tests



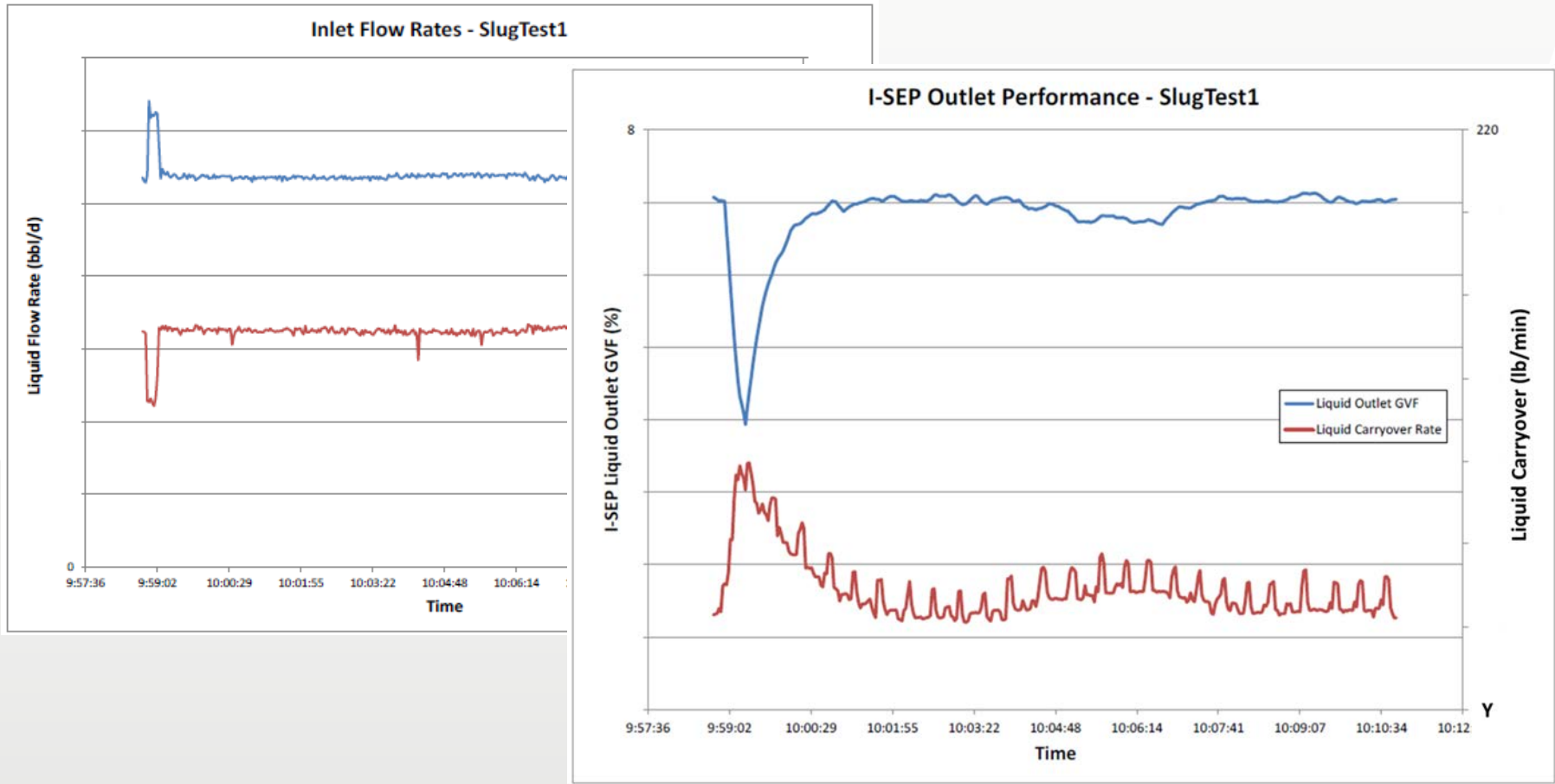
Chevron ETC Testing at SwRI

Pressure Drop From Inlet to Liquid Outlet



Chevron ETC Testing at SwRI I-SEP Performance Under Upset Conditions

The artificially created most severe slug resulted in a rapid inlet gas volume fraction decrease:



Inlet flow rate changes from slugging to stable flow

Multiphase Boosting – case study

Malaysia - MOPU

Issue

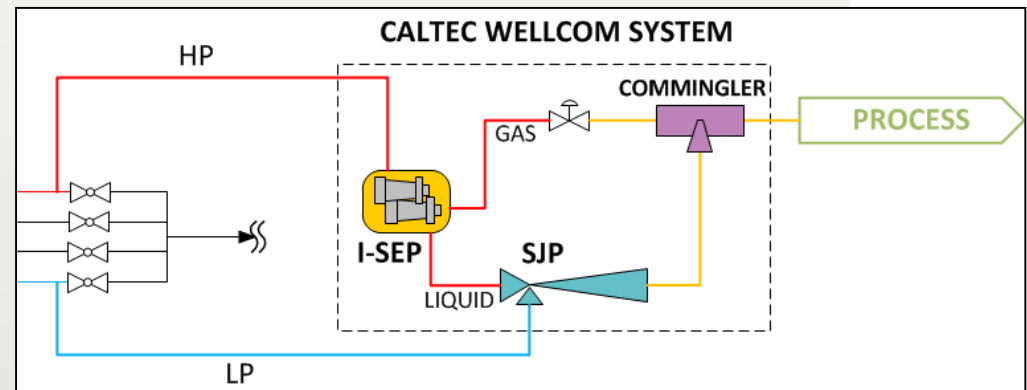
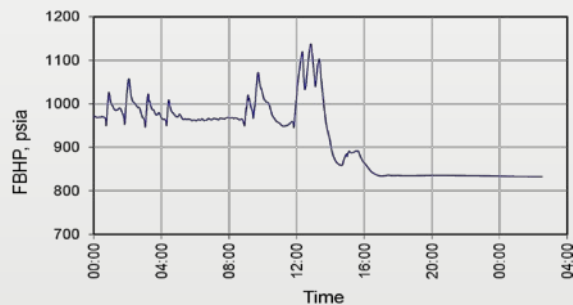
- Shut in multiphase LP wells

Solution

- Multiphase HP wells used to reduce back-pressure

Results

- Used energy otherwise lost in choke from HP well
- 20% pressure boost for LP wells
- Increased production by over 35%
- Improved flow regime in well bore, stabilising production
- **Reduced FBHP by 140psi**



I-SEP® System in UBD Operation

UK - Offshore

Issue

- Conventional UBD physically large units
- Loosing Tungsten Carbide Chokes every 4 hours
- Large gas pressure drops

Solution

- Caltec supplied 2 vertical I-SEP/Hi-SEP, rated to WHSIP (10,000 Psig)

Results

- Removal of gas from drilling mud and cuttings without incurring significant pressure drop (only 2 bar)
- Operates upstream of the choke system
- Max. gas handled 105 MMscfd
- Max. mud rate 300 to 500 GPM



I-SEP® in Sand Separation Duty



Slurry Inlet



I-SEP®



**Light Phase
Outlet**



**Heavy Phase
Outlet**

Well Test / Multiphase Meter Package

Middle East - Onshore

Issue

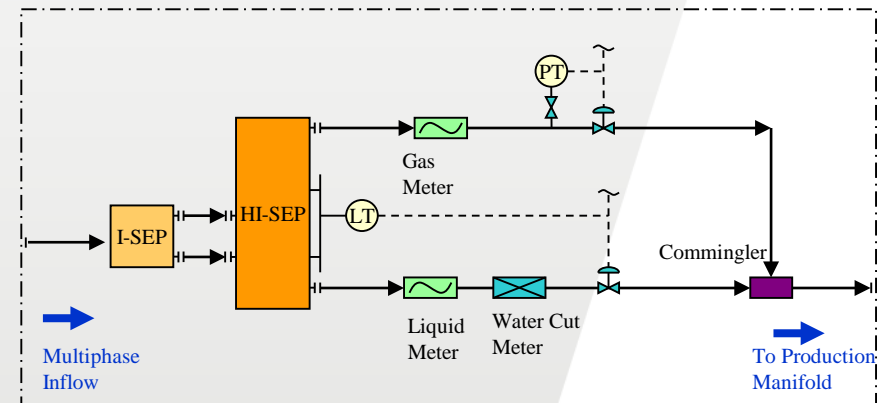
- Metering uncertainties due to multiphase flow

Solution

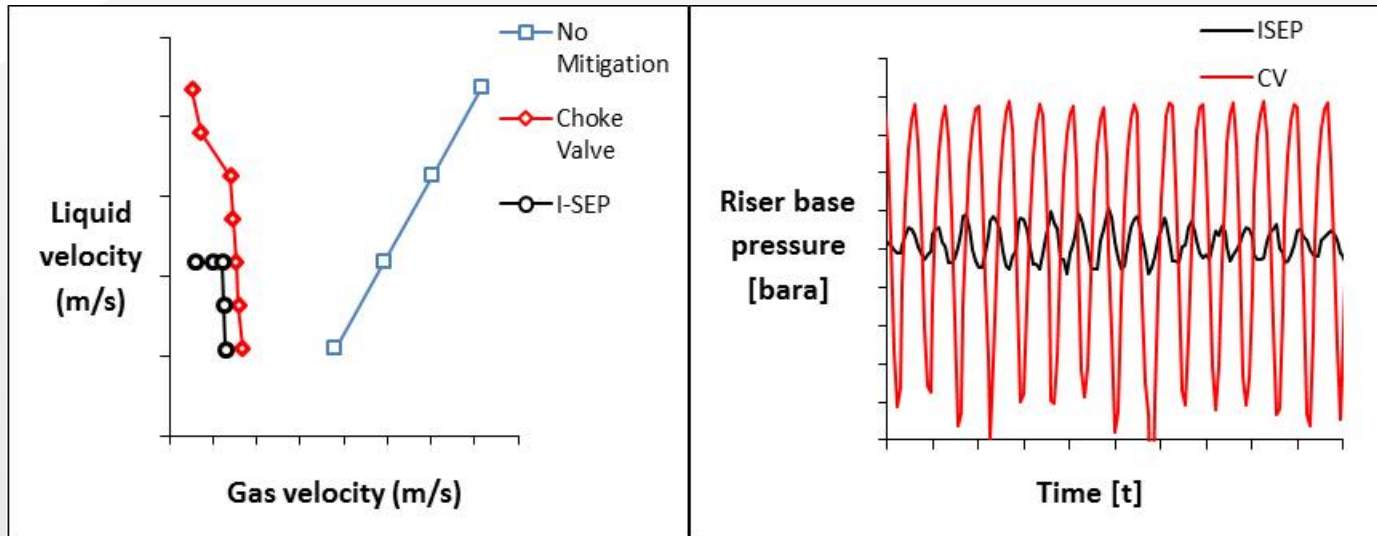
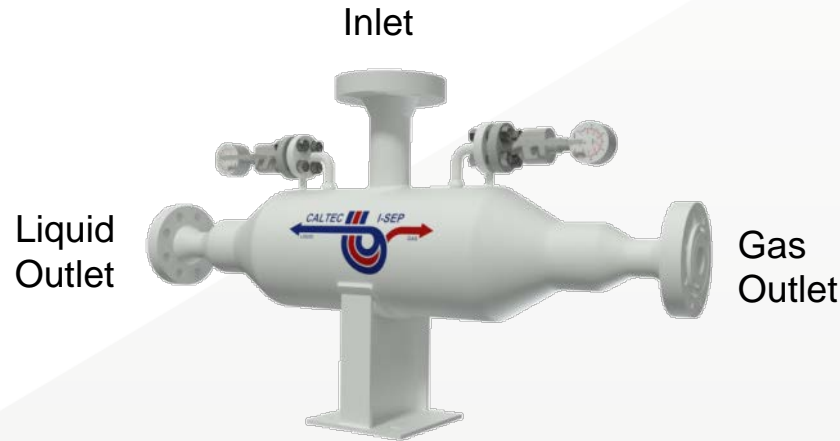
- Using Caltec's patented I-SEP technology, gas and liquid phases are separated and then metered with conventional single phase meters

Results

- Multiphase well testing using conventional meters
- Ability to withstand slug flow
- High turn-down capabilities, better than 10:1
- Handles a wide range of gas-oil-ratios (GORs)
- Low pressure loss, typically 5 to 15 psi

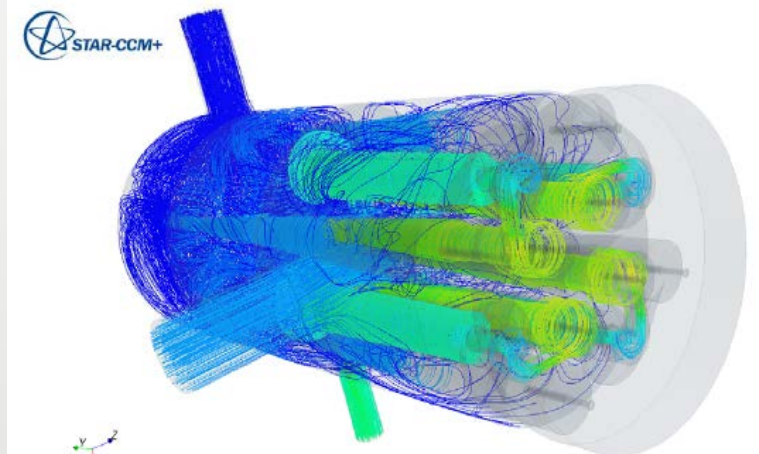


Severe Slugging Mitigation



Flow regime map comparing I-SEP® to CV and no mitigation. SS region to the left of each respective boundary.

Time series data comparison of I-SEP® to CV during a 3 hours period.



Samples obtained:

- 1) Fluid from Final Polishing Unit (60% WC)
- 2) Wx water outlet sample (500 – 1000 ppm)
- 3) Wx oil outlet sample

- I-SEP is a patented field proven compact bulk separator
- Tests at SwRI confirmed I-SEP ability to perform suitably under a range of operating conditions at high pressures
- I-SEP can handle slug flow whilst conditioning and stabilising the incoming flow
- Should be considered as an alternative candidate for subsea application
- Modular - Parallel units can be installed for higher flow rates
- Can be designed to full wellhead pressures
- Small footprint and light weight with minimal fluid inventory
- No moving parts and relatively low pressure drop
- No active control required
- Manual control valves at outlets can be used for enhanced separation efficiencies