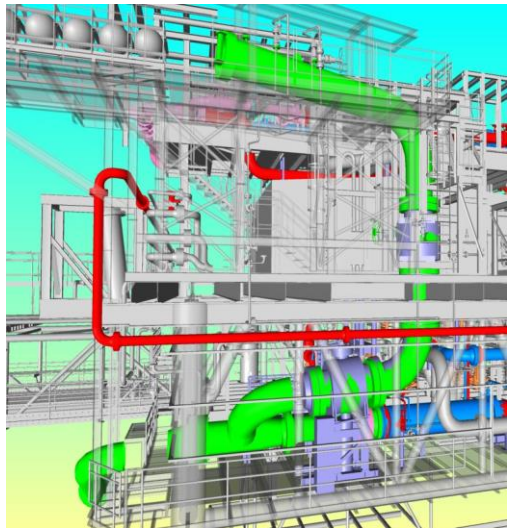
Leman Stuck then Stalled Sphere Rescue Pigging



Against the odds, and the clock

Andy Studman

Principal Pipeline Engineer, Shell International

Plus sincere thanks for contributions by:

- Scott Olson (Shell)
- Aidan O'Donoghue (Pipeline Research Ltd)
- Jim Evans (Pigtek)
- and many others…

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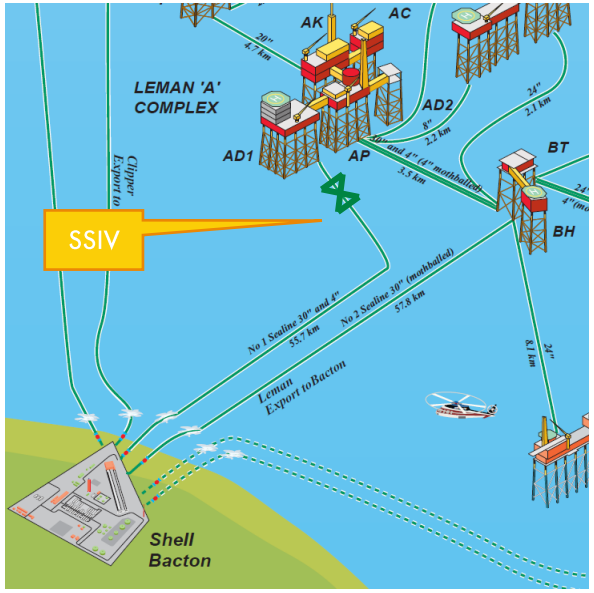
Background

Location, U.K. Southern North Sea

Leman Pipeline System



Leman to Bacton Pipeline Information:

- 30", 55km length, 99 bar design pressure, built in 1967
- Multiphase gas, condensate & water/MEG
- Sphered daily to manage liquid build-up.
- Launcher piping is only currently designed to accommodate spheres
- Includes Subsea Isolation Valve (SSIV) some 250 meters downstream of Leman AP platform

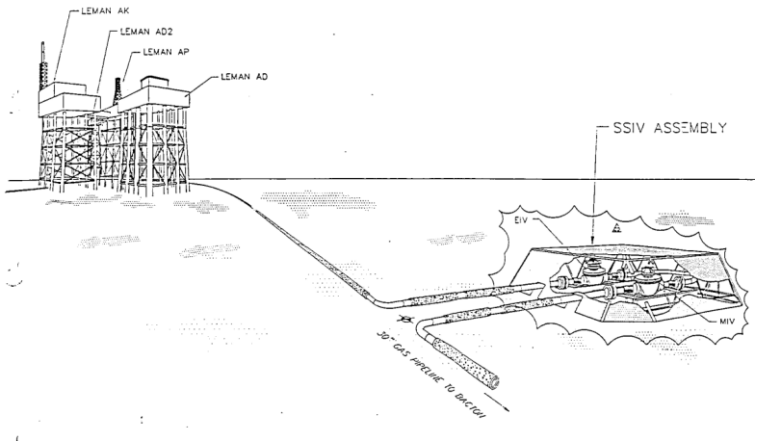
The Two-pronged Challenge:

- March 2022, SSIV function test conducted, valve believed to be left in open position
- Immediate sphere launch became stalled in the partially open SSIV

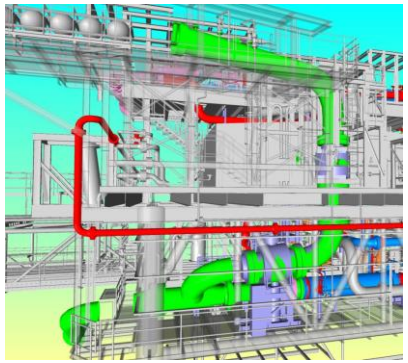
Workstreams created in response:

1. Ascertain options and plans from a flow assurance perspective
2. Plan for rescue pigging of the sphere
3. Attempt to open the valve via topside hydraulics and instrumentation
4. Execute a subsea campaign to manually open the valve

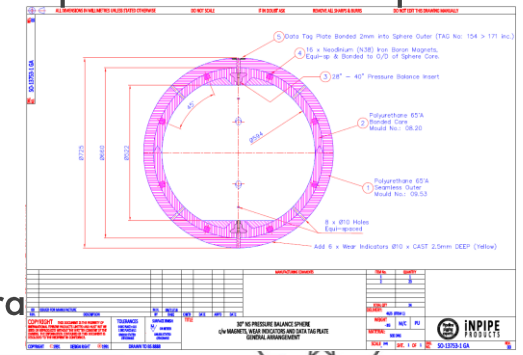
SSIV Subsea Configuration / "Igloo"



Sphere Launching Arrangement

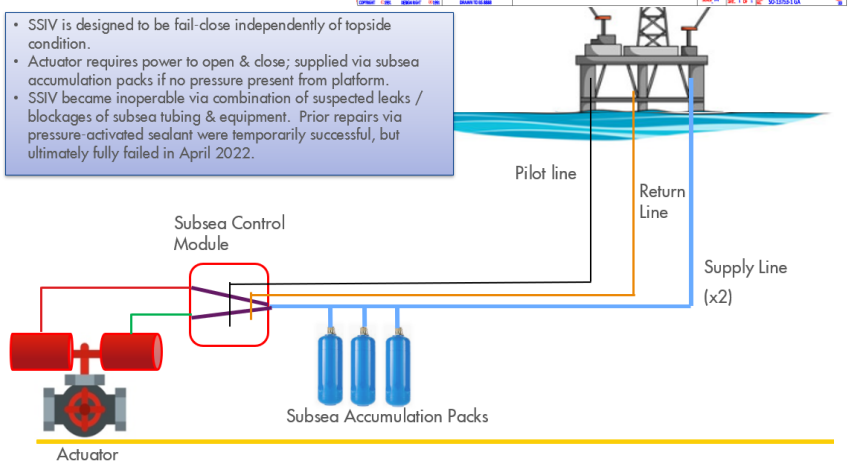


Hollow bodied pressure balanced sphere



SSIV Actuator & Hydra

- SSIV is designed to be fail-close independently of topside condition.
- Actuator requires power to open & close; supplied via subsea accumulation packs if no pressure present from platform.
- SSIV became inoperable via combination of suspected leaks / blockages of subsea tubing & equipment. Prior repairs via pressure-activated sealant were temporarily successful, but ultimately fully failed in April 2022.



Challenges & Considerations

Challenges:

- Unknown state of sphere (Just damaged, or chopped up? Magnets?)
- How to launch and get pig through topside piping ('traditional' pig trap had been removed years prior, current configuration only designed to accommodate spheres).
- Production significantly curtailed. Clock was ticking!

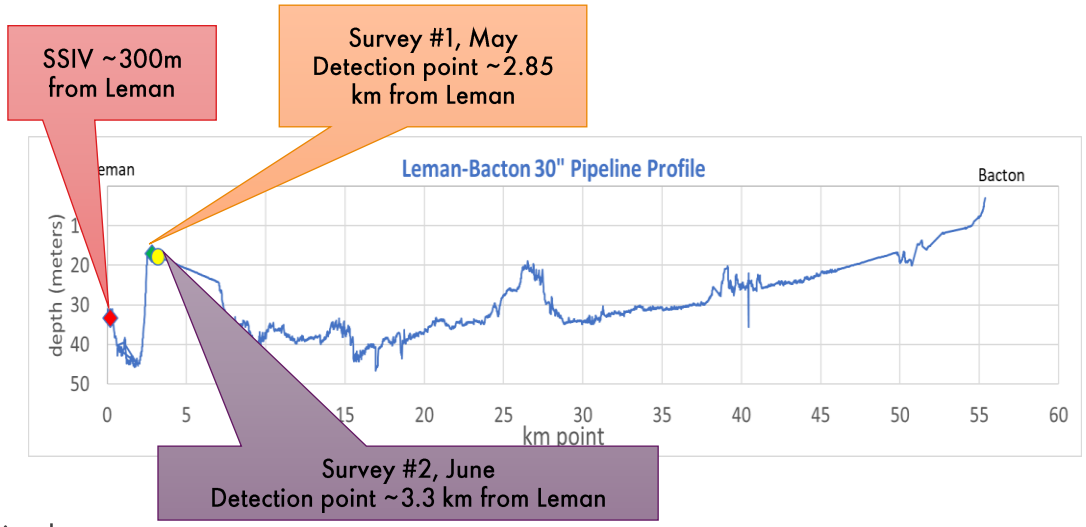
Key Trade-offs:

- Pig type (foam, mandrel, etc.) that could be launched and would be flexible enough to get through topside, but robust enough to push out any type of sphere remnants t could be present.
- How much testing and customization was enough, given available time?

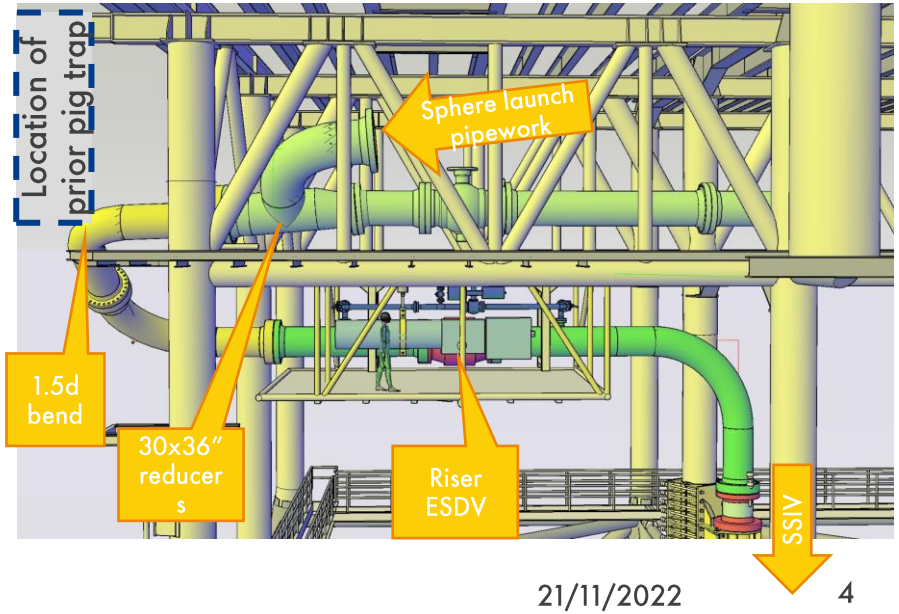
Other data / challenges:

- Piping configuration topside > lack of immediate complete up-front documentation; ambiguity due to project work in late 2000's; etc.
- Resulted in gradual understanding of configuration
- Pressure pulse surveys (Halliburton InnerVue) x2 > indicated blockage was downstream of SSIV. Was this real, or not?
- Flow data not conclusive

Pressure Pulse Survey Results



Leman Platform Topside Pipework



Rescue Pig Design & Testing

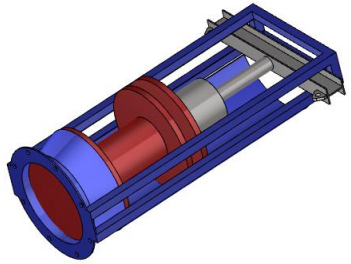
- Primary Option Pig: modular semi-rigid disk/cup pig > SUN "Super Pig"
- Full mock-up of topside piping replicated and tested
- Custom mechanical press insertion tool designed and fabricated
- Backup options: Foam spheres, foam pigs
- All arranged on an emergency basis
- Proved to be extremely valuable & critical for success

Test Loop @ yard

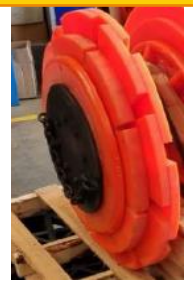
Pigtek Ltd

S.U.N. Engineering, Inc.
10031 East 52nd Street, Tulsa, OK 74146 USA

Custom mechanical press insertion tool



Initial Configuration



- Flat discs
- Compact spacing
- Smaller front plate
- Disks sandwiched together

Intermediate Configuration Results

- Pig stalled on bend
- Sphere pieces bypassed under disks / cups
- "jacknifing"

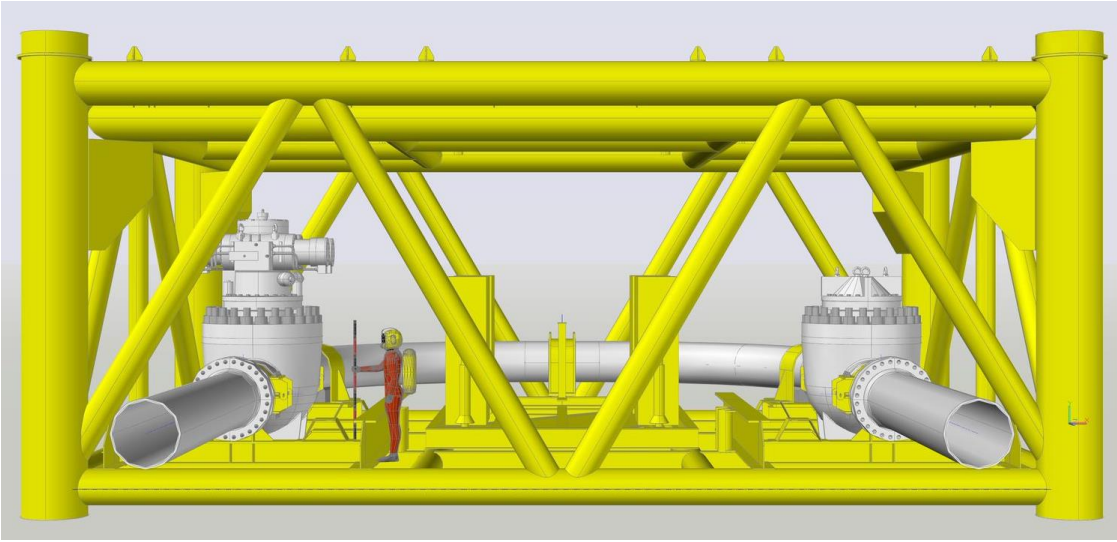
Modified Final Configuration

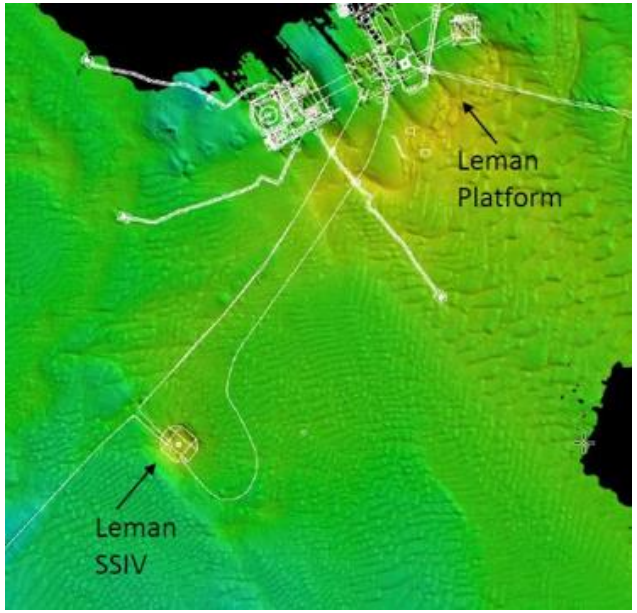
- Disk + Cup arrangement
- Disks bolted together to increase stiffness
- Wider spacing of disks
- Internal foam added
- Larger front flat plate

Opening SSIV by Diver

Challenges:

- Tight timeframe / vessel availability
- Unknown sediment / debris on and in the "igloo"
- Uncertainty regarding hydraulics / fittings condition
- Uncertainty regarding hatch operability
- Working on a live / pressurised system





Pig Loading

Sphere launcher

36″

30″ 1.5D bend

36″

30″

30″

30″

pressure equalization

30x16″ Removal Spool

Spool remova

Pig insertion

0.6m

1.45 m

0.6m

30″

30″ Inj Spool
2.7m length

RESDV

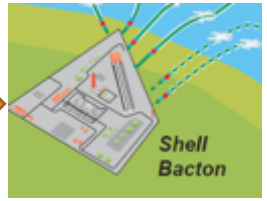
SSIV

Sun Pig

Stricken Sphere

Liquid slug (Water/Condensate/MEG)

Gas



Note: Careful consideration was given to also including a slug of Gel in front of pig, but ultimately not done.

Outcome

- Original SSIV failure and stuck pig: March 30, 2022
- SSIV manually opened: June 21, 2022
- Rescue pig launched: July 14, 2022

- Rescue pig received: July 18, 2022:
  - Overall flawless performance
  - Pig successfully pushed damaged sphere out
  - Damaged sphere found to be “mostly” in one piece

- Prelim learnings:
  - Piggability of Design (removal of prior pig trap)
  - Importance & value of pig flow loop testing
  - Need for good piping drawings / documentation
  - Piggability of spheres in subsequent testing
  - Pressure pulse survey and Gel applicability for other challenges (pressure pulse survey mixed results > likely correct that the sphere was past the SSIV, however incorrect in that it led us to believe the sphere was in pieces)
  - Operational aspects > slug catcher filling & draining, etc.