Primary funding is provided by

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The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME
Capping a Subsea Blowout Is Not Rocket Science – Or Is It?

Andy Cuthbert
Seeking a Solution

An Aerospace Industry approach!
Examination of actual field data.
Use of computational fluid dynamics based on exit conditions.
Simulated plume characteristics.
Shallow Water High GOR Blowout Simulation

ROV Footage

300MM scfd Simulation

Time: 2,000
Deepwater Oil Blowout Simulation
Simulate Full Range GOR on Plume

Depth: 800'
Density: 17.65 kg/m³

Depth: 5000'
Density: 304.0 kg/m³

Depth: 5000'
Density: 700.0 kg/m³
Deployment Considerations

- Defining capping concept based on blowout specifics.
- Analyzing geographical metocean conditions.
- Seasonal / diurnal considerations.
Effect of Metocean Conditions

- Simulations from 4/01/2009 to 9/1/2014
- Significant week to week variance in surfacing location

Prediction of Blowout Surfacing Location Distribution Using HYCOM Historical GOM Predictions

- Mississippi Canyon
- 1500’ depth
- 30000 bbl/day released

Gas Surfacing Distribution

Well located at (0,0)
Deployment Vessel Operations

- Impact of metocean conditions transmitted across hull geometry.
- Reaction of heave compensation to blowout induced loading on capping stack.
- Reaction of deployment cable to fluctuating stack loading.
- Combined cross-current dynamic loading of surface vessel and plume.
- Remotely Operated Vehicle (ROV) multi-body interaction with capping stack in plume.
Deployment Methods

<table>
<thead>
<tr>
<th>Item</th>
<th>Description (Provided by PVR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crane cable (just for Illustration)</td>
</tr>
<tr>
<td>2</td>
<td>100F ROV Shackle</td>
</tr>
</tbody>
</table>

**Vertical Cable Deployment**

**Offset Cable Deployment**

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</tbody>
</table>

To Vessel "1"

To Vessel "2"
Suspension System Dynamics

- Prediction of stack loading as a function of depth, flow rate, GOR, and stack specifics.
- Fully coupled system dynamics and specific risks.
- ROV interactions in near-jet operations and subsea current.
- Combined dynamics of the system, movement tolerances.
Deepwater – Vertical Deployment
Surfing Plume – Offset Deployment


Bay of Bengal 2012, courtesy of the Indian Air Force,
Surfacing Plume – Offset Deployment

Conceptual Multipoint Capping Stack Deployment Process Demonstration
Docking Sequence Simplified
- Reaction of control systems as the stack enters the plume.
- Blowout flowfield induced operational limits.
- Additional blowout hazards to successful capping operations.
Operational Awareness
Rigid Body Modeling

- Overset grid methodology.
- OpenFLOW CFD derivative - Caelus.
- Coupled Caelus flow solver with Chrono dynamics.
- Simulation time-step to avoid anomalies.
Overset Grid & Caelus Flow Solver

Overset grids provide high quality, fast moving grid generation, using rapid and memory efficient algorithms.

Caelus: computational continuum mechanics and computational fluid dynamics solution to partial differential equations on complex geometries to acquire accurate boundary representation.

Global Triangulation

Overlapping Grid

Courtesy of Bill Henshaw, Center for Applied Scientific Computing, Lawrence Livermore National Laboratory, CA

Space shuttle images courtesy of William Chan, NASA Ames Research Center and Reynaldo Gomez, NASA Johnson Space Center
Chrono Dynamics Software

Chrono Dynamics: multibody simulation tool, supports rigid and soft body dynamics, finite element analysis (FEA) and collision detection (FSI) dynamics.
Case Study 1

- Use “as-built” geometry
- Perform stack flowfield analysis with fully coupled CFD/Dynamics solver
- Perform simulation at “Worst Case” flow conditions:
  - 5000ft. water depth
  - 3.25 Bscf/day
  - Release density of 130kg/m³
  - Turbulent flow release (Re > 2300)
- Evaluate and reproduce industry accepted flowfield analysis capability
Comparison with Existing Landing CFD
Myths & Legends – “Centering Force”

- Red area represents “core flow”
- High momentum
- Stable flow
- Strong gradients
- Core flow ends 5 – 7 exit diameters downstream
- Exit velocity drops at $1/D_{exit}$

18 3/4-in. Mandrel Exit Geometry
Same flow, three different turbulence assumptions

- Industry “Standard” (Centering Force)
- Engineering Model (Analytical Average)
- OpenFOAM Turbulence Model

- Correctly constructed, scaled, unsteady, large eddy turbulent jet simulations
- Veracity of modeling against actual field data
- Accurate geometries, capping stack and exit conditions.
- High fidelity analyses have never encountered “centering force”
Case Study 2

Water depth: 282 ft.
Casing diameter: 13-3/8"
Release temp: 84° F
Release rate: 8,255 BOPD
Oil API: 41°
GOR: 621

Release mass flow rate: 61.47 kg/sec
Release density: 6.53 kg/m³
Release mean velocity: 103.9 m/s

- Combined liftoff forces < 16% of the weight of the stack.
- Lateral plume forces remain within capabilities of work class ROVs.
Case Study 3

Water depth: 5,426 ft.
Casing diameter: 13-5/8"
Release temp: 190° F
Release rate: 58,500 BOPD
Oil API: 30°
GOR: 586

Release mass flow rate: 71.42 kg/sec
Release density: 663.1 kg/m³
Release mean velocity: 1.38 m/s

• ROV interventions, in the order of 100 pounds laterally, will keep stack on centerline.
Ongoing Studies:
Wave Period & Frequency
Study Conclusions

• Applied aerospace domain expertise to turbulent plume-force dynamics with high speed jet velocities, “rocket science”.

• NASA methodology for examining jet induced uplift forces.

• Accurate modelling and veracity of simulations based on actual data, combined a fully coupled system algorithm.

• Challenged industry accepted modeling results.

Salient lessons from aerospace engineering assisting the oil industry in knowing what it doesn’t know!
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation

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#SPEdl
Operational Awareness
Capping Stack – Landing Sequence
Mandrel Exit Pressure Differential
Initial Exit Conditions