OIL & GAS

DOWSES & AIRRE

Upcoming Research

Dan Allason

11th October 2017

Confidential

SAFER, SMARTER, GREENER

Introduction

1. Explosion Research @ Spadeadam
2. DOWSES
   a) Background
   b) Experimental Programme
   c) Analysis
3. AIRRE
   a) Background
   b) Experimental Programme
   c) Modelling

Explosion Research @ Spadeadam Testing & Research

Joint Industry Projects / Contract Research / Internally Funded

- Explosions
- BLEVE – LNG & LPG
- High Explosives

Confidential

DNV·GL

DOWSES: Background

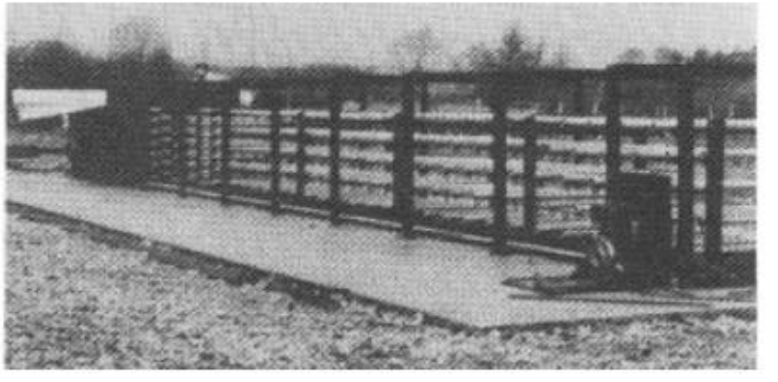
Development Of Water Spray Explosion Suppression

Confidential

DOWSES: Background

Early Studies

- 45 x 3 x 3 m congested explosion rig
  - Expensive
- 1/5th linear scale rig to reduced costs
  - Flame acceleration with low repeatability
  - Correlation of low flame speeds with rain on test day
  - Droplet sizes invariant with scale of rig → proportionally more water in smaller scale



Confidential

DOWSES: Background

Early Studies

- Demonstration experiment in full scale rig
- 500 $m.s^{-1}$ reduced to 40 $m.s^{-1}$
- 4 bar to <100 mbar
- Confirmation in 1/5th scale experiments

- Attempts with poly. bags did not replicate effects

Confidential

DOWSES: Background

Post Piper Alpha: 45m Rig

	No Water Sprays	Open Pendant Nozzles	High Velocity Nozzles
Natural Gas	4 bar	0.35 bar	1.0 bar
Propane	30 bar	1.7 bar	-

In all cases, the presence of general area deluge at the time of ignition led to a reduction in explosion overpressures, particularly in cases involving the highest overpressure without deluge

DOWSES: Background

Post Piper Alpha: Water Spray Characterisation

- 180 m³ explosion chamber
- No vent restriction → high velocity req'd for high pressure
  - Provided by congestion
- Vent restriction → pressure provided by confinement
  - Low flame speeds

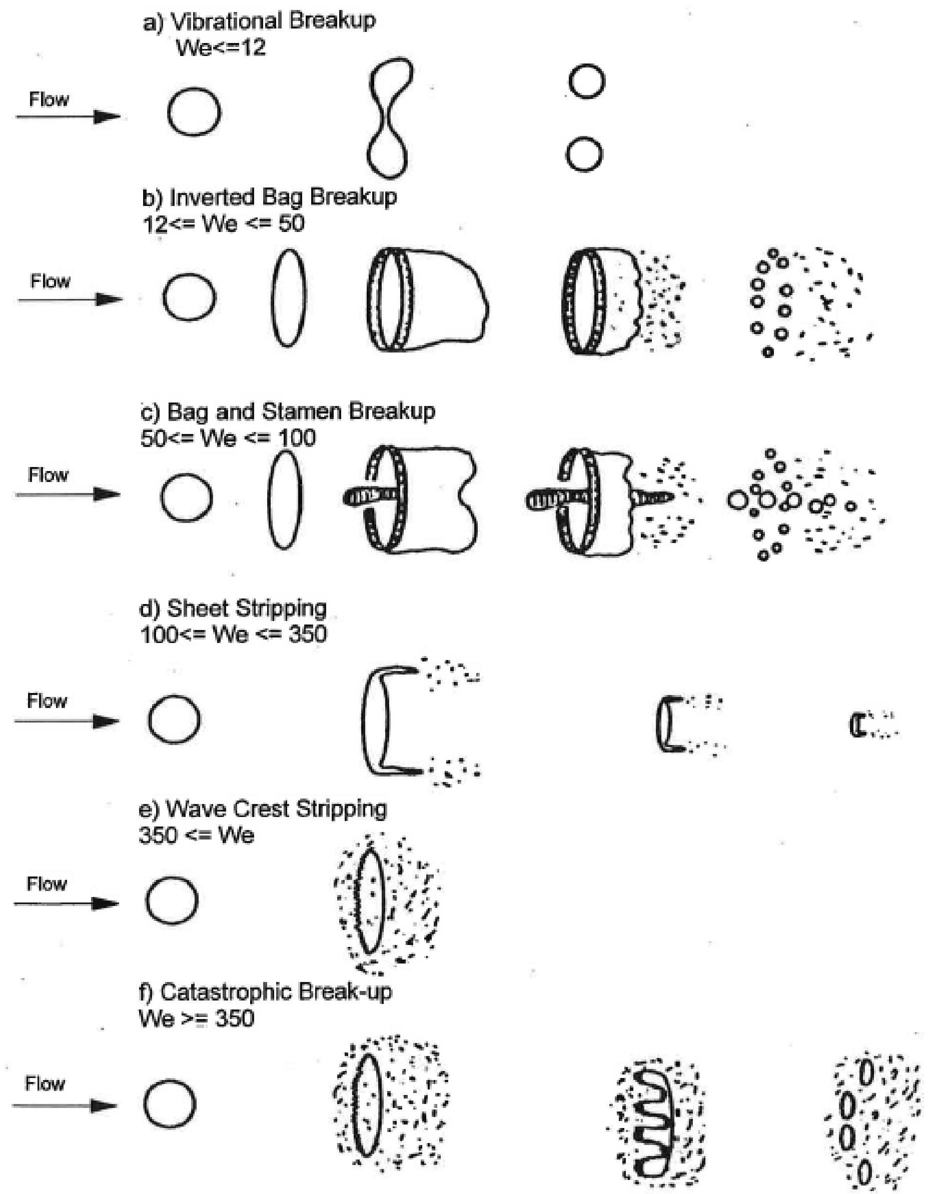
- No restriction – water works as expected
- Restricted vent – water droplets don't break up. Turbulence from sprays increases explosion severity

Confidential

DOWSES Background

$$W_e = \frac{\rho . d . u^2}{\sigma}$$

- P is density (of air, kg.m^{-3})
- d is Sauter Mean Diameter (m)
- u is slip velocity (m.s^{-1})
- σ is surface tension (N.m^{-1})



Confidential

DOWSES Background

Summary of Spray Characterisation Experiments Results

- All water sprays in partially confined geometry gave lower OP
- Generally: misting nozzles showed no significant improvement over fire deluge sprays with larger droplets
- Nozzles producing larger droplets still gave better mitigation than fire deluge sprays
- Highly confined experiments showed increase OP for all sprays
  - Exception being the large droplet sprays in highly confined, highly congested experiments

DOWSES: Background

Post Piper Alpha: Full Scale Experiments

- General Area and Water Curtain experiments all provide reduction in explosion severity

Confidential

DOWSES: Background

Project MEASURE

- Interaction of process regions in gas cloud explosion
- Relevant to highly congested process areas – e.g. FLNG topside
- Data from tests to validate update to FLACS CFD code

Participants

GexCon (Lead)
DNV GL
Total
Engie
Statoil
BP
ExxonMobil
Shell (contribution in kind)

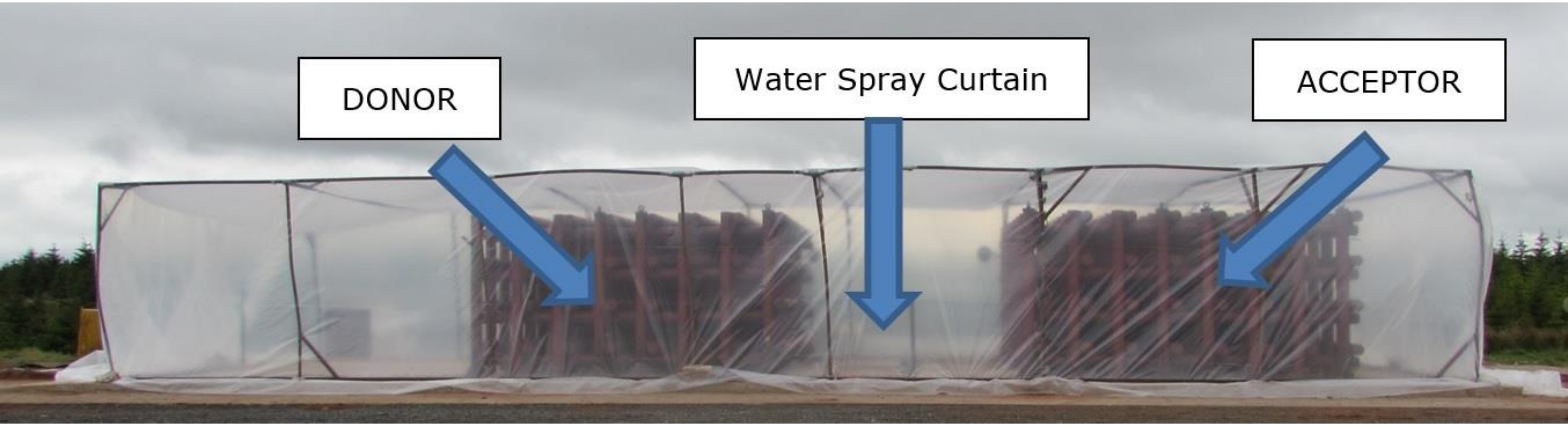
Confidential

Project: MEASURE

- FLNG facilities a significant investment
- Safety gaps can be expensive
- Research to provide some validation for modelling
- Additional contract research looking at deflagration to detonation transition

Confidential

DOWSES



- Build on early studies and MEASURE
- Develop knowledge of water curtain potential to reduce Critical Separation Distance
- Variables: Congestion type, fuel, severity of unmitigated
- Invitations for modelling exercise open soon

Participants

DNV GL
Total
Shell
Woodside
Research Council of Norway (DEMO2000)

Confidential

DOWSES

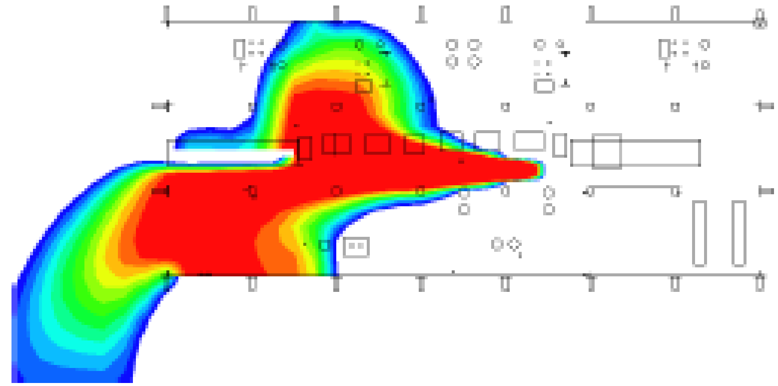
Experiment ID	Congestion Type	Fuel	Unmitigated Interaction Level (from MEASURE)	Curtain Arrangement	Nozzle Arrangement	OBJECTIVE
1	Rig9	Propane	DDT	Single, central	Fan, downwards	Optimal curtain location in high interaction
2				Single, Donor exit	Fan, downwards	
3				Single, Acceptor entry	Fan, downwards	
4				Optimal Chosen from 1-3	Narrow Cone, downwards	Optimal curtain arrangement in high interaction
5					Fan, upwards	
6					Narrow Cone, upwards	
7				Optimal from 1-6	Optimal from 1-6 but increased water qty	Check sensitivity to water quantity
8				Optimal from 1-6	Optimal from 1-7 but different water qty	Check sensitivity to water quantity
9				Donor exit and Acceptor entry	Optimal from 1-8	Check double curtain effects
10				General Area Deluge on Acceptor		Comparison with General Area Deluge
11			Low	Optimal chosen from 1-7		Effect of optimal arrangement on low interaction case
12		Methane	High	No curtain		Baseline Methane Rig9 case (not present in MEASURE)
13				Optimal chosen from 1-8		Effect of fuel type on optimal arrangement
14	Rig7					Effect of congestion type on optimal arrangement
15				Different arrangement to 14		Check optimal arrangement still optimal
16-20	Repeatability Experiments					
21	Rig9	Propane	DDT	Optimal from 1-8 but with particulate injection		Assess mitigation effect with introduction of particulates into water
22	Rig9	Propane	DDT	TBC curtain arrangement with particulate injection		Assess potential effect of particulate injection with different curtain arrangement

Confidential

AIRRE: Background

<u>A</u>ssessing the <u>I</u>nfluence of <u>R</u>eal <u>R</u>eleases on <u>E</u>xplosions

AIRRE



- Most experimentation involves quiescent, homogeneous gas : air mixtures
- Realistic releases can give inhomogeneous, turbulent volumes
  - Equivalent cloud concepts
- Need to understand turbulence and concentration gradients

Participants

Gexcon
Engie
Total
Shell
Research Council of Norway (DEMO2000)

Confidential

AIRRE WP-A: Experiments

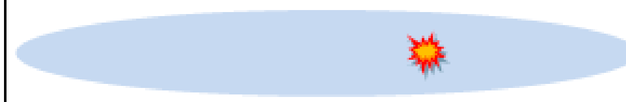
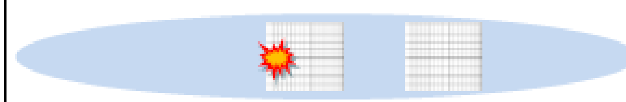
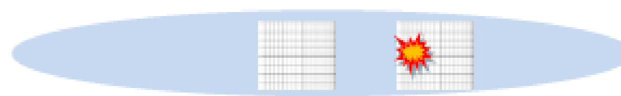
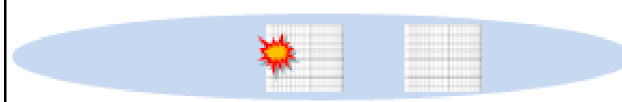
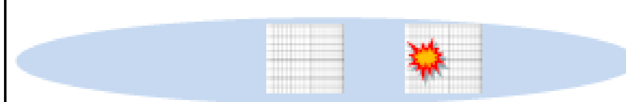
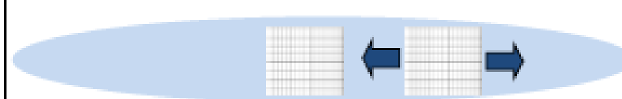
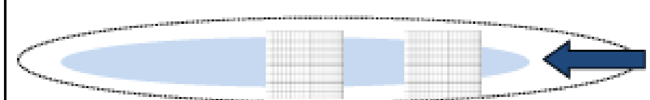
- Large size natural gas wall-jets
- Target mass flow rate is ~100 $kg.s^{-1}$ for ~40 seconds
- Initial experiments without pipework congestion
  - Commissioning of instruments
  - Assessment of pre-ignition turbulence effects
- Remaining experiments impinge on pipework congestion (see MEASURE)
  - Vary ignition position
- Budget dependent: add confinement?

LFL distance	Flame length	Flame height	Heat flux in the downwind direction [$kW\ m^{-2}$]			
			5.0	12.5	20.0	37.5
140-170 m	115 m	35 m	190 m	155 m	140 m	130 m

Confidential

DNV·GL

AIRRE WP-A: Experiments

Test no.	Illustration	Comments
1		Wall jet No congestion Ignition in fuel-rich region
2		Wall jet No congestion Ignition stoichiometric region
3		Low-congestion modules Safety gap Ignition in fuel-rich region
4		Low-congestion modules Safety gap Ignition in fuel-lean region
5		High-congestion modules Safety gap Ignition in fuel rich region
6		High-congestion modules Safety gap Ignition in fuel-lean region
7-10 (option 1)		Idem 3 to 6 with modified separation distance
11-16 (option 2)		Idem 1 to 6 with reducing release rate

Confidential

AIRRE WP-A: Experimen

Confidential

DNV·GL

AIRRE WP-B: Modelling

- B.1: Simulating the effect of pre-ignition turbulence
- B.2: Improved source term modelling
- B.3: Extensive literature study on DDT and Detonations
- B.4: Modelling and validation of DDT and detonations in FLACS
- B.5: Modelling blast wave propagation in FLACS
- B.6: Selected model improvements in FLACS

Confidential

Contact Information

- Both DOWSES and AIRRE are still open to partners
  - DOWSES: Dan Allason (daniel.allason@dnvgl.com)
  - AIRRE: Trygve Skjold (trygve.skjold@gexcon.com)

Confidential

Thank you for your attention

Dan Allason
daniel.Allason@dnvgl.com
+44(0)20 381 64140

www.dnvgl.com

SAFER, SMARTER, GREENER

Confidential