Appendix 2: Subsea sensors

System	Description	Utility	Weaknesses	Maturity*	Key data
Continuous monitoring					
Active acoustic	Acoustic radar which "looks" for the acoustic reflection which a leak will/can generate	Detection of oil under water. Area coverage. More sensitive to detection of gas leaks	Sensor needs a lot of electric power and a large bandwidth. Sensitive to nearby equipment (shadow effect). Generates large volumes of data	Supplied commercially for inspection, prototype for subsea monitoring	Resolution better than 10°/1m, ranges depend on the system
Biosensors	Instrumented biological organisms (such as mussels)	Point sensor suitable for leak detection down to 500 metres of water depth	Ocean currents may lead the hydrocarbons away from the sensor	Pilot (shallow water, < 100m), conceptual phase (deep water, 100-500 metres)	High specific sensitivity
Fibreoptics	Fibreoptic cable laid along a pipeline to measure changes as a result of a leak, by measuring either temperature changes or contact (sound waves)	Area coverage. Can locate a leak along a pipeline	Primarily for pipelines at present	Delivered commercially for pipelines, conceptual version for subsea facilities	Detects temperature changes, pressure, vibrations/ loads (µm)
Fluorescence	Uses a light source with a certain wavelength to excite molecules in the measured object to a higher energy level	Point sensor, possibly with a sight line of 3-5m.	Sensitive to marine fouling	In use together with ROV, delivered commercially for pipelines, conceptual version for subsea	High sensitivity (ppm), high specific classification ability for hydrocarbons, range: > 100m in air, 1-10m under water
Capacitance	Measures the dielectric constant to the surroundings (very	Point sensor for use around templates, subsea isolation	Requires a collector. Ocean currents may lead the leak away from the sensor,	Delivered commercially, false alarms have been	Detection of hydrocarbons at 10-50% filled probe

* Maturity describes whether the remote measurement method is well-tested, in a development phase or at the research stage

Appendix 2: Subsea sensors

	significant difference between oil and seawater)	valves, manifolds, etc	shallow gas/natural leaks from the seabed can accumulate and give false alarms	reported	volume
Methane sniffer	Diffusion of methane (dissolved in water) through the membrane and into the detection chamber	Point sensor able to detect all types of hydrocarbons containing methane	Recalibration necessary after one year of operation, and maintenance required after two. Sensitive to marine fouling	Delivered commercially, long-term stability not demonstrated	Depends on supplier
Optical camera	Video camera for subsea monitoring	Photographing leak makes it possible to classify	Camera image can be made available in the control room, but no automated detection. Particles and pollution in the water can make the visibility of the object difficult. Problems with overtrawlability and maintenance	A number of systems in operation for up to three years. Supplementary monitoring with the aid of video analysis is being developed	Area +/- 45° in all directions with fixed lighting. Distance to object: 1-10m
Laser optical systems	Use of range gated vision/ light detection and ranging (Lidar) and laser radar (Ladar)	Provides 3D image and continuous or intermittent operation, functions in limited visibility	Optical systems require cleaning and maintenance	Experimental systems being tested	Can image volume within a range of 10-50m
Passive acoustics	Hydrophones pick up irregularities in the light picture around the sensor	Area coverage, can detect subsea leaks, can also be used for condition monitoring of moving equipment	Unsuitable for leaks with a differential pressure close to 0 bar. Influenced by acoustic noise	Qualified to ISO 13628-6, Statoil TR1233. Almost 100 systems delivered. Operational experience since 2007. Incorporates redundancy and self-	Range limited by pressure differential between leak and surroundings

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Appendix 2: Subsea sensors

				testing	
Mass balance with simulation model	Real-time flow simulations based on measurement data from instrumentation distributed across the production system	Alarm if the simulation indicates loss of mass in the production stream. Existing instruments can usually be used, feasibility study must be conducted	Reduced accuracy with unstable production, and has little effect when production is starting/ stopping, etc. Calls for simulations, and will be less effective when production/pressure falls	Mature technology	Depending on installation, up to ~5% accuracy
Pressure/ temperature sensors in the production/ control system	Checking measurement data from instrumentation distributed across the production system	Big leaks can have effects which an operator can potentially register.	Reduced accuracy with unstable production, and has little effect when production is starting/ stopping, etc. Picking up a gradually growing leak could be difficult. Considerably less sensitive than mass balance with simulation	Sensors are normally included in the production facility, but are intended for production control rather than leak detection	Assumes that pressure downstream from the choke valve is significantly higher than the ambient pressure
Periodic monitoring					
Internal inspection of pipelines by pigging		Suitable for risers and pipelines			
Periodic inspection by ROV and AUV (both pipelines		Checking all visible equipment	Weaknesses depend on the sensor type used. Some will require clear visibility. A number of sensor types will generate large amounts of	Mature technology	

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and subsea facilities)			data which must be analysed		
Periodic inspection by AUV (primarily pipelines		External inspection of equipment	Weaknesses depend on the sensor type used. Some will require clear visibility. A number of sensor types will generate large amounts of data which must be analysed		
Periodic testing (function and barrier) of Xmas-tree valves		Checking Xmas trees and manifolds		Mature technology	

Mass balance and pressure sensors are the most relevant solutions for pipelines. Fibreoptic technology could also be relevant in the future.

A distinction should also be made between technologies which can be used in the 500-metre zone and those which cannot. Sensors used outside this zone must be overtrawlable, which could limit the use of the technology. It is also likely that infrastructure and access to electricity and transmission capacity will be significantly better close to a surface installation. In general, hese restrictions mean that active acoustic sensors, for example, can only be used within the 500-metre zone.

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