ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Visual observations					
Ad hoc visual detection of oil from facility/ship/helicopter/ airplane	Visual observation, cf. routines for use on patrol watches, in emergency situations, etc. No technical assistance required, but hand-held binoculars, camera/video camera, GPS for measurements at distance can/should be used.	Good operative procedures can yield significant cost benefits. Visual assessments of oil volume and combatability require systematic mapping, cf. next point.	Not suitable in darkness or in reduced visibility. Requires moderate expertise. Other phenomena than oil can give false detection, e.g., power outages/silent chains, algae, etc. Only thick oil layers with a true oil color allow for definite detection.	Visual detection is readily available, provided that the observer has the necessary expertise. Methodology and reporting form for visual observation are readily available.	Detection: In daylight and clear visibility, most significant oil spills are visible to the naked eye in winds of 0-15 m/s. Normally, only large spills are visible to the naked eye in winds of 15+ m/s. Definite detection (of the oil´s true color) is only possible at an observational angle of view of at least 45 degrees.
Systematic visual detection and mapping from ship/helicopter/airplane/ drone	Visual observation, cf. operative routines for systematic remote measurement. Airplanes and helicopters should use optical stabilization sensors, distance measurements by	Primary method used for distance measurement in daylight. Observations are carried out in accordance with Bonn Agreement Appearance Code (BAOAC), which incorporates both detection and	Frequency and quality depend on daylight and visibility. Requires good expertise and operative experience. Reliable detection and volume estimates depend heavily on visibility, light, sea condition and oil	Existing method (BAOAC) is developed and is used to support and complement automatic systems. Good routines are in place for detection and mapping of spill volume, as well as evaluating the degree of compatibility.	Visual detection and mapping of spills across large areas require an airplane, helicopter, or drone. Otherwise, same performance as in previous point.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	map (and possibly manual GPS).	mapping of compatibility. www.bonnagreement.com	volume. Systematic mapping is not usually possible from a stationary facility ¨unless the oil spill is located beside or below said facility.		
Platform and ship-based radar sensors					
Navigation radar with Oil Spill Detection (OSD)	Automatic processing of X-band radar data using internal or external OSD processor. Oil spill resembles dark shadows (capillary wave reduction) on a lighter-colored surrounding sea surface.	Can only detect oil on the sea surface. Enables continuous monitoring and automatic detection.	Cannot map thickness/volume of oil spill. False alarms and insufficient alarms are to be expected. Does not function if little wind or clear waters.	Developed and tested technology. Several suppliers. Reliability is improved when dedicated OSD radar with VV-polarization is used.	Covers an area of up to 3 kms. around the installation/ship, or over 5 kms. in ideal wind conditions (5-12 m/s). Performance is heavily dependent on wind, oil type and volume.
Millimeter wave radar system (Integrated Sensor and Processor for Advanced Situational Awareness (ISPAS))	Ku-band radar sensor which measures wave attenuation and relative thickness of oil films.	Similar to OSD, but more sensitive and detailed. No moving parts (electronically controlled antennae)	Technically complex and more costly sensor than OSD but allows for a bigger weather window (wind). Minimal operative	Operatively tested for detection and found suitable for installations and ships.	Detection range is 30-50% greater than OSD when applying normal, unmodified X-band radar with HH polarization.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
			measurement of oil thickness to date.		
Microwave radiometer (MWR)	Measures thermally emitted radiation from the sea surface.	Direct measurement of thickness of thick oil slicks. Inferior to IR.	Performance is affected by wind conditions and precipitation.	Exists only in experimental system form and on individual surveillance planes.	Minimum oil film thickness of 5-100 µm. Short range.
Gas detectors mounted on/near installations	Detection of hydrocarbons is carried out using selective sensors.	Pre-existing gas detectors on platforms which can also notify of potential hydrocarbon spills.	Location of sensors is not necessarily optimal for leaks to sea/sea surface.	Existing sensors are located at critical sites. Technology is developed.	Selectively detects concentrations which are indicative of spills.
Platform/ship-based optical sensors					
Surveillance camera (electro-optical, (EO)), with or without zoom/steering/ stabilization	Stationary surveillance camera which can be pointed towards installations or above the sea. These cameras can also be mounted on drones and aerostats.	Provides a good situational overview and is suitable as a supplementary tool for visual assessments.	Can only function in daylight. 4K/8K sensors are suitable for documenting and supplementing visual assessments using the Bonn Agreement Appearance Code (BAOAC).	Developed technology with increasing resolution and light sensitivity, also added functions such as stabilization and Geographic Information Systems (GIS).	Range varies considerably and is influenced by observational angles of view. Definite detection and BAOAC are only possible at angles greater than 45 degrees.
Hand-held infrared camera, uncooled (8-14 µm – Long-Wave Infrared (LWIR)	Differing thermal radiation emitted from seawater and oil respectively, detected using	Simple sensor for observation of thick oil slicks on the sea. Can also provide a situational overview	Unpredictable detection capacity due to simplicity of sensor and influential factors	Robust, developed, and straightforward technology. Thermal imaging is used, inter alia, in fire and rescue	Detection range is determined by the observer´s distance above water, visibility, and parameters listed under “disadvantages”.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	uncooled camera and shown as dark, light, or color-coded areas. Can be used in both daylight and in darkness.	in the dark (to enable navigation or movement in dark areas)	such as temperature, humidity, precipitation, thermal properties of oil, etc.	operations, perimeter surveillance radar systems, etc.	Can provide detection at low observational angles of view.
Mounted or controllable thermal imaging camera, uncooled (8-14 µm – Long-Wave Infrared (LWIR))	Differing thermal radiation emitted from seawater and oil respectively, detected by thermal sensor as dark, light, or color-coded areas. Can be used in both daylight and darkness.	Simple sensor for observation of thick oil slicks on the sea. Mounted equipment will normally have a somewhat better sensor than hand-held, but simple. Provides a situational overview.	Unpredictable detection capacity due to simplicity of sensor and influential factors such as temperature, humidity, precipitation, thermal properties of oil, etc.	Commercial systems now available from several suppliers. Extras such as stabilization and GIS projection also possible.	Detection range is determined by the observer´s distance above water, visibility and parameters listed under "disadvantages". Can provide detection at low observational angles of view.
Mounted, controllable thermal imaging camera, cooled (3-5 µm – Medium-Wave Infrared (MWIR)	Detection and thickness assessment of thick oil films on the sea surface due to differing thermal radiation from seawater and oil	High sensitivity assures long range, as well as more predictable detection and mapping. May be combined with other sensors (OSD) within the GIS system.	Cooled technology requires annual inspection and maintenance. Requires expertise for optimal usage. Requires visibility but can also be of	Developed. Often found as part of a system in which several sensors are incorporated into a map-based console connected to a network (Gives a local Common	Detection range is determined by the sensor´s distance above water. Relative assessment of slick thickness is possible at an observational angle of view of above approx. 20 degrees.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	respectively. A cooled sensor is 10-50 times more sensitive than an uncooled sensor.		use in misty conditions.	Operating Picture – COP).	
UV (ultraviolet) scanner	Direct detection of hydrocarbons based on oil illumination using UV source and response registration (fluorescence).	Gives direct detection of hydrocarbons, fluorescent spectrum. Has potential to differentiate between different types of hydrocarbons.	Active UV requires local illumination. Passive UV requires daylight. Can also detect thin oil films, but not relative differences in thickness. Other substances than oil may display similar characteristics.	Systems exist for testing purposes and in-situ use but are not yet commercially available for oil detection and stationary use.	Detection and classification possible for distances of up to 100 m.
Laser camera, near infrared spectrum	Use of eye-safe infrared illumination offers extremely long range and detailed imaging of the sea surface.	Detailed imaging of the sea surface with high resolution and long range.	Affected by light fog and rain. Uncertain interpretation of data from oil films on the sea.	Commercial products and their application for oil spills are not commercially available.	Range of up to 10 kms., resolution better than 10 cm. lateral, and down to 1 m. distance resolution.
Hyperspectral Laser Induced Fluorescence (HLIF) LIDAR	Direct detection, classification and quantification of hydrocarbons in the water masses from the surface and	Operates independently of light and sea conditions. Detects oil on the surface and in the water column.	Close-range detection. Measures hydrocarbons at a specific point from a moving ship or scans	TRL 7 Tested and utilised for monitoring hydrocarbon pollution.	Detection range – 50m-300m onboard ship or on platform. Detects hydrocarbons in water column down to water depth of 3 meters.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	down to a depth of approx. 3 m. Laser pulses and a hyperspectral detector are used to register the fluorescent spectrum of the hydrocarbon molecules for identification and quantification.		the sea surface from a gin pole. Limited capacity to measure thick slick volumes (> 1 mm).		Sensitivity from 1 ppm or 1 µm oil film thickness.
Airplane/helicopter/aerostat/drone-based systems					
Side Looking Airborne Radar (SLAR) on airplane or drone	Robust "analogue" radar mounted on airplane or drone. Provides lateral imaging which is scanned by the aircraft´s motion. Detects oil spills as an attenuation of ripples on the sea surface.	Robust detection and measurement of area covered by oil spill in both daylight and darkness. Can cover large areas and is suitable for regular monitoring purposes.	Relies on moderate wind. Can only be used for detection. Not capable of mapping oil film thickness or type of oil. Lateral current, seaweed, etc., may lead to false positive detection.	Established and tested technology. Requires skilled operator.	Line scanner, able to detect up to 40 kms. either side of the aircraft. Can be used at an airspeed of up to 500 km/hr. Primary detection sensor used in surveillance aircraft.
Synthetic Aperture Radar (SAR)	Compact radar suitable for use on mobile platforms. High spatial	Can provide high resolution, long-distance images. Measures degree of	Expertise required due to multiple modus/operational parameters.	Developed technology. However, application and calibration for oil detection is limited.	Typically delivers at 1,000 m x 1,000 m per image (SPOT mode), 10,000 m x 10,000 m (SCAN mode), down to 10

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	resolution regardless of distance. Detects oil spills as an attenuation of ripples on the sea surface.	ripple attenuation on the sea surface, correlation with thickness of oil uncertain. Good detection capacity.	Dependable performance under multiple conditions at sea poses a challenge.		cm. resolution, maximum range 30 kms. from aircraft or drone.
Mounted or controllable IR thermal imaging camera, uncooled	Differing thermal radiation from seawater and oil respectively detected by uncooled sensor in form of dark, light, or color-coded area. Can be used in both daylight and darkness.	Simple sensor used to observe thick oil on the sea. Mounted equipment normally has a better sensor than hand-held, but simple. Provides a situational overview.	Unpredictable detection capacity due to simplicity of sensor and influential factors such as temperature, humidity, precipitation, thermal properties of oil, etc.	Developed technology. Most applicable for use on drones where low weight and price are most important criteria. Cooled systems are preferable for aircraft.	Range of detection is determined by the observer´s distance above water, visibility and parameters listed under "disadvantages". Can provide detection at low observational angles of view.
Mounted or controllable IR thermal imaging camera, cooled (3-5 µm – MWIR)	Detection and thickness estimation of thick oil films on the sea surface due to differing thermal radiation from seawater and oil respectively. Often supplied in stabilized gin pole.	High sensitivity gives long range, as well as more predictable detection and mapping. Often connected to a GIS system.	Cooled technology requires annual inspection and maintenance. Requires expertise for optimal usage. Requires good visibility.	Developed and costly technology. Cooled systems are normally suited to airplanes or helicopters. Provides excellent situational overview in both daylight and darkness.	Range of detection is determined by the sensor´s distance above the water. Relative thickness of oil layer denotes combatability.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Hyperspectral imaging camera used on aircraft and on drones	Camera or scanner which analyses reflected light from many wavelength band areas, including IR.	Identification and classification of oil based on IR signatures and “colors” in the visible light spectrum.	Requires good visibility, and daylight for the visual wave spectra. Large amounts of data, and challenging to calibrate, operate and interpret.	Developed. Practical application for oil is limited. Potential for automated use of Bonn Agreement Appearance Code (BAOAC).	Spatial resolution down to 10 cm., applicable from aircraft and drones up to 3,000 ft.
Hyperspectral Laser Induced Fluorescence (HLIF) LIDAR	Direct detection, classification, and quantification of hydrocarbons in the water masses from the surface and down to a depth of approx. 3 m. Laser pulses and a hyperspectral detector are used to register the fluorescent spectrum of the hydrocarbon molecules for identification and quantification.	Operates independently of light and sea conditions. Detects oil on the water surface and in the water column.	Close-range detection. Measures hydrocarbons at a specific point from a moving ship or scans the sea surface from a gin pole. Limited capacity to measure thick slick volumes (> 1 mm.)	TRL 7. Tested and utilised for monitoring hydrocarbon pollution.	Detection range: 50m-300m onboard ship or on platform. Detects hydrocarbons in water column down to water depth of 3 meters. Sensitivity from 1 ppm or 1 µm of film thickness.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Satellite based systems					
Synthetic Aperture Radar (SAR)	Satellite-based radar with high spatial resolution and large area coverage capacity. Indirect detection of oil spills by attenuation of ripples on the sea surface.	Planned, routine monitoring of pre-determined marine areas. Detection is not affected by light/darkness/cloud cover/fog. Numerous satellites with varying levels of performance and sensor technology.	Detection requires wind speeds of 2-15 m/s and depends on surface volume/area. Phenomena other than oil may cause ambiguity and must be assessed manually.	Established technology and services with a good performance level. Used in combination with AIS and GIS data. An important source for Common Operating Picture (COP).	Numerous products with differing area coverage capacity and resolution. The smaller the area, the higher the resolution. Oil detection is largely unaffected by resolution.
Polarimetric SAR Satellite	Polarimetric radar provides supplementary data on attenuation of ripples on the sea surface and spreading mechanisms.	Additional processing amplifies the weather window for correct operation.	Inconclusive performance for oil detection.	Used experimentally for more reliable detection and classification of spills/incidents.	1km.x 1km, up to 100km.x 100km. per scene, maximum coverage twice daily.
Geostationary Optical Satellite Imaging	Imaging from geostationary satellite in IR or visible area, hyperspectral imaging.	Optical imaging from geostationary satellite over large marine areas.	Resolution quality of images of large areas tends to be low.	Operationally available.	May only be used for extreme incidents covering large marine areas.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Optical Imaging from Low Earth Orbit (LEO) Satellite	High resolution camera specifically for use in polar orbit satellites. Functions like a "telescope" – camera is pointed downwards at Earth´s surface.	Detailed optical images of down to 25 cm. resolution. Requires expertise in visibility, light and weather conditions before ordering.	Coverage area is limited. Knowledge of exact spill site is required. Performance is largely determined by light and visibility conditions at spill site.	Operationally available from most service suppliers. Time from ordering to delivery can be lengthy.	From 1 km x 1 km coverage, up to 100 km x 100 km per scene.
Radiometric sensor, thermal or microwave	Measurement of radiometric radiation in the microwave range.	General, low-resolution situational images, able to detect large spills.	Very limited spatial resolution.	Established data product, still at the experimental stage for oil spill detection.	From 100km x 100 km coverage, resolution from 100 m (infrared), 10 km (microwave).
Multi-satellite service delivery	Service/system uses various satellite sensors from different suppliers. Delivers composite images based on various imaging sensors.	Pre-ordered delivery of oil detection products in close to real time.	Must be pre-planned and ordered as a service. The technology requires the supplier to compose and interpret a situational image.	Few suppliers (in Europe). Data products are under constant development. Cluster satellites launched in 2019. "Time lapse" SAR of the same area alternatively available.	Example: SAR Radar, Optical Images, IR and Radiometry feature together on map. From 1m – 100m resolution, up to 2 situational images per day. Time from data capture to composition is 1-6 hrs.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Support systems					
Wind, visibility, precipitation measurement	Uses designated weather stations, often connected to models or prognoses.	Support system for manual or automatic assessment. Used to assess operative conditions, oil protection, etc.	Sensors give point measurements.	Good, reliable solutions are commercially available.	Accuracy is variable, e.g., air temperature < 1 degree, wind speed <1 m/s. Temperatures are affected by structures around/close to the sensors.
Information portal for environment and meteorology	Uses real-time systems for gathering data, and historical records.	Nowcast provides a forecast of meteorological conditions, (data on waves, current, wind field and precipitation). Used to assess operative conditions for oil protection.	Local data is generally unavailable or may be unreliable. Models depend on good input data.	Developed solutions exist from national and international suppliers, and new data products are being added continuously.	Measurement accuracy and data frequency – cf. description of individual data sources/sensors.
HF radar for measurement of ocean currents	Measures ocean current using HF-band radio waves. The ocean current is measured using a secondary Doppler for waves which resonate with high frequency	Gives real-time information about surface ocean currents.	Range and coverage vary, depending on atmospheric conditions. Needs to be merged with ocean current models to illustrate reliable current vector.	Established products from suppliers in USA and Germany. Certain system chains are assembled and in operation in USA (CODAR). Mobile equipment has been tested on Goliat	Range is out to 70 kms. from the installation, measures radial surface current with 10-50% relative accuracy, measures current vector with 20-60 degrees accuracy when triangulation is used. Accuracy is improved when merged with ocean current models.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	(wavelengths of 10 m or 30 m).			over a period of several months.	
Drifting buoys	Measure the movement of oil on sea in real time. The buoy drifts with the oil and is put out to sea/dropped on the surface once the oil spill has been confirmed.	Give fixed reference points during an operation, positioned at the terminal point of the spill or in areas of thick, combatable oil.	Require prior storage, not usually recyclable.	Available from several suppliers. Can incorporate data into Common Operating Picture (COP).	Positioned as an Automatic Identification Treatment (AIS) Object, or alternatively uses Satellite Communications (SATCOM) to report position. Can also be equipped with sensors for in-situ measurements.
SUBSEA – Continuous monitoring					
Active acoustic detection	Sonar system which monitors a 3D volume of the sea out to a maximum of 1,000 m. for a gas leak (less for oil).	Detection and mapping of acute pollution from gas and oil hydrocarbons, hydraulic oil, and CO_2 in large areas in the water column, from the seabed to the surface.	Sensitive to constructions and nearby equipment (shadow effect). Direct oil detection is limited to <400 m radius from the sensor due to rate of rise. Above 400 m, the measured gas leak rate is used to estimate the oil leak	TRL7 per API17N. Qualified in accordance with API17F v4 and Equinor TR1233. 25-year lifetime guaranteed by accelerated lifetime testing of several units. Performance tested by Equinor on Troll B.	High sensitivity, also to alarms. Alarm sounds at <8 l/minute within 500m range. Maps: • Spreading • Direction of drift • Spill volume • Location • Properties (gas, oil or multiphase).

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
			rate based upon the gas/oil ratio (GOR) in multiphase systems.		
Local active acoustic detection.	Point sensors based on active acoustics which can detect leaks locally.	Detection is carried out locally at the structure. A type of continuous measurement which denotes the size of the leak.	Must be positioned close to critical points, to allow the gas/oil drops to pass through the instrument.	Has been retrofitted on several existing fields.	
Fiberoptic measurement of pressure differentials	A fiber is passed along the pipeline to measure the pressure differentials caused by a leak, either by measuring the temperature changes or by using sound waves (vibration).	Area coverage. Allows leak to be detected along a pipeline.	Primarily used for pipelines to date.	Commercially supplied for pipelines, conceptual version available for subsea.	Detects temperature changes, pressure, vibrations/tension (um).
Fluorescence	Uses a light source with a specific wavelength which raises certain targeted molecules	Point sensor, with a possible 3- 5-meter line of visibility. Used in conjunction with ROV. Has been commercially supplied	Sensitive to marine growth.	In use with ROV. Commercially supplied for pipelines and as a conceptual version for subsea.	High sensitivity (ppm). High specific classification capacity for hydrocarbons. Range >100m through air, 1-10 m underwater.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	to a higher energy state.	for pipelines and as a conceptual version for subsea.			
Capacitance	These sensors measure the dielectric constant of the medium (which changes significantly when oil is introduced to the water).	Point sensor for use around well frames, Surface Safety Valves (SSIV), manifolds, etc. Requires a signal conditioner, or amplifier.	Must have signal conditioner, or amplifier. Ocean currents can drive the leak away from the sensor, shallow gas/natural leaks from the seabed can collect and give “false” alarms. The impact from a major leak may lead to a process of dilution with the surrounding seawater, resulting in insufficient concentration of material for definite detection.	Supplied commercially. Challenges with robustness and reliability, high number of reported false alarms and sensor faults.	Detection of hydrocarbons with 10-50% filled probe volume.
Methane sniffers	Continuous direct measurement of methane in water. Methane molecules (diluted in water)	Point sensor which can detect all types of hydrocarbons containing methane. Can be used both	Older sensors require inspection every two years. New sensors have a 25-year lifetime.	Commercially supplied, and in operation for over three years. Some types of sensors are qualified pursuant to API17F v4	Depending upon the supplier, some sensors have a theoretical sensitivity of 2-3 parts per million by volume (ppmv).

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	pass over the membrane and into the detection chamber.	locally and for area coverage. Detection does not depend on bubbles, pressure changes, or noise.	The sensor measures direct methane molecules in the surrounding water and registers changes in concentration. In areas with large naturally occurring fluctuations in methane concentration, this will affect the alarm threshold (sensitivity) and may thus affect the operational reliability (potential for false alarms).	and Equinor TR1233. Built-in self-testing mechanism.	Field-specific performance must be assessed.
Electro-Optical Camera, (EO)	Video camera used for subsea monitoring.	Imaging of leak enables classification. Camera image can be made available to the control room, but no automatic detection.	Particles and pollution in the water can interfere with visibility. Over-trawling and maintenance can cause challenges.	Several systems in operation for up to three years. Additional monitoring using video analysis is under development.	Region of +/- 45 degrees in all directions with mounted light. Distance from object: 1-10 m.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
Laser-optic systems	Use of range gated vision/LIDAR and LADAR.	Gives 3-D imaging, and continuous or intermittent operation, functions in limited visibility.	Optic systems require cleaning and maintenance.	Experimental systems currently undergoing trials.	Can capture volume images within a range of 10-50 m.
Passive acoustic	Hydrophones capture sound from leaks. The sensor can denote the direction of the leak. Continuous measurement.	Area coverage within template (manifold and XMT), also coverage for surrounding structures (e.g., PLET, PLEM, ILT). Can also be used for monitoring condition of equipment (vibrations, e.g., FIV-FLIP, choke/valve, rotating machinery).	Not suitable for leaks with a differential pressure down to 0 bar. Affected by acoustic background noise. Alarm level must be calibrated at time of commissioning.	Qualified pursuant to ISO 13628-6, API17F 4th. ed. with Equinor attachment to TR1233. Almost 100 systems supplied. In operation since 2007. Built-in redundancy and self-testing. Established method for functional testing of sensors after installation in accordance with regulatory requirements when using leak simulator (ROV/EROV operated leak simulator).	Range is limited by differential pressure at leak site and in surroundings.
Mass balance with: a) Real-time simulation model b) Software – adjustment component	Measurement data from instrumentation is distributed across the production system as input to:	Leak alarm overrides pre-defined alarm thresholds for loss of mass. Estimates leak rate and leak location. Suitability and	Reduced sensitivity (rate/time until detection) or reduced reliability (false alarms) during unstable production	Developed technology for single-phase use. Limited operational experience in multi-phase systems.	Performance is primarily dependent on accurate and reliable measurements, as well as system transients.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
c) Statistical algorithms	a) Real-time flow simulations b) Adjusted mass balance based on inventory estimate c) Statistical conclusion algorithm which defines a unique pattern (change) for leaks, based on operating data for normal conditions and operational scenarios. May be a stand-alone system or used in conjunction with a) or b).	performance must be assessed on a case-by-case basis.	and operational scenarios such as production start/stop, pigging, etc. Requires routine tuning and follow-up to maintain performance.		Sensitivity depends on the installation: Single-phase: 1-5% of nominal flow Multi- phase: 10-30% of nominal flow.
Pressure/temperature sensors in production/control system	Alarm based on pressure drop in production system. Manual monitoring of measurement data from instrumentation	Significant leaks may activate the alarm or may indicate less pollution than an operator is able to register. The sensor is normally included in the production facility but is designed for	Reduced accuracy during unstable production, and is ineffective during production start/stop, etc. May be difficult to detect a gradually occurring leak. Significantly	Sensor is normally included in the production facility but is designed for production control rather than leak detection.	Requires the pressure downstream choke to be significantly larger than the surrounding pressure.

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
	distributed across production system.	production control rather than leak detection.	lower sensitivity than in mass balance sensor. Suitability and performance must be assessed on a case-by-case basis.		
Periodic monitoring					
Internal inspection of pipeline by pigging		Suitable for risers and pipelines			
Periodic inspection using ROV and AUV (Autonomous Underwater Vehicle) technology (for both pipeline and seabed installations)		Inspection of all visible equipment.	Disadvantages depend on the type of sensor used. Certain sensor types require clear visibility. Several sensor types generate large volumes of data which require analysis.	Developed technology.	
Periodic inspection using AUV (primarily for pipelines)		External inspection of equipment	Disadvantages depend on the type of sensor used. Certain sensor types require clear visibility. Several		

ATTACHMENT: SENSORS FOR DETECTION OF ACUTE SPILLS

System	Description	Advantages	Disadvantages	Development Status	Key Facts
			sensor types generate large volumes of data which require analysis.		
Periodic testing (function and barrier testing) of Christmas tree valves.		Inspection of Christmas trees and manifolds.		Developed technology.	