



Oil Companies International Marine Forum
29 Queen Anne's Gate, London SW1H 9BU

INFORMATION PAPER

MARINE BREAKAWAY COUPLINGS

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INFORMATION PAPER

MARINE BREAKAWAY COUPLINGS (MBC)

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1. INTRODUCTION

Offshore marine terminals providing bulk liquid transfer facilities to tankers through floating and sub-sea flexible hose strings may be at risk of tanker breakout and surge pressures within the hose strings. Tanker breakouts may be as a result of parting of mooring hawsers due to excessive environmental forces and surge pressures may be experienced due to operational errors, such as the incorrect operation of transfer valves. Where no protective device has been installed, such incidents have resulted in the rupture of hoses or damage to Single Point Mooring systems (SPMs) and tanker pipework and fittings, with consequent pollution of the environment.

The value of a device that serves as a part of the risk mitigation strategy and provides protection in such events to critical assets, and also reduces pollution to relatively minor amounts in the event of an incident, is recognised by industry and Marine Breakaway Couplings (MBCs) are now routinely specified for new offshore installations.

However, a relatively small number of incidents of MBC activation not precipitated by surge event or tanker emergency have occurred, resulting in interruption to operations and, in some cases, pollution. It is considered that terminal operators, maintenance staff and support vessel crews may not universally understand the requirements and limitations in design, fitment, operation and maintenance of MBCs to reduce such inadvertent activations to a minimum. Manufacturers of such equipment may also not be totally familiar with the working environment to which their product is exposed to, and consequential incompatibilities in design may not be recognised.

The OCIMF Ports and Terminal Committee agreed that an Information Paper should be prepared addressing issues associated with MBCs. This paper has been produced drawing on OCIMF Member Companies' operating experience and practices, and with reference to MBC and hose manufacturers. It is considered that the information within this paper represents a balanced commentary on the use of Marine Breakaway Couplings. The paper includes considered best practice in design and operation and highlights occurrences and contributory factors that have resulted in inadvertent activations of MBCs.

It should be noted that in this paper the term 'SPM' includes CALM (Catenary Anchor Leg Moored) buoy (also known as a single buoy mooring 'SBM'), SALM (Single Anchor Leg Mooring), F(P)SO and a turret type mooring to a Spar or similar structure.

2. DESCRIPTION OF A MARINE BREAKAWAY COUPLING

A marine breakaway coupling is a device fitted within a flexible hose string that will part when subjected to an axial load, i.e. a pull of a certain force along the hose string, and/or when subjected to a rapid internal pressure rise, i.e. a surge pressure of a certain value.

There are a number of differing designs for breakaway couplings used in a variety of roles, including both oil and liquefied gas transfer systems. Breakaway couplings are commonly fitted to railway tanker oil loading hoses and are designed to part and shut off in the event of the rail tanker moving during the loading operation. Breakaway couplings may also be found in land-based tanker truck oil loading installations, marine (onshore) oil terminals utilising flexible hoses, in offshore rig/platform supply operations and in offshore marine terminals including CBMs, SPMs and F(P)SO/FSUs where both floating hoses and catenary suspended hoses are utilised for bulk oil transfers.

Breakaway couplings may also be fitted within rigid pipework where separation may be activated additionally by lateral force, but such couplings are not used in marine flexible hose applications and are not discussed further within this paper.

Marine breakaway couplings used in marine offshore oil terminals generally comprise of a unit joined in two halves incorporating a shut off valve(s) which requires no external power or control source to activate i.e. it is a passive device. The valve(s) are mechanically locked in the open position and fail safe to close when activated. The two halves of the unit will part on load/surge and separation initiates the closure of the valve(s). As the unit separates, flow of the liquid being transferred is stopped and contained within each part of the separated hose (where double closure units are fitted).

Break bolts are utilised to hold the unit together in service, designed to withstand axial loads and internal pressure increases up to the calculated permissible loads, with instantaneous breakage occurring when these loads are exceeded. Break bolts are manufactured from material with a highly predictable tensile breaking load, and are critical to the reliability of the unit. They should break on tensile load only, and not shear. Breakaway couplings may be single closure, i.e. closing the upstream end of the separated hose, or double closure whereby both upstream and downstream ends of the separated hose are closed.

Breakaway couplings used in small bore applications may utilise a flap valve(s) or internal butterfly valve(s).

Where such devices have the valves situated within the bore of the unit, i.e. within the product flow, they will cause a pressure drop across the unit due to the restriction within the bore. MBCs with flap valves may be used in offshore crude transfer systems but are more commonly used in liquid gas, low viscosity and white product applications.



FIGURE 1
MBC WITH INTERNAL FLAP VALVE

MBCs used in offshore marine terminals with high throughputs and large diameter loading hoses are invariably of the smooth, unrestricted, full bore design, commonly with closure effected by a valve divided into segments located around the circumference of the unit and protected by an internal sealed sleeve. This arrangement permits unrestricted product flow without causing a drop in pressure during cargo transfer operations, and the design maintains all of the moving parts of the MBC separate from the product path by means of an internal sleeve. A spigot arrangement between the two sections of the MBC provides rigidity of the unit, designed to protect the break bolts from shear forces and bending moments.

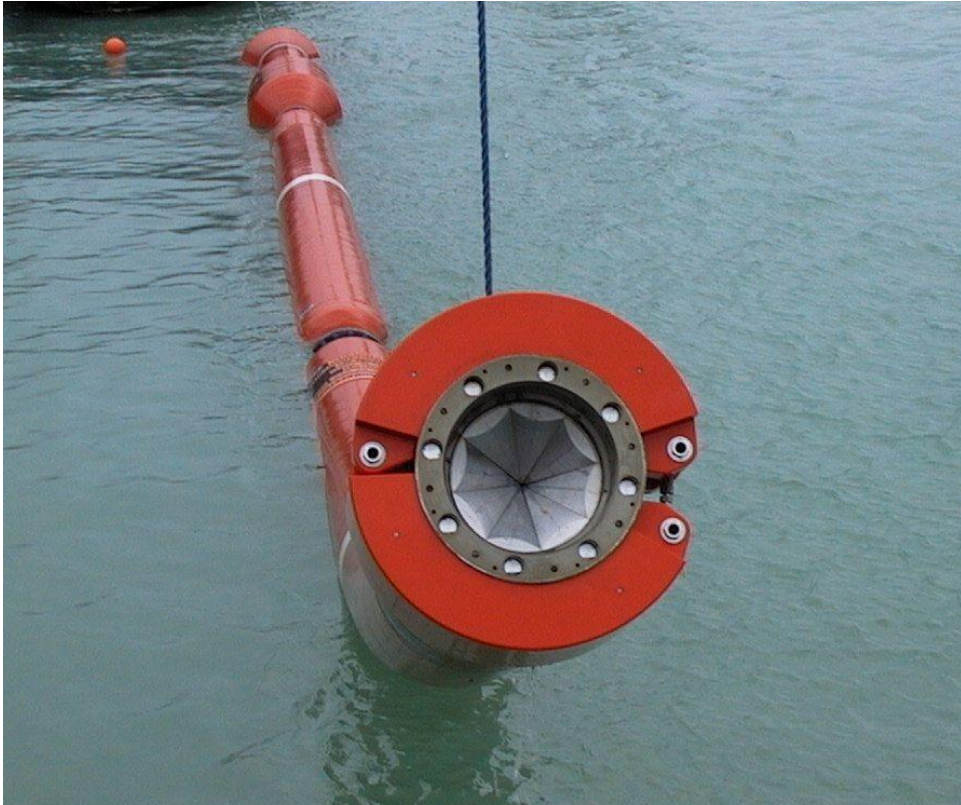


FIGURE 2
MBC WITH RADIALLY MOUNTED PETAL VALVES
UPSTREAM SECTION SHOWN IN CLOSED POSITION
(FLOATATION COLLAR FITTED)

An animated diagram depicting the activation process of a typical MBC may be accessed by following the link to the OCIMF website:

http://www.ocimf.com/view_document.cfm?id=1169

3. PURPOSE OF A MARINE BREAKAWAY COUPLING

MBCs are fitted to mitigate the consequences of:

- Primarily - Mooring hawser failure, loss of tanker position or tanker breakout leading to excessive axial load on, and potential rupture of, the loading hoses(s) as the tanker's drift leads to the hose(s) being over-stressed
- Secondly - Surge pressure, possibly due to tanker loading valves closing against full flow loading pressure, which may potentially damage the hose, SPM, sub-sea hoses and associated pipework.

MBCs are configured in accordance with the requirements of the terminal and may provide protection against one or both of the above events. It is usual to protect against the axial load resulting from tanker breakout and the consequences of surge pressure originating at the tanker may also be mitigated. A full HAZOP (Hazard Operability study), including a pressure surge analysis, of the loading system must be undertaken to determine if an MBC is suitable to provide surge protection, either independently or in conjunction with other surge alleviation method. In either case, the MBC is designed to separate and close against the liquid flow in a controlled manner that will avoid a rapid pressure increase, protecting the loading system components against damage. Double closure units will close valves within the downstream end of the unit, as well as the upstream, isolating both ends of the separated hose string from the environment.

Separation of the MBC is initiated by a load exceeding the design load. The physical separation of the unit occurs instantly the loading of the break bolts is exceeded. Closure of the MBC valve(s) commences as the two parts of the MBC separate. The upstream valve will close at a rate that will not induce a surge event in the upstream pipework. This is generally achieved by arranging closure of the valve over a pre-set calculated time period, permitting a relatively small amount of oil to escape during closure to avoid excess pressure build up. The downstream valve, on the tanker side at an export terminal where pressure is not an issue, may be set to close instantaneously to prevent leakage.

Due to the required timed closure of the upstream side of the MBC, it is not a device that will totally prevent pollution, but one which will mitigate it and protect the cargo transfer system against excessive pressure. Loss of containment to the sea will be minimised consistent with the permissible internal pressure of the cargo transfer system.

Without an MBC fitted in the hose string, a tanker breakout incident could potentially cause loss of integrity of the transfer hose and significant pollution could result. This may be up to, or in excess of, the capacity of the cargo transfer system, depending upon pump stoppage and the time taken for the loading system pressures to dissipate. Damage to SPM and tanker fittings have been recorded in such incidents.

In the event of an unprotected surge event, the loading hoses, SPM and sub-sea pipework are exposed to potential damage and leakage of the hose contents to sea could be significant. The MBC will separate instantly if a surge pressure in excess of the design load passes the MBC. The action of the MBC separating reduces the surge but may not completely eliminate it. However, in the reported cases where MBCs have activated as a result of a surge event, the loading system has not suffered damage.

An MBC is designed to minimise, but not completely eradicate, the pollution that could result from a tanker breakout or surge event.

4. ASSESSING THE REQUIREMENT FOR AN MBC

MBCs may be fitted in flexible hose strings including subsea, surface floating hoses and catenary hoses. They are generally sized and located to protect the smallest or weakest component within the system e.g. the smaller diameter tail hoses in a floating string.

The requirement for an MBC should be determined as a result of a risk assessment of the loading system, considering the terminal location, configuration, pipework and hose types, product flow rates and pressures, environmental conditions and limits for operation, mooring system and the number and type of tankers using the terminal. Historical experience within a region may provide quantitative input to the risk assessment of tanker breakout and/or surge. Where risk of a tanker breakout and/or surge event is determined to require protection, then MBCs may be considered as a mitigating option.

Tanker breakout is generally attributable to one or more of the following primary causes, in isolation or in combination:

- Tanker equipment maintenance and condition
- Terminal equipment maintenance and condition
- Human error/non-adherence to procedures
- Environmental conditions exceeding design operable parameters

Marine offshore terminals, particularly FPSO/FSU facilities, are increasingly established further offshore in more exposed locations. Tanker loading operations are conducted in increasingly harsh environmental conditions and although equipment specifications may be increased, the risk of tanker breakout cannot be entirely discounted when moored with a hawser. Where offtake tankers operate in dynamic positioning mode, loss of position could similarly lead to over stress of the loading hose.

Hose damage due to tanker breakout may be mitigated by installing a quick release system on a loading hose e.g. as fitted to a number of FPSO/FSU terminals and bow loading shuttle tankers, which releases the hose by means of a dry-break coupling at the connection point. However, such quick release systems may require user intervention to activate and would be difficult to incorporate at a CALM buoy or at a conventional buoy terminal. An MBC is a passive protection device. It is designed to activate automatically at a pre-set load without additional external influence, separating the hose by design and protecting against damage. It should also be noted that the unintentional closing of bow loading tanker manifold valves during loading have initiated surge events and MBC activation has protected the loading system against damage.

Surge protection may be provided with the aid of surge drums or tanks but, at CALM buoy facilities, such arrangements are difficult to incorporate with subsequent operational consequences. The surge protection afforded by an MBC, if determined to be suitable for the specific loading system, is simpler in design. However, by the nature of the controlled valve closure process, a calculated amount of oil will leak to sea before the valve is fully closed. The oil loss will be determined by the closure time of the valve, dictated by the surge calculation. The distance of the pipeline from the terminal and increased loading rates will generally call for a longer closure time of the MBC. However, this controlled loss of oil will be of a relatively minor quantity compared to that associated with a total hose or containment failure and the potential pollution that could result without any surge protection.

The protection of hoses and pipework from damage is a further consideration for which an MBC may provide benefits in addition to the minimisation of pollution. MBC activation may significantly reduce the time a terminal is out of service compared to the requirement to replace hose strings or repair pipework, connections and joints exposed to an over-pressure event. Tanker manifolds and pipework may also be damaged in event of breakout incidents without a hose separation device fitted.

MBC manufacturers should be consulted during the process of assessment, particularly with regard to surge analysis, to determine if an MBC will provide, either independently or in conjunction with other measures, a practical asset protection and pollution mitigation philosophy for a terminal. Manufacturers should provide appropriate information on the MBC in order for hose manufacturers to accurately model the impact of the inclusion of the unit within a hose string.

Hose manufacturers should be advised of the intention to incorporate MBCs within hose strings in order for the hose string design, configuration (sub-sea, floating or catenary) and, where applicable, stowage arrangements can consider the impact of the MBC's inclusion. The fitting of an MBC should be considered in the most extreme design environmental conditions that the offshore terminal will be exposed to in order to properly examine the environmentally-induced loads exerted on the MBC and the hoses.

5. HOSE MODELLING

Floating hose modelling and the specific analysis of the effects of hose motion on MBCs has not commonly been undertaken. However, an understanding of the forces experienced by an MBC in a dynamic hose string may be necessary to confirm the suitability of the MBC's inclusion in the hose string and in determining inspection and maintenance intervals. For example, a floating hose string can be subjected to 30,000 wave cycles per day in an area such as the Campos Basin, offshore Brazil.

A limited dynamic analysis of floating hose strings in a seaway, without a tanker connected, has been undertaken by a hose manufacturer on behalf of OCIMF in support of this paper. The study specifically examined the axial tension in the hose string at the location of the MBC in a range of wave heights and wave periods, with and without current. The model used an import terminal CALM buoy in 45m of water and two double carcass hose strings, 294 and 299 metres long, comprising of 20" diameter main line and 16" tail hoses. Wave heights considered ranged from 5 to 12 metres (maximum) and the wave period from 6 to 20 seconds. Zero current and a 1 metre/second current running parallel with the wave direction, were considered. The sea conditions, buoy mooring and hose configuration were modelled on an actual terminal.

The 20" MBCs were located 244 m and 246 m from the CALM buoy on the inner and outer hose string, 5 hose joints from the tanker end of the hose. In the specific case modelled, the MBC is fitted within the 20" diameter hose section, with the lighter 16" tail hoses connected via a steel reducing spool two hose lengths after the MBC. This is not a typical MBC arrangement, but was specific to the terminal under consideration and one that had some previous history with inadvertent MBC activation.

The floating hose analysis results showed:

- Highest tension at the MBC occurred with shorter wave periods (<13 >6 seconds) and large wave heights, although increasing wave periods from 15 to 20 seconds also showed an increase in tensions, although not as notable as the shorter period.
- There is a strong correlation between the wave height and the measured effective tension at the MBC location. For a 10 second wave period, a 10 m wave height shows 2 to 3 times the tension experienced in a 5 m wave height.
- The plot of effective tension along the hose string shows a maximum at the CALM buoy connection, reducing along the hose string, increasing at the location of the MBC, followed by a rapid fall-off in tension towards the hose end.
- Analysis with the hose string pressurised showed inconclusive results. Tension was slightly reduced in the inner string and increased in the outer string for a stiffer hose.

The maximum tensions measured at the MBCs in the above model were 206 kN and 191 kN in the inner and outer strings in a 12 m wave/10 second period. The figures that follow are extracted from the Hose Modelling report for the specific case studied.

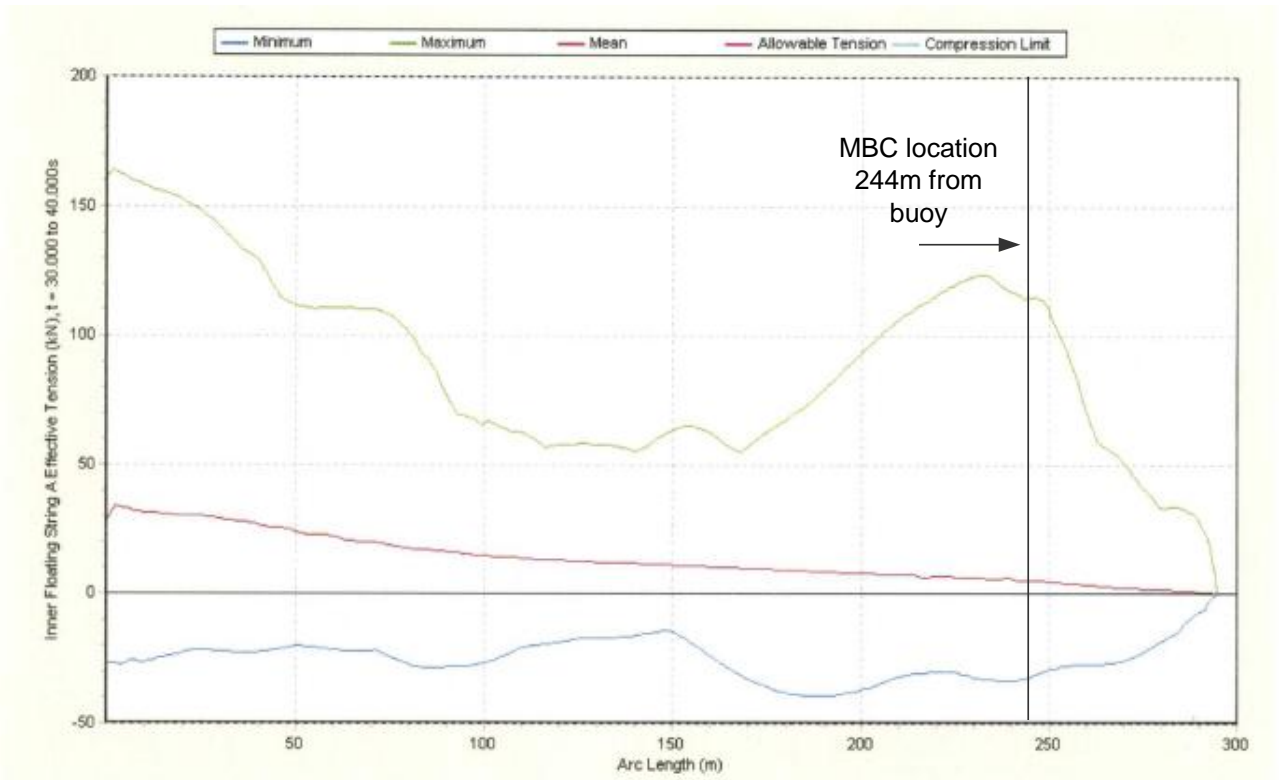


FIGURE 3
MAXIMUM EFFECTIVE TENSION DISTRIBUTION ALONG THE INNER HOSE STRING
 10 m wave height, 10 second duration, zero current. Arc length is measured from SPM towards tanker end of the hose. MBC location is 244 m from the buoy.

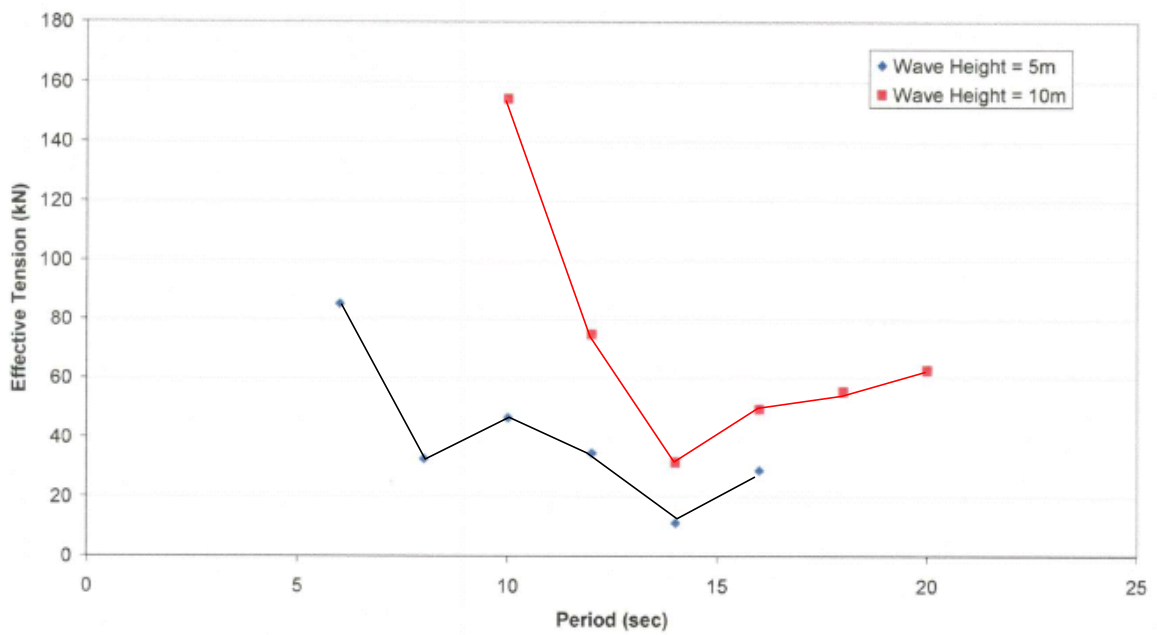


FIGURE 4
EFFECTIVE TENSION VERSUS WAVE PERIOD
 Measured at MBC, inner hose string

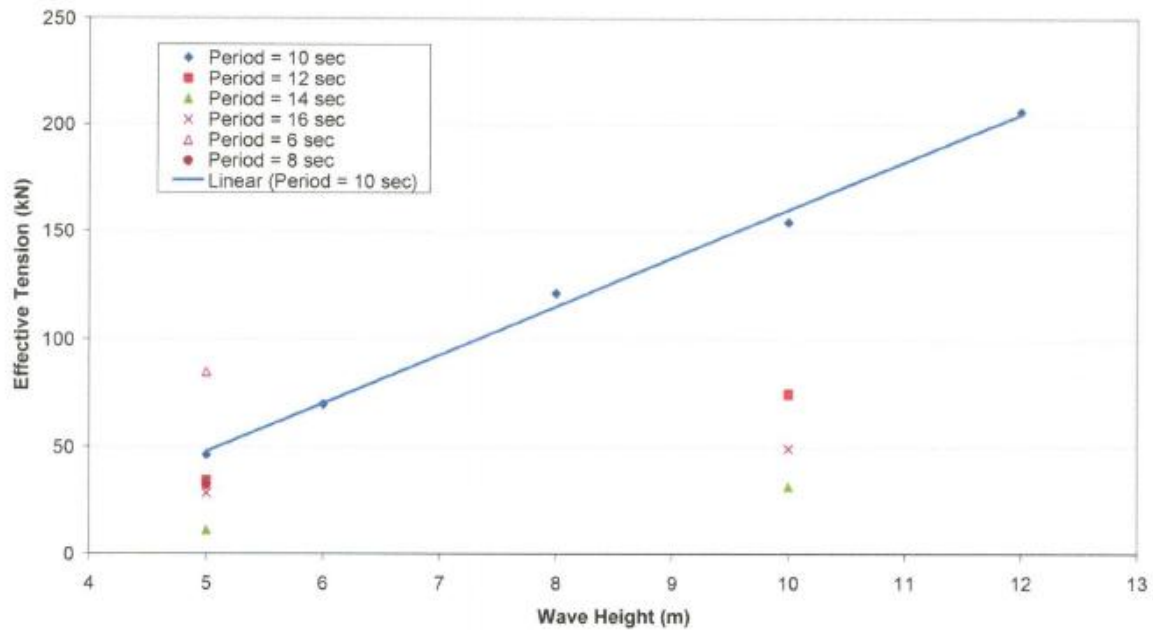


FIGURE 5
EFFECTIVE TENSION VERSUS WAVE HEIGHT
 Measured at MBC, inner hose string

Consideration of bending moments within the study was limited but identified a bending moment of approximately 40 kN-m at the location of the MBC in the 10 second/10 m wave condition.

The 20" MBCs in the particular case modelled have break bolt settings of 55 tonnes and hence possess a safety factor of around 2.75 of maximum tensions recorded in the most extreme conditions measured. However, the varying sources of load exerted on MBCs must be considered cumulatively, and tension, bending moment, loading pressures and lateral drag caused by a connected tanker would need to be considered for a full assessment of operational loads. Depending upon manufacturer's specifications, an MBC should not normally be subjected to operational loads in excess of 70% of the design parting load.

Analyses of other hose configurations, with MBCs situated within the 16" tail hoses, show tensions at the buoy connection of between 280-350 kN, reducing to 80-100 kN at the location of the MBC. Studies for a North Sea FPSO bow loading catenary hose, not specifically focused on the MBC location within the string, have shown a hose end tension of up to 200 kN in a 9.28 m maximum wave of 8.8 seconds period.

From the limited studies undertaken of floating hose strings, it is evident that a full analysis of a hose configuration intended to include an MBC should be undertaken at the hose system design stage. This should provide terminal operators with a more informed understanding of the cumulative forces acting on MBCs in service and should highlight any limitations that may affect the operability of MBCs. Such studies should involve MBC manufacturers and the results should be taken into account in specifying the placing of the MBC within the hose string, break bolt settings and recommended service intervals. Consideration of design or configuration changes may be necessary to maintain factors of safety consistent with reliable MBC operation.

Hose modelling, whether of floating, sub-sea or catenary suspension systems, should consider the following (where applicable):

- Construction and stiffness of hose (double/single carcass), material, nipple length and flange rating, minimum bend radius, diameter, length of string, reducers and method of reduction (i.e. steel or tapered hose), Y piece inclusion, tail hoses, hose end ancillary equipment
- The height, period and form of waves to be experienced and design maximum conditions
- Current
- MBC location in hose string
- Type, size and optimum break-bolt setting for MBC
- Critical MBC capacities, including permissible bending moments and axial load design
- Flotation fitted to MBC
- The forces imparted on a hose string with a tanker connected and the 'drag' effect of the tanker movement on the hose as it weather vanes
- Force required to move turntable of CALM buoy
- Pressurised and non-pressurised hose conditions
- Motions of the buoy and sub-sea behaviour of the hose string due to buoy excursion (for sub-sea fitting)
- Method of stowage e.g. reel stowage and MBC location on reel when stowed (for FPSO/FSO)
- Design catenary for suspended hose and forces applied up to ESD limit of bow loading system
- Length of subsea pipeline and maximum expected flow rates.

6. OPERATIONAL EXPERIENCE WITH MBCs

In 2006, OCIMF conducted a survey of member companies operating offshore terminals to collect information on MBC operating experience. This was undertaken in order to assess the impact on pollution mitigation and to collate information on incidents and operational practices. The results of the survey are summarised below.

6.1 Survey Results

Survey returns were received from 9 Operating Companies, a total of 34 terminals, representing 126,561 tanker/SPM operating days. Combined MBC experience totalled 473 MBC years in service.

It is evident that estimates of pollution from tanker breakout and surge events, prior to the fitting of MBCs, may not be accurate and may be considerably underestimated, particularly from incidents that occurred 20 years or more ago. Additionally, all incidents from such periods may not be recorded or records have not been obtainable. It has therefore been difficult to determine accurate figures for pollution mitigation from MBC activation.

The estimates of pollution related to events prior to the fitting of MBCs are considered to be conservative. However, the following points are highlighted:

- The historical (average) frequency of a tanker breakout or surge event from the survey sample is 1 event every 4,570 days i.e. operating days of a tanker occupying the SPM. Returns indicate that tanker breakout events are decreasing (1 event every 3,518 operating days prior to MBC fitting and 1 event every 5,621 days after MBC fitting).
- The estimated pollution occurring from an event where MBC's have activated is 35 times less than events where MBC's were not fitted (comparing averaged pollution per event figures). Note that pollution estimates are not considered to be concise.
- Tanker, SPM and hose damage has been recorded where events have occurred without MBCs fitted. In the majority of cases where MBCs have activated, no asset damage has been recorded. A clear example is the case on a CALM buoy where two cargo hoses were protected by MBCs, but the bunker hose was not. In a tanker breakout event, the cargo hoses separated at the MBC without damage but the bunker hose tore out 3 metres of manifold structure on the tanker and caused an unspecified amount of pollution. A number of reports have quoted CALM buoy damage, particularly at the offtake elbow pipework, as a result of tanker breakout without MBCs.
- The estimated mitigation of pollution from events where MBC's have activated in response to an incident is 14 times that spilt from spurious MBC activation.
- The spurious MBC event frequency is 1 event every 28 years i.e. calendar time for MBC exposure in a hose string. However, this includes numerous examples of operator error leading to premature separation.

6.2 Operator-induced Separation

A number of spurious separations described in the survey returns included operator-influenced factors that contributed to, or directly caused, the activation of the MBC. Such events have included the following:

- Incorrectly placing the MBC within the mid section of a 20" diameter hose string, utilising a 20" diameter MBC to protect 16" tail hoses, with break bolts set to part at a lesser load than a 20" unit is designed for. The increased loads induced in the mid length section of the hose due to the greater length downstream of the MBC, including a steel Y piece, together with the reduced-sized break bolts, is considered to have led to premature separation.
- Incorrectly placing the MBC within a section of tail hose partly suspended at the tanker's side. The dynamic forces were considered contributory to premature separation. Manufacturers generally recommend that there is at least one clear hose length in the water between the tanker's side and the MBC at all times.
- Leaving an MBC within a hose string beyond the recommended maintenance interval. This has resulted in a number of break bolts failing. In one case 6 out of 8 break bolts had failed after the longest period reported in service without maintenance, namely 9 years. This would have led to partial separation or incomplete operation of the device (see also additional comments in Section 6.3).
- Impact from a dropped mooring assembly on an MBC caused separation.
- Incorrect stowage on a hose reel with the MBC not within the designed location, led to a partial opening of the MBC joint in service.
- Pulling the MBC over the stern roller of an AHTS vessel. This may have imparted unacceptable bending loads on the unit and led to fatigue of the break bolts.
- A service vessel's propeller fouled the flotation pick-up buoy and lifting wires attached to the hose end. The force on the hose caused separation of the MBC.
- Separation during routine terminal and offshore pipeline pressure testing, exceeding the rated surge pressure of the unit (several reports).
- The inner sleeve of an MBC was milled down during maintenance by the operator to expedite reassembly. The resulting movement due to bending forces is considered to have led to premature failure of the break bolts. In this case, the MBC parted under 18,700 Kgf instead of the rated 35,000 Kgf. Other mechanical damage inflicted by inadequately trained operators during maintenance and reassembly of MBCs has also been identified as the cause of incorrect operation.
- Locating the MBC adjacent to a steel reducer or a Y piece. The combined stiff length of a hose nipple, reducer/Y piece, MBC and a second hose nipple is considered to form a stress concentration area which may detrimentally affect the integrity of the MBC and the adjacent hoses, leading to premature fatigue.
- Loss of buoyancy of adjacent hoses has been reported as contributing to premature failure.

6.3 Un-attributable Separation

Notwithstanding the operator-induced separations, a number of separations of breakaway couplings have occurred without known cause. At least two cases have been reported of hoses separating at the MBC and drifting away from the terminal when no declared terminal activity was taking place.

A rarely-verifiable cause for separation may be product pressure within the hose string. A design requirement for the MBC entails establishing the maximum hose pressure that may be achieved if product is left in the hose system and is subject to expansion in increasing temperatures. The actuation pressure of the MBC must be greater than any naturally occurring pressures that may occur within the hose.

A number of premature or spurious actuations have occurred and, in some of these cases, incident investigations have concentrated on premature fatigue of the MBC break bolts, permitting partial or total separation of the unit at lesser loads than the design load. One investigation raised the possibility that the machining process of the break bolts may leave surface imperfections leading to stress concentrations. The design of the break bolts is critical to the MBC's correct operation, with pre-tension and physical size requiring examination in relation to the proposed environmental conditions the unit will be subjected to.

The subject of cyclical fatigue on break bolts is a contentious issue. Manufacturers contest that the material selected for break bolts, combined with the very rigid design of offshore MBCs, should not suffer such stresses where the unit is installed and maintained in accordance with their instructions.

If the unit is subjected to a surge or axial tension (tensile pull) that exceeds the pretension loads of the break bolts (i.e. the break bolts pass from the elastic state, where full recovery would be achieved, into the plastic state, where the break bolts suffer permanent deformation) the components will suffer subsequent fatigue. Evidence that this condition exists may be the partial opening of the separation joint of the unit. It is important that, following a suspected high axial pull or surge pressure, the MBC is examined for evidence of partial separation. It is unlikely that the break bolts would show visible signs of distress unless the load is such as to initiate total breakage. However, a gap should then be visible between either the MBC coupling halves, or where the head of the break-stud meets the flange.

Three in-depth investigations of MBCs parting under spurious circumstances have revealed that a number of the break bolts on each unit were subjected to fractures attributable to fatigue, with common characteristics. It is considered that if a proportion of the break bolts fatigue, they may break at a reduced load and the remaining intact break bolts would then part under a less-than-designed axial load on the MBC, allowing it to separate. This may be a reason for some premature or spurious failures of MBCs. The MBCs in question were all at offshore terminals and were subjected to considerable wave action. At one terminal, it was reported that a 55 metre support vessel was allowed to moor to the hose pick up lines.

As discussed in Section 5, a thorough examination of dynamic loading on the hose string and MBC should be undertaken by computer analysis to understand the loads that may be imparted on the MBC and its components. Such analysis should be contributory to the design and selection of the MBC and hose string.

The difficulties of in-water inspection may also be an issue in recognising damage to an MBC and the inspection would require removal of any flotation fitted.



FIGURE 6
MBC AFTER THREE YEARS IN THE WATER

6.4 Partial Separation

A number of reports have indicated incomplete separation or, where separation has been achieved, incomplete closure of the MBC valves. There have been a number of reported or suspected reasons for this. In the case of the petal valve MBC, there is a view that where the MBC is not supported with a floatation collar, the weight of the two, separated halves of the MBC, which for a 16" diameter unit will be around 250 kg each, will cause the unit to sink to a point where dynamic wave action, combined with the static pressure head of water, may overcome the spring closure of the valves and permit oil to leak from the valve. Where the adjacent hose has also lost buoyancy over a period of time, the situation may be exacerbated.

One report of partial closure of the MBC valve was attributable to an assembly or maintenance defect.

In the case of partial separation, this has usually been associated with an in-service failure of a number of break bolts that has permitted the MBC to partially separate over a period of time. This may have permitted water to enter the unit which, in turn, led to seizure of the internal spigot, preventing total separation and closure of the valves.

One case was reported of operators covering the unit in a fibreglass jacket. This prevented the MBC separating upon actuation due to a surge event, leading to extended leakage before the condition was noticed.

7. RECOMMENDATIONS

7.1 Operational and Design Considerations

The machining process, material and the design of the break studs should be considered by manufacturers in light of available investigation reports on incidents where fatigue has been identified as a possible contributory cause.

MBCs should be designed and tested against the environment they are intended to operate in, considering the prevailing conditions the unit will be exposed to throughout its life cycle and not limited only to the conditions considered applicable for tanker offload operations (see Section 5).

The following should be taken into account:

- The MBC design tensile separation load should not exceed the design axial load of the hose string.
- A full analysis should be undertaken of the loads an MBC will be subjected to and should be modelled before finalising the hose system design and confirming the requirement for an MBC. This analysis should include the loads exerted by dynamic wave action, calculated surge pressures and pressure exerted by product expansion in the system. In addition, a proposed change in hose manufacturer during the terminal's lifetime should be similarly examined to assess any effect on the dynamic stresses likely to be imparted on the MBC (see Section 5).
- Manufacturer's recommendations on MBC installation, handling, visual examination and maintenance, particularly maintenance intervals, should be strictly adhered to. Maintenance intervals should consider the environmental loadings analysed, as well as the frequency of tanker operations that may require a reduction in service life.
- Mechanical damage to the MBC may be caused during dockside handling, friction through being pulled to the dock or when pulling over the high stern of a vessel. The launching of a hose string and tow to field should consider the location of the MBC, with the tow from the buoy/FPSO end to reduce towing stresses on the MBC. Alternately, the MBC should only be inserted when the hose string is at the field.
- Maintenance contracts with manufacturers should be considered to ensure required maintenance is undertaken by adequately trained personnel, utilising approved parts. Manufacturers should consider licensing local/regional companies to undertake maintenance, thereby facilitating continuation of manufacturer's warranties.
- Means for the opening, flushing and draining of the hose sections following MBC actuation should be available to operators. This may require specific fittings and tools. Operating procedures should include the recovery of separated hose sections and their flushing, draining and re-attachment for continued operation in an approved manner. It is recommended that all MBCs are provided with the necessary equipment to enable draining and recovery of the hoses after activation.
- MBCs with internal sleeves that are exposed upon separation require particular care when handling during recovery to avoid damage to the sleeve which could impact on the ability to properly re-assemble the unit.
- Spare MBCs should be onsite, permitting change-out and maintenance while maintaining a consistent standard of protection.

- Vessels and equipment shall be suitable for recovering the hose and MBC from the water using, for example, shallow-angled ramps, lifting beams or other means approved by manufacturers that will not apply unacceptable loads to the MBCs.
- All personnel, including terminal, field personnel and service vessel crews who may be required to handle the export hoses and MBCs, should be provided with specific awareness training of the sensitivities of the units and the specifics regarding handling and actuation loads.
- It is not recommended that support craft be permitted to moor at the end of hose strings fitted with MBCs.
- It is not recommended that vessels capable of applying a dynamic load in excess of the breaking load of the MBC are used to handle hoses. However, where this is unavoidable, boat crews should be aware of the breaking load of the MBC to avoid inadvertent actuation.
- As far as possible, the MBC should be regularly cleaned to enable a positive visual examination of the casing with the aim of detecting early signs of partial separation.
- Manufacturers should consider adoption of a means for providing a robust, visual indication on the external casing that would indicate partial separation of the unit, even when encrusted with growth.
- Every MBC separation incident should be investigated thoroughly, preferably with the involvement and cooperation of manufacturers, to identify the root cause of the actuation. Operating and maintenance practices should be adapted to take account of lessons learnt.

7.2 Recommendations Relating to Hose Systems

It is recommended that operators consider the following:

Floating hoses:

- An MBC should not be fitted adjacent to a steel reducer as the additional stiffness may increase the loads on the MBC. Reducing/tapered hoses should be used in preference to steel reducers or the MBC should be situated at least one hose length from the reducer.
- Where a Y piece is used on a single export hose to present two smaller diameter tail hoses to the tanker, the MBCs should be placed in the tail hoses and separated from the Y piece by at least one (and preferably more) clear hose length.
- The MBC should be fitted as close to the end of the hose string as possible, normally within the tail hose section, commensurate with the usual requirement to maintain the MBC in the floating section of the hose. For a terminal handling VLCCs, this may be around 4-5, or even 5-6 joints from the hose end. It is noted that one FSO terminal does have the MBC within the lifted section of hose i.e. two hoses from the end, in order to avoid damage from floating ice and also to optimise the location on the hose stowage reel. A specific study should be undertaken before adopting such a configuration.
- Where two tail hoses are utilised, the MBCs should be staggered so as to avoid any contact between MBCs.
- MBCs should be of a lesser outer diameter than the outer diameter of adjacent hoses to avoid steel/steel contact with hose flanges, the tanker's hull or the MBC in the second tail hose.

- It is recommended that a floatation collar designed for the MBC is fitted in order to provide support to the MBC in case of loss of buoyancy in adjacent hoses and, importantly, to provide buoyancy to the separated halves of the MBC following activation. To avoid restricting the operation of the MBC, only collars approved by manufacturers should be used.
- The anti-corrosion coating of the MBC should be adequate for the designed maintenance interval. However, the galvanic potential of the MBC relative to the adjacent hose flanges should be assessed. In areas where accelerated in-water corrosion is known to occur e.g. tropical climates with highly oxygenated/polluted waters and/or increased saline content, a corrosion specialist should consider the proposed coating of the MBC, hose flanges and bolts for adequacy. Anodes may be attached to an MBC following advice from manufacturers of both the MBC and hoses.

Catenary Hoses

- The MBC should not be fitted at the bottom of the catenary where it may be exposed to increased bending moments and be within the splash zone in a suspended catenary or the immersed section in a submerged catenary.
- The MBC should preferably be fitted close to the tanker end of the hose string, but so placed that it will not be damaged from contact with the tanker structure after the two parts separate.
- The MBC should not be subjected to snatch loads if hose separation is made from either the Quick Release Coupling on the offtake tanker or the FPSO/SPM.
- Minimum lateral stand-off distance for the tanker, in a catenary hose terminal, will consider the minimum bend radius (MBR) of a catenary hose. The compatibility of the MBC for the specific hose MBR and minimum stand off distance must be verified, particularly with regard to the resultant bending moment the MBC would be subjected to.
- Changing the hose specification from the original design may require MBC compatibility to be reassessed.
- High pressure rated flanges and hoses e.g. 300 ASA, may provide a much stiffer system than hoses with 150 ASA flanges.

Reeled Storage

- The bending moments imparted on an MBC in a reeled hose must be considered, taking into account the diameter of reel, the MBC location in the hose string, diameter of adjacent hoses and stiffness of the hose, including nipple length.
- Where a hose replacement of differing manufacturer or construction (including hose length) from the original is to be undertaken, the replacement hose design should be analysed to determine the forces imparted on the MBC in the stored position. Nipple length and hose stiffness may affect the bending forces imparted on the MBC and a change in hose length may vary the stored position of the MBC on the reel.
- Moving the location of the MBC from the original position may affect the bending forces on the MBC.