INVESTIGATION REPORT

MONOETHYLENE GLYCOL (MEG) SPILL
JANUARY 2006

SABLE OFFSHORE ENERGY PROJECT
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1.0 Summary

On January 12, 2006, the Canada-Nova Scotia Offshore Petroleum Board (the Board) was notified by ExxonMobil Canada Properties (ExxonMobil), operator of the Sable Offshore Energy Project (SOEP), of a leak of monoethylene glycol (MEG) into the ocean. The leak came from a 3 inch carbon steel flowline that transports MEG from the central Thebaud production complex to the satellite Alma production platform. These facilities are part of the SOEP offshore production facilities that are located approximately 200 kilometers off the coast of Nova Scotia.

MEG is an industrial anti-freeze that is injected into a natural gas pipeline to prevent the formation of hydrates, or “ice plugs”, which can cause a blockage of the pipeline and can lead to integrity and safety concerns.

Analysis of production information determined that the volume of MEG that was released into the ocean was as much as 158 m$^3$.

At the time of the notification, ExxonMobil advised the Board that it would take the steps necessary to suspend use of the 3 inch MEG flowline as soon as possible, but that it could not be immediately suspended due to safety concerns. ExxonMobil conveyed that it needed to continue to inject MEG into the Alma to Thebaud natural gas pipeline as current concentrations were below the threshold level to prevent hydrate formation.

The requirement to initiate safe shutdown procedures and conclude them as soon as possible was confirmed in writing by the Board’s Chief Conservation Officer on the following business day (January 13, 2006).

The Board immediately commenced an investigation of this incident to determine its cause, and to determine if there were cases of noncompliance to regulatory requirements. ExxonMobil was fully cooperative throughout this investigation.

The investigation identified that the leak came from a cracked elbow on the sub-sea flowline, near the base of Thebaud platform. Analysis indicated that the crack in the elbow was caused by metal fatigue that had initiated as a result of bending loads, possibly related to observed axial movement of the pipe.

MEG is known to have a low toxicity, and an environmental impact assessment of the potential effects of this spill concluded that it is unlikely that there would have been any measurable effects on marine species resident in the vicinity of the platform.

The Board’s investigation concluded that certain corrective actions should be taken by ExxonMobil to prevent recurrence.
2.0 Regulatory Framework

2.1 Board Authority

The Board was established in 1990 by the proclamation of the Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act, S.C. 1988, c.28 by the Government of Canada, and the Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act, S.N.S. 1987, c.3 by the Province of Nova Scotia (“Accord Acts”). The Board is the independent joint agency of the federal and provincial governments responsible for the regulation of petroleum activities in the Nova Scotia Offshore Area, including:

- health and safety for offshore workers;
- protection of the environment during offshore petroleum activities;
- management and conservation of offshore petroleum resources;
- compliance with the provisions of the Accord Acts that deal with Canada-Nova Scotia employment and industrial benefits;
- issuance of licences for offshore exploration and development; and
- resource evaluation, data collection, curation and distribution.

2.2 Applicable Legislation and Regulations

The legislation governing offshore oil and gas activities in the Nova Scotia Offshore is the Accord Acts cited above.

Offshore oil and gas production activities must also be conducted in accordance with the Nova Scotia Offshore Area Petroleum Production and Conservation Regulations which are promulgated under the Accord Acts.

Pursuant to the Accord Acts, any offshore development project requires that a Development Plan be approved. Furthermore, the Production and Conservation regulations cited above require that there be a valid Production Operations Authorization (POA) in place, and an approved Environmental Protection Plan. At the time of this incident, all required approvals and authorizations were in place.

Prior to issuing a POA, a Certificate of Fitness and a Declaration of the Operator are required.

The Certificate of Fitness is to be issued by one of five certifying authorities that are designated in the Nova Scotia Offshore Certificate of Fitness Regulations. The certifying authority is contracted by the operator of the production installation (ExxonMobil). The certifying authority is required to certify that the design, construction, transportation and installation of a production installation is in compliance with the regulations, is fit for the purpose for which it is to be used and can be operated safely without polluting the

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1 Although mirror legislation and regulations exist federally and provincially, for convenience, this report references section numbers in the federal versions of legislation and regulations.
environment, and will continue to be so if the installation is maintained in accordance with the inspection, maintenance and weight control programs approved by the certifying authority. The Certificate of Fitness that includes the Thebaud to Alma MEG flowline was issued by Lloyd’s Register (as certifying authority) on October 16, 2003, with an expiration date of October 10, 2008.

The Declaration of Operator is signed by a senior officer of the company to which a POA is issued (ExxonMobil), and states that the equipment and installations are fit for the purposes for which they are to be used, the operating procedures relating to them are appropriate for those uses, and the personnel who are to be employed in connection with them are qualified and competent for their employment. The Declaration of Operator is submitted prior to the issuance of the POA, and is then amended from time to time.

3.0 Incident Description

3.1 Background Information

The 3 inch Thebaud to Alma MEG flowline is part of the SOEP production facilities located offshore Nova Scotia. The SOEP produces natural gas from five offshore fields, namely Thebaud, North Triumph, Venture, Alma and South Venture. All natural gas produced from these fields is routed by interfield pipelines to a centralized processing platform located at the Thebaud field, and then transported to shore by way of a 26” pipeline. The SOEP is operated by ExxonMobil.

![Figure 1: Sable Offshore Energy Project – Facilities](image)
MEG, which is a type of industrial antifreeze, is used as an additive to natural gas when it is transported by pipeline so as to prevent the formation of hydrates. Given the pressure and temperature under which the SOEP pipelines operate, moisture contained in the natural gas can cause formation of hydrates, or “ice plugs”, which, if large enough, can lead to a blockage of the pipeline. This can lead to integrity and safety concerns as well as impact production.

Appendix I to this report contains a schematic of the MEG system that operates between the centralized Thebaud processing platform and the Alma satellite platform. MEG is delivered from the Thebaud platform to the Alma platform through the 3 inch carbon steel flowline. At the Alma platform, MEG is then injected into the 12 inch interfield pipeline that transports the natural gas from the Alma production field to the centralized Thebaud processing platform. The Thebaud processing facility then separates the MEG from the gas, and recycles it back to the satellite platforms like Alma.

3.2 Description of Incident

Although the leak of MEG into the natural environment was not identified by ExxonMobil personnel until January 12, 2006, data made available during the course of the investigation from ExxonMobil’s Production Information Management System (PIMS) showed that, on January 6, 2006, the rate of flow of MEG being received at the Alma platform from the Thebaud processing platform began to drop. This was measured by a flow meter installed at the Alma platform (identified as FE-6129 in the schematic included in Appendix 1). The flow meter steadily recorded lower values, trending down from approximately 32 m$^3$/day to approximately 9 m$^3$/day by January 9, 2006. By the morning of January 10, 2006, flow as recorded by the Alma flow meter fell to approximately 0 m$^3$/day, and a low flow alarm was transmitted into the control room at the centralized Thebaud platform. This initiated an automated process shutdown of the Alma platform, as per design.

The Control Room Operator (CRO) evaluated the situation, and was not able to identify the cause of the alarm. It was suspected at the time that the Alma flow meter to which the alarm was attached was not functioning correctly. The CRO disabled the flow alarm to prevent additional automated process shutdowns, and restarted production from the Alma platform shortly after the shutdown occurred.

An ExxonMobil intervention team was dispatched and arrived at the Alma platform later in the afternoon of January 10, 2006. The intervention team reportedly inspected the subject flow meter and checked for platform leaks, of which none were found. The intervention team re-routed the flow of MEG to bypass the flow meter based on a suspicion that the strainer affixed to it may be plugged, and the team departed so that the helicopter could reach shore prior to nightfall.

On January 12, 2006, an intervention crew returned to the Alma platform. During this afternoon intervention, the flow meter was again checked and then put back in service. A pressure test of the MEG flowline was performed. While conducting this pressure test, a
MEG flow line low pressure alarm was transmitted to the Thebaud control room, and the control system initiated an automated process shutdown of the Alma facility, as per design. Alma production was subsequently restarted, and a second MEG delivery pump was started on the Thebaud platform to boost MEG flowline pressure. With the second pump running, the MEG flow meter on the Alma platform again recorded flow.

On the evening of January 12, 2006, the Board was verbally informed by ExxonMobil of a possible leak in the MEG flowline. ExxonMobil subsequently informed the Board later that evening that it had confirmed that the MEG flowline was in fact leaking. ExxonMobil stated that it would take the MEG flowline out of service as soon as possible, but that the flowline needed to remain in service in the short term. This was to allow ExxonMobil to attempt to bring the level of MEG that is injected into the Alma to Thebaud natural gas pipeline up to the required level to prevent hydrate formation. ExxonMobil conveyed that the concentration of MEG in this 12” pipeline was below the threshold to prevent the formation of hydrates that could cause a blockage. This could lead to an elevated safety risk for those personnel who would be tasked with trying to remove such a blockage, should it occur.

On the morning of January 14, 2006 ExxonMobil shutdown the Alma MEG flowline.

4.0 Regulatory Response

Section 60 of the Nova Scotia Offshore Area Petroleum Production and Conservation Regulations requires an operator to suspend a production operation forthwith where the continuation of that operation would cause a spill into the natural environment that exceeds the limits specified in the environmental protection plan or any limit specified in a requirement of the production operations authorization.

Upon receiving verbal notification of the leak on January 12, 2006, ExxonMobil was reminded of its obligations under Section 60 of the above cited regulation. The requirement to initiate safe shutdown procedures for the defective portion of the MEG system, and to conclude them as soon as possible, was also confirmed in writing by the Board’s Chief Conservation Officer on the following business day (January 13, 2006).

The Board considered the possibility of hydrate formation at the time the verbal notification was provided, and concurred with ExxonMobil’s determination that an immediate shutdown could result in an increased risk to the safety of personnel should they have to subsequently deal with a hydrate blockage. In making this determination, the Board did take into account the fact that the toxicity of MEG being released into the environment was low.

Section 67 of the above cited regulation requires the Chief Conservation Officer or the Chief Safety Officer to investigate or cause to be investigated any incident, accident or other event at a production site that results, or could result, in a spill into the natural environment exceeding the limits specified in the environmental protection plan or in the requirements of the production operations authorization. Upon receiving notification of
this incident from ExxonMobil, the Board immediately assigned conservation officers to investigate this incident using officer powers afforded to them under the Accord Acts.

5.0 Investigation Findings

5.1 Technical Analysis and Findings

A horizontal section of the MEG flowline containing the leaking elbow was cut-out and retrieved from its installed sub-sea location by ExxonMobil using a remote operated vehicle. The sample was inspected by magnetic particles and a crack indication was detected in the intrados of the upstream elbow of the removed section.

Figure 2 – Photograph of horizontal cut-out section of MEG flowline. Red arrow shows direction of flow. White arrow indicates location of leak.

Figure 3 – Outside surface of the intrados of elbow containing a crack indication.
The elbow was sent by ExxonMobil to Metallurgical Consultants Inc. of Houston, Texas for failure analysis. Their report included the following findings and conclusions:

1. The elbow that leaked exhibited longitudinal cracks that initiated in the base metal and weld metal on the inside surface in the intrados.

2. The crack surfaces showed the characteristic appearance of fatigue cracks. The appearance of the cracks indicated that the cracks responsible for the leak had started on the inside surface of the elbow, but there were also similar cracks that initiated on the inside surface in the weld metal and on the outside surface.

3. A finite element analysis of the piping system indicated that cyclic in-plane bending loads produced by 35mm of relative axial movement at a pipe support would cause stresses of an orientation and magnitude sufficient to cause fatigue cracks at the leak location.

4. X-ray diffraction indicated that the internal deposits were sand, barium sulfate and mill scale. There was no evidence of significant internal corrosion in the MEG flowline.

5. The cracked elbow exhibited satisfactory and appropriately uniform wall thickness, microstructure and hardness. The tensile properties and composition of each elbow satisfied the requirements of CSA Z245.11 for Grade 359. No manufacturing defects were observed.

6. Residual stress measurements by the ASTM E837 hole-drilling technique indicated that the residual stresses were not excessive.

7. The leak was caused by longitudinal fatigue cracks that initiated on the inside surface in the intrados of an elbow. The location and orientation of the fatigue cracks indicated that they were caused by cyclical in-plane bending loads, probably related to the observed axial movement of the pipe. Identification of the source of the axial movement was beyond the scope of the report.

ExxonMobil's internal investigation identified that the mechanism of flowline support coupled with intermittent movement of the Thebaud platform was a possible cause of the fatigue. At the time of the failure, the intermittent Thebaud platform movement was being evaluated by ExxonMobil.
5.2 Environmental Analysis and Findings

5.2.1 Permissible MEG Discharges

In the approved Environmental Protection Plan for the SOEP, ExxonMobil commits to adhering to the *Guidelines Respecting the Selection of Chemicals Intended to be Used in Conjunction with Offshore Drilling and Production Activities on Frontier Lands* that are jointly published by the Canada-Nova Scotia Offshore Petroleum Board, the Canada-Newfoundland and Labrador Offshore Petroleum Board, and the National Energy Board. Consistent with these guidelines, the approved Environmental Protection Plan identifies that low concentrations of MEG will be discharged within the produced water stream emitted from the Thebaud platform into the ocean. This discharge stream consists of water that is produced from the natural gas well from the underground formations. Produced water is treated prior to discharge primarily to remove hydrocarbons; however, small amounts of MEG do remain (typically up to 30,000 parts per million).

It is important to note that the Guidelines referred to above apply to the selection of chemicals planned for discharge, and are not intended to address unplanned discharges such as releases of undiluted MEG. These Guidelines require that regulators be consulted and further risk assessment be considered should operational discharges of MEG from production installations exceed 1000 tonnes per year. ExxonMobil does monitor and report the discharge of MEG to the CNSOPB, and their operational discharge in 2006 was reported to be approximately 172.6 tonnes (or 153.3 m$^3$). In comparison, the unplanned discharge of undiluted MEG resulting from the subject leak totaled as much as 175 tonnes (or 158 m$^3$).

In addition to the limits allowed for in the Guidelines, a condition was affixed to the POA issued on December 5, 2004 stating that “the Operator shall exercise due diligence to limit discharges of Monoethylene Glycol (MEG), and other deleterious substances, into the marine environment.”

5.2.2 Environmental Impact Assessment

ExxonMobil commissioned a third party consultant (Martec Limited) that was acceptable to the Board to study and assess the risks to marine organisms that may result from the MEG that was discharged during this incident. Martec’s report concluded that it is unlikely that there would be any measurable effects on marine species resident in the vicinity of the platform. The report does, however, acknowledge that MEG concentrations may be sufficient to cause sub-lethal effects within a small zone, less than 100 meter radius from the source. These conclusions were based on: (i) a previous environmental risk assessment of monoethylene glycol discharges at the Thebaud platform carried out by Martec in 2001; (ii) the results of modeling of the unplanned discharge for dilution and concentration of MEG at varying distances; and (iii) a review of recent literature on MEG toxicity to marine organisms.
The dispersion modeling completed by Martec predicted that the concentration of MEG would be between 1300 and 1810 mg/L at 10 meters from the source, 70 and 190 mg/L at 100 meters from the source and 0.8 to 4 mg/L at 850 meters from the source, based on assumed discharge rates. In its report, Martec states that these concentrations are well below acutely lethal concentrations for marine species (which is generally >10,000 mg/L), but that sublethal inhibition of algal growth might be expected within 10 meters of the source. Furthermore, it is understood that MEG does not bioaccumulate and can be readily metabolized. The report does recognize that there are uncertainties due to the fact that the MEG concentrations were not measured to validate the model results, and there are relatively few data reports on toxicity of MEG to marine species.

The findings of the study are consistent with the Board’s review of the potential impacts of MEG on the marine environment.

5.2.3 Regulatory Analysis and Findings

The Board investigation was carried out by way of conducting interviews, and collecting and analyzing documentation.

The investigation did identify certain noncompliances to regulatory requirements. In addressing these, the Board has available to it a number of compliance and enforcement tools, including:

- Seeking voluntary compliance;
- Issuance of safety officer / conservation officer notices, directions and orders;
- Suspension / revocation of an authorization to carry out work or activities;
- Cancellation of rights; and
- Prosecution

The above options are typically used in a general progression to achieve compliance. However, any option may be exercised directly, as deemed necessary by the Board (within the scope of the authority of individual staff members). In making the decision as to the appropriate response to a noted noncompliance, the following factors are taken into consideration:

1) the seriousness of the personal injury, or damage from a spill or waste, or potential thereof;
2) the intent of the alleged violator;
3) whether the noncompliance is a repeat occurrence;
4) whether there were attempts by the Operator or any other person to circumvent Accord Act requirements;
5) the history of compliance by the alleged violator;
6) the willingness to co-operate with Officers of the Board;
7) the need for deterrence, specific or general;
8) the existence of other enforcement actions by other authorities; and,
9) consistency in approach with other Board decisions on compliance / enforcement matters.

After considering the above criteria, and taking into account the fact that it is unlikely that there would have been any measurable harm to marine organisms from the release of MEG, it was determined that the Board would seek voluntary compliance by way of a commitment by ExxonMobil to implement certain corrective actions to prevent recurrence.

6.0 Corrective Actions to Prevent Recurrence

As previously discussed, the metallurgical analysis of the failed section of the Alma to Thebaud MEG flowline determined that the failure was due to a fatigue crack in a subsea flowline elbow. The positioning of the MEG flowline is maintained by support brackets designed to be attached to the Thebaud platform. The presence of these support brackets coupled with intermittent movement of the Thebaud platform was identified as a possible cause of the fatigue. In 2007 the Thebaud platform movement was eliminated through the addition of a grouting material inside the platform’s jacket legs to stabilize and further support the platform.

There are three other MEG flowlines of similar size and metallurgy installed at the Thebaud platform in the vicinity of the Alma to Thebaud MEG flowline. As a follow up to this incident, these flowlines were examined in the field to confirm their integrity in both 2006 and 2007 using visual examinations and magnetic particle inspection. In addition, they have been, and will continue to be, subjected to periodic pressure tests.

The Thebaud Central Control Room operator monitors the flow rate and pressure within the MEG system through the control system. As a follow up to this incident, the leak detection logic and alarm mechanism within the leak detection system have been updated so that they alarm earlier. Operations are to be suspended where the evidence suggests a possible unauthorized release to the sea.

In keeping with the concept of continuous improvement, learnings from incidents such as this are taken into account during regular reviews and updates to ExxonMobil’s pipeline integrity management systems, which include detailed hazard assessments that are performed on flow lines and pipelines.

The Board has in place an effective monitoring system to evaluate Operator compliance with health, safety and environmental regulatory requirements while conducting authorized petroleum related activities. Such monitoring programs include following up on identified corrective actions to assure that they have been effectively implemented.
Appendix I

Thebaud MEG Flow meter, FE-3509
Thebaud to Alma MEG Flowline – 52.5 km
SDV-6129B
Alma MEG Flow meter, FE-6129
Alma MEG Flow meter bypass, normally closed
Gas Production from Alma wells

Alma gas pipeline, 52.5 km - Production with MEG to Thebaud

Schematic – MEG Flow between Alma and Thebaud Platforms