ABS ADVISORY ON

FATIGUE MONITORING OF FLOATING PRODUCTION INSTALLATIONS

FEBRUARY 2021

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INTRODUCTION

BACKGROUND

Offshore floating production and/or storage units (FPSOs/FSOs) are designed for a specific design service life. In the dynamic offshore environment where operators apply all viable strategies to maximize the recovery of oil, operators and owners seek to increase the service life of their units.

Considering that, knowledge of a unit's operational history has gained increased attention and study. During the design phase, all possible operational conditions the vessel might encounter are considered. For life extension purposes, knowledge of the actual experienced conditions during operation can change the design premises.

Project wise, operators may look for better ways to operate and minimize the potential fatigue damage caused by the cyclic loads to which offshore units are exposed.

Since all site-specific units are subject to environmental and operational cyclic loads, it is intuitive that the parameters related to these two main sources of loads will greatly influence the unit's fatigue life. Sometimes, this translates to an increased service life, but it also serves to avoid undesired fractures on structural connections leading to expensive repairs during operation.

Based on observations of the operation of several units, and combined with ABS's experience with the structural behavior of offshore units, this study was conducted to identify key environmental and operational parameters impacting the fatigue life of the structural connections as well as characterize an optimized loading sequence for maximizing the fatigue life of a unit.

GOALS AND SCOPE

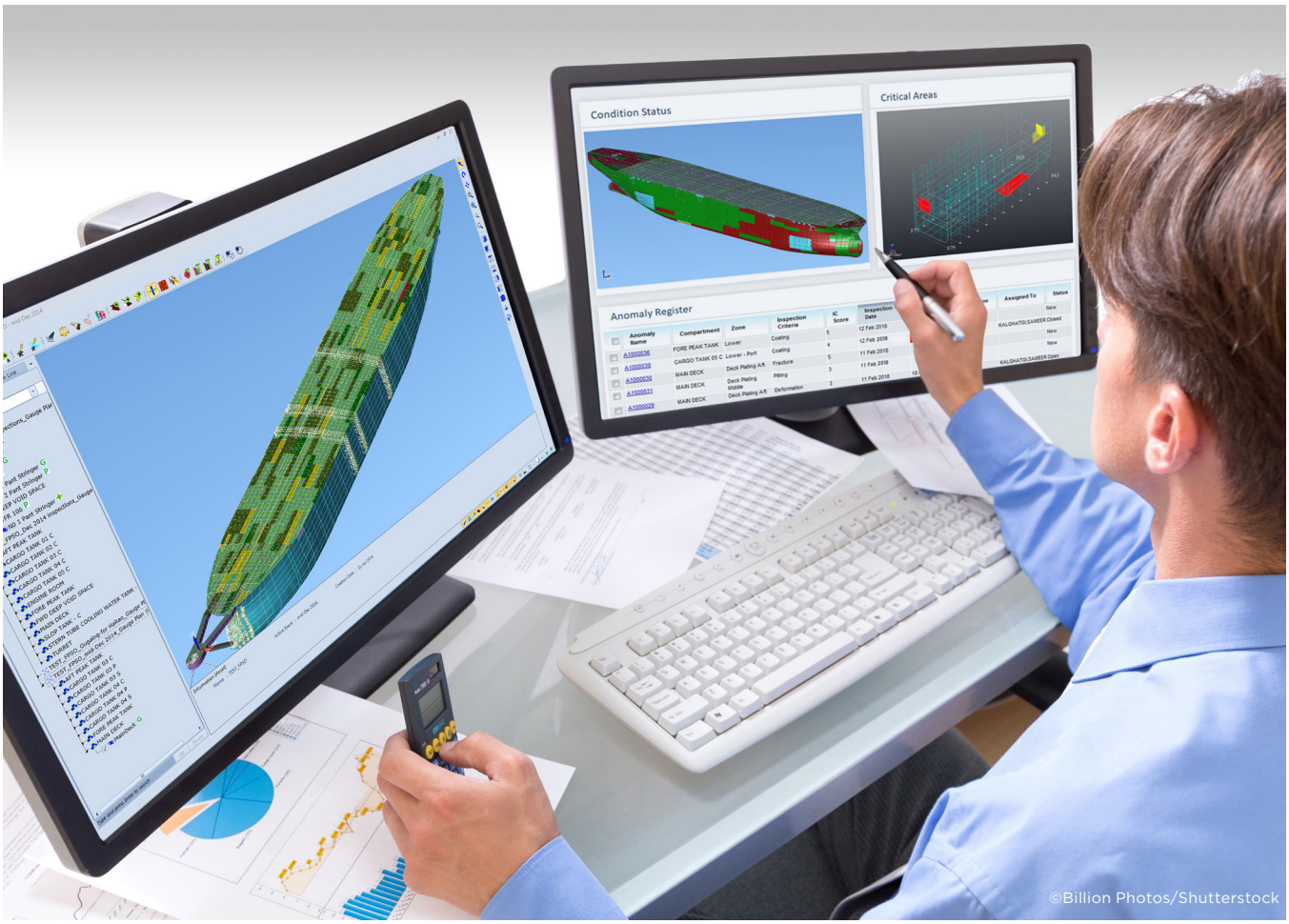
This Advisory provides an overview of the relevant parameters that significantly impact the fatigue life calculations for the structural connections of ship-type offshore units.

The recommended data acquisition including sensors and sensor specification for the relevant measurements are summarized in the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches*. Sensor data quality assessment, monitoring and control procedure, as well as recommended approaches for applying data quality metrics and rules suitable for marine data, are described in the ABS *Advisory on Data Quality for Marine and Offshore Application* and the ABS *Guide for SMART Functions for Marine Vessels and Offshore Units* and, therefore, are not described here. The prescriptive requirements for the remaining fatigue life estimation are presented in the ABS *Rules for Building and Classing Floating Production Installations* as well as other publications incorporated by reference in these Rules.

The purpose of this Advisory is to describe the parameters that can be measured during a unit's lifecycle using actual operational historical data as an alternative method to the Rule prescriptive requirements for the estimation of remaining fatigue life of structural connections.

With this Advisory and the quality measurement procedures described in the publications mentioned above, owners and operators will have the necessary tools to measure the main parameters that will lead to a customized, asset-specific estimation of fatigue life of structural connections.

The methodology for the fatigue life calculation, using the measured data during a vessel's operational life, is described under the ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations*.



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CHALLENGES

The objective of this section is to highlight the main challenges related to the increase of fatigue life of structural connections. They are summarized below, but are not restricted to:

LOADING SEQUENCE OPTIMIZATION

Finding the best loading sequence to maximize service life with respect to fatigue damage is usually a difficult task. This problem has multiple competitive objective functions, meaning it is not possible to find a single solution that serves all the goals. In these cases, the best solution is actually a set of equally optimal solutions (Pareto front), which can be tricky if not impossible to be defined manually.

Additionally, it may be difficult to optimize objective problems using trial and error. For example, regarding a vessel's loading sequence, there are so many different possible configurations and combinations of loading conditions that even a powerful computer will require significant time to compute all the possibilities and select the best one.

For this purpose, ABS has studied several parameters which would impact the optimization of loading sequences maximizing the service life with respect to fatigue damage.

IMPLEMENTATION ON BOARD OF OPTIMUM LOADING SEQUENCE/CONDITION

Once an optimum loading sequence is identified, it may be a challenge to implement it on board. Strict adherence to the optimum loading sequence may impact existing operational procedures and make it more difficult to implement on board.

QUALITY AND FREQUENCY OF MEASURED DATA

For both possible solutions to increase fatigue life (the utilization of optimum loading sequence to operate and the possibility of taking advantage of vessel operation history for the calculated life), the quality of data measured and the frequency it is collected is decisive for its utilization. This Advisory suggests possible main parameters and the minimum measurement frequency to obtain useful data for better estimations of Remaining Fatigue Life (RFL).

MAIN OPERATIONAL PARAMETERS FOR FATIGUE CALCULATIONS

INTRODUCTION

As stated above, it is clear that the vessel's operational data can be used for an asset-specific estimation of remaining fatigue life of structural connections, provided that quality standards for the data collection and processing are implemented, as described in the ABS *Guide for SMART Functions for Marine Vessels and Offshore Units*.

Therefore, in order to guide owners and operators on the main parameters that, once measured, can be useful for the fatigue life calculations, presented below is a table listing parameters. Also listed are parameter description and main objective, as well as the minimum measurement frequency that should be considered in order that the data can be used.

ENVIRONMENTAL DATA

The main source of cyclic loads for an offshore unit and, as a consequence, for the fatigue life of structural connections, is the environment to which it is subjected. Focusing on fatigue evaluation, the following are to be considered:

- Wave direction
- Wave height
- Wave period
- Vessel's heading

Other parameters such as wind and current may also have an impact, but for ship-type offshore units, it is on a lesser scale than the parameters mentioned above.

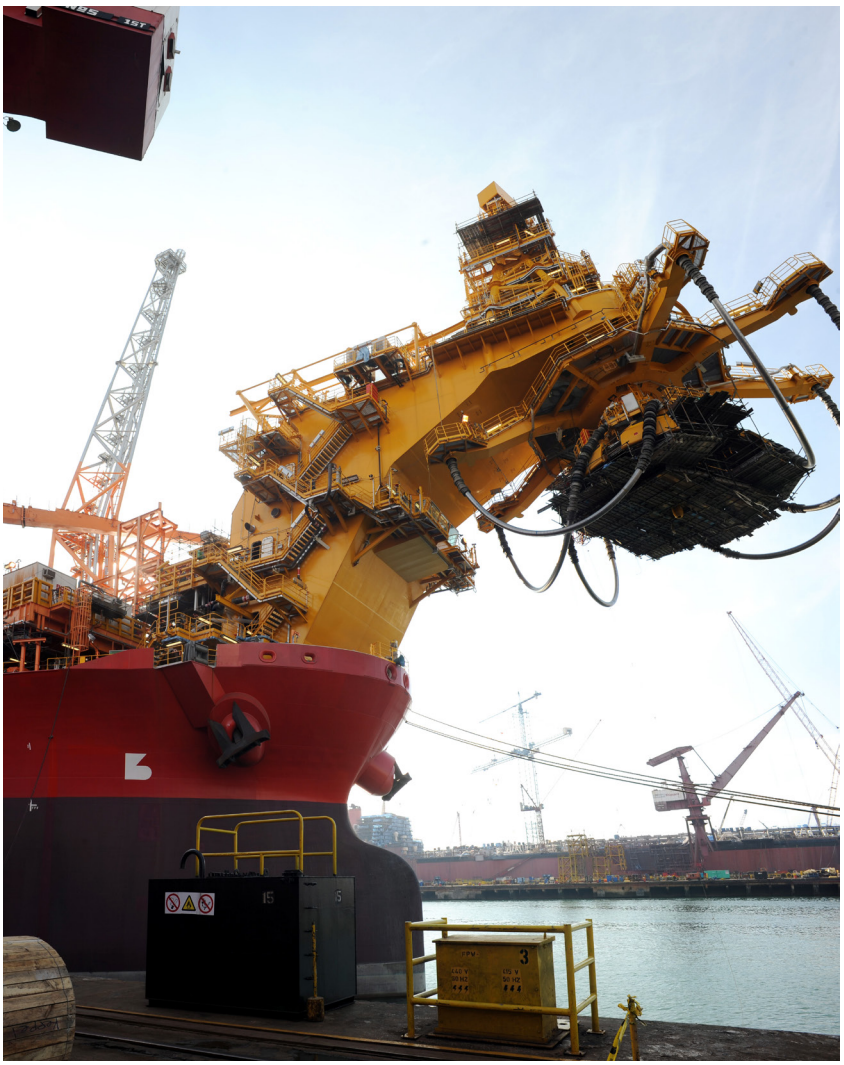
These four important parameters (wave direction, wave height, wave period and vessel's heading) are used for the calculation of the environmental severity factors that are the basis for all structural calculations of the FPSO/FSO, based on ABS Rules.

It is important to mention that not only these parameters, but also the measurement position for this data shall be considered for a specific FPSO/FSO or location. Three hours is recommended as a minimum measurement frequency for these parameters.

STABILITY AND LONGITUDINAL STRENGTH PARAMETERS

Other important parameters that once measured can lead to a substantial impact on the calculated fatigue life of structural connections are those related to the stability and longitudinal strength of the unit: draft (aft/forward/midship), trim, list, maximum still water bending moments (total maximum) and maximum still water bending moments at each frame (desirable information).

For optimization purposes, the above data should be collected preferably from an approved onboard loading computer; however, other sources would be acceptable on a case-by-case basis. For these parameters, the recommended measurement frequency is six hours for typical FPSO operations.



DRAFT

The measured draft is important for the proper definition of the coefficients for the fatigue loading conditions and represents how much time the unit spends in the minimum, maximum and intermediate drafts. As per Appendix 5A-3-A2 of the ABS *Rules for Building and Classing Floating Production Installations*, for fatigue damage evaluation, the following loading conditions distribution should be used:

FLC1 (Tmin) = 0.15

FLC2 (Tint1) = 0.35

FLC3 (Tint2) = 0.35

FLC4 (Tmax) = 0.15

The above distribution is based on the premise that the unit spends 15% at minimum draft, 70% at intermediate drafts and 15% at the maximum draft.

The observation of the operating loading conditions indicates that specific assets may be subject to loading and offloading conditions that produce a draft pattern different from the above. Using the asset-specific actual draft data as an alternative may reduce the impact caused by operating under maximum drafts, contributing to the decrease in the calculated fatigue damage.

The measurement and recording of the draft during the unit's life provides not only the actual estimation of the time spent under each draft but also the value of each operating draft.

The observed historical operation data of FPSOs has indicated that the use of actual data as an alternative to the traditional methodology may provide benefits when applied to fatigue calculations.

BENDING MOMENT

The study identified that the fatigue calculations of the structural connections on offshore units are very dependent on the maximum still water bending moment (SWBM). Since a safety margin is usually considered, the vessel can only reach a certain percentage of the maximum allowable still water bending moment during operations. This reduction can also be considered for the estimation of fatigue life of structural connections that are currently verified using the maximum allowable SWBM.

If more detailed information is available, such as the maximum SWBM for each frame (instead of only the maximum overall), it is also possible to calculate the fatigue life of structural connections for each frame and achieve different results that may prove to be advantageous for specific units.

ROLLING ANGLE

The rolling angle is also a desirable parameter to be measured, since it is useful for the investigation of actual damping effects. However, the measurement devices should be precise enough to provide at least one decimal number in order to produce useful information.

Motions/accelerations of the units are also a desirable parameter for extracting the accelerations of structural elements such as topside modules and flare towers, which are important for fatigue life estimation of main hull interface structures.

OFFLOADING NUMBER OF CYCLES

A non-negligible part of the damage on structural connections is due to the low-cycle fatigue caused by the number of offloading cycles, which is a parameter that is readily available. Therefore, a measured and accurate value can contribute to reduce the total number of cycles used in the calculations, leading to lower low-cycle fatigue damage and, consequently, higher remaining fatigue life.

The use of the actual data as an alternative to the Rule-required minimum value of 1200 cycles for 20 years of service (equivalent to 1200 offloading operations performed) may result in a more favorable remaining fatigue life value.

LOADING SEQUENCES

The actual loading sequences used during the operational life, especially if it represents a pattern consistently followed rather than random loading sequences, are also of great value for the fatigue life calculations and can be used for this purpose.

Regular and constant sequences observed for the unit can be alternatively used in lieu of the loading pattern prescribed by the Rules.

TANK FILLING LEVELS

Tank filling levels are relevant for the consideration of hydrodynamics and sloshing loads on the tank boundary structures and therefore are a distinguished parameter to be measured and used for both purposes: establishment and identification of loading sequences and the level of internal loading inside the tank.

The recommended frequency for measurement the tank filling level is six hours for typical FPSO operations.

SUMMARY

This advisory provides information on the recommended data and minimum suggested measurement frequency that can significantly influence the fatigue calculation of ship-type offshore unit structural connections.

Most of this information is already commonly measured during a unit's operational life and can be used as an alternative method to estimate the remaining fatigue life for life extension determination purposes. See Table 1 below for more information.

DATA CATEGORY	DATA TO BE MEASURED	FREQUENCY
Environmental Data	Wave direction	Every 3 hours
	Wave height	
	Wave period	
	Vessel's heading	
Stability and Longitudinal Strength Parameters	Draft (aft)	Every 6 hours
	Draft (forward)	
	Draft (midship)	
	Trim	
	List	
	Maximum still water bending moment (total)	
	Maximum still water bending moment at each frame	
	Rolling angle	
Loading	Number of offloading cycles	Every 6 hours
	Loading sequence	
	Tank filling levels	

Table 1: Summary Table: Data to be Measured

The methodology for the remaining fatigue life calculation is described in the ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations*. This methodology offers an alternative that considers the potential benefits of using the actual parameters measured during the unit's life.

REFERENCES

ABS *Guide for Dynamic Loading Approach for Floating Production, Storage and Offloading (FPSO) Installation, 2017*

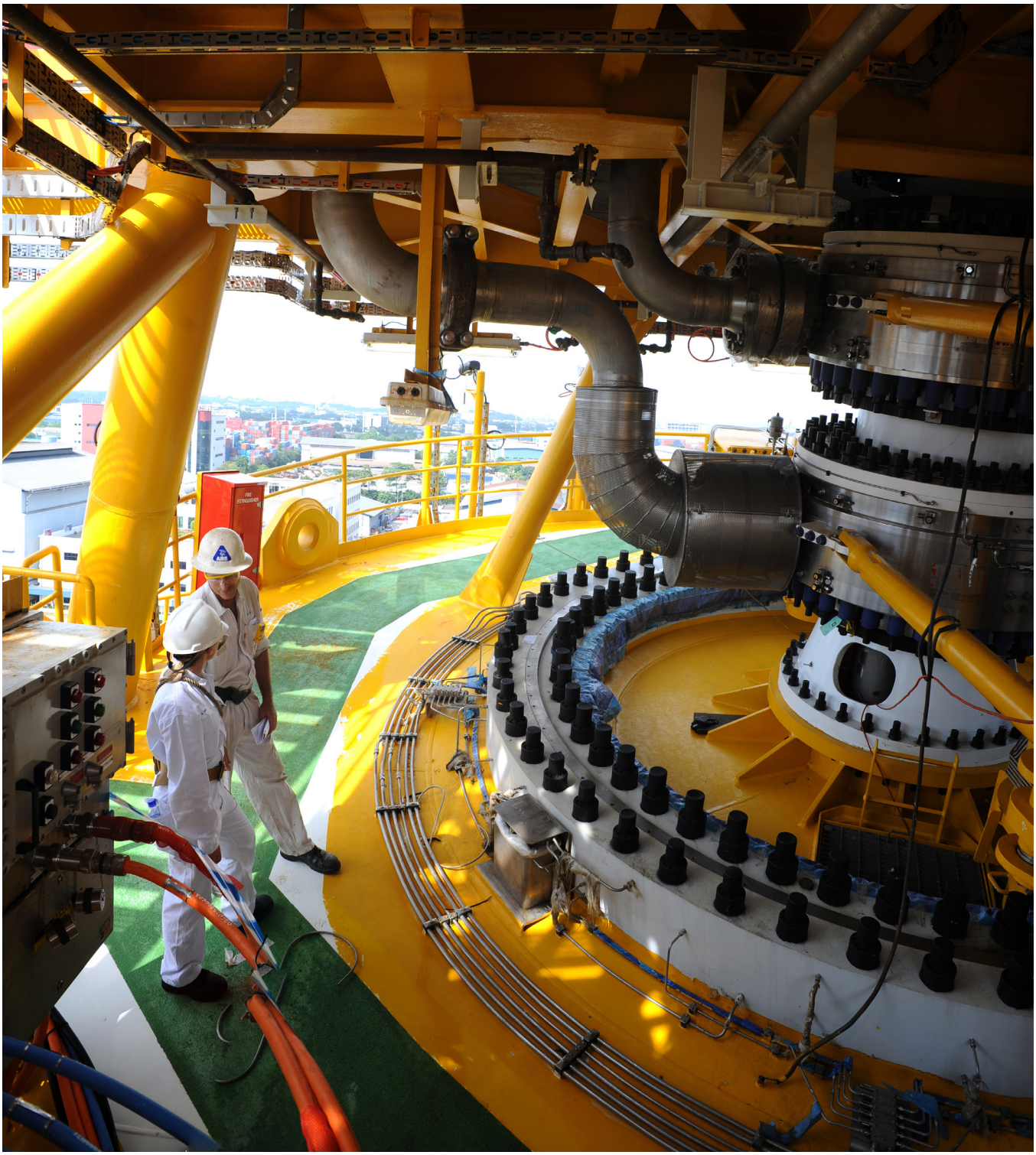
ABS *Rules for Building and Classing Floating Production Installations, 2020*

ABS *Advisory on Data Quality for Marine and Offshore Application, 2019*

ABS *Guide for SMART Functions for Marine Vessels and Offshore Units, 2020*

ABS *Guidance Notes on Life Extension Methodology for Floating Production Installations, 2017*

ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches, 2019*



CONTACT INFORMATION

NORTH AMERICA REGION
1701 City Plaza Dr.
Spring, Texas 77389, USA
Tel: +1-281-877-6000
Email: ABS-Amer@eagle.org

SOUTH AMERICA REGION
Rua Acre, nº 15 - 11º floor, Centro
Rio de Janeiro 20081-000, Brazil
Tel: +55 21 2276-3535
Email: ABSRio@eagle.org

EUROPE REGION
111 Old Broad Street
London EC2N 1AP, UK
Tel: +44-20-7247-3255
Email: ABS-Eur@eagle.org

AFRICA AND MIDDLE EAST REGION
Al Joud Center, 1st floor, Suite # 111
Sheikh Zayed Road
P.O. Box 24860, Dubai, UAE
Tel: +971 4 330 6000
Email: ABSDubai@eagle.org

GREATER CHINA REGION
World Trade Tower, 29F, Room 2906
500 Guangdong Road, Huangpu District,
Shanghai, China 200000
Tel: +86 21 23270888
Email: ABSGreaterChina@eagle.org

NORTH PACIFIC REGION
11th Floor, Kyobo Life Insurance Bldg.
7, Chungjang-daero, Jung-Gu
Busan 48939, Republic of Korea
Tel: +82 51 460 4197
Email: ABSNorthPacific@eagle.org

SOUTH PACIFIC REGION
438 Alexandra Road
#08-00 Alexandra Point, Singapore 119958
Tel: +65 6276 8700
Email: ABS-Pac@eagle.org

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