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## Technical Note

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# PROPOSED PROCEDURE FOR ASSESSMENT OF EXISTING PLATFORMS IN INDONESIA

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### Catatan Redaksi:

Sejak tahun 1970-an di Indonesia terdapat banyak anjungan lepas pantai, tetapi sampai saat ini belum ada peraturan atau tata cara untuk perencanaan dan penelaahannya. Anjungan lepas pantai biasanya direncanakan berdasarkan *Recommended Practice* yang diterbitkan oleh *American Petroleum Institute*, API RP2A. Pada saat ini dirasakan adanya kebutuhan untuk melakukan penelaahan kelayakan struktur anjungan lepas pantai yang telah dibangun sejak tahun 1970-an tersebut. Makalah ini membahas prosedur cara penelaahan anjungan lepas pantai yang diatur dalam API RP2A WSD edisi 21, API RP2A LRFD, dan ISO 19902 (draft E – 2001). Masalah biasanya akan timbul karena perencanaan didasarkan kepada API RP2A edisi 10 sedangkan penelaahan kelayakan didasarkan kepada edisi yang terbaru (edisi 21)

### Note from the Editor:

*Off-shore platforms were built since the 1970's in Indonesia, but there is no local code or recommended practice for their design or assessment procedure. The common practice is to use the recommended practice issued by the American Petroleum Institute, API RP2A. The off-shore platforms built in the 1970's must be re-qualified due to exceedance of the design life. This paper discuss the assessment procedure given in the API RP2A WSD 21<sup>th</sup> edition, API RP2A LRFD, dan ISO 19902 (draft E – 2001). Problems usually arise due to the fact that the original design was based on API RP2A 10<sup>th</sup> edition and assessment is done using the new edition which is the 21<sup>th</sup> edition.*

## INTRODUCTION

An assessment to determine “fitness for purpose” may be required during the life of a platform. This procedure is normally initiated by a change in the platform usage such as revised manning or loading, by modifications to the condition of the platform such as damage or deterioration, or by a re-evaluation of the environmental loading or the strength of the foundation.

In accordance with API RP2A [1,2] and ISO 19902 [3], an existing platform shall undergo an assessment process to demonstrate its fitness for purpose if one or more of the following condition exist:

1. Exceedance of intended design life [3,4]
2. Damage or deterioration of a primary structural component found during inspections [1,2,3]
3. Changes from the original design or previous assessment basis. These changes include:

- Addition of personnel or facilities such that the platform exposure level is changed to a more onerous level
- Modification to the facilities, such that the magnitude or disposition of the gravity or environment actions on a structure are more onerous
- More onerous environment criteria
- More onerous component or foundation resistance criteria
- Physical changes to the platform's design basis, e.g. excessive scour or subsidence
- Inadequate deck height, such that waves associated with previous or new criteria will impact the deck, and provided such action was not previously considered

API RP2A stated that cumulative damage or cumulative changes from the design premise are considered to be significant if the total of the resulting decrease in capacity due to cumulative damage and increase in loading due to cumulative changes is greater than 10 percent

Any structure that has been totally decommissioned (for example, an unmanned platform with inactive flow lines and all wells plugged and abandoned or is

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in the process of being removed such as, wells being plugged and abandoned) is not subject to assessment process.

Some major oil companies in Indonesia, as part of their program to enhance oil/gas production with minimum capital investment, are planning to extend platforms lifetime that exceeded the original service design life. In order to optimize structural and lifetime of platform, the companies intend to do structural integrity assessment of their existing platforms that exceeded the original service design life. Despite of the fact that the structures can stand for about 30 years, problems are usually arising in assessment result due to the fact that the original design was based on API RP2A 10<sup>th</sup> edition where fatigue analysis and punching shear check were not considered.

Structural integrity assessment for platform exceeding the original service design is required by Indonesian Regulation [4]. However, there is no clear standard procedure or guidelines from the Indonesian government currently available. Therefore, as alternatives to MIGAS and related parties, this paper illustrates methodology for assessment of existing platforms provided in API RP2A [1,2] and ISO 19902 [3]. Figure 1 shows a procedure for existing platform assessment based on API RP2A [1,2] and Figure 2 shows a procedure for existing platform assessment based on ISO 19902 [3].

In the case of assessment of existing platform that exceeded the original design life, there are 4 (four) components involve in the assessment process. Those are:

1. Categorization
2. Condition assessment
3. Analysis check
4. Consideration of mitigations

The assessment process for existing platforms separates the treatment of life-safety and consequence-of-failure issues, and applies criteria that depend upon location and consequences.

## PLATFORM EXPOSURE CATEGORIES

Structures can be categorized by various levels of exposure to determine criteria for the design of new platforms and the assessment of existing platforms that are appropriate for the intended service of the structure.

The levels are determined by consideration of life-safety and consequences of failure. Life-safety considers the maximum anticipated environmental event that would be expected to occur while personnel are

on the platform. Consequences of failure should consider the factors selecting design criteria. Such factors include anticipated losses to the owner (platform and equipment repair or replacement, lost production, clean up), anticipated losses to other operators (lost production through trunk lines), and anticipated losses to industry and government.

Categories for life-safety are as follows:

S-1 = manned-non-evacuated.

S-2 = manned-evacuated.

S-3 = unmanned.

Categories for consequences of failure are as follows:

C-1 = high consequence of failure.

C-2 = medium consequence of failure.

C-3 = low consequence of failure.

The level to be used for platform categorization is the more restrictive level for either life-safety or consequence of failure. Platform categorization may be revised over the life of the structure as a result of changes in factors affecting life-safety or consequence of failure.

## PLATFORM ASSESSMENT INFORMATION SURVEY

Sufficient information should be collected to allow an engineering assessment of the platform's overall structural integrity. It is essential to have a current inventory of the platform's structural condition and facilities. The operator should ensure that any assumptions made are reasonable and information gathered is both accurate and representative of actual conditions at the time of the assessment.

**Surveys for assessment of existing platform include the following:**

### Topside:

The topside survey should, in most instances, require only the annual level I survey. The survey levels are described in Section O.3 of API RP 2A-LRFD [1]. The accuracy of the platform drawings should be verified when necessary. Where drawings are not available or are inaccurate, additional walk around surveys of the topside structure and facilities could be required to collect the necessary information, for example, topside arrangement and configuration, platform exposure category, structural framing details, and the like.

### Underwater:

The underwater survey should, as a minimum, include a level II survey (existing records or new survey) [1]. In some instances, engineering judgement may necessitate additional level III / level IV surveys [1], to verify suspected damage, deteriora-

tion due to age, lack of joint cans, major modifications, lack of or suspect accuracy of platform drawings, poor inspection records, or analytical findings. The survey should be planned by personnel familiar with inspection processes. The survey results should be evaluated by a qualified engineer familiar with the structural integrity aspects of the platform.

### Soil Data

Available on-site or near-site soil borings and geophysical data should be reviewed. Many older platforms were installed based on soil-boring information a considerable distance away from installation site. Interpretation of the soil profile can be improved based on more recent site investigations (with improved sampling techniques and in-place tests). More recent and refined geophysical data might also be available to correlate with soil boring data, thereby developing an improved foundation model.

## ANALYSIS CHECK

The structure should be evaluated based on its current condition or future intended condition, accounting for any damage, repair, scour, modifications, or other factors which may affect its performance or integrity. The global structural model should be three-dimensional. Special attention should be given to defensible representation of the actual stiffness of damaged or corroded members and joints.

There are two potential sequential analysis checks:

1. Design-level analysis.
2. Ultimate-strength analysis.

The design-level analysis is a simpler and more conservative check, while the ultimate-strength analysis is more complex and less conservative. It is generally more efficient to begin with a design-level analysis, only proceeding with ultimate-strength analysis as needed. However, it is permissible to bypass the design-level analysis and to proceed directly with an ultimate-strength analysis. If an ultimate-strength analysis is required, it is recommended to start with a linear global analysis, proceeding to a global inelastic analysis only if necessary.

Note that mitigation alternatives, such as platform strengthening, repair of damage, load reduction, or changes in exposure category, may be considered at any stage of the assessment process.

### Design-Level Analysis Procedures:

These procedures are similar to those for new platform design, including the application of all load and resistance factors for Load and Resistance Factor Design (LRFD) or including the application of all safety factors for Working Stress Design (WSD), the use of nominal rather than mean yield stress, and so on. These procedures may be bypassed by using the ultimate-strength analysis procedures. This paper will discuss the criteria based on API RP2A- LRFD combined with ISO 19902

### Loads for In-place Analysis

#### Operation Condition

Each member, joint, and foundation components should be strength checked for the internal force  $Q$  caused by the action of these factored loads:

$$Q = 1.3 D1 + 1.3 D2 + 1.5L1 + 1.5L2 + 0.9 \gamma_{FE} (W_o + \gamma_{FD} D_n) \quad (1)$$

Where  $D1$ ,  $D2$ ,  $L1$ , and  $L2$  are defined below.

Dead load 1,  $D1$ . Dead load 1 is the self weight of the structure including:

- Weight of structure in air, including where appropriate the weight of piles, grout, and solid ballast
- Weight of equipment and other objects permanently mounted on the platform that do not change with the mode of operation
- Hydrostatic forces acting on the structure below the waterline including internal and external pressure and resulting buoyancy.
- The weight of water enclosed in the structure, whether permanently installed or temporary ballast.

The nominal value of  $D$  is the value computed from nominal dimensions and densities.

Dead load 2,  $D2$ . Dead load 2 is the load imposed on the platform by the weight of equipment and other objects. These loads may change from one mode of operation to another or during mode of operation but otherwise remain constant for along period of time, dead load 2 should include the following:

- The weight of drilling and production equipment that can be added or removed from the platform.
- The weight of living quarter, heliport and other life-support equipment, which can be added or removed from the platform.

The nominal value of  $D2$  should be the estimated lift weight of the object plus any field installed appurtenances.

Live load 1,  $L1$ . Live load 1 includes the weight of consumable supplies and fluids in pipes and tanks.

The nominal value of L1 is computed from the nominal weight of the heaviest material and the largest capacity under the mode of operation considered.

Live load 2, L2. Live load 2 is the short duration force exerted on the structure from operations such as lifting of drill string, lifting by the crane, machine operation, vessel mooring and helicopter loading. The nominal value should be the load caused by the rated maximum capacity of the equipment involved and should include dynamic and impact effects.

$W_o$  is the force applied to the structure due to the combined action of the operating wave (typically 1-yr return period) and associated current and wind, accounting for the joint probability of occurrence of winds, waves and currents (both magnitude and direction).

$D_n$  is the nominal inertial load at the time when the total global dynamic response (static and inertial) is a maximum. For platform with sufficiently short natural periods (less than three seconds),  $D_n$  may be neglected.

$\gamma_E$  is the partial action factor for extreme environmental actions. API RP2A give the factor as 1.35 whilst ISO 19902 will determine the factor based on regions within geographical areas provided in Annex C, Regional Information. Annex C contains clauses for a number of geographical regions sharing similar environments and additional requirements for fixed steel offshore structures. The information in Annex C would be normative for structures in the defined areas and informative for other regions.

$\gamma_D$  is an additional partial action factor for the equivalent quasi-static action representing dynamic response  $D_n$  caused by extreme wave action.

#### Storm Condition

Each member, joint, and foundation components should be strength checked for the internal force  $Q$  caused by the action of these factored loads:

$$Q = 1.1 D1 + 1.1 D2 + 1.1 L1 + \gamma_{jE} (W_e + \gamma_{jD} D_n) \quad (2)$$

Where  $D1$ ,  $D2$ ,  $L1$ , and  $L2$  are already defined.  $W_e$  is defined below.

$W_e$  is the force applied to the structure due to the combined action of the extreme wave (typically 100-yr return period) and associated current and wind, accounting for the joint probability of occurrence of winds, waves and currents (both magnitude and

direction). For some structures whose fluid loading is not strongly dominated by waves, some other combination of wind, wave, and current may be appropriate. In some areas, special consideration must be given to effects of tidal and general circulation currents in calculating  $W_e$ .

### **Earthquake Analysis**

#### Strength Level

Strength requirements are intended to provide a platform which is adequately sized for strength and stiffness to ensure no significant structural damage for the level of earthquake shaking which has a reasonable likelihood of not being exceeded during the life of the structure.

Each member, joint, and foundation components should be strength checked for the internal force  $Q$  caused by the action of these factored loads:

$$Q = 1.1 D1 + 1.1 D2 + 1.1 L1 + 0.9 E_s \quad (3)$$

Where  $D1$ ,  $D2$ ,  $L1$ ,  $L2$  and  $D_n$  are already defined,  $E_s$  is defined below.

$E_s$  is the inertial induced load produced by the strength level ground motion using dynamic analysis procedures such as response spectrum analysis or time history. Usually  $E_s$  is ground motion 100 year return period or further discussion.

#### Ductility Level

The ductility requirements are intended to ensure that the platform has sufficient reserve capacity to prevent its collapse during rare intense earthquake motions, although structural damage may occur.

Each member, joint, and foundation components should be strength checked for the internal force  $Q$  caused by the action of these factored loads:

$$Q = 1.1 D1 + 1.1 D2 + 1.1 L1 + 0.9 E_d \quad (4)$$

Where  $D1$ ,  $D2$ ,  $L1$ ,  $L2$  and  $D_n$  are already defined,  $E_d$  is defined below.

$E_d$  is the inertial induced load produced by the ductility level ground motion using dynamic analysis procedures such as response spectrum analysis or time history. Usually  $E_d$  is ground motion 800 year return period or further discussion.

### **Fatigue**

As part of the assessment process for future service life, consideration should be given to accumulated fatigue degradation effects. Where Levels III and/or IV surveys are made and any known damage is assessed and/or repaired, no additional analytical demonstration of future fatigue life is required.

Alternatively, adequate fatigue life may be demonstrated by means of an analytical procedure compatible with Section F in API-RP2A LRFD.

For reused platforms having tubular connections inspected in accordance with the minimum requirements, fatigue considerations must include appropriate allowances for fatigue damage that may have occurred during the initial in-service period of the platform as well as the planned service life at the new location. Beneficial effects on fatigue life from full inspection and/or remedial measures may be considered when determining prior damage or selecting safety factors.

The simplified fatigue analysis provisions addressed in Section Comm. F.1 from API –RP2A LRFD may be used to assess tubular joints in reused platforms, provided they are inspected per the minimum requirements, have prior and new locations in less than 122 m (400 ft) of water, have similar wave climates with respect to platform orientation, are constructed of ductile steels, have redundant structural framing and have natural periods less than three seconds for both locations.

The design fatigue life,  $L$ , in years should satisfy the following expression.

$$L = SF_1 L_1 + SF_2 L_2 \tag{5}$$

Where:

- $L_1$  = Initial in service period, years
- $L_2$  = Planned service life at new location, years
- $SF_1$  = 2.0 for minimum requirements

If the weld in a tubular connection is 100% NDE inspected in accordance with requirements and is upgraded if defects are found,  $SF_1$  may be between zero and 2.0 selected on rational basis.

$$SF_2 = 2.0$$

For both safety factors,  $SF_1$  and  $SF_2$  higher values for failure critical elements should be considered.

### Ultimate-Strength Analysis Procedures

These procedures reduce conservatism by providing an unbiased estimate of platform capacity. The ultimate strength of a platform may be assessed using inelastic, static pushover analysis. However, for LRFD approach, a design-level analysis with all load and resistance factors set to 1.0 and sources of conservatism removed is also permitted, as this provides a conservative estimate of ultimate strength. For WSD approach, a design-level analysis with all safety factor and sources of conservatism removed is also permitted. In both cases, the ultimate strength metocean criteria should be used.

Platforms of all exposure categories, either bypassing or not passing the requirements for screening and/or design-level analysis, shall demonstrate adequate strength and stability to survive the ultimate-strength loading criteria set forth in Sections assessment process and metocean and seismic criteria in order to ensure adequacy for the current or extended use of the platform. The provisions of Fatigue apply even if the design-level analysis is bypassed.

### Linear Global Analysis

A linear analysis may be performed to determine if over stressing is local or global. The intent is to determine which members or joints have exceeded their buckling or yield strengths. The structure passes assessment if no elements have exceeded their ultimate strength.

The following guidelines may be used for the ultimate- strength analysis:

1. The ultimate strength of undamaged members, joints, and piles can be established using the formulas of Sections cylindrical member design, connections, foundation design, and structural components and system with all resistance factors set to 1.0. The ultimate strength of joints may also be determined using a mean formula or equation versus the lower bound formulas for joints in connections.
2. The ultimate strength of damaged or repaired elements of the structure may be evaluated using a rational, defensible engineering approach, including special procedures developed for that purpose.

When few overloaded members and/or joints are encountered, local overload considerations may be used as outlined in Section local overload consideration, otherwise, a detailed global inelastic analysis is required.

### Local Overload Considerations

Engineering judgement suggests that overload in locally isolated areas could be acceptable with members and/or joints having stress ratios greater than 1.0 if it can be demonstrated that such overload can be relieved through a redistribution of load to alternate paths or a more accurate and detailed calculation would indicate that the member or joint is not, in fact, overloaded. Such a demonstration should be based on defensible assumptions with consideration being given to the importance of the joint or member to the overall structural

integrity and performance of the platform. In the absence of such a demonstration, it is necessary to perform an incremental linear analysis (in which failed elements are replaced by their residual capacities), perform a detailed global inelastic analysis, and/or apply mitigation measures.

### Global Inelastic Analysis

Global inelastic analysis is intended to demonstrate that a platform has adequate strength and stability to withstand the loading criteria with local over stress and damage allowed, but without, if collapse.

For existing structures, ISO 19902 permit to accept limited individual component ‘failure’ (i.e. forces exceeding the component capacity or local failure), provided that both the reserve against overall system failure and deformations remain acceptable.

At this level of analysis, stresses have exceeded elastic levels and modelling of over stressed members, joints, and foundation shall recognize ultimate capacity, as well as, post-buckling behaviour, rather than the elastic load limit.

The specific method of analysis depends on the type of extreme environmental loading/applied to the platform and the intended purpose of the analysis. Pushover and time-domain analysis methods are acceptable.

### In-place Analysis

RSR is defined as the ratio of platform’s ultimate lateral load carrying capacity to its 100-years environmental condition lateral loading. For platforms with high consequence category, API RP2A requires a minimum RSR of 1.6 obtained from static in-place ultimate strength analysis (Static Push-over Analysis). For platforms with low consequence category, the minimum RSR is 0.8.

### Seismic Analysis

Strength requirements are intended to provide a platform which is adequately sized for strength and stiffness to ensure no significant structural damage for the level of earthquake shaking which has a reasonable likelihood of not being exceeded during the life of the structure.

The ductility requirements are intended to ensure that the platform has sufficient reserve capacity to prevent its collapse during rare intense earthquake motions, although structural damage may occur. Seismic Reserve Capacity Factor  $C_\gamma$  represents a structure’s ability to sustain earthquakes beyond the Strength Level Earthquake (SLE) and is defined

as the ratio of spectral acceleration of the earthquake causing failure to the SLE spectral acceleration.

ISO 19902 indicates  $C_\gamma$  shall not exceed 2.8 for L-1 platforms, 2.5 for L-2 platforms, and 2.2 for L-3 platforms. In addition, static pushover analysis shall be performed to ensure that the platform Seismic Reserve Capacity Factor is equal to or higher than the requirement above. In this case, pushover actions should represent the pattern of Ductility Level Earthquake (DLE) seismic actions on the structure and foundation.

## MITIGATION ALTERNATIVES

Structures that do not meet the assessment requirements through screening, design level analysis, or ultimate strength analysis will need mitigation actions. *Mitigation actions* are defined as modifications or operational procedures that reduce loads, increase capacities, or reduce exposure.

## CONCLUSION

Procedure for assessment of existing platforms is available in API RP2A – WSD 21<sup>st</sup> edition, API RP2A – LRFD, and ISO 19902 Draft E. Those procedures could be used as a reference for assessment of existing platforms in Indonesia. However, further discussions need to be carried out so that the procedure will include local considerations.

The load factor for extreme environmental actions  $\gamma_{fE}$  available in API RP2A LRFD is defined based on Gulf of Mexico environment. Therefore, for the purpose of assessment of existing platforms in Indonesia, the partial action factor for extreme environmental actions  $\gamma_{fE}$  should be determined based on environmental condition within Indonesian geographical areas. The results could then be used for input in Annex C, Regional Information, ISO 19902.

Platforms in Indonesia that were built in 1970’s were designed based on API RP2A 10<sup>th</sup> edition. In addition, in most original designs, fatigue analysis and punching shear check were not considered. Therefore, despite of the structures have been proven to stand for 30 years operation, failure in joint punching shear checks is likely to occur in the assessment based on current standard. To overcome the problem and still in line with standard requirements, global inelastic analysis must be carried out to demonstrate that the platform has adequate strength and stability to withstand the loading criteria without collapse. The criteria of RSR for

static push-over in API RP2A could be used in this analysis.

To overcome similar problem in seismic analysis, static pushover analysis, by using static equivalent load that represent the pattern of Ductility Level Earthquake (DLE) actions on the structure and foundation, shall be performed to ensure that the platform has sufficient reserve capacity to prevent its collapse during rare intense earthquake motions, although structural damage may occur. Similar criteria for Seismic Reserve Strength Ratio with static push-over could be used in this analysis.

The condition and integrity of joints for fatigue resistance could be determined by inspection of the joints considered critical or with fatigue life less than the intended total service life. The remaining service life of the platform shall be established after the condition of critical joints is determined.

## REFERENCES

1. American Petroleum Institute, *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platform – Load and Resistance Factor Design (API RP 2A – LRFD, Supplement 1)*, first edition, 1993.
2. American Petroleum Institute (1997), *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platform–Working Stress Design (API RP 2A – WSD)*, 21<sup>st</sup> edition, 2000.
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4. Keputusan Direktur Jenderal Minyak dan Gas Bumi Nomor 21-K/38/DJM/1999, *Petunjuk Pelaksanaan Tatacara Pemeriksaan Teknis Atas Konstruksi Platform Yang Dipergunakan Dalam Usaha Pertambangan Minyak dan Gas Bumi*, Direktorat Jenderal Minyak dan Gas Bumi, 1999.

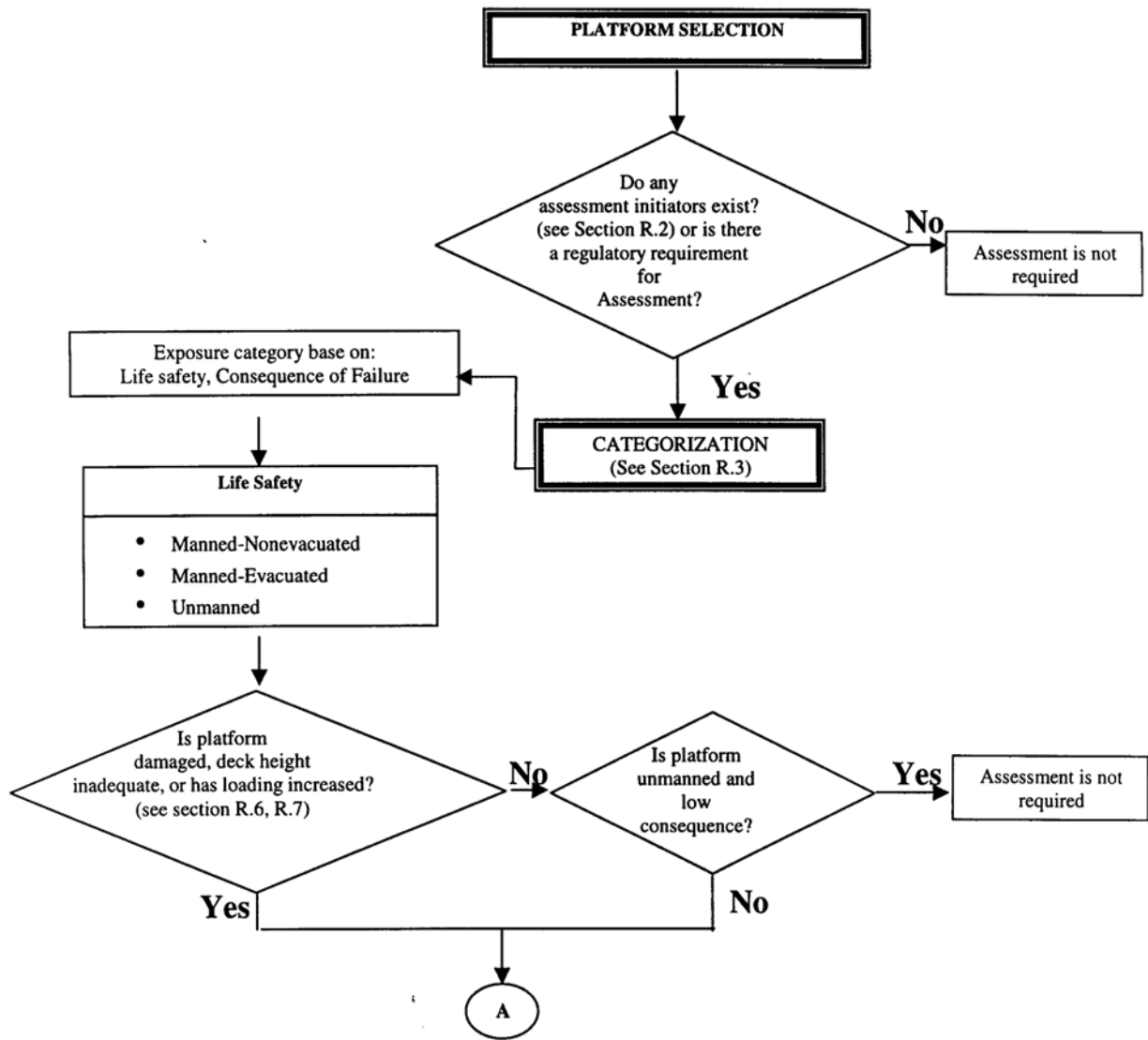


Figure 1.a. Procedure for existing platform assessment based on API RP2A [1,2]



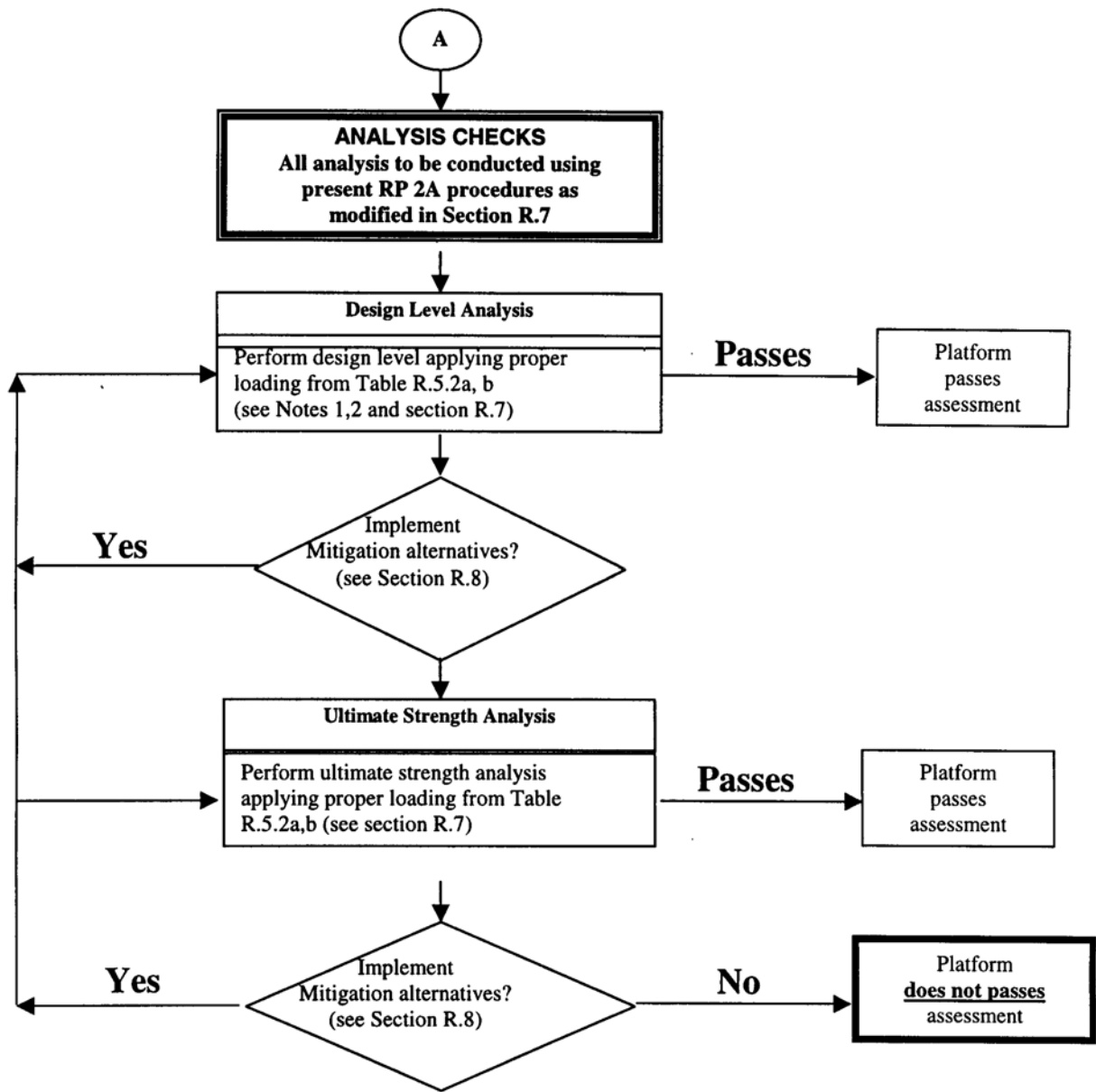


Figure 1.b. Procedure for existing platform assessment based on API RP2A [1,2]

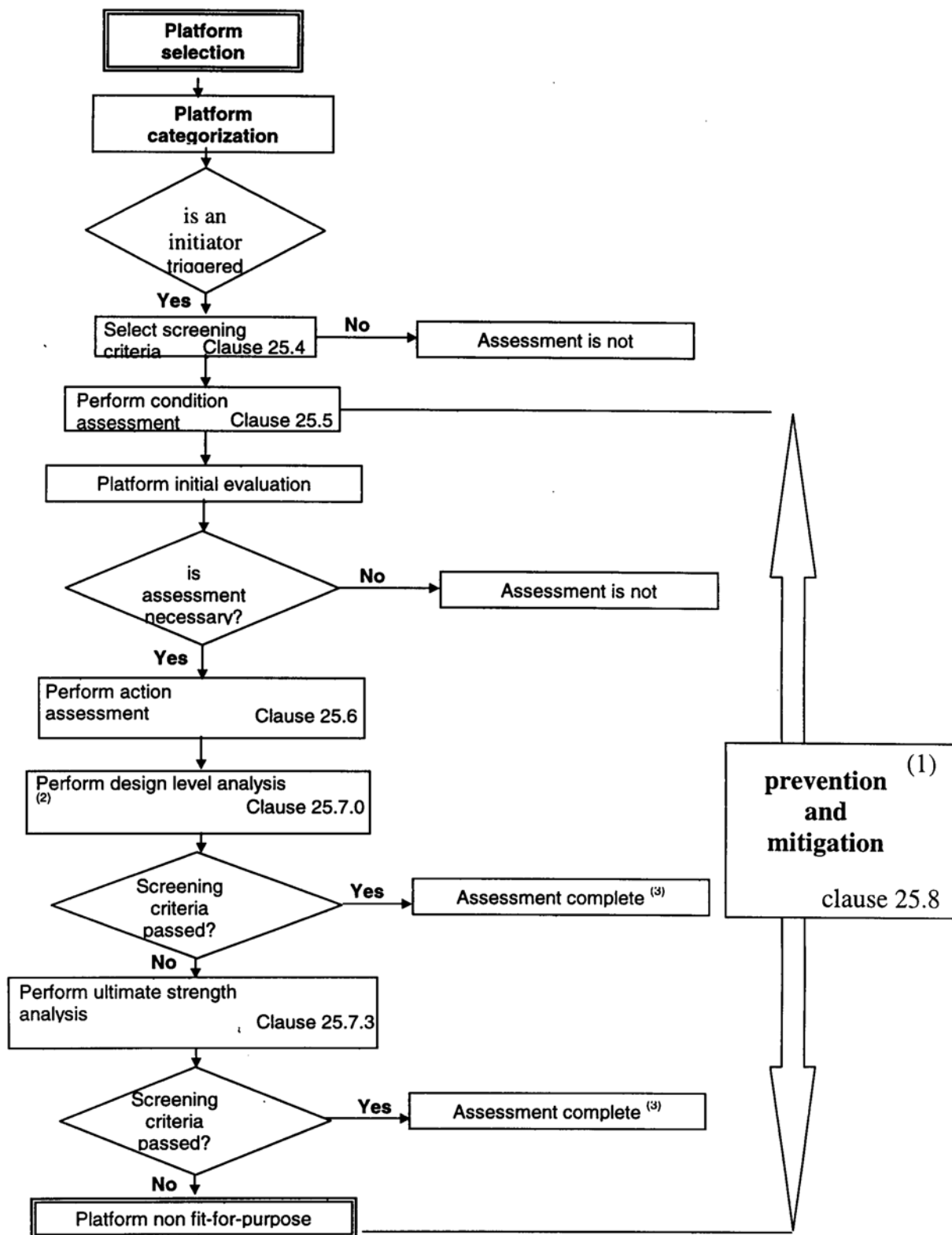


Figure 2. Procedure for existing platform assessment based on ISO 19902 [3]