



OTC 17697

## API Offshore Structure Standards: RP 2A and much more

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### Abstract

From the generally accepted “birth” of the offshore industry in the Gulf of Mexico in 1947, 22 years elapsed before the first offshore structure design “standard”, the 1<sup>st</sup> Edition of API RP 2A<sup>1</sup>, was issued. In the ensuing 35 years, the offshore structure technology, design practices and standards have seen a continuing evolution, a broadening of the original scope to encompass many diverse types of offshore structures, and an expansion from the original birthplace to an increasing number of other geographic areas. In turn, the “technology export” planted seeds that resulted in significant contributions to the industry growth from the international community.

With the API RP 2A 22<sup>nd</sup> Edition currently under preparation, this paper presents a high-level overview of the evolution of the US offshore industry design practices and standards over the past 50 years, the leading role of the API Committee on Standardization of Offshore Structures, and a preview of the major changes expected in the new edition.

### Introduction

Drilling and production operations over waters started well over 100 years ago, usually carried out from decks supported by wooden piles, connected to shore by long piers. This solution was successfully replicated in diverse locations such as the coast of Louisiana, the Caspian Sea, and Venezuela’s Lake Maracaibo.

The term “offshore” came into use some time later, in reference to drilling and production facilities hosted by man-made islands, physically separated from the shore.

The installation in 20 feet (6 m) of water off the coast of Louisiana of a steel platform owned by Kerr-McGee and designed by Brown & Root, in 1947, is generally accepted as the “official” birth of the offshore industry. Today, just over half a century later, production facilities in 6,000 feet (2,000 m) of water are a reality, while drilling in 10,000 feet of water is well within the industry’s sights.

The history of the offshore industry, from its beginning to this day, is a multidimensional, multinational, and very colorful tapestry, with interweaving threads of extreme challenges, breathtaking drama, daring innovation, occasional failures, and, most of all, outstanding accomplishments.

Over the years, many (companies and individuals alike) have contributed to the industry’s advances and successes. Today, through the ebb and tide of business fortunes, the relentless erosion of time, and the constant winds of change, most of the pioneers are gone, companies have been swallowed up by “leaner and meaner” competitors, old time names and logos have disappeared as part of “corporate re-branding”, and much of the “old way” of working has been washed away by the tidal waves of “new business models”.

Fortunately, the memories and knowledge remain, thanks in part to an ample body of literature that, albeit in piecemeal fashion, captures much of the industry’s lore, its collective experience and expertise. Some examples of the available sources are provided in the list of references.

This paper focuses on some less dramatic and visible (and yet very significant) aspects of the evolution and growth of the offshore industry: the progressive development of design technology and the systematic encapsulation of the practices in industry standards under the leadership of the American Petroleum Institute (API).

### The American Petroleum Institute

The American Petroleum Institute (API), incorporated in 1919, is a trade association representing over 200 companies involved in all aspects of the oil and gas industry, including exploration, production, transportation, refining and marketing.

The objectives of the Institute, as stated in its charter, are to:

- afford a means of cooperation with governmental authorities in all matters of national concern;
- foster foreign and domestic trade in US petroleum products;
- promote the interest of the petroleum industry in all its branches;
- promote the mutual improvement of the members and the study of the arts and sciences connected with the petroleum industry.

More information on the API, its history and its organization can be found at [www.api.org](http://www.api.org).

### **The API Committee on Standardization of Offshore Structures**

API's active involvement in offshore structures was in part prompted by Hurricanes Carla (1961), Hilda (1964) and Betsy (1965), which caused varying degrees of damage to several offshore platforms. Consultation with the industry suggested that the time was ripe to address the issue of consolidating and publishing adequate guidance and sound design criteria for the design of offshore platforms.

An initial organizational meeting held at the Rice Hotel in Houston, Texas, on November 29, 1966, resulted in the formation of the API "Committee on Standardization of Offshore Structures", charged with developing standards for the design and construction of offshore platforms, including standards for equipment packaging and arrangement..

Since its inception, the original Committee has seen many changes in its name, internal structure, responsibilities, composition, etc. Its size has varied from an initial membership of 5 to an overall roster of over 100, including the members of the Task Forces, Work Groups, Resource Groups that participate, in various capacity, in the Committee's activities.

Rather than attempting to keep track of all the transformations, for the sake of clarity, the term Offshore Structure Committee (OSC) will be used throughout this paper to refer to the individuals that, under different labels, have served and continue to serve the industry providing the leadership required by this continuing effort.

### **API RP 2A – The Offshore Structure Committee Flagship**

Once established, the first task the OSC set for itself was to develop a recommended practice for fixed steel platforms. The 1<sup>st</sup> Edition of API RP 2A was issued in 1969.

Some important principles, which still underpin the OSC strategy, were established at the very beginning of the development effort:

1. Build on existing applicable engineering codes and guidelines, such as the AISC and AWS specifications. API RP 2A was intended to fill the "gaps" where these two publications, primarily intended for conventional onshore structures, were not adequate for offshore platforms.
2. Use a Working Stress Design (WSD) approach, also referred to as Allowable Stress Design (ASD), reflecting the then prevalent US design practices.

Three main areas of technology were initially identified for inclusion in RP 2A, where the standards mentioned above were not felt to be adequate: environmental loads, foundations, and tubular joints. In time, other subjects such as fatigue, dynamics, material selection, welding, and grouted connections were deemed in need of special consideration for offshore platforms, and were progressively addressed in the API RP 2A. These design topics continue to this day to be active technology development areas.

### **API RP 2A – A living document**

The formation of the OSC and the publication of API RP 2A represented major milestones in several ways. With a technical basis to build on, and a forum established for the industry to meet and debate issues, both the scope of API RP 2A and the level of technical detail expanded to mirror the development of technology of the industry at large, and to accommodate the increasing business requirements. To manage these changes, a systematic and very effective update process was established that led to a number of revisions at a very fast pace.

The publication of the 7<sup>th</sup> Edition of API RP 2A (1976) represented a significant milestone, with the recommendation for using the "100-year wave" as the design condition. Up to this point, the choice of return period was left to the owner/operator, and the use of both the 25 year and the 100 year event was common. With the 7<sup>th</sup> Edition, the 100-year wave became standard practice.

API RP 2A 20<sup>th</sup> Edition, published in 1993, presented a completely revised wave force formulation. This included additional terms in the traditional wave load formulation, and recommended using 100-year load conditions (rather than the 100-year wave) as the basis for design.

In the same year, 1993, the 1<sup>st</sup> Edition of the Load and Resistance Factor Design (LRFD) version of API RP 2A made its long-awaited appearance. As described in a later section, the document's content was essentially identical to that of the traditional RP 2A (still based on the original WSD approach), except for the different design format. For the sake of clarity, the API RP 2A title was changed, so the two documents were

renamed respectively API RP 2A-WSD<sup>6</sup> and API RP 2A-LRFD<sup>7</sup>.

API RP 2A WSD 21<sup>st</sup> Edition, the latest, was issued in 1999, after considered review of the ongoing process of globalization of the offshore petroleum industry standards, which will be further discussed in OTC 17698.

The size of the document has grown progressively from the 20-odd pages of the 1<sup>st</sup> Edition to the 90 pages of the 9<sup>th</sup> Edition, to the 160 pages of the 18<sup>th</sup> Edition (1989) to the over 220 pages of the 21<sup>st</sup> Edition.

The current plans for the API RP 2A WSD 22<sup>nd</sup> Edition planned for 2006 and further discussed in a later section, point to a continuation of the recent trend of a noticeable slow-down of the pace of revisions. For many reasons, not the least of which is the increasing difficulty in securing availability of experienced technical resources, the average time interval between the last two editions is 6 years. This provides a dramatic contrast with the average interval of 15 months during the 24 years elapsed between the 1<sup>st</sup> Edition and the 20<sup>th</sup> Edition.

### **Broadening horizons, expanding the scope**

The publication of API RP 2A 1<sup>st</sup> Edition was no more than an auspicious beginning. This was soon followed by API Spec 2B, providing specifications for the rolling of the large diameter steel cylinders required for offshore structures. The activities continued into associated subjects such as cranes for offshore structures, drilling rig and production facilities layout, anchor chain and marine risers (fixed platform risers were later transferred to another API committee).

Until the early to mid-60s the offshore industry remained strongly focused on the U.S. Gulf of Mexico. However, once API RP 2A came into existence, the attention of the OSC was soon drawn towards the needs and special requirements of other domestic areas. Exploration along the US West Coast and in Alaska spawned a flurry of activities to address issues related to seismic design and to the particular environmental considerations applicable to these areas. This work resulted in expansion of the original scope of the API RP 2A.

By 1976, a total of eight publications had been issued and work on several others was in progress. Shortly afterwards, reflecting the industry's growing interest in deep waters, The OSC mission, originally limited to fixed platforms, expanded to include compliant bottom-supported structures as well as floating structures. This resulted in a number of enhancements to API RP 2A, and in a major effort (discussed in a later section) to address the emerging Tension Leg Platform (TLP) technology.

In the early 1960s, the industry had also started operating in areas with significant amounts of sea ice, such as the Cook Inlet in Alaska. This was followed in the 1970s by a substantial exploration effort in the U.S. and Canadian

Beaufort Sea, so the OSC recognized the need to develop appropriate design guidance for offshore structures in ice environments. In 1979 a Work Group was formed, which produced in January 1982, in bulletin form, "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Structures in Ice Environments". After industry review and substantial revisions, the document was issued in 1988 as API RP 2N.

By the late 1980s and the 1990s, as it became obvious that the future of the Gulf of Mexico lay in deep waters, renewed efforts were put into floating structures and associated technology. After completion of the API RP 2T, other documents were developed addressing stationkeeping systems and components (API 2SK, API RP 2SM). These were complemented by the publication, in 2001, of API RP 2FPS, "Recommended Practice for Planning, Designing and Constructing Floating Production Systems".

### **Going abroad**

As suggested by the many references to the 1970s, this decade heralded many a major change in the offshore industry. None was perhaps as significant as the rapid development of the North Sea petroleum province, fueled by increasing oil prices, significant discoveries and the ability to move to deeper waters economically. To a less dramatic extent, the industry expanded also in other geographic areas, the Middle East, the Far East, and Brazil among others.

Initially, for lack of suitable design standards in the countries affected by the new developments, API RP 2A was by default used as the basis of design for structures around the world. Before the end of the 1970s, however, other standards and codes were introduced. The most notable of these were the governmental issues of the UK Department of Energy Guidelines and the Norwegian Petroleum Directorate Rules. In addition, a number of ship classification agencies were integrally involved in the offshore industry and released rules of their own, some based on API RP 2A with supplements, others completely independent. Notable in this area were the American Bureau of Shipping rules, the Det Norske Veritas rules and the Lloyd's Register rules. Later additions to the offshore design standards family came from Denmark and Canada, among others.

Still, to this day, thanks in part to the effective mechanism provided by the OSC for rapid updates and enhancements, in many areas of the world API RP 2A is being used for the design of fixed structures, either as a de facto standard or as a basic document, supplemented by suitable additions or extensions.

### **The LRFD version**

In the late 1970s, while the day to day offshore platform design work in the US (and largely in the rest of the world) was still based on the traditional WSD approach, the API OSC

initiated development of a design document based on a partial safety factor philosophy. This strategic decision intended to take advantage of and reach alignment with engineering practices and enhancements underway in other nations, particularly (but not exclusively) in Europe. Denmark was the first country to implement a partial factor standard in the North Sea area.

This initiative resulted in what at the time was the longest-running single project in the history of the OSC. An industry-wide effort of over 10-year duration was required to develop the necessary technology and to perform an extensive calibration. The initial Load and Resistance Factor Design (LRFD) Draft was published in December 1989. A few years later, in 1993, API RP 2A – LRFD 1<sup>st</sup> Edition was finally issued.

The LRFD document represents an interesting paradox. It was developed essentially as a US document, with an expectation that US designers would progressively adopt it. Yet, there is no indication that any platform for US waters was ever designed in accordance with this document, as the WSD version continued to be overwhelmingly the standard of choice. Conversely, once API RP 2A LRFD was officially issued, it was quickly adopted for use in the North Sea UK Sector. After an initial transition period, during which appropriate load factors were developed, the large majority of the platforms installed in the UK Sector after 1995 was designed using the LRFD version in preference to the WSD document.

## The Tension Leg Platform RP

During the late 1970s, with the industry poised to move into deep waters (at the time, anything over 1,000 feet, or 300 m), the API OSC considered establishing a parallel stream of activities dealing with floating systems. Substantial actions were deferred until sufficient industry interest could justify allocating resources to this emerging technology.

The 1983 installation of the first tension leg platform in the Hutton field, in the UK Sector of the North Sea, provided the necessary impetus. In conjunction with the completion of the design and the award of fabrication contracts in mid-1981, the API OSC sanctioned the formation of a Task Group to develop a recommended practice for TLP design criteria. The Task Group initial meeting was held on April 27, 1982. A consensus was reached to tailor the document to the needs of the designer, to utilize the WSD approach, and to focus on those aspects of technology that were considered unique to vertically moored structures.

Breaking with traditional practice, the U.S. Mineral Management Service, United States Coast Guard and the American Bureau of Shipping were invited to participate in the development of the recommended practice.

The activities connected with the TLP RP represented probably the largest, high-intensity single project (in human

resource terms) promoted by the OSC. Work continued for the next 4 years. During this time the Task Group was raised to the rank of Subcommittee, and expanded to encompass 11 Work Groups, involving well over 100 professionals. The end product consisted of three documents submitted for ballot approval in 1986. In addition to the API RP 2T, “Planning, Designing, and Constructing Tension Leg Platforms,” the TLP Subcommittee proposed the publication of two supporting bulletins dealing with generic aspects of structural design, specifically, API BUL 2U, “Stability Design of Cylindrical Shells”, and API BUL 2V, “Design of Flat Plate Structures”.

All three documents were approved by general ballot and published in April of 1987, exactly five years after the initial meeting.

## Platform reassessment

In 1984, the passage of hurricane Andrew through the heart of the Gulf of Mexico offshore producing area and its effects on many offshore platforms set off an initiative by the OSC to introduce a consistent and well-tested process for assessing existing platforms, and ensure their fitness-for-purpose.

This effort involved most segments of the industry, owner/operators, contractors and consultants alike. The end result was a new section of the RP 2A, “Section 17”. Initially published in 1994, as a supplement to API RP 2A WSD 20<sup>th</sup> Edition, Section 17 was later fully incorporated in the API RP 2A WSD 21<sup>st</sup> Edition.

This groundbreaking work represented a major contribution to the advancement of the offshore technology in many ways, but possibly none quite as significant as the introduction of “exposure categories”. Though not the first offshore standard to propose the use of different design conditions and criteria for different levels of consequence, as both the Norwegian and Danish standards had previously proposed similar concept, Section 17 has the distinction of being the first to do so in the US design practices.

## Today – A comprehensive portfolio

Thirty-six years after the initial organizational meeting, the API OSC can boast a remarkable record of accomplishments. A considerable number of documents has been published. Several documents have had numerous revisions and enhancements. A few documents have been transferred to other API Committees. Others, after serving their original purpose, were withdrawn or superseded by new ones. The total number of active documents is currently 25, and the complete list is presented in Table 1.

The present document portfolio covers, in full or in part, the planning, design and construction of most types of drilling and production platforms currently in used in the US and worldwide, from bottom-supported offshore platforms (conventional template-type structures, guyed towers,

compliant towers, gravity structures) to floating structures such as TLPS and FPSOs. The design of major subsystems such as foundations, stationkeeping catenary systems or vertical moorings is also extensively covered. Arctic systems addressed include pile-supported, gravity, ice, earth-fill and hybrid structures.

Furthermore, the API OSC and the associated Work Groups provide an industry-wide forum for the exchange of ideas, identification of research needs and the establishment of priorities. The standardization activities provide also a very valuable channel to allow regulatory bodies to have input to the development of standards. Such input has resulted in an efficient mechanism for identifying strategies in the best interests of all parties involved.

### API RP 2A WSD – 22<sup>nd</sup> Edition

As agreed at the October 2004 meeting of the OSC, the API RP 2A WSD 22<sup>nd</sup> Edition will see substantial changes, in the intent not only to enhance its contents, but also to simplify the future document enhancement and maintenance effort.

According to the current plans, API RP 2A WSD 21<sup>st</sup> Edition will be subdivided into three separate documents:

1. A new document, named API RP 2SIM “Structural Integrity Management”. This will contain a number of changes, enhancements and expansions of Section 17 of the previous edition. More details on the scope and the extent of this document are presented in OTC 17699.
2. A new document, named API RP 2FB “Fire and Blast Assessment”, which will provide new guidelines on the analysis and design of offshore platform topsides. Details on this subject are given in OTC 17700.
3. The API RP 2A WSD 22<sup>nd</sup> Edition, from which both Section 17 and most of the material related to the fire and blast analysis and design will be removed. This document will contain substantial revisions to the provisions relative to strength and fatigue performance of tubular joints. Details on these topics are presented in OTC 17236, OTC 17310 and OTC 17295.

The publication of API RP 2A WSD 22<sup>nd</sup> Edition is planned for 2006.

### Acknowledgements

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thank their respective employers for permission to publish this paper.

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**Table 1**

<b>API Offshore Structural Committee Documents</b>		
RP	2A-LRFD	Planning, Designing and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design
RP	2A-LRFD-S1	Supplement 1 to Planning, Designing and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design
RP	2A-WSD	Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design
Spec	2B	Fabrication of Structural Steel Pipe
Spec	2C	Offshore Cranes
RP	2D	Operation and Maintenance of Offshore Cranes
Spec	2F	Mooring Chain
RP	2FPS	Recommended Practice for Planning, Designing, and Constructing Floating Production Systems
Spec	2H	Carbon Manganese Steel Plate for Offshore Platform Tubular Joints
RP	2I	In-service Inspection of Mooring Hardware for Floating Drilling Units
RP	2L	Planning, Designing and Constructing Heliports for Fixed Offshore Platforms
Spec	2MT1	Carbon Manganese Steel Plate with Improved Toughness for Offshore Structures
Spec	2MT2	Rolled Shapes with Improved Notch Toughness
RP	2N	Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions
RP	2RD	Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
Bull	2S	Design of Windlass Wildcats for Floating Offshore Structures
RP	2T	Planning, Designing and Constructing Tension Leg Platforms

Bull	2U	Stability Design of Cylindrical Shells
Bull	2V	Design of Flat Plate Structures
Spec	2W	Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing (TMCP)
RP	2X	Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Technicians
Spec	2Y	Steel Plates, Quenched-and-tempered, for Offshore Structures
RP	2Z	Preproduction Qualification for Steel Plates for Offshore Structures

**NOTES:**

RP = Recommended Practice

Spec= Specification

Bull= Bulletin