DESIGN, FABRICATION AND INSTALLATION OF FIXED OFFSHORE PLATFORMS IN THE ARABIAN GULF

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ABSTRACT: This paper briefly describes the design considerations of an offshore platform as practiced by Saudi Aramco and the terminology used. It highlights the design loads and forces, fabrication and assembly procedures and explains the quality control using different methods of testing at the fabrication yard. Also it describes the load-out, transportation and installation procedures of a fixed offshore platform in the Arabian Gulf.

1. INTRODUCTION

Offshore marine facilities are very important to Saudi Aramco operations. In fact, one third of the oil produced in Saudi Arabia comes from the offshore fields. In order to maintain crude production, Saudi Aramco must continue drilling new wells and therefore new offshore platforms are required to support these wells. Offshore structures are universally designed for functional purposes based on rational and empirical design data. The need for a fixed offshore structure is usually specified as a requirement at a designated offshore site for an operational deck carrying a prescribed minimum weights and loading conditions. The choice of the type of structure to support this deck in an economical way depends primarily on the environmental and local site conditions and to a lesser extent on loadout from the fabrication yard, transportation and installation procedures. Environmental conditions normally include the maximum wind, current and waves likely to be experienced by the structure. Local site conditions involve the water depth and sea floor characteristics including geological conditions.

Most of the fabrication occurs in a construction yard onshore adjacent to water. Platforms are constructed in accordance with the design drawings. The majority of structural members used in steel platforms are tubular made of rolled plates and welded together to make up the required modules forming the structure. Inspection and testing are conducted throughout all stages of construction. This is performed to confirm compliance with the specified requirements (i.e., welding quality control, application of coatings for corrosion control, tolerances, etc.).

After completion of fabrication, the jacket and other components of the platform are loaded out to the barge. The various components of the platform are fastened on the deck in preparation to be transferred to the installation site according to the designed plans. On-site installation involves positioning the jacket in-place, pile driving, placing the deck structure and welding all these components into a single unit.

2. PLATFORM TYPES

Over the sixty or so years since Saudi Aramco was founded and since oil production began from beneath the Arabian Sea, fixed platforms with a steel template had been the main type of structures built and installed. A Template Platform mainly consists of a *jacket structure*, the top-side known as the *deck* and the *piles*, Figure 1. The jacket consists of prefabricated tubular steel legs which extend from the mudline to a predetermined elevation above the waterline. The legs are framed together with smaller tubular members known as chords and braces. The jacket is fixed to the seafloor by means of piles which are driven through the jacket legs to the necessary penetration below mudline. The deck above the jacket is designed to carry the design loads and consists of floor beams, girders and trusses. Where the deck space is not covered by a module, the floor area is covered with steel plates. The deck weight and loads are supported by the piles. By world standards, Saudi Aramco offshore platforms are considered to be in relatively shallow water ranging from 15 feet (4.6 m) to 180 feet (54.9 m).

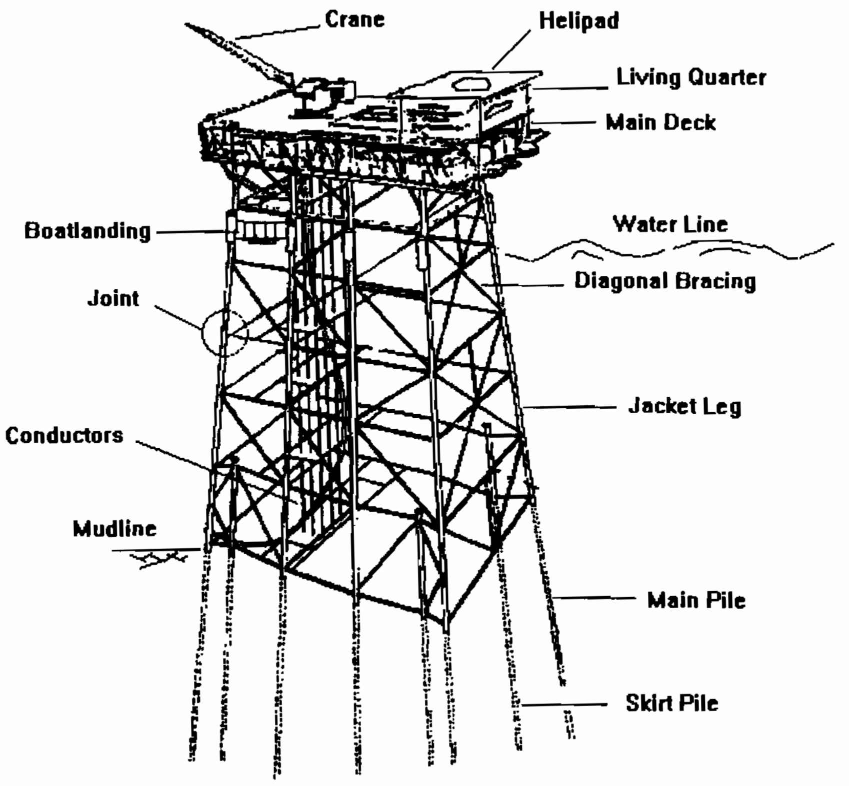

Figure 1- Template platform

Other types of platforms being used around the world are:

- Concrete Gravity Platforms
- Tension Leg Platforms
- Guyed - Tower Platforms
- Ice - Resistant Platforms

Functionally the platforms are divided into the following types:

- Development Well Platform: This is built to protect the risers on production wells from ship collisions and environmental forces. It supports flowline risers, conductor tubes, boatlanding, etc. It is usually installed prior to drilling and it may have a helipad.

- Tie - In Platform: This serves as the connecting platform to which many flowlines are connected from neighboring well platforms and from which a trunkline connects with the production platform.

- Production Platform: This type is usually designed to support different equipment and utilities (i.e., compressors, storage tanks, etc.). It is basically a platform for separating the oil-gas-water mixture of the crude petroleum into crude oil, natural gas and water and treating each one of these prior to transportation.

- Auxiliary Platform: This is usually used to increase the space available and to support compressor stations, oil storage, etc.

- Accommodation Platform: This usually provides sleeping and living accommodation for the crew and is built near the production platform and ties into it by a bridge.

Any two neighboring platforms can be joined together by catwalks. A catwalk may serve as a bridge for pedestrian crossing, as well as for material handling and supporting pipelines.

3. ENGINEERING DESIGN CONSIDERATIONS

After identifying the need for an offshore structure, specifying the location, evaluating the environmental and the site local conditions the project will be evaluated in terms of economics and feasibility. Preliminary and detailed structural design follows in accordance to preset Saudi Aramco design standards and industry codes and practice. Some of these standards are :

SAES - M - 005	Design and Construction of Fixed Offshore Platforms.
AER - 2359	Arabian Gulf Hindcast Study.
API - RP2A	Planning, Designing and Constructing Fixed Offshore Platform (American Petroleum Institute).
AISC	Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings (American Institute of Steel Construction).

The engineering and technologies involved in offshore platform design are:

- Oceanography- Which is used to evaluate the local environmental conditions such as wind, wave, wave surge, current and tide.

- Geotechnical Engineering -Which provides the soil characteristics, foundation design and pile design and the required number of piles.

- Structural Engineering - Which includes material selection for corrosion control, static and dynamic structural design, stress analysis, fabrication and installation.

- Naval Architecture - Which is involved in the evaluation of sea transportation, flotation, towing, launching and controlled flooding.

4. DESIGN LOADS AND FORCES

The platform is subjected to different loads and forces during its fabrication, loadout, transportation, installation and operation under normal and extreme operating conditions. During the design life of the platform, it should withstand all the imposed loads and forces and resist dynamic loading and any fatigue damage. It is designed for the appropriate loading conditions which will produce the most severe stresses on the platform, as listed in Table 1.

Table 1. Loading Combinations [1]

	Loading Combination			
	A	B	C	D
Dead Weight	x	x	x	x
Live Loads - Floor	x	x	x	
- Operating	x	x		
Equipment & Piping Loads:			x	
- Operating	x			
- Hydrotest		x		
- Empty				x
Environmental Conditions:				
- Operating (1 yr recurrence)	x	x		
- Extreme (100 yr recurrence)			x	x

The forces which should be considered acting on a platform are define in API-RP2A [3] as:

1. **Dead loads**: Are the weights of the whole structure including the jacket, deck, grating, piping, boatlanding, cathodic protection anodes and the weight of any other permanent equipment which does not change with the mode of operation. Tubular members should be considered buoyant or flooded.

2. **Live loads**: Are the loads imposed on the platform during its operation in addition to the dead loads. Live loads may change either during a mode of operation or from one mode of operation to another. Live loads may include impact loads, crane operation, dynamic amplification and helicopter loading. In the absence of more specific requirements, the minimum live loads listed in Table 2 should be used.

3. **Environmental loads / forces**: Depend on environmental conditions and naturally differ from one location to another. Environmental loads are very important in the design of offshore platforms and include wind, wave and current and tidal forces. AER - 2359 (Arabian Gulf Hindcast Study) is used to determine environmental loads. The worst combination of wave height, current velocity and wind speed for a given directional sector is used to determine the maximum environmental loads acting on the platform. In general, prevailing storms occur from the north west direction giving 3 second gust wind speed of up to 64 knots with wave heights up to 36 feet (11 meters) [2] . Other environmental effects to be considered are vortex shedding and scour.

4. **Fabrication, loadout, transportation and installation forces**: Fabrication and assembly guidelines and procedures need to be strictly followed to prevent cracks in the welds and to reduce stress concentration due to misalignment and welding. Forces occurring during loadout and lifting, such as lifting with unequal slings and the effect of cargo barge motion are considered to ensure that the structural members can withstand these forces.

5. **Earthquake forces**: The Arabian Gulf is considered to be a non-active seismic zone, therefore no earthquake forces are considered.

Table 2. Live Loads on Deck Beams, Plates & Grating [1]

	ALTERNATIVE LOADS	
	DISTRIBUTED LOAD	CONCENTRATED LOAD
Deck plate and grating except accommodation platforms and walkways	200 lb/sq. ft (10 kPa)	500 lb (2250 N) over 1 ft x 1 ft area
Deck beams on all platforms except accommodation platforms	200 lb/sq. ft (10 kPa)	45000 lb (10000 N) over 3 ft x 3 ft area
Deck beams, plate and grating on accommodation platforms	100 lb/sq. ft (5 kPa)	5000 lb (22500 N) over 3 ft x 3 ft area
Walkways for connecting bridges catwalks, personnel, etc.	50 lb/sq. ft (2.5 kPa)	500 lb (2250 N) over 1 ft x 1 ft area

5. **Fabrication**

Before starting fabrication, the required material such as steel plates, tubular and wide flange sections, etc., is ordered . All structural components need to be free of defects and excess mill scale and rust. Mill certificates, indicating strength, ductility, notch toughness etc., need to accompany the material and any unidentified steel is not used. Steel should conform to a definite specification and to the minimum strength specified by the designer. Usually at least two grades of steel are used: low-carbon structural steel and high-strength, low-alloy steel. Fabrication is carried out according to the fabrication drawings which include detailed descriptions, thicknesses and dimensions of all structural members.

Tubular members are prepared in the fabrication shop where they are cut to the required length and the proper bevel. Cutting is performed with manually controlled or programmable cutting torch. The jacket is usually constructed on two parallel skid runners laid on leveled ground over foundations strong enough to hold the weight of the jacket after completion. First the jacket legs at one bent are joined together by welding the tubular chord and brace members in a horizontal position and then the completed frames are lifted by cranes into the vertical position and joined to other bents of the jacket. Attention is given to tolerances, alignment, roundness and straightness.

While the jacket is being fabricated, other members and structures are also being fabricated such as the deck, piles, handrails, boatlanding, padeyes, etc. The deck, which is an important part of the platform, might be fabricated at the same fabrication yard or at another location. Usually the deck consists of trusses laid out in rows and joined together by beams and girders normally made of wide flange sections. The deck floor which is not covered by modules is covered by steel plates. Dimensional control should be carefully exercised to ensure proper measurement of the distance between the stabbing guides to ensure proper alignment on top of the jacket during installation. Piles are made of high strength tubular steel sections. These sections are welded end to end to form the required length of the pile. The pile section length depends on the lifting capacity of the installation crane. The total pile length depends on the required pile penetration, which may be as much as 200 ft. (61 m).

Careful attention is given to welding of the tubular members. Welding procedures are written in accordance with the applicable provisions of the American Welding Society (AWS) and pre-qualified welders are used. Methods of improving the welds include: preheating, postheating, proper joint preparation, stress relieving and weld profiling.

Inspection of the material is performed to verify that it is of good quality and in accordance with the specified requirements. Inspection of the structure is performed during all phases of fabrication (i.e., prefabrication, rolling, welding, assembly, etc.). Welding inspection is performed through all phases of fabrication to identify any defects in the welds. Beside visual inspection of the welds, they are also inspected by means of nondestructive methods such as dye penetrant technique (PT), ultrasonic testing (UT), magnetic particle technique (MT) and radiography technique (RT).

All steel surfaces on the deck are coated in accordance with Saudi Aramco standard SAES-H-001 (Selection Requirements for Industrial Coatings). In the splash-zone area, monel sheets are used to provide corrosion protection to the jacket legs where as structural members below water level are cathodically protected. [4]

6. **Loadout, Transportation and Installation**

After completion of the fabrication of the jacket, decks and other substructures they are loaded out to a cargo barge in preparation to be transferred to the specified location offshore for installation. The jacket is usually transferred to the barge by means of trolleys or by sliding on skids. The cargo barge is ballasted so that the skid runners on the barge align with those on the quayside. The barge tanks are continually deballasted to maintain proper alignment with the skids. The decks, boatlanding, piles and other loose items are lifted to position on the cargo barge. Once all the components are on the barge, they are tied to the barge deck plating by seafastenings to prevent their shifting while in transit. These seafastenings are designed to withstand the forces predicted for the barge motion and made so that they can be easily removed once they arrive at the location.

Once the cargo barge is at the installation site, the seafastenings are cut and the jacket is lifted off the barge by the crane and lowered into the water. The jacket is lowered into position over the sea bed and leveled as specified in the installation plan.

Once jacket is leveled, main piles are installed inside the jacket legs and driven, by steam or diesel hammer, to refusal or to the predetermined penetration to develop adequate capacity to resist axial and lateral loads. Skirt piles are installed if additional supports are required by design. After all piles are installed, the annular space between the piles and the jacket legs are filled with grout. The pile ends extending out the tops of the jacket legs are cut off and welded to the jacket legs. After that, the deck is lifted into position on top of the jacket and the stabbing guides are welded to the pile ends. After deck installation is completed, all remaining substructure (i.e., boatlanding) are installed.

ACKNOWLEDGMENTS

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