Protective coatings are ubiquitous on offshore oil structures. As with most situations, the use of coatings is driven by myriad factors unique to the industry. The paper will provide an overview of the types of structures, the coatings used in different zones of the structures, and the pragmatic and regulatory criteria which influence the coating process.

The Offshore Oil and Gas Industry

Approximately 30% of the US domestic oil production and 20% of the domestic gas production is generated from the outer continental shelf (OCS). By far the majority of that production is in the Gulf of Mexico. The remainder of US domestic production is in the Pacific and Alaska regions (which have similar production levels) and the Atlantic region (which is a distant fourth in terms of production). Beyond the current production, OCS resources are projected to contain the majority of undiscovered gas and oil in the United States. The OCS Lands Act (Title 43, Chapter 29 of the US Administrative Code) required the Department of the Interior to manage Federal offshore lands used for oil and gas production. The DOI determines the size, timing and location of areas to be used and ensures that the US Governments is fairly compensated for acreage made available through leases. Importantly, the DOI is also charged with responsibility to protect the environment and ensure that the offshore activities operate safely. The DOI carries out these operations through the Mineral Management Service (MMS). The MMS Offshore program coordinates the extensive offshore production activities. The key mechanism includes frequent Notices to Lessees and Operators (NTL) as well as the Federal Administrative Record (FAR).

Extensive infrastructure is required to support the offshore production industry. There are more than 6500 offshore oil and gas installations in some 53 countries around the world. More than 50% of these installations are in the US Gulf of Mexico. The next five largest areas in descending order are Asia, Middle East, North Sea, West Africa coast, and South America. These six regions account for the majority of the existing offshore oil and gas installations. The installations are built for exploration (drilling) and production (including preparing water or gas for injection, processing oil or gas, cleaning produced water for disposal, and various accommodations). There are several types of drilling rigs including:
- Jackups – usually towed to a location after which the legs are lowered to the seabed and the hull is jacked above the sea surface.

- Drill Ships – look like ordinary ships with a derrick on top which drills through a hole in the hull. They can be anchored or positioned with computer-controlled propulsion systems.

- Submersibles – can be floated to shallow water locations and ballasted to sit on the seabed.

- Semi-submersibles – have the superstructure supported on a hull or pontoons which are ballasted below the water surface.

Once the drilling rigs have completed their work, they are generally replaced by production platforms. Production platforms vary in size and shape, but generally contain accommodations for larger crews and the various production processes required to extract the oil or gas and render it suitable for transport. Sometimes smaller, satellite platforms will be situated around a larger production platform. Production platform types include:

- Fixed production platforms – typically constructed of steel and attached to the seabed with piles.

- Floating Production Storage Offloading (FPSO) and Floating Storage and Offloading (FSO) vessel – either anchored or tethered.

- Tension Leg Platform (TLP) – typically used in deepwater applications, these platforms are built from steel or concrete and anchored to the sea floor with vertical “tendons.”

Other supporting infrastructure for the offshore oil and gas industry includes the ships and aircraft which transport people and supplies to the platforms and pipelines which transfer the product back to refineries and other users on shore. For the purposes of this paper we will focus on coatings used for the offshore structures themselves.

**Considerations for Corrosion Control**

Perhaps the most obvious consideration for corrosion control of offshore structures is the marine environment in which they operate. An offshore platform has significant exposure in seawater immersion, splash zone, and salt air. Corrosion of steel in these environments can be greater than 100 mils per year. Corrosion rates are highest in the splash zone as illustrated in figure 1. In addition to the marine environment, offshore platforms have areas subjected to severe abrasion and highly corrosive water chemistries. For floating structures, ballast tank interiors comprise a significance portion of the coated surface.
Since offshore platforms appear similar in many respects to ships, it might be anticipated that much of the corrosion control design would be similar. Indeed, most coating systems are heavy duty epoxies which are also common on ships. Inorganic zinc pre-construction primers are used in new construction, and may be repaid and kept depending on the design philosophy of the owner. Cathodic protection is typically used below the waterline. However there are some substantial differences between the operating environments for ships versus offshore platforms. For example, once located at sea, offshore platforms rarely come back to port for maintenance whereas a ship is frequently drydocked. Offshore platforms do not usually have the same weight consideration as ships, allowing the use of sacrificial cathodic protection as the sole method of corrosion control for the underwater portions in some instances. Even among offshore platforms, different design considerations exist. Weight reduction is a more important issue for FPSO’s than fixed structures.

Corrosion control on offshore structures commonly includes the following five approaches (though this paper will focus on the use of coatings):

- No Protection (wastage allowance)
- Protective Coatings
- Cathodic Protection of Bare Steel
- Cathodic Protection of Coated Steel
- Corrosion Resistant Metallic or Plastic
Corrosion Control Coatings

In the early days of offshore oil and gas production (1940’s – 1950’s) protective coating systems typically consisted of vinyl or chlorinated rubber coatings. The typical system for the atmospheric exposed areas was multiple coats with a total build of 250-300 microns (10-12 mils). With time, inorganic zinc silicate primers were incorporated into the systems as well as epoxy intermediate coats. These systems were used for several decades with good results – indeed, inorganic zinc/epoxy/urethane systems are still used today. Underwater and splash zones typically were protected with a thicker system such as 12-20 mils of coal tar epoxy.

Current technologies include the use of organic zinc-rich primers, higher build epoxies, and polysiloxane coatings. The transition to organic zinc-rich primers (predominately epoxies but also moisture cure urethanes) has been driven by cost and schedule considerations. Organic zinc primers are less expensive than zinc silicates and can be applied under a broader range of environmental conditions. Higher build epoxy intermediate coats have a number of environmental, production and performance benefits. The higher build formulation typically had lower VOC and HAPS than more solvent laden counterparts. The high build requires fewer coats to achieve the required thickness and retains film build around sharp edges. Polysiloxane coatings are formulated to provide a durable surface that is resistant to abrasion, wear, and weathering.

Recently there has been some use of thermal spray aluminum (TSA) coatings on offshore structures. TSA can be a high performance coating system but does not appear suitable for all areas of the structure. Specifically, in immersion areas the TSA will act as an anode and sacrifice itself to protect exposed steel. Even at thick builds of 10-15 mils, the sacrificial action will quickly consume the TSA coatings, leaving bare steel. The bare steel left behind increases the galvanic reaction on the remaining TSA.

Coating Evaluation and Maintenance

Corrosion of offshore structures results in a significant operational cost to the operators and/or owners of the structures, especially as the structures age. An assessment of the relative effectiveness as well as costs is central to investment decisions concerning life extension and integrity management for older structures. MMS recognizes the importance of corrosion and corrosion control as part of the overall maintenance effort. While MMS does not evaluate structures to the level of detail required for effective maintenance management, they regulate inspection through the requirements outlined in API RP-2A, Recommended Practice for Planning, Design, and Constructing Fixed Offshore Platforms. API RP 2A requires annual inspection of protective coatings, cathodic protection, and other corrosion control systems. There are various interpretations of the requirements, but they typically contain the following characteristics:
Multiple levels of inspection including basic visual inspections with more sophisticated testing (UT, Radiographic) as required.

An inspection effort sufficient to identify imminent safety hazards, critical areas of concern, and prioritize needs on the remainder of the structure.

Use of a relatively simple grading system with extensive visual and written documentation to support and archive the findings.

Maintenance of offshore structures includes a number of challenges unique to the physical environment in which the work takes place. Perhaps most significantly, the logistical requirements of working in confined quarters at a remote location place great pressure on highly visible operations such as coatings maintenance. If challenges arise on the job, the stresses placed on the relationship among the paint crew, inspector, and facility manager (owner) can be magnified by the fact that they must live and work together for 24 hours per day for several weeks. The remoteness of the work location makes it extremely difficult to change out personnel, get additional supplies and equipment, or defer decisions up the “chain of command.”

Of course, platform operations and other maintenance activities are being conducted concurrently with coatings work. This limits the accessibility, requires efficient sharing of resources, and may require the work area to be isolated from other activities. As a result, planning and coordination are critical to minimize wasted resources. Once a work crew and equipment are mobilized to the platform the owner will pay for those assets until they return to shore. If the work cannot be executed as planned due to weather or other complications, contingency plans involving alternate work options should be executed. Note that these plans cannot be made on an ad hoc basis, substantial planning is required to ensure that the proper tools and materials are available for the contingency work.

Planning an offshore project begins during “load-out,” long before the crew arrives on-site. It is tremendously helpful if the inspector, paint crew and owner discuss issues early in the mobilization process. If possible, they should agree that the equipment being taken to the platform is sufficient and in working order before it leaves shore. Coating materials and other supplies sufficient for the planned work and any contingency work should be inventoried during mobilization to minimize the downtime once work begins.

Conclusion

Offshore structures are unique environments in which to perform coating work. The critical nature of corrosion control requires that protective coatings are properly monitored and maintained. Because much of the work is performed remotely, the cost of downtime and rework is considerably more than might be experienced on other coatings projects. As a result, planning and coordination become even more critical to successful, cost-effective projects.