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DECOMMISSIONING OF OFFSHORE STRUCTURES: CHALLENGES AND SOLUTIONS

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Abstract. *Removal of abandoned offshore structures represents technical and economical challenges to companies in the oil and gas industry companies especially with the increase in environmental awareness worldwide. This paper addresses technical issues related to the removal of abandoned offshore structures and highlights possible removal options.*

1 INTRODUCTION

The first fixed offshore platform was built in 1947 in the Gulf of Mexico (GOM) in a 5 m water depth and 20 km distance from shore line[1]. Since then, thousands of platform structures had been built worldwide. At present, there are more than 6,800 offshore structures installed in 53 countries and at least 4,000 structures are located in the United States alone, see Figure 1. Many platforms exceeded their design life and are no longer used. Many countries regulations required the operators to remove such facilities. The current rate of platform removal is about 150 per year[2]. The total estimated cost of removal of all of these structures varies between $ 25 billion to $ 40 billion, a significant sum in the petrochemical industry.

Environmental awareness plays a significant rule in limiting the future deployment of offshore structures and total removal of the existing ones. For example recent environmental regulations in California required 2,000 m water depth for steel disposing sites to be used as artificial reefs. Also, structures in less than 75 m water depth weighing less than 4,000 tons must be removed. Similarly, offshore structures designed today in less than 100 m weighing less than 4,000 tons must be made to be removed in the future. And after 1/1/1998 no offshore structures can be placed if it is not feasible to remove, while for a partial removal option, the structure needs to be removed to a 60 m below sea level to be safe the navigation traffic above the effected site[3].

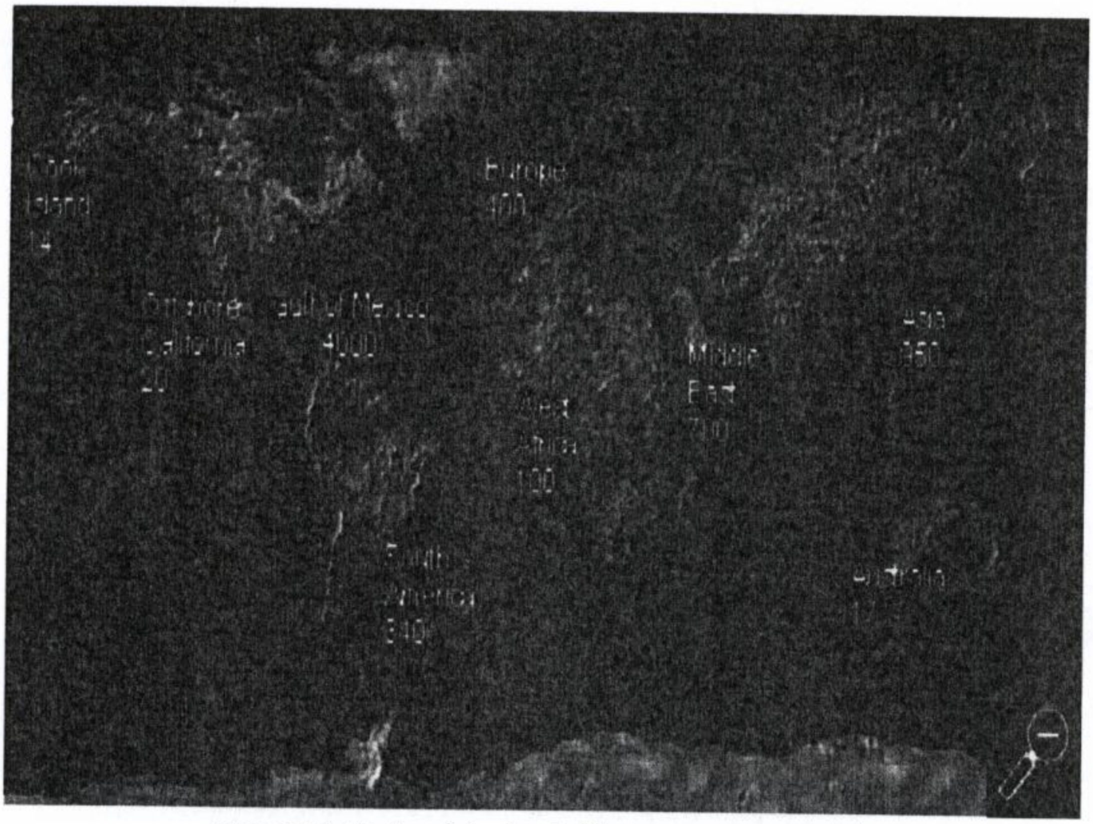

Figure 1: Distribution of abandoned offshore structures world wide[3]

2 REMOVAL OPTIONS

Abandoned offshore structures must be removed as soon as the facility quits producing or is not in service. For example, U. S. federal regulations state that abandoned structures must be removed within one year after wells are plugged and abandoned. However, total removal of the offshore structures including topside and jacket is very expensive especially in deep water. Thus, offshore structural and construction engineers have come up with other alternatives to minimize expenses on abandoned facilities that are not generating cash. These options are reviewed in the following sections.

Before addressing the removal options, it might be suitable to talk about the factors playing important rule in determining the removal options. The most important factor in the removal option is the water depth. Thus removal of a 1,000 tons steel structure in the Arabian Gulf at water depth of 200 ft is completely different than the removal the same mass in the North Sea where water depth can reach 2,000 ft. The second determinate factor is the platform mass. Large mass requires a larger lifting vessel (LV) at a higher utilization cost. The average platform mass vary from 5,000 tons in GOM to 40,000 tons in the North Sea. At 500 tons LV cost $25,000 per day and the cost can reach up to $500,000 per day for 15,000 tons LV[4], see Figure 2. LV are available from limited sites worldwide thus, mobilization of the LV is another critical factor. An oil company may wait until it has enough abandoned platforms so that the mobilization cost per platform will be acceptable. Environmental aspects of the removal process are quite important. Thus the structure must be cleaned from any hydrocarbon materials and the cutting techniques, such as explosive cutting, must be safe to the environment. Safety of the operators, equipment and structures during the removal process is an important factor. Other decisive factors include weather and climate, legislation, and final destination of the steel structure materials.

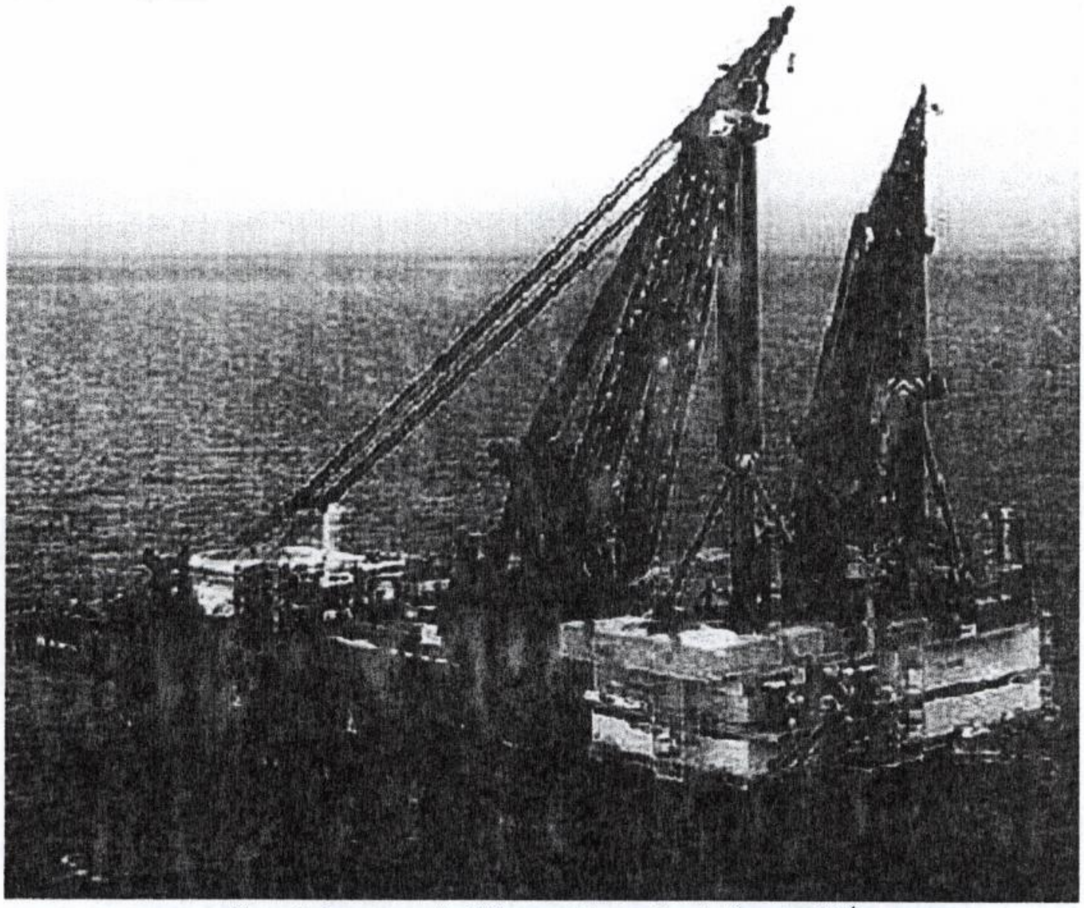

Figure 2: Large capacity lifting vessels carrying platform topside[4]

Based on statistics of platform removed from oil field worldwide, cost breakdown is as follows:

1. Cutting and lifting of topside
2. Cleaning, cutting and lifting of jacket
3. Divers for inspection, survey and logistic support
4. Cargo boats to ship scrap materials
5. Barge vessels to lift topside modules and jacket parts
6. Service and tug boats

2.1 Leave-in-place option

This option might be considered as the least expensive option when compared to other options listed below. However, the environmental impact of an existing rusted facility is not tolerable. Structures can be maintained properly by maintaining the cathodic protection underwater and using protective coating for the above-water components. However, protection against corrosion is expense and does not prevent other failures due to lack of structural integrity. An example of such a failure includes pile destruction at storm condition. Navigation lights are needed for this option which means additional operating cost.

Other drawbacks of this option include potential hazards due to accidents and collisions. However, the option of leaving a structure in place may bring back some money if the facility is accessible and can be used as recreational facilities or a sporting site. Abandoned offshore structures can also be used as emergency ports if they are structurally sound, see Figure 3.

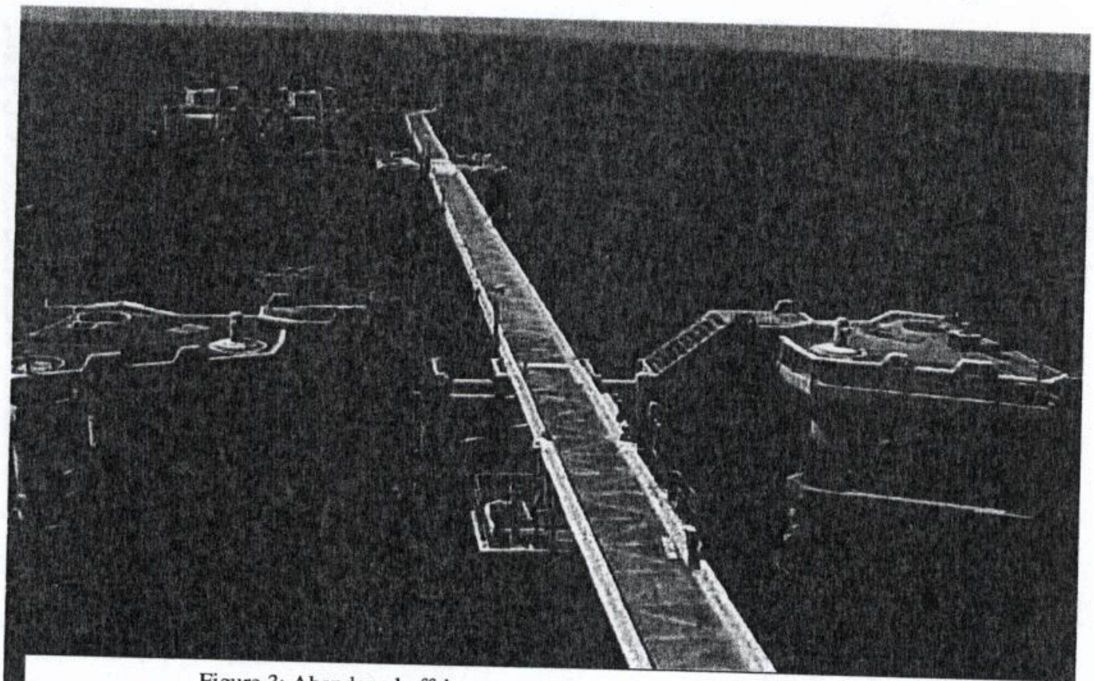

Figure 3: Abandoned offshore structures being used as emergency port

2.2 Partial removal option

Whether it is partial or complete removal, money has to be spent by the lessor of the offshore farm (operator). This money is a waste to the operator and only benefits for contractors. In this option the platform can be lifted in one piece, or as group of modules depending on the lifting vessel, total mass of the platform and time frame of the project. A decision has to be made based on economical factors regarding all at once (one piece) vs. lagged over time (several modules) options. It may turn out to be economically feasible to lease high lifting barge for a short period of time at high cost than leasing low capacity vessel at low rate for a longer time.

Cost of partial removal varies from 30% to 70% of the total removal cost depending on the percentage of the topside of the platform to the whole structure and the removal depth below sea surface. In partial removal at least the topside of the platform is removed. However, this includes removal of the deck support structures to a depth that safeguards sea navigation. Nevertheless, the potential hazard of the remaining underwater structures (the jacket) is a valid concern unless the removal depth is quite deep. If the removal depth is not safe for navigation, buoys must be maintained which is another long term expense that has to be considered in this option.

Existing structure may not be the same as the one shown in the original drawings due to project expansion, maintenance and replacement. Also, marine growth can add up to 30% of the structural weight. Special attention has to be paid to structural integrity and structural deterioration and in some cases a contractor needs to stiffen the platform before lifting it. Removal depth is a valid concern to shrimpers and fishermen because limited (reduced) trawable water affects the productivity of invested site[1].

2.3 Complete removal option

In this option all of the components structures need to be removed up to 5 m below mudline[5]. This 5m depth may represent a technical challenge to the lifting barge, thus a 1 m depth has been proposed[1]. This becomes a valid concern when using explosive charges to sever platform piles. Explosive cutting produces a bell shape structure for the effected pile and makes it harder for the lifting vessel to remove the pile from the seabed. Structures to be removed can be reused again; specially the topside, disposed to the sea bed or sold as scrap metal, see Figure 4. Recent statistics in the GOM reveal that 25% of the topsides have been resold as used platforms[6] at a salvage value 50-75% of new equipment[7].

Total removal option is always more expensive then all other options due to the high cost of lifting vessels and cargo boats. The salvage value may account to 10% of the total removal cost.

Advantages of the total removal option include: removed offshore structure poses no navigation hazards, no buoys are needed and it is environmentally safe. Like any construction project, decommissioning project has to be planned in advance and early planning prevents errors and contingencies. Engineering and planning can cost up to 4% of the total removal cost[8]. From environmental point of view, there is no sound scientific evidence supporting the idea that platforms enhance or reduce regional stocks of marine species[9,10].

2.4 Topple-in-place option

Topple in place is achieved by severing offshore pile near the seabed so that the structure will rest on its side on the sea floor. Most of the time, the crumpled structure is used as an artificial reef. In GOM over 100 petroleum structures have been converted into reefs[6]. Explosive charges can be used for cutting while no lifting vessel or a transportation boat is needed for in-place crumpling. The jacket can be winched onto its side or can be demolished in place, the later option is called demolish in place. Because no lifting vessels or cargo boats are used, this option is the least expensive decommissioning option.

The crumpled structures need to be submerged to a depth that is safe for navigation. It is highly recommended, or even required by environmental agencies to topple or tow the structures into deep water, this is called topple in a different place. If the distance above the crumpled structures and sea water level is less than 60 m, a buoy must be installed. Although the demolition option is economically attractive, in 1989 the International Maritime Organization required complete removal of all structural components in waters less than 100 m depth.

3 CUTTING TECHNIQUES

Historically, there have been many techniques in cutting tubular members of the platform and severing platform piles and conductors. The most common techniques are:

1. Hydraulically driven revolving carbide tungsten blades
2. Abrasive jet cutters using sand or water
3. Oxy-arc torches (diver cuts)
4. Hydraulic shears
5. Explosive charges

Only using an explosive charge is highlighted in this paper due to its wide application as the main cutting technique in decommissioning offshore structures.

Recent statistics show that 70% of the pile cutting in the United States and 90% in United Kingdom were done using explosives[3]. Materials such as C4 or Comp B are used for such purposes. These materials are safe to mold and handle and can be shaped to fit the pile dimension. There are two major types of explosive: bulk explosive and shaped charges. The price of shaped charges is five times the price of bulk explosives due to their effective cutting per unit mass and hence less environmental effect, see Figure 5.

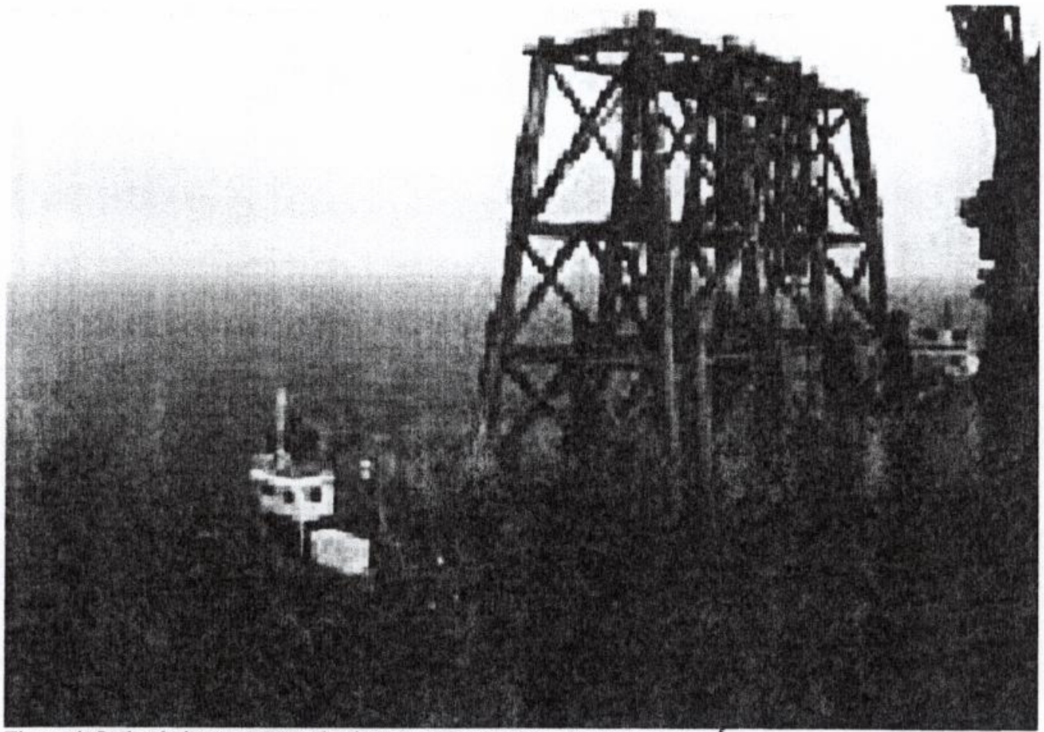
Figure 4: Jacket being transported using cargo boat to be sold as scrap steel[5]

Advantages of explosive cutting include the massive cutting power and the quick response that leads to minimal onsite operating time and minimal diver effort. The success rate is high for properly sized charge. With these advantages of explosive cutting method, it was concluded that "Explosives are economical and reliable tools for removing most structures, especially in deep water," in a report funded by U.S. National Research Council in Washington. D. C.[1].

Disadvantages of explosive cutting include, mass fish killing, shock waves can damage close pipelines or facility and can not be used in the vicinity of combustible gasses. Mass fish killing can be avoided by having early 24 hrs marine observation using acoustic and sonar equipment. To compare explosive cutting with other methods, it was found that total removal cost using bulk explosive is the cheapest option when compared to other cutting techniques[1]. See Figure 6.

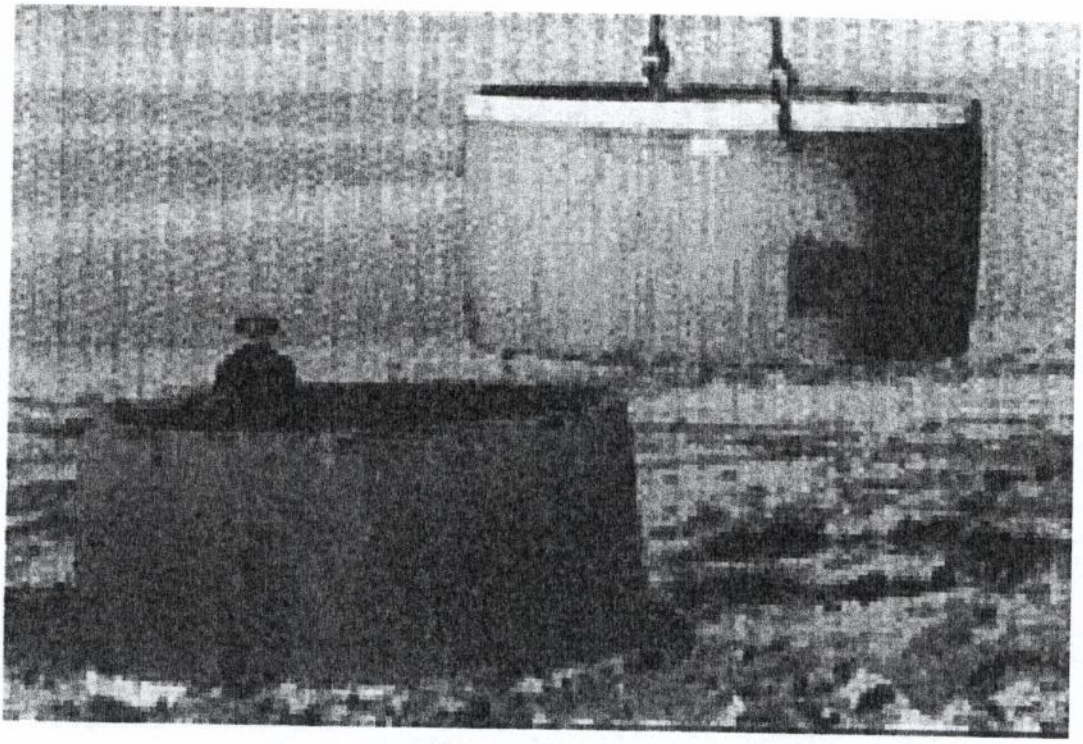

Figure 5: Pile after being cut using explosive charges at UMIST[11]

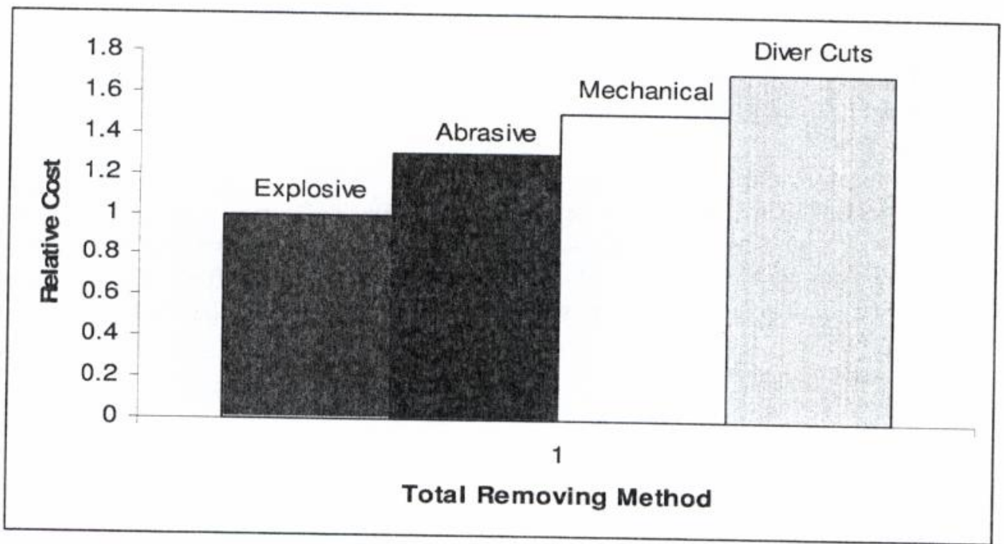

Figure 6: Relative cost for total removal option using different cutting techniques

4 COST BREAKDOWN

Based on business statistics revealed from GOM and projects such as the Odin Platform in the North Sea, the money spent on the total removal of offshore structures is distributed as follow,

1. Lifting vessels and cargo boats (60%)
2. Site clearance (18%)
3. Decommissioning (11%)
4. Mobilization and miscellaneous 7%
5. Pipe abandonment 4%

4.1 4H project

Four platforms in California water were removed in 1996[8]. These are Hazel, Heidi, Hilda and Hope. There were 138 wells plugged and abandoned. Platforms were standing in 30-45 m water depth. Explosive were used as cutting techniques. Total topside mass is 10,000 tons while the total mass is 38,000 tons. Total cost of removal is $38.5 million. Thus the cost per ton of steel is $1,000/ton. $1.6 million was spent in engineering and analysis and $1.8 million in administrative (fishermen compensation, environmental affairs). Wells P&A cost $11.9 million while mobilization and demobilization cost $ 2.9 million.

Partial removal can cost somewhere between 30% and 70% of the total removal cost. That depends on the percentage of structure to be removed, depth of removal below sea level and the percentage of topside to the total structures. Topple in place and demolition can cost anywhere between 25% for demolition in place to 50% for toppling in another location.

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