OCS Study
MMS 2004-074

Operational and Socioeconomic Impact of Nonexplosive Removal of Offshore Structures

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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1. EXECUTIVE SUMMARY

The decommissioning of offshore structures is a severing intensive operation. Cutting is often required throughout the structure above and below the waterline and mudline on braces, pipelines, risers, umbilicals, manifolds, templates, guideposts, chains, deck equipment and modules. More significant cutting operations are required on elements that are driven into the seafloor, such as multi-string conductors, piling, skirt piling, and stubs which need to be cut at a minimum of 15 below the mudline, pulled, and removed from the seabed.

A variety of technology exists to perform severance operations. These include abrasive water jet, diamond wire, diver torch, explosives, mechanical and sand cutters. For severing operations that occur above the waterline, the cutting technique selected is usually dictated by the potential for an explosion. Cold cut methods are used when the potential for an explosion exists; otherwise hot cuts are employed. Cutting in the air zone is conventional[1] since it involves methods which are regularly used for dismantling onshore industrial facilities. Below the waterline cutting is more specialized. In water depths that do not exceed 150 feet or so, divers perform cuts on simple elements such as braces and pipeline, and for shallow water structures such as caissons, torch cutting is sometimes the preferred severance method. Divers are also used to cut when other techniques produce an incomplete cut. In water depths exceeding 150 feet, remotely operated vehicles and automated diving systems are deployed with abrasive and diamond wire cutters and explosive charges. Major cutting operations on conductors, piling, and stubs normally employ mechanical, abrasive water jet, and explosive charges. Mechanical and explosive methods are primarily used for conductors with abrasive water jet and explosives predominately used for pile severance.

The decision to use explosive and/or nonexplosive methods depends on the outcome of a risk-based comparative assessment involving cost, safety, technical, environmental, and operational considerations. The purpose of this report is to describe the factors involved in the decision to use explosive or nonexplosive methods; the business, market, and contract environment of nonexplosive technology; and the environmental, physical, safety, and activity requirements associated with nonexplosive methods.

The technology of nonexplosive removal techniques and the regulatory environment in the Gulf of Mexico (GOM) has not changed dramatically over the past decade, and so the scientific and technical aspects of this report draw on the National Research Council's 1996 report [28], which provided a comprehensive assessment of removal techniques for offshore structures up through the mid-1990's. The reader is encouraged to consult [28] for additional background information. Mechanical, abrasive water jet, diamond wire, and diver torch methods are the primary nonexplosive techniques applied in the offshore environment, and each method will be discussed within the context of decommissioning activities.

The outline of the report is as follows. In Section 2, the business context of decommissioning is outlined. The management of decommissioning activities, the bid process, and the decommissioning network that operates in the GOM is described. The factors that arise in the selection of a specific severance technique are presented in Section 3. In Section 4 the size of the GOM nonexplosive severance market is estimated according to removal method, and in Section 5, the general structure of nonexplosive service contracts are described, including the formal derivation of cost functionals derived from average contract parameters. In Section 6, the science and technology of mechanical, abrasive water jet, diamond wire, and diver torch methods is described, and in Section 7, the cutting systems and activity requirements associated with each method are discussed. In Section 8, a summary of the environmental and physical impact and safety issues associated with nonexplosive cutting technology is described. The main body of the report concludes in Section 9 by presenting the issues dealing with the use of a "shallowing-up" (also called "hopping") technique to allow severing sections of the jacket in air. This applies in any situation where the jacket can not be easily lifted in one piece, as an alternative to complete removal *in-situ*. A summary of the overall conclusions for the report are presented in Section 10.

[1] Conventional but not hazard-free. All decommissioning operations are potentially hazardous to human life.

2. THE BUSINESS OF DECOMMISSIONING

2.1. THE MANAGEMENT OF DECOMMISSIONING ACTIVITIES

Decommissioning activities in the GOM are driven by economics and technological requirements and governed by federal regulation. Decisions about when and how a structure is decommissioned involve issues of environmental protection, safety, cost, and strategic opportunity, and the factors that influence the timing of removal as well as the manner in which the structure is severed from the seabed are complicated and depend as much on the technical requirements and cost as on the preferences established by the contractor and the scheduling of the operation.

Federal regulations require that all oil and gas wells and platforms are removed from a lease within one year after production on the lease ceases. The operator has essentially two options available to manage the decommissioning process. The operator can devote resources to manage the decommissioning activities within the company (in-house) or contract out the requirement to a 3rd party, which specializes in project management (independent) or provides decommissioning management as part of an integrated service package (contractor). Management options for decommissioning thus include

- an in-house project management team;
- an independent project management team; and
- a contractor project management team.

The choice of which management option to embrace depends upon the business model of the operator and the size of the operator's offshore inventory. Offshore structures have been removed for decades and most removals was accomplished by doing the work internally with company personnel or hiring an outside contractor on a day-rate basis under the operator's control. ChevronTexaco for example has over 500 structures in the state and federal waters offshore the GOM, and so it is logical that ChevronTexaco chooses to manage their own decommissioning activity to take advantage of scale economies, to ensure the quality and cost of service, to provide flexibility to their field management teams, and to maintain control over potential liability issues. In-house project management teams also establish significant experience and expertise on decommissioning activities which builds over time. For most of the other operators in the GOM, however, the detailed project management will be contracted to outside project management, since decommissioning is generally viewed as a non-core business activity.

In the standard decommissioning business model, the operator maintains the structure until it is no longer economic, and then a 3rd party plans the decommissioning activities. In an alternative business model, the operator divests the structure to a third party operator sometime *before* the economic limit is reached. In this manner, the 3rd party operator (presumably with lower operating cost) can enjoy revenue for a time before decommissioning is required, and as long as the 3rd party is financially stable and performs decommissioning activities in a sound manner, the operator can potentially transfer the liability risk and cost of decommissioning with the divestiture of the assets. However, the application of Federal regulations has the effect that the original lease holder can not avoid decommissioning liabilities if the later operator defaults. Nevertheless, by maintaining a portfolio of structures near their economic limit, it is possible for the 3rd party to schedule decommissioning activities to balance out the cash flow of the operation. Cal Dive subsidiary Energy Resource Technology, Tetra Technologies subsidiary Maritech, and Global Industries subsidiary Global Production Services are three service companies that actively seek the acquisition of mature and end-of-life properties. These companies integrate many of the facets of well P&A and decommissioning within the same company to streamline the process, provide a more cohesive safety/environmental program, and reduce removal cost.

2.2. THE BID PROCESS AND CONTRACTOR SELECTION

The manner in which decommissioning activities are performed are based upon the business model of the operator, but regardless of the business model realized, each decommissioning job requires a dedicated project management team to oversee the operation. The project management team will review the blueprints and history of the structure and send engineering personnel to the site to assess the work requirements. The project management team will then report on the options available to the operator, including the scope of work that needs to be performed and how best to prepare the bid. A Request for Quotation (RFQ) is then created. This process is shown schematically in Figure 2.1.

The project management team specifies the work requirements of the bid based upon the information available at the time. Normally, the information required to write a bid include the job specification, which would include the following: platform location, water depth, number/size/type of piles and conductors, component weights, center of gravity of major component lifts, coordinates and dimensions of major equipment, and special requests such as platform and jacket disposition, preference for severance methods, if any, and any other relevant information.

In most cases the contractor is responsible to furnish all labor, equipment, and material, including a crane vessel with sufficient capacity, cargo barges, tugs, and necessary construction equipment to perform the operation. The contractor generally will specify the severance procedure to be used in the operation and may provide various options if requested by the operator. If the operator specifies the severance method to be employed in the bid documents, this may result in the contractor qualifying the bid to transfer the risk related to severance to the operator.

Typically, a lump sum (base) bid is specified that generally includes weather downtime, except downtime due to named tropical storms for work during the prime season (May 15 to October 15). The base bid will normally assume that the contractor will dispose of all platform components and the operator will accept the cost of the National Marine Fisheries Service (NMFS) observers and aerial survey, required for use of explosives, and delays associated with the severance method specified by the operator, if any.

A lump sum optional bid may be offered. This gives the contractor the ability to quote an alternative decommissioning method not specified in the scope of work, but which still meets all specifications and goals of the job. The contractor may be required to perform extra work which is not covered in the scope of work and is not included in the base bid. If extra work is required that alters the critical path crane vessel time, the operator is charged at "extra work rates." Extra work may result from obstructions and/or bent stabbing guides in casings or piles, or anything other than soil that prevents the placement of jetting systems, explosives, cutting tools, etc. If extra work is required that does not alter the critical path crane vessel time, the operator is normally charged an hourly composite rate for all personnel and material required to correct the problem. The important point is that the *operator* normally assumes the risk and cost of uncertainty since extra work costs are passed through. The project management team acts as the representative of the operator and is responsible to ensure that the operator is treated fairly. It is therefore in the operator's interest to clearly specify the scope of the job and to perform as much planning and preparatory work as possible to minimize cost overruns.

Contractors submit their bids based upon the job specification, the supply/demand for construction services in the GOM, and the manner in which the job can be scheduled with the contractor's other work activities and obligations. For activities that the contractor cannot perform directly, the contractor will solicit quotes for additional services such as severing, diving, surveying, catering, etc., to cover required activities when preparing their bids. Some of these services may already be under contract, while other services – especially pile/conductor severance – are contracted out on a job-by-job basis. The extent to which a contractor requires subcontractor services obviously depends upon the size, experience, and financial resources of the contractor and alliance structure. Some specific services such as site clearance are required by Federal law to be performed by the operator directly.

The project management team, in consultation with the operator, examines the received bids and then selects the bid that represents the best value for the operator based upon the job specification, the past performance of the contractor, and other conditions, such as timing. After selecting the preferred contractor, it is not unusual for further negotiations to occur between the operator (via the project management team) and contractor as the job specification becomes more clearly defined. Each contract is site, time, technology and operator specific, and so it is difficult to generalize the final negotiation process that occurs. Generally speaking, the operator will try to write a contract as specific as possible to eliminate contingencies and minimize the cost/risk of unforeseen events in the operation. Contractors prefer operational flexibility, a wide time window and contingencies where uncertainty exists. Contractors prefer the operator to accept any unexpected cost/risk associated with the operation. For example, if explosive methods are used, the operator will incur all the cost associated with NMFS observers, aerial surveys, diver surveys, as well as any delays associated with the presence of sea

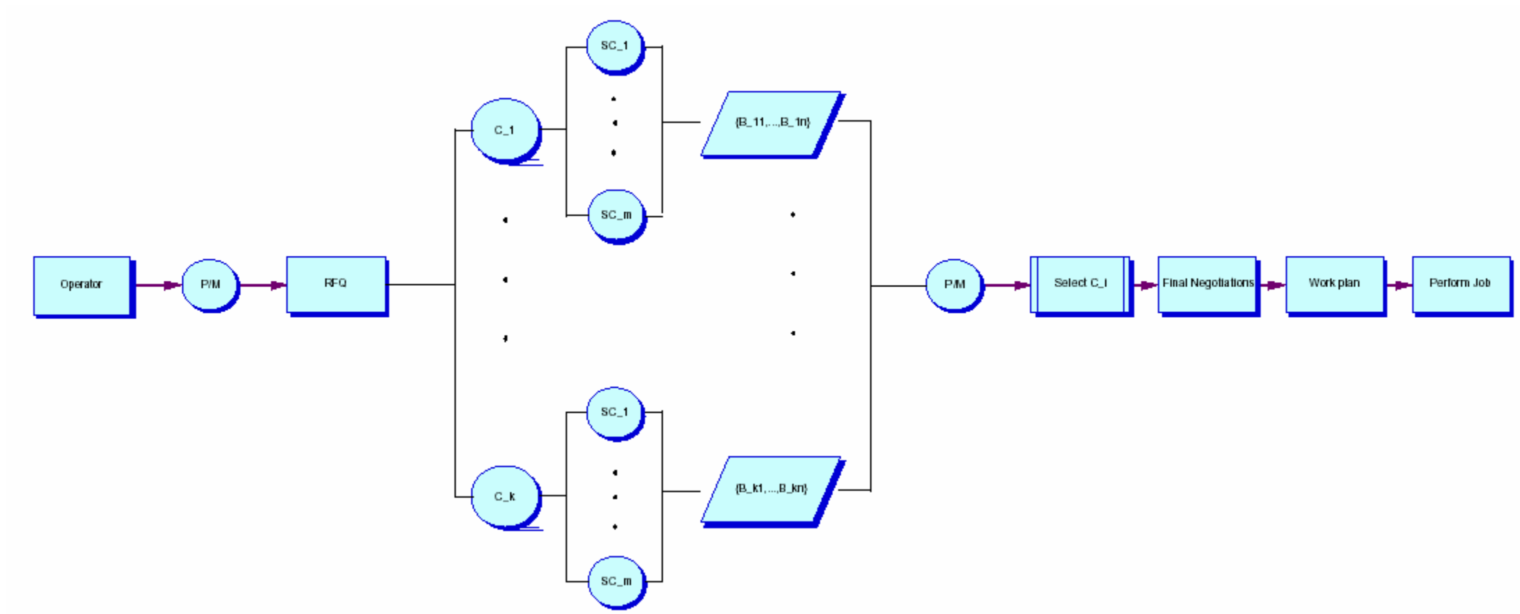


Figure 2.1. Bid and Contractor Selection Process.

turtles/mammals, night-time restrictions, pile flaring, etc. that may occur with the operation. The final negotiation is thus a give and take process based upon the contract terms, precedence, market conditions, negotiation strategy, and the history of the relationship between the operator, project management team, and contractor.

2.3. THE DECOMMISSIONING NETWORK IN THE GULF OF MEXICO

Operators, contractors, and subcontractors form the decommissioning network in the GOM, as illustrated schematically in Figure 2.2. The 140 or so operators in the GOM currently maintain about 4000 active platforms and 200 subsea completions in federal waters. The contractors involved with decommissioning include: Berry Brothers, Bisso Marine, Cal Dive, Diamond Offshore, Global Industries, Horizon, Laredo, Manson, McDermott, Offshore Specialty Fabricators, Superior, and Tetra Applied Technologies.

The characteristics of the structure to be removed, including the water depth, deck weight, jacket weight, and equipment weight determine which contractors can perform the operation based on their available spreads. Figure 2.3 shows the numbers of HLV's and contractors by lifting capacity**.** In sorting out the decommissioning vessels, the following criterion was used: Works mainly in the GOM, has a lifting capacity over 200 tons, actively bids on decommissioning work. The first two criteria were determined from the HLV list shown in Table 2.2. The third is based on past experience with HLV contractors. Lift boats and special purpose vessels were not considered. Typically, these vessels are used to decommission caissons or minimal structures in shallow waters. Contractors that are the most cost competitive can usually low bid a tender based on their ability to organize and sequence a number of different offshore activities for different operators to achieve economies of scale in their overall operation**.**

Cutting services are typically contracted out to a severance subcontractor. Cal Dive, Superior, and Tetra Applied Technologies offer both shallow water sand cutting and diver services, but for abrasive water jet, diamond wire, and mechanical cutting, contractors will seek the services of specialty subcontractors. Numerous contractors in the GOM provide diver and mechanical cutting services as part of the general requirements to prepare the wells, topsides, decks, jackets, and pipelines for removal. Cutting conductors and piling, however, is a more specialized service provided by just a few service subcontractors.

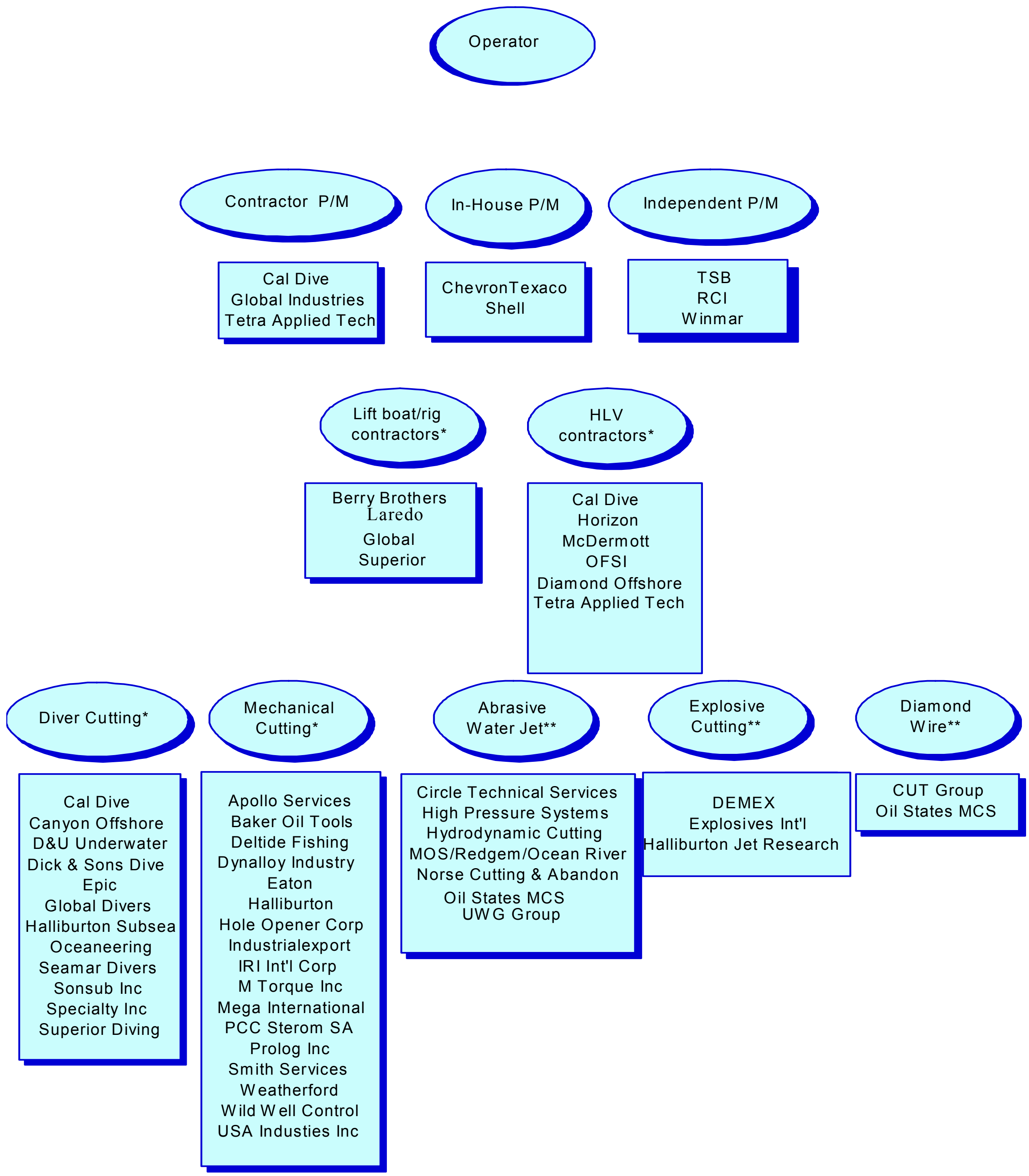
Table 2.1 provides a survey of the lift boat and heavy lift vessels (HLV) generally operating in the GOM. Table 2.2 provides a summary of HLV's and the contractors who operate them**.** *Offshore* magazine publishes a detailed summary that lists the HLV working in the GOM and includes lift boats, stiff-legs, float-over systems, revolving cranes and derrick barges. At first glance, there seems to be a large number of HLV's that work in the GOM, 86 in total.

Eleven contractors have been identified which operate 20 HLV's in the GOM, 8 of which have a lifting capacity between 200 and 500 short tons and 7 HLV's that have a lifting capacity between 500 and 1,000 short tons. There are five vessels in the GOM capable of lifting more than 1,000 tons and only one capable of lifting more than 2,000 tons. There are five other HLV's capable of lifting more than 2,000 tons but these generally work in the North Sea or the West Africa region and enter the GOM only for large projects.

2.4. NONEXPLOSIVE SEVERANCE CONTRACTORS

Abrasive cutting is a specialty service that operates within the constraints of a limited demand potential and a strong seasonal component. Abrasive subcontractors currently operating in the GOM provide a number of services in addition to cutting and represent a diverse group in terms of their ownership and financial structure, as shown in Table 2.3. The GOM is one of the most diverse and dynamic offshore service contract environments in the world and also one of the most competitive. In recent years there has been an influx of North Sea abrasive water jet contractors setting up operations further increasing the competitive nature of severance operations.

As many as seven abrasive cutting subcontractors claim to offer services in the GOM. However, only two from this group are currently active, most notably Circle Technical Services and Hydrodynamic Cutting Services. Oil States MCS was active in the GOM through 2000. The two active contractors



* Represents a sample of the number of service providers in the Gulf of Mexico

** Represents the universe of service providers in the Gulf of Mexico

Figure 2.2. Decommissioning Network in the Gulf of Mexico.

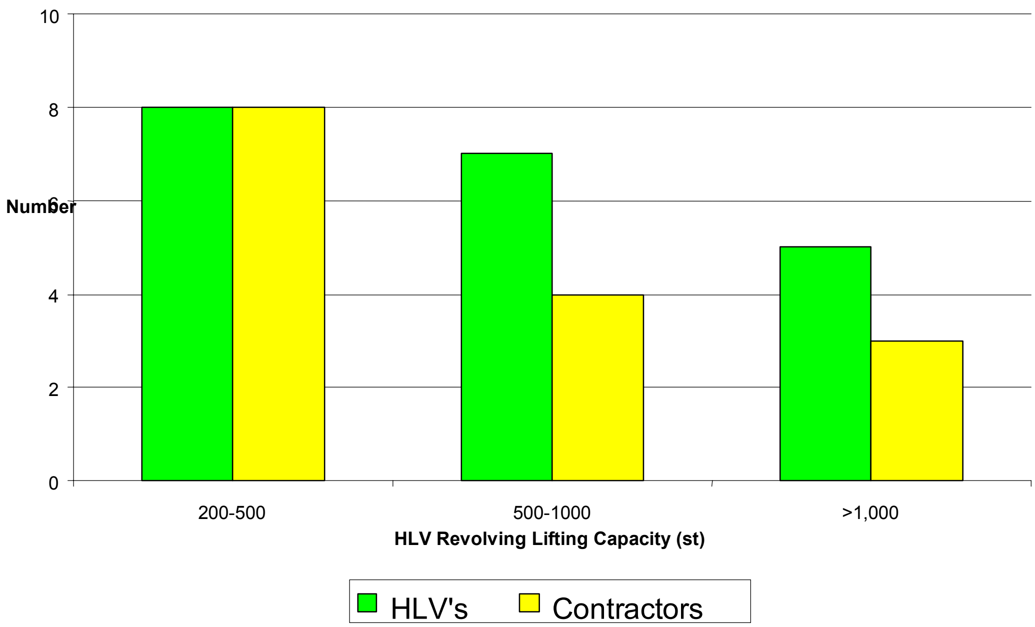


Figure 2.3. Gulf of Mexico Heavy Lift Vessels and Contractors Count.

Table 2.1

Survey of Liftboats and Heavy Lift Vessels Operating in the Offshore Gulf of Mexico (2002)

Equipment Type	Static Main Revolving Lift Capacity (st)												
	5-50	50-100	100-150	150-200	200-250	250-500	500-1000	1000-1500	1500-2500	2500-3500	3500-5000	5000-7000	7500+
Liftboats	176	10	10	3	3								
Crane Barge [a)]	3	8	1		2								
Derrick Barge					7	6	14		5	2	2	1	2

Footnote: a) Includes stiff-leg and spud crane barges.
Source: Trade journals.

Table 2.2

GOM Decommissioning Heavy Lift Vessel Summary (2002)

Contractor	Heavy Lift Vessel	Lifting Capacity (Revolving st)	Lay Barge Capability (Y/N)
Cal Dive International	Cal Dive 1 Barge	200 fixed (A-Frame)	N
Horizon Offshore	Phoenix Horizon	238	N
Bisso Marine Company	Boaz	250	N
Stolt	Hawk	250	N
Diamond Services	Diamond 85	256	N
Tetra Technologies	Southern Hercules	400 fixed (Shear Leg)	N
Laredo	Illuminator	500 fixed (Stiff Leg)	N
Manson	Wotan	420	N
Horizon Offshore	Atlantic Horizon	500	N
McDermott	DB 16	600	N
Offshore Specialty Fab	DB 1	600	N
Global Industries	Arapaho	650	N
Global Industries	Cherokee	650	Y
Offshore Specialty Fab	DB Raeford	700	N
Horizon Offshore	Pacific Horizon	800	N
Offshore Specialty Fab	S Thompson	1200	N
Offshore Specialty Fab	W. Kallop	1600	N
Global Industries	Hercules	1600	Y
McDermott	DLB 1601	1740	Y
McDermott	DB 50	3527	Y

currently have a total of five cutting spreads in the GOM. This may present a limitation to use of these services. However, if demand for the services increased, the availability of these services would also increase.

Contractors providing mechanical and diamond wire cutting services are shown in Figure 2.3. Mechanical cutting services, which are generally limited to conductors, are provided in an entirely different way than either abrasive cutting or diamond-wire cutting. The latter two services are provided as an essentially complete and self contained cutting service. In the case of mechanical cutting, the equipment and services required are generally provided piecemeal by several suppliers. For example, mechanical cutting tool suppliers generally do not provide the pumps (and operators) required to perform the cutting. Mechanical cutting is generally provided by a contractor who will hire the individual equipment and services necessary to perform the work. This is generally less efficient (and more expensive) than other methods.

Table 2.3

Gulf of Mexico Abrasive Water Jet & Diamond Wire Service Contractors

	Circle	High Pressure Systems	Hydrodynamic Cutting Services (now Well Cut)	Norse Cutting and Abandonment	Oil States MCS Ltd.	UWG Group Ltd	CUT Group	MOS
Incorporation	1990	2001	1982	1999 Norse Group	1979	1989	1999	1999
Affiliation(s)						PACT Consortium (UWG, Baker Oil Tools, Baker Atlas, Progentive Services, Team Energy Resources, Claxton Eng.) and Applied Net Technologies	SBC Consortium (TC Technospamec, University of Genoa, Hydakraft As, Montyana Eng. Services, ICCS of Athens)	Redgem Industrial Service, UK
Location(s)	Aberdeen, Scotland; Houston, TX ; Singapore, Singapore	Aberdeen, Scotland	Lafayette, LA	Tanager, Norway	Cumbria, UK Kuala Lumpur, Malaysia Arlington, TX	Norwich, UK Aberdeen, Scotland Houston, TX Kuala Lumpur, Malaysia	Norwich, UK Houston, TX	Bradford, UK Aberdeen, Scotland Houston, TX Singapore
Employees	22	12	15	15	35	50	15	35
Services	Cold cutting Diver/ROV dredging Friction stud welding Subsea maintenance	Cold cutting Tubular cleaning Pump sales	Cold cutting Jet services	Cold cutting Rigless well operations Machining	Cold cutting Diamond wire Structure leveling Pile swaging Caisson repairs Pressure testing	Cold cutting Band saw Wellhead intervention Explosive cutting Riser technology	Diamond wire Band saw Underwater inspection Pipeline engineering Dredging	Cold cutting Top deck sales
Market(s)	North Sea GOM SE Asia	North Sea GOM	GOM	North Sea GOM Middle East SE Asia	North Sea GOM Middle East SE Asia	North Sea GOM SE Asia	North Sea GOM SE Asia	North Sea GOM SE Asia
Website(s)	circletech.co.uk prpartnership.co.uk	aquastenger.com	–	norse-group.no	oilstatesmcsltd.com	uwg.co.uk	cut-group.com	moscoldcut.com

Two contractors, CUT Group and Oil States MCS, claim to offer diamond wire cutting services in the GOM. However, only CUT Group have been active in the GOM in the past work season. Diamond wire cutting is limited to external cutting, therefore limiting its application. However, it has the major advantage of not being sensitive to the section characteristics of the member being cut. It also has the advantage of being relatively easy to adjust to large or small member diameters.

2.5. THE CUTTING SEASON IS SHORT

There is a strong seasonal variability in the removal of offshore structures. As shown in Table 2.4, 80% of all GOM platforms are removed during the seven months from June-December of each year. Operators plan for offshore construction to take place during the early summer to take advantage of the normally calm seas during those months. It is important to realize that heavy lift vessel contractors are also involved with installation activities which compete directly for resources and labor during the decommissioning season.

Table 2.4

Seasonal Variation in Structure Removals in the Gulf of Mexico (1946-2001)

Configuration Type	Water Depth (feet)	Number of Structures Removed By Month												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
Caisson	0-80	52	30	13	10	34	52	53	107	91	63	88	328	921
	80-200	6	5	3	7	6	9	15	8	10	8	7	28	112
	200+									1				1
Well	0-80	15	5	5	3	6	20	13	19	23	3	8	83	184
Protector	80-200	3	2	3	6	11	9	2	7	6	6	6	27	88
	200+			1		2		1	1	1	1			8
Non-Major[a]	0-80	6	2		5	4	4	9	6	8	1	7	33	85
Fixed	80-200	1	2		2		5	2	1	5	3	2	1	24
	200+	1					1	1		2	1			6
Major[a]	0-80	17	17	10	13	18	28	37	39	49	17	34	64	343
Fixed	80-200	11	6	11	10	17	35	19	43	38	22	19	50	281
	200+	7	1	1	6	4	8	8	14	12	8	6	10	85
Total		119	70	47	62	102	171	160	245	246	133	177	625	2157
QUARTER FREQUENCY		11%			16%			30%			43%			100%

Footnote: (a) A major structure is defined to include at least 2 pieces of production equipment or 6 completions. Major structures will normally include all braced caissons, conventional piled structures with wells, skirt platforms, special platforms, and floating structures.

The short cutting season has significant implications. The income flow for severance subcontractors will primarily occur over only half of the year. If a company does not have other revenue generating activities, the business cycle can have a strong negative impact on the financial health of the company.

Companies that are supported through diversified services are expected to be more competitive during the main working season since they can offer lower cost and do not need to recover as great a percentage of their fixed cost within their rate structure. Subcontractors that provide only cutting services cannot realize such an advantage. However, one of the primary reasons why severing operations are contracted out is that the specialized severance subcontractors can operate more cheaply and efficiently while developing an expertise and research base that more diversified contractors are not generally willing to pursue. Companies that actively participate in research and development are also expected to maintain a long-term competitive advantage, since they are not merely users of technology but are at the cutting edge of its application and development.

3. FACTORS INVOLVED IN SEVERANCE SELECTION

A large number of factors are potentially involved in selecting the severance technique for a specific job with cost, safety, risk of failure, and technical feasibility the primary factors that are considered when alternative options are available. Many different severance operations are required during decommissioning, and depending upon the job, more than one alternative may be available. In general, cutting techniques are expected to be reliable, flexible, adaptable, safe, cost effective and reasonably certain [28]. If a cutting technique fails with respect to one or more of these factors, or if an operator has more than one "bad experience" with a particular method, then chances are that the technology will not gain popularity or acceptance among GOM contractors.

Variables that drive the cost and risk associated with a specific severance technique are numerous and involve factors such as the location and nature of the site, sensitivity of the marine habitat, structural characteristics, the amount of pre-planning involved and the schedule of the operation, salvage/reuse decisions of the operator, marine equipment availability, operator experience and preferences, contractor experience and preference, the number of jobs the contractor is scheduled to perform, the weather at the time of the procedure, market conditions, etc. Some of these variables are observable, but the degree of correlation between the observable variables and severance decision factors is expected to be weak, and so the extent to which cutting methods can be accurately predicted based on these factors is uncertain.

3.1. DIRECT COST

The cost of a derrick barge is at least an order-of-magnitude larger than the cost of a cutting spread, so cutting decisions are *not* expected to be a primary focus in decommissioning operations *unless* they negatively impact the time on-site of a derrick barge. The direct cost of a cutting spread is approximately $10,000/day, and when compared to a derrick barge spread of $100,000-$300,000/day, it is clear that cutting techniques will not drive decommissioning activities directly. The direct cost to sever piles and conductors is generally in the range of 1-3% of the total cost to decommission the structure.

3.2. COST OF FAILURE

If the cutting operation is not successful on the first attempt, then either the contractor or the operator, depending on who chose the severing method, will assume the cost of failure and the additional time required to re-shoot or re-cut the tubular element(s). Contractors typically charge at- work rates that depend upon the critical path crane[2] vessel time. Normally, if "extra work" is required that alters the critical path crane vessel time, the contractor charges the operator hourly rates for equipment and personnel affected. If extra work is required that does not alter the critical path crane vessel time, the operator is charged a different (substantially smaller) hourly composite rate. The cost of a failed cut thus depends on the timing of the cut relative[3] to the operational activity of the barge. Failure to cut a conductor prior to the arrival of a barge is not nearly as significant as a cutting failure that occurs when a barge is on-site. This is a primary decision factor in the selection of a cutting method and the timing of the work. The failure cost of cutting varies with its "proximity" to critical path barge activities and, because of this, as much work as possible is performed prior to the arrival of the crane vessel. Conductors can be cut and pulled in advance of the crane vessel arrival. However, if this operation is not economic, then cutting and/or pulling will be postponed. This is often the case. If mechanical cutting is chosen for conductors, they are almost always cut in advance and "proved" with hydraulic jackets, then later pulled by the crane vessel.

3.3. SAFETY ISSUES

The offshore environment is a potentially hazardous location which presents special risk to the personnel involved in the operations. At each stage of decommissioning there is the potential for work

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[2] Critical path activities on a barge are considered "bottleneck" operations that directly extend barge on-site time.

[3] Similarly, there is a distinct difference between a crew *preparing* for a cutting operation while barge activities are on-going versus a crew *cutting* on the barge while other activities wait for the operation to finish.

injury and fatality. Cutting, welding, rigging, moving cranes, hydraulic equipment, explosives, and old rusty structures create the potential for a hazardous work environment, and so proper precautions are always required to ensure that operations are performed in as safe a manner as possible. Fortunately, decommissioning activities are fairly standard and relatively safe, if properly planned and executed. The exposure time of the work force in a platform removal operation is usually of short duration (7-14 days) which helps to ensure the potential for injury is minimized.

Cutting the piles and conductors is probably the most critical and important part of a decommissioning project, since if the piles and conductors are not cut properly, a potentially dangerous condition could arise during the lift. The cuts on jacket members, piles and conductors must be "clean" and "complete" to allow for a safe operation. The most dangerous situation is created when an element is not completely cut and "lets go" after the crane vessel has applied a significant pulling force. Experienced crane operators are careful to avoid this situation.

3.4. Environmental Issues and Structure Disposition

Under some circumstances, the choice of severance method may be determined exclusively by the location of the structure and/or the decision to re-use the jacket; e.g.,

- the structure is located in a known turtle, marine mammal, or other sensitive habitat;
- the structure is located in an artificial reef planning area; or
- the jacket will be re-used.

These circumstances do not occur frequently in the GOM, but they do occur in about 10-20% of the structures removed.

If the jacket is to be re-used or the structure is located in a sensitive area, then nonexplosive methods will likely be used if technically feasible. Clean cuts are desirable for re-used structures to avoid the diver cost/risk associated with flared piles and the possible damage that can occur to the jacket with explosive cutting. If a structure is located in an artificial reef planning area it may be toppled-in-place or partially abandoned (topped). To topple a structure in place, the piles and conductors are severed and the jacket is pulled over to form the reef. In a partial abandonment, the jacket top is cut off to achieve at least 85 feet clearance from the waterline. The top of the jacket may be placed on the seabed near the bottom of the jacket, which will be left in place. In a partial removal, the piles and conductors do not need to be severed from the bottom structure, and since the use of explosives is currently prohibited in the water column, nonexplosive methods are used to make the mid-water cuts.

3.5. Operator Preference

The project management team overseeing the decommissioning activities, in consultation with the operator, prepares the bid package and specifies the work requirements to be performed. This information will include special requests, such as platform and jacket disposition, and preference (if any) for the severance method. The operator may also have special concerns or preferences that dictate that a specific removal method be employed. For example, between November 13, 2000, and August 1, 2002, some operators (e.g., ExxonMobil, Shell, and El Paso) specifically requested that contractors employ nonexplosive methods for cutting because federal regulations concerning the incidental take of bottlenose and spotted dolphins expired. Therefore, the NMFS could not issue Letters of Authorization for structure removal activities [11]. As a result of the expired regulation, operators were potentially exposed to penalties and under some circumstances could be held criminally liable should a take be recorded due to an underwater detonation. Some operators simply see it in their long-term interest to be more sensitive to the environment.

3.6. Operational Scheduling

Conductor severing and recovery may be completed as part of well plugging and abandonment activities unless the platform configuration, equipment availability or scheduling of the activities prevents the operation. Conductors are cut and pulled, if possible, early in the decommissioning process to avoid delay when the barge is on-site. Mechanical casing cutters and AWJ cutters can be used to perform the cut if a crane is available on the platform for the deployment of the tool. If tubing and casing strings have not been cut prior to the arrival of the derrick barge, then explosive charges will likely be used after the derrick barge arrives to cut all the elements at once. Mechanical and/or AWJ cutters are rarely deployed to cut conductors with a derrick barge on-site due to the time-consuming and inefficient nature of the operation. However, AWJ cutting is used with the derrick barge for cutting piles, a much simpler operation than conductor cutting.

Depending on the number of structures to be decommissioned, the type of structure and the sequencing of the activities, a small spread may be sent to pre-cut the conductors. This saves derrick barge time if the conductors are successfully severed but also cost additional money to dispatch the cutting crew and necessary support. To verify a complete cut, a jacking system may be used to lift the conductor after the severing attempt. To jack the conductors ("prove" the cut), the platform must have the structural capacity to jack against *and* have a crane large enough to set the cutting system, jacks, and load spreading beams.

3.7. STRUCTURAL CHARACTERISTICS

Pile and conductor severing is the most critical and typically the most expensive of all the severance operations required on the structure. The physical characteristics that describe piles and conductors are important since they allow engineers to determine the technical feasibility and potential problems of removal options.

Conductors are configured in various diameters and wall thickness and are characterized by the number of inner casing strings, the location of the strings relative to the conductor (eccentric vs. concentric), and whether or not the annuli are grouted. Conductors typically contain multiple strings of casing, often eccentric within the well, and grouted, often with voids. Figures 3.1 and 3.2 show conductors with concentric and eccentric casing strings and grouted annuli. Grouted annuli are usually easier to cut than annuli with voids, since the water in voids dissipates the energy and focus of the abrasive and explosive cutting mechanisms. The preferred method to cut conductors is with mechanical or explosives charges, while piles can be effectively cut with abrasive water jet and explosive charges. Since piling cannot be examined before the topsides are lifted off the jacket, bulk explosives are usually preferred for piling since they can be sized for unexpected field conditions and give a clear indication of a complete cut.

Figure 3.1. Grouted Conductor Cross-section with Concentric Casing Strings.

Figure 3.2. Partially Grouted Conductors with Eccentric Casing Strings.

3.8. Structure Age

Contractors select severance methods that are cost-effective, reliable, efficient, adaptable, and safe. If a structure is old or has been owned by several operators, it is less likely to have accurate records and drawings available, and if accurate information is not available to the cutting crew before the cut is performed, the ability to plan and anticipate potential problems in the operation is severely constrained. Old structures are also less likely to be re-used, and so we would expect explosive methods to be more frequently applied as the age of the structure increases [13].

3.9. Reliability

The ability of a severance technique to perform a cut, and to perform it reliably, is a significant factor and one of the most important criteria contractors consider in their selection of a removal method – especially if cutting is to occur with a derrick barge on site. No cutting technique is 100% reliable. Therefore, the operator/contractor's experience with the technology and their perception of reliability is as important as actual reliability statistics. Unfortunately, it is difficult to acquire reliability statistics that can be meaningfully compared across severance methods due to the lack of appropriate data and record keeping. The industry consensus is that explosives remain the most predictable, flexible, and reliable severance technique. Until other techniques provide the reliability and effectiveness of explosives, these methods will continue to be used. There are more delays associated with nonexplosive methods and a complete cut during the first pass is less likely to occur than if explosives are used, particularly in the case of conductors.

Explosive contractors maintain the best statistical data available in the GOM, and hence, the reliability of explosives serves as the baseline for all severance methodologies. Based on data provided by DEMEX, the percentage of elements severed on the first shot is summarized as follows: for piles with outer diameter 20" to 30" – 97%, 36" to 42" – 92%, >42" – 86%.

3.10. Configuration Type

Nonexplosive methods usually carry less financial and operational risk with shallow water simple structures than for complex deep-water structures. Mechanical and lower pressure sand cutters (as opposed to higher pressure AWJ cutting) have been used effectively on shallow-water caissons. Small well-protector jackets and large caissons have been effectively cut by divers [19]. As the complexity, size, and water depth of a structure increases, however, the reliability of some nonexplosive methods tend to decrease while the cost and risk/uncertainty of operations increase. On larger platforms, especially platforms with wells, the preferred severance method often is with explosives. Explosive cut quickly and reliably in many applications and crew exposure time is minimized. However, as pile sizes increase beyond approximately 48 inches, explosive charge weights tend to exceed 50 pounds, which is the limit for application without special permits. In these cases AWJ cutting will be more attractive for pile cutting. Skirt-piled platforms[4] are not generally candidates for mechanical or diver cuts. These are severed with explosives or AWJ methods. The charges or tools are stabbed by divers or ROV's and detonated or operated from the surface. As the complexity and water depth of a structure increases, we expect that explosive methods to be used more frequently, when possible. This is borne out by a statistical analysis of the data [13, 15]. However, AWJ cutting capability has improved in recent years and will see applications for larger pile diameters.

[4] Skirt-piled platforms are predominately used in deepwater with skirt piling driven through sleeves that terminate underwater and provide additional axial and lateral load bearing support.

4. THE VALUE OF CUTTING SERVICE PER DECOMMISSIONING AND ONSHORE ALLOCATION

Summary cost statistics based on sixty decommissioned structures from 1991-2000 are reported in Table 4.1 for 4-pile and 8-pile categories on a per structure basis [16]. Cost data is reported as nominal values; i.e., no adjustment for inflation was taken into account. The average total cost to remove a 4-pile structure in the GOM is estimated to be $885,000, while the average total cost for an 8-pile structure is $1,344,000.

The single most important cost in decommissioning activities is the structure removal stage. The removal operation, where the deck, conductors, piling, and jacket are cut and removed from the seabed, is the core of the decommissioning project. The time involved to perform removal operations coupled to the high day rates of the derrick barges required results in the large costs observed in Table 4.1. For the most part, 8-pile structures are not only larger than 4-pile structures and occur in deeper waters, they are also more complex and require greater personnel in the removal operation. In some cases, the plugging and abandonment of problem wells may rival the removal cost.

Table 4.1

Average Cost Data Per Activity Requirement

Activity Requirement	Average Structure ($1000) 4-pile	8-pile
1: Plugging and abandonment	95	305
2: Structure preparation	82	134
3: Pipeline abandonment	126	141
4: Structural removal	535	672
5: Site clearance and verification	50	131
6: Diving services	131	160
TC: Total Cost[a]	885	1,344

Footnote: (a) Since individual projects may not report cost data across every category, the sum of the average component cost across the six categories will overestimate the average total cost.

Source: Kaiser, et al. [16].

The cost distribution for decommissioning activities is shown in Table 4.2. The removal operation is the primary cost category, and so any activity that can be performed to minimize the time involved with the derrick barge spread on site would significantly reduce the cost of decommissioning. Plugging and abandonment, pipeline abandonment, structure preparation, and diving services are all important activities contributing roughly the same cost per activity on an average structure basis and generally about 10% of the total cost of decommissioning. Site clearance and verification operations represent the smallest cost activity requirement. The cost of cutting is a subcomponent of plug and abandonment, pipeline abandonment, and/or structure removal operations. The cost of cutting is about 1-2% of the total decommissioning cost, and usually no more than 3-5% of the total cost. Or in other words, for a 4-pile structure a reasonable cost estimate will range between $27,000-44,000 per structure, while for an 8-pile structure the range is $40,000-67,200 per structure.

Assigning the distribution of activities to an onshore allocation of expenditures is an exercise in assumption since industry-wide statistics at this level are neither tabulated nor maintained, and activity levels and alliances frequently change. Nonetheless, it is possible in a broad sense to assign the cost of cutting on a regional basis according to activity requirements. A cutting crew performs services on behalf of the contractor, and as such, the requirements of the cutting crew (catering, air, lodging, diesel fuel, etc.) are absorbed by the contractor. Because of the time and scale of the operation, the direct and indirect cost of cutting is best aggregated within one industry sector.

Table 4.2

Average Decommissioning Cost Distribution Across Activity Requirements

Activity Requirement	Cost Distribution (%)	
	4-pile[a]	8-pile[a]
1: Plugging and abandonment	9.3	19.8
2: Structure preparation	8.0	10.0
3: Pipeline abandonment	12.4	9.1
4: Structural removal	52.5	43.6
5: Site clearance and verification	4.9	8.5
6: Diving services	12.9	10.4

Footnote: (a) The percentage values were computed from the average component cost shown in Table 5.1 divided by the sum of the component cost.

Source: Kaiser, et al. [16].

Decommissioning activities are supported from onshore service bases in Southeast Louisiana, including Port Fourchon, Leeville, Grand Isle, Venice, and Morgan City; Southwest Louisiana, including Cameron and Lake Charles; Pascagoula, Mississippi; and the Texas coast, including Port Aransas, Galveston, Houston, Ingleside, Pelican Island, Freeport, and Sabine Pass. The cutting market is conservatively estimated to be split 50:50 between nonexplosive and explosive methods, and the geographic distribution of this activity is further allocated according to region as shown in Table 4.3.

Table 4.3

Cutting Activity Onshore Allocation

Activity	Activity Allocation (%)	SE Louisiana Coast (%)	Texas Coast (%)
Mechanical	5	50	50
Abrasive Water Jet	40	80	20
Diver	5	50	50
Explosive	50	70	30

The total value of cutting activities is determined by multiplying the cutting value per structure by the number of structures expected to be removed in the Gulf of Mexico. If 94 to 155 structures are removed from the federal waters of the gulf per year for the next five years [13], and the structures are distributed 50:50 between 4-pile and 8-pile structures, then the value of cutting services disaggregated according to activity and geographic region is shown in Table 4.4. The abrasive market is estimated to range between \$1.4M and \$4.8M, with the bulk of activity occurring in Southeast Louisiana.

Table 4.4

Value of Cutting Service Activity Onshore Allocation

Activity	Activity Allocation (%)	SE Louisiana Coast (%)	Texas Coast (%)
Mechanical	(0.2, 0.6)	(0.1, 0.3)	(0.1, 0.3)
Abrasive Water Jet	(1.4, 4.8)	(1.1, 3.8)	(0.3, 1.0)
Diver	(0.2, 0.6)	(0.1, 0.3)	(0.1, 0.3)
Explosive	(1.8, 6.1)	(1.3, 4.3)	(0.5, 1.8)
TOTAL	(3.6, 12.1)	(2.6, 8.7)	(1.0, 3.4)

5. THE STRUCTURE OF NONEXPLOSIVE SERVICE CONTRACTS

5.1. THE ELEMENTS OF A STANDARD SERVICE CONTRACT

The severance subcontractor generally agrees to provide cutting services as defined in the terms and conditions of work. Cutting services are usually written on a time and material basis with respect to the following elements:

A. Mobilization/Demobilization to/from dock site(s), $\$ K_1$

B. Equipment, $\$ K_2$ /day

C. Price per cut, $\$ K_3$ /cut

D. Personnel, $\$ K_4$ /day

E. Equipment standby onshore, $\$ K_5$ /day

F. Personnel standby onshore, $\$ K_6$ /day

G. Idle time, $\$ K_7$ /day

H. Equipment testing, $\$ K_8$ /test

I. Document preparation, $\$ K_9$

The terms and conditions of each contract are unique and, therefore, the following discussion is meant only to highlight the primary terms involved in nonexplosive contracts. Abrasive water jet and diamond wire subcontractors only perform severance operations, while diver and mechanical cutting crews are typically deployed as part of a larger service package; e.g., diving crews may be involved with site clearance and structure preparation activities, and mechanical crews are also involved with pulling and removing the tubular elements. It is thus difficult to isolate the "cutting" services in diver and mechanical cutting operations and so the following discussion is primarily aimed at abrasive and diamond wire contracts where cutting is clearly delineated from other activities.

The mobilization/demobilization cost to/from the dock site(s) is specified at a fixed cost $\$ K_1$ and covers the cost for the service provider to transport all personnel, equipment, and materials from the company facilities to dockside. The value for K_1 will depend on the distance between the service facility and the dockside location(s), the size and weight of the equipment that needs to be transported, and the form of the transportation arrangement negotiated between the subcontractor and the trucking company.

The major cost elements in nonexplosive cutting systems include (1) the capital cost of the equipment, (2) the cost of maintenance, (3) the cost of power, and (4) the cost of consumables. The capital cost of the equipment and maintenance requirements depends upon factors such as the age and type of technology deployed. The pressure pots, deployment systems and hydraulic units of AWJ systems are different in most respects from diamond wire and mechanical cutters. The power cost varies with the cutting method and duration of activity and is provided as a part of the fixed cost to the subcontractor, with qualifications. The contractor/operator is required to provide a water source, diesel fuel and electrical power. For AWJ services, consumables include the abrasive (either copper slag or garnet), nozzles, hoses, and sensitive components, such as gear-boxes. For diamond wire, the wire is consumed. For mechanical cutting, cutting blades must always be refurbished and are occasionally broken. The capital, maintenance and consumable cost must be recovered through the rate structure. Nozzles and hoses wear out and must be replaced and abrasive material is not recycled. In diamond wire and mechanical cutting the cost of the wire and cutting blades are included in the contract as defined costs, usually based on cuts performed. A usage rate $\$ K_2$ /day is normally based on a utilization level of x days or y jobs and is intended to cover a *portion* of the capital cost and wear of the machine over the expected lifetime of the equipment.

A separate charge is expensed for the number of cuts that need to be performed based upon the size and type of each cut. There are various ways in which the cutting charge may be specified, but typically, rates are based on the diameter $d(i)$ and/or the type of element to be cut; e.g., abrasive water jet contracts charge on a per string basis:

$$K_3(d(i)) = \begin{cases} K_{31}/\text{string}, \text{ if } 7" \le d(i) \le 48" \\ K_{32}/\text{string}, \text{ if } 49" \le d(i) \le 69" \\ K_{33}/\text{string}, \text{ if } 70" \le d(i) \le 96", \end{cases}$$

while for diamond wire contracts, the cutting charge is usually based only on the number and size of each element cut; e.g.,

$$K_3(d(i)) = \begin{cases} K_{31}/\text{element}, \ 7'' \le d(i) \le 69'' \\ K_{32}/\text{element}, \ 70'' \le d(i) \le 96''. \end{cases}$$

The values of K_{3i} are determined from engineering calculations based on the operational wear of the equipment and the expected time to perform the cut. The functional $K_3(d(i))$ is typically linear in $d(i)$ reflecting the fact that the time to cut steel is linearly dependent on the diameter of the element. Departure from linearity in the rate structure may occur to account for additional factors such as the thickness of the steel and the water depth of the cut.

Personnel is charged on a per-day basis (\$$K_4$/day) to provide 24-hour service availability. Abrasive water jet subcontractors in the GOM usually maintain a 3- or 4-person crew per 12-hour shift, while diamond wire subcontractors usually consist of a 2-person crew. The use of equipment standby (\$$K_5$/day), personnel standby (\$$K_6$/day), idle time (\$$K_7$/day), and equipment testing (\$$K_8$/test) are charged on a "as needed" basis and the rates depend upon the personnel and equipment involved. For large abandonment projects; i.e., multiple jackets or full field removals, equipment standby essentially serves as insurance providing a back-up in case of a component breakdown. Since several jobs may be performed on a single mobilization there may not be a mob/demob cost for each job; i.e., crew and equipment may transfer barge as they move from site-to-site. In jobs where crew and equipment transfer without returning to shore the mob/demob cost is replaced with an idle time charge. Equipment testing may be performed on "unusual" diamond wire jobs to prove the method, but this is not commonly applied to other cutting methods. Document preparation and a close-out report is a typical component in North Sea service contracts charged at a flat fee \$$K_9$, but for service providers operating in the GOM this cost is not normally specified.

The contractor picks up the cutting crew and equipment at dockside, provides for their meals and board while on the barge (or accommodation and living expenses are charged at cost plus 15%), and then delivers them back to dockside (or to another agreed site) when the service is complete. All rates commence at the point of departure and terminate upon return to land at the point of departure. The terms and conditions of each contract are unique, but typically the contractor is responsible to ensure that the insides of all piles to be cut are free of mud, clay, and other obstructions. The cutting subcontractor may provide this service with specialized jetting equipment, but more often than not, this service is performed by the derrick barge crew. If piles are not jetted and cleared of obstructions prior to the arrival of the cutting crew, the crew will need to wait until the piles are clear to begin their operation. Changes in the scope of work and technical complications – such as hangers and/or bent stabbing guides that prevent the placement of cutting tools – will also impact on the time to cut and may result in broken equipment. Water, electricity, air, on board communications and diesel fuel requirements for the cutting equipment and crew are provided by the contractor.

5.2. JOB AND CONTRACT SPECIFICATION

The job specification is defined by the location of the job(s); the number, size and type of pile that needs to be cut; and the number, size, and type of conductor that needs to be cut.

The location of the job specifies the water depth where the cutting activities will occur, and depending upon the cutting technique and specific technology employed, may represent a technical limitation. Water depth is not considered a cost driver in water depth less than 200 feet, but in deep water the economics of severing technology is sensitive to the water depth of the cut. Increasing water depth adds to the time to go in/out of the hole and may degrade the cutting performance, and as the time on-site increases, so does the cost of service.

Piling is hollow steel tubing welded in sections and driven into the legs of the jacket to secure the structure to the seafloor. Piling is characterized by its batter (angle), diameter and wall thickness. Grout may be applied inside and/or outside the pile to provide additional structural support. Conductors are characterized by their diameter and wall thickness, as well as by the number and type of casing strings within the conductor, the eccentricity of the strings within the annuli, and the material that reside between the annuli of the strings (mud, drilling fluid, water, grout).

To describe job *J* the following notation is employed:

$N_p(J) =$ Total number of piles of job *J*,

$d_p(i) =$ Outer diameter of pile *i*, $i = 1,\dots,N_p$,

$N_c(J) =$ Total number of conductors of job *J*,

$d_c(i) =$ Outer diameter of conductor *i*, $i = 1,\dots,N_c$,

$n_{cs}(i) =$ Number of casing strings of conductor *i*, $i = 1,\dots,N_c$.

The work activity required to complete job *J* is specified by the following variables:

$T_1(J) =$ Total number of days on-site,

$T_2(J) =$ Total number of days for equipment standby,

$T_3(J) =$ Total number of days for personnel standby,

$T_4(J) =$ Total amount of idle time incurred,

$M(J) =$ Total number of tests performed.

5.3. TOTAL COST FUNCTIONALS

The total cost of job *J* using AWJ technology, $\mathrm{TC}_{\mathrm{AWJ}}(J)$, is given by the value,

$$\mathrm{TC}(J) = K_1 + (K_2 + K_4)T_1 + \sum_{i=1}^{N_p} K_3(d_p(i)) + \sum_{i=1}^{N_c} (n_{cs}(i)+1)K_3(d_c(i)) + K_5T_2 + K_6T_3 + K_7T_4 + K_8,$$

where the configuration charge is specified as:

$$K_3(d_p(i)) = K_3(d_c(i)) = \begin{cases} K_{31}/\text{string, if } 7" \le d_p(i), d_c(i) \le 48" \\ K_{32}/\text{string, if } 49" \le d_p(i), d_c(i) \le 69" \\ K_{33}/\text{string, if } 70" \le d_p(i), d_c(i) \le 96'', \end{cases}$$

The total cost of job *J* using diamond wire methods, $\mathrm{TC}_{\mathrm{DW}}(J)$, is given by the value,

$$\mathrm{TC}_{\mathrm{DW}}(J) = K_1 + (K_2 + K_4)T_1 + K_3(N_p + N_c) + K_5T_2 + K_6T_3 + K_7T_4 + K_8M,$$

where the configuration charge is specified as

$$K_3(d(i)) = \begin{cases} K_{31}/\text{element, } 7'' \le d(i) \le 69'' \\ K_{32}/\text{element, } 70'' \le d(i) \le 96''. \end{cases}$$

5.4. PARAMETER SPECIFICATION

The job parameters $N_p(J)$, $N_c(J)$, $n_{cs}(i)$, $d_p(i)$, and $d_c(i)$ are determined by the scope of the work and are known prior to the start of the job in most cases. The value of $N_p(J)$, $N_c(J)$, and $d_p(i)$ are available from public records, while data on $n_{cs}(i)$ and $d_c(i)$, and more specific information on the wall thickness of the piles/conductors, the application of grout, the eccentricity of the casing strings, etc. are available from blueprints, operator records, and on-site inspection. The values of $T_1(J)$, $T_2(J)$, $T_3(J)$, $T_4(J)$ and $M(J)$ are known after the job is complete and are determined in part by the characteristics of the structure and exogenous factors such as the schedule/success of the cutting and the weather conditions during the operation.

The parameters K_i, i = 1,…, 8 are determined through the terms of the contract, and as previously described, these values are selected to recover a portion of the subcontractor's fixed cost and all the variable cost of the operation. A typical range of values for K_i, i = 1,…, 8 for abrasive water jet and diamond wire cutting contracts is depicted in Table 5.1.

Table 5.1

Typical Abrasive and Diamond Wire Contract Parameters for
Gulf of Mexico Service Subcontractors (2002)

Contract Parameter (Unit)	Abrasive Water Jet ($1,000)	Diamond Wire ($1,000)
K_1 ($)	6-10	7-8
K_2 ($/day)	3-5	1-3
K_3 ($/member)	1-3	1.5-3.5
K_4 ($/day)	3-4	1-2
K_5 ($/day)	2-3	0.75-1.25
K_6 ($)	0.3-0.5	1-2
K_7 ($)	1-3	1.5-3.5
K_8 ($)	3-5	3-4

6. THE SCIENCE AND TECHNOLOGY OF NONEXPLOSIVE REMOVAL METHODS

The science and technology of nonexplosive severance methods has changed remarkably little over the past decade, although significant progress has been made in diamond wire and AWJ technology. The following discussion can be considered an update and extension of the National Research Council's 1996 report on cutting techniques [28]. For the most part, the resources required in decommissioning involve standard, readily available technology and tools which have been available for some time. There has been only incremental technological advancement associated with cutting technology over the past decade, or indeed, over the past half century. Mechanical pipe cutters and diver torches are roughly the same today as they were 10 years ago, and while AWJ and diamond wire applications continue to see an increase in the frequency of application, a variety of factors continues to limit their application in practice. Nevertheless, while the routine application of diamond wire methods is still several years away, the technology has made significant strides. Further, the physical limitations associated with AWJ systems (e.g., water depth, cost, reliability) are significantly better than they were a decade ago, due to the steady influx of new contractors into the GOM and their product development.

6.1. MECHANICAL METHODS

Cutting mechanisms that use hydraulically actuated, carbide-tipped tungsten blades to mill through tubular structures are called mechanical cutters. Figure 6.1 shows a schematic of this type of system. The mechanical casing cutter is perhaps the oldest method for cutting well conductors. The casing cutter is deployed on a drill pipe string and the cutting tool has 3 blades which fold up against the drill pipe. The tool is lowered into an open pile or well using a drill rig. When hydraulic pressure is applied to the tool, the blades are forced outward as the tool is rotated by a power swivel. The carbide-tipped blades cut through the strings of the well while centralizers on the tool keep it concentric inside the tubular member. Drillers watch the back pressure on the drill water to determine when the cut is complete and cut verification can be made after the tool is recovered by the marks of penetration of the blades [17].

Mechanical cutters are frequently used for cutting shallow-water, small-diameter caissons with individual wells and well protector platforms with vertical piles [7, 19]. Mechanical cutting is rarely used in conjunction with a derrick barge spread since the operation is time-consuming and inefficient and rig-up and rig-down time may be considerable. After wells are plugged and casing tubing cut and pulled, the contractor may run a mechanical cutting tool (or sand cutter) downhole to cut the conductors, or depending on the preference of the operator and configuration of the platform, may subcontract for abrasive water jet or explosive severance methods.

A number of limitations are associated with mechanical cutting. For conductors with casing string that is not cemented, lateral movement of the string may cause uneven cutting of the next casing. If strings are pulled after each cut, lifting equipment is required which adds to the time to remove and reinstall the tool. For cemented strings, trips in and out of the well may be required to replace worn blades which add to the time to complete the cut. Realignment of a partial cut after re-entry is problematic and eccentricity of the casing strings may result in incomplete cuts forcing the deployment of divers to perform the operation. Mechanical cutting is also problematic for tubular members at a batter and for conductor removals in which close tolerance conductor guides on the jacket are smaller than the deformed cut end of the conductor which must pass through the guide during recovery. To cut piling with mechanical cutters, the piling must be open at the surface to accommodate the power swivel. Thus, the deck of the platform must be removed prior to the operation using a derrick barge, and after the deck is removed, it is highly unlikely for a barge to stay on-site when the mechanical cutters operate. Re-mobilizing a derrick barge, however, is usually not an option and would represent a significant cost increase in the operation. Mechanical cutting is therefore rarely used for piling.

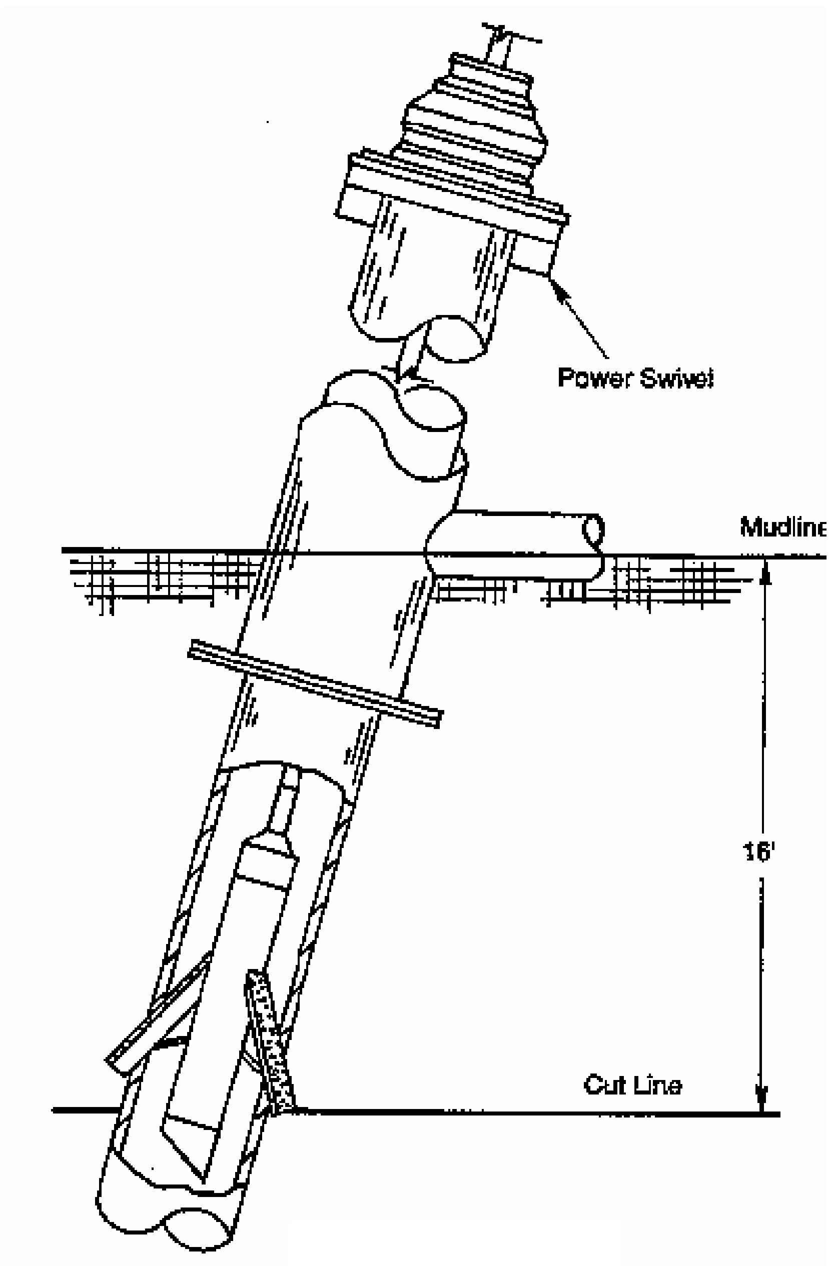

Figure 6.1. Schematic of a Mechanical Cutting System.

6.2. ABRASIVE METHODS

Mechanisms that inject cutting materials into a water jet and abrasively wear away steel/concrete are called abrasive cutters. Abrasive technology has a long history of application in industrial and manufacturing processes, and has been used in shipyards for many years. Several different systems of abrasive cutters exist.

Abrasive cutters can be classified as

(1) low pressure/high volume systems (sand cutting), or

(2) high pressure/low volume systems (AWJ).

Cutters that use sand or slag mixed with water at low pressure (4000-10,000 psi) and high volume (80-100 gal/min) are called sand cutters, while cutters that use garnet injected at the nozzle at high pressure (50,000-70,000 psi) and low volume (50-80 gal/min) are commonly referred to as abrasive jet cutters [28]. The abrasive provides the force for cutting and is introduced at the cutting nozzle and sent down a hose with air pressure or through a water-based solution. The abrasives typically used are garnet and copper slag. Figure 6.2 shows a AWJ tool capable of cutting piles and caissons to 72 inches.

Figure 6.2. Abrasive Water Jet Cutting Tool for Piles or Caissons from 30 to 72 Inches Diameter (Courtesy of Circle Technical Services).

Sand cutters use a turning mechanism (or power swivel) like a mechanical cutter. The power swivel is connected to the top of an open pile and as the drill string turns, the cutting nozzle cuts the caisson and casing strings through the abrasive action of the water jet. Abrasive jet cutters produce a jet of water mixed with garnet under high pressure and directed through a diamond orifice. Abrasive jet cutters can cut both internal to the tubular member as well as external to the member, although internal cutting is the preferred method if below mudline access to the foundation pile can be achieved.

The minimum inside diameter that can be accessed with abrasive cutters is approximately 7 inches, and beyond 200-250 feet, some of the abrasive cutting technology employed in the GOM is not effective. Improvements to the systems over the past decade, especially with the influx of North Sea technology, has allowed abrasive cutters to work in deeper waters than in previous years. Figure 6.3 shows a cutting tool intended for use in conductors or small piles. Air delivery systems are limited to shallow water application, while systems with a fluid delivery have been used in water depths exceeding 600 feet [1]. Abrasive cutting has also been deployed by ROV's to depths exceeding 1,100 feet. Casing strings that are eccentric (see Figure 3.2) and with void areas rather than grouted annuli remain problematic since the water in the void dampens the energy of the abrasive jet and may cause an incomplete cut.

Figure 6.3. Abrasive Water Jet Cutting Tool for Conductors or Small Piles (Courtesy of Circle Technical Services).

There also exists the problem of verifying that the cut has been made when using an internal abrasive cutter. Unlike explosives, the conductor or pile often does not drop, confirming that the cut was successful. With an abrasive tool, the width of the cut is small and when combined with the soil friction, a visual response generally does not occur. To verify the cut, the conductor is pulled with either the platform crane or hydraulic jacks, and the lift force must overcome the conductor weight and the soil friction. The cut is considered unsuccessful if the conductor cannot be lifted with a force approximately two times the conductor weight [2]. In such case, the abrasive cutting tool is either re-deployed to make another complete run or explosives are used to complete the cut.

6.3. Diamond Wire Methods

A diamond wire cutting system uses a diamond embedded wire on a chain saw-like mechanism to cut steel, concrete, or composite material above and below the waterline. The wire is veered onto hydraulically driven pulleys resembling a band saw and mounted on a frame. The system can be configured to cut virtually any structural component, caissons, conductors, risers, and pipelines and is not limited by size or material as long as the cutting tool can be attached to the member. Water depth is also not an issue, since an ROV or diver wearing a hard suit can take and set the tool at the desired location. Diamond wire cutting has been used since the early 1990's in the North, Adriatic, and Red Seas, but in the GOM, diamond wire has only been applied a handful of times. Figures 6.4 and 6.5 show diamond wire cutting tools for different applications. Figure 6.6 shows a close-up view of the cutting wire and industrial diamond beads.

Figure 6.4. Diamond Wire Cutting System Applied to a 72-inch Deck Leg on the Surface (Courtesy of CUT USA, Inc.).

Figure 6.5. Diamond Wire Cutting System Deployed from an ROV for Use in Pipeline or Small Member Cutting (Courtesy of CUT USA, Inc.).

Figure 6.6. Local Detail of the Diamond Wire, Showing Industrial Diamond Beads and Spacers (Courtesy of CUT USA, Inc.).

The cutting machine is hydraulically clamped or manually strapped to the structure, and a surface-activated motor activates the tool. The diamond wire is driven at high speeds and depending on the material and thickness, wire speeds are maintained to produce the cut. Even under large axial compressive loads, tubular members can be cut with diamond wire, and one of its strengths lies in its ability to cut large wall section thickness [1]. The operator monitors the progression of the cut and makes adjustments to improve the efficiency of the machine.

6.4. DIVER TORCH METHODS

Underwater diver cutting is virtually the same as land-based cutting but the torch used is somewhat different. In underwater arc cutting, an outside jet of oxygen and compressed air is needed to keep the water from the vicinity of the metal being cut. A tube around the torch tip uses air and gas pressure to create a gas pocket. This will induce an extremely high rate of heat at the work area since water dispels heat much faster than air. As the water depth of the cut increases, higher air pressure is required to form the gas pocket [30]. Figure 6.7 shows a schematic of a diver cutting a pile or small caisson.

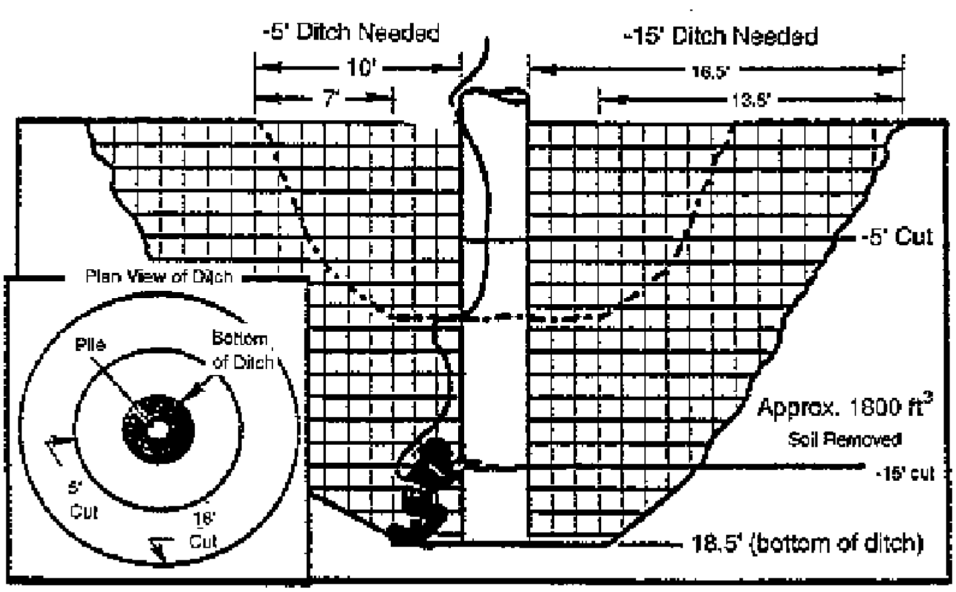

Figure 6.7. Schematic of a Diver Externally Cutting a Pile or Small Caisson.

Underwater cutting can also be accomplished with an oxy-hydrogen torch. Hydrogen is typically used instead of acetylene because of the greater pressure required in making cuts at increased depths. Oxyacetylene may be used up to 25 feet while depths greater than 25 feet require the use of hydrogen gas. Underwater cutting is generally limited to caissons, pilings, bracing, or other structural components, but not wells.

In shallow water and for simple structures such as caissons, diving is sometimes the preferred method. In deep water, because of the physical limitations associated with diving, an ROV or ADS system is commonly used in conjunction with a cutting torch. Diver cuts usually cost far more than other cutting technology and the risk involved to the diver – especially in deep water – makes torch cutting generally less attractive than other removal options (see [19]).

7. NONEXPLOSIVE CUTTING SYSTEMS AND ACTIVITY REQUIREMENTS

7.1. MECHANICAL SYSTEMS

A mechanical cutting system requires a tool to be lowered into an open pile or well with a crane or drill rig. If the cutting tool is operated by a drilling rig, diesel-fired engines drive generators which provide electrical power to motors, which rotate the turntable, which turn the drill string, which mills the tubular element. In addition, a water pump capable of up to 5000 psi pressure provides the force to keep the mechanical blades extended as the cutting process progresses. If a drilling rig is not used, the rotary table is replaced by a power swivel, which is driven by a hydraulic power pack. The independently driven cutting tool does not approach the rig-based tool in cutting capacity. Mechanical cutting generally requires approximately three dedicated operators, although this is not easy to define, since a drilling rig requires significantly more people to function, and an independent operation would also require significant more personnel to be self supporting. The mechanical cutting operation is generally only conducted from a platform without an attending derrick barge, or from a drilling rig.

7.2. ABRASIVE WATER JET SYSTEMS

A standard abrasive water jet unit consists of a cutting tool or manipulator to control the positioning and movement of the nozzle, the abrasive mixing or dispensing unit, high pressure water pump(s) and hydraulic power unit, control panels and cut monitoring systems. The total weight of the AWJ system may range from 5-15 tons and have a footprint of 200-400 ft. Several different AWJ systems are commercially available with prices ranging from $250,000-$500,000 for a complete system.

In a conventional internal pile cutting operation, the cutting tool is lowered into the pile from a wire line winch (or deployment frame) or by a construction vessel crane. The arms of the tool's centralizing system stabilize the tool and the cutting nozzle is positioned against the pile wall. A diesel-driven water pump supplies the high pressure water stream to the cutting nozzle and the pressure required is determined by the cut parameters (e.g., wall thickness, cut configuration, abrasive mixing system, etc.). The cutting speed, direction of travel, and nozzle position is controlled and monitored by the operator at the surface control station [1]. External cutting operations on legs, piles, and brace members are carried out using diver or ROV installed tracks. Subsea video equipment, lights, and audio systems for cut observation and monitoring is common for both internal and external cutting.

The surface personnel required for 12 hour operations are generally 2 operators and 2 roustabouts. External underwater AWJ systems need to be placed either by divers or ROV's. The operation can be supported from any work platform that has sufficient lifting capabilities, i.e., derrick barge, platform with a capable crane, lift boat, etc.

7.3. DIAMOND WIRE SYSTEMS

Diamond wire cutting systems are typically composed of a clamping frame, cutting frame with wire drive pulleys and motors, wire feeding system, wire tensioning system, cut wedging system, underwater power unit, umbilical assembly, diamond wire cable [1]. The power to the system can be provided from the surface, by means of a dedicated hydraulic power pack, or by a work-class ROV power unit. Monitoring of the cutting progress can be provided by video cameras mounted on the machine frame, ROV, or by divers from a safe distance. The cutting machine is hydraulically damped or manually strapped to the structure, and a drive mechanism is either remotely controlled by an operator at the surface or configured for automatic operation by an ROV or diver.

7.4. DIVER TORCH SYSTEMS

Arc torches for underwater cutting are produced in a variety of types and forms and are constructed to connect to oxygen-air pressure sources. Electrodes may be carbon or metal and they are usually hollow in order to introduce a jet of oxygen into the molten crater surrounding the arc. The current practice is to use direct current for underwater cutting and welding.

The torch used in underwater cutting is a fully insulated celluloid underwater cutting torch that utilizes the electric arc-oxygen cutting process using a tubular steel-covered, insulated, and waterproofed electrode. It utilizes the twist type collect for gripping the electrode and includes an oxygen valve lever and connections for attaching the welding lead and an oxygen hose. The arc is struck normally and compressed oxygen or air is fed through the electrode center hole to provide cutting due to the intense heat generated by combustion of the electrode. The burning electrode tip is shielded from the surrounding water by the rapidly expanding gas from the combustion process.

8. ENVIRONMENTAL AND SAFETY ISSUES

8.1. ENVIRONMENTAL AND PHYSICAL IMPACT

Energy is required to do work and all cutting operations require the expenditure of energy. As work is performed, energy is transferred and transformed which may have some impact on the ocean environment where these operations are performed. The power requirements of a cutting spread are approximately the same as a small offshore fishing vessel (less than 200 horsepower, or 150 kW). Unlike a typical sport fishing vessel, the typical cutting spread is fully self-contained with no marine discharges, other than the jet in the case of AWJ systems. Nonexplosive cutting methods are considered to be ecological and environmentally sensitive severance methods. For that reason, environmental and physical impact data of nonexplosive techniques are quite limited in the academic and trade literature. No record of negative environmental impacts for nonexplosive cutting methods has been found in the literature.

In mechanical, AWJ, and diamond wire removals, diesel fueled mechanical systems are employed in the operation which result in vibrations, the emissions of CO_2 and other gases to the atmosphere, and, potentially, low frequency sound waves into the ocean environment. Abrasive water jet cutting involves using sea water and garnet or copper slag (grit). There is the question of the impact of the fluid and grit on the marine environment. Since the fluid involved in abrasive cutting is sea water and the grit is essentially inert – the environmental impact is believed to be inconsequential. Garnet is an inert rock material that poses no environmental consequences that have been reported. The level of available copper present in the slag is very low and there are currently no restrictions on its use, or reported environmental issues. The noise level of the supersonic cutting jet is safe for divers and is not considered harmful to marine life. Mechanical, abrasive water jet and diamond wire methods are generally considered harmless to marine life and the environment. No adverse environmental impacts related to any of these cutting methods have been reported in the literature. The direct products of the processes are water, metal cuttings, and abrasive grit particles. Therefore, we conclude that there are no adverse environmental impacts associated with any of the nonexplosive cutting methods.

8.2. SAFETY ISSUES

Offshore oil and gas operations involve a number of distinct phases – exploration, development, production, and decommissioning – and present a continuing risk of accident and injury to the personnel involved in the operations. Drilling operations involve moving heavy equipment into place (e.g., pulling or hauling pipe) and the continual adjustment of controls and rotary equipment. Production operations involve the maintenance of process equipment as well as activities associated with changing flow rates and reservoir depletion. Decommissioning activities involve the lifting and moving of heavy loads, cutting operations above and below the waterline, and numerous other manual tasks such as rigging and welding.

Drilling, production, and decommissioning operations are all personnel intensive, but the exposure time involved with drilling and production operations are orders-of-magnitude greater than with decommissioning activities, and so if all operations are assumed to be “equally hazardous,” we would expect no significant safety issues to be associated with decommissioning projects since the time for a possible occurrence is so small, and indeed this is the case. Injuries and accidents that occur on decommissioning projects can not be detected relative to the exposure time involved in the activity.

On a drilling facility the crew size consists of about 20 people per 12-hour shift, while on a production platform, the crew size varies with the number of wells and the complexity of the equipment. Many platforms in the GOM are unmanned and serviced from a central platform with 20 or fewer people. In the Western GOM, where gas fields are widely scattered and platforms smaller, crew sizes tend to be smaller (2-10 people). The average crew size on platforms that are larger than average, have more wells per platform and more equipment, are expected to have larger crew sizes. In decommissioning operations, the number of personnel required on the job is determined by the size of the equipment used. A small decommissioning project on a single platform in shallow water may require 14-20 personnel and 3-7 days to operate the marine equipment spread. A moderately sized project with multiple platforms in shallow to medium water depth may require 50 to 100 personnel spread out over 30 to 45 days. A deep water decommissioning project with large equipment may require in excess of 100 to 200 personnel over a number of months.

All GOM leaseholders are required to notify MMS of all serious accidents, any death or serious injury, and all fires, explosions, or losses of well control connected with any activities or operations on the lease. This data is reported to MMS and processed during each calendar year. The MMS makes a distinction between the terms *events* and *incidents*, where an event refers to a reported happening which may involve more than one incident. An incident refers to a category of accident that occurred during an event. From 1995-2000, the majority of incidents occurred during development/production activities. Eighty percent of the events occurred during development/production activities and 20 percent occurred during exploration activities [29]. The breakdown of incidents according to welding/cutting-related and crane-related incidents can be found in [29]. Welding and cutting operations caused no deaths in the GOM, but it did cause injury, pollution, and accidents causing fire.

The basic safety issues with respect to mechanical, abrasive, and diamond wire cutting methods are somewhat comparable. Mechanical cutting tools and safety precautions are familiar to any drilling crew. The AWJ system involves high pressures, but the cutting spread area is considered a restricted work zone with safety barriers and warning signs posted. The cutting manipulators and hydraulic power units incorporate high pressures ranging from 5,000 psi (350 bar) to 50,000 psi (3,500 bar). The tools, hoses, winches or power units could cause injury if damaged or mishandled. The diamond wire methods may require a diver to be deployed, which presents special risks.

9. JACKET HOPPING

NOTE:

To date, MMS's GOM Region has never received an application for nor granted permission to perform "jacket hopping" or "progressive-transport" related to any OCS decommissioning. Any "hopping" activities that may have been employed in the past would have been unauthorized and conducted after permit approval. To counter reoccurrence and to ensure MMS's future involvement, current procedures require an operator to formally-request a written approval prior to any proposed "hopping" activity, regardless of the operation's pre- or post-permit status.

"Jacket Shallowing-up," or "Jacket-Hopping," refers to the tasks of picking up the jacket, towing it to shallow water, then cutting and removing the portion above the waterline. The process is repeated until the jacket is completely removed. This process is carried out when the jacket cannot be lifted and disposed of in a single piece, for a variety of reasons. Figure 9.1 illustrates how the procedure might work with a large jacket.

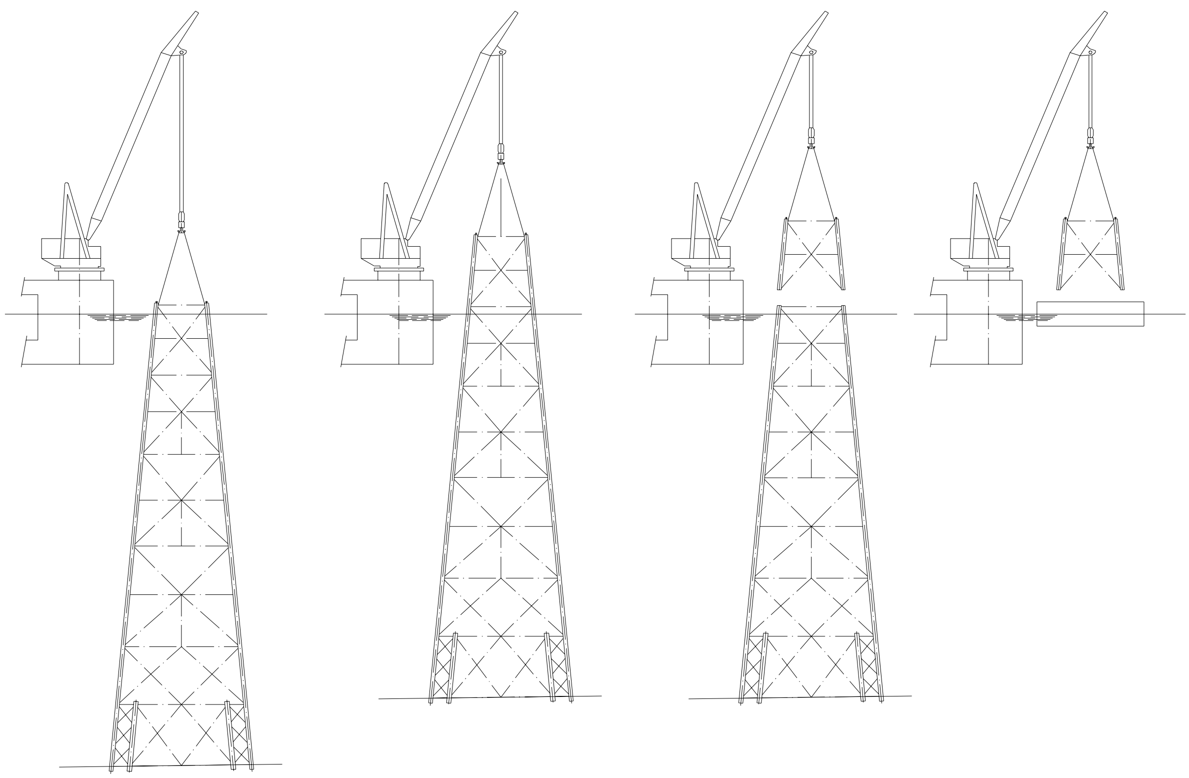

Figure 9.1. "Shallowing-up" or "Hopping" of a Large Jacket.

9.1. METHODOLOGY DESCRIPTION

After the deck is removed and the piles severed, the jacket is then made buoyant to reduce the bottom weight. To maximize buoyancy, the water inside each pile is evacuated. To accomplish this, closure plates are welded on the top of the piles and the water is evacuated from the legs using compressed air. A valve is welded to the closure plate on each pile. Compressed air is forced into the pile until the pressure inside the pile increases to match hydrostatic pressure and the water is forced out of the pile at the point where the pile was severed.

Having de-ballasted the jacket, it is then lifted off the seafloor by the heavy lift vessel (HLV). The jacket is supported by the HLV's crane and swung to the stern of the HLV. Rope hawsers are passed around two of the jacket legs and secured to the stern of the HLV. The jacket is then boomed away from the stern of the HLV until the hawsers are tight. The rope hawsers keep the jacket from swinging and being pulled out of the boom radius by its movement through the water. The HLV's anchors are shifted or completely picked up and the jacket is towed to shallower water.

At the new location, the jacket is ballasted and set on the seafloor. The water depth at the new location is such that the horizontal elevation to be cut is several feet above the water. Welders set up scaffolds around the jacket legs and begin cutting the jacket legs.

After the legs, piles and any diagonal braces have been cut, the jacket section is rigged, lifted, removed, and sea-fastened on a cargo barge. The cargo barge is then sent to the onshore disposal yard. This procedure is repeated until the jacket is completely removed and placed on cargo barges. The jacket is de-ballasted, picked up, towed to shallower water, set, cut in two (vertically), and removed in sections. At times, the jacket is severed at each horizontal elevation because of its dimensions.

9.2. Frequency of Use

The procedure described above has only been used infrequently in the GOM to date for decommissioning. Currently there are 61 fixed platforms installed in water depths ranging from 414 to 2860 feet depth in the Gulf of Mexico that would be candidates for the "shallowing-up" removal method. These platforms are either too heavy to be removed in a single lift or in water depths that are too deep to facilitate a conventional removal. Installations installed in shallower water depths would not generally be candidates for this removal option. However, the applicability of this method is dependent on the relative size of the jacket and crane vessel. A small crane vessel could use this approach with a relatively small jacket.

9.3. Feasibility of Methodology

For this method to be applicable, the jacket dimensions and architecture must be analyzed. Jackets must have sufficient horizontal bracing to allow it to be cut and the pieces removed in modular form. In most older platforms the jacket will have bracing that will allow this method to be feasible. However, in some instances the jacket may not have the appropriate bracing arrangement to allow the pieces to be removed in the modular form required. This is particularly true for newer jackets and those that carry relatively light topside loads, such as pipeline manifold platforms. These jackets are not required to be as robust as drilling or production platforms due to the minimal support requirements. The key issue is the vertical spacing of horizontal bracing levels. If the spacing is too great, this method becomes difficult to apply. To be feasible, the bracing level spacing must match the crane barge's ability to lift the jacket out of the water and the availability of a site to set it down. If the bracing level spacing level is too great, the barge will not be able to lift it high enough.

In determining the feasibility of the method, the seafloor conditions must be considered. The preferred bottom conditions would be firm and relatively flat. This method can be accomplished if these conditions are not available. However, soft bottom may allow settling of the jacket, causing the bottom elevation to be buried and making repositioning more difficult.

9.4. Equipment and Personnel Requirements

Equipment and personnel required to perform this scenario are the same as a conventional jacket removal. A heavy lift vessel capable of lifting the jacket from its original location must be utilized to move the jacket into shallower water. Personnel requirements will be the same as any other decommissioning, i.e., riggers, welders, crane operators, etc.

9.5. "Shallowing-Up" Path Determination

A route survey should be conducted to determine the locations to set down and cut the jacket. The survey would identify anything on the bottom that is not charted, i.e. ship wreck, oyster beds, etc. The results of the route survey and pipeline maps would be studied to locate appropriate areas to set the jacket on bottom, without crossing pipelines or anything else that might present a safety hazard. The appropriate State and/or Federal agencies should be notified of the path determination along with the required removal permit applications prior to initiating any work. Prior approval of the path is required.

9.6. ACCIDENTS/INCIDENTS

To date this method has not been used frequently in the removal of offshore structures. Shallowing-up the jackets increases the duration of a typical decommissioning project, but allows for use of small crane vessels. The alternative, cutting and removing the jacket in-situ, increases the exposure to diving personnel in that all of the cuts are made underwater.

9.7. ECONOMIC FACTORS

This procedure in jacket removal has not been applied frequently, although evidence of its occasional use has been found. For this reason meaningful economic data are not available. This method is used only when the available crane vessel capacity is not sufficient to lift the jacket out of the water. This will apply to most of the deep water jackets to be removed in the future. Therefore, it is expected that this method of jacket severing will be used more frequently in the future.

While it is not possible to put a firm number on the savings allowed by this method, in the case of larger jackets (depths greater than 400 feet), it is estimated that the savings could be as much as 50%. For smaller jackets, the savings would be in the order of 15% to 20%. This method of jacket removal will have no impact on the onshore expenditure for jacket disposal. It relates only to the use of crane barge and diving services.

10. SUMMARY AND CONCLUSIONS

10.1. SUMMARY OF NONEXPLOSIVE REMOVAL OF OFFSHORE STRUCTURES (NEROS) SEVERING OPTION LIMITATIONS

- AWJ cutting is used primarily for piles.
- Mechanical cutting is primarily for conductors and has depth limitations.
- Diamond Wire cutting only applies to external cuts.
- Diver cutting is generally restricted to external cuts.

10.2. OTHER PRIMARY CONCLUSIONS

- The total cost to perform AWJ or Mechanical cutting cannot be reasonably predicted prior to execution of the work.
- The cost to sever piles and conductors is generally in the range of 1-3% of total decommissioning cost.
- No environmental issues have been found related to NEROS.
- NEROS services are readily available in the GOM in shallow water.
- Only one AWJ contractor currently offers deepwater capability in GOM.
- Selection of severing methods is primarily based on the perception of reliability.
- “Shallowing-up” or “Hopping” is a technique that is not widely used, but may be seen more often as deeper water structures are removed.

11. GLOSSARY OF TERMS FREQUENTLY USED IN OFFSHORE CONSTRUCTION AND DECOMMISSIONING

Abandonment—A term occasionally used synonymously with "decommissioning," which is the preferred term.

Anchor—A heavy hooked instrument which, when lowered to the seabed, holds a vessel in place by its connecting cable.

Anchor Buoy—A buoy through which the anchor pendant wire passes. The buoy holds the eye of the free end of the anchor pendant wire above the water surface.

Anchor Pendant—A wire which is attached to the crown of an anchor, enabling it to be pulled out of the seabed. The pendant wire is used by the anchor handling tug to set and retrieve anchors using the cable eye on the free end of the wire.

Anchor Handling Tug (Resource)—A tug equipped with a winch to lift a working barge's anchors. It is also often used as the working barge's tow tug.

Anchor Pile—A section (20 - 50 ft.) of large diameter (30 - 48 in.) pipe, with an anchor chain attached to it, driven below the seabed to a predetermined depth, usually 20 feet or more. Anchor piles are used to moor drilling rig tenders, other vessels or terminal mooring buoys. Anchor piles are normally installed in a pattern or system consisting of 4 to 8 anchor piles. They are generally used in conditions unfavorable to drag-embedment anchors.

Annulus—The space between two concentric tubular elements or structural members. An example is the space between the inside face of an outer casing string and the outside face of the next smaller casing string in a well or the inside of the jacket leg and the outer face of the pile.

Arc Gouging—The use of a carbon arc rod an electrical arc and compressed air to cut steel.

Artificial Reef—A disused structure or vessel placed in a designated area or left in situ to promote marine habitat for many varieties of marine life and plants.

Assist Derrick Barge Standby (Task)—The standby or idle period between the assist derrick barge's arrival at the platform location and the commencement of its work.

Barge Damage Deductible (Resource)—The deductible for a typical cargo barge hull insurance policy.

Bell Guides—See "Conductor Guides."

Blasting Cap—See "Detonator."

Blasting Machine—A mechanical, battery or radio operated device used to electronically ignite a detonator.

Bottom Clean Up/Scrapping (Task)—The removal of debris by divers from the seafloor.

Bottom Time (B.T.)—The total elapsed time measured in minutes from when the diver leaves the surface in descent to the time the diver begins his return to the surface.

Bring In Cargo Barge (Task)—The process of maneuvering and securing the cargo barge along side the working barge.

Buoy—A float of any type used as a marker.

Caisson—A large diameter pipe driven into the seafloor through which well casings are run, generally in single well developments. The purpose of the caisson is to protect and support the well casings and tree. The caisson may have a small deck to access the tree.

Cargo Barge (Resource)—A flat deck barge used to transport platform components, equipment modules and other cargo.

Casing—Steel pipe which makes up the casing string that is placed in an oil or gas well as drilling progresses to prevent the wall of the hole from caving in and to provide a means of extracting petroleum if the well is productive.

Casing String—A series of casings made-up in a string, inside an oil or gas well conductor installed during the drilling operations and often cemented to the conductor.

Closure Plates—Plates welded into the tops of piles or jacket legs to seal them so that water can be evacuated using compressed air.

Clump Weight (see **Concrete Gravity Anchor**)

Coil Tubing—An injector head and pipe reel used to feed a continuous length of pipe into a well. Can perform many of the functions of a drilling rig, but is much smaller and less expensive.

Communication—The movement of a substance (hydrocarbons, water, cement) from one position to another.

Concrete Gravity Base Structure—A concrete or steel substructure which is not fixed into the seabed by piles but resists wind and wave force by its own weight and added ballast.

Conductor or Drive Pipe—A large diameter pipe driven into the seafloor to protect the surface casing and to protect against a shallow gas blowout.

Conductor Guides—Guides built into the jacket, during fabrication, used to install the conductors in their correct location.

Consumable Items (Resource)—Items consumed in the course of a typical project.

Continental Shelf—The shallow submarine plain of varying width forming a border to a continent and typically ending in a steep slope to the oceanic abyss.

Crew Boat (Resource)—A small fast boat used to transport personnel and supplies to and from the job site to shore.

Critical Path—The sequence of events that determine the duration of a project.

Cut Deck Legs, Equipment and Miscellaneous (Task)—The cutting of all equipment, miscellaneous piping and the deck leg to pile splices to allow lifting of the equipment from the deck and the deck from the jacket.

Cut Jacket—The cutting of all braces necessary to remove the jacket in two or more sections. If a jacket is so large that its weight will exceed the capacity of the derrick barge, or if it is not structurally sound, it may have to be cut and removed in pieces. If this is required, the members to be cut above the surface would be cut by welders in the conventional manner and those members below water would be cut by divers using the Oxy-arc method.

Deballast Piles (Task)—The displacement of water inside the piles with compressed air to reduce the on-bottom weight of the jacket by causing it to be more buoyant.

Deck—The platform superstructure which supports drilling, wellhead, and/or production equipment.

Decommissioning—The process of deciding how best to shut down operations at the end of a field's life, then closing the wells, cleaning, making the installation safe, removing some or all of the facilities and disposing or reusing them.

Decommission Pipeline (Task)—The process of flushing a pipeline with seawater to purge it of hydrocarbons. After the pipeline is flushed, a pig is run using water and the pipeline is left filled with water.

Decommission Platform (Task)—A two phase operation, performed prior to the arrival of the derrick barge spread, to prepare the platform for salvage. The first phase is to make the environment safe for burning and welding. The second phase is to do any work which does not require, or will facilitate, the derrick barge operation.

Deep Water Disposal—Offshore disposal of a structure by placement at designated deep water sites.

Demobilize Assist Derrick Barge (Task)—The movement of the assist derrick barge from the platform location to it's point of origin.

Demobilize Cargo Barges (Task)—The movement of a cargo barge and it's tow tug from the platform location to the disposal contractor's yard.

Demobilize Derrick Barge (Task)—The movement of the derrick barge from the platform location to it's point of origin.

Depth Pay—Premium paid to divers that dive below 50 feet, increasing at each 50 foot interval. Depth pay is paid once in 24 hours for the divers deepest dive.

Derrick Barge (Resource)—A vessel equipped with a crane, a mooring system and crew quarters for marine construction.

Detonation—The act of setting-off an explosive charge.

Detonator—A device or small quantity of explosives used for detonating high explosives.

Disposal Contractor—Contractor that will dispose of the platform components (scrap dealer).

Diving Services (Resource)—Services of a diving contractor used during an inspection, salvage or construction project.

Dolphins—A cluster of piling at the entrance to, or alongside, a dock or wharf for service as a fender, alongside of which boats may be moored.

Drive Pipe or Conductor—A large diameter pipe driven into the seafloor to protect the surface casing and to protect against a shallow gas blowout.

Dumping—Unauthorized offshore disposal of any material.

E&P Forum—The Oil Industry International Exploration and Production Forum, a global association of the oil and natural gas exploration and production industry based in London.

Electric Line Unit—A piece of equipment with a powered drum holding a long braided two-conductor wire line which can be fed into a well to perform tasks that require tools which use an electrical current.

Emplacement—Regulated lowering of a platform in a designated disposal area, principally a designated artificial reef area.

Explosive Charges (Resource)—High explosives and their sized containers used to sever conductors and piles (normally not to exceed 50 lbs. In weight).

Explosive Magazine—A portable container used to transport explosive charges and equipment from the explosive contractors facility to the job site.

Fabricate Deck Padeyes (Task)—Replacement deck lifting padeyes are fabricated for decks cut into sections and for decks whose padeyes are no longer safe for the lift. These padeyes are fabricated at the decommissioning contractors facility. The contractor would install these padeyes during its decommissioning.

Fabricate Explosive Charges (Task)—The assembly of high explosives in properly sized containers. The explosive charges container are sized to fit the internal diameter of either the pile or conductor pipe. The quantity of explosive material is determined based on the size and type of material to be severed (steel, cement, etc.). This work is performed at the explosive contractor's facility then packaged for shipment.

Flame Cutting—The cutting of steel using a controlled flame provided by the burning of acetylene and oxygen.—

Flame Washing (Scarfing)—The use of a controlled flame provided by the burning of acetylene and oxygen to remove metal from other metal.

Flared Conductor—See "Flared Pile."

Flared Pile—The outward spreading (mushrooming) of the metal above the area where the pile is explosive severed.

Gang Way—A portable access walkway used to span the gap between the platform and the derrick barge.

Gas Free—Free of explosive or poisonous gas. A safe working area.

Gravity Anchor—A crude form of anchor which generally consists of a concrete block, often cast with scrap iron to increase its weight. This type anchor is not as efficient as drag-embedment anchors except when used on very soft or very hard (i.e. Stone) bottoms.

Grout—Cement slurry used between concentric structural members. Grout was used to secure one member to another.

Grouted Pile—A pile where the annular region between the pile outside wall and the inside wall of a jacket leg or sleeve is filled with grout.

Grout Plug—A plug of cement placed in a pile extending above and below the mudline to strengthen the pile, sometimes with reinforcing bar cages.

Hand Jet—High pressure water nozzle used by divers to move soil on the seabed.

Helideck—A pad to land helicopters on an offshore vessel or platform.

In-Water Decompression (IWD)—The time a diver must spend in the water decompressing at specific depths to allow the diver to reach the surface without developing the bends.

In-situ—In the original position, on site.

Injection Rate—The rate at which fluids can be injected into the production formation and the pressure required to inject the fluids; example 10 barrels per minute at a pressure of 4200 pounds per square inch.

Inspector (Resource)—A representative of the oil company required to be present during all phases of the platform removal when work is being performed. His function is to observe the work, report progress and maintain a daily log of activities, to verify that the work is performed in accordance with the specifications and to verify extra contractual work.

Installation—A generic term for an offshore platform or drilling rig (excluding pipelines).

Install Closure Plates (Task)—Placing and welding prefabricated steel plates in the tops of piles or jacket legs so that the water inside can be evacuated by compressed air.

International Maritime Organization—The United Nations body charged with shipping safety and navigation issues.

Jacket—The portion of a platform extending from the seabed to the surface used as a template for pile driving and as a lateral bracing for the pile which supports the deck.

Jet/Airlift—A device used to remove a pile mud plug. High pressure water breaks up the mud plug and expanding air lifts the particles to the surface.

Jet/Airlift Mud Plugs (Task)—The removal of the soil from inside the piles using a jet/airlift system.

Lifting Block—A block, containing one or more sheaves, connected to the crane boom by wire rope, that is used to lift and lower loads.

Lifting Capacity—The weight a crane can lift at a given boom radius or angle.

Lifting Eyes—See "Padeyes."

Load Spreader—A pad of wood, steel, etc. Normally placed on a cargo barge to distribute a concentrated load over a larger area.

London Convention—An international treaty signed by more than 70 nations governing disposal of substances at sea.

Magnetometer—An electrical device towed by a boat over a location to locate metal objects, i.e. pipelines, wellheads, wrecks, and similar ferrous objects.

Marine Growth—Sea life (e.g. barnacles) attached to hard objects submerged in the sea.

Members—The structural pieces or components that make up a jacket or deck structure.

Mobilize Assist Derrick Barge (Task)—The movement of the assist derrick and it's tow/anchor handling tug boat from its point of origin to the platform location.

Mobilize Cargo Barge (Task)—The movement of a cargo barge and it's tug boat from their point or origin to the platform location.

Mobilize Derrick Barge (Task)—The movement of a derrick barge and it's tow/anchor handling tug boat from its point or origin to the platform location.

Mosaic—Number of pictures making up a big picture.

Mud Plug—The soil (mud, clay, sand) inside an open ended pile that has been driven into the seabed.

Mudline (M.L.)—The elevation of the natural seabed.

North East Atlantic—The sea area to which OSPAR Conventions apply, This is defined as westwards to the east coast of Greenland, eastwards to the continental North Sea coast, south to the Straits of Gibraltar, and north to the North Pole. This maritime area does not include the Baltic or Mediterranean seas.

North Sea—The sea bounded primarily by the coasts of Great Britain, Norway, Denmark, Belgium, Germany, Sweden, France and the Netherlands.

OD—Outside diameter of a tubular element of member.

Off-Load Cargo Barge (Task)—The removal of all sea fastening and the platform components from the cargo barge at the disposal contractor's yard.

Offshore—Operations carried out in the ocean as opposed to on land.

Operator—The company either solely or in a joint venture which manages the operation of oil and gas production for itself or on behalf of the partners.

Oslo Commission—See "OSPARCOM." The Oslo Commission was a predecessor of the Oslo – Paris Commission.

OSPARCOM—The Oslo - Paris Commission which regulates pollution from offshore and onshore sources in the North East Atlantic for signatory countries.

Oxy Acetylene Torch—A device using oxygen and acetylene to flame cut steel.

Oxy-Arc Torch—A device using oxygen and an electrical arc to cut metal, usually underwater.

Padeye—A plate with a hole in it that is attached (welded) to a structure which allows a shackle connection for lifting the structure.

Paris Commission—See "Osparcom."

Pendant Wire—The cable connected to the head of an anchor used by the anchor handling tug to raise or lower the anchor. The free end is held at the water surface by a buoy.

Pick Up Assist Derrick Barge Anchors (Task)—The retrieval of the assist derrick barge's anchors at the end of its portion of the project.

Pick Up Derrick Barge Anchors (Task)—The retrieval of the derrick barge anchors at the end of the project.

Pig—A device which is forced through a pipeline by liquid or gas pressure. Pigs are used for a variety of purposes, including cleaning the pipe's interior and separating different fluids or gases.

Pile—Steel pipe driven into the seabed to secure and support an offshore structure.

Pile Driving Hammer—A steam, diesel or hydraulically operated impact hammer used to drive piles into the seabed.

Pipeline—A conduit of steel pipe extending from platform to platform or platform to shore used to transport oil and/or gas.

Pipeline Abandonment (Task)—The cutting, plugging and burying of a pipeline that is to be abandoned in place. Prior to the jacket removal and after the pipeline decommissioning is completed, the pipeline is cut and abandoned in place using a diving crew.

Pipeline Surveying Services (Resource)—The services of a surveying contractor and his equipment or mark pipelines and other submerged objects to avoid interference with derrick barge anchor placement.

Platform—A structure secured to the seabed and extending above water for the production of oil and gas.

Processing Facilities—Part of the topsides that treat oil and gas, remove impurities and pump the product into pipelines to shore.

Production Casing—A pipe set in the well after it is drilled. The tubing is inside the production casing.

Production Formation—The sub strata in which hydrocarbons are present. Where the oil and gas enters the tubing to be transported to the surface.

Recycling—Removal of an installation or parts of an installation to shore where they are separated into different materials and melted down or reprocessed to be reused.

Remove Conductors(Task)—The removal of the conductors from the jacket and placing them on a cargo barge. The conductor guides in the jacket cannot support the weight of the conductors, therefore they must be removed prior to the removal of the jacket.

Remove Deck(Task)—The lifting of the deck from the jacket and placement of it on a cargo barge.

Remove Equipment (Task)—The lifting, placing and seafastening on a cargo barge, of all equipment removed from the deck.

Remove Jacket (Task)—The lifting of the jacket from the seafloor for transport to shore or to a reef site.

Remove Piles from Jacket Legs (Task)—The removal of the piles from the jacket to reduce the jacket's lift weight.

Rig—The derrick or mast, drawworks, and attendant surface equipment of a drilling or work over unit.

Rigless Abandonment—Well plugging and abandonment without the use of a drilling or workover rig.

Rig Up Cargo Barge (Resource)—The installation of protective pads to prepare a cargo barge for receiving the salvaged platform components.

Rigs to Reefs—A national policy in the US enshrined in legislation, promoting the conversion of disused platforms into artificial reefs for the enhancement of marine life at designated sites.

Riser—The portion of a pipeline that rises form the seabed to the water surface, supported by the platform jacket.

Riser Bend—The section of the riser that turns the pipeline from horizontal to vertical.

Sea Buoy—The first buoy encountered when approaching the entrance of a river or port from sea.

Seafasten—The securing by welding of platform components or cargo to the cargo barge for transport at sea.

Set Up Derrick Barge (Task)—The placement of the derrick barge's mooring anchors on the seafloor around the platform location at pre-selected positions. The derrick barge will be positioned along side the platform using its mooring system. A walkway is placed between the derrick barge and the platform.

Sever Conductors (Task)—Cutting the conductors using high explosives, mechanical or abrasive cutting methods.

Sever Piles (Task)—Cutting the piles using high explosives, mechanical or abrasive cutting methods.

Shackle—A "U" shaped device with a removable pin or bolt across the end used to connect a sling or cable to a padeye.

Shaped Charge—An explosive charge designed to focus its blast onto a very small area to produce a very precise cut.

Shim—Curved steel plates wedged between and welded to the jacket leg and pile, used to tie the jacket and piles together at the top of the jacket leg.

Shoe—A device installed on the end of the casing when it is run into the well bore (i.e. that point in which the casing ends).

Side-scan Sonar—An acoustic device used to determine the characteristics of, and see objects on, the seafloor.

Skirt Pile—A steel pipe driven into the seafloor that passes through a sleeve attached to the jacket. The sleeve and skirt pile extend from the mudline up 50 to 100 feet along the jacket leg. The annular region between the pile and sleeve is filled with grout. The purpose of a skirt pile is to secure and support offshore structures.

Slickline—A machine with a hydraulically controlled spool of wire used for setting and retrieving safety valves, lugs, gas lift valves, and running bottom hole pressures. Slicklines are also used for a variety of other jobs such as recovering lost tools and swedging out tubing. Slickline wire generally ranges in size from .072 inches to .108 inches.

Sling—Usually a wire rope of a given length with a loop formed on each end, used for lifting loads.

Spreader Bar—A pipe or beam arrangement used to spread the slings to keep them from damaging the load while lifting.

Spreader Frame—See "Spreader Bar."

Spud Barge—A derrick barge moored by dropping pipe or beam spuds into the seabed.

Stakeholders—All the parties having an interest in an issue, including among others corporate shareholders, regulators, employees, community groups, the public at large.

Stiff-leg Barge—A derrick barge with a crane that does not revolve and which may or may not boom up and down.

Stops—Metal plates welded to the sides of a pile to hold the pile at a desired elevation in the jacket leg.

Subsea Tie-In—Point where a branch pipeline ties into a main pipeline on the seabed.

Surface Casing—The upper-most casing string in a well. In an offshore well it is drilled through the conductor or drive pipe and cemented into the sediment back to the mudline, forming support for smaller casing strings which follow.

Survey Location for Pipelines (Task)—The locating and buoying of pipelines around a platform. A survey boat and crew are mobilized to the location to locate and mark, with buoys, all pipelines within a 4000 foot radius of the platform to enable the derrick barge(s) to place its anchors safely.

Tension Leg Platform (TLP)—A floating platform anchored to the sea bed by long steel pipes (tension legs). The tension legs keep the platform from moving up and down on the waves.

Tonne—A metric ton, 1000 Kilograms or 2204 pounds, a common weight unit used in offshore structure design and construction; also occasionally used as a volumetric measure for oil (approximately 1200 liters of crude oil).

Toppling—Controlled "tipping over" of the platform (generally but not always without topsides) from it's vertical position to resting horizontally on the seabed.

Topsides—The facilities that contain the plant for processing oil and gas and accommodations.

Tow Tug (Resource)—A tug boat used to tow a barge. It may also be used as an anchor handling tug by the derrick or lay barge.

Tubing String—The smallest diameter pipe suspended in a well. The hydrocarbon product flows to the surface inside the tubing.

Trunk Line, Explosives—A detonation cord that connects all the explosive charges so they may be detonated in a group.

Walk Way—See "Gang Way."

Weather Contingency (Task)—An allowance of 6% of the estimated onsite derrick barge spread work time to account for lost time due to weather.

Well—The holes drilled through the seabed into the reservoir where oil or gas is trapped, often two thousand or more meters below the seabed. The hole is lined with piping which extends up through conductors onto the platform deck.

Well Head—The well head sits on top of the drive pipe. Casing and tubing strings are suspended from the well head. Valves on the well head allow the entrance to the tubing and the casing annuli.

Wire Rope—Steel wire formed into a cable.

Wood Piles—Wooden (timber) piles driven into the seabed to support equipment offshore and driven in clusters to form dolphins.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.

MMS Securing Ocean Energy & Economic Value for America