OTC 12023

The Use of Explosives in Decommissioning and Salvage

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This paper was prepared for presentation at the 2000 Offshore Technology Conference held in Houston, Texas, 1–4 May 2000.

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Abstract

Presently, there are over 3,750 platforms installed in the OCS region of the Gulf of Mexico. Ever since platforms have been installed, there has only been 1 year in which removals outnumbered installations. As many of these platforms reach the end of their useful life (average of 20 years), the liabilities and cost associated with their removal become a major concern for oil companies. During the years between 1986 and 1999, approximately 1,414 structures were removed. Of those structures, approximately 66% were removed by explosive methods. Explosives are widely used because they are safe, reliable, and cost effective.

This paper will present the methodology of explosive usage for platform removals. Included in the paper will be a review of field data, cost comparisons with other methods, safety, and governmental regulations relative to platform removals involving explosives. The limitations regarding explosive usage will also be discussed.

Development of new products and processes involving explosive technology will be presented.

Introduction

Explosives have been widely used in the oil industry from the beginning. Explosives have been used in seismic activities, perforating of formations, construction of trenches for pipelines, and the extinguishing of oil well blowouts. The first use of explosives for decommissioning and salvage of offshore structures is impossible to document. More than likely explosives were first used to sever well conductors in the mid to late 1950's. Eventually, explosives were primarily used for all platform removals in the Gulf of Mexico. During the early 1980's, there were no less than 10 companies offering explosive services for platform decommissioning. Many companies offering explosive services were actually diving and wireline operations. Environmental concerns relative to endangered species in the mid 1980's caused a drastic change in the way explosives were used offshore. Before this time, there were no rules or regulations to follow. The basic rule of thumb was, "if 5 pounds does a good job, 10 pounds does a hell of a good job". To date explosives have been used for platform removals all over the world. Since the Gulf of Mexico has the most platforms as well as the most removals this paper will concentrate on the rules, regulations, and technology that is employed in the Gulf.

Historical Perspective

The use of explosives for platform decommissioning before 1986 was not documented formally by the owners, operators, or governmental agencies. On April 15, 1986, the National Marine Fisheries Service (NMFS) sent a letter to Regional Director of the Mineral Management Service (MMS), Gulf of Mexico Outer Continental Shelf (OCS) Region. This letter expressed the concerns regarding stranding (to run ashore) events in 1985 & 1986. These strandings coincided with a number of explosive platform removals that were conducted in the State of Texas territorial waters. NMFS suggested that a correlation could exist between these stranding and the use of explosives for platform decommissioning. (Ref. 1) Consequently, MMS imposed an "unofficial moratorium" on platform removals. This was in an effort for industry to take the environmental issue seriously. Non-explosive removals were allowed to continue. Rules and regulations were then enacted upon the industry for using explosives for platform removals. NMFS started doing individual consultations for explosive removals. Aboout thirty of these individual consultations were completed by the time the "generic consultation" was completed. (Ref. 2)

The platform removal market started to come back slowly. At the same time, various alternative methods for severing piles and conductors were applied and improved. Alternative methods include diver cut, abrasive cutting, diamond wire, chemical, and mechanical cutting methods. The industry also researched unusual methods such as pyronol torches and cryogenics.

The chart below shows a synopsis of the yearly activity of platform removals and the removal method.

Year	Explosive	Non-explosive	Total
1986	1	0	1
1987	8	11	19
1988	63	9	72
1989	71	14	85
1990	67	32	99
1991	81	34	115
1992	64	37	101
1993	120	59	179
1994	91	35	126
1995	95	36	131
1996	58	71	129
1997	125	76	201
1998	46	41	87
1999	48	21	69
TOTALS	**938**	**476**	**1,414**

Table 1- Data obtained from the MMS, Gulf of Mexico Region – List of Structures Removed and Method of Removal, Compiled on 13–OCT-1999. (Ref 3)

Federal Environmental Statutes

The use of explosives for platform removals and the corresponding regulations came about because of long established federal laws. The two major federal laws are the following.

Endangered Species Act (ESA): The ESA was passed by Congress in 1973 to "provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, and to provide a program for the conservation of these species." This Act prohibits the "taking" of endangered species. "Taking is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" listed species. Offshore, in US waters, the National Marine Fisheries Service has responsibility for protection of threatened and endangered marine species. (Ref. 4)

Marine Mammals Protection Act (MMPA): The MMPA was enacted in 1972 and is the principal Federal legislation that guide's marine mammal protection and conservation policy. Enforcement of this Act is the responsibility of the NMFS. (Ref. 5)

Governmental Regulations

Different governmental bodies regulate the decommissioning and abandonment of offshore structures. Primarily, the regulatory body with responsibility is dependent on the physical location of the structure. The governmental bodies are broken into two categories, state and federal.

Federal waters begin 3 miles from shore off Louisiana and 9 miles off Texas. The Department of Interior's Mineral Management Service regulates all activities in these areas. Specific regulations are found in the Code of Federal Regulations, Title 30 – Mineral Resources, Part 256 – Leasing of Sulfur or Oil and Gas in the Outer Continental Shelf. In order to remove a platform from OCS waters a Structure Removal Application and Site Clearance Plan (30 CFR 250.143) must be submitted to the proper field office of the MMS. This process has an approval time of about 30 days. When using explosives for platform removals it is necessary to receive an Endangered Species Act Section 7 consultation. This Section 7 consultation has been applied so often that for most removals it is considered "Generic".

There are basic regulations that must be followed when using explosives offshore. These basic regulations are as follows:

- Transporting explosives offshore requires a permit from the U.S. Coast Guard.
- National Marine Fisheries Service observer must be on site for a period of 48 hours prior to, during, and after the detonation of explosives.
- If sea turtles are observed in the area and are thought to be resident – pre-detonation and post-detonation diver surveys must be conducted.
- On the day of blasting, a 30-minute aerial survey must be conducted within 1 hour before and one hour after the blast. If weather conditions prevent the aerial surveys, the explosive operations can continue if approved by the NMFS observer on site except when marine mammals are present.
- If sea turtles and/or marine mammals are observed within 1,000 yards of the platform, blasting must be delayed. The delay must remain in affect until the sea turtles and/or marine mammals are removed beyond 1,000 yards of the platform. If marine mammals are observed an additional survey must be performed. Either a diver survey within 24 hours after the blast or an aerial/vessel survey within 2-7 days after the blast.
- In general, explosives can be detonated no sooner than 1 hour after sunrise and no later than 1 hour before sunset. Special circumstances may allow for modification of these times if allowed by the observer on site.
- During diving operations (if required during a removal), divers will be requested to scan the area around the platform for sea turtles and marine mammals. Any sightings shall be reported to the NMFS observer.
- After the explosives are detonated, if sea turtles and/or marine mammals are sighted, either dead or injured, attempts should be made to recover.
- The types of explosives to be used for platform removals must be high velocities, i.e. Composition-B, C-4, Cyclotol, HMX, RDX, and PETN.
- Explosive charge weight shall not exceed 50 pounds. Increased explosive weights are allowed, only with prior approval from MMS and NMFS.
- Generic permits allow 50 pounds to be detonated within a pile, conductor, or caisson. If a requirement is necessary for an external charge, a special consultation will be required.
- The detonation of explosive charges must be staggered with at least 0.9 seconds between each charge. This is to limit the cumulative effect of the blasts.
- The interval between groups of charges (usually, a group

of charges is limited to 8) should be minimized. This interval is usually 1 minute. This is to avoid the “chumming” effect (attracting other fish).

- If the interval between detonations is over 90 minutes, the 30-minute pre-detonation survey must be repeated.
- The use of scare charges should be avoided. They may be allowed if approved by the NMFS observer on site.
- A report summarizing the explosive usage and mitigation measures must be submitted to the MMS and NMFS within 15 days of the removal. (Ref. 6)

Platforms in state waters closely follow the rules and regulations established for the OCS federal waters.

Present Explosive Methodology

Offshore targets for explosives are broken into two categories: single layer targets and multi-layered targets. Most piles and open conductors are considered single layer targets. In other words, the target is only the wall thickness of the pile or conductor. Well conductors with two or more strings are considered multi-layered targets. Multi-layered targets as in well conductors include not only the wall thickness of the casing but also the material in the annuli of the strings. The material in the annuli of well conductors can be water, air, drilling fluid and/or grout. Explosives can be used to sever most piles and conductors that make up offshore platforms.

Explosive service companies take into consideration a multitude of variables before they perform an offshore severance project. The following is a list of variables that can affect the performance of an explosive severance operation.

Target Considerations: for both single layer target and multi-layered targets. OD of each layer, wall thickness of each layer, length of each layer, steel type of each layer, manufacturing process of each layer, type of material in each annulus, and the concentricity of the strings in the multi-layer target. Other target considerations include internal obstructions and degree of access to the target severance location, i.e.-stabbing guides, etc.

Environmental Considerations: variables that surround a specific target. They include the water medium, which are the water depth and hydrostatic head as well as the soil medium i.e. soft, firm, stiff, etc.

Operational Considerations: How are the explosives to be set and detonated. Are the explosives set from the surface by the explosive technician, diver set, or ROV set? Are the explosives to be set from the platform, work vessel, from a workbasket, or some other way? Will the explosive be detonated from the platform or work vessel? How far away does the work vessel need to be from the explosion, i.e. DP vessels with thrusters are more sensitive to shock waves.

There are a multitude of explosive devices/charges that are used for severing offshore piles and conductors. The following is a review of the various charges that are presently used.

Bulk Charges (Figure 1): One single mass of explosive material detonated at a single point. The energy release from this type of charge is not well directed. The field technician is relying on the “brute strength” of the explosive to overcome the target material by a shattering and tearing effect. Bulk charges are cylindrical in design. These charges vary in length and diameter to achieve the best fit with a wide range of typical offshore tubulars. These charge diameters range in size from 4” to 12”.

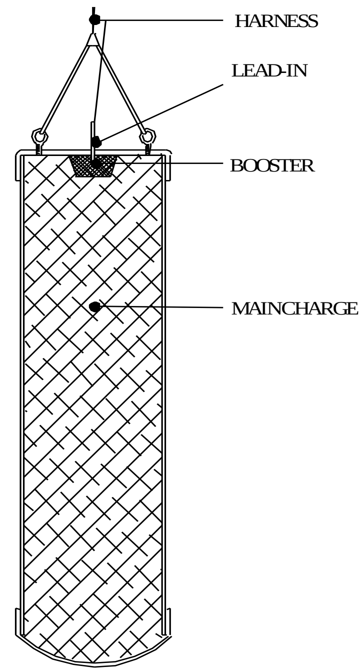

Figure –1 Bulk Charge

Smaller bulk charges can be arranged to create a larger diameter **(see Figure 2).** This technique allows the technician to configure the cast explosive material for whatever conditions may arise. For instance, in some cases it might be advisable to use smaller charges in a circular ring configuration to maximize the explosive concentration and proximity to the target material as shown.

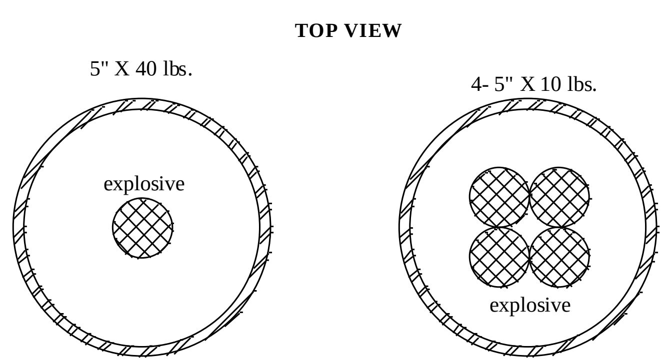

Figure 2 – Bulk Charge arrangement for larger diameters

Double Detonation Bulk Charges (Figure 3): The use of a double detonation bulk charge creates more "cutting power", pound for pound, than an ordinary bulk charge. Double detonating the bulk charge is accomplished by using instant non-electric or electric detonators at opposite ends of the charge. This detonation creates a confluence of energy at the center of the charge which is dissipated radially outward directly perpendicular into the target material. It is this directing of explosive energy that makes double detonating bulk charges more effective.

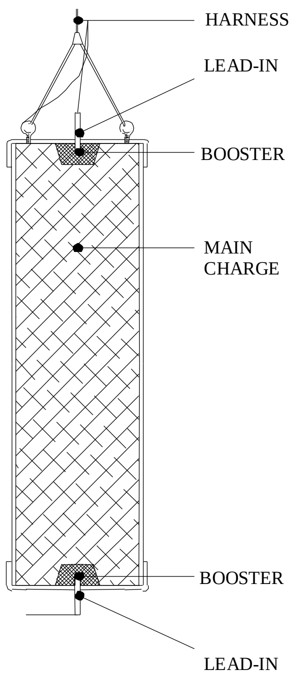

Figure 3- Double Detonation Bulk Charge

Configured Bulk Charges (Figure 4&5): For larger offshore tubulars, the configured charge uses explosive material in close proximity to the target material. Upon detonation, this results in a higher average pressure on the target material. Multiple points of detonation on this charge on the inner periphery can effectively direct the explosive energy to the target material.

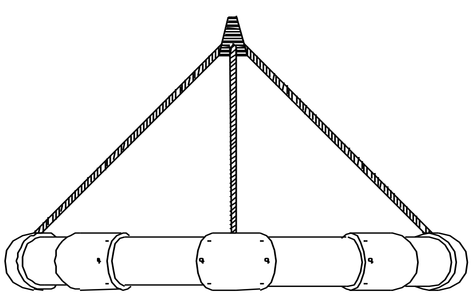

Figure 4 – Configured Charge – Side View

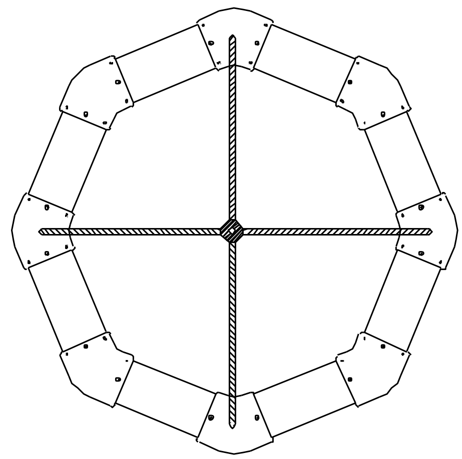

Figure 5 – Configured Charge – Top View

ShockWave Enhancement/Focusing Devices (Figure 6): This is the ultimate combination of all the best features of the above charges with the added benefit of extreme confinement to concentrate all of the explosive energy on the target material. Using increased confinement, multiple point detonation, and the actual water inside of the tubular to direct energy, this device is the most reliable bulk explosive severance device available.

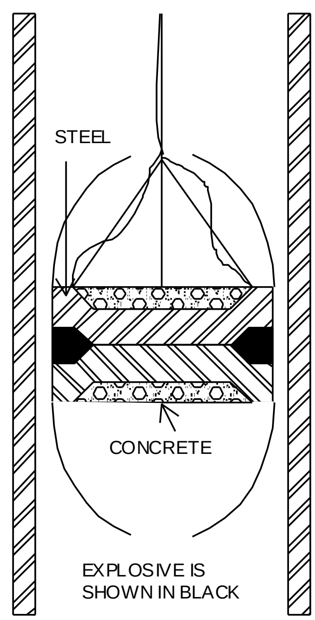

Figure 6 – Shock Wave Enhancement/Focusing Device

Bridge Plugs (Figure 7): The energy released by a bulk charge can be enhanced by the use of a bridge plug. A bulk charge is used with a metal and/or concrete plug above the charge. The addition of the bridge plug increases the energy that is released by the explosive towards the target material.

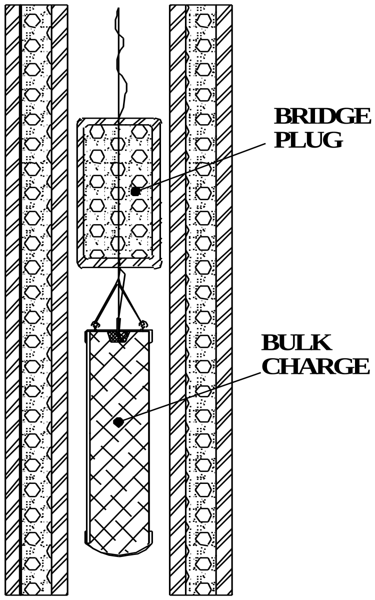

Figure 7 – Bulk Charge with Bridge Plug

Shaped Charges (Figure 8&9): The most effective use of explosives for severing is the shaped charge. The shaped charge uses the energy produced by the detonation to drive a liner at high velocity at the target. The liner striking it at this accelerated velocity then cuts the target.

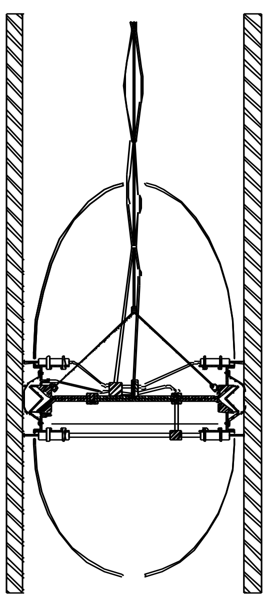

Figure 8 – Internal Shaped Charge

While the quantity of explosives required to do the cutting can be reduced, shaped charges have a multitude of manufacturing and design criteria, which can drastically affect performance. The design criterion of shaped charges also requires that target specifications be known. Manufacturing of shaped charges can take weeks and can cost five times as much as conventional bulk charges.

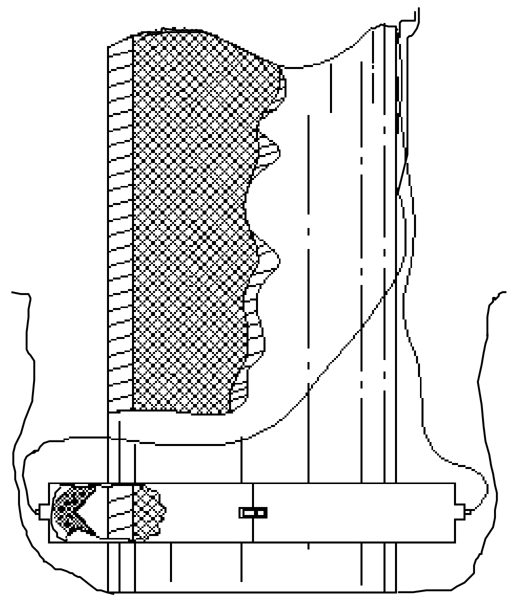

Figure 9 – External Shaped Charge

Safety Issues

Historically, the explosive industry enjoys an excellent safety record. The use of explosives for offshore decommissioning and salvage has had only one accident in its entire history. As with most accidents, this incident should be blamed on human error. Explosives are hazardous materials. As such, they must be handled properly.

When using explosives in any operation, general safety rules must be followed. These include:

- Qualified, trained, and licensed technicians only, should handle explosives.
- Store explosives in approved magazines.
- Keep explosives away from fires and welding/cutting operations.
- When using electric blasting caps beware of stray currents and electrical transmission devices i.e. radios, cell phones, radar, welding machines, etc.
- Blasting operations should be suspended during electrical storms.
- In general, detonators should not be tied into explosives while divers are in the water.
- If the detonator has a mis-fire, wait at least 30 minutes before approaching.

Limitations

The use of explosives for platform removals can have limitations but in general, very few. The limitations will relate to governmental and operational considerations.

Governmental Limitations: these limitations include explosive weight, placement (external and internal) relative to the mudline, and several other limitations that are outlined in the previous sections. It must be remembered that most of these limitations can be addressed with proper planning. The planning includes approval from MMS and NMFS for the use of explosives. If the usage is not considered “generic”, reasonable and prudent measures must be implemented. Approval has been given, if just cause is shown, to exceed the standard explosive operational parameters. An example, is the 175-pound external shaped charges used for a platform removal in the Gulf of Mexico. This charge type and weight was required to sever a large diameter pile that was set with reinforced concrete and rebar.

Operational Limitations: these limitations include not only the standard governmental limitations but also things that can be affected by the use of explosives. Pipelines near the detonation could be damaged if they are too close. Other operations being performed in the area must also be considered. The shock wave from a detonation can damage subsea equipment, vessels, and divers. Shaped charges as well as bulk charges offer extremely effective performance but have limitations. The shaped charge must maintain an air standoff to allow the jet to form and must be placed in close proximity of the target. Water can destroy the effectiveness of a shaped charge jet. The target parameters must be known. Out-of-round targets and dimensions that are larger (i.e.- increased wall thickness) than the charge was designed for, could result in failure

Cost Comparisons

In a broad sense, explosive severance on a large removal project can be less than 1% of the total cost of the project. On small removal projects, the explosive cost can be as high as 5%. The explosive and technician rates are consistent. The cost driving factors of removal projects are the work vessels. If a severance method is unsuccessful on its first attempt, the project over runs primarily relate to the work vessel and associated equipment. From historical field records the success ratio for explosive severance on the first shot is usually around 95% to100% depending on the specific target. (Ref. 7) Experienced explosive contractors, if the variables are known, will be able to predict their success ratio for a given target.

Cost differentials between severance methods are difficult to analyze on a 1 to 1 basis. Generally, explosives are less expensive than all other severance methods. However, the use of explosives for platform removals has other cost that must be included to make comparisons applicable. These cost include NMFS observers, the 48-hour survey, helicopter searches, and in some cases daylight hours shooting limitations.

Before trying to make comparisons, we must also consider intangible costs and benefits when using explosives. Intangible cost includes public perception from using explosives, which can adversely affect the industry. If the jacket is to be reused, we must consider the flaring of piles and conductors from explosives. The flaring associated with explosive severance can cause difficulty in removing the pile from the jacket and could cause damage to the bell guides when extracting the severed conductors. One major benefit of using explosives is time. Explosives are the quickest way to sever a pile or conductor. Less time on a project, with fewer personnel, equate to savings of potential liability from accidents by having less exposure time. Another intangible benefit from using explosives can be confirmation of severance. In general, if the piles are not grouted, the platform is not on mud mats, and the conductors are not tied back – the target will drop thereby confirming that the severance has been successful. Confirmation of severance by other methods involves lifting the target by some means.

Historically, explosives have been the least expensive of all platform removal methods. Operational considerations including water depth, platform design, and conductor make-up can affect cost. To compare explosives to other methods we will use explosives as the base line and present the differences as percentages of the cost. (Ref. 8)

Water Depth	Mechanical	Abrasive	Diver
0 –50 feet	+41%	+29%	+67%
50 – 100 feet	+40%	+26%	+73%
100 – 150 feet	+38%	+22%	+81%
150 –200 feet	+35%	+23%	N/A
200 – 250 feet	+30%	+19%	N/A
250 plus feet	N/A	N/A	N/A

Table 2 – This table compares the percentage over explosive cost for a 4-pile platform with 6 conductors.

Water Depth	Mechanical	Abrasive	Diver
0 –50 feet	+48%	+27%	+45%
50 – 100 feet	+50%	+27%	+63%
100 – 150 feet	+45%	+23%	+90%
150 –200 feet	+41%	+20%	N/A
200 – 250 feet	+32%	+16%	N/A
250 plus feet	N/A	N/A	N/A

Table 3 – This table compares the percentage over explosive cost for an 8-pile platform with 6 conductors.

The above percentages assume a successful severance on the first attempt. A single reshot with explosives can take less than 1 hour whereas the other methods can take as much as 8 hours. It is then the vessel cost starts to add up. There are other alternative methods for severing piles and conductors. These other severance methods include diamond wire cutting, chain cutting, and various chemical cutting methods. For this paper, we did not review these methods as their history and performance in the Gulf of Mexico is still being developed.

Application of New Technology

New technology includes not only development but also improvement of existing technology for severing. One of the major problems to effectively sever a tubular is placement of the device.

Improved Shaped Charges – Explosive service companies believe that the best way to sever a tubular is by the use of shaped charges. Efforts are being made to improve every aspect of design and performance. Improvements are being made in liner design, weight reduction, and charge placement. Articulate/mechanical devices to place the shaped charge against the target thereby maintaining optimum standoff are improving. Different devices are also employing improved bladders to maintain standoff. As increased water depths for platform removal and salvage become more common, designs to compensate for increased hydrostatic pressure will need to be addressed.

Flexible Linear Shaped Charges - These charges are commonly referred to in the industry as ECT (Explosive Cutting Tape) and are now commercially available. They are composed of a flexible plastic explosive, a flexible colloidal copper liner, and it is enclosed in polyurethane foam. Due to the flexibility causing non-uniformity in the explosive and the liner, they are limited in their operating performance. A further draw back in offshore use is the compressibility of the foam underwater.

Planar Symmetric Shape Charges- this is a system made up of multiple conical shape charges. These charges normally produce a small diameter hole. Adding heavy peripheral weighting for ninety degrees on opposite sides provides confinement that produces a different type of liner collapse. This collapse produces a jet that fans out radially on one plane normal to the target material. A series of these charges are lined up around the inner periphery of the target to make a complete radial cut. Again, all problems associated with shape charges in general are amplified using a PSC where absolute precision is required.

Shock Wave Focusing - Shock wave focusing is a method of using two high explosive strips radially wrapped around the target surface for severance. The strips are canted about 15 degrees off parallel to cause the shock waves to converge at the back surface of the target material. Shock waves are opaque in nature (as opposed to sound waves, which are transparent), and as such do not readily pass through each other. At the point of convergence, a region of extreme pressure called a Mach stem is created. The energy (and pressure) contained in the stem may be several times greater than the sum of the shock waves. If this stem is formed at the back of the target material, the rapid compression followed by enormous tensile stresses will cause the material to sever from the "outside in". The explosive pressure bearing down on the surface of the target carries out the rest of the severance. Drawbacks to this system are numerous. The target material's thickness must be known exactly, the surface must be cleaned for the charge to be placed in direct contact by a diver, and there can be only water or air on the outside of the target. (Ref. 9)

Conclusions

The use of explosives will continue to be an efficient and cost effective method for the decommissioning and salvage of offshore platforms. In actuality, the rules and regulations established because of environmental considerations has been good for the industry. These rules and regulations have increased the industry's awareness towards endangered and threatened turtles and marine mammals. Explosives do have an impact on the environement but according to NMFS, preliminary results indicate effects on sea turtles and fish population appear to be small in relation to other sources of mortality. NMFS will be publishing findings relative to this in the coming year. Several reports have requested changes or relief on some of the present rules and regulations but these changes will not come about unless industry pursues the changes. Changes to these rules and regulations will only make explosives more cost effective.

There are a variety of explosive charges used for severance of offshore piles and conductors. In the Gulf of Mexico, the full ranges of piles and conductors have been successfully severed with one explosive device or another. Limitations have usually been associated with lack of planning and permitting.

The capabilities of explosives for platform removal and salvage are well documented. The only limitations of the applications of explosives for platform removals are with respect to the experience and imagination of engineers and explosive contractors.

Acknowledgements

We thank Gregg Gitschlag with the NMFS for clarifying some of the historical perspectives; Joe Kallaby with Offshore Structures, Inc. for this unique opportunity; and everyone at Demex who helped in the final review process.

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