High Explosives Technology and Applications

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An introduction to High Explosives, their use in Decommissioning Operations and the Mitigation of their effects on the Marine Environment.

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Section 1

What is an Explosive?

What is an Explosive?

"A substance, that when subjected to a suitable stimuli, undergoes a violent chemical decomposition with the evolution of heat and gas."

Or, in simpler terms:

"A material containing stored chemical energy, which can be rapidly released in the form of heat and high pressure gas, when triggered to do so."

Explosives do not necessarily contain a lot of chemical energy; it is more their ability to release this energy rapidly that make explosives such a useful tool.

If we take two items of the same size, both of which contain stored chemical energy, we can illustrate this fact:

Candle

Plastic Explosive

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If we take two items of the same size, both of which contain stored chemical energy, we can illustrate this fact:

The Candle releases far more energy than the Plastic Explosive, but takes approx. 50,000 times as long to do it!

8 x Heat
4 x Gas

1 x Heat
1 x Gas

✓

Candle

Plastic Explosive

High Explosives

The distinguishing feature of a High Explosive (HE), is that it will ***Detonate*** under its normal conditions of use.

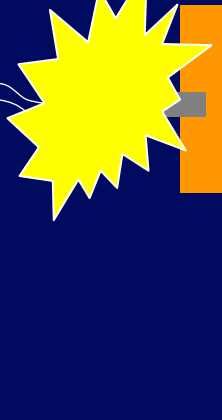
A ***Detonation*** is a specific type of explosion, where the chemical decomposition occurs so violently that it produces a shock wave.

High Explosives

The shock wave passes through the HE at or faster than the speed of sound of the material (sound travels faster through dense materials than it does through air).

As the shock wave meets unconsumed HE, the energy within the shock wave causes the explosive to Detonate, thus feeding and sustaining the shock wave.

As such, once a Detonation within an HE has been initiated,it will propagate through the entire charge until all available explosive material has been consumed.



High Explosives

HE’s are divided into two sub groups:

Primary Explosives

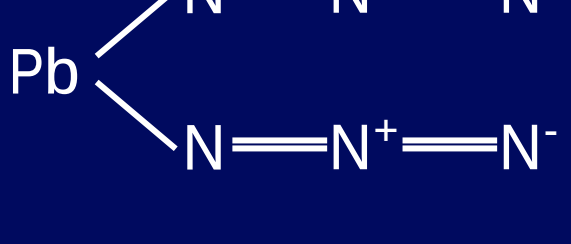
&

Secondary Explosives

Primary Explosives

There are many examples of materials within this sub-set of High Explosives, including:

Lead Azide



Silver Azide

Lead Styphnate

Primary Explosives

The characteristic that groups these materials as Primary Explosives, is that they are all easily initiated by one or more common stimuli such as:

Heat

Impact

Stabbing

Percussion

&

Friction

Primary Explosives

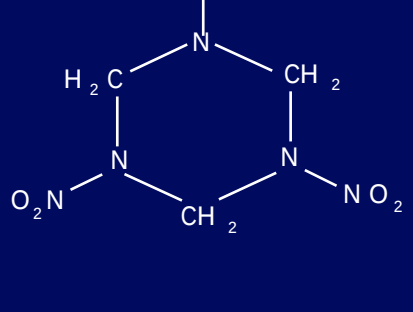
Primary Explosives are listed as ‘Very Sensitive’.

Since these materials are so easily initiated, they tend to be used in very small quantities as the initial elements of Detonators - which are used for initiating Secondary Explosives.

Secondary Explosives

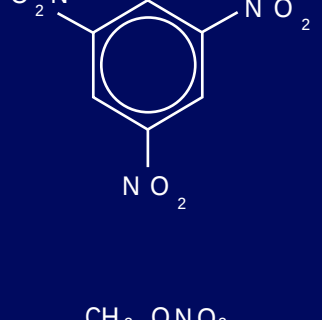
As with Primary Explosives, there are many different materials within this sub-set of High Explosives, including:

RDX

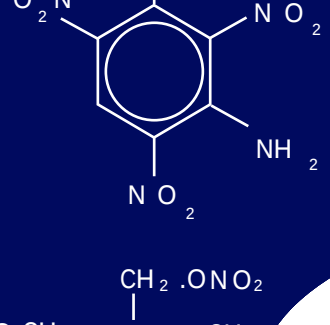


TNT

Picric Acid

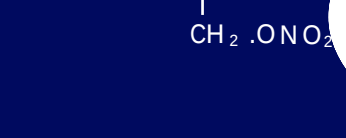


DATB



Nitroglycerine

PETN



Secondary Explosives

The common characteristics that differentiates Secondary Explosives from Primary substances is that in general, they are relatively difficult to initiate and require a shock wave donor, such as a Detonator in order to establish a sustainable Detonation.

Secondary Explosives are generally listed as 'Comparatively Insensitive', although some fall into the range of 'Sensitive materials'

Since most Secondary Explosives are difficult to initiate by accident, they can be transported and used reasonably safely. It is for this reason that Secondary Explosives are by far the most common explosive tool used.

Video Demonstrations

Hollywood ‘High Explosives’ & Real High Explosives

Section 2

The Shaped Charge Phenomenon

The Shaped Charge Phenomenon

Shaped Charges are a means of focusing the stored chemical energy that is found in explosives to perform efficient and useful work by rapidly penetrating or cutting tough materials.

Military Shaped Charges are often referred to as HEAT rounds, which has lead to the common misconception that they, somehow melt a hole through their target.

H.E.A.T. stands for High Explosive Anti-Tank and has nothing to do with the temperature at which it penetrates.

In fact a copper jet formed by a shaped charge only reaches about 400 C. Jets are simply the liner metal behaving as a Newtonian viscous fluid. They are not plasmas.

Basic Types of Shaped Charge

Many industries use Shaped Charges for different applications there are two main configurations that are used:

Conical Shaped Charges

Used to create single deep circular
Their uses include; Anti-Tank Weap
and Oil Well Perforators .

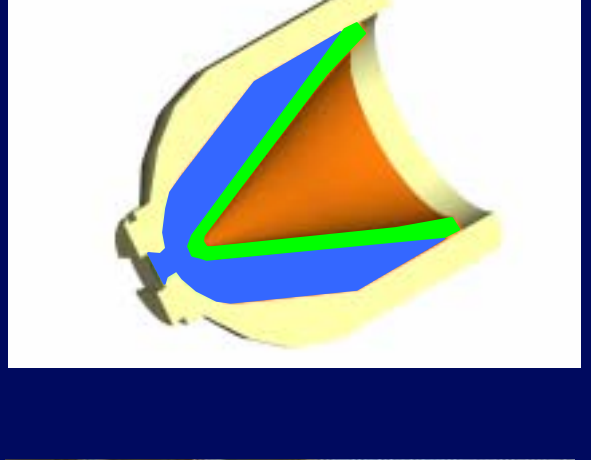
Linear Cutting Charges

Used to create a cutting effect as th
name suggests. Their uses include;
severance of structural members, p
plates, re-enforcing, etc. - often use
Demolitions and Bomb Disposal.

'Blade' Photographs

Basic Types of Shaped Charge

Both of these configurations share the same cross-sectional features:

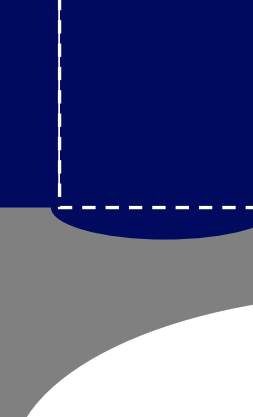


A Triangular Liner Backed with Explosive

'Blade' Photographs

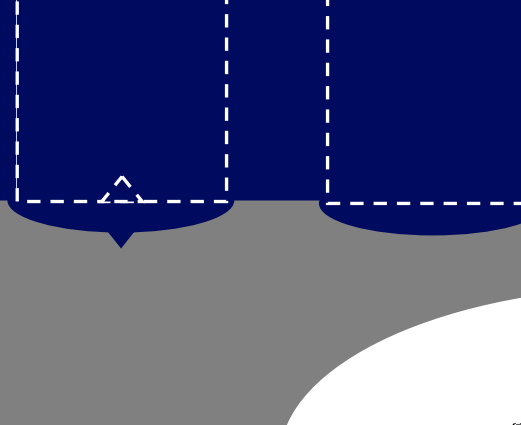
The Munroe Effect

As you might expect, detonating an explosive charge against the metal surface of a solid target will form a dent or crater:



The Munroe Effect

While experimenting with compressed charges of Nitro-cellulose in 1888, Charles Edward Munroe noticed that the manufacturer's name – which was pressed into the block, was reproduced on the targets surface:

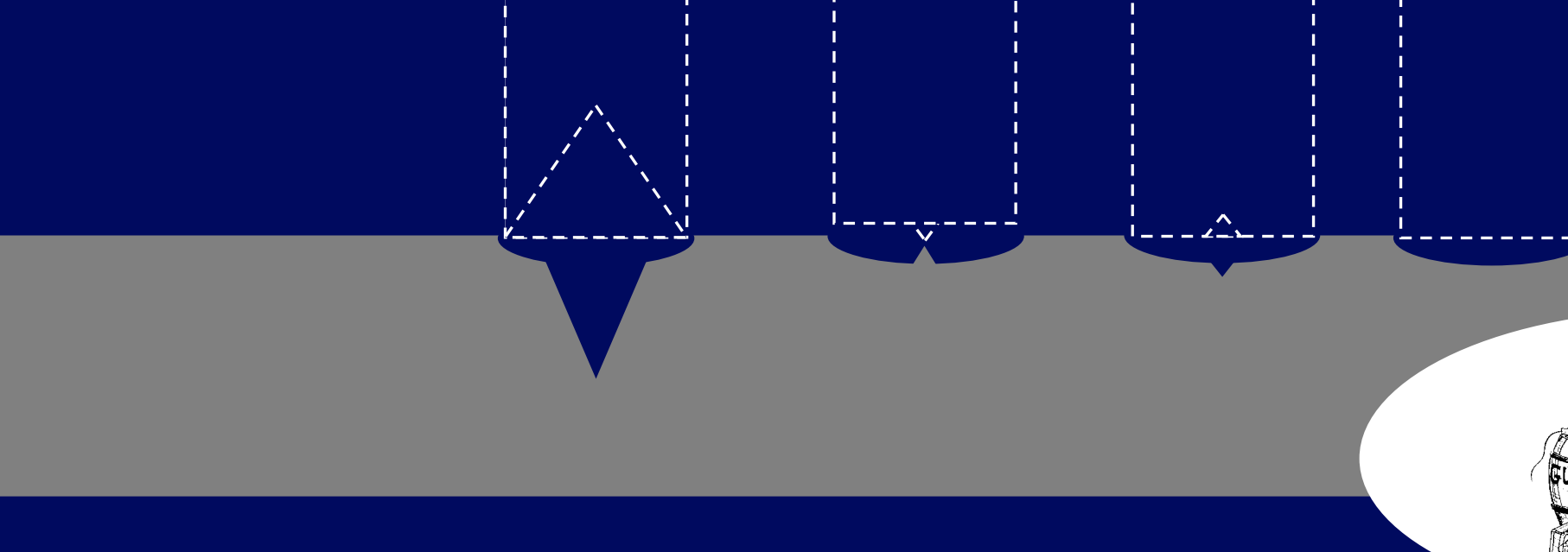


The Munroe Effect

Further experimentation lead him to discover that a raised oin
instead of a depression in the end of an explosive charge
created a crater with a similar raised point at its centre:

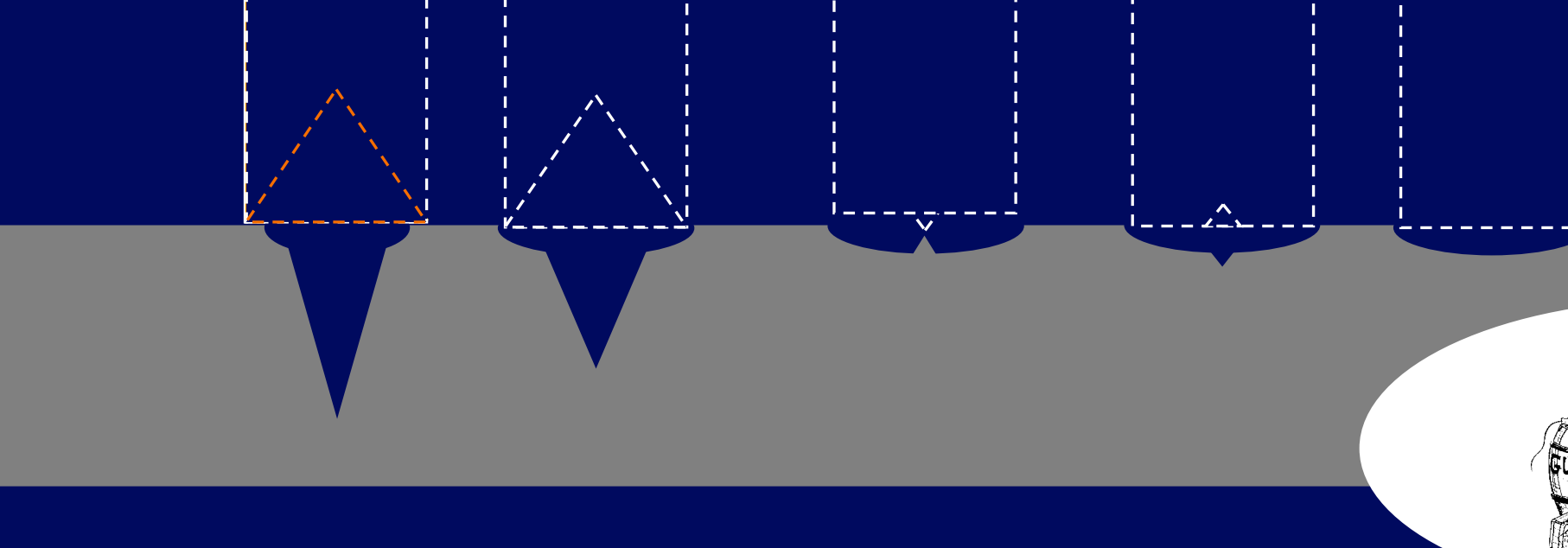
The Munroe Effect

His investigations revealed that the larger the cavity, the larger the cutting effect:



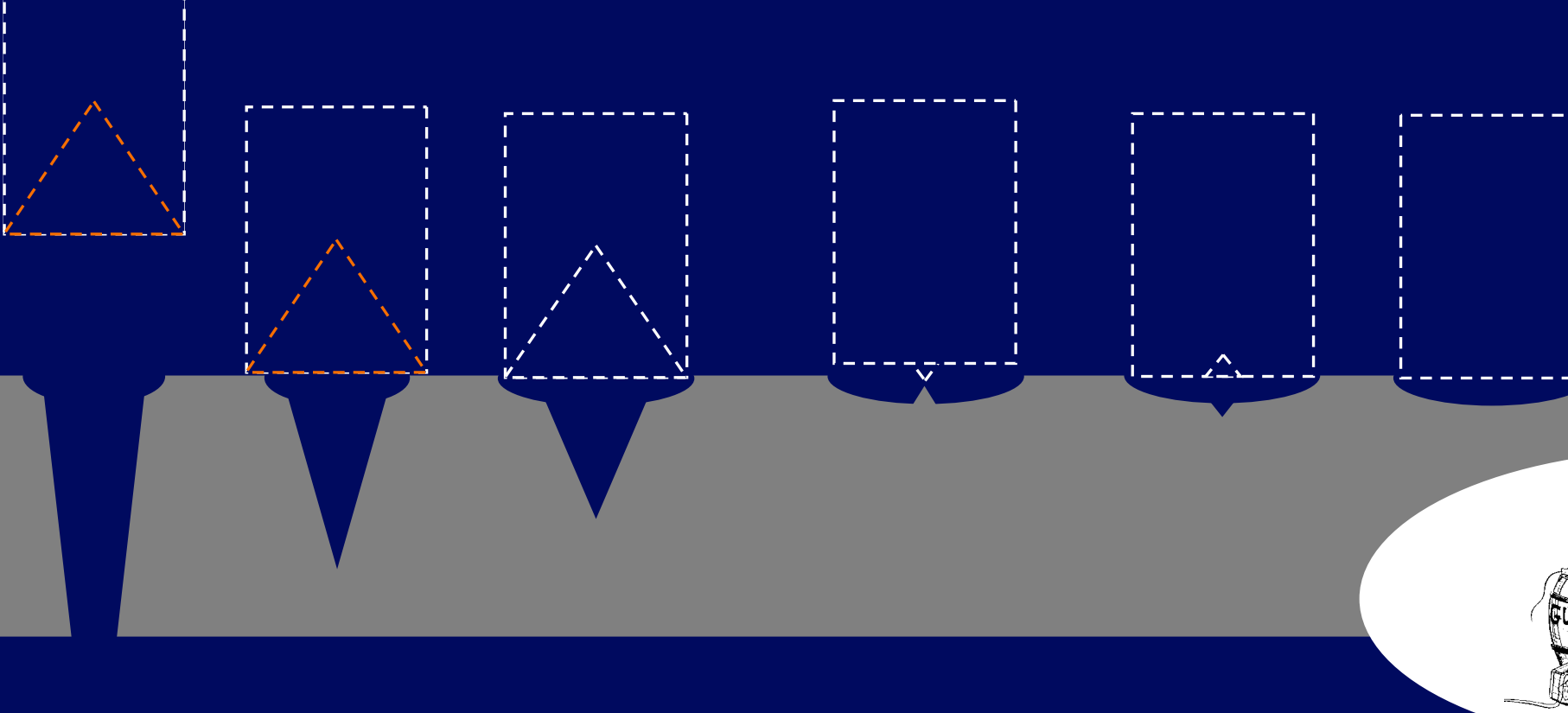
The Munroe Effect

Putting a metal liner inside the cavity increases the depth of penetration:



The Munroe Effect

And moving the charge away from the surface further increased the cutting effect:

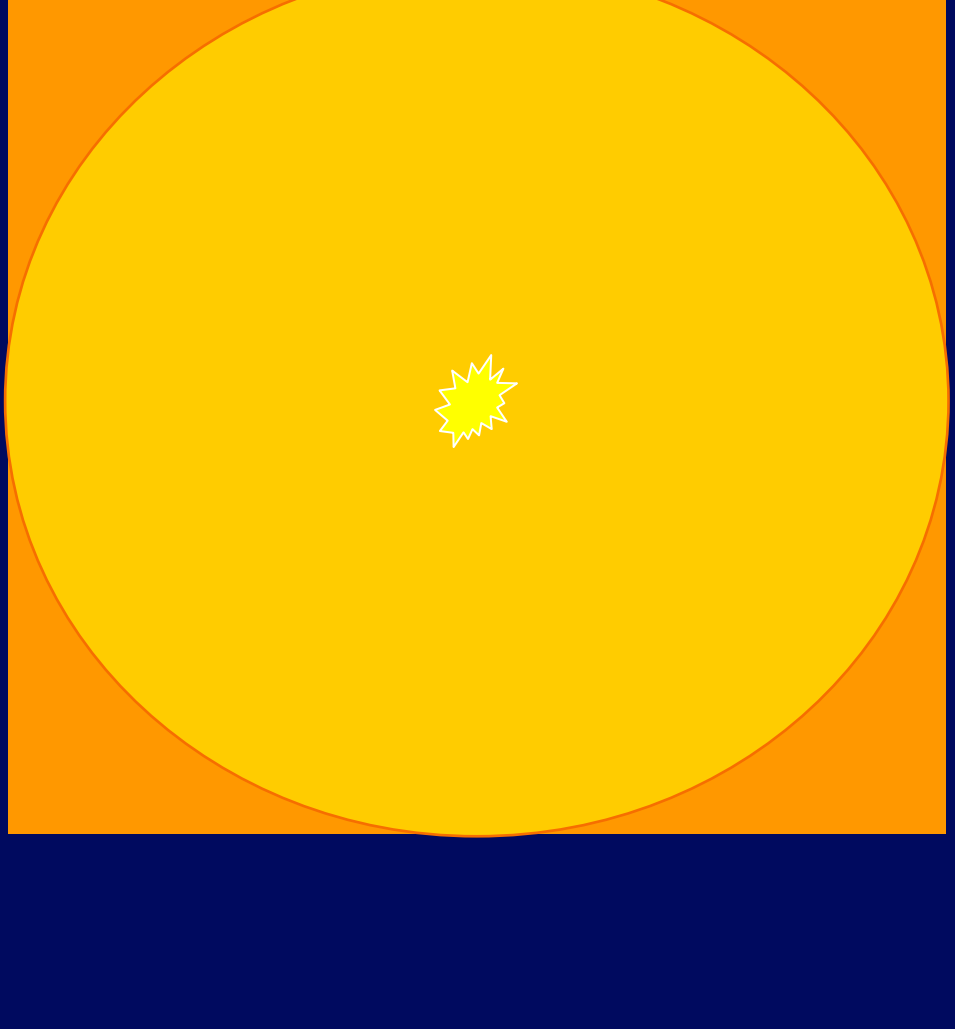


Basic Detonation Theory

Unimpeded an explosive detonation front will propagate in
all directions at the same rate:

Therefore a detonation front travelling through an explosive charge will spread in a spherical pattern (Huyghens Principle) with the point of initiation at its epicentre.

Basic Detonation Theory



Basic Detonation Theory

Here, we see the same effect from the side:

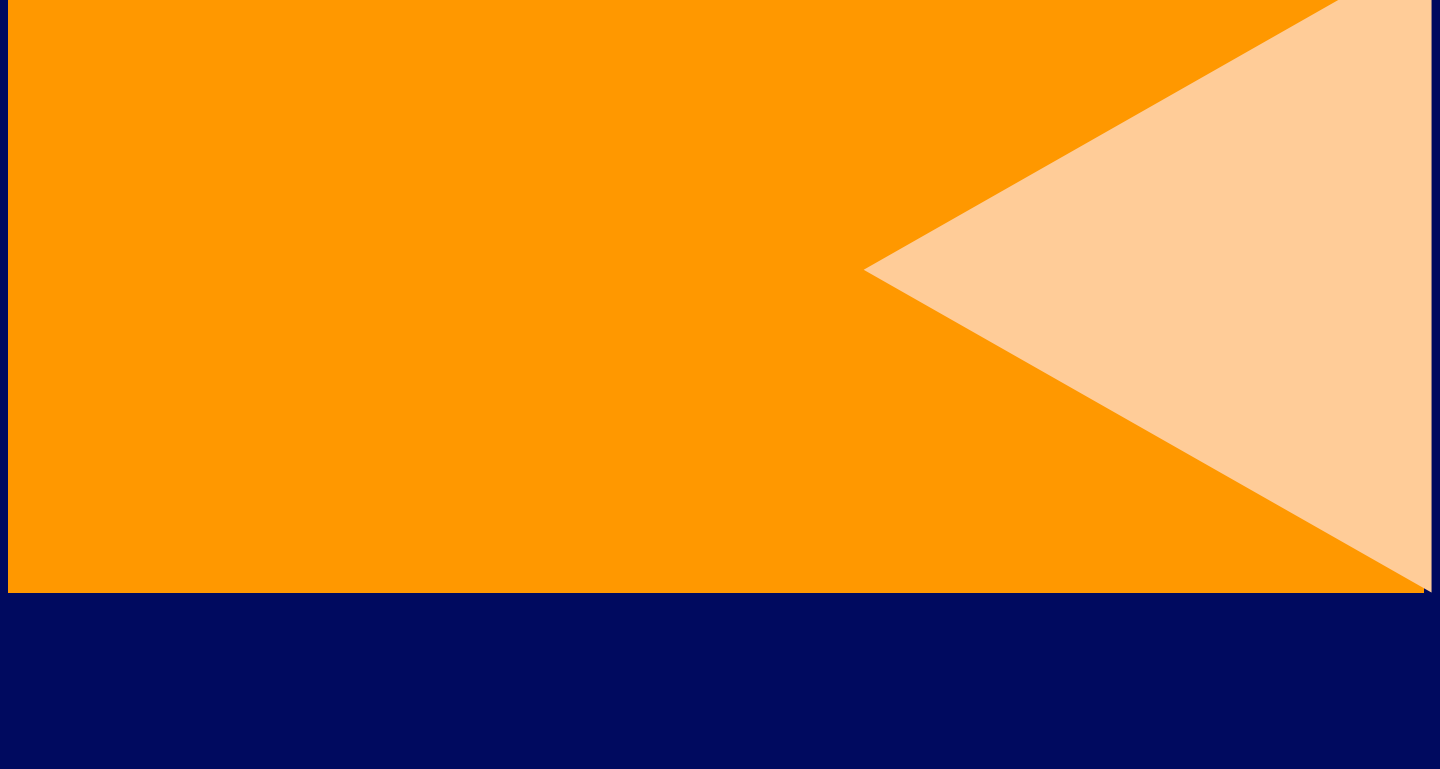
An extremely long explosive charge can be used to generate a detonation front that is (for all intents and purposes) flat: i.e. a ‘Plane Wave’.

The Configuration of a Shaped Char

Firstly we take a solid explosive charge:

The Configuration of a Shaped Charge

A hollow void is formed in one end of the charge:



The Configuration of a Shaped Charge

A close fitting metal liner is inserted into the void:

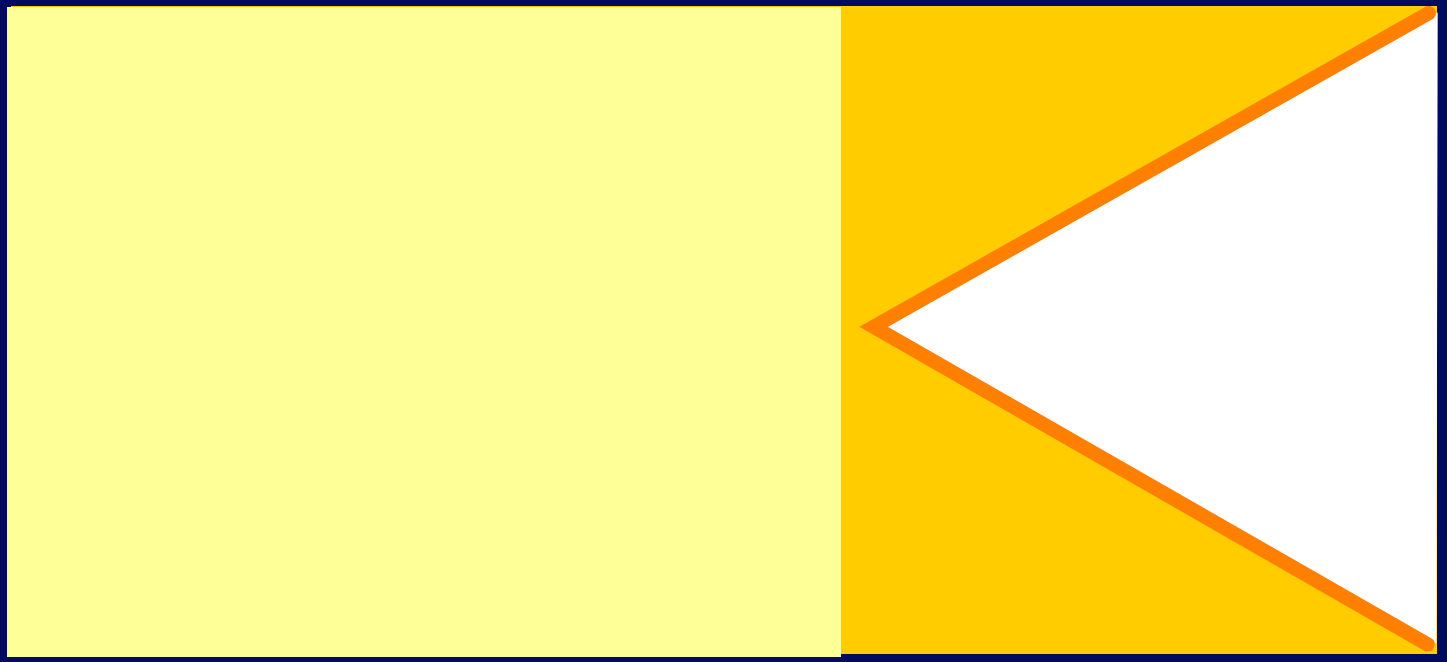
The Configuration of a Shaped Charge

We'll change the colour scheme, to make the following examples clearer:

Detonation of a Shaped Charge

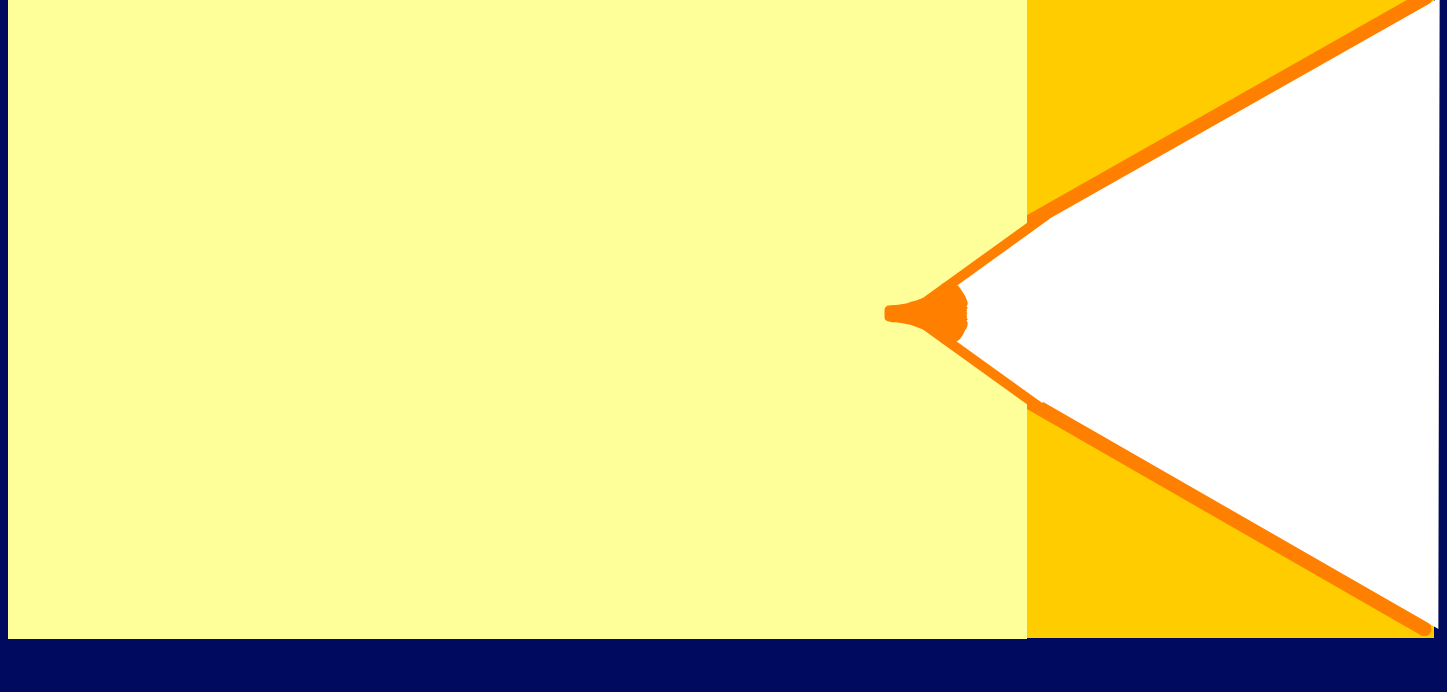
For simplicity, these examples will show a ‘Plane Wave’ detonation.

The detonation front travels down the charge:



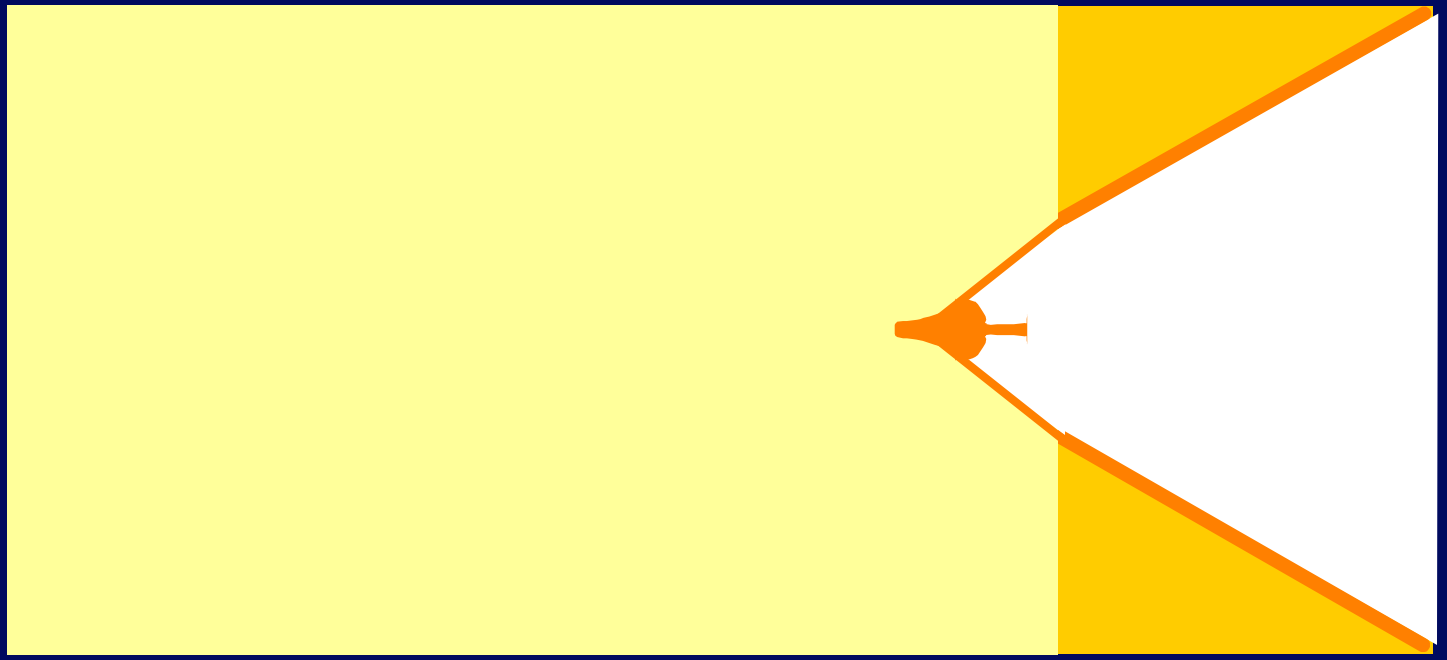
Detonation of a Shaped Charge

The detonation front meets the metal liner:



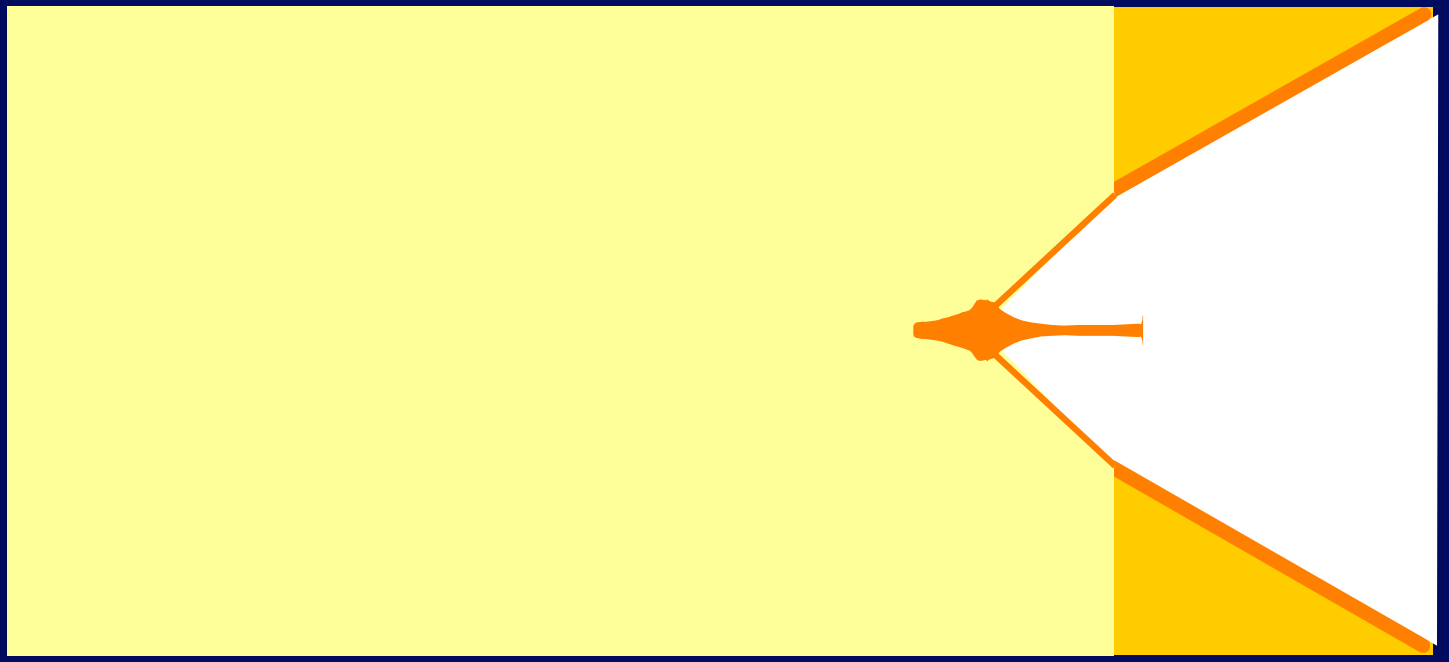
Detonation of a Shaped Charge

The detonation front meets the metal liner:



Detonation of a Shaped Charge

And forces the metal towards the centre of the hollow:



Detonation of a Shaped Charge

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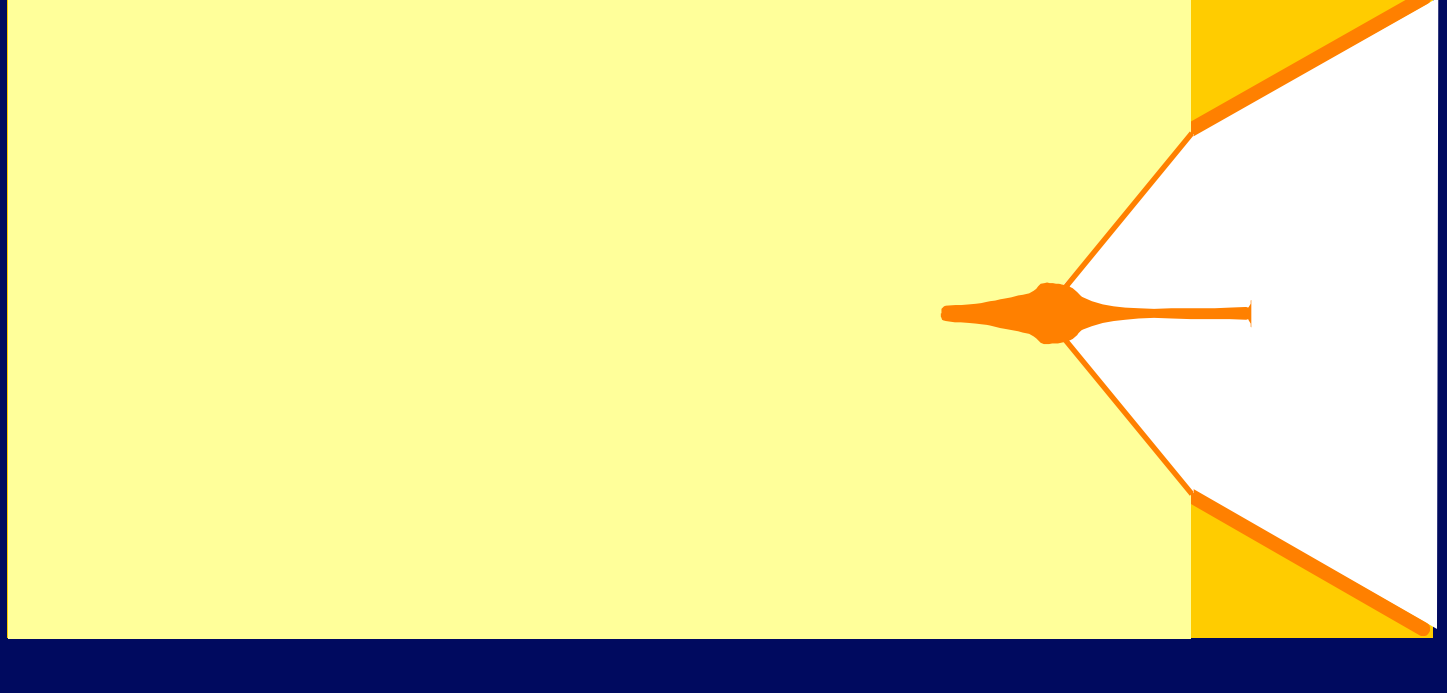
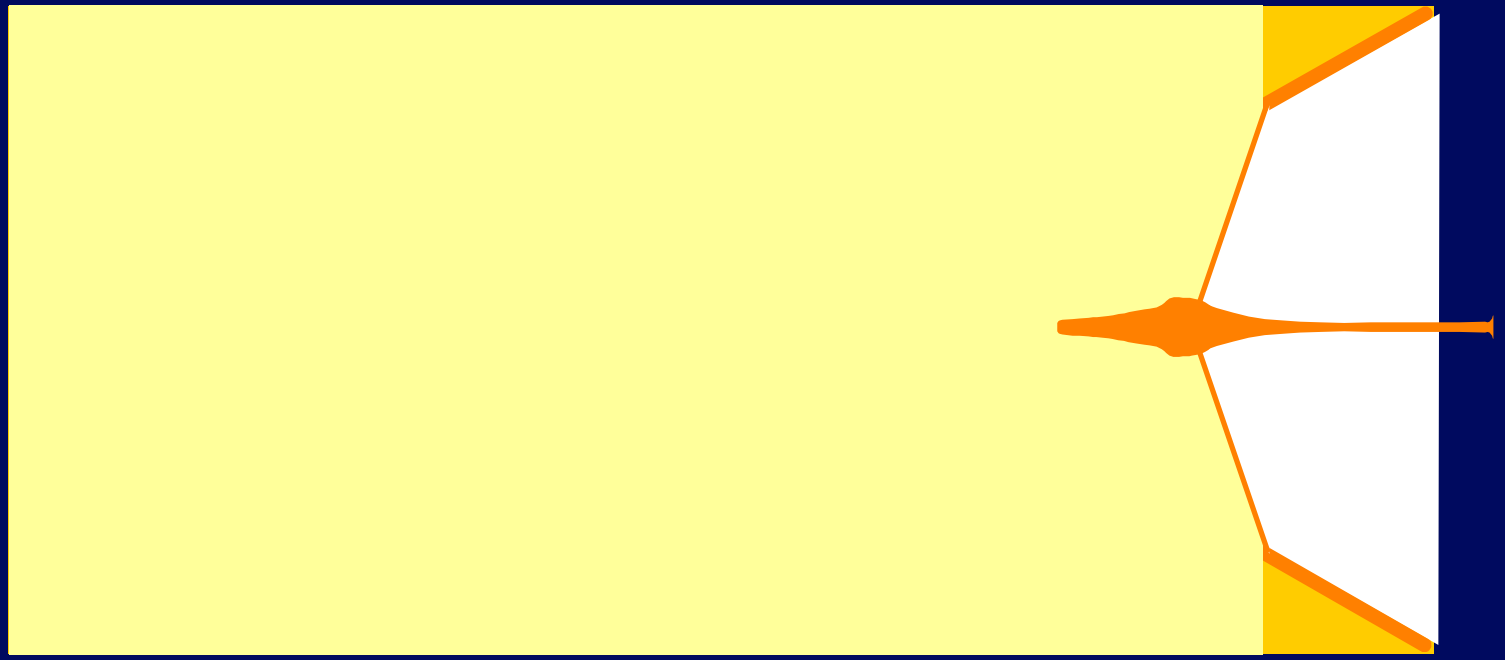


Detonation of a Shaped Charge

Forming a ‘Jet’ that can travel as fast as 10 Km per second:



Detonation of a Shaped Charge

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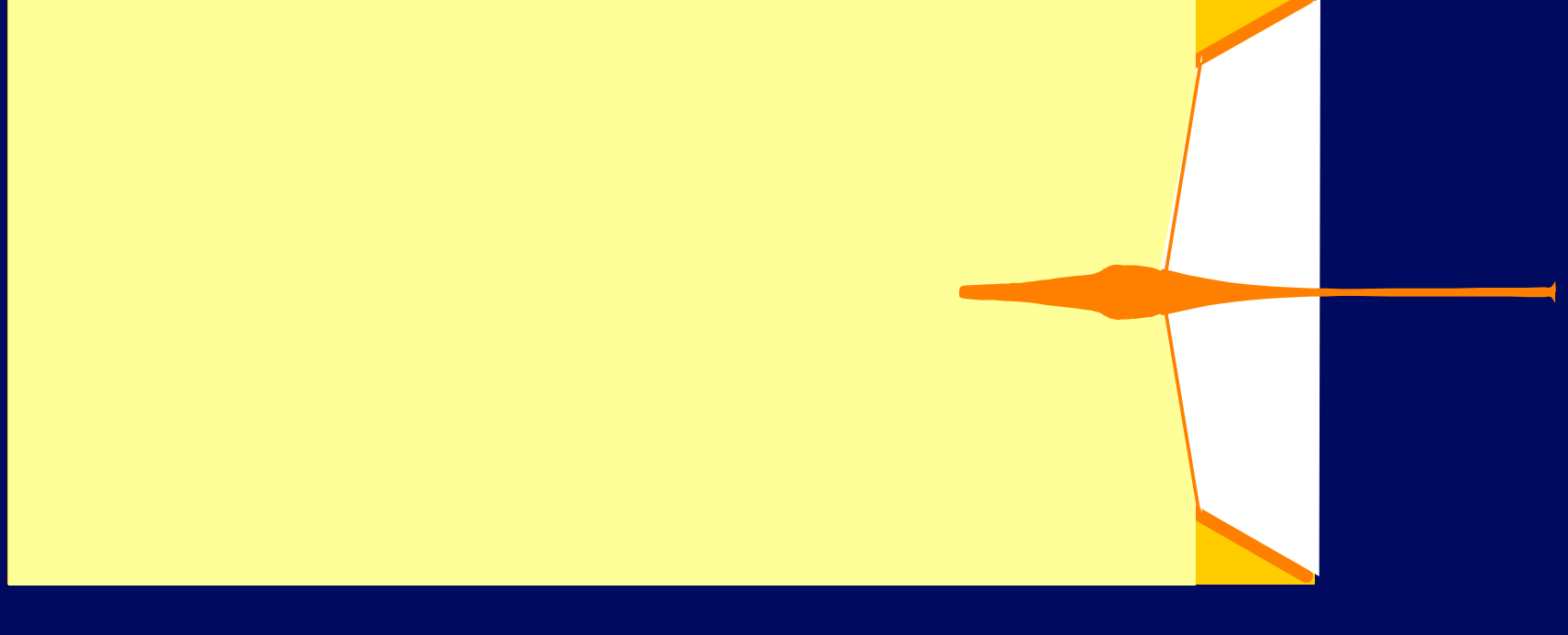
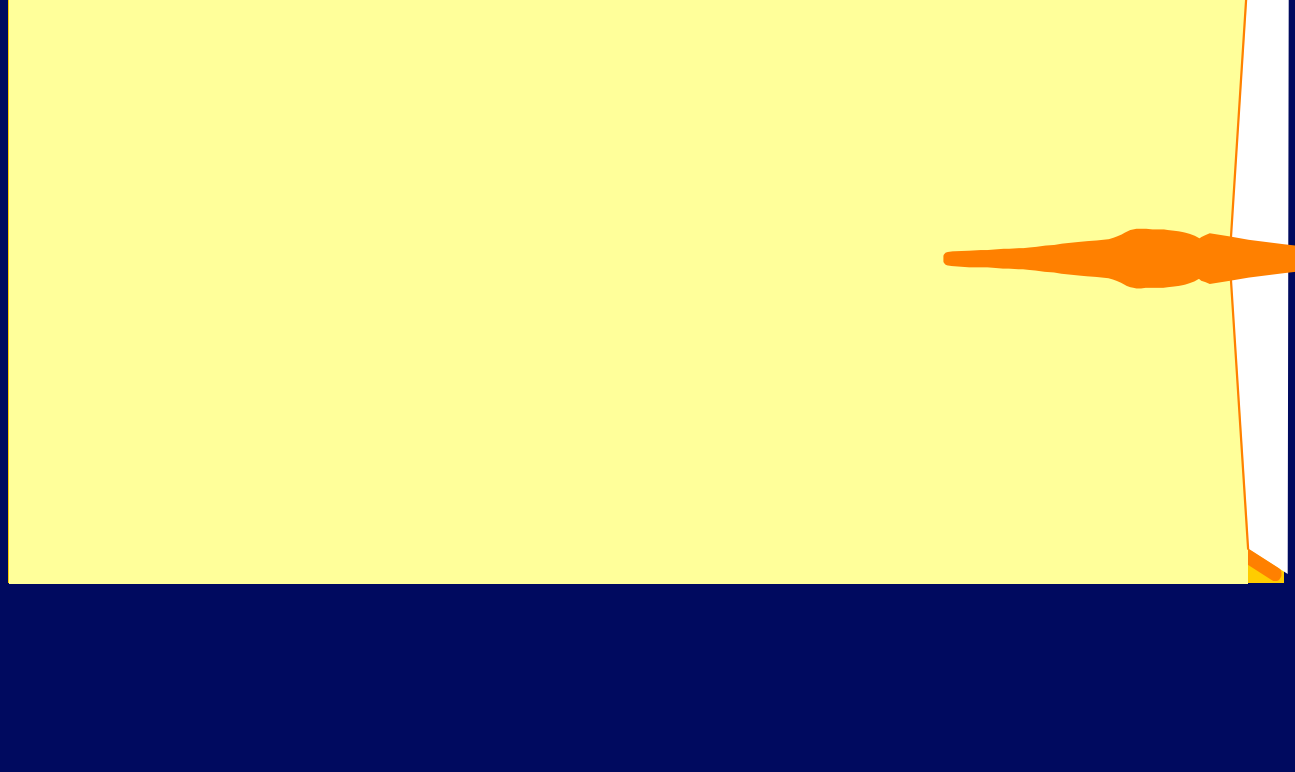


Detonation of a Shaped Charge

Energy from the explosive imparts momentum to the liner material



Detonation of a Shaped Charge

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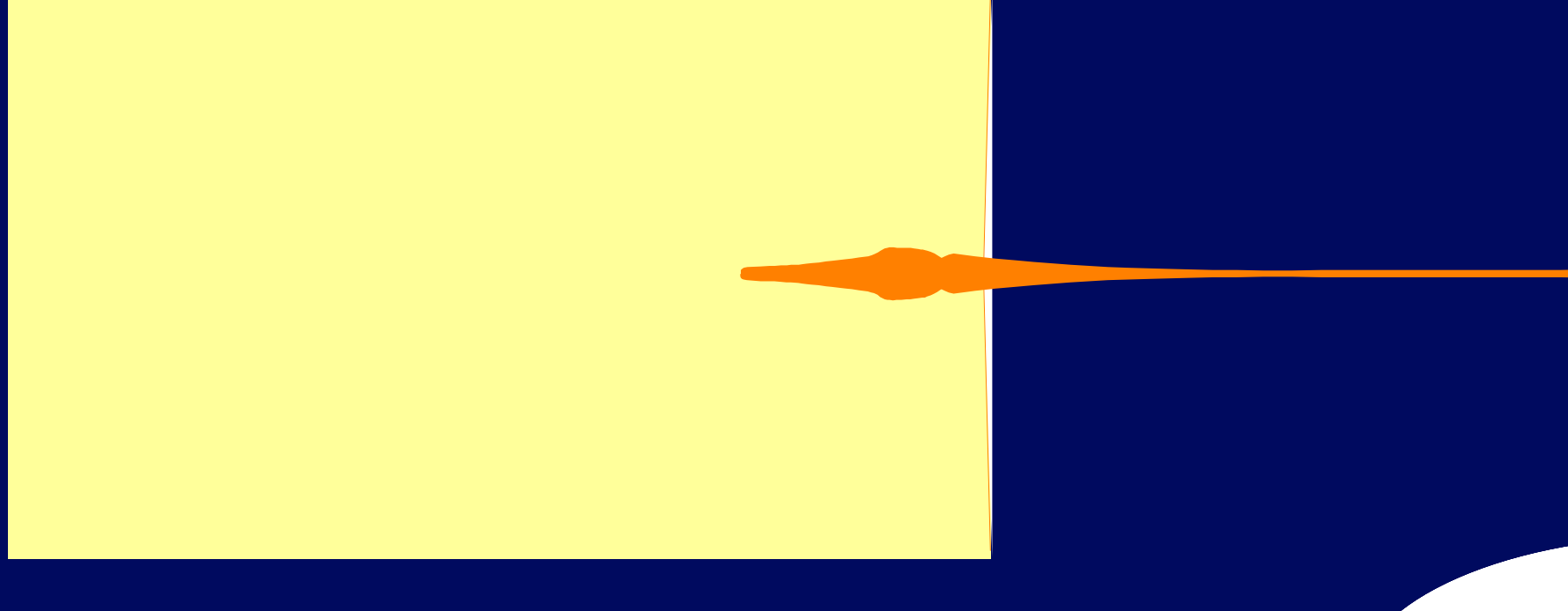
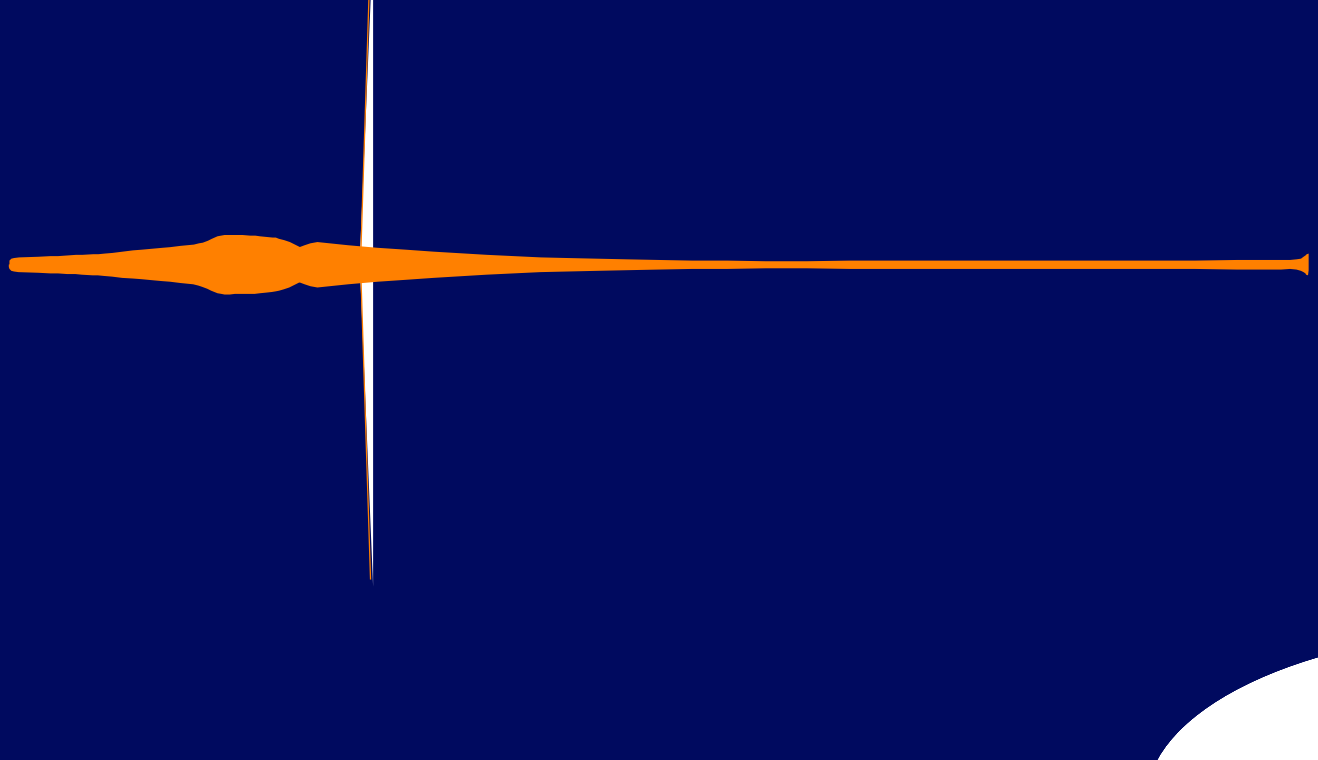


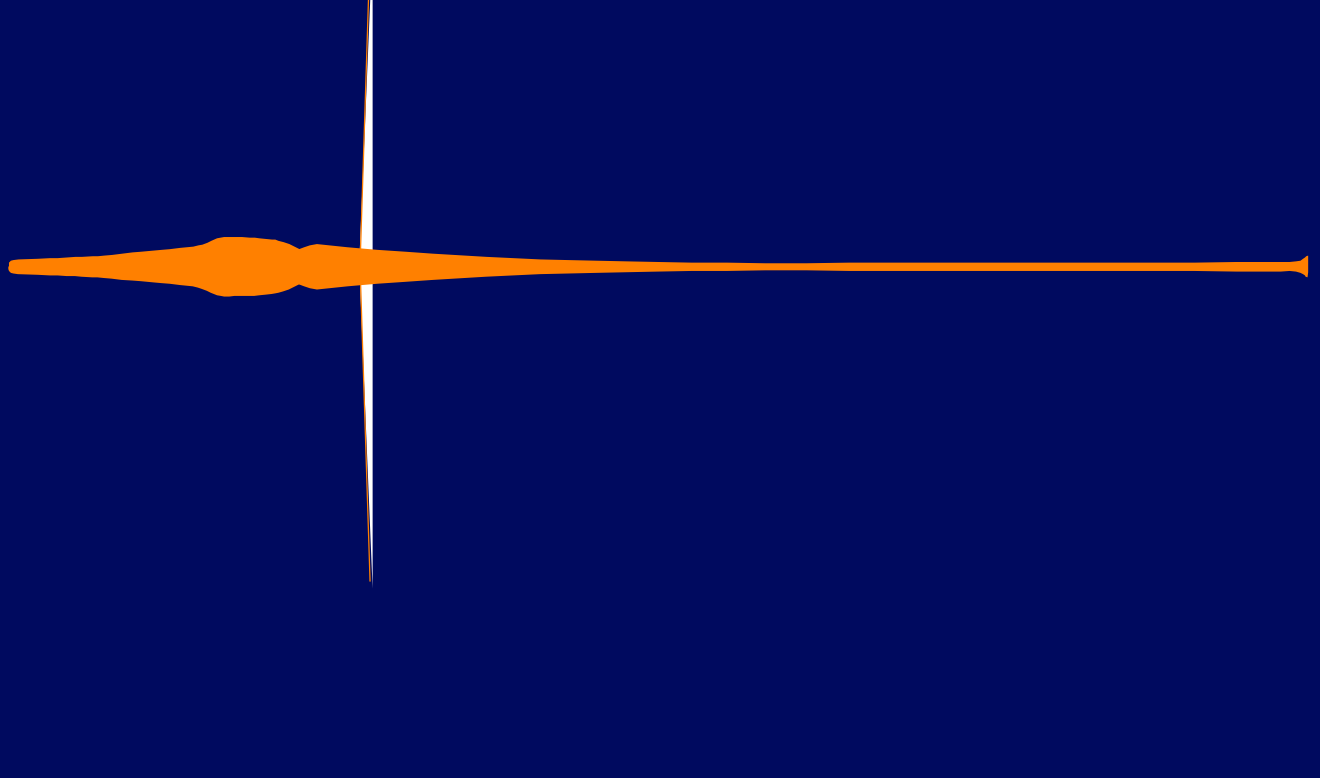
Detonation of a Shaped Charge

Making the liner flow into the ‘Jet’, even after all of the explosive has been consumed:



Detonation of a Shaped Charge

Because the tip of the ‘Jet’ is travelling faster than the rear; the ‘Jet’ stretches, becoming longer:



Shaped Charge Jet Formation

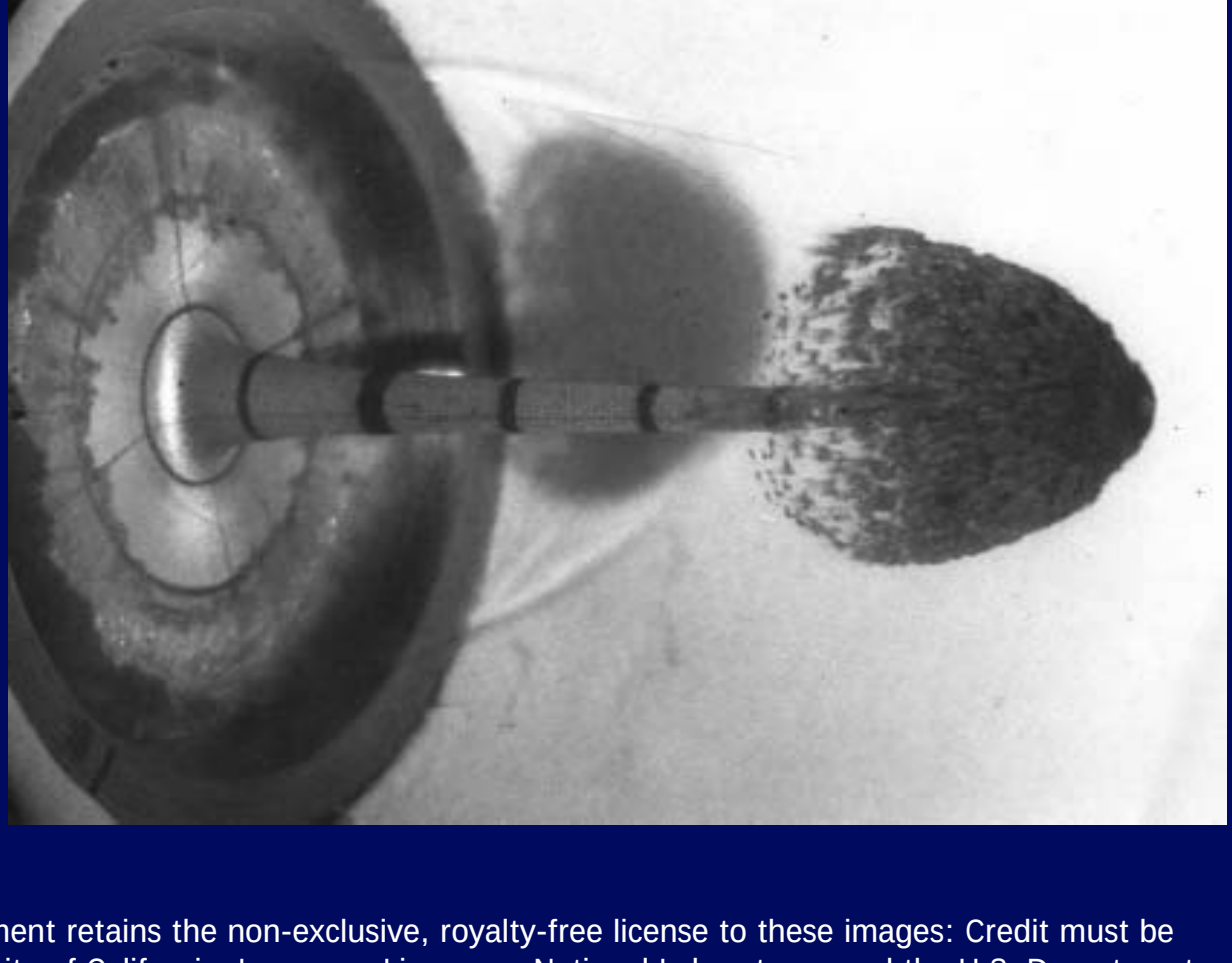
And longer:

Shaped Charge Jet Formation

This is a Flash X-Ray of a Shaped Charge Jet:

Shaped Charge Jet Formation

This image was created by a high powered laser illumination technique that allows the light produced by the explosive detonation, to be filtered out.



Shaped Charge Jet Formation

The ‘Jet’ continues to stretch:

Shaped Charge Slug & Jet Formation

The slowest moving, rear portion of the ‘Jet’ is called the ‘Slug’ or ‘Carrot’ and only travels at a few hundred meters per second and contributes nothing to the penetration process

Shaped Charge Slug & Jet Formation

As the ‘Jet’ continues to stretch, the ‘Slug’ breaks off and falls behind the main part of the ‘Jet’:

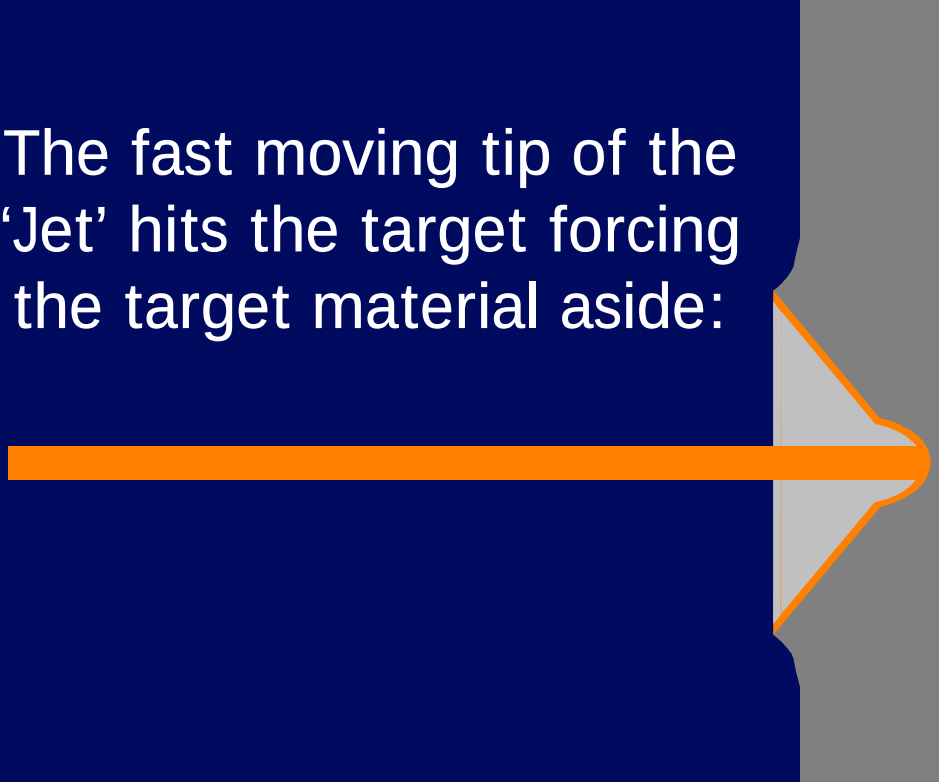
Shaped Charge Target Penetration

The ‘Jet’ approaches the target at approx. 10 Km per second:

Target

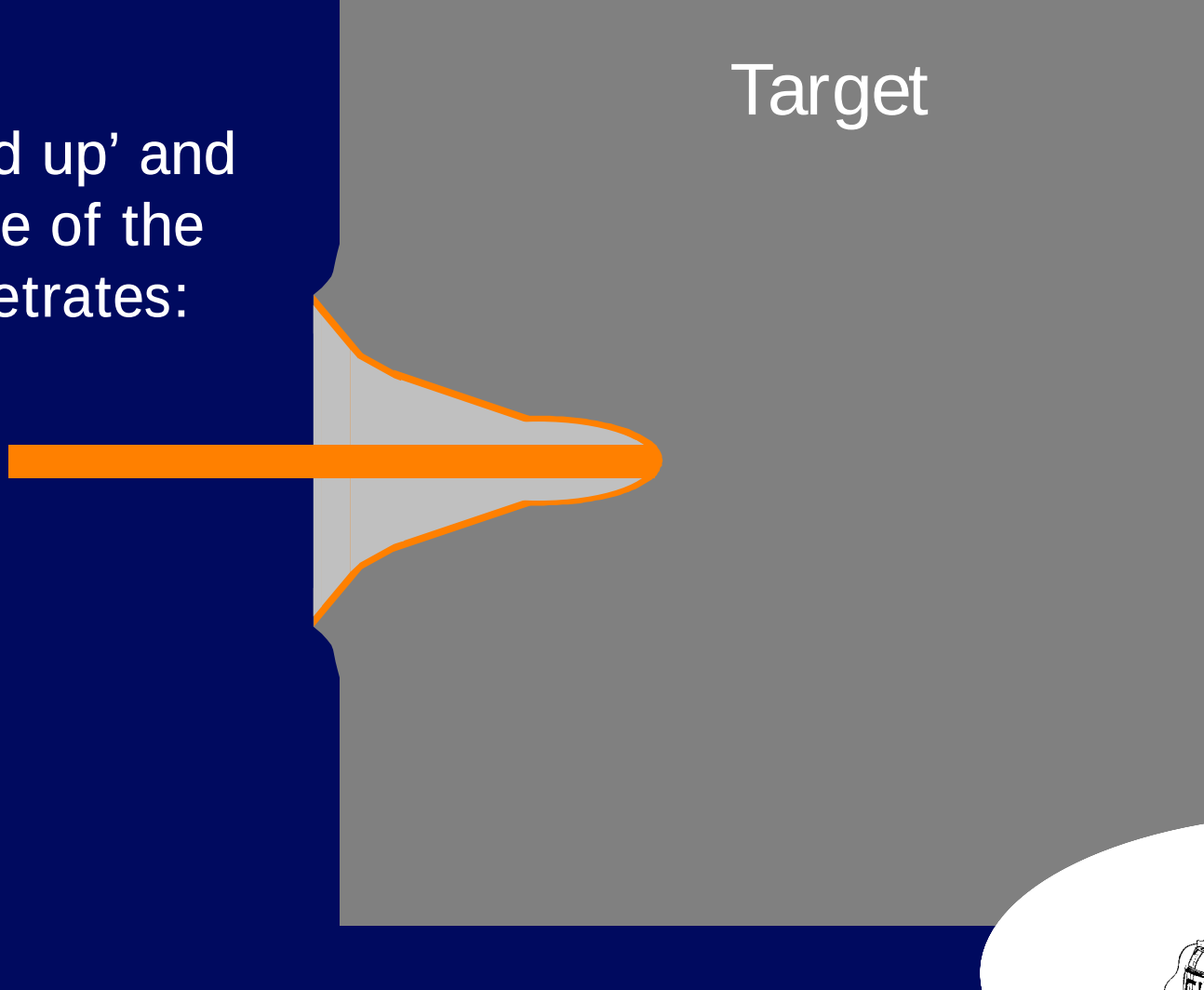
Shaped Charge Target Penetration

The fast moving tip of the ‘Jet’ hits the target forcing the target material aside:



Shaped Charge Target Penetration

The ‘Jet’ is ‘used up’ and coats the inside of the hole as it penetrates:



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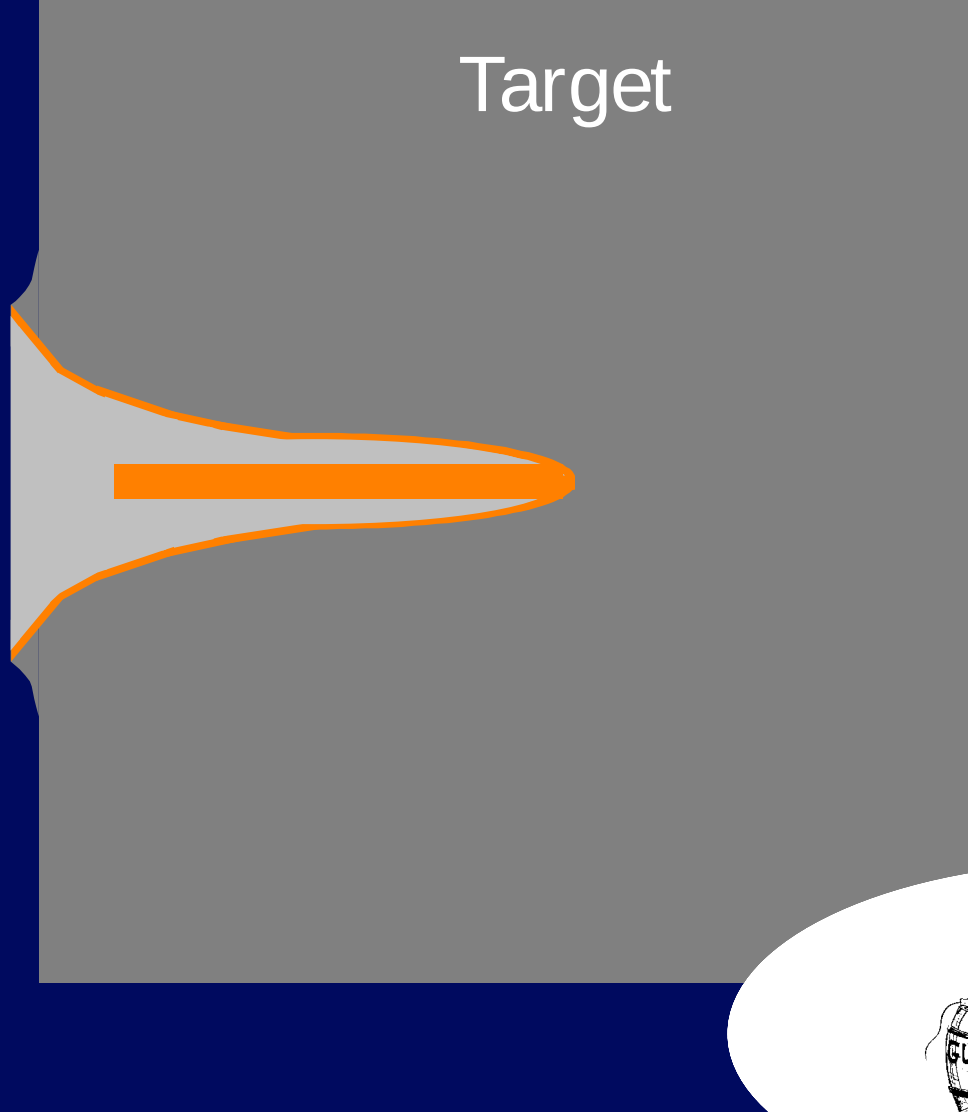
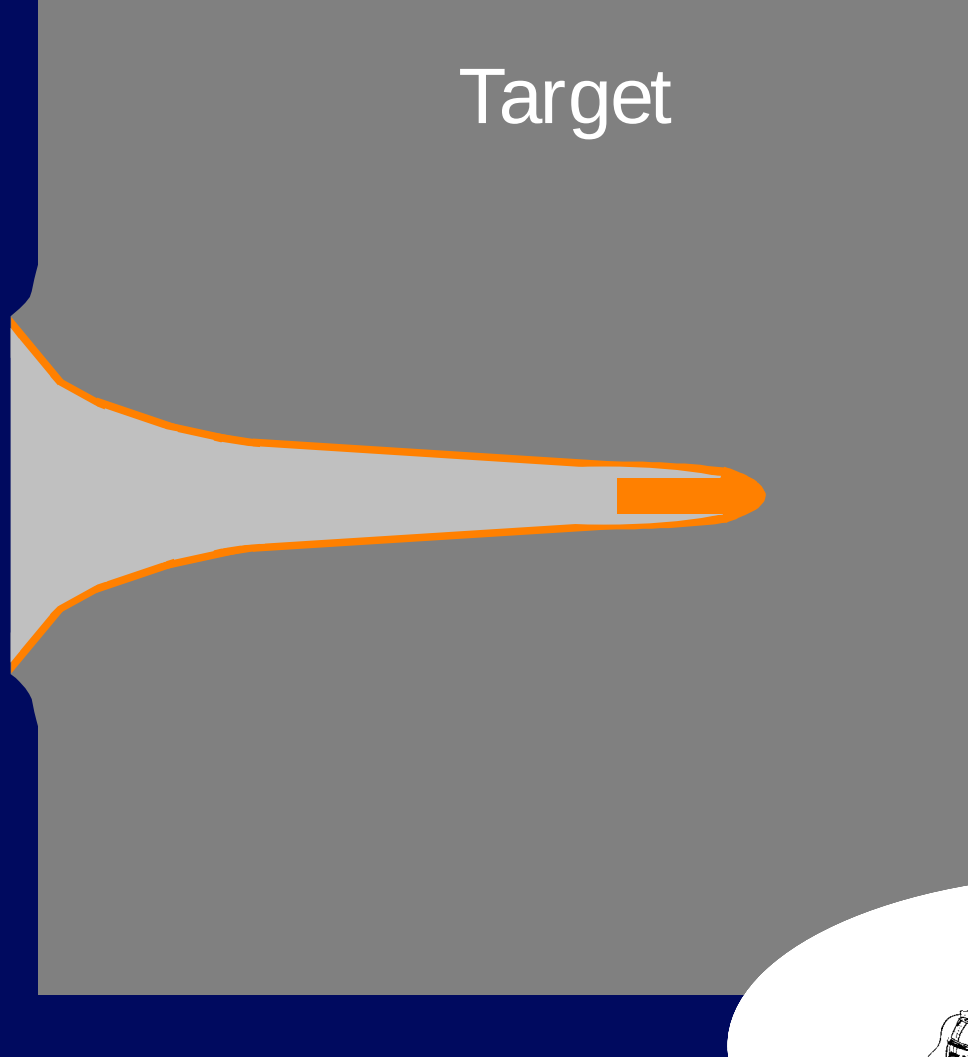


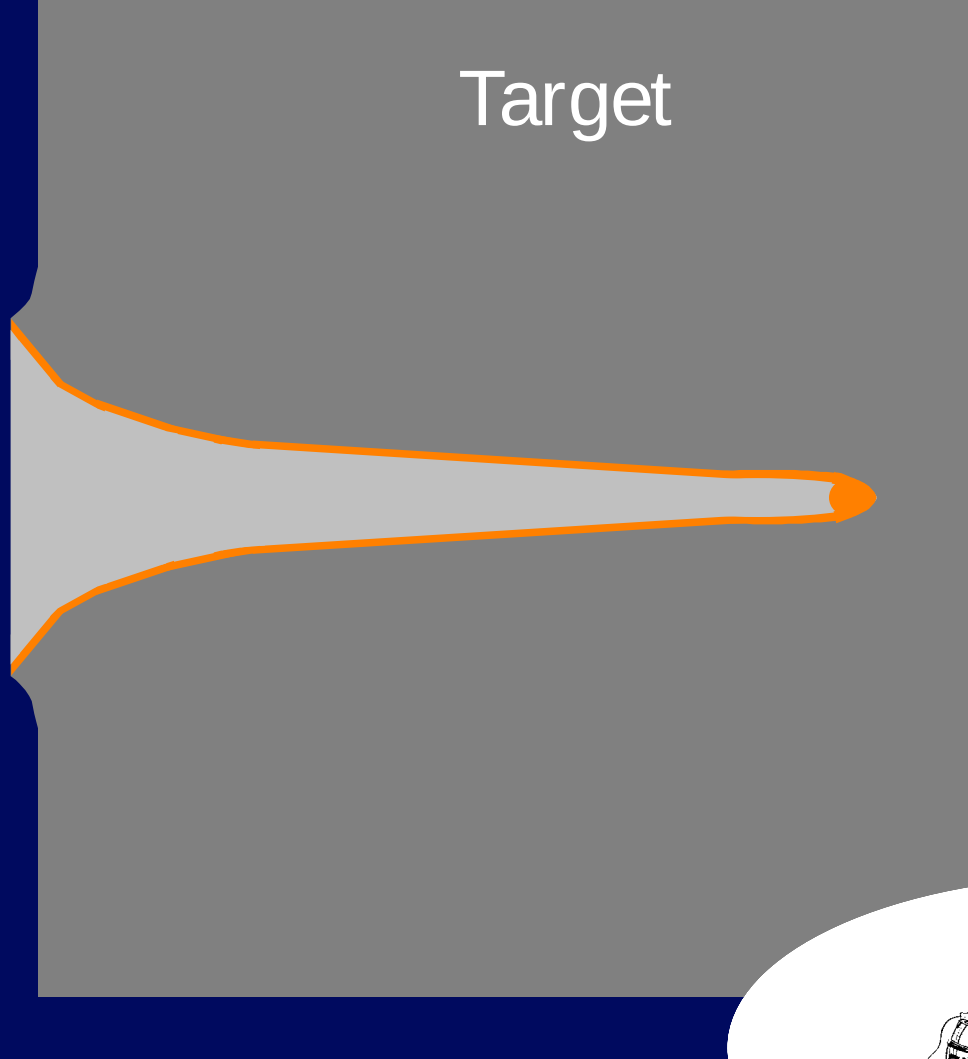
Shaped Charge Target Penetration

The slower rear end of the ‘Jet’ delivers less energy into the target, making a narrower hole:



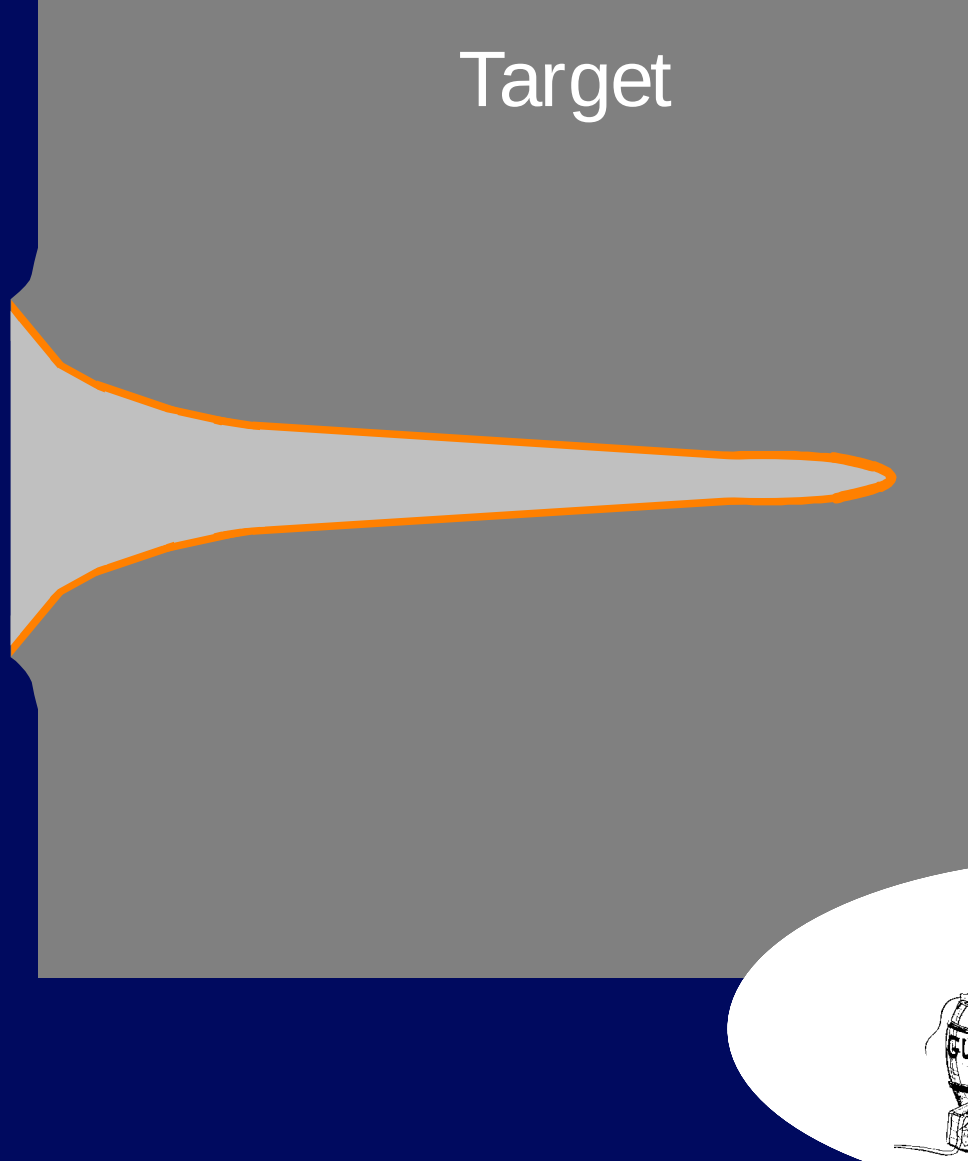
Shaped Charge Target Penetration

The whole ‘Jet’ is gradually ‘used up’ as it penetrates the target:



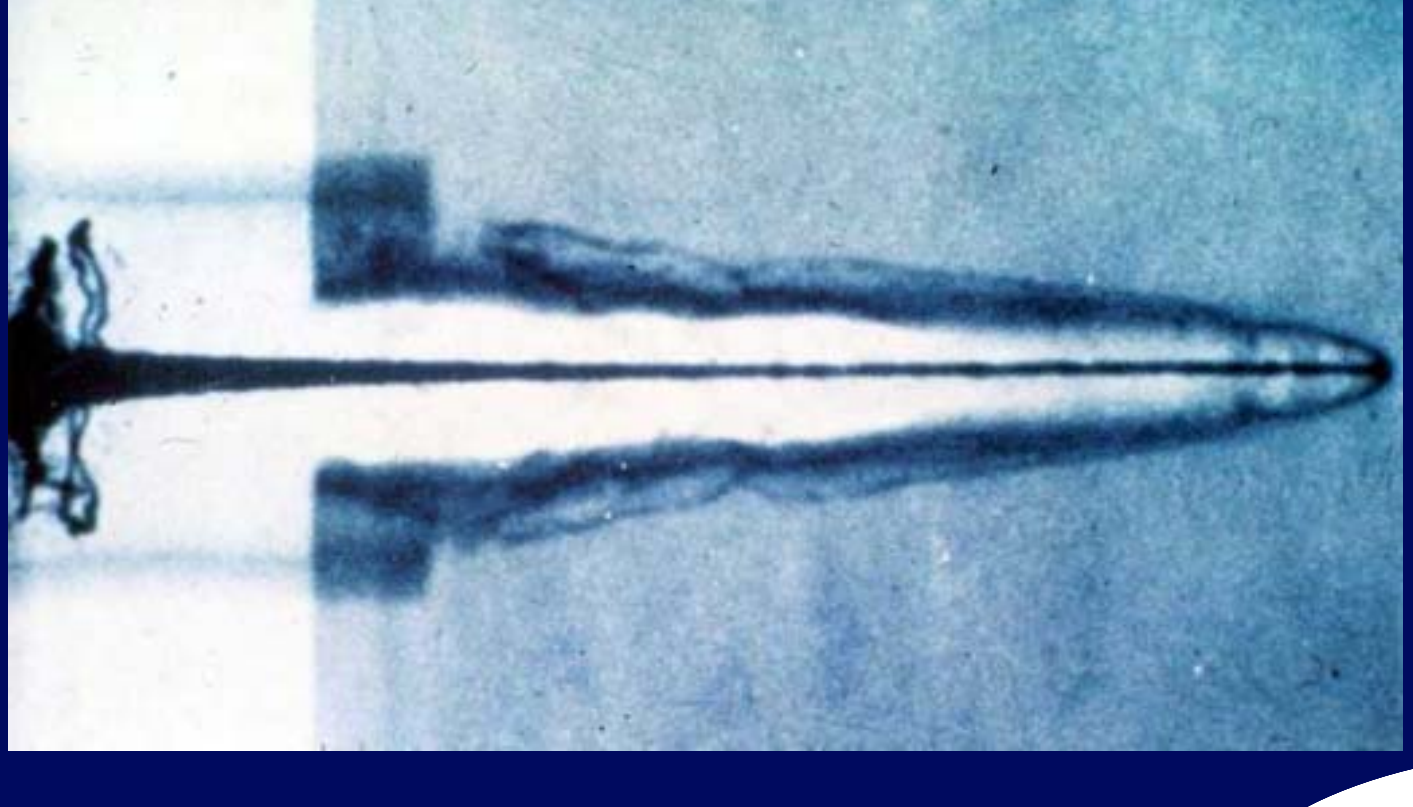
Shaped Charge Target Penetration

Until the whole of the ‘Jet’ has been ‘used up’ and penetration stops:



Shaped Charge Target Penetration

This is a Flash X-Ray Showing A Jet Penetrating A Target

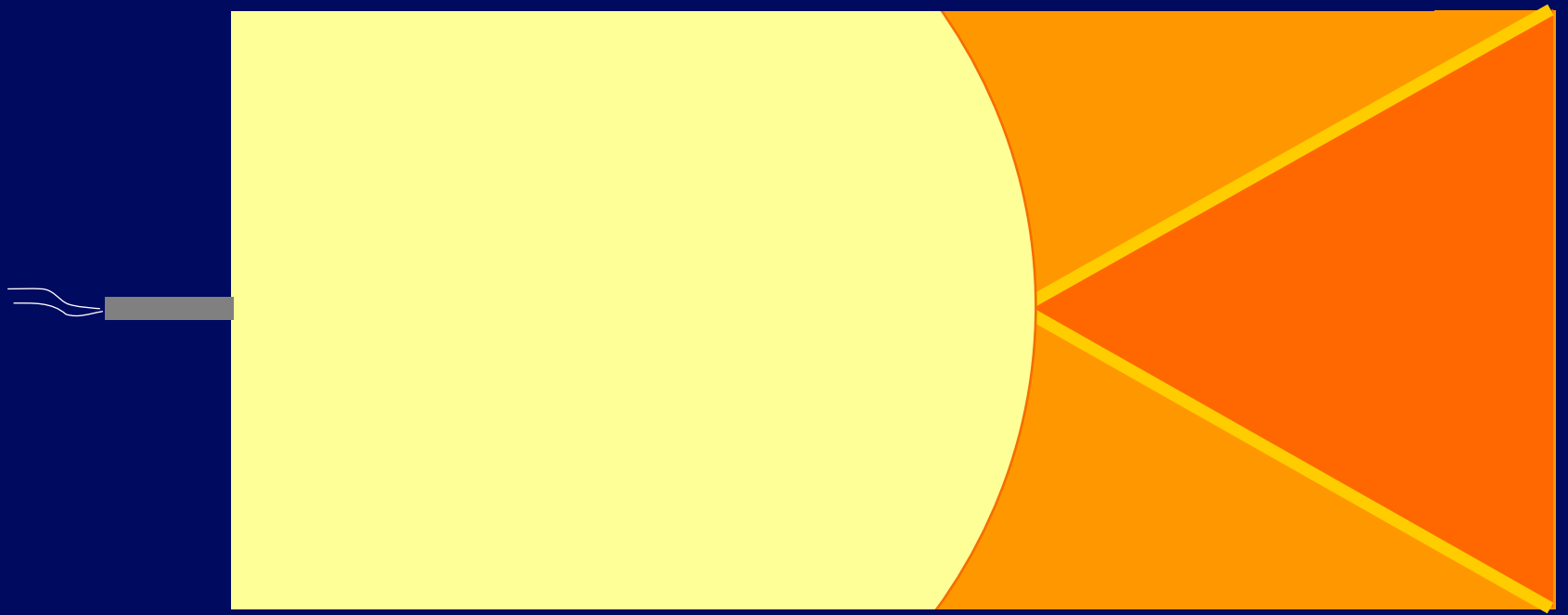


Shaped Charge Target Penetration

This is a picture of a sectioned steel block which has been attacked by a shaped charge ‘Jet’ - It clearly shows the smooth central portion where the ‘Jet’ has penetrated cleanly:

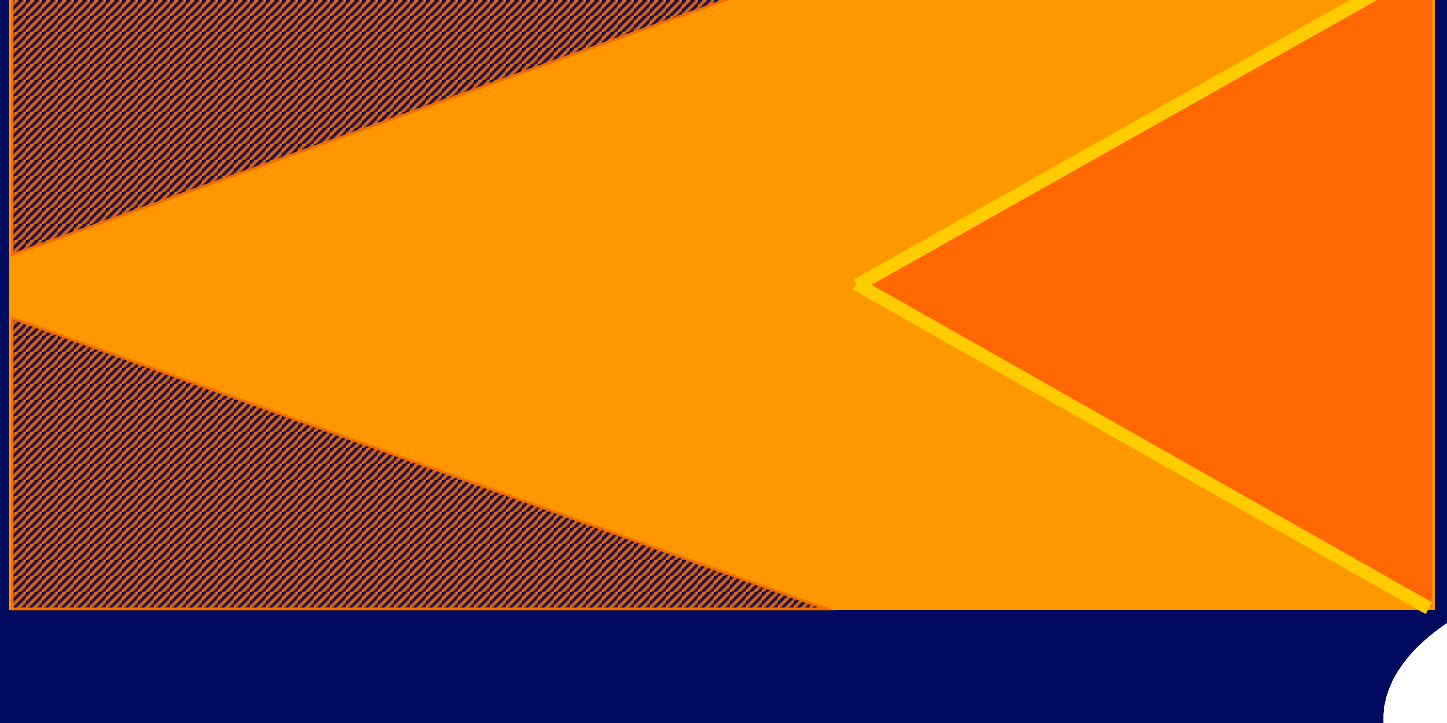
Shaped Charge Explosive Mass Reduction

As we know, a detonation front propagates in a spherical pattern with the point of initiation at its centre:



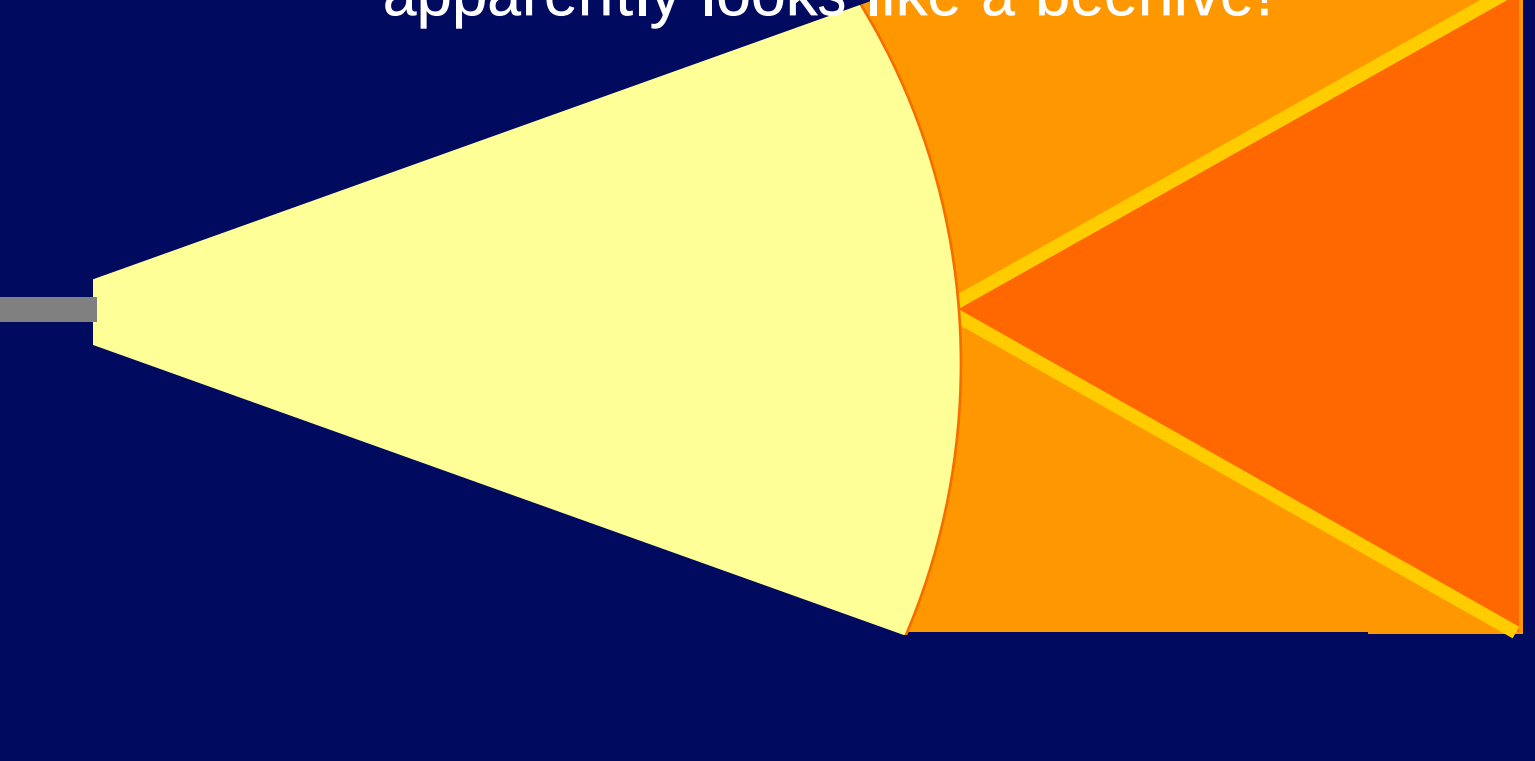
Shaped Charge Explosive Mass Reduction

The shape of the detonation wave as it comes into contact with and travels down the liner is important, but any explosive that does not contribute to this, is redundant and can be removed:



Shaped Charge Explosive Mass Reduction

Forming a Shaped Charge in this fashion is referred to as Beehiving' or the charge itself may be called a 'Beehive', as it apparently looks like a beehive!

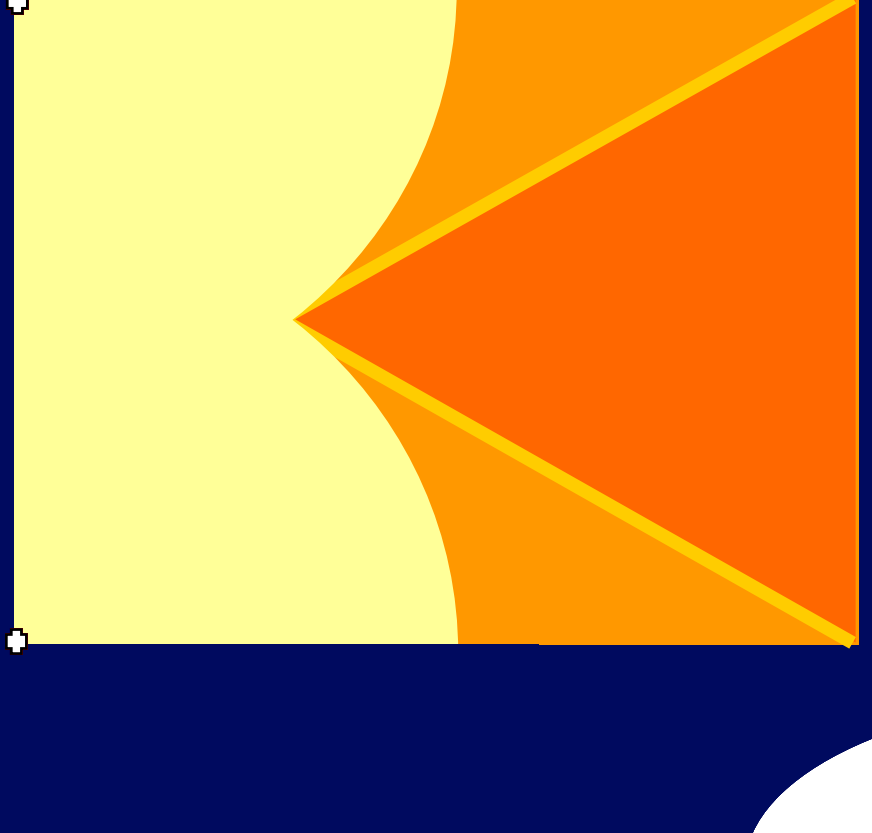


Shaped Charge Explosive Mass Reduction

The explosive mass can be reduced quite significantly, if we can simultaneously initiate the detonation wave around the edge of the the charge:

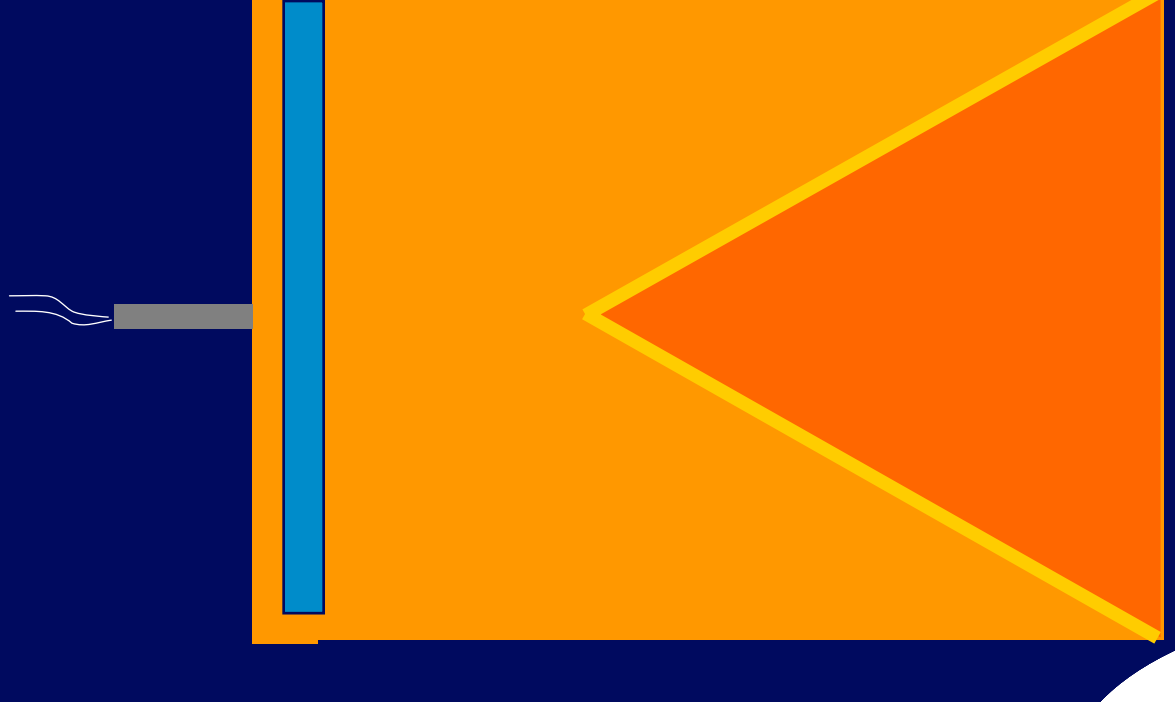
Shaped Charge Explosive Mass Reduction

This is a sectioned view of the same effect.
Firstly a considerable amount of explosive can be removed:



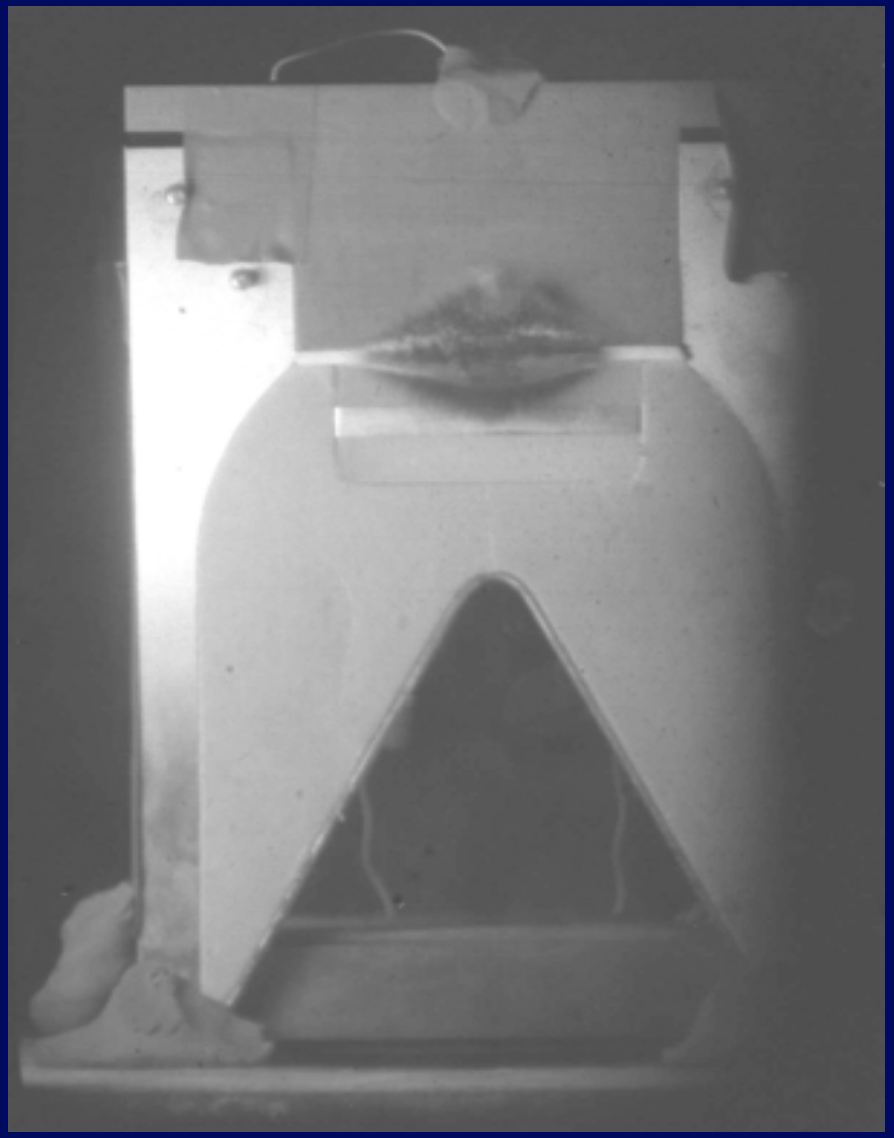
Shaped Charge Explosive Mass Reduction

This can be achieved through ‘Peripheral Initiation’ which is a more efficient, but more technically demanding alternative means of reducing the charge mass than using ‘Beehive’ charges:



A ‘Peripherally Initiated’ Shaped Charge

A ‘Peripherally Initiated’ Shaped Charge



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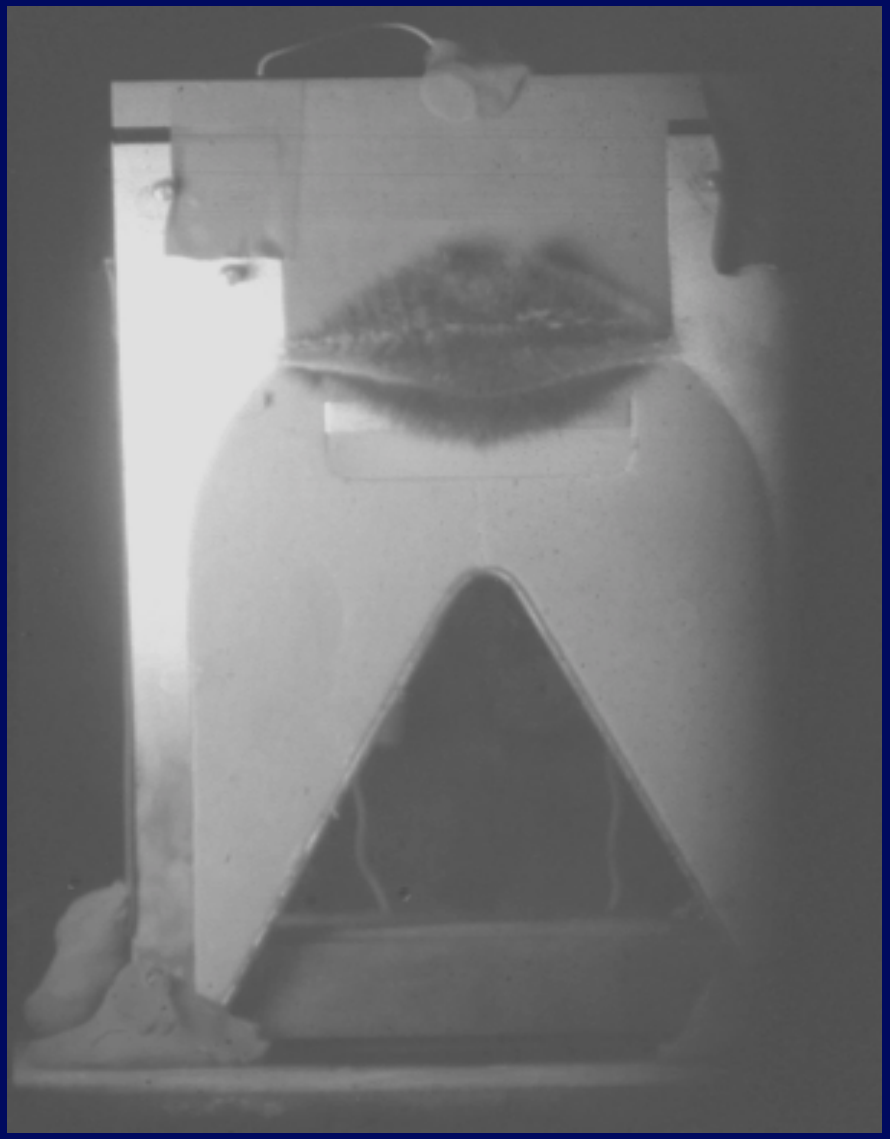
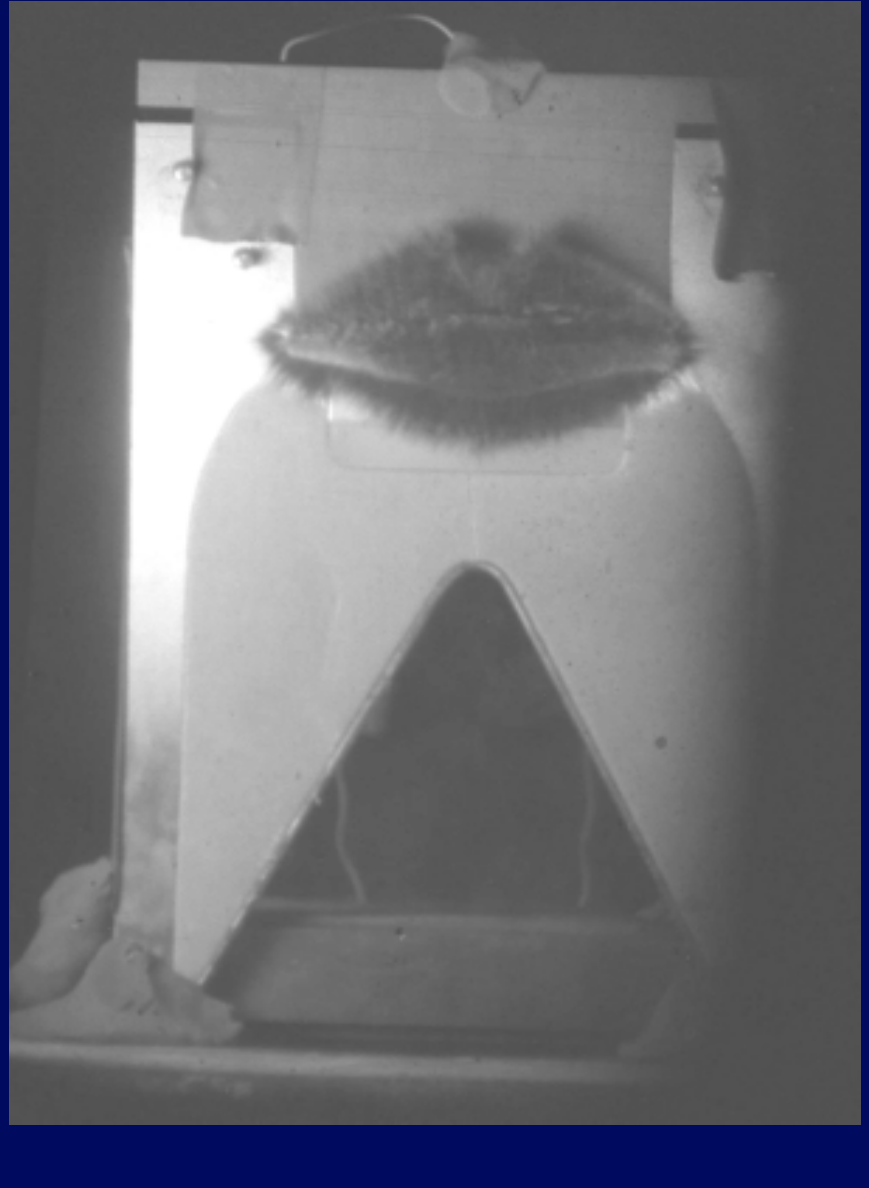
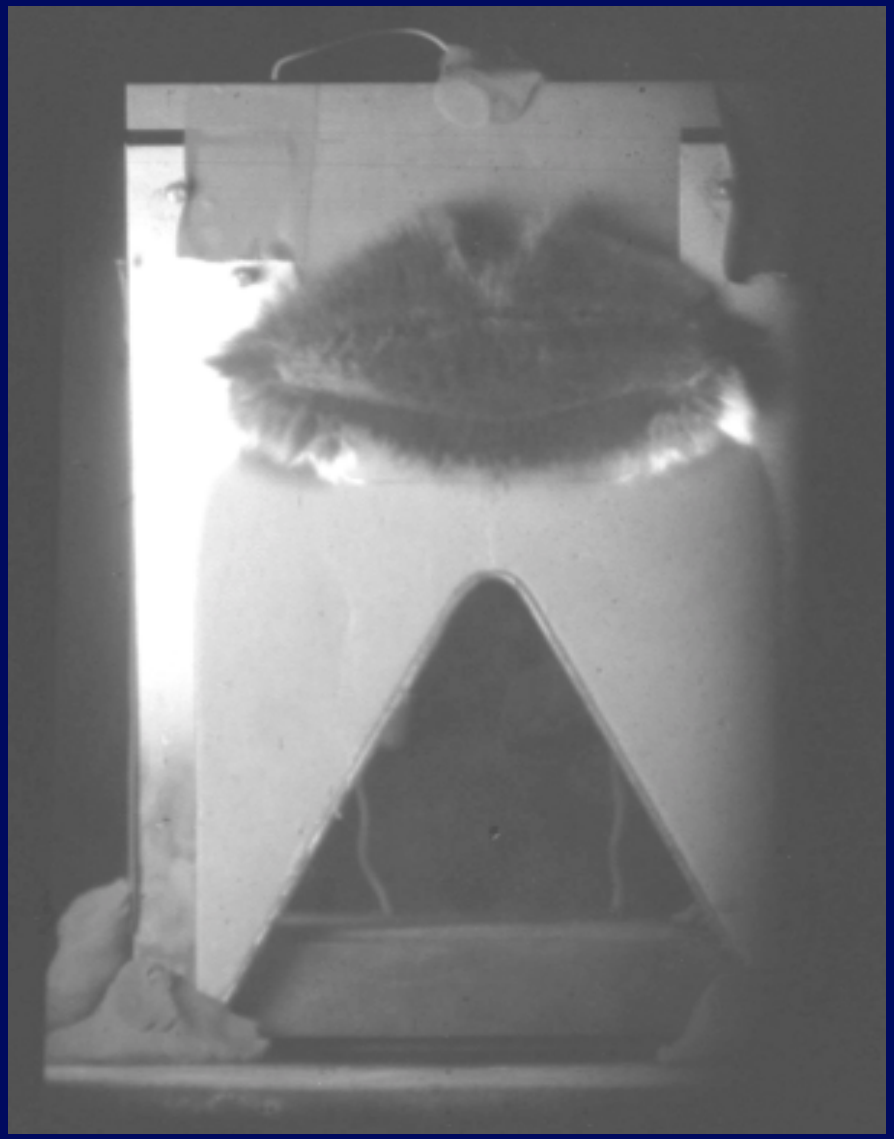


A ‘Peripherally Initiated’ Shaped Charge



A ‘Peripherally Initiated’ Shaped Charge



A ‘Peripherally Initiated’ Shaped Charge

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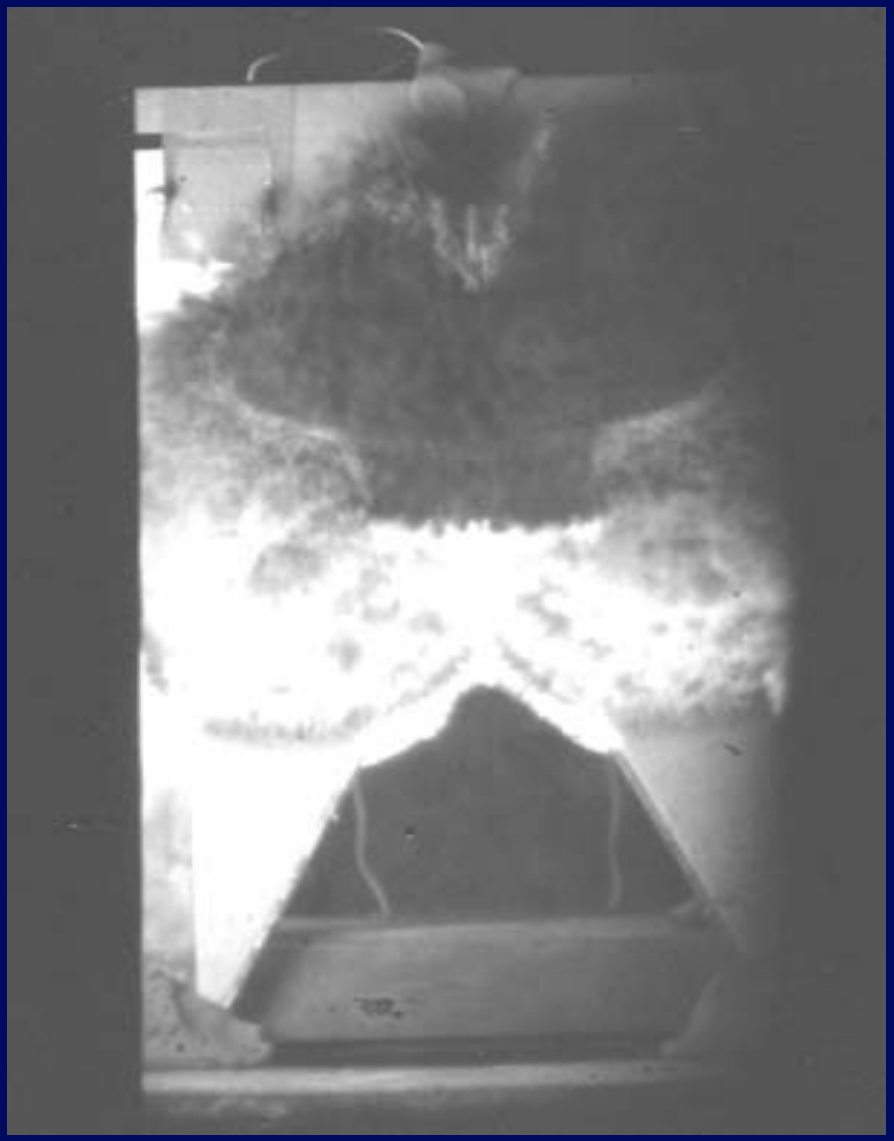

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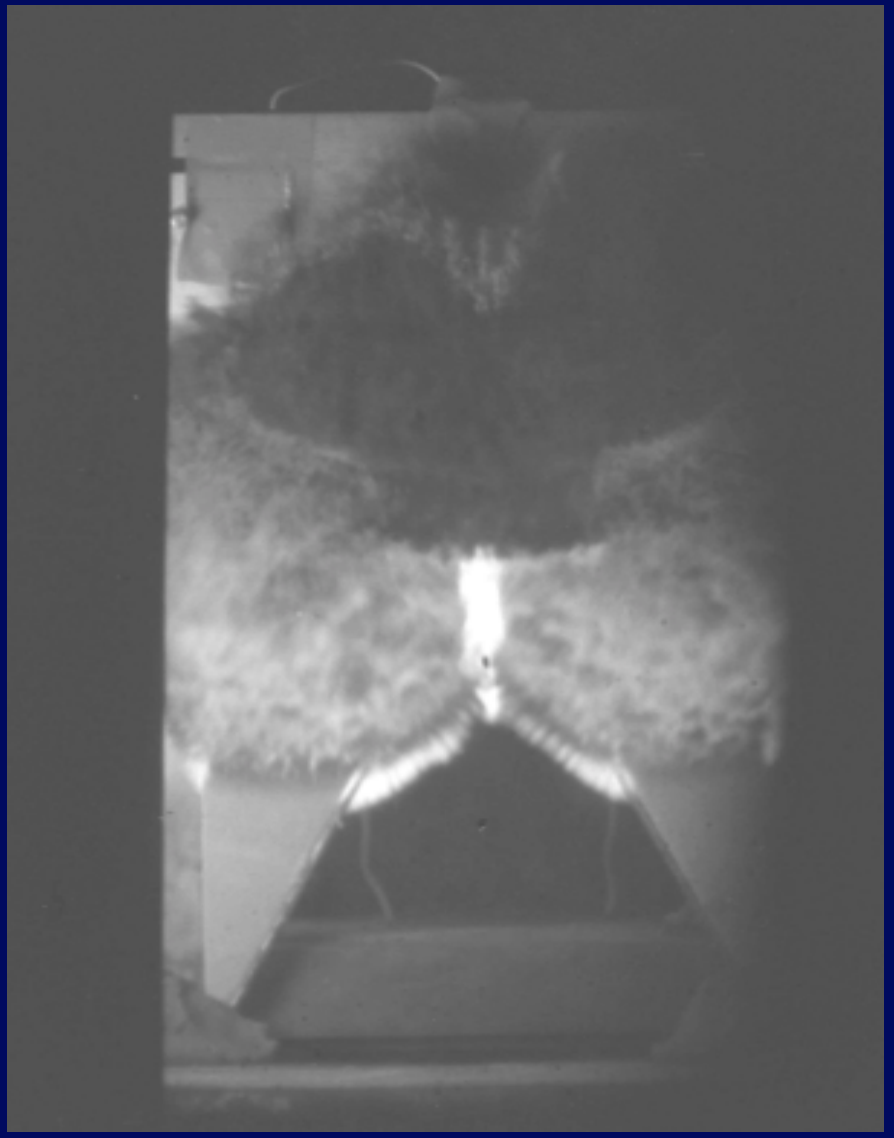


Section 3

Linear Cutting Charges

Types of Linear Cutting Charge

As we've seen, there are two main configurations of Shaped Charge:

Conical Shaped Charges - These penetrate, creating single, deep, narrow, circular holes.

Linear Cutting Charges - That can cut through structural members, pipes, re-enforcing, etc.

Linear Cutting Charges can be sub-divided into a number of different types including:

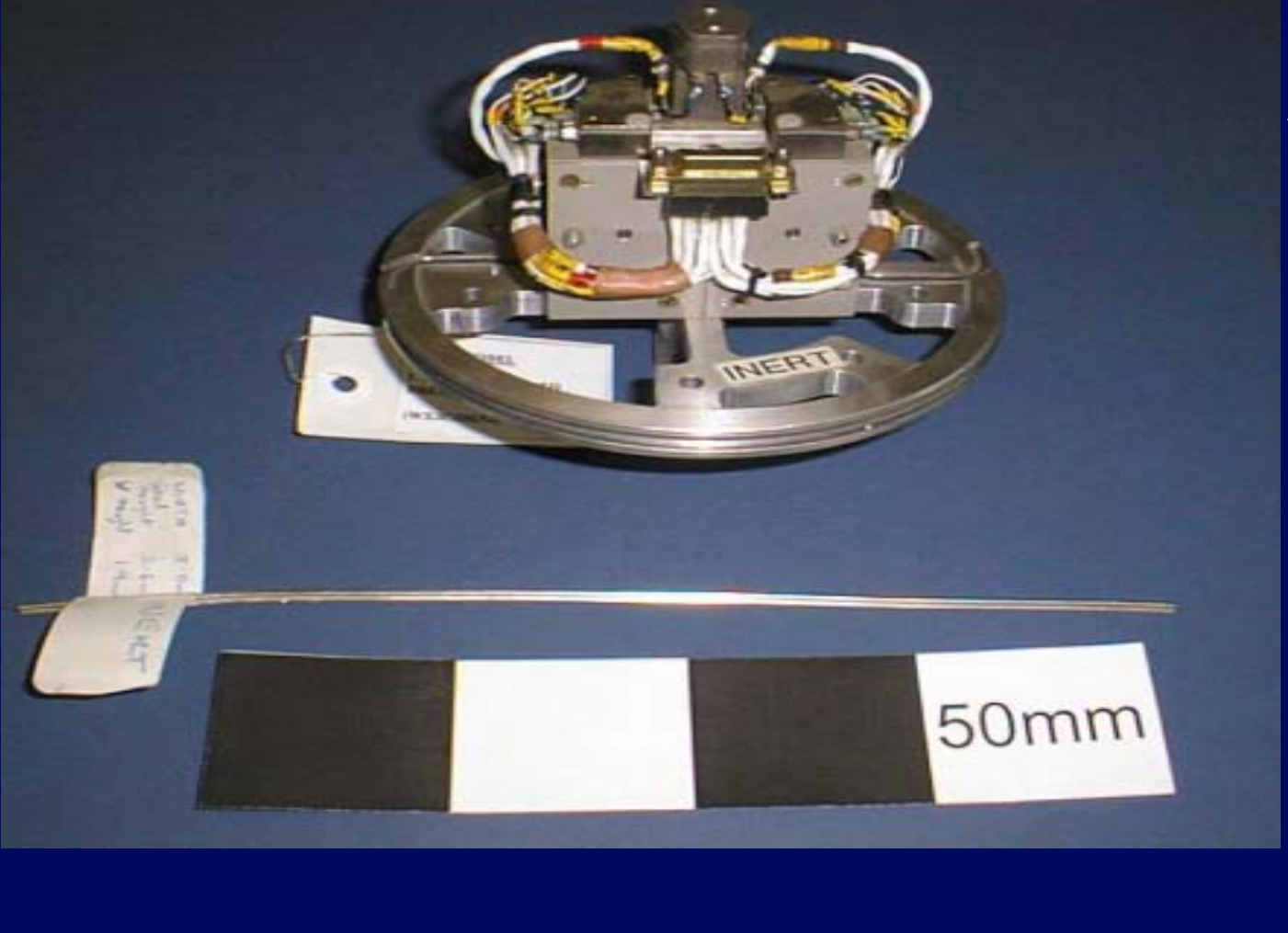
Cutting Cord/Tape

Continuous Cutting Charges

Boxed Cutting Charges

Cutting Cord/Tape

Cutting Cord/Tape can be applied to a structure to be cut, either internally or externally.



An example of the internal configuration of a silver sheathed cutting cord. As used in a missile break up system.

Cutting Cord/Tape

Examples of tubes cut by internal arrangements of Cutting Cord/Tape:

250mm tube

75mm tube

Continuous Cutting Charge

Continuous Cutting Charges come in long lengths that can be cut down or joined together to create a suitable charge to produce the required length of cut.

An example of this is ‘Blade’ from Royal Ordnance

Boxed Cutting Charge

Boxed Cutting Charges, as the name suggests, consist of a box like body fitted with a shaped charge liner and filled with high explosives.

An example of this is ‘Charge Demolition No. 14’ Or ‘Hayrick’

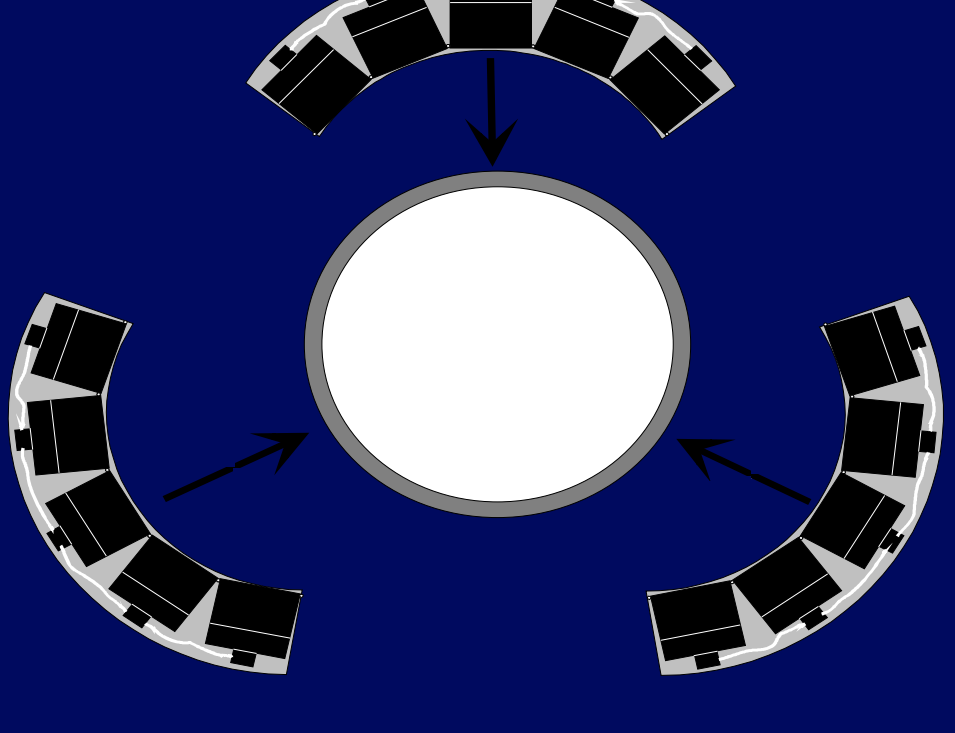
Boxed Cutting Charge

Boxed Cutting Charges, as the name suggests, consist of a box like body fitted with a shaped charge liner and filled with high explosives.

‘Hayrick’ Charges can be joined together by inserting pins through the fittings on each end, to form a ‘necklace’ around the structure to be cut.

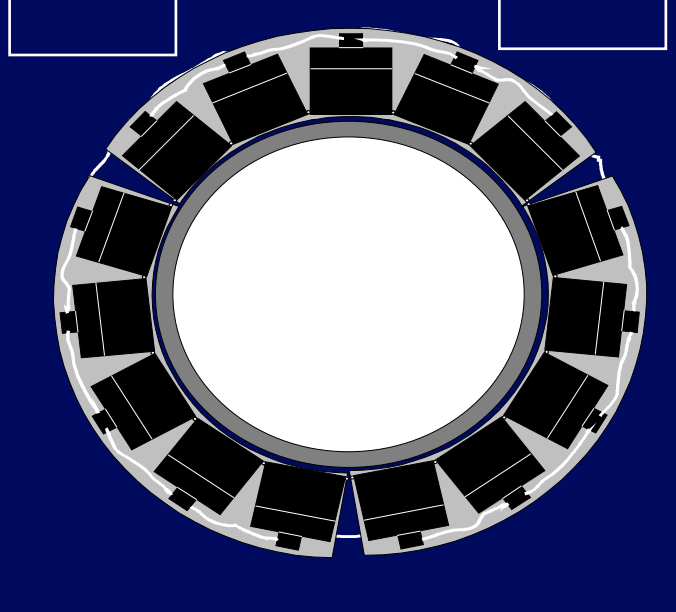
Boxed Cutting Charge

Arrangement of Boxed Cutting Charges around a large pipe/leg structure:



Boxed Cutting Charge

Arrangement of Boxed Cutting Charges around a large pipe/leg structure:



Video Demonstrations

Application & Use of Linear Cutting Charges

Section 4

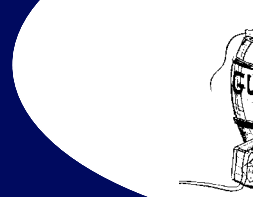
Shockwave Mitigation

The Problem of Explosive Shock Wave

Shock waves travel 4 times faster and considerably further in water than they do in air.

As such, massive safety cordons must be established around sub-sea blasting operations to ensure that divers, equipment, shipping and other structures are not put at risk.

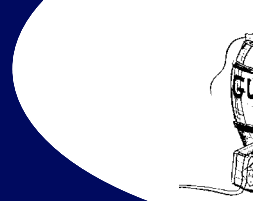
Example:
In the Gulf of Mexico a 1000 ton platform was cut 6 feet below the mud line in 40 feet of water using tri-plate cutters.
The entire fish population perished in the vicinity including protected green turtles!



A Solution to Explosive Shock Waves

Experiments have been done with different shock mitigation materials, with a view to developing an effective means of mitigating both air and water born shock waves in the marine environment.

To date considerable successes have been recorded and reductions of peak overpressures in excess of one order of magnitude have been achieved!



A Solution to Explosive Shock Waves

Example:

100kg of High Explosive was detonated in air.
the peak overpressures were recorded.

This was directly compared with a firing of the same size surrounded by a mitigating curtain.

The pressure measured at 15 metres from the charge was so small that a person could have stood there and suffered no ill effects!

Video Demonstrations

Shock Wave Mitigation Experiments

Experimental Results

	Unmitigated Fired in Air		Mitigated By Material 'X'	
1Kg Plastic Explosive (PE4)	270 kPa	*(39 PSI)*	27 kPa	*(4 PSI)*
6Kg Plastic Explosive (PE 4)	1106 kPa	*(160 PSI)*	46 kPa	*(7 PSI)*
12Kg Plastic Explosive (PE4)	1659 kPa	*(240 PSI)*	64 kPa	*(9 PSI)*

PE4 = Plastic Explosive Mk 4

Conclusion

When considering options for Decommissioning Operations explosive cutting is recognised as an option and is for some components, the only one available.

Unfortunately, the wider use of explosives in marine decommissioning is often not considered, as it is often regarded as an “over the top” and excessively destructive method.

However, we have seen that the proper application of explosive cutting technology can be used effectively for ‘micro surgery’.

Conclusion

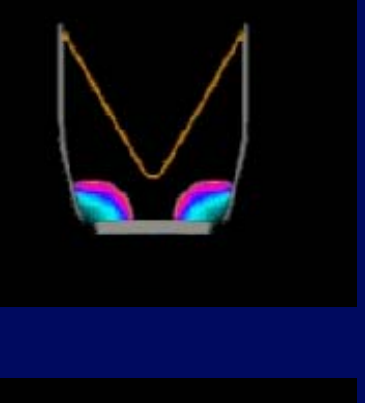
Those that consider the use of explosives for decommissioning are rightly mindful of their effect on the Marine Environment.
A great deal of energy has to be expended to cut metal or concrete components and this must be contained and controlled.

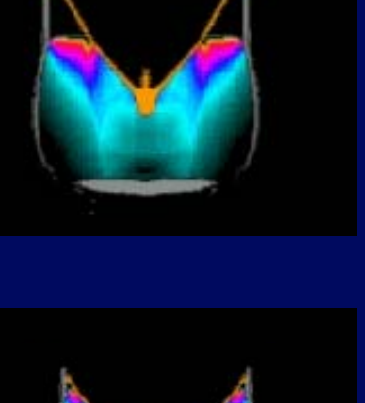
The research into Shock Mitigation has shown that the environment can be protected from the effects of peak pressure and pulse duration.

The use of explosive cutting charges is fast and efficient, where as mechanical means can be painfully slow.

Remember that even conventional cutting methods like milling, produce a great deal of debris that will effect the environment.

Any Questions?





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