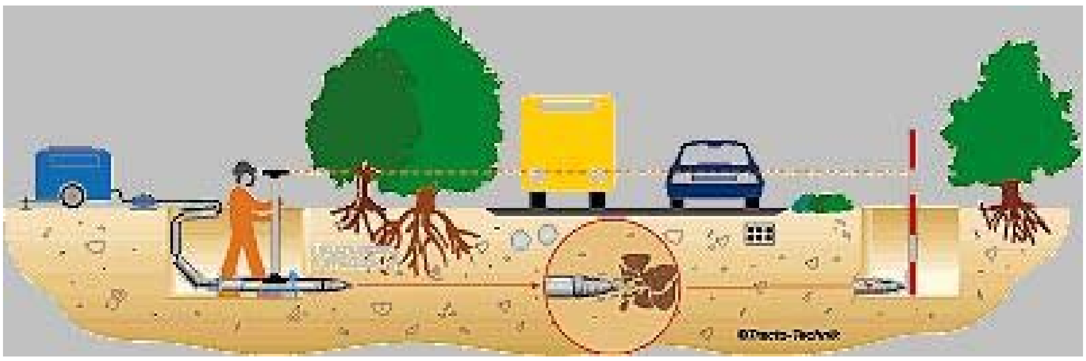
INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	**TRENCHLESS TECHNOLOGIES RESOURCE CENTRE**	
	TRENCHLESS TECHNOLOGY GUIDELINES	SECOND EDITION
	IMPACT MOLING AND RAMMING	UPDATED JUNE 2006

1 OVERVIEW

Although the first attempts at producing Impact mole systems occurred during World War I, practical impact moles first appeared from Poland and Russia in the 1960s. The early systems were heavy for the size of bore, and frequently gave problems such as large deviation from the intended route, or the unit even being lost in the ground. Since then, impact moles have been developed to a much finer degree, and are now probably one of the most commonly used of all items of trenchless equipment worldwide, to the point where many operators now are not even aware of their 'trenchless' origins. They offer solutions to a wide range of installation problems, particularly over short distances. The simplicity of the tool and the minimal amount of training required to ensure operators know how to work with them safely and correctly is what has made the impact mole the common tool it has become today.
Impact moling and ramming use essentially the same type of equipment to install new utility services underground, but employ two different techniques. Each will be discussed individually in this Section.

2 IMPACT MOLING

Impact moling, or 'earth piercing' as it is commonly known in North America, is defined as the creation of a bore by the use of a tool that comprises a percussive hammer within a suitable cylindrical casing, generally torpedo shaped. The hammer may be hydraulic or pneumatic. The term is usually associated with non-steered or limited steering devices without rigid attachment to the launch pit, relying for forward movement upon the internal hammer action to overcome the frictional resistance of the ground. During operation the soil is displaced, not removed. An unsupported bore may be formed in suitable ground, or a pipe may be drawn or pushed in immediately behind the impact moling tool. Cables may also be pulled in.



Schematic of the Impact Moling process.

A distinction needs to be drawn between percussive moles discussed in this Section, and hydraulic moles that operate by expansion rather than hammer action. Expanding hydraulic moles are generally used for pipe-bursting applications (see Section On-Line Replacement) rather than new installations. Although hydraulically driven percussive moles are available, most are powered by compressed air. A potential drawback of air-driven moles, particularly for water supply installations, is contamination of the product pipe by lubricating oil in the exhaust, although there are methods of overcoming this. Hydraulic moles require two hoses (flow and return), and tend to have greater mechanical complexity.

The basic mechanism of impact moling is the reciprocating action of the pneumatically or hydraulically powered hammer within the cylindrical steel body. The piston is driven forward and on striking the forward end of the unit, imparts its kinetic energy to the body, which is driven forward. The energy of the piston for the return stroke is regulated so as to reposition it for the next forward stroke, rather than reversing the unit out of the bore (unless required to do so).

Impact Moling hammer in it's launch pit. Picture courtesy of Tracto-Technik.

Repeated impacts of the hammer piston advance the whole unit through the ground. As forward movement takes place, the soil in front of the mole is forced aside and compacted by the conical or stepped nose to form the walls of the bore. The power of the unit is also often used to pull the product pipe, cable or cable duct through the bore at the same time as the impact mole advances.

Impact moling tools are known by several other names including earth piercing tools, soil displacement hammers, impact hammers, percussive moles or pneumatic moles, depending on the term used by the manufacturer and the region of the world where the equipment is being used.

2.1 Ground Conditions

The compacting action of the impact mole means that, in general, it can operate only in soils that can be compressed or displaced. Obstacles along the bore path can deflect or stop the mole, so a thorough ground investigation regime is essential prior to work commencing, in order to establish a clear route.

This should include not only knowledge of existing utilities but also soil sampling to ensure that cobbles or boulders are unlikely impede progress. Some impact mole designs have been developed to try to overcome unexpected obstacles or even relatively small known ones.

2.2 Alignment & Launch

Motive power is supplied to the rear of the impact mole via pneumatic or hydraulic pressure pipes, which normally pass through the product pipe or duct, or run alongside the new cable.

Once the ground investigation has been completed and the desired route established, the following procedure should be followed to complete an impact mole bore.

A launch pit and a reception pit are first excavated at the ends of the bore path, to a little over the planned depth of the installation. The launch cradle, if used, is then set up, or the mole can be positioned directly on the floor of the launch pit. Using a ranging rod in the reception pit and a sighting telescope in the launch pit, the initial line of the bore is established by physically aiming the mole towards the ranging rod target. The mole is launched and allowed to advance a short distance. The line is checked for a final time before the whole of the body of the mole enters the ground. If the line is not correct, the bore is restarted. The bore is completed when the mole arrives at the reception pit, and the tool can be removed after the product pipe, duct or cable has been drawn into the pit.

2.3 Monitoring

Most moles can now be fitted with radio sondes, similar to those used for monitoring the progress of directional drilling units (Section Horizontal Directional Drilling), which allow the progress of the mole to be followed closely both in direction relative to the planned course, and in depth. Sondes can be fitted either to the rear of the impact mole or, increasingly within the front end.

Although rear-mounted sondes give an indication of progress, they provide less useful information than front-mounted units. Depending on the mole size and length, the sonde can be some distance from the-penetrating end of the tool, and therefore responds much later than, a front-mounted sonde to changes in the bore path. Front- or nose mounted sondes react immediately to changes in direction and pitch, and so give the operator more time to halt the bore and assess the next move. However, nose-mounted sondes have to be far more robust and well protected, as they must withstand the shock of the drive forces applied to the front of the unit by the hammer action.

Whilst most impact moles are non-steerable, there are a few steerable tools that normally use steering vanes outside the body, or an angled head (that is directionally adjusted through keyhole excavations) to apply corrective action.

The latter system does however require regular monitoring and adjusting because as the tool progresses without regular adjustment the directional shift will increase. Monitoring is achieved using similar systems to those already described.

If a bore is forced off-line or prevented from advancing by an obstacle, it is often easier to dig down to the unit, remove the obstruction, realign the mole and re-launch it, rather than to start the bore again. This is often aided by the reversing facility that almost all impact moles now have, which enables the unit to be backed away from an obstruction to a point where it was on the correct line and level. After removing the obstacle and backfilling the hole, the mole is restarted on the intended course.

2.4 Applications

Because impact moling is generally unsteered, the technique is most suitable for shorter bores: a straighter bore can often be maintained more easily at larger diameters and with longer mole bodies. Diameters range from about 45 to 200 mm depending on the pipe or cable being installed.

Because of soil compaction restrictions and the need to minimize or eliminate surface heave, a widely accepted rule for impact moling installations is that there should be at least 1 m of depth for every 100 mm diameter of the tool. As most utility mains and services (except sewers) are laid at depths of less than 2 m in most countries, this gives an effective upper limit of 200 mm for impact mole diameters.

Despite this limitation, impact moling can be a very cost-effective method of installing small to medium sized pipes, ducts and cables for a broad range of utilities including gas, electricity, water and telecommunications. The technique is in common use for simple road crossings and the installation of service connections between main lines and individual properties as well as for environmental protection on installations running beneath mature trees, street furniture and protected structures. Moles are relatively easy to use, monitor and maintain in the field, and many utility companies carry moling systems as standard equipment for every team on installation and service vehicles.

In more recent years there have been two new interesting areas for the application of impact moles. These are HDD Assist/Rescue (see also Horizontal Directional Drilling) and Piling both of which are described in detail under Ramming Hammers.

2.5 Head Types

Two basic head shapes are commonly used for impact moles. The first is the simple cone which, during operation, pierces the ground and pushes the soil aside. The second is the step or chisel head, which is effectively a stepped cone. In normal operation the spaces between the steps fill with soil, and the head operates as a simple cone. However, when the head strikes an obstacle, the stepped edges concentrate the impact energy against the obstruction. Whereas a smooth cone would tend to be deflected by an obstacle, the stepped shape may apply sufficient longitudinal force to move the obstruction or shatter it, reducing the risk of going off line.

Many moles have fixed heads, which means the head is an integral part of the mole body once the unit is assembled. When the piston operates, it acts on the whole of the mole body propelling it forward.

An alternative is the moving head mole, in which the head is not directly attached to the body, but floats on a shaft passing through the front end of the mole. The rear of this shaft is the anvil against which the reciprocating hammer strikes. Using this configuration, the initial and highest impact force from the hammer is transferred to the head alone, advancing it into the ground. Several advantages for this system are claimed, including higher impact energy to penetrate harder ground and move or break up obstacles. The body of the mole acts as an initial directional anchor to the head as it drives forward, giving better directional control.

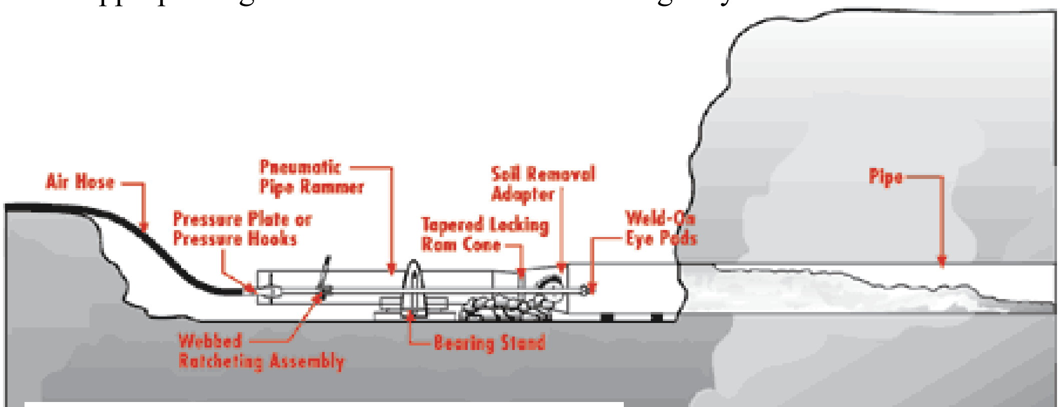
2.6 Installation Variations

In addition to the basic installation technique, there are some variations in how impact moles can be operated, and how installations are performed for different types of utility. Where the inner surface of a new pipeline has to be kept clean, for example a new drinking water pipe, two methods have been developed for use with pneumatic moles.

Pneumatic moles operate with compressed air, which carries the lubricating oil required by the moving parts in the unit. Since compressed air is not recycled as in hydraulic systems, used air is vented out of the mole. In most cases, this is done through the rear of the mole into the pipeline being drawn in behind, which tends to coat the inner wall of the pipe with an oil film that can be difficult to remove. The oil film can be ignored if it is unlikely to cause a problem, but for drinking water the oil is usually regarded as unacceptable.
To overcome the problem, installation is often done using a liner film within the pipeline. Exhaust air deposits the oil film on the liner, which is removed on completion of the bore, leaving a clean inner surface. To avoid the need for a liner, moles have become available which vent used compressed air from the front of the machine. This air then discharges along the outside of the new pipe, without affecting the inner surface.

3 PIPE RAMMING

Pipe ramming is a non-steerable system of forming a bore by driving a steel casing, usually open-ended, using a percussive hammer from a drive pit. The soil may be removed from an open-ended casing by augering, jetting (with water) or compressed air. In appropriate ground conditions a closed casing may be used.



Schematic of the Pipe Ramming Technique.

3.1 Applications

Pipe ramming is most often used to install new pipelines or casings into which new utilities will be installed. Installation distances have increased dramatically in recent years from about 50 meters on average to up to 100 meters today. Steel pipe is used for the casing, as no other material is strong enough to withstand the impact forces generated by the hammer. The technique is often favored for crossings beneath railways, roads and waterways. Once the steel pipe is installed, it can be used as a pipeline in its own right, or as ducting for most types of pipe or cable.
Bores up to 3,000 mm diameter have been installed in suitable ground conditions, using impact ramming hammers of up to 800 mm diameter generating ramming forces of up to 40,500 Nm. But, as with all trenchless systems, much of the capability of this equipment depends very much on the prevailing ground conditions and the skills and experience of the operator.

Piling utilizes an impact mole or more commonly a Ramming Hammer in the vertical plane to push steel pipe into the ground to a required depth. The pipe is then either used directly as the pile or the ground within the pipe is removed and replaced with concrete to create the required structure.

HDD Assist/Rescue is probably the most useful development for Ramming hammers in the past few years. With HDD installations there is always the possibility that ground conditions will vary to an extent that has not been predicted by ground investigation surveys, whether this be due to unknown ground or variations in ground water due to changing weather patterns. Should a drill string or pipe being pulled into a bore get stuck in such circumstances, Ramming Hammers are now ready to help. Techniques have been developed whereby a Ramming Hammers can be attached to a drill string or pipeline in a manner that can enable operators to recover the stuck equipment or to assist in completing the product pipe placement. 'Recovery' or rescue is achieved by utilizing the Ramming Hammers in conjunction with the power of the HDD rig in a direction opposite to that in which it got stuck, so pulling the equipment back out of the ground to start again if required. 'Assistance' is achieved by connecting the Ramming Hammer to the free end of the pipe string with the hammer working in the direction of the pipe pull. The extra impetus on the pipe string supplied by the hammer working in conjunction with the pulling power of the HHD rig more often than not is sufficient to allow the pipe pull-in to be completed where the power of the HDD rig along would not have achieved completion of the installation.

3.2 Set-up

A typical ramming operation requires the establishment of a solid base, normally a concrete mat, on the launch side of the installation. This mat will usually be either against the side of a slope or in a start pit. Guide rails set to the line of the bore are then installed on the mat. The first length of steel pipe is positioned on the guide rails, a cutting edge is formed or fitted to the lead end of the pipe, and the ramming hammer is attached to the rear of the pipe. Depending on the diameter, inserts may have to be used to ensure solid and uniform contact between the hammer and the pipe.

The power supply is attached and the hammer started. The ramming hammer forces the steel pipe into the ground along the line dictated by the guide rails. When one pipe has been driven the hammer is stopped and removed, and the next length of steel pipe is welded in place. The cycle is repeated until the leading edge of the first pipe arrives at the reception end or shaft.

A Ramming Hammer in position to ram a steel casing. Picture courtesy of Earth Tool Corporation

As with impact moling, thorough ground investigation is an essential requirement of pipe ramming projects. Large obstacles can deflect a pipe off course, or may damage the cutting edge, causing a steering bias. As there is usually no means of monitoring the direction of the pipe during a bore, it is vital to establish a clear bore path prior to work commencing.

3.3 Bore Options

Depending on the nature of the ground, ramming may be carried out with either open ended or closed-end pipe. Open-ended ramming is generally preferable, having several advantages including lower reaction against the ramming force, since only the cutting edge is pushed against the ground. Harder ground can be penetrated by open-ended ramming, as the soil does not have to be compressible. Because the surface area of pipe presented to an obstacle is far less with an open-ended pipe, there is also less likelihood of the pipe deflecting.

However, for open-ended ramming the ground has to be relatively self-supporting, otherwise there may be loss of ground ahead of the cutting edge as soil moves into the open pipe and flows along it to the start pit. In severe cases, this could cause surface subsidence or loss of support to adjacent pipelines. Closed-end ramming may be effective under such conditions, as soil is displaced around the pipe and compacted around the wall of the bore. As with impact moling, there is the risk of surface heave during a compacting bore.

When using an open-ended system, the cylinder of ground within the circumference of the cutting edge stays inside the pipe during the bore. Over the short distances normally undertaken with pipe ramming, this accumulation of spoil is not usually a problem.

However, for longer bores, it should be remembered that the spoil adds to the weight of the pipe string being rammed, and will therefore affect advance rates. In some instances it may be advisable to clean out spoil from the pipe during pipe string extension works, to limit the extra burden on the ramming hammer.

Depending on diameter, this can be done either manually or by means of a scraper winch system.
If intermediate cleaning is not required and the spoil remains in the pipe for the whole bore, there are techniques other than shovels or scrapers for achieving spoil removal. On arrival at the reception pit, the open end of the pipe can be sealed with a suitable plug. Pressurized water or compressed air is then introduced between spoil and seal, and the cylinder of soil in the pipe is forced out into the launch pit where it can be removed. The seal is then removed, and the pipe or casing cleaned and put into service.
The principles of both impact moling and pipe ramming are relatively simple, and these techniques can offer highly cost-effective solutions to relatively short length installation projects.

4 PIPE BURSTING

Impact hammers are also used for various forms of on-line pipeline replacement work. This application is covered elsewhere in the section On-Line Replacement.

5 SUMMARY

Moling is one of the simplest and most widely used no-dig techniques, especially for small diameter service installation over relatively short distances.
With some exceptions, moles are not steerable and rely on launch orientation and soil conditions to follow the desired route.
Pipe ramming is a common method of installing steel casings in a straight line, and is frequently used under railway and road embankments.
As with moling, pipe ramming is generally employed for relatively short drives, and is not a steerable technique.
Pipe rammers can install large diameter casings. Although the steel casing can act as the product pipe, it is more usual for it to be treated as a duct through which conventional mains or services are installed.