CFA Guidance Note:
Powder Actuated Fixing Systems

Note: The guidance given in this Guidance Note is provided in good faith but the CFA cannot accept any liability for adverse consequences of this advice being followed.

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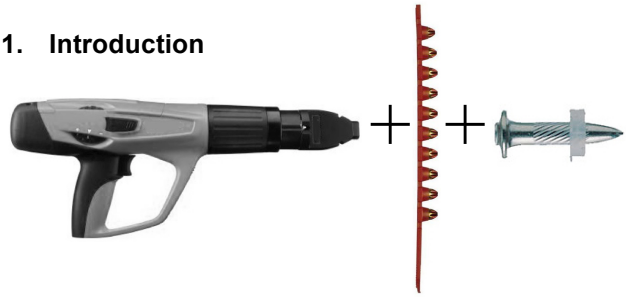
1. Introduction



This Guidance Note is an introduction to the various aspects which should be considered in using Powder Actuated Technology (PAT). In case of any doubt refer to the supplier/manufacturer for technical support. PAT is a fastening system in which specially designed and hardened fasteners are driven into steel, concrete or masonry. The system includes the **fastener** (a nail or stud), the **power source** (a cartridge containing combustible propellant powder) and a specially designed **tool**. It is different to drilling and fixing or screw fastening in that during the fastening process the base material is usually displaced, it is not removed.
To use PAT tools, operators must have completed a Certified Operator Training programme (Section 13).

2. Benefits of using PAT

The technology offers an alternative fastening method to traditional drilling and fixing in concrete or masonry or self-drill / self-tap screws in structural steel. The main benefits of using PAT Technology are:

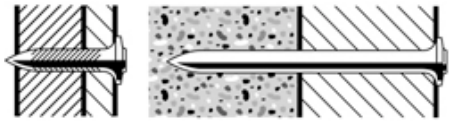
Productivity
- High fastening speed, leading to significant productivity gains

Health & Safety
- A cordless fastening system (no battery or trailing cables) which is weather independent
- Virtually dust free fastening
- More fastenings per day are typically possible if concerns exist about Hand Arm Vibration (HAV)

3. Suitable Base Materials

PAT fastenings are suitable for a range of different base materials including structural steel, concrete and masonry (brick / block). Different fastener types have been developed to optimise performance in these different materials. It is recommended to check with the manufacturer / supplier for the relevant data for the particular base material / nail combination chosen.

The following may be helpful as a general guide:



3.1 Steel:

PAT fixings work in a range of construction grade structural steels. It is likely to work best in the steel grades of S235, S275 and S355 or equivalent i.e. typical UTS range of ~350-600 N/mm^2. The optimum thickness of base steel required to get the best results is likely to be in the range of 5-20mm with a minimum of 3mm. Minimum edge and centre spacings are typically 15mm.

3.2 Concrete:

In-situ cast structural concrete with a cube strength (f_{cc}) in the range of 20-45 N/mm^2 is most likely to give the best results. A minimum thickness of concrete of 80mm is likely to be required and fasteners should typically be spaced at least 70mm apart & from a free edge.

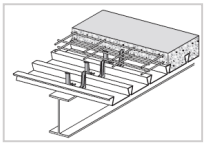
Hollow core pre-cast/pre-stressed concrete

Due to the inherently increased hardness of concrete in these sections a higher rate of installation failures can be expected. Users should seek advice from manufacturers of both the fixing system ***and*** the concrete regarding suitability and application limits.

3.3 Masonry (brick / block):

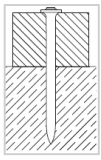
Due to the wide range of material and strength types which exist, if safety critical fastenings are to be considered in masonry, check for detailed advice from your supplier / manufacturer. It is likely that test fastenings may be required to determine the suitability and relevant load capacity. Soft and hollow blocks are unlikely to offer significant holding power.

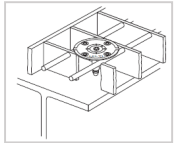
4 Suitable Applications



PAT systems are suitable for a wide range of applications. Some examples are:

- Thin metal sheets (multiple layers possible) up to 4mm for roof decking, wall liners & floor decking depending on configurations.
- Fastening thicker steel brackets & cable clips (≥ 3mm needs pre-drilling).
- Fastening soft materials such as wooden battens or insulation to steel, concrete or masonry
- Threaded studs for suspended ceilings[i], installing building services, open tread grating or checker plate flooring.
- Shear connections in composite structures and shear connectors for composite floors.





5 Legislation & CE Marking

Tools: The recent introduction of BS EN 15895:2011 '*Cartridge operated hand-held tools – safety requirements – fixing and hard marking tools*' means that Cartridge Tools are now regulated in the same way that other construction / power tools and they now carry CE marking to show compliance with the standard (mandatory from 2013)

Cartridges: Likewise, the power source (cartridge) has also been brought under the European Regulations with the publication of BS EN 16264:2014 '*Pyrotechnic articles. Other pyrotechnic articles. Cartridges for powder actuated tools'*. This means that both the tool and the cartridge are regulated on a European basis and both elements, tools and cartridge must carry CE marking. Further, it is strongly recommended that the tool and cartridge are selected as a 'system'. This can be assured when the cartridges which are selected carry the tool designation, name of certified body and system test number printed on the cartridge packaging.

Fasteners (nails & studs): Currently there is no harmonised standard (hEN) for nails or studs designed for use in PAT Tools. However, approvals (ETAs[ii]) are now possible in accordance with an EAD[iii]. This defines the stringent test programme required to check the functionality and determine the performance of any tested system (tool, cartridge and fastener) to permit CE Marking of the fastener. Where fixings with an ETA are available they should be used.

6 Design Standards

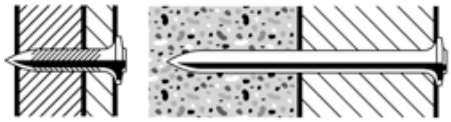
Note: In this context the term "Design" is taken to mean selection of the correct fastener.

Except for fasteners with ETA, no design standards are currently available. Manufacturers provide their own data for the different fasteners they have tested in the different base materials. As a general rule if the application is of a structural nature (designed to carry load) then single point fastenings are possible in structural steels S235, S275 and even S355. However, in structural concrete e.g. C20 – C50, multi-point fastenings are typically required (5 fasteners per fastened unit) and in masonry structural fasteners should only be considered after testing has been carried out on site to determine suitability and the allowable load. Contact the manufacturer for advice on a suitable procedure.

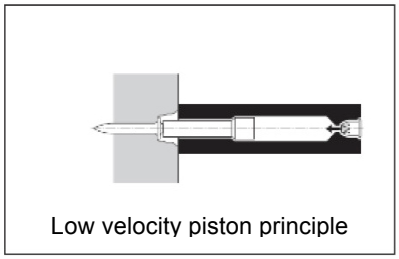
7 Operating Principles

One of the main concerns about the use of powder-filled explosive cartridges to drive fasteners is what happens if the base material is missed by the fastener or it is too thin or weak to offer significant resistance. All PAT tools covered by BS EN 15895:2011 '*Cartridge operated hand-held tools – safety requirements – fixing and hard marking tools'* contain an internal piston and work on the low velocity 'piston principle' (sometimes called in-direct acting tools).

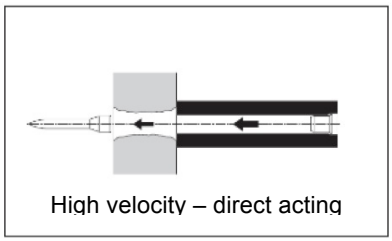
The inclusion of a piston means that the energy from the propellant in the cartridge is transferred to the piston, the accelerated mass of which then drives the fastener.



Because the piston is captive within the tool, roughly 95% of the driving energy is absorbed by the tool in the event of the fastener missing the base material. Thus, the velocity of a fastener that misses the base material, or passes through a thin one, is far lower than the velocities associated with fasteners from high-velocity tools (tools that do not contain a piston, sometimes called direct acting tools).



Low velocity piston principle



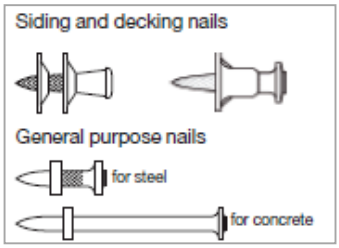
High velocity – direct acting

Note: This Guidance Note only covers tools operating to the low velocity piston principle.

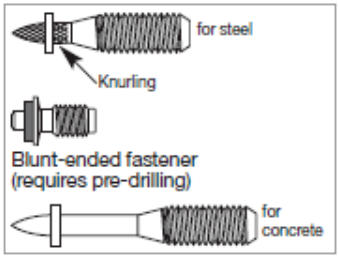
8 Fasteners (Nails and studs)

A wide range of fasteners is available to cover the many applications that are possible using PAT fastening systems. Typically the fasteners fall into three main groupings nails, threaded studs and composite fasteners

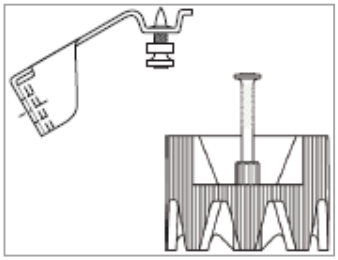
Nails: are manufactured from a high strength steel and are equipped with washers designed to meet the needs of the application and to provide guidance when driven.



Studs: are essentially nails with a threaded upper section instead of a head.



Composite fasteners: are an assembly consisting of a nail with an application-specific fastening component such as a clip, plate or disk made of metal or plastic.



9 Cartridges

Cartridges are available in various standard sizes which determine the power output and each size is available in a range of power levels which also regulates the power output. The standard colours available are:

Colour Code	Power Level
Brown	2
Green	3
Yellow	4
Red	5
Black	6

Cartridges are also available in two formats

'strip' and 'disc'

9.1 Cartridge Requirements:

It is important to make sure that the cartridge selected is suitable for the tool to be used. As a minimum, to confirm with BS EN 16264:2014 cartridge packaging must display:

- The CE conformity mark
- The proof mark of fire-arm test house
- The tool designation
- The identification number of the EU notified Body
- The number of the type test

Fire arms test house Proof mark	CE conformity mark	Tool Designation	FP 959
	CE 0598	Proof House ID	PTB
	ABC 01234/56	Number of Type test	ST 9876 GT

If in doubt ask your supplier / manufacturer.

9.2 Cartridge storage and disposal

Storage: Follow the manufacturer's recommendations (see Material Safety Data Sheet). Good practice is as follows:

- In their original packaging
- In a metal cabinet or a dry cool room (locked with restricted access)
- Issued under the control of a nominated person.

Disposal

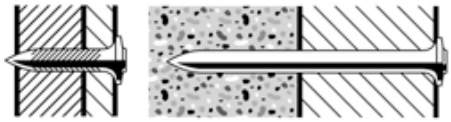
Fully used strips / discs:

- Dispose of in site waste

Partially used strips / discs

- Retain & re- use until fully used or
- Dispose of as Hazardous Waste

NEVER tamper with a cartridge



10 Selection process (Five steps)

10.1 Application:

1. Application

- Material to be fastened e.g. Wood, drywall track etc.
- Base material e.g. Concrete, steel, masonry
- Load required e.g. 'Structural' / 'Non-structural' / 'redundant', magnitude & direction.
- Environment fastening will be used in e.g. Temperature, Corrosion e.g. Humidity, Salts / other chemicals.
- Location: Downward, horizontal or overhead

10.2 Fastener (see Section 8)

2. Fastener

- Nails
- Studs
- Composite fastener

10.3 Tool

3. Tool

- There are many tools types available. Some are 'general purpose' suitable for a range of applications and some are 'application specific'. If in doubt ask your supplier for advice

10.4 Cartridge

4. Cartridge

- Cartridge size and colour

10.5 Accessory

5. Accessory: Fastener guide, piston, propellant, pole tool

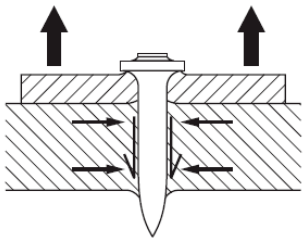
- Fastener guide:- Single fix or r Magazine
- Piston: matched to tool / Fastener guide
- Pole tool: overhead

11 Working principles

11.1 Steel

The following mechanisms cause a PAT fastener to hold when driven into steel:

- clamping
- keying
- fusing (welding)
- soldering



11.1.1 Factors influencing fastener resistance

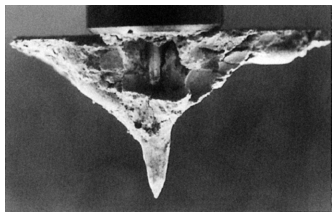
PAT fastening systems must be designed and manufactured to ensure that the tensile and shear resistance will be adequate for the applications intended. Through understanding of the anchoring mechanisms, experience and testing, factors that influence fastener strength have been identified. Some of these factors are:

- Depth of penetration in the base material
- Surface characteristics of the fastener
- Coatings on the steel base material
- Driving velocity
- Diameter of the fastener shank

Knowledge of the influencing factors is vital to the design of the fastening system and is useful for operator in understanding the various application guidelines and restrictions that apply to a fastening system.

11.2 Concrete

The following three mechanisms cause a PAT fastener to hold in concrete:



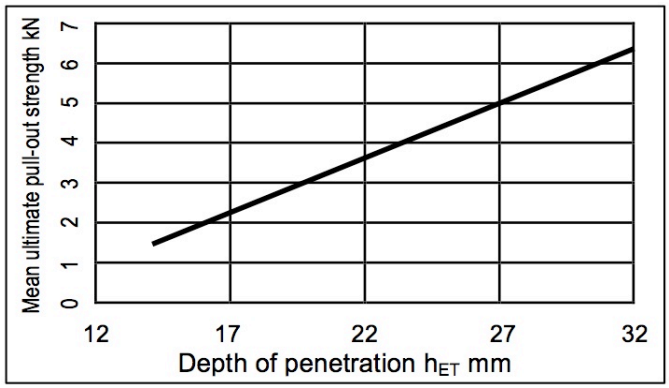
- Bonding / sintering
- Keying
- Clamping

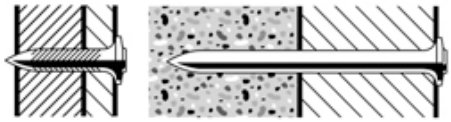
11.2.1 Factors influencing fastener resistance

Factors that can affect the tensile and shear strength of fastenings to concrete include:

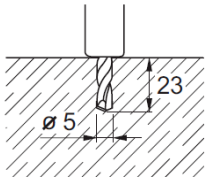
- Depth of penetration into the concrete
- Concrete parameter (compressive strength, aggregate, direction of concrete placement)
- Distance to concrete edge and fastener spacing

Fasteners with a greater **depth of penetration** in concrete typically have a higher resistance to pull-out. However, the value of increasing the depth of penetration in order to increase pull-out strength is limited by the increasing fastener driving failure rate. As could be expected, the depth of penetration at which the failure rate is at a minimum decreases with increasing concrete strength.

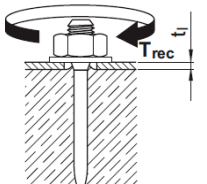




The concrete parameters (such as the type and size of concrete aggregates, type of cement and the location on top or bottom surface of a concrete floor) do affect the fastener driving failure rate, sometimes significantly.
Presence of reinforcement may limit applications and influence fastener spacing. For example uni-directional reinforcement in pre-cast / pre-stressed concrete units will influence fastener depth and spacing.
Fastener driving failures are caused by the fastener hitting a hard aggregate, such as granite, located close to the concrete surface. A hard aggregate can deflect the fastener and in a severe case, the fastener may bend excessively, leading to concrete fracture in a cone shape and no hold being obtained by the fastener. In case of slight fastener bending, concrete spalling may occur at the surface. However, because pull-out strength is obtained mostly in the area of the fastener point, concrete spalling does not affect the permissible load of the PAT fastening.
There are several possible ways of reducing the failure rate when powder-actuated fasteners are used for fastening to concrete. There are two basic ideas. One is to reduce concrete tensile stresses near the surface of the concrete by pre-drilling a very small hole (5mm diameter, 18 or 23 mm deep), the stresses are relocated to greater depth in the concrete. With this method, virtually no fastener driving failures occur.



Pre-drill with drill bit



Tightening torque

This technique should only be adopted as part of a manufacturer supplied and recommended system.

The other is to delay the effect of these stresses by using a 'spall stop' fastener guide. Its weight and inertia counteract the stresses at the surface for a very short time. This allows redistribution of the stresses to other parts of the concrete.

Edge distances. If fasteners are placed too close to the concrete edge, pull-out load capacity will be reduced. Minimum edge distances are therefore published with a view to reducing the effect edges have on pull-out strength, (see 3.2).

11.3 Masonry

PAT can also be used on masonry. However, because of the wide variety of types and forms of masonry in use, users are advised to carry out tests on site or on masonry of the type and form on which the fastenings are to be made prior to use.

12 Installation Guidance

Prior to using a PAT tool and in line with the requirements of BS 4078 Pt 1 (see Section 6) operators must receive training in the correct and safe use from the manufacturer or his agent. This section is not a substitute for the training but seeks to offer some useful tips of the how to get the best results from your PAT system.

12.1 Prior to use:

- Read the instruction manual and follow the manufacturer's instructions for safe usage.
- Make sure the **components** you are using i.e. the tool, the cartridge and the fastener have been **tested as a system**. Only use components which have been approved for use together or are of equivalent quality. If in doubt, ask the supplier.
- Follow the correct Selection Process (see 10)
- Carry out standard inspection checks on the piston and stop ring / buffer and make sure the tool is in good working order.

12.2 Using the tool

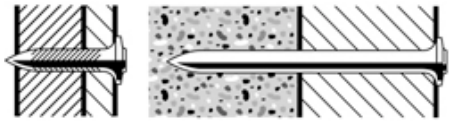
- PPE. In addition to PPE requirements specific to a particular site and arising from a risk assessment users should wear the correct PPE as recommended by the manufacture (see instruction manual). This will include eye protection to EN 166, Class B and Ear protection to BS EN 352.
- Be aware of and follow the mis-fire procedure (covered in the training) in the event that the cartridge does not ignite when the trigger is pulled (i.e. wait 30 secs.)
- Carry out test fixings if necessary to determine correct cartridge colour / power setting on the tool
- Keep arms relaxed
- Always remove cartridge(s) prior to any maintenance on the tool (remember it may be HOT!)

12.3 After using the tool

- Remove the cartridges and store in a safe and suitable location (see Material Safety Data Sheet). Note: individual projects may have their own issuing / return procedures.
- Put tool back in case, lock away safely and notify the person responsible if any problems have occurred during the last use of the system.

12.4 Attaching to Stud type fasteners

- Once stud type fasteners have been installed the fixture may be located over the stud and a washer and nut applied to clamp it to the base material. Care should be taken not to overtighten the nut. From finger tight this will take less than half a turn. Refer to manufacturer's instructions for guidance.



13 Tips for Users (Troubleshooting)

In addition to these tips users should refer to the manufacturer for guidance.

13.1 Concrete

Fault	Cause	Possible remedies
Fastener penetrates too deeply	■ Fastener too short ■ Driving power too high	■ Use longer fastener ■ Reduce power setting ■ Use lighter cartridge
Fastener does not penetrate deeply enough	■ Fastener too long ■ Driving power too low	■ Use shorter fastener ■ Increase power setting ■ Use heavier cartridge
Nail bends	■ Hard and/or large aggregate in concrete ■ Rebar close to surface of concrete ■ Hard surface (steel)	■ Use shorter nail ■ Use a nail with a higher applicati-on limit ■ Use Pre-drilled ■ Change to single fasteners
Damaged nail head	■ Driving power too high ■ Wrong piston used ■ Damaged piston	■ Reduce power setting ■ Use lighter cartridge ■ Check nail/piston combination ■ Change piston
Base material is spalling	■ High strength concrete ■ Hard and/or large aggregate in concrete ■ Old concrete	■ Stud application Use spall stop: ■ Nail application Use shorter nail Use Pre-drilled

Rules of thumb:
The higher the concrete strength, the shorter the fastener.
The greater the embedment depth the higher the holding power and the higher the risk of installation failure.

Fastener length, Ls (mm): $Ls = h_{ET} + t_{fix}$

h_{ET} = optimum embedment depth = 20 to 25mm depending on concrete strength and manufacturer's guidance.

t_{fix} = thickness of item to be fastened

Example of training certificate.

13.2 Steel

Fault	Cause	Possible remedies
Nail does not penetrate surface	■ Driving power too low ■ Application limit exceeded (very hard surface) ■ Unsuitable system	■ Use a higher power setting or heavier cartridge ■ Use stronger nail ■ Change to single fasteners ■ Switch to more powerful system
Nail does not hold in base material	■ Thin steel base material (4 to 5 mm steel) **NOTE:** Steel base material must be > 4 mm	■ Use a different power setting or different cartridge ■ Use a nail suitable for thin steel base materials.
Nail breaks	■ Driving power too low ■ Application limit exceeded (very hard surface)	■ Try higher power setting or heavier cartridge ■ Use shorter nail ■ Use stronger nail
Nail head penetrates through material fastened (metal sheet)	■ Driving power too high	■ Reduce power setting ■ Use lighter cartridge ■ Use nail with top hat ■ Use nail with washer

Note: Worn, damaged or incorrect pistons can cause many of the above faults (concrete and steel): match pistons to nails and check condition!

14 Certified Operator training

In certain countries including the United Kingdom, standards were put in place requiring operators to be trained prior to using PAT tools. These standards remain current in the UK namely BS 4078 Pt 1 Powder actuated fixing systems Part 1 Code of Practice for safe use. Section 9 of the Code deals with training and states that 'The manufacturer or his agent should be responsible for the training of instructors'. It also details the main topics that the trainer should cover when training Operatives, namely:

a. How the system works
b. How to choose fasteners, cartridges and tools correctly for the specific application
c. How to operate the tools
d. How to maintain the tools
e. Storage and care of tools, cartridges and fasteners
f. Safe use of tools and equipment
g. How to identify suitable base materials

Member Companies can provide training on the operation, care, maintenance and application of their own individual systems and can issue appropriate certificates upon satisfactory completion of the relevant training and a demonstration of satisfactory understanding on the part of the trainee. Please ask your manufacturer / supplier about training.

[i] For further guidance please see "Best practice guidance – to fixings for suspended ceilings' Published jointly by CFA and Association of Interior Specialists.
[ii] ETA = European Technical Assessment under the Construction Products Regulation since July 2013, previously European Technical Approval under the Construction Products Directive.
[iii] EAD – European Assessment Document under CPR, previously a "CUAP" Common understanding of Approval Procedure under the CPD.