





2. The direct fastening system

The fastener, tool and driving energy form a **fastening system** with its own specific characteristics. Examples of Hilti direct

fastening system components are shown below.

Fasteners	Fastening tools	Driving energy
		
Powder-actuated tool		
		
Gas-actuated tool		

2.1 Fasteners

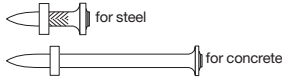
Fasteners can be classified in three general types: nails, threaded studs and composite fasteners.

Nails

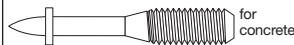
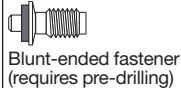
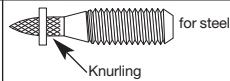
Siding and decking nails



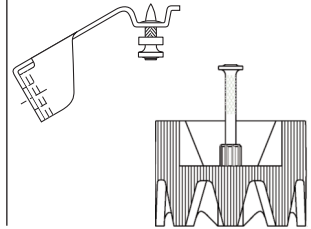
General purpose nails



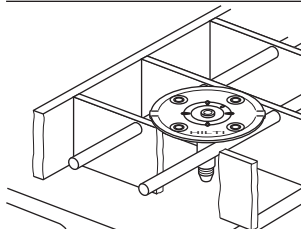
Threaded studs



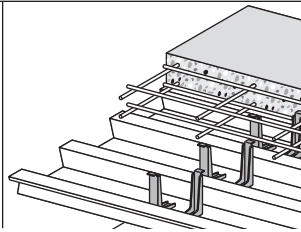
Composite fasteners



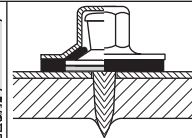
Multi-part fasteners



X-FCM grating disk with threaded stud



X-HVB shear connectors fastened with **X-ENP-21** HVB nails



X-ENP nail with **SDK 2** sealing cap

The nails used (also known as drive pins) are of a special type equipped with washers to meet the needs of the application and to provide guidance when driven. Threaded 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.

Siding and decking nails can be recognized by their washers which are specially designed to hold down the metal sheets and to absorb excess driving energy. Fasteners designed for driving into steel usually have

knurled shanks which increase their pull-out resistance. Fasteners for use on concrete have longer shanks than those for use on steel. Threaded studs may have either a metric (M6, M8 or M10) or Whitworth ($1/4"$, $5/16"$ or $3/8"$) thread.

Nails and threaded studs are commonly zinc-plated for resistance to corrosion during transport, storage and construction. As this degree of protection is inadequate for long-term resistance to corrosion, use of these zinc-plated fasteners is limited to applications where they are not exposed to the weather or a corrosive atmosphere during their service life. The zinc layer on

fasteners driven into steel is, in fact, a disadvantage in that it reduces pull-out resistance. For this reason, the thickness of zinc on the fastener must be optimized to ensure good corrosion protection as well as high holding power. During production, tight control of the galvanizing process is necessary to prevent excess zinc thickness and thereby poor fastening performance.

Fasteners must be 2 to 3 times harder than the material into which they are driven. The tensile strength of structural steel is com-

monly between 400 and 600 MPa. Fasteners for use on steel thus require a strength of approximately 2000 MPa. As Rockwell hardness is much easier to measure than strength, but good correlation exists between hardness and strength, this characteristic is used as a parameter in the specification and manufacturing of the fasteners. In the table below, HRC hardness is given for a range of tensile strengths (DIN 50150).

Tensile strength (MPa)	770	865	965	1810	1920	1995	2070	2180
HRC	20.5	25.5	30	52.5	54	55	56.5	58

2.2 Manufacturing process

Standard hardened steel fasteners

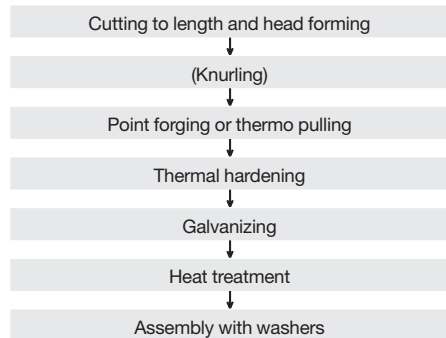
Almost all powder and gas-actuated fasteners used throughout the world are manufactured from carbon steel wire which is subsequently thermally hardened to provide the strength needed for driving into steel and concrete. In nail manufacturing, shank diameter is determined by the wire diameter used. Threaded studs are made from wire corresponding to the required thread diameter. The manufacturing process, which is summarized in the diagram below, consists of cutting the wire to length, shaping the head, knurling, forging or thermo pulling the point, hardening, galvanizing and assembling with washers.

The process of hardening the steel to more than HRC 50 combined with the zinc plating presents a risk of hydrogen embrittlement.

This risk is mitigated by heat-treating the galvanized product at the optimum temperature for the correct time. Galvanized and heat-treated fasteners are subjected to impact bending tests to check the effectiveness of the process. Depending on their intended application, some fasteners are additionally sampled and tested under tension and shear.

Manufacturing Process

Standard zinc-coated fasteners

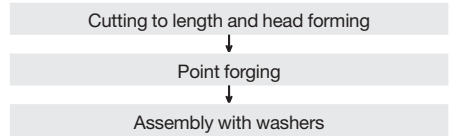


Stainless steel fasteners

Hilti introduced the first powder-actuated stainless steel fastener in 1994. These fasteners, which are not thermally hardened, are manufactured from special stainless steel wire with an ultimate tensile strength of 1850 MPa. One effect of using steel of such high strength as a raw material is that the forming and forging processes present greater technical difficulties. These fasten-

ers, on the other hand, suffer no risk of hydrogen embrittlement and their strength decreases only very slightly when subjected to high temperatures such as in a fire.

Manufacturing Process Stainless Steel Fasteners

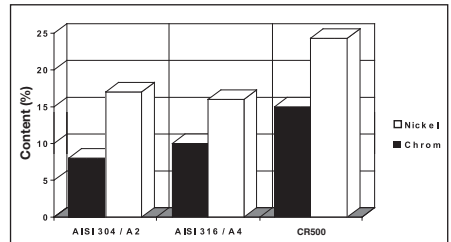


2.3 Fastener raw material

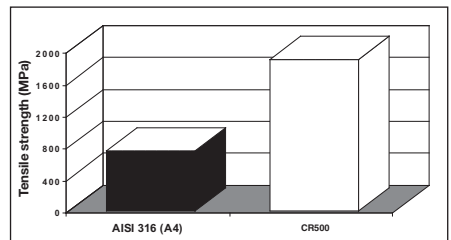
Hilti standard zinc plated fasteners are made from carbon steel wire with an ultimate tensile strength of 590 to 760 MPa.

Hilti **X-CR / X-CRM / X-BT** stainless steel fasteners are made from high-strength nitrogen alloyed stainless steel wire (Hilti designation CR500).

Nickel and chromium are the components of stainless steel that make it resistant to corrosion. CR500 steel is compared to commonly used stainless steels like AISI 304 and 316 (European A2 and A4) in the graph at the right. Note that CR500 steel contains considerably more nickel and chromium than both 304 and 316.



Another comparison of interest is the difference in ultimate tensile strength, as shown in the graph at the right.



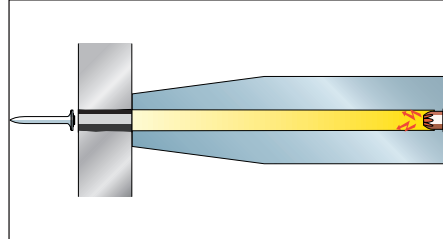
2.4 Powder- and gas-actuated tools

Definitions

In the ANSI A10.3-2006 standard, two basic types of tool are referred to: direct-acting and indirect-acting. The two types are defined by the manner in which the energy is transferred from the hot expanding gases to the fastener.

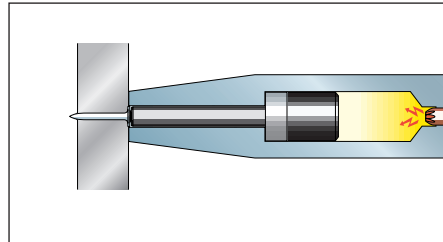
Direct-acting tool:

The expanding gases act directly on the fastener and accelerate it to a velocity of 400 to 500 m/s (1300 to 1600 fps). This velocity places the tool in the high-velocity class, thereby subjecting it to more stringent rules for usage.



Indirect-acting tool:

The expanding gases act on a captive piston that drives the fastener, which in Hilti indirect-acting tools reaches a velocity of less than 100 m/s (328 fps). Because of the lower velocity, the possibility and extent of injury due to incorrect operation is very much reduced. Rules for usage are less stringent than for high-velocity tools.



ANSI A10.3-2006 classifies powder-actuated tools according to velocity. With increasing velocity, rules for usage become more stringent, for example with regard to equipping the tools with shields. The lowest velocity tool capable of performing the application should be used.

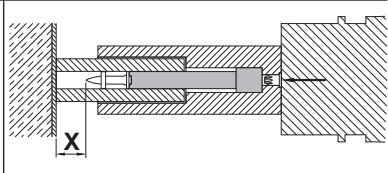
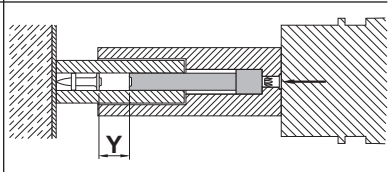
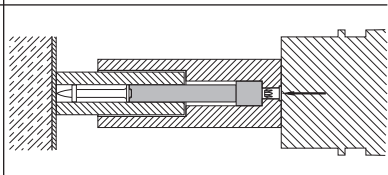
Class of powder-actuated tool	Average test velocity in m/s [fps]	Maximum single test velocity in m/s [fps]
Low-velocity	100 [328]	108 [354]
Medium-velocity	150 [492]	160 [525]
High-velocity	>150 [492]	>160 [525]

Hilti tools

All Hilti tools supplied for construction applications are low-velocity, indirect-acting tools.

Indirect-acting tools operate according to one of three different principles – co-acting, impact or contact operation – which each affect the operating characteristics and the application limit of the system. It should be noted that 100% co-acting operation can be

achieved by pushing the fastener all the way back against the piston with a ramrod or, if the tool is so designed, with a built-in ramrod mechanism. Tools with nail magazines do not achieve 100% co-action because of the need for clearance between the piston end and the collated nail strip. Some single-shot tools allow the operator to make an impact-type tool work as a co-acting tool by using a ramrod.

Operating principle	Characteristics	
Co-acting operation	<ul style="list-style-type: none"> • $X > 0$; $Y = 0$ • Highest application limit • Lowest recoil 	
Impact operation	<ul style="list-style-type: none"> • $X = 0$; $Y > 0$ • Lower application limit • Higher recoil 	
Contact operation	<ul style="list-style-type: none"> • $X = 0$; $Y = 0$ • Lowest application limit • Highest recoil 	

2.5 Cartridges (power loads, boosters)

Cartridges for indirect-acting tools are available in various standard sizes and each size is available in up to 6 power levels. In the United States, the powder in a cartridge, the sensitivity of the primer, and the cartridge dimensions are governed by technical data published by the Powder-Actuated Tool

Manufacturers Institute, Inc. (PATMI). PATMI defines the power level by the velocity measured in a standard test in which a standardized 350 grain [22.7gram] cylindrical slug is fired from a standardized apparatus. The identification and limitations of use are addressed in ANSI A10.3-2006.

PATMI colour codes, power levels and definition of cartridges

Size	Colour code	Power level	Velocity of 350 grain slug		Calculated energy (joules)		
			ft./sec.	[m/sec.]	minimum	average	maximum
6.8 / 11 [Cal. 27 short]	Gray	1	370 ± 45	[113 ± 13.7]	111	144	182
	Brown	2	420 ± 45	[128 ± 13.7]	148	186	228
	Green	3	480 ± 45	[146 ± 13.7]	200	243	291
	Yellow	4	560 ± 45	[171 ± 13.7]	280	331	386
	Red	5	610 ± 45	[186 ± 13.7]	337	392	452
	Purple / black	6	660 ± 45	[201 ± 13.7]	399	459	524
6.8 / 18 [Cal. 27 long]	Green	3	550 ± 45	[168 ± 13.7]	269	319	373
	Yellow	4	630 ± 45	[192 ± 13.7]	361	419	480
	Blue	4.5	725 ± 45	[221 ± 13.7]	488	554	625
	Red	5	770 ± 45	[235 ± 13.7]	554	625	700
	Purple / black	6	870 ± 45	[265 ± 13.7]	718	798	883

The German DIN 7260 standard specifies cartridge dimensions, colour codes and power levels, which are defined in terms of energy delivered when a cartridge is fired in

a standardized apparatus. DIN 7260 specifies a 3.66 gram slug with a somewhat more complex geometry than that of the PATMI slug.

DIN 7260 colour codes, power levels and definition of cartridges

Size	Colour code	Power level	Specified energy (joules)
6.8 / 11	White	weakest	120 ± 50
	Green	weak	200 ± 50
	Yellow	medium	300 ± 50
	Blue	heavy	400 ± 50
	Red	very heavy	450 ± 50
	Black	heaviest	600 ± 50
6.8 / 18	Green	weak	200 ± 50
	Yellow	medium	400 ± 50
	Blue	heavy	500 ± 50
	Red	very heavy	600 ± 100
	Black	heaviest	800 ± 100

In order to achieve interchangeability of the tools and cartridges from various manufacturers, PATMI provides guidelines on cartridge dimensions. Manufacturers optimize the cartridge characteristics for their tools in order to achieve functional reliability and long life.

Interchanging of components is mentioned in 7.10 of ANSI A10.3-2006: “Only

those types of fasteners and power loads recommended by the tool manufacturer for a particular tool, or those providing the same level of safety and performance, shall be used.”

It is the responsibility of the user of powder-actuated products to comply with this requirement.