



SURFACE VEHICLE STANDARD

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Internal Combustion Engines - Piston Vocabulary

RATIONALE

This standard has been updated to reflect restricted substances and clarifications of modern conditions, and to make grammatical/non-technical changes.

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1. SCOPE

This SAE standard defines the most commonly used terms for pistons. These terms designate either types of pistons or certain characteristics and phenomena of pistons.

1.1 Field of Application

The terms and definitions apply to pistons for reciprocating internal combustion engines and compressors working under analogous conditions.

2. REFERENCES

There are no referenced publications specified herein.

3. DEFINITIONS

3.1 ALFIN BOND

A special casting process used to metallurgically bond a cast iron or Ni-Resist ring groove reinforcement to the piston aluminum alloy. This method is also used to bond cylinder liners in air-cooled engines.

3.2 ANTI-THRUST SIDE

The piston skirt side opposite the thrust side. (This is also called the minor thrust side.)

3.3 APPARENT DENSITY

A relationship of piston mass to cylinder bore size. Also referred to as K-factor, it is determined by dividing piston weight in grams by the bore diameter (in centimeters) cubed.

3.4 ARTICULATED

Two-piece piston having separate crown and skirt pieces, joined by the wrist pin and able to rotate independently about the pin.

3.5 BOTTOM GUIDED CONNECTING ROD PISTON DESIGN

The connecting rod is located along the axis of the wrist pin by creating a small clearance between the large or "bottom" end of the connecting rod and the crankshaft. This allows a relatively large axial clearance between the inner sides of the wrist pin bosses and the small or "top" end of the connecting rod. The inner sides of the wrist pin bosses are typically "as cast" for this piston design.

3.6 COATINGS

See Section 4.

3.7 COMBUSTION BOWL

Recessed area on the crown. The bowl adds clearance volume to the combustion chamber reducing compression ratio. The shape may also enhance combustion and provide for valve clearance.

3.8 COMBUSTION BOWL REINFORCEMENT

A formed ceramic fiber material that is mechanically bonded within the alloy of an aluminum piston, usually at the combustion bowl rim, for increased fatigue resistance.

3.9 COMBUSTION BOWL RIM

The outer edge of the combustion bowl at the top of the piston, which is the transition between the combustion bowl and the piston crown.

3.10 COMBUSTION BOWL RIM REMELT

A process which remelts the aluminum in the bowl rim to improve the mechanical properties.

3.11 COMPRESSION HEIGHT

The distance from the centerline of the pin bore to the top of the piston.

3.12 COMPOSITE PISTON

A piston where two pieces are bolted together (see Figure 21).

3.13 COOLING GALLERY

A channel behind the piston ring belt area that receives cooling oil from an oil nozzle attached to a pressurized oil gallery. This channel can be formed by various methods.

3.14 COOLING (SHAKER) TRAY

A tray at the top of the articulated piston skirt that is designed to carry oil so that it can splash up into the cooling channel of the piston.

3.15 COVER PLATE

A plate that encloses the cooling channel on articulated pistons as well as single-piece steel pistons with open cooling gallery that the plate closes off. One hole in the cover plate allows sprayed oil to enter. Oil is splashed around inside the cooling channel. Oil then exits another hole in the cover plate at the opposite side of the piston.

3.16 CREVICE VOLUME

Any space that traps unburned combustion gases. Trapped unburned gases when later released contribute to hydrocarbon emissions. The spaces within the ring belt, head gasket, valves, and spark plug are potential sources for crevice volume.

3.17 CROAKING NOISE

Relatively low frequency noise typically caused by impact of a flexible part of the piston skirt with the cylinder bore due to secondary motion, during warm-up. (This is sometimes referred to as piston slap noise.)

3.18 CROWN

Top of the piston. This surface, also referred to as the dome, is part of the combustion chamber and sometimes includes a combustion bowl, crown pop-up, or valve pockets.

3.19 CROWN HEIGHT

For an articulated piston crown, the distance from the bottom of the skirt to the top of the piston.

3.20 CROWN POP-UP

Raised portion on the crown of the piston that enhances combustion by either its shape or by reducing the clearance volume (higher compression ratio).

3.21 CROWN STRUT

For an articulated piston, the support that holds the piston pin and transfers the force exerted on the crown to the pin.

3.22 DIAMETER-OVER-PINS

To define the width of a keystone groove it is common to measure the diameter over gage pins. Gage pins (of a specified diameter) are put in the ring grooves and the diameter to the outermost edge of the pin is the "diameter-over-pins." Increasing the groove width will decrease the diameter-over-pins.

3.23 EUTECTIC

- a. The isothermal (constant temperature) reversible reaction of a liquid that forms two different solid phases (aluminum and silicon in pistons) during cooling.
- b. The alloy composition that freezes at constant temperature, undergoing the eutectic reaction completely.
- c. The alloy structure of two (or more) solid phases formed from the liquid eutectically. (Also hyper-eutectic and hypo-eutectic.)
- d. A term commonly used to describe a piston alloy having around 11.5 to 12.0% silicon.

3.24 FIXED PIN

The piston pin is not free to rotate other than when the connecting rod pivots about the crankshaft. The pin is generally restrained by an interference fit in the connecting rod small end or, less commonly, in the piston.

3.25 FLOATING PIN

The piston pin is free to rotate. It is restrained axially by retainer clips or other devices at its ends which keep the pin centered in the piston/rod assembly. Occasionally a floating pin is assembled with slight interference fit in the piston pin bore at ambient temperature. Clearance occurs when engine combustion temperature causes the pin bore to expand.

3.26 FRONT ORIENTATION MARK

The mark on the piston that indicates the orientation of the piston for installation. The mark should be placed/pointed toward the front of the engine.

3.27 GAGE PIN

Used to measure the diameter-over-pins dimension (typically for keystone ring groove widths).

3.28 GROOVE BOTTOM SIDE ANGLE

The angle on the bottom side of a keystone ring groove.

3.29 GROOVE INCLUDED ANGLE

The angle enclosed by the bottom side and top sides of a keystone groove.

3.30 GROOVE OD CHAMFER

The chamfer at the OD edge of the ring groove.

3.31 GROOVE POUND-OUT

A widening of the piston ring groove caused by the ring pounding or impacting itself into the aluminum groove sides. Conditions leading to groove pound-out include groove wear, an un-reinforced ring groove, high piston temperatures, detonation, and lower silicon alloys, to name a few. Top side pound-out can be caused by engine speed and ring inertia. Bottom side pound-out is a function of pressure, temperature, and groove surface metallurgy. Groove pound-out can also lead to ring breakage when clearances become too large.

3.32 GROOVE RADIAL TILT

Refer to SAE J2275.

3.33 GROOVE ROOT DIAMETER

The diameter at the back of the ring groove.

3.34 GROOVE ROOT FILLET RADIUS

The fillet radius at the inner corners of the ring grooves.

3.35 HEAD LAND/TOP LAND

The piston land above the top ring.

3.36 HEAD LAND RING

An L-shaped top ring designed to function at the top of the piston crown.

3.37 HYPER-EUTECTIC

Piston aluminum alloys with a silicon percentage greater than the $\approx 12\%$ eutectic point. Primary silicon particles exist in the alloy since the quantity of silicon exceeds the solubility limit. (Also eutectic.)

3.38 HYPO-EUTECTIC

Piston aluminum alloys with a silicon percentage less than the $\approx 12\%$ eutectic point. (Also eutectic.)

3.39 INTER-RING VOLUMES

The volume between any two piston rings. This volume, when filled with blow-by gas, can influence the motion and function of the compression rings. This volume can also accumulate oil which may affect oil consumption.

3.40 K-FACTOR

See apparent density.

3.41 LAND HEIGHT

The axial width of the land at the OD of the piston.

3.42 LUBRICATION SLOT

Axial machined grooves in pin bores that provide path for oil to lubricate pin/bore interface (sometimes referred to as pin bore slots). If machined wider, these slots can also provide clearance for pin ovalization caused by combustion loading (sometimes referred to as ovalization slots or side relief).

3.43 MICROWELDING

The adhesive removal of aluminum piston material, during engine operation, from the piston groove side face (most commonly on the bottom side), and potential transfer to the side of piston ring. Frequently associated with elevated piston groove temperature, poor lubrication conditions, rougher ring or groove side surface finish, and ring to groove contact pressure. Severity ranges from microscopic levels with no observable effect to large scale damage where the sealing function is adversely affected.

3.44 MONOBLOCK

A term for a piston design comprised of one material and one piece construction. May contain inserts such as a ring carrier.

3.45 NI-RESIST

A special cast iron alloy with high levels of nickel used as a piston insert for ring-groove reinforcement in aluminum pistons. Ni-Resist is ideal for this application since its coefficient of thermal expansion, $19.3 \times 10^{-6} \text{ mm/(mm } ^\circ\text{C)}$, nearly matches that of piston aluminum alloys, $19.0 \text{ to } 21.6 \times 10^{-6} \text{ mm/(mm } ^\circ\text{C)}$. Normally installed in the piston casting using the Alfin bond process.

3.46 OIL DRAIN HOLE

A hole in the oil ring groove that provides a path for the oil scraped by the piston rings to return to the inside of the piston and back to the oil sump. These are commonly put in the back of the ring groove but may be put on the bottom side. The intent is that oil will drain from the ring belt back down into the sump. However, if it is incorrectly designed, this can feed oil into the ring groove, causing high oil consumption.

3.47 OIL DRAIN SLOTS

Radial slots in the bottom side of the oil ring groove that provide a path for oil scraped by the piston rings to return to the oil sump at the outside of the piston. The slot will commonly extend the whole depth of the ring groove and into the back of the groove. The slots are commonly placed in the pin axis so that oil will drain down the sides of the piston.

3.48 PANEL

The wall that connects the pin boss and the skirt.

3.49 PIN BOSS PIER OR PIN BOSS SUPPORT

The transition from pin bore to crown.

3.50 PIN BORE SLOT

Axial machined grooves in pin bores that provide path for oil to lubricate pin/bore interface (sometimes referred to as lubrication slots). If machined wider, these slots can also provide clearance for pin ovalization caused by combustion loading (sometimes referred to as ovalization slots or side relief).

3.51 PIN BORE

The bore through which the piston pin is inserted.

3.52 PIN BOSS

The structure that transmits piston forces to the pin.

3.53 PIN BOSS ANGLE

The angle of the inner edges of the pin boss (or crown strut).

3.54 PIN BOSS SPACING

The distance between the inner edges of the pin boss or crown strut at the centerline of the pin bore.

3.55 PIN OFFSET

A condition where the piston pin bore axis does not intersect with the piston axis. Pin offset toward the thrust side of the piston can be used to reduce slap noise during piston secondary motion in the cylinder bore.

3.56 PISTON LANDS

The parts of the piston that are above and below the ring groove. The width of these ring lands affects inter-ring volume. The lands are typically called: top land, second land, third land, and so on.

3.57 PISTON LAND PROFILE

Refer to SAE J2275.

3.58 PORT CUT-OUTS

Openings or windows in the skirt of a loop scavenged two-stroke piston that allow scavenge air to flow from the crankcase to the cylinder head.

3.59 RATTLING NOISE

Relatively high frequency noise typically caused by impact of a stiff part of the piston with the cylinder bore due to secondary motion.

3.60 RING BELT

The region of the piston that contains the piston rings. This includes the lands and the grooves.

3.61 SCAVENGING DEFLECTOR

The piston crown of a cross scavenged (cross flow) two-stroke piston is shaped to deflect the incoming charge toward the combustion chamber to facilitate the removal of exhaust gases and avoid the direct flow of incoming charge out the exhaust. This method of scavenging has been almost completely replaced by loop scavenging.

3.62 SECONDARY MOTION

The lateral (side to side) movement of the piston as it reciprocates up and down the bore. This lateral piston motion is caused by resultant forces from gas pressure, inertia, and friction in combination with the connecting rod angle.

3.63 SKIRT

The portion of the piston that provides the bearing surface to guide the piston in the cylinder bore.

3.64 SKIRT COLLAPSE

Permanent reduction in piston skirt diameter (usually measured at the gage point) due to deformation of the structure during running.

3.65 SKIRT CONTACT PATTERN

The wear pattern developed on the piston skirt due to normal operation and contact with the mating cylinder.

3.66 SKIRT GAGE POINT

Height at which the skirt diameter is measured on the thrust axis to fit the piston to the bore.

3.67 SKIRT NOTCH FOR PISTON COOLING NOZZLE

A notch cast in the skirt at its bottom edge that provides clearance to the piston cooling nozzle at BDC.

3.68 SKIRT OVALITY

Deviation from a true circle as a function of angle from the thrust axis. By definition, this relief is zero at the thrust axis. The ovality can vary from the top to the bottom of the skirt. The ovality is necessary for skirt bearing performance and distribution of skirt contact forces. The ovality also offsets the effects of the piston thermal expansion and skirt deflection in the pin direction during operation.

3.69 SKIRT PROFILE (VERTICAL PROFILE, BARREL SHAPE)

Radial relief along the thrust axis as a function of height on the piston skirt. The profile must account for piston thermal expansion and provide appropriate geometry for noise, friction, and contact pressures.

3.70 SKIRT TAIL

The lower skirt protrusion on the major axis.

3.71 SLAP NOISE

Noise caused by impact of the skirt with the cylinder bore due to secondary motion, typically during warm-up from a cold start. This can be influenced by many parameters including clearance, shape of the skirt profile, piston pin offset, cylinder block wall stiffness, and piston design. (This is sometimes referred to as croaking noise.)

3.72 STAKING PIN

A pin that is located in the ring groove of a two-stroke piston that prevents the ring from rotating. The pin is located such that the end gap of the ring cannot pass over a port in the cylinder wall.

3.73 STRUT OUTER DISTANCE

The distance to the outer edge of the crown strut on an articulated piston.

3.74 TOP LAND/HEAD LAND

The piston land above the top ring.

3.75 THRUST SIDE

The piston skirt side that carries the piston side load in the power stroke. (This is also called the major thrust side.)

3.76 TOP GUIDED CONNECTING ROD PISTON DESIGN

The piston serves the function of locating the connecting rod along the axis of the wrist pin. The inner sides of the wrist pin bosses are parallel to the sides of the connecting rod and are held to a tight tolerance such that a small clearance is maintained between the small or "top" end of the connecting rod and the inner sides of the wrist pin boss. The inner sides of the wrist pin bosses are typically machined for this piston design.

3.77 UNDER CROWN

The region under the center of the piston crown.

3.78 VALVE POCKETS

A machined or cast recess on the piston crown to provide clearance to the open intake or exhaust valve.

3.79 WELD ENHANCED RING GROOVES

Mechanical properties of the ring groove and top land are enhanced by locally incorporating a harder material into the piston via a welding process prior to finish machining. Nickel alloys are commonly used for this application.

4. COATING ALPHABETICAL INDEX (COMMON COATINGS)

4.1 Anodizing (Hard)

Microwelding Protection
Thermal Crack Prevention

4.2 Chrome

Wear Reduction

4.3 Resin Bonded Anti-Friction Coating (e.g., Graphite)

Lubrication Coatings
Friction Reduction
Noise Abatement

4.4 Iron

Wear Reduction

4.5 Nickel Composite Coating (NCC)

Wear Reduction
Microwelding

4.6 Phosphate

Corrosion Protection
Lubrication

4.7 PTFE

Friction Reduction

4.8 Tin

Lubrication Coatings

5. COATINGS FUNCTIONAL INDEX (COMMON COATINGS)

5.1 Lubrication Coatings

Resin Bonded Anti-Friction Coating
Tin
Phosphate

5.2 Thermal Crack Prevention

Hard Anodizing

5.3 Microwelding Protection

Hard Anodizing
Nickel Composite Coating (NCC)

5.4 Corrosion Protection

Phosphate Coating

5.5 Friction Reduction

PTFE
Resin Bonded Anti-Friction Coating

5.6 Noise Abatement

Resin Bonded Anti-Friction Coating

5.7 Wear Reduction

Iron
Chrome
Nickel Composite Coating (NCC)

6. PISTON BLANK PRODUCTION PROCESSES

6.1 Gravity Casting

Is used for high volume medium/heavy duty aluminum piston applications. Metal multi-piece molds are used. The molten alloy flows into the mold by means of gravity. Niresist ring carriers for ring groove protection and/or salt cores that generate cooling galleries can be cast in. Multi-piece cores are commonly used to allow for undercuts to lower the weight.

6.2 Squeeze Casting

Is used if porous inserts such as ceramic fibers need to be cast into the piston for localized reinforcement of the piston. High pressures are applied on the molten metal in order to penetrate the porous insert. Single piece cores are required which do not allow for any undercuts.

6.3 Pressure Diecasting

Is used for light duty, low cost pistons. This is used on high volume production only, due to high tooling costs. Medium pressure is applied on the molten metal in order to fill the die. The rapid cooling rates tend to result in segregations, porosities, and gas pores which lead to low material properties. Single-piece cores are required which do not allow for any under cuts.

6.4 Forging

Is applied for aluminum and steel pistons. Forging generally leads to the highest material properties. Only single piece cores can be used economically. No under cuts are possible. Aluminum forgings are typically used for high performance and racing applications. Low tooling costs also makes this viable for low volume applications. However there are higher machining costs because the pistons are not made as close to the net shape as the other methods. Steel forgings are typically used for articulated piston crowns, piston crowns for composite pistons, and for monoblock steel pistons.

6.5 Gravity Sand Casting

Is applied for nodular and grey cast iron pistons. This process is applied for low volume, large bore pistons. Material properties are inferior to forged steel; therefore not used for highest load duties. Multi-piece cores can be applied. Undercuts are possible.