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SURFACE VEHICLE STANDARD

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Internal Combustion Engines—Piston Vocabulary

TABLE OF CONTENTS

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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.

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

2. Reference

2.1 Applicable Publication—The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2275—Internal Combustion Engines—Piston Ring—Grooves

3. Definitions

3.1 Alfin Bond—A special casting process used to mechanically 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.

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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—Strengthened material (typically fiber reinforced) that is used as an insert to strengthen the bowl rim

3.9 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.

3.10 Combustion Bowl Rim—The OD edge of the combustion bowl at the top of the piston.

3.11 Compression Height—The distance from the centerline of the pin bore to the top of the piston

3.12 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.

3.13 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.

3.14 Cover Plate—A plate that encloses the cooling channel on an articulated piston. 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.

3.15 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.

3.16 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.)

3.17 Cross Scavenged Engine—A type of two-stroke engine where the incoming charge is directed upward into the combustion chamber with a deflector on the piston. See scavenging deflector. The ports of this type of engine are commonly machined through the cylinder wall such that the intake charge enters diametrically opposite the exhaust port.

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 strut to the top of the piston.

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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 supports 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 rings 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 towards the front of the engine.

3.27 Gage Pin—Used to measure the diameter-over-pins dimension (typically for ring groove diameters).

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 unreinforced 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—(SAE J2275)

3.33 Groove Root Diameter—The diameter at the ID of the ring groove.

3.34 Groove Root Fillet Radius—The fillet radius at the inner corners of the ring grooves.

3.35 Headland Ring—An L-shaped top ring designed to function at the top of the piston crown.

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3.36 Hyper-eutectic—Piston aluminum alloys with a silicon percentage greater than the ≈12% eutectic point. Primary silicon particles exist in the alloy since the quantity of silicon exceeds the solid solubility limit. (also eutectic)

3.37 Hypo-eutectic—Piston aluminum alloys with a silicon percentage less than the ≈12% eutectic point. (also eutectic)

3.38 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.

3.39 K-Factor—See apparent density.

3.40 Land Height—The axial distance of the land at the OD of the piston.

3.41 Loop Scavenged Engine—A type of two-stroke engine where the incoming charge is directed upward into the combustion chamber by means of transfer ports in the cylinder. Multiple transfer ports located opposite one another are used to create a flow that is aimed away from the exhaust port and up into the combustion chamber such that the flow path takes on the shape of a loop. A scavenging deflector on the piston is not required because the porting directs the airflow.

3.42 Microwelding—The removal of aluminum piston material, during engine operation, from the piston groove bottom side, and potential transfer to the side of piston ring. Frequently associated with elevated piston groove temperature, poor lubrication conditions, 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.

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

3.44 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, 19.3×10^{-6} mm/(mm °C), nearly matches that of piston aluminum alloys, 19.0 to 21.6×10^{-6} mm/(mm °C). Normally installed in the piston casting using the Alfin bond process.

3.45 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.

3.46 Oil Drain Slots—As-cast radial slots in and below the oil ring groove on the pin axis sides 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 extend the whole length of the ring groove and into the back of the groove. The slots are placed in the pin axis so that oil will drain down the sides of the piston.

3.47 Panel—The wall that connects the pin boss and the skirt.

3.48 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).

3.49 Pin Bore—The bore through which the piston pin is inserted.

3.50 Pin Boss—The structure that transmits piston forces to the pin.

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3.51 Pin Boss Angle—The angle of the inner edges of the pin boss (or crown strut).

3.52 Pin Boss Spacing—The distance between the inner edges of the pin boss or crown strut at the centerline of the pin bore.

3.53 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.

3.54 Piston Land Profile—(SAE J2275)

3.55 Pin Offset—A condition where the piston pin bore center does not intersect with the piston axial center. 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 Port Cut-Outs—Openings or windows in the skirt of a loop scavenged 2-stroke piston that allow scavenge air to flow from the crankcase to the cylinder head.

3.57 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.

3.58 Ring Belt—The region of the piston that contains the piston rings. This includes the lands and the grooves.

3.59 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.

3.60 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.

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

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

3.63 Skirt Contact Pattern—The wear pattern developed on the piston skirt due to normal operation and contact with the mating cylinder.

3.64 Skirt Gage Point—Height at which the skirt diameter is measured on the thrust axis to fit the piston to the bore.

3.65 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.

3.66 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.

3.67 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.

3.68 Skirt Tail—The lower skirt protrusion on the major axis.

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3.69 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.)

3.70 Staking Pin—A pin that is located in the ring groove of a 2-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.

3.71 Strut Outer Distance—The distant to the outer edge of the crown strut on an articulated piston.

3.72 Thrust Side—The piston skirt side that carries the piston side load in the power stroke. (This is also called the Major Thrust Side)

3.73 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.

3.74 Under Crown—The region under the center of the piston crown.

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

3.76 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 Emralon

Lubrication coatings
Friction Reduction
Noise Abatement

4.4 Graphite

Lubrication coatings
Friction Reduction
Noise Abatement

4.5 Iron

Wear Reduction

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4.6 Lead

Corrosion Protection
Emergency lubrication coatings

4.7 NCC (Nickel Composite Coating)

Wear Reduction

4.8 Phosphate

Corrosion Protection
Lubrication

4.9 PTFE

Friction Reduction

4.10 Tin

Lubrication coatings

5. Coatings Functional Index (Common Coatings)

5.1 Lubrication Coatings

Emralon
Graphite
Lead
Tin
Phosphate

5.2 Thermal Crack Prevention

Hard Anodizing

5.3 Microwelding Protection

Hard Anodizing

5.4 Corrosion Protection

Lead
Phosphate Coating
Tin

5.5 Friction Reduction

Graphite
PTFE
Emralon

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5.6 Noise Abatement

Graphite
Emralon

5.7 Wear Reduction

Iron
Chrome
NCC (Nickel Composite Coating)

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.

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7. Articulated Piston Nomenclature—See Figures 1 to 5.

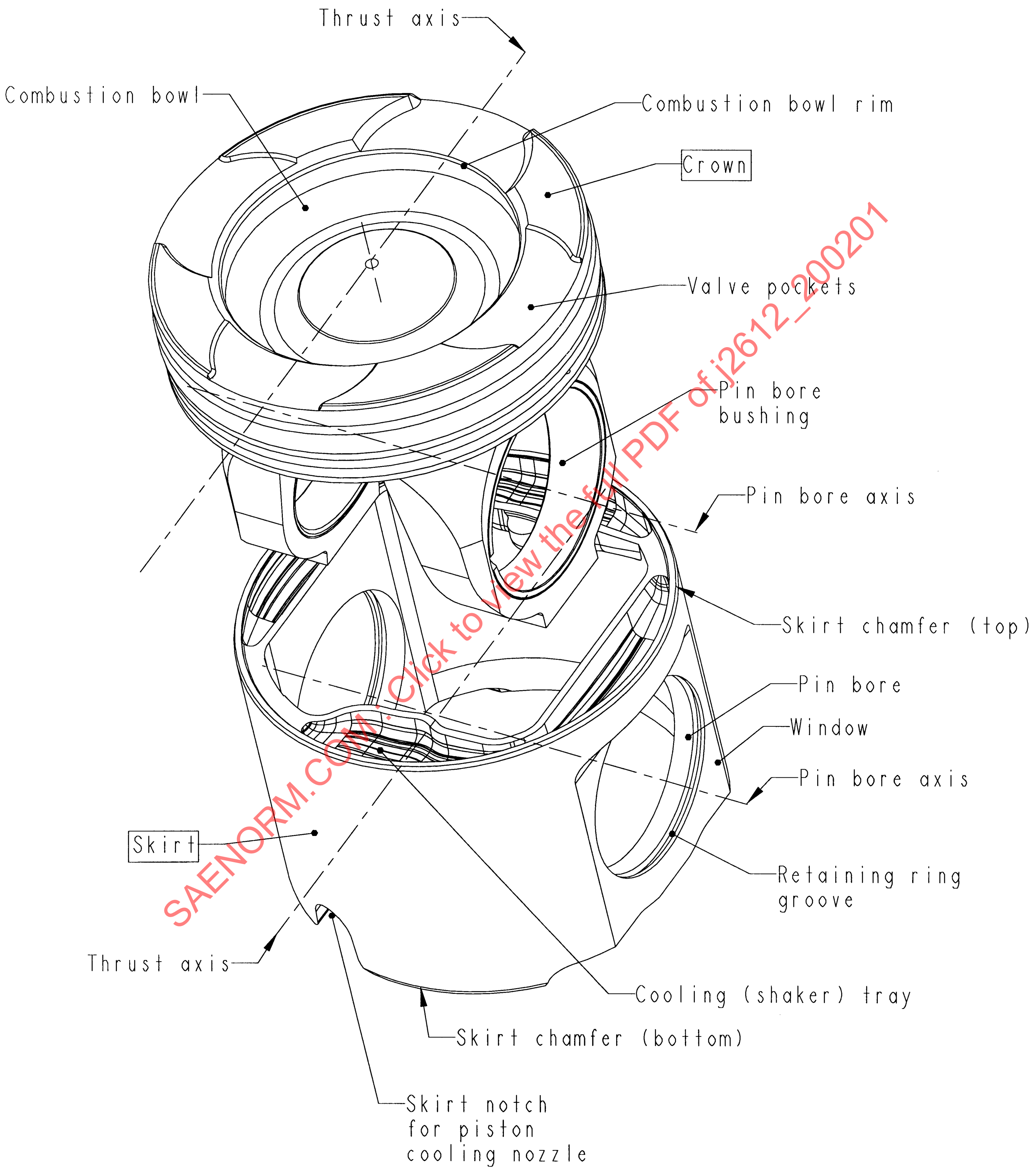

FIGURE 1—ARTICULATED PISTON

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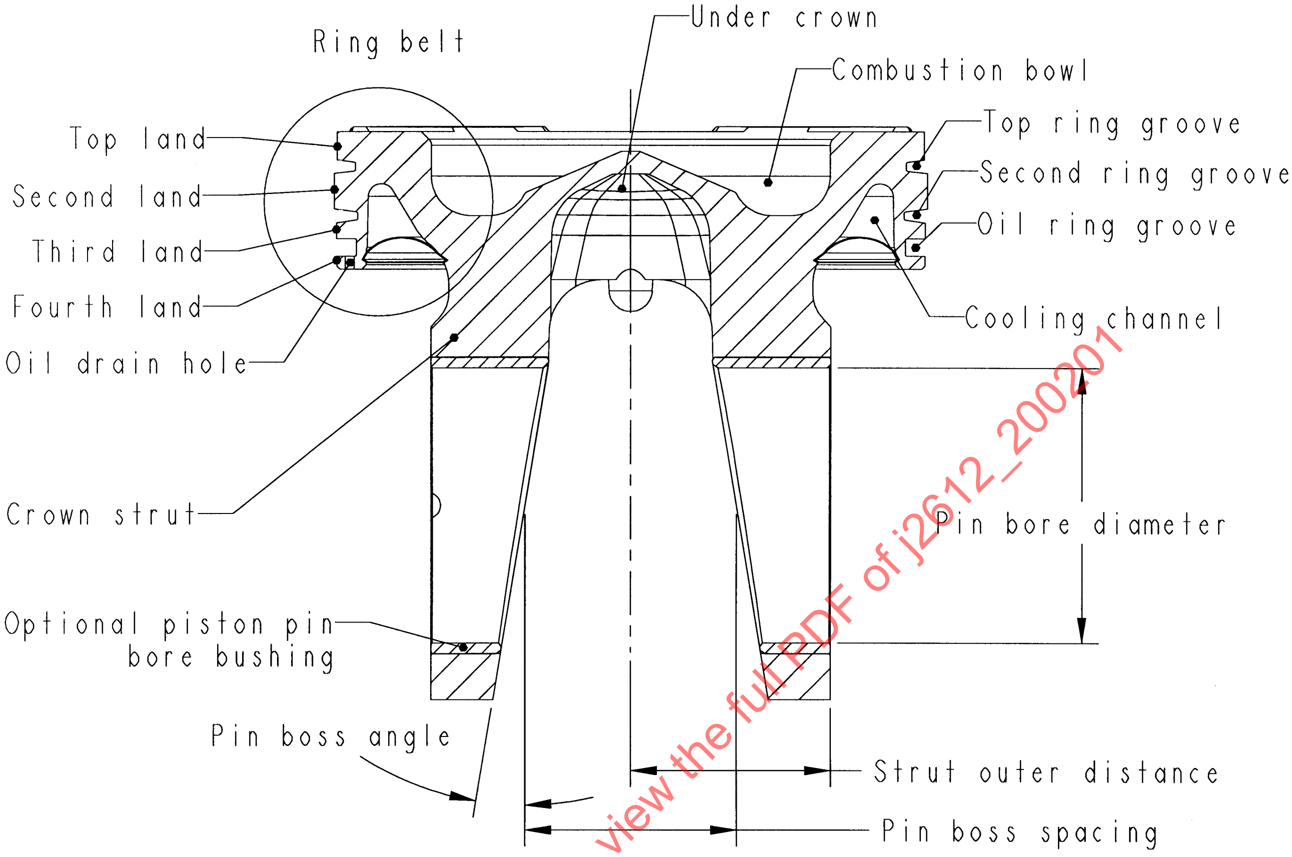

FIGURE 2—ARTICULATED PISTON CROWN – VIEW ALONG THRUST AXIS

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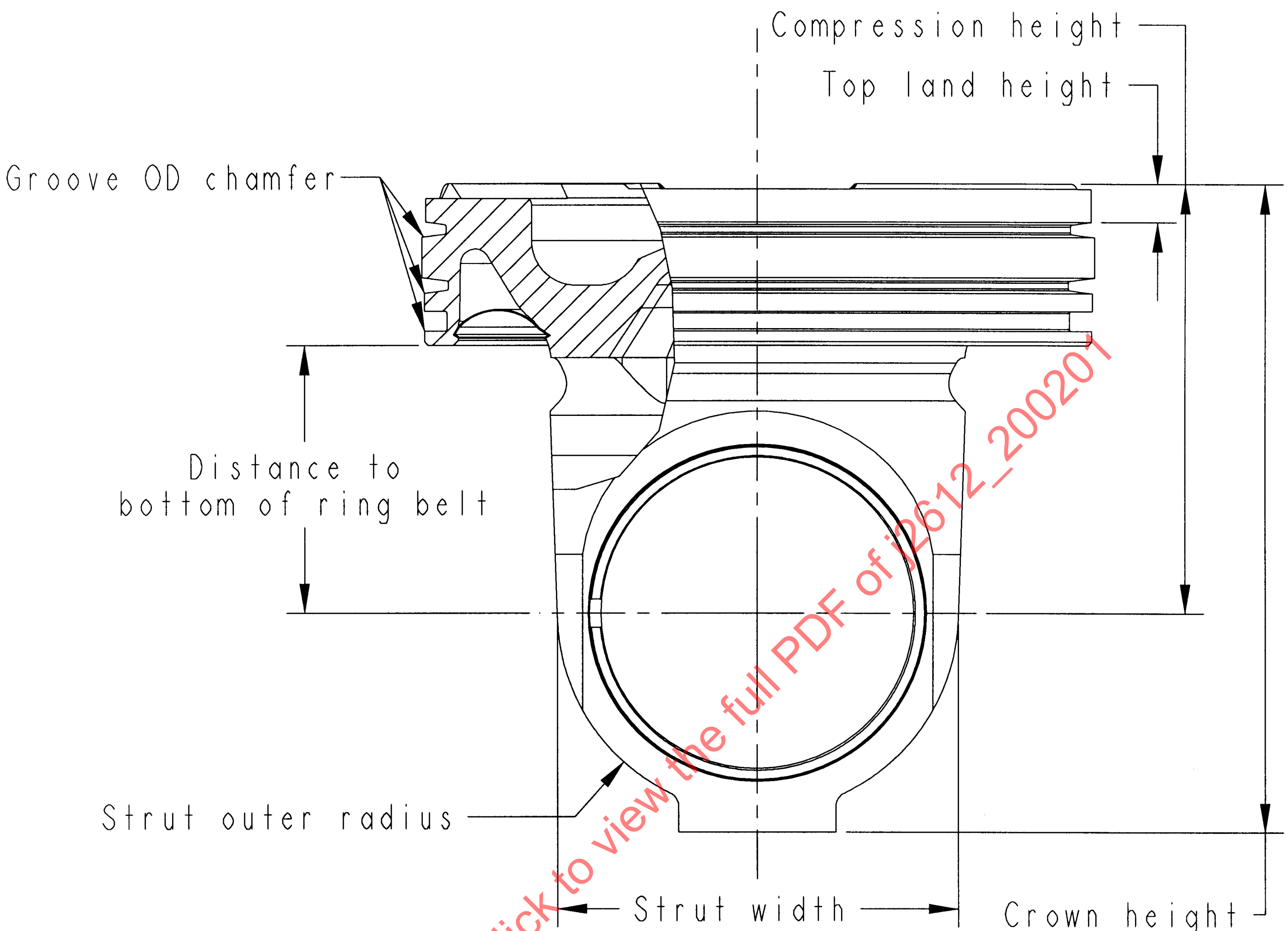

FIGURE 3—ARTICULATED PISTON CROWN - VIEW ALONG PIN AXIS

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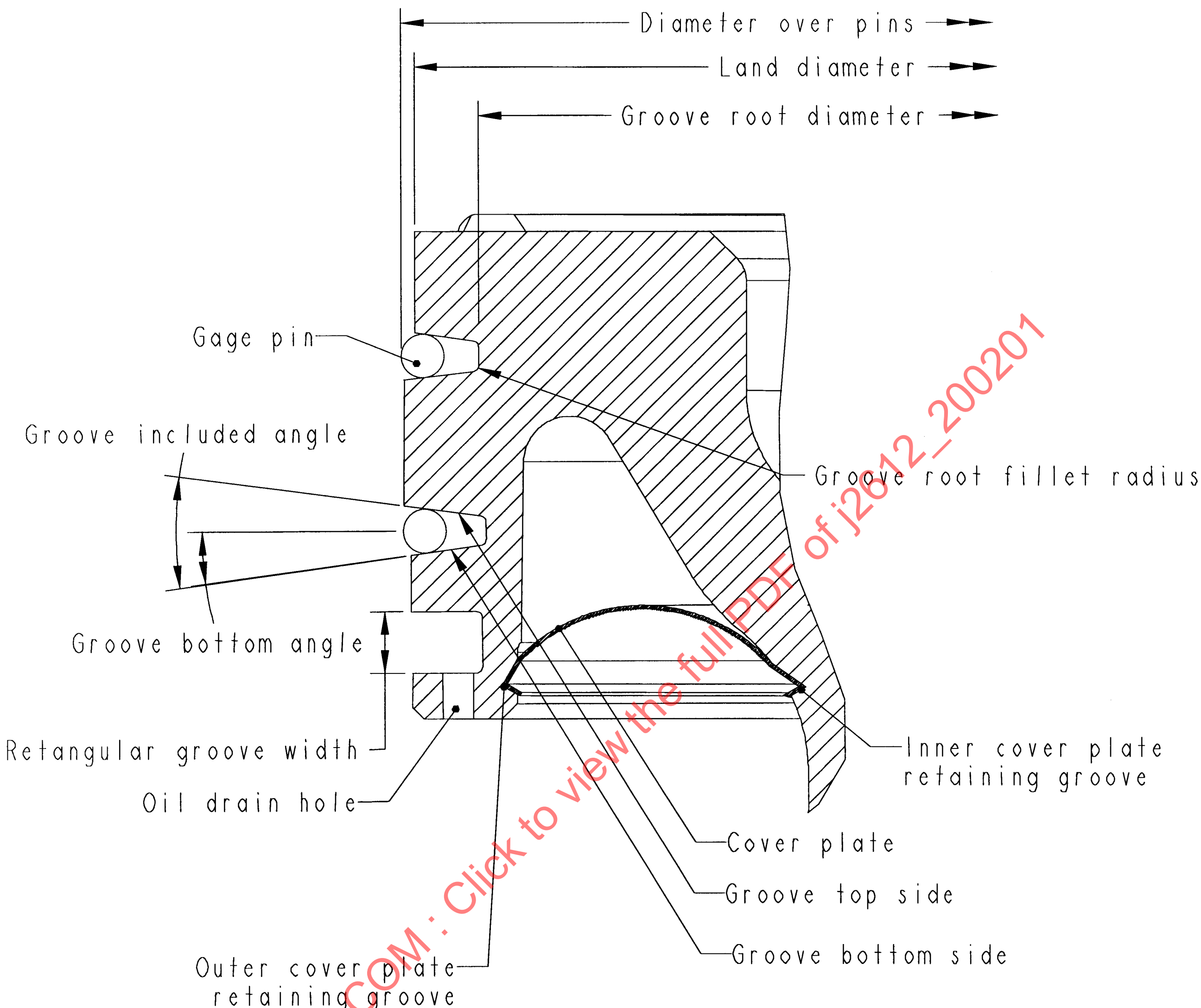

FIGURE 4—ARTICULATED PISTON - RING BELT REGION

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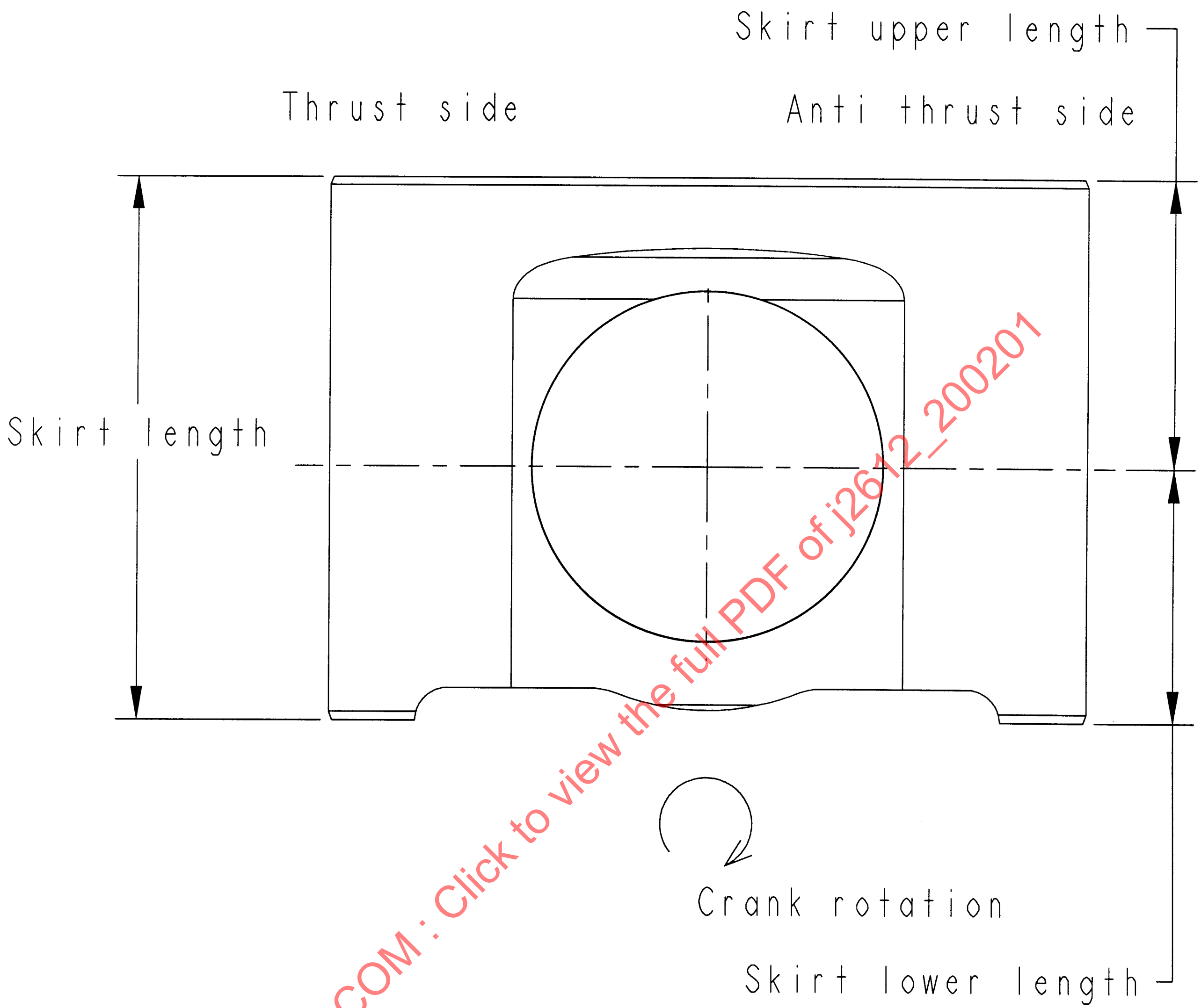

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FIGURE 5—ARTICULATED PISTON SKIRT

8. ***Monoblock Piston Nomenclature—***See Figures 6 to 13.

8.1 Medium/Heavy Duty

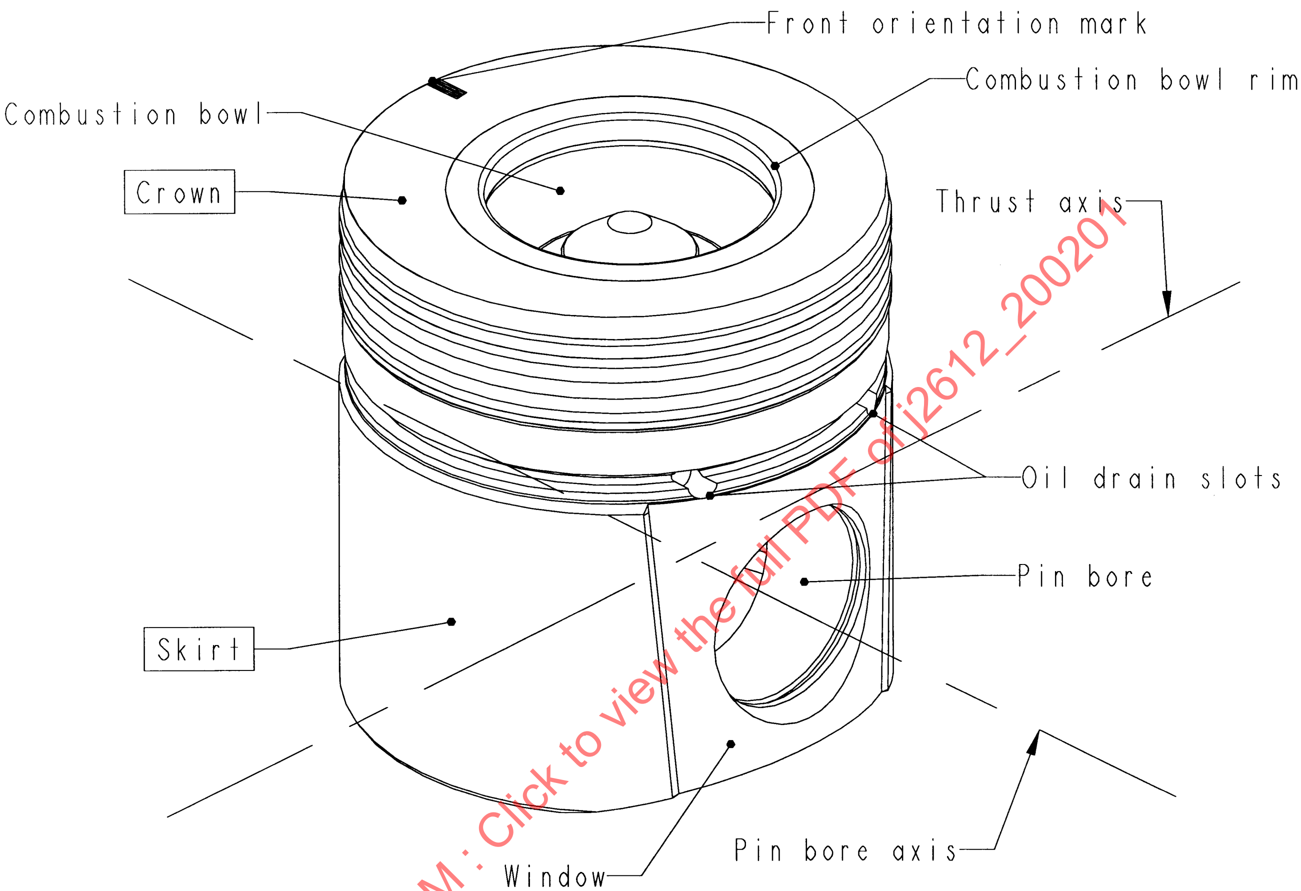

FIGURE 6—MEDIUM/HEAVY DUTY MONOBLOCK PISTON

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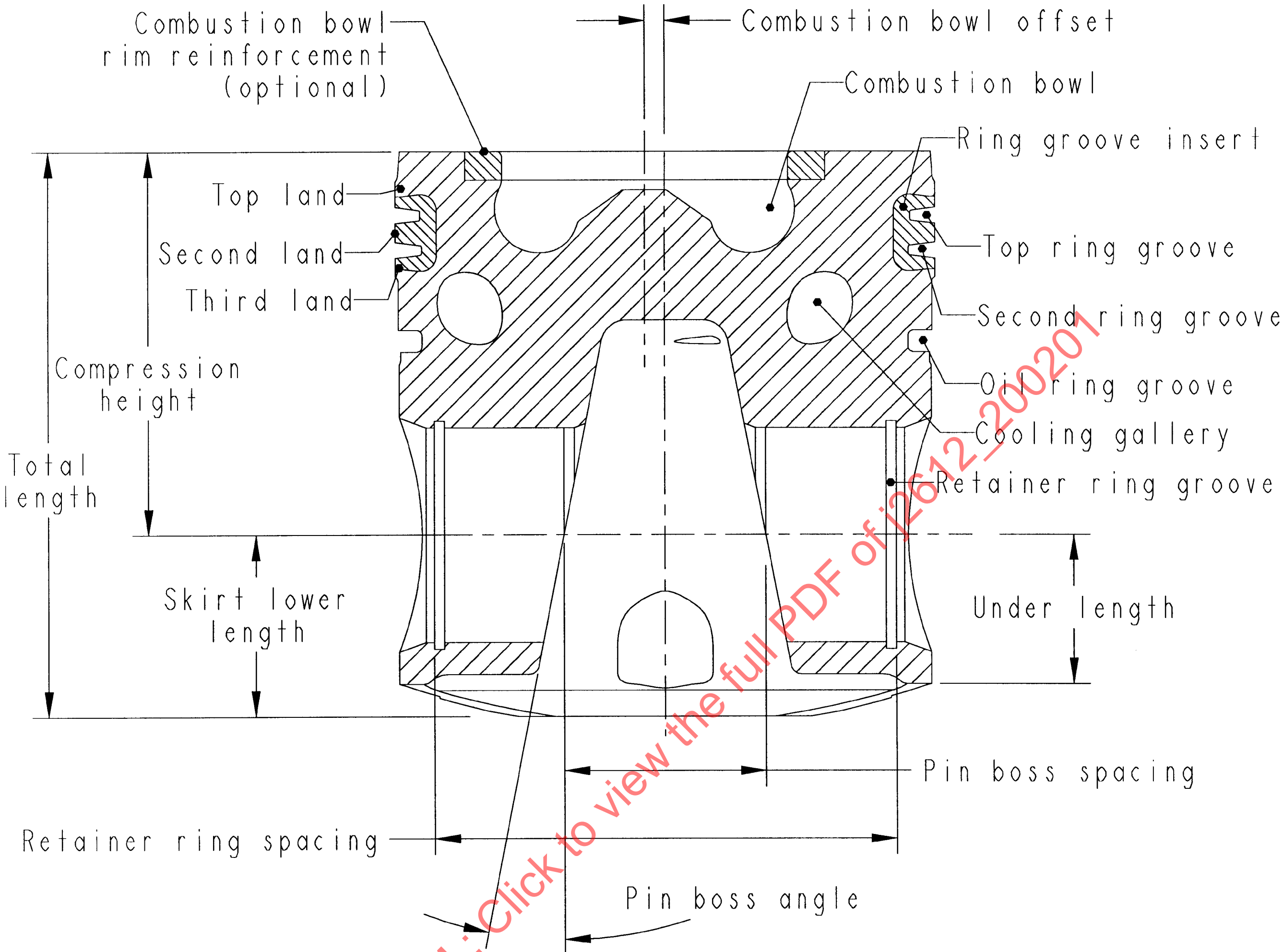

FIGURE 7—MEDIUM/HEAVY DUTY MONOBLOCK PISTON: VIEW ALONG THRUST AXIS

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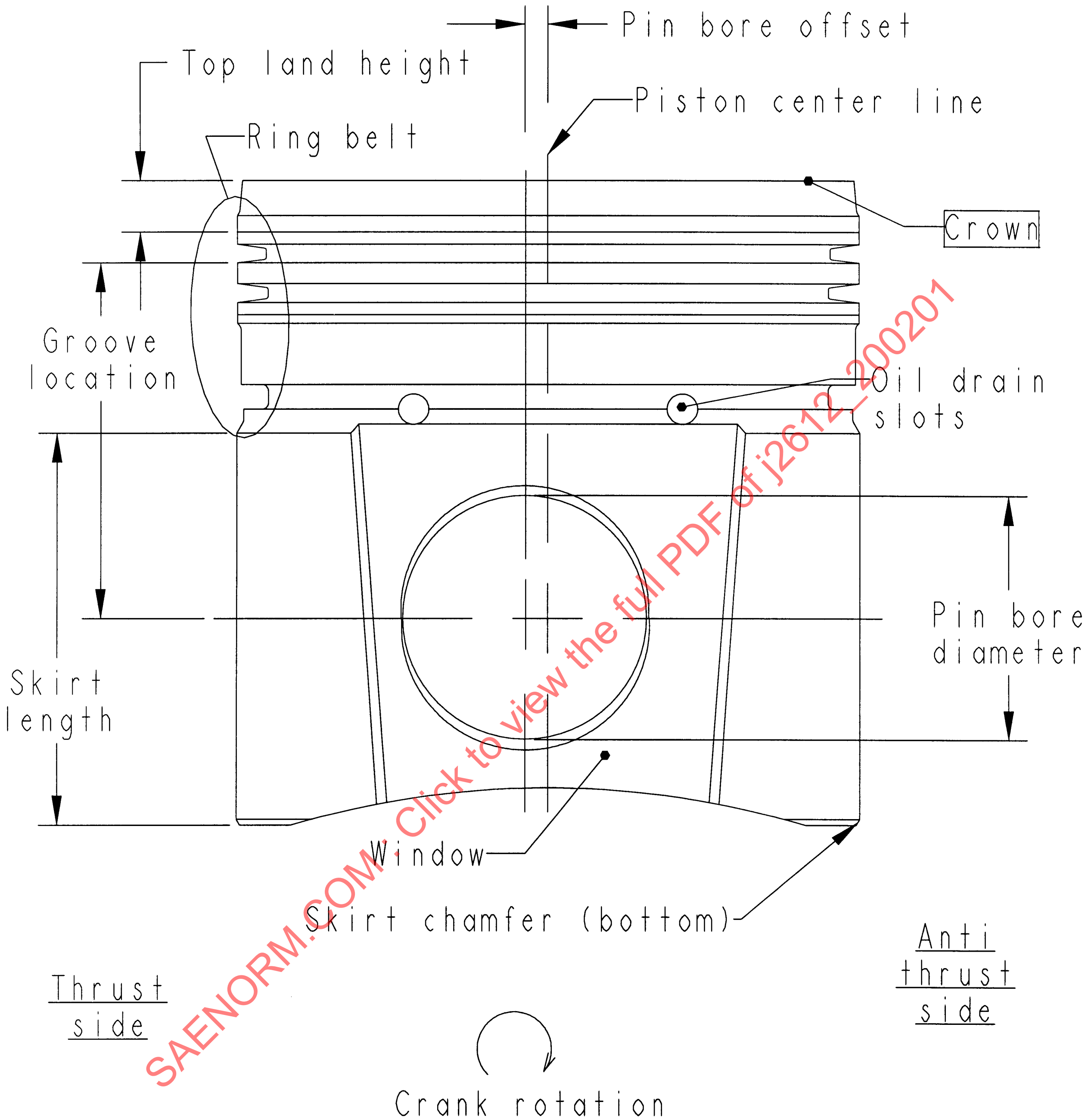

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FIGURE 8—MEDIUM/HEAVY DUTY MONOBLOCK PISTON: VIEW ALONG PIN AXIS

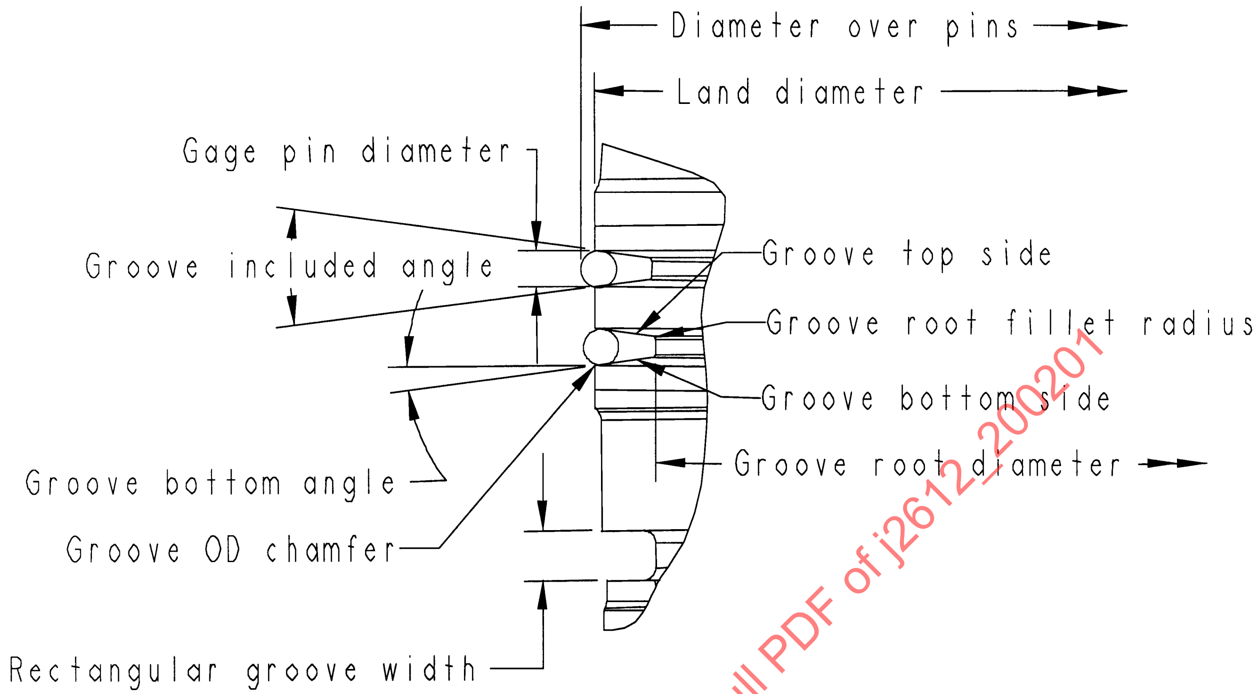

FIGURE 9—MEDIUM/HEAVY DUTY MONOBLOCK PISTON: RING BELT REGION

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8.2 Light Duty—See Figures 10 to 13.

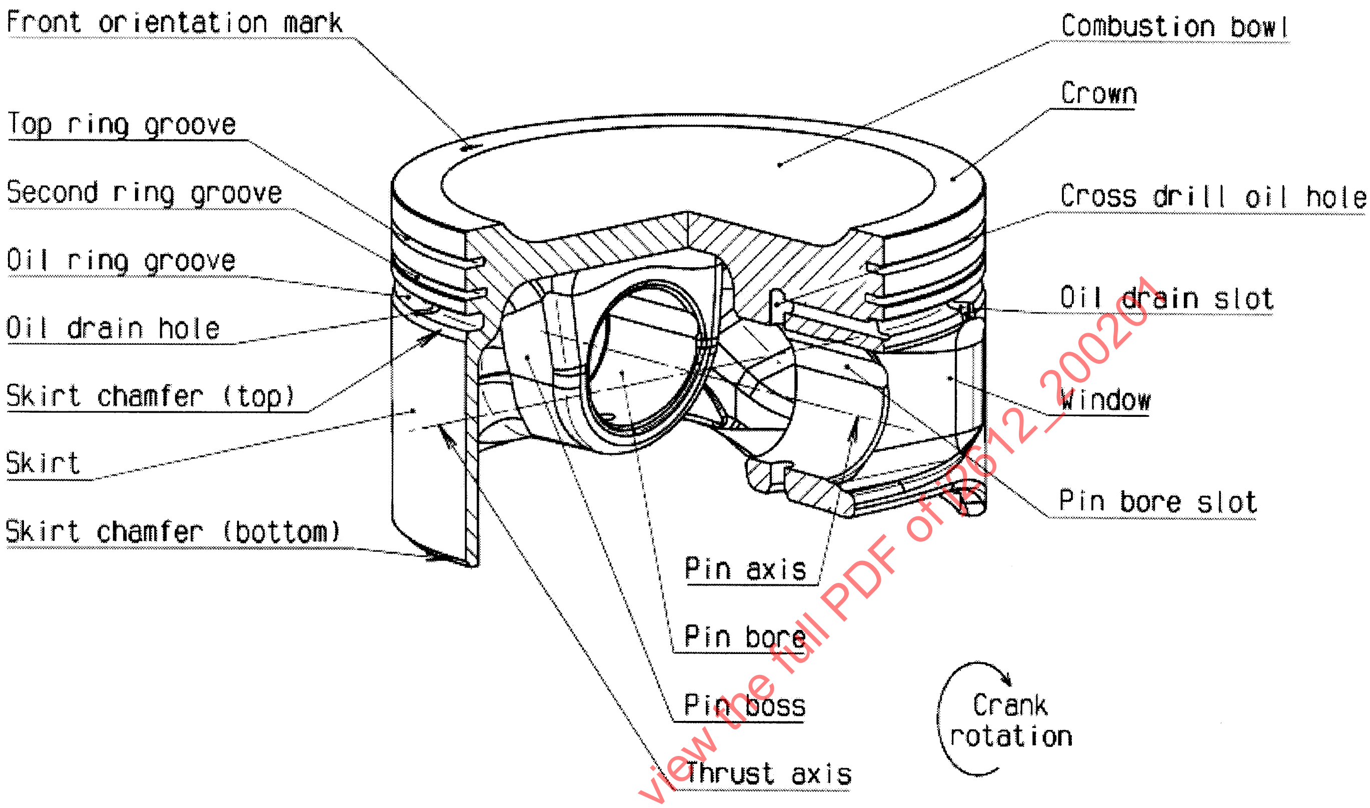

FIGURE 10—LIGHT DUTY MONOBLOCK PISTON — ISOMETRIC VIEW

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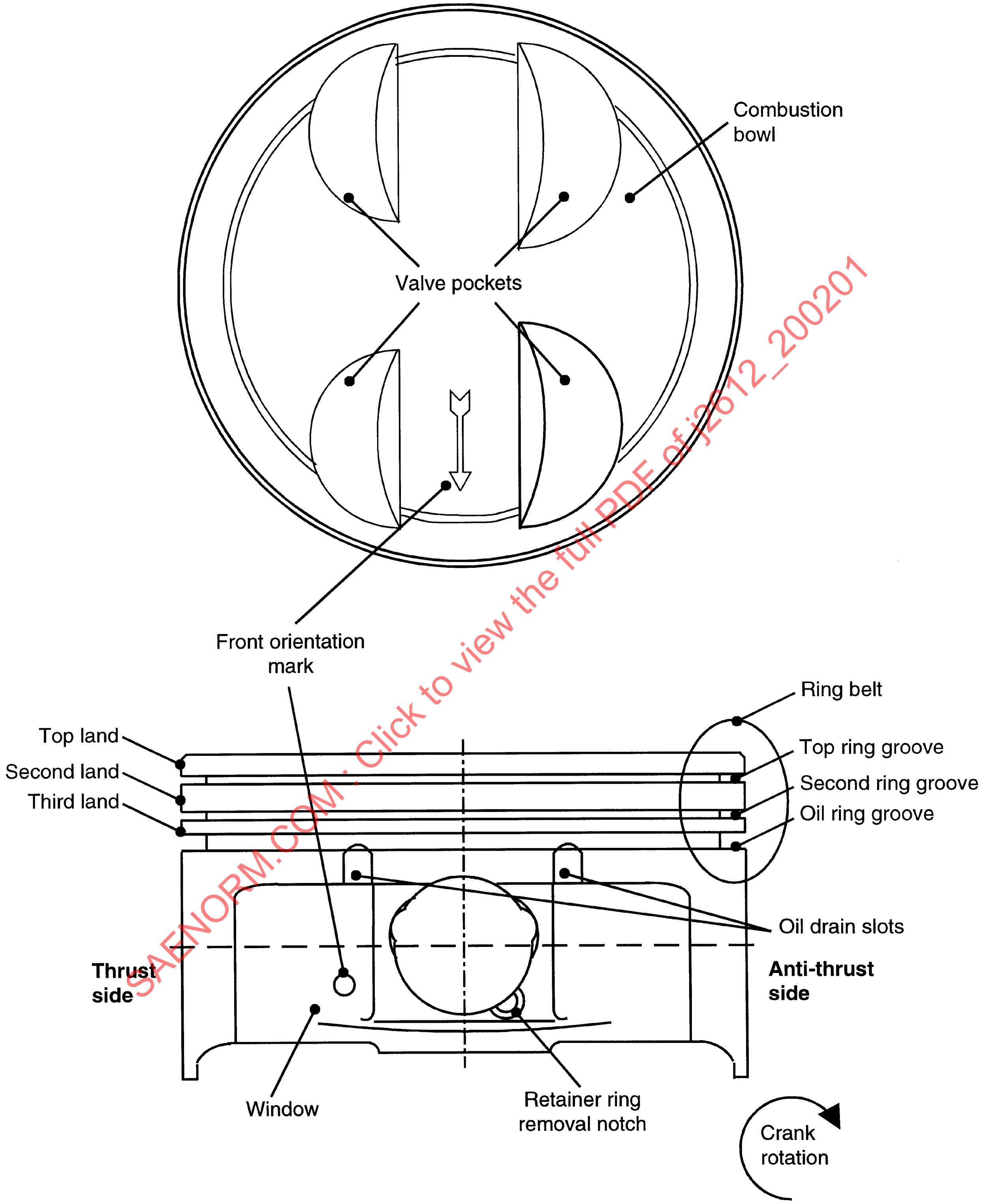

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FIGURE 11—LIGHT DUTY MONOBLOCK PISTON — TOP AND SIDE VIEW

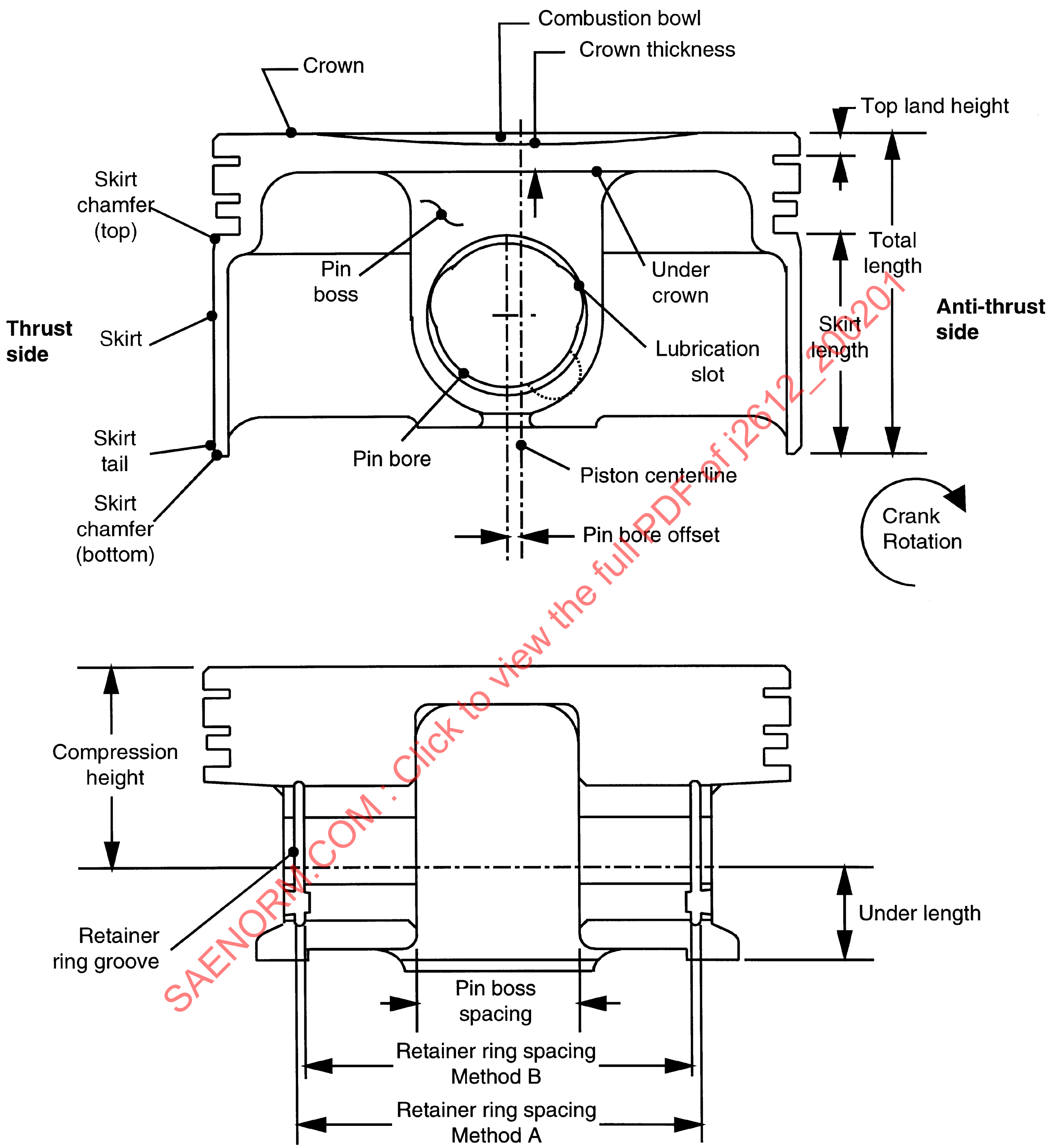

FIGURE 12—LIGHT DUTY MONOBLOCK PISTON: CUTAWAY VIEWS

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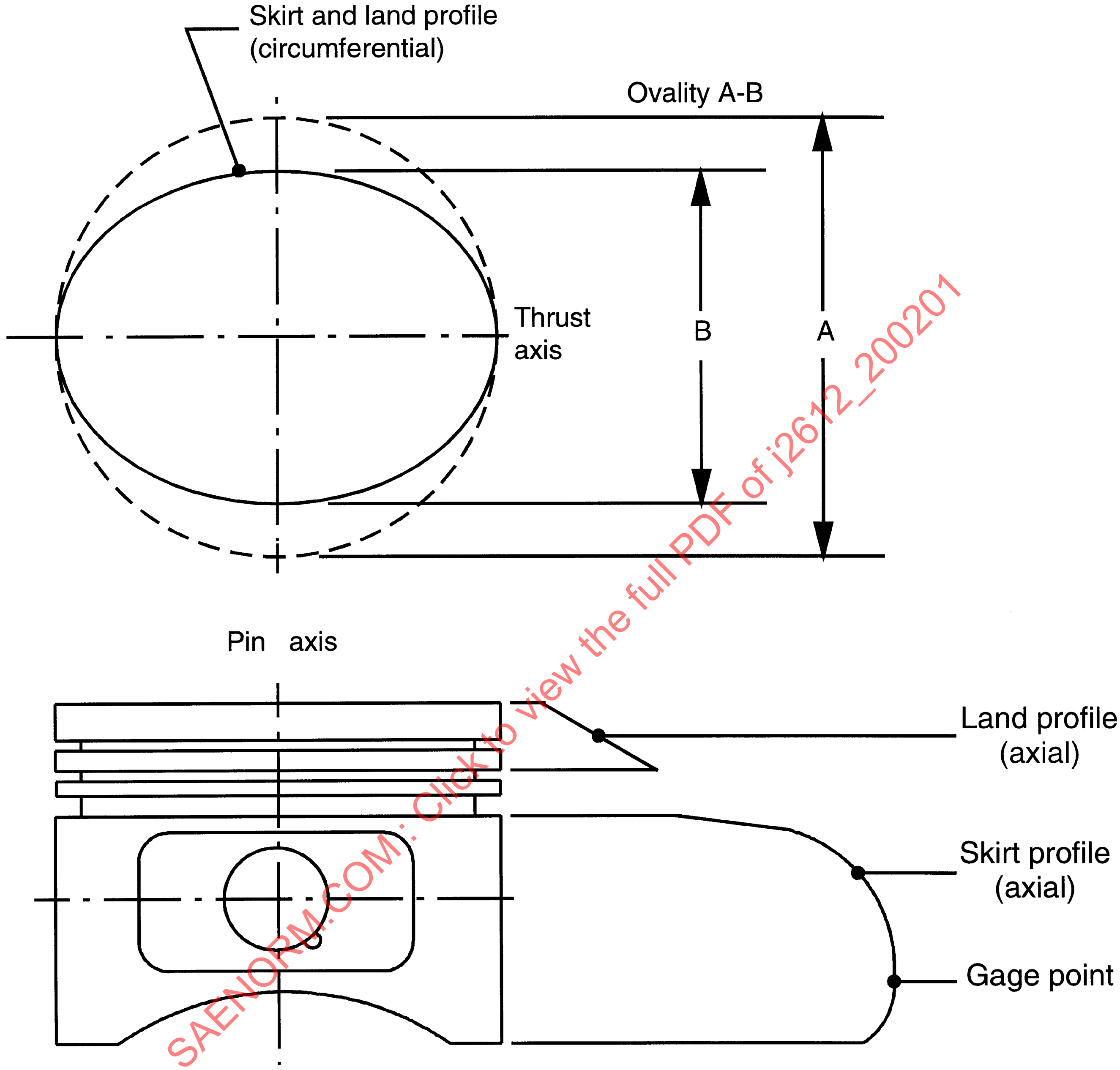

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FIGURE 13—LIGHT DUTY MONOBLOCK PISTON: PROFILES

9. Two-stroke—See Figures 14 to 21.

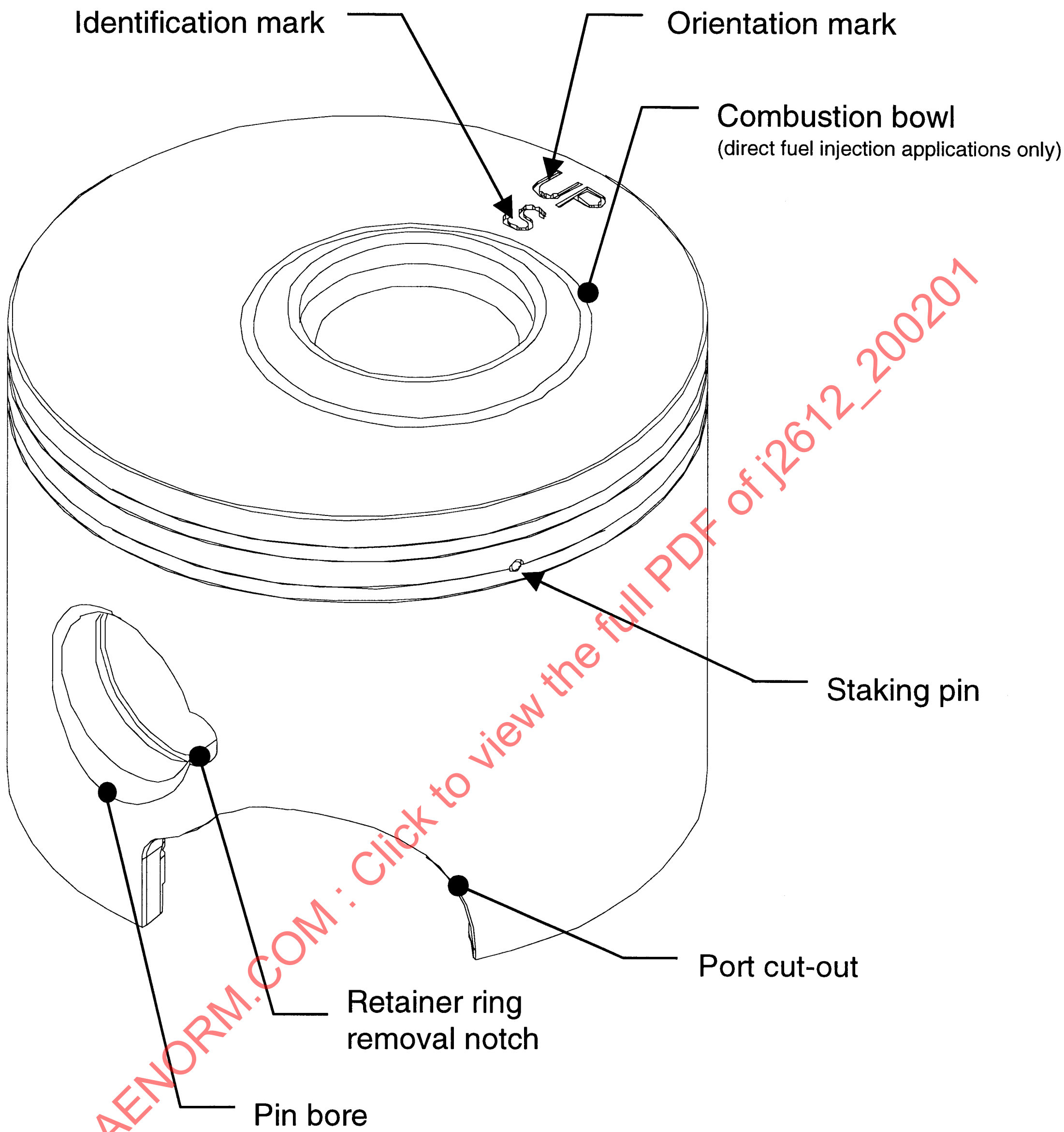

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FIGURE 14—TWO-STROKE DIRECT INJECTION PISTON (LOOP SCAVENGED)

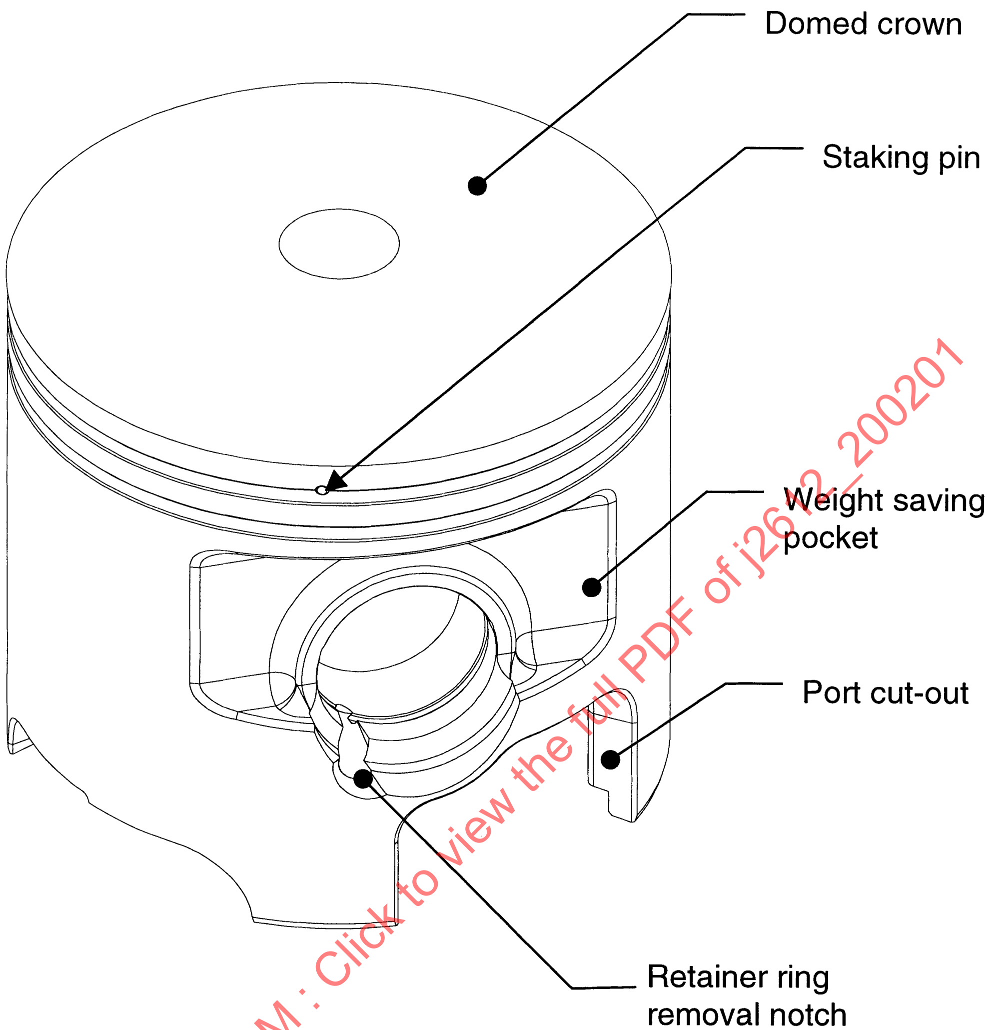

FIGURE 15—TWO-STROKE ELECTRONIC FUEL INJECTION PISTON (LOOP SCAVENGED)

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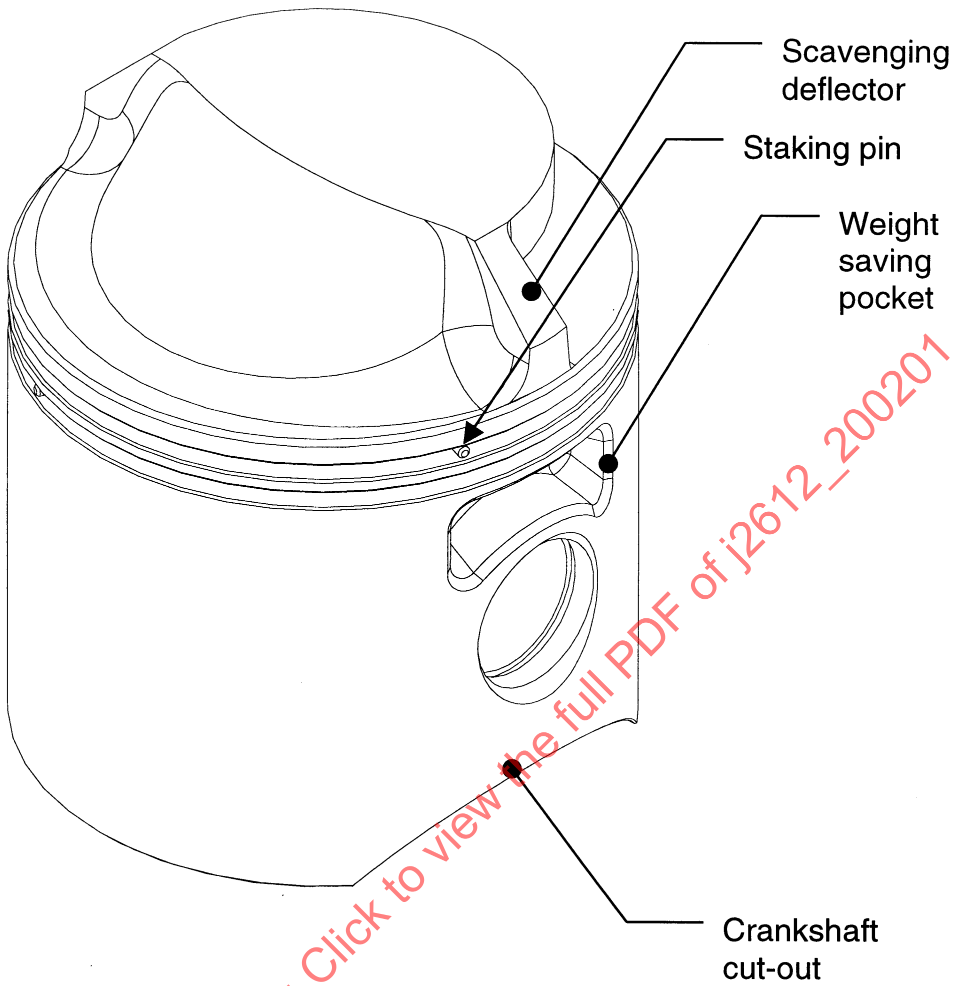

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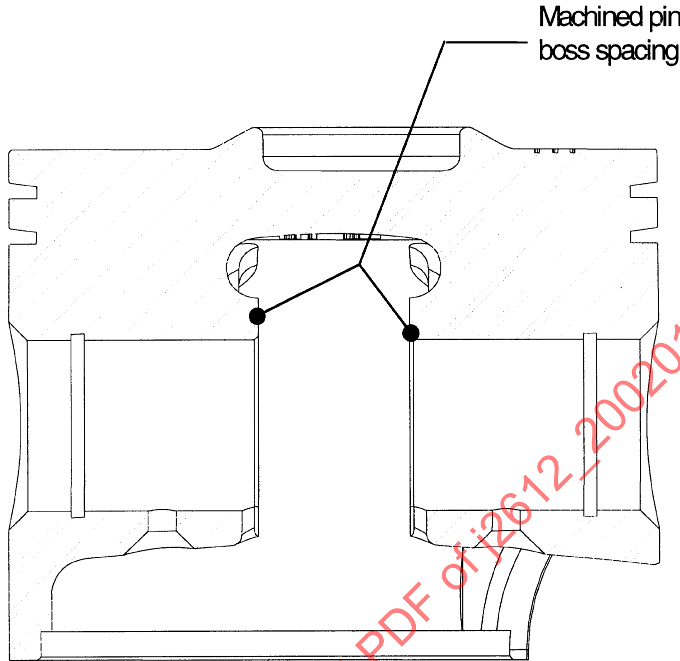
FIGURE 16—TWO-STROKE CROSS SCAVENGED PISTON

Top guided



Bottom guided

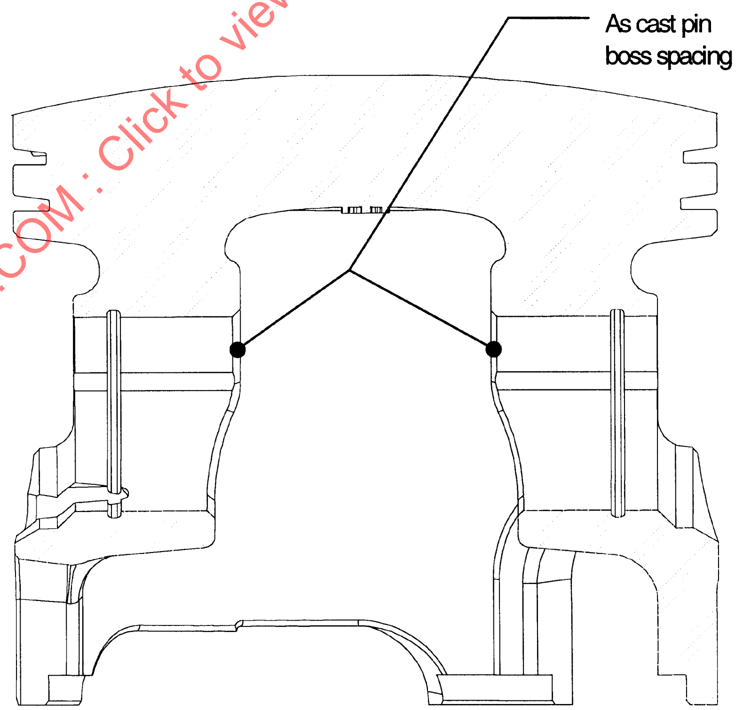


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FIGURE 17—COMPARISONS OF PISTON DESIGN FOR TOP GUIDED/BOTTOM GUIDED CONNECTING RODS

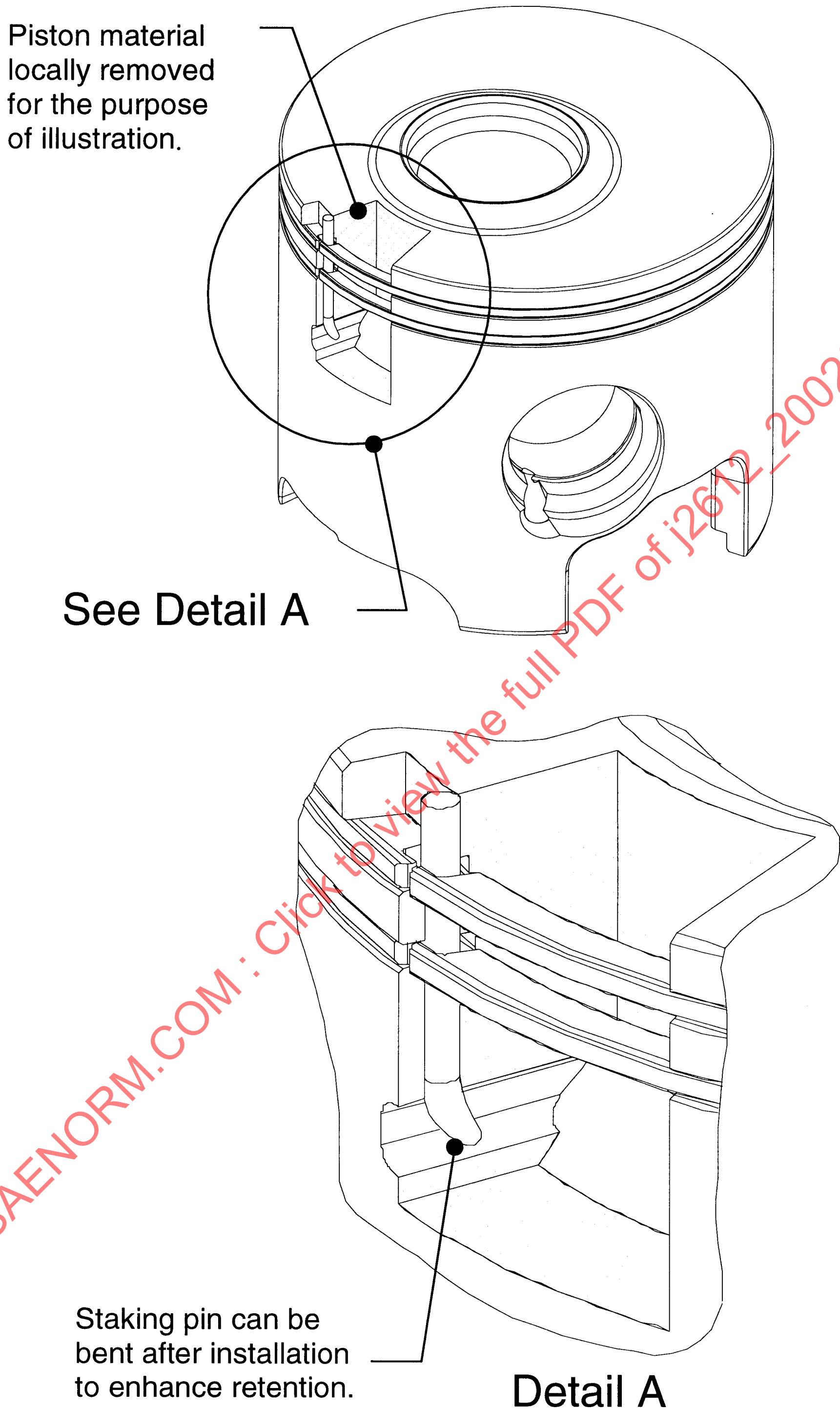

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FIGURE 18—STAKING PIN VERTICAL, RADIAL STOP

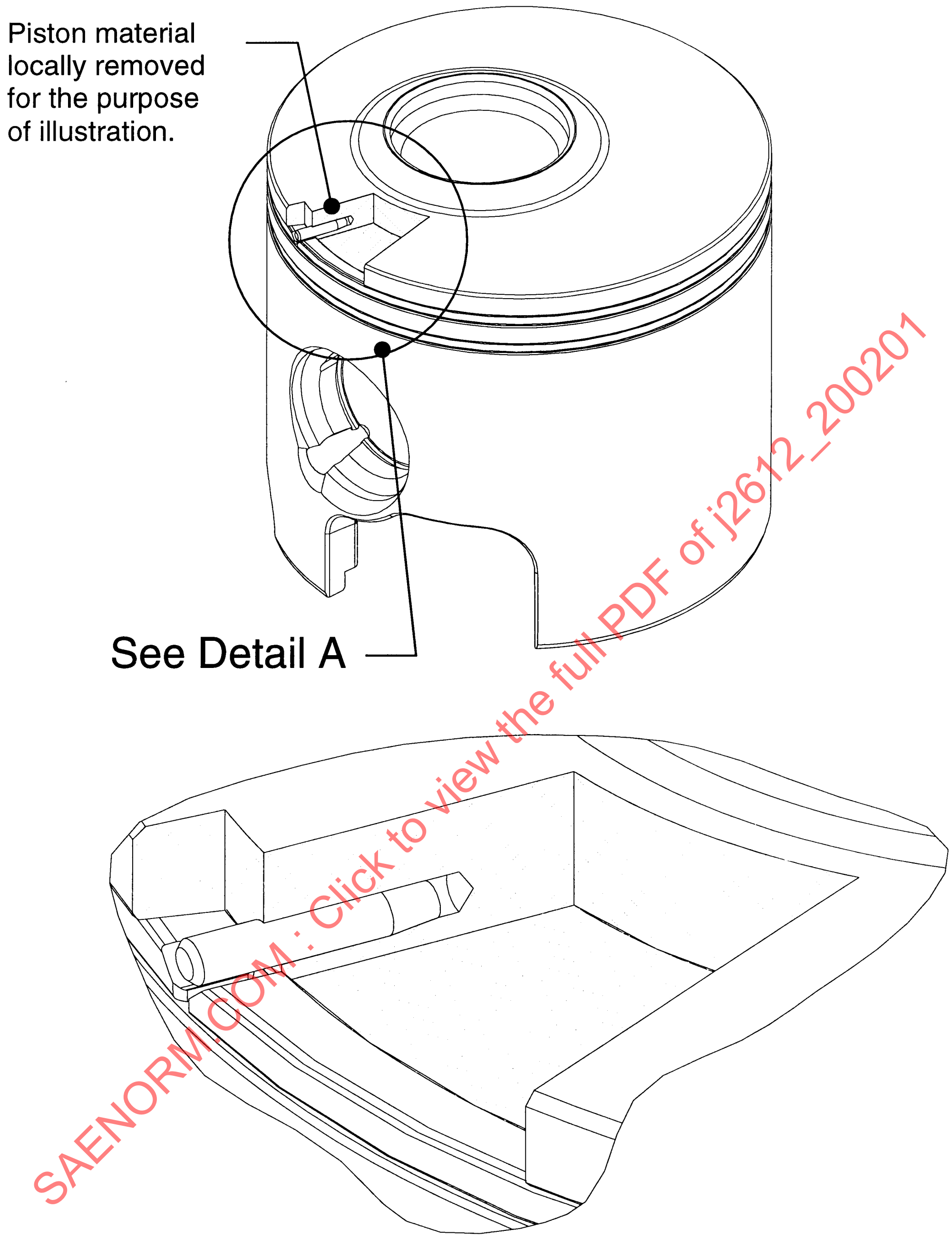

FIGURE 19—STAKING PIN HORIZONTAL, LATERAL STOP

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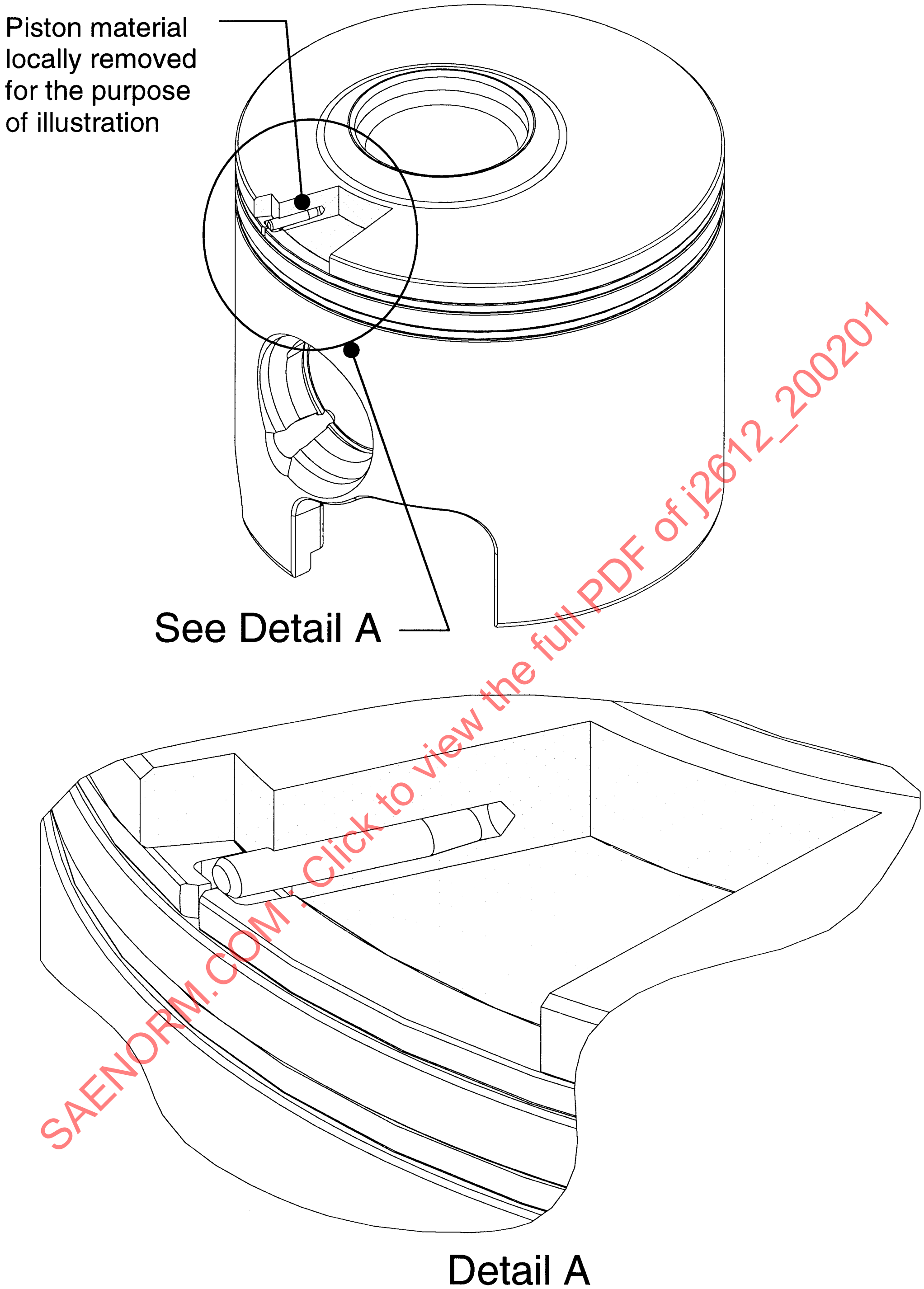

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FIGURE 20—STAKING PIN HORIZONTAL, RADIAL STOP