

STAGE SEAL STACK SPECIFICATION

Multi-stage telescoping strut — every stage interface — arctic + abrasive duty

Document	HL-SEAL-001	Revision	C
System	Skimmer 3-stage legs — Ø80 / Ø140 / Ø180 locked	Date	27 August 2026
Duty	−40 °C to +50 °C, ice, grit, 250 bar	Status	PRELIMINARY — RFQ / first article
Related	HL-LEG-001 · HL-ANK-001 · ISO 6195 / 5597 / 7425-2	Next	HL-SEAL-002 gland cartridge

1. Intent

A telescoping leg that lives in packed snow and granite grit dies at the first stage interface that packs solid. This sheet is the contract for that interface: six elements in a fixed order, repeated at the outer-to-intermediate joint and the intermediate-to-inner joint. The piston / primary actuator inside the inner stage uses the same primary + secondary + wear philosophy, but does not get the ice scraper.

Preferred vendor family is Trelleborg (Zurcon / Turcon / Orkot) because they already publish a tandem telescopic arrangement: Stepseal + Rimseal + DA22-class scraper + Slydring. Parker and Hallite are approved equals. Mix families only if an application engineer signs the stack. Do not mix PTFE and PU compounds without checking swell and back-pumping.

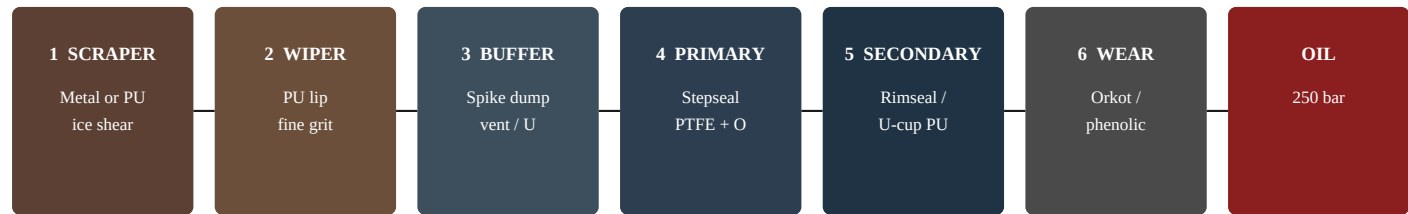
2. Operating envelope

System pressure	210–250 bar nominal, 300 bar proof	Matches HL-ANK-001 drive circuit
Pressure spikes	Assume 1.4× on impact / one-leg plant	Buffer exists for this
Ambient	−40 °C to +50 °C	−50 °C preferred on elastomers
Fluid	ISO VG 46 mineral; VG 32 arctic option	Ester / HEES only after compound check
Motion	Reciprocating, full stroke, thousands of cycles / year	Slow crawl + sudden extend
Contamination	Ice crystals, granite grit, mud, melt water	Scraper is not optional
Side load	Wear rings carry it. Seals stay concentric.	See HL-ANK-001 moments
Rod / tube finish	Ra 0.2–0.4 µm, no spiral grind	Hard chrome, Ni-Cr, or HVOF carbide
Hardness of running surface	≥ 55 HRC equivalent on chrome	Softer tube eats the scraper

3. Stack sequence (environment → oil)

FIG. 1 — STAGE INTERFACE STACK (environment left, pressurized oil right)

Same sequence at every stage interface. Outer stage sees ice and grit first.



Optional leak-sense port sits between 4 and 5. Wear rings also sit outboard of 4 if side load is high.

1	Ice scraper / excluder	Shear packed ice and large grit before anything elastomeric sees it	Trelleborg Zurcon DA22 or DA24 Venting; metal-cased WRM / WKE; Hallite 820 / 831 (umbrella)	ISO 6195 Type C (closed) or Type B (open, metal-cased)
2	Secondary wiper	Fine dust and melt water the scraper missed	Zurcon Excluder ESA or second PU lip if DA22 is the only wiper; Parker PDW	ISO 6195 Type A or C
3	Buffer / pressure-relief	Dump spikes. Stop inter-stage trap from blowing the wiper out	Parker BU Ultrathan; Hallite 653; Trelleborg buffer / DA24 vent path	ISO 7425-style short groove
4	Primary rod seal	Takes the 250 bar. Must back-pump oil film inbound	Turcon Stepseal 2K (or Stepseal K) + O-ring energizer	ISO 7425-2
5	Secondary / redundant seal	Dry rod. Survives if grit nicks the primary. Leak-sense volume lives here	Zurcon Rimseal or RU9; Hallite 605 / 621 twin-lip; Parker Type B PolyPak	ISO 5597
6	Wear rings (guide)	Take side load. Keep lips concentric. Never metal-on-metal	Orkot / Luytex Slydring C380; PTFE or fabric-phenolic equal	ISO 10766

Trelleborg's published tandem for telescopics is exactly this idea: Stepseal primary + Rimseal / RU9 secondary + DA22-class double-acting scraper + Slydring, with a guide ring in the oil pocket between the two pressure seals. DA24 Venting is the telescopic-specific scraper because inter-stage volume change will otherwise pressure-trap and pop a wiper.

4. Locked running diameters

ISO 3320 preferred sizes. Inner stage OD is the HL-ANK-001 wrist. Intermediate and outer are two ISO steps up so walls can be 8–12 mm steel or equivalent aluminum without eating the utility bore.

Inner actuator rod (inside inner stage)	Ø80 mm	f8	Actuator gland only — no ice scraper
Inner stage tube OD	Ø140 mm	f8	Intermediate-stage gland (full ice stack)
Intermediate stage tube OD	Ø180 mm	f8	Outer-stage gland (full ice stack)
Outer stage tube OD	Ø220 mm	h9 / structural	No dynamic seal on the OD. Flange to hull.

5. Gland table — cut these

Housings are ISO. Seal dash numbers are the published Trelleborg / ISO-equivalent rows for those housings. A Parker or Hallite equal must drop into the same groove, not a near-groove.

Rod / tube d	ISO 3320	80 f8	140 f8	180 f8
1 Scraper / wiper Type C	ISO 6195-C	D1 90 H11 · S 5.0 · L1 6.3 +0.2/0 · D2 87	D1 155 H11 · S 7.5 · L1 9.5 +0.3/0 · D2 150	D1 195 H11 · S 7.5 · L1 9.5 +0.3/0 · D2 190
Published wiper row	ISO 6195-C catalog	ISO 6195-C 80 × 90 × 6.3 (S 5.0)	SKF CR PWY 140×155×9.5×13 or Zurcon DA22 / DA24 in 140×155×9.5	SKF CR PWY 180×195×9.5×13 or Zurcon DA22 / DA24 in 180×195×9.5
3 Buffer (PU)	ISO 7425-2 short	D 95.5 H9 · S 7.75 · L 4.2 +0.2/0	D 155.5 H9 · S 7.75 · L 4.2 +0.2/0	D 195.5 H9 · S 7.75 · L 4.2 +0.2/0
4 Primary Stepseal	ISO 7425-2 / TSS RSK	RSK300800 · D1 95.1 H9 · L1 6.3 · 85.09 × 5.33	RSK301400 · D1 155.1 H9 · L1 6.3 · 145.42 × 5.33	RSK301800 · D1 195.1 H9 · L1 6.3 · 183.52 × 5.33
Order number (jacket + O-ring)	Trelleborg	RSK300800-T46T (T = low-temp NBR; T46N if -30 °C ok)	RSK301400-T46T	RSK301800-T46T

5 Secondary PU rod seal	ISO 5597 medium	D 100 H11 · S 10.0 · L 12.5 +0.25/0 · Rmax 0.4	D 165 H11 · S 12.5 · L 16.0 +0.25/0 · Rmax 0.6	D 210 H11 · S 15.0 · L 20.0 +0.25/0 · Rmax 0.8
Published secondary series	ISO 5597	Zurcon RU9 / Hallite 605 in 80×100×12.5	Zurcon Rimseal or RU9 / Hallite 605 in 140×165×16	Zurcon Rimseal or RU9 / Hallite 605 in 180×210×20
6 Wear ring	ISO 10766	d 80 · D 85 · L 9.7 · t 2.5	d 140 · D 148 · L 15.0 · t 4.0	d 180 · D 185 · L 15.0 · t 2.5 (ISO) / t 4.0 if side-load
Lead-in chamfer C min	ISO 7425-2 / 6195	4.0 mm, 15–20°, polished	5.0 mm, 15–20°, polished	5.0 mm, 15–20°, polished
Stepseal groove radius r max	ISO 7425-2	0.3 mm	0.3 mm	0.3 mm
Extrusion gap Smax at 25 MPa	TSS Stepseal table, heavy	0.25 mm	0.25 mm	0.25 mm

Published Trelleborg rod Stepseal 2K standard-application rows: RSK300800 (Ø80, D1 95.1, 85.09 × 5.33), RSK301400 (Ø140, D1 155.1, 145.42 × 5.33), RSK301800 (Ø180, D1 195.1, 183.52 × 5.33). ISO 7425-2 alternate grooves are RSKD00800 (D1 95.5) and RSKD01800 (D1 195.5) — do not mix a standard RSK3 part into an ISO-only groove without checking D1. Wipers: ISO 6195-C 80×90×6.3, 140×155×9.5, 180×195×9.5. Heavy-duty Stepseal option is RSK4 (L1 8.1) if extrusion gap grows under side load.

Groove-to-groove: leave ≥ 7.5 mm metal between the Type C scraper groove and the Stepseal groove on Ø140 / Ø180 so the back-pumping primary does not pressure-trap against a double-acting lip. Leak-sense M10×1 boss taps the pocket between Stepseal and ISO 5597 secondary.

5b. Ø80 actuator — full stack (no ice scraper)

Lives inside the inner stage. Sees oil and chrome, not packed ice. Skip element 1 (ice scraper). Keep a light Type C wiper so grit from assembly does not walk into the Stepseal.

2 Wiper ISO 6195-C	d 80 f8 · D1 90 H11 · S 5.0 · L1 6.3 +0.2/0 · D2 87	Zurcon DA22 or Hallite 831 in 80×90×6.3
3 Buffer	d 80 f8 · D 90.7 H9 · L 4.2 +0.2 (TSS light) or D 95.1 / L 6.3	Parker BU / Hallite 653 in the 4.2 groove, or second RSK2
4 Primary	d 80 f8 · D1 95.1 H9 · L1 6.3 +0.2 · r1 1.3 · r max 0.3	RSK300800-T46T · O-ring 85.09 × 5.33
ISO-groove alt. primary	d 80 f8 · D1 95.5 H8 · L1 6.3 +0.25/0 · ISO 7425-2	RSKD00800-T46T · O-ring 85.09 × 5.33
5 Secondary	d 80 f8 · D 95 H11 · S 7.5 · L 12.5 +0.25/0 · ISO 5597 medium	Zurcon RU9 / Hallite 605 80×95×12.5
6 Wear ring	d 80 · D 85 · L 9.7 · S 2.5 · ISO 10766	Orkot / Luytex Slydring C380
Chamfer / finish	C min 4.0 mm, 15–20°, Ra 0.2–0.4 µm on rod	No spiral grind
Smax at 25 MPa	0.25 mm radial (TSS RSK3 heavy column)	Hold concentricity with the wear ring
Heavy-duty option	D1 100.5 · L1 8.1 · O-ring 88 × 7.00	RSK400800-T46T if gap grows

5c. Ø180 intermediate — full ice stack

Outer gland runs on the intermediate tube OD. This is the dirty interface: ice pack, grit, largest annulus-volume change. Prefer DA24 Venting here.

1 Ice scraper ISO 6195-C	d 180 f8 · D1 195 H11 · S 7.5 · L1 9.5 +0.3/0 · D2 190	Zurcon DA24 Venting in 180×195×9.5; or SKF CR PWY 180×195×9.5×13; Hallite 831 metric only
3 Buffer	d 180 f8 · D 195.1 H9 · L 4.2 +0.2 or share the 6.3 Stepseal pitch	Parker BU / Hallite 653
4 Primary	d 180 f8 · D1 195.1 H9 · L1 6.3 +0.2 · r1 1.3 · r max 0.3	RSK301800-T46T · O-ring 183.52 × 5.33
ISO-groove alt. primary	d 180 f8 · D1 195.5 H8 · L1 6.3 +0.25/0 · ISO 7425-2	RSKD01800-T46T · O-ring 189.87 × 5.33

5 Secondary	d 180 f8 · D 210 H11 · S 15.0 · L 20.0 +0.25/0 · ISO 5597 medium	Zurcon Rimseal / RU9 / Hallite 605 180×210×20
6 Wear ring	d 180 · D 185 · L 15.0 · S 2.5 ISO 10766 (S 4.0 if side-load)	Orkot / Luytex Slydring C380, two rings
Chamfer / finish	C min 5.0 mm, 15–20°, Ra 0.2–0.4 µm on tube OD	Hard chrome or HVOF
Smax at 25 MPa	0.25 mm radial	Wear rings take the HL-ANK-001 moment
Inter-stage breath	DA24 vent path or M10×1 orifice to tank	Do not hermetically seal this annulus
Heavy-duty option	D1 200.5 · L1 8.1 · O-ring 189.87 × 7.00	RSK401800-T46T
Leak-sense	M10×1 between primary and secondary	Empty = primary still alive

6. Compounds and temperature

Scraper / wiper	Zurcon Z20 / Z201 PU; Hallite Hythane 181 / 371 (aggressive scrape)	–45 to +100 °C typical PU	Standard NBR alone in ice. Too stiff at –40.
Buffer	High-grade PU (Parker Ultrathane / Hallite 653 compound)	–40 to +110 °C	Unbacked O-ring as the only buffer at 250 bar
Primary Stepseal jacket	Turcon T46 or M12 PTFE bronze / carbon fill	–50 to +200 °C jacket	Virgin PTFE — creeps under side load
Primary energizer	NBR 70 for mineral oil; HNBR if heat; FKM only if fluid demands it	NBR –30; specify low-temp NBR or HNBR for –40	FKM in arctic mineral oil unless required
Secondary PU	Zurcon Z20 / Hallite Hythane 181 / Parker Resilon or Molythane 90A	–45 to +110 °C	90A PU stored in UV for a year then fitted
Wear ring	Orkot / fabric-phenolic / filled PTFE	Full ambient range	Bare bronze against hard chrome in ice — galls
Face O-ring (ankle)	HNBR 70, AS568-240, per HL-ANK-001	–40 °C	Buna that sat in a truck cab all summer

7. Hardware that is not a seal and still kills the stack

Running surface	Hard chrome 20–50 µm, Ni-Cr, or HVOF carbide. Final polish Ra 0.2–0.4 µm. No spiral grind marks — they pump oil out.
Extrusion gap (diametral)	Target ≤ 0.3 mm at 250 bar with PU + back-up; ≤ 0.2 mm if the primary is PTFE without a dedicated anti-extrusion ring. Hallite 605 published max gap ~0.40 mm at 400 bar with backup — do not use that as a design target.
Anti-extrusion	PEEK or fabric ring behind every PU pressure lip that can see 250 bar and a side-loaded gap. Stepseal jackets usually include this function.
Wear ring placement	One outboard of the primary (takes the moment), one between primary and secondary (oil pocket + concentricity). ISO 10766 widths.
Inter-stage breathing	Do not hermetically seal the annulus between stages. Use DA24-style vented scraper, a floating buffer, or a calibrated orifice back to tank. Volume change on extend will otherwise hydro-lock or blow a wiper.
Leak-sense cavity	Port the volume between primary and secondary to a 1/8 NPT or M10×1 boss. Rise in pressure or oil in a sight bottle = primary is dying while secondary still holds.
Ice heat (optional arctic kit)	Low-power heater band or grease-inject gallery immediately inboard of the scraper. Not required for first article.

8. Approved vendor map

Full stack + tandem notes	Trelleborg Sealing Solutions	Parker EPS / Praedifa	Published telescopic tandem + DA24 venting
Aggressive ice / mud scraper	Hallite 820 / 831 / 371 compound	Trelleborg WKE metal-cased	Umbrella lip covers the groove so slurry does not sit in the gland
Primary PTFE step seal	Turcon Stepseal 2K	Parker OD / step profiles; Freudenberg Omegat	Back-pumping is the whole game
Secondary dry-rod PU	Zurcon Rimseal / RU9	Hallite 605 / 621; Parker Type B PolyPak	Twin lip, easy install, –45 °C class PU
Wear rings	Orkot / Luytex Slydring	Parker fabric-phenolic; Hallite bearings	Side load off the lips

9. Installation order and first-article

Install environment-side to oil-side, or follow the vendor cartridge drawing if the gland is a bolt-on head. Never roll a Stepseal jacket. Never twist a PU U-cup. Lube with the same ISO VG 46 the circuit will run. After assembly: ten slow full strokes at ≤ 20 bar to seat lips, then 50 bar, then system pressure. A dry first stroke at 250 bar cuts the primary.

First article is one stage interface, not four legs. Cycle in a freezer at –30 °C with grit on the rod. Pass = no lock, no weep at the secondary after 200 strokes, leak-sense port stays empty. Attach this Rev B gland table to the Trelleborg / Parker inquiry. Diameters are no longer open.

10. Spare kit (one stage interface)

Scraper	2	One running, one spare in the dry bag
Wiper (if separate)	2	—
Buffer	2	—
Primary Stepseal + energizer	2	Keep energizer with the jacket
Secondary PU	2	—
Wear rings	1 set	Replace when you see the chrome witness
Anti-extrusion rings	2	If not integral to the primary
Face / static O-rings for that gland	4	HNBR –40 °C
Installation cone / bullet	1 per diameter	Protects lips over the thread and ports

11. Still open — not diameters

Diameters and ISO glands are locked. Remaining:

- Bolt-on gland cartridge vs integral grooves. Cartridge is HL-SEAL-002. Field swap matches the ankle.
- Confirm energizer suffix T (low-temp NBR –45 °C) vs HNBR on RSK300800 / 1400 / 1800 against VG 46 at –40 °C. Jacket T46 is not the limit.
- Prefer DA24 Venting on Ø180. Ø140 can stay DA22 if the annulus is orificed.
- Hallite 820 umbrella is Type D / North American housing. Do not drop an 820 into the ISO 6195-C groove. Use Hallite 831 (metric) if Hallite is the scraper.
- First article: one Ø140 interface, freezer + grit, 200 strokes, leak-sense dry.

Rev C adds published TSS rows RSK300800 (85.09 × 5.33) and RSK301800 (183.52 × 5.33). Do not mix RSK3 parts into RSKD ISO-only grooves without matching D1. Highliner.org