ROTH TECHNOLOGIES, LLC • APPLICATION ENGINEERING TECHNICAL NOTE

Moving Wire Seal (MWS) Hole-Sizing Theory & Multi-Pass Guidelines

Document No.: RT-MWS-TN-007, Rev R8 | Elastomer: 35A–40A EPDM | Reference: www.movingwireseal.com

The Core Process Dilemma: PTFE Snow Flaking vs. Roller Dripping

In continuous bottom-entry wire coating lines—such as multi-pass aqueous polytetrafluoroethylene (PTFE) dispersion coating running at 6 to 8 ft/min over a 24-hour production campaign (8,600 to 11,500 linear feet per pass)—the Moving Wire Seal (MWS) must balance two competing failure modes:

- **Hole Too Tight — Mechanical Micro-Plowing & PTFE "Snow" Buildup:** Even though the dispersion bath above the seal lubricates the interface, excessive radial contact pressure presses the elastomer entry lip against the soft, crystalline sintered PTFE layer from prior passes. Over 10,000+ linear feet of travel, microscopic surface asperities are shaved off and accumulate at the entry lip as white particulate debris ("PTFE snow"). When this collar breaks free or pulls into the bath, it causes coating lumps, pinholes, and dielectric voids on subsequent passes.
- **Hole Too Loose — Low-Surface-Tension Weeping onto Lower Rollers:** If the seal hole provides insufficient circumferential contact, liquid dispersion weeps past the lip and drips down the wire onto the lower guide rollers. Once dispersion dries on the roller sheaves, it flakes off and is carried upward back into the bath, contaminating the dispersion and creating coating defects.

Why Aqueous PTFE Dispersion Leaks Through a Seal

Aqueous PTFE dispersion is substantially harder to seal than plain water for two physical reasons:

- **Low Surface Tension (~28–35 dynes/cm):** Wetting surfactants added to stabilize the PTFE dispersion sharply reduce surface tension, preventing the strong capillary meniscus that would otherwise bridge a microscopic clearance gap. Any continuous micro-channel allows fluid to wick straight through.
- **Shear Coagulation at the Seal Lip:** Aqueous PTFE dispersions are shear-sensitive. When the seal hole is overly tight, high radial squeeze subjects the dispersion trapped between the moving wire and the 35A–40A EPDM lip to intense mechanical shear. This coagulates solid PTFE particles directly inside the seal throat, wedging the soft elastomer lip open and causing delayed dripping onto the rollers several hours into a run.

> **Counterintuitive Failure Cycle: Why Over-Tightening Causes Delayed Leaks**
>
> Operators often respond to weeping by punching a smaller hole. On long aqueous PTFE dispersion runs, excessive interference shear-coagulates solid PTFE particles inside the throat within the first few hours. Those solid particles prop the compliant 35A–40A EPDM lip off the wire, creating capillary channels that wick low-surface-tension dispersion onto the lower rollers.

Seal Throat Mechanics & Online Reference Model

MWS units molded from 35A–40A EPDM exhibit a low small-strain Young's modulus (typically ~1.3 to 2.0 MPa), enabling the seal lip to conform around fine wire with gentle radial contact stress compared to standard 70A elastomers. At the seal throat, performance is governed by three interacting factors:

- **Radial Contact Stress vs. Hydrostatic Bath Head:** Hoop expansion of the relaxed hole around the incoming wire generates radial sealing pressure that must exceed the shallow hydrostatic head of the bath above it while remaining below the threshold that abrades sintered PTFE or shear-coagulates the dispersion.
- **Boundary Lubrication & Upward Viscous Drag:** The liquid bath directly above the lip wets the contact zone, lowering sliding friction, while upward wire motion (6–8 ft/min) generates a viscous boundary-layer drag that opposes downward gravity weeping during steady-state operation.
- **Online Contact-Stress & Sizing Model (movingwireseal.com):** Detailed radial contact-pressure calculations, geometry parameters, and interactive multi-pass sizing tools are maintained on our website at movingwireseal.com. Users should consult the online model for baseline stress comparisons when evaluating custom wire diameters or bath conditions.

> **Important Notice — No Assumed Elastomer Recovery Rule or Prescribed Tooling**
>
> Our website and this technical note intentionally do NOT apply a universal elastomer recovery percentage (such as an assumed 5% spring-back rule) and do NOT prescribe specific punch outer diameters or hypodermic needle gauges. Actual hole recovery in 35A–40A EPDM varies with batch durometer tolerance, punch sharpness, lubrication, backing anvil hardness, and punching technique. All target dimensions in this document specify the finished RELAXED HOLE DIAMETER; end users must validate their own punching process and measure actual relaxed hole IDs.

Recommended Fit Levels (Light, Medium, and Heavy)

To provide a structured starting point for process development, Roth Technologies defines three diametral interference levels based on the finished relaxed hole diameter (d_hole) relative to the incoming wire diameter (D_in):

Fit Level	Diametral Interference	Target Relaxed Hole ID (d_hole)	Recommended Starting Application & Notes
Light Fit	2% Interference	0.98 × D_in (98.0% of wire OD)	Starting recommendation for Passes 2–N (sintered PTFE layers) on shallow dispersion baths during extended runs to minimize PTFE snow and shear coagulation.
Medium Fit	5% Interference	0.95 × D_in (95.0% of wire OD)	Starting recommendation for Pass 1 (bare metal wire) and general-purpose shallow baths where positive 360° sealing against surfactant wicking is needed.
Heavy Fit	8% Interference	0.92 × D_in (92.0% of wire OD)	Starting recommendation for taller bath heads, lower-viscosity fluids, or short bare-metal runs. Generally avoid on long sintered PTFE dispersion runs.

Engineering Qualification: These 2%, 5%, and 8% interference tiers represent our starting recommendations based on shop experience—they are not universally validated operating laws across all dispersions, bath depths, or line speeds. Light Fit reduces the risk of PTFE snow and shear-induced weeping, but does not by itself guarantee zero debris or zero dripping under every condition. End users should treat these values as initial baselines and establish their own validated internal guidelines for their specific line hardware and fluid chemistry.

Generalized Multi-Pass Hole-Sizing Equations (Any D_o, t_total, and N)

Because each coating pass adds radial wall thickness, the wire diameter entering each successive bath increases. Using a single hole size across all passes either starves/scrapes later passes or under-seals Pass 1. For a starting bare wire diameter D_o, total target radial wall build t_total, and N equal passes:

- **Step 1 — Per-Pass Radial Wall Build (Δt):** $\Delta t = t_total / N$ (diametral growth per pass = $2 \cdot \Delta t$)
- **Step 2 — Incoming Wire Diameter at Pass n (for n = 1, 2, ..., N):** $D_in(n) = D_o + 2 \cdot (n - 1) \cdot \Delta t$
- **Step 3 — Target Relaxed Hole Diameter at Pass n:** $d_hole(n) = (1 - I_n) \cdot D_in(n)$, where I_n is the selected interference fraction (0.02 for Light, 0.05 for Medium, 0.08 for Heavy).
- **Step 4 — Empirical Punch Selection:** Select a sharp hollow punch based on measured hole recovery in your specific 35A–40A EPDM lot so the finished relaxed hole matches d_hole(n).

Worked Example: 0.0220 in Silver-Plated Copper Wire (4 Passes)

Consider a bare silver-plated copper (SPC) wire with D_o = 0.02200 in receiving a total radial PTFE wall build of t_total = 0.00050 in across N = 4 equal passes (Δt = 0.000125 in radial build, or +0.00025 in OD growth per pass), running at 6–8 ft/min for 24 hours:

Pass #	Incoming Wire Surface	Incoming Wire OD D_in(n)	Recommended Starting Fit	Target Relaxed Hole ID d_hole(n)
Pass 1	Bare Silver-Plated Copper	0.02200 in (0.559 mm)	Medium Fit (5%)	**0.02090 in (0.531 mm)**
Pass 2	1× Sintered PTFE Layer	0.02225 in (0.565 mm)	Light Fit (2%)	**0.02181 in (0.554 mm)**
Pass 3	2× Sintered PTFE Layers	0.02250 in (0.572 mm)	Light Fit (2%)	**0.02205 in (0.560 mm)**
Pass 4	3× Sintered PTFE Layers	0.02275 in (0.578 mm)	Light Fit (2%)	**0.02230 in (0.566 mm)**

Rationale: Medium Fit (5%) on Pass 1 vs. Light Fit (2%) on Passes 2–4

Using Medium Fit (5% interference) on Pass 1 and stepping down to Light Fit (2% interference) on Passes 2–4 reflects the physical transition from bare drawn metal to sintered polymer at the seal lip:

Pass 1 — Bare Silver-Plated Copper (Medium Fit: 5% Interference, 0.95 × D_in)

- **No Fragile Polymer Coating to Shave:** On Pass 1, the wire entering the seal is bare, drawn silver-plated copper. There is no sintered PTFE layer on the surface yet that can be scraped or plowed into "PTFE snow."
- **Harder, Smooth Metallic Surface:** Drawn SPC wire presents a smooth, continuous metallic surface with a predictable diameter, allowing firmer circumferential contact to form a reliable 360° fluid dam against low-surface-tension dispersion without generating wear debris.
- **Prevents Initial Bath Weeping on Bare Metal:** Bare metal lacks the ultra-low surface energy of sintered PTFE, so surfactant-laden dispersion wets silver readily and can wick along micro-draw lines if the seal is too loose. Medium Fit (5%) closes off that capillary path at the first bath entry.

Passes 2–4 — Sintered PTFE Layers (Light Fit: 2% Interference, 0.98 × D_in)

- **Protects Soft Sintered PTFE from Mechanical Micro-Plowing:** Once the wire exits Oven 1, it carries a thin, relatively soft crystalline PTFE layer. Over a 24-hour campaign (~10,000 linear feet at 6–8 ft/min), higher radial squeeze gradually shaves microscopic PTFE asperities off the wire, accumulating a collar of "PTFE snow" at the entry lip.

- **Reduces Shear Coagulation Inside the Seal Throat:** Because sintered PTFE already exhibits ultra-low surface energy (resisting capillary wicking) and benefits from boundary lubrication with the bath above, heavy radial squeeze is unnecessary on a shallow bath head. Stepping down to Light Fit (2%) lowers shear stress on the dispersion in the contact zone, helping prevent coagulated PTFE wedges from propping the lip open.
- **Absorbs Cumulative Wall-Build Tolerances:** Across Passes 2, 3, and 4, minor pass-to-pass variations in wall build accumulate. Light Fit keeps radial contact gentle.

Critical Shop-Floor Setup & Hole Inspection Details

Even with an optimal target hole diameter, mechanical setup and inspection errors are the primary causes of roller dripping and particulate buildup. Follow these shop-floor controls:

- **Concentric Alignment Is the #1 Leak Cause:** Because 35A–40A EPDM is highly compliant (~1.3–2.0 MPa), any lateral pull from an off-center lower guide roller ovalizes the hole—pushing hard on one side (causing localized snow/coagulation) while opening a crescent gap on the opposite side where dispersion drips straight down the wire. Align the lower sheave directly on the MWS centerline.
- **Use a Razor-Sharp Cylindrical Punch (Never a Needle Puncture):** A simple needle slit or torn puncture leaves V-notches at the corners that capillary-wick surfactant dispersion onto the rollers. A clean, round slug punch produces uninterrupted 360° hoop contact.
- **Punch Outside-In on an Internal Support Mandrel & Label Housings by Pass:** Seat the MWS unit onto an internal support mandrel fitted with a sacrificial Delrin/HDPE backing plug in the apex pocket. Using a water- or alcohol-wetted hollow punch held perpendicular to the tip, punch straight outside-in (from the exterior wire-entry face into the internal anvil) without rotating the tool. Mark each MWS housing (P1, P2, P3, P4) so pass-specific seals are never swapped.
- **Measure Relaxed Hole ID with Non-Contact Optical Inspection (Never Pin Gauges):** Verify the finished relaxed hole diameter using an optical comparator, toolmaker's microscope, or calibrated vision system—and inspect the cut edge at 20×–40× magnification for burrs or tears. Do NOT use mechanical pin gauges or calipers to measure soft 35A–40A EPDM holes; physical contact elastically stretches the compliant elastomer wall, producing falsely oversized readings and risking damage to the freshly punched sealing lip.
- **Keep Bath Head as Shallow as Wetting Dwell Time Allows:** Hydrostatic pressure drives weeping directly. Maintaining the dispersion level at 1.5–2.5 inches above the MWS tip cuts leakage driving pressure roughly in half compared to a 4–5 inch bath.
- **Stop-Line / Thread-Up Drip Protection:** When line speed drops to zero during thread-up or pauses, upward viscous drag vanishes and static head is at its maximum. Slide a small split catch-collar or drip cup onto the wire above the lower roller before stopping the line.

7. Limitations & End-User Qualification Notice

> **Limitations & No-Warranty Engineering Disclaimer (RT-MWS-TN-007, Rev R8)**
>
> The analytical relationships, interference tiers (Light 2%, Medium 5%, Heavy 8%), and multi-pass sizing equations presented in this technical note and on movingwireseal.com are unvalidated engineering estimates intended solely as general starting guidance. They do not establish, predict, or guarantee leakage performance, coating quality, void-free operation, seal wear life, or acceptable production fit for any specific wire, dispersion chemistry, bath geometry, or line speed. Because elastomer durometer tolerances, punching methods, fluid rheology, and alignment vary across installations, each end user must empirically measure relaxed hole dimensions using non-contact optical methods and qualify their own operating parameters under representative production conditions.