# Flow Marks and Knit Lines in Liquid Silicone Rubber Injection: Optimizing Injection Speed and Barrel Pressure Profiles

FLUID DYNAMICS & RHEOLOGICAL ENGINEERING SPECIFICATION | REEMANE SILICONE

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| **Primary Compliance Standards:** | American Society for Testing and Materials D412, International Organization for Standardization 13485 | **Target Audience:** | Process Engineers, Tooling Designers, Quality Assurance Directors |
| **Manufacturing Framework:** | Computational Fluid Dynamics / Scientific Injection Molding | **Document ID:** | REEMANE-TECH-WP-310K |

## 1. The Rheological Mechanics of Surface and Structural Defects

In the high-precision molding of Liquid Silicone Rubber, visual imperfections are rarely superficial; they are physical indicators of underlying macromolecular failure. Two of the most heavily audited defects in medical and automotive manufacturing are flow marks (tiger stripes or surface ripples) and knit lines (weld lines). Flow marks destroy the optical clarity and hygienic smooth finish required by International Organization for Standardization 13485 medical device regulations. More critically, knit lines represent severe structural vulnerabilities. A knit line occurs when two separate fluid flow fronts meet and fuse around a tooling obstacle, such as a core pin. If this fusion is sub-optimized, the localized tensile strength of the component plummets, practically guaranteeing a rupture during the American Society for Testing and Materials D412 elongation testing.

Both defects share a common root cause: the failure to manage the non-Newtonian, shear-thinning fluid dynamics of Liquid Silicone Rubber. Silicone viscosity drops dramatically as injection speed (shear rate) increases. If the injection velocity fluctuates, or if the melt front pauses for even a fraction of a second, the dynamic viscosity changes mid-flow, causing the material to fold over itself and generate visual ripples.

Eradicating these defects requires abandoning primitive single-stage injection methods in favor of absolute kinetic control over the injection speed and barrel pressure profiles.

## 2. Profiling Multi-Stage Injection Velocities

Generic manufacturers typically inject silicone into a mold cavity at a single, constant speed. This is a catastrophic error for complex geometries. When the elastomer passes through a narrow gate into a wide cavity, a constant injection stroke causes the melt front velocity to plummet due to the sudden expansion of volume. This deceleration allows the silicone to absorb thermal energy from the heated steel tool, initiating premature cross-linking at the leading edge of the flow front before the cavity is fully packed.

Reemane Process Engineers eliminate flow marks by programming highly segmented, multi-stage injection velocity profiles into the machine's Proportional-Integral-Derivative controller. The initial injection stage is executed at maximum velocity to generate intense shear thinning, rapidly pushing the low-viscosity elastomer through the runner system and gates. As the fluid enters the primary cavity, the machine automatically ramps down the velocity to maintain a perfectly constant melt front speed as the cross-sectional volume expands. This ensures the silicone flows smoothly and continuously across the cavity walls, completely eradicating the folding and rippling that generate surface flow marks.

## 3. Eradicating Knit Lines: Pressure Control and Molecular Entanglement

When two flow fronts converge to form a knit line, the polymer chains must physically entangle across the boundary to establish structural integrity. If the leading edges of these flow fronts have begun to cross-link, or if there is trapped atmospheric air in the convergence zone, the chains will bounce off each other, leaving a microscopic V-shaped notch and a severe mechanical weak point.

To achieve flawless molecular entanglement, the injection profile must aggressively decelerate the flow fronts just milliseconds before they collide, allowing microscopic vacuum vents to evacuate trapped air without flashing the tooling. Immediately following this collision, the injection machine must execute a rapid transition into the holding pressure phase. By applying a sustained, high-tonnage barrel pressure directly to the convergence zone while the silicone is still in its liquid state, the polymer chains are physically crushed together, forcing deep macromolecular entanglement and restoring the component's absolute tensile strength across the knit line.

## 4. The Criticality of the Velocity-to-Pressure Switchover Point

The transition from filling the mold (velocity control) to packing the mold (pressure control) is defined as the Velocity-to-Pressure switchover point. This is the most sensitive parameter in Scientific Injection Molding. If the switchover occurs too late, the massive kinetic energy of the injection stroke will over-pressurize the cavity, blowing the mold open and creating unacceptable flash. If the switchover occurs too early, the flow front hesitates, instantly generating a deep flow mark and severely starving the knit line of the packing pressure required for polymer entanglement.

Reemane Silicone abandons the unreliable method of switching over based on the injection screw position or a time delay. Instead, we integrate highly sensitive cavity pressure transducers directly into the tooling steel. These sensors continuously monitor the internal fluid pressure of the silicone in real-time. When the internal cavity pressure reaches a precise, mathematically verified threshold (indicating the mold is exactly ninety-eight percent full), the sensor instantly triggers the machine controller to seamlessly transition from velocity to holding pressure. This closed-loop sensory architecture guarantees zero-defect consistency, eradicating flow marks and structural knit line weaknesses across millions of production cycles.

| Process Engineering Metric | Sub-Optimized Factory Sourcing | Reemane Scientific Molding Architecture |
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| **Injection Velocity Profile** | **Single-stage constant speed (Causes severe flow marks)** | **Multi-stage profiled velocity (Constant melt front speed)** |
| **V/P Switchover Trigger** | **Position or Time-based (High variance, flash, hesitation)** | **Cavity Pressure Transducer triggered (Absolute precision)** |
| **Knit Line Tensile Strength** | **Fails ASTM D412 due to lack of polymer entanglement** | **Matches baseline material strength via extreme packing pressure** |
| **Visual Surface Finish** | **Tiger stripes, ripples, and hesitation lines present** | **Flawless, optical-grade smooth finish** |

## Eradicate Structural Vulnerabilities Before Mass Production

Do not allow uncontrolled fluid dynamics to compromise the tensile strength or visual perfection of your engineering components. Partner with Reemane Silicone to deploy closed-loop Scientific Injection Molding, cavity pressure transducers, and rigorous Computational Fluid Dynamics flow profiling.

**Submit your Three-Dimensional CAD models for a ruthless rheological flow analysis:**
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**Review our precision tooling and Scientific Molding capabilities:**
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