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START-UP AND OPERATING INSTRUCTIONS MANUAL
STAMIXCO SMN INJECTION MOLDING STATIC MIXING NOZZLE

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Installation and Operating Instructions Manual

StaMixCo SMN Injection Molding Mixing Nozzle

A) Start-Up and Operating Guidelines

The following key points are critical for Start-Up and Operation of the SMN Static Mixing Nozzle. With over 4,000 installations world-wide, the mixing elements crushed in 11 instances (0.3% failure rate). In all instances, root-cause analysis revealed failure due to improper pre-injection heat up time. Please pay special attention to this manual. You and we don't want your installation to become a failure statistic.

1) Maximum Operating Conditions
   A SMN Mixing Element Assembly with eight (8) static mixing elements (Fig. #6) is designed for the following maximum operating conditions:
   a) 300 ^{o}C (572 ^{o}F) maximum continuous operating temperature
   b) 150 bar (2,175 psi) maximum allowable pressure drop

   Where these limits are expected to be exceeded, special mixing element assemblies are available. If the end user has any questions regarding the ability to use a static mixer in a specific application, contact StaMixCo for rating the equipment for your application.

2) Anti-Seize Compound
   Apply anti-seize copper containing grease compound to all threads. This assures the ability to unscrew the nozzle parts after operation and that there is good heat conductivity between the individual nozzle parts.

3) Installation Direction of Mixing Elements
   The Mixing elements may be installed with flow in any direction (see Fig. #6) under the condition that no alignment pins extends beyond the front and rear rings of the mixing elements. The Filter must be installed on the feed side of the nozzle body (near injection molding machine). For discussion on proper orientation of adjacent mixing elements, see Section B) of this manual.

4) Temperature Sensor
   The Mixing Nozzle housing must be equipped with a temperature sensor to control housing heater band operation on a dedicated circuit. This is required to assure heat is supplied to the housing to prevent possible damage to the mixing elements during start-up and operation. For thermocouple installation and operation, follow the instructions of the thermocouple supplier.

5) Heater Bands
   The Mixing Nozzle housing must be heated on the outside surface. Housing heater bands and thermocouple must be connected to a dedicated auto tuned control zone to assure than an accurate housing temperature is maintained. The recommended heating capacity is 4 to 5 W/cm^{2} of heated surface. Installation and operation of the heater bands should be made in accordance to the supplier's instructions

   Assurance of good tight contact between the heater bands and nozzle body should be verified before and after the first heat-up. Once in operation, continued good contact between heater band and housing body should be checked periodically.

6) Start-Up and Operation of SMN Mixing Nozzle
   The SMN Mixing Nozzle must be allowed to soak at the operating temperature so that all internal parts of the mixing element fingers and frozen polymer within the mixing elements is melted and is at operating temperature prior to processing polymer. Proper heat-up is required to prevent a cold-start induced mixing element failure.
   a) Heat the nozzle until it reaches its normal operating working temperature and the controller switches on-and-off regularly for 5 minutes. Wait for an additional amount of time noted below to allow complete melting of the polymer inside the nozzle:

      Recommended additional heating time:
      SMN-12-8: approximately 10 min
      SMN-18-8: approximately 15 min
      SMN-22-8: approximately 20 min
      SMN-27-8: approximately 25 min
      SMN-33-8: approximately 30 min
      SMN-40-8: approximately 35 – 40 min

The reason heat-up time increases with increasing mixer diameter is that the frozen polymer inside the mixer body is larger in diameter and must be melted by thermal conductivity alone. Polymer melts are insulators which mean they have very low thermal conductivity. The polymer layer thickness in the screw section is much thinner and thus takes less time to melt completely.

Extreme caution is required for any location upstream of the static mixing nozzle where a solid “rod” of frozen polymer exists. These areas must be heated for complete melting prior to processing into the mixer section. Extreme caution is required because a frozen slug of solid polymer takes longer to melt that the same frozen slug of polymer within the mixing elements. This is because the mixing elements provide heating of the polymer via two modes; i) on the OD on the mixing elements; and ii) via “fin-effect” heat conduction” where the heat travels through the mixing bar fingers deep inside the frozen polymer mass. With a solid slug of upstream polymer, complete melting is very slow unless very high heater band wattages are used around the area where slugs of frozen polymer can exist or very long soak times are practiced. If a frozen slug of upstream polymer travels into the mixing element assembly, assuming that the polymer within the mixing elements is already melted, the high strength of the mixing element may not be adequate to prevent crushing when a “dead-head cold start” pressure event occurs. A “dead-head-cold start” event can cause destruction and tear-out of the mixing element fingers that may subsequently damage the nozzle tip, hot runner system and mold.

b) When the additional heat-up time has elapsed:
Force molten polymer (about the volume of 3-5 shots) continuously for about 30 seconds in the extrusion mode into the air. Extrude at low rpm (3-to-5 times longer than the normal injection time in production). If any major resistance of the melt is felt (listen to the sound the machine makes), stop and soak for another 5 minutes and start again with extrusion mode. Compare temperature of molten polymer and nozzle body. As soon as the difference is only slight, normal production may begin. When the polymer is flowing regularly out of the nozzle, switch to injection mode.

c) Inject the first 3 to 5 shots using an injection time that is 3-5 times longer than normal operating conditions. Reduce injection time in 2 to 3 steps to reach normal operating conditions. Then begin normal production operations.

7) <u>Interruption to Injection Molding Operations</u>

a) For brief interruptions to injection molding operations, temperature to the Mixing Nozzle housing may be lowered about 10-20 C^o (~20-40 ^oF).

b) During longer interruptions, the heating should stop to avoid burning of polymer.

c) For normal and emergency shutdowns when thermally sensitive polymers are being processed, normal purge procedures prior to shut-down should be followed. The static mixer should be purged with polyethylene or a purging compound so that upon next start-up, the long soak time required does not cause polymer degradation. Polymer degradation may cause carbonization within the mixing elements, housing and transition pieces requiring auxiliary equipment burn-out.

d) In all above cases, the above procedures starting with step 6) must be followed for re-start of normal operations.

8) <u>Color Changes</u>

The SMN Mixing Elements have a very narrow residence time distribution (see Fig. #4) as compared to an empty pipe (see Fig. #2-top, #3, #4). This means that when changing polymers or color, the contents of the mixing elements will be purged completely in a short period of time by the new material (~ 5 mixing element volume residence times). In the event <u>streaks of color</u> are observed after a color change, it is probably material that is hung-up somewhere downstream of the mixing elements (e.g., inside the hot runners/mold) that is breaking-off/purging slowly/intermittently. If a <u>hue of color</u> appears continuously or intermittently that is blended throughout the polymer, it is probably material that is hung-up somewhere in the upstream equipment such as the screw flights or upstream transition pieces which is breaking-off/purging slowly/intermittently and is being mixed by the mixing elements. The SMN mixing elements will mix all upstream color hang-up/breakthrough material so that a well blended hue of color will appear (see Fig. #2-bottom). Continue color change-over operations until the equipment upstream and downstream of the static mixer have purged.

9) <u>Cleaning of Static Mixing Elements & Filter</u>

In the event it is desired to clean the mixing elements, “Open Flame” cleaning is prohibited since it is detrimental to the heat treatment of the mixing elements. It is suggest that a temperature controlled oven or fluidized bed with afterburner be used to clean the mixing elements.

a) If the mixing elements require cleaning, a purge compound is recommended. If a complete removal of polymer is required, a fluidized bed bath or a vacuum pyrolysis oven with afterburner is recommended. Maximum cleaning temperature should be 400 ^{o}C (750 ^{o}F) to retain the integrity of the mixing element material heat treatment.

   To clean the mixing elements, some very creative customers use an alternative cleaning method to avoid the high cost of a fluidized bed or pyrolysis oven with an afterburner. Against our recommendation, they purchase a heavy-duty gas-fired home barbecue which they retrofit with a flame-impingement-plate to distribute heat and prevent direct flame contact with the mixing elements and install 4-5 thermocouples at different locations to observe and control the barbecue operating temperature. They claim to be satisfied with its performance but we recommend against its use because the noxious gases of combustion do not undergo safe pyrolysis in an afterburner.

b) If removing the mixing elements from the housing is necessary for inspection or cleaning, they should be extruded/pushed out while warm. If the polymer is frozen in the housing, it is best to warm the housing slightly to melt polymer near the wall and to then extrude/push the mixing elements out of the housing. If this is not possible where mixing element removal must be done cold, they may be rammed out of the housing (e.g., hydraulic press) with the stipulation that the rod used to ram the mixing elements out of the housing is flat at the end and is near the full outside diameter of the mixing elements so that the force of ramming is carried by the ring of the mixing elements and that no force is imparted on the finger bars of the mixing elements.

10) <u>Injection Pressure</u>
When installed on an injection molding machine, the mixing nozzle will cause a drop in injection pressure from 5% for normal flow grade polymers to as much as 15% for some very viscous polymers. After the injection molding machine is running, it will be necessary to fine-tune the machine parameters to obtain maximum injection molding machine and mixer performance. Changes should be made in small increments with adequate time, such as 15 minutes between changes, so that the full effect of each change can be observed.

11) <u>Process Improvements</u>
Process improvements are normally observed after installation of the SMN Mixing Nozzle. The following process improvement should be focused upon to maximize return on the investment of the mixing nozzle as further described in a case history pay-back analysis in Section E) of this manual.

a) Improved homogeneity of resin and additives
(Fig. #2-bottom and #5)

b) Reduction of colorant additives (Fig. #5)

c) Increased use of regrind (Fig. #2-bottom)

d) Improved cycle time (Fig. #1)

e) Improved surface finish (Fig. #1, #2-bottom and #5)

f) Lower part weight (Fig. #1)

g) Less cavity-to-cavity part weight variation (Fig. #1)

h) Closer tolerance parts (Fig. #1)

i) Reduction of fill and cooling times (Fig. #1)

j) Reduction of holding pressure (Fig. #1)

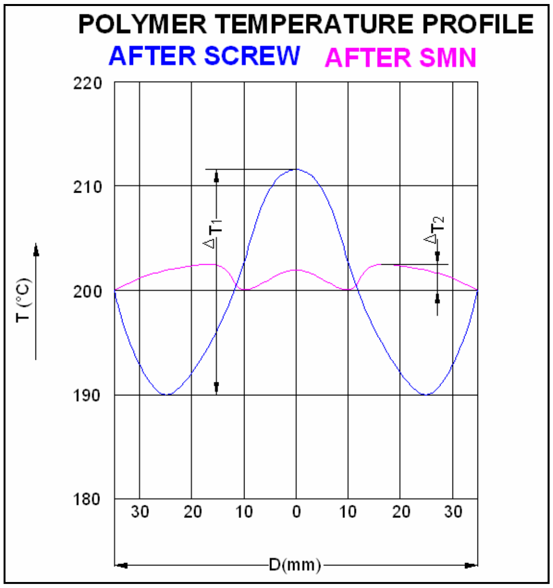


Figure #1: *SMN Static Mixer homogenizes large temperature gradient created by the screw.*

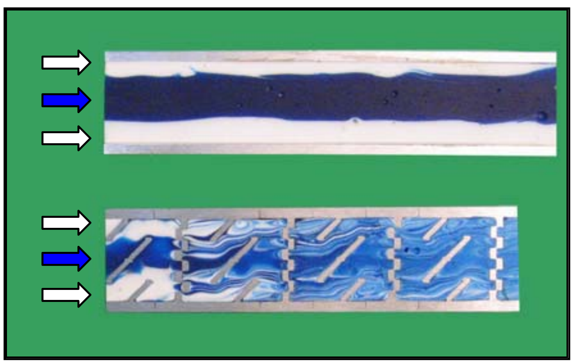


Figure #2: *Empty pipe (top) provides no mixing. Eight (8) SMN Mixing Elements (bottom) create a high degree of mixing in a short length.*

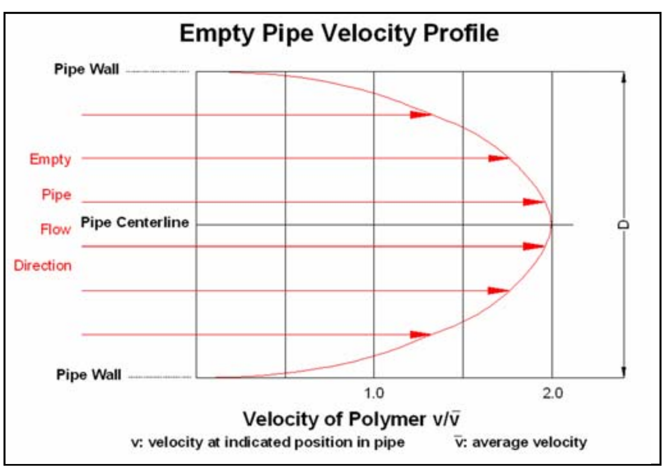


Figure #3: Velocity profile in an empty pipe

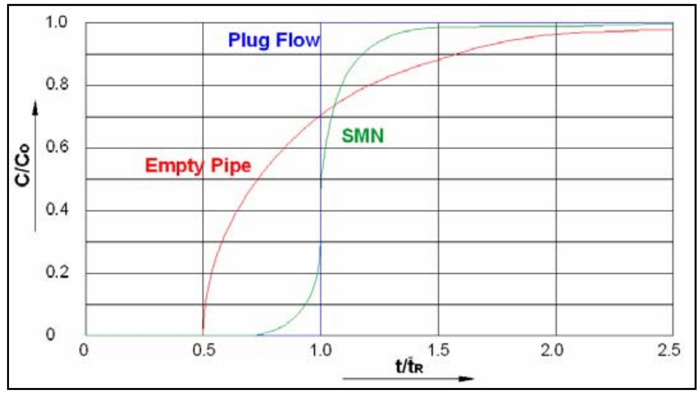


Figure #4: *Plug Flow Step Response curve of SMN Mixing Elements show good plug flow self cleaning abilities as compared to an empty pipe.*

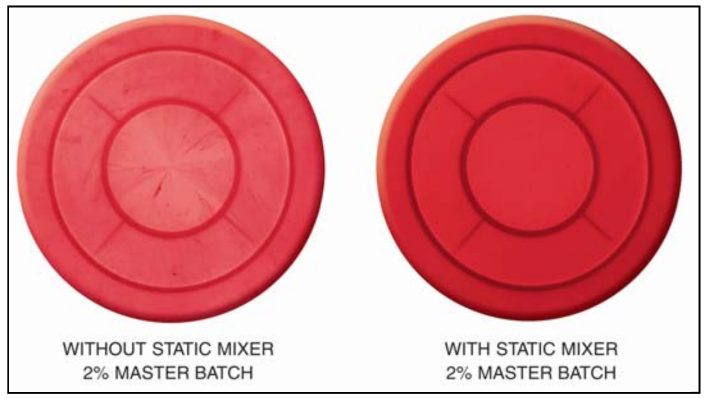
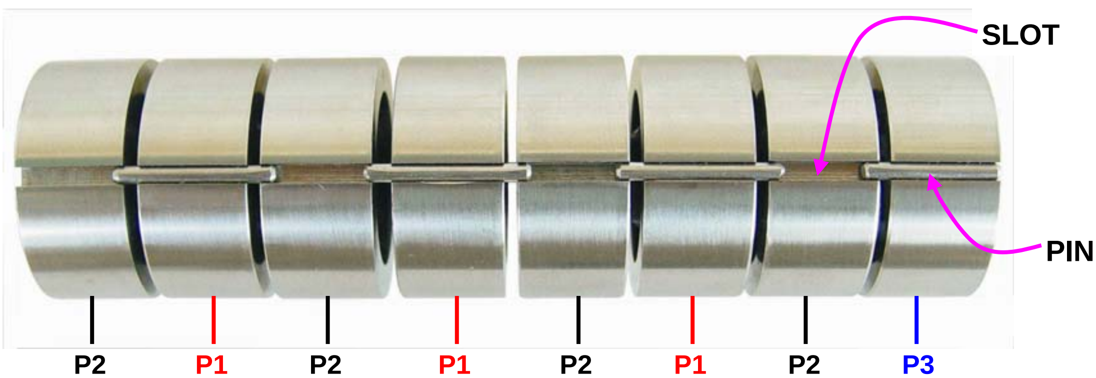


Figure #5: Reduction of color concentrate additives of as much as 30% can be achieved with comparable part color density

B) SMN Injection Molding Mixing Element Construction and Orientation

The Standard SMN Mixing Element Assembly consists of eight (8) mixing elements and is shown in Figure #6. The Alignment Pin & Slot arrangement on the mixing element outside diameter assures that the mixing elements are oriented 90^o relative to each other as shown in Figure #7. With the Pin & Slot orientation system, the mixing elements can be assembled in only one way under the condition that no pins extend beyond the front and rear face of the mixing element assembly.

The mixing element assembly is flow symmetrical and can therefore be installed into the Mixing Nozzle Housing in either direction. The mixing elements are made of high strength 17-4 PH stainless steel material which has been heat treated. The mixing element design is licensed from Bayer AG, Leverkusen, Germany which was developed in their High Viscosity Polymer Laboratories where this design is used in very large sizes in their polymer manufacturing operations.



STANDARD SMN MIXING ELEMENT ASSEMBLY WITH 8-STATIC MIXING ELEMENTS

P1: Orientation Pins Extending on Both Sides of Mixing Element (3 Pieces)

P2: Slots Only - No Orientation Pins (4 Pieces)

P3: Orientation Pins Extending Only on One Side of Mixing Element (1 Piece)

Figure #6: *Standard SMN Mixing Element Assembly with 8-mixing elements slightly separated for visual clarity. Slot and Pin arrangement assures adjacent mixing elements are oriented 90^o relative to each other. The mixing element assembly is flow symmetrical and can therefore be installed into the Mixing Nozzle Housing in either direction.*

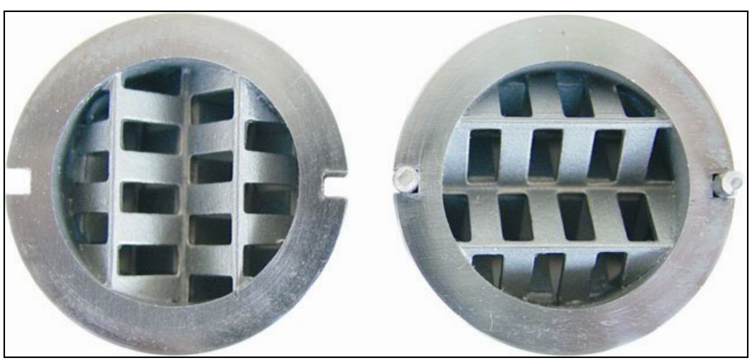


Figure #7: *Adjacent SMN Mixing Elements are oriented 90^o relative to each other. Individual mixing elements can be separated and inspected from both sides.*

C) SMN Mixing Element Dimensions and Selection

The standard arrangement of the SMN Injection Molding Mixing Nozzle contains eight (8) high performance SMN mixing elements that homogenize the polymer melt as it enters the mold (see Fig. #2-bottom). The correct nozzle size is a function of flow rate and viscosity of the polymer processed. SMN mixing element dimensions and sizing are shown in Figure #8 and Table #1. Table #2 provides a quick budget size rating for different size mixing nozzles.

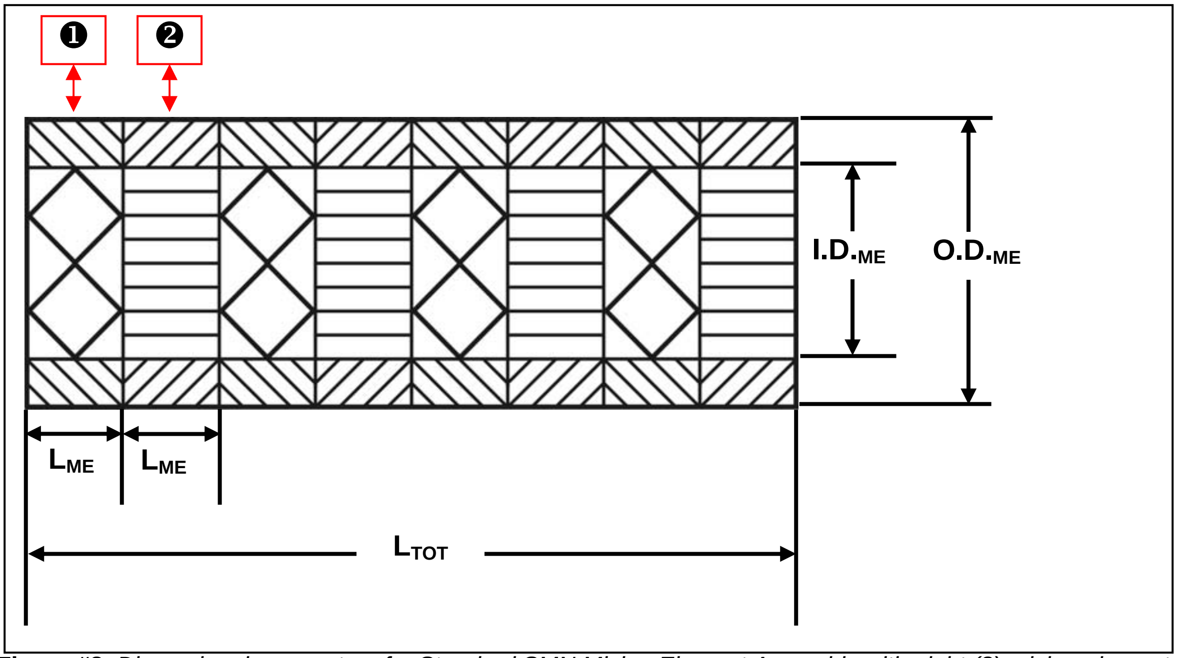


Figure #8: *Dimensional parameters for Standard SMN Mixing Element Assembly with eight (8) mixing elements*

Table #1: *Key Sizing and Dimensional Parameters for SMN Mixing Elements showed in Figures #8.*

	Injection Flow Rate			Mixing Elements				
Screw Size Range (mm)	Low Viscosity Polymer (cm^3/s)	High Viscosity Polymer (cm^3/s)	Mixing Nozzle Type	I.D. (mm)	O.D. (mm)	L_{ME} (mm)	8 Mixing Elements L_{TOT} (mm)	Nozzle Bore (mm)
20-50	300	200	SMN-12-8	12	18	8.0	64.0	18
40-75	1,000	700	SMN-18-8	18	26	11.25	90.0	26
50-90	1,800	1,200	SMN-22-8	22	30	13.5	108.0	30
70-120	3,400	2,300	SMN-27-8	27	35	16.5	132.0	35
80-140	6,200	4,000	SMN-33-8	33	42	20.0	160.0	42
100-180	11,000	7,400	SMN-40-8	40	50	24.0	192.0	50
Tolerances (category/mm):				-	f7	0/-0.1	0/-0.8	H7

For other O.D., larger and smaller sizes, please contact StaMixCo. Dimensions are approximate

***Table #2**: Budget Sizing to Determine Correct Mixing Nozzle Size for Your Application*

SMN Mixing Nozzle Model Number	**Technique ① Clamping Force Method (tons)**	**Technique ② Screw Size Method (mm)**	**Technique ③ Injection Flow Rate Method**	
			Low Viscosity Polymer (cm^3/s)	**High Viscosity Polymer (cm^3/s)**
SMN-12-8	Up to 120 tons	20 - 50	300	200
SMN-18-8	Up to 450 tons	40 - 75	1,000	700
SMN-22-8	Up to 800 tons	50 - 90	1,800	1,200
SMN-27-8	Up to 1,100 tons	70 - 120	3,400	2,300
SMN-33-8	Up to 1,500 tons	80 - 140	6,200	4,000
SMN-40-8	Up to 2,000 tons	100 - 180	11,000	7,400
SMN-52S-8	For Very Large Machines or Very Viscous Polymers such as PET			

D) Basic Housing Design and Installation of the Mixing Elements:

Complete Nozzle Purchased from StaMixCo

If a complete mixing nozzle with housing, heater bands and thermocouple probe was purchased from StaMixCo, the remainder of this Section D) may be skipped.

Customer Supplies Nozzle Body to fit StaMixCo Mixing Elements

If customer decides to purchase only the mixing element assembly from StaMixCo and manufacture their own nozzle, the following design considerations are important:

Nozzle Body Construction:
The two principle methods of installing SMN mixing elements into a nozzle are shown in Figure #9.

- Tight Installation Method
  Installation of the mixing elements into the nozzle body with a narrow gap between the O.D. of the mixing elements and the I.D. of the nozzle body.

- Floating Installation Method
  Installation of the mixing elements into the nozzle body where there is a small gap between the mixing element O.D and the nozzle body I.D. which in operation is filled with polymer.

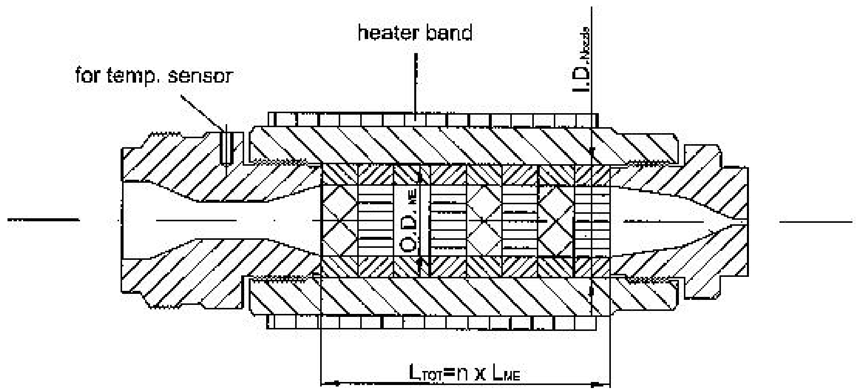
StaMixCo prefers the Floating Installation Method which has been put into practice in thousands of installations. Figure #9 shows the basic design and principle methods of installing SMN mixing elements into a nozzle. This information is based on experience, but more importantly, the methods are based on an FEA (finite element analysis method) study conducted at the University of Winterthur ZHW, Switzerland in April – July 2004. If a complete mixing nozzle was supplied by StaMixCo, the Floating Installation Method was used.

Temperature Sensor:
Each nozzle must be equipped with a temperature sensor to control nozzle heater band operation on a dedicated circuit. This is required to assure heat is supplied to the nozzle to prevent possible damage of the mixing elements during start-up and operation. For thermocouple sensor installation and operation, follow the instructions of the thermocouple supplier.

Heater Bands:
The mixing nozzle body must be heated on the outside surface. The recommended heating capacity is 4 to 5 W/cm^2 of heated surface. Installation and operation of the heater band should be made in accordance to the supplier's instructions.

Assurance of good tight contact between the heater band and nozzle body should be verified before and after the first heat-up. Once in operation, continued good contact between heater band and nozzle body should be checked periodically.

Tight installation of Mixing Elements into Nozzle Bore

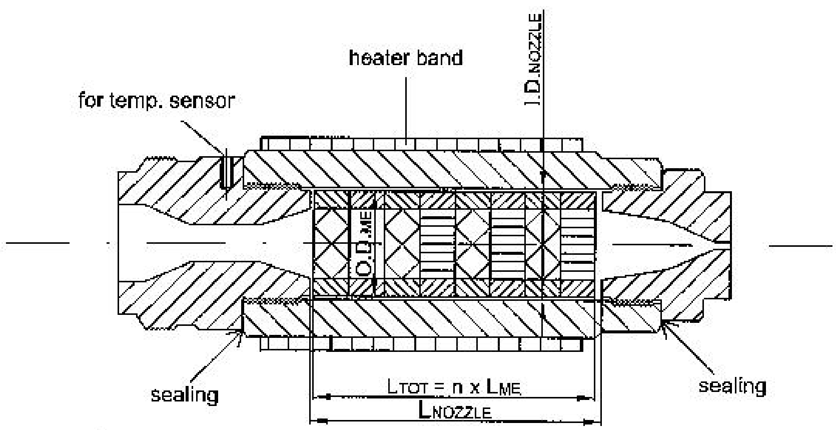


Tolerances:

$I.D._{NOZZLE}$	F7	or	H6
$O.D._{ME}$	h6		g6

$L_{NOZZLE} = L_{TOT}$

"Floating" installation of Mixing Elements into Nozzle Bore



$I.D._{NOZZLE} = O.D._{ME} + 0.2 - 0.3$ mm

$L_{NOZZLE} = L_{TOT} + 0.3 - 0.5$ mm

Figure #9: *Principle Methods of Installing SMN Mixing Elements into a Nozzle Body. Shown in top sketch is the "Tight Installation Method" . Shown in bottom sketch is the preferred "Floating Installation Method".*

E) <u>Payback Calculations for Static Mixing Nozzle</u>:

The StaMixCo SMN Injection Molding Static Mixing Nozzle can pay for itself in a matter of weeks, if not days, depending on the size of your output.

A customer case history payback period calculation is shown below. It is conservative in that the calculated is based only on savings realized in reduced colorant usage and the resulting cost savings. The below case history pay-back calculation makes no provisions for additional savings in reduced reject rates due to poor color mixing, rapid color changes, or other process benefits such as increased use of regrind, improved cycle time, lower part weight and less part weight variation (cavity-to-cavity), closer tolerance parts, reduction of fill and cool times, etc. To take into account these other costs savings, which can be significant, follow the below calculation methodology for each process improvement component cost savings you desire to calculate.

The general formulas used for the calculations are shown in Table #5 where the definitions of the variables are shown in Table #6.

In the customer case history installation that is analyzed below, Table #3 captures the raw data regarding SMN Mixing Nozzle cost, shot size - cycle time, production hours/day and colorant usage before and after mixing nozzle installation. Table #4 calculates the actual savings achieved per shot, per hour and per day. A summary of the pay-back period analysis is as follows:

Summary of Case History Pay-Back analysis calculations as referenced in Table #3 and #4 is as follows:

- Estimated % Reduction in Colorant used: 25%
- Cost of Nozzle: $2,590
- Savings per Day: $105.65
- **Pay-Back Period: 24.5 Days**

Table #3: *Case History example of data used in Pay-Back Calculations (Equipment Cost, Production Rate, Colorant Data)*

NOZZLE & PRODUCTION DATA	
Stamixco Nozzle Used	SMN-27-8
Cost of Nozzle	$2,590
Production Hours Per Day	24
Total Shot Weight	2,250 grams
Total Cycle Time	72 seconds

COLORANT DATA	
Colorant Material Cost	$2.85/pound
Original % Colorant Used	2.5%
Original Colorant Costs per shot	$0.352
New % Colorant Used	1.875
New Colorant Cost per shot	$0.264

Table #4: *Case History example of actual savings achieved in Reduced Colorant Costs*

ACTUAL SAVINGS ACHIEVED IN REDUCED COLORANT COSTS	
Savings Per Shot ($\mathbf{V_1}$)	8.765 cents
Savings Per Hour ($\mathbf{V_2}$)	$4.38
Savings Per Day ($\mathbf{V_3}$)	$105.65

The general formulas used for pay-back calculations are shown in Table #5 and #6.

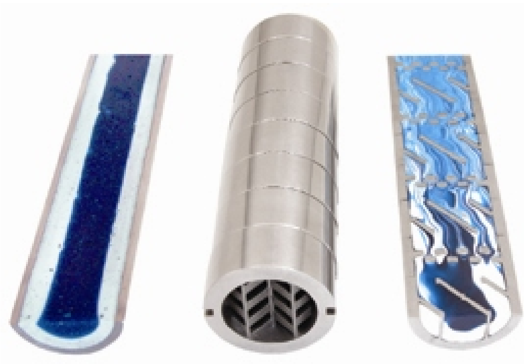
Table #5: *General formulas for pay-back calculations*

Definition	Variable	Formula
Savings per Shot ($ Savings/Shot)	V_1	$V_1 = \frac{(C) \times (F) \times (E) \times (G)}{4{,}454{,}000}$
Savings per Hour ($ Savings/Hr.)	V_2	$V_2 = (V_1) \times \frac{(3{,}600)}{D}$
Savings per Day ($ Savings/Day)	V_3	$V_3 = (V_2) \times (B)$
Mixer Pay-Back Period (Days)	**PBP**	$PBP = \frac{A}{V_3}$

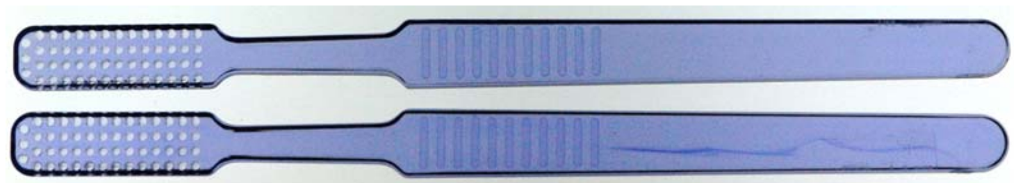
Table #6: *Definition of Variables in general formulas used in pay-back calculations*

VARIABLE USED IN PAY-BACK CALCULATIONS	UNITS	VARIABLE DESCRIPTION
A	$	Cost of SMN Mixing Nozzle
B	Hours/Day	Operating hours per day
C	grams	Shot Weight
D	sec	Total Cycle Time
E	$/lb	Cost of Colorant
F	%	% Colorant Used in Part prior to SMN Mixing Nozzle Installation (e.g., 2.3%)
G	%	Estimated % Reduction in Colorant Used as a Result of Installation of SMN Mixing Nozzle (usually 10% - 40%)

NOTES FOR YOUR PERSONAL INSTALLATION PAY-BACK CALCULATIONS:









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