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# SECTION C: THEORY OF OPERATION

There are two “modes” of operation used with Fishertech Injected Metal Assembly equipment: either with or without a sprue. These modes of operation are referred to as Sprue and Sprueless operation. A look at the machine sequence for each mode of operation will help to understand how Fishertech equipment operates.

The operating sequence is controlled by the Programmable Logic Controller. The time chart provides the details for the control sequence programmed into the controller. This should be used in conjunction with the machine’s connection diagram to obtain a complete understanding of the operating sequence.

Timer settings will be varied as required to suit each tool. Generally, different tools may be used in the system with the given operating sequence.

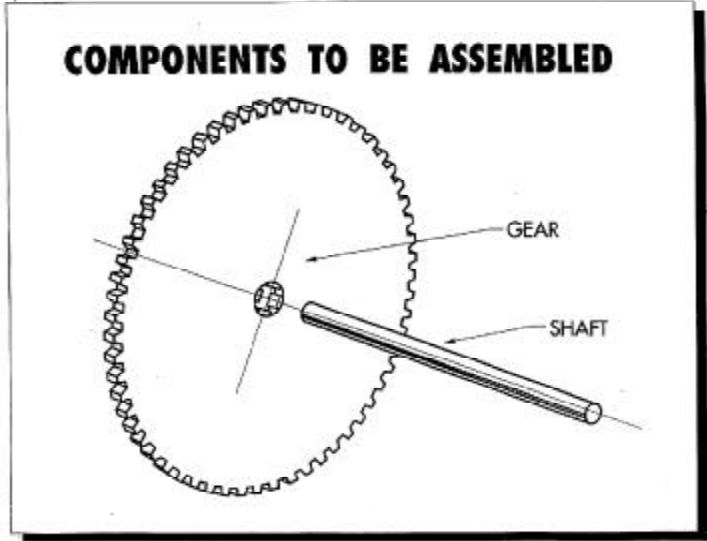


***The programmed operating sequence incorporates features which provide for the safe operation of the system. Under no circumstances should the program be altered or changed in any way. The program has been written to maximize the efficiency of the equipment and safety of the operator. Altering the program, in even the smallest manner, could jeopardize the efficiency and safety of the equipment.***

***Fisher Gauge Limited cannot accept responsibility for damage or injury resulting from changes to the programmed operating sequence.***

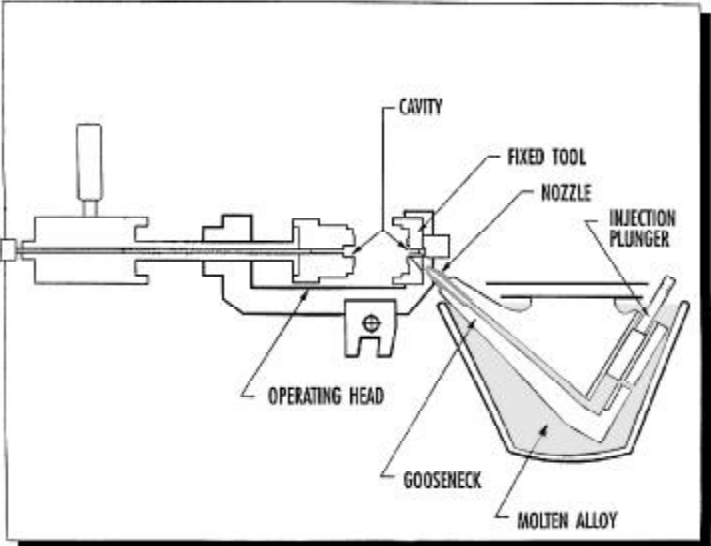
## Sprue type operation

The operating sequence varies according to the nature of the assembly. The following description is for a basic assembly sequence. However, the theory applies to virtually all operating sequences.

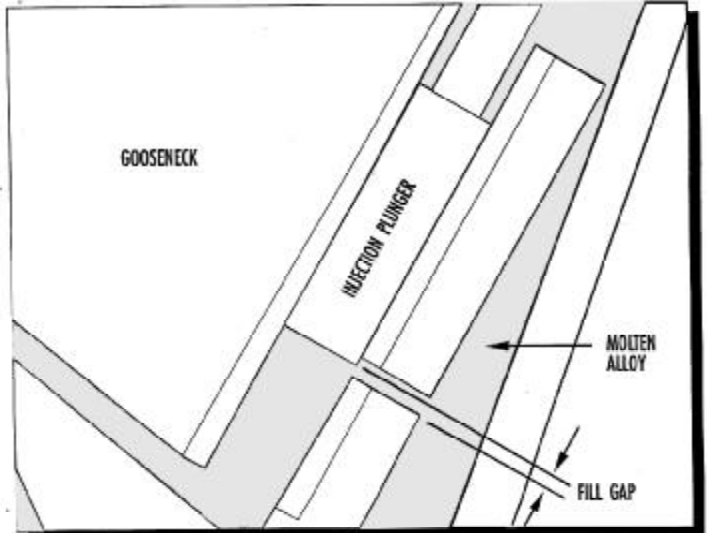


This illustration shows a shaft and gear to be joined by the Injected Metal Assembly process. Note the shape of the hole through the gear. This shape prevents the gear from rotating on the shaft after the components have been assembled. The shaft could be knurled for the same reason.

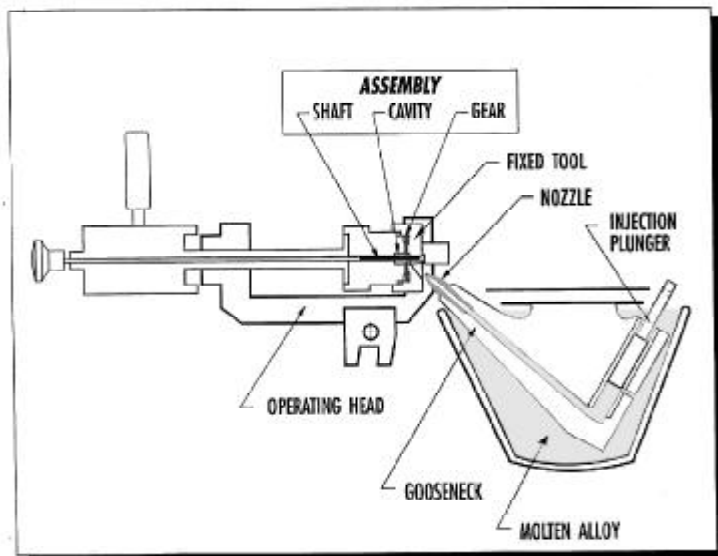
This illustration shows the injection unit and the operating head. The operating head holds the tooling. The fixed tool is bolted to the operating head frame and the movable tool bolts to the end of the main slide. The cavity can be seen in both the movable and fixed halves of the tool.



The injection plunger is shown in the retracted position.

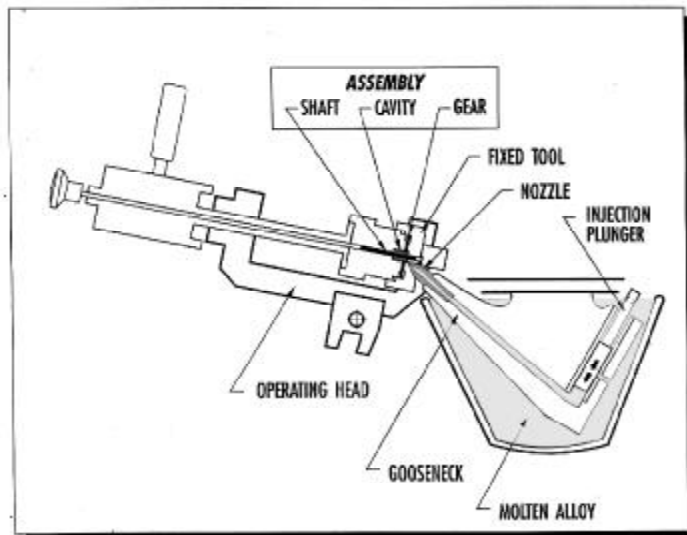


This shows a close up look at the fill gap. The fill gap should be at 1 mm (.04 inches).



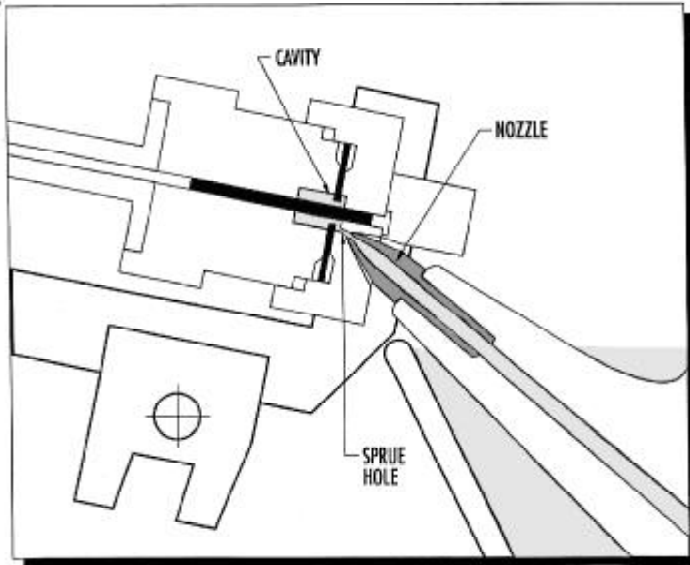
This illustration shows the parts loaded into the tooling and the operating head closed and locked. In the locked position, the Head Closed switch closes. If the machine is in Auto mode, the cycle would start at this point. In Manual mode, the Cycle Start button would have to be depressed. In addition to the Head Closed switch, a Part-In-Place switch can be added to inhibit cycling if no shaft was loaded. If the gear was not loaded in this example, the Head Closed switch would “over-travel” and the machine would not cycle.

The operating head/tool combination has advanced onto the nozzle as shown in this illustration. The moving mechanism provides the motive force to advance the operating head and tooling. Once fully advanced, a second switch closes - the Moving Mechanism Advanced limit switch. In the event of an obstruction of some sort on the nozzle, the moving mechanism would not advance fully and the cycle would stop.



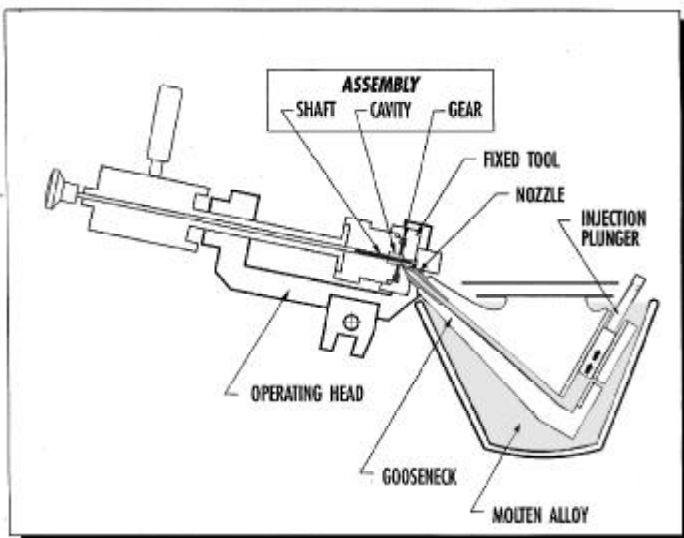
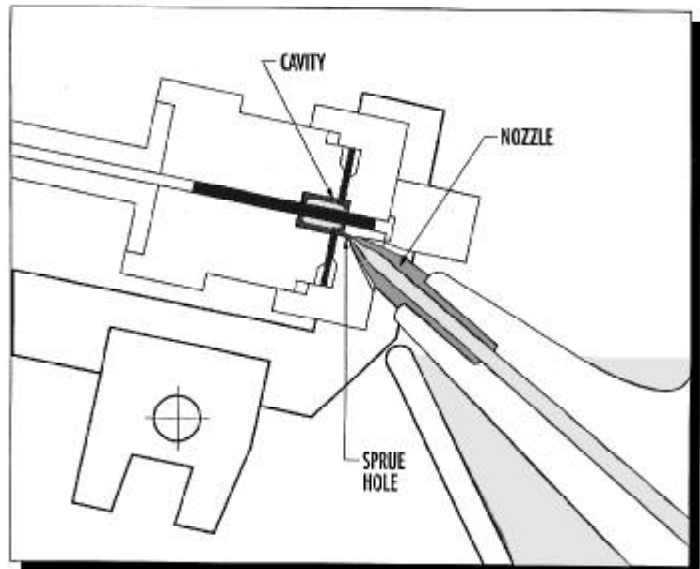
When the Moving Mechanism Advanced switch has closed, the conditions are correct for an injection to take place and the plunger advances. The fill gap, being very small, is immediately sealed off by the advancing plunger. Molten alloy is rapidly pumped into the cavity. Typically, the plunger advances for only 0.10 - 0.15 seconds. This time is called the injection time and it can be adjusted to suit a wide variety of assemblies.

Note: It is imperative that the alignment of the nozzle seat and the nozzle tip be such that when the operating head/tool advances onto the nozzle, the nozzle tip and nozzle seat create a perfect seal between them. This is necessary to prevent the escape of molten alloy between the nozzle tip and nozzle seat during injection. If the alignment between the nozzle tip and the nozzle seat is not perfect, the operation of the system could be adversely affected. This condition could be dangerous to the operator.

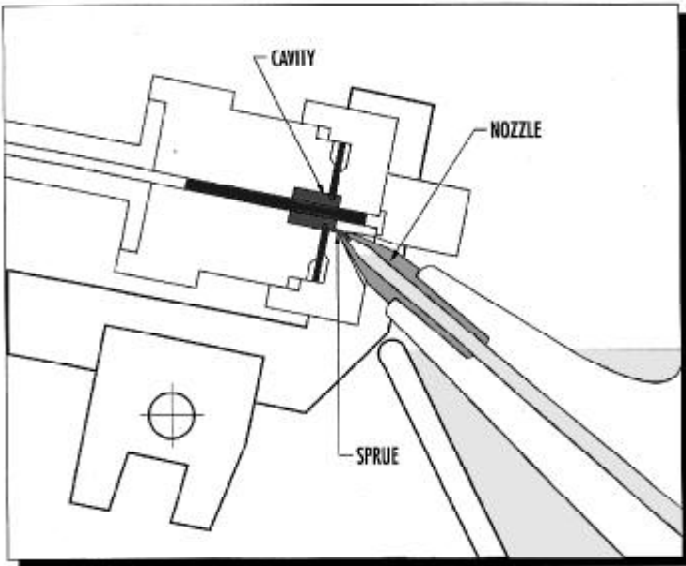


The alloy in the cavity freezes almost instantaneously. However, for a very brief moment, the alloy is molten as seen in this illustration. When the cavity is full, the injection plunger will “dead head”.

The alloy freezes from the outside of the cavity towards the center. This illustration shows the outside of the cavity already solidified. Note the alloy has solidified down the sprue hole and slightly into the nozzle.



At this point it is safe to retract the plunger without fear of sucking molten alloy back out of the cavity. Correct sprue formation is vital to proper machine operation and assembly integrity. If the plunger is retracted before the sprue has formed, the alloy will be drawn back out of the cavity. A defect like this can be seen clearly as a small pin hole where the sprue was sheared.

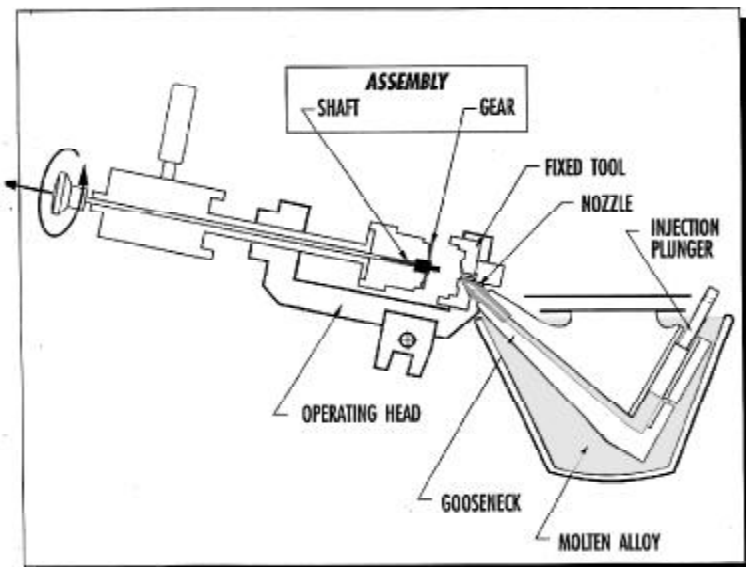


To this point in the cycle, the operating head/tool combination are advanced. One timer has timed out - the injection time. This illustration shows the tooling still on the nozzle and a column of molten alloy sitting in the nozzle, above the alloy level in the melt pot. A small amount of air was sucked into the nozzle when the plunger retracted. The fill gap is open now and the only thing holding this column of alloy above the melt pot is the sprue plugging the nozzle.

Note: This “injection time” should be set as short as possible while permitting the system to operate effectively. Too little time will result in:

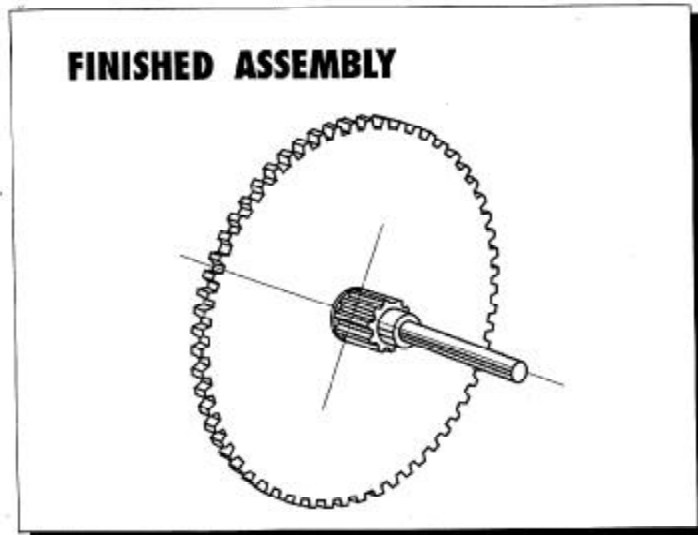
- a) an incomplete or hollow hub because the molten alloy will be sucked out of the cavity if the sprue is not completely solidified when the injection plunger retracts.
- b) the sprue remaining in the sprue hole between cycles, resulting in a plugged sprue hole. This occurs because the sprue was not allowed to solidify far enough into the nozzle. As a result, the solidified sprue remained in the sprue hole instead of on the tip of the nozzle.

Too much time will result in an excessively slow melt back of the sprue into the nozzle between cycles, reducing the productivity of the system.



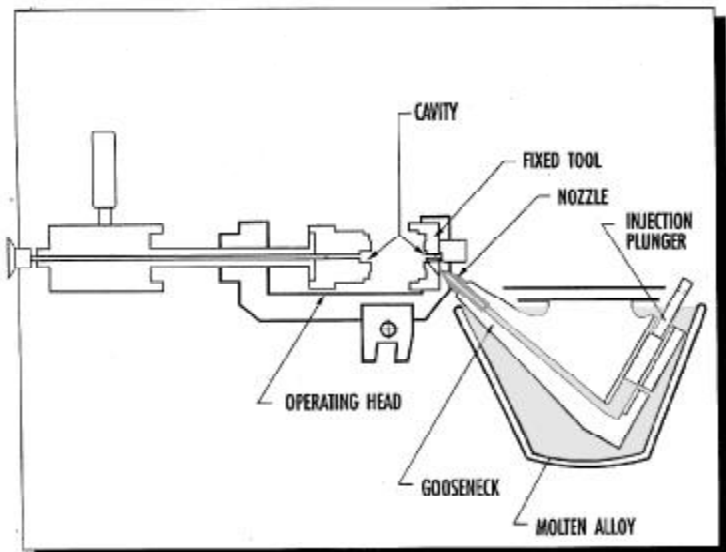
A second timer starts when the injection time is complete. This timer allows the alloy in the cavity to solidify completely before the operating head unlocks.. The operating head begins to unlock and shear the sprue when this timer has timed-out. The operating head can be seen opened in this illustration.

Note: This solidification time should be set as short as possible while permitting the system to operate effectively. Too little time will result in molten alloy escaping from the cavity when the tool is unlocked, creating an ineffective and unsightly hub. Too much time will result in slow sprue melt back, reducing the productivity of the system.

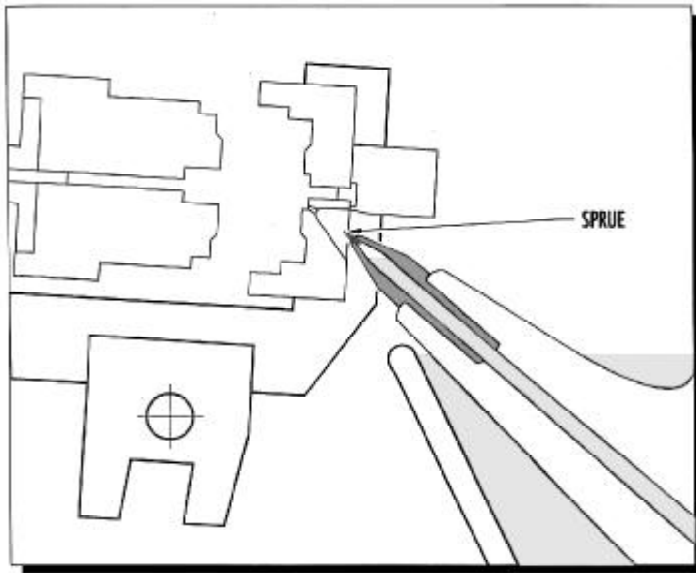


The movable tool cavity is usually configured to hold the cast hub during the unlock and sprue shear motion. In this example, a pinion gear shape is in the movable tool. The pinion gear forces the assembly to rotate with the operating head, thus shearing the sprue. The finished assembly can be seen here.

A third timer starts timing when the operating head starts to unlock. This delay ensures the operating head has unlocked completely and the sprue has sheared before the moving mechanism retracts. When the third timer has timed out, the moving mechanism retracts as shown here.

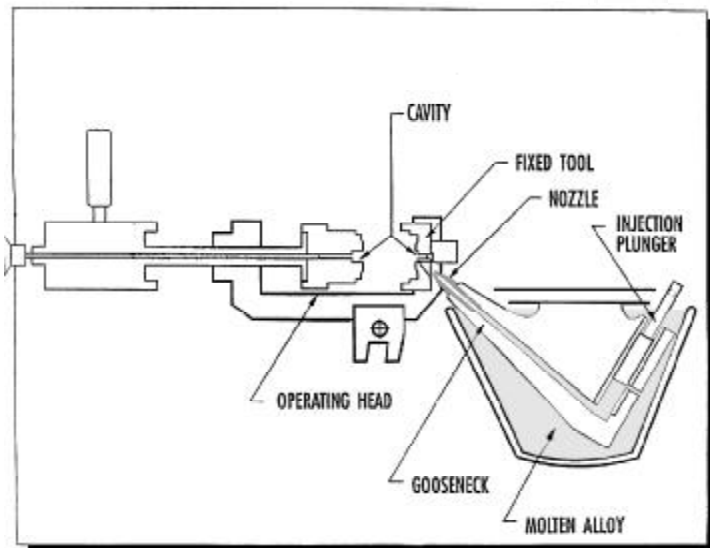
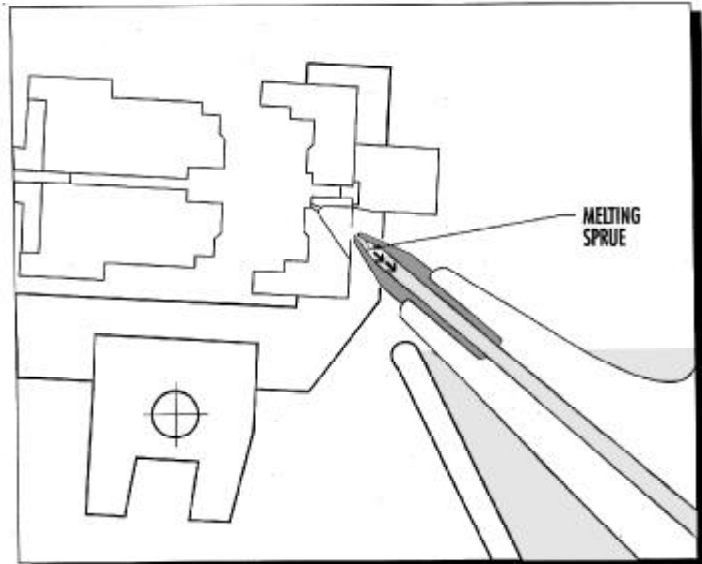


Note: It is vital that the sprue be sheared from the injected metal hub on the assembly before the operating head/tool is retracted from the nozzle. This ensures that the sprue stays on the nozzle tip and not in the sprue hole. This delay before the moving mechanism retracts should be set as short as possible while permitting the system to operate effectively. Too little time may result in the sprue sticking in the sprue hole. Too much time will result in slow sprue melt back, reducing the productivity of the system.



The assembly has also been ejected by this time. The sprue is still sitting on the end of the nozzle as seen here.

Heat from the melt pot and additional heat from the nozzle heater melts the sprue. When the sprue becomes molten, the column of alloy above the alloy level in the melt pot draws the sprue down the nozzle and the sprue is “melted back”. This typically takes 1-2 seconds after the moving mechanism has retracted. This illustration shows the sprue melting back.



This illustration shows the system at rest ready for parts to be loaded for the next cycle.

Note: The longer the operating head /tool combination is in contact with the nozzle, the more time it will take to reheat the nozzle sufficiently to melt the sprue. Subsequent assemblies cannot be produced until the previous sprue has melted back into the nozzle.

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## Sprueless type operation

Sprueless type operation was developed for the Cable Processor Module to solve a particular problem with cable manufacturers who use coated cable. Many Fishertech (cable termination) customers use plastic coated cable and must cast the cable termination onto, or very close to, the coating. Through research and development, Fishertech found that if the tooling was held closed for a longer time period, the coating had sufficient time to cool after the injection of the molten alloy. This prevented the molten coating from “spilling” out of the tooling when the tooling was opened. The sprue type operation did not allow the tooling to be held closed for any length of time or the sprue melt back became very slow - effecting the cycle rate.

During the sprueless cycle, the part is cast and then there is the normal freeze time. The moving mechanism then retracts with the tooling still closed and the part still in the cavity. The tooling can be held closed for any length of time without influencing the nozzle temperature. This was not possible with the sprue type operation. After the preselected time period, the tooling opens and the part is ejected. There is no sprue to melt back into the nozzle.

Virtually all “assembly” machines use the sprue type operation. Some cable terminations are made on sprue type machines. Any cable termination made on a Cable Processor style operating head uses the sprueless type operation.

## Nozzle heat balance

There are many factors which affect the nozzle temperature, the formation of the sprue and the sprue melt back.

1. Melt pot temperature

The majority of the heat required to melt the sprue is conducted up the gooseneck and nozzle from the melt pot. If the melt pot temperature is set too low, the sprue will take longer to melt back.

2. Nozzle torch temperature

The flame should be adjusted so that a soft, blue flame envelopes the nozzle. If the flame is set too hot, the nozzle can be damaged. If the flame is too cool, the sprue melt back will be slow.

3. On nozzle time

From the time the Moving Mechanism Advanced switch closes until the third timer times out, the tool is in contact with the nozzle. The tool is relatively cool, and the nozzle is hot. Once in contact with one another, the nozzle will cool down and the tool will warm up. The longer the tool sits on the nozzle, the cooler it will become. The cooler the nozzle becomes, the longer it will take to warm up enough to melt



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the sprue, and sprue melt back will be slow. Likewise, if the tool is not on the nozzle long enough, the nozzle will not be cooled sufficiently for a sprue to form. This usually results in alloy being drawn back out of the cavity or “suck-back”.

**4. Cycle time or rate**

The longer the delay between cycles, the warmer the nozzle can get before the next cycle starts. This will cause the sprue to melt back faster. In this case, the “on nozzle” time can be longer, as the nozzle has sufficient time to warm up between cycles. Fast sprue melt back is less important. If the cycle rate is very fast, the nozzle would have less time to warm up between cycles. The “on nozzle” time should be as short as possible in this case.

**5. Ambient conditions**

The ambient conditions in a factory will affect the sprue melt back. In summer when the windows and doors are usually open and fans are on, the sprue melt back can become slow. The flame must not be blown around, (or blown out), by fans or breezes. Portable barriers can be erected if required.

**6. Tool cooling**

All Fishertech zinc type tooling has water cooling in both the fixed tool and the movable tool. The coolant must be of consistent temperature and flow rate for consistent sprue melt back.

