Diagnosing the LFM / Injector Pair

General

The following write up discusses the problems of isolating the defective or faulty device in an LFM / Injector pair. The STEC HORIBA LFMs and injectors are the focus of this write up since the majority of LFMs and injectors are sold to AMAT which has dominated the liquid semiconductor equipment market. Other liquid devices and systems will be discussed in later white papers.

Liquid Flow Technology, Inc has certified and rebuilt over 1000 STEC HORIBA injectors in the last 2 years. It has the combined expertise to reverse engineer and understand the OEM design. The understanding of the operation of these specific devices has required the team to not only determine the design sense of the devices but also to determine the needs and problems of its clients. End users who have struggled with liquid and vapor flow control trying to maintain the production line for as long as possible without downtime. This has not been a success story for the most part and we are here to support those frustrated line maintenance technicians with solutions. Sometimes there are issues only specific to a peculiar machine and with the right communication with end user we can solve those problems as expeditiously as possible.

Operation

The LFM is the most deceiving of the LFM /Injector pair. The LFM is typically determined to be at fault if there is any kind of flow issue. This is not the case. It is almost always the injector.

The following figure illustrates a simplified liquid setup and is similar to the setup that LFT uses for most of the vaporization curves in later discussions. Note that the LFM / Injector pair is comprised of the STEC HORIBA devices that are most familiar in the fabs for AMAT equipment. There may be variations in the configuration such as distance between the LFM and Injector, heating blankets and of course mounting attitude. Some of the device may even be the MV/MI injector STEC HORIBA series, or the VC/VS vaporizer STEC HORIBA series but the basic operation of the configuration is very similar.

The AMAT IV2410AV series is the most commom in the fabs because they were the original STEC HORIBA injectors in all AMAT equipment, therefore these will be the point of focus in this write up.

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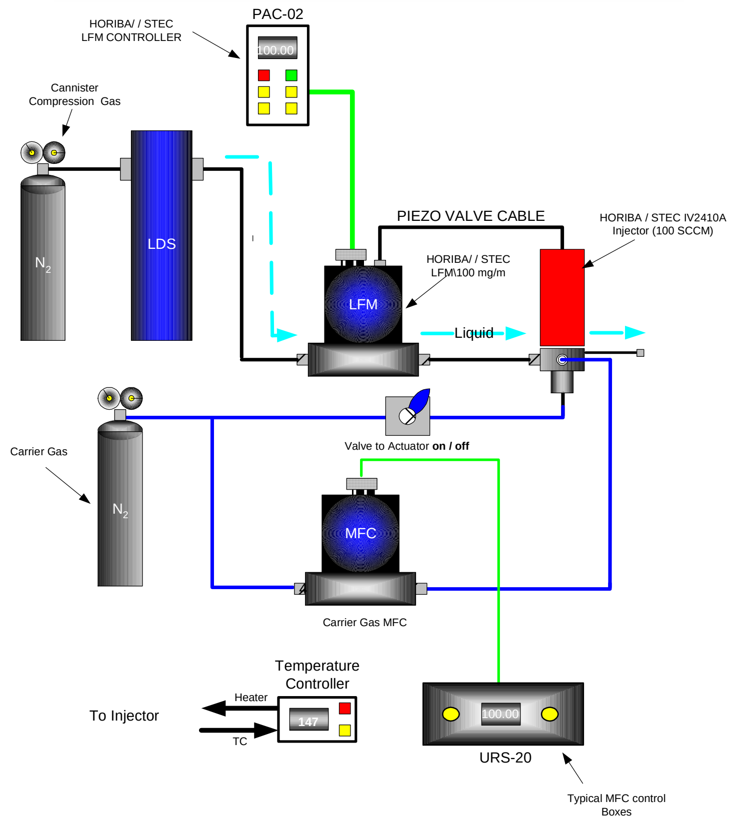

Typical Liquid Setup
Simplified

The injector is a mechanical device, while the LFM is not, and therefore the injector is naturally more prone to failures. The operation and function of the LFM in the pair is as follows:

Liquid control at non-vapor temperatures

1. The LFM measures the flow through the Sensor.
2. The flow output signal (0-5 Volts) is measured and accessed at the LFM connector
3. The flow output voltage is compared to the setpoint voltage set by the system or user. The setpoint and flow output voltage is then compared and an error voltage is generated
4. The error voltage is then conditioned to a injector valve output voltage (a cable from the LFM to the Injector)
5. The valve opens or closes and controls the flow until the error voltage nulls (setpoint / output voltage equal)
6. The valve stops and the LFM /Injector pair maintains the flow until a different setpoint is applied to the LFM.

NOTE

There is no electrical feedback from the injector. The LFM is merely comparing the flow against the setpoint which is all calculated by the LFM based on the flow measurement.

The above operation of the LFM relative to the injector is what happens when the process liquid is not heated or at non-vapor producing temperatures. The vapor operation and function of the injector in the pair is as follows:

Liquid control at vapor temperatures

1. The process liquid enters the liquid inlet of the injector
2. The process liquid is heated by the injector into a vapor when the injector is set to the vapor temperature
3. The vapor instantly increases the pressure inside the injector mixing chamber shooting the valve open for a short time then closing and returning to the set flow rate
4. The vapor is sent to the chamber in bursts every time the liquid hits the mixing chamber at vaporization temperatures.

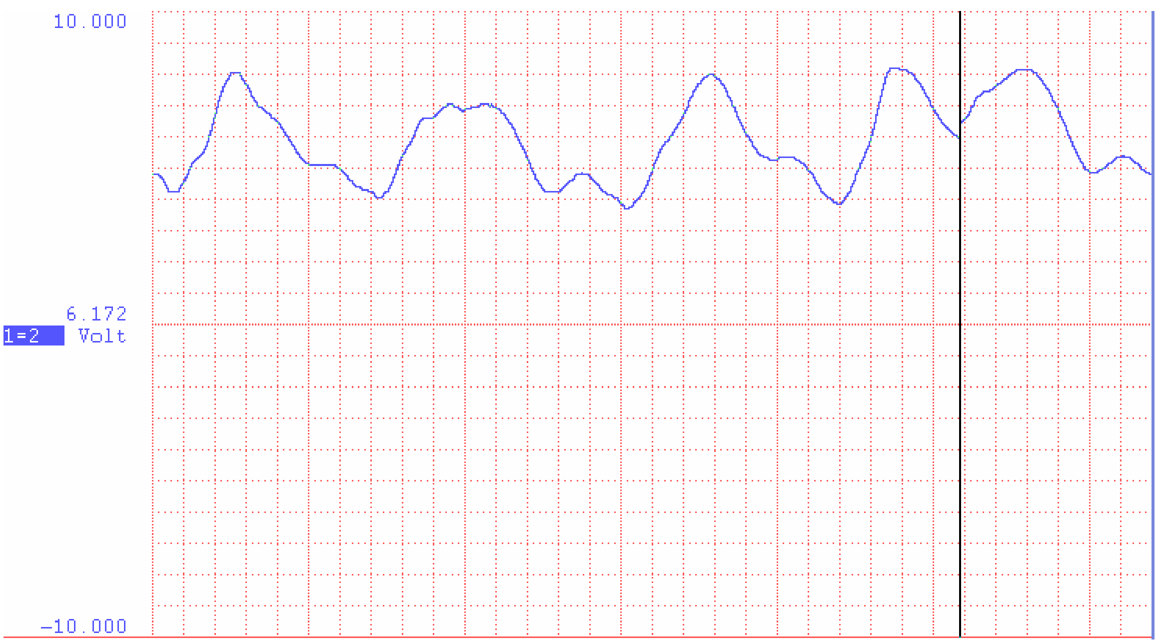

Figure 1
Erratic Vaporization Cycles – Poor Valve Response, needs Gain and Phase Adjustment

Figure 2
Uniform Vaporization Cycles – Good Valve Response, Gain and Phase Adjustment

<u>Common Symptoms Pointing to the Injector</u>

The following is a list of common faults to better understand what to look for when troubleshooting the LFM / Injector pair. These items are catastrophic and do not require any special test equipment. The symptoms are easily detected by the technician.

Table 1

Symptom	Faulty Device	Probable Cause
1. NO flow	Injector LFM	Some Clogging Control Voltage HIGH
2. MAX flow	Injector Injector LFM	Piezo valve adjustment Massive Clogging Control Voltage Missing
3. LOW FLOW	Injector LFM	Some Clogging PCB
4. Flow drops/drifts after short term usage	Injector	Some Clogging
5. Unsteady fluctuating flow readings	Injector LFM	Some Clogging PCB
6. Temperature control loss	Injector	Thermocouple
7. No heat	Injector	Pin Heater
8. Overheat	Injector	Thermocouple
9. No Heat and Max Flow	Injector	Thermo switch

Most flow faults are a result clogging in the injector vapor chamber. The injector vapor chamber is comprised of the block and a valve plate. The valve plate is depressed by the piezo and moves either toward the liquid entrance to the vapor chamber or away from it dependant upon the selected the setpoint. The injector is NORMALLY OPEN until it is connected to the LFM by the valve control cable.

Common Causes of Clogging

Teflon Breakdown

Process Chemical Build-up

The Teflon surface is only coated on the upper wetted area of the vapor chamber. The valve diaphragm is located in the center of this part and serves as the valve mechanism by moving closer or away from the liquid entrance at the block. This diaphragm is positioned by a piezo valve that applies pressure to a ruby bead rested on the upper dry portion of the diaphragm. The piezo valve providing even and reinforced pressure to the dry side of the diaphragm. The LFM applies a high voltage to the piezo valve which changes or bends the piezo valve material respective to the valve voltage.

This Teflon area is a uniform coat which can withstand the high temperatures of 150 degrees Celsius and it resists the buildup on and around the diaphragm. Unfortunately, like any other Teflon material, it does wear down and eventually peels from the stainless steel surface. The process liquid adheres more and more to the stainless steel surface as more and more is exposed from the teflon breakdown. Finally, the buildup of process material is so great that the injector begins to shutdown after a short time. The time is completely unpredictable but it can be monitored to provide an advance alarm system while IN-SITU. A brief description of method used by Liquid Flow Technology, Inc will be discussed later in this write-up

Teflon Flakes and Powder

The Teflon, while breaking down and exposing more stainless steel for the process chemicals to build up, also begins to flake or granulate. This increase of loose particles in the small volume in the injector vapor chamber also plays a major part in reducing the flow by covering the holes as the Teflon breakdown continues. The teflon flakes also decrease the already small volume of the vapor chamber. This volume decrease changes how the vaporization cycles respond therefore changing pulsed vapor output to the process chamber.

The slow increase in the build up of the process chemical and the increasing number of teflon flakes and granules finally will shutdown the flow and therefore the injector.

NOTE
WEAR IS INEVITABLE !

Inside the Vapor Chamber Section

The following figure illustrates the components of the injector less the actuator found in some of the STEC HORIBA devices. The actuator is designed to provide positive shutoff to the liquid path. The seal is not shown and the bolts are shown loosened to better see inside the vapor area. The control voltage to the piezo valve is generated at the LFM and connects directly to the injector. The piezo is contorted by the control voltage which in turn depress the ruby bead. The pressure from the ruby bead then applies centralized pressure to the Teflon coated diaphragm which covers the liquid feed to the vapor chamber when it is closed and moves away from the liquid feed when it is opened. The liquid can be mixed with a carrier gas at the chamber which provides higher flows to the process chamber.

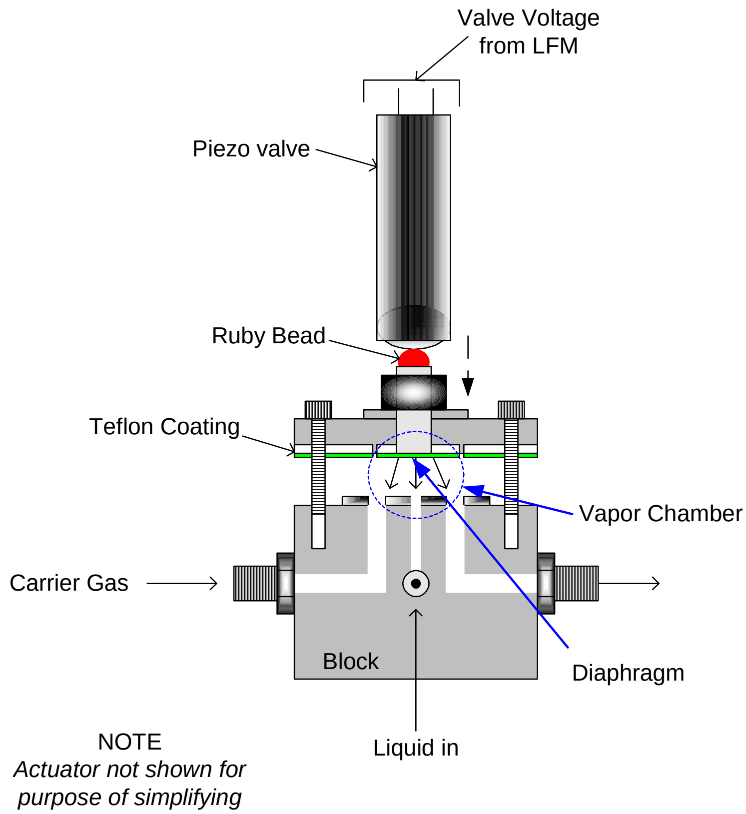

Figure 2 – Illustrated vapor chamber section of the Injector block

The next set of photos at magnification show the difference between a clean Teflon Surface and a dirty one. It also shows the same for the lower stainless steel at the block and liquid feed.

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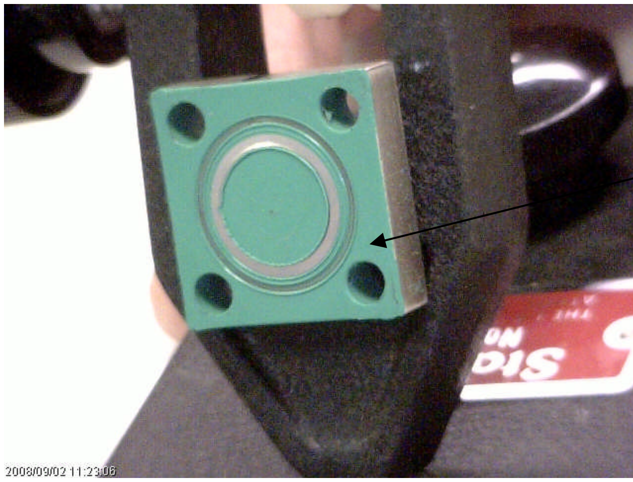
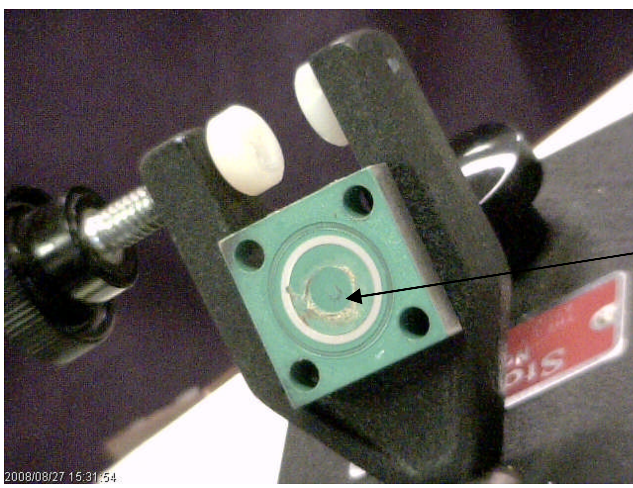
Clean Teflon Surface



Smooth unblemished Teflon coating

Dirty Teflon Surface #1



Teflon lifted exposing stainless steel

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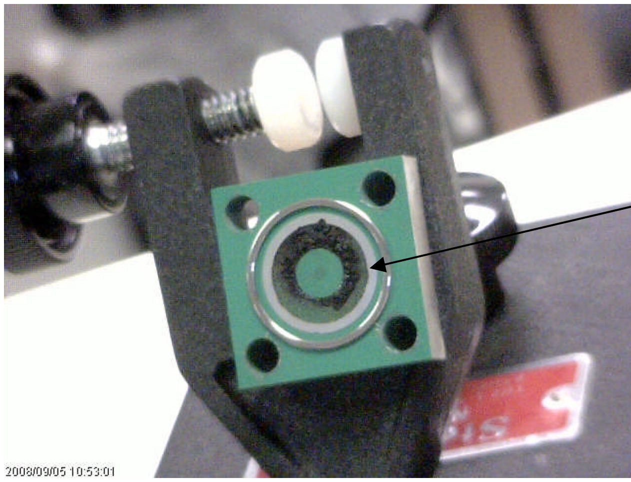
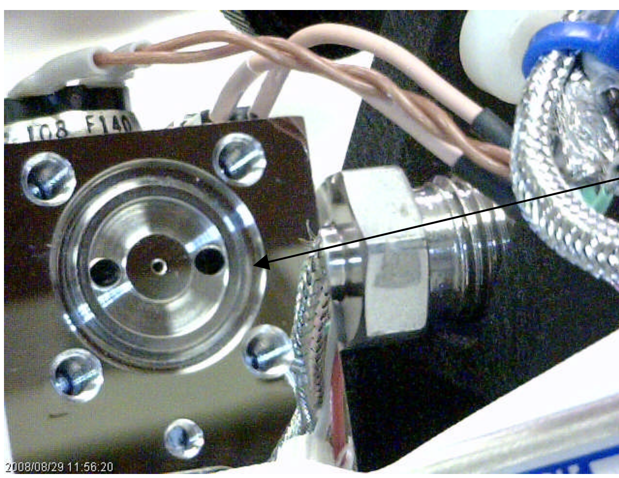
Dirty Teflon Surface #2



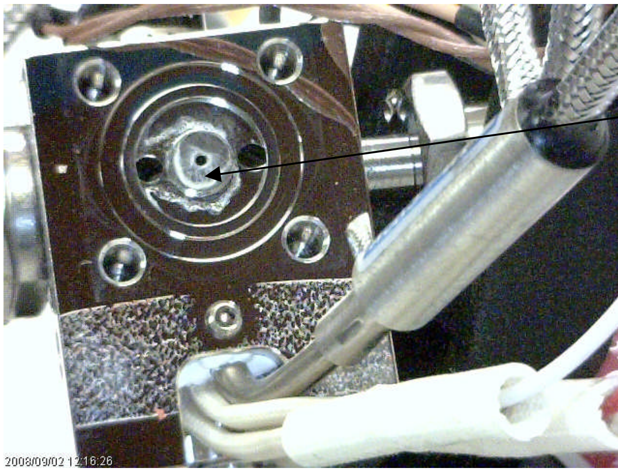
Process chemical build up

Clean Injector Block



The stainless steel surface is clean

Dirty Injector Block



The stainless steel surface

Phase and Gain Adjustments

The Phase and Gain adjustments are the means to fine tune the response of the injector cold or hot. These adjustments are made originally at the calibration site by optimizing them at the center position by adjusting the piezo valve (not recommended at the tool). These adjustments go hand in hand in order to better adjust for the PID in the loop. This loop is critical to maintain a stable flow for vapor cycle. The adjustments are located at the LFM, typically on the side panel with openings to tweak the potentiometers to the optimum setting. This is sometimes difficult because they are not always accessible. If they are accessible, it is still a difficult task because the adjustment cannot be made effectively without the proper test instrument. We have developed a portable instrument to aid with this adjustment and it will be discussed later in this write up. Some line maintenance technicians have tried to make these adjustments to provide the proper step response while either in the cold or the hot cycle by simply listening to valve audible variations. This has not been very successful, but it does indicate the need for such a tool.

In most cases, the adjustment of the Phase and Gain can help, but there are times when the injector is past the ability to perform within an optimal PID loop. When this occurs, the technician should analyze the symptoms and determine whether the faulty device is the LFM or the injector. Refer to Table 1. The bad device is then sent out for LFM calibration or injector re-certification and when it returns it is installed and should work 100% of the time at optimal vaporization. This sounds good and well but it doesn't always work that way. The probably of success is higher if the faulty device is replaced with a new one but the cost of new injectors and LFMs is relatively high and would require a budgeting consideration. The rebuilt version of the injector is about one-quarter of the cost of a new one. Sounds attractive, but the probability of a random LFM or injector replaced in the pair does not guarantee optimal operation and sometimes they work for a short time and other times not at all from installation. Once again, as mention earlier in this write up, there are several issues to consider.

Pairing the LFM and Injector

Liquid Flow offers several options which all have there good and bad side. Ultimately the ideal option for most fabs is to remove move both the LFM and Injector and send both in to the service center for pairing. Pairing these devices provides much more than just calibration or re-certification. The LFM and the Injector are dynamically operated after the LFM is calibrated and the injector is rebuilt. They can be adjusted for the temperatures, flows of the specific process used by the end user. The PID loop is then adjusted for optimum vaporization. When the end user receives the pair, they would be packaged in one box under one work order and with a pairing number. This way you would never lose track of either if the are accidentally separated. The cost is higher but typically when most fabs have a problem with either, they send both for service but not necessary keep them in pairs when they are returned and installed.

Liquid Flow Technology, Inc. feels from its experience that the pairing eliminates the need to do any adjustments or part jockeying.

Portable Liquid Injector Analyzer

The PLIA-200, Portable Liquid Injector Analyzer, is for true hand-held operation. All of it's the functions are preset for the STEC IV2410AV and Lintec VU series style injectors. An RS232 interface included for PC connectivity.

The PLIA -200 connects piggy back between the 8-pin connector from the tool and the 8-pin connector on the liquid flow meter. The handheld PLIA-200 analyzer starts operating and the display immediately shows the flow output of the LFM without setting up a single parameter.

The following is a list of the compatible injectors and LFMs that the PLIA – 200 was designed to troubleshoot.

NOTE

Injectors and LFM Models are recommended based on tests performed by Liquid Flow Technology, Inc.

Compatible Injectors:

- STEC/HORIBA IV2410AV Series
- LINTEC VU Series

Compatible Liquid Flow Meters (LFMs):

- STEC/HORIBA LF 210, 310, 410A-EVD
- STEC/HORIBA LF-A20M, A30M and A40M
- LINTEC LM-1100, 2100

The PLIA – 200 was designed to originally help our current clients, but LFT has found that many fab end users need it as a method to quickly diagnose the LFM and injector pair. The PLIA – 200 is capable of performing this task and more. The following is a brief listing of some the symptoms that it can detect and therefore help the technician isolate the faulty device.

- Slow response
- Overshoot
- Fluctuations
- Step response (cold / hot)
- Vaporization Quality
- Pairing (LFM to Injector)

The PLIA graphically displays the vaporization cycle of the LFM / Injector PID loop and allows the technician to determine whether the LFM / Injector pair is optimized or not. Used in conjunction with the LFM GAIN and PHASE adjustments, it can be used to fine adjust the PID loop in the pair. The tests are all performed IN-SITU. The connector to the LFM is removed and replaced with the PLIA piggyback connector and it is instantly operational taking measurements. All power requirements are provided by the LFM connector.

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