



LABORATORY RRIM MACHINES

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Laboratory RRIM Machines

Laboratory Urethane Machines for processing unfilled and filled urethane chemicals are in many instances the driving force for successfully marketing a product or process. To determine production requirements of a product to the industry, laboratory process equipment must be able to simulate high volume production equipment and produce high quality prototype parts.

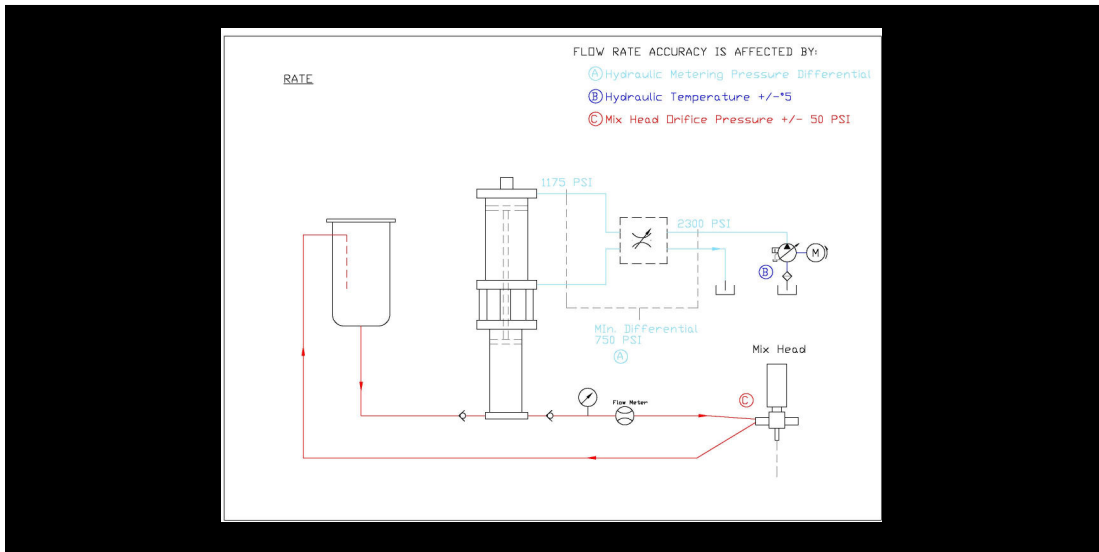
The Laboratory Machine will develop the process parameters of the production equipment and therefore must have the controls and accuracy for making parameter control changes efficiently with minimal amount of materials. Production equipment is not required to have many adjustable variables which typically results in higher costs and higher maintenance. The production equipment, however, must have fixed values and settings that have been developed on the Laboratory Machine.

Laboratory Machines must be versatile enough to process a wide range of chemicals with a wide range of process parameters. This makes it difficult to develop a machine that covers all urethane research applications. It is very possible to design a machine with a few added options that will allow it to process a wide range of materials and produce a wide range of products.

1. Main Objectives of the Laboratory RRIM Machine:

The Main objective of a laboratory machine as well as a good production machine is to efficiently control RATE, TEMPERATURE, and PRESSURE. These three parameters are interactive and inaccurate control of one will affect the others.

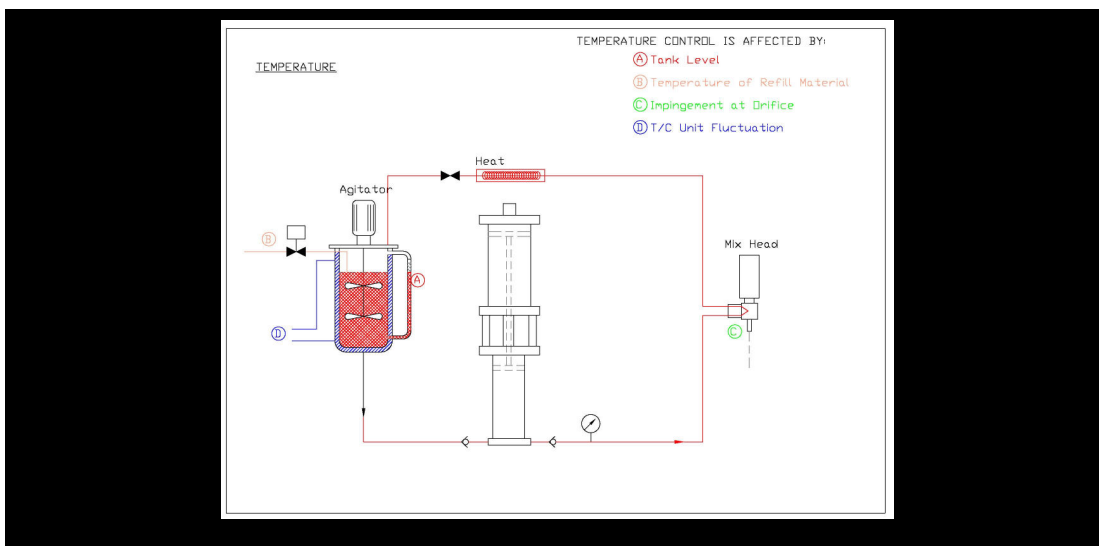
RATE:



Flow Rate and Ratio control is the most critical aspect of any RIM or RRIM machine. Correct flow rate and ratio determines product quality which will impact product acceptance, reduce scrap rate, and increase efficiency.

Quality and accuracy of the chemical metering components can not be sacrificed. High efficient metering components must be used to obtain accuracy and repeatability. Since the chemical viscosities will vary greatly from formulation to formulation and temperature changes will affect viscosities it is important to use positive displacement metering systems such as cylinders that eliminate slippage and by-pass.

TEMPERATURE:

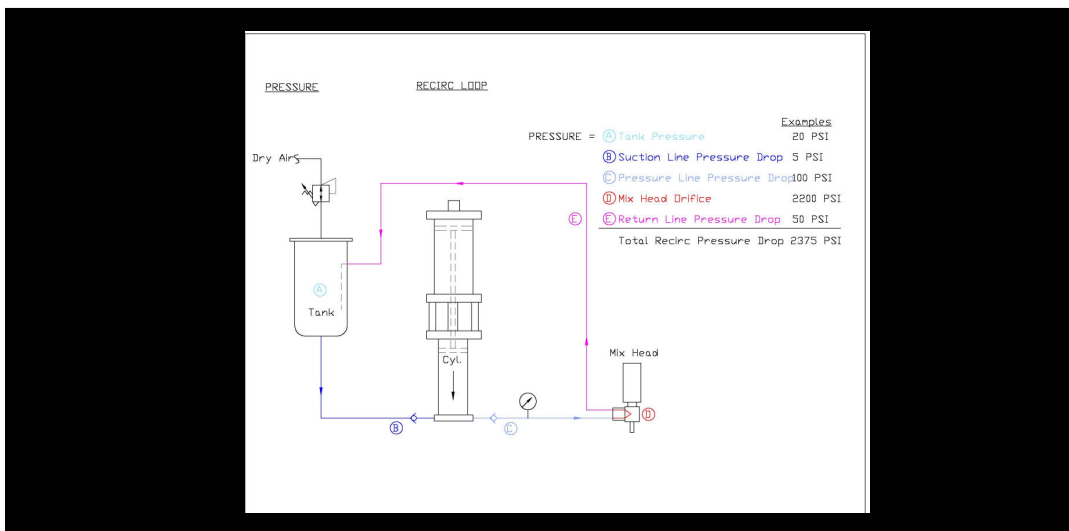


Accurate temperature control is important since material process temperature directly affects the reaction parameters of the chemicals. Temperature fluctuations will also affect the flow rate and ratio, especially when using metering pumps that do not have efficiency ratings above 93%.

The most efficient method of temperature control is by maintaining the day tanks at a constant temperature (+/- 1 deg F). A key factor in maintaining constant day tank temperature control is to use automatic tank refills and keep the tanks filled at approx 75% level. Constant temperature feed to the metering device will make the metering device more accurate and efficient.

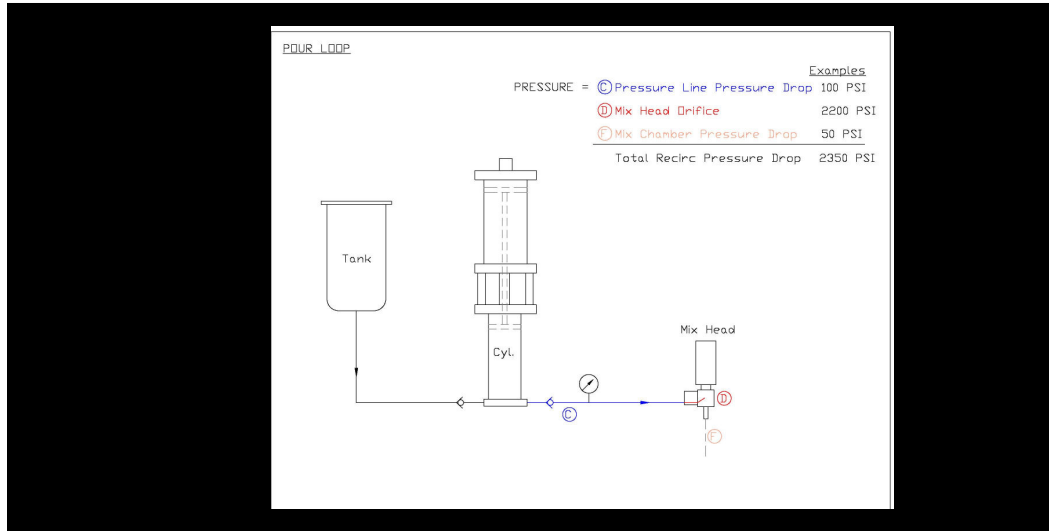
Keeping the chemicals in recirculation through the dispensing head is important to maintain constant temperature feed to the dispense head and remove any additional heat that has been developed from the high pressure recirculation on processes that require lower temperatures (below 100 F). A separate heat exchanger on the recirculation line prior to returning to the day tank is helpful in the temperature balance to take out the heat before it gets back into the tank. This also helps to reduce catalyst losses when using low blanket pressures on the day tanks.

PRESSURE:



Process pressures are the most dynamic parameter of the urethane process equipment. A deviation from desired or preset process pressures is the first indication that some other component in the system is out of specification or not able to maintain the correct parameter (flow and temperature).

Higher pressures will indicate lower temperatures or restrictions in the recirculation loop. The higher pressures will result in lower flow rates and incorrect ratio. The flow rate of the metering component of the equipment is inversely proportional to the pressure differential.



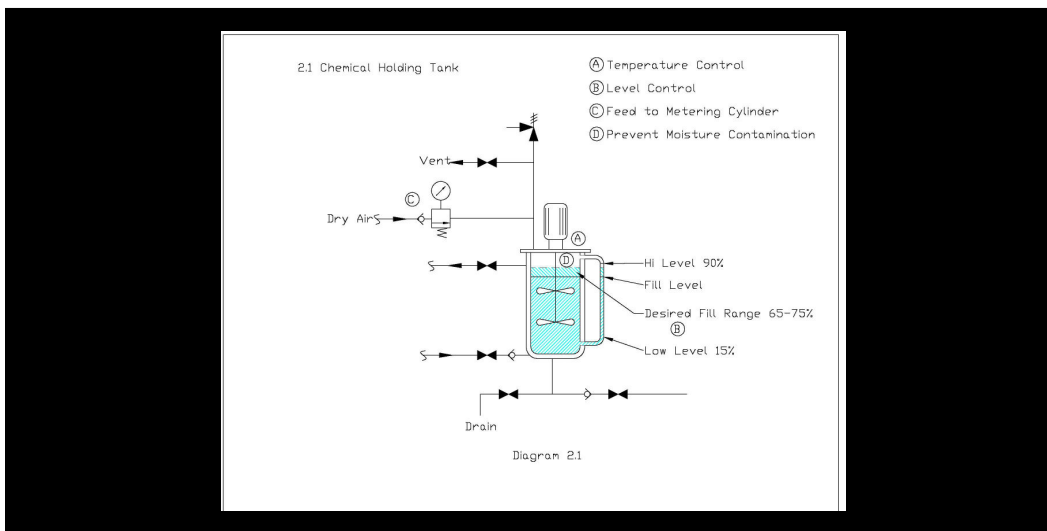
Lower pressures will indicate higher temperatures or damaged orifices in the recirculation loop. The lower pressures will result in higher flow rates and incorrect ratio. Insufficient feed to the suction side of the metering components will also result in lower pressure. The flow rate of the metering component of the equipment is inversely proportional to the pressure differential.

2. Selecting the Main Components of the Laboratory RRIM Machine:

The Three main components of process of a Laboratory Machine are:

Chemical Holding Tanks
 Metering System
 Mixing System

1. Chemical Holding Tanks:



The Chemical Holding Tanks are usually not considered a key item in the accuracy of the metering equipment or the affect they have on the mixing efficiency. They are, however, just as important as the metering and mixing components of the equipment since the chemical tanks controls of level and temperature affect the metering and mixing efficiency.

The main purpose of the chemical holding tanks is to provide prepared chemicals to the metering system. Chemical preparation prior to entry into the Holding Tanks is critical. The Metering Holding Tanks should not be used as "PREP" tanks. Material should be prepared prior to entry into the holding tanks. The Metering Holding Tanks are mainly designed to maintain the chemicals at the required temperature and mixture and provide a pressurized feed to the metering system.

Temperature Control is critical. It is especially critical on high viscosity formulations, usually formulations with fillers added into the Polyol component.

Temperature fluctuations will not only vary the pressure drop in the lines and impingement mix pressure at the mix head but will also affect the atomization and reaction of the chemicals in the mix chamber. Higher viscosities and lower temperatures will cause in-efficient mixing. Temperature Control of the Metering Holding Tanks is best accomplished by the use of jacketed tanks and full sweep agitators.

- Agitators should have 1 or 2 sets of paddles, depending on the tank height.
- Agitator speeds should be kept at a minimum to provide efficient blending of the chemicals without nucleation.
- for most tank sizes, agitator speeds should be 10-17 rpm.

The temperature control media on the tank jackets should be tempered so as not to allow recirculation of media that is too hot or too cold.

- If the recirculation media is too hot, it can cause blowing and deterioration of the catalyst or blowing agents.
- If the recirculation media is too cold, it can cause the material to gel along the tank walls and insulate itself from the temperature control media.

The **Level Control** of chemicals in the Metering Holding Tanks is critical to good temperature control. Metering Holding Tanks should be kept at 75% full of available volume.

- Operating at a lower volume will cause the temperature of the chemicals to have a wider than desired range. Normal range should be +/- 2° F.
- Operating at lower volumes may cause the agitators to “splash” and produce unwanted nucleation in the chemicals.

It is advisable to use AUTOMATIC FILL systems to have the chemicals automatically transferred from drums, totes, or bulk tanks, to maintain a constant level in the Metering Holding Tanks.

- By adding small amounts of chemicals, also helps to maintain a constant blanket pressure and feed to the metering system.
- This reduces the usage of blanket media (dry air or Nitrogen) and reduces the loss of blowing agents by eliminating the “bleed-off” pressure during the tank fill process.

Caution must also be taken so that the recirculation line returning to the tank (usually on tank top or side) is NOT in close proximity with the feed line to the metering system (usually on tank bottom). Many times the return line to the tank contains a “down-tube” which may be directing material flow close to the suction. In this case, this can cause a “closed-loop” of the material flow in the tank and the material will not be tempered properly.

2. Metering System:

The Metering System of a urethane process machine contains the most critical logic control of the equipment. Since the metering system determines the exact mix formulation and flow rate, it is the most important factor in obtaining correct shot sizes and repeatability.

RRIM machines use cylinder metering by which a cylinder filled with chemicals is driven by a hydraulic cylinder. To obtain higher metering accuracy on the chemical cylinder, it is recommended that the hydraulic cylinder volume is at least two times the volume

(surface diameter) of the chemical cylinder.

- Most urethane chemical impingement mix at 2250-3000 psi
- The pressure rating of most hydraulic valving components is 3000 psi.
- Operating the hydraulic cylinder at two times the surface area requires $\frac{1}{2}$ the hydraulic pressure.
- This provides longer life for the hydraulic components
- This provides higher efficiency on the hydraulic Components.
- This provides higher accuracy of the metering system.
- It is recommended that the hydraulic metering supply pressure is 750psi above the desired chemical pressure:

Example:

Chemical Process Pressure = 2500 psi

Using 2:1 ratio hydraulic/chemical cylinder ratio

Hydraulic Pressure Requirement = 1250 psi

Add 750 psi differential for accurate metering

Required hydraulic system pressure = 2000 psi.

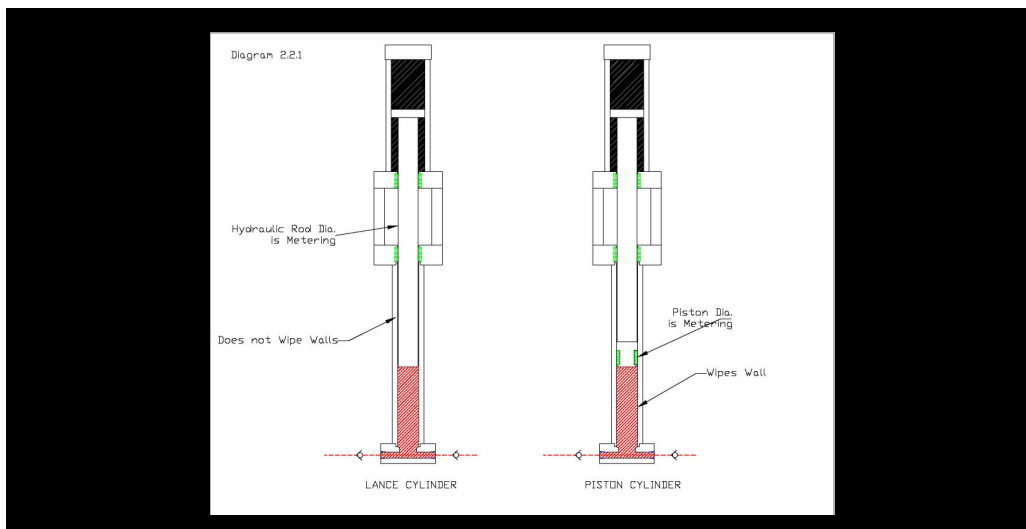
It is important that the hydraulic system temperature is kept as constant as possible:

- Ideal Hydraulic Process Temperature = 115° F +/- 5° F
- Cold Hydraulic Oil System may cause sluggish valve reaction
- Hot Hydraulic Oil System will cause premature component failure and slippage in metering.

It is common in hydraulic power units that have manual controls that the flow rates and ratios will change from Morning start-up to Afternoon production due to temperature changes in the hydraulic oil.

There are 3 types of cylinder Metering Systems:

- Lance Cylinders
- Piston Cylinders
- Tandem Cylinders (Lance or Piston)



The **Single** cylinder Lance or Piston metering allows the chemical cylinder to fill by tank or feed pressure, then meter for the required timing of the shot cycle. It is always recommended that the metering cylinder completely empty prior to the next shot cycle to maintain accurate material temperature control. It is NOT recommended to use a single cylinder to meter in both directions.

The **Tandem Cylinder** operation uses 2 cylinders. While one cylinder is metering, the other cylinder is filling. The fill rate is always greater than the metering rate so that the opposite cylinder is always ready to start metering whenever the current metering cylinder reaches empty.

- The switchover of the cylinders during metering is critical and can be programmed to “balance” the flow through PLC timing by allowing one cylinder to ramp up at the same rate that the previous cylinder ramps down.

Lance Cylinders may be used for metering. However they are not efficient in cleaning out the entire cylinder volume. Since the inside of the cylinder barrels are not completely wiped, filler material can collect along the walls and cause “set-up”. This would require cleaning of the cylinder barrels occasionally. If not cleaned, it could set up around the piston rod and “seize” the piston rod.

Piston Cylinders are best suited for filler material application since they continually wipe the entire chemical cylinder and prevent “seizing”.

There are 3 types of metering systems for metering cylinders:

- Manual Flow Control
- Proportional Flow Control
- Servo Flow Control

The **Manual Flow Control** may not be the most accurate but it is the least expensive. It consists of directional valves and an in-line flow control metering valve. The metering valve should be pressure/temperature compensated to allow for 10% (+/- 5%) variation in temperature and system pressure without affecting the flow rate setting.

Manual Flow Control units do not interface with the Process Controller and do not provide digital feed back for Flow Rate settings.

- When using a Manual Flow Control, a “dry cycle” must be run on the machine to obtain the flow rate which is calculated by timing the cylinder from FULL to EMPTY. Using this timer with the preset cylinder volume and specific gravity of the material, the PLC can calculate the flow rate of the chemical.
- The Manual Flow Control Valve does not allow digital setting or multiple flow valve setting for selecting Formulas.

The **Proportional Flow Control** is more expensive than the Manual Flow Control and less expensive than the Servo Flow Control and allows digital entry of the flow rate via the PLC and Operator Interface. The Proportional Valve Flow Control is not very accurate. It allows the valve to go to a fixed valve position using analog output signal from the PLC. The Valve Position is not always the exact position required for the flow rate. Using a Feed Back Spool for the Proportional valve setting is helpful in obtaining a higher accuracy setpoint for the flow valve.

- The Proportional Flow Control Valve should be used in conjunction with a Transducer feedback signal from the cylinder to allow the PLC Processor to calculate the flow rate and ration of the system. This will allow the PLC processor to make corrections to the Proportional Valve set-point to maintain the correct flow rate and ratio.
- Using the PLC processor for accumulating and updating flow rate data will cause some delay on a closed loop system and may not be accurate enough for all applications due to the loop time of the Processor.
- On very fast reacting system with shot time less than 1 second, the Proportional Flow Control System with Linear Feedback System will not be fast enough.

The **Servo Control System** is more expensive than the Proportional Flow Control but also the most accurate. The Servo Control System is used with digital Linear Transducer Feedback and has an update time of two milliseconds. The Servo Valves react instantaneously to any preset changes and allow “On-The-Fly” adjustments for varying flow rate and ratio. This is especially helpful when trying to make shots with variable ratio within one shot.

- Servo Control Valves need to have Hydraulic High Pressure Filters for protection of the more expensive servo valves.
- Servo Control Valves like to see a minimum of 750 psi differential from hydraulic system supply pressure and the required cylinder metering pressure.

3. Mixing System:

The Mixing System of a RRIM process machine is the final and most critical step in the process. Efficient mixing depends on: Pressure Control; Metering Control; and Temperature Control.

We had already discussed the Temperature and Metering Control Systems.

The Pressure Control System is the Mixing Head. The Mixing Head impingement pressure must be kept constant and very close to the recirculation pressure. Variations in the recirculation and pour pressure will cause OFF ratio shots; shot size variation; and improper mix.

The most critical part of the Mixing Head Pressure is that the dispensing pressure is the same as the recirculation pressure.

- When the process machine is recirculating, the pressure developed consists of the line pressures (supply and return), the mix head orifice pressure, the restrictions within the mixing head, and the tank blanket pressure.
- When the mixing head is dispensing, the pressure developed consists of the feed line pressure, the orifice pressure, and the mixing chamber/outlet nozzle pressure.
- It is most desirable to keep the pressures balanced or drop less than 50 psi during recirculation and dispense.

- **Pressure Increase** during dispense is caused by:
 - Mixing Head mix chamber/outlet nozzle too small
 - On L-heads – the clean out is restricted too much
 - Gating or entry into tool too small.
- **Pressure Drop** during dispense is caused by:
 - Return Line too small
 - Mixing Head mix chamber/outlet nozzle too large
 - On L-heads – the clean out is restricted too low.

Mixing efficiency can be increased by:

- Temperature Increase:
 - Try to match the viscosity by varying the temperature.
 - Polyols usually have higher viscosity and should be processed at higher temperatures.
- Pressure Increase:
 - Higher pressures, especially on higher viscosity materials, will cause higher atomization.
- Flow Rate Adjustment:
 - The Mixing Head may not be sized properly for the desired flow rate.
 - The mixing head normally has a range of approx 2:1 and the process equipment normally has a range of 5:1.
 - Adjusting the flow rate DOWN should improve mix quality unless the flow rate is already low: in that case, adjusting the flow rate up will improve the mix quality.
 - The mixed chemicals coming out of the mixing head should have a good laminar flow. Pressure drop within the mix head should be 15-30 psi.
 - If pressure drop is too low, the material will not atomize properly.
 - If pressure drop is too high, the material will not be held up long enough in the mix chamber for proper mixing.

CONTROLS:

To be able to run an efficient laboratory RRIM machine and provide minimal set-up time as well as provide accurate Data Recording the RRIM lab machine must have the following control logic.

The Laboratory RRIM machine must have a good control system with easy access for setting:

- Temperatures
- Rate and Ratio
- Process shot timers

The Operator Interface should have a good report data for each shot:

- Pressures
- Temperatures
- Rate and Ratio
- Shot Weight

The PLC Processor should have:

- Pressure Transducer Inputs
- Temperature (Thermocouple) inputs
- Linear Transducer Inputs (for Rate and Ratio)

Formula Set-Up and Recall:

The PLC processor and operator interface should have easy access for setting up formulas and adjusting rate, ratio, temperature, and pressure limits.