A FreeBee Publication

The BENDIX Fuel Control On The PT6A Engine Explained

A FreeBee Publication

In Very Simple Terms

for

Training Purposes Only

A MAMMOTH UNDERTAKING

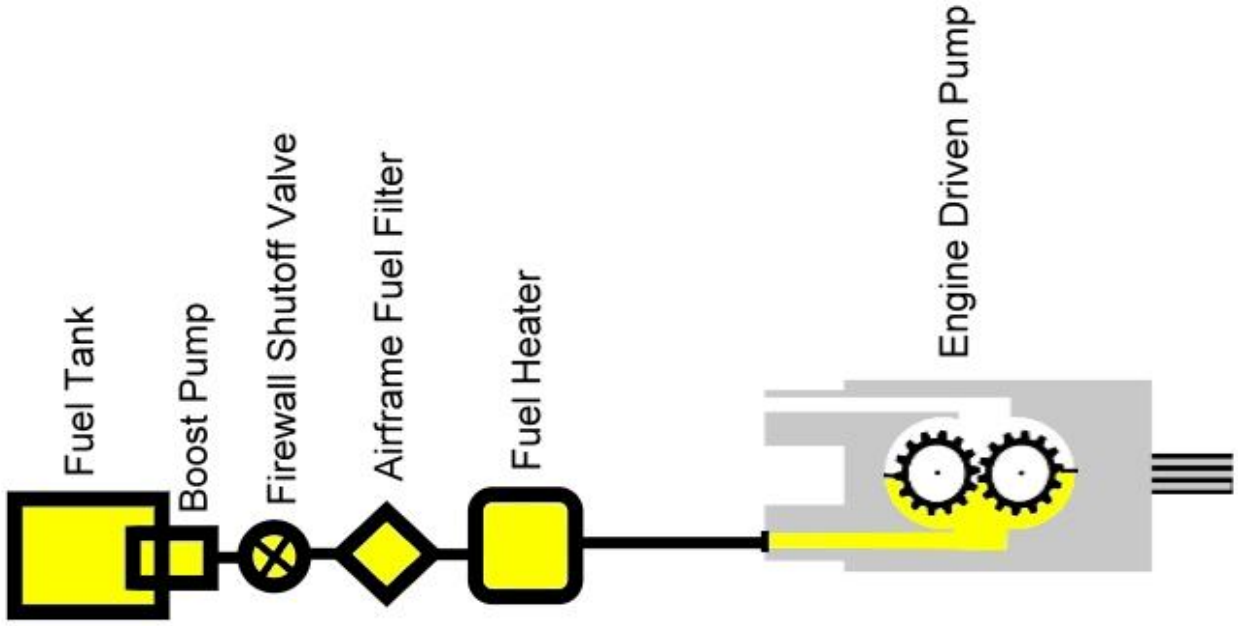
A FreeBee Publication

Let's Build a Fuel Control Unit

We'll Work on the Fuel Side First

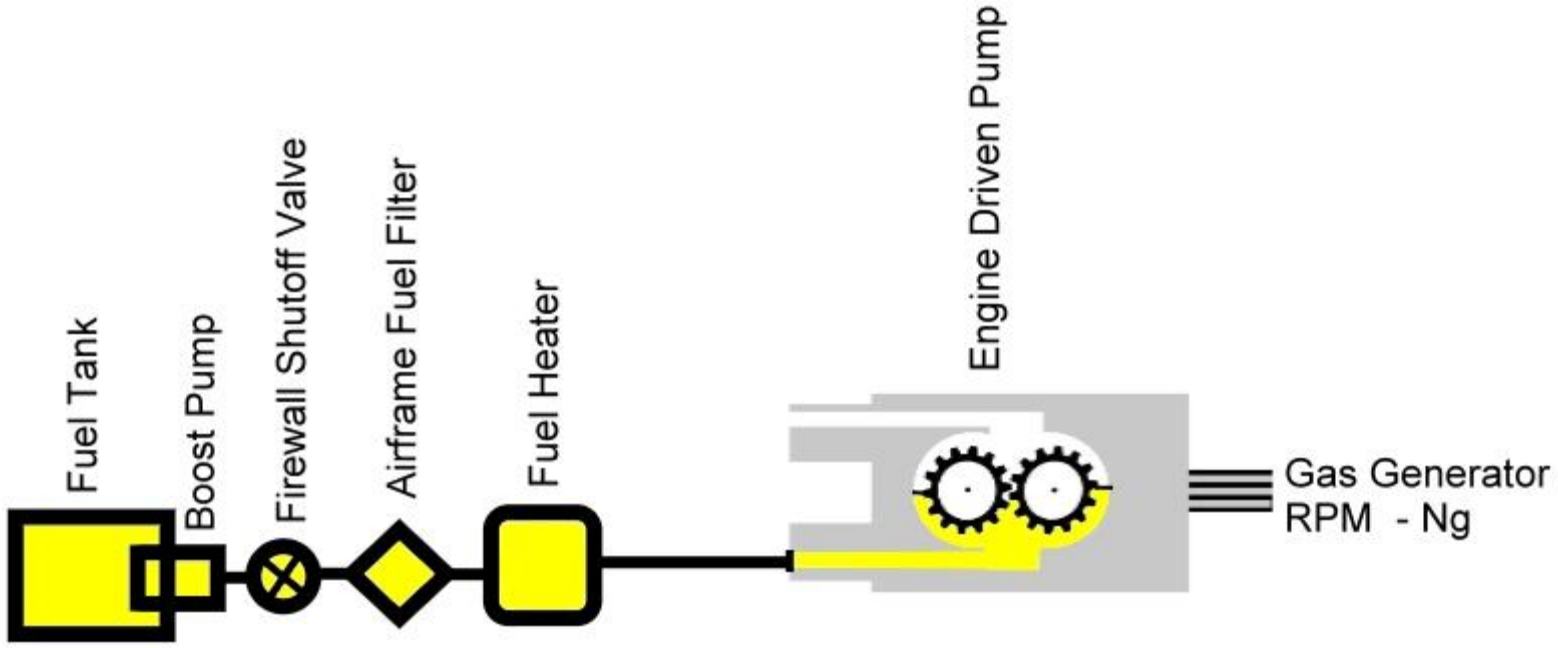
Someone has already designed the fuel system in the aircraft so we won't redo it!!

We'll start with the engine driven fuel pump mounted on the Accessory Gearbox



Engine Driven Fuel Pump is a positive displacement pump.

At any engine speed the pump will produce
120% of the fuel flow needed to operate the engine.



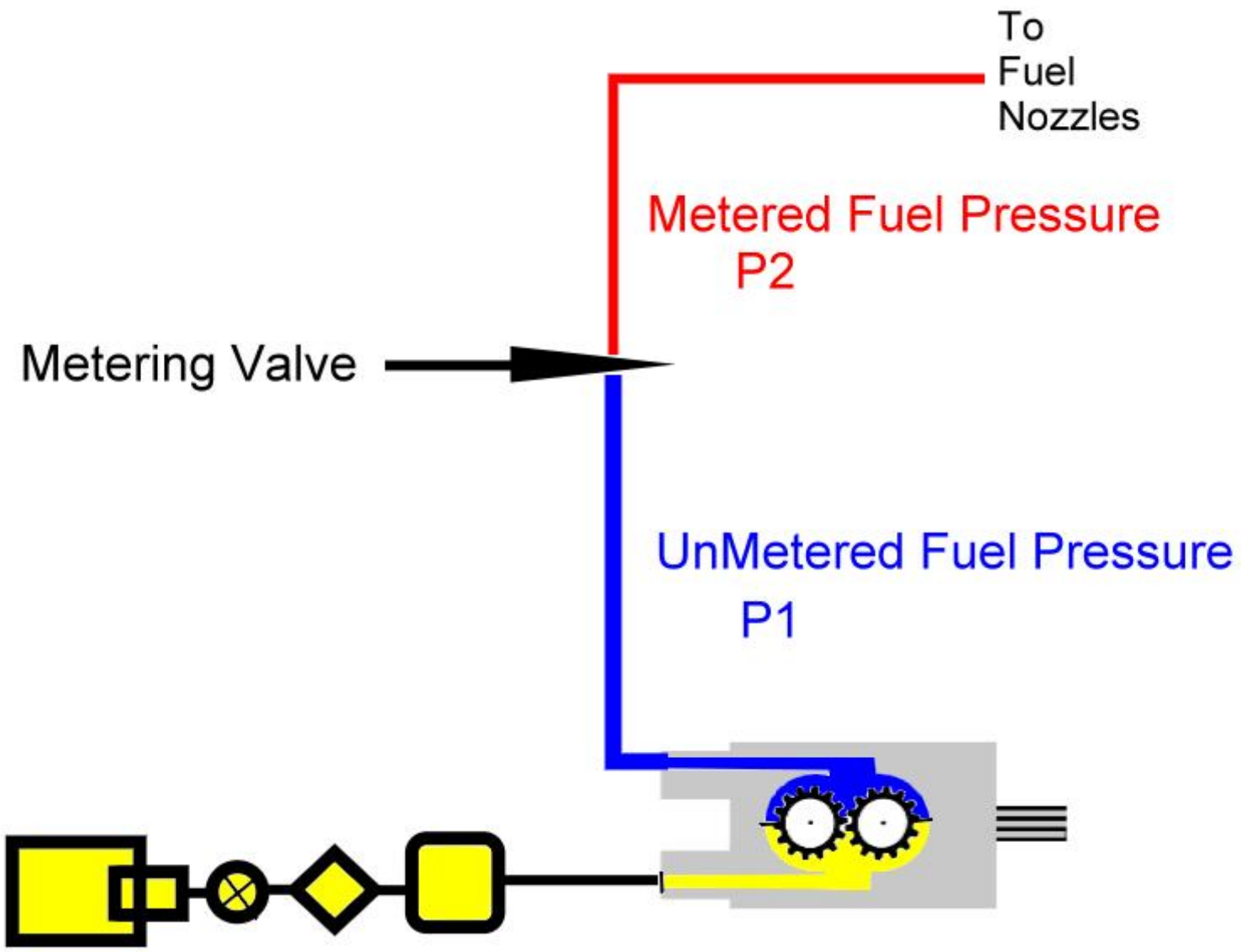
We Need to be able to control the fuel into the engine!!!

We will use a mechanical Fuel Metering Valve.

Just for fun we will name the fuel pressure from the pump to the metering valve - Un-metered Fuel Pressure

And after the valve we will call it Metered Fuel Pressure

Or P1 and P2 Respectively



Now I can get fuel to the engine

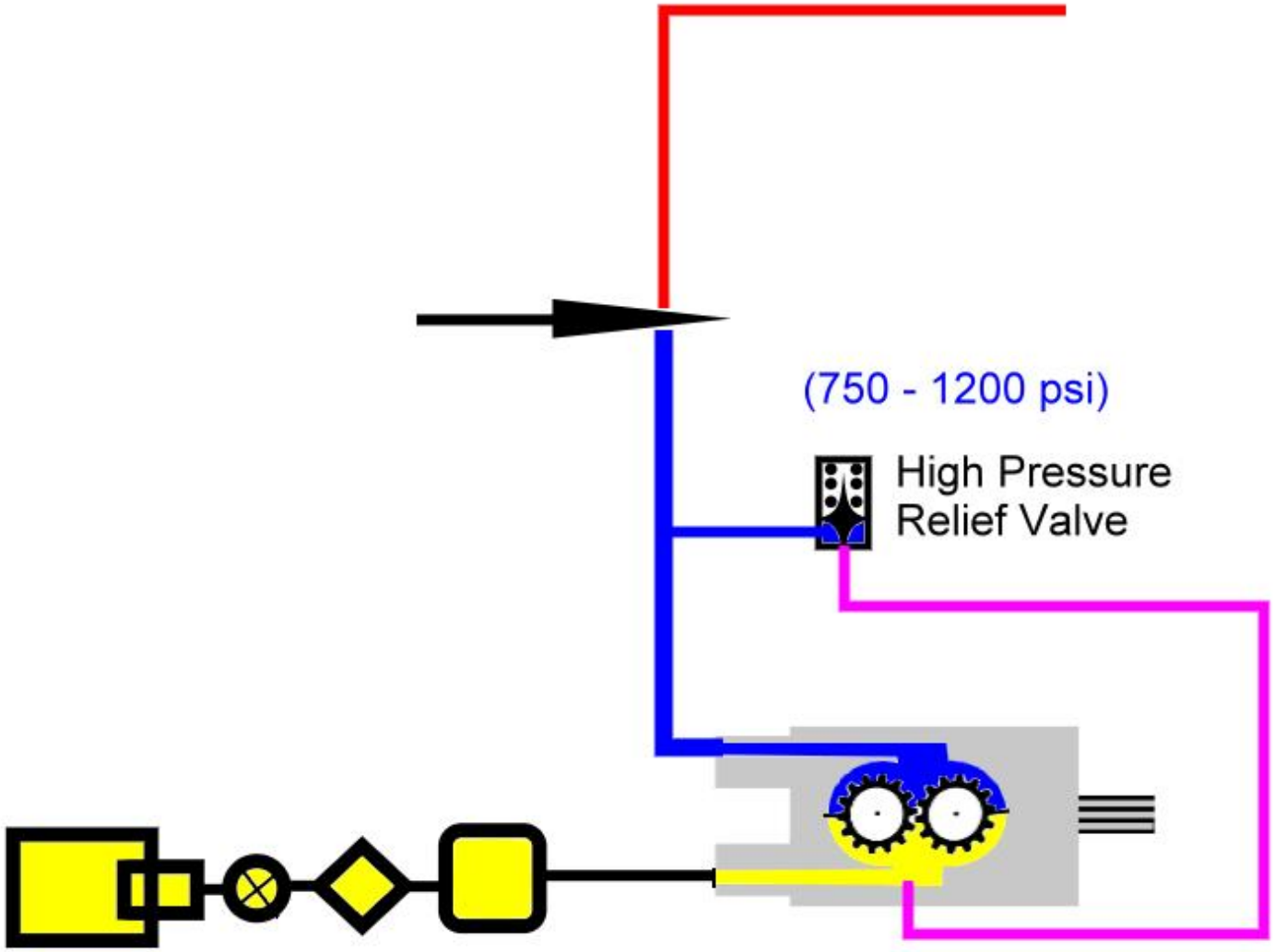
But I have a problem

Since the fuel pump produces more fuel than the engine needs the pressures will be very high and I am going to start to damage things.

I know - let's put in a high pressure relief valve

- just like in a hydraulic system!!

The high pressure relief valve will allow the fuel to bypass back into the inlet side of my fuel pump.



That's Better !!!!

But I still Have a problem.

My P1 Un-metered fuel pressure is always at the relief valve opening pressure!!

In addition I have 2 other concerns.

1. **The metering valve has a large pressure drop across it and very small movements cause huge fuel flow changes - it is way tooo sensitive.**

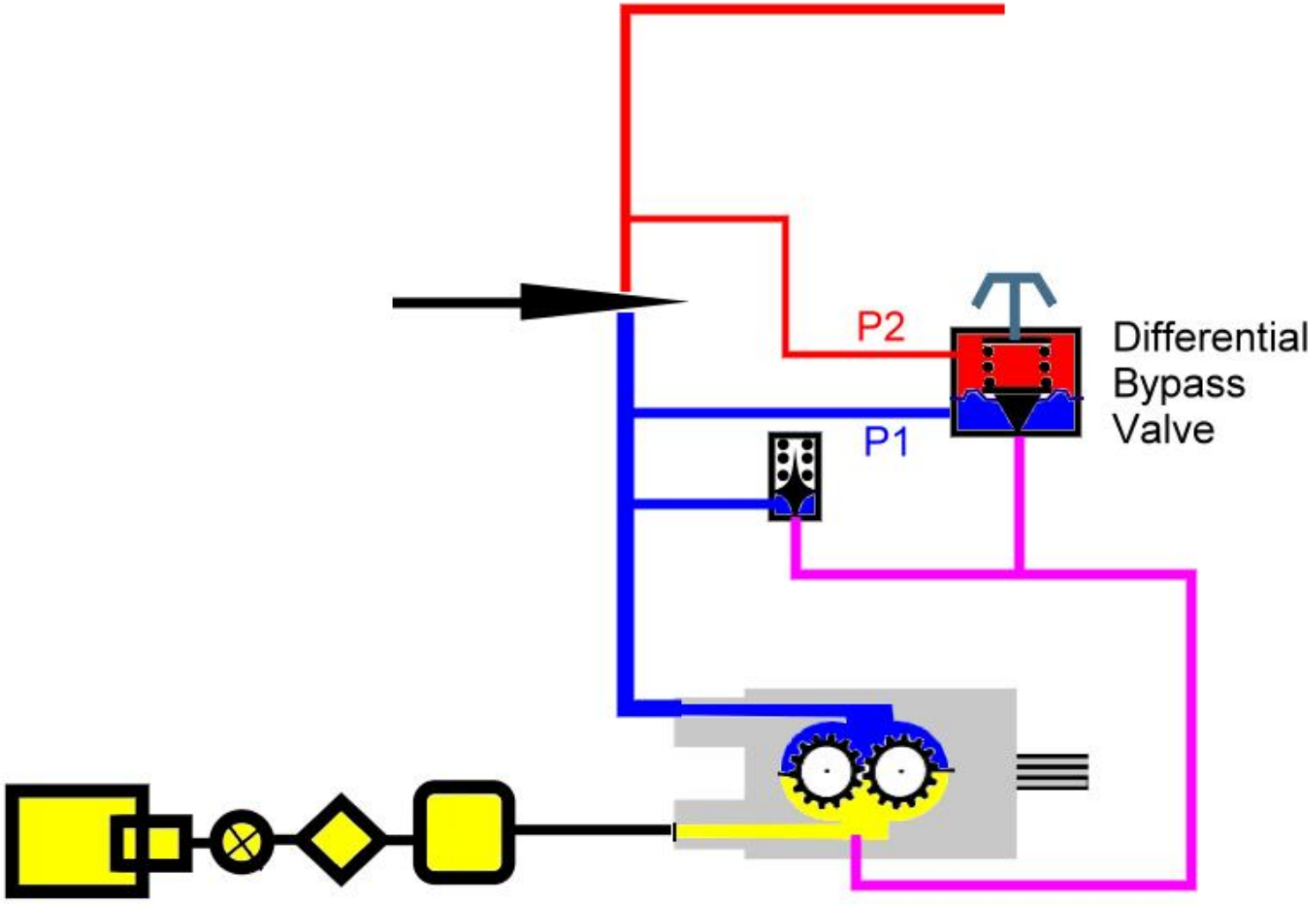
2. **The pump has a short life and the wear on my gearbox is high because it is always running against the full backpressure set by the relief valve.**

I still need almost the relief valve pressure for my maximum power, but off power I could use a lesser pressure!!

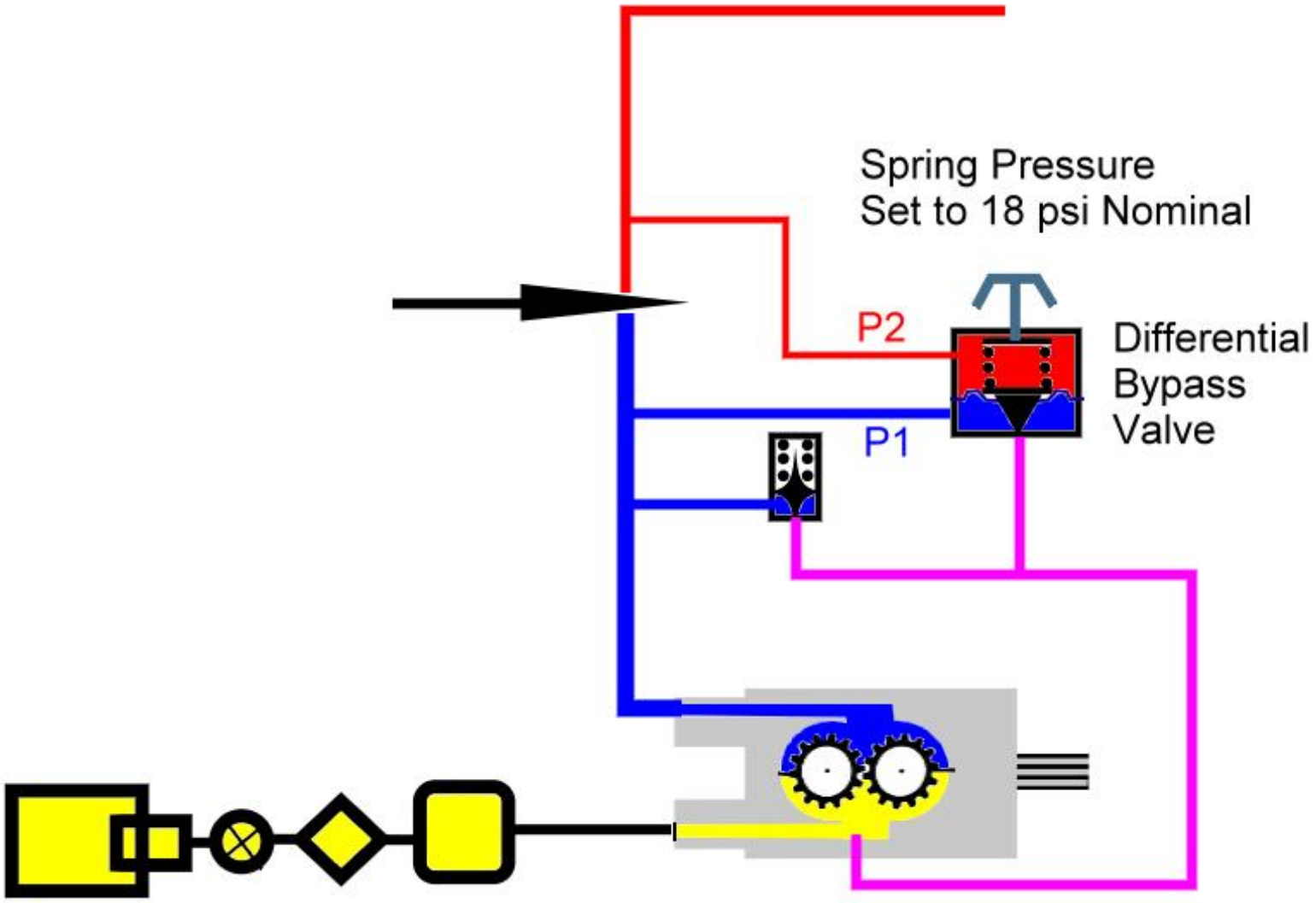
Let's put in a special valve that senses P2 Metered fuel pressure and controls P1 pressure to be slightly higher.

This I will call the Differential Bypass Valve!!!

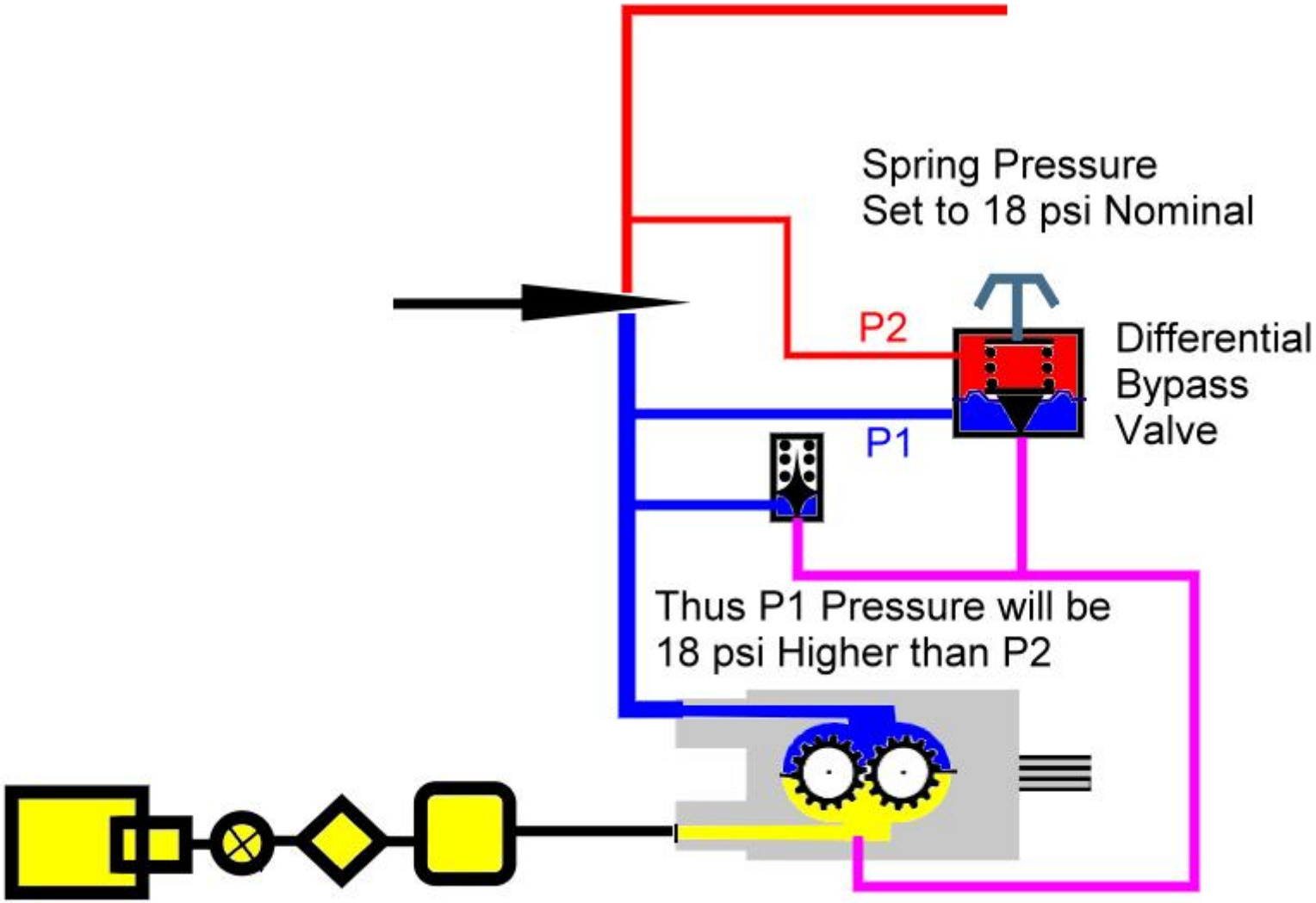
The Differential Bypass Valve



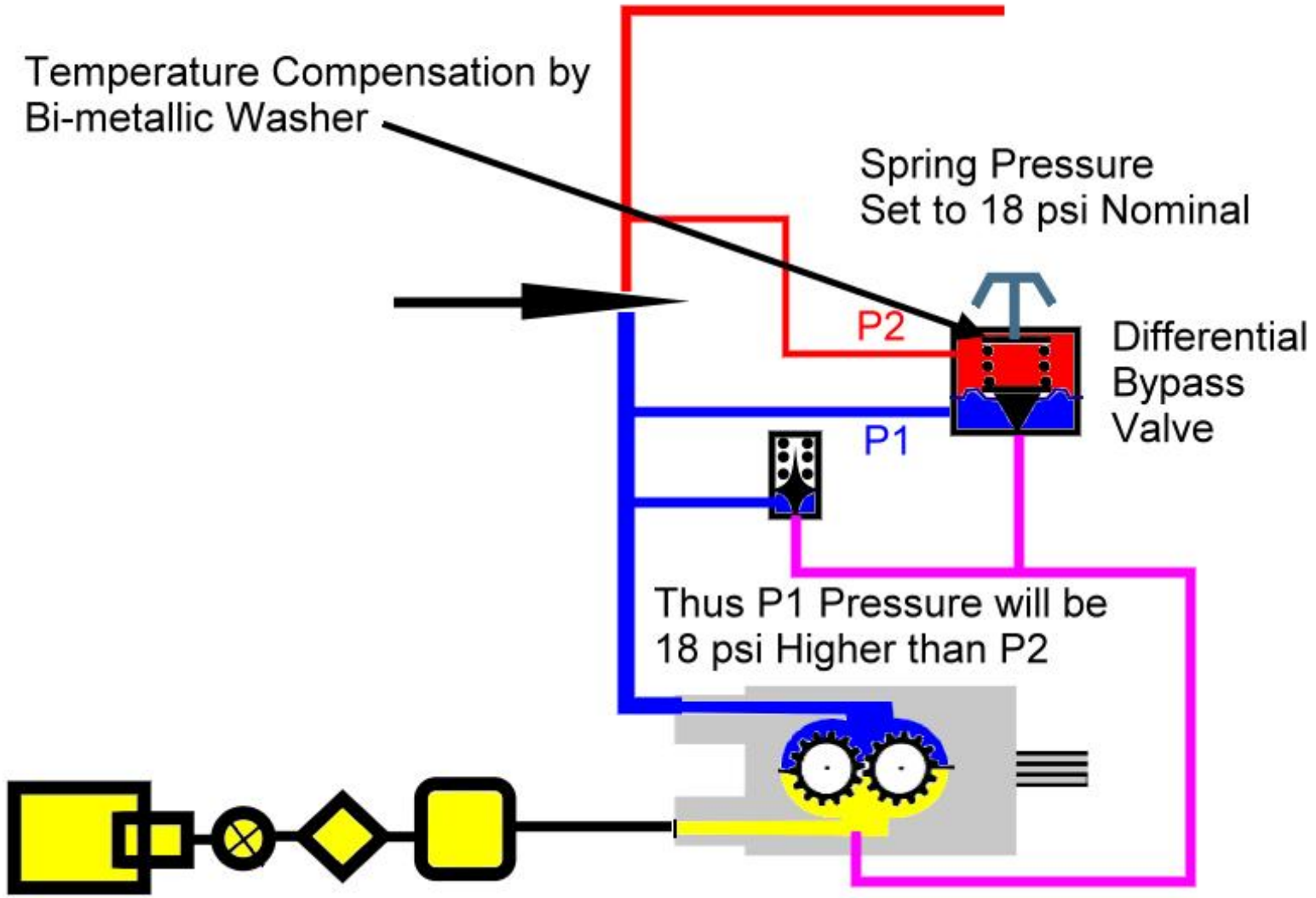
Differential Bypass Valve Spring Function



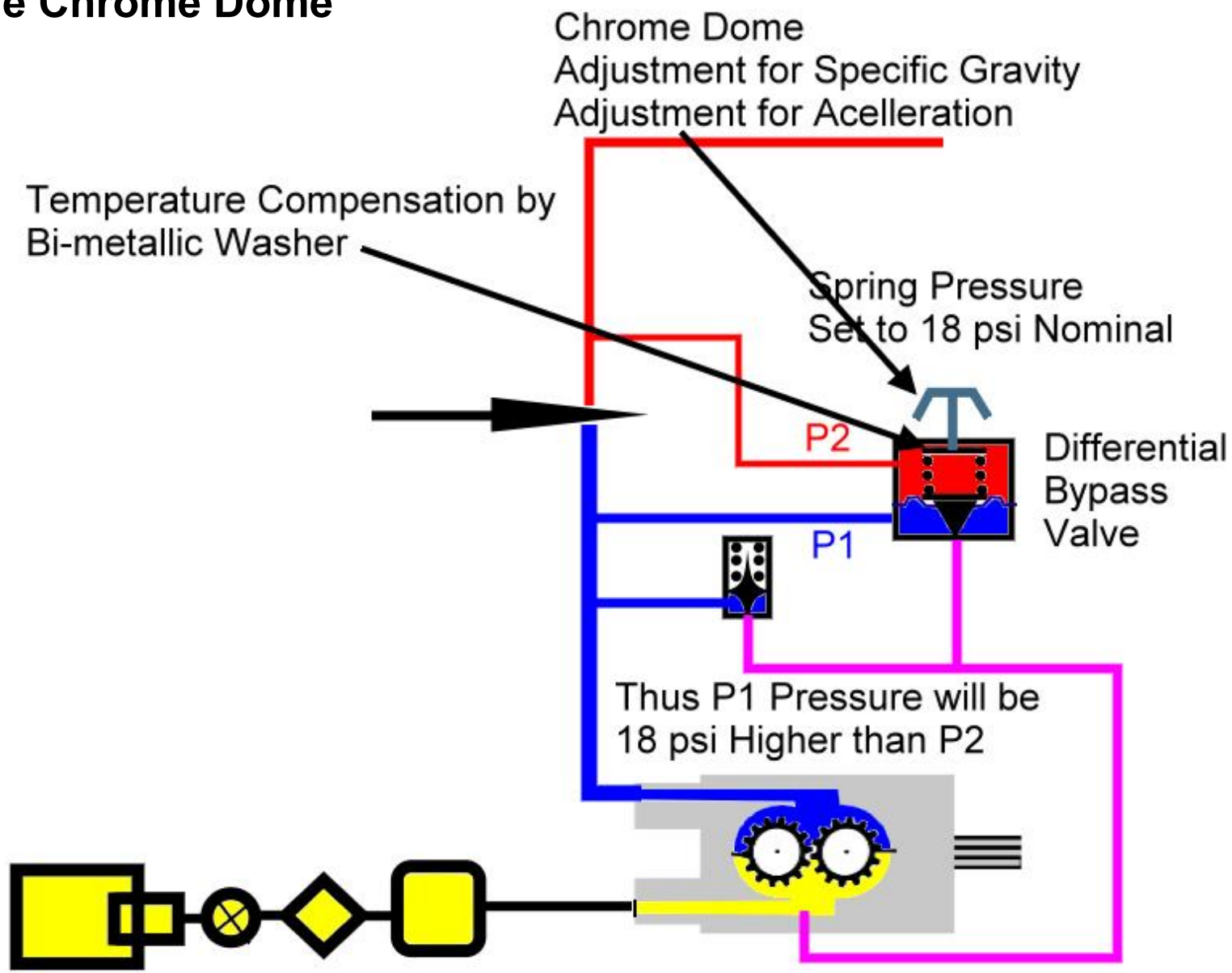
P1 Pressure as a function of P2 Pressure and Spring Pressure



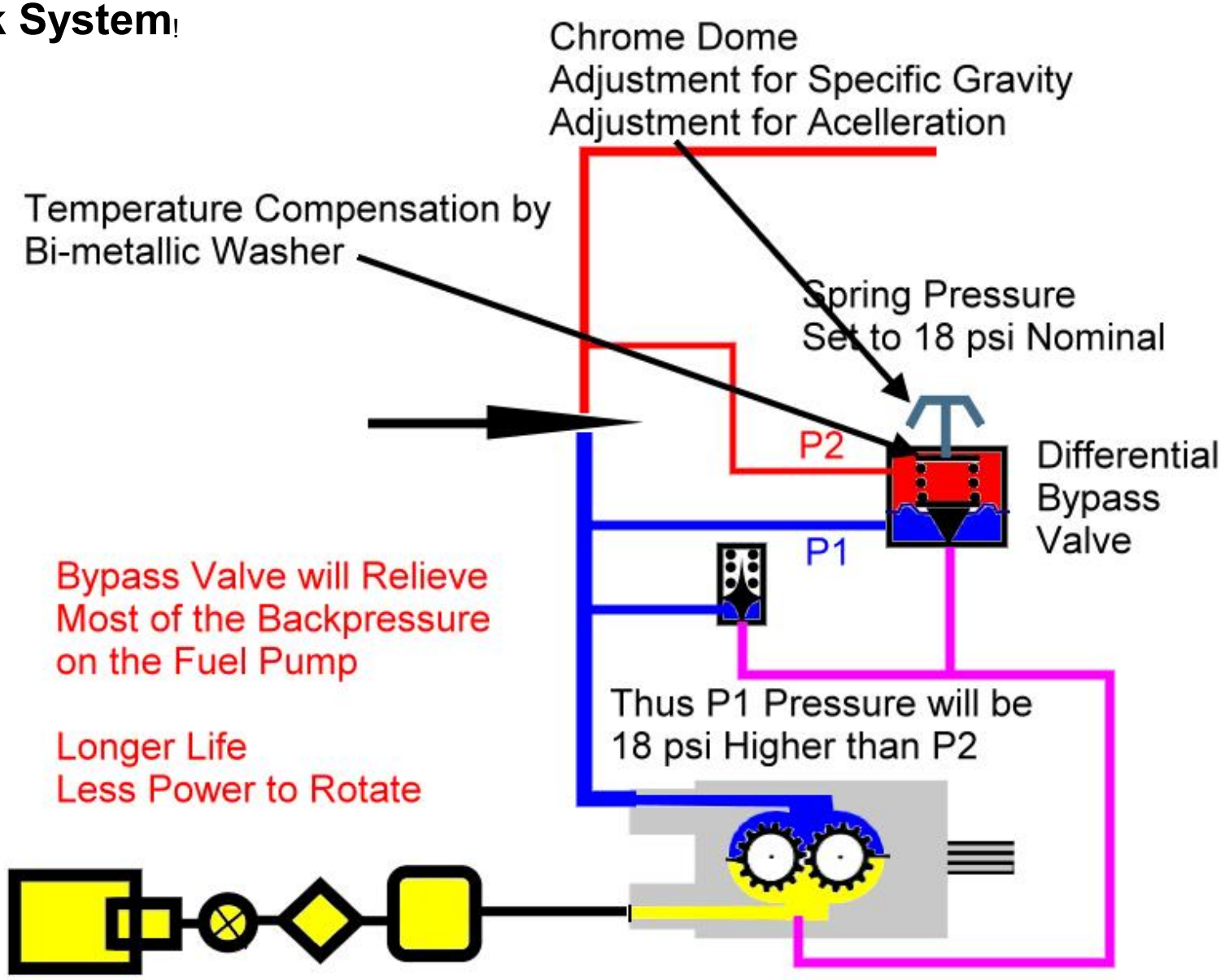
Built in Temperature Compensation



The Chrome Dome



Slick System!



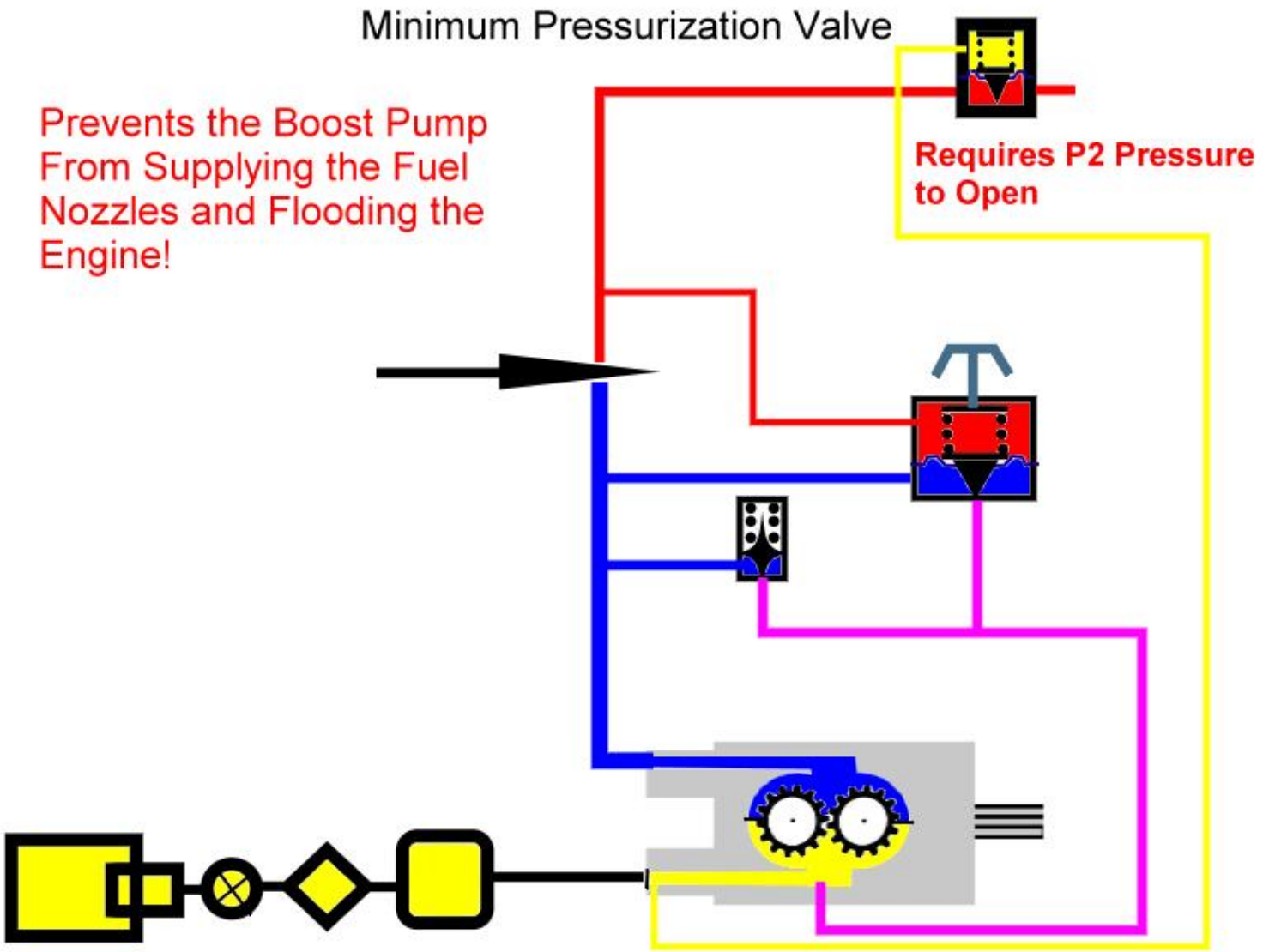
OOPS!!!!

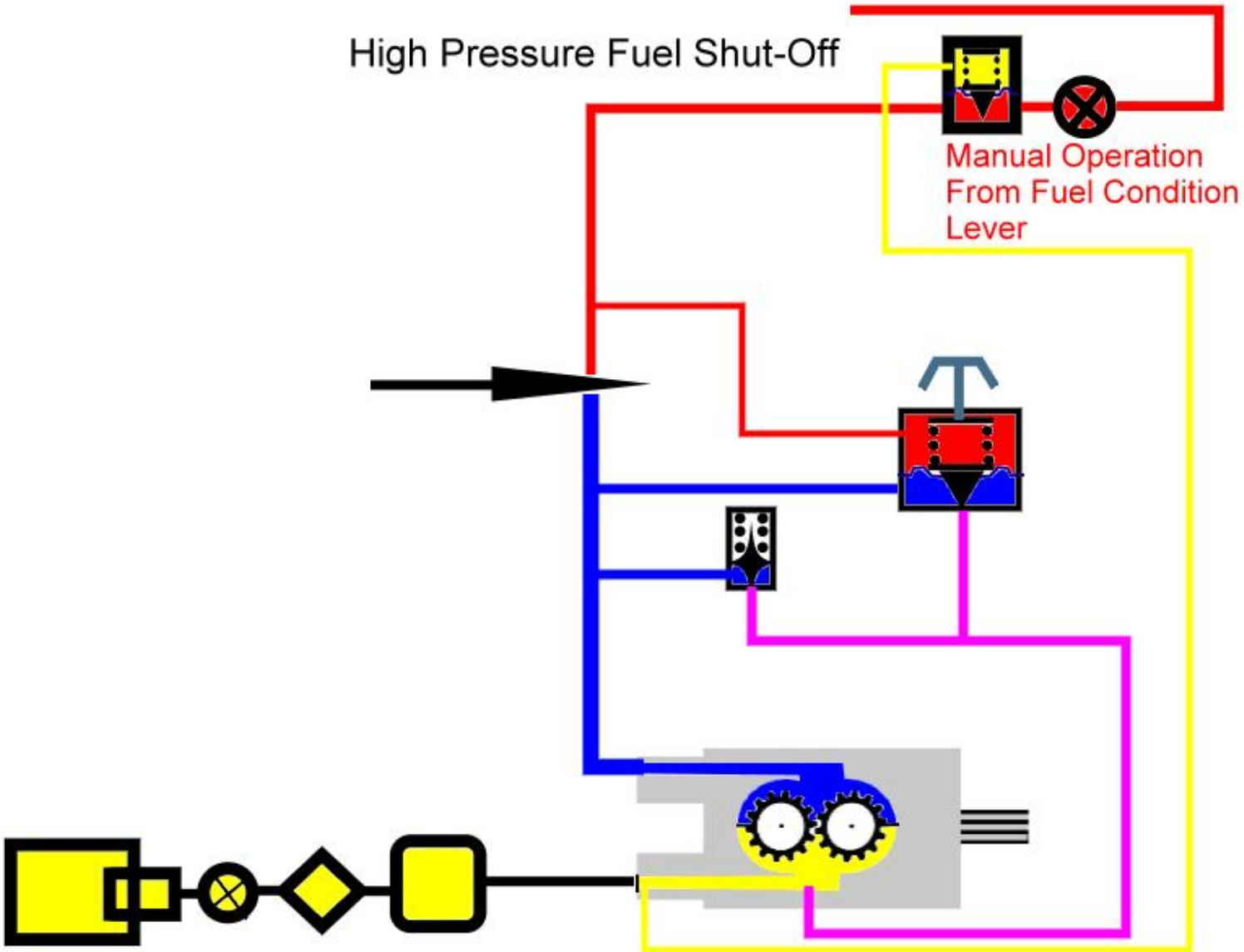
At this stage of development if the engine is not running and I turn on the fuel boost pump I will fill up the combustion section with fuel.

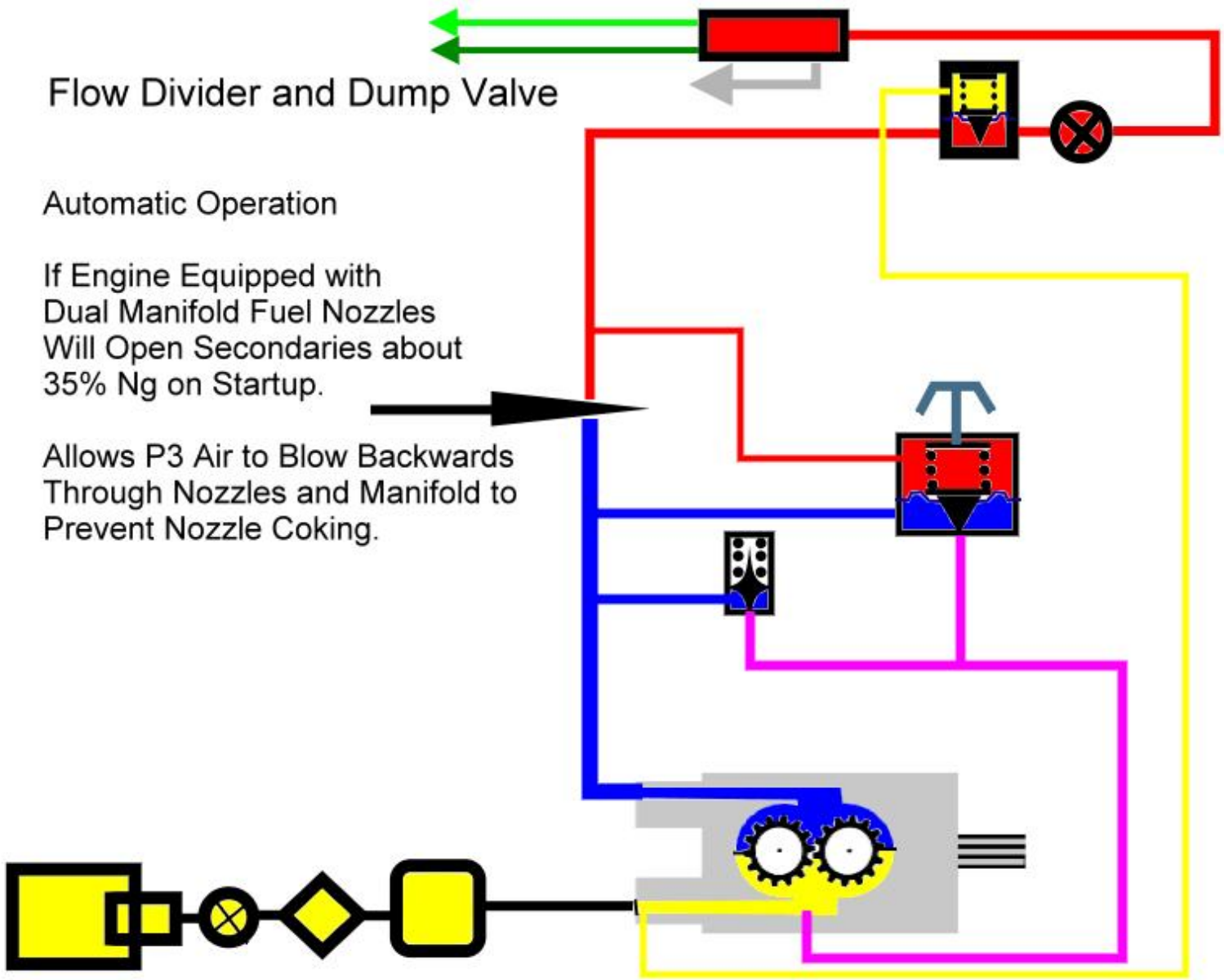
I am going to put a manual shutoff valve in the system but I just know those pesky pilots are going to move it to the open position and I will still have fuel flow into the engine with the boost pump on.

Let's design a Minimum Pressurizing Valve

That way if the boost pump is on and the engine is not running the fuel pressure from the boost pump will ensure the valve is forced closed.







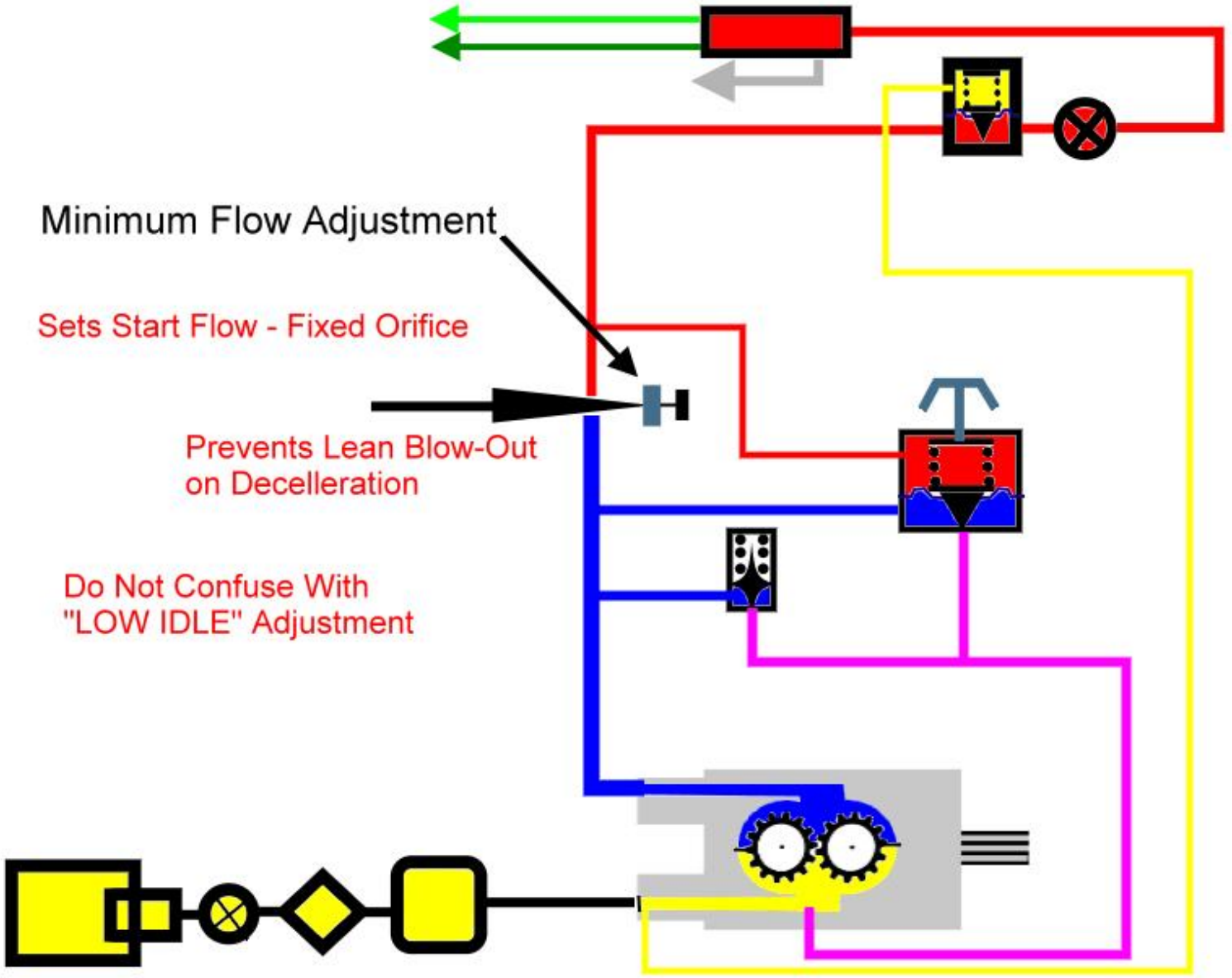
Sometimes when I pull back the power lever the engine flames out!!

POOF!!!

I need something in the system to Guarantee that the fire will stay lit.

The easiest way is to just prevent the Fuel Metering Valve from closing all the way

Minimum Fuel Flow Adjustment



I have another problem!!!

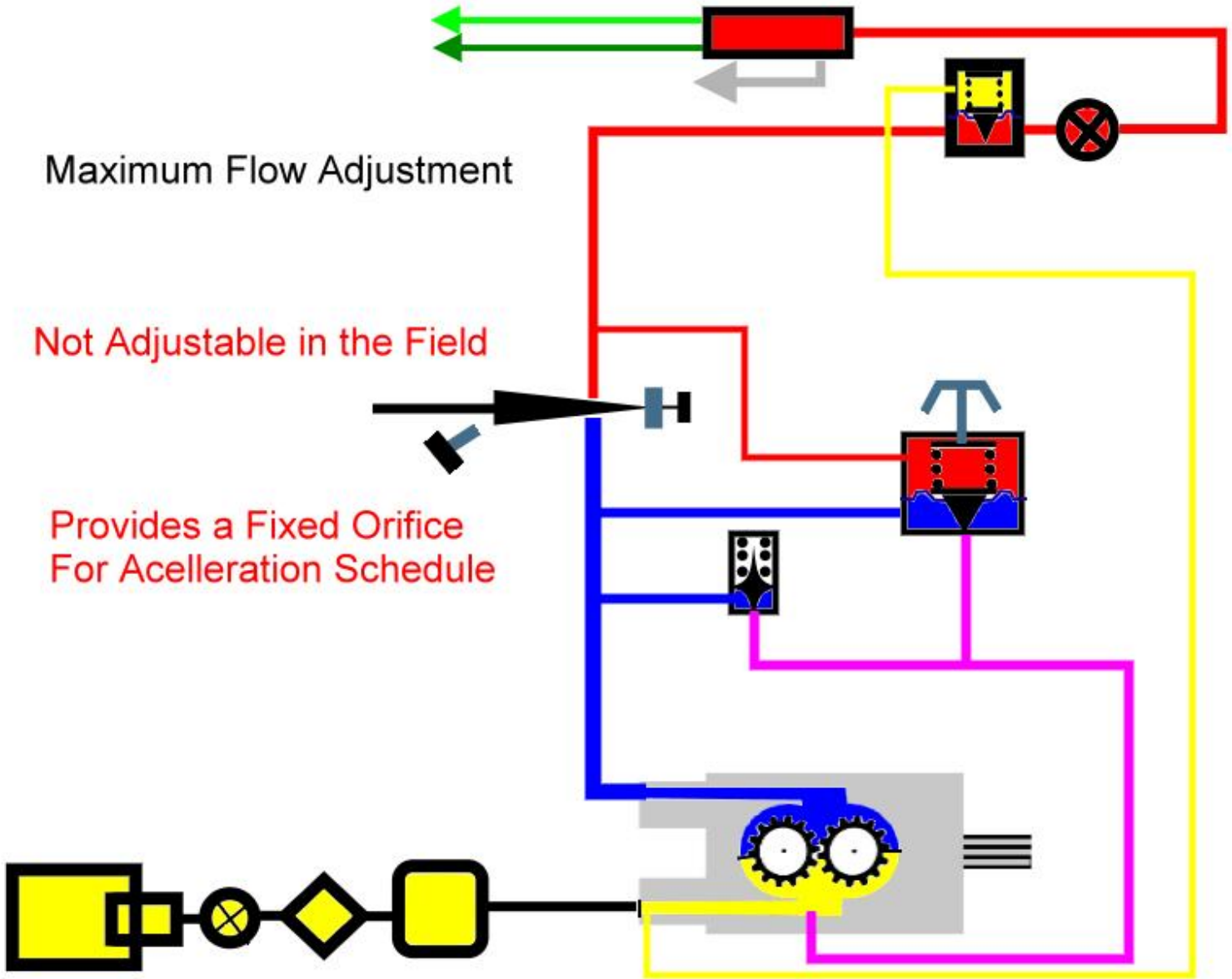
When I slam the Power Lever all the way open quickly

POOOOOOOF!!!

I get a rich blow out.

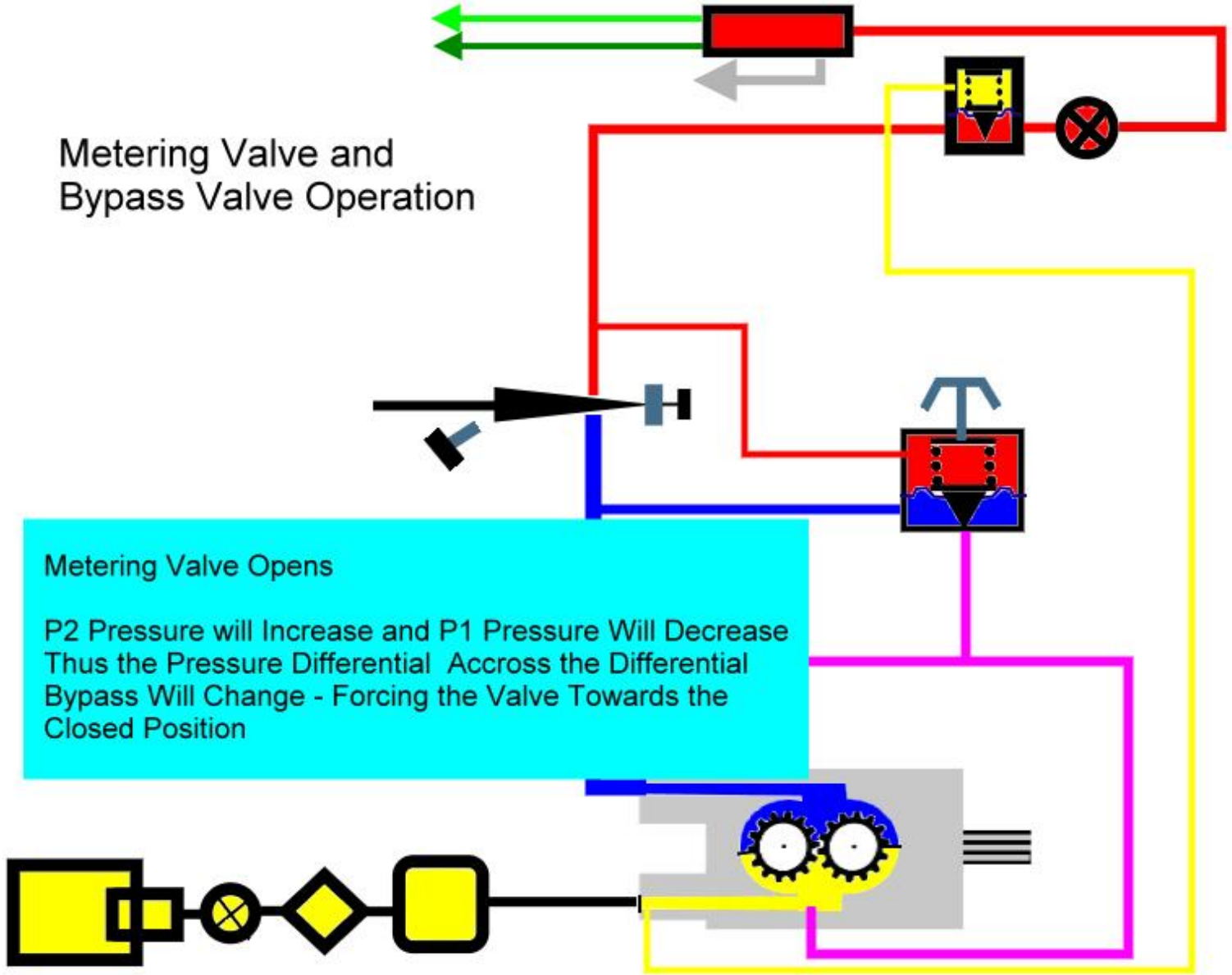
The easiest way to fix that problem is to stop the Fuel Metering Valve from Opening too far

Maximum Fuel Flow Adjustment

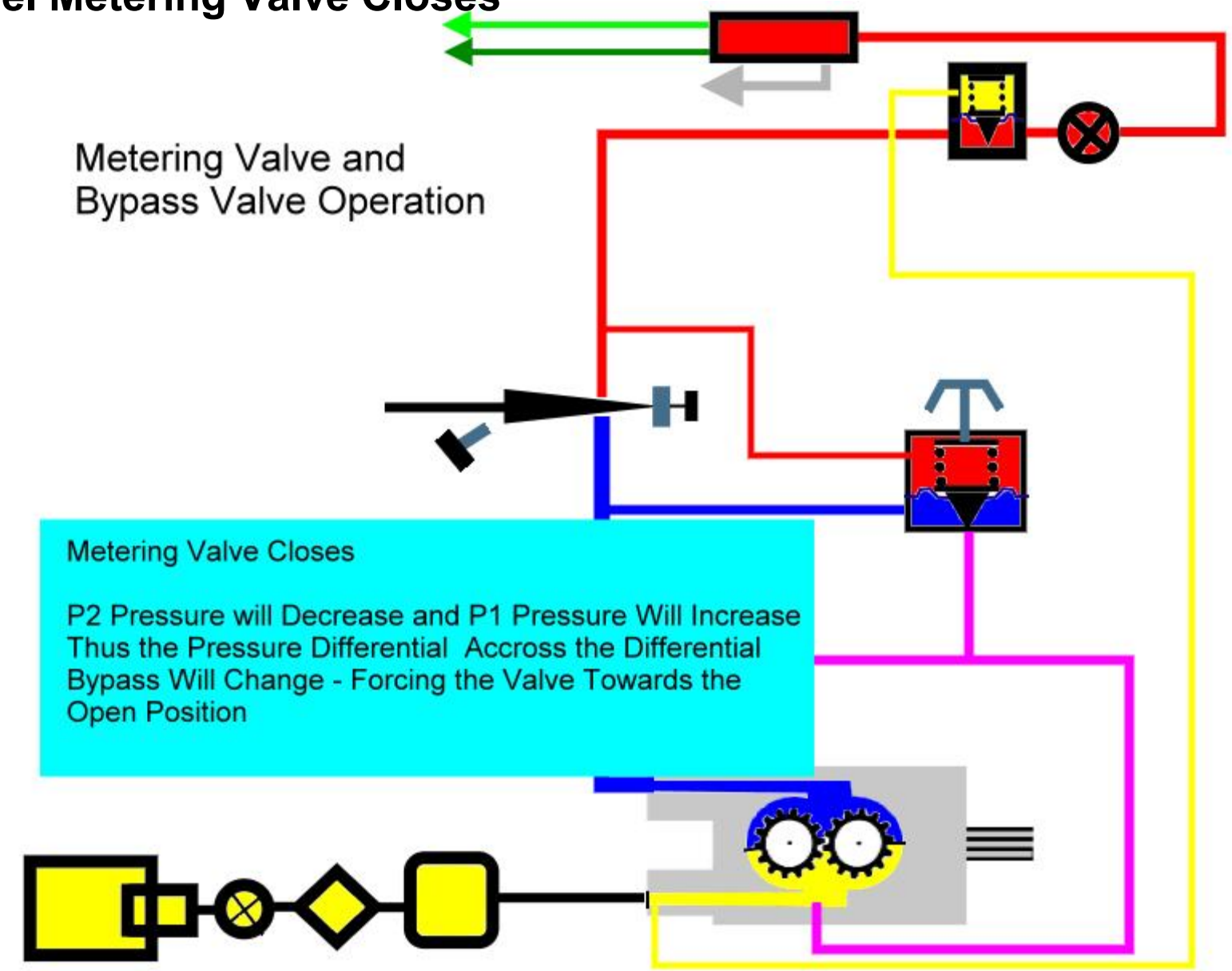


So Here's How It Works!!!

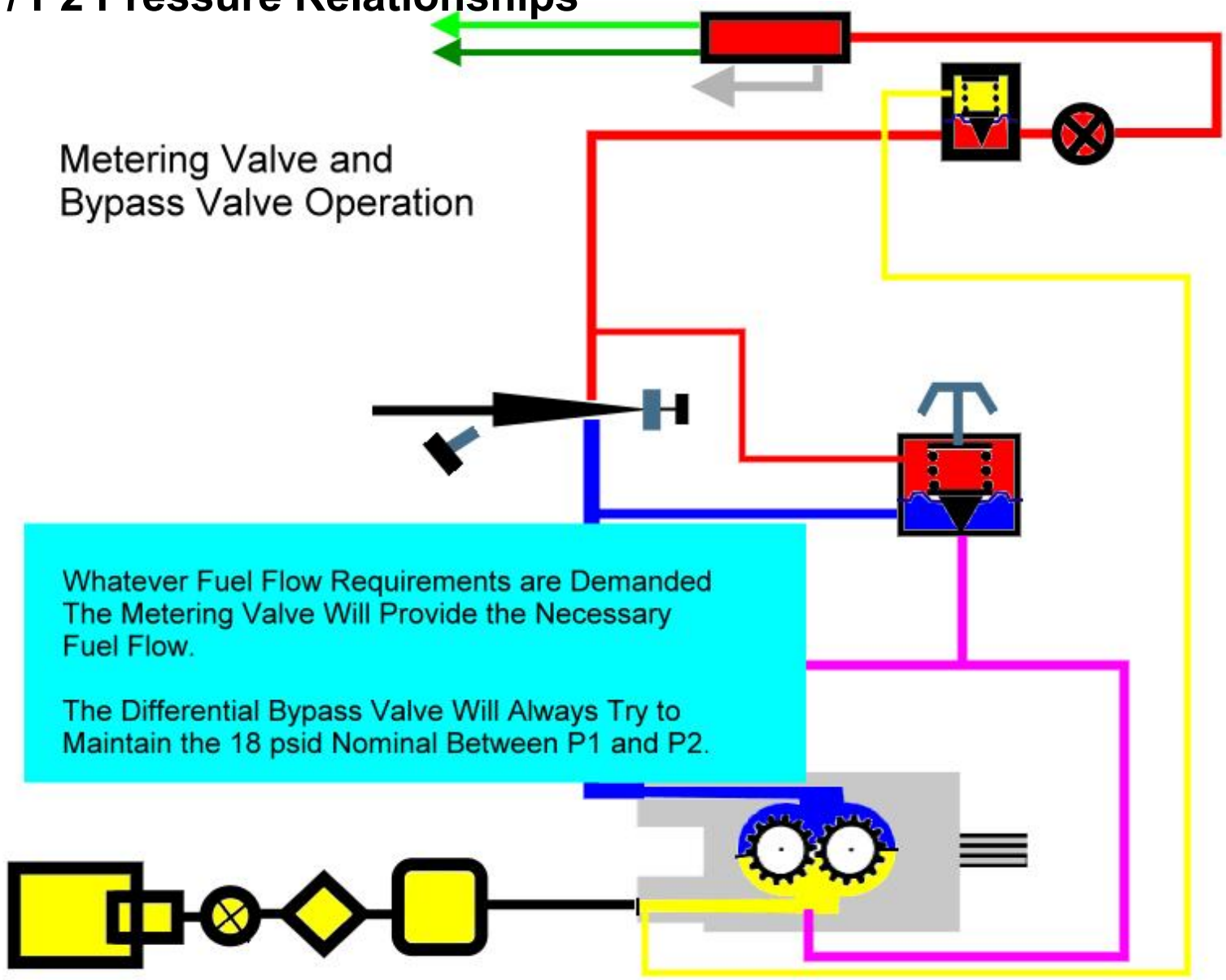
Fuel Metering Valve Opens



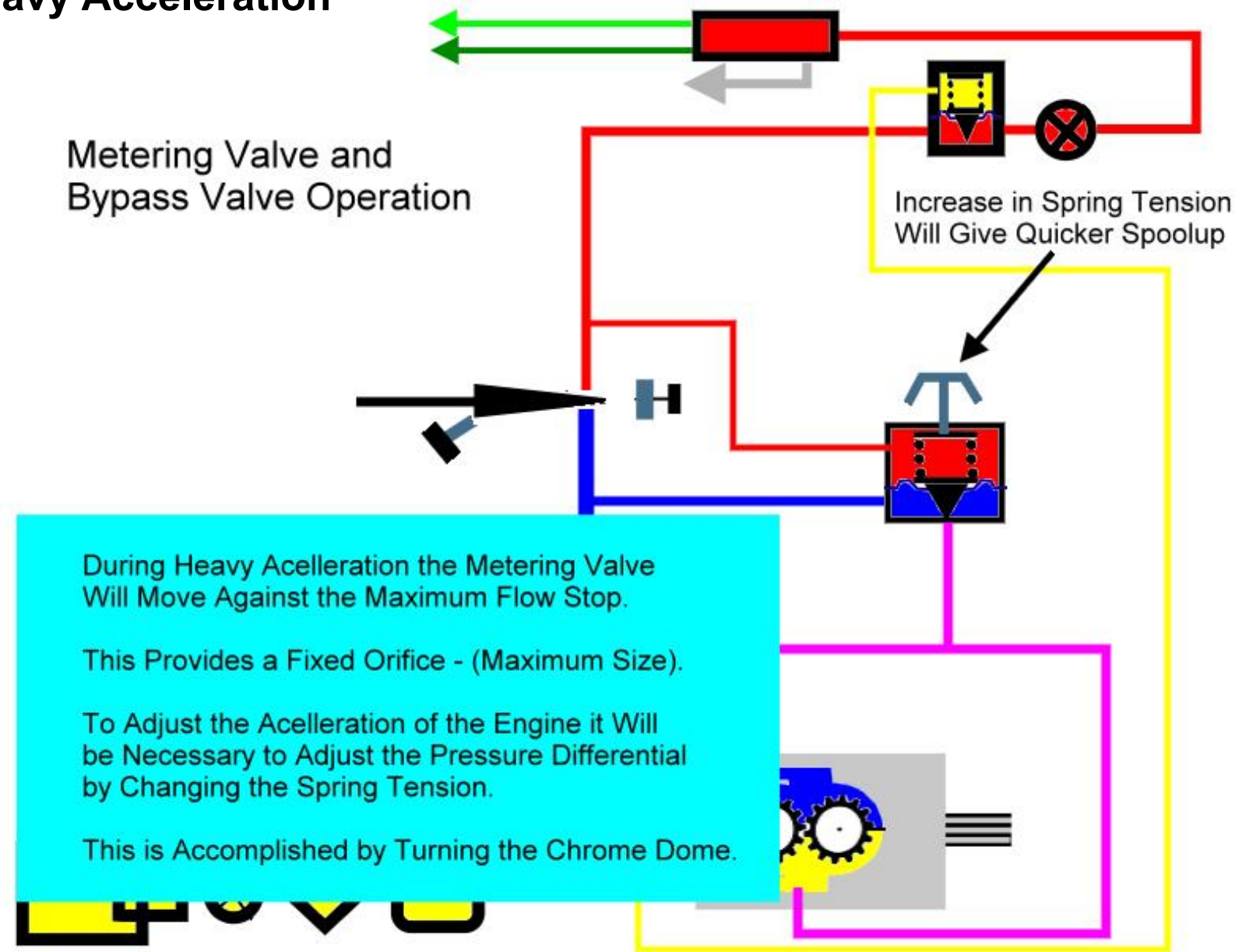
Fuel Metering Valve Closes



P1 / P2 Pressure Relationships

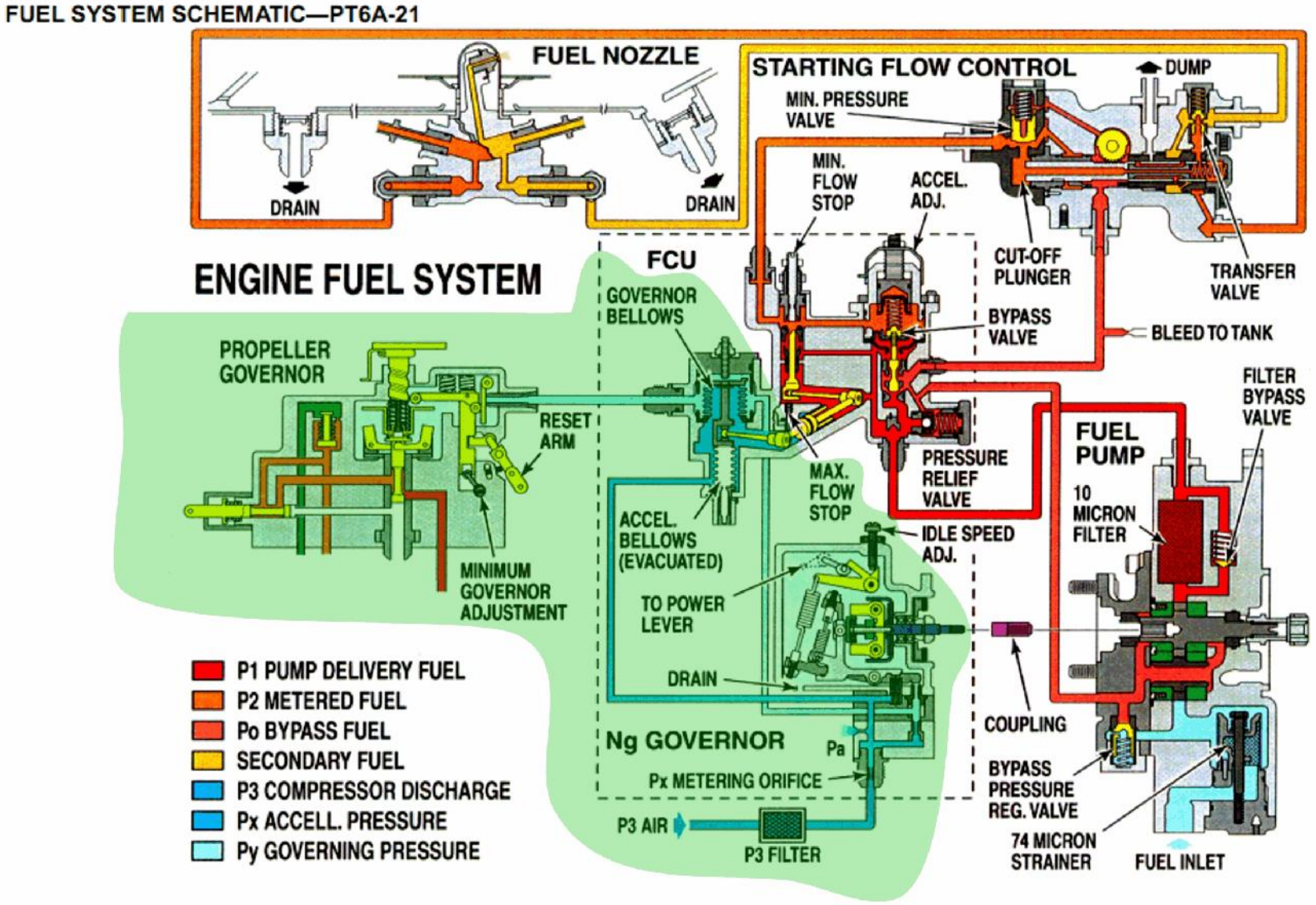


Heavy Acceleration



Well That's all for the Fuel Side

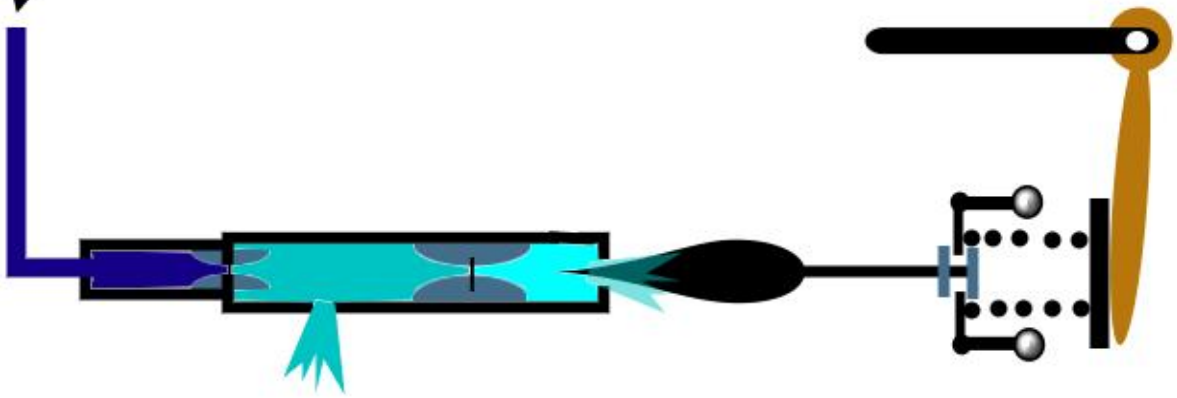
Manufacturers Diagram Showing the Fuel Side of The Fuel Control Unit

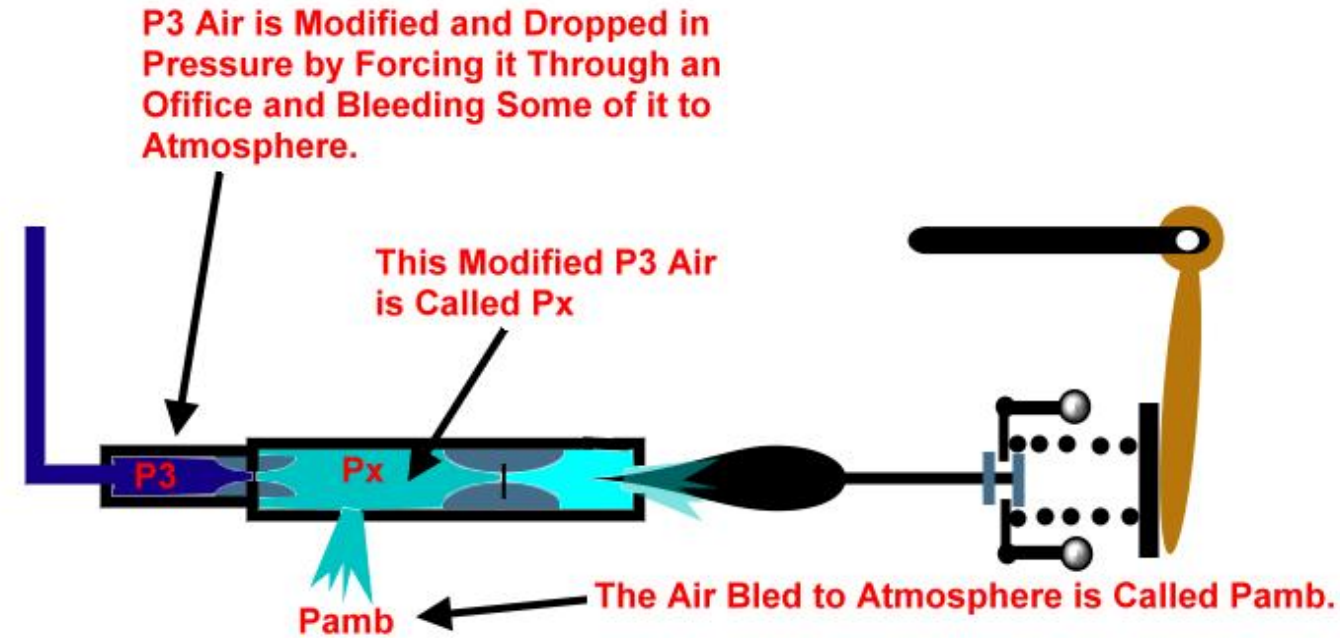


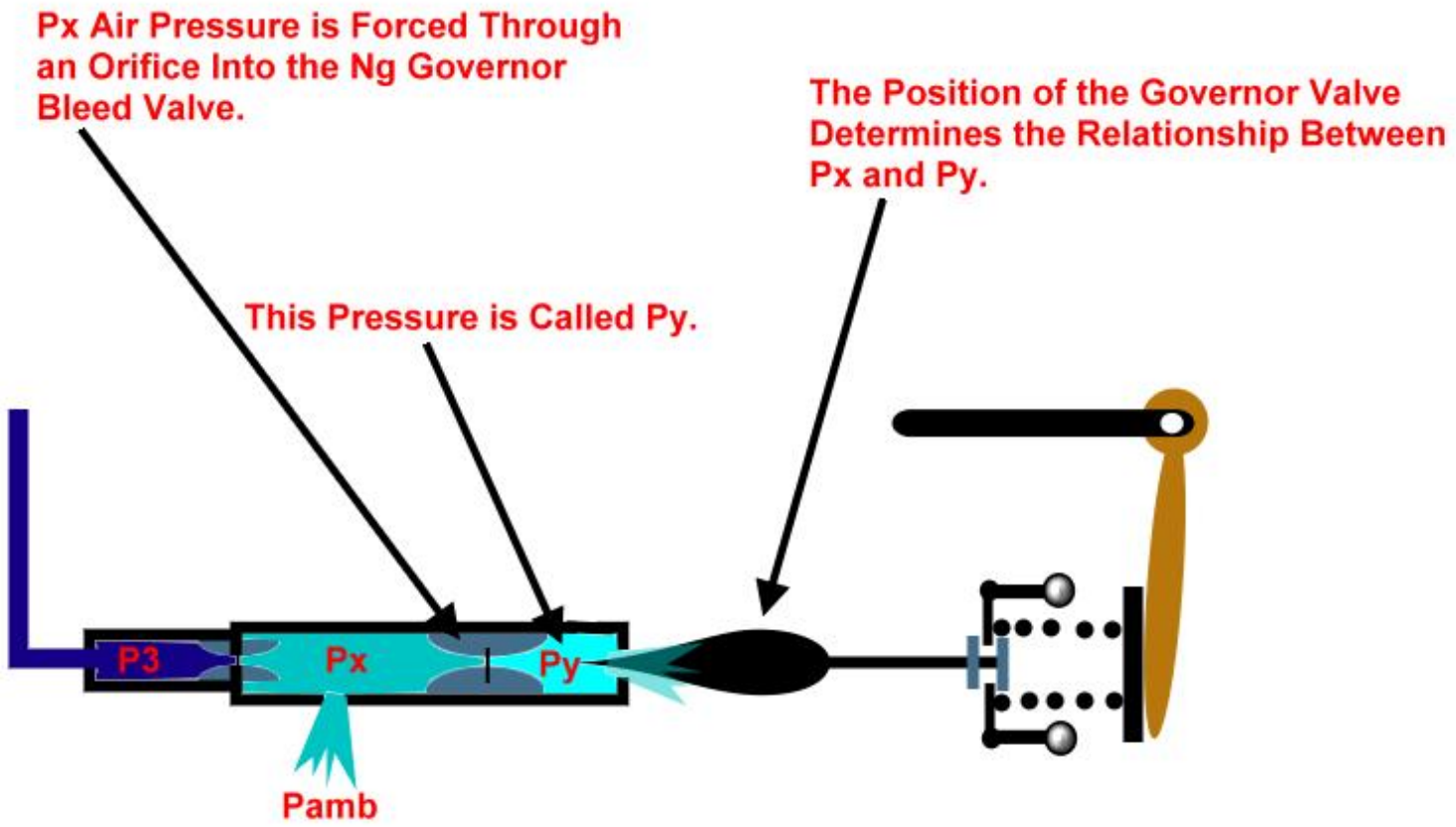
Now for the Air Side

P3 or Pc - Compressor Discharge Pressure

This Pressure has a Direct Relationship to the Mass of Air Flowing Through the Engine.

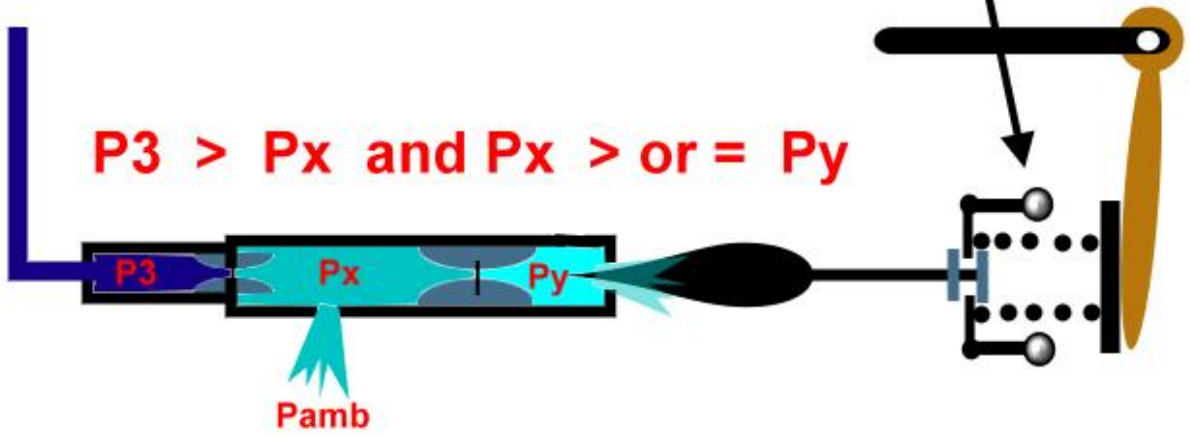






The Ng Constant Speed Governor Provide Py Bleed Valve Positions From FULLY CLOSED to A MAXIMUM OPEN Position.

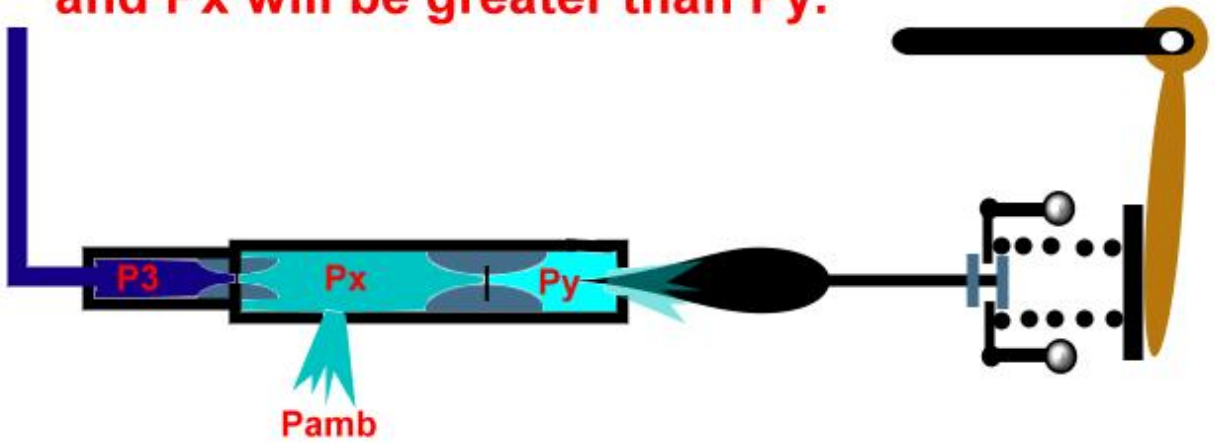
Thus the Following Relationships are Established:



P3 > Px and Px > or = Py

If the Py Bleed Valve is Fully Closed Py will equal Px. - No Bleed - Closed Chamber

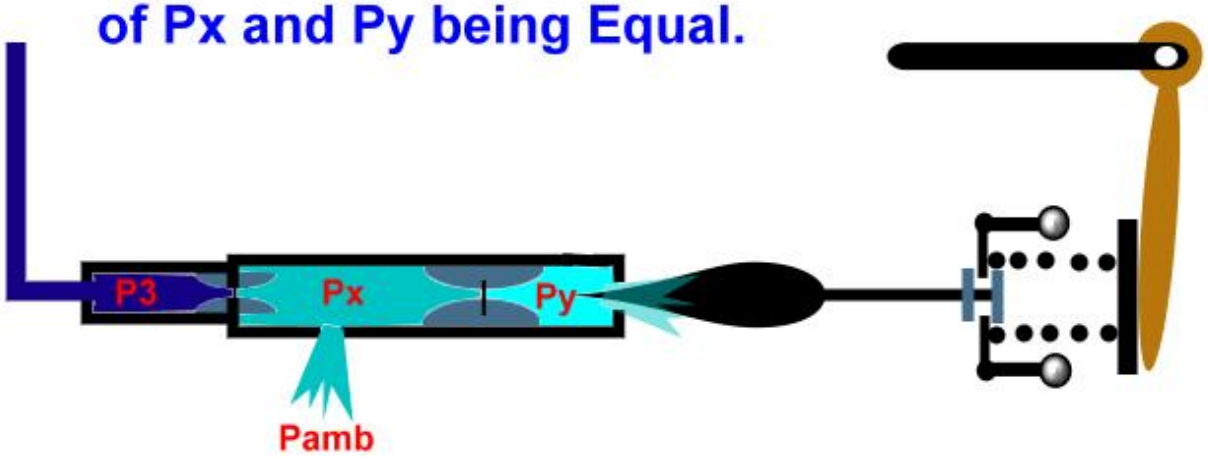
If The Bleed Valve is Open, the Bleed Action will Cause Py Pressure to Decrease and Px will be greater than Py.



P3 > Px and Px > or = Py

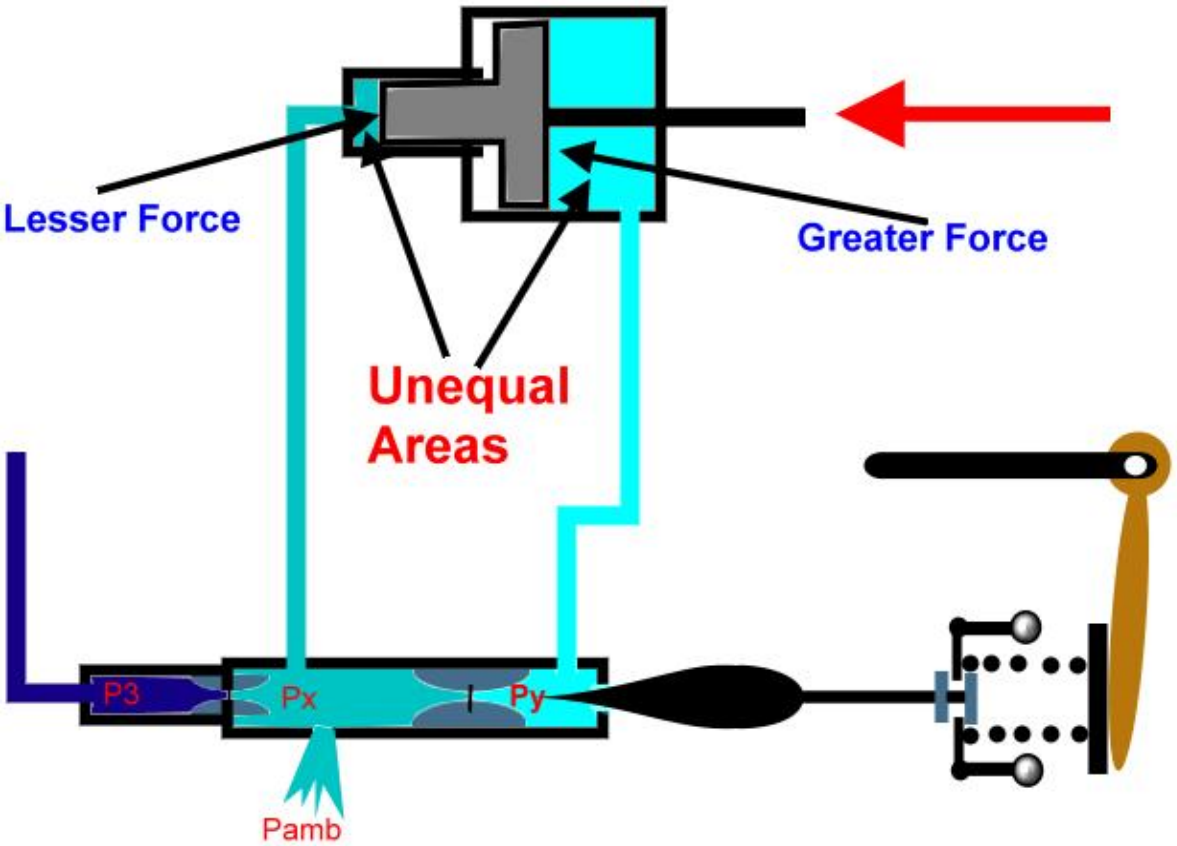
A Governor Overspeed Condition will Bleed More Py to Ambient. Thus the Action produced by the Governor will Decrease Py Pressure.

A Governor Underspeed Condition will Bleed Less or Stop the Py Bleed to Ambient. Thus the Action Produced by the Governor will Raise the Py Pressure - to a Maximum of Px and Py being Equal.



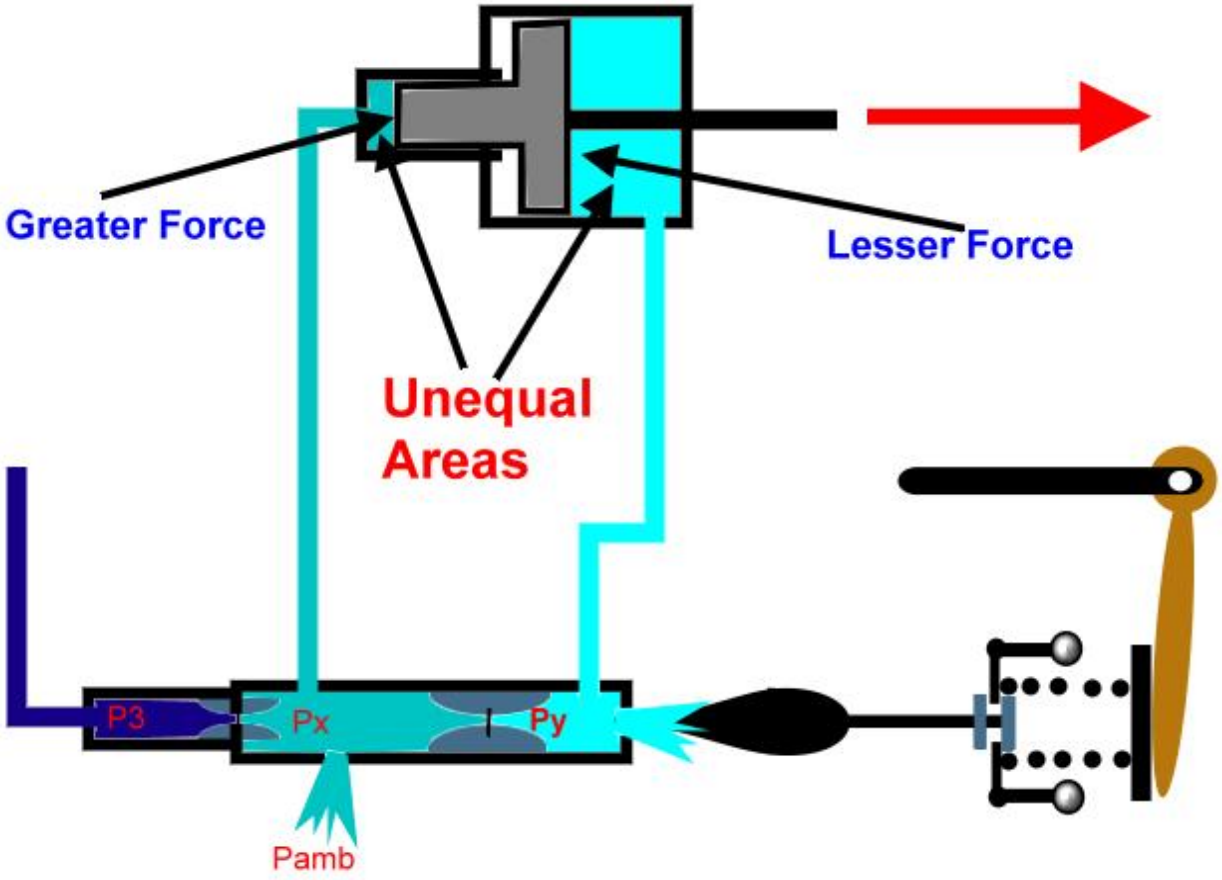
If Px and Py are Equal

The unequal Areas with The Same Pressure will Cause the Mechanicals to Move to the Left.



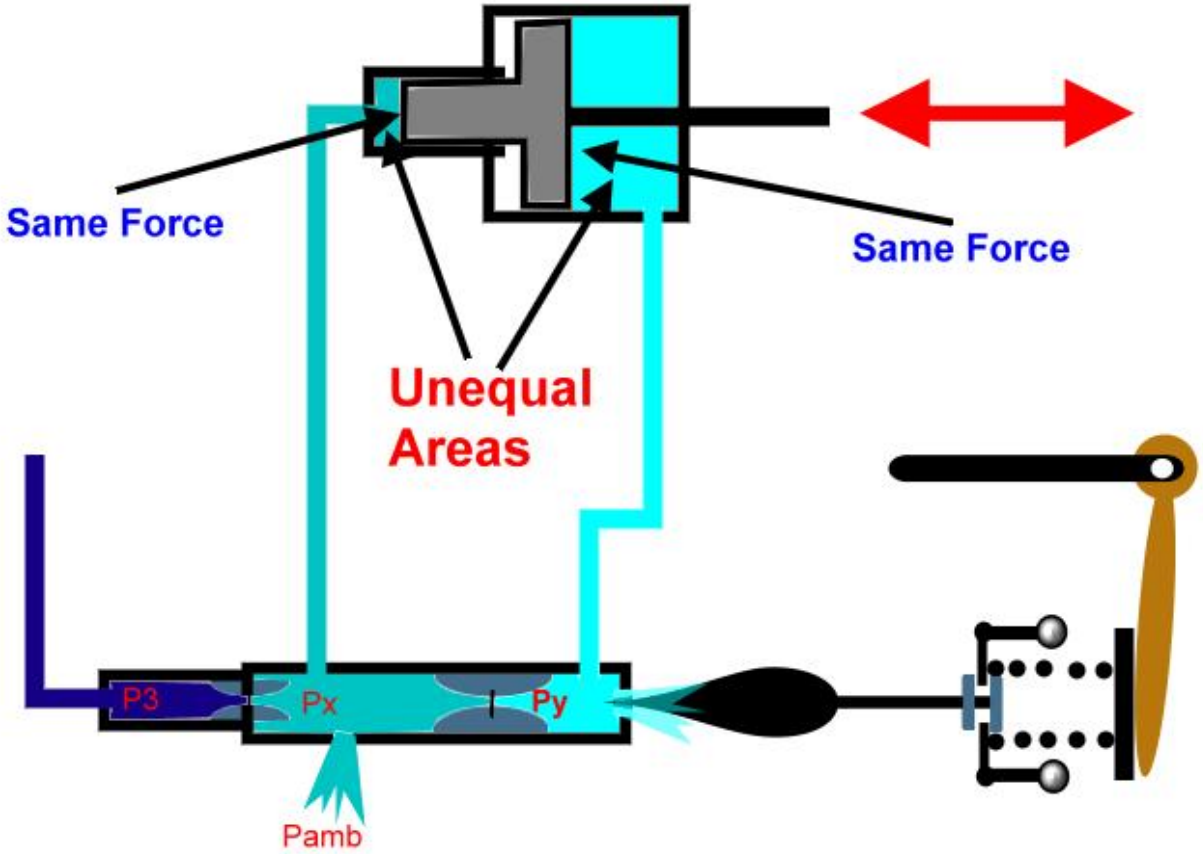
If Px is Greater Than Py by the Maximum Amount.

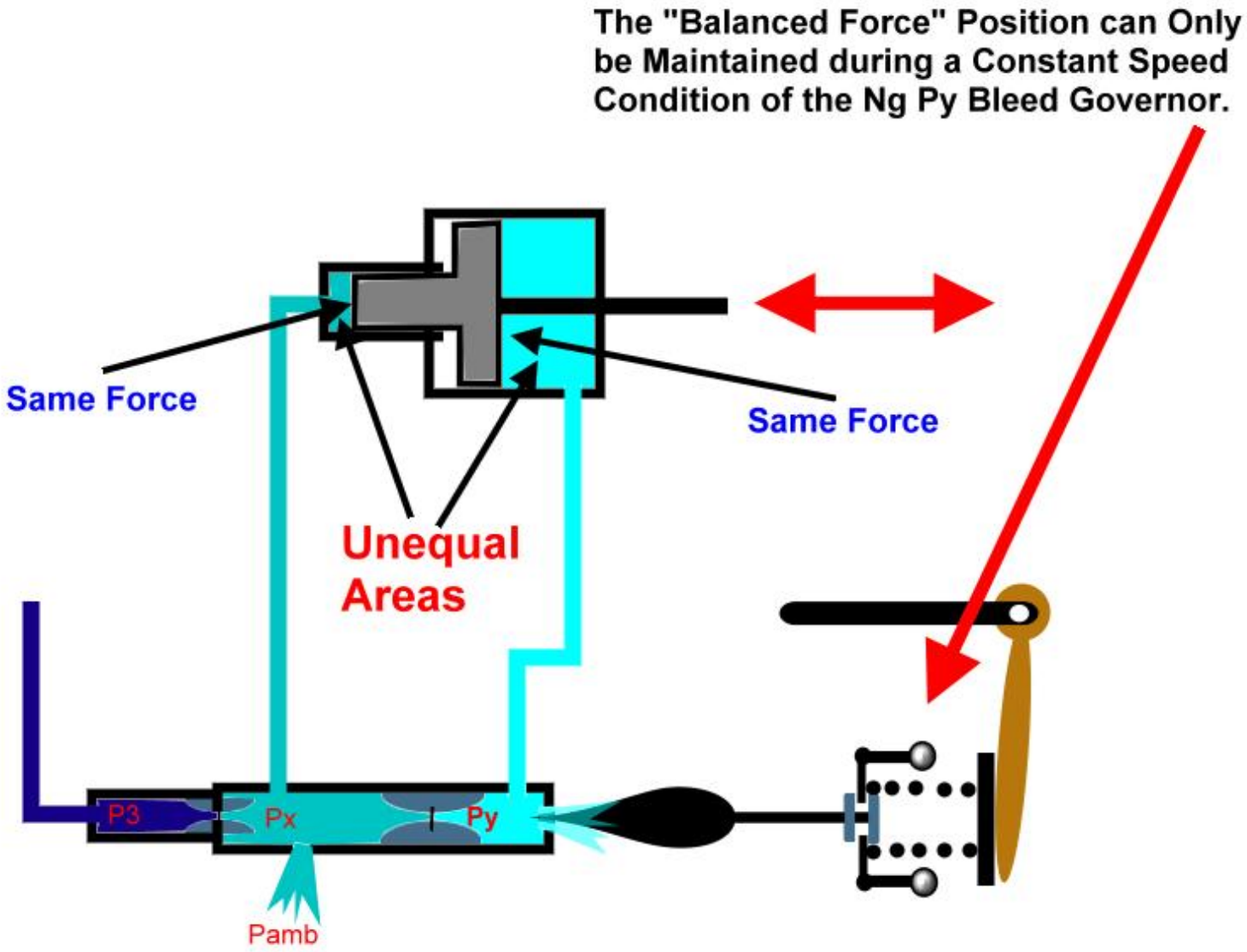
The Unequal Areas with Different Pressures will Cause the Mechanicals to Move to the Right.



If Px is Greater Than Py by a Specific Amount.

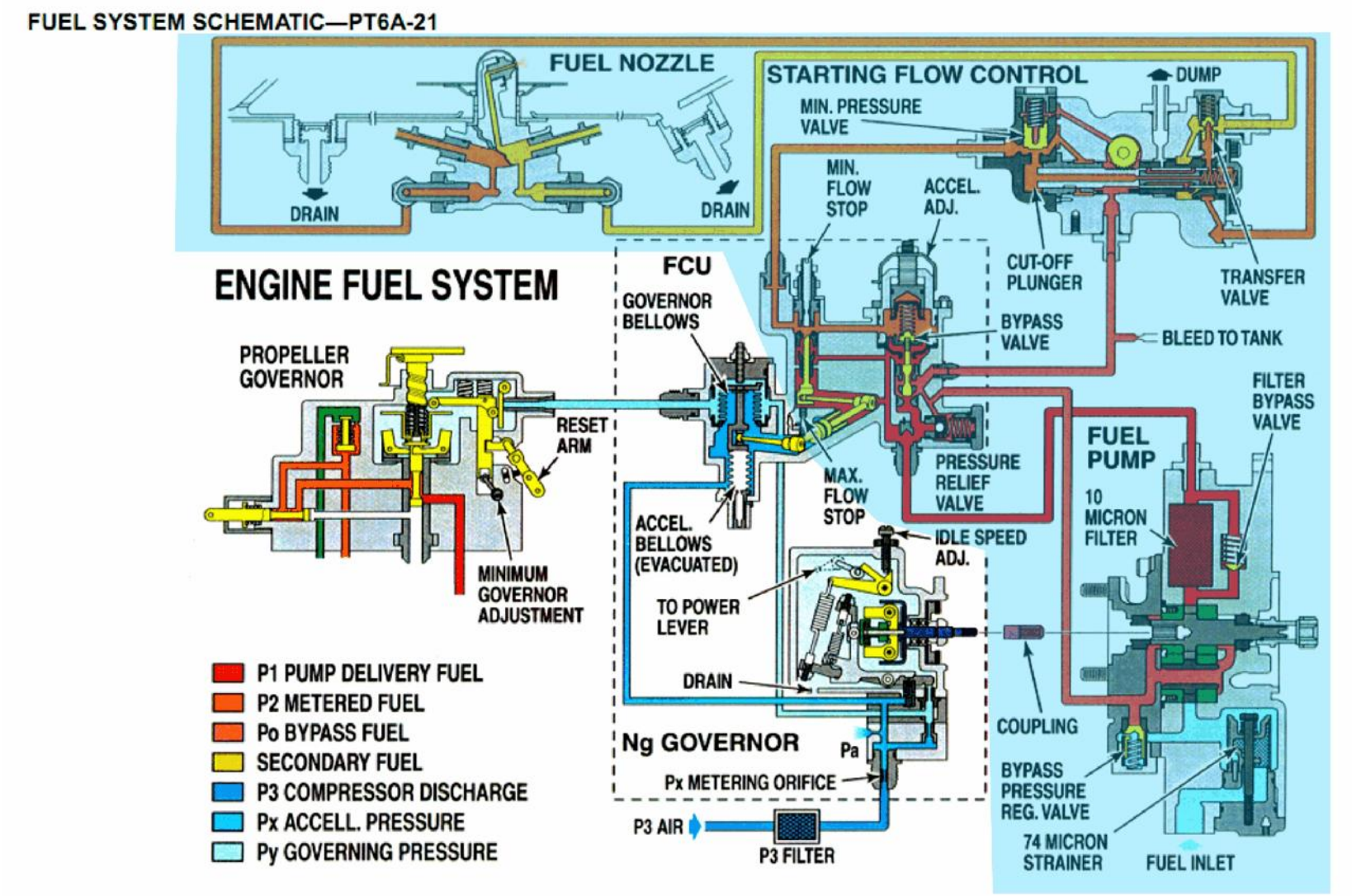
The Unequal Areas with Different Pressures
Will Produce "EQUAL FORCES"
and will Cause the Mechanicals to Maintain a
Constant Position.

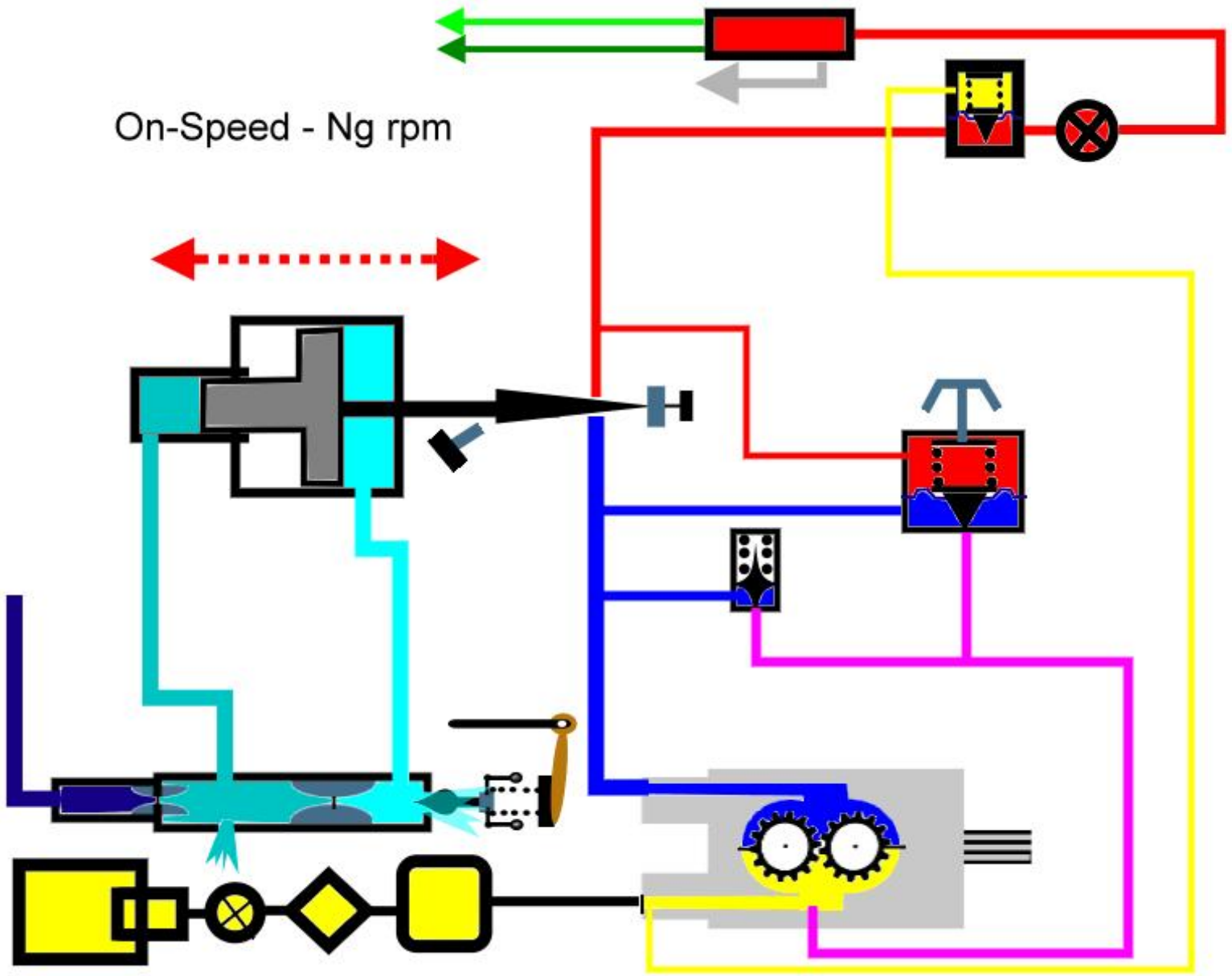


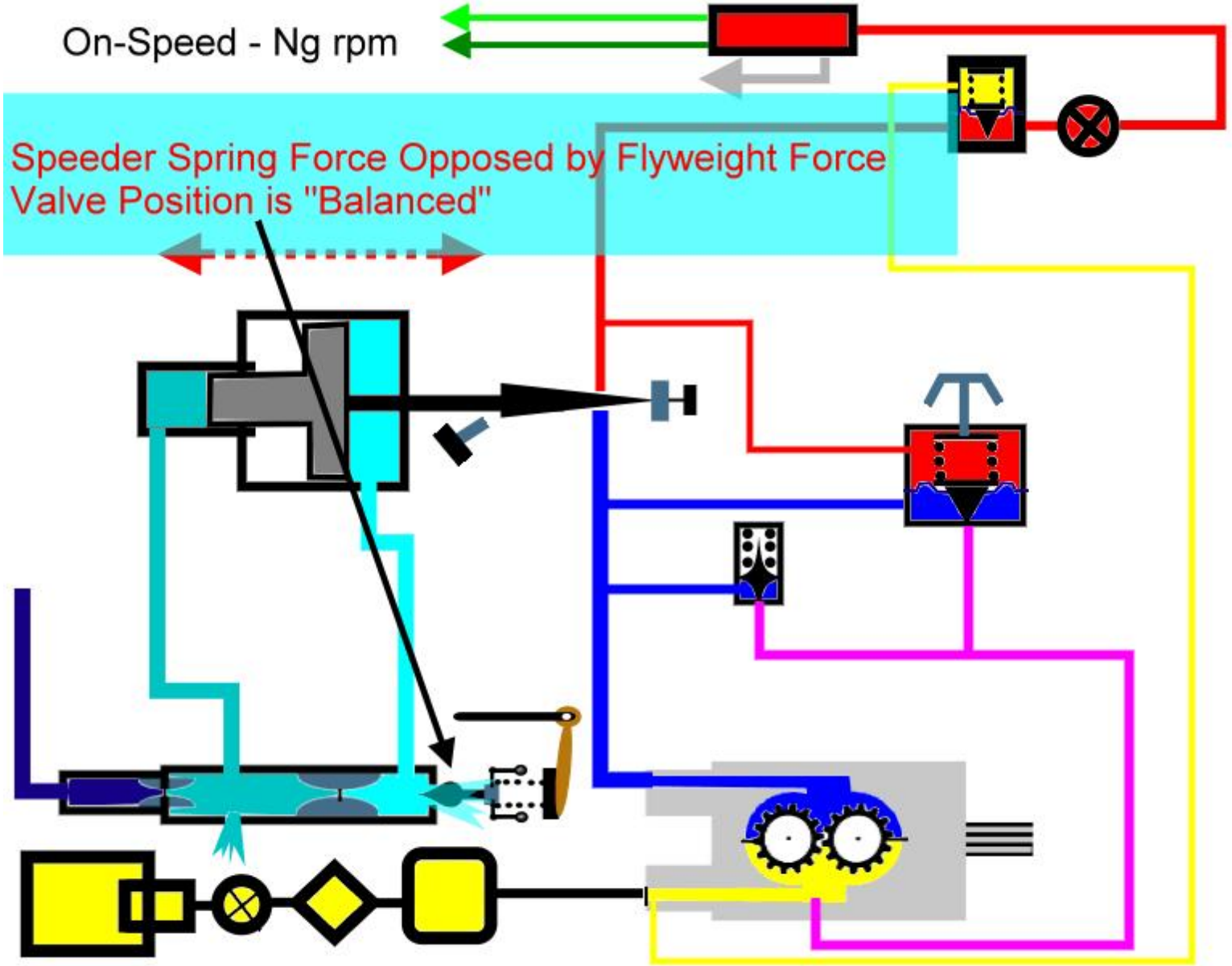


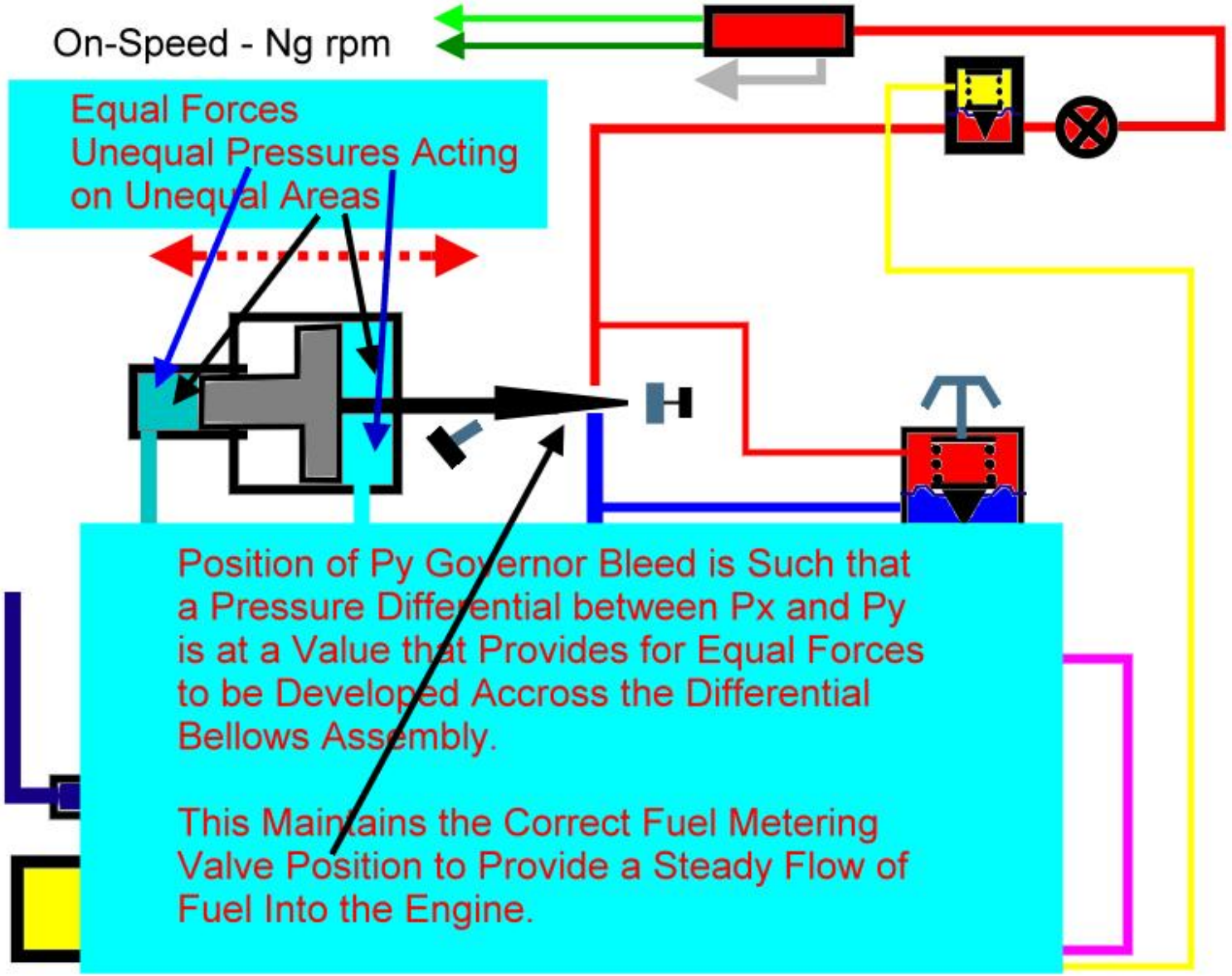
Now Lets Put it All Together

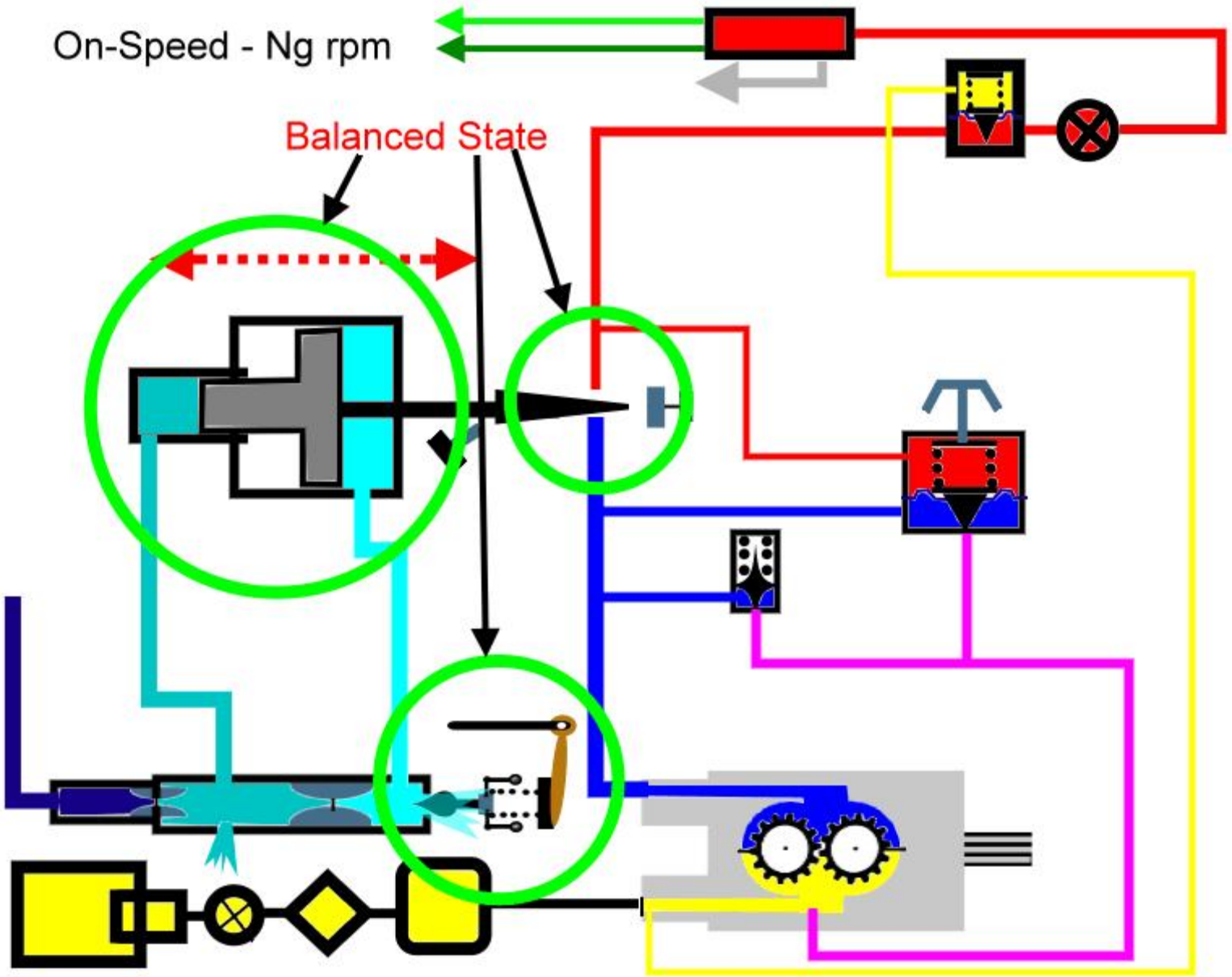
Manufacturers Diagram Showing the Air Side of the Fuel Control Unit



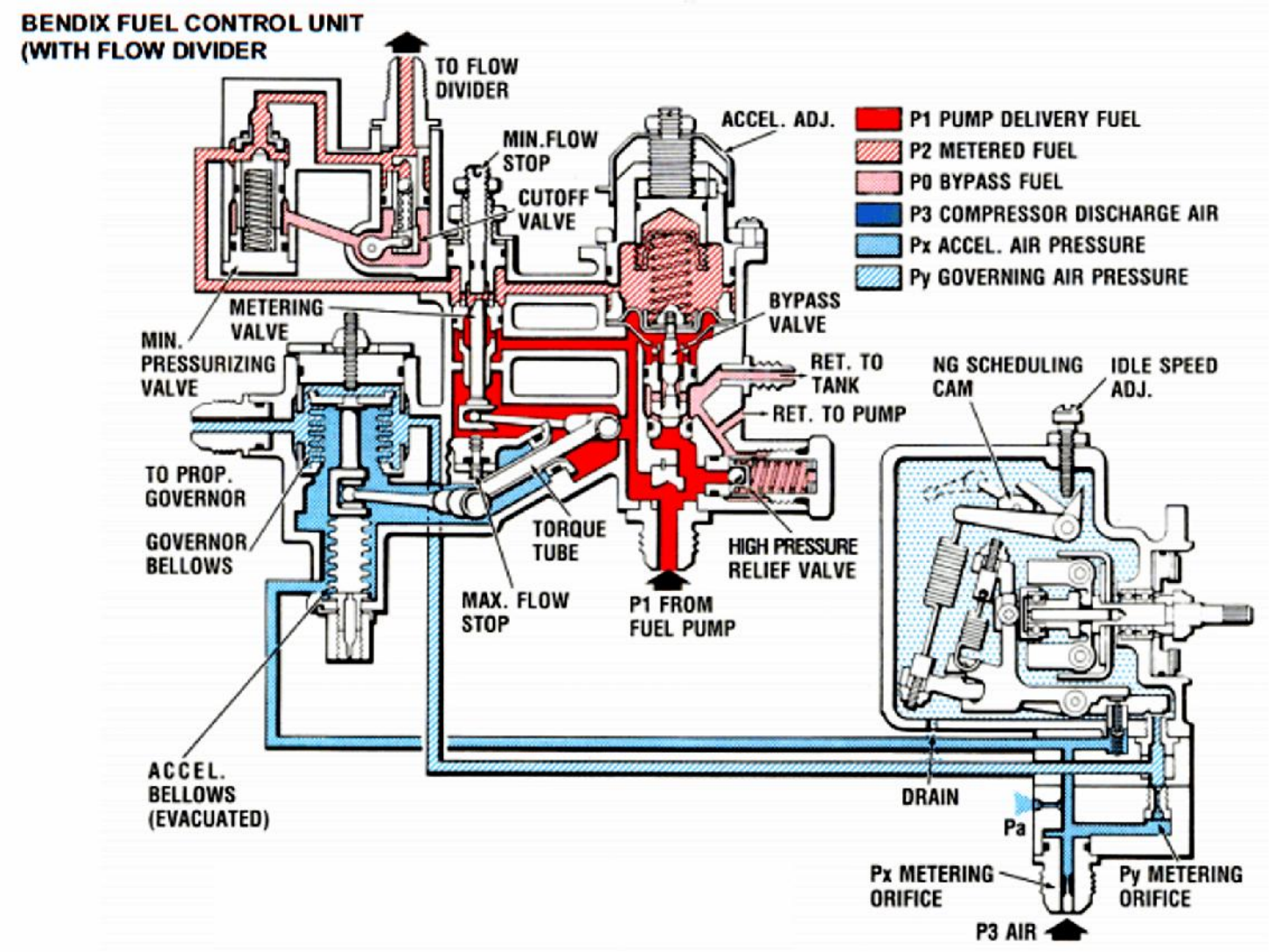








Bendix Fuel Control System Diagram



Since I am going to use this engine with reversing propeller I must find a way of ensuring the propeller speed while in reverse (BETA) will never reach the 100% speed.

An overspeed condition on the propeller will cause the propeller governor pilot valve to direct oil into the case and move the blades in a coarse direction.

The problem is that in reverse the initial blade movement is towards zero degrees of blade pitch!!!

This will cause the power section to over-speed and fling blades.

NOT GOOD!!!

What we need is a governor that will sense Propeller speed and somehow prevent it from going too fast.

But I need that governor to not interfere with my CSU (Constant Speed Unit) while I am in the normal cruise (ALPHA) mode.

Sound like I have a complicated set of conditions to obtain.

Since the propeller will be selected to the -14 degree internal stop when in reverse it will act as a *fixed pitch propeller*.

A fixed pitch propeller will vary its speed as a function of engine power.

All I have to do is limit the power delivered to the propeller to a value that is less than 100% propeller speed and then my CSU can never change the blade pitch.

What I need to do is TOP the Fuel Schedule - just like a logger tops a tree.

The Fuel Topping Governor or Nf governor as it is also called will be driven by the reduction gear case. This mechanical flyweight governor will sense what speed the propeller is running at.

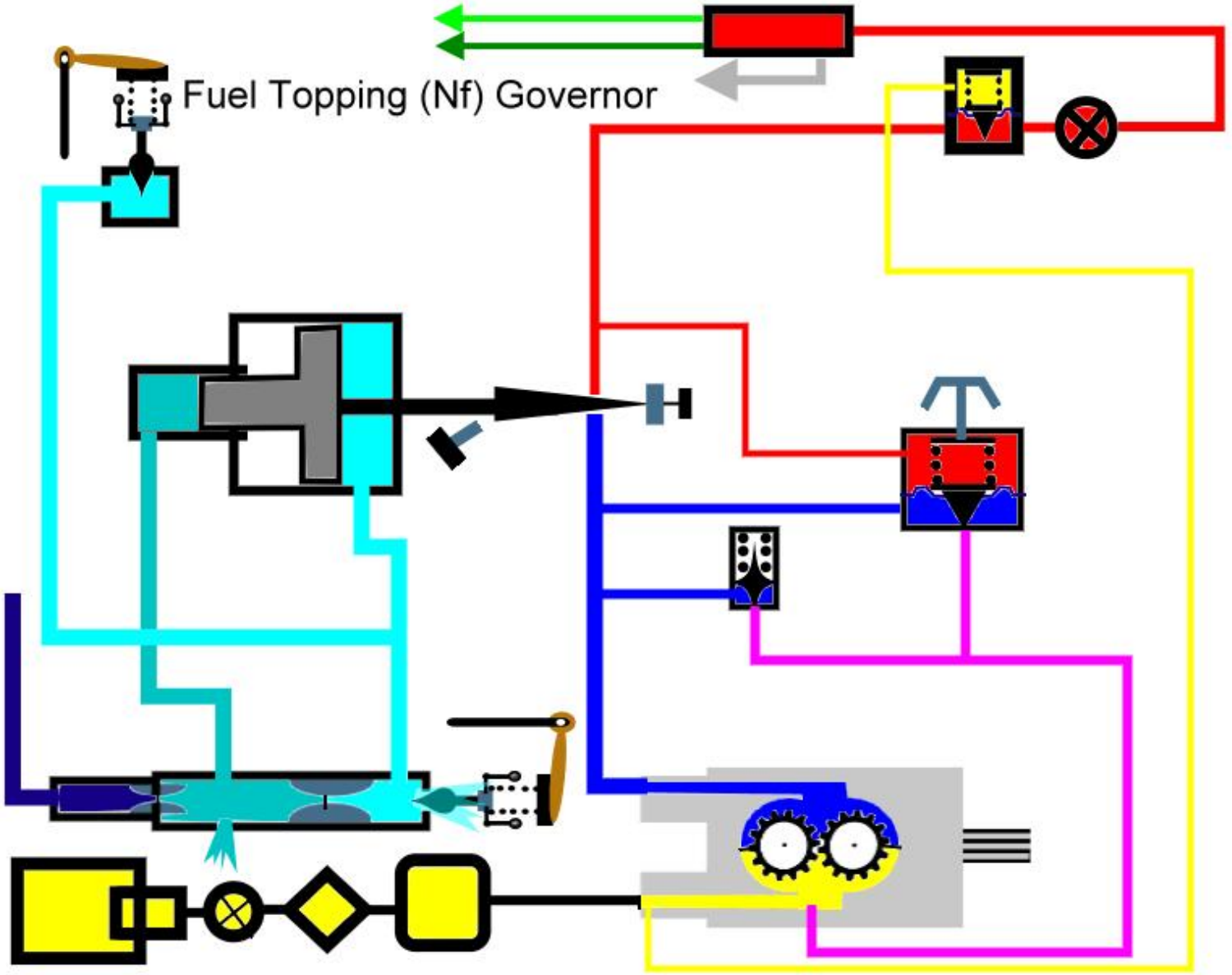
In addition since I have a reversing propeller I will need some RESET LINKAGE to put the Fuel Topping Governor speeder spring pressure at the correct value for ALPHA and for BETA ranges.

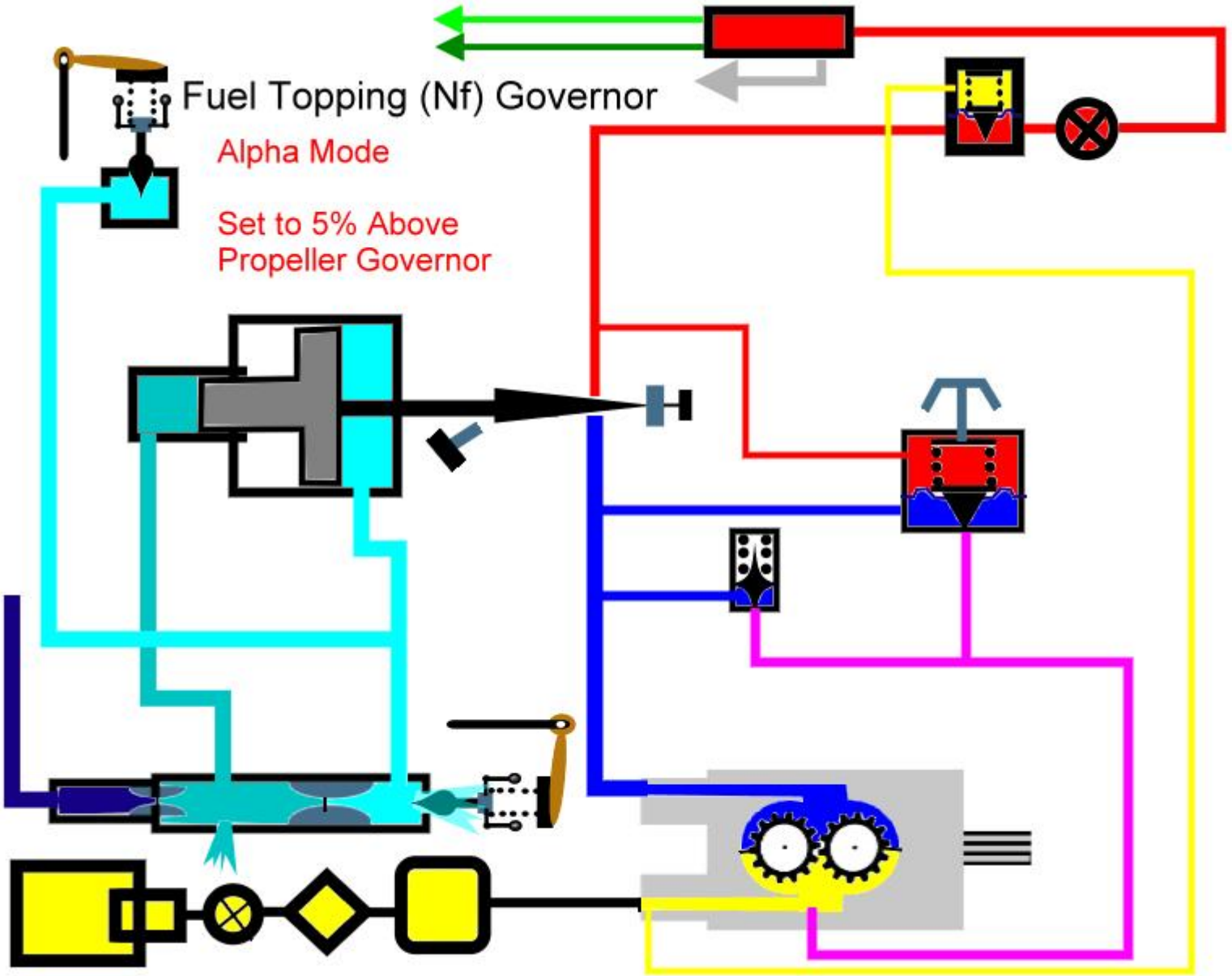
To prevent interference in ALPHA mode I will ensure the Fuel Topping Governor is set to 5% above whatever I have selected by the propeller speed lever.

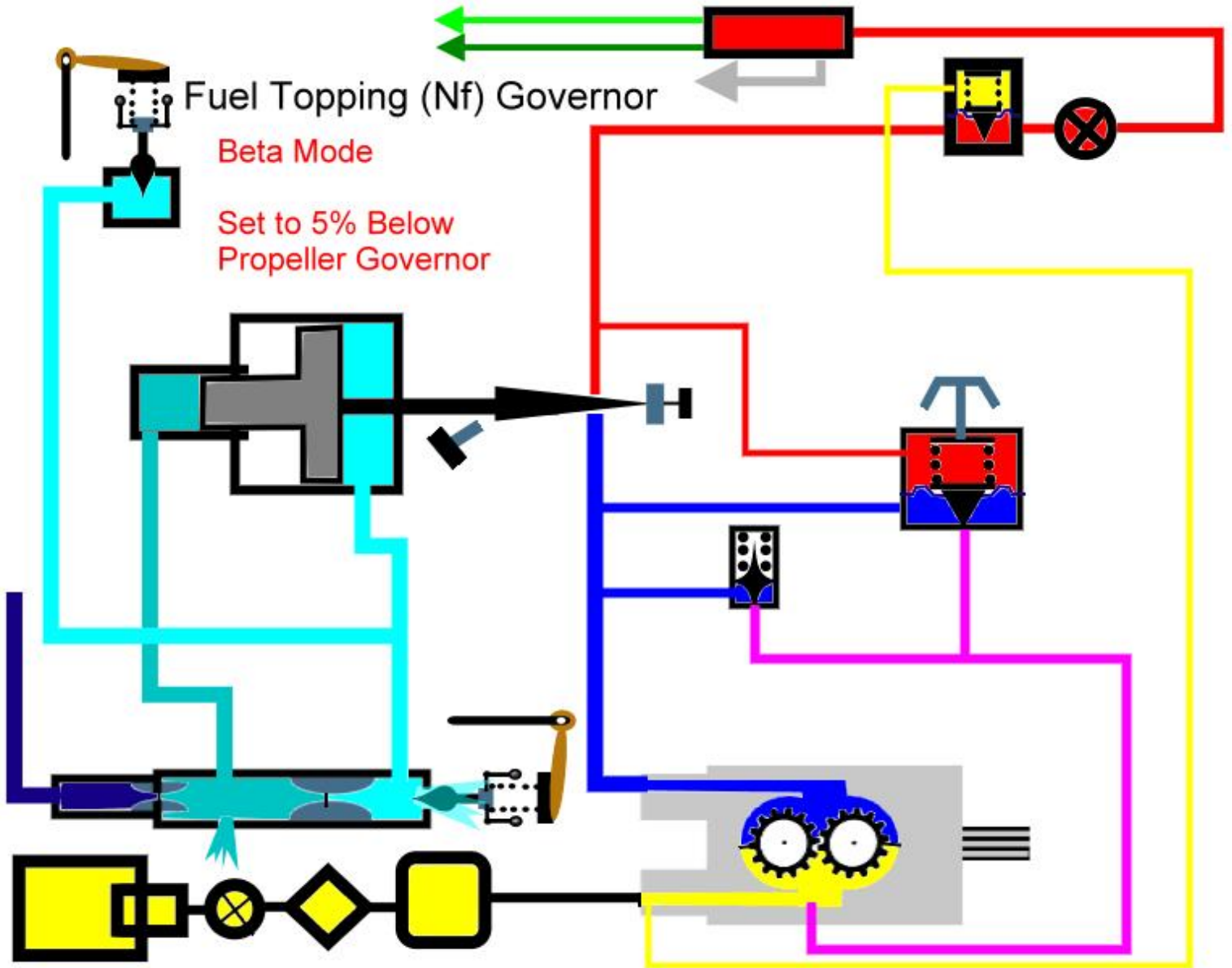
When I enter into Beta mode I will reset the Fuel Topping Governor by this linkage to a value of 5% below what I have my CSU speed set to.

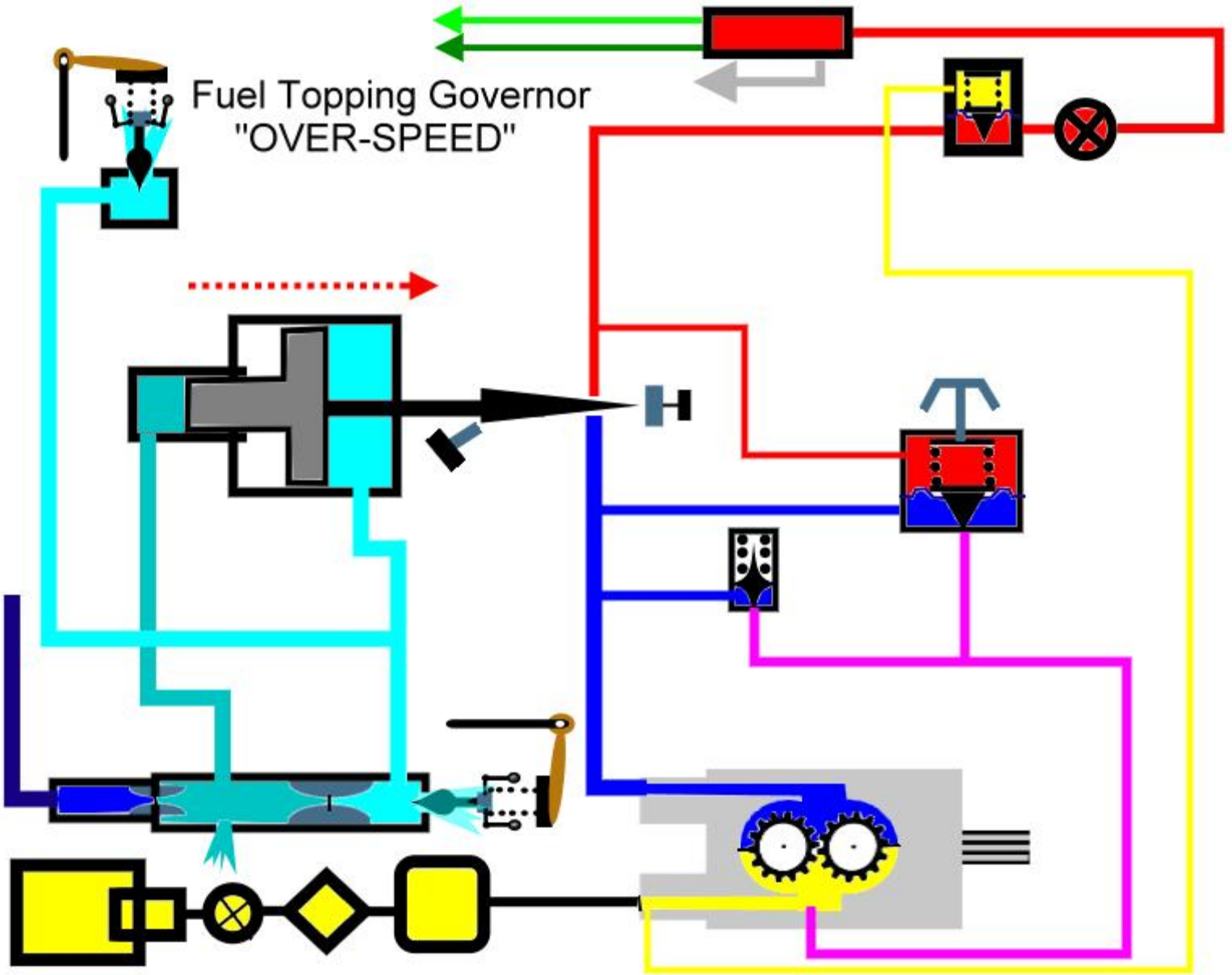
I will need to ensure the CSU is set to 100% prior to selecting reverse with the Power Lever - Thats an easy fix - just put a Mechanical Interlock on the Power Lever that prevents it from moving into reverse until the Propeller Speed Control is in the 100% position.

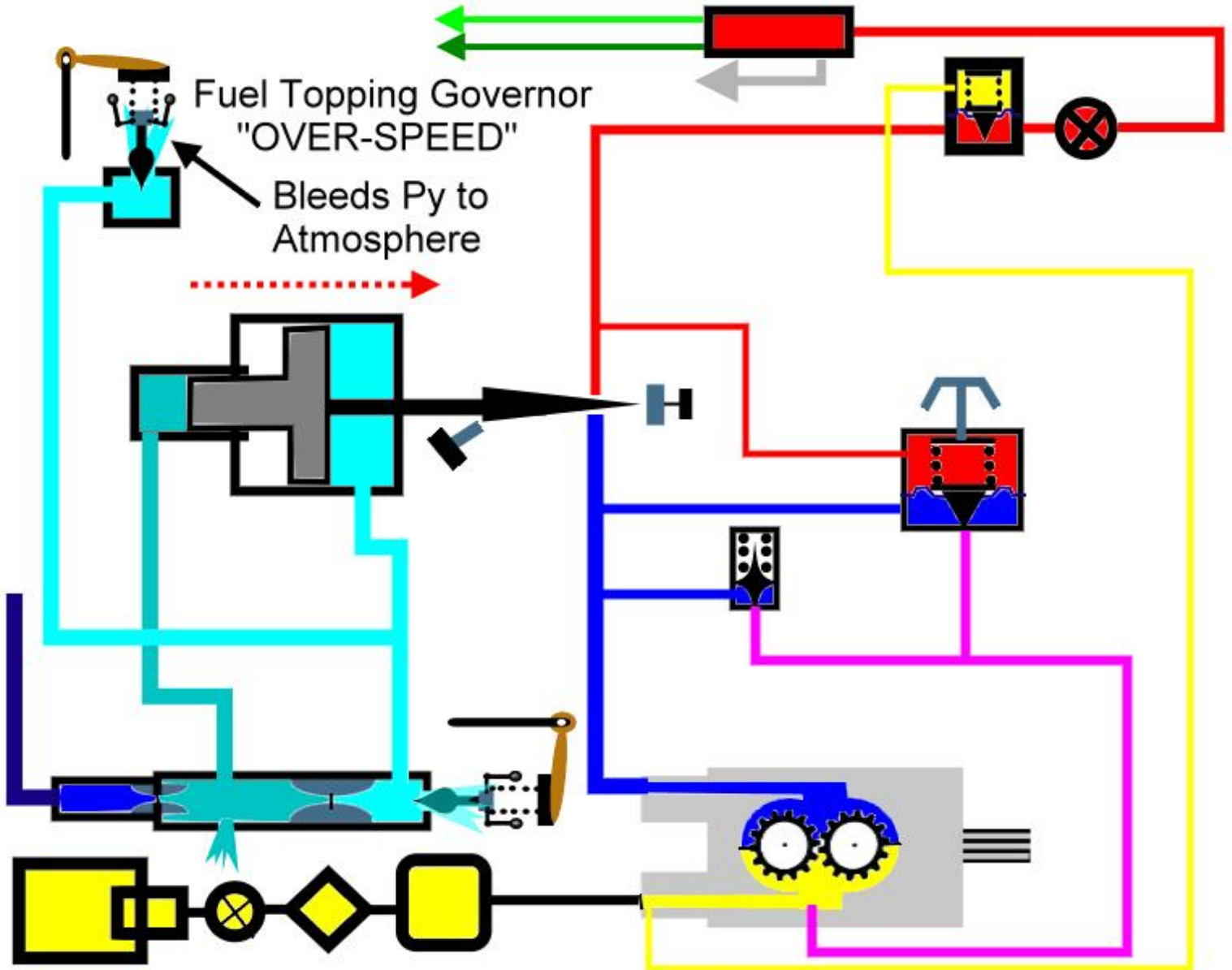
Now we are Cooking!!!

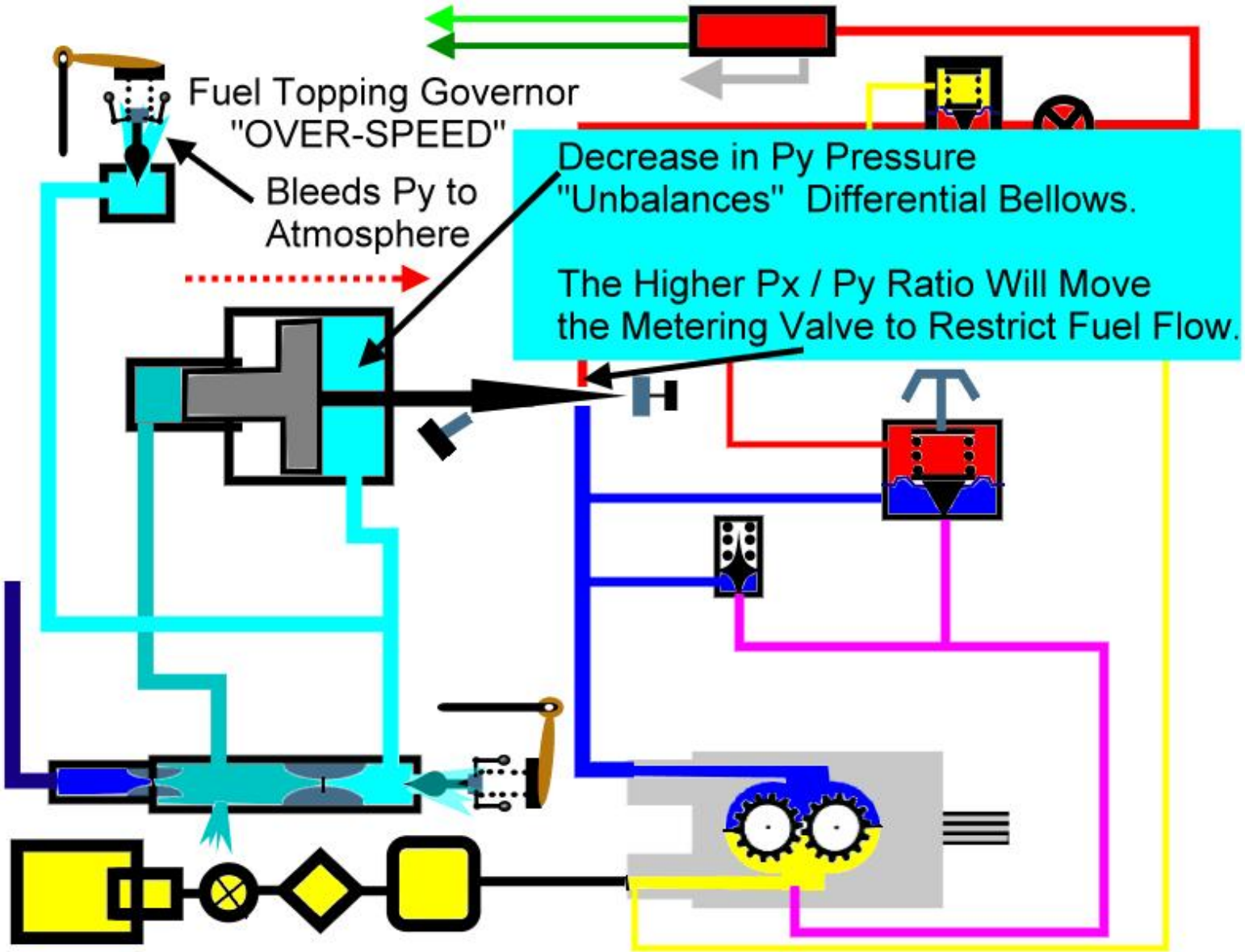






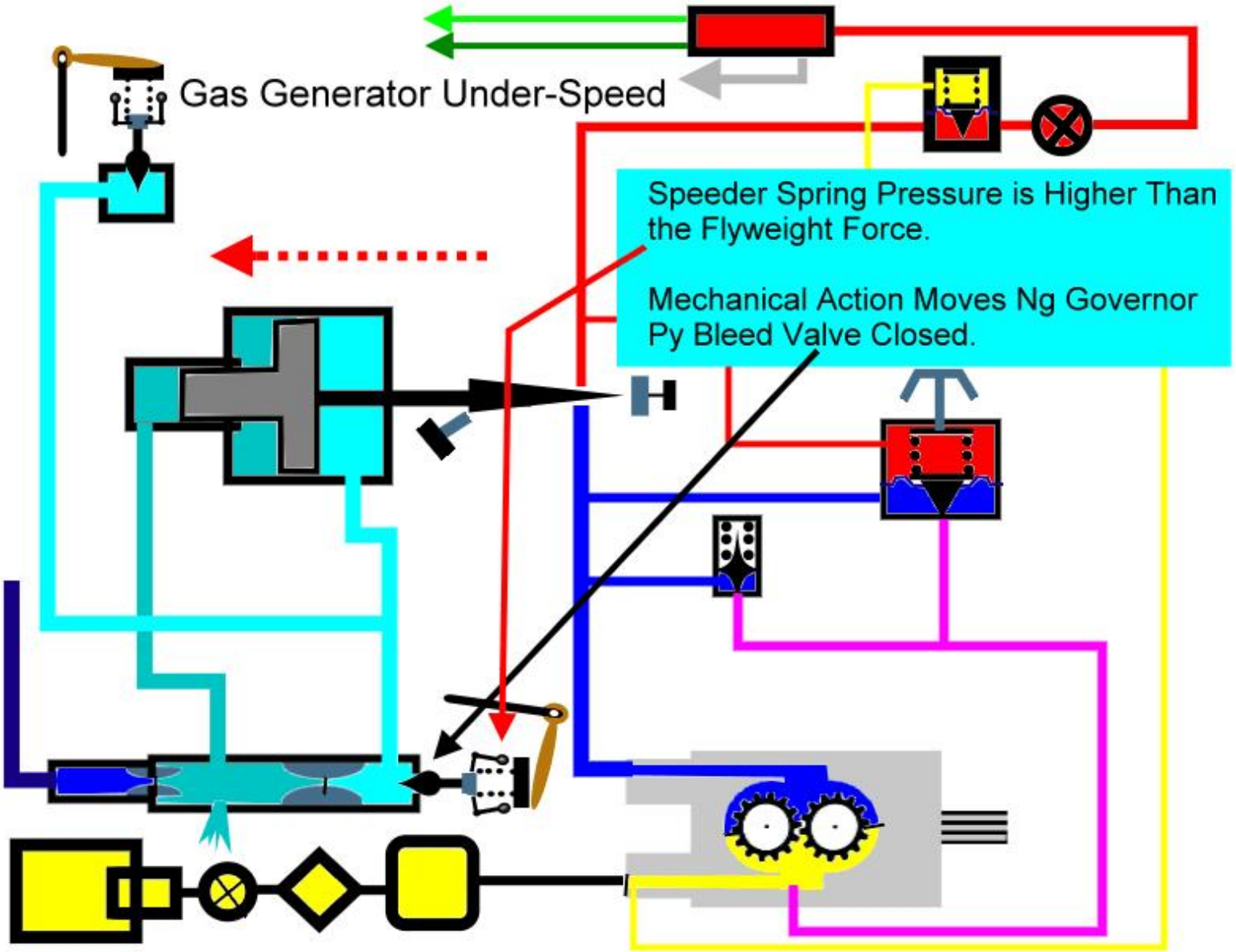


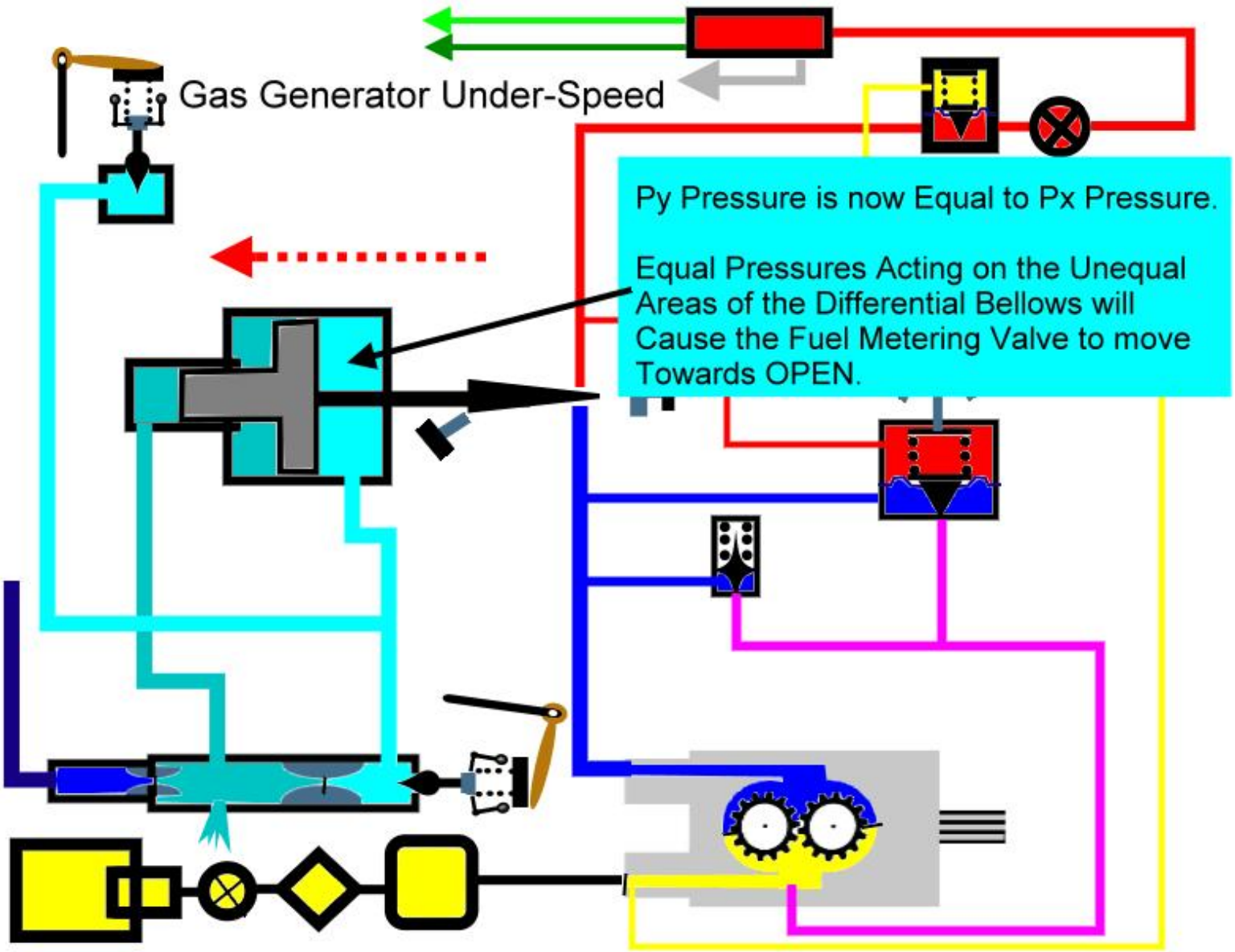




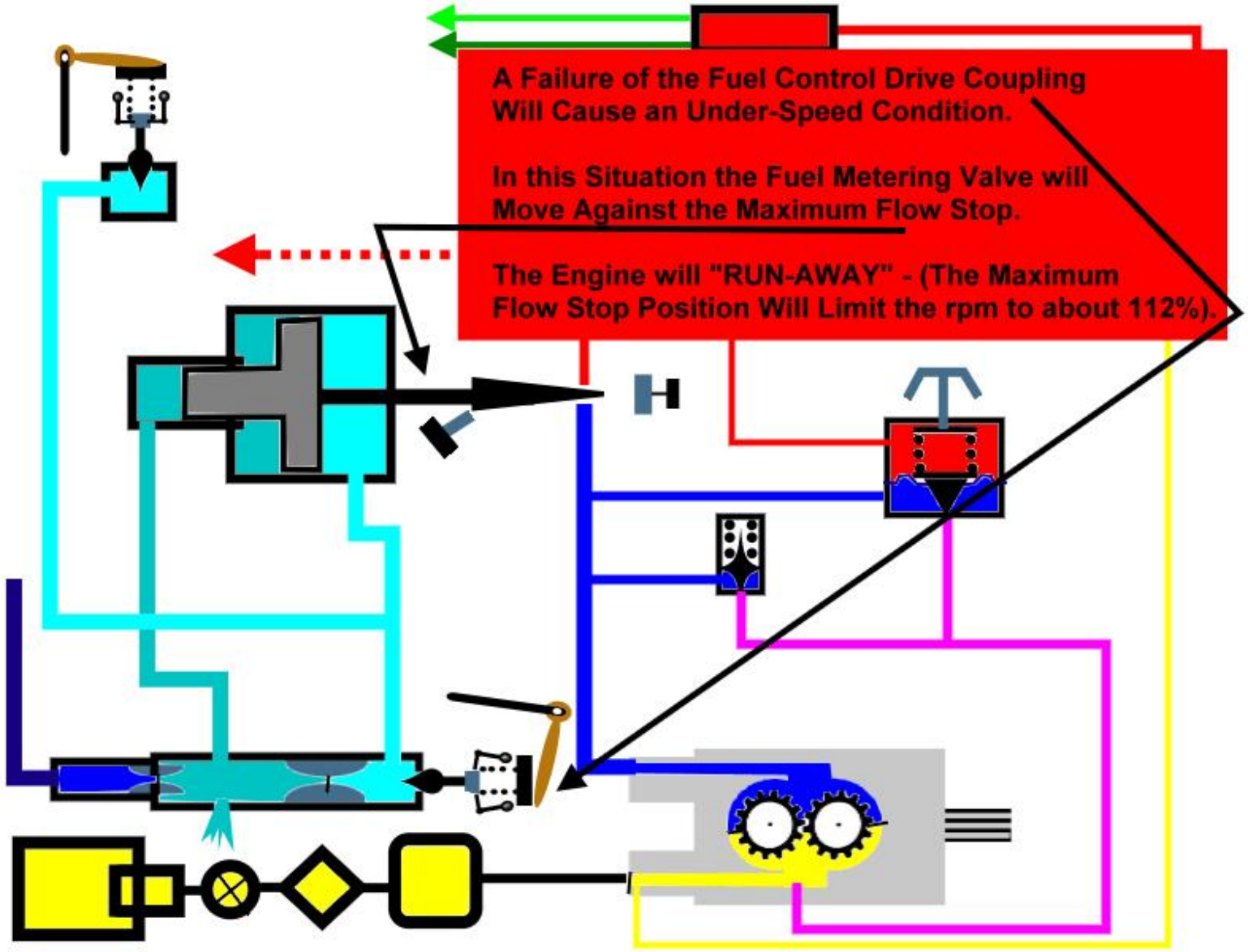
OK

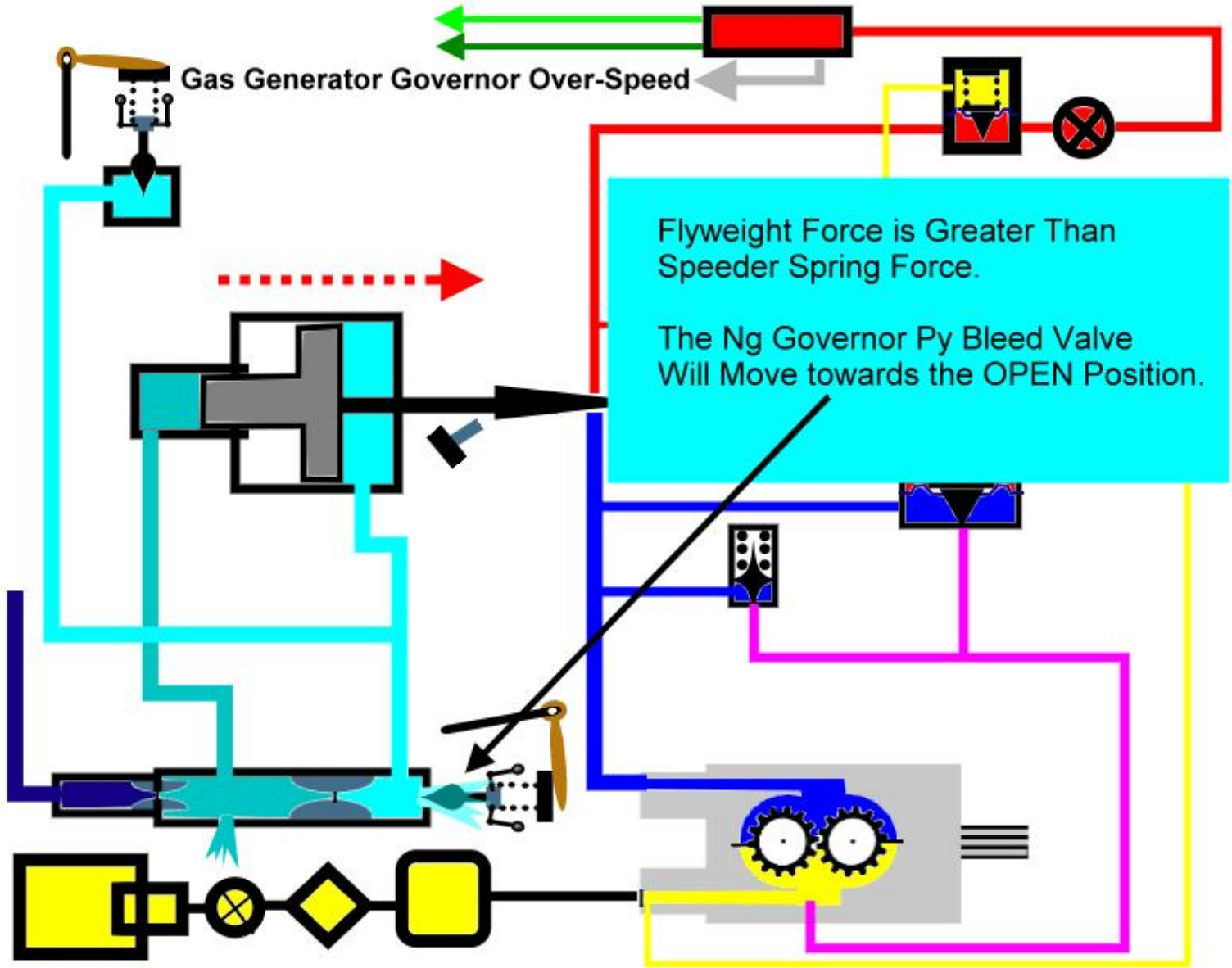
Now we need to look at the operation of the FCU Mechanical Governor!!

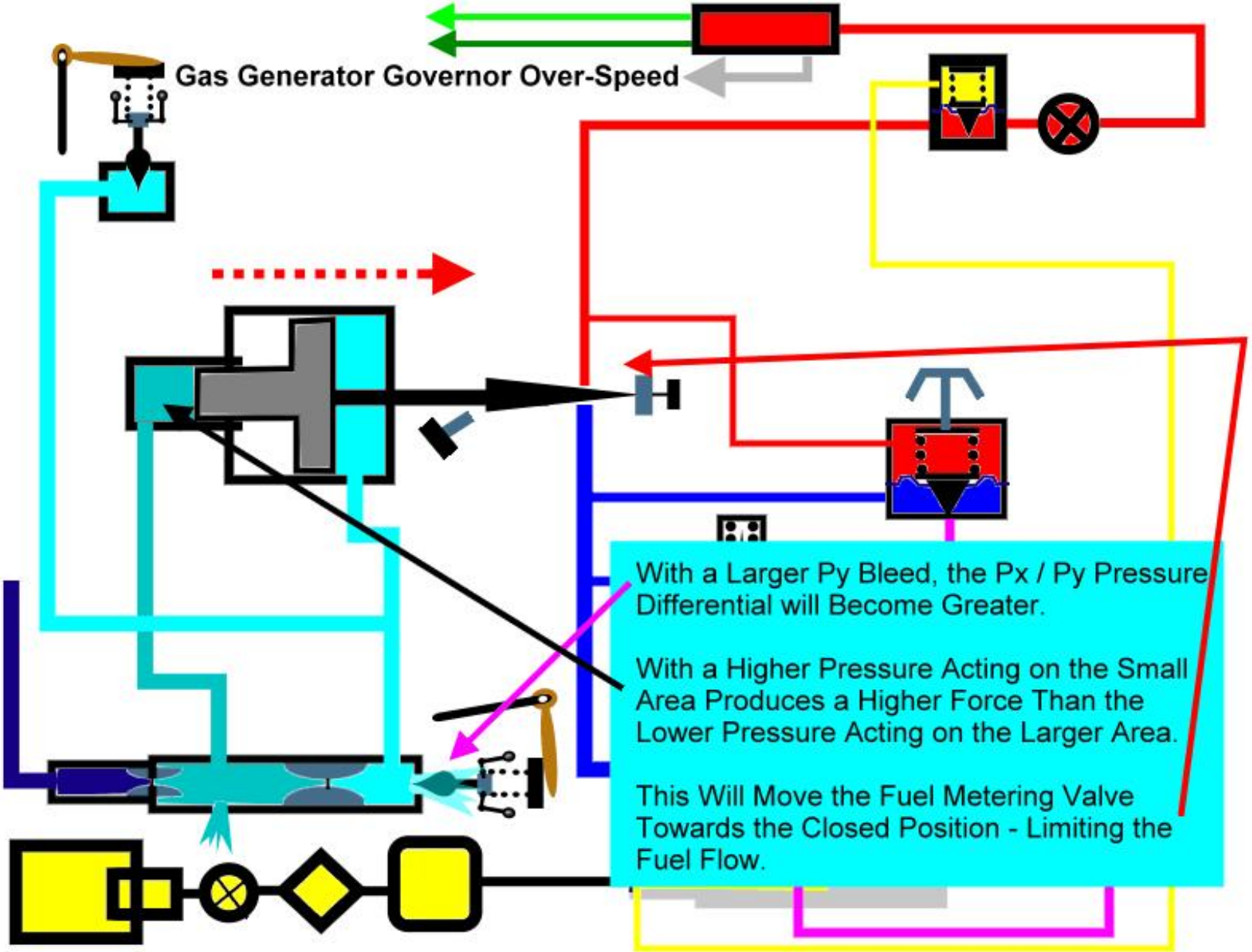




What happens if the input drive is lost to the FCU Governor?

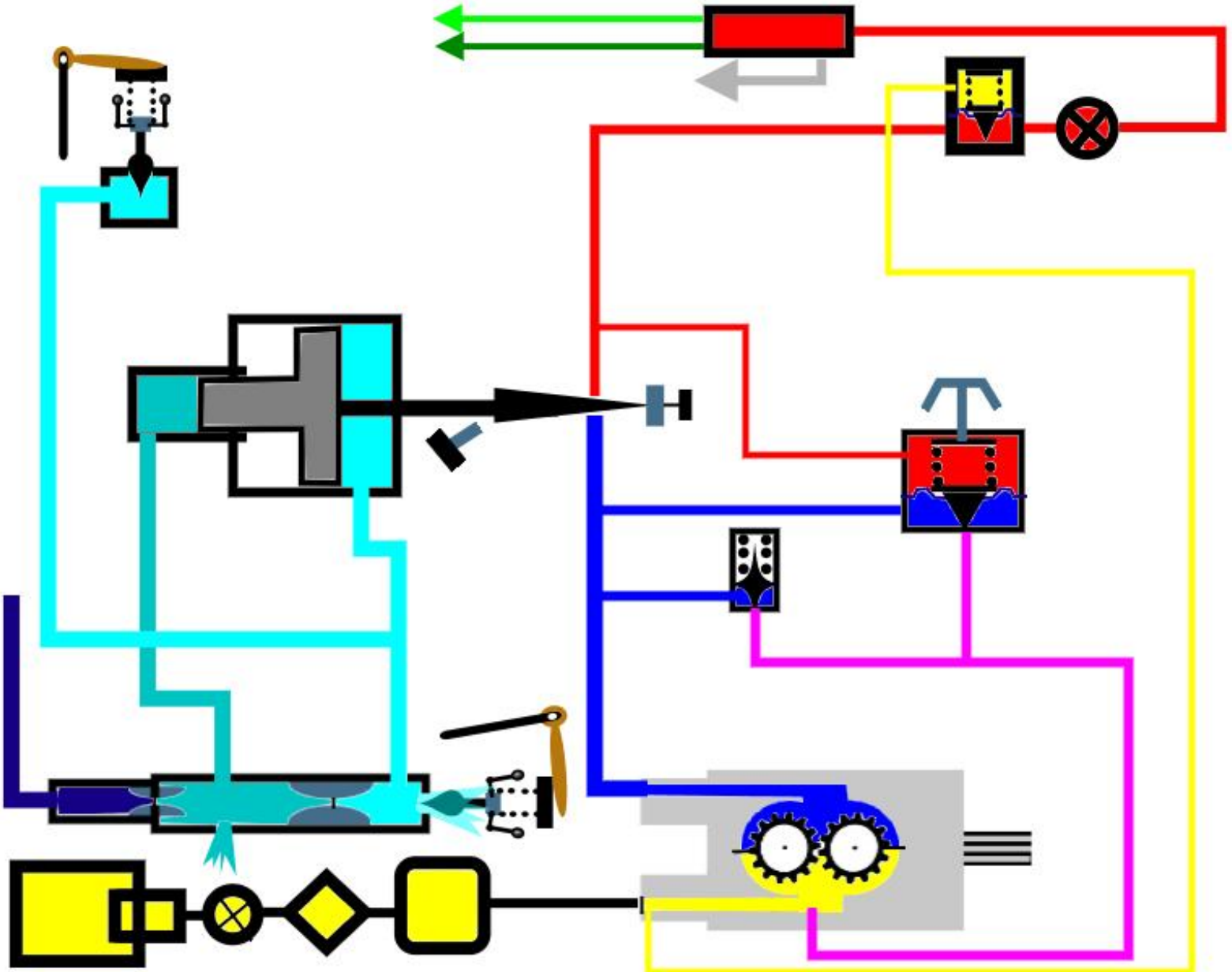




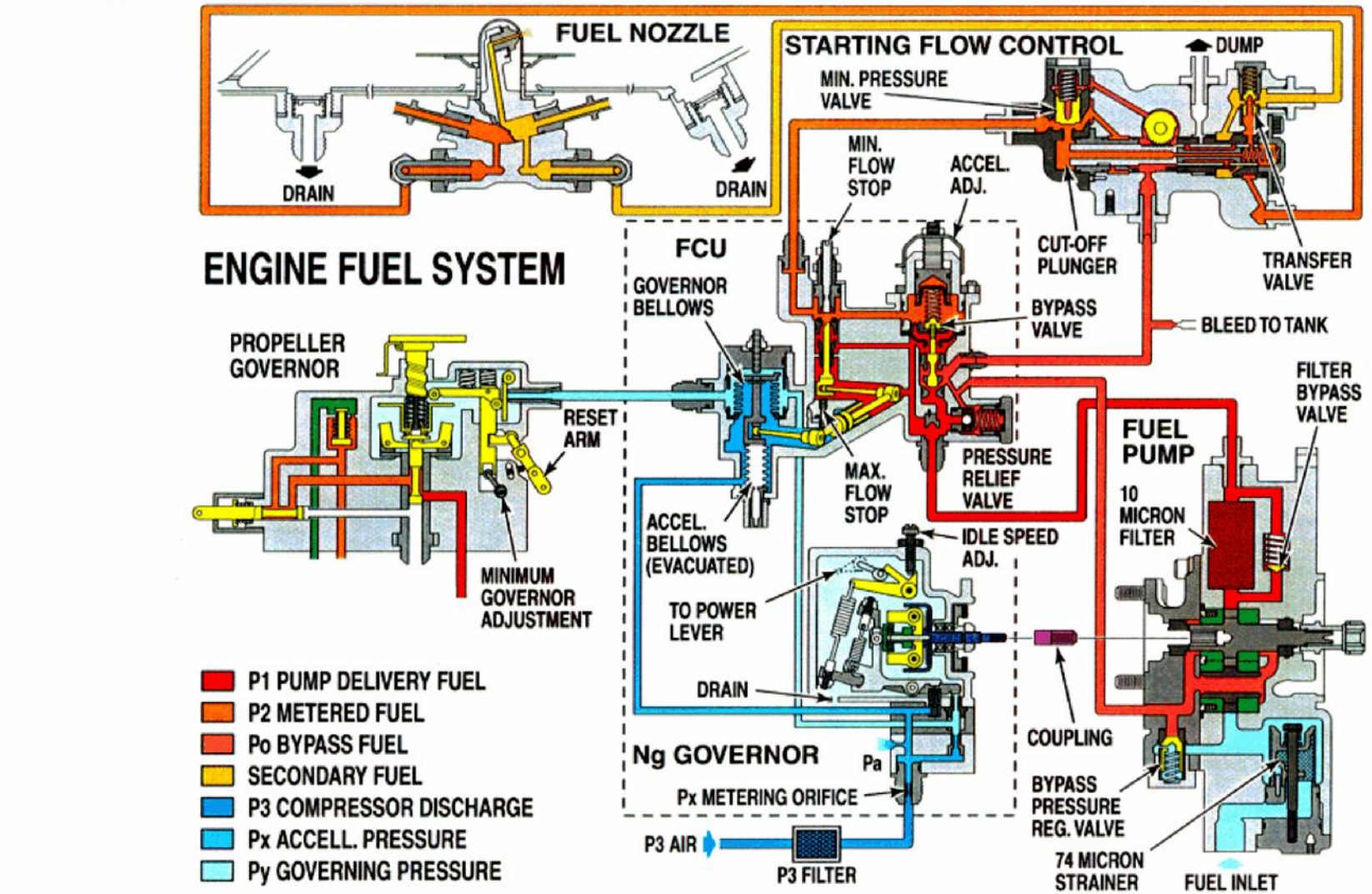


Our Finished System

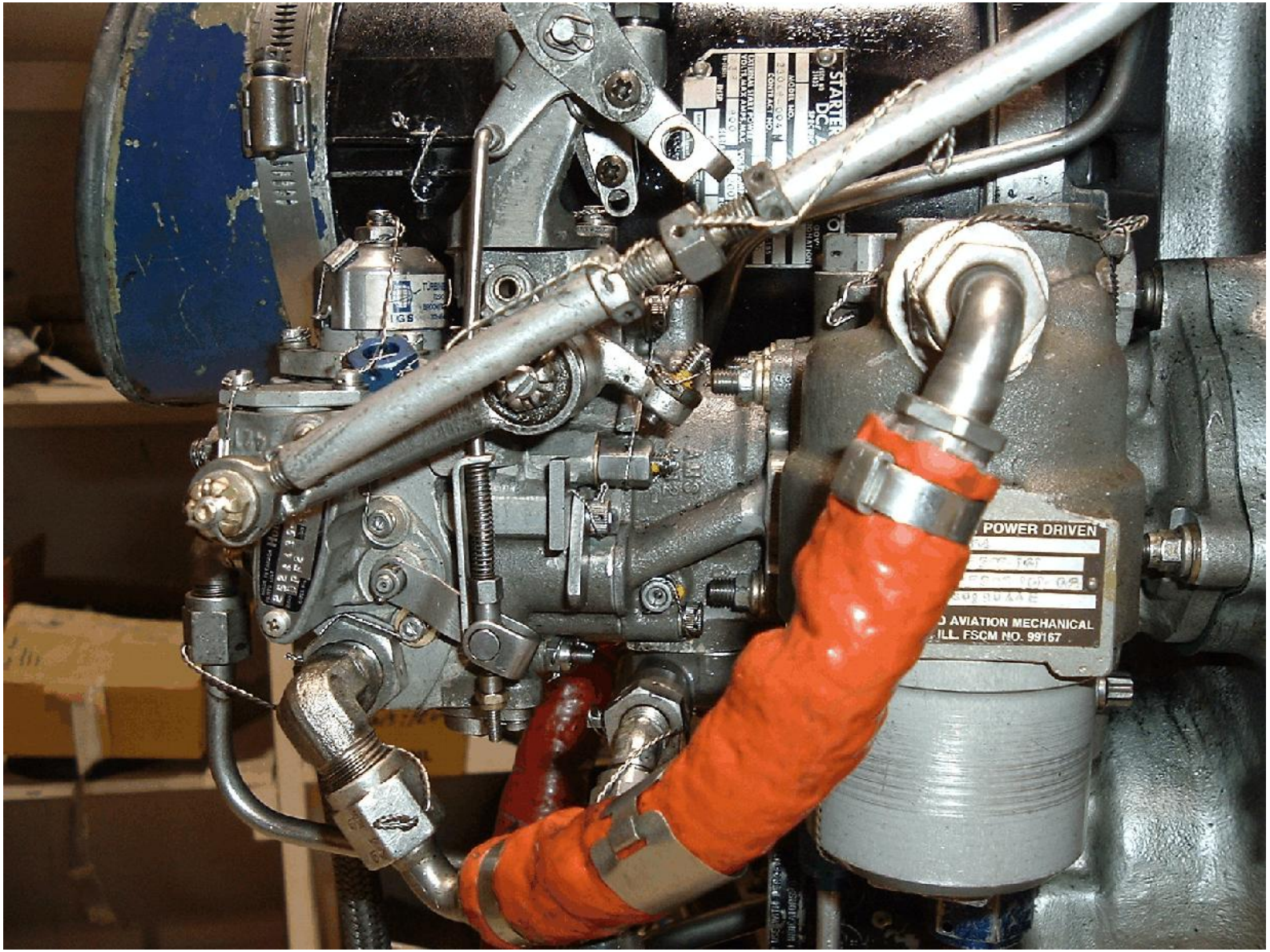
NOT BAD !!!!!



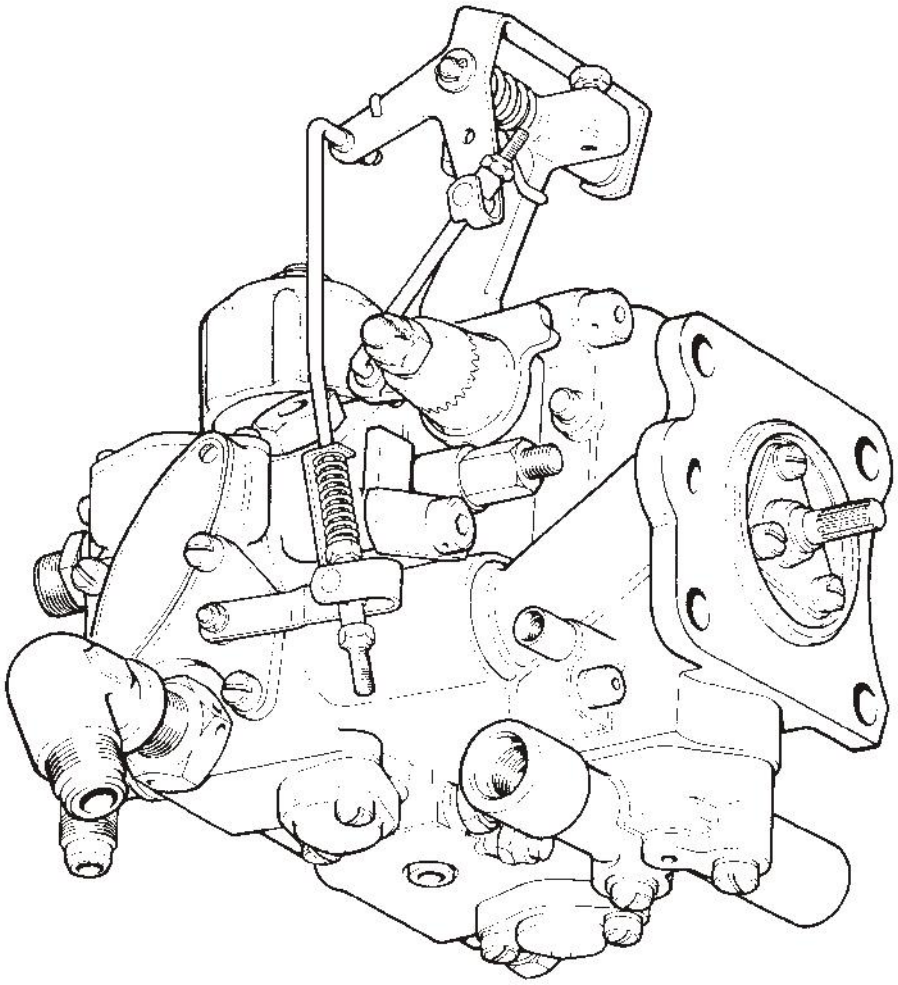
Propeller Control System With Fuel Control



Governor and Fuel Pump Installation



Governor View from the Drive End



References

Pratt and Whitney PT6A - Maintenance, Parts, and Training Manuals
Hawker / Beech / Raytheon - Maintenance, Parts, and Training Manuals
Bendix Fuel Control Division - Maintenance and Training Manuals

Thanks to the original company Illustrators - without your drawings this document would have very little impact.