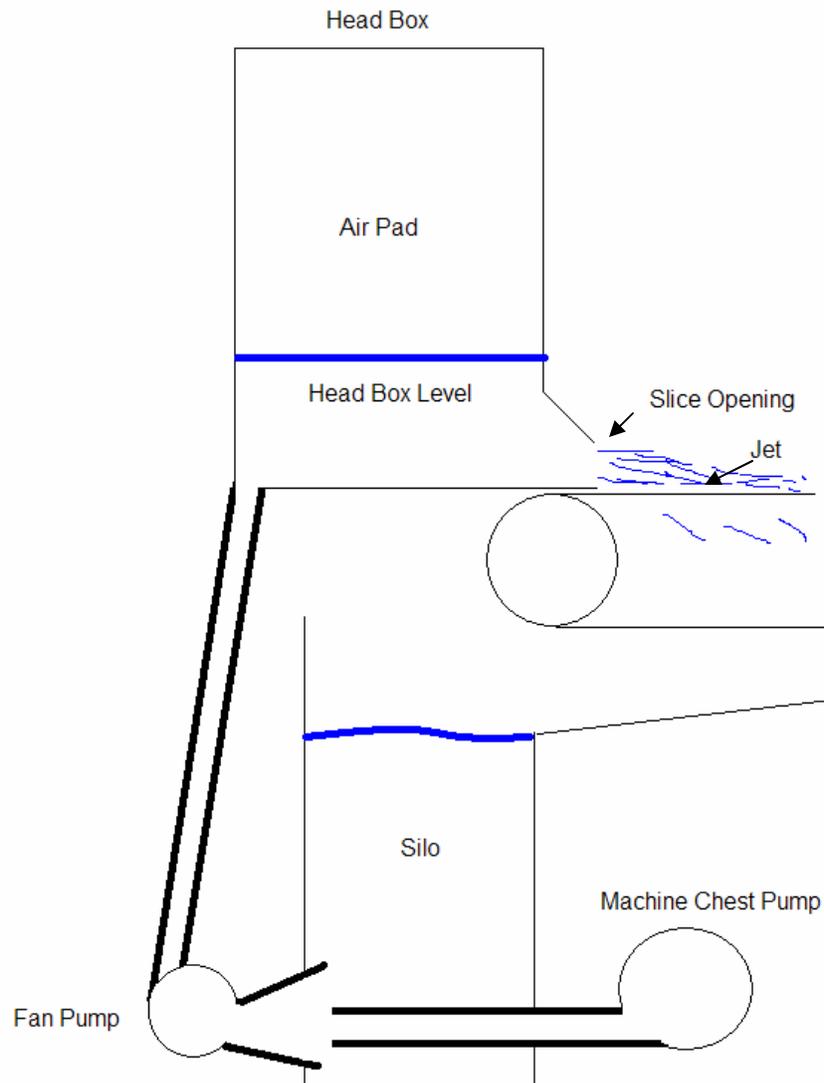


# HEAD BOX SIMULATION

## Head box operation

<b>Introduction</b>	<p>For many operators the head box runs in “auto” without the operators having a real understanding of what the controls are doing. This makes it difficult for operators to understand when the controls are not operating correctly due to control, process equipment or instrumentation issues.</p> <p>In this exercise the student will use a simulator to manually control a head box to produce stable basis weight and jet/wire ratio.</p>
<b>Learning Objectives</b>	<p>Upon completion of this section, you will be able to describe the influence on basis weight, jet/wire ratio of the following items:</p> <ul style="list-style-type: none"><li>• Fan pump</li><li>• Machine chest consistency</li><li>• Head box pressure</li><li>• Head box level</li><li>• Machine speed</li></ul>
<b>Initial Learning Activities</b>	<p>Run the simulator using the directions on the next page</p>
<b>Knowledge Check</b>	<p>There is no knowledge check associated with this demo</p>
<b>Contacts</b>	<p>For questions about this simulator call Managed Reliability @ 253.333.6685</p>

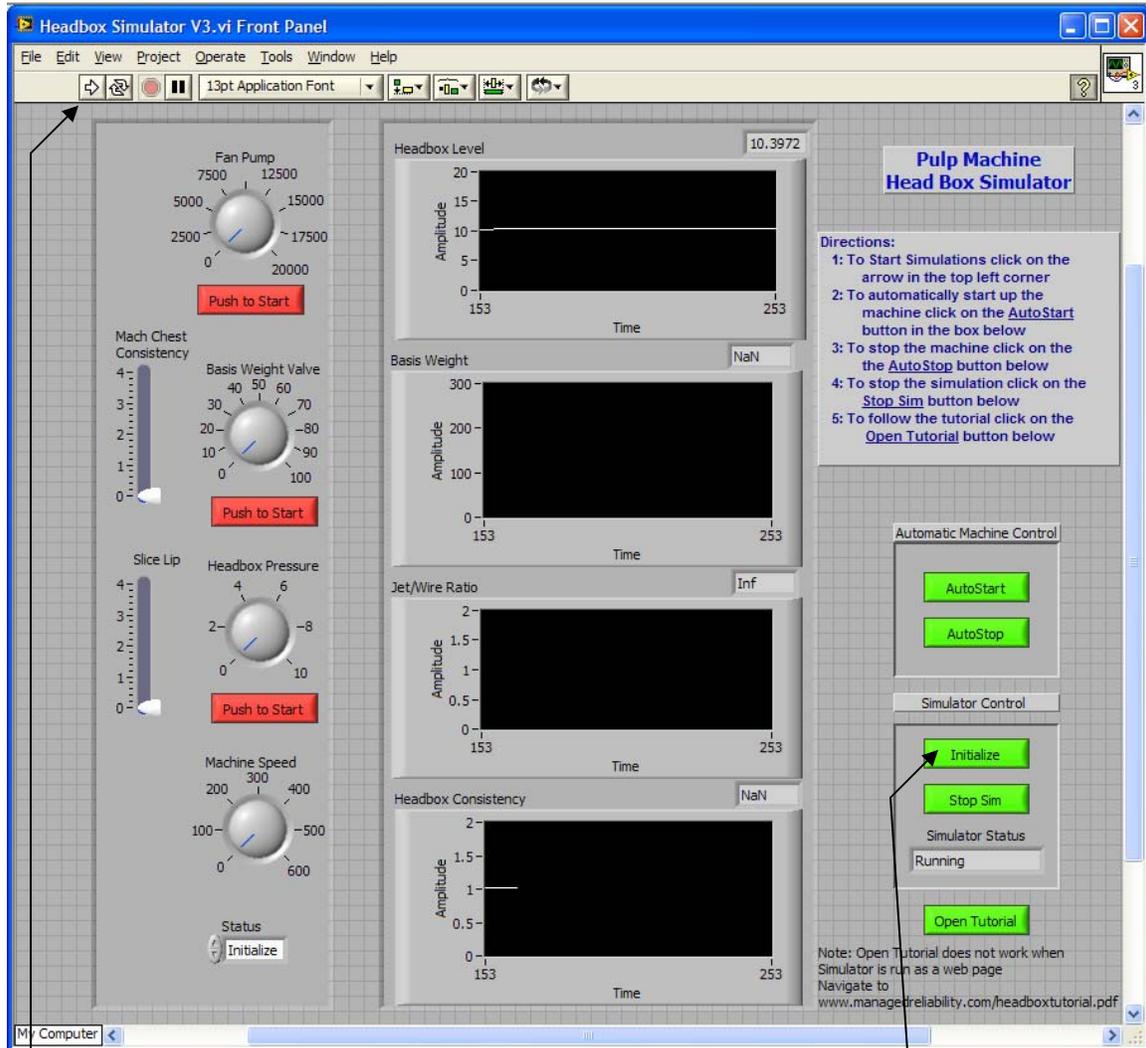
The head box simulator is based on the system shown below.



Stock is pumped from a machine chest (not shown) by the machine chest stock pump into the suction of a fan pump. The fan pump is a variable speed pump which allows fine control of total flow to the head box. The head box is a pressure head box in that there is an air pad which is maintained at a constant pressure. The pressure of the air pad plus the head provided by the stock level in the head box drives the stock through the slice onto the Fourdrinier wire. The speed of the jet relative to the wire is called the jet to wire ratio and is an important formation parameter.

# Simulation

The simulator is at [http://www.managedreliability.com/services\\_training\\_headbox.htm](http://www.managedreliability.com/services_training_headbox.htm). Print these instructions then open the simulator at the above address. Note that the simulator was built using Labview from National Instruments (<http://www.ni.com>). The simulator installs a National Instruments runtime engine. Once you install the simulator – you should see something like the following figure



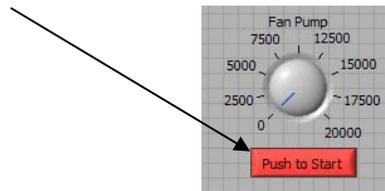
Note that when the simulation is first started all settings are at whatever values existed the last time someone ran the simulation. To actually run the simulations, click on the arrow directly under the label Operate in the title bar. Next press the Initialize button which will stop the simulated pulp machine and bring all values to zero. When you are finished with the simulation press AutoStop, wait for the machine to stop and then press Stop Sim

## Exercise 1: Head Box Level

### Learning Points:

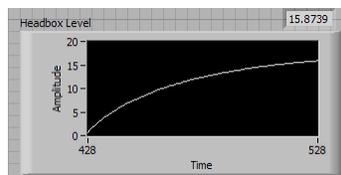
- **How head box level changes over time**
- **Impact of level on machine operation**

At the start nothing happens – because nothing is started. We will at first be interested in head box level. This is the top graph on the page. Each graph shows the current value in a box above the upper right corner of its graph. Start the fan pump by clicking on the “Push to Start” button under the “Fan Pump” speed control



Once the start button is pushed, notice that nothing happens to the level. This is because the pump speed is set to zero. Before pumping into the head box we need to open the slice so that flow in to the head box will be able to flow out on to the wire. Find the slice level control and raise the slice to about 2.5 inches. Note that the slice opening varies by machine, its product, and its design. For the examples that follow, a 2.5 inch opening works well, but later in the exercises we will be adjusting this.

Now we can set the fan pump to pump. Increase the speed to about 15000 gpm by placing the mouse over the blue line on the fan pump knob, holding down the left mouse button and dragging the line over to the 15000. Observe the head box level graph which should appear as shown below.



Note how the level increases quickly but as time goes by it levels out. This is because the flow out of the head box is dependant on the level in the head box. The higher the level, the more flow out of the head box occurs. Also – as we will see later – the flow out (that is jet speed) is faster as well.

On first starting the fan pump, there is no level in the head box and so no flow out. As the fan pump fills up the head box, flow out increases slowly, but there is less flowing out than flowing in. Therefore level continues to rise. As the level rises, flow out increases until finally the flow out matches the flow in and the head box reaches equilibrium. For the conditions given this should be at about 16.5 inches.

Head box level is an important parameter for good machine operation. There is typically internal equipment such as rectifier rolls and such that must be submerged to provide good formation. In this head box however we do not have that concern and in fact the head box can operate with unrealistically low levels without disturbing the simulation. However, if the slice is too low such that the head box can fill, then the simulation will exit with a plugged head box warning. Luckily it is easier to restart the simulator from a plugged head box than it is to restart a machine after a similar occurrence.

## **Exercise 2: Head Box Consistency**

### **Learning Points:**

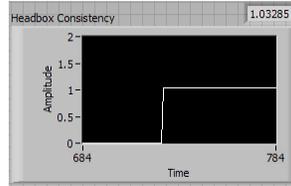
- **Impact of consistency on machine operation**
- **Interactions between the machine chest stock pump, fan pump and silo**

Now we turn our attention to consistency. For the time being, ignore the basis weight and jet/wire graphs, we will be discussing those later. Observe the consistency graph and its current value. It is zero because we are adding no stock to the system through the machine chest stock pump. The level in the head box is simply water with no stock. To get stock to the machine we need to first set the consistency in the machine chest. Move the Machine Chest Consistency slider to about 2.5 which is a typical consistency for many mills.

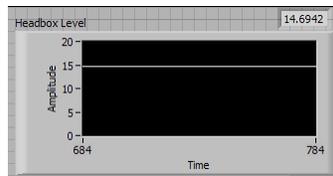
Next we need to set the basis weight valve which controls flow from the pump to about 50%. Most control valves operate most efficiently in the 40% to 60% range and our simulator is designed to follow this norm. Now start the basis weight (stock) pump by pressing the “Push to Start” button under the Basis Weight Valve control. The head box consistency should jump up very quickly to about .92 which is in the range of what most machines run.

Typical pulp machines run in the range of .9 to 1.2 % consistency. At higher consistencies, the machine can produce more product because there is less water for the machine to remove. However, formation issues occur as consistency rises so - depending on the finished product requirements - a lower consistency may be required to gain sheet uniformity. 1.05 to 1.5 is a range that provides a compromise for many machines.

Two things should be noted when we started the machine chest stock pump. First, as shown below, the consistency rose fairly rapidly. In this simulation there is no model of the mixing or time delay that occurs in the piping and head box. In real life the change in consistency would be more gradual. However, it is still very fast and does not show the same delay as we saw with the head box level. The consistency in the head box can change very rapidly.



The second thing to be noted about the start of the machine chest stock pump is that the level in the head box did not change as shown below. This is because the fan pump is the only pump controlling flow to the head box. It has an open suction as shown in the schematic in the introduction. The outlet of the machine chest stock pump is not directly connected to the fan pump suction; rather the outlet of the pump sits just short of the fan pump suction. When the fan pump is running and the stock pump is off, the fan pump will draw water from the silo at the rate indicated on the controller.



When the machine chest pump is started, the fan pump will still draw the same amount of fluid, but now it will draw all the output of the machine chest stock pump and the remainder of the flow will come from the silo. In other words, when the machine chest stock pump starts up, some of the flow previously sucked from the silo, will now come from the machine chest stock pump instead. Likewise, if the fan pump is not running and the machine chest pump starts up, it can fill the silo up with stock. For this reason, most systems interlock the machine chest stock pump to the fan pump so that this can not occur.

### Exercise 3: Jet/Wire Ratio

#### Learning Points:

- **Impact of jet/wire ratio on machine operation**

Up until now, the stock that has been leaving our simulated head box has been piling up on our simulated Fourdrinier table because we have not started the wire. Again, in real life all the startups would be interlocked to the wire so that this would not happen. Start up the wire to get a basis weight and a jet/wire ratio. Set the machine speed dial to 600 (top speed) which should result in a basis weight of about 183 and a jet/wire ratio of .94. In our simulator, we have a perfect machine which dries the stock to 0% moisture so the basis weight is only affected by stock to the machine.

Jet to wire ratio is an important parameter for formation on the machine and controls fiber placement on the wire. At 1.0 (jet speed and wire speed are equal) fibers tend to be oriented randomly. As the ratio changes from 1.0 the fibers tend to fall into the machine direction as they are placed on the wire. This results in a stronger sheet. Typically plants will run about 10% away from 1.0 so values of .9 or 1.1 are common.

Some experimental data indicates that there is little difference between rushing the sheet (ratios greater than 1.0, jet speed is greater than wire speed) or dragging the sheet (ratios less than 1). The difference from 1.0 is important (i.e. .9 is the same as 1.1). However, many plants are passionate about whether they drag or rush. Also many plants hold the (quite logical) view that what is important is the difference in speed, not the ratio of speeds. In these plants they will maintain a constant rush (or drag) of x fpm regardless of machine speed.

#### **Exercise 4: Head Box Pressure**

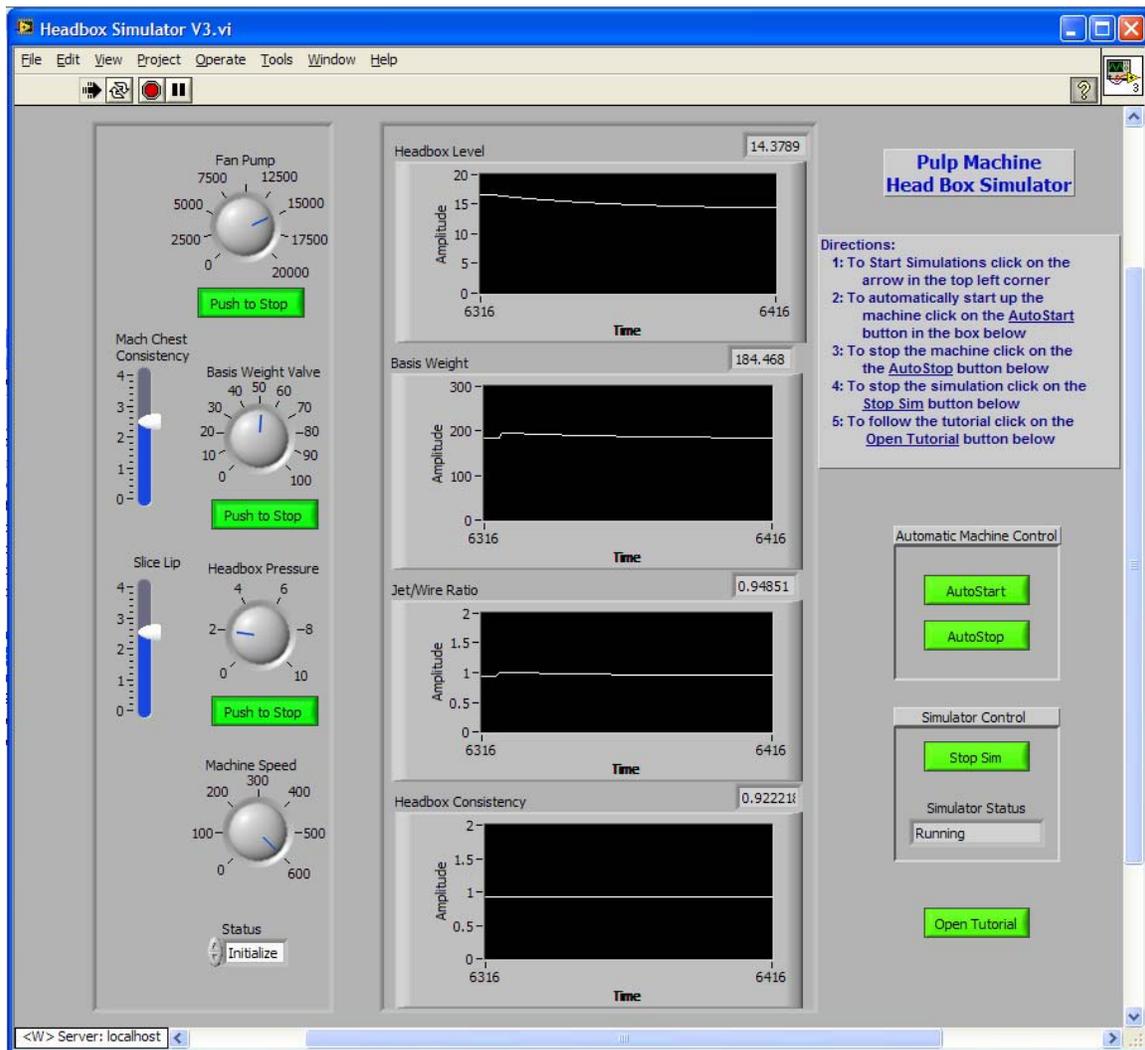
##### **Learning Points:**

- **Short term impacts of head box pressure changes on machine operation**
- **Long term impacts of head box pressure changes on machine operation**

The last piece of equipment to start on the simulator is the head box pressure system. Here as in the real world the head box pressure system maintains a constant pressure in the head box. This allows us to maintain a reasonable level in the box. On older low speed machines, the head box was open to the atmosphere, but as speed increased, the pulp level required to obtain adequate jet speed and flow out of the head box became excessive. Therefore closed boxes with air pads were developed to allow reasonable head box levels and adequate head to generate proper flows.

Do the following in this order. Set the head box pressure knob to 2 and then push the associated start button. Observe the level, the basis weight and the jet/wire ratio graphs. The level drops off with a pattern similar to our first exercise. It drops off quickly at the beginning, but changes more slowly as it approaches its final level of about 12. Basis weight and jet/wire behave in a most interesting fashion. The basis weight jumps up quickly and then drops back to its original value. Jet/wire has the same behavior. This is because the pressure system can provide air fairly quickly to the head box. The force acting on the pulp and causing it to flow out of the head box is the combination of air pad pressure and head box level.

When we first add the air pressure, we still have the head box level. The added force now forces more flow out of the head box. In fact, at this point there is more flowing out of the head box than the fan pump is pumping in. As a result, the head box level begins to drop. It will continue to drop until a new equilibrium is found that is – when the flow out matches the flow in. The new equilibrium is the point where flow out matches the flow in from the fan pump. Because the fan pump has not changed speed, this equilibrium is actually the same flow we had before. As basis weight and jet/wire ratio are impacted by flow out of the head box they experience a short term change but return to original values as the flows return to equilibrium. This short term behavior is one reason most control systems make machine changes very slowly, so that the process never wanders too far from equilibrium.



### **Exercise 5: Operate the head box**

#### **Learning Points:**

- **How the various machine controls interact**

At this point the machine is running and you can adjust the various settings to see the impact on machine operation. Try adjusting the slice opening, the machine chest consistency or the basis weight to see their impacts on machine operation.

### **Exercise 6: Operate the head box to a set of targets**

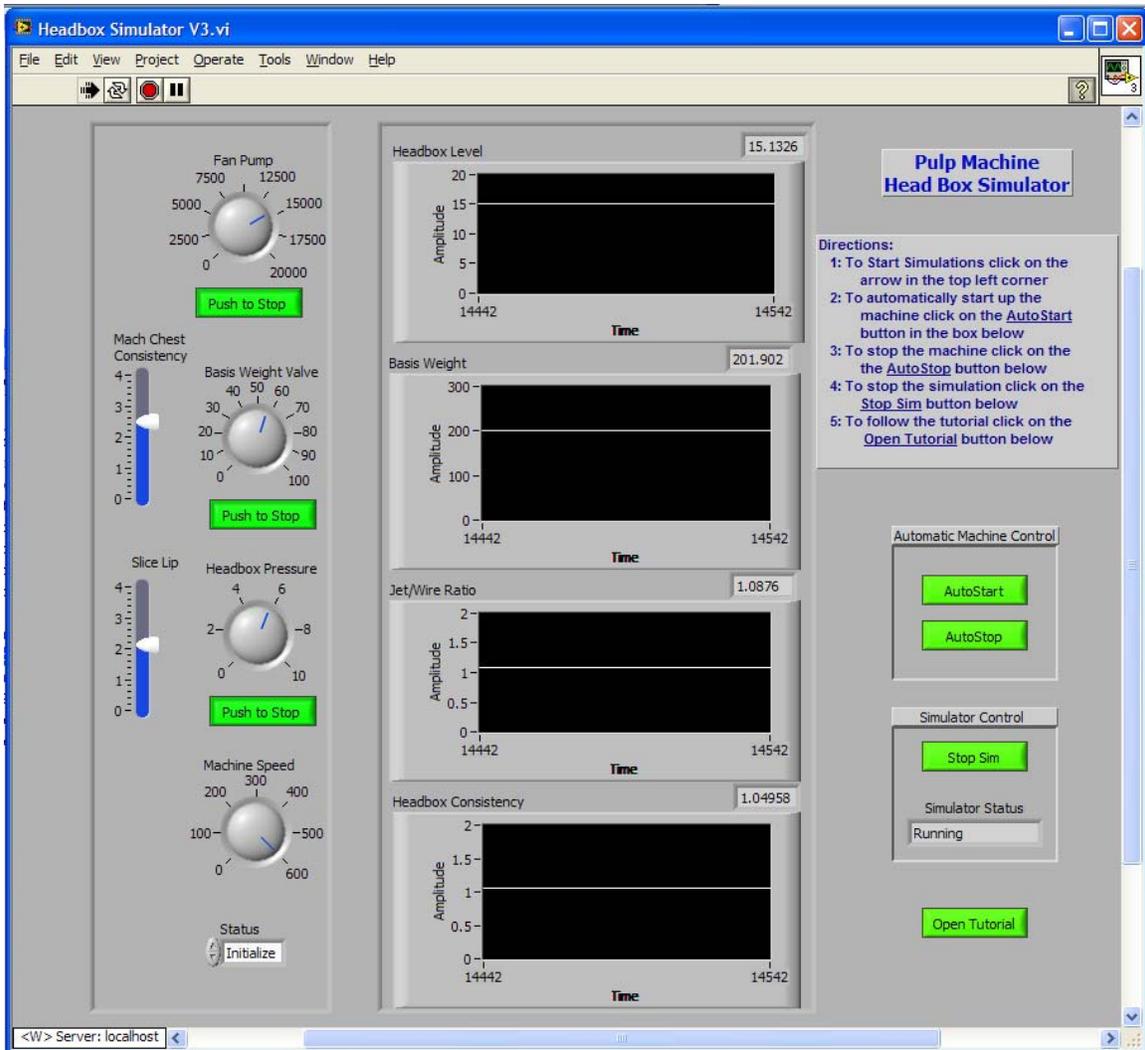
#### **Learning Points:**

- **Exercise previous learnings to show how to achieve a set of desired targets**

For the last exercise we will attempt to move the machine to a set of operating parameters. First return the machine to the operation shown in the above figure, i.e. head box pressure of 2, basis weight valve of 50%, slice of 2.5, machine chest consistency of 2.5, machine speed of 600 and fan pump speed of 15000. This should give you a head box level of ~14, a jet/wire ratio of ~.94, a basis weight of ~183, and a head box consistency of ~.92. What we want to do is to change this so that basis weight is 200, jet/wire is 1.1, head box level is 15, and head box consistency is 1.05. We will change the other variables such as basis weight valve to change to achieve the new machine operation.

There are probably many different settings that will achieve this. In trying to get to this you should observe that changing the air pad pressure has very little effect on anything other than the head box level. In fact - in control systems - this is how head box level is controlled, rather than via the fan pump flow which is what most people think.

Changing the fan pump flow causes the head box consistency to change, but also changes the basis weight in the short term. In the long term the basis weight returns to its previous setting. Changing the basis weight valve changes the basis weight, but also changes the head box consistency. These two variables can be changed to achieve the desired results, but then it will be seen that the jet/wire ratio is not at spec value. To achieve this value the slice lip must be moved, but that upsets the rest of the head box. In the end, to achieve the desired parameters, all of the head box variables must be adjusted. One solution is shown below.



The actual values are:

Variable	Setting
Fan Pump	14410
Basis Weight Valve	56.073
Machine Chest Consistency	2.36375 (unchanged)
Head Box Pressure	5.75
Slice Lip	2.08163

### Process

The easiest way to set the machine up for the given targets is to first work with those parameters that have the most direct impact on the targets. Start with the basis weight valve. This has a direct impact on the basis weight. A side effect of the basis weight valve adjustment is to change the head box consistency. Use the fan pump to bring the head box consistency in line. This will have a short term impact on basis weight, but it should eventually return to pre-fan pump adjustment levels. Next adjust the slice lip to get the desired jet/wire ratio. This will cause another short term upset, but wait for the

head box to settle out. Finally adjust the head box pressure control to get the desired head box level.

### **Other Simulation Tools**

There are two other buttons of interest on the simulator. AutoStart and AutoStop. Auto Start will start the machine up from stopped to a running state with stock on the wire. It does this in a staged fashion, much as a human operator might start the machine. Likewise AutoStop stops the machine in an orderly fashion.